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CONTROL TECHNOLOGY ASSESSMENT

in the

PULP AND PAPER INDUSTRY

Anderson-Nichols and Co., Inc.
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Effective control technologies used in the pulp and paper industry (SIC-2621) to prevent or minimize worker exposure to toxic chemicals and harmful physical stresses were evaluated and documented. The study included a literature review, preliminary mill surveys, and detailed surveys of selected major unit processes. The indepth surveys were conducted at 18 mills and resulted in 40 survey reports for one or more mill unit processes. These reports related to wood preparation, sulfite pulping and stock washing, Kraft pulping and stock washing, Kraft chemical recovery, multistage bleaching, bleach chemical preparation, and paper production. Over 1000 air samples were analyzed to evaluate the effectiveness of the control systems associated with these mill processes. The major workplace contaminants studied and methods for sampling and analysis were described. Among various findings, the authors note that chlorine (7782505) and chlorine-dioxide (10049044) concentrations were frequently high in chlorine-dioxide generator buildings, particularly during startups, shut downs, and following collection of quality control samples.

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ABSTRACT

An assessment of hazard control technology in the pulp and paper industry was made through a program that included a literature review, consultations with members of the industry, and surveys of facilities by a team of industrial hygienists and engineers. Hazard control technology is defined as a systems approach involving the interaction of engineering controls, work practices, monitoring systems, and personal protective equipment to prevent or limit occupational exposure to hazardous substances.

Forty survey reports, either of specific unit operations or plant production processes were written based on in-depth studies at 18 mills. These mills were selected as having good controls for the prevention of occupational exposure to hazardous materials based on preliminary (walk-through) surveys of approximately 30 facilities. Processes surveyed include: wood preparation and mechanical pulping, Kraft and sulfite pulping, brown stock washing, Kraft chemical recovery (evaporation, recovery furnaces, and recausticizing), bleach chemical handling and preparation, multistage bleaching, and papermaking. Survey reports describe processes, operations, equipment, and controls used to prevent occupational exposure. Over 1,000 air samples were analyzed to evaluate the effectiveness of the control systems in preventing worker exposure to toxic substances. Case studies also address natural, general mechanical, and local exhaust ventilation; personal protective equipment use; work practices; and workplace monitoring systems. Where appropriate, maintenance operations and procedures are discussed. Noise exposure and controls are discussed in several reports.

The results of this study are useful to pulp and paper mill personnel interested in adopting effective control technology, and to industry and government personnel responsible for formulating research and development plans. Control systems capable of preventing worker exposure in excess of OSHA PELs during routine operations exist in many mills.

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This contract expired before the summary report could be put in final form by the contractor. The NIOSH project officer has edited and revised the draft and the report and tables were reformated to NIOSH standards by Ms. Ruby Watson. It is recognized that the individual reports included in the appendix are uneven in the descriptions and discussions presented and could be improved by a thorough editing. However, because of the desire to make the information available in a timely manner, they have been reproduced exactly as prepared by the contractor.

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I. INTRODUCTION

STUDY OBJECTIVES AND METHODS

This study was conducted to evaluate and document effective control technologies used in the pulp and paper industry to prevent or minimize worker exposure to toxic chemicals and harmful physical stresses. Its scope included assessment of all processes in Standard Industrial Classifications: Pulp Mills (SIC 2611); Paper Mills, except Building Paper Mills (SIC 2621); Paper Board Mills (SIC 2631); and Building Paper and Building Board Mills (SIC 2661); and encompassed most segments of the industry except converting operations. The following methods of reducing or eliminating worker exposure to air contaminants and physical agents were assessed.

Engineering control technology - process or process control characteristics; isolation of workers and/or sources of exposure; local or general exhaust ventilation; substitution of raw materials or process equipment.

Work practices - specified work techniques that minimize the generation and subsequent emission of air contaminants or harmful physical agents, or minimize worker exposure to them; scheduled maintenance procedures that anticipate and prevent process upsets or leaks, and subsequent exposure; housekeeping procedures that maintain a clean, orderly workplace conducive to hazard control; emergency procedures.

Monitoring/Warning systems - methods that monitor process, control, or workplace variables to warn of malfunctions that could create worker exposures.

Personal protective equipment - respirators, hearing protection, face masks, or protective clothing worn by or available to workers to minimize inhalation of or contact with toxic chemicals, or exposure to physical agents.

The study included a literature review, preliminary mill surveys, and detailed in-depth surveys of selected major unit processes. The literature review

revealed little information pertinent to workplace exposure agents and their control, although extensive process and environmental data were obtained.

Preliminary surveys were conducted in 27 pulp and/or paper mills whose managers volunteered to participate through a questionaire distributed by the American Paper Institute. These surveys provided a means to assess the suitability of major unit processes for subsequent indepth study. The primary criteria for the selection of various unit processes for in-depth study were potential for exposure, control effectiveness, and industry representativeness. In-depth surveys were conducted in 18 mills and resulted in 40 survey reports for one or more mill unit processes. These reports form the core of this document, and they are arranged and presented by related unit processes: wood preparation (including mechanical pulping); sulfite pulping and stock washing; Kraft pulping and stock washing; Kraft chemical recovery; multi-stage bleaching; bleach chemical preparation; and papermaking.

Mill surveys included the following activities:

1. Collection of personal samples to measure worker exposure to air contaminants and thereby evaluate control effectiveness.

2. Collection of area samples to identify and rank exposure sources and where possible, to measure workplace emission rates.

3. Measurement of ventilation system operating parameters including face, capture, and transport velocities. These are related to worker exposure data included in the assessment of control technology.

4. Observation and assessment of process operations including the effect of control methods in preventing or minimizing worker exposure to air contaminants and harmful physical agents.

6. Determination of process variables and cycles and their effect on control effectiveness.

7. Collection of information from mill personnel including:

a. Process flow charts and descriptions.

b. Ventilation blueprints.

c. Collection of existing exposure data for subsequent evaluation relative to control effectiveness.

d. Use of process or workplace monitoring and alarm systems.

e. Descriptions of work practices including maintenance and operating procedures.

f. Installation and operating costs of controls where readily available.

8. Detailed description of engineering controls including photos and dimensional sketches.

STUDY REPORT FORMAT

Major results, conclusions, and findings for each of these unit processes are summarized in this volume. Following this introduction is Section II, a brief overview of the pulp and paper industry; Section III contains a description of the major workplace contaminants studied and the methods used for sampling and analysis. Section IV comprises recommendations for further research. The bulk of this report is Section V: Unit Process Summaries. These are grouped into ten areas of interest. Basically an inventory of the processes and control technology options studied (including workplace air sampling results), the individual study reports are referenced and should be consulted for specific information. For convenience, these study reports are consolidated in the Appendix to this report.

II. INDUSTRY OVERVIEW

Pulp and paper production can conveniently be divided into wood pulping and papermaking processes. There are five basic types of pulping processes, and yearly production totals for each are presented in Table 1. The number of in-depth surveys conducted for each type of pulping process is also shown.

Table 1. Wood pulp production (1,000 tons).*

	1981**	% Total	No. Surveys
Dissolving	1,248	3	1
Sulfite	1,636	4	3
Kraft	31,893	74	14
Semichemical	3,616	8	1
Groundwood & TPM	4,560	11	4
	42,943		

* Based on January-August 1981 production figures (annualized) as published in Paper, Paperboard, and Wood Pulp Monthly Statistical Summary, Vol. 59, No. 10, October 1981, American Paper Institute.
**Estimated.

The Kraft, sulfite, and dissolving pulp processes use chemicals and high temperatures and pressures to dissolve the wood lignin and produce raw pulp. Groundwood and thermomechanical (TMP) pulps are produced by physically separating wood fibers under mechanical forces obtained with grinders or refiners. Semi-chemical pulping employs some degree of both techniques. Kraft pulping accounted for 74 percent of the 1981 pulp production in the United States, and given this predominance, fourteen Kraft pulp mills were surveyed during this study. However, each of the other pulping processes was also assessed as part of at least one in-depth survey.

Paper and paperboard products are produced with large, complex Fourdrinier or cylinder papermaking machines. General types of products and production figures [1979, 1980, 1981 (EST.)] for each are shown in Table 2.

Table 2. Paper and paperboard production (1,000 tons).*

	1979	1980	1981**
PAPER			
Newsprint	3,778	4,660	5,222
Uncoated groundwood papers	1,800	1,538	1,411
Coated papers	4,580	4,751	4,978
Uncoated free sheet	7,655	8,008	7,939
Cotton fiber paper	130	131	118
Thin papers	371	333	344
Bleached bristols	957	941	990
Tissue paper	4,601	4,474	4,529
Unbleached Kraft packaging and industrial conversion papers	3,911	3,718	3,728
Other paper	1,797	1,609	1,712
Total paper grades	29,580	30,164	30,971
PAPERBOARD			
Solid wood pulp furnish	23,585	23,902	24,916
Unbleached Kraft linerboard	13,857	14,249	14,788
Other unbleached Kraft paperboard	1,046	1,036	1,117
Bleached Kraft paperboard	4,065	4,034	4,235
Semi-chemical paperboard	4,617	4,583	4,777
Recycled paperboard	7,583	7,242	7,475
Total paperboard grades	31,168	31,143	32,391
WET MACHINE BOARD	144	138	173
CONSTRUCTION PAPER AND INSULATION BOARD	3,131	2,020	2,245
TOTAL ALL GRADES	64,023	63,865	65,780

*Paper, Paperboard and Wood Pulp Monthly Statistical Summary, Vol. 59, No. 10, October 1981, American Paper Institute.
**Estimated.

SECTION III. WORKPLACE CONTAMINANTS AND AIR MONITORING METHODS

Many chemicals are utilized in the manufacturing processes of the pulp and paper industry. In addition, various chemicals are generated as by-products of these processes. It was impossible to assess exposure conditions for all of these chemicals, but the major ones received considerable study. They included reduced sulfur compounds in Kraft pulping, sulfur dioxide in sulfite pulping, chlorine and chlorine dioxide in bleaching, lime dust in recausticizing, and formaldehyde, ammonia, sodium hydroxide, sulfuric acid, nuisance dusts, and asbestos in papermaking.

The uses, nature of generation and consumption, and atmospheric emission points of these major chemicals are reasonably well understood because of data developed for pollution control studies. However, information on workplace emission sources, worker exposures, and other characteristics is scarce. This study provides significant new data on chemical workplace contaminants, emission sources, and the potential for worker exposure.

For the reader's convenience, the major chemical agents are summarized in Table 3. This table includes both a listing of process areas or unit operations where exposures could occur and a summary of current exposure limits (OSHA, ACGIH, and NIOSH Recommendation). Specific workplace emission sources are discussed in detail in the Unit Process Summary, Section V, and in the individual mill reports, Appendix. Sampling and analytical methods for the agents are summarized in Table 4.

Because the HNU P101 photoionization analyzer responds nonselectively to many pulp mill air contaminants (reduced sulfurs, ketones, and terpenes), it was used in some mills only to locate workplace emission sources, to compare responses in different work areas, and to correlate the relative magnitude of contaminant changes to process changes or cycles. The analyzer is valuable for these types of evaluations, but will require considerable laboratory and field research before it can be used as a reliable (stable and capable of calibration), direct-reading survey instrument, or as a continuous process or workplace air monitor.

Airborne particulate matter, judged to be nuisance dusts in this study, and so sampled for, included wood matter, clay, starch, titanium dioxide, calcium stearate, crystalline and amorphous calcium carbonate, and lime mud (calcium carbonate). Although lime (quicklime or calcium hydroxide) is not a nuisance dust, worker exposures to it were measured by collecting total airborne particulate samples. When these results exceeded the OSHA PEL for lime (5 mg/m^3 CaO), the total particulate matter was also analyzed for total calcium (reported as CaO and/or $CaCO_3$). Investigators wishing to evalute lime exposures in recausticizing/lime kiln areas are recommended to concurrently collect and compare appropriate samples for total and/or respirable airborne particulates, total calcium (and sodium) by NIOSH Method P&CAM 173, and perhaps, soluble acid-titratable base (hydroxide expressed as $CaCO_3$) as collected on a PVC or MCE filter. This will allow estimating relative percentages of process and environmental dusts and the amount of soluble lime [CaO and $Ca(OH_2)$] in the process dust fraction.

Table 3. Air contaminants, physical agents, and their exposure limits.

Potential Exposure Agent	Major Associated Unit Operations for Processes	OSHA PEL (1981)[1]	ACGIH TLV (1980)[1]	NIOSH Recommended (1981)[2]
Chlorine	Bleach plant; bleach chemical preparation; paper mill; waste water treatment	1 ppm (ceiling)	1 ppm 3 ppm STEL[3]	0.5 ppm (15-minute ceiling)[4]
Chlorine dioxide	Bleach plant; chemical bleach preparation	0.1 ppm	0.1 ppm 0.3 ppm STEL[3]	--
Hydrogen sulfide	Digesters; brown stock washers; evaporators; black liquor oxidation; recovery furnaces; recausticizing tanks; lime kilns; TRS gas collection systems; water treatment plants	20 ppm (ceiling) 50 ppm [acceptable peak for a one-time exposure of 10-minutes (if no other measurable exposure occurs)]	10 ppm 15 ppm STEL[3]	10 ppm (10-minute peak)[3]
Methyl mercaptan	Digestors; brown stock washers; evaporators; black liquor oxidation; recovery furnaces; other boilers; lime kilns; TRS gas collection systems	10 ppm (15-minute ceiling)	0.5 ppm	--
Sulfur dioxide	Digesters; brown stock washers; evaporators; recovery furnaces; sulfite liquor preparation systems (burners, absorption towers, and liquor tanks)	5 ppm	2 ppm 5 ppm STEL[3]	0.5 ppm
Dimethyl sulfide Dimethyl disulfide	Digesters; brown stock washers; evaporators; black liquor oxidation; recovery furnaces; other boilers; lime kilns; TRS gas collection systems	--	--	--
Turpentine	Digesters; brown stock washers; evaporators; black liquor oxidation; recovery furnaces; other boilers; turpentine decanter	100 ppm	100 ppm 150 ppm STEL[3]	-- --
Ethyl mercaptan	Digesters; brown stock washers; evaporators; black liquor oxidation; recovery furnaces; other boilers; lime kilns; TRS gas collection systems	10 ppm (ceiling)	0.5 ppm 2 ppm STEL[3]	-- --
Formaldehyde	Coating preparation and application operations	3 ppm 5 ppm (ceiling) 10 ppm (maximum peak above the acceptable ceiling for a maximum duration of 30 minutes	2 ppm (ceiling)	1 ppm (30-minute ceiling)[3]
Asbestos	Papermill; maintenance; furnaces and boilers; pipe repair and demolition	2 fibers/cc[5] 10 fibers/cc[5] (ceiling)	Amosite: 0.5 fiber/cc[5] Crocidolite: 0.2 fiber/cc[5] Chrysolite and other forms: 2.0 fibers/cc[5]	0.5 fibers/cc[5]
Ammonia	Coating preparation and application operations	50 ppm	25 ppm 35 ppm STEL[3]	50 ppm (5-minute ceiling)[3]
Sodium hydroxide	Coating preparation; coating operation; recausticizing; evaporators; chemical preparation; bleach plant	2 mg/m^3	2 mg/m^3	2 mg/m^3 (15-minute ceiling)[3]
Nuisance particulates[6]	Papermill; recausticizing and lime kilns; woodyard; woodrooms; coating preparation	15 mg/m^3	10 mg/m^3	--
n-Propyl alcohol	Digesters; brown stock washers	200 ppm	200 ppm 250 STEL[3]	--
Sulfuric acid	Papermill and bleach chemical preparation	1 mg/m^3	1 mg/m^3	1 mg/m^3 (10-hr. TWA)
Heat stress	Boiler areas, paper machine rooms; precipitator maintenance; digesters; lime kilns			
Noise	All major process areas			

1. 8-hour time-weighted average exposure limits, except as noted.
2. Based on time-weighted average of up to 10-hours; 40-hours week, except as noted.
3. Short-term exposure limit (15-minutes) tentative values.
4. When "ceiling" and a time period such as "15-minutes" appear together, the recommended limit is an acceptable peak not to be exceeded in the sampling period denoted by the time.
5. Fibers longer than 5 um.
6. Includes wood dust, paper dust, starch, clay, titanium dioxide, calcium stearate, and calcium carbonate.

Table 4. Air monitoring methods.

Potential Air Contaminant	Personal Sampling Method	Air Sampling Method(s)
Ammonia	NIOSH Method P&CAM 205[1] (liquid media samplers with H_2SO_4; Nessler's reagent; colorimetry)	Draeger detector tubes or NIOSH Method P&CAM 205
Chlorine and/or chlorine dioxide	NIOSH Method P&CAM 209 (for chlorine equivalent) (liquid media samplers with methyl orange; colorimetry)	Mast oxidant monitor (Model724-7), field calibrated for chlorine with a certified permeation tube; or Draeger detector tubes
Formaldehyde	NIOSH Method P&CAM 125 (liquid media samplers with 1% bisulfite solution; chromotropic acid-sulfuric acid solution; colorimetry)	Draeger detector tubes or NIOSH Method P&CAM 125
Hydrogen sulfide	NIOSH Method P&CAM 126 (midget impinger with alkaline $Cd(OH)_2$; colorimetry for methylene blue)	Draeger or Bendix/Gastec detector tubes; HNU P101 photoionization analyzer or NIOSH Method P&CAM 126
Lime and lime mud	See total airborne particulates	
Mercaptans (ethyl and methyl)	Method of Knarr and Rappaport (Anal. Chem. 52, 1980, pp. 733-736) with gas chromatography and flame photometric detector	Draeger or Bendix/Gastec detector tubes; method of Knarr and Rappaport, and/or HNU P101 photoionization analyzer
Alcohols (ethyl and methyl)	NIOSH Method P&CAM 247 (with silica gel) or S56 (with charcoal tube)	Draeger detector tubes; NIOSH P&CAM 247 or S56, and/or HNU P101 photo ionization analyzer
Ketones (acetone and MEK)	NIOSH Method P&CAM 127 (charcoal tube; desorption with CS_2; GC with FID)	Draeger detector tubes; NIOSH P&CAM 127, and/or HNU P101 photoionization analyzer
Terpenes and MEK)	NIOSH Method P&CAM 127 (charcoal tube); desorption with CS_2; GC with FID)	NIOSH Method P&CAM 127 and/or HNU P101 photoionization analyzer
Phenolics	Charcoal and/or silica gel tubes; desorption with CS_2; GC with FID	
Sodium hydroxide	NIOSH Methods P&CAM 241 or S381(liquid media sampler with HClsolution or PTFE filter; electrometric back titration)	NIOSH Methods P&CAM 241 or S381
Sulfur dioxide	NIOSH Method P&CAM 160 (liquid media samplers with TCM solution; colorimetry)	NIOSH Method P&CAM 160; Drager detector tubes; and/or Interscan sulfur dioxide monitor
Total airborne particulates (nuisance dusts)	Closed-face, 5.0 u, pretared PVC filters; gravimetric analysis (Ref: NIOSH Manual of Sampling Data Sheets, Method #29.02	See personal sampling

NOTE: Dimethyl sulfide, dimethyl disulfide, and other reduced sulfur compound concentrations in Kraft pulping areas were estimated by detector tubes.

1. NIOSH Manual of Analytical Methods, 2nd Ed., Vols. 1-4, DHEW(NIOSH) Publication No. 77-157-A, April, 1977. Available from U. S. Government Printing Office, Superintendent of Documents, Washington, D. C. 20402).

SECTION IV. RECOMMENDATIONS FOR FURTHER RESEARCH

METHODS DEVELOPMENT AND VERIFICATION

Compound-specific personal and area sampling techniques are needed for chlorine, chlorine dioxide, dimethyl sulfide, and dimethyl disulfide. The Knarr and Rappaport method for methyl mercaptan (Anal. Chem. 1980, 52, 733-736) requires additional verification to demonstrate specificity in workplaces containing other reduced sulfur compounds.

CONTINUOUS MONITORS

Reliable continuous air monitors with specific response to chlorine dioxide should be developed and field tested. Continuous air monitors responding quantitatively to hydrogen sulfide, mercaptans, dimethyl sulfide, and dimethyl disulfide should be developed and evaluated for specific applications in Kraft pulp mills (leak detectors, warning alarms, etc.). We believe that it would be helpful to develop a manual to assist mills in the optimum selection, design, location, calibration, maintenance, and overall use of both types of monitoring systems.

CHLORINE/CHLORINE DIOXIDE EXPOSURES IN GENERATOR BUILDINGS

We found that chlorine/chlorine dioxide levels were frequently high in chlorine dioxide generator buildings, particularly during start-ups and shut-downs, and following collection of quality control samples. Further study is needed to better understand the nature and extent of worker exposure to these sources, and to document effective controls.

V. UNIT PROCESS SUMMARIES

As discussed in tne Introduction, this section is divided into ten major processes or areas of interest. Each section contains references to individual study reports where details of the technology involved or circumstances influencing the results of air sampling are described. The reports are consolidated in the Appendix, arranged in the sequence of this section, as shown in the following table.

Table 5. Index to summary reports.

Major Unit Process or Subject	Survey Report Number
Wood Preparation and Mechanical Pulping	03, 07, 14, 15, 40
Kraft Pulping and Stock Washing	01, 08, 11, 20, 26, 29, 33, 36, 38
Kraft Chemical Recovery -- Evaporators and Recovery Furnaces	18,31,34
Kraft Chemical Recovery -- Recausticizing and Lime Burning	16, 19, 27
Sulfite Pulping and Stock Washing	21, 28, 39
Bleach Chemical Handling and Preparation Operations	10, 12, 22, 25, 30, 32, 35, 37, (01, 39)*
Multi-Stage Bleaching	(01, 03, 07, 10, 12, 17, 22, 25, 30, 32, 35, 37, 39, 40)*
Papermaking Operations	02, 06, 09, 13, 24, (40)*
Mill Maintenance Operations and Procedures	05, 07, (01, 08, 11, 19, 20, 24, 25, 30, 35, 38)*
Noise Exposure and Controls	04, 23, (03, 07, 14, 15, 27, 28, 40)*

* Report numbers in parentheses contain information on this subject, but the reports are located in other subsections.

WOOD PREPARATION AND MECHANICAL PULPING

Wood preparation operations were surveyed in Mills 07, 14, and 40. Each of these woodyard/woodrooms was associated with a mechanical pulping process, but the operations employed are typical of most pulp mills.

Also included are surveys of two refiner groundwood pulping processes (15, 40), one thermo-mechanical pulping (TMP) process (03), and a stone-grinder groundwood pulping process (07). Detailed process descriptions and evaluations of contaminant control techniques are provided in the individual mill reports.

Process Abstract

Wood Preparation--
Roundwood is typically washed with high pressure water jets, slashed (cut to size), debarked, and then chipped or sent directly to the pulp mill.

Mechanical Pulping--
Mechanical pulps are produced by grinding wet, debarked logs (stone groundwood), by separating wood fibers from chips in refiners (refiner groundwood), or by softening wood chips with steam, followed by mechanical refining (TMP). In the refining process, chips are attrited by passage between two discs having alternating bars and depressions on the surfaces; the discs are rotated in opposite directions by directly-connected motors.

Table 6 is an outline of the wood preparation and mechanical pulping processes observed in this study.

Job Categories and Descriptions

Job categories and descriptions for each process are outlined in Table 7. There are wide variations in these categories among the five mills, and job descriptions are generally not comparable. Depending on the degree of process automation, many workers remain in control rooms, acoustical booths, or other enclosed spaces for much of each shift.

Air Sampling Data and Noise Measurements

Personal and area sampling was conducted in Mills 03, 07, and 15, and the results are summarized in Tables 8 and 9. Of 26 samples collected to measure total dust exposure, all were below the OSHA PEL of 15 mg/m^3 for total nuisance dust and only two exceeded 1 mg/m^3 (1.3, 3.4 mg/m^3). Workplace concentrations of turpentine, terpenes, total hydrocarbons, alcohols, ketones, and phenols were very low, or non-detectable. Appreciable levels of resin acids (8.7, 33 mg/m^3) were detected in Mill 03.

Control Technology

The following process characteristics and other factors prevent significant air contamination and exposure in mechanical pulping:

- No chemicals are used; potential air contaminants are restricted to wood dust and volatile wood constituents.

- The processes are largely closed, and the roundwood or wood chips are handled wet, which minimizes dust generation.

- Except for the stone groundwood mill (07), all of the pulping processes are automated and workers remain mostly in control rooms or acoustic enclosures.

- Housekeeping was excellent in the surveyed mills.

The major potential air contaminant in wood preparation processes is wood dust. Sampling data and observations indicate that dust exposures are low, primarily because most operations are conducted on wet material, and effective housekeeping is employed.

Noise levels are relatively high in many areas of wood preparation and mechanical pulping processes. The primary means of reducing worker exposures in the surveyed mills are presented by each process in Table 10.

Table 6. Wood preparation and groundwood technology surveyed.

Mill No.	Geographic Location	Woodyard/Wood Room	No. of Workers	Pulping Process	No. of Workers
03	Midwest	--	-	TMP (2 lines)	6
07	Midwest	Steambarker, slasher, drum barker	3	Groundwood (13 Four-pocket grinders)	15
14	Northwest	High-pressure water spray, slasher, ring debarker, summer chippers	10	--	-
15	Northwest	--	-	Refiner groundwood (3 lines; double-disc refiners)	3
40	Germany	Slashing, debarking, autofeed chain grinders	-	Refiner groundwood	-

Table 7. Job categories and descriptions for wood preparation and groundwood process workers.

Mill No.	Process	Job Categories	Number of Workers/Shift	Job Descriptions*
03	TMP (2 lines)	Operators	2	Monitor process; start-up (95%)
		Assistant operators	2	Process inspections; assist operator (95%)
		Tester	1	Collects and tests stock samples (60%)
		Utility	1	Housekeeping (25%)
07	Wood Preparation	Steam barker operator	1	Clear jams; inspection; housekeeping
		Slasher operator	1	Monitor feed conveyor (90%)
		Drum barker operator	1	Inspect debarked logs
	Stone Groundwood	Grinder operators	8	Load and operate grinders
		Block pilers	5	Transport logs to grinders
		Tester	1	Collect and test pulp samples; foreman (70%)
14	Wood Preparation	Log unloading crane operator	1	Unload river rafts (75%)
		Haul-up crane operator	1	Transfer classified logs to woodroom conveyor (75%)
		Chip line operators	2	Monitor chipping lines (75%)
		Utility	2	Housekeeping
15	Refiner Groundwood	Operator	1	Monitor process (40-70%)
		Assistant operator	1	Collect/test stock samples (40-70%)
		Utility	1	Housekeeping; assist operators (15-75%)

*Estimated time spent in control rooms, booths, etc., is shown in parentheses.

Table 8. Personal air monitoring data in wood preparation and groundwood operations.

Mill No.	Job Category	Number Samples	Concentration (mg/m^3) Range	Mean	Reference
Contaminant			Total Nuisance Dust (mg/m^3)		
03	Thermo Mechanical Pulp				
	Operator	2	0.08 - 0.10	0.09	Table 03-1
	Asst. Operator	2	0.05 - 0.11	0.08	"
	Tester	1		0.13	"
	Cleaner	2	0.30 - 0.50	0.40	"
07	Wood Preparation				
	Stream Barker Operator	3	0.10 - 0.51	0.26	Table 07-1
	Drum Barker Operator	2	0.20 - 3.4	1.8	"
	Slasher Operator	1		0.04	"
	Stone Groundwood				
	Grinder Operator	5	0.01 - 0.20	0.10	"
	Tester	1		0.07	"
Contaminant			Turpentine (mg/m^3)		
07	Grinder Operator	2	<0.02 - 0.04	<0.03	Table 07-2
Contaminant			Terpenes (mg/m^3)		
07	Grinder Operator	2	<0.04	<0.04	Table 07-2
Contaminant			Total Hydrocarbons (mg/m^3)		
07	Grinder Operator	2	<0.04	<0.04	Table 07-2

Table 9. Area air monitoring data in wood preparation and groundwood operations.

Mill No.	Location	Number Samples	Concentration (mg/m^3) Range	Mean	Reference
Contaminant		Total Nuisance Dust			
03	Chip Washing and Feeding	3	0.04 - 0.16	0.10	Table 03-1
07	Slasher	2	0.61 - 1.3	0.96	Table 07-1
	Log Bins	1		0.57	"
	Bull Screen	1		0.07	"
Contaminant		Turpentine			
03	Stream Barker	1		0.15	Table 03-2
	TMP Process Area	5	0.02 - 0.15	0.15	"
07	Stream Barker	1		<0.15	Table 07-2
	Grinder Room	3	<0.02 - <0.06	<0.04	"
Contaminant		Other Terpenes			
03	Stream Barker	1		0.15	Table 03-2
	TMP Process Area	5	0.02 - 0.15	0.15	"
07	Stream Barker	1		<0.15	Table 07-2
	Grinder Room	3	<0.02 - <0.06	<0.04	"
15	Refiner Area	3	<0.01 - 0.49	<0.18	Table 15-1
	Decker Area	3	<0.01 - 1.30	<0.45	"
Contamimant		Resin Acids			
03	TMP Process Area	2	8.70 - 33.0	20.9	Table 03-2
15	Refiner Area	2	<0.03	<0.03	Table 15-1
	Decker Area	2	<0.03	<0.03	"
Contaminant		Alcohols			
03	TMP Process Area	5	0.02 - 0.18	0.07	Table 03-2
07	Grinder Room	1		<0.04	Table 07-2
15	Refiner Area	3	<0.03	<0.03	Table 15-1
	Decker Area	3	<0.03	<0.03	"
Contaminant		Phenol			
03	TMP Process Area	1		1.7	Table 03-2
15	Refiner Area	2	<0.03	<0.03	Table 15-2
	Decker Area	2	<0.03	<0.03	"
Contaminant		Ketones			
15	Refiner Area	3	<0.03	<0.03	Table 15-1
	Decker Area	3	<0.01 - 0.05	<0.25	"
Contaminant		Total Hydrocarbons			
07	Grinder Room	2	0.02 - 0.06	0.04	Table 07-2
15	Refiner Area	1		<0.03	Table 15-1
	Decker Area	1		<0.03	"

Table 10. Noise control in woodrooms and grinding areas.

Mill No.	Process	Noise Control
03	Thermomechanical	Worker isolation
07	Wood Preparation Stone Groundwood	Slasher enclosure Grinders not noisy
14	Wood Preparation	Acoustical booths Enclosed office and knife rooms Enclosed crane cabs Partial isolation of chippers Partial enclosure of ring barkers Building design features and layout
15	Refiner Groundwood	Worker isolation (Control Rooms)
40	Wood Preparation	Worker Isolation Drum barker enclosure Damping for slasher and wood sorting conveyors
	Refiner Groundwood	Worker Isolation (Control Rooms) Acoustic barriers and isolation of refiners

KRAFT PULPING AND BROWN STOCK WASHING

Kraft pulping and brown stock washing operations were surveyed in nine pulp mills (01, 08, 11, 20, 26, 29, 33, 36, and 38). Table 11 summarizes the Kraft pulping processes observed in the surveyed mills.

Process Abstract

Wood chips are cooked in sodium hydroxide and sodium sulfide solution at high temperature and pressure in large batch or continuous digesters. The pulp is then deknotted (undefibrated, partially cooked wood particles removed), washed, and pumped to the bleach plant or directly to the paper mill. Unbleached (brown) stock washing is done to remove the spent cooking liquor from the wood

fibers. This may be accomplished in several ways, including 2- to 4-stage washers with vacuum filters, in-digester washing, and diffusion washers. The most common system observed was the 3-stage system using rotary filters and counter-current washing. Pulp, suspended in black liquor is pumped to the first filter where it forms a cake which is washed by effluent from the second filter. The effluent from this stage (black liquor) is sent to the recovery unit to reclaim the chemicals used in cooking. The cake is redispersed in the No. 2 filter washings and then pumped to the second filter. The cake formed here is washed by effluent from the third filter and then redispersed in the same type of effluent. Cake formed on the No. 3 filter is washed with fresh hot water.

Job Categories and Descriptions

Specific job titles and responsibilities vary considerably among the surveyed mills. In general, there are five broad job categories:

- Digester operators.
- Chip feeders.
- Wash and screen operators.
- Quality control testers.
- Utility employees.

Table 12 outlines the staffing arrangement for each of the surveyed mills.

Air Sampling Data

A total of 130 short-term personal samples were collected and analyzed for hydrogen sulfide and methyl mercaptan (Table 12). These samples were taken during periods when the employees were out of the control room for at least five minutes. The results, therefore, represent the highest probable exposure from routine operations.

None of the 42 hydrogen sulfide samples resulted in exposure levels above 1 ppm (less than 5 percent of the OSHA ceiling PEL of 20 ppm.) Of 88 methyl mercaptan samples, none resulted in exposures above the OSHA ceiling PEL of 10 ppm. These exposure data were distributed as follows:

- 67 samples below 0.5 ppm (76 percent).
- 20 samples between 0.5 ppm and 5 ppm (23 percent).
- One sample above 5 ppm (7.7 ppm).

The results of 139 area samples are shown on Tables 14 and 15. The hydrogen sulfide and methyl mercaptan data parallel the personal sampling results, and none of the measured levels were above the OSHA PEL's for these contaminants. Small quantities of turpentine, alcohol, ketones, phenolics, and organic compounds were measured, but potential exposure to these compounds is judged to be low. No resin acids were detected in any of the samples.

Control Technology

Worker exposure in Kraft pulp mills is usually well controlled by a combination of the following factors:

- Process characteristics - Continuous pulping processes are almost totally closed, and there are no persistent sources of workplace contamination. Air contaminants are periodically emitted when batch digesters are open during chip loading operations; however, our data demonstrate low exposures regardless of the type of loading system.
- Worker isolation - Because Kraft pulping processes are highly automated, most operators and other employees spend considerable portions of each shift inside various types of control rooms (Table 16). Many of these control rooms provide protection from workplace air contaminants during leaks or process upsets.

- Brown stock washer ventilation - Surveyed washer ventilation systems are characterized in Table 16. All washers are exhausted through canopy hoods or full enclosures, with design air flows ranging from 16,500 cfm to 94,000 cfm for single washing lines, and up to 150,000 cfm for hoods covering two lines. As demonstrated by the brown stock washer area sampling data in Tables 14 and 15 (Mills 08, 11, 20, 26, 33, 36, and 38), all of the hoods were effective in preventing workplace contamination.

- Environmental control - Noncondensable gas collection systems installed to prevent or reduce air pollution also reduce workplace exposures.

Table 11. Kraft pulp digestor operations surveyed.

Mill No.	Location	Digesters	Digester Loading	Wood Species	Primary Process Control	Cooking Heat	Stock Washing Equipment	Lines
01	Midwest	6 Batch	Capping valve	HW & SW[1]	Computer	Direct and indirect	3-Stage vacuum washers	1
08	Midwest	1 Kamyr continuous	High pressure feeder	HW or SW	Analog	Indirect	3-Stage vacuum washers	1
11	South	13 Batch	Tube-turns closure	HW & SW	Analog	Direct	3-Stage vacuum washers 4-stage vacuum washers	2 1
20	Northwest	11 Batch	Sliding-gate valve	SW	Computer	Direct	3-Stage vacuum washers 4-stage vacuum washers	2 1
26	South	2 Kamyr continuous	High pressure feeder	HW & SW	Analog	Indirect	In-digester washing; 2-stage vacuum washers	2
29	South	2 Kamyr continuous	High pressure feeder	HW & SW	Computer	Indirect	In-digester washing; 2-Stage vacuum washer; Kamyr diffusion washer	
33	South	1 M&D continuous	Metering feeder	SW	Analog	Direct	3-Stage vacuum washers; 2-Stage vacuum washer with vacuum assist	
36	South	19 Batch[2]	Manual	SW	Computer	Indirect	3-Stage vacuum washers	2
38	South	6 Batch; 1 Kamyr continuous	Capping valve	SW & HW	Computer	Direct	3-Stage vacuum washers; 2-Stage vacuum washers	

1. Hardwood and softwood.
2. Modified Kraft pulping process used to make dissolving pulp.

Table 12. General job categories for pulping operations.

Job Category	Mill Code								
	01	08	11	20	26	29	33	36	38
Digester operator	1	1	1	1	1[d]	2[e]	1[g]	2	2[h]
Chip feeders	-	-	2	-	-	-	-	2	-
Wash and screen operator	1[a]	1	4[b]	2	2[d]	-	-	1	1
Tester	1	1	2[c]	1	1	3[f]	-	1	1
Utility employee	1	1	-	-	-	-	-	-	1

a. Also responsible for bleach plant including the chlorine dioxide generator and vaporizer.
b. Washer room operator, two helpers, and a screen room operator.
c. Pulp tester (brown stock washers, refiners) and stock sampler (digesters).
d. Control room operator, responsible for the digesters, lime kiln, and the recausticizing operations; and two assistant pulp mill operators (one for the digesters, washers, and chip silo; the other for the deknotters, screens, and deckers).
e. One operator for each continuous digester and associated vacuum drum washers on Kamyr displacement washer line.
f. Collect and analyze samples from the pulp mill and the bleach plant.
g. Operates M&D digester and a one-stage vacuum washer.
h. Separate operators for the batch and continuous digesters.

Table 13. Personal air monitoring data in Kraft processing mills.

Mill No.	Job Category	Number Samples	Concentration Range	Concentration Mean	Reference
Contaminant		Total Nuisance Dust (mg/m^3)			
11	1st Helper	2	0.56 - 0.88	0.72	Table 11-1
	2nd Helper	2	1.49 - 2.48	1.99	"
36	Chip Feeder	2	0.3 - 0.4	0.35	Table 36-1
Contaminant		Hydrogen Sulfide (ppm)			
01	1st Helper/Tester	4	<0.04 - <0.07	<0.07	Table 01-1
	2nd Equipment Tender	5	<0.01 - <0.11	<0.10	"
	Utility Worker	4	<0.01 - 0.08	<0.08	"
08	Tester	6	<0.05 - 0.12	<0.07	"
	Utility Worker	3	<0.06 - 0.20	<0.20	"
11	Pulp Tester	5	0.06 - 0.30	0.16	Table 11-1
	Sampler	3	0.22 - 0.80	0.41	"
	1st Helper	2	0.13 - 0.86	0.50	"
	2nd Helper	1		0.05	"
	Washer Operator	2	0.22 - 0.33	0.28	"
	Screen Room Operator	1		0.10	"
20	Asst. Brown Stock Washer	3	0.08 - 0.16	0.12	Table 20-2
26	Asst. Operator (Knotters)	2	0.7	0.7	Table 26-1
36	Washer Operator	1		0.05	Table 36-1
Contaminant		Methyl Mercaptan (ppm)			
01	1st Helper/Tester	3	<0.04 - <0.11	<0.11	Table 01-1
	2nd Equipment Tender	2	<0.05	<0.05	"
	Utility Worker	3	<0.05 - 0.13	<0.13	"
08	Tester	12	<0.05 - 0.26	<0.01	Table 08-1
	Utility Worker	4	<0.05 - 0.91	<0.40	"
11	Tester	5	<0.03 - 0.06	<0.05	Table 11-1
	Sampler	3	<0.03 - 0.08	<0.05	"
	1st Helper	2	<0.03 - 0.06	<0.05	"
	2nd Helper	1		0.20	"
	Washer Operater	2	<0.03 - 0.03	<0.03	"
	ScreenRoom Operator	1		<0.03	"
20	Brown Stock Worker	4	<0.03 - 0.20	<0.10	Table 20-2

Table 13. Personal air monitoring data in Kraft processing mills. (cont'd)

Mill No.	Job Category	Number Samples	Concentration Range	Concentration Mean	Reference
26	Asst. Operator (Knotters)	3	2.6 - 3.5	2.9	Table 26-1
	Asst. Operator (Digester)	3	1.4 - 4.5	3.3	"
	Pulp Tester	3	<0.02 - 1.9	<1.0	"
	Utility Worker	1		1.0	"
29	1st Asst. Operator (Hardwood)	3	0.3 - 0.6	0.43	Table 29-1
	1st Asst. Operator (Softwood)	3	<0.2 - 0.4	<0.27	"
33	Operator	3	<0.07 - <0.08	<0.08	Table 33-1
36	Chip Feeder	4	0.6 - 3.3	1.7	Table 36-1
	Cook	4	<0.02	<0.02	"
	Crew Leader	2	<0.02 - 0.30	<0.30	"
	Solution Mixer Operator	2	<0.3	<0.30	"
	Washer Operator	4	<0.2 - 0.2	<0.2	"
38	2nd Asst. Operator	3	<0.08 - 0.18	<0.13	Table 38-1
	3rd Asst. Operator	4	0.16 - 0.83	0.52	"
	Digester Helper	2	0.08 - 1.10	0.56	"

Table 14. Area air monitoring data for reduced sulfur compounds in Kraft processing mills.

Mill No.	Location	Reference	Hydrogen Sulfide Number Samples	Hydrogen Sulfide Concentration Maximum	Hydrogen Sulfide Concentration Mean	Methyl Mercaptan Number Samples	Methyl Mercaptan Concentration Maximum	Methyl Mercaptan Concentration Mean	Ethyl Mercaptan Number Samples	Ethyl Mercaptan Concentration Maximum	Ethyl Mercaptan Concentration Mean	Dimethyl Sulfide Number Samples	Dimethyl Sulfide Concentration Maximum	Dimethyl Sulfide Concentration Mean
	Contaminant (ppm)													
01	Control Room	Table 01-2	1		<0.012	1		<0.008						
	Operating Floor	"	2	<0.09	<0.05	2	<0.05	<0.04	2	<0.09	<0.05	2	<0.05	<0.03
	Mezzanine	"	1		0.02	1		0.06						
	Bottom of Digester	"				1		<0.01	1		<0.01	1	<0.007	
	Blow Tank	"				1		0.01	1		<0.01	1	<0.007	
08	Brown Stock Washer	Table 08-2	3	0.04	0.02	3	0.67	0.33						
	Brown Stock Washer Control Room	"	2	0.14	0.08	2	0.08	0.08						
	Digester Floor	"	1		7.5									
	Digester Control Room	"	2	0.08	0.07	2	0.02	0.01						
	Presteaming Vessel	"	1		0.007	1		0.01						
11	Digester Area	Table 11-2	4	1.00	0.34	4	0.90	0.31						
	Digester Control Room	"				1		0.02						
	Screen Room	"	2	0.14	0.10	2	0.03	<0.03						
	Brown Stock Washer	"	1		0.12	1		0.93						
20	Chip Mezzanine	Table 20-2	1		0.15	2	0.27	0.24						
	Digester Area	" 20-2				1		0.13						
	Control Room	"				1		0.01						
26	Digester Floor	Table 26-2	1		0.2	1		0.6						
	Control Room	"	1		0.7	5	5.3	4.61	1*		3.0	5*	20	13
	Test Shack	"	1		0.9	2	4.2	4.0				1*		13
	Brown Stock Washer	"	1		0.6									
29	Digester Area	Table 29-2	3			2	0.80	0.48				3*	5	3
	Control Room	" 29-3				1*		ND				2*	7	6
	Pulp Testing Lab	"				2	0.05	<0.04				1*		1
	Chip Bin Penthouse	Table 29-3	1*		20	1*		40	1*		15	1*		>15
	Chip Bin Penthouse	" 29-2				3	8.5	6.9						
	Knot Washer	Table 29-2				1		2.8						
	HVAC Intake	"				2	0.06	<0.05						
	HVAC Return	"				2	1.0	0.6						
	Black Liquor Filter	" 29-3				1*		ND				2*	7	6
33	Control Room	Table 33-1				3	0.08	0.03						
	Near Blow Tank Relief Valve	"				1		0.24						
	In Blow Tank Relief Valve Plume	"	1*		ND	1*		15	1*		17			
	Brown Stock Washer	"	2*		ND	1*		2	1*		1			
	Brown Stock Washer Control Panel	"				1		0.05						
36	Chip Feeder Floor	Table 36-2	1		0.2	1		0.2						
	Chip Feeder Floor	"	1*		ND	1*		1				3*	8	4
	Digester Control Room	"				1		0.04				2*	<1	<1
	Brown Stock Washer	"	4	0.4	0.2									
	Brown Stock Washer	"	1*		ND	2*		ND				3*	0.2	<0.2
38	Control Room	Table 38-2				2	0.06	0.06						
	Testing Lab	"				1		0.2						
	Kamyr Chip Bin	"				1		0.8						
	Presteaming Vessel	"				1		0.03						
	Brown Stock Washer	"				2	<0.04	<0.03				1*		8

*Evaluation made using detector tubes.

Table 15. Area air monitoring miscellaneous compounds in Kraft processing mills.

Mill No.	Location	Reference	Turpentine Number Samples	Turpentine Concentration Maximum	Turpentine Concentration Mean	Other Terpenes Number Samples	Other Terpenes Concentration Maximum	Other Terpenes Concentration Mean	Resin Acids Number Samples	Resin Acids Concentration Maximum	Resin Acids Concentration Mean	Ketones Number Samples	Ketones Concentration Maximum	Ketones Concentration Mean
Contaminant (ppm)														
01	Digester Floor	Table 01-2	1		0.035									
11	Digester Floor	Table 11-2				2	1.6	1.1	2	<0.05	<0.03	2	0.47	0.25
	Control Room	"				2	6.6	5.2	2	<0.05	<0.04	2	0.21	0.18
	Screen Room	"				1		0.16	1		0.01	1		0.06
	Washer Room	"				1		0.12	1		0.05	1		0.07
29	Control Room	Table 29-2	3	1.0	0.44	3	<0.2	<0.02	1		<0.24			
	Steaming Vessel	"	2	0.9	0.50	2	<0.03	<0.02	1		<0.14			
	Pulp Test Lab	"				2	<0.02	<0.02						
	Chip Bin Penthouse	"	3	18	8.0	3	<0.45	<0.23	2	<6.8	<4.1			
	Knot Washer	"	1		0.9	1		<0.01						
	HVAC Intake	"	2	0.05	0.03	2	<0.01	<0.01	1		<0.14			
	HVAC Return	"	1		0.14	1	<0.02	<0.02						
36	Digester Control Room	Table 36-2	1		1.6									
	Chip Feed Floor	"	1		15.3									
38	Control Room	Table 38-2	2	0.75	0.63	2	<0.01	<0.01						
	Chip Bin	"	1		13.9	1		<0.01	1		<0.12			
	Chip Loading Floor	"	1		1.5	1		<0.01						
	Brown Stock Washer	"							1		<0.13			

Mill No.	Location	Reference	Phenols Number Samples	Phenols Concentration Maximum	Phenols Concentration Mean	Alcohols Number Samples	Alcohols Concentration Maximum	Alcohols Concentration Mean	Other Organics Number Samples	Other Organics Concentration Maximum	Other Organics Concentration Mean
Contaminant (ppm)											
11	Digester Floor	Table 11-2	2	<0.03	<0.02	2	3.2	1.8	2	0.48	0.32
	Control Room	"	2	<0.03	<0.03	2	1.0	0.8	2	4.3	3.0
	Screen Room	"	1		<0.01	1		0.36	1		0.03
	Washer Room	"	1		<0.03	1		0.5	1		0.09
29	Control Room	Table 29-2				1		0.09	3	0.4	<0.13
	Steaming Vessel	"				1		0.07	2	<0.04	<0.03
	Pulp Test Lab	"							2	0.7	<0.04
	Chip Bin Penthouse	"				2	4.5	3.8	3	2.6	<1.15
	Washer Platform	"							1		<0.01
	HVAC Intake	"				1		0.07	2	0.26	<0.15
	HVAC Return	"							1		<0.04
38	Control Room	Table 38-2							2	<0.02	<0.02
	Chip Bin	"							1		<0.02
	Chip Loading Floor	"	1		<0.02	1		<0.12	1		<0.02
	Brown Stock Washers	"	1		0.13	1		2			

Table 16. Control rooms and worker isolation for pulp processing and bleaching.

Mill Number	Estimated Percentage of Time in Control Room: Digester Operators	Chips Feeders	Washer Operators	Testers	Utility Employees	Description of Control Room, Type of Air Handling System, and Comments
01	90	-	90	75	30	Central control room for all pulping and bleach plant operations; recirculating HVAC system with fresh air make-up; positive pressure with double doors.
08	90	-	90	80	40	Digester control room has 100% recirculating HVAC system; wash and screen control room has recirculating heating system and forced fresh air system for warm weather.
11	90	70	0* 90	50** 85	-	Digester control room has 100% recirculating system; there is no stock washing control room; screening control room has 100% recirculating system.
20	90	-	80	-	-	Central control room; recirculating HVAC system with fresh air make-up; positive pressure.
26	95	-	35	70	-	Central control room with 100% recirculating HVAC system.
29	90	-	-	80	-	Central control room HVAC system designed for 90% recirculation and 10% fresh air make-up; both return and make-up air passes through Purafil filters; positive pressure.
33	90	-	-	-	-	Digester control room HVAC system 100% recirculation.
36	70	0	70	90	-	Digester control room on ground floor below batch digesters; 100% recirculating HVAC system; stock washing operator remains in sound booth adjacent to control panels.
38	90	-	65	75	30	Central control room; HVAC system is 80% recirculation and 20% fresh air make-up, and both air streams pass through Purafil filters; positive pressure with double doors.

* Top percentage is washer operator; bottom is screen room operator.
**Top percentage is pulp tester; bottom is stock sampler.

Table 17. Brown stock washer exhaust systems.

	Mill 01	Mill 08	Mill 11	Mill 20	Mill 26	Mill 29	Mill 33	Mill 36	Mill 38
Type of hood	Closed	Canopy (perimeter curtains)	Canopy (2 hoods, 3 lines)	Canopy[4] (3 lines)	Canopy (2 lines)	Canopy[5]	Canopy	Canopy (2 lines)	Canopy (2 lines)
Design CFM	28,000	20,000	150,000 90,000	22,000 16,500 16,500	--	60,000	--	--	75,000[7] Unknown
Measured CFM	--	--	--	--	--	42,000	--	--	--
Average face velocity (fpm)[1]	100-350[3]	0-150	--	50	100-250	--	150-250	50-250	100-250 100-200
Estimated air[2] changes/hour	--	2.2	9 18	--	--	9	--	--	7.5
Separate knotter hood (and face velocity)	Canopy 150-300 fpm	No	No	No	No	Canopy[6] 10,000 cfm (measured) 50-200 fpm	No	Canopy (1 line) 100-150 fpm	No
Exhaust treatment	Incinerator	Incinerator	Vent to atmosphere	Vent to atmosphere	Vent to atmosphere	Vent to atmosphere	Vent to atmosphere	Vent to atmosphere	Vent to atmosphere

1. Not an actual face velocity; measurement taken in vertical plane just below side of hood.
2. Estimated by dividing design cfm by appropriate hood volume.
3. Actual face velocities through open observation ports.
4. Plus canopy hood for reject screens.
5. One line uses Kamyr diffusion washer.
6. Also closed hood for bleach liquor filters.
7. Has vacuum assist system.

KRAFT CHEMICAL RECOVERY - BLACK LIQUOR EVAPORATORS AND RECOVERY FURNACES

Black liquor evaporation operations were surveyed in two Kraft pulp mills (31, 34), and recovery furnaces in one mill (18). For detailed process descriptions, and evaluation of control technology, refer to the individual mill reports.

Process Abstract

Spent black liquor is concentrated in multiple-effect vacuum evaporators, may be stabilized in oxidation towers, and is then pumped to a deaeration tank to remove entrapped air. The evaporator condensate, collected in one or more hot wells, is either pumped to a stripping tank or sewered. The non-condensable gases may be vented to an incinerator or to a lime kiln. From the deaeration tank, liquor is pumped through the bottom of an electrostatic precipitator, a chemical ash tank, and two ash hoppers to recover additional solids. The liquor overflows the hoppers into a cascade evaporator where it contacts hot flue gases for additional evaporation. It is then pumped through a salt cake mix tank, and injected with steam in primary and secondary heaters. Finally, the concentrated liquor is sprayed into the center of a hearth in a recovery furnace. Organic compounds are combusted, and the inorganic compounds are oxidized and melted, and flow down into a smelt bed. These molten chemicals are reduced, and then discharged through water-jacketed smelt spouts into a dissolving tank. The resulting green liquor is pumped to green liquor mixing or storage/clarification facilities in the recausticizing area.

Job Categories and Descriptions

The evaporators in the mills surveyed (Mills 31 and 34) are operated by a single employee working out of the recovery boiler building or a separate control room located between two sets of evaporators. Normal duties are similar and include:

- Monitoring and controlling the process.

- o Taking periodic temperature and specific gravity measurements of the strong and weak black liquors.

- o Conducting water and acid boil-outs (cleaning) of the evaporators.

- o Conducting periodic inspections of the process equipment.

- o Recording process data in production logs.

The operator is usually inside the control room about 80 percent of each shift.

In Mill 18, a control room operator is responsible for the operation of both recovery furnaces. He monitors and adjusts the process from a control room, and conducts frequent equipment inspections. It is estimated that he spends 90% of each shift in the control room. A helper cleans the char bed ports, clears the smelt spouts, and collects and tests process samples. He remains near the furnaces for most of each shift.

Air Sampling Data

A total of 16 personal samples (Table 18) were collected for hydrogen sulfide on evaporator operators during routine inspection tours and quality control sampling runs. Approximately half of these samples were taken while one of two sets of evaporators in each mill were being boiled out with water. None of the samples resulted in exposures above 0.13 ppm, which is well below the OSHA ceiling PEL of 20 ppm. In twelve of the samples (75 percent), no hydrogen sulfide was detected (detection limits ranged from 0.01 ppm to 0.07 ppm). Three of four area samples collected in control rooms resulted in non-detectable levels of hydrogen sulfide (<0.02 ppm); the remaining sample resulted in a very low level (0.03 ppm). These data demonstrate that worker exposure to hydrogen sulfide is usually very low under normal operating conditions, primarily because evaporators and associated equipment are closed and located outdoors.

Eight sets of area samples (Table 19) collected in the recovery furnace building were analyzed for hydrogen sulfide, sulfur dioxide, and methyl mercaptan.

Sulfur dioxide was not detected (<0.002 ppm) in any of the samples; and methyl mercaptan and hydrogen sulfide levels were very low (0.03 to 0.24 ppm; 0.01 to 0.65 ppm respectively). Unless there is a major upset, employee exposure to air contaminants in recovery furnace buildings should be low.

Control Technology

In Mills 31 and 34 the evaporator operators are usually not exposed to significant levels of hydrogen sulfide or other air contaminants primarily because:

- The processes are totally closed.
- The evaporators and other equipment are located outside and are very well maintained.
- The operators are frequently inside control rooms, and therefore isolated from the potential sources of exposure.
- The hotwells are sealed, and the non-condensable gases are vented to an incinerator or to a lime kiln.
- Contaminated process water is piped to a feed tank where contaminants are stripped with air (Mill 31), or passed through sealed drains into the combined pulp mill sewer (Mill 34).
- Both mills have continuous workplace monitoring and alarm systems for hydrogen sulfide -- a four-channel system is used in Mill 34; a single monitor is used in Mill 31.

There are several aspects of Kraft recovery furnaces that combine to preclude extensive employee exposure to air contaminants during normal operation:

- With the exception of the recovery furnace exhaust stack and the green liquor dissolving tank vent, the process is totally closed. There are no sources of workplace emission except from leaks, process upsets, and possibly certain maintenance activities.

- Except for the recovery furnace and the dissolving tank, all process tanks and equipment are located outside where natural ventilation can disperse and dilute any emission of contaminants.

- The recovery furnace is operated at a negative internal pressure of up to 0.5 inch of water (a pressure sensor located before the superheater tubes near the top of the furnace is connected to the induced draft fan to maintain this pressure differential). This negative pressure effectively prevents the escape of gases.

Table 18. Air monitoring for hydrogen sulfide near multi-effect evaporators.

Mill No.	Job Category or Location	Number Samples	Concentration (ppm) Range	Mean	Reference
31	Assistant Operators	10	<0.01 - <0.07	<0.04	Table 31-1
	Control Room	2	<0.02 - 0.03	<0.03	"
	Near 7th Effect	1		<0.02	"
34	Operators	6	<0.04 - 0.13	<0.08	Table 34-1
	Control Room	2	<0.02	<0.02	"

Table 19. Area sampling near recovery furnace.

Location	Number Samples	Concentration (ppm) Range	Mean	Number Samples	Concentration (ppm) Range	Mean
Contaminant		Hydrogen Sulfide			Methyl Mercaptan	
Control Room	2	<0.02 - 0.05	<0.03	2	0.04 - 0.24	0.14
Operating Areas	4	<0.01 - 0.05	<0.03	4	0.02 - 0.17	0.11
Near Char Ports	2	0.08 - 0.65	0.37	2	0.03 - 0.08	0.05

* Reference: Table 18-1. In addition, all (8) determinations for sulfur dioxide were below the detectable limit (0.002 ppm).

KRAFT CHEMICAL RECOVERY - RECAUSTICIZING AND LIME BURNING

Liquor causticizing and lime mud burning operations were surveyed in three Kraft pulp mills. Major steps and equipment used for these two operations are summarized below.

Process Abstract

Two important operations in recovering Kraft pulping chemicals are: 1) reacting (causticizing) green liquor (sodium carbonate and sodium sulfide) with quicklime (calcium oxide) to form fresh white liquor (sodium hydroxide and sodium sulfide) and lime mud (calcium carbonate); and 2) burning (calcining) the lime mud in rotary lime kilns to regenerate quicklime. The overall major steps in these two inter-related operations are:

1. Clarifying (settling) green liquor.

2. Slaking (dissolving) quicklime with green liquor, and removing (classifying) insoluble matter (dregs) [$CaO + H_2O \rightarrow Ca(OH)_2$].

3. Washing the dregs to recover lost sodium.

4. Causticizing the green liquor with calcium hydroxide (formed during the slaking step) to make white liquor and insoluble lime mud [$Na_2CO_3 + Ca(OH)_2 \rightarrow 2\ NaOH + CaCO_3$].

5. Clarifying the white liquor, and separating and recovering the lime mud.

6. Washing the lime mud to recover lost sodium.

7. Thickening the lime mud.

8. Burning the mud in rotary kilns (or fluidized bed calciners) to convert it back to quicklime [$CaCO_3 \rightarrow CaO + CO_2$].

Equipment used to perform the steps can vary from mill to mill, but is usually very similar. Table 20 summarizes the processes and equipment for the surveyed mills.

Job Categories and Descriptions

The number of kilns and/or liquor causticizing lines, and the degree of process automation, determine the size of the work force and worker duties. The number of workers and their task assignments in the surveyed mills are summarized in Table 21. The major tasks are:

- o Process monitoring and control (performed inside a control center located near the kiln firing ends).
- o Equipment inspections and manual adjustments, and cleaning mud and white liquor filters (if used).
- o Process quality control sampling and testing.
- o Housekeeping and spill cleanups.

Air Monitoring Data

Table 22 summarizes potential physical and chemical workplace contaminants, and their potential emission sources. The primary potential contaminant during routine operations is process dust - a variable combination of quicklime (CaO), limestone ($CaCO_3$), calcium hydroxide ($Ca(OH)_2$), sodium sulfide (Na_2S), and other minor inorganic salts. Quicklime or limestone is probably the predominant component in direct kiln emissions, but workplace dusts undoubtedly vary widely in composition, and potentially contain wood dust and other environmental particulates.

Extensive personal and area monitoring data were collected for process dust (as total particulates), and are summarized in Tables 23 and 24. A few investigative area and personal samples were collected also for hydrogen sulfide, mercaptans, and caustic mist.

Control Technology

Table 25 summarizes factors which influence control of dust and other contaminants in the surveyed mills. They include:

- o Process characteristics - most dust-handling equipment is closed and automated; significant quantities of hydrogen sulfide or other reduced sulfur gases do not normally offgas from green and white liquor.

- o Equipment isolation - kilns, lime storage silos, slakers, causticizers, and green and white liquor clarification and storage tanks are usually outside; lime mud filters are usually inside unoccupied buildings at a kiln feed/exhaust end.

- o Worker isolation - except for utility workers, all other employees are inside protective control rooms for over fifty percent of their shift.

- o Dust emission controls - kiln exhaust cyclones and scrubbers, and slaker and lime silo vent scrubbers, are commonly used.

- o Respiratory protection - all mills provide at least disposable dust masks for their workers.

- o Housekeeping and spill cleanup procedures - all the mills had at least a part-time worker who regularly cleaned process areas.

The air monitoring results and survey observations indicate process dust poses the greatest exposure risk, but there are few sources of emissions when equipment is operating correctly. Failure of kiln air seals or leaks in the kiln exhaust, hot lime transport, or slaker feed systems can result in dust emissions and workplace contamination, but only workers who are frequently outside control rooms (utility, testing, and kiln exhaust-end workers) are probably at risk of overexposure. Respirators and other personal protective equipment were often worn by workers cleaning up dust spills. Canopy-type exhaust hoods are often placed over indoor lime mud (and white liquor) filters to contain and remove steam. However, they may also help control escape of hydrogen sulfide

(from the white liquor) and hydrochloric acid (from the washing solution) during filter cleaning.

Table 20. Description of recausticizing and kiln operations surveyed.

Operation	Mill 16	Mill 19	Mill 27
Recausticizing:			
Green liquor clarification	1 - single tray	2 - double tray	2 - single tray
Dregs Washing	Yes	Yes	Yes
Slakers	1	3 - with separate storage silos	2 - with common storage silos
Causticizers	1 line; 3 stages	3 lines; 3-4 stages each	1 line; 6 stages
White liquor clarification	2 - single tray	2 - single tray	3 filter drums (parallel)
Mud Washer	1 - single tray	2 - one with double trays	Not used
Mud Filtering	1 drum filter	3 drum filters	2 drum filters
Lime Burning:			
Kilns	1 - rotary	3 - rotary	2 - rotary
Burn noncondensible gases	Yes	2 of 3 kilns	No
Lime Make-up	Quicklime	Quicklime	Limestones

Table 21. Job categories and tasks for kiln and liquor processing workers.

Mill No.	Total No. of Workers	Job Categories	Job Tasks
16	2	Operator	All major tasks
		Utility worker (day)	Housekeeping and spill clean-ups
19	3	Kiln operator	Monitoring, control, inspection, and process testing of the kilns.
		Causticizing operator	Monitoring, control, inspection, and testing of the causticizing lines.
		Utility worker (part-time pulp mill worker)	Housekeeping and spill clean-up, as needed.
27	5	Chief operator	All process monitoring and control operations and direction of other workers.
		Assistant operator*	Assisting operator in all process monitoring and control operations.
		First helper (tester)	Process quality control sampling and testing.
		Second helper	Operation and servicing of white liquor and lime mud filters.
		Utility person	Housekeeping and spill clean-up.

*This worker also spends up to 50% of a shift operating nearby equipment used to prepare an alkaline sulfite pulping liquor.

Table 22. Potential workplace contaminants in pulp mill liquor processing.

Potential Contaminant	Potential Sources	Mills Investigated 16	19	27
Process dust	- Leaks in the hot lime discharge chute, chain conveyor, and bucket elevator. - Leaks in the hot lime transport and feeding system from storage silos to slackers. - Leaks in kiln exhaust gas ducts (after induced draft fans). - Leaks in kiln exhaust end air seals. - Discharge side of white liquor or lime mud drum filters.	Yes	Yes	Yes
Hydrogen sulfide	- Slaker tank vents and openings. - Off-gassing from green liquor, causticizer, and white liquor storage tanks. - Off-gassing from green or white liquor when mixed with acid during cleaning white liquor or mud filters. - Leaks in pulp mill noncondensible waste gas systems (when burned in kiln).	Yes	No	No
Mercaptans and reduced sulfur compounds[2]	- Leaks in pulp mill noncondensible waste gas systems (when burned in kilns).	Yes	No	N/A
Caustic mist	- Slaker tank vents and openings.	Yes	No	No
Noise	- Kiln air fans and fuel guns. - White liquor and lime mud drum filters. - Miscellaneous motors and pumps.	Yes	Yes	Yes
Heat	- Kilns (primarily around enclosed firing ends).	Yes	Yes	Yes

1. Process dust can be a combination of quicklime (CaO), calcium carbonate ($CaCO_3$), calcium hydroxide ($Ca(OH)_2$), and sodium sulfide (Na_2S), plus a number of miscellaneous inorganic salts.
2. Mercaptans and other reduced sulfur compounds are of concern mainly when pulp mill noncondensible gases are burned in a kiln, although very small amounts may off-gas from hot green liquor.

Table 23. Personal air monitoring data in Kraft chemical recovery systems.

Mill No.	Job Category	Number Samples	Concentration Range	Concentration Mean	Reference
Contaminant			Total Nuisance Dust[1] (mg/m^3)		
16	Operator	2	0.15 - 0.51	0.33	Table 16-2
	Utility Worker	1		<0.66	Table 16-2
19	Kiln Operator	1		0.6	Table 19-2
	Recausticizing Operator	1		0.2	Table 19-2
27	Filter Operator (2nd Helper)	4	9.38 - 20.05	12.67	Table 27-1
	Utility Worker	4	1.14 - 2.81	1.96	Table 27-1
Contaminant			Hydrogen Sulfide[2] (ppm)		
16	Operator	4	All<0.1	<0.1	Table 16-2
Contaminant			Mercaptan[3] (ppm)		
16	Operator	4	All<0.04	<0.04	Table 16-2
	Utility Worker	1		<0.01	Table 16-2

1. Total dust samples were collected on closed-face, pretared 5.0 um PVC filters and analyzed gravimetrically.
2. Samples were collected and analyzed according to NIOSH Method P&CAM 126.
3. Samples were collected and analyzed according to the method of Knarr and Rappaport, Anal. Chem. 52:733-736 (1980).

Table 24. Area air monitoring data in Kraft chemical recovery systems.

Mill No.	Location	Number Samples	Concentration Range	Concentration Mean	Reference
Contaminant			Total Nuisance Dust[1] (mg/m^3)		
27	Control Room	3	0.16 - 0.28	0.24	Table 27-1
Contaminant			Hydrogen Sulfide[2] (ppm)		
16	Lime Kiln Control Room	1		<0.02	Table 16-1
	Kiln, Firing End	1		<0.04	Table 16-1
19	Control Room	1		<0.02	Table 19-2
	Control Room[4]	1		ND	Table 19-2
	Kiln, Firing End	1		<0.02	Table 19-2
	Kiln, Firing End[4]	1		ND	Table 19-2
	Green Liquor Clarifier[4]	1		ND	Table 19-2
27	White Liquor Filter	3	All<1.0	<1.0	Report p. 27-12
Contaminant			Mercaptan[3] (ppm)		
16	Control Room	1		0.008	Table 16-1
19	Control Room[4]	1		ND	Table 19-2
	Kiln, Firing End[4]	1		ND	Table 19-2
	Green Liquor Clarifier[4]	1		ND	Table 19-2

1. Total dust samples were collected on closed-face, pretared 5.0 µm PVC filters and analyzed gravimetrically.
2. Samples were collected and analyzed according to NIOSH Method P&CAM 126.
3. Samples were collected and analyzed according to the method of Knarr and Rappaport, Anal. Chem. 52:733-736 (1980).
4. Draeger Tube

Table 25. Control technology in pulp mill liquor processing operations.

Type of Control	Mill 16	Mill 19	Mill 27
Protected Control Center			
100% air recirculation	No	No	Yes
Make-up air and positive pressure	Yes	Yes	No
Entranceway air-locks	No	Yes	No
Equipment Isolation (outside)			
Kilns	Yes	Yes	Yes
Slakers and causticizers	Yes	Yes	Yes
Green and white liquor clarifiers and storage tanks	Yes	Yes	Yes
Lime mud filters	Inside with hood	Inside with hood	Inside with hood
White liquor filters	N/A	N/A	No
Air Pollution Controls			
Kiln cyclones and scrubbers	Yes	Yes	Yes
Slaker vent scrubbers	Yes	Yes	Not known
Burning of pulp mill noncondensibles	Yes	Yes	No
Housekeeping and Spill Clean-up (for process dust control)	Yes (part time)	Yes (part time)	Yes (full time)
Respiratory Protection	Yes	Yes	Yes
Hearing Protection	Not required	Not required	Available
Ventilation of hot lime transport systems	No	No	Yes

SULFITE PULPING AND BROWN STOCK WASHING

Sulfite pulping and brown stock washing operations were surveyed in three pulp mills. Detailed process descriptions and evaluations of control technologies are presented in Mill Reports Nos. 21, 28, and 39.

Process Abstract

Typical major unit operations associated with sulfite pulping include:

1. Preparation of pulping liquor (acid sulfite, bisulfite, or neutral sulfite) by:

   a. Burning liquid sulfur in rotary burners to produce sulfur dioxide gas.

   b. Cleaning and absorbing the sulfur dioxide gas in a soluble chemical solution (usually in packed towers).

   c. Fortifying (strengthening) this weak fresh liquor with hot sulfur dioxide-containing gases from the digesters, liquor recovery, and/or brown stock washing systems.

2. Loading of digesters with chips and liquor.

3. Cooking chips under regulated pressures, temperatures, and times using direct or indirect steam heat.

4. Relieving digester pressure, and recovery of spent gases and liquor [typically, gases are relieved through manifolds to the fresh liquor fortification system; liquor is either concentrated in steam-heated evaporators and used to make saleable by-products (either yeast or alcohol), or burned to produce heat or recover the base].

5. Pulp washing (in-digester, vacuum- or pressurized-drum, and extraction-belt type washers).

There is considerable variety in: types of sulfite pulping liquors; equipment for liquor preparation, chip cooking, chemical recovery, and pulp washing; and pulp mill layout and staffing. Table 26 summarizes important variables for the three surveyed mills.

Job Categories and Descriptions

Because the staffing arrangements in the three mills are dissimilar, job categories and descriptions are summarized separately.

In Mill 21, the cook and assistant cook are equally involved in all phases of the digestion process. They control and monitor the process from a control room on the digester loading level but are frequently near the digesters to conduct liquor tests, load the digesters, and operate manual and semi-automatic process equipment. Approximately 25 percent of their shift is spent in the process area. Liquor preparation, gas and liquor recovery, and brown stock washing operations are all conducted by other workers.

The three-man staff in Mill 28 operates an automated neutral sulfite semi-chemical pulping process and an adjoining Kraft process. The operator is responsible for both, and has a highly variable work routine. The two assistant operators service the washer lines, adjust and inspect process equipment, take tank measurements, clean stock spills, and perform general cleanups of process areas. The operator is in the process area about 30 percent of the shift, whereas the assistant operators work 50 - 70 percent of the time in this area.

The chief operator in Mill 39 monitors and adjusts the pulping process from a control room, remote from the operating floor; and directs the two assistants. The assistants load the five digesters, monitor cooking conditions, wash the cooked pulp while it is in the digesters, and pump it to the brown stock pits. The assistants are in the processing area about 75 percent of their shift and the chief operator is in this area only about 20 percent of this time.

Air Sampling Data

Personal exposure monitoring for sulfur dioxide was conducted only in Mill 21. Results are summarized in Table 27. Calculated TWA exposures for the cook and assistant cook were consistent (0.9, 0.9, 0.9, 0.9, 2.2 ppm), and are below the OSHA PEL of 5 ppm. The samples collected when the workers were outside tne control room are more variable, and range from 0.4 ppm to 5.0 ppm. Thus, the calculated TWA exposures are low primarily because workers remain in the control room (where SO_2 level is 0.5 - 0.6 ppm) for the majority of each shift. Detector tube samples near the digesters in this mill showed highly variable concentrations ranging to 100 ppm directly above an open digester during loading. Detector tube readings taken at various workplace locations indicate

sulfur dioxide levels are usually low (<0.5 ppm). This is because the continuous M&D digester is closed, and the alkaline sulfite liquor contains (or results in production of) little free sulfur dioxide (i.e., only 12 ppm was measured directly in the blow tank vent).

In Mill 39, sulfur dioxide concentrations on the digester operating floor (within 15 feet from the digesters) were measured over a consecutive 29-hour period using an Interscan SO_2 Monitor. Concentrations ranged from 1 ppm to over 10 ppm, and varied according to the loading and emptying cycles of the nearby digesters. Detector tube results collected in the breathing zone of workers near the digesters revealed periodic exposures of up to 50 ppm.

Control Technology

In Mill 21, worker exposures to sulfur dioxide are controlled primarily because of worker isolation in the control room (for 75% of shift). Although the control room is not ventilated, the enclosure prevents excessive contamination, except during major process upsets. Sulfur dioxide levels in the workplace are largely a result of emissions when the digesters are opened for loading. The digester vent system designed to prevent these emissions is not fully effective; greater exhaust volume is required to improve its efficiency. Additional factors or systems which assist in minimizing exposure are:

- The process is almost totally closed, except during the digester loading operations.

- Digester relief gases are piped to a Jensen Tower for recovery.

- The liquor, blow, and stock tanks (and the Eimco stock washers) are vented into an overgas system that leads to a separate absorption tower (See Mill Report for a summary of corrective action undertaken following problems with this system).

Worker exposures in Mill 28 are low primarily because the cooking process is totally closed and continuous, and the digestion chemistry (alkaline sulfite)

minimizes free sulfur dioxide generation. The brown stock washers are hooded and well-ventilated.

The two workers on the digester operating floor in Mill 39 may be exposed to excessive levels of sulfur dioxide. The high exposures are attributed to the following factors:

- The general lack of process automation which necessitates two workers remaining on the operating floor in excess of 75% of their shifts.

- The ineffectiveness of the respirator program (The use of respirators is acceptable as a permanent control in Germany).

- The poor capture of sulfur dioxide (escaping through open digester tops during unloading and loading) by the loading cap exhaust system.

- No general ventilation of the digester operating floor.

Table 26. Sulfite pulping operations surveyed.

Mill No.	Location	Prod. Vol. (TPD)	Process Description	Digester Relief and Recovery System	Stock Washing Systems
21	Northwest	280	Ammonium-base acid sulfite with 8 batch digesters; semi-automated loading; manual capping; indirect heating; unloading pumps discharge to closed and exhausted stock tanks.	3-Stage relief pressure manifold to Jenson tower; liquor concentration for on-site yeast production.	In-digester washing; dual EIMCO belt-extraction type washers (hooded); single vacuum-drum not hooded) for final stage.
28	Southeast	170	Neutral sulfite semi-chemical with sodium sulfite, buffered alkaline liquor; continuous, modified M&D digester; double-disk mechanical refiner.	Continuous to flash tank, separator and surface condenser; waste liquor is stored and then chemicals recovered.	2-Stage, hooded vacuum-drum washers
39	Germany	220	Calcium-base acid sulfite with 5 batch digesters; semi-automated chip loading; manual capping; indirect heating; unloading pumps discharge to closed and ventilated stock pits.	3-Stage relief pressure manifold to fresh liquor fortification system; liquor is evaporated and used for on-site lignin recovery and alcohol production.	In-digester washing; 3-stage, pressurized drum washers (outside).

Taole 27. Air monitoring data for sulfur dioxide in sulfite processing.

Mill No.	Job Category/ Location	Sampling Method	Number Samples	Concentration Range	Concentration Mean	Reference
			Personal Monitoring*			
21	Cook	P&CAM 160	9	0.4 - 3.6	2.2	Table 21-2
	(Calculated TWA)		3	0.9 - 2.2	1.3	Table 21-2
	Assistant Cook	P&CAM 160	7	0.5 - 6.1	1.97	Table 21-3
	(Calculated TWA)		2	0.9	0.9	Table 21-3
			Area Monitoring			
21	Control Room	P&CAM 160	5	0.5 - 0.6	0.56	Tables 21-2,3
	Control Room	Detector tube	3	ND - 2.5		Table 21-4
	Near Digesters	Detector tube	8	ND - 25		Tabel 21-4
	Above Digester	Detector tube	2	>25 ->100		Table 21-4
28	Control Room	Detector tuoe	1	ND		Table 28-1
	Stock Washer	Detector tube	1	1		Table 28-1
	Pre-Steamer Feeder	Detector tube	1	ND		Table 28-1
	Washer Filtrate Tank	Detector tube	1	0.5		Table 28-1
	Blow Tank Vent	Detector tube	1	12		Table 28-2
39	Above digester	Detector tube	9	<0.5 - 50		Table 39-2
	8 feet from Digester	Detector tube	4	<0.5 - 25		Table 39-2

* Personal samples were taken whenever workers exited control rooms to perform tasks in processing areas; TWA exposures were calculated from these data plus results of composite samples taken in control room.

BLEACH CHEMICAL HANDLING AND PREPARATION OPERATIONS

Bleach chemical handling and preparation operations were surveyed in ten mills (01, 10, 12, 22, 25, 30, 32, 35, 37, and 39).

Process Abstract

All bleach plants have equipment and operating staffs to unload, store, dilute, and/or prepare various bleaching chemicals. Major operations for multi-stage bleach plants can include:

- o Liquid chlorine unloading and vaporization in steam-heated vaporizers.
- o Caustic soda unloading and dilution.
- o Hypochlorite solution preparation using chlorine gas and caustic soda.
- o Chlorine dioxide solution preparation using a one- or two-stage reactor and a one- or two-stage gas absorption tower.
- o Miscellaneous handling systems for chemicals such as sulfur dioxide, sulfuric acid, sodium chlorate, salt, and methanol. These chemicals are used primarily in the on-site generation of chlorine dioxide gas.

The specific operations surveyed are summarized in Table 28.

General Job Categories and Descriptions

The complexity, size, degree of automation, and location of equipment determine the number of required workers and the tasks they perform. Table 29 summarizes the specific staffing arrangements and worker assignments in the mills surveyed. Major work tasks common to all mills are:

- o Equipment monitoring and control.
- o Equipment inspecting and manual adjustments.
- o Unloading of incoming chemicals.
- o Housekeeping and spill cleanup.
- o Process quality control sampling and testing.

Air Monitoring Data

The primary air contaminants associated with bleach chemical handling and preparation operations are chlorine and chlorine dioxide. Extensive personal and

area monitoring data were collected for each or both; and the results are summarized in Tables 30 and 31, expressed as parts per million chlorine. Air sampling methods are summarized in Table 4. Minor potential workplace contaminants, for which limited or no data were collected, include caustic mist, sulfur dioxide, sulfuric acid, methanol, and sodium chlorate.

Control Technology

Table 32 characterizes the specific controls employed in each of the mills. The general types include:

- Process isolation - outside equipment or equipment located in isolated, unoccupied buildings.
- Local ventilation for chlorine dioxide generators.
- General ventilation (including natural ventilation of equipment located outside).
- Process characteristics - the closed nature of most equipment; process automation, monitoring and control systems, and alarms.
- Respiratory protection.
- Air monitoring systems.
- Worker isolation through use of control rooms.

Most handling and preparation equipment is: 1) outside, in remote buildings, or in areas of the bleach plant; 2) automated (Mill 22 excepted); 3) remotely operated; and 4) tightly closed. These conditions result in few potential sources of workplace contamination except as a result of an unusual upset or leak, or from a process startup/shutdown; i.e., excessive chlorine gas pressure, a leaking chlorine unloading line, high vaporizer temperatures, and startup or shutdown of a chlorine dioxide generator).

The personal monitoring data indicate that worker exposures are normally restricted to chlorine dioxide (potentially containing indeterminate amounts of chlorine) released during collection of some chlorine dioxide generator quality control samples (absorber, spent acid, and storage tank solutions). The exposures are of less than fifteen minutes duration and are controllable by: 1) locating sampling points outside or within small enclosures having some ventilation and flushable drains (see Mill 32 Report): 2) using respirators; and 3) training workers in better collection practices (standing upwind, using water to quickly flush the solutions into nearby drains, and standing away from sampling lines during initial flushing).

Area monitoring inside some normally unoccupied generator buildings indicates other intermittant workplace contamination and potential excessive exposure conditions occur. Unidentified generator leaks and brief direct chlorine dioxide emissions are associated with a generator startup, shutdown, or process change. Reactor puffs (explosions) relieved through a safety valve, sewer off-gasing when weak absorber solution is wasted, leaking seals or gaskets in gas or solution pipelines, or poor operation of the generator gas absorption tower cause high local chlorine dioxide concentrations. Exhaust hoods over reactor safety relief valves, restricted building entries, and general building ventilation are used to control potential exposures when these conditions exist. However, good process monitoring and control, equipment inspections and preventive maintenance, and locating and controlling specific emission points (sewer and equipment vents) are equally important.

Liquid chlorine unloading equipment and gaseous chlorine preparation and distribution systems (vaporizers, hypochlorite reactors, and piping networks) are completely closed and equipped with emergency gas expansion, pressure relief, and blowdown systems (eductors, air purge lines, and caustic tanks). Other controls used to reduce or warn of leaks and upsets and to insure protection of personnel include: process monitoring and alarm systems, preventative maintenance, respiratory protection (some northern mills require workers and visitors to carry respirators in designated areas), chlorine air monitoring and alarm systems, emergency escape and response plans, restricted building entries, special worker training, equipment isolation, and general ventilation (see Table 32).

Table 28. Summary of surveyed bleach chemical handling and preparation operations.

Mill No.	Location	Nature of Operations	Types of Operation/Equipment: Chlorine Dioxide Generator	Hypochlorite/ Caustic Reactors	Chlorine Unloading/ Vaporizing	Other
01	North Central	Integrated in bleach plant and operated by its staff	Hooker R-2	Inside and remotely operated	Inside bleach plant in separate room	None
10	North Central	Separate from bleach plant but operated same staff	Improved Solvay	Remotely operated in separate building	Remotely operated in separate building	None
12	South	Outside and separate from bleach plant; operated by bleach plant staff	Improved Solvay (outside)	Remotely operated and outside	Remotely operated but inside separate building	None
22	Northwest	Integrated in bleach plant and operated by its staff	Not used	Manually operated and inside	Remotely operated and outside	None
25	South	Integrated in bleach plant and operated by its staff	Hooker R-2 (outside)	Remotely operated and outside	Remotely operated and outside	None
30	Northeast	Separate from bleach plant; operated by separate staff	Modified Matheison	Remotely operated and inside	Remotely operated and inside	SO_2 Sol.*
32	South	Separate from bleach plant; operated by separate staff	ERCO and Matheison	Remotely operated and outside	Remotely operated and inside	SO_2 Gas*
35	South	Separate from bleach plant; operated by separate staff	Hooker R-2 (outside)	Remotely operated and outside	Remotely operated and inside	SO_2 Gas*
37	South	All except ClO_2 preparation are in bleach plant	Not surveyed	Remotely operated and outside	Remotely operated and outside	None
39	West Germany	Separate from bleach plant; operated by separate staff	Not used	Remotely operated and outside	Remotely operated and outside	None

*Sulf dioxide is used to reduce the pH of the pulp after the final stage of bleaching, to destroy residual ClO_2, or to make chlorine dioxide.

Table 29. Summary of staffing arrangements for surveyed mills.

Mill No.	General Staffing Arrangement*	Total No. Full-time Workers	General Task Assignments				
			Equipment Monitoring and Control	Equipment Inspection and Manual Adjustments	Chemical Unloading	Quality Control Sampling and Testing	Housekeeping and Spill Clean-up
01	A	4	Bleach plant operator	Bleach plant 1st equipment tender	Bleach plant 1st equipment tender	Bleach plant 1st helper	Pulp mill utility
10	B	3	Bleach plant operator	Bleach plant Assistant operator	Bleach plant Utility worker or assistant operator	Bleach plant Assistant Operator	Bleach plant Utiltiy worker
12	B	3	Bleach plant operator	Bleach plant Assistant operator	Pulp mill chemical Unloader	Bleach plant Assistant operator	Pulp mill Chemical unloader
22	A	2	Bleach plant operator	Bleach plant Utility worker	Bleach plant Utility worker	Bleach plant Utility worker	Bleach plant Utility worker
25	A	3	Bleach plant operator	Assistant bleach plant operator	Pulp mill evaporator man	Assistant bleach plant operator	Assistant bleach plant operator and evaporator man
30	C	2	Operator	Operator	Helper	Helper	Helper
32	C	2	Operator	Operator	Helper	Helper	Helper
35	C	3	Operator	Operator	Tester	Tester	Utility worker
37	B**	4	Bleach plant operator	Bleach plant operator	Bleach plant utility relief operator	Bleach plant operator	Bleach plant utility operator
39	C	1	Operator	Operator	Operator	Operator	Not known

* No. A - Chemical handling and preparation facilities are in the bleach plant and operated by that staff.
No. B - Chemical handling and preparation facilities are near the bleach plant and operated by that staff.
No. C - Chemical handling and preparation facilities are remote from bleach plant and operated by a separate staff.
**Chlorine dioxide generator facility is remote from the bleach plant and operated by a separate staff. It was not surveyed.

Table 30. Personal air monitoring data for chlorine/chlorine dioxide in bleach chemical handling and preparation facilities.*

Mill No.	Job Title or Task	Sampling Method	Number of Samples	Concentration Range	Reference
01	ClO_2 Generator Tester	P&CAM 209	9	<0.01 - 0.13	Table 01-1
10	Chemical Handling Tester+	P&CAM 209	10	0.05 - 0.78	Table 10-1
12	Chemical Handling Tester+	P&CAM 209	9	0.07 - >0.13	Table 12-2
22	Manual Preparation of Hypochlorite	P&CAM 209	3	All<0.05	Report p. 22-7
25	Chemical Handling Tester	P&CAM 209	1	<0.096	Table 25-2
30	Chemical Handling Tester	P&CAM 209	9	<0.06 - 5.53	Table 30-3
35	Chemical Handling Tester	P&CAM 209	2	<0.05 - 1.7	Table 35-1
37	Tester of Hypo System	P&CAM 209	4	All<0.05	Table 37-1

*All concentrations are reported as ppm chlorine, but some samples were collected in areas where chlorine dioxide was the sole concurrent contaminant. The sampling methods respond positively to this contaminant, but at unknown sensitivity; hence, preclude accurate analysis.
+Chemical handling testing tasks were concurrently performed during some sampling periods. See mill survey report for additional information.

Table 31. Area air monitoring data for chlorine/chlorine dioxide in bleach chemical handling and preparation facilities.*

Mill No.	Location	Sampling Method	No. Samples or Time	Concentration Range	Reference
01	ClO_2 Generator Bldg	Mast monitor	1 hr	0.05 - 0.1	Table 01-3
	Vaporizer Room	Mast monitor	10 min	0.05	Table 01-3
	Control Room	Mast monitor	11 hrs	0.0 - 0.05	Table 01-3
	Hypo Prep Room	Mast monitor	2 hrs	0.03 - 0.09	Table 01-3
10	ClO_2 Generator Bldg	Mast monitor	29 hrs	<0.1 ->1.0	Diagram 10-6
	Vaporizer/Hypo Bldg	Mast monitor	6 hrs	0.15 - 0.30	Diagram 10-5
12	Generator Control Bldg	P&CAM 209	2	<0.05 - 0.06	Table 12-3
	ClO_2 Generator (outside)	P&CAM 209	1	>0.22	Table 12-3
22	Hypo Prep Area	Mast monitor	1 hr	0.1	Figure 22-2
	Hypo Prep Area	P&CAM 209	2	<0.05 -<0.06	Table 22-1
30	ClO_2 Generator	Mast monitor	65 hrs	0.05 - 2	Figure 30-3
	Process Sampling Points in ClO_2 Bldg	Draeger tubes	4	0.1 - 1.0	Table 30-4
	Near Hypo Tank	P&CAM 209	1	<0.05	Table 30-3
	Above Hypo Tank	Draeger tube	1	0.3	Table 30-4
32	Control Building	Mast monitor	23 hrs	0.05 - 2.0	Figure 32-7
	ClO_2 Generator Building (Mathieson)	Mast monitor	12 hrs	0.5 - 2.0	Figure 32-8
	ClO_2 Generator Building (ERCO)	Mast monitor	23 hrs	0.1 - 2.0	Figure 32-9
	Process Sampling Locations in ClO_2 Bldg	Draeger tube	1	1.0	Table 32-2
	Hypo Solution Sampling Point (Outside)	Draeger tube	2	0.2 - 0.5	Table 32-2
35	Control Building	Mast monitor	23 hrs	<0.05	Report p. 35-13
37	Near Vaporizers Tank	Mast monitor	1 hr	0.09	Report p. 37-4
	Near Hypo Prep	Mast monitor	1 hr	0.1	Report p. 37-4
	Inside Hypo Prep Bldg	Mast monitor	1 hr	0.1	Report p. 37-4

*All concentrations are reported as ppm chlorine, but some samples were collected in areas where chlorine dioxide was the sole concurrent contaminant. The sampling methods respond positively to this contaminant, but at unknown sensitivity; hence, preclude accurate analysis.

Table 32. Significant workplace control technology for chemical handling and preparation operations.

Significant Controls	Surveyed Mills									
	01	10	12	22	25	30	32	35	37	39
Local Ventilation										
ClO_2 generator	Yes	Yes*	N/A	-	N/A	Yes*	Yes*	N/A	-	-
Hypochlorite reactor	No	Yes*	N/A	Yes	N/A	No	-	N/A	N/A	No
General Ventilation										
Generator building	Yes	No	N/A	-	N/A	Yes*	Yes	N/A	-	-
Chlorine vaporizer	No	Yes*	N/A	N/A	N/A	Yes*	No	Yes*	N/A	No
Hypochlorite reactor	No	Yes*	N/A	No	N/A	Yes	-	N/A	N/A	No
Equipment Isolation										
Generator	No	Yes	N/A	-	N/A	Yes	Yes	N/A	-	-
Chlorine vaporizers	No	Yes*	N/A	N/A	N/A	Yes	Yes	Yes	N/A	Yes
Hypochlorite reactor	No	Yes*	N/A	No	N/A	No	N/A	N/A	N/A	Yes
Enclosure of Quality Control Sampling Lines	No	No	No	No	No	No	Yes*	No	No	No
Respirator Use										
Written programs	Yes	Yes	Yes	Yes	Yes	Yes*	Yes*	Yes*	Yes	No
Mandatory possession requirement	No	Yes*	No	No	No	Yes*	Yes*	No	No	No
Supply air system	No	Yes	No	No	Yes	Yes*	No	No	-	No
Air Monitoring Systems (with alarms)	Yes	Yes*	No	NO	No	**	No	No	-	No
Preventive Maintenance	Yes	Yes	Yes	Yes	Yes	Yes*	Yes	Yes	Yes	No
Work Practices, Worker Training, and Other Miscellaneous Controls	Yes	Yes	No	No	No	Yes*	No	No	No	No
Automated Process Monitoring and Control Systems	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No

* This control is particularly well-developed and reader should reference the mill report for further information.
**Planned.
N/A: Control is not used because equipment is outside.
-: mill does not have the particular chemical handling system.

MULTI-STAGE PULP BLEACHING

Multi-stage bleaching operations were surveyed in ten mills. The major processes and stages, and other observed single- or double-stage bleach processes, are summarized below.

Process Abstract

Multi-stage bleach processes are used to whiten pulp before it is made into paper. Bleaching is achieved by selectively treating the pulp with certain chemicals in three or more distinct stages. The major stages and chemicals include:

- Chlorination with chlorine gas.
- Alkaline extraction with sodium hydroxide solution.
- Hypochlorite treatment with sodium or calcium hypochlorite solution.
- Chlorine dioxide treatment with a chilled solution of chlorine dioxide.

Table 33 summarizes the processes and stages, and describes important characteristics of the surveyed mills.

Minor stages, or bleach processes commonly used to brighten mechanical pulps to low or moderate levels, include:

- Treatment with sodium or hydrogen peroxide solution (Mills 03 and 40).
- Destruction of residual chlorine dioxide and/or reduction of pulp pH using sulfur dioxide gas or solution (Mill 03).
- Single- or double-stage bleaching with sodium borohydride, or sodium or zinc hydrosulfite solutions (Mills 03 and 40).

General Job Categories and Descriptions

The number of bleach plant workers and their job assignment is dependent upon the process size, the degree of automation, the plant layout and equipment, and the integration of bleach chemical handling and preparation operations. The staffing arrangements, number of workers, and major job task assignments for the surveyed mills are summarized in Table 34. Four major job tasks are:

- Process monitoring and control.
- Manual operation and adjustment of equipment, or inspections.
- Process quality control sampling and testing.
- Housekeeping and spill clean-up.

Air Monitoring Data

The primary air contaminants in multi-stage bleach plants are chlorine and chlorine dioxide. Extensive personal and area monitoring data were collected for one or both contaminants, and the results are summarized in Tables 35 and 36. The presence of chlorine and/or chlorine dioxide in the workplace is expressed as parts per million of chlorine, unless a mill report states otherwise. Specific monitoring methods used during the surveys are summarized in Table 4. Other minor potential workplace contaminants for which no data were collected include caustic mist from alkaline extraction stages and sulfur dioxide from dechlorinating/pH adjustment agents.

Control Technology

The surveys indicate that the types of controls vary among multi-stage mills depending on the nature and complexity of the process, the equipment design and location, the overall mill layout, the degree of process automation, and other dynamic process factors. Table 37 summarizes the specific controls employed in each of the mills. General types include:

- Process characteristics and control systems; closed and/or automated equipment; equipment isolation; and outside bleach towers, chlorine/chlorine dioxide injectors, mixers, and dosage control systems.

- Local and general ventilation - washer hoods, atmospheric bleach tower and filtrate tank vents; forced ventilation of bleach towers and filtrate tanks with and without exhaust gas scrubbing.

- Worker isolation in control rooms.

- Respiratory protection.

- Chlorine air monitoring and alarm systems.

- Worker training, education, and other special practices.

In general, survey data (monitoring results, air flow measurements, and technical discussions) indicate that the following are fundamental to limiting chlorine offgasing from pulp and controlling release to the workplace: (1) accurate chlorine gas dosage control in first-stage bleaching; (2) proper performance of washer exhaust hoods and, (3) good overall process control. Process and equipment characteristics may have equal importance. However, no definitive conclusions could be made concerning the effectiveness of automated versus manual or semi-automated dosage control systems, varieties of automated control systems, design and performance of washer hoods, or other equipment designs. Table 38 does summarize important design and performance data of the surveyed washer hoods.

The personal air sample results indicate low risk of overexposure during normal process operations with proper control of the chlorination and chlorine dioxide stages. Area monitoring data in some mills indicate increased workplace contamination during process alterations, upsets, and startups or shutdowns. The controls listed above are of importance either individually or in combination to insure worker protection during such process conditions. Each mill varied considerably in its application and administration of these controls.

Table 33. Description of bleach plants.

Mill No.	Location	Bleach Process*	Mill Description				
			Age	Towers	Washers	Control Room	Chemical Handling
01	North Central	CEDED for high brightness, Kraft hard and softwood pulp	Post 1970	Outside	Inside, hooded vacuum drums	Shared with pulp mill	Integrated but isolated
10	North Central	CEHD for high brightness, Kraft hard and softwood pulp	Post 1960	Inside	Inside, hooded vacuum drums	Inside near washers	Separate but operated by bleach plant
12	Southeast	CEDED for high brightness, Kraft hard and softwood pulp	Post 1950	Outside	Inside, hooded vacuum drums	Inside near washers	Separate but operated by bleach plant
22	Northwest	CEH for moderate brightness acid sulfite, softwood pulp	Pre-1920	C, E-Outside H-Inside, open top cells	Inside, hooded vacuum drums, not ventilated	Inside near washers; shared with brown stock washers	Integrated
25	Southeast	CEHD for high brightness, Kraft hardwood; CEHDD for high brightness Kraft softwood	Post 1960	Outside	Outside, hooded vacuum drums**	Shared with pulp mill	Integrated but outside
30	Northeast	CEHD for high brightness, alkaline hardwood pulp	Post 1950	C-Inside All others outside	Inside, hooded vacuum drums**; ClO_2 stage diffusion washers	Open controls near washers	Separate and operated by separate staff
32	Southeast	2 CEHDH; 1 each for high brightness Kraft hard and softwood pulp	Post 1970	Outside	Outside diffusion washers above towers	Shared with pulp mill	Separate and operated by separate staff
35	Southeast	CEHD for high brightness, Kraft softwood pulp	Post 1950	Outside	Inside, hooded, vacuum drums with vacuum assist	Inside near washers	Separate and operated by separate staff
37	Southeast	2 CEHDED for high brightness Kraft dissolving pulp	Post 1960	Tops are inside	Inside, hooded vacuum drums with vacuum assist	Open controls near washers	Chlorine vaporizers and hypo make-up are integrated in bleach plant
39	Germany	CEH for moderate brightness, acid sulfite softwood pulp	Pre-1920	Outside	Inside, hooded vacuum drums	Inside near washers	Separate and operated by separate staff

*Capital letter codes used for bleaching stages are:
C: Chlorination with chlorine gas
E: Alkaline extraction with caustic solution
H: Hypochlorite solution treatment
D: Chlorine dioxide solution treatment.

**Mills also scrub the exhaust air from chlorine, hypochlorite, and/or chlorine dioxide stage washer hoods.

Table 34. Staffing arrangements, work force size, and job task assignments for bleaching operations.

Mill No.	Staffing Arrangement	Total No. Production Workers*	Major Job Task Assignments**			
			Process Monitoring and Control	Equipment Inspection and Operation	Quality Control Testing	Housekeeping and Spill Clean-up
01	Combined staff for bleaching and bleach chemical handling	4-5	Operator	Operator and 2nd equipment tender	Pulp mill 1st helper	Pulp mill utility
10	Combined staff for bleaching and bleach chemical handling	3	Operator	Operator and bleach plant helper	Bleach plant helper	Bleach plant utility worker
12	Combined staff for bleaching and bleach chemical handling	2	Operator	Operator or assistant operator	Assistant operator	Operator or assistant operator
22	Combined staff for bleaching, washing, and chemical handling	3	Operator	Operator and assistant operator	Assistant operator	Utility worker
25	Combined staff for bleaching and bleach chemical handling	3	Operator	Assistant operator	Bleach plant tester	Assistant operator or pulp mill utility worker
30	Separate staff assigned strictly to bleach plant	2	Operator	Operator and bleach plant helper	Helper	Operator or pulp mill utility worker
35	Separate staff assigned strictly to bleach plant	3	Operator	Assistant operator	Tester	Assistant operator
37	Separate staff operates two bleach lines; one worker does chemical handling tasks	5	Operators Crew leader	Operator	Operator	Utility relief operator
39	Separate staff assigned strictly to bleach plant	2	Operator	Operator and assistant operator	Assistant operator	Assistant operator

* Excludes supervisory and maintenance personnel.
**See mill reports for more detailed job descriptions.

Table 35. Personal air monitoring data for chlorine/chlorine dioxide exposure in pulp bleaching facilities.*

Mill No.	Task or Job Category	Sampling Method	Number of Samples	Concentration Range	Reference
01	Equipment Inspection	P&CAM 209	1	<0.015	Table 01-1
10	Utility Worker	P&CAM 209	4	<0.05 - 0.20	Table 10-1
	Bleach Plant and Chemical Handling Tester+	P&CAM 209	10	0.05 - 0.78	Table 10-1
12	Bleach Plant and Chemical Handling Tester+	P&CAM 209	9	0.07 ->0.13	Table 12-2
	Utility Worker	P&CAM 209	1	<0.05	Table 12-2
	Maintenance Worker	P&CAM 209	1	0.07	Table 12-2
25	Bleach Plant Tester	P&CAM 209	3	<0.07 - 0.11	Table 25-2
	Utility Worker	P&CAM 209	1	<0.05	Table 25-2
	Maintenance Worker	P&CAM 209	2	<0.05	Table 25-2
30	Bleach Plant Tester	P&CAM 209	5	<0.05 - 0.25	Table 30-2
32	Bleach Plant Tester	P&CAM 209	9	<0.05 - 0.51	Table 32-1
35	Bleach Plant Tester	P&CAM 209	5	<0.05	Table 35-1
37	Bleach Plant Tester	P&CAM 209	11	<0.05 - 0.12	Table 37-1
			1	>0.86	

*All concentrations are reported as ppm chlorine, but some samples were collected in areas where chlorine dioxide was the sole concurrent contaminant. The sampling methods respond positively to this contaminant, but at unknown sensitivity; hence, preclude accurate analysis.
+Chemical handling testing tasks were performed concurrently during some sampling periods. See mill survey report for additional information.

Table 36. Area air monitoring data for chlorine/chlorine dioxide exposure in pulp bleaching facilities.*

Mill No.	Location	Sampling Method	No. Samples or Time	Concentration Range	Reference
01	Washer Floor	Mast monitor	2 hrs.	0.03 - 0.07	Table 01-3
10	Control Room	Mast monitor	3 hrs.	0.05	Diagram 10-5
	Washer Floor	Mast monitor	10 hrs.	0.05 - 0.10	Diagram 10-5
	Other Plant Areas	Mast monitor	7 hrs.	0.05 - 0.20	Diagram 10-5
12	Control Room	Mast monitor	12 hrs.	0.05 - 1.85	Diagram 12-4
	Washer Floor	Mast monitor	12 hrs.	0.05 - 0.8	Diagram 12-4
22	Control Room	Mast monitor	12 hrs.	0.05	Figure 22-1
	Near Hypo Cells	Mast monitor	6 hrs.	0.05 - 0.3	Figure 22-1
	Near Cl_2 Washer	Mast monitor	15 hrs.	0.05 - 0.3	Figure 22-1
	Above Hypo Cells	Draeger tube	2	<0.1	Table 22-1
	Near Cl_2 and Caustic Washers	Draeger tube	2	<0.1	Table 22-1
25	Control Room	Mast monitor	24 hrs.	0.05	Report p. 25-10
	Near Cl_2 Washer	Mast monitor	4 hrs.	0.05 - 1.0	Figure 25-2
	Near Leaking Washer Seal Tank	Mast monitor	1 hr.	0.4 - 1.0	Report p. 25-10
30	Control Room	Mast monitor	14 hrs.	0.05	Figure 30-3
	Washer Floor	Mast monitor	45 hrs.	0.05 - 1.0	Figure 30-3
	Washer Floor	P&CAM 209	2	<0.05 - 1.27	Table 30-2
	Inside Cl_2 Washer	P&CAM 209	2	<0.05 - 0.09	Table 30-2
35	Control Room	Mast monitor	24 hrs.	0.05	Report p. 35-11
	Washer Floor	Mast monitor	36 hrs.	0.05 - 0.15	Report p. 35-11
	Inside Cl_2 Hood	Draeger tube	1	10	Table 35-2
	Near Cl_2 Hood	Draeger tube	2	<0.1	Table 35-2
	Inside Hypo Hood	Draeger tube	1	<0.1	Table 35-2
	Inside ClO_2 Hood	Draeger tube	1	<0.1	Table 35-2
	Seal Tank Floor	Draeger tube	2	<0.1	Table 35-2
37	Washer Floor	Mast monitor	51 hrs.	0.1	Report p. 37-3
	Near Washers	Mast monitor	1 hr.	0.05 - 0.1	Report p. 37-4
	Above Cl_2 Tower	Mast monitor	2 hrs.	0.05	Report p. 37-3
	Mixed Floor	Mast monitor	1 hr.	0.1	Report p. 37-4
39	Washer Floor	Mast monitor	28 hrs.	0.05	Report p. 39-14

*All concentrations are reported as ppm chlorine, but some samples were collected in areas where chlorine dioxide was the sole concurrent contaminant. The sampling methods respond positively to this contaminant, but at unknown sensitivity; hence, preclude accurate analysis.

Table 37. Control technology in bleach plant operations.

Significant Controls	Surveyed Mills									
	01	10	12	22	25	30	32	35	37	39
Process Characteristics and Equipment Isolation										
Automated chlorine dosage control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-w/oxidation-reduction sensor	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-w/optical brightness sensor	No	No	Yes	No	Yes	Yes	No	No	No	No
Computer-assisted control	No	[1]	No	No	Some	No	Yes	No	[1]	Some
Outside Cl_2 injector	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Outside Cl_2 tower	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes[2]	Yes
Outside ClO_2 injector	Yes	No	Yes	N/A	Yes	Yes	Yes	Yes	No	N/A
Outside ClO_2 tower	Yes	No	Yes	N/A	Yes	Yes	Yes	Yes	Yes[2]	N/A
Outside Cl_2 and/or ClO_2 washers	No	No	No	No	Yes	No	No	No	No	No
Destruction of residual ClO_2 with SO_2[3]	No	No	No	N/A	No	Yes	No	Yes	Yes[3]	N/A
Closed pulp conveyance system										
-post-chlorination stage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
-post-hypo stage	Yes	Yes	Yes	No[4]	Yes	No	Yes	Yes	Yes	Yes
-post-ClO_2 stage	Yes	No	Yes	N/A	Yes	Yes	Yes	Yes	Yes	N/A
Ventilation										
Cl_2 washer exhaust hood	Yes	Yes	Yes	Yes[5]	Yes	Yes	N/A[6]	Yes	Yes	Yes
ClO_2 washer exhaust hood	Yes	Yes	Yes	N/A	Yes	N/A[6]	N/A[6]	Yes	Yes	N/A
Hypo washer exhast hood	Yes	Yes	Yes	No	Yes[5]	Yes[5]	N/A[6]	Yes	Yes	Yes
Ventilated Cl_2 & ClO_2 towers	[7]	No	No	No	Yes[8]	Yes[8]	No	No	Yes	No
Ventilated Cl_2 & ClO_2 washer filtrate tanks	Yes	No	No	No	Yes[8]	Yes[8]	No	Yes	Yes	No
General dilution ventilation of washer room	Yes	Yes	Yes	Yes	N/A	Yes	N/A	Yes	Yes	No
Worker Isolation										
Isolated control room	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	[1]	Yes
-w/100% recirculated air	No	No	Yes	Yes	Yes	No	No	No	No	No
-w/fresh make-up air (positive pressure)	Yes	Yes	No	No	No	No	Yes	Yes	No	Yes
Respirators	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Written plan	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Mandatory possession reqired	No	Yes	No	No	No	Yes	No	No	No	No
Self-contained breathing apparatus	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Supplied-air system for control room	No	No	No	No	No	No	No	No	Yes	No
Chlorine Air Monitor(s)	Yes	Yes	No	No	No	[1]	No	Yes	No	No
Worker Training, Education and Other Practices										
Preventive maintenance[9]	Yes	Yes	Yes	Yes	Yes	Yes[6]	Yes	Yes	Yes	Yes
Special worker training or education material	Yes	No	No	No	Yes	Yes	No	Yes	No	No

1 Planned.
2 Top of tower is inside.
3 Destruction of chlorine dioxide residual is not preformed to control exposures, but rather to maintain desired pulp qualities after bleaching.
4 Mill uses open-top hypo cells.
5 Exhaust fan was not operating.
6 Outside diffusers.
7 Unknown.
8 Exhaust gases are also scrubbed.
9 Also see Mill Report 17 for specific information on bleach plant maintenance in a kraft mill.

Table 38. Ventilation data on vacuum-drum washer exhaust hoods.

Mill No.	No. of Hoods	Hood Description	Face Velocities (Avg. or Range)** C	E	H	D	Hood CFM (Design/Measured) C	E	H	D
01	5	Full coverage with 4 observation hatches per side; made of polyester resin with 3% antimony oxide.	145-185	150-178 100-145	N/A	190-225 150-240	4000/2300	2400/2300 2400/2700	N/A	4000/2950 4000/4300
10	4	Half coverage with extension over inlet vat; made of fiber glass or rubber-coated steel; C-stage exhaust is scrubbed with caustic.	150-240 200-270	N/O	0-255	75-150 350	5000***	N/O	5000***	5000***
12	5	Half coverage; C and E stages have extensions over inlet vat and are made of polyester resin with fiberglass; D stages are galvanized steel.	50-150	50 100-200	N/A	100-200 100-350	6000/2470	6000/650 6000/200	N/A	6000/520 6000/500
22	2	Full coverage with 4 observation hatches; hypo washer has no hood.	----------(Exhaust fans were either removed or inoperable)----------							
25	9*	Full coverage with 8 observation hatches; made of fiberglass; all C and D stages exhausted to separate scrubbers (washers are outside).	150-250	N/O	N/O	150-250	4000***	N/O	N/O	4000***
30	3	Full coverage with 15 observation hatches; made of fiberglass; chlorine dioxide stage uses outside diffusion washer; no hoods or caustic extraction washers.	150	N/A	N/O	N/A	6000/7000	N/A	7260	N/A
32	-	----------N/A - Mill has outside diffusion washers----------								
35	4	Full coverage with 16 observation hatches; made of fiberglass; C stage is exhausted with separate fan; one washer hood is exhausted but unused.	200-400	--	200	200-375	15,000***	7500***	7500***	7500***
37	12*	Full coverage with 4 observation hatches; made of polyester resin with antimony	125-225 125-200	N/O N/O	150-275 200-250 125-150	300-350 325-350 250-300 100-250 150-250	?/2600 ?/800	N/O N/O	?/1600 ?/400	?/1100 ?/600 ?/1700
39	5	Full coverage with 4 observation hatches; made of fiberglass	----------No data available----------							

*These mills have two bleach lines.
**See mill reports for description of where open faces are and where face velocity readings were made.
C - Chlorination stage; E - alkaline extraction stage; H - hypochlorite stage; and D - chlorine dioxide stage.
***Total hood cfm's could not be measured because of poor access to ducts.
N/A: not applicable
N/O: not operating

PAPERMAKING OPERATIONS

Certain aspects of papermaking operations were surveyed in six mills. Major operations and brief summaries of the surveyed operations are presented below. The reader should refer to reports 02, 06, 09, 13, 24, and 40 for more specific process details, air monitoring results, job descriptions, and control technology.

Process Abstract

Papermaking is a complex process that may also include a number of initial stock preparation and post-production paper finishing operations. The major papermaking operations and their sub-steps can include:

1. Preparing pulp stock and wet-end additives, including:

   - o Dissolving dry pulp (mills with nonintegrated pulp processing).
   - o Beating, refining, thickening, cleaning, and/or blending pulps.
   - o Preparing wet-end additives such as sizes, fillers, and coloring agents. and
   - o Blending and mixing all ingredients to produce the final machine "furnish."

2. Preparing coatings: Usually on- or off-machine coating formulations are prepared in a separate area or facility, but it may be integrated into the area used to prepare wet-end additives.

3. Wet-end papermaking operations: Web forming and water removal by suction and/or pressing are conducted on a Fourdrinier or cylinder-vat machine. The latter consists essentially of a wire-covered cylinder mounted in a vat containing the slurried pulp. Water drains inwardly through the wire screen and a sheet of fiber is formed on the outside.

The top of the rotating cylinder projects above the surface of the slurry and the wet sheet is removed, then passed through press rolls. The Fourdrinier is more complicated, utilizing a long, flat, continuous wire screen. The slurry is spread evenly across one end of the screen by means of a headbox and sluice, and water is drained as the screen moves away from the headbox. The sheet is removed and passed through press rolls as with the cylinder machine.

4. Dry-end papermaking operations:

   - o Web drying.
   - o On-machine coating and drying.
   - o On-machine calendaring.
   - o Reeling.
   - o Slitting/rewinding.
   - o Quality control testing.
   - o Packaging and shipping.

5. Off-machine coating (excluding coating preparation).

Table 39 is a brief abstract of the operations surveyed in the six mills. As shown, the surveys focused on potential exposures and controls involved with preparation and application of wet-end additives and coatings, and dry-end paper dust. Data on paper mill noise exposure and control is discussed in the last subsection of this report and in case study reports 04, 23, and 40.

Job Categories and Descriptions

It is very difficult to provide generalized job descriptions because mills combine work tasks depending on the specific equipment layout, automation, and

complexity. The number of workers involved with papermaking also varies considerably depending on factors such as: 1) the number and location of paper machines, coaters, and slitter/rewinders; 2) the nature and complexity of the wet-end operations; 3) the nature, number, and complexity of the dry-end operations; and 4) to a lesser extent, the complexity, speed, and automation of equipment. Table 40 is a summary of job categories (and estimated number of workers per shift) typically involved with papermaking operations.

Air Monitoring Results

Wet-end additive and coating components vary widely depending on the intended use of the paper. It was possible to study handling and control practices for only a few of the more common ingredients; namely, clay, starch, titanium dioxide, sodium hydroxide, soda ash, calcium carbonate, calcium stearate, latex, ammonia, and wet strength resin (urea- or melamine- formaldehyde). Air monitoring results are summarized in Tables 41 and 42. With the exception of sodium hydroxide, dusts generated during the handling of dry chemicals were judged to be nuisance hazards, and total particulate samples were used to determine exposures in the bulk handling and coating prep areas of Mills 06 and 09. Preparation and/or application of coating formulations resulted in the potential for formaldehyde (Mills 02 and 09) and ammonia (Mill 09) exposure. Therefore, personal samples were collected in these mills to assess exposure and control of these agents. Coating prep workers were potentially exposed to sodium hydroxide which was added at a tank used to cook a coating formulation in Mill 06. A number of full-shift personal samples were collected to assess the significance of this exposure. Other additive and coating ingredients were not assessed because: 1) they are used intermittently and in such small quantities that there was little exposure risk; 2) they were handled automatically in closed systems, or 3) they are not recognized as being toxic.

The Mill 13 report presents results of personal and area sampling for paper dust during dry-end operations on a number of different papers. Mill 24 developed effective asbestos dust exposure controls for friction-grade paper manufacturing, and provided extensive data documenting pre- and post-control exposure conditions. Mill 40 had highly automated preparation operations for wet-end additives and coating formulations and very modern paper machines.

Therefore, few potential airborne exposure agents were identified and no air monitoring was warranted.

Control Technology

Table 43 summarizes significant control technology observed in the six mills. Nuisance dust exposures during unloading and transferring dry bulk chemicals used in wet-end additives and coatings were controlled by: 1) automated and closed conveyance systems, which in some cases had good dust collection and recovery systems (Mills 06, 09, and 40); 2) local exhaust systems for preparation tanks (Mills 02, 06, 09 and 40); 3) good housekeeping practices; and 4) periodic respirator usage (where required).

Low exposures to volatile liquid ingredients of coatings (ammonia, caustic, and formaldehyde) occurred because: 1) small quantities and low concentrations of volatile components were used; 2) handling concentrated ingredients was brief and intermittent; 3) preparation tanks were kept closed and were sometimes ventilated (Mills 02 and 09); and 4) general workplace ventilation was good.

Low exposures to volatile residual free formaldehyde occurred during paper coating (Mill 02; Off-machine Coater) because: 1) the amount of free formaldehyde was low ($<1\%$); 2) the coater's dryer section was covered with a large exhaust hood; and 3) general area ventilation was good.

Mill 24 developed a number of engineering, work practice, process, personal protective, and administrative controls for asbestos dust exposure during friction-paper manufacturing. The controls were very effective for asbestos (especially the ventilated bag opening enclosure), and may have applications for other toxic dusts.

Table 39. Paper-making operations surveyed.

Mill No.	Report Title	Operation(s) Surveyed
02	Off-machine coating operations	Preparation of a coating formulation containing clay, starch, titanium dioxide, calcium stearate, ammonia, and formaldehyde-containing wet strength resin.
06	Coating Preparation Operations	Preparation of coating formulations and wet-end starch for 5 papermachines (includes information on handling of clay, starch, titanium dioxide, soda ash, calcium carbonate, calcium stearate, and latex).
09	Coating Preparation Process	Preparation of coating formulation and wet-end additives for 2 paper machines, including handling of clay, starch, titanium dioxide, ammonia, calcium carbonate, latex, melamine-formaldehyde resins, calcium stearate, defoamers, castor oil, optical brighteners, and tinting agents.
13	Dry-End Papermaking Operations	Evaluation of paper dust exposure and control in two mills (with a total of 8 machines) during dry-end papermaking operations.
24	Friction-Grade Papermaking	Evaluation of asbestos exposures and controls during manufacture of a friction-grade paper. (Includes summaries of the mill's written training, respirator, personal hygiene, and housekeeping programs, plus design data for an effective bag opening station, and a special shower/locker room.
40	General Control Technology in a German Pulp and Paper Mill	Walk-through survey of an automated coating preparation facility, and a 3-machine paper mill.

Table 40. General job categories for papermaking operations.

General Process Operations	General Job Categories	Est. No. Workers (per machine)
Wet-end additives and stock preparation	Operator (beater man)	1
	Helper or assistant	1-2
	Utility	0-1
Coating preparation	Operator	1
	Assistant or helpers	1-2
	Utility	0-1
Papermachine wet-end	Machine tender	1
	Assistant or helper	0-1
	Utility	0-1
Papermachine dry-end	Back tender	1
	Slitter/winder operator (3rd hand)	1
	Assistants, helpers or 4th/5th "hands"	1-3
	Utility	0-2
	Coater operator (if there is on-machine coating)	1
Off-machine coating	Operator	1
	Assistant or helper	1
	Utility	0-2
Quality control testing	Tester (may not collect samples)	1
Management, supervisory, and clerical	Superintendent, crew leaders, foreman, clerks, etc.	Variable
Maintenance	Millwrights, oilers, welders, carpenters, electricians, etc.	Variable

Table 41. Personal air monitoring data in paper coating preparation and papermaking facilities.

Mill No.	Job Category	Number of Samples	Concentration Range	Concentration Mean	Reference
Contaminant		Formaldehyde (ppm)			
02	Coating Preparation Operators	3	0.03 - 0.12	0.07	Table 02-1
	Off-Machine Coater Operator	4	0.02 - 0.31	0.15	"
	Assistant Operator	3	0.17 - 0.47	0.24	"
	Utility Worker	1		0.08	"
09	Color Room Operators	17	0.01 - 1.76	0.18	Table 09-1
Contaminant		Total nuisance dust (mg/m^3)			
06	Coating Preparation Operators	5	0.2 - 0.6	0.4	Table 06-2
	Bulk Plant Operator	3	2.4 - 8.5	5.1	"
09	Bulk Materials Handlers	10	0.3 - 3.5	1.1	Table 09-1
13	Tissue Machine Workers	8	0.7 - 10.0	4.5	Table 13-1
	Tissue Towel Machine Workers	6	0.6 - 9.1	3.7	"
	Newsprint Machine Workers	6	0.3 - 1.0	0.4	"
Contaminant		Sodium Hydroxide (mg/m^3)			
06	Coating Preparation Operators	6	All <0.06	<0.06	Table 06-2
Contaminant		Ammonia (ppm)			
09	Color Room Operators	8	0.5 - 3.5	1.2	Table 09-2
Contaminant		Asbestos (fibers >5 μm in length/cc)			
24	Before Development of Controls:				
	Pulper Operator	13		7.36	Report text
	Pulper Helper	9		3.65	p. 24-7
	Rewinders/Helpers	8		0.63	"
	Back Tenders	3	0.06 - 0.32	0.19	Table 24-1
	After Development of Controls:				
	Pulper Operator	15		0.36	Report text
	Pulper Helper	6		0.20	p. 24-7
	Rewinders/Helpers	6		0.21	"
	Back Tenders	2	<0.02 - 0.03	<0.02	Table 24-4
	Bag Opening Station Operator	8	0.02 - 0.05	0.03	"

Table 42. Area air monitoring data in paper coating preparation and papermaking facilities.

Mill No.	Location	Number of Samples	Concentration Range	Concentration Mean	Reference
Contaminant		Formaldehyde (ppm)			
02	Color Building	2	0.04 - 0.07	0.06	Table 02-2
	Off-Machine Coater	10	0.02 - 2.27	0.67	"
Contaminant		Asbestos (fibers >5 µm in length/cc)			
24	Before Development of Controls				
	Pulper Control Panel	4		1.58	Report text
	Raw Materials Storage Warehouse	2		1.75	p. 24-7
	After Development of Controls				
	Pulper Control Panel	13		0.057	Report text
	Raw Materials Storage Warehouse	3		0.051	p. 24-7

Table 43. Control technology in papermaking.

Mill No.	Report Title (Air Contaminants Controlled)	Significant Controls
02	Off-Machine Coating Operations (Formaldehyde)	- Local exhaust hood for coating formulation mix tank. - Large open hood over first and second stage dryers, coating stations, and infrared heaters of an off-machine paper coater. - Good general ventilation of coater area (heated supply air fan and 2 floor-mounted man-coolers).
06	Coating Preparation (total nuisance dust and sodium hydroxide)	- Exhaust hoods and recirculating dust collection systems (cyclone and bag filter) for starch blending tanks and wet-end starch mixing tank. - Local exhaust for each of 6 main mill starch blending tanks. - Five roof exhaust fans for bulk plant (27,800 cfm; 6-10 air changes/hour). - Three roof exhaust fans for main mill (48,000 cfm; 6-10 air changes/hour). - Process factors - many bulk materials purchased as slurries; clay and starch are unloaded and transferred with automated and closed (pneumatic or auger) systems; minimal handling of raw materials; sodium hydroxide purchased as a liquid. - Housekeeping
09	Coating Preparation Process (total nuisance dust, formaldehyde, and ammonia)	- Bulk quantities of clay, starch, and calcium carbonate are unloaded with automated and closed vacuum unloader and pneumatic conveyance system (to roof-mounted storage silos with exhaust air bag filters). - Closed auger system to transfer clay and crystalline calcium carbonate to mixing tanks. - Closed auger system to automatically transfer starch to make-down tank (tank has auto-replenisher which continuously maintains proper level of starch slurry). - Good housekeeping and work practices for handling bags of titanium dioxide. - Unloading dock and mixing areas are cleaned each shift to minimize secondary dust generation sources. - Closed screw-conveyor transfer system for amorphous calcium carbonate in color room with effective recirculating dust collection system (with exhaust air cyclone and bag filter). - Process factors - melamine formaldehyde contains less than 1% free formaldehyde; dumping resin takes less than 5 minutes; infrequent ammonia use involves small quantities. - Local exhaust hood over blade-coating formulation screen. - Storage tank exhaust system (inoperative).
13	Dry-End Papermaking Operations (total nuisance dust)	- General roof exhaust fans. - Unwinding station canopy hood. - Ejector-type twin blower system for pneumatic conveyance of trim from slitters. - Dust masks. - Machine "blowdowns" each shift to remove accumulated paper dust.
24	Friction-Grade Paper Manufacturing (asbestos dust)	- Enclosed and ventilated bag opening station for dry bulk materials (has a cyclone and bag filter for exhaust air). - Formal written programs for worker education and training, respirators, medical monitoring, personal hygiene, housekeeping, and air monitoring. - Special shower/locker rooms. - Other process, work practice, and administrative controls.
40	General Control Technology in a West German Pulp and Paper Mill (Dust in coating preparation and dry-end paper-making)	- Worker isolation (control room). - Automated and closed bulk material unloading and transfer systems. - Local exhaust of coating preparation tanks. - Dust masks. - Extensive process automation. - Excellent housekeeping.

MILL MAINTENANCE

In two mills, surveys were devoted to evaluating worker exposures and controls during routine maintenance operations. In Mill 05, employees acid cleaned the press and drier section felts of a paper machine. In Mill 17, a worker was observed for two days while performing typical maintenance tasks in a Kraft pulp mill and multi-stage bleach plant.

Similar surveys were attempted in several other mills, but were unsuccessful because of the highly variable nature of maintenance operations. However, the survey teams documented details of maintenance programs and procedures, equipment sealing techniques and materials, and special chlorine handling procedures at twelve mills. Limited exposure data were collected for maintenance workers in four of these twelve mills.

Maintenance Programs

The structure of mill maintenance programs varied considerably and is difficult to summarize. Table 44 outlines areas surveyed in this study. Most mills had formal preventive maintenance programs with scheduled inspections and repair schedules (some computerized) for various process equipment. Pre-planned process shutdowns for maintenance work ranged in frequency from once a year to every few weeks for some multiple process lines. Operators and/or supervisory staff make regular inspections each shift to locate leaks or other problems in many process areas.

Vessel Entry Procedures

All mills had written procedures for worker protection during entry into tanks or other confined spaces. It was impossible to evaluate adherence to these procedures, but discussions with mill personnel indicated strict enforcement. Entry procedures are summarized or presented in full in the individual mill reports. Common features among the various programs include:

- Outline of responsibilities;
- Lock-out and/or tag-out requirements.

- Preparation of vessel for entry.
- Air monitoring requirements.
- Personal protective equipment (including respirators).
- Completion of "safe entry" permits or check lists.
- Use of safety harnesses.
- Requirements for standby employees.
- Emergency procedures.

Equipment Seals

The integrity of packing, gaskets, and other seals are obviously important for prevention of leaks and resulting workplace contamination. In several mills, information on effective sealing techniques and materials was obtained, primarily for corrosive applications in pulp mills and bleach plants. In most instances, the specific applications for mechanical seals were also noted.

Chlorine Handling Procedures

Mill Reports Nos. 01 and 35 contain exemplary and generally representative written procedures for storing and handling chlorine in multi-stage bleach plants.

Air Sampling Data

The evaluation of worker exposures and controls during maintenance operations is extremely difficult because each task is totally different, exposure periods are highly variable, and maintenance schedules and work frequently change without notice. The limited exposure data presented in Table 45 should be evaluated within the context of the activities and conditions that existed at the time the sample was taken.

Table 44. Maintenance-related operations or procedures in pulp processing.

Mill No.	Process	Maintenance Program	Vessel Entry	Equipment Seals	Chlorine Handling Procedures	Type of Data Collected
01	Kraft pulping and bleaching	X	X	X	X	
05	Felt cleaning					Sulfuric acid, sodium hydroxide
08	Kraft pulping	X	X	X		
11	Kraft pulping		X			
17	Maintenance	X	X	X		Hydrogen sulfide, methyl mercaptan, chlorine
19	Recausticising	X				
20	Kraft pulping	X				
21	Sulfite pulping		X			
24	Friction-grade papermaking	X				Asbestos
25	Bleaching and chemical preparation	X		X		Chlorine
26	Kraft pulping	X	X	X		Methyl mercaptan, hydrogen sulfide
29	Kraft pulping	X	X			
30	Bleaching and chemical preparation	X		X		Chlorine
35	Bleaching and chemical preparation	X			X	
38	Kraft pulping		X			

Table 45. Personal and area sampling data during mill maintenance operations.

Mill No.	Operation	Activities Surveyed	Contaminant	Number/ Type of Sample*	Concentration Range	Reference
05	Felt Cleaning	Acid cleaning press	NaOH (mg/m^3)	5/A	All <0.75	Table 05-1
			H_2SO_4 (mg/m^3)	7/A	All <0.97	Table 05-1
				1/P	<1.98**	
17	Maintenance	Various maintenance activities	Cl_2/ClO_2 (ppm)	1/P	<0.01 - >0.58	Table 17-1
			H_2S (ppm)	2/P	All 0.08	Table 17-2
			CH_4SH (ppm)	2/P	0.13 - 0.25	Table 17-2
24	Friction-Grade Papermaking	Various maintenance activities	Asbestos (fibers <5 μm/cc)	3/P	0.015 - 0.08	Table 24-4
25	Bleaching and Chemical Preparation	Cleaning shower nozzle in bleach washer	Cl_2/ClO_2 (ppm)	2/P	All <0.05	Table 25-2
26	Kraft Pulping	Installing check valve on black liquor surge tank	H_2S (ppm)	1/P	0.3	Table 26-1
			CH_4SH (ppm)	1/P	0.5	Table 26-1

* Area P personnel.
**Short-time exposure while employee prepared acid cleaning solution.

NOISE

During each preliminary survey, mill personnel were asked to identify noise abatement projects designed to reduce employee exposures. In general, mills have relied on worker isolation in control rooms or acoustical booths as the primary means of controlling exposures. Most pulp and paper processes are highly automated, and allow operating personnel to remain in these protected areas for up to 90 percent of each shift. Therefore, although workplace noise levels may frequently exceed 90 dBA, worker 8-hour TWA exposures are usually within acceptable limits.

Most mills possessed extensive workplace noise level data, and have identified high exposure areas where hearing protection is required. All have developed audiometric testing programs. Some employee exposure indices and/or area noise levels are summarized in the following individual mill reports:

Mill 03 - Thermomechanical pulping.

Mill 04 - Supercalendar, winder, and off-machine coater.

Mill 07 - Wood preparation and groundwood pulping.

Mill 14 - Wood preparation.

Mill 15 - Refiner groundwood pulping.

Mill 27 - Recausticizing and lime kiln operations.

Mill 28 - Alkaline sulfite pulping.

Mill 40 - Wood preparation and refiner groundwood pulping.

Noise level data for other processes were not summarized in the mill reports because of the impracticality of comparing area data among mills with widely varying process equipment, layouts, and other individual characteristics.

Table 46 summarizes specific noise abatement techniques undertaken in three mills: Mill 04 (papermaking); and Mills 07 and 14 (wood preparation). These reports should be consulted for details about the noise sources and control methods.

Mill report 23 is a summary of noise control projects and studies conducted in a number of mills operated by a large corporation. Each case study includes a description of the noise sources and attendant employee exposure levels, some alternate control strategies, the actual control measures implemented, and estimates of the effectiveness. The report contains extensive practical information accumulated over a number of years by this corporation. It should be stressed that many possible solutions exist for a noise problem and other approaches may be equally or more effective depending upon the contributing factors in a specific situation.

Table 46. Major noise sources and possible controls for pulp and paper mills.

Mill	Process	Noise Source	Controls
04	Papermaking	Supercalendar	-Roll stack shield -Wall and ceiling treatment -Control console shield
07	Wood preparation	Slasher	-Enclosure
14	Wood preparation	Chippers, slashers, debarkers	-Worker isolation -Enclosure -Structural features
23	Varied	Caterpillar tractor	-Acoustical treatment of cab -Hydraulic tank cover
		Lamson air compressor	-Suspended curtain
		Chip blower	-4-sided, open top enclosure -Receiver surge tank isolation
		Forced draft boiler fans	-Partial inlet enclosure -Inlet air silencers -Damp for housing
		Air compressors	-Acoustical enclosure
		Jordan-type refiners	-Lagging -Partial barrier -Full enclosure
		ASEA drive motor	-Accoustical treatment of cooling air inlet
		Wide supercalendar motor	-Enclosures
		Rewinder trim blower	-Pressure blower silencer
		Rewinder	-Motor enclosure
		Vacuum pump	-Lagging -Exhaust silencers -Gearbox rebuild -Motor replacement -Motor air silencer
		Paper machine wet ends	-Silent drilling pattern on couch or suction rolls -Full acoustical enclosures -Partial enclosures
		Winders	-Replacement or resurfacing of older winder drums -Portable noise screens -Acoustical enclosure
		Slitters	-Web driven slitters -Plexiglass barriers -Slitter disc damping
		Trim chute blowers	-Lower transport velocity -Through-type sound traps -Duct lagging -Fan enclosure

MATRIX OF SURVEY REPORTS

The survey reports were numbered according to the time sequence in which the work was done. However, they are not arranged serially, but are grouped according to the principal unit operation(s) discussed. The following matrix may be used to find specific reports. Locate the survey report number in the sequence at the top, then drop down that column to where the number appears in the matrix. The unit operation in which the report is filed is listed at the left. For instance, survey report 11 is located in the section titled "Kraft Pulping and Brown Stock Washing." A number 11 in parentheses is found further down the column opposite "Maintenance Operations and Procedures;" this is a cross reference to show that information pertinant to maintenance operations is also discussed in this report. On the other hand, to locate all reports dealing with "Papermaking Operations," survey reports 02, 06, 09, 13, and 24 will be found in that section; but in addition, survey report 40, which also contains information about this subject will be found in the "Wood Preparation and Mechanical Pulping" section.

Unit Process	Survey report number																			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Wood Preparation and Mechanical Pulping			03				07							14	15					
Kraft Pulping and Brown Stock Washing	01							08			11									20
Kraft Chemical Recovery - Evaporation and Recovery Furnaces																		18		
Kraft Chemical Recovery - Recausticizing																16			19	
Sulfite Pulp																				
Bleach Chemical Handling and Preparation	(01)									10		12								
Multi-stage Bleaching	(01)		(03)				(07)			(10)		(12)					(17)			
Papermaking Operations		02				06			09				13							
Maintenance Operations and Procedures	(01)				05			(08)			(11)						17		(19)	(20)
Noise Exposure and Controls			(03)	04			(07)							(14)	(15)					

Unit Operations	Survey Report Number																			
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Wood Preparation and Mechanical Pulping																				40
Kraft Pulping and Brown Stock Washing						26			29				33			36		38		
Kraft Chemical Recovery - Evaporation and Recovery Furnaces											31			34						
Kraft Chemical Recovery - Recausticizing							27													
Sulfite Pulp	21							28											39	
Bleach Chemical Handling and Preparation		22			25					30		32			35		37		(39)	
Multi-stage Bleaching		(22)			(25)					(30)		(32)			(35)		(37)		(39)	(40)
Papermaking Operations				24																(40)
Maintenance Operations and Procedures				(24)	(25)	(26)			(29)	(30)					(35)			(38)		
Noise Exposure and Controls			23				(27)	(28)												(40)

SECTION I WOOD PREPARATION & MECHANICAL PULPING

Mill 03	Thermo-Mechanical Pulping
Mill 07	Groundwood Pulping
Mill 14	Woodyard/Woodroom
Mill 15	Refiner Groundwood Pulping
Mill 40	Refiner Groundwood Pulping (German Mill)

MILL 03 THERMO-MECHANICAL PULPING PROCESS

PROCESS SUMMARY

Mill 03 produces approximately 150 tons per day (tpd) of pulp in two separate but similar thermo-mechanical pulping (TMP) processes. The larger system is located within a new wing built off the original pulp mill and has two (2) side by side chip feed systems, digesters and primary and secondary refiners. The other process is a converted chemi-mechanical system and is located in the old section of the pulp mill. Hardwood chips (usually aspen) are purchased from local sawmills and chip producers, transported in tractor-trailers, and hydraulically dumped into a large hopper. From the hopper, the chips are augered to a feeder, and pneumatically conveyed to one of two large enclosed chip bins within the TMP building or to bins for the other TMP process. For the newer and larger system, variable-speed screw conveyors located at the bottom of each bin transport the chips into an open-top washer and vibrating screen in the basement of the new TMP plant. Fines and rejects are removed, collected, and transported to a landfill. 'Accepted' chips are bucket conveyed up to the interim bins or, if necessary, to a surge bin all located on the upper levels of the TMP building. The surge bin is interlocked with the chip bin screw conveyors to halt the chip feed should overloading be sensed.

From the interim bins, the chips are conveyed down into a rotary, vented feed valve and heated with 30 psig steam. As the rotary valve cycles, the chips are dropped into a cylindrical, horizontally-mounted digester.

A variable-speed screw passes the chips through the digester in about three minutes, during which time additional steam is added to penetrate and soften the lignin in the chips. From the digester, the chips are dropped into a sealed twin screw conveyor that maintains a constant feed to the primary refiners located on the plant operating floor. These refiners are fully enclosed, air cooled, and water-sealed. The constant outflow of refined pulp is blown into a cyclone, located above the operating floor, where the steam is condensed and the stock is dropped into an agitated primary refiner chest. The stock is then pumped to the secondary refiners (atmospheric) located on the plant operating floor and gravity fed into an agitated secondary refiner chest.

From the secondary chest, the stock is pumped into a silo, and diluted (3-1/2% to 1% consistency) with brown water from the decker. The diluted stock is then pumped through the primary screen; accepts go to the main centricleaning system; 'rejects' go to the secondary screen. Secondary screen accepts are returned to the primary screen. Secondary rejects go to a storage tank and are pumped to the reject system, consisting of

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two hydraseives, a helipress, two small refiners, and primary and secondary centricleaners. Reject system 'accepts' are returned to the main centricleaning system - 'rejects' are removed through the sewer.

The main centricleaning system consists of 38 primary centricleaners, 10 secondary centricleaners and 6 tertiary centricleaners. Primary 'accept' stock goes to the deckers and excess water is removed (consistency increased to 3%). Primary 'reject' stock goes to the secondary centricleaners. Secondary 'accept' stock is returned to the primary centricleaners, etc.; 'reject' stock goes to the tertiary centricleaners. Tertiary cleaner 'rejects' go to the reject system for processing.

Clean, accepted stock from the primary cleaning system is transferred through the deckers to the decker chest where the consistency is raised to 3 percent. Following the bleaching process, the stock is pumped through two small refiners into large storage tanks.

BLEACH PLANT PROCESS SUMMARY

From the decker chest, the stock is pumped to a thickener where consistency is increased to 15 percent then dropped into a mixer. As the stock is dropped from the mixer, the peroxide bleach liquor (25% sodium peroxide equivalent) with chelating agent and Epsom salt is added in line, and is thoroughly dispersed in a double blade mixer. The stock and bleach liquor mixture continuously drops from the mixer into the bleach tower. Stock retention time in the tower ranges from 1.5 to 2.5 hours. Fully bleached stock is augered into a sealed single shaft mixer, neutralized with sulfur dioxide, and water, and dropped into a dilution/neutralization tank controlled automatically through an in-line pH sensor and controller.

JOB CATEGORIES AND DESCRIPTIONS

There are six employees per shift responsible for both TMP processes. Each process includes an operator and an assistant operator; a tester and a cleaner are common to both processes:

Operators - The operators have primary responsibility for the operation of the TMP process. Their main function during normal operation is to monitor critical process parameters. The operators also assume responsibility for process startups. It is estimated that the operators remain in their respective control rooms for an average of 95 percent of each shift.

Assistant Operator - The assistant operators conduct periodic surveys of the process to assure proper operation. They are available to assist the operators during process startups or during emergencies. On an average, the assistant operators are also in their control room during 95 percent of each shift.

Tester - Four times per shift, the tester collects and analyzes stock samples from various operations including the refiners, screens, deckers, centricleaners, and chests. It is estimated that the tester is in the control room for over 60 percent of each shift.

Cleaner - The cleaner has primary housekeeping responsibility for both TMP processes and an adjacent woodroom area (day shift only).

POTENTIAL WORKPLACE HAZARDS

Possible workplace hazards are wood dust, sulfur dioxide, noise, and volatile wood constituents (resin acids, terpenes, phenolic compounds, etc.)

AIR SAMPLING RESULTS

Full-shift gravimetric samples were collected for each job classification over several different shifts (Table 03-1). Time-weighted average exposures for total nuisance particulates ranged from 0.05 mg/m^3 to 0.50 mg/m^3, or well below OSHA PEL of 15 mg/m^3. Area samples were similarly very low. Furthermore, the two (2) personal samples collected on the 1st shift cleaner man over two (2) consecutive days were judged to include very atypical high exposure conditions during parts of his shift due to cleaning of accumulated wood dust from ceiling rafters in parts of the TMP (chemi) building.

Area samples were collected on charcoal and silica gel tubes to investigate the presence of volatile wood constituents (Table 03-2). They were analyzed by gas chromatography. A very low level of turpentine was detected on one sample; no alcohols or other terpenes were detected. Two of the samples revealed appreciable levels (33 mg/m^3; 8.7 mg/m^3) of resin acids to be present. There is no applicable standard for these compounds and the significance of these data are difficult to assess. A measureable but low level (1.7 mg/m^3) of a phenolic compound was also detected for one sample.

A plant consultant investigating equipment corrosion problems collected a steam condensate sample from the cyclone separator. Gas chromatography analysis of it revealed over one hundred (100) unidentifiable organics compounds to be present.

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TABLE 03-1 GRAVIMETRIC SAMPLING DATA-THERMO-MECHANICAL PULPING PROCESS

Job Classification or Location	Day	Shift	Sampling Time (Minutes)	TWA Total Dust (mg/m3)	OSHA PEL (mg/m3)
Assistant Operator	1	1	350	0.11	15
		2	441	0.05	15
Operator	1	1	352	0.10	15
		2	442	0.08	15
Tester	1	2	445	0.13	15
Cleaner	2	1	396	0.30	15
	3	1	379	0.50	15
Area - At Chip Screen and Washer (Basement of TMP Plant)	1	2	423	0.04	15
Area - Chip Chute (To Other TMP Process)	3	1	403	0.16	15
Area - 2nd Level, near #2 & #3 Overflow Screws	3	1	280	0.11	15

TABLE 03-2 AREA SAMPLES

Location	Type of Sample[1]	Turpentine (mg/m^3)	Other Terpenes (mg/m^3)	Resin Acids (mg/m^3)	Alcohols (mg/m^3)	Phenols (mg/m^3)
One Floor Above TMP Digesters	Charcoal[2]	0.07	< 0.04			
	Silica Gel[2]				< 0.03	
Above Chip Washer and Screen	Charcoal	< 0.15	< 0.15			
	Silica Gel				< 0.18	
Between Secondary Refiners on Operating Floor	Charcoal	< 0.06	< 0.06			
	Silica Gel			33	< 0.06	1.7
Top Floor Above TMP Digesters	Charcoal	< 0.02	< 0.02		< 0.02	
	Silica Gel			8.7		
Above Other TMP Digesters, (Near Chip Bin)	Charcoal	< 0.03	< 0.03		< 0.03	
	Silica Gel					
Near Steambarker	Charcoal	< 0.15	< 0.15			

NOTES

1 Jumbo charcoal and silica gel tubes

2 Analysis by gas chromatography with FID after desorption with carbon disulfide

WORKPLACE NOISE LEVELS

Noise levels in various areas or during selected tasks in the TMP mill are presented below.

Location or Activity		Minimum dBA	Maximum dBA
Operating Floor	-General area	-	95 steady
	-Control Room	75	77
	-Post Refiners	95	96
	-Refiners	94	96
	-Reject System	91	94
Basement	-Chip Washers	92	93
	-General Area	-	94 steady
	-Filters	-	94 steady
	-Reject System	95	96
	-Sample Valves	-	94 steady
Digester Floor	-Deckers	91	92
	-Reject System	90	91
Supervisors Office		70	71
Acivities	-Equipment Check/Repair		95 steady
	-Equipment Inspection Tour		95 steady
	-Instrument Inspection Tour		95 steady
	-Equipment Check/Oil		95 steady

These measurements show that noise levels range from 91 dBA to 95 dBA throughout the TMP mill. However, considering the percentages of time the mill employees remain in low-exposure areas (control rooms), it is seen that only the cleaning employee may be exposed:

Job Classification	% Time In Process Areas	Maximum Exposure Level	Exposure Index (Maximum)
Operator	10	95 dBA	0.2
Assistant Operator	5	95 dBA	0.1
Tester	40%	95 dBA	0.8
Cleaner	70-80%	95 dBA	1.5

CONTROL OF WORKPLACE HAZARDS

The thermomechanical pulping process has a number of characteristics which preclude significant exposures to air contaminants:

- No chemicals are added to the process; potential air contaminants are thus restricted to wood dust and wood constituents which are volatile under the various applied and created pressures and temperatures attained during the process and escape into the workplace through various steam leaks and vents.
- The process consists primarily of entirely closed unit operations. A number of uncharacterizable, miscellaneous steam leaks can occur in chip and stock systems.
- Employees remain in closed, positive-pressure control rooms except for routine inspection tours, sample collection runs, and planned or emergency maintenance operations.
- The majority of the unit operations are conducted wet; there are essentially no primary continuous sources of wood dust generation, provided chip transport systems are well-maintained and tightly sealed, and chips remain moist until fed to digesters.

MILL 07 GROUNDWOOD PULPING PROCESS

PROCESS SUMMARY

Balsam, spruce, or poplar logs are stored in the woodyard and, as needed, are floated on the hot pond to the woodroom. There workers manually direct logs onto a chain conveyor which runs through a stream barker, a rectangular casing over the chain conveyor where high pressure water jets are used to remove bark and debris. The logs exiting the barker then drop back into the hot pond and are transported to the slasher. Bark and other solid materials that have been removed are separated from the water on a vibratory screen and two vacuum filters, and are trucked to the powerhouse for fuel. The clean water is recirculated back to the drum barker.

The slasher is an inclined platform through which large, circular high speed cutting blades protrude. As logs are conveyed up the slasher by a rotating chain of hooks, they are cut to 25 inch lengths. Sawdust and some bark falls below the slasher and is collected and transported to the powerhouse. From the top of the slasher, the sized logs fall down into a large rotating drum barker where the remaining bark is removed by the abrasive action of tumbling logs. Waste bark drops out of the bottom of the drum and is sent to the powerhouse. The cleaned logs drop out of the far end of the barker onto a conveyor and are visually checked by the drum barker operator before being sent to one of four groundwood storage bins or, occasionally, to a chipper.

From the storage bins, located at the rear of the grinder room, the sized logs are manually loaded on carts and wheeled to one of 13 electric, four-pocket grinders arranged on either side of a center aisle. The grinder operators (usually one for two grinders) sequentially load each pocket while the grinder runs continuously and the logs are forced against the grindstone by water pressure. The wood is reduced to a fine pulp by the abrasive mechanical action and high frictional temperatures. The water spray keeps the stone cool, cleans and lubricates the surface, and carries away the pulp in a ditch located below each grinder. The pulp is collected and pumped to one of three primary screens. Rejects, wood slivers and other course debris, are passed to the secondary screens; 'accepts' are returned to the grinder ditch; and 'rejects' are pumped to the reject system in the TM Plant. Accepted pulp from the primary screens is thickened on one of nine deckers and is transferred to the unbleached groundwood storage chest. The pulp is then refined and/or bleached in-line with a Borol solution (an alkaline sodium borohydride solution).

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JOB CATEGORIES AND DESCRIPTIONS

Stream Barker Operator - The operator is responsible for the continuous flow of logs through the stream barker. Duties include clearing jams on the in-feed conveyor, removing off-size logs, cleaning underneath the barker, and cleaning the general work area.

Slasher Operator - The slasher operator is primarily responsible for maintaining a constant flow of logs from the hot pond to the slasher feed conveyor. The employee is stationed in a partial enclosure opposite the slasher and the hot pond.

Drum Barker Operator - The drum barker operator is responsible for assuring that the sized logs exiting the drum barker are of acceptable size. The employee stands next to the sluiceway leading from the barker and pulls out any logs with bark remaining on the surface. Periodically, this employee operates the chipper located adjacent to the sluiceway, and sweeps up sawdust accumulated below the slasher.

Block-Pilers - Five Block Pilers remove the logs from the storage bin, stack it on carts, and wheel it to each of the pocket grinder positions. Block-Pilers relieve grindermen during break time.

Grinder Operators - There are eight grinder operators, each generally responsible for feeding logs into two separate four-pocket grinders.

Tester - The tester collects pulp samples from each grinder and conducts tests for "freeness". He also serves as shift foreman for the loader and grinder crew.

POTENTIAL WORKPLACE HAZARDS

Since no chemicals are used in the process, possible workplace hazards are limited to wood dust, noise, and volatile constituents of the wood (resin acids, terpenes, phenolic compounds, etc.).

AIR SAMPLING RESULTS

Full shift gravimetric samples were collected for all job categories in the groundwood mill. As shown on Table 07-1, all results are well below the OSHA PEL of 15 mg/m^3, total nuisance dust. With the exception of one sample which covered periods while the drum barker operator was sweeping dry sawdust underneath the slasher and operating the chipper (3.4 mg/m^3), none of the results are much in excess of normal background

TABLE 07-1 GRAVIMETRIC SAMPLING DATA, GROUNDWOOD MILL

Job Classification or Location	Day	Shift	Minutes Sampling Time	Total Dust (mg/m3)	OSHA PEL (mg/m3)
Stream Barker Operator	1	1	344	0.51	15
	1	2	394	0.16	15
	2	1	401	0.10	15
Slasher Operator	1	1	368	0.04	15
Grinder Operator	2	2	404	0.01	15
	2	2	400	0.05	15
	2	2	401	0.15	15
	3	1	371	0.09	15
	3	1	370	0.20	15
Drum Barker Operator	2	1	395	3.4	15
	2	2	408	0.2	15
Freeness Tester	1	1	367	0.07	15
Area-Beside Bull Screen	1	1	385	0.07	15
Area-Beside 25" Log Bins	2	2	394	0.57	15
Area-Hallway Beside Slasher	1	1	371	1.3	15
	1	2	285	0.61	15

TABLE 07-2 AIR SAMPLING DATA, GROUNDWOOD MILL**

Location	Type of Sample*	CONCENTRATION (mg/m^3) Turpentine	Other Terpenes	Total Hydrocarbons	Resin Acids	Alcohols	Phenols
Near Stream Barker	Charcoal	< 0.15	< 0.15				
Grinders #4 & #5 (Balsam)	Charcoal	< 0.02	< 0.02	< 0.02			
Grinder #8 (Spruce)	Charcoal	< 0.06	< 0.06	< 0.06			
Grinder Room - 2nd Level	Charcoal	< 0.04	< 0.04				
	Silica Gel					< 0.04	
Personal Sample - Grinder Operator #8	Charcoal	< 0.04	< 0.04	< 0.04			
Personal Sample - Grinder Operator #4 & #5	Charcoal	< 0.02	< 0.04	< 0.04			

*Analysis performed by gas chromatography

**Values reflected on this table are "less than" due to the limit of detections of the analytical techniques.

levels for total airborne particulates. Area and personal samples were also collected on charcoal and silica gel tubes to evaluate the importance of volatile constituents of the wood. As shown on Table 07-2, no terpenes, hydrocarbons, or alcohols were detected.

WORKPLACE NOISE LEVELS

Noise levels in various areas in the groundwood plant are presented below:

TABLE 07-3 GROUNDWOOD MILL NOISE LEVELS

Area	Location	Minimum (dBA)	Maximum (dBA)
Streambarker	Catwalk Along Hot Pond	93	96
	Discharge End	92	94
	Feed End	95	97
	Hot Pond Feed	84	85
	Hot Pond Outfeed	79	81
	HUSQ Chain Saw	102	103
	Stiehl Chain Saw	106	107
Slasher	Slasher Operator Seat	82	83
	Slasher Room	94	95
Drum Barker (Chipperman)	Barker Operator Seat	93	95
	Barker Discharge	95	96
Grinder Room	Bull Screen	86	88
	Log Bins	84	85
	Main Aisle	85	87
	Grinder Pits	85	89

These data show that only the streambarker and drum barker operators are exposed to noise levels in excess of the OSHA PEL. The slasher operator is effectively protected by the partial enclosure separating his work station from the slasher. Noise levels throughout the grinder room are relatively low.

CONTROL OF WORKPLACE HAZARDS

The nature of the groundwood pulping process excludes significant exposures to air contaminants: 1) no chemicals are used, 2) most unit operations are conducted wet, 3) operating

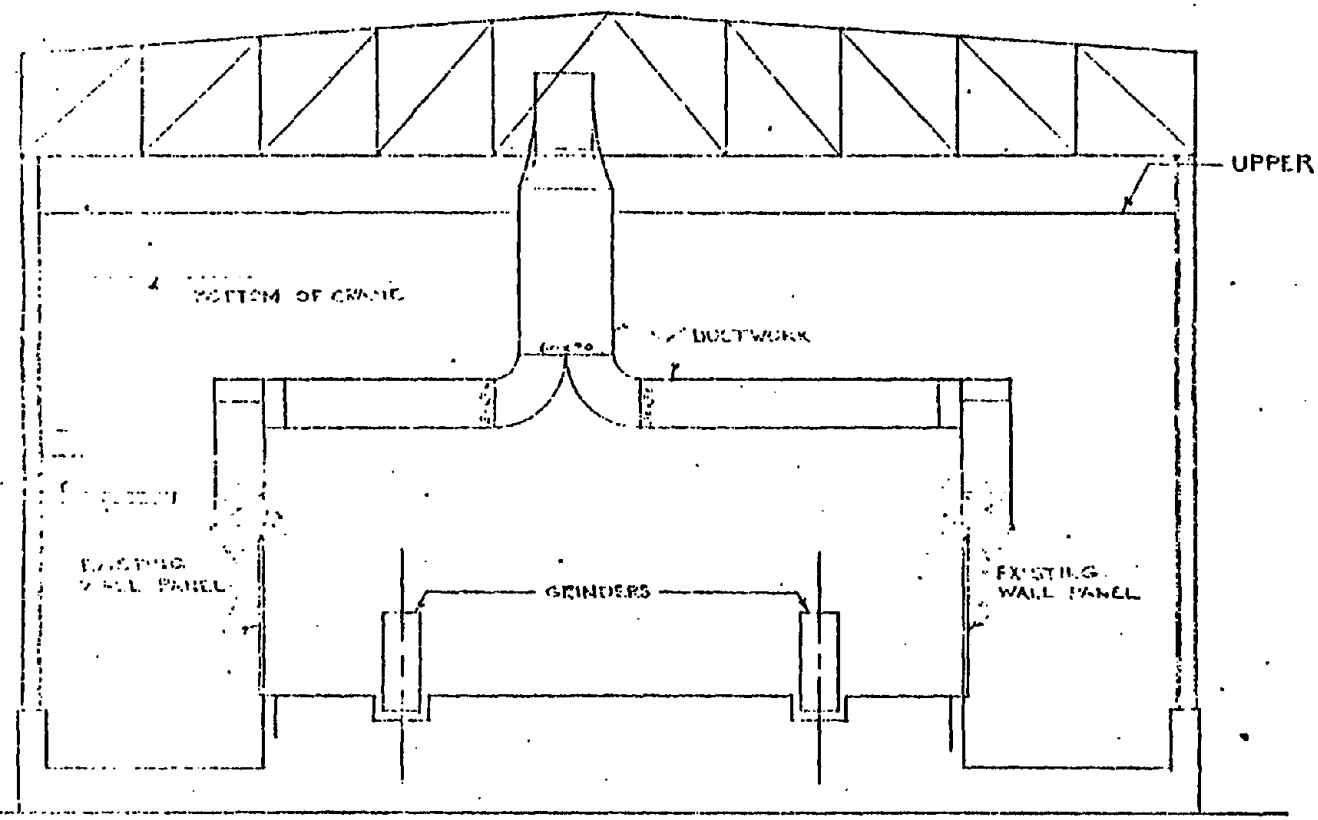
temperatures are too low to cause extensive emission of turpentine and other volatile wood constituents; and 4) the water spray quickly removes pulp material from the high temperature grinder chamber.

The slasher is the only unit operation having a significant potential for generating airborne particulates. The slashing operation is totally enclosed in a separate room: one half of the room contains the operator, the hot pond and the feed-end of the slasher conveyor; the other half contains the slasher. The two halves are separated by a wall extending from the ceiling to just above the conveyor. The wall includes a large observation window through which the operator can monitor the operation of the slasher. This arrangement provides two significant benefits: 1) first, the operator is isolated from the airborne particulate generated at the slasher (operator's integrated exposure to total dust is less than 0.1 mg/m^3), and 2) the wall provides an effective barrier to the acoustical energy generated at the slasher. As refelcted in Table 07-3, the wall effects a reduction in noise levels from 94/95 dBA in the slasher room to 82/83 dBA in the operator's room.

In 1970, the general ventilation system in the grinder room was modified to provide a flow of clean supply air at each of the 13 grinders. As shown on Figure 07-1, the system consists of curved diffusers located approximately four feet above and six feet behind the top of each grinder. The grinder operators can control both the quantity and direction of the air flow by adjusting chain operated dampers in each outlet. Behind each diffuser, supply air is also exited through an outlet. Behind each diffuser, supply air is also exited through an outlet in the bottom of the main duct. The system is designed with a total capacity of 30,000 cfm, or approximately 1300 cfm through each curved diffuser and an additional 1000 cfm through each bottom outlet. The system is very well accepted by the employees, as it provides both a cooling effect in the summer and a means of diluting and removing volatile wood constituents from the grinder operations.

As explained previously, the generation of wood dust is effectively prevented because most operations are conducted wet. However, were housekeeping not stressed, spilled chips, bark and other debris could dry out and become a significant secondary dust source. The housekeeping at Mill 07 is, however, extremely effective - floors and other work surfaces are frequently hosed down and cleaned; accumulated debris are promptly removed. The housekeeping program is effective for several reasons:

1. mill management takes exceptional pride in maintaining a clean, attractive workplace



SECTION "A" - "A"

SCALE 1/8" = 1'-0"

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FIGURE 07-1

2. employees are personally directly responsible for housekeeping in each area.

3. a full-time cleaner is available for housekeeping duties

MILL 14 WOODYARD/WOODROOM OPERATIONS

INTRODUCTION

This report summarizes the survey of an automated woodyard/woodroom in the Pacific-Northwest. Unit operations consist of: unloading and stocking of hard and softwood logs from river rafts; log slashing; ring debarking; mechanical chipping; and pneumatic conveyance of chips through closed lines to outside segregated chip piles. Additional purchased chips (approximately 70 percent of mill demand) are delivered by barge or truck, and unloaded with a crane at an outside facility along the river. They are then penumatically conveyed directly to the chip piles. Chip washing and screening operations are performed just prior to use of chips, and are conducted in separate buildings.

Potential workplace exposures were identified as noise and wood dust. A scheduled maintenance shutdown of the woodroom and an extensive period of rain during the survey restricted survey observations and data collection. Wood dust generation and exposures under such weather conditions was judged too atypical, and air monitoring was not performed. The subsequent discussions are largely directed toward assessment of effective noise control technology.

PROCESS DESCRIPTION

The woodyard/woodroom operation at Mill 14 was started up in 1967. It supplies both hard and softwood chips for Kraft and groundwood pulp mills. Only minor improvements and additions have been made since 1967. The availability of land and river transport of incoming logs dictated the mill's general location and design. It also facilitated an efficient, straight-through equipment layout and process flow scheme that results in very good operator visibility and control over all equipment. The mill is operated for approximately twenty hours per day consisting of two ten hour shifts (two hours in between for performance of required maintenance tasks). Both hardwood (approximately 25%) and softwood (approximately 75%) logs are debarked and chipped in the woodroom. The chips are then pneumatically conveyed to either a separate building for washing and/or screening, or directly to the pulp mill storage bins. Shipments of pre-chipped wood (delivered by either barge or trailer truck) are unloaded as they arrive, and pneumatically conveyed to segregated chip piles.

Woodroom operations consist of the following sequence. Long logs are transported to the mill by river rafts, picked up in bundles with a Starr crane and dropped onto a parallel-type log haul-up. This transports them up to the woodroom inlet deck,

where they are selectively classified according to their diameters. The logs are then placed by a large overhead Nicholson crane onto one of two chain conveyor chutes running horizontally into the woodroom. Classification is performed by the operator who sits in an enclosed cab atop the crane. The crane straddles each chain conveyor line at the end of the woodroom inlet deck.

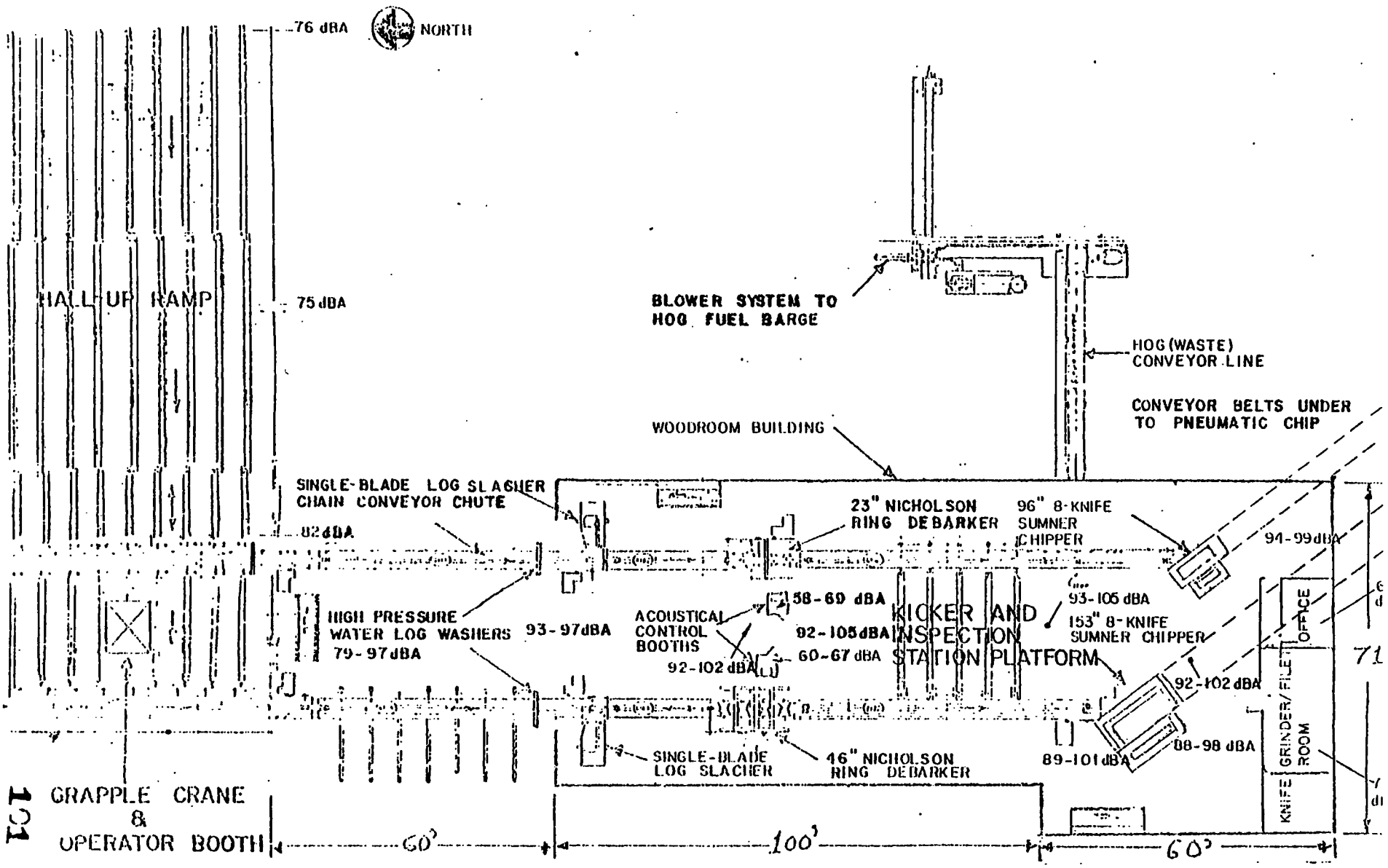
A separate operator, located within a special acoustical booth, controls each chipping line. The west line is used for large diameter logs (up to 3 feet) and the east line for smaller logs. As shown in Figure 14-1, the chipping lines run in parallel. Each consists of a chain-belt conveyor chute which runs horizontally down the center of the room transporting individual logs through an arrangement of equipment. These are, in sequence:

- a high pressure water spray to remove dirt and loose bark;
- a single, circular-saw slasher to reduce crooked logs to less than 20 feet;
- partially enclose 27 or 44 inch Nicholson ring debarkers with pneumatically held arms;
- an inspection station with a pneumatically-activated kicker to drive logs to a center aisle platform for additional attention;
- a 96-inch 8-knife (east line) or 153-inch 8-knife (west line) Sumner chipper; and
- a ground floor belt conveyor line which collects chips discharged below the chippers and feeds them to an outside pneumatic conveyor.

Chips are then blown through closed lines to the segregated chip piles located outside of the building. Process wash water, waste bark, and other waste material drops through the operating floor to the ground level. Bark is then separated from the other waste and water, diverted to hog conveyor line, and transported to a system for blowing onto a hog storage pile.

Additional facilities located within the woodroom building include a foreman/production office with a sound-attenuating, double-door entryway; and an enclosed grinder room for sharpening chipper knives. The foreman/production office is designed with a large north-facing observation window that provides the shift foreman an excellent view of the entire length of both log treatment lines. Additionally, the full length of the woodroom's north wall has an approximately 10 foot high opening which readily affords access and observation of the outside log deck.

FIGURE 14-1 WOODROOM EQUIPMENT LAYOUT



POTENTIAL WORKPLACE EXPOSURES

Potential worker exposure to noise and, to a lesser extent, wood dust (or other particulate matter) were the only significant hazards identified in the woodyard and woodroom. Airborne particulate matter (wood dust) would be generated mainly from the slashing, debarking, and chipping operations. It is considered a nuisance dust with a PEL of 15 mg/m3. It was judged, however, not to be directly generated in significant quantities by this mill's equipment and the wet technique for slashing/debarking/chipping.

The resuspension in air of accumulated wood dust and other waste materials during cleanup or housekeeping operations was also judged to occur very infrequently. This is because most process waste remains in a wet condition, and a conveyor system is used to remove it from the building.

Since the woodroom was shutdown for routine maintenance work during the survey, detailed noise source and control data were not obtained. However, an independent noise consultant performed a sound level survey of the woodroom in the summer of 1979. Their data was judged to be accurate and representative of existing conditions. Sound level readings were taken by the consultant using a calibrated, A-scale General Radio Company meter at various locations in the woodroom during normal operations and production levels. Their results, expressed as dBA ranges, are plotted on the operating floor plan in Figure 14-1.

Based on these data and our field observations, sound levels during normal operations are above the current OSHA PEL of 90 dBA over the entire woodroom operating floor. The apparent significant noise-generating equipment and estimated exposure hazards for areas near them are:

	Source	Proximate SLM Intensity Range*, dBA
Major:	Sumner multi-knife chippers	88-105
	Nicholson ring debarkers	92-105
	Single-blade slashers	93-97
	Haul-up crane (outside)	79-97

Minor:	Chipping line chain conveyors	NA
	Hog (Bark) conveyor system	NA
	Chip conveyor system	NA
	Knife grinders	NA
	Haul-up chain conveyor system	< 80
	Starr crane (outside)	< 90
	High pressure ring water sprayer	NA

* Actual SLM readings were taken in mid-aisle areas with hand-held meter 4 feet above floor, 18 inches from observer, and perpendicular to sound source(s).

NA = Data insufficient to estimate.

As indicated, sound intensities vary considerably throughout the operating floor depending on the types and number of equipment operating at a given time, and their operational speeds. The slashers produce the typical whinning sound of a high-speed circular saw, whereas the ring barkers and multi-knife disk chippers produce a lower-pitched, rattling or staccato-like sound. It could not be determined if the larger, west-line debarking/chipping equipment produced a correspondingly higher noise level than the smaller east-line.

Significant sound levels also exist on the ground floor of the woodroom building but these readings have not been plotted due to poor clarity of floor plan details on the layout diagram provided by the mill. Values ranged from 88 to 94 dBA below the slashers and debarkers to 86 to 96 dBA in areas below the chippers and around the chip conveyor systems. The individual or combined noise levels produced by other woodroom equipment could not be accurately assessed, but is thought to be relatively minor. Data on the noise levels in the operating cabs of the various outside roundwood handling equipment was also not available.

Effective engineering, personal protective equipment, administrative, and other controls have, however, been developed by the mill to control worker exposures to noise. These are summarized and discussed below under "Control of Workplace Exposures".

JOB DESCRIPTIONS

Out of a total production staff of 10 employees per shift, only the haul-up crane operator, the two chipping line operators, and the shift foreman were judged to be potentially at significant exposure risk to noise. Utility men (1 or 2) that are assigned to the area, may also be at risk while performing irregularly scheduled cleanup/housekeeping tasks. However, because such tasks are performed at unscheduled times and for varying lengths, quantitative assessment of exposures is difficult.

The above four workers were judged to spend the majority of their time in or around potentially high noise exposure areas of the woodroom. Compilation of job summaries and detailed investigation of potential exposure situations for other woodyard employees (chip unloader operator, hog fuel loaders, maintenance workers, and supervisory personnel) were not conducted due to judged low exposure risks and survey time constraints.

Foreman - The shift foreman has overall responsibility for performance of all production, maintenance, cleanup, and safety tasks within the woodyard. It is estimated that, on the average, he spends the majority of his time outside of the woodroom office, but his work schedule is typically unpredictable. He may potentially be required to oversee operations anywhere in the woodyard or woodroom. Such supervisory tasks require him to spend significant periods of time outside a controlled area. Additional time is also spent performing routine equipment and process inspection tours, and checking the arrival of incoming raw material shipments.

Log Unloading and Haul-up Crane Operators - The log unloading and haul-up crane operators spend the majority of their time (est. >75%) within the cab of their respective pieces of equipment. Typically they leave them only for short periods of time to unjam logs or service equipment and conveyor lines. Both pieces of equipment are located ouside and the only significant workplace exposure agent is noise.

Chipping Line Operators - The two chipping line operators also spend the majority of their time (est. > 75%) within the protective acoustical booths which contain all the controls for their respective lines. As with the crane operators, their equipment must typically be stopped (for safety reasons) before they would leave their control stations to inspect or service any item. These two operators are also responsible for changing dull or defective slasher blades and debarking arms, removing jammed or oversized logs, and inspecting and diverting out-of-specification logs or chips.

CONTROL OF WORK PLACE EXPOSURES

Noise - The major controls which combine to achieve effective worker protection to excessive noise exposure in the woodroom include:

- o the acoustical control booths for enclosure of the chipping line operators;
- o the enclosed office and knife grinder rooms;
- o the enclosed control cabs for the log unloading and haul-up crane operators;
- o the mandatory requirements for all workers to use hearing protection while outside any of the above enclosed areas;
- o the partial isolation of the major noise generating pieces of equipment (the chippers) at the far end of the process line;
- o the partial enclosure of the ring debarkers; and
- o the use of sound-attenuating building design features, construction materials, and a horizontal equipment layout plan.

Additionally, the four woodroom employees (three operators and a foreman) typically required to enter high noise areas in the mill, all spend the majority of their time in protected areas (i.e. significantly less than 90 dBA). They must wear ear protection during any unscheduled period they are required to be outside these enclosures. In addition, individual pieces of equipment or the entire process line is usually shutdown during periods that an operator is outside his control booth.

The previously presented noise data indicate that the worker enclosures provide an almost 30 dBA noise reduction in the case of the chipping line operator's control booths; and an approximately 25 dBA reduction for the office area. The acoustical booths were reported to be recently-added off-the-shelf replacements for original ones (supplied by the building contractor) which were found to provide little noise reduction. No data were available, however, for the increased attenuation from these new booths, or their purchase and installation costs. The knife grinder room provides only 10-20 dBA reduction, but this is sufficient to drop levels below the OSHA PEL of 90 dBA.

Other woodyard employees either spend the majority of their time outdoors or in low noise areas. All are provided ear protection for the periods they are required to work in the woodroom building. Eight hour TWA noise exposures, therefore, do not likely approach the OSHA PEL of 90 dBA for any worker. Confirmatory personal noise dosimetry data is not available.

Additional pertinent features and comments concerning the design of the woodroom and its inherent sound-attenuating properties include:

- o a high, open ceiling with a center apex some 30 feet above the operating floor;
- o the use of wood structural members for the roof and walls of the building with corrugated, galvanized steel wall and roof panels attached to these;
- o an open north woodroom wall to reduce reverberant sound from the slashers and debarkers;
- o the recession of the chipper disks partially into the operating floor; and
- o the long horizontal distance between the signficiant noise-generating debarking and chipping equipment.

No data were available to assess the contribution of these features to noise reduction.

The availability of river raft transport of roundwood and sufficient nearby building land facilitated the construction of an automated, compact, and efficient woodyard and woodroom at this mill. A relatively small operating staff is required, especially for the woodroom. The single-level woodroom operating floor and its straight, horizontal arrangement of equipment is also very efficient and safe. This indirectly reduces noise exposure since workers spend less time outside of protective areas servicing equipment. It is also important to note that such an efficient layout of equipment would greatly facilitate installation of noise control systems in a mill if ever required.

Hearing Conservation Program - Worker protection provided by the above effective engineered controls in this woodroom is supported with a strict, mandatory, mill-wide hearing conservation program. The elements of this program which is administered by the mill safety/personnel director and in-house medical staff include:

1. Mandatory initial baseline audiograms and physical exams with employment histories for all new employees;

2. Audiograms performed and reviewed by the mill nurse with a copy of all results permanently maintained;

3. Repeat audiograms at least annually for all woodyard employees, and review of results with the employee by the nurse;

4. Employee referral to a professional audiologists if threshold shift of 10 decibels is observed;

5. The providing of each woodyard employee with a suitable and comfortable ear protection device at no cost; and instructions in its proper and required use.

No data could be assembled on the costs of administering this hearing conservation program. Its enforcement, however, especially the required use of hearing protection while outside of designated, low noise areas, was judged very strict.

Wood Dust - Continuous sources of wood dust or other particulate matter emissions are not apparent in this woodroom/woodyard operation. Typically, the wet state of incoming roundwood and the additional cleaning water applied to the logs serve to reduce generation of airborne particulate matter during log slashing and debarking. The wood chipping step is accomplished in closed, disk chippers with the chips immediately thereafter blown to storage piles through closed systems. During all operations, operators are effectively isolated from the equipment and are usually enclosed in protective booths.

Housekeeping and cleanup of waste materials is usally done while equipment is off, and the waste is still largely wet. Wind-transported wood dust from the open chip storage piles and other woodyard operations (truck and barge chip unloading) poses a potential worker exposure problem. These sources and resulting worker exposures are highly dependent on environmental factors (season of year, percipitation, wind direction and speed, etc.), and the degree of activity in the woodyard. Worker exposures were not quantified during the survey period due to the inclement weather conditions, altered work practices, and survey time restrictions. Periodic worker exposures in these areas are best controlled through use of personal protective equipment, as needed. Use of respirators in the woodyard was not observed, (or required) although they are available though the plant safety office, and a written program exists for their use.

MILL 15: REFINER GROUNDWOOD PULPING PROCESS

INTRODUCTION

Mill 15 is a refiner groundwood pulp mill consisting of three parallel process lines producing 300 tpd of pulp for newsprint.

A small degree of final pulp bleaching is accomplished by adding a sodium hydrosulfite solution into the sump of the final stage refiner of each line. The bleaching solution is purchased pre-made and no other chemicals are involved in the process. The entire process is carried out in a large, three story (with mezzanine) building. Chip screening operations are performed in a separate building and were not included in this survey. Noise, wood dust, and volatile wood constituents are the only potential workplace exposures.

MILL AND EQUIPMENT LAYOUT

All equipment is located in a three story, closed building. The second (or operating) floor contains the three lines of refiners, primary and secondary cleaners, secondary screens, two electrical rooms, a laboratory and adjoining office, and a central control room. Above the north half of the operating floor is an open mezzanine containing Jones disk filters (deckers), primary screens, Hydrosieves, and the rejects conveyor line. Chip storage and feed systems for each refiner line extend down from the roof to just above the refiners.

PROCESS DESCRIPTION

This mill produces approximately 300 tons per day of hemlock or alder pulp in three parallel lines. Each line is identical with the exception that Lines No. 2 and 3 do not have a recleaner stage.

Chips from the outside storage piles are blown to one of two cyclones, then down through four sizing screens which are located in the screening building. Oversize chips are routed to the rechipper for additional size reduction operations. The accepts are pneumatically conveyed to one of three cyclones located on the roof of the groundwood building. Air and fine dust is exhausted from the cyclone, and the chips drop through a rotating spout into storage silos.

Chips (and small fibers) are then processed through three consecutive and similar Bauer No. 480 double-disk refiners. After being mechanically pulped in the refiners, the stock is flushed into an agitated sump and then rotorlifed to the next

refiner. From the third refiner sump, the pump is mixed with additional water from the white water tank, and then pumped to seven parallel primary screens. The remaining process operations consist of pulp screening (two stages) and cleaning (three stages) steps where reject flows are recycled and reprocessed to minimize stock losses. The clean and properly sized fibers from the last stage of cleaning are pumped to one of three deckers where the pulp is washed and thickened. It is then transferred to one of two outside high density storage chests (100 ton capacity) until required by the papermill.

Bleaching is performed using the V-Brite bleach system where sodium hydrosulfite solution is added continuously to both the last refiner sump (sump C) of each line and the high density storage chest. This solution is purchased pre-made and is unloaded and stored in a building adjacent to the Kraft pulp mill in this complex. Small day tanks are located on the groundwood building roof.

JOB CATEGORIES AND DESCRIPTIONS

There are three employees per shift responsible for the entire groundwood mill operation - two production operators and one utility man. The utility man is assigned for 50% of his time to the nearby chip screening building.

Operators - The operators have primary responsibility for the operation of the refiner groundwood process. Since the process is analog controlled, their main function during normal operation is to monitor and adjust critical process parameters from the control center. It is estimated that both the 2nd and 3rd shift operators spend about 75% of their time in the control room. The remaining 25% of their time is spent performing miscellaneous tasks or equipment inspections. The 1st shift operator is also responsible for maintenance inspections of various equipment, performance of quality control tests on stock, and reversing the direction of rotation of the refiner disks. Performance of these additional tasks results in him spending only aout 40% of his shift in the control room.

Assistant Operators - Twice per shift the assistant operators collect and test stock samples from: 1) the 3rd refiner sumps of each line; 2) the deckers; 3) the high density storage chests; 4) the 1st and 3rd stage refiners; and 5) each chip line. Once per week they (along with the utility person) change bad segments in the decker filter fabrics, and clean the decker shower heads. These operations can take as long as 8 hours per decker. The assistant operators are also available to assist the operators during emergencies, process startups

and stock spills. On the average, the 2nd and 3rd shift assistant operators are in the control room or laboratory about 75% of the shift and the day shift operator only about 40% of his shift.

Utility - The utility man is available as needed to assist the assistant operator in: make-up new decker segments; changing decker segments; cleaning decker shower heads; and cleaning-up stock, chip, or sawdust spills. His time spent outside of the control room is equally divided between the refiner groundwood building and the chip screening building. It is estimated that the 1st shift utility person is in the control room for one hour per day; the 2nd shift utility person for three to four hours per day; and the graveyard shift utility person for up to six hours per day.

POTENTIAL WORKPLACE EXPOSURES

Possible workplace contaminants are wood dust, noise, and volatile wood constitutents (resin acids, terpenes, phenolic compounds, etc.).

Since the sodium hydrosulfite bleaching agent is purchased in solution, stored in closed tanks, and added directly to the closed, last-stage refiner sumps (and high density storage tanks), worker exposure is unlikely.

No other chemicals are used in the process. Significant worker exposure to wood dust is probably restricted to chip spills and housekeeping tasks around the various outside conveyance equipment. Primary noise exposures result from the refiners, and various stock and water pumps. To a lesser extent, the screens, the stock and chip transport systems, and other miscellaneous equipment throughout the building contribute to overall noise exposure.

Some of the process equipment is open and can potentially emit volatile wood constituents to the workplace. In some cases, this is by design or necessity in order to remove the great amount of steam generated by friction within the refiners. The primary sources of release or venting of such steam (and any volatile wood constituents) is by forced ventilation of the refiner sumps. To accomplish this, a duct leads from each sump to a main overhead header duct which then leads out the west wall of the building and up to a roof ran. Condensed steam in this main header is drained off and sewered. Additional high pressure steam, which the refiners generate, is vented (not by design) through the overhead chip (or stock) feeding system and enters the workplace. This venting is possible because overhead covers and plates on this system have either been removed or are not securely fastened.

Exhaust hoods are provided for each of the three deckers (i.e. disc filters) and the tailing screens. These systems are also provided solely for venting the large amount of steam generated in these units from the hot wash water. Various sumps of the screens and cleaners are also open and emit a small amount of steam to the workplace.

AIR SAMPLING RESULTS

Gas chromatography analysis of steam condensate samples in a previously studied thermo-mechanical mill had indicated a wide assortment of organic compounds believed derived from wood constituents. Therefore, a fresh, condensate sample was collected from the drain on the refiner sump ventilation duct, and analyzed by both direct injection gas chromatography (10% FFAP on Chromosorb W column, and flame ionization detection), and by chloroform extraction with gas chromatography analysis. This technique was thought to be sensitive to the presence of any condensible terpenes, aromatics, higher molecular-weight aliphatics, resin acids, and perhaps, some ketones and alcohols. However, phenolic compounds were not expected to be extracted and detected, as would any other species that has low solubilities in chloroform, or that have overlapping column retention times. Our laboratory estimated the total extractable hydrocarbons in the condensate to be less than 10 ppm.

Air samples were collected to assess the existance of volatile wood constituents in the workplace. Samples were collected on the operating floor near the C-refiners, and on the mezzanine level near the No. 2 line decker. Two samples were collected concurrently at each location. One consisted of a jumbo charcoal tube followed by a silica gel tube, and the other a 37 mm glass fiber filter (Whatman Grade 934 AH). Samples were collected over a five and a half hour period. Each of the three collection media were then separately desorbed with carbon disulfide and analyzed by gas chromatography using a flame ionization detector, and the following selective columns: Tenax GC for phenols; Carbowax 20 M treated with H_3PO_4 for organic acids; and a broad spectrum 10% FFAP on Chromosorb W. A sampling blank was also analyzed by the same procedure. As with the steam condensate sample, no measureable quantities were detected at either sampling location except a small amount of terpenes (.49 mg/m^3 and 1.3 mg/m^3) and an even smaller amount of a ketone compound (0.05 mg/m^3, mezzanine level only). The results, expressed as estimated detection limits for general types of compounds, are summarized in Table 15:1.

In summary, the results indicate that few organic species of wood derivation are generated or enter the workspace from this refiner groundwood process. However, the adequacy of existing

TABLE D-1 - SUMMARY OF GREENWOOD PLANT AIR SAMPLING RESULTS

Location	Sample Type[A]	Sampling Time (Minutes)	AIR CONCENTRATIONS[AA] Hydrocarbons	Terpenes	Resin Acids	Alcohols	Ketones	Phenolics
Operating Floor Level, Near C Stage Refiners for Lines 2 and 3	Charcoal Tube	111		486 ug/m^3	----	< 29 ug/m^3	< 29 ug/m^3	- -
	Silica Gel Tube	111	< 29 ug/m^3	< 29 ug/m^3	< 29 ug/m^3	< 29 ug/m^3	< 29 ug/m^3	< 29 ug/m^3
	Glass Fiber Filter	111	- -	< 2 ug/m^3	< 2 ug/m^3	< 2 ug/m^3	< 2 ug/m^3	< 2 ug/m^3
Bleaching Level, Front of Decker #1	Charcoal Tube	110		1301 ug/m^3	----	< 80 ug/m^3	85.5 ug/m^3	- -
	Silica Gel Tube	110	< 80 ug/m^3	< 80 ug/m^3	< 80 ug/m^3	< 80 ug/m^3	< 80 ug/m^3	< 80 ug/m^3
	Glass Fiber Filter	110	----	< 2 ug/m^3	< 2 ug/m^3	< 2 ug/m^3	< 2 ug/m^3	< 2 ug/m^3
Condensate Drain Line From Refiner Sump Ventilation System	Steam Condensate	- -	- - - -	< 10 ppm	EXTRACTABLE	HYDROCARBONS	----------	------

[A] Charcoal and silica tube, and glass filter blanks all gave responses of less than 1 ug; see text for description of analysis procedures.

[AA] No specific workplace standards exist for any of the below reported classes of compounds.

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sampling and analysis technology is largely unverified for the observed conditions; and recognized workplace standards do not exist for exposure to many of the potential types of wood-derived compounds.

Worker exposure to wood dust was judged to occur very infrequently, and air sampling was not performed. As discussed, chips are pneumatically conveyed to the storage bins, and then dropped into closed screens and a wash system. From this point on the chips are handled wet, and are not a significant source of dust generation. Spills rarely occur, and housekeeping is not regularly required nor performed. The groundwood plant utility man is, however, potentially exposed to wood dust during the estimated 50% of his shift spent working in the woodyard and chip screening building.

NOISE DATA

Noise data from a 1979 sound level survey by an independent consultant was obtained and reviewed. Readings were taken by the consultants throughout the building in worker-frequented areas or walkways using a calibrated sound level meter (A-weight scale, slow response). The plant was in full, normal operation when the levels were recorded, but no notations were made regarding which pieces of equipment were operating when the readings were taken.

The data indicate that sound levels throughout the refiner, primary cleaner, and secondary screen areas on the operating floor are slightly above 90 dBA (i.e. 89-93 dBA). However, the control room (77 dBA "DO"*, 67 dBA "DC"*), the office (83 dBA "DO"; 68dBA "DC"), the laboratory (69 dBA "DC") on this floor all provide excellent sound protection for the workers. As summarized in the job descriptions section, they spend most of their time in these rooms. No formal sound-reducing materials or unusual designs were used for these rooms.

The north mezzanine and the ground floors have fairly constant sound levels ranging from 86 to 89 dBA, except the aisleway along the north wall of the ground floor where numerous stock transfer pumps create levels slightly above 90 dBA. Workers infrequently remain in the aisleway or near the equipment.

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* DO is door open
DC is door closed

CONTROL OF WORKPLACE EXPOSURES

The refiner groundwood pulping process has a number of characteristics which preclude significant exposures to air contaminants:

- No chemicals (except sodium hydrosulfite) are added to the process; potential air contaminants are thus restricted to wood dust and wood constituents. The latter must be volatile under the various pressures and temperatures attained during the refining process, and must escape into the workplace through various steam leaks and vents.

- The process is analog-controlled and employees can remain in a closed, positive-pressure control room for the majority of their time except for brief routine maintenance tours, sample collection runs, and planned or emergency maintenance operations.

- The majority of the pulping operations are conducted on wet or slurried material, and there are essentially no primary sources of wood dust generation provided chip transport systems are well-maintained, tightly-sealed, and chips remain moist until fed to the refiners.

Additionally, both local and general air exhaust systems provide removal of process steam. The entire building is ventilated by three roof-mounted fans (50,000 cfm each). The three deckers are hooded and exhausted by separate blowers, each originally designed to provide 11,000 cfm. In addition, the tailing screen is ventilated using a 10,000 cfm exhaust fan. Tempered make-up air is provided by four 50,000 cfm axial fans, and one 25,000 cfm Heil fan. In response to concerns over heat stress, the mill has recently (1981) installed three mancoolers on the operating floor (16,500 cfm each). This is in addition to an existing mancooling fan installed in 1971 (20,000 cfm).

Excessive noise exposures are effectively controlled by: 1) both of the production employees spending at least 40% of their time within the control center or other low noise area; 2) the mandatory requirement for hearing protection when outside either the control center, office, or laboratory; 3) the infrequent need of workers to enter areas exceeding 90 dBA (i.e., around the refiners, primary cleaners, or secondary cleaners); and 4) the fact that high noise producing equipment would normally be shutdown whenever a worker was required to spend a significant period of time servicing it. In addition, the plant has a mandatory worker hearing conservation program which includes pre-employment physicals, baseline audiograms, and yearly repeat audiograms that are reviewed by a professional health consultant.

MILL 40: General Control Technology in a West German Pulp and Paper Mill

INTRODUCTION

Mill 40 is a large, integrated pulp and paper mill located in the Ruhr Valley of West Germany. It has an automated mechanical pulping process that uses chain grinders, and three modern Fourdrinier paper machines that produce lightweight coated papers for primarily magazines, and some uncoated paper. The mill was surveyed (with Mill 39) to provide comparative data on the development of foreign workplace control technology.

A brief walk-thru survey of the mill revealed very few potential physical or chemical exposure agents other than noise. The absence of contaminants is attributable to the mechanical pulping process, the use of only weak and non-volatile bleaching solutions, and the automation of the coating preparation and papermaking facilities. Therefore, this report will briefly summarize the mill's operations, present a short summary of West Germany's labor protection and safety regulations, and then discuss the mill's general worker health protection program and noteworthy noise controls.

MILL DESCRIPTION

The mill has at least six distinct process areas or major operations:

1) Woodyard/woodroom
2) Mechanical pulp mill
3) Coating preparation facility
4) Paper mill with integral pulp bleaching and stock preparation operations
5) Water and wastewater treatment plants
6) Fertilizer plant (for composting bark and other wastes)

Each of these will be briefly described below.

Woodyard/Woodroom - The woodyard/woodroom is highly automated, and can handle 125,000 cubic meters per year of roundwood. Most roundlogs arrive by truck, and are unloaded onto a continuous conveyor which transports them through the subsequent slashing (to one meter lengths), debarking, and final inspection operations, which are each conducted in separate buildings. The slashing and inspection buildings are constructed of corrugated metal panels, and are elevated above the ground. The two drum debarkers are located in a separate

building specially designed about 5 years ago to reduce community noise complaints. The building has concrete slab walls and a high metal roof with steel I-beams and cross supports.

Woodyard/Woodroom workers monitor equipment, inspect the logs after they are slashed and debarked, unjam logs or the waste conveyance systems, and service and adjust equipment. Cameras and television screens help them to monitor remote operations.

There is little potential for wood dust exposure in the woodyard/woodroom area because equipment is highly automated and little dust is generated during slashing and debarking. In addition, logs are sometimes wet and moist waste is discharged below the equipment and then conveyed to the fertilizer plant. Attention to housekeeping and waste cleanup was excellent, and all areas appeared very clean.

Mechanical Pulping - Debarked logs from the woodroom are brought to the pulp building on a conveyor system. They are then placed on an automatic feeding system for the ten Voith chain grinders, located on the floor below. The pulp produced in the grinders is flushed out from below with water, and then screened and mechanically refined in a nearby area.

Steam and volatile wood constituents are generated from the frictional heat of pulping, but are contained inside the closed grinders and then vented to the outside. As a result, temperature and humidity on the grinder and log unloading floors are elevated, but not uncomfortable. The grinders are automated, and are monitored and controlled from an isolated, air-conditioned control room. The potential for over-exposure to heat or volatile wood constituents is low because few workers are near the grinders, and none of them perform strenuous manual tasks for long periods of time. No wood dust is generated during pulping, and process areas appeared very clean.

Coating Preparation Facility - Coatings for the papers are prepared in a separate, single-story building which is near the paper mill. This new facility was built to handle up to 500 tons per day of production, and consists of separate preparation line for each of the five major coating formulations.

The coatings are prepared in batches in large, closed tanks, and have a number of possible ingredients including pigments, starch, protein material, native binders, and latex. Formaldehyde was an ingredient until 1980. Any dry chemicals are usually unloaded to storage tanks with a pneumatic transport system, then are similarly transferred to the

TABLE 40-1: SUMMARY OF SOUND LEVEL READINGS NEAR PAPERMACHINE NO. 4

Location	Sound Level Reading, dBA*
Wet Laboratory Area (Stock Preparation)	77
Main Control Room	68
Adjacent to Fourdrinier	92
Adjacent to Suction or Couch Roll	95
Machine's Press Section @ Operator's Control Bench	96
Middle of Dryer Section	90
Near Takeup Reel (End of Machine)	88

*Readings taken with Bruel & Kjaer Model 2203R Sound Level Meter

preparation tanks. Small quantities of various liquid ingredients (about 1 liter) are added by hand; and water is added automatically as the ingredients are stirred. When a batch is completed, the formulation is pumped to the paper mill.

Four workers operate the coating facility, but they stay inside an isolated, air-conditioned control room for 75% of the time in order to monitor and operate the automated processes. Although some dust may escape when dry materials are unloaded or added to tanks, the workers usually are not nearby, and exposure is unlikely. Dust masks are available if they should encounter particularly dusty conditions, but this is rare because equipment is automated and tightly closed, and some of the dry bulk transfer systems have dust exhaust systems. Chemical spills are promptly cleaned up, and as a result, the facility appeared very clean.

Papermaking - The mill has three Fourdrinier paper machines, each with separate bleaching systems. The oldest machine has a 2-stage system that uses dilute hydrogen peroxide for the first stage, and dilute hydrosulfite solution for the second. The two newer papermachines have single-stage hydrosulfite systems. The bleaching solutions do not contain volatile chemicals, and are added and reacted in closed tanks and pipelines. This essentially eliminates the potential for contamination of workplace air.

The oldest papermachine was installed in 1927, but it now has highly automated, computer-assisted stock handling and paper forming, dewatering, drying, and rolling systems like the two newer machines (1970 and 1980). The machines operate at speeds of 500 to 1200 meters per minute, and can produce a combined total of 400,000 tons per year of lightweight coated paper (54-170 grams per square meter basis weight). The oldest machine has both an on-machine and off-machine coater; the two newer machines have off-machine coaters. The machines are monitored and controlled from air conditioned rooms located above and in front of the wet ends. Additional worker isolation rooms are located along the sides near the wire, press, and dryer sections.

The wet end equipment of each machine generates noise ranging from 77 dBA at the stock preparation area (wet laboratory of a newer machine) to 95-96 dBA at the couch roll and press section (See Table 40-1). Workers are exposed when near the machines, but the control and other isolation rooms provide important protection during monitoring or break periods (see Control Technology section).

The dryer section of each machine generates a lot of heat and steam, and must be enclosed and ventilated. The enclosures effectively reduce workplace heat and humidity to acceptable

levels. Rollup doors on each side of these enclosures provide worker access when required.

Dry-end and coater workers are outside control or isolation rooms longer than wet end workers because they have to insure the paper stays properly threaded, cut finished rolls and insert new takeup rolls, transfer full rolls, and slit and rewind completed paper. Slitting, rewinding, and handling dry paper can generate some dust, but the lightweight grades of paper being run during the survey produced no visible quantities. Work areas are kept very clean, and paper broke is quickly cleaned up and placed in a recovery system.

Water and Wastewater Treatment Plants, and Fertilizer Plant - The mill is very proud of these three advanced plants which demonstrate their efficient use of natural resources under West Germany's strict water consumption and degredation regulations. (West Germany has monetary assessments for water degradation.) The efficient, automated water filtration and two-stage (mechanical aeration and biological oxidation) wastewater treatment processes are often so effective that process water is returned to its source with less suspended solids and organic material than it had before use. Although some chlorine gas is used to disinfect incoming fresh water, it is added and reacted through a closed system, and workplace contamination is unlikely in the absence of upsets.

The fertilizer plant composts woodroom waste bark and part of the sludge from the wastewater treatment plant in large, aerated, outside piles. The resulting fertilizer is periodically removed and shipped to buyers. Volatile composting gases vent to the atmosphere.

CONTROL TECHNOLOGY

Labor Protection and Safety Regulations in West Germany

For the interest of the reader, the following is a brief summary of worker safety and health protection programs in West Germany (as provided by mill officials):

Social security started in Germany with the social laws of 1881 which implemented statutory health, accident, and pension insurance. The Reich Insurance Code of 1911 asked for the establishment of Industrial Cooperatives of occupational groups as an accident insurance institution. These cooperatives, of which there are now 35 in West Germany, are public-law entities with a self-governing body. Employers pay premiums to them, and the pulp and paper companies pay their contributions to the cooperative of the Pulp and Paper Industry.

The cooperatives establish safety rules, train employees in special courses of instruction, provide the accident insurance, and retrain incapacitated persons. All 35 cooperatives support a research institute and a library which has data banks of safety literature.

In addition, each cooperative employs technical supervisors who control and observe the safety rules in the shops and factories; and every mill, depending on its size, is legally required to have a half- or full-time safety engineer and several employee safety representatives.

Besides the Industrial Cooperatives, the State Trade Supervisory Authority of the Regional Labor Ministry controls industries and trades in accordance to the Industrial Code. The factory and shop inspectors of this office have free access to mills at any time. They make regulations (by special federal laws) on working hours, safety rules, noise levels, contaminant levels, and the proper functioning of water treatment plants.

The Labor Protection and Safety Analysis (BAU) is an institute of the federal government, which is divided into four sections and employes 250 people. The institute trains safety engineers and other employees through special courses, and has a library with data banks of special literature.

Workers are represented in health and safety matters through the worker councils.

Workplace Exposure Limits

Table 40-2 summarizes workplace exposure limits for contaminants potentially found in the German pulp and paper industry. The limits are published (with general industry safety standards) in a small book available to the public. The limits are time-weighted averages based on an 8-hour day and 40-hour week, and are generally equal to or lower than OSHA P.E.L.'s, (the lower values correspond to NIOSH-recommended limits).

Mill 40's Worker Health Protection Program

The mill has developed a good worker health protection program organized around its legally-required safety engineer, a works physician, and several employee safety representatives (the Safety Engineer and a Safety Foreman are full-time employees). The program includes: 1) pre-employment physical examinations to screen for prior adverse health conditions, 2) baseline hearing tests, 3) formal worker education in health and safety policies and practices, 4) training in the proper use of

Table 40-2:

Summary of Select Exposure Limits in West Germany[1]

Airborne Contaminant	Maximum Allowed Concentration in Working Place
Asbestos	Limits are based on the types of fibers and their sizes
Chlorine	0.5 ppm
Chlorine Dioxide	0.1 ppm
Formaldehyde	1.0 ppm
Hydrogen Sulfide	10 ppm
Lime	5 mg/m^3
Methyl and Ethyl Mercaptan	0.5 ppm
Noise	85 dBA
Sulfuric Acid	1.0 mg/m^3
Sulfur Dioxide	2 ppm

1 These standards were selected from a listing published by a government agency for "working and social activities" (August 29, 1980). They are legally enforceable "maximum working concentrations" adopted as "work-material-regulations" as part of the Federal Law concerning the use of chemicals. The factory inspectors of the State Trade Supervisory Authority perform workplace health inspections.

respirators (mainly SCBA), 5) equipment to conduct air tests during an upset or maintenance activity, or in response to worker complaints, 6) extensive monitoring of noise levels, and 7) development and use of engineering, worker isolation, and personal protective controls for noise exposure.

The Safety Engineer reported that requests for air testing occur infrequently, mainly because of the mill's relatively simple mechanical pulping and bleaching processes. Most tests are made to evaluate a temporary problem, or to verify safe conditions prior to maintenance work (welding, confined space entry, or use of a cleaning agent). He maintains Draeger pumps, length-of-stain detector tubes, and a combustible gas and oxygen deficiency meter for this testing.

Pre-employment physicals and hearing tests are performed by outside specialists. Worker education and training is provided both by individual department managers and supervisors, and by the Safety Department. Special safety training courses, specific workplace safety instructions, and quarterly meetings of safety personnel are all legally-mandated for the mill.

Noise Controls

Workers are potentially exposed to high levels of noise in certain areas of the woodyard/woodroom, the pulp mill's grinder room, the pulp refining area, and the papermill. Extensive analysis of the source and nature of this noise (and resulting exposures) is very difficult to perform because of the many sources and the variability of worker activities. Over the past few years, the mill has performed a number of noise surveys to determine area sound levels, and investigate controls. Some of the sound readings from these surveys are summarized in Table 40-3. For identified high noise areas, the mill has developed a program to reduce exposure or permanently control the sound. The program includes:

1) Research and development of permanent engineering controls;

2) posting work areas with noise levels above 85 dBA for required use of hearing protection;

3) yearly audiometric testing of all potentially exposed workers;

4) continued measurement of sound levels to determine effectiveness of controls, noise changes, and the accuracy of prior measurements; and

5) development of noise criteria for all new equipment purchases (pumps, refiners, couch rolls, rewinders, and fans).

TABLE 40-3: SUMMARY OF SOUND LEVEL READINGS IN VARIOUS MILL AREAS

Mill Area	Location	Sound Level, dBA	Comments
Pulp Mill Grinder Room	Basement, Near Grinder No. 7	92-92.5	Grinders Operating
	Basement, Near Grinder 8 and 9	93.8-94.2	Grinders Operating
	Mezzanine Near Entrance of Wood Transport Bridge	96-97	Grinders Operating
	Mezzanine, Near Plant 4 Drivestand	91-92.5	Grinders Operating
	Mezzanine, Near Plant 5 Drivestand	93-95	Grinders Operating
Woodroom-Slashing and Sorting Areas	At Slasher Monitoring Stand	100-101*	With saw going through log
	At Slasher Monitoring Stand	<105*	Sound rebounding at Inclined Conveyor
	Wood Sorting Monitoring Stand	<105*	Reading taken near where logs fall off onto chain conveyor
	Sorting Line (While Running)	90-92*	-
	Sorting Line Where Logs Fall Into Recirculation Line	<105*	-
Pulp Preparation Building	Worker Station	80	Papermachine down
	Worker Station at Conveyor Loading	86	Papermachine down
	Behind Sound Protection Wall	86 (87)-	Papermachine down: conveyor not being loaded
	In Front of Sound Protection Wall	79 (82)-	" " "
	Work Station at Conveyor Loading	84	Papermachine in full production
	Work Station For Forklift Bale Transport	86	-
	Bale Cutting at Conveyor	86-87	-
Pulp Mill Stock Refining Area	Claflin Refiners (1)	97.8-101*	Sound meter 1 M. from refin
	Claflin Refiners (5)	100-105*	" " " "
	Pest Refiners (1)	96-97*	" " " "
	(3)	99-100*	" " " "
	Voith Refiners (3)	94-94.5*	" " " "
	(5)	96-97*	" " " "
	Entranceway to Refiner Area	91-91.5*	- -
	In front of Control Desk For Pulp Conveyor	83-84.5*	See Fig. 40-1

- Reading in parentheses is with papermachine in full production.
* See text for a description of the controls implemented as a result of these high sound level readings.

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In general, the program strives to develop permanent engineering controls when and where noise sources can be clearly identified and assessed, and the control's effectiveness guaranteed. In other cases, restricted entry, hearing protection, and audiometric monitoring are applied singly or in combinations to provide protection. In addition, equipment and plant designers are requested to provide new or replacement equipment with significantly less noise.

The following is a brief summary of some of Mill 40's more significant permanent engineering controls:

Protective Sound Wall in Refiner Area - As shown in Table 40-3, sound levels around the pulp refiners are very high (94-105 dBA). A number of workers are exposed to this noise while loading bales of purchased chemical pulp (and other materials) onto conveyors in a nearby area. Rather than installing restrictive and damage-susceptible enclosures around the individual refiners (or around the entire refiner area), the mill installed a special acoustical barrier (with doors) between the sound sources and the workers (see Figure 40-1). The sound readings in Table 40-3 indicate this wall reduces the work area noise levels to below 90 dBA (i.e., from 105 dBA maximum at one refiner to 83-84.5 dBA at a control desk). The total cost for this control was about $85,000.

Papermill Noise Controls - The readings in Table 40-2 indicate sound levels can be high along a papermachine's entire length. Workers who have to be near a machine to monitor equipment, operate controls, or quickly respond to upsets usually require some noise protection. The protection is usually achieved by use of hearing protection and enclosing control consoles and/or workers in special sount booths. In contrast, Mill 40 designed the building for its two newer papermachines to incorporate a number of rooms on either side of wide machine access isleways. Workers gain relief from high sound levels inside the rooms (where levels are about 70 dBA) while still monitoring their equipment through one large viewing window. Hearing protection is required when they go near operating and posted high noise equipment to operate controls or respond to upsets.

Sound levels in areas around the two newer paper machines were reported to be 2-3 dBA's lower than the older machine. This was achieved during design and construction of the newest machine (P.M. 5) by:

- Constructing building walls with noise absorbing material (estimated reduction: 2-3 dBA);

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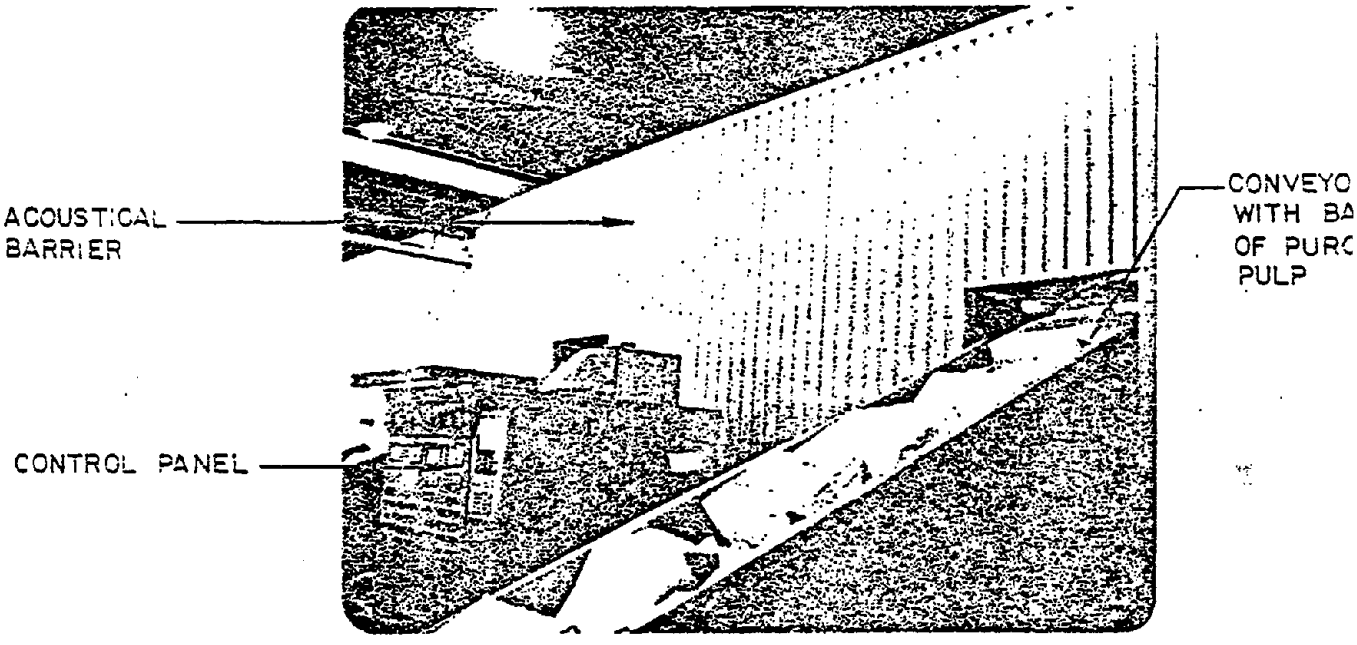

Figure 40-1 : Acoustical Barrier Used To Protect Workers In The Pulp Refiner and Purchased Pulp Preparation Area

- Requesting all suppliers of ventilators to meet certain noise-generating criteria (criteria not available);

- Requiring other equipment manufacturers and suppliers to provide equipment with noise levels less than 80 dBA, (measured at a 1.0 meter distance); and

- Selecting suction rolls that give the lowest noise levels.

In addition to the above controls costing about $280,000, the mill reduced noise levels at the older paper machine's wet end by installing a different couch roll cover. Unfortunately, details and costs of this improvement were not available.

Debarking Drum Building - Noisy drum debarkers usually can be placed in isolated outside areas because they are large, durable, and operate with comparatively little attention or service. In response to high workplace levels and noise complaints by neighbors, Mill 40 placed a building around its two drum debarkers about five years ago. Special contractors were hired for this project, but unfortunately specific design data is no longer available. Sound levels inside the building are high (readings not available), but excessive exposure is not of concern because workers perform only brief inspection, maintenance, and clean up tasks inside it, usually while equipment is off. Equipment operation is successfully monitored using television cameras. The enclosure building cost about $280,000, but stopped noise complaints.

Slashing and Wood Sorting Conveyor Noise - Sound level readings (Table 40-3) showed log conveyors in the slashing and sorting buildings contributed to the high noise levels. To reduce this noise, the mill bolted wooden blocks to the guide plates in the conveying system. This reduced noise, but the mill had no comparative sound level readings.

SECTION II KRAFT PULPING

A. Pulping and Washing

(1) Batch Digesters

Mill 01 Includes Bleach Plant
Mill 11
Mill 20
Mill 36

(2) Continuous Digesters

Mill 08
Mill 26
Mill 29
Mill 33 M & D Digesters

(3) Batch and Continuous Digesters

Mill 38

B. Black Liquor Evaporation & Recovery Furnaces

Mill 18 Recovery Furnaces
Mill 31 Multiple Effect Evaporators
Mill 34 Multiple Effect Evaporators

C. Recausticizing and Lime Kiln Operations

Mill 16
Mill 19
Mill 27

MILL 01 KRAFT PULPING AND BLEACHING OPERATION

INTRODUCTION

This survey encompassed a Kraft pulp mill, a five-stage CEDED (chlorine, caustic extraction, chlorine dioxide, caustic extraction, chlorine dioxide) bleach plant, and a chlorine dioxide generating plant. This section of the overall mill was constructed in 1972. All of the above operations are controlled from a central control room in the Kraft mill.

PROCESS SUMMARIES

Kraft Pulping Process - Approximately 800 tpd of hardwood and softwood pulp are produced in six batch digesters (6500 cubic feet apiece). The process is totally computer controlled.

At the beginning of each cooking cycle, the capping (ball) valve is opened and chips are automatically dropped through a feed chute into an empty digester. After about ten tons of chips have been loaded, white and black liquor are pumped into the digester in parallel with the remainder of the chips. When the desired quantities of chips and liquor have been added, the capping valve is closed and the steam cycle is begun. The liquor is circulated through a steam heater, raising the temperature of the cook to 300°F. The relief valves are then opened, direct steam is applied to the bottom of the digester, and the temperature is further increased to about 350°F.

After a cooking cycle of two hours, the internal pressure (~90 psi) in the digesters is used to "blow" the cook into one of two blow tanks. From the blow tanks, the pulp and liquor are pumped to the knotters, centrifugal screens used to remove large uncooked particles. The large particles are gravity fed into a double disc refiner, diluted with black liquor and pumped back to the digesters. The accepted stock is fed into the three-stage brown stock vacuum washers where the spent liquor is removed. The liquor is collected in the first stage filtrate storage tank, concentrated in the multiple-effect evaporators, and pumped to the recovery boiler. The clean stock is screened, thickened on the decker, and pumped to the high density storage tanks.

Chlorine Dioxide Generator - The chlorine dioxide generator (and sodium hypochlorite make-up system) is located in a five-story building adjoining the Kraft mill.

Mill 01 utilizes the Hooker R-2 process to generate chlorine dioxide; the system is largely automated. Chlorine dioxide is produced in a large vertical, titanium reactor tower housed

within the building. Two reacting solutions are metered into the generator - one a solution of sodium chloride and sodium chlorate (R-2); the other 66° Baume sulfuric acid. They react and evolve a concentrated gas mixture of chlorine dioxide and chlorine with small quantities of various impurities. A vacuum pump is used to pull the gas mixture through a condenser (to remove water vapor) and into a two-stage gas absorption/ purification system. This system consists of two large vertical, fiberglass towers located above the generator. The first tower has a counter-current flow of chilled water to preferentially absorb chlorine dioxide (and a small amount of chlorine). The rate of flow of the chilled water determines the strength of chlorine dioxide solution exiting the bottom of the absorber. Unabsorbed gases (mostly chlorine) exit the top of the first-stage tower and enter a nearby secondary absorber. This tower is supplied with a counter-current flow of unchilled water to absorb the remaining chlorine. The secondary tower is vented to atmosphere from the top of the building.

The chlorine dioxide solution from the first-stage tower is pumped to a large, cooled storage tank until needed. It is normally used at a strength of 9 grams per liter (gpl) ClO_2. The chlorine solution from the second stage tower is injected into the stock line along with the chlorine gas. Depending on bleaching demands, about 5 to 8 tons of bleaching solution are produced each day. The generator system is easily brought off or on line by halting the reactant flow, while continuing to purge the vessel with air.

Chlorine Vaporizer - Chlorine gas and hypochlorite solutions are received from liquid chlorine unloaded from railroad tank cars. The tank cars are unloaded two at a time (total storage capacity of four cars). Flexible hoses are used between the tank cars and the chlroine line to the plant. Separate air compressor with two air dryers are used to provide clean, dry padding air at safe pressures to the tank cars.

The padding air is used to force the liquid chlorine into one of two steam-heated, completely closed vaporizers housed in a small, isolated room in the basement of the Kraft mill. Vaporized chlorine gas is metered to either the chlorine mixers (1st stage of bleaching) or to the hypochlorite generator. Sodium hypochlorite (hypo) is used in the first caustic extraction stage of the bleach plant. To produce it on-site for extra bleaching requirements, five percent sodium hydroxide is mixed with the chlorine gas to yield a solution of 50 gpl Cl_2. This operation is undertaken in a small, closed mixer at the bottom of the chlorine dioxide generator building.

Bleach Plant - Clean stock from the high density storage tanks is pumped to a blend chest and diluted to a 3% consistency. The diluted stock is pumped through a series of chlorine mixers, then into the bottom of the chlorine tower. Just upstream of the mixers, chlorine gas and chlorine solution (from the chlorine absorption tower) are injected directly into the stock line.

Stock passes through the chlorine tower in about one hour, and then enters the chlorine washer. A shower of fresh water and caustic filtrate washes the stock as it is pulled through the drum. The washed stock is repulped, mixed with steam, caustic, and hypo, then pumped to the top of the first caustic extraction tower. After about an hour, the stock is pumped to the first caustic washer and diluted with second caustic filtrate. A shower of second chlorine dioxide filtrate is used to wash the stock. It is again repulped and heated in a steam mixer. Chlorine dioxide solution from the generator is injected into the line, and the stock is passed through additional in-line mixers, pumped through a pre-retention tube and into the top of the first chlorine dioxide tower. After passing through the tower, the stock is pumped to the first chlorine dioxide washer, diluted with a second ClO_2 filtrate, and washed with second caustic filtrate. The last two stages (second caustic and second ClO_2) are repetitions of the previous two, with the exception that the last washer uses clean water showers instead of filtrate from a previous stage. The bleached stock from the last bleach stage is pumped to large storage tanks for subsequent use in the paper plants.

JOB CATEGORIES AND DESCRIPTIONS

There are six employees per shift responsible for the operation of the Kraft mill (including the bleach plant, vaporizer and the chlorine dioxide generator):

Digester Operator - The digester operator is responsible for the operation of the digesters and the waste heat recovery system. Since the system is computer controlled, the primary tasks are to interface with the computer during critical process cycles (digester loading, blowing, etc.) and to monitor the process to assure efficient, uninterrupted operation. In addition, during each cooking cycle, the operator must record such details as quantities of chips and liquor, operating temperatures, pressures and times for important cooking cycles. Primary activities in the production area include:

- "dipping" the blow tanks - checking the stock height in the blow tanks to assure that a digester can be blown without overloading (if necessary)

- o helping to unplug a chip loading chute - inserts an air lance into the top of the plugged chute
- o valving digesters - if they are going on or off line

The digester operator is in the control room for over 90% of each shift.

Bleach Plant Operator - The bleach plant operator monitors the operation of the brown stock washers and the bleach plant including the chlorine dioxide generator and vaporizer.

The operator rarely enters the production area, remaining in the control room an average of 99% of each shift.

First Helper (Tester) - Once every hour, the tester collects process samples and analyzes them in the control room laboratory. Samples are collected from the following operations:

- o each bleach washer (except first stage caustic)
- o last stage of brown stock washer
- o second stage chlorine dioxide tower
- o decker
- o knotters

Each sample collection run requires about 10 to 15 minutes. The remaining 75% of each shift is spent in the control room.

First Equipment Tender - The first equipment tender is responsible for the operation and inspection of the following systems and equipment:

- o chlorine dioxide generator including all reactant makeups and flows to the generator and the storage tanks
- o chlorine tank car unloading and transport system to the vaporizer
- o chlorine vaporizers
- o hypochlorite production system
- o bleach plant washers and bleaching agent mixers
- o collection of process samples from the above operations
- o testing process samples

It is estimated that the first equipment tender normally is in the production area less than 25% of the time.

Second Equipment Tender - The second equipment tender conducts periodic (approximately every hour) inspections of various mill equipment to check for leaks or other abnormal conditions. Other activities include washing down after leaks or spills, and assisting as needed during upsets or other problems. Although highly variable, it is estimated that the second equipment tender is in the production area 50% or more of each shift.

Utility Person - The utility person is primarily responsible for keeping the Kraft mill clean. Other activities include conducting inspection tours with the second equipment tender and assisting any other Kraft mill employee. The utility person will average approximately 70 percent of the time in the production area.

POTENTIAL WORKPLACE HAZARDS

The primary air contaminants that may be emitted from the Kraft pulp process are hydrogen sulfide, methyl mercaptan, dimethyl sulfide and dimethyl disulfide. Much smaller quantities of terpenes, alcohols and potentailly many other compounds may also be present in process streams. However, relative to the above primary air contaminants, these compounds are of little concern.

The primary air contaminants that may be emitted from the bleach plant operations are chlorine and chlorine dioxide. There is also the possibility of exposures to sodium hydroxide and sulfuric acid.

Air samples for chlorine dioxide, dimethyl disulfide, and dimethyl sulfide, could not be collected because of the absence of verified sampling and analytical protocols. Worker exposures to hydrogen sulfide, methyl mercaptan, and chlorine were evaluated based on short-term ceiling samples.

EVALUATION OF POTENTIAL SOURCES OF EXPOSURE

The pulping and bleaching processes are essentially a series of totally closed unit operations. Both processes are controlled by computers and monitored by employees in a central closed control room.

Because the processes are closed, there are very few constant, predictable sources of worker exposure. When significant workplace contamination occurs, it usually results from random leaks from various process equipment, during process upset conditions, and possibly during maintenance operations. There are, however, several exceptions:

- digester loading cycle - as the batch digesters are filled with chips and liquor, air is displaced from the digesters through the chip chute and onto the mezzanine area above the operating floor. Small quantities of volatile sulfur and other compounds are contained in the displaced air and periodically enter the workplace.

- knotters - the knot drainer is open to the workplace. Local ventilation is required to prevent this operation from becoming a consistent source of workplace contamination.

- brown stock washers - the brown stock washers (three stage vacuum washers) are basically open operations requiring enclosure and ventilation to contain process gases and vapors.

- bleach washers - the bleach washers are similar open operations, also requiring partial or total enclosure and ventilation to contain potential workplace contaminants.

PERSONAL SAMPLING RESULTS

Short-term ceiling samples were collected for hydrogen sulfide, methyl mercaptan, and chlorine for all Kraft mill employees except the digester and bleach plant operators, who rarely enter the production area. Personal samples were taken only when the employees were out of the control room for at least 10 minutes. The survey encompassed two shifts for each of three consecutive days.

Measured ceiling exposures for each job category are presented on Table 01-1, and are discussed below.

First Helper (Tester) - Seven ceiling samples were collected during four process sample collection runs conducted by the first helper. As shown, none of the samples resulted in detectable concentrations of either hydrogen sulfide or methyl mercaptan. Since the detection levels are 1% or less of the respective OSHA permissible exposure limits (PELs), it is very clear that during normal operating conditions, exposure is exceedingly low.

First Equipment Tender (generator operator) - Ceiling samples for chlorine were taken during nine process sample collection runs conducted by the first equipment tender. Measured ceiling exposures ranged from < 1% to 13% of the OSHA PEL of 1 ppm ceiling. This employee is also potentially exposed to chlorine dioxide during each sample collection run. Such exposure would result in a positive interference on the chlorine results

TABLE 01-1 PERSONAL SAMPLE RESULTS

Job Classification	Date	Shift	Sampling Period	Contaminant	Concentration	OSHA PEL Ceiling (p.p.m)	Comments
Pulp Dumper (Tester)	9/10	2	18^{45}-18^{59}	Hydrogen sulfide[1]	< 0.044 ppm	20	Collection of samples
		2	18^{44}-18^{59}	Methyl mercaptan[2]	< 0.067 ppm	10	
	9/11	1	10^{24}-10^{39}	Hydrogen sulfide	< 0.037 ppm	20	Collection of samples (10 min.)
	9/11	1	11^{29}-11^{49}	Hydrogen sulfide	< 0.038 ppm	20	Collection of samples (11 min.)
		1	11^{29}-11^{49}	Methyl mercaptan	< 0.043 ppm	10	
		1	12^{49}-12^{55}	Methyl mercaptan	< 0.113 ppm	10	
		1	12^{49}-12^{55}	Hydrogen sulfide	< 0.065 ppm	20	
Second Equipment Tender	9/9	1	12^{52}-13^{12}	Hydrogen sulfide	< 0.110 ppm	20	Inspection tour (16 min.)
		1	12^{52}-13^{11}	Chlorine[3]	< 0.015 ppm	1	" " (22 min.)
	9/10	1	7^{50}- 8^{12}	Methyl mercaptan	< 0.049 ppm	10	" " "
		1	9^{28}-10^{01}	Hydrogen sulfide	< 0.022 ppm	20	" " (28 min.)
		1	10^{36}-11^{14}	Methyl mercaptan	< 0.046 ppm	10	" " (22 min.)
		1	12^{22}-12^{46}	Hydrogen sulfide	< 0.033 ppm	20	" "(24 min.)
		2	15^{21}-16^{23}	Hydrogen sulfide	< 0.03 ppm	20	Washing down brown stock & bleach washer floor (22 min.)
		2	19^{02}-19^{44}	Hydrogen sulfide	< 0.016 ppm	20	Inspection tour (42 min.)
Utility person	9/9	1	8^{44}- 9^{04}	Methyl mercaptan	< 0.05 ppm	10	Inspection tour w/2nd Equipment Tender
		1	11^{34}-11^{50}	Hydrogen sulfide	< 0.046 ppm	20	Cleaning digester operating floor
		1	11^{34}-11^{50}	Methyl mercaptan	< 0.067 ppm	10	" "
		1	12^{47}-13^{02}	Hydrogen sulfide	0.082 ppm	20	Shoveling chips from under chip conveyor
	9/10	1	7^{51}- 8^{13}	Hydrogen sulfide	< 0.03 ppm	20	Inspection tour w/2nd equipment tender
		1	9^{43}- 9^{59}	Methyl mercaptan	0.127 ppm	10	Shoveling chips on mezz. fl.
		2	15^{08}-16^{17}	Hydrogen sulfide	< 0.014 ppm	20	Cleaning digester operating floor
First equipment Tender	9/9	1	11^{26}-11^{44}	Chlorine	0.130 ppm	1	Collecting samples
		2	11^{30}-11^{45}	Chlorine	0.051 ppm	1	" "
	9/10	1	9^{30}- 9^{45}	Chlorine	0.0026 ppm	1	" "
		1	11^{26}-11^{41}		< 0.011 ppm	1	" "
		2	13^{37}-13^{52}		0.023 ppm	1	" "
		2	15^{58}-16^{13}		0.124 ppm	1	" "
	9/11	1	10^{18}-10^{33}		0.097 ppm	1	" "
		1	11^{47}-12^{04}		0.052 ppm	1	" "
		2	15^{39}-15^{54}		0.016 ppm	1	" "
Oiler	9/9	1	8^{44}- 9^{06}	Methyl mercaptan	< 0.046	20	Fill oil reservoirs on pumps and agitators — grease equipment

[1] NIOSH Method P&CAM 126.
[2] Perry, J of Envir and Toxicology, Anal. Chem. Vol. 52, 1980, pp 733-736.
[3] NIOSH Method P&CAM 244.

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presented on Table 01-1. It should also be noted that the first-stage ClO_2 absorber (generator plant) was run without chilled water throughout the survey period. This abnormal situation results in less chlorine dioxide being absorbed in the first tower (resulting in a weaker ClO_2 solution) and more in the second tower (resulting in elevated ClO_2 concentrations in the chlorine solution).

It is thought that this condition may have resulted in slightly elevated chlorine results during the sample collection runs.

Second Equipment Tender - Ceiling samples were collected during six inspection tours and one additional period while the second equipment tender was hosing down the washer floor. None of the nine samples resulted in detectable exposures to hydrogen sulfide, methyl mercaptan, or chlorine. With the exception of one chlorine sample (< 2% OSHA PEL), all results are less than 0.5% of the appropriate OSHA PELs. It can be concluded that during normal mill operations, this employee's exposure should be very low.

Utility Person - Five ceiling samples were collected while the utility person was removing chips from the digester operating floor and mezzanine. An additional two samples were collected when he was accompanying the second equipment operator on an inspection tour. Detectable concentrations of hydrogen sulfide (0.082 ppm) and methyl mercaptan (0.127 ppm) were measured on two of the seven samples, both collected while the utility operator was removing chips from the digester operating floor and mezzanine. It can be concluded that, without significant leaks or process upsets, this employee's exposure to hydrogen sulfide and methyl mercaptan is very low.

Oiler - During one shift the oiler was filling oil reservoirs on pumps and agitators, and greasing various equipment in the Kraft mill. A ceiling sample collected for methyl mercaptan resulted in a nondetectable (< 0.46 ppm) concentration.

AREA SAMPLE RESULTS

Long Term Samples (Table 01-2): Long-term area samples were collected at various locations within the mill. Two of the samples were collected in the control room to evaluate contamination from vented or workplace gases or vapors. The results for hydrogen sulfide (< 0.012 ppm) and methyl mercaptan (< 0.0075 ppm) indicate a lack of such contamination.

The remaining samples were collected to determine what additional compounds besides hydrogen sulfide and methyl mercaptan may be present, and for comparison with side-by-side HNU Photoionization Gas Analyzer results.

TABLE 01-2 LONG-TERM AREA SAMPLES

Location	Date	Shift	Sampling Period	Contaminant	Concentration	Comments
Control Room	9/9	1	11^{23}-13^{46}	Methyl mercaptan[2]	<0.0075 ppm	
	9/10	1	8^{50}-10^{45}	Hydrogen sulfide[1]	<0.012 ppm	
Digester Operating Floor	9/9	2	13^{50}-14^{12}	Hydrogen sulfide	<0.093 ppm	All digesters in "cook" cycle
		2	13^{50}-14^{14}	Methyl mercaptan	<0.045 ppm	
				Dimethyl disulfide	<0.047 ppm*	
				Ethyl mercaptan	<0.091 ppm*	
Digester Operating Floor	9/10	1	7^{57}- 9^{53}	Hydrogen sulfide	<0.012 ppm	Beside HNU Photoionization Gas Analyzer
		1	8^{07}- 953	Methyl mercaptan	0.032 ppm	
				Dimethyl disulfide	<0.01 ppm*	Inclusive of 5 digester loading cycles
				Ethyl mercaptan	<0.0076 ppm*	
		1	9^{10}-10^{08}	Turpentine	0.035 ppm	
				n-Propyl alcohol	0.0052 ppm	
On Mezzanine Above Digesters	9/10	2	14^{44}-16^{38}	Hydrogen sulfide	0.019 ppm	Beside HNU Photoionization Gas Analyzer
		2	14^{48}-16^{38}	Methyl mercaptan	0.059 ppm	Inclusive of 6 digester loading cycles
Bottom of Digesters	9/11	1	11^{10}-13^{05}	Methyl mercaptan	<0.0095 ppm	Beside HNU Photoionization Gas Analyzer
				Dimethyl disulfide	<0.0065 ppm*	
				Ethyl mercaptan	<0.0043 ppm*	Collection period includes 1 digester blow cycles
Bottom of Blow Tanks	9/11	2	13^{08}-14^{15}	Methyl mercaptan	0.013 ppm	Beside HNU Photoionization Gas Analyzer
				Dimethyl disulfide	<0.0068 ppm*	
				Ethyl mercaptan	<0.0047 ppm*	Collection period includes 1 digester blow cycles

Collection efficiency has not been verified for these gases.

[1] NCSH Method P&CAM 126.

[2] Method of Knarr and Rappaport, Anal. Chem., Vol. 52, 1960, pp 733-736.

Our conclusions are as follows:

- Hydrogen sulfide was not detected (< 0.093 ppm and < 0.012 ppm) in two samples taken on the digester operating floor. Since the second sample was collected during three separate digester loading cycles, it is judged that this potential source of contamination may not be significant. This conclusion is reinforced by the result of an additional hydrogen sulfide sample (0.019 ppm) collected on the digester mezzanine during three different loading cycles.

- Methyl mercaptan was not detected (< 0.045 ppm) on the digester floor when all digesters were in a "cook" cycle. It was also not detected (0.095 ppm) on the first floor at the bottom of the digesters (sampling period inclusive of two digester "blow" cycles).

- Very small but measurable quantities of methyl mercaptan were detected on the digester floor (0.032 ppm), on the digester mezzanine (0.059 ppm), and at the bottom of the blow tanks (0.013 ppm). These very low concentrations strongly indicate that, at least during stable process conditions, workplace contamination is minimal.

- A charcoal tube sample was also collected on the digester floor (side-by-side with the above hydrogen sulfide and methyl mercaptan samples). This sample reflects that small quantities of turpentine (0.035 ppm) and n-propyl alcohol (0.0052 ppm) are also contained in process gases and vapors.

* Method of Knarr and Rappaport, Anal. Chem. Vol. 52, 1980, pp 733-736.

Chlorine Measurements (Table 01-3) - Area monitoring for chlorine and/or chlorine dioxide was conducted using a field-calibrated, Mast Oxidant Monitor. None of the recorded chlorine/chlorine dioxide levels exceeded 10% of the OSHA PEL of 1 ppm ceiling. The highest measured concentrations (0.09 ppm - 0.1 ppm) occurred in the chlorine dioxide generator building and the hypo room, both of which are relatively isolated areas with access generally restricted to the first equipment tender. As expected, the lowest concentrations (0.00 ppm - 0.05 ppm) were measured in the control room.

Of all the Kraft mill employees, the first equipment tender is the most likely to be exposed to significant quantities of chlorine and/or chlorine dioxide). The most significant and the only non-process upset related exposure likely occurs during the collection of various concentrated process control liquid samples. Here short-term exposures are possible from the necessity to open and flush liquid sampling pipes. During one such sample collection run (11:26 a.m. - 11:44 a.m., on the second day of the survey), the Mast Oxidant Monitor was used to estimate chlorine and/or chlorine dioxide air concentrations near these various sampling points. The following data was obtained:

Process Sample Identification	Approximate Time Required to Collect Sample	Chlorine/Chlorine Dioxide (Mast Oxidant Monitor)
1. R-2 salt solution	~1 minute	-
2. First-stage (ClO_2) absorber	0.25 minute	0.25 ppm
3. Second-stage (Cl_2) absorber	0.25 minute	> 0.65 ppm
4. Generator Solution	0.5 minute	0.6 ppm
5. Hypo Solution	0.25 minute	> 0.65 ppm
6. Caustic (10%)	0.25 minute	-
7. Caustic (5%)	0.25 minute	-

The personal sample (Table 01-1) worn by the first equipment tender during this run resulted in a ceiling concentration of 0.130 ppm (18.5 minute sample). It is clear that the majority of this exposure results from the short periods when the process samples are collected. It is less clear what effect the absence of chilled water for the first stage absorber system on the chlorine dioxide generator has on these results.

TABLE 01-3 AREA CHLORINE AND/OR CHLORINE DIOXIDE DATA USING MAST OXIDANT MONITOR

Location	Date	Time Period	Chlorine/Chlorine Dioxide Concentration
1. Washer Floor, North Wall adjacent 2nd caustic washer	9/11/80	10^{00}-10^{55} A.M.	0.03 ppm - 0.07 ppm
2. Washer Floor, East Wall between chlorine and brown stock washers	9/9/80	5^{55}- 7^{00} P.M.	0.06 ppm - 0.07 ppm
3. Control Room	9/10/80	8^{05}- 1^{05} P.M.	0.00 ppm - 0.05 ppm
4. Control Room	9/9/80	8^{25}- 2^{20} P.M.	0.00 ppm - 0.04 ppm
5. Hypo Room - Near Cl_2 Air Sensor	9/11/80	11^{10}- 1^{05} P.M.	0.03 ppm - 0.09 ppm
6. Generator Building - 2nd level near generator	9/11/80	2^{43}- 3^{50} P.M.	0.05 ppm - 0.1 ppm
7. Generator Building - 3rd level, top of generator	9/11/80	3^{35} P.M.	0.1 ppm
8. Generator Building - 4th level, top of absorbers	9/11/80	3^{40} P.M.	0.07 ppm
9. Vaporizer Room - Near Cl_2 Air Sensor	9/11/80	1^{05}- 1^{15} P.M.	0.05 ppm

It should also be noted that in addition to chlorine, the Mast Oxidant Monitor responds to chlorine dioxide. Since the monitor was field-calibrated with chlorine only, the nature of this response is not known. Therefore, the effect of chlorine dioxide in the workplace on the sample results cannot be determined.

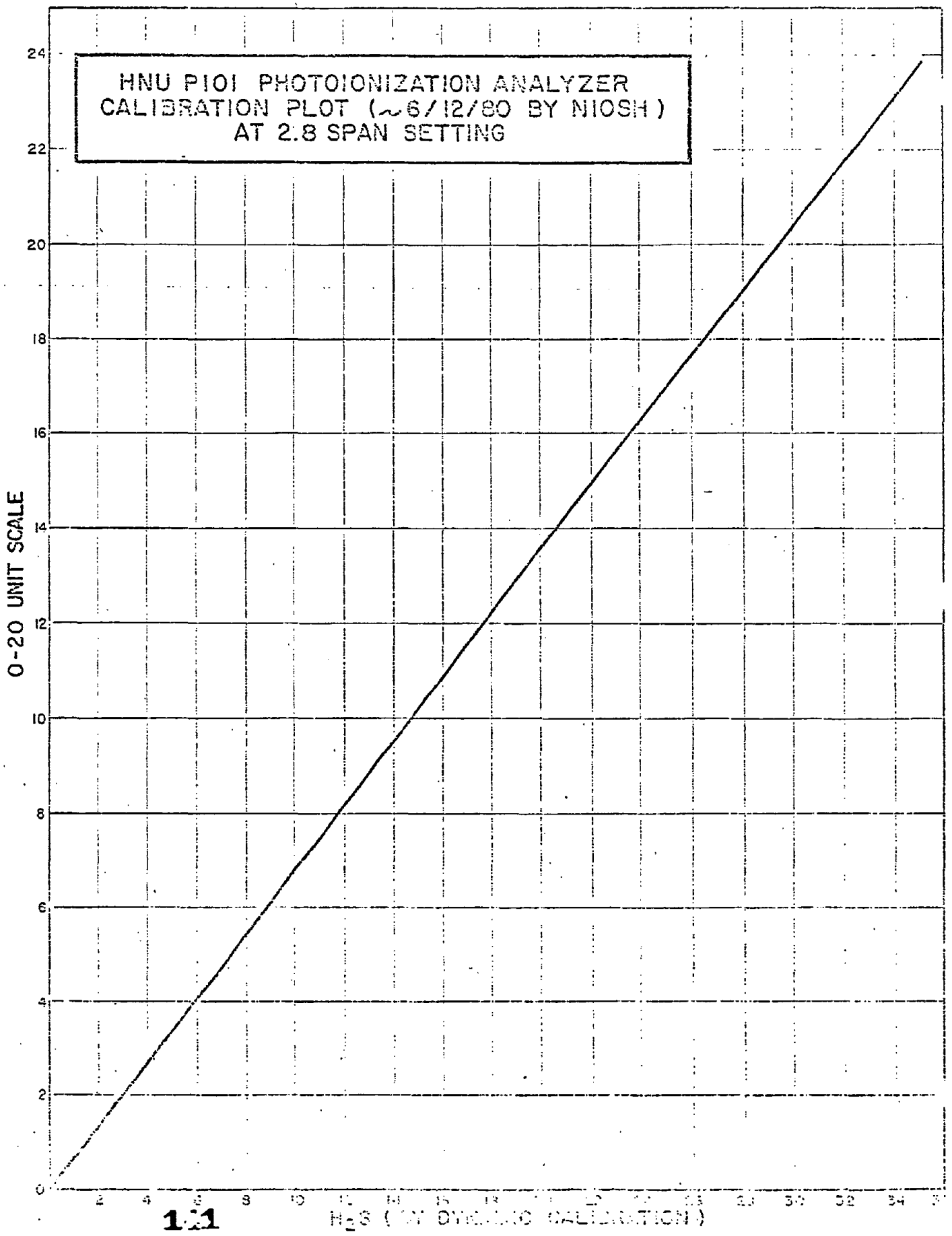
HNU Photoionization Analyzer: An HNU Analyzer was used to qualitatively assess the effect of digester loading cycles on the release of air contaminants, and to compare the relative response in various process areas. A calibration plot for hydrogen sulfide performed by NIOSH is presented in Figure 01-1. Observed air concentration responses for this analyzer were documented on a strip chart recorder and concurrent, side-by-side sampling was conducted for hydrogen sulfide, methyl mercaptan and other compounds. The results of these test are discussed below for each monitoring site.

- Digester Operating Floor - to determine if there is correlation between digester loading cycles and instrument response, both are illustrated on Table 01-4 for a four hour period. There was very little instrument response during loading cycles 1, 3, and 4. There were, however, definite response peaks corresponding to loading cycles 2 and 5.

  Side-by-side sampling data collected during the four hour monitoring period are also presented on Table 01-4. Very low concentrations of methyl mercaptan, turpentine, and alcohol (probably n-propanol) were measured, but hydrogen sulfide, dimethyl disulfide, and ethyl mercaptan were not detected. These data yield no information relative to what the HNU Analyzer was responding to during the test. It is speculated that the response was due to low concentrations of one or more complex compounds found in the process gases or vapors.

- Digester Mezzanine - The above tests were repeated on the digester mezzanine. Since the tops of the digester chip chutes are located on this floor, the HNU analyzer should exhibit a maximum response during the loading cycles. The results are depicted on Table 01-5 and show a positive correlation during four of six loading cycles. Side-by-side samples collected during the test again show very low concentrations of hydrogen sulfide and methyl mercaptan.

Figure 01-1


HNU P101 PHOTOIONIZATION ANALYZER
CALIBRATION PLOT (~6/12/80 BY NIOSH)
AT 2.8 SPAN SETTING
0-20 UNIT SCALE
0
2
4
6
8
10
12
14
16
18
20
22
24
H2S (BY DYNAMIC CALIBRATION)

SIDE-BY-SIDE DATA

(1) HYDROGEN SULFIDE - < 0.012 ppm

(2) METHYL MERCAPTAN - 0.032 ppm

(3) DIMETHYL DISULFIDE - < 0.01 ppm

(4) ETHYL MERCAPTAN - < 0.0076 ppm

(5) TURPENTINE - 0.035 ppm

6 n-PROPYL ALCOHOL - 0.0052 ppm

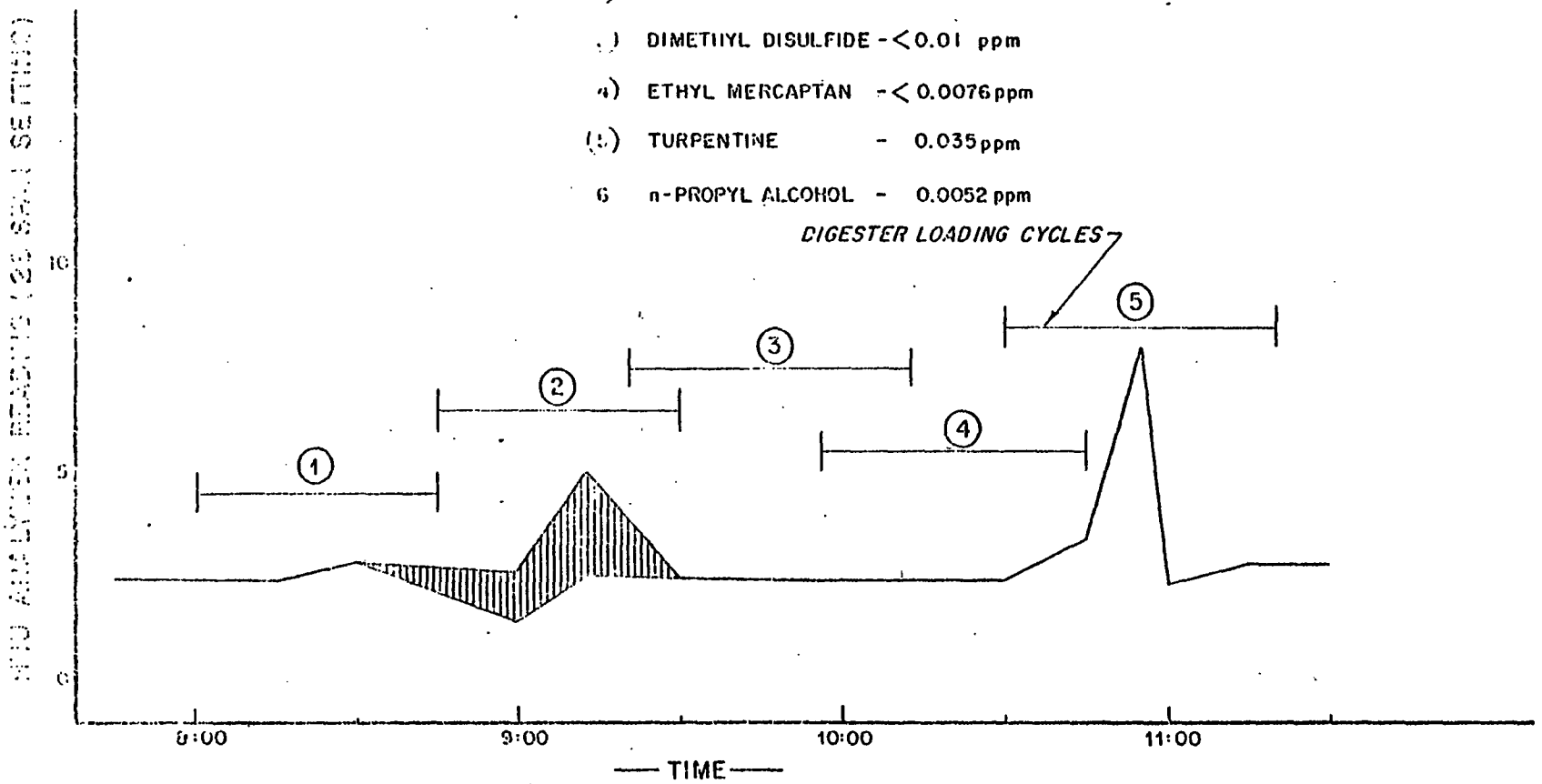


TABLE 01-4: HNU ANALYZER READINGS - DIGESTER OPERATING FLOOR

SIDE-BY-SIDE DATA

1. HYDROGEN SULFIDE - 0.019 ppm
2. METHYL MERCAPTAN - 0.059 ppm

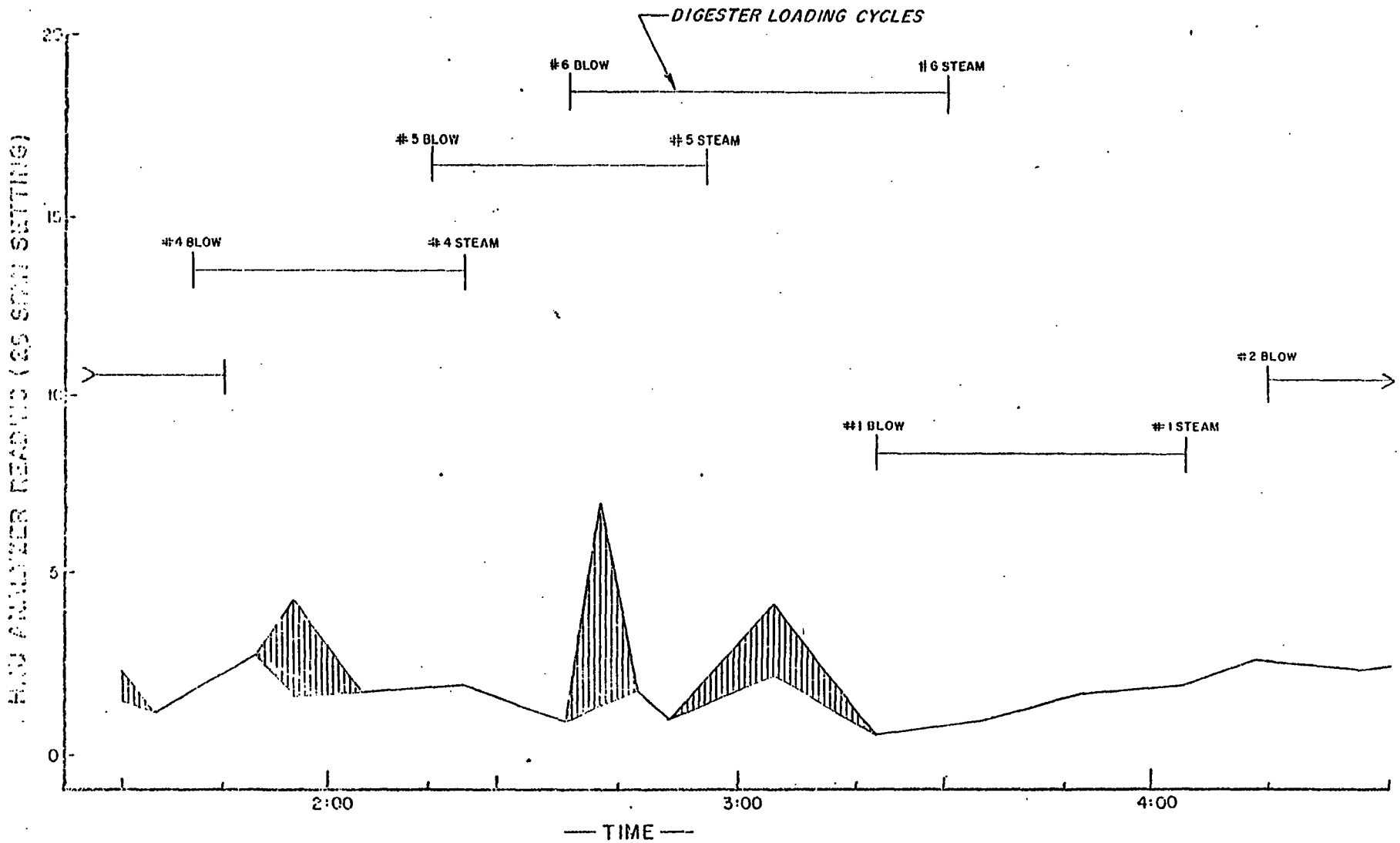


TABLE 01-5: HNU ANALYZER READINGS - DIGESTER MEZZANINE

It is concluded that either significant quantities or organic sulfur compounds and hydrogen sulfide are not contained in the air displaced from the digesters, or they are condensed or absorbed on the chips in the chip chute. Either way, it does not appear that this operation is a major source of workplace contamination.

- Brown Stock and Bleach Washers - two sets of data were collected on the washer floor using the HNU Analyzer. One set was collected between 5:55 p.m. and 6:30 p.m. on the third day of the survey at the north wall between the bleach and brown stock washers. Instrument response was extremely steady during the period and never exceeded 0.5 units.

  An additional data set was collected at the south wall of the washer floor (9:30 a.m. to 10:30 a.m. on the fourth day of the survey). HNU Analyzer readings went from about 7 units at 9:30 a.m. to 1 unit at 10:30 (in a roughly exponential fashion).

- Digester Bottoms - on the fourth day of the survey, HNU Analyzer readings were recorded between 11:15 a.m. and 12:30 on the first floor between digesters 1-4. The response was stable at about 1.5 units throughout the period except for a brief (about one minute) peak to 16 units at 11:45 a.m. The only digester blown during the test period was No. 4 at 11:51 a.m., or five minutes after the peak. The test indicates that, digester blow cycles have little influence on contaminant levels at this monitoring point. Side-by-side area air samples resulted in non-detectable concentrations of dimethyl disulfide and ethyl or methyl mercaptan.

- Blow Tanks - Between 1:05 p..m. and 2:05 p.m. on the fourth day of the survey, HNU Analyzer readings were recorded at the bottom of blow tank No. 2. The instrument response was highly erratic throughout the period, ranging from about 3 units to over 20 units. No clear patterns could be discerned from the strip chart recording of the results. Although digester No. 6 was blown at 1:11 p.m. (to blow tank No. 1), it is uncertain if this was the reason for the high, erratic results (similar results were recorded prior to the blow). Side-by-side samples revealed a small concentration (0.013 ppm) of methyl mercaptan, but no dimethyl sulfide or ethyl mercaptan was detected.

CONTROL OF PROCESS

Computer Control - Kraft mill processes are almost totally computer controlled. This reduces the potential for worker exposure in three highly significant ways. First, it reduces the number of employees required to operate the processes - only six employees per shift are necessary to handle all operational aspects of the Kraft mill.

More importantly, the computer control system minimizes the need for employees to be in production areas where there is a potential for exposure. As an average, employee time is distributed as follows:

Job Category	Percent Time in Control Room
Digester Operator	>90%
Bleach Plant Operator	99%
First Helper	75%
First Equipment Tender	75%
Second Equipment Tender	50%
Utility Person	25%

Because the control room is under a strong positive pressure from an independent air handling system, it can be considered a non-exposure area.

Finally, computer control reduces the frequency of process upsets due to operator error or failure. The system contains a number of redundant safety controls to monitor and react to critical process parameters such as temperature, pressure, stock and chemical flowrates, etc. For example, the digester capping valves are interlocked with a pressure switch such that they cannot be opened if the internal pressure is in excess of 1 psi.

LOCAL VENTILATION

Bleach Washers - The bleach washers are fully enclosed with separate exhaust hoods. The six hoods, installed as original equipment in 1972[1], are made of corrosive resistant panels (COR-RES 6692-FR Resin with 3% antimony dioxide).

[1]A new chlorine hood was recently installed; within the next year all other bleach hoods will be replaced with the same type. The major difference in the new hoods is that the exhaust duct exits from the side to allow room for the operation of an overhead crane.

Both the chlorine and the two chlorine dioxide hoods are part of a central exhaust system also serving the vaporizing room, the chlorine mix room, the pre-retention tube vent and the chlorine dioxide filtrate tank vent. The system has a design capacity of 20,000 cfm, provided by an ejector-type blower (to prevent corrosion) mounted on the roof. In 1978, in response to complaints that the control room was periodically being contaminated with exhausted chlorine and chlorine dioxide, the exhaust stack for this system was extended an additional 100 feet above the roof. The two caustic washer hoods are exhausted through separate systems, each with a roof-mounted blower rated at 2400 cfm.

Each hood is equipped with four access doors (32" x 32") on each side. Usually a maximum of four doors are left open to facilitate sample collection or to allow observation of the washers. Face velocity measurements were made in open doors on each hood (Table 01-6).

TABLE 01-6 FACE VELOCITY MEASUREMENTS - BLEACH HOODS

Washer Hood	No. of Open Access Doors	Average Face Velocities (fpm)	Total Estimated Air Flow (cfm)	Desig Air (cfm)
Chlorine	2	145;185	2300	Est. 400
First Caustic	2	170;150	2300	240
First Chlorine Dioxide	2	190;225	2950	Est. 400
Second Caustic	3	100;145;135	2700	240
Second Chlorine Dioxide	3	210;240;150	4300	Est. 400

With two or three access doors open, measured face velocities are sufficient for each hood. Obviously control effectiveness would be diminished significantly if all doors were left open. Additional comments:

- o high face velocities (150 fpm or above) are necessary to overcome turbulence effects caused by the showers and the rotation of the vacuum washers.
- o hood air flow estimates may be conservative (too low) due to unmeasurable open areas.

Brown Stock Washers - The brown stock washers are fully enclosed in a single, corrosive resistant exhaust hood. The system was designed with an exhaust capacity of 38,000 cfm. Exhausted air from the brown stock washer hood feeds the recovery boiler.

There are a number of hood openings: 1) two doors and six access panels on the aisle side, 2) six access panels at the final-stage end, and 3) various irregular openings. Face velocities were measured in the following hood openings:

Opening	Face Velocity (fpm)
1. First Door	100-150
2. Second Door	100-150
3. Side Access Panels	closed
4. End Access Panels- #1	closed
#2	250-350
#3	150-250
#4	300-350
#5	200-300
#6	200-300

These air flows are more than sufficient to contain process gases and vapors within the hood.

Knot Drainer Hood - The knot drainer is provided with a canopy hood connected to the brown stock washer hood exhaust. The face of the hood extends three feet above the knot drainer. Measured face velocities ranged from 150-200 fpm, and appeared effective.

General Ventilation - Blueprints of the HVAC system were only available for the bleach plant. Forced supply and exhaust air, and air turnover rates were calculated and are presented below.

Floor	Operations/Equipment Present	Supply Air (cfm)	Exhaust air (cfm)	Approximate Turnover Rate
First	blend tank, brown stock tank, bleach washer filtrate tanks bleach towers, blend chest, fiber reclaim tank, decker filtrate chest	35,000	35,000	5
Second	blend chest, screen chest refiner, pumps, filtrate tanks, bleach towers	28,000	28,000	5

Third (operating)	brown stock washers, deckers	98,000	98,000 bleach washers,	7 1/2

Although HVAC plans were not available for the pulp mill, it appeared that a similar system was in place and operating. In particular, it was observed that the two large roof fans above the digester mezzanine were very effective in removing potential contaminants released during the digester loading cycles.

LEAK PREVENTION

Both prevention and timely identification and correction of process leaks are essential to the reduction of potential exposure. This is accomplished in several ways:

- The preventive maintenance program is computerized. Based on a set schedule, the maintenance program is provided with a daily schedule of required inspection or other service.
- The second equipment tender conducts frequent inspection tours of the Kraft mill. Abnormal conditions are reported for each shift and maintenance is scheduled based on the severity of the problem. Conditions that significantly affect the process or create hazards are scheduled for immediate attention. Non serious problems are delayed to coincide with planned shutdowns or other convenient times.
- Mechanical seals are used for transport systems involving concentrated black and white liquor, chlorine and chlorine dioxide solutions.

CHLORINE/CHLORINE DIOXIDE MONITORING SYSTEM

In 1977, an eight channel Cl_2/ClO_2 monitoring system (International Sensor Technology, Santa Barbara, CA) was installed to provide early warning of high workplace concentrations of these gases. It was reported that the initial cost was approximately $12,000, not including installation. Five Cl_2 and one ClO_2 sensors were originally installed; however the ClO_2 sensor never worked properly and was removed.

The response of the monitoring system was evaluated using a field-calibrated Mast Oxidant Monitor. The results of comparative readings are presented on Table 01-7.

TABLE 01-7 FIELD EVALUATION OF IST Cl_2/ClO_2 MONITORING SYSTEM (INTERNATIONAL SENSOR TECHNOLOGY SYSTEM)

Sensor Location	Type of Sensor	Control Panel Readout (10:23 AM)	Mast Reading At Air Sensor (10:35 - 10:55 AM
1. Hypo Room	Cl_2	0 ppm	0.05 ppm
2. Vaporizer Rm.	Cl_2	7 ppm	0.06 ppm
3. Chlorine Washer	Cl_2	0 ppm	0.03 - 0.04 ppm
4. Chlorine Dioxide Mixers		could not be located	
5. Generator Plant	Cl_2	0 ppm	0.05 ppm
6. Optichlor	Cl_2	2 ppm	0.07 ppm

These data indicate that the IST system was not functioning properly at the time of the survey. Based on an interview with a plant instrument service engineer, it was reported that the system is not purged regularly as required, causing corrosion of the sensors. It was reported that an average of one sensor has been lost every six weeks due to this problem. For effective long-term operation, the system must be manually purged by bleach plant personnel once a shift by activating heated elements in the sensors from the control room. It appears that this problem could be eliminated by automating the purging cycle.

The chlorine sensors are inspected and calibrated every six weeks as part of the regular plant maintenance schedule, and inspection results recorded in a maintenance log. A static-type calibration check is made to insure activation of the alarm at its set point (set point unknown). This is accomplished by injecting with a gas syringe a measured quantity of a standard chlorine gas in air from a disposable aluminum cylinder into a known-volume glass vial which then fits tightly over the sensor. A quantitative method of calibrating the ClO_2 sensor was never found. Before it was removed, its response was assessed qualitatively by only using a fresh highly concentrated ClO_2 solution from the generator.

A new IST Cl_2 sensor is being installed south of the chlorine car unloading station with an audio alarm in the maintenance department. Estimated costs for the sensor module, housing, and Cl_2 sensor is $410.00. Installation and alarm costs were not reported.

TANK ENTRY MAINTENANCE SAFETY PROCEDURES

Mill 01 has developed and used a written tank entry procedure, as summarized below:

1. No maintenance of any pipe line, tank, vessel, drum or other apparatus is undertaken until the pressure has been relieved, the contents drained, and the tank or apparatus has been purged with air and properly ventilated. The foreman is reponsible for assuring that these conditions are met.

2. No employee can enter a closed pipe line, tank, vessel, drum, or other apparatus until connections have been closed off and locked out, the closed tank or other apparatus has been emptied and ventilated, and clearance has been issued by the foreman. Mechanical blowers are used to clear all pipe lines, tanks, vessels, drums, or other apparatus before entry and to maintain adequate ventilation.

3. The air in closed vessels is tested for oxygen deficiency and the presence of both toxic and explosive gases/vapors before workmen are allowed entry. Designated employees conduct the air tests using an oxygen analyzer, a combustible gas indicator, and/or detector tubes.

4. Upon entering a closed vessel or other apparatus, employees are required to use safety belts with attached life lines, and be attended by at least one man on the outside. Self-contained breathing units (Scott Air Packs) or oxygen-supply masks must be readily available for use during an emergency.

CHLORINE HANDLING AND EMERGENCY PROCEDURES

Mill 01 has developed and printed a plant-specific Chlorine Emergency Handbook outlining numerous requirements and procedures designed to prevent and/or react to potential problems associated with the handling of large quantities of chlorine. Among other items, the handbook includes:

- tank car unloading description and written work practices
- location and use of personal protective equipment, Chlorine Institute Emergency Kit "C" (for repair of leaks in chlorine cars), emergency deluge showers, etc.

- o fire precautions
- o equipment inspection requirements and frequency
- o training requirements
- o organizations of emergency crews
- o emergency shutdown procedures
- o warning/alarm and evacuation procedures

The handbook appears to be both comprehensive and useful as a training tool and reference document.

PERSONAL PROTECTIVE EQUIPMENT

All Kraft mill and maintenance employees are issued full facepiece respirators with chlorine canisters. For emergency escape, the employees are also provided with (and encouraged to carry) mouthpiece respirators with acid gas cartridges. In addition, there are four or five full facepiece, chlorine canister units permanently stored at the entrance to the chlorine dioxide plant, in the bleach plant elevator and on the second and third floor of the Kraft Mill. There are also five self contained breathing units located throughout the Kraft mill - one on each floor and two in the control room.

The mill has also developed a written respiratory protection program, specifying cleaning procedures, inspection schedules and responsibilities, and training requirements. Where respirators are assigned to employees, it is their responsibility to periodically clean, inspect, and maintain inspection records. The manager of each department is responsible for the permanently stored respirators and self contained breathing units.

Each supervisor is required to conduct annual respiratory protection training sessions and to provide introductory training to new employees. The safety department conducts periodic audits of the respirator program.

Other personal protection requirements for various conditions are outlined in the Employee Safety Handbook for Mill Chemicals.

MILL 11 KRAFT PULPING PROCESS (BATCH DIGESTERS)

PROCESS SUMMARY

Chips are either purchased (35 percent) or produced in the woodyard from locally harvested roundwood stock (65 percent). The purchased chips are received at a tractor-trailer and railcar dumper, and pneumatically conveyed to the storage bins. The woodyard operation includes three plate-type barking drums, a hydraulic log splitter, a 112-inch disc chipper, a 126-inch chip screen and a pneumatic conveying system to transport the chips to the storage bins.

The chips are transported from the storage bins to the 13 batch digesters as follows:

Storage Bin	Type of Stock	Means of Conveyance	Service
Bin #1 (50,000 ft^3)	pine	chain conveyor	Digesters #1-#7
Bin #2 (50,000 ft^3)	hardwood	belt conveyor	Digesters #8-#13
Bin #3 (20,000 ft^3)	pine	pneumatic conveyor, star feeder	Digesters #1-#13

The CB&I digesters are each 12-feet in diameter and 40-feet high, and are designed for a maximum pressure of 150 psig at 400°F.

Eight of the digesters were installed in the past 20 years, replacing original units installed in the 1940's. The remaining five digesters were installed in the 1953. All 13 digesters are arranged in a single line, with the tops extending through the operating floor opposite the control rooms.

A typical 'cook' yields 13 tons of pulp and requires about three hours. The first or second helper automatically opens the tube - turns closure and positions the chip chute over the top of the digester. As the chips are being loaded, white and black liquor are automatically metered into the digesters. At the end of the loading operation (~25 minutes), the chip chute is removed and the digester is automatically closed and sealed. Over the next 90 minutes, the chips and liquor are slowly heated with saturated steam (135 to 140 psig) injected directly into the bottom of the digester. When the digester

pressure reaches 110 psig, the steam is shut off and the chips are allowed to cook for about 40 minutes. The digester is automatically relieved to remove the non-condensible gases formed during the cooking reaction. The relief gases and liquor carryover pass into a separator, where the black liquor is recovered and piped to the blow tanks. The gases and vapors pass to a condenser where the non-condensibles are vented and the condensed liquids are dropped into a decanter. Turpentine is pumped from the top of the decanter into a storage tank.

After a period of about 40 minutes at the cooking pressure and temperature, the blow valve is opened and the batch is discharged to one of three blow tanks (CBI, 2-92,000 gallons, 1-60,500 gallons: each equipped with IMPCO vertical agitators in cone bottoms).

The blow sequence is shown on Figure 11-1 and outlined below:

Digesters #1 & #2	Blow Tank #1
Digesters #3 - #6	Blow Tank #1 or #3
Digesters #7 - #9	Blow Tank #2 or #3
Digesters #10 - #13	Blow Tank #2

The blow gases pass through a drop separator, where fiber and liquor carryover is collected and returned to the blow tank. The gases continue to a jet condenser - the condensate is collected in an accumulator tank and pumped to the brown stock washers; the non-condensible gases are vented. The contents of the blow tanks are continuously agitated and mixed with weak black liquor to maintain the desired consistency.

From each blow tank, the pulp slurry is pumped through a Solvo Fibrilizer (IMPCO Model 3-25) to break up knots and remove foreign substances. Oversize 'reject' material is removed in a sealed centrifugal screen (IMPCO Model A-25C) and the stock is pumped to one of three washer lines. As shown on Figure 11-1, lines #2 and #3 consists of 3 stage vacuum washers and line #1 consists of 4 stages. Each line employs a countercurrent flow of washing liquid, with accumulator water added to the final stage and filtrate used at each preceding state. The washed stock from lines #1 and #3 are pumped into storage chests for subsequent transfer to the paper machines. Line #2 also discharges into a storage chest, but the stock is further processed through a centrisorter system. Screen rejects pass over a thickener (IMPCO vacuum filter) and into a double-revolving discs refiner (Bauer No. 411-FV-40"); the refined stock is returned to the paper machines. From the screens, the accepted stock is thickened on one of two deckers and pumped into a stock chest for subsequent transfer to the bleach plant.

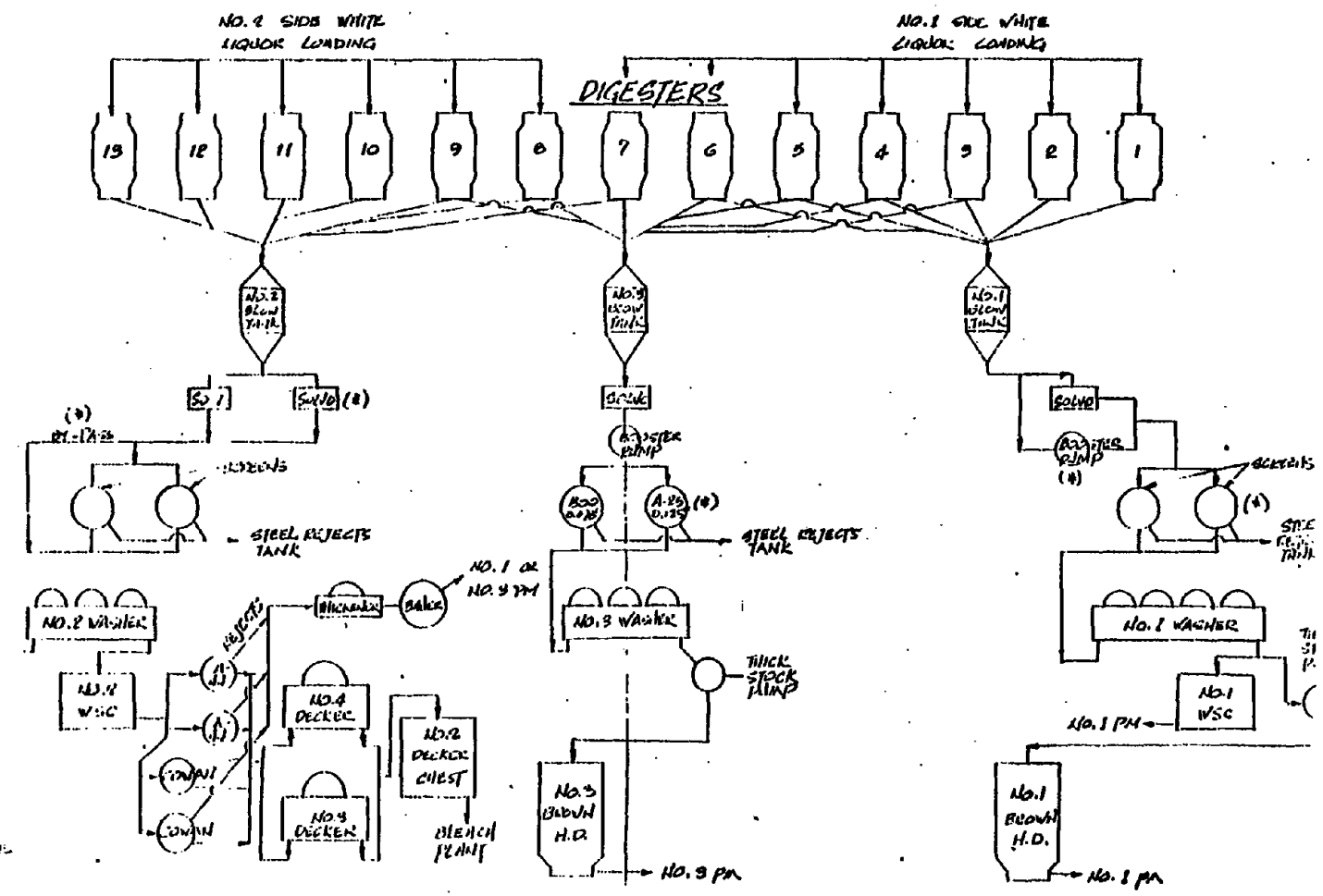


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FIGURE II-1 KRAFT Pulping Process

JOB CATEGORIES AND DESCRIPTIONS

There are nine employees per shift required to operate the pulping process. These employees are located in three separate areas depending on the unit operations for which they are responsible:

Digester Control Room

- Cook - The cook has overall reponsibility for the operation of all digesters during his tour of duty. He directs all activities and handles all emergencies in this area, and supervises the first and second helper, the sampler, and the pulp tester. He monitors all pertinent process variables, noting the progress of the cooking cycle on each digester. It is estimated that the cook remains in the control room for more than 90 percent of each shift.

- First and Second Helper - Under the supervision of the cook, the first and second helpers operate digesters #1 through #7 and #8 through #13 respectively. Generally, these employees initiate the various cooking operating sequences from the control room. However, the following activities require that the helpers be in the production area for up to 30 percent of each shift:

  1. operating the tube-turn closures
  2. positioning and operating the chip chutes
  3. cleaning and replacing O-rings on the tube-turn closures
  4. measuring the stock level in the blow tanks
  5. cleaning chip spills
  6. operating the blow back system to clean the relief line screens
  7. unplugging the line separator
  8. manually operating the relief and chip blower systems when necessary

- Pulp Tester - The pulp tester leaves the control room every hour for 7 to 10 minutes to collect stock samples at the last stage of each brown stock washer. Every two hours, an additional sample is collected from the Bauer refiner. The samples are returned to the control room and analyzed by the tester. Once a shift samples of black liquor are collected from the digester feed line and the first stage extraction tank. It is estimated that the tester remains in the control room for 80 to 85 percent of each shift.

- Sampler - This employee collects stock samples from each of the digesters prior to transferring the batch to one of the blow tanks. Additional responsibilities parallel those of a utility man, primarily minor maintenance of process equipment and various housekeeping tasks. It is estimated that the sampler spends up to 50 percent of each shift in the control room.

- Brown Stock Washer Room Operator, First and Second Helper - These employees monitor and control the operation of the three brown stock washer lines, including the fibrilizers, hot screens, filtrate tanks and high density storage tanks. Since there is no control room in the washer area, the employees are in the production area for essentially the entire shift, usually at the operating consoles.

- Screen Room Operator - The screen room operator is responsible for the IMPCO and Cowan screens on line No. 2. Typically this operator remains in a closed control room for about 90 percent of each shift.

POTENTIAL WORKPLACE HAZARDS

The primary air contaminants that may be emitted from this process are hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. There is also a potential for exposure to wood dust, particularly while the digesters are being filled with chips. Much smaller quantities of terpenes, alcohols and potentially many other compounds may also be present.

PERSONAL SAMPLING RESULTS

Because of a higher potential of exposure to process contaminants, the majority of the personal samples were directed toward employees in the digester area. As shown on Table II-1, concurrent ceiling samples for hydrogen sulfide and methyl mercaptan were collected on the first and second helpers, the sampler, and the pulp tester. Long-term total

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TABLE II-1 PERSONAL SAMPLES

Job Category	Day	Shift	Sampling Period (Minutes)	Hydrogen Sulfide (ppm)	OSHA PEL (ppm)	Methyl Mercaptan (ppm)	OSHA PEL (ppm)	Total Dust (mg/m^3)	OSHA PEL (mg/m^3)
Pulp Tester	2	1	15	0.11	20	0.06	10		
		1	15	0.11	20	0.06	10		
		2	15	0.06	20	0.06	10		
	1	1	16	0.24	20	< 0.01	10		
		2	15	0.10	20	< 0.01	10		
Sampler	1	1	16	0.08	20	0.08	10		
		1	15	0.22	20	< 0.01	10		
		1	15	0.22	20	< 0.01	10		
Front Helper	2	1	121					0.08	15
		1	15	0.11	20	< 0.01	10		
		1	15	0.06	20	0.06	10		
	1	1	433					0.56	15
Second Helper	2	1	127					2.48	15
		1	15	0.05	20	0.20	10		
	1	1	420					1.49	15
Winder operator	0	2	15	0.22	20	< 0.01	10		
		2	16	0.11	20	0.01	10		
Screen Room Operator	0	2	15	0.10	20	< 0.01			

dust samples were also collected on the first and second helpers. Measured ceiling exposures range from 0.05 ppm to 0.86 ppm for hydrogen sulfide, and from < 0.03 ppm to 0.20 ppm for methyl mercaptan, or well less than five percent of the respective OSHA PEL for these compounds. Total dust exposure levels are somewhat higher (0.56 mg/m^3 to 2.48 mg/m^3), but also fall well below the OSHA PEL of 15 mg/m^3 for total nuisance dust.

Several ceiling samples for hydrogen sulfide (0.1 ppm to 0.33 ppm) and methyl mercaptan ($\leq$ 0.03 ppm) were also collected on the washer operators and the screen room operator. These samples demonstrate similarly low exposures to these contaminants. It is thus concluded that, during normal process conditions, pulp mill employees are not exposed to significant concentrations of hydrogen sulfide, methyl mercaptan, or wood dust.

AREA SAMPLING RESULTS

Area samples were collected and analyzed for methyl mercaptan, hydrogen sulfide, alcohols, ketones, phenols, organics and resin acids (Table 11-2). Five samples were collected on the digester operating floor - concentrations of methyl mercaptan and hydrogen sulfide were all below 10 percent of the respective OSHA PEL's. Detectible concentrations of terpenes, alcohols, ketones, and organic vapors were also measured, but levels were very low. It should be noted that the silica gel samples for alcohols and ketones revealed significant breakthrough and/or migration to the back-up sample section, and reported results may be lower than actual. No resin acids or phenolic compounds were detected. Although these data demonstrate the existence of numerous contaminants emitted from the digesters, they do not suggest a significant potential for extensive exposure.

Two area samples were also collected in the control room. It is interesting to note that the results are generally equal to or higher than those collected out in the operating floor. This is probably due to the recirculating ventilation system (no fresh makeup air) in the control room. Whereas emissions into the operating floor are quickly diluted and removed by the high degree of natural and forced ventilation, contaminant concentrations in the control room are likely to remain and equilibrate at a higher level.

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TABLE II-2 AREA SAMPLES

Location	Day	Sampling Period (Minutes)	Methyl[1] Mercaptan (ppm)	Hydrogen[2] Sulfide (ppm)	Terpenes[3] (mg/m³)	Alcohols[4] (mg/m³)	Ketones[4] (mg/m³)	Phenolics[4] (mg/m³)	Organics[3] (mg/m³)	Resin Acids[4] (mg/m³)
Between Digesters B9 & B10	2	60			9.1	0.06	0.12	<0.03	2.1	<0.03
Digester B1	2	15	0.9	0.19	1.2	0.0	1.5	<0.13	0.7	<0.13
Outside Control Room	2	180	0.05	0.04						
Digester B11	2	42	0.05	0.14						
Digester B8	2	17	0.21	1.0						
Control Room	1	15	-		17	1.9	0.5	<0.13	38.9	<0.13
	1	15	0.02		21	1.4	0.15	<0.07	7.1	<0.07
Screen Room	1	15	<0.01	0.05						
	1	15	0.01	0.10						
	4	60			0.9	0.69	0.15	<0.03	0.13	<0.03
Washers B5 & B6	4	15			0.67	0.95	0.17	<0.13	3.9	<0.13
Outside Bldg. South Side B7 Washer	4	15	0.01	0.12						
TLV/TWA PEL			10 ppm	20 ppm	300 mg/m³ (turpentine)	260 mg/m³ (methanol)	590 mg/m³ (MEK)	19 mg/m³ (phenol)	435 mg/m³ (ethyl benzene)	—

[1] Method of Kaars and Rappaport, Anal. Chem., Vol. 52, 1980, pp. 713-716

[2] NIOSH Method P&CAM 126

[3] Anasorb Charcoal Tubes - Analysis by gas chromatography with FID after desorption with carbon disulfide

[4] Silica Gel Tubes - Analysis by gas chromatography with FID after desorption with carbon disulfide

Several detector tube samples were taken for dimethyl sulfide to determine if this compound is emitted to the workplace from the digesters. Two samples were taken above and to the side of digesters while they were being charged with chips and liquor. Both samples resulted in concentrations at or slightly above 15 ppm. An additional sample was taken directly adjacent to a visible leak emanating from a relief valve on one of the digesters. This resulted in a concentration of 4 ppm dimethyl disulfide. These samples were purposefully collected during "worst case" situations and are thus not directly translated into estimates of potential worker exposure.

Additional area samples were collected in the screen and washer rooms (Table 11-2). Like the samples collected on the digester operating floor, these data resulted in very low concentrations of methyl mercaptan, hydrogen sulfide, terpenes, alcohols, ketones, and organics. Resin acid and phenolic compounds were not detected.

CONTROL OF WORKPLACE HAZARDS

Process Characteristics Except during the loading operation, the cooking process is a totally closed system - workplace emissions are limited to leaks from process equipment or major process upsets. Downstream operations are similarly closed, with the exception of the brown stock washers, which are exhausted through overhead canopy hoods.

Automatic Digester Capping Prior to 1964, digester covers were bolted to the throat piece requiring manual removal and replacement during the loading cycle. Relative to worker exposure, there were three primary deficiencies in this system:

- the covers were difficult to seal, and there were frequent leaks from the digesters during the cooking cycles.
- It was possible for workers to remove the lids before the internal pressure had been reduced to a safe level (<1.5 psig)
- the workers were required to be closer to the open digester and for longer periods of time.

During 1964 and 1965, all digesters were equipped with tube-turns, automatic hinged closures (#300 VAB 30"). As shown on Figure 11-2, the closure consists of a hub (1) that is butt welded or flanged to the digester, a full-circumference yoke (2) that separates into two halves to permit the hinged head (3) to be swung open, and a static O-ring gasket (4) that provides a leakproof seal. The head (5) and hub laps (6) & (7) are tapered to match the internal bevels of the yoke halves so that head and hub are wedged together when the unit is in the

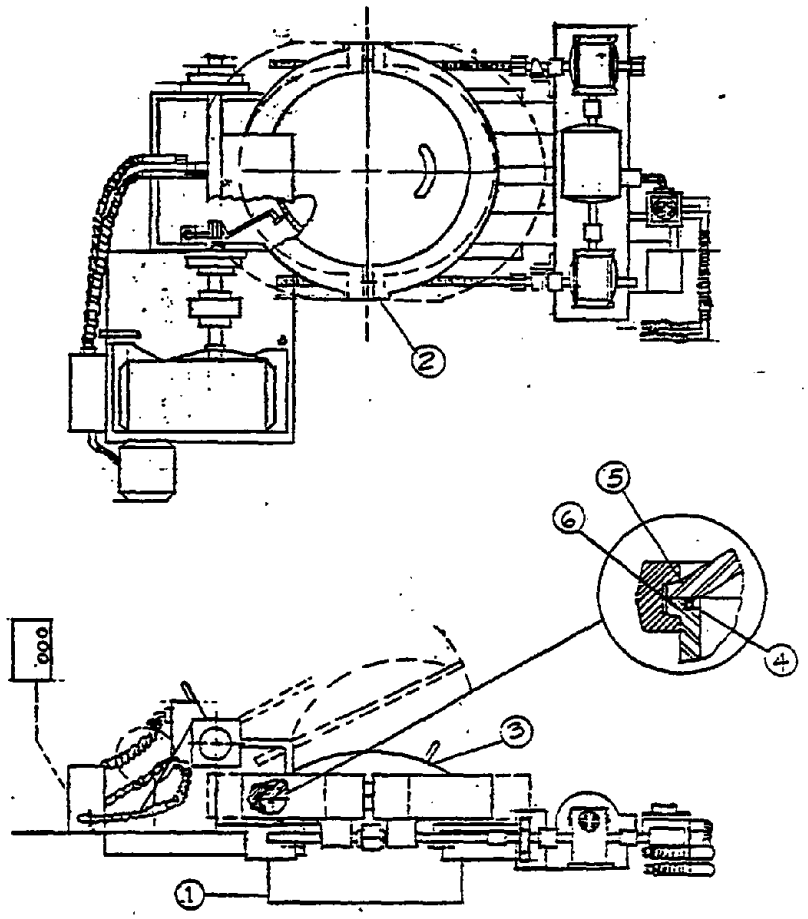

Fig 11-2

TUBE-TURNS DIGESTER CLOSURE

full-closed position[1]. The system is interlocked with a pressure switch to prevent operation when the closure contains internal pressure above 1 psig. Obviously, the potential for exposure has been significantly reduced with the tube-turns closure system. Because of the pressure switch interlock, the volume of gases and vapors emitted to the workplace during the loading cycle is significantly reduced. Although the O-rings must be replaced every several weeks, the automatic closures provide a much improved seal. More importantly, the employee can open and close the digester from a distance, away from the plume of steam, gases and vapors emitted when the digester is first opened and during the charging operation.

Automatic Control Systems In 1968, a white and black liquor metering system was installed, replacing the existing measuring tank feed system. There are three separate metering systems, each independently supplying black and white liquor to four or five of the 13 digesters. One complete system is depicted on Figure 11-3. At the start of a digester charging cycle, the operator pushes buttons to activate the black and white liquor pumps, and the two streams are combined and mixed in-line. The mixed liquor flow is measured by an 8 inch orifice meter and the volume is displayed in the control room on a recorder/-integrator panel. When the pumps have run for a predetermined period of time, they are shut down and an automatic control valve in the mixed liquor line is closed. The control system also includes a level indicator that (which has precedence over the timer) can shut the system down should the desired level in the digester be exceeded. There is also a pneumatic digester control system which:

- produces a uniform pulp with minimum screen rejects
- controls the steaming rate for maximum steam efficiency and complete circulation in the digesters
- controls relief to eliminate liquor pullover, removes all non-condensibles from the digester, and controls plugging of the relief screen (automatic and manual blow back)
- records the digester temperature and pressure

[1] PULP AND PAPER MANUFACTURE, VOL. I, The Pulping of Wood , Joint Textbook Committee of the Paper Industry, pages 444-445.

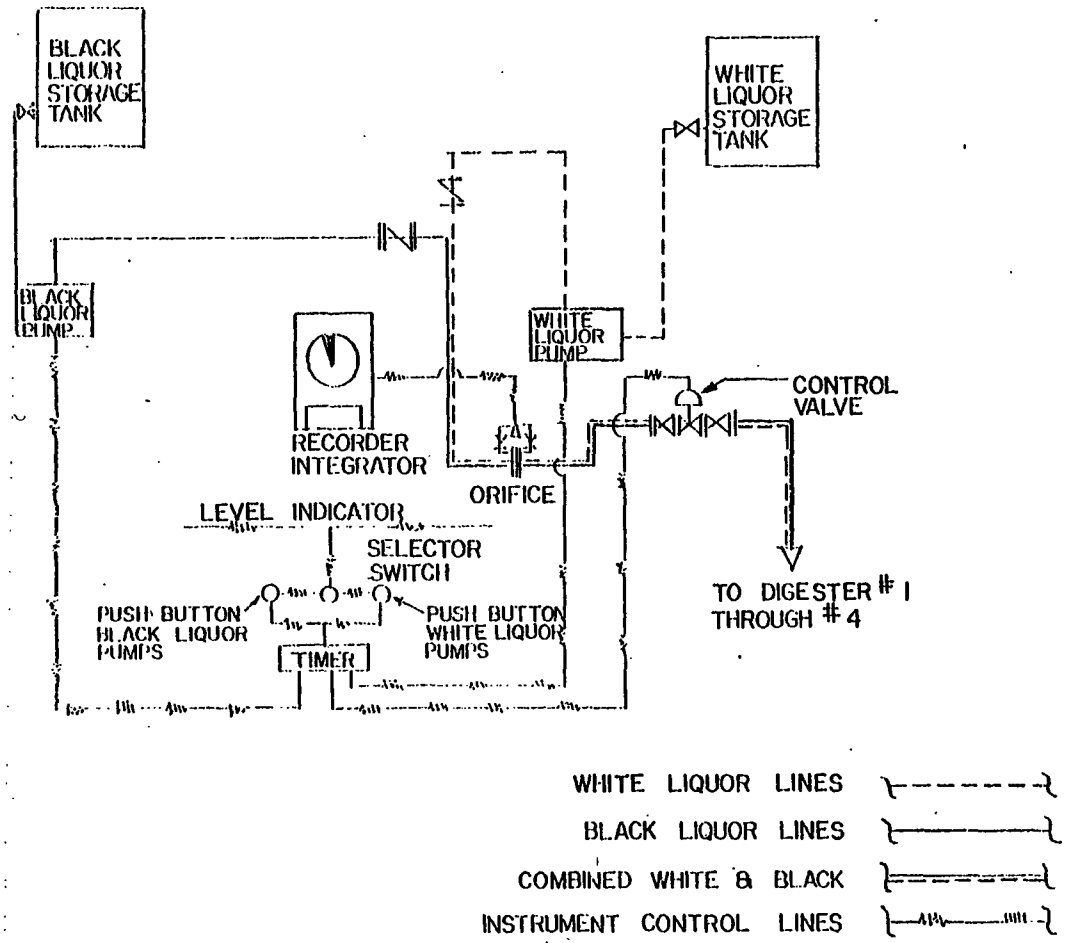

FIGURE II-3 BLACK & WHITE LIQUOR FEED SYSTEM

With this system, the operator generally need only push a button to complete a fully automatic cook. These automatic systems reduce the frequency of upsets and enhance worker isolation from the process. In fact, the control room was installed in parallel with the automatic control systems in 1968. As outlined previously, most of the digester employees spend large portions of each shift inside of the control room.

- operator - 90 percent
- first and second helper - 70 percent
- tester - 80 to 85 percent
- sampler - 50 percent

The control room is not currently provided with any fresh air makeup - air is continuously recirculated. As demonstrated by the air sampling data, contaminant concentrations inside the control room are roughly equivalent to those measured in the operating floor. Although the concentrations were very low, the control room should be provided with a system to introduce and circulate clean fresh air, particularly for use during a major upset or other emergency situation.

Brown Stock Washer Hoods There are two separate canopy hoods providing ventilation for the three brown stock washer lines. As shown on Figure 11-4, one hood covers the four stages of the No. 1 washer line - another hood is provided for the six stages making up the No. 2 and No. 3 washer lines. These hoods and all new ductwork were installed six or seven years ago, and are manufactured from reinforced polyester resins. These units replaced existing metal hoods and ducts, and have largely eliminated problems with corrosion.

The large hood (line Nos. 2 & 3) is provided with three fiberglass vane-axial fans, each rated at 50,000 cfm. Given the volumes of the hood, the three fans will produce approximately 9 air changes per minute design. The small (line No. 1) hood is provided with two similar fans, rated at 50,000 cfm and 40,000 cfm respectively. This corresponds to about 13 air changes per minute design. By observation, it was evident that the hoods are more than adequate to prevent excessive escape of contaminants into the workplace. The exhaust from each hood is exited just above roof level of the washer building. It is possible that exhausted contaminants may re-enter the workplace under certain meteorological conditions, although this did not occur during the survey.

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FIGURE 11-4 BROWN STOCK WASHER HOODS

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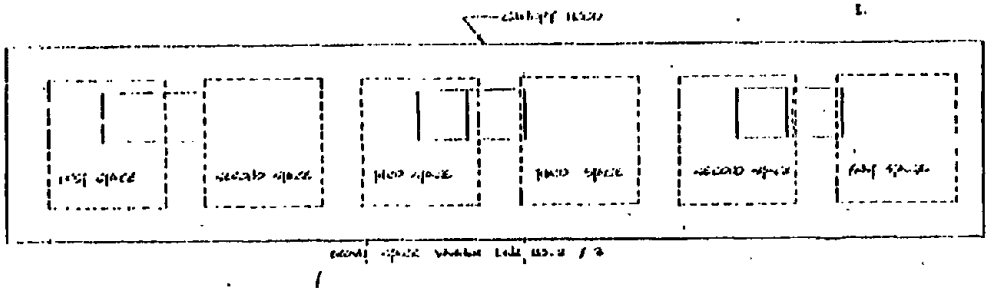

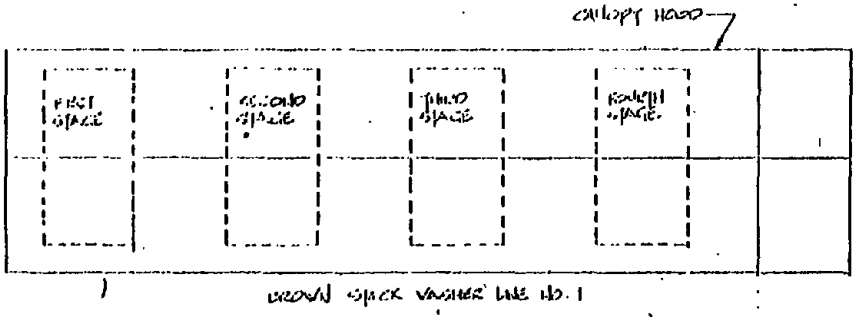

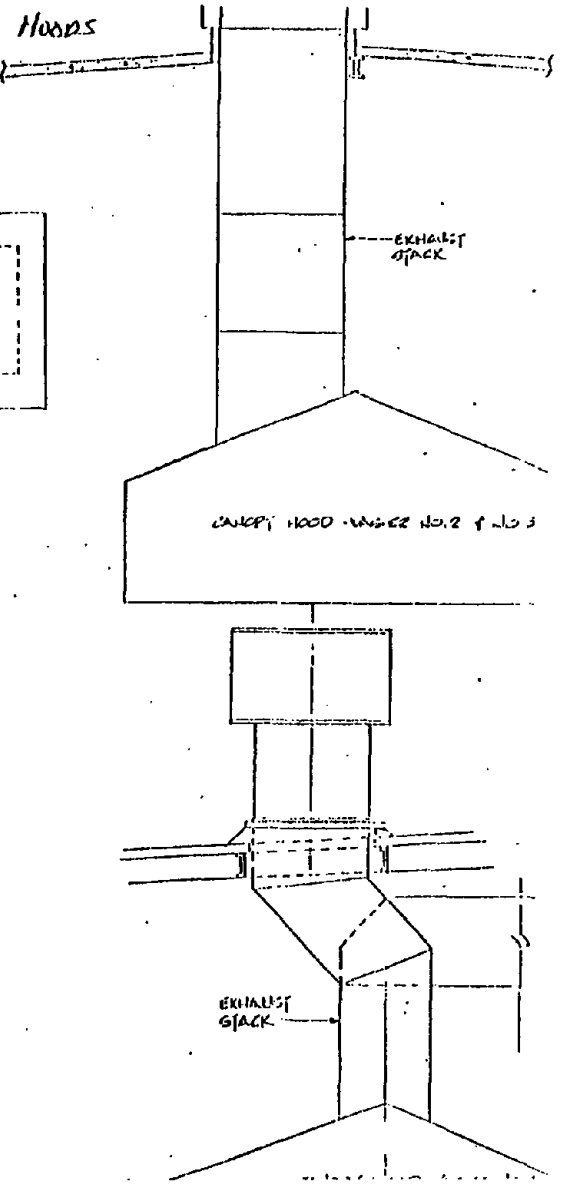

General Ventilation The digester operating floor and the connecting brown stock washer rooms are under a very strong negative pressure due to the lack of forced makeup air to replace the large volume of air exhausted through the washer hoods. Measured air flows through the numerous windows, louvers and other wall openings ranged from 100 fpm to well over 500 fpm depending on the orientation relative to the prevailing winds. This combination of induced makeup air and natural ventilation through structural openings in the building provides rapid dispersal, dilution and removal of process contaminants emitted to the workplace. Although the significant air currents resulting from this large inflow of makeup air interferes somewhat with the collection efficiency of the brown stock washer hoods, the impact is not sufficient to produce high worker exposures in these areas.

The exhaust streams from the washer hoods exit to atmosphere just above the roof level of the pulp mill building. Although there appears to be a potential for contaminant re-entry into the workplace under certain meteorological conditions, this phenomenon was not observed during the survey. The geometry of the building and the position of the exhaust stacks makes it unlikely that undiluted contaminant streams would be re-entered on a frequent basis.

Personal Protective Equipment Each employee in the pulp mill is issued a half-face, acid-gas cartridge respirator for use during emergencies. These units are inspected by lab personnel every week. The use of these respirators is solely at the discretion of the individual worker and, based on observations during the survey, it is concluded that they are rarely required.

Vessel Entry Procedures Mill 11 has developed written practices and procedures with strict requirements for entering closed vessels, tanks, stock chests, chip bins and similar confined areas. The program consists of the following features:

- Responsibility - Supervisor is responsbile for determining the previous contents of any confined area to be entered and for assuring that the necessary ventilation, protective clothing, respiratory equipment, emergency stand-by equipment, and fire prevention precautions are specified, provided and used.

- Vessel Purging - The contents of any vessel must be drained, pumped out, or otherwise removed. Cleaning is performed outside of the vessel by washing with hot or cold water, or by purging with steam or air. Any acid remaining in the vessel must be neutralized with soda ash or lime.

- Failsafe Precaution - All pipelines, electrical lines, agitators, and other services leading to the vessel must be disconnected, blanked or valved off, (or otherwise rendered inoperative) and tagged out prior to entry.

- Ventilation - Adequate fresh air must be blown into the breathing zone of all workers inside of the vessel. The air intakes must be located such that no air contaminants may enter the air system.

- Testing - The atmosphere in any vessel must be tested by lab personnel prior to entry and during work if necessary. A 'Checklist for Gases' must be completed by a lab technician, signed and authorized by the project supervisor, initialed at job completion by the participating maintenance workers, and finally returned to the safety office. Tests may be conducted for oxygen deficiency, and the presence of combustible or toxic gases and vapors.

- Tank Entry Permit - A tank entry permit must also be completed and signed by the project supervisor prior to any vessel entry. The permit covers all steps required to prepare a vessel for safe entry and is valid for one shift only. If the work is discontinued and it becomes necessary to re-enter a tank at a later time, new tank entry permits must be issued.

- Safety Precautions - 1) a means of rapid, safe entry and exit must be provided and maintained throughout all tank entry work operations: 2) lifelines and harnesses will be worn by each worker entering a vessel; 3) canister type gas masks, an emergency air-supplied breathing apparatus must be maintained at the work site; 4) rubber boots, waterproof clothing, and eye, face, head and foot protection must be worn under direction of the project supervisor and/or the safety office; 5) an observer must be stationed outside the tank at all times, and be equipped with a means of communication in case of an emergency; 6) steam hoses and fittings must be grounded; 7) lights used in the vessel must be the low voltage type or an isolation transformer must be used; 8) where lighting and power requirements cannot be met by using battery lights and pneumatic equipment, 110-120 volt electric tools may be used if they are equipped with heavy duty cable of sufficient length so that no 'plug in' connections are made inside or on the surface of the tank (except for tanks containing moisture, volatile and/or flammable materials or those having process histories).

- Welding and Burning - All welding equipment used in a tank must be provided with quick shutoffs under the control of the operator, and must be removed from the vessel immediately after it is used.

MILL 20 BATCH KRAFT DIGESTERS AND BROWN STOCK WASHING

INTRODUCTION

Mill 20 includes a Kraft pulp mill with eleven fully-automated batch digesters and three lines of stock washing with displacement vacuum-drum washers.

The mill produces approximately 1050 tons per day of softwood Kraft pulp to supply its integrated paper mill. Two other Kraft-type pulping operations are also present at the facility. Pulp from these systems is washed in one of the three displacement washing lines. The mill was originally constructed in the mid 1950s and has been continuously improved and expanded since that time. The most recent and significant improvement in terms of this study was the total automation and computer control of the batch digesters accomplished in 1977.

The mill was surveyed for four days in early December. Projected potential chemical exposure agents included hydrogen sulfide, mercaptans, and other reduced sulfur agents that are potentially given off during the pulp digesting and washing stages. Both area and personal monitoring sampling were performed, with the results indicating minimal exposure for production workers. This was attributed to the inherent nature of the process; the extent of digester automation; and effective 'general' building and 'local' washer ventilation. The combined digesting and brown stock washing processes are operated by a production staff of three people, assisted by maintenance and utility workers on an as needed basis.

Noise levels in the brown stock washing area were comparatively higher than in other mills, but compliance to the OSHA TWA standard was being attained by use of hearing protection and worker isolation. Heat stress did not appear to be a problem as good air movement was attained in most work spaces, overall air temperatures were not significantly elevated, and workers perform few strenuous tasks of long duration.

MILL LAYOUT

The operating floor for the eleven digesters and three brown stock washing lines is located on the top level of an enclosed, rectangular building with a short wing off its center (see Figure 20-1). This wing contains the three most recently added digesters (Nos. 9-11). The other eight digesters run along one wall of the building, and are separated from the straight line arrangement of the three washer lines by a floor to ceiling partition. The new digester control room, containing the computer and its control console, is located off the far back end of the building. It is fully air conditioned to protect the computer, and also well-insulated for sound. Three blow tanks (for the eleven digesters) are all located outside, but near the digester building.

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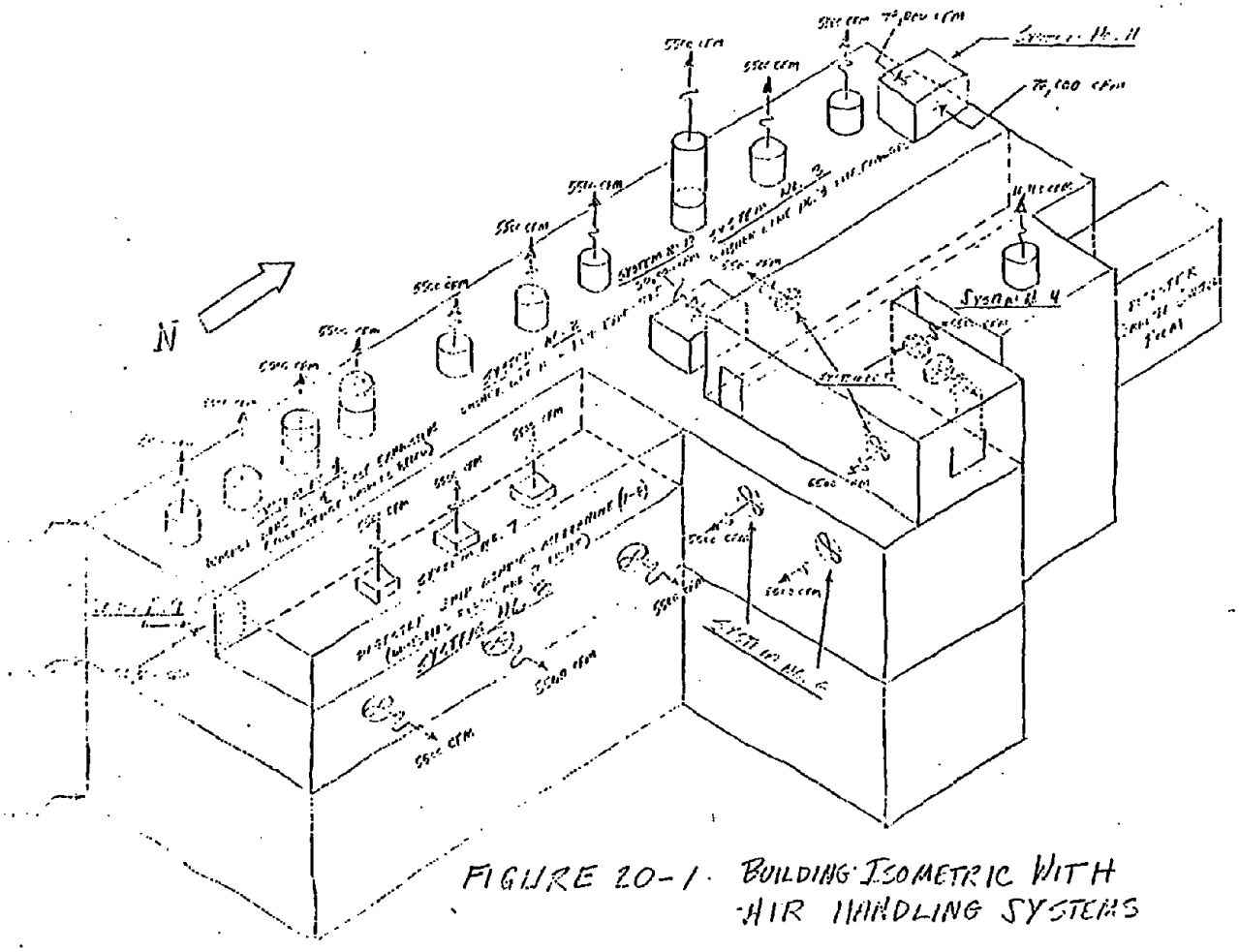

FIGURE 20-1. BUILDING ISOMETRIC WITH AIR HANDLING SYSTEMS

Chips are fed to the digesters automatically from a conveyor line that runs above them on a mezzanine level. This is accessible from the operating floor by stairs, but is only occasionally entered by workers in order to clean up chip spills or inspect equipment.

PROCESS SUMMARIES

Batch Digesters - Eleven batch digesters of varying age but equal size (4650 ft^3) are used to cook softwood chips. All are made of carbon steel, and use basically the same automatic loading/capping (sliding-gate with teflon seat) and blow (8 inch Jamesbury or new Kamyr) valves. Digesters Nos. 1-4 were original equipment when the mill started in 1957. Nos. 5-8 were added in 1959; No. 9 in 1965; and Nos. 10 and 11 in 1969.

Pulp digesting is accomplished under almost total computer control. Each digester is charged with approximately 120 tons of material -- chips and liquor. Chips, purchased by the mill on the open market, are primarily Douglas fir (75-80%); however, pine, other firs, cedars, and occasionally redwood are also used (but in no set portion). A typical digester filling cycle lasts about 20 minutes and involves the following automatically-controlled steps to insure good chip packing and liquor penetration:

1. Fill with chips to about one half full;
2. Shut off chip flow and add 5000 gallons of black liquor, depending on chip moisture content; (Chips are restarted during b ack liquor fill)
3. Start white liquor flow;
4. Continue chip flow until radiation sensor detects full digester;
5. Continue liquor flows until desired cooking strengths are achieved;
6. Close capping valve and commence cooking cycle.

Direct steam is then used to heat the digester and commence cooking of the chips. The cooking cycle is controlled to the preset H-factor (cooking time versus temperature). Turpentine (and other gases generated during cooking) is periodically flashed off the digesters during the first and middle stages of cooking, and is recovered. During the later stages of cooking, all excess digester pressure is relieved to the blow tank. If necessary, pulp samples can be collected from an individual digester at any time in order to check the results of the cooking cycle. These are usually collected (and tested) by the

operator from a push button sampling tap located near the digester's center. Occasionally, the brown stock washer operators may collect this sample if the digester operator is too busy.

After the programmed amount of cooking time (or H-factor), the computer signals the Operator that the digester is ready for blowing. However, in order to actually blow the digester, the Operator must first manually instruct the computer to open the blow valve. This feature is used for safety reasons to insure that two digesters cannot be concurrently blown to the same blow tank, or a single digester to a nearly full blow tank. A typical digester operating cycle, including normal times and conditions for each step, is summarized below:

TYPICAL DIGESTER OPERATING CYCLE

Event	Approx. Total Time (mins.)	Conditions
Loading	20	Capping valve open; blow valve closed; chip system on; liquor added as specified
Cooking	110-150	(Mill-specify typical H-factor, temperature and steam requirements)
Blowing	~10	Manually activated to 1 of 3 blow tanks; down to final pressure of 0-3 psig.
Uncapping Delay	15 or 30 seconds	Computer Execution Schedule

Typically, digesters Nos. 1-4 are blown to blow tank No. 1; Nos. 5-8 to blow tank No. 2; and Nos. 9-11 to blow tank No. 3. All are located outside with blow steam relieved to an accumulator for heat recovery. Blow line piping is so arranged, however, that stock from four digesters can also be blown to another blow tank, if required. High blow tank pressure (during an actual digester blow) is relieved to atmosphere through a relief valve on top of the blow tanks.

This is mentioned because the relief valve on tank No. 2 is near an open door leading into the chip mezzanine level above digesters Nos. 9-11. Gases released from this tank could (if wind direction is right) enter this mezzanine area and potentially expose any utility worker performing cleanup tasks.

Brown Stock Washing - From blow tanks Nos. 1 and 3, hot stock passes through an IMPCO fibrillizer, and then is pumped through a Jones refiner up to IMPCO rotary screens. Stock from blow tank No. 2 is not refined and is pumped directly to a separate set of screens. Blow tank No. 1 stock is pumped to two of three screens; No. 2 and No. 3 blow tank stock to one of two sets of two parallel screens. Screen rejects are sent to a reclaim system. The screens are closed and under vacuum and are not thought to be a significant workplace emission source of hot reduced sulfur gases. From the screens, stock then passes directly to the inlet vat of the first washer of the washer lines. Blow tank No. 1 feeds to washer line No. 1. Blow tank No. 2 supply stock to washer line No. 2. Blow tank No. 3 feeds to washer line No. 3. M&D digester stock can be washed in either washer line No. 2 or washer line No. 3. Washer line No. 1 has four stages of washing, but Nos. 2 and 3 use only three stages -- all have countercurrent wash water flow schemes with fresh hot water used only for the final stage showers. Wash water filtrate from each stage drops to sealed filtrate tanks located below the operating floor or adjacent to the building.

It is then pumped back up to the showers of the preceding stage. First stage filtrate is either pumped to the IMPCO screens to dilute and wash out stock in these units, or flows into a large outside foam tank. The foam tank collects any foam that develops and builds up in the tops of the individual filtrate tanks. Black liquor from the filtrate tanks is then pumped either: 1) back to a digester blow tank to cool and dilute incoming stock; 2) to a black liquor oxidation tank, and then into the evaporator and chemical recovery system; or 3) to a measuring tank for black liquor which is to be recharged to a digester being filled with chips. Since these washer filtrate tanks, foam tanks, and black liquor oxidation tanks are all closed and outside, worker exposure to any reduced sulfur gases from them is unlikely. Brown pulp stock after the final stage of washing is then diluted to the desired consistency, and pumped to a number of high density tanks used for temporary storage.

Each of the three washer lines are covered by separate canopy hoods which are exhausted to the roof. The washers comprising line No. 1 each have steam doctors on their discharge ends to remove the washed pulp from the vacuum drum. Washer line No. 2 uses air doctors on its three washers, with pressurized air supplied by three centrifugal fans located adjacent to the last washer. Both this air and also the steam place an additional load on the washer hoods. Washer line No. 3 uses only a roll assembly to remove stock from the drum.

JOB DESCRIPTIONS

The process automation achieved when the computer was installed in 1977 resulted in a production work force reduction to only three people -- Digester Operator, Brown Stock Washer (BSW) Operator, and an assistant BSW Operator.

Utility and maintenance personnel are assigned to the batch digester and brown stock washing area largely on an "as needed" basis. A cleanup crew of utility personnel may typically work part of one shift each day cleaning up spilled chips on the digester mezzanine level and doing other miscellaneous housekeeping tasks on the digester and washer operating floor. Their work routine is, however, unpredictable and could vary from day to day. A maintenance "oiler" person may also be in the digester and brown stock washing area quite often to lubricate various pieces of machinery, but this is not predictable either. Pulp mill production management staff and shift foremen only make periodic inspections of the areas, and do not remain for significant periods of time unless upsets or malfunctions are occurring.

Digester Operator - The Digester Operator spends nearly all his time in the new control center where he monitors the process and interfaces with the computer. During the four day survey, he was observed leaving this control room only for very brief periods (<5 minutes) mainly for personal business. Tasks which may require him to leave the control center would include: collection and testing of digester samples during a particular cooking cycle; inspection and adjustment of equipment; and communication with the washer operators or other personnel. The process is almost entirely automated and the Operator has all the controls and monitors he requires within the control center. Cameras and view screens are provided so that he can periodically check remote process areas, such as the chip loading mezzanine.

Brown Stock Washer Operator and Assistant - The two employees operating the three brown stock washing lines perform essentially similar duties and tasks, and are at nearly equal exposure levels. The Operator is technically responsible for the safe and efficient operation of all the washers, screens, and refiners. The Operator oversees process startups and shutdowns and is responsible for entering all data on the daily brown stock washing production log sheet. He also will make adjustments to the washers and screens, as necessary; and keeps constant watch over process parameters displayed on the control panels located alongside each washer line.

The Assistant will assist the Operator in startups and shutdowns when required, and will also make periodic equipment adjustments. He is trained to operate the entire process, if the Operator is absent or busy with other tasks. He is also

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responsible for collecting and making periodic tests of washed stock from each line. Test parameters include: Kappa number, washed stock chemical loss, pumps shive count, and liquor strength. Tests are performed in a small testing lab situated beside Washer Line No. 2.

At least once per shift the Assistant also hoses down the digester operating floor and around each washer line. If stock spills over at any washer or screen, he will also be assigned its cleanup, although an Operator may occasionally also do this. In addition, either of these two employees may be asked by the Digester Operator to collect a sample or make process adjustments for him (if he is unable to leave the control center). It is estimated that these two employees, therefore, spend almost 100% of their time near the washers or around the digesters.

AIR SAMPLING RESULTS

Nature of Workplace Chemical Exposure Agents - Employees working around the batch digesters and brown stock washers could be exposed to any gases used or formed during the chip digesting and pulp washing operations. For the softwood chips and conditions used in this process, such gases might include hydrogen sulfide, mercaptans, dimethyl sulfide, dimethyl disulfide, turpentine, and perhaps, some low-molecular-weight alcohols and ketones. Applicable OSHA standards include the ceiling limits for hydrogen sulfide (20 ppm) and methyl mercaptan (10 ppm); and the 8-hour TWA for turpentine (100 ppm). At the beginning of the survey, detector tubes (Drager) were utilized to assess the presence and relative magnitude of hydrogen sulfide, mercaptans, and dimethyl sulfide in the workspaces around the brown stock washers and batch digesters. Results are summarized in Table 20-1, with no measurable quantities detected at any of the locations except a small amount of dimethyl sulfide (DMS) on the digester chip mezzanine level (near Digester No. 2). However, the Drager DMS detector tube also responds positively to both mercaptans and hydrogen sulfide, so the small positive reading cannot be attributed entirely to DMS. These detector tube results do, however, indicate a low background level of reduced sulfur gases in the brown stock washer area.

In the nearby digester area, concentrations of air contaminants are thought to be related to digester operating cycles, with direct emission of significant amounts of gases taking place only when a digester loading cap is open to begin the chip refilling operation. The sliding gate-type valve used with this cap does not appear to leak significantly during a digester cooking cycle. The capping valves are Rovang Valves with Teflon 'o' rings and soft rubber seals. They rarely leak and when they do, seals are changed.

TABLE 20:1 -- SUMMARY OF DRAGER DETECTOR TUBE READINGS

Location	Contaminant	Concentration, ppm[1]
• Chip Mezzanine Near Digester No. 2	Hydrogen Sulfide	No Reading, est.<0.5
Near Digester No. 2	Dimethyl Sulfide	~2 (see Note 3)
Near Digester No. 7	Mercaptan	No Reading, est.<1.0 (see Note 4)
Between Digesters Nos. 9 & 10	Hydrogen Sulfide	No Reading, est.<0.5
Between Digesters Nos. 9 & 10[2]	Mercaptan	No Reading, est.<5
Between Digesters Nos. 9 & 10	Mercaptan	~1.7 (see Note 5)
Between Digesters Nos. 9 & 10	Dimethyl Sulfide	~1.5 (see Note 6)
Between Digesters Nos. 9 & 10	Hydrogen Sulfide	No Reading, est.<0.5
• Control Panel for Washer Line No. 1	Mercaptan	No Reading, est.<1.0
• Control Panel for Washer Line No. 1	Hydrogen Sulfide	No Reading, est.<0.5

Notes

1. All tests used 10 pump strokes unless otherwise noted.
2. Loading cap for Digester No. 9 opened at ~18:38 and digester vented until 18:52, started feeding chips to Digester No. 9 at 18:48, stopping at 18:58; restarted feeding chips again at 18:59 continuing until ~19:09.
3. Detection limit is 1 ppm for 10 pump strokes; used 20 pump strokes.
4. Digester No. 7 completed filling cycle at ~18:35.
5. Detection limit for 10 pump strokes is 5 ppm; used 30 pump strokes.
6. Mercaptans and hydrogen sulfide are positive interferents.

However, when the valve is first opened after a blow, small amounts of remaining digester pressure are released into the workplace and up into the chip mezzanine.

A portable HNU photoionization monitor was used to attempt to assess the variability and effect of this emission on workplace air quality. Severe electrical noise around the digesters affected the monitor's response and results could not be accurately interpreted. No direct detector tube or other measurements from this emission were made for reduced sulfur and organic gases.

As the digester is slowly filled with chips, additional contaminated air is displaced from it through the filling cap and enters the workplace. Emission of potentially toxic process gases from other equipment, such as the rotary screens or liquor lines, did not appear to occur to any appreciable degree.

Personal and Area Sampling Results - Although the detector tube readings indicated very low hydrogen sulfide and mercaptan levels, additional area and personal samples were collected to verify the extent of worker exposures. Samples were collected for hydrogen sulfide according to NIOSH Method P & CAM 126; and for mercaptan according to the method of Knarr and Rappaport (Anal. Chem., 52, 1980, pp. 733-736). Personal samples (4 mercaptans, 3 hydrogen sulfide) were collected for approximately 15 minute periods (during performance of projected high exposure tasks) to assess compliance to the respective OSHA ceiling limits. Area samples (4 mercaptan; 1 hydrogen sulfide) were collected for periods of 1 to 5 hours mainly on the chip mezzanine level. All results are summarized in Table 20:2.

No attempt was made to assess worker exposures to other reduced sulfur and organic contaminants (dimethyl sulfide, dimethyl disulfide, turpentine, etc.) due to the: 1) lack of an accurate, convenient method; 2) judged low concentration of these contaminants; 3) lack of specific OSHA standards; 4) observed good ventilation of the workspaces and the isolation of workers.

As shown in Table 20:2, the Assistant Brown Stock Washer Operator's exposure to both methyl mercaptan and hydrogen sulfide during three 15 minute sampling periods were shown to be very low (0.03, 0.20, and 0.08 ppm CH_3SH; 0.08, 0.16, and 0.11 ppm H_2S). His highest exposures resulted when he was near the batch digesters hosing down the operating floor (0.20 ppm CH_3SH; 0.16 ppm H_2S). An additional 233 minute sample for mercaptan on the following day resulted in a similarly low measured exposure of only 0.06 ppm.

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TABLE 20:2 -- SUMMARY OF PERSONAL AND AREA AIR SAMPLING RESULTS

PERSONAL SAMPLES

Job Category	Day	Contaminant*	Sample ID	Concentration (ppm)	Job Tasks
Assist. B&W Oper.	Wed.	MM	1	<0.03	o Recording data from control panel (4.5 min.) o Standing in front of Washer No. 2 (13 mins.) o Near Washer No. 2 (2.5 mins.)
Assist. B&W Oper.	Wed.	MM	2	0.20	o Hosing down floor around Digesters 5-7 and 9-11 (15 mins.); Digester No. 12 loading cap opened at 15:32
Assist. B&W Oper.	Wed.	MM	3	0.08	o Recording data from control panel (9 mins.) o Hosing down floor of Washer Line No. 1 (6 mins.)
Assist. B&W Oper.	Thurs.	MM	4	0.06	o Typical job tasks around Washer Lines 1-3
Assist. B&W Oper.	Wed.	H_2S	5	0.08	o Same as Sample No. 1
Assist. B&W Oper.	Wed.	H_2S	6	0.16	o Same as Sample No. 2
Assist. B&W Oper.	Wed.	H_2S	7	0.11	o Same as Sample No. 3

AREA SAMPLES

Chip Mezzanine @ Digester No. 7	Wed.	MM	8	0.27	o Digester No. 7 was filling at start of sampling o Digester No. 6 was uncapped near end of sampling
Chip Mezzanine @ Digester No. 7	Wed.	H_2S	9	0.15	o Same as Sample No. 8
Chip Mezzanine @ Digester No. 7	Thurs.	MM	10	0.20	o Sampling period includes at least one complete cycle for all digesters
Digester Operating Floor near Digester No. 7	Thurs.	MM	11	0.11	o Same as Sample No. 10
Digester Control Room	Thurs.	MM	12	0.008	o Same as Sample No. 10

*MM is methyl mercaptan; utilized sampling and analysis methods were: NIOSH P & CAM 126 for hydrogen sulfide; and method of Kwart and Boppaport for mercaptans (Anal. Chem, 52, 1980, pp. 733-736).

The area sampling confirmed that low levels of both mercaptan and hydrogen sulfide were present in the washer and digester operating floor workspace. Two samples for mercaptan (No. 8-0.27 ppm; No. 10-0.20 ppm) and one for hydrogen sulfide (No. 9 -0.15 ppm) were taken on the digester chip loading mezzanine level (near Digester No. 7). Single samples for mercaptans were taken on the digester operating floor near Digester No. 7 (No. 11 0.13 ppm, 283 minutes), and in the digester control room (No. 12- 0.008 ppm CH_3SH, 221 minutes). Samples Nos. 8-11 all included periods when Digester No. 7 (and nearby Digesters 6 and 8) was uncapped and loaded with a new batch of chips -- the operation judged to release the most significant quantities of air contaminants.

CONTROL TECHNOLOGY

Extent of Worker Exposure - The air monitoring results indicate low exposure potential to hydrogen sulfide and mercaptans for the brown stock washer assistant operator in this mill. This worker is projected to be at slightly higher exposure than the Operator because he normally spends more time around the digesters (hosing down the floor) and near the washers (cleaning up stock spills). Both of these workers are, however, at considerably higher exposure risk than the Digester Operator who remains in an isolated, well-protected control room for essentially his entire shift. Although some quantities of reduced sulfur gases (mercaptans and hydrogen sulfide) are probably emitted to the workplace from the washers and digesters (mainly during upsets and digester uncapping), none of the three production workers are significantly exposed. Excellent control over the release of process gases is, therefore, occurring in this mill.

Types of Controls - The effective controls are believed to be a result of the combined effects of: 1) good local ventilation of the washers; 2) good general ventilation of the entire washer and digester operating floor; 3) the degree of digester automation and control; 4) worker isolation (results mainly from extent of automation); 5) the closed nature of the process and the automated controls.

Ventilation - The local and general ventilation systems (for the washer and digester operating floor) all afford a high degree of control over worker exposure to process gases. The major building air handling systems are sketched isometrically in Figure 20-1. As shown, they include the following components:

Component I.D. Number	Description	CFM Rating
1	Canopy hood over Washer Line No. 1 with 4 takeoff ducts to roof and 4 separate exhaust fans	22,000 (4x5500)
2	Canopy hood over Washer Line No. 2 with 3 takeoff ducts to roof and 3 separate exhaust fans	16,500 (3x5500)
3	Canopy hood over Washer Line No. 3 with 3 takeoff ducts to roof and 3 separate exhaust fans	16,500 (3x5500)
4	Canopy hood over reject screens	10,000
5	Three wall fans on chip loading mezzanine above digesters Nos. 9-11	16,500 (3x5500)
6	Two wall fans behind digesters Nos. 9-11	11,000 (2x5500)
7	Three roof exhaust fans above chip loading mezzanine for digesters Nos. 1-8	16,500 (3x5500)
8	Four wall fans behind digesters Nos. 1-8	22,000 (4x5500)
9	Supply air system on south side of building distributing air to washer area and chip mezzanine (for Digesters Nos. 1-8)	36,500
10	Supply air system in center of building distuributing air to center of washer area	50,000
11	Supply air system on north side of building distributing air to washer area and chip mezzanine for digesters 1-8 and 9-11	155,000

As the air volumes indicate, a significant amount of air turnover is occurring in both the washer and digester areas (131,000 CFM exhaust versus 242,500 CFM supply), when all systems are operating correctly. Although a number of the wall fans were inoperative during the survey, the two mezzanine levels where chips are loaded to the digesters are well-ventilated -- 16,500 CFM each for the mezzanines above digesters Nos. 1-8 (roof fans) and Nos. 9-11 (wall fans). Good general ventilation of these areas is important for heat removal and reduction of the fire hazard from chip and wood dust buildups, as well as worker protection. In addition, the areas around the digester tops (capping valves) are also normally well ventilated by means of wall fans (Components 6 and 8). However, the two fans behind digesters Nos. 9-11 were inoperable during the survey. Each of these major systems will be further discussed below.

Washer Ventilation - Since two of the production workers spend the majority of their time near the three washer lines, ventilation and air movement in this workspace were evaluated in detail. Each of the three canopy hoods extend down from the roof to just below the top of the washer drums. They cover the full length and width of the washers. Dimensions for the individual canopies are: 16' wide by 74' long for Line No. 1; 16' wide by 58' long for Line No. 2; and 16' wide by 55' long for Line No. 3. Take-off ducts from each hood extend vertically up through the roof to axial duct fans located just above the roof top.

The current effectiveness of the hoods to capture process gases was determined by taking smoke tube and velometer readings at the hood faces (sides, front, and back), and at worker observation points along the main walkway between the washer and the control panels. Generally these face velocity readings were all well in excess of 50 feet per minute; and excellent air movement downward and towards the washers in the main walkway was observed. Most of this downward air movement is caused by air distribution registers from the largest supply air system (Component No. 11), which are located just above the entire length of this walkway. They are directed downward and effectively blast this area with fresh air, insuring that any escaping gases from the washer would stay out of worker breathing zones.

The canopy hoods, however, are not totally effective in capturing the steam plume emitted at the inlet ends of the first washer of each line. This is because the amount of steam is variable and creates a slight pressure just above the inlet vat. Undoubtedly, a small amount of process gas (reduced sulfur compounds) also escapes with this steam plume, but it is not thought to be a significant exposure source in this mill. In order to fully capture these gases and steam, the canopy would have to extend out further or completely down and around the inlet vat.

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Digester Area Ventilation - In the digester area (operating floor and chip mezzanine), the most important ventilation controls are the roof exhausters above the chip loading chutes for Digesters Nos. 1-8. These are important because of the amount of hot process gases that rise up through the loading chute and accumulate in the mezzanine level when the digesters are first opened and filled with chips. There are open stairways at either end of this particular mezzanine leading down to the digester operating floor and washer room. Without ventilation, gases would eventually diffuse down through the stairways and into those workspaces to pose a potential worker exposure. When a digester is first uncapped, the three roof exhausters cannot immediately ventilate the great amount of steam and hot gases that are released. However, ventilation is usually achieved before the gases have a chance to diffuse down into the work areas. Smoke tube readings taken at the two access stairways to this mezzanine indicated air movement slowly downward and towards the washers. Also at the south stairways, a small amount of draft is induced from the adjoining recovery building which is under considerable negative air pressure. Air movement at the other access stairway is largely non-directional, and supports the contention that digester gases would not have a significant impact on major work areas on the washer/digester operating floor. Therefore, these emission sources pose little exposure risk to the two production workers provided the ventilation systems are operating properly.

In contrast, ventilation of the other digester mezzanine (above digesters Nos. 9-11) is not as critical. This is because this space is well isolated from work areas, and workers are only infrequently required to go up into it, mainly only to clean up chip spills. Access is by means of an outside stairway. As shown in Figure 20-1, three wall fans (north, south, and west walls) are used to ventilate the workspace, but during the survey only one of them (south) was operating. In spite of this, the detector tube readings revealed little potential accumulation of reduced sulfur gases in this area (even when a digester capping valve is open for refilling).

In addition, some passive ventilation of these mezzanine levels also occurs. Permanent (sheltered) wall openings are provided along the entire wall length from digesters 1 through 8; and two open doors to the outside exist on the mezzanine above digesters 9-11.

On the digester operating floor, the six wall exhausters (4 behind digesters Nos. 1-8, 2 behind digesters Nos. 9-11) serve to ventilate the small amount of gases that may escape from the digester capping valve during cooking. They also assist in ventilating the sizeable amount of steam and process gases that are given off when the loading valve is first opened; and help cool the area.

Smoke tube readings taken at small openings in the wall behind the digesters indicated that both digester areas are under some negative pressure and good ventilation is occurring. The provided ventilation is thought to be more than adequate to protect workers from exposure since few spend time directly near the digester tops.

A ventilated hood is also provided over the rejects screens located on a platform above the pulp refiner. Actual emission of hazardous process gases from the screens was not ascertained; however, with a rated 10,000 CFM of exhaust air, the hood would be more than sufficient. This exhaust may also provide some ventilation of any gases that might be released from the refiner located just below the screens.

Supply Air Systems - Excluding air exhausted from the chip mezzanine above digesters Nos. 9-11, about 114,500 CFM of total air is exhausted from the washer/digester area of the building when air systems are operating. Because of this, air is supplied back to this area using three separate distribution systems, as shown in Figure 20-1.

Component System No. 9 brings air in through the south wall of the building and distributes it down through the top of the partition separating the washer area from the digester area.

Rectangular registers are evenly spaced along this partition, and distribute the air alternately between the washer side and the chip mezzanine side (for digesters Nos. 1-8). The distribution duct extends the full length of Washer Line No. 1, and from digester No. 1 to No. 5.

The second supply air system (component No. 10) brings air in through the center of the building roof and distributes it through a large duct fitted with a dispersion end plate. Air is thus directed into the washer room side of the partition separating the washers from the digesters.

The newest and largest (156,000 CFM) supply system brings air in from two opposed intakes on the north side of the building roof. It then distributes it down through the center of the main walkway of the washer room, as previously described. A branch duct comes off the center of this main duct to supply a small amount of air to the chip mezzanine (above digesters Nos. 1-8), and to the entranceway of the wing containing digesters Nos. 9-11.

Based on the provided ratings of these three supply systems, the washer/digester area should be under considerable positive air pressure (242,500 supply CFM vs. 131,000 exhaust). Numerous smoke tube tests at room entranceways and wall-

openings, however, indicated an undersupply situation or negative pressure. Inspection of the roof exhaust and intake air systems then revealed considerable clogging of intake grills and air filters on both Component Systems Nos. 10 and 11. Both of these were in fact so clogged that the filter access doors had to be left open so that air could bypass the filters and intake screens to reach the fan. This clogging probably results from the fact that both of these intakes are located in a horizontal position and near the short exhaust stacks of the brown stock washers. The clogging of these systems with brown pulp stock (brown stock probably is in distribution duct also) undoubtedly accounts for greatly reduced air flow. The present poor performance of these supply systems is not, however, thought to be detrimental to controlling workplace air contaminant levels. A negative workplace air pressure is generally not of concern provided: 1) workplace temperature and humidity conditions are acceptable; 2) the sources of the required outside makeup air are understood and not already contaminated (for example, by the outside blow tank relief vent); and 3) major workplace emission sources are properly contained. The observed conditions and air monitoring conducted in this mill indicate that these are not a problem in this mill.

It should be briefly mentioned that the control room HVAC system was new and also performs well. It both regulates the air temperature and provides for a positive pressure to limit the entry of any hazardous process gases. Makeup air for this system is taken in through the north wall of the room, and is not likely to be contaminated.

Process Monitoring and Control - Significant process efficiencies and control/monitoring improvements have undoubtedly been obtained with the automated chip loading and digester computer control systems. Detailed summaries and analysis of these are however, beyond the needs and scope of this study, and will not be discussed. From the perspective of controlling workplace emissions and any resulting worker exposures, however, automation has probably had the following six beneficial results:

1. Facilitated the early and rapid diagnosis and correction of potential process upsets or equipment malfunctions;

2. Resulted in more precise and balanced control of chip loading and cooking cycles; use of chemicals; and venting/recovering of digester relief gases during and after cooking;

3. Reduced the production work force; the number of potentially high exposure work tasks (manually loading chips, capping/uncapping digesters, etc.); and the extent of worker involvement with the process;

4. Allowed for good planning and maintenance to daily production schedules;

5. Facilitated the balancing of 'batch' digester operations with the continuous dynamic operations of other units -- i.e., timing of blows so that heat and turpentine recovery/relief systems are not overloaded and can operate effectively. This may also result in less emission of gases at the screens, refiner, and washers; and better operation of these units;

6. Enhanced the ability of the mill to assemble and evaluate data on process conditions and their effects on product quality and production rates.

The brown stock washers, screens, refiners, and other equipment are conventional, and are largely analog-controlled and monitored from control panels alongside the three washer lines. None of these are particularly significant in terms of contributions to workplace control technology. The vacuum drum washers must be periodically inspected to insure that stock is being picked up by the drums; the water showers are operating correctly; the filter wires are clean; and that the pulp takeoff doctors are working correctly. Stock spills occur occasionally, but resulting worker exposure risks could not be judged. They are thought to be of little concern. Inlet vat (stock) level sensors and alarms are, however, provided to warn of an impending washer overflow condition so that a worker can then promptly attend to them.

In addition, another excellent process warning device has been developed to alert workers of the status of the digester capping valves. This consists of a rotating, flashing yellow light located on top of the control panel for each capping valve.

The lights are activated automatically by the digester control system approximately 15 seconds before the valve opens, and their bright flashes alert any nearby workers that the capping valve is opening. A worker can then safely avoid the initial blast of steam and hot gases released to the workplace.

Worker Isolation - With installation of the digester computer control system, the Digester Operator is now very effectively

isolated from any potential exposure sources. He now remains for essentially his entire shift within the fully-enclosed and air conditioned control center. From within this room he can totally monitor and control all digester functions by using either the automated computer system, or the manual over-ride for analog control. Individual digester (cycle) status is shown on an overhead lighted schematic diagram, with more detailed information instantly available on the computer CRT screen or printer. Four TV monitors are also provided to give him visual checks of equipment located in remote areas, such as the chip loading mezzanine.

Miscellaneous Control Programs - Good preventive maintenance of pulping equipment is an important factor in limiting process upsets and minimizing the occurrence of workplace emissions. Details of the program were not discussed with mill personnel other than making note of the following facts:

1. Each digester is given a complete yearly inspection and overhaul;

2. Maintenance men and production foremen perform regular daily equipment inspection and lubrication tours;

3. A detailed maintenance program does exist with a prioritized repair task system to insure the orderly and timely performance of required repairs.

It was not determined if the recent process automation had simplified and decreased the amount of required maintenance in the pulp mill.

Review of air quality tests that are performed before or during performance of pulp mill repair tasks (or in response to complaints) indicated that maintenance workers periodically encounter potentially high exposure conditions. Most of these appear to occur when workers must enter a tank (such as the defoamer); or when they work in areas near the turpentine recovery system, or around open process sewer vents and manholes. The mill Technical Services Department will perform air quality testing whenever anyone suspects unhealthy or dangerous conditions. An assortment of length-of-stain detector tubes and combustible, toxic gas, and oxygen deficiency meters are available for this purpose. Also, when a test is made, a written report must be sent to the requesting person (copy to Safety Supervisor); and recommendations made for protecting the worker if unhealthy or dangerous conditions are found.

Use of respirators was not observed in the studied areas of the pulp mill, nor do they appear to be routinely required. (The exception may be for workers performing chip cleanup tasks for long periods of time on the digester mezzanine level.) Regardless, there is an excellent overall respiratory protection program established (and written) for the entire pulp and paper mill complex. This program includes provisions for worker training and education in the use of respirators; and more than ample supplies of an assortment of respirators to meet any type of exposure situation likely to be encountered.

MILL 36: SULFATE PULPING PROCESS (BATCH DIGESTION)

INTRODUCTION

Mill 36 produces dissolving Kraft pulp in batch digesters. Approximately half of the digesters were installed when production first began. The remaining half of the digesters were added during three separate expansions. In 1981, a Modicon Programmable Controller was installed to automatically operate certain portions of the pulping process. The survey includes two three-stage brown stock washer lines which are located on the bleach plant operating floor. Mill 36 is located in the Southern United States.

PROCESS SUMMARY

At the beginning of each cooking cycle, the lid of the digester is manually removed and a chip hopper is positioned above the opening. The digester is then filled with chips and recapped. When dissolving pulps are produced, the chips are cooked in two stages. In the acid pre-hydrolysis stage, the chips are steamed under pressure with dilute acid or water to extract the non-cellulosic carbohydrates. At the end of the pre-hydrolysis cycle, the digester pressure is released to a blow tank, cleaned in a Zurn filter, and pumped to the evaporators. Additional condensate is drained from the digester to a closed sump, and pumped to the Zurn filter. This portion of the pulping operation is almost totally controlled by the process computer.

The second or alkaline cooking stage is basically a standard Kraft digestion, with the chips cooked in white and black liquor under high temperature and pressure. The cooking liquor is constantly circulated through a heat exchanger to maintain the desired cooking temperature. The digesters are automatically relieved to two cyclone separators arranged in parallel. The entrained liquor is removed from the gas stream and piped to a black liquor tank. The relief gases exit the cyclones and pass through two turpentine condensers. From the condensers, the non-condensible gases are piped through a stripping column, and are usually incinerated (if the temperature exceeds an acceptable level, the non-condensible gases are vented to the atmosphere instead of being incinerated). The liquid from both condensers is gravity fed to a decanter. Here it is separated into turpentine, which is stored and sold, and separated water which is sewered.

At the end of the cooking cycle, the chips and liquor are discharged from the digester to one of two blow tanks. The mixture is diluted with strong filtrate, and pumped to either of the two brown stock washer lines. Each line consists of

three vacuum drum washers with counter-current wash water flow. The washed stock is dumped into a surge tank, then is screened, thickened, and stored.

The gases from the blow tanks are piped through a cyclone separator into an accumulator tank, quenched with reclaimed water, and vented to the atmosphere. The contaminated accumulator water is piped to one of three heat exchangers for heat recovery.

JOB CATEGORIES AND DESCRIPTIONS

The pulp mill is operated by a nine person crew, including a crew leader, three cooks, two chip feeders, a solution mix operator, a washer operator, and screen operator:

Crew Leader - The work routine of the crew leader is highly variable, and includes supervising, trouble-shooting, process coordinating, and monitoring the cooking, washing, and screening operations. When possible, (s)he makes hourly inspection tours of all pulping operations. We estimate that the crew leaer is in the control room for about half of each shift.

Cooks - There are three cooks, one responsible for digesters 1 through 7, one for 8 through 12, the other for digesters 12 through 19. These three employees operate the process from the control room using both a computer process controller and an analog system. Activities during a typical cooking cycle include:

- notifying the chip feeder to load the digester
- initiating the computer controlled pre-hydrolysis operation
- opening the liquor charging valve
- closing the liquor charging valve
- initiating the cooking cycle
- manually checking the level in the blow tank (using a plumb line)
- opening the digester blow valve

The cooks are usually in the control room for at least 70 percent of each shift.

Chip Feeders - The two chip feeders load the digesters at the beginning of each cooking cycle. This is primarily a manual task, requiring about 20 minutes for completion. Upon authorization from the cook, the employees unbolt the lid using a pneumatic wrench, and remove it with a chain block and tackle. The chip feed hopper is positioned over the open digester, and the vessel is filled with chips. The chip feeders then remove the hopper and manually re-cap the digester. These operations are repeated every thirty minutes or so, and occupy most of each shift.

Solution Mix Employee - This employee's primary responsibility is to titrate and correct liquor strength and is in the control room for 90 percent of the shift.

Washer Operator - This employee operates the brown stock washing lines, and the knotters. Every two hours, (s)he measures the temperature, specific gravity, and conductivity of the washer filtrate. (S)He also collects and tests a pulp sample from each washer every hour. The operator monitors process variables displayed on two control panels located between the two washing lines. (S)He remains in an acoustic booth adjacent to the control panel for about 70 percent of each shift.

AIR SAMPLING DATA

We collected personal samples on employees in each job category over a three day period (Table 36-1). None of the twelve methyl mercaptan samples taken on the crew leader, the solution mix operator, the three cooks, and the washer operator exceeded 0.3 ppm, or 3 percent of the OSHA ceiling PEL. Additional personal samples for hydrogen sulfide and chlorine were collected on the washer operator. They indicated low exposure.

The chip feeders are undoubtedly exposed to the highest concentration of process gases, primarily during the digester loading operations. Four short-term samples for methyl mercaptan collected during these operations resulted in higher, but not excessive, exposures (0.6 ppm to 3.3 ppm). We also collected long-term personal samples for total dust on the chip feeders. The samples indicate that these employees are not exposed to significant quantities of wood dust or other airborne particulate matter (0.3 mg/m^3, 0.4 mg/m^3).

A total of 28 area samples were also collected to evaluate the potential for employee exposures to other contaminants, or to assess possible sources of exposure (Table 36-2). These data are discussed below:

- Seven detector tube and impinger samples demonstrate that hydrogen sulfide levels are very low (<0.3 ppm). These samples were collected in the areas where

TABLE 36-1: PERSONAL SAMPLING DATA

Job Category	Day	Shift	Sampling Time (Min.)	RESULTS Hydrogen Sulfide[1] (ppm)	Methyl Mercaptan[2] (ppm)	Chlorine[3] (ppm)	Total Dust (mg/m^3)
No. 1 Mill Chip Feeder	2	2	14		1.7		
	3	1	365				0.4
No. 2 Mill Chip Feeder	1	1	18		0.6		
	2	1	15		3.3		
		1	20		1.0		
	3	1	360				0.3
No. 1 Mill Cook	2	1	15		<0.2		
		1	15		<0.2		
No. 2 Mill Cook	1	2	13		<0.2		
		2	15		<0.2		
Crew Leader	2	1	18		<0.2		
	3	2	24		0.3		
Solution Mix Operator	2	1	10		<0.3		
		1	10		<0.3		
Washer Operator	1	2	12	0.05	<0.2	0.01	
	2	1	17		0.2		
		1	18		0.2		
		2	15		0.2		
		2	15		0.2		

[1] NIOSH P&CAM 126

[2] Method of Knarr & Rappaport, Anal. Chem., Vol. 52, 1980, pp. 733-736

[3] NIOSH P&CAM 209

contaminate concentrations were thought to be highest (the chip feed floor and adjacent to the brown stock washers).

- Methyl mercaptan levels were very low in the digester control room (0.04 ppm), and were not detected near the brown stock washers. Concentrations on the chip feed floor (1 ppm, 0.2 ppm) are lower than the personal sampling results, indicating that background levels are not as important to employee exposure as the direct emissions from the open digesters. One detector tube sample collected in the vent of the prehydrolysis condensate Zurn filter resulted in a concentration of 5 ppm. The potential for re-entry of these and other vented gases is highly dependent on weather conditions, and could not be adequately assessed.

- Detector tube samples for dimethyl sulfide resulted in low concentrations inside and outside of the digester control room, and around the brown stock washers (<1 ppm). Higher levels were recorded on the chip feed floor (1 ppm to 8 ppm), directly above an open digester during loading (30 ppm), and in the north Zurn filter vent (>150 ppm). Although the detector tubes are subject to unknown positive interferences, these data indicate very low levels of sulfur compounds in and around the control room, and near the washers, and moderate background levels on the chip feed floor.

- Turpentine levels on the chip feed floor (15.3 ppm) and in the digester control room (1.6 ppm) are below the OSHA PEL of 100 ppm. During both sampling periods, one of the cyclone separators was plugged, and contaminated water and turpentine were being drained to an open sump. Since this is an abnormal situation, we judge that turpentine levels are usually not this high.

- One area sample for chlorine collected at the brown stock washer test stand reflects little contamination (0.02 ppm) from the adjacent bleach washers.

- One long-term area sample collected on the chip feed floor resulted in a low total dust level (0.2 mg/m^3), roughly equivalent to the personal sampling results (0.3, 0.4 mg/m^3).

In addition to the above samples, a HNU Photoionization Analyzer was connected to a strip chart recorder, and operated over long periods at various locations in the mill. The instrument responds to many of the probable process

TABLE 36-2: AREA SAMPLING DATA

Location	Day	Shift	Sampling Time (Min.)	RESULTS Hydrogen Sulfide (ppm)	Methyl Mercaptan (ppm)	Dimethyl[5] Sulfide (ppm)	Turpentine[6] (ppm)	Chlorine[7] (ppm)	Total Dust (mg/m^3)
Chip Feed Floor	1	1	-	ND[1]	1[3]	1			
		2	113	0.2[2]					
		2	64		0.2[4]				
	2	2	-			2			
		2	-			8			
	3	1	359						0.2
	3	1	117				15.3		
Digester Control Room	2	1	-			<1			
			-			ND			
	3	2	103		0.04[4]				
		2	120				1.6		
Outside Control Room	2	2	-			<1			
In Vent for North Zurn Filter		2	-		5[3]	>150			
Above Digester During Chip Loading	2	2	-			30			
Brown Stock Washer Test Bench	1	2	15			0.2		0.02	
Beside No. 1 Brown Stock Washer	1	1	-		ND[3]	ND			
	2	1	36	0.3[2]					
	2	2	132	0.1[2]					
Beside No. 2 Brown Stock Washer	1	1	-	ND[1]	ND[3]	ND			
	2	1	24	0.4[2]					
	2	2	51	0.02[2]					

[1] Drager Detector Tube

[2] NIOSH P&CAM 126

[3] Gastec Detector Tube

[4] Method of Knarr and Rappaport, Anal. Chem., Vol. 52, 1980, pp. 733-736

[5] Drager Detector Tube

[6] Charcoal Tube

[7] NIOSH P&CAM 209

contaminants, and can therefore be used to qualitatively assess the gross effects of process cycles or upsets on workplace contaminant levels. Comparison of the instrument response can also provide some understanding of relative contaminant levels in different areas of the mill. It must be understood, however, that the nature of the response to the process contaminants is not understood, and may not be consistent if the relative concentration of the various contaminants are not constant. It should also be stressed that the instrument's response is recorded in arbitrary units, not in ppm or other calibrated measures of concentration.

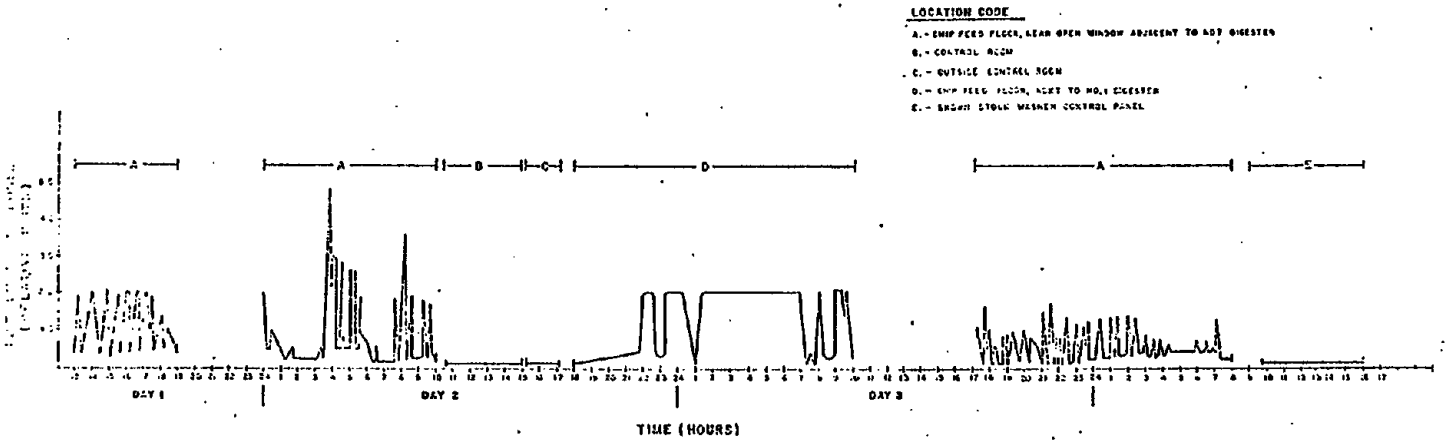
The HNU Analyzer's continuous monitoring results are plotted on Figure 36-1, and discussed below for each area:

A. Chip Feed Floor (near open window adjacent to No. 7 digester) - The instrument was operated at this location on three separate occasions for a period of 31 hours. During the first period (Day 1, 13:00 to 19:00), the response shows highly regular peaks of 20 units apiece occurring at about 30 minute intervals. The peaks coincide exactly with the digester loading cycle, and demonstrate the effect of this operation on contaminant levels on the chip feed floor. The recording also shows that the pedestal fans and natural ventilation are very effective in dispersing the contaminants following their release (i.e there appears to be no build-up of contaminant levels with time). During this monitoring period, the direction of airflow was from the digesters to the HNU Analyzer. During the next period (Day 2, 24:00 to 10:00), the recording does not clearly show the effect of the digester loading cycle because of a change in the wind direction. The wind was now blowing through the open windows, past the detector, and toward the digesters. We also observed that these conditions allowed the re-entry of process gases that are vented from the accumulator tank and the Zurn filters (located just outside). The large peaks (>30 units) may have been caused by this phenomenon.

   During the final monitoring period (Day 3 & 4, 17:50 to 8:00), the wind conditions were similar to those on the first day. The recording again shows regular, but smaller, peaks corresponding to the digester loading cycles.

B,C. Digester Control Room - The HNU Analyzer was next placed inside the control room for a five hour period (Day 2, 10:30 to 15:00). The response was very stable and never exceeded 2 units. To determine if these low results were due to the control room or to the absence of contaminants in the general area, the instrument was moved outside,

FIGURE 36-1: HNU PHOTOIONIZATION DETECTOR RESPONSE



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and operated for an additional two hours. The response was essentially identical to that previously recorded inside. The lack of contamination is therefore attributed to the location of the control room on the ground level, well below the process vents and chip feed floor.

D. Chip Feed Floor (next to No. 1 Digester) - This monitoring period (Day 2 & 3, 18:00 to 10:00) illustrates the effects of a process upset on contaminate levels on the chip feed floor. At about 22:00 the cyclone separator for the digester relief gases became plugged. As a result, the contaminated black liquor collected in the separator and had to be drained into a sump located about 30 feet from the No. 1 digester. This caused the release of significant quantities of reduced sulfur compounds and turpentine. Because the HNU analyzer was set at the 0 to 20 unit scale, the recording is clipped at the upper end, and the magnitude of the response is not known.

E. Brown Stock Washer Control Panel - The instrument response during this six-hour monitoring period (Day 4, 10:00 - 16:00) never exceeded a level of two units. These data demonstrate the effectiveness of the washer exhaust hoods, and parallel the low personal sampling results for hydrogen sulfide.

CONTROL OF WORKPLACE EXPOSURES

Except for the digester loading operation on the chip feeding floor, all pulping processes and equipment are closed and located outdoors. Leaks or other process upsets do not usually result in significant worker exposure because emitted process gases are rapidly removed and dispersed by natural ventilation. In addition, the control room is located on the ground level, well below the chip feeding floor, the process vents, and other potential emission sources. Therefore, the crew leader, the cooks, and the solution mix employee are rarely exposed to significant concentrations of process gases.

Chip Feeding Floor - Steam and some reduced sulfur compound are emitted into the chip feeding floor when the digesters are uncapped at the beginning of each cooking cycle, and as the chips are loaded into the digesters (see Figure 36-1). Although chip feeder exposures to methyl mercaptan are low (0.6 to 3.3 ppm), there are basically no direct controls for these emissions. The apparent low exposures are attributed to the following factors:

- the chip feeders do not open the digesters until the internal pressure has been reduced to a low level (<5 psi), as authorized through electrical interlocks, and visual observation of pressure gauges by the cooks.

- o as the chips are loaded into the digester, the displaced gases pass through the chip chute and enter the workplace above and generally away from the chip feeders. Some of the reduced sulfur compounds are apparently absorbed on the moist chips, and the remainder are rapidly dispersed and removed by natural ventilation.

- o although there is no mechanical ventilation on the chip feeding floor, there are many open windows and natural ventilation appears to be a very effective means of control. The HNU Analyzer results (Figure 36-1) do not show any problems with contaminant build-up on the chip feeding floor.

- o three large pedestal fans are sometimes used by the chip feeders to help disperse the contaminants and provide heat control. The fans are probably most effective when there is little natural ventilation.

Several personal and area total dust samples (Tables 36-1 and 36-2) indicate that wood dust is not normally a significant problem on the chip feeding floor. This is probably because chips are wet, and the chip feeders keep the area clean.

Control Room - The control room is located on the ground level beside the bottom of the digesters. It is well below the chip feeding floor and the process vents, and is therefore not usually subject to extensive contamination. Except for the chip feeders and the wash and screen operator, all pulp mill employees spend most of each shift in this low exposure area. The control room is air conditioned with a 100 percent recirculation system. Because there are no outside air intakes, process leaks or other emissions would not normally cause significant exposures to employees inside the control room.

Process Vents - Digester relief gases are usually incinerated after passing through the turpentine recovery system. They are therefore rarely a source of workplace contamination. However, the accumulator tank vent is relatively close to the chip feeding floor, and may periodically be a source of contaminant re-entry. The Zurn filters are partially enclosed, but also emit process contaminants (Table 36-2). These filters are also located near the chip feeding floor, and emitted contaminants may periodically enter the workplace. The effect of these emission sources on chip feeder exposure is highly dependent on weather conditions and is therefore difficult to fully assess based on limited sampling data. However, the fact that the vents are elevated probably prevents frequent contamination of the control room.

Washing and Screening Operations - The knotters, brown stock washers, and screens are all located in the bleach plant next to the pulp mill. Each brown stock washer line is provided with a large canopy hood covering all three stages. The No. 1 mill hood also covers the knot washers preceding the first stage. In the No. 2 mill, the knot washers are provided with a separate canopy-type exhaust hood.

The design air flows (cfm) were not available for any of the hoods. Ventilation measurements revealed the following face velocities around the perimeter of each hood:

(1) No. 1 mill - 100 fpm to 225 fpm
(2) No. 2 mill - 50 fpm to 250 fpm
(3) No. 2 mill knot washer - 100 fpm to 150 fpm

These measurements, and observations based on smoke tube tests, indicate that each of these hoods is very effective in containing process emissions. Personal and area samples for hydrogen sulfide and methyl mercaptan (Tables 36-1 and 36-2) and the results of long term HNU Analyzer monitoring (Figure 36-1) also demonstrates the effectiveness of these hoods.

Vessel Entry Procedures - A detailed procedure must be followed before workers can enter any tank or vessel. A "Tank" Entry Permit" (Figure 36-2) must be filled out and signed by both the department production manager and maintenance manager. The permit certifies that the tank is properly isolated, that all incoming lines are valved off and locked (or that blanks are installed), and that all electrical equipment is locked out. After all these precautions are completed, a safety department employee tests the tank for percent oxygen and process contaminants by using detector tubes and an explosimeter. If the tests indicate the tank is safe for entry, the tester also signs the permit and attaches it to the tank's entrance point. One portion of the permit is returned to the Safety Department to document proper precautions and to provide a permanent record of the air tests. All mill personnel have been instructed not to enter any vessel unless a properly signed and dated permit is attached.

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PERMIT FOR ENTERING TANK (24 HOURS ONLY)

Tank #_____ Date of issue_____ Time_____

Date expires_____ Time_____

IMPORTANT — Lines are not to be unbolted or connected while tank is under this permit.

Department_____ Location of Tank_____

Last stock in tank_____

Work to be done_____

_____

SPECIAL PRECAUTIONS:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

ENTRY APPROVAL:

_____ Dept. Supervisor

_____ Mech. Supervisor

_____ Safety Check

CHECK LIST ON OTHER SIDE BEFORE APPROVING

TEAR ALONG THE PERFORATED LINE

PERMIT FOR ENTERING TANK

Tank #_____ Date of issue_____

Dept._____ Date expires_____

Name of Vessel_____

Signatures — Dept. Supervisor_____

Mech. Supervisor_____

Safety Check_____

IMPORTANT: THIS PORTION OF THE PERMIT IS TO BE RETURNED TO THE SAFETY ENGINEER AFTER THE SAFETY CHECK AND SIGNATURES ARE COMPLETED.

TANK ENTRY SAFETY CHECK LIST

GENERAL

- A1 ☐ Stock in tank — Depth, if any
- A2 ☐ Stock lines blanked
- A3 ☐ Steam lines blanked
- A4 ☐ Acid or Caustic lines blanked
- A5 ☐ Other lines blanked
- A6 ☐ Natural and or mechanical ventilation provided
- A7 ☐ 6-0 volt lights provided
- A8 ☐ Agitators, electrodes or other electrical connection disconnected
- A9 ☐ Temperature (110° F. maximum) of stock and atmosphere within tank are safe
- A10 ☐ Other precautions to be taken
- A11 ☐ Is safety watch required?

_____

_____

PROTECTIVE EQUIPMENT NECESSARY

- B1 ☐ Air line respirator
- B2 ☐ Gas mask
- B3 ☐ Dust respirator
- B4 ☐ Fume respirator
- B5 ☐ Goggles
- B6 ☐ Safety belt and line
- B7 ☐ Special boots or shoes
- B8 ☐ Protective clothes
- B9 ☐ Source of water
- B10 ☐ Face shield
- B11 ☐ Other precautions to be taken

_____

_____

TANK CHECKS MADE

- C1 ☐ Explosive atmosphere
- C2 ☐ Sufficient oxygen
- C3 ☐ Hydrogen Sulfide
- C4 ☐ Chlorine Dioxide
- C5 ☐ Chlorine
- C6 ☐ Carbon monoxide
- C7 ☐ Sulphur Dioxide
- C8 ☐ Other toxic material

Figure 36-2: Tank Entry Permit

MILL 08: KRAFT PULPING OPERATION (CONTINUOUS)

INTRODUCTION

Mill 08 produces over 250 tons per day of bleached Kraft pulp alternatively from hardwood (oak, maple, beech, poplar, cottonwood) and softwood (pine, spruce) stock. This survey encompasses all operations from the chip bin to the bleach plant.

PROCESS SUMMARY

The chips pass through two orbital screens, enter a storage bin, and are discharged via a hopper into a variable-drive rotary chip meter. From the meter, the chips pass through a low pressure feeder (rotary closed pocket valve) into a presteaming vessel to drive off air and low temperature volatiles. The steam pressure is maintained at 24 psig (265°F) and the required steam is obtained from a low pressure service line and from the digester flash tank. The chips are augered through the vessel in about 30 seconds and drop through a chip chute into a high pressure feeder. The liquor level (a mixture of white liquor and water) is controlled in the chip chute so that the rotor inlet port of the feeder is totally submerged. The liquor is used to flush the chips into the feeder and the liquor mixture is returned to the chip chute by means of a chip chute circulating pump. As the feed rotor turns, the chips enter the digester high pressure system and are conveyed to the top of the digester by means of a top circulating pump. The liquor is extracted from the digester through a screw-cleaned strainer and recirculated back through the high pressure feeder.

The Kamyr continuous digester is a narrow, 100-feet high cylindrical vessel consisting of four consecutive zones. The chips first pass through an impregnation zone (40 to 45 minutes) and become saturated with cooking liquor under pressure (160-165 psig) and temperature (250°F). The chips and liquor next enter the heating zone (30 minutes) where the temperature is raised in two consecutive steps. At the top of the heating zone, liquor is removed through an extraction strainer, pumped through a steam heater (300°F to 310°F) and returned to the digester through a vertical tube discharging just above the upper strainers. The lower circulation system is identical except that the liquor is heated to a temperature of 340°F and is returned to the digester at a point slightly above the lower strainers.

After heating, the chips and liquor pass through the cooking zone (40 minutes), and the lignin and other wood adhesives are chemically dissolved. At the bottom of this zone, the spent black liquor is extracted, flashed, and pumped to the recovery

system. The spent liquor is replaced with cold blow liquor pumped from the brown stock washers. The chips pass into the final zone (20 minutes), and are diluted and washed with additional cold blow liquor. The chips and liquor are continuously discharged through an outlet device at the bottom of the digester, pass through a blow unit, and enter tangentially at the top of a blow tank. The stock drops into the tank while the blow gases pass to a second blow tank employed as a trap to retain liquor carryover. The blow gases continue to a spray condenser where the non-condensable gases are separated and pass to the odor control incinerator.

The condensibles are collected and pumped to an air stripper. The stock is agitated, and weak black liquor is added to maintain a four percent consistency in the bottom of the tank.

Diluted stock is continuously pumped from the bottom of the blow tanks into an open vibratory knotter adjoining the first stage brown stock washer. Knots are collected in a trough and returned to the chip bin. The stock flows onto the first stage washer cylinder and passes under a shower of filtrate from the second stage washer. The wash filtrate and the black liquor contained in the stock pass through the cylinder and drop into the first stage filtrate tank. The filtrate is subsequently used for dilution in the blow tanks and the knotters. The washed stock enters a repulping vat and is diluted and scrubbed with filtrate from the second stage washer. The process is repeated in two additional washing stages with the third stage filtrate used in the seconds stage showers and repulping tank, and fresh wash water employed at the final stage. The washed stock is pumped from the third stage repulping vat into stock chests for subsequent cleaning and screening operations.

JOB CATEGORIES AND DESCRIPTIONS

Four employees per shift are required to operate the entire pulping process in Mill 08. The digester operator is located in a closed control room on the third floor adjacent to the steaming vessel. The wash/screen operator, utility man, and tester are all located in an additional closed control room on the fourth floor next to the brown stock washers.

Digester Operator - The digester operator is responsible for the operation of the continuous digester, including the chip meter, the steaming vessel, the high pressure feeder, the liquor feed and extraction systems, and the blow system. The process is run automatically by pneumatic analog controllers, with process flows, temperatures, pressures, liquid levels, and stock consistencies regulated through numerous control loops and displayed on the control panel. The operator monitors these operating parameters and maintains a written log with

hourly entries. As required, but particularly when wood species are changed, the operator readjusts the controller set points. It is estimated that the operator remains in the control room is excess of 90 percent of each shift.

Wash/Screen Operator - The wash/screen operator is responsible for the blow tanks, the knotters, the brown stock washers, the screens, and the stock cleaners. These operations are automatically controlled by pneumatic analog controllers, with the operator monitoring and recording important process parameters displayed on the control panel. Like the digester operator, this employee periodically adjusts the controller set points. The wash/screen operator remains in the control room at least 90 percent of each shift.

Tester - Each hour, the tester collects the following process samples:

- white liquor from the feed line
- pulp from the digester blow line
- black liquor from the secondary flash tanks
- pulp and 'brown water' from the repulping vat on the third stage washer
- cleaned pulp in transport to the bleach plant

Each sample collection cycle requires the tester to be in the production area for ten minutes or less. The samples are then analyzed in a small laboratory area located in the wash/screen control room. The tester remains in the control room for at least 80 percent of each shift.

Utility Man - The utility man is responsible for keeping the pulp mill clean, conducting routine maintenance operations, and assisting the two operators. It is estimated that the utility man is in the production area for at least 60 percent of each shift.

POTENTIAL WORKPLACE HAZARDS

The primary air contaminants that may be emitted from the Kraft pulping process are hydrogen sulfide, methyl mercaptan, dimethyl sulfide and dimethyl disulfide. Much smaller quantities of terpenes, alcohols, and a variety of other compounds may also be present to process streams.

PERSONAL SAMPLING RESULTS

Fifteen-minute personal samples were collected on the utility man and the tester to assess ceiling exposures to hydrogen sulfide and methyl mercaptan. The samples were restricted to intervals when these employees were outside of the control room for at least ten minutes. Because the digester and the wash/screen operators rarely leave their respective control rooms, no personal samples were collected for these employees.

Measured ceiling exposures for both job categories are shown on Table 08-1, and are discussed below:

Tester - Twenty short-term personal samples for hydrogen sulfide [1] and methyl mercaptan[2] were collected during two shifts on three consecutive days. None of the six samples for hydrogen sulfide exceeded one percent of the OSHA Ceiling PEL of 20 ppm. Methyl mercaptan was not detected (< 0.08 ppm) on eight of the samples, and measured concentrations ranged from 0.08 ppm to 0.26 ppm on the remaining four samples. These levels are extremely low relative to the OSHA Ceiling PEL of 10 ppm. It is thus concluded that employees in this job category are not exposed to significant quantities of either of these compounds.

Utility Man - Eight short-term personal samples were collected to assess ceiling exposures to hydrogen sulfide and methyl mercaptan. The three samples for hydrogen sulfide resulted in very low exposure levels (< 0.1 ppm, < 0.06 ppm, 0.2 ppm). Four of the five methyl mercaptan samples also resulted in very low exposure levels (< 0.05 ppm, to 0.91 ppm). The remaining sample (7.7 ppm) while significantly higher, is still below the OSHA Ceiling PEL of 10 ppm. This particular sample was collected while the utility man was hosing down the area around the brown stock washers. Two of the other personal samples were collected during the same task on different days and did not result in similar exposure levels. Thus, although the reason for the higher result is not known, it can probably be attributed to a process leak or some other atypical occurance.

It can be concluded that employees in this job category are usually not exposed to significant levels of hydrogen sulfide or methyl mercaptan. However, during process leaks or other upset conditions, short-term exposure levels may approach the OSHA PELs for these compounds.

1 NIOSH Method P&CAM 126
2 Method of Knarr and Rappaport, Anal. Chem., Vol. 52, 1980, pp 733-736.

TABLE 08-1 PERSONAL SAMPLES

Job Classification	Day	Shift	Time (Minutes)	Hydrogen Sulfide (ppm)	OSHA PEL (ppm)	Methyl Mercaptan (ppm)	OSHA PEL (ppm)
Tester	2	1	15			< 0.08	10
			15	< 0.05	20	0.13	10
			15	0.06	20	< 0.08	10
			15	0.06	20	0.26	10
		2	15	0.08	20		
			16			< 0.08	10
			21			< 0.05	10
	3	1	9			< 0.07	10
			15			< 0.08	10
		2	15			< 0.07	10
			15	0.06	20		
	4	1	24			< 0.08	10
		1	15	0.12	20	0.08	10
		1	15			0.08	
Utility Man	2	1	15			7.7	10
		2	15	< 0.10	20		
	3	1	13	< 0.06	20		
		1	19			0.51	10
		1	10	0.20	20		
		2	21			< 0.05	10
	4	1	15			0.91	10
		1	15			0.08	10

Area Samples - The results of several area samples for hydrogen sulfide and methyl mercaptan are presented on Table 08-2. With one exception, all measured concentrations were very low and roughly equivalent.

The sample located outside of the digester control room was collected while a recirculating liquor heater was drained and cleaned with acid. This operation is conducted once every two or three weeks by contract employees. While the heater is being drained, process gases are given off and dispersed up through the mill.

Several charcoal and silica gel tube samples were collected beside the brown stock washers to estimate workplace concentrations of terpenes, alcohols and ketones (Table 08-3).

As expected, significantly greater quantities of turpentine and other terpenes are produced from softwoods (22 ppm) than from hardwoods (0.05 ppm). To a lesser extent, workplace concentrations of ketones and alcohols are also a function of the type of wood being run. As these samples were all collected very close to the first stage washer, the results do not represent concentrations to which employees would normally be exposed.

An HNU Photoionization Analyzer was used to qualitatively assess and compare relative air contaminant concentrations as a function of time and location. Instrument response (in relative, non-specific units) was recorded over extended periods of time at various locations in the mill, and is plotted on Figure 08-1.

- Instrument response does not appear to be a function of wood species. This correlates well with the area sampling data for hydrogen sulfide and methyl mercaptan, but is contradictory to other data showing a strong correlation between wood species and workplace concentrations of terpenes, alcohols and ketones.

- The highest and most variable instrument response was obtained during the two periods when the analyzer was next to the brown stock washers. This is consistent with the area sampling data, and would be expected because this operation is partially open to the workplace.

- Tests conducted in the two control rooms resulted in instrument responses equivalent to or slightly higher than those recorded in production areas (except around the brown stock washers). This is not particularly

TABLE 08-2 AREA SAMPLES

Location	Day	Time	Hydrogen Sulfide (ppm)	Methyl Mercaptan (ppm)
Beside Brown Stock Washer	2	8:09 - 10:30	0.035	0.67
		14:06 - 15:47	0.016	0.16
	4	8:48 - 13:06	0.011	0.16
Brown Stock Washer Control Room	1	15:37 - 16:21	0.14	0.07
	4	12:56 - 15:41	0.014	0.08
Digester Control Room	2	8:43 - 11:14	0.06	0.015
	2	15:00 - 16:35	0.08	0.012
Beside Presteaming Vessel	2	17:50 - 20:50	0.007	0.014
Outside Digester Control Room	3	9:57 - 10:20	7.5	

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FIGURE 98-1 HNU ANALYZER READINGS

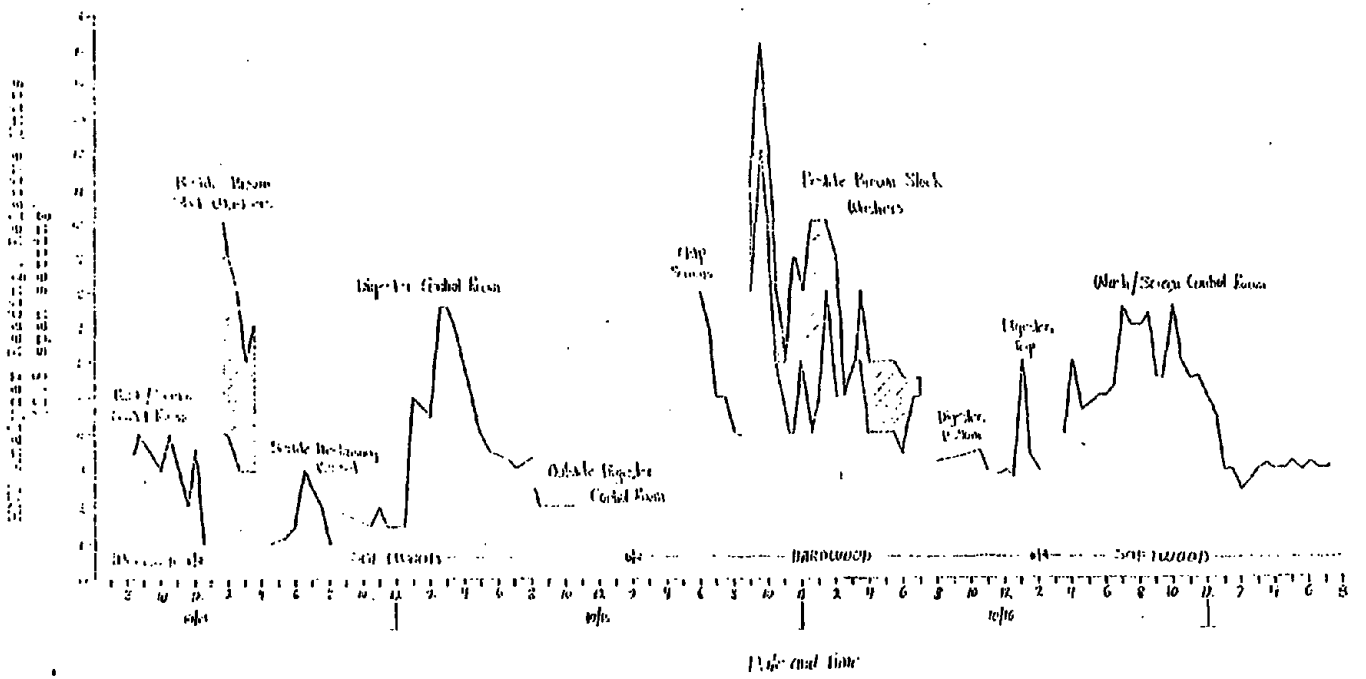

TABLE 08-4 AREA CHARCOAL AND SILICA GEL TUBE SAMPLES

Type of Sample	Day	Shift	Sampling Period (Minutes)	Turpentine and Other Terpenes	Ketones (as Acetone)	Alcohol (as Methanol)	Wood Type
Charcoal tube	2	2	101	22	2.3	2.8	Softwood
Silica gel tube	2	2	101	-	-	1.5	Softwood
Charcoal tube	4	1	189	0.05	< 0.02	0.14	Hardwood

suprising since control room area samples resulted in hydrogen sulfide and methyl mercaptan concentrations roughly equivalent to personal sampling data collected while employees were in various production areas. It is, however, very possible that cigarette smoke in the control room contributed somewhat to the HNU analyzer results.

- The instrument response recorded at the chip screens can be at least partly attributed to low temperature volatiles (resin acids) given off by the wood chips.

CONTROL OF WORKPLACE EXPOSURES

Process Control - The process is largely monitored by two pneumatic analog control panels - one for the pulping operations; one for the pulp washing, screening, and cleaning operations. Based on set points established by the operators, various recording or indicating control loops regulate all important operating variables, including (for the pulping process):

- the flow of makeup low pressure steam to the steaming vessel (to supplement the steam from the high pressure flash tank)
- the venting of non-condensible gases from the steaming vessel
- the flow of both white and black liquor
- white liquor levels in the chip chute and the liquor tank, (which controls the feed rate of makeup liquor to the top of the digester)
- the temperature of the liquor circulating through the heaters for each cooking zone
- black liquor levels in the high and low pressure flash tanks
- the flow of dilution liquor to the bottom of the digester
- the flow of counterwash liquor to the digester outlet device
- the flow of stock to the blow tanks
- the stock level in the blow tanks

Many other process flows, temperatures, pressures, and tank levels are recorded and/or displayed in the control room and closely monitored by the operator.

The process controllers limit the potential for worker exposure primarily by reducing the time that employees are in the production area (operators - <10%; tester <20%; utility man <60%). In addition, the control system reduces the potential for process upsets due to employee error.

Process Characteristics - Except for the knotters and brown stock washers, which are provided with a well-ventilated canopy hood, the entire process is totally closed. Unless there are leaks or process upsets, air contaminant levels will remain very low, as reflected in the personal and area sampling data.

- of 26 personal samples for hydrogen sulfide and methyl mercaptan, only one exceeded 10 percent of appropriate OSHA Ceiling PEL (7.7 ppm methyl mercaptan while the utility man was cleaning the area around the brown stock washers)
- only one of 17 area samples for these contaminants exceeded 10 percent of the appropriate OSHA Ceiling PEL (7.5 ppm hydrogen sulfide outside the digester control room while one of the liquor heaters was drained)
- the HNU analyzer data, recorded almost continuously over three full days, reveal the relative absence of significant release of process contaminants.

Pertinent process characteristics relative to potential workplace exposure are outlined below:

Unit Operation	Comments
chip hopper	- vibratory to prevent chip jams
	- chips preheated with relief steam from rotary closed-pocket valve
rotary closed-pocket valve	- pressurized with low pressure steam from 30 psig service line
	- relieved through four inch line to chip hopper

Unit Operation	Comments
rotary closed-pocket valve	- water lubricated packing glands for drive shaft requires frequent adjustment; any leaks will be relatively minor and consist primarily of steam. Repacking done on digester shutdowns as needed.
steaming vessel	- supplied primarily with flash steam from the low pressure flash tank
	- automatically supplemented with low pressure steam from the 30 psig service line
	- relief of non-condensibles to the atmospheric flash condensor automatically controlled by the pressure level in the vessel; the same pressure measurement used to control flow of low pressure make-up steam
	- relief line safety valve vented to outside atmosphere set at 30 psig
	- water lubricated packing glands for the auger drive shaft; no problems reported
liquor makeup system	- makeup liquor pumps spared; mostly white liquor; water lubricated packing glands - no problems reported
	- water lubricated packing glands for cold blow liquor pump; no problems reported; mostly weak black liquor from brown stock washers
continuous digester	- chip level measured with a special torsion type level indicator; packed seal-stuffing box cooling; changed annually regardless of need; no problems reported with leaks
	- top of digester can be manually relieved to the steaming vessel
	- upper and lower cooking circulation pumps; water lubricated packing glands - no problems

Unit Operation	Comments
continuous digester	- heater safety valves set at 250 psig -vented to evaporators
	- butterfly valves on upper and lower cooking zone strainer outlets alternately opened and closed by a sequence timer to keep strainers clean
	- increased number of spent liquor extraction units from 4 to 12 allowing more liquor to be extracted without causing 'hangs'; also result in cooler blow because more cool dilution and counterwash liquor can be added at bottom of digester
	- high pressure flash tanks relieved to steaming vessel; low pressure flash tank relieved to atmospheric flash condenser, vented to odor control system
	- outlet device equipped with two seals - central and external
blow tanks	-located outside
	- enlarged cyclone portion of primary blow tank to reduce liquid carryover
	- agitator shaft sealed
	- added spray condenser for blow gases
brown stock washer filtrate tanks	- vented to foam tank
	- foam tank vented to seal tank
	- filtrate pumps

All seals used in the pulp mill area are water lubricated, graphite packed; no mechanical seals are employed, as the water pressure is above the process pressure, leaks should be into the process stream. Packings are "taken up" as needed and are replaced as needed during minor shutdowns (2-3 hours). The graphite packing has proven to be much superior to the teflon-asbestos type previously used.

Brown Stock Washer Exhaust System - The knotters and the brown stock washers are ventilated through a large canopy hood. As illustrated on Figure 08-2 , the hood overlaps the perimeter of the knotters and washers (two feet on each side). The hood side panels extend down to a point just below the tops of the washer cylinders.

Prior to the installation of the odor control system, the hood was exhausted through three 42-inch ducts extending horizontally through an adjacent wall. Each duct was supplied with a fan rated at 27,300 cfm, for a total capacity of almost 82,000 cfm.

When the odor control system was installed, it was found that it could not handle the existing air flow from the brown stock washer hood. In response to this problem, the three ducts were capped, and replaced with a single system rated at 20,000 cfm. To reduce the potential adverse affects of the reduced hood exhaust capacity, a series of plastic curtains were installed around the entire perimeter of the hood. The curtains extend from the bottom of the hood side panels to the floor level, and are easily adjusted by the operator as necessary. The curtains provide an "increased" level of process enclosure and therefore enhance the containment and removal of air contaminants.

At 20,000 cfm (assuming perfect air distribution), the hood will theoretically provide about 2.2 complete air changes per minute and a face velocity of less than 20 fpm.

Actual face velocities measured during the survey were highly erratic, ranging from 0 fpm to 150 fpm. Although the design and measured air flow rates are well below recommended values, the sampling data demonstrate that the hood is effective in preventing excessive escape of process gases.

VESSEL ENTRY SAFETY PROCEDURES

Mill 08 has developed and uses a vessel entry permit system to protect employees who must enter enclosed spaces. The supervisor must fill out a permit prior to any work involving:

- enclosures with limited access opening such as closed storage tanks, tank cars or process vessels (with only a manhole for entering)
- tanks, pits, tubs, vaults, vessels, or other confined spaces with one side open to the air but deep enough to require the aid of an assistant in case of an emergency
- confined spaces such as ventilation or exhaust ducts, sewers, underground utility tunnels, or pipe lines.

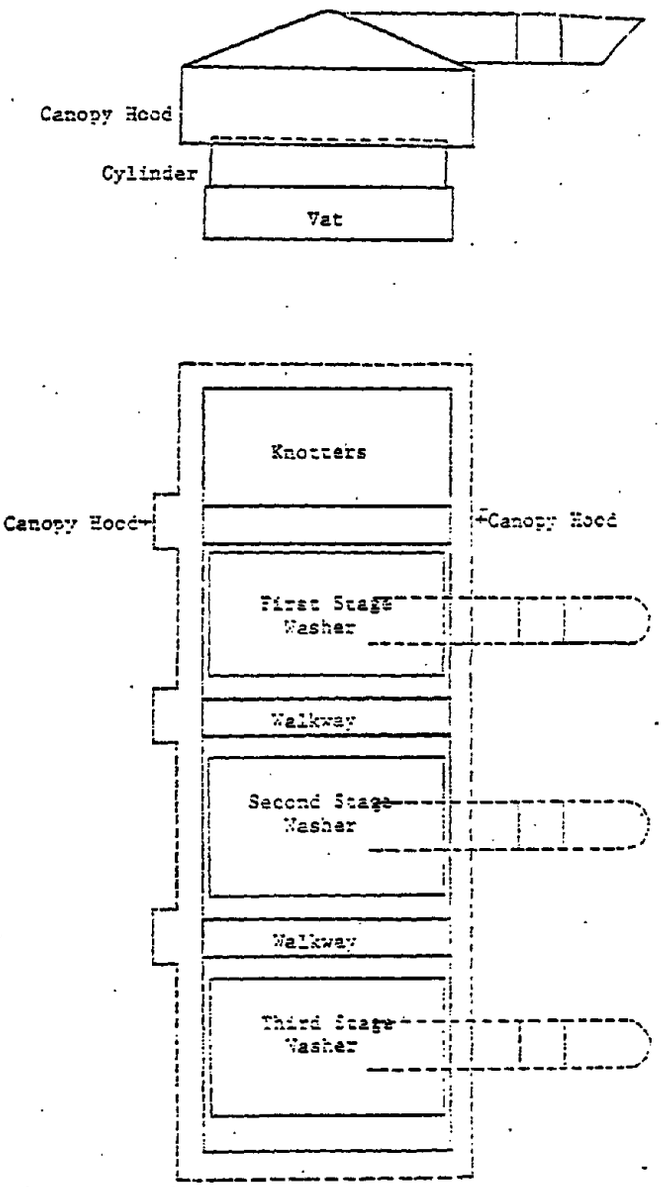

FIGURE 19-2 KNOTTERS AND BROWN STOCK WASHERS

The permit includes the date, location and description of the work to be completed, and designation of 2 stand-by employees to be available in case of an emergency. The supervisor is further required to certify in writing that he has personally inspected the vessel or area and that:

- all connecting lines have been blanked properly or disconnected
- the lock and try procedure has been completed for agitators, pumps, dryer drives, etc.,
- forced ventilation will be provided during the entire operation or proper fresh air distribution has otherwise been assured
- it is clear of flammable, corrosive, or toxic materials
- chemical hazards have been guarded against
- protective equipment has been provided
- tests for the presence of harmful chemicals agents have been made
- explosion meter tests have been made
- oxygen deficiency tests were made and a reading above 19 percent was noted

After the permit has been completed by the supervisor, one copy is forwarded to the mill safety director, and one copy is displayed at the site during the entire operation.

Vessel entry air testing is conducted by safety department or technical service personnel unless the responsible supervisor has received appropriate training. Tests are conducted using a portable oxygen monitor, a combustible gas indicator, and/or detector tubes.

As a guideline for maintenance or other supervisory personnel, a listing of the specific tests required prior to entry into various process vessels has been prepared. The tests required for pulp mill locations are shown on Figure 08-3.

PERSONAL PROTECTIVE EQUIPMENT

Mill 08 has developed a formal respiratory protection program establishing a uniform policy for the proper selection, use, and maintenance of respiratory protection to protect employees from inhalation of particulate matter, noxious gases and vapors, and oxygen deficient atmospheres. The written program includes detailed information on the following:

	Lower Exposure Level	Oxygen	Hydrogen Sulfide	Methyl Mercaptan	Cl₂
P[illegible] MILL					
1. Three filtrate tanks	X	X	X	X	
2. Washer drums and knotters	X	X	X	X	
3. Two black liquor storage tanks	X	X	X	X	
4. Hot water tank	X	X	X		
5. Two blow tanks	X	X	X	X	
6. Foam tower	X	X	X	X	
7. Two washed stock chests	X	X	X		
8. Two flash tanks	X	X	X	X	
9. Steaming vessel	X	X	X	X	
10. Chip chute	X	X	X	X	
11. Chip bin	X	X	X	X	
12. Digester	X	X	X	X	
13. Hot water accumulator	X	X	X	X	
14. Stripper storage tank (feed)	X	X	X	X	
15. Stripper Building	X	X	X	X	
16. Acid tank	X	X			
17. Blo-surd seal tank	X	X	X	X	
18. Level tank	X	X	X	X	
19. Spill containment pit	X	X	X	X	
20. Turpentine Building	X	X	X	X	
21. Soap Skim Tank	X	X	X	X	
22. Soap Surge Tank	X	X	X	X	

FIGURE 18-1

SAMPLING REQUIREMENTS PRIOR TO VESSEL ENTRY

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- definitions of pertinent words and phrases
- description of the different types of respiratory hazards
- types of respirators used at the mill
- color codes for gas-mask canisters
- maximum effective duration of each type of respirator
- danger signals while using respirators
- guidelines for selection of respirators
- training procedures
- equipment maintenance requirements (inspection, cleaning, repair, and storage)
- specific requirements for each location in the mill

Specifically, every person working in or entering the pulp mill must carry a pocket-type respirator with a chlorine canister. In addition, all employees are issued full facepiece respirators with organic vapor/acid gas canisters. For emergency use, each control room is provided with 2 self-contained respirators (Scott or MSA 401 Air Pacs). For use during maintenance operations, there are four mobile supply air manifolds on each floor.

MILL 26: KRAFT PULPING PROCESS (Continuous Digesters)

INTRODUCTION:

Mill 26, located in the Southeast United States, produces over 1200 tpd of Kraft pulp in two Kamyr continuous digesters. There are separate process lines for hardwood and softwood chips. The survey includes all operations from the chip bins up to the bleach plant.

PROCESS SUMMARY

Both process lines are essentially identical, except that the hardwood line does not include a turpentine condenser. The process through the blow tanks is based on conventional Kamyr continuous digester technology (see Mill 9 report for a detailed process description). However, based on operating experience and other considerations, the quench and wash circulation lines for each continuous digester are no longer used.

From the blow tanks, the pulp is pumped to the two-stage brown stock washers (Impco vacuum drum washers). In the first stage, the pulp is washed with second stage filtrate; the second stage uses clean water. The pulp from the washers is dropped into a surge tank, then pumped to the five Aptew knotters. The deknotted stock is then screened, dewatered, and pumped to the storage tanks.

JOB CATEGORIES AND DESCRIPTION

At Mill 26, essentially all pulp mill operations are monitored and controlled from a large, central control room. Excluding supervisory personnel and operators not covered in this report, there are three relevant job categories:

Control Room Operator: The operator monitors and controls the digesters, lime kiln, and the recausticizing operations. It is estimated that this employee remains in the control room for at least 95 percent of each shift.

Assistant Pulp Mill Operators: There are two assistant pulp mill operators. One is responsible for the continuous digesters, the brown stock washers, and the chip silos; the other for the knotters, the screens, and the lockers. Job tasks for these employees are somewhat variable, but include equipment inspection, troubleshooting, and area clean-up. It is estimated that each employee is in the control room for up to 30 percent of each shift.

Dirtyman Oarman (Second Helper): The dirtyman collects process samples and conducts quality control tests including:

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- Digester and white liquor samples which are taken every two hours and require about fifteen minutes to collect. The stock samples are collected in sample bins connected to the cooking zone of each digester. The white liquor sample is drawn from a small spigot attached to the central white liquor feed line.

- Decker samples--every two hours stock samples are collected from the decker on each production line.

- Black liquor samples--spent black liquor samples are drawn from the No. 2 flash tanks of each digester once each shift. These samples require about fifteen minutes for collection.

The quality control tests are conducted in the test shack located next to the control room. The tester remains in the test shack at least 70 percent of each shift.

AIR SAMPLING DATA

Personal Sampling Results: A total of eleven short-term personal samples for hydrogen sulfide and/or methyl mercaptan were collected on both assistant operators, the tester, and on utility and maintenance employees. The data are presented in Table 25-1, and are discussed below for each job category:

- Assistant Operator (knotters, screens, and deckers): Each of these samples was collected while this employee was conducting equipment inspections, adding defoamer to the brown stock washers, and hosing down the floor (none of the sampling periods were spent in the control room or test shack). Both of the hydrogen sulfide samples resulted in concentrations of 0.7 ppm, well below the OSHA ceiling PEL of 20 ppm. The three samples for methyl mercaptan ranged from 1.6 to 3.5 ppm, or less than a third of the OSHA ceiling PEL of 10 ppm.

- Assistant Operator (digesters, brown stock washers, chip silos): During these three sampling periods, this employee was either in the control room or conducting inspection tours in the process area. No hydrogen sulfide samples were collected; methyl mercaptan samples ranged from 1.4 to 1.8 ppm, less than half of the OSHA ceiling PEL.

- Tester: Three short-term personal samples were collected for methyl mercaptan while the tester was taking digester and white liquor/black liquor quality control samples. The results range from less than 0.7 ppm to 1.8 ppm.

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JOB CLASSIFICATION	DAY	SHIFT	SAMPLING PERIOD (min.)	CONCENTRATION (ppm) Methyl Mercaptan[1]	Hydrogen Sulfide[2]	% Time in Process Areas
Assistant Operator	2	1	15	3.5	0.7	100
(Digesters, etc.)		1	15	3.5	0.7	100
		1	15	2.6		100
Assistant Operator	2	2	17	3.9		18
(Digesters etc.)		2	16	1.4		96
		2	16	4.5		50
Pulp Tester	2	2	16	1.9		72
		2	15	<0.2		88
	3	1	15	0.7		67
Utility Employee	2	2	15	1.0		100
Maintenance Employee	1	1	15	0.5	0.3	100

[1] Method of Knorr and Rapoport, Analytical Chemistry, 1980, vol. 52, pp. 733-736.

[2] NIOSH P & CAM 126.

TABLE 26-1 PERSONAL SAMPLING RESULTS

- Maintenance Employee: One short-term sample was collected while this employee was installing a new check valve on the weak black liquor surge tank. Results for both methyl mercaptan (0.5 ppm) and hydrogen sulfide (0.3 ppm) were very low.

- Utility Employee: A short term sample was collected on this employee while checking burners at the chlorine towers, caustic tanks, and evaporators (8 minutes) and hosing down the floor around the white liquor storage tanks (7 minutes). The sample resulted in a concentration of 1 ppm methyl mercaptan.

Area Sampling Results

A total of 26 area samples were collected for reduced sulfur compounds inside and outside the control room, in the test shack, and beside the softwood brown stock washers. The results are presented in Table 26-2 and are summarized below:

- Short-term methyl mercaptan samples were collected (method of Knarr and Rappaport) in the control room (5.3, 4.9, 0.9, 4.2 ppm), outside the control room (0.2 ppm), and in the test shack (3.7 and 4.2 ppm). One Gastec detector tube sample was collected in the control room and resulted in a concentration of 5 ppm.

- Hydrogen sulfide samples (NIOSH P&CAM 126) were collected over periods of fifteen to sixty minutes in the control room (0.7 ppm), outside the control room (0.2 ppm), in the test shack (0.5 ppm) and beside the softwood brown stock washer (0.6 ppm). No hydrogen sulfide was detected on the Drager detector tube taken in the control room.

- Drager detector tubes for dimethyl sulfide were also taken in the control room (5 to 20 ppm) and in the test shack (13 ppm).

- A Gastec detector tube for ethyl mercaptan was taken in the control room (3 ppm).

It should be noted that, because of numerous probable interferences, the detector tube data do not necessarily confirm that methyl mercaptan or dimethyl sulfide are present in the control room and test shack at or even near the levels reported in Table 26-7.

LOCATION	CONCENTRATION (ppm) Methyl mercaptan[1]	Ethyl mercaptan[2]	Total mercaptans[3]	Dimethyl Sulfide[4]	Hydrogen Sulfide[5]
Control Room	5.3	3.0	4.0	10	0.7
	4.9		2.5	14	ND[7]
	0.9		3.5	8	
	4.2		2.5	13	
	5.0[6]		8.0	20	
Outside Control Room	0.6				0.2
Weir Stock	3.7				0.9
	4.2		4.0	13	
Recon Stock Weiser (Collapsed Line)					0.6

[1] Method of Kneer and Rappaport, Analytical Chemistry, 1980, vol. 52, pp. 733-736 15 minute samples

[2] Draeger Detector Tubes

[3] Drager Detector Tubes

[4] Drager Detector Tubes

[5] Matheson P & C #4 126 - 15 to 60 minute samples

[6] Drager Detector Tubes

[7] Drager Detector Tubes

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TABLE 26-2: AREA SAMPLING RESULTS

Discussion of Data

Personal samples for hydrogen sulfide resulted in very low exposure levels (<1 ppm) relative to the OSHA ceiling PEL of 20 ppm. Since the area samples resulted in similarly low levels, it can be concluded that hydrogen sulfide is typically not a significant workplace contaminant in surveyed areas of the pulp mill.

Exposure levels for methyl mercaptan were less than 45 percent of the OSHA ceiling PEL of 10 ppm. The area sampling data (Table 26-2) focused on contamination in the control room and the test shack, where six out of seven samples, were between 3.7 and 5.3 ppm. A single sample taken outside of the control room resulted in a lower methyl mercaptan concentration (0.6 ppm). However, contaminant concentrations in this area (around the brown stock washers, and steaming vessels) may generally fluctuate up to and possibly above levels in the control room. This judgement is reinforced by the personal samples for the assistant operator (knotters, etc.) which resulted in concentrations up to 3.5 ppm even though the employee was not in the control room or the test shack during the sampling periods. However, the remaining personal sampling data indicate that ceiling exposure levels are inversely related to the percentage of the sampling period spent outside of the control room or test shack (i.e. the longer the sampled employee remains in either of these rooms, the higher the exposure level).

CONTROL OF WORKPLACE EXPOSURES

Exposure levels at Mill 26 are largely a function of process characteristics and the layout of the pulp mill. The process is essentially closed with only a few sources of workplace contaminations. Although highly variable and difficult to assess, the following emissions sources are likely to be significant.

- Chip bins--The low pressure feeders atop the steaming vessels are relieved into the chip bins. The relief gases are primarily non-condensables from the No. 2 flash tank, and are therefore likely to contain significant quantities of reduced sulfur compounds. Although a portion of the relief gases are absorbed by the chips, a significant amount undoubtedly enters the workplace through the top of the two chip bins above the control room[1].

---

[1]The absorption of non-condensable gases by the chips is a function of the intake of entrapped air in the bin, the moisture content, the type of wood (softwood or hardwood), and probably other factors as well.

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- Steaming vessels--The two low pressure feeders and steaming vessels, located directly outside of the control room, contained leaks which were contaminating the workplace.

- Re-entrainment--The pulp mill is essentially an open building, periodically subject to the downwash and entry of exhausted and/or vented process gases. Although highly variable and based on weather conditions, sources may include the brown stock washer stacks, and vents from the condensers, blow tanks, black liquor storage tanks, foam tanks, etc.

- Brown stock washers--The brown stock washers are exhausted through large, fiberglass-coated hoods (Figure 26-1). Each hood is exhausted by two roof-mounted, fiberglass tubeaxial fans. Although design air flows (cfm) were not available, face velocities measured through the opening between each stage ranged from 100 to 250 fpm. It was observed that the hoods were very efficient in containing and removing the steam emitted from the stock. Although the brown stock washers are located in a relatively enclosed area, the effectiveness of the exhaust hoods may periodically be reduced by drafts entering from the south end of the building.

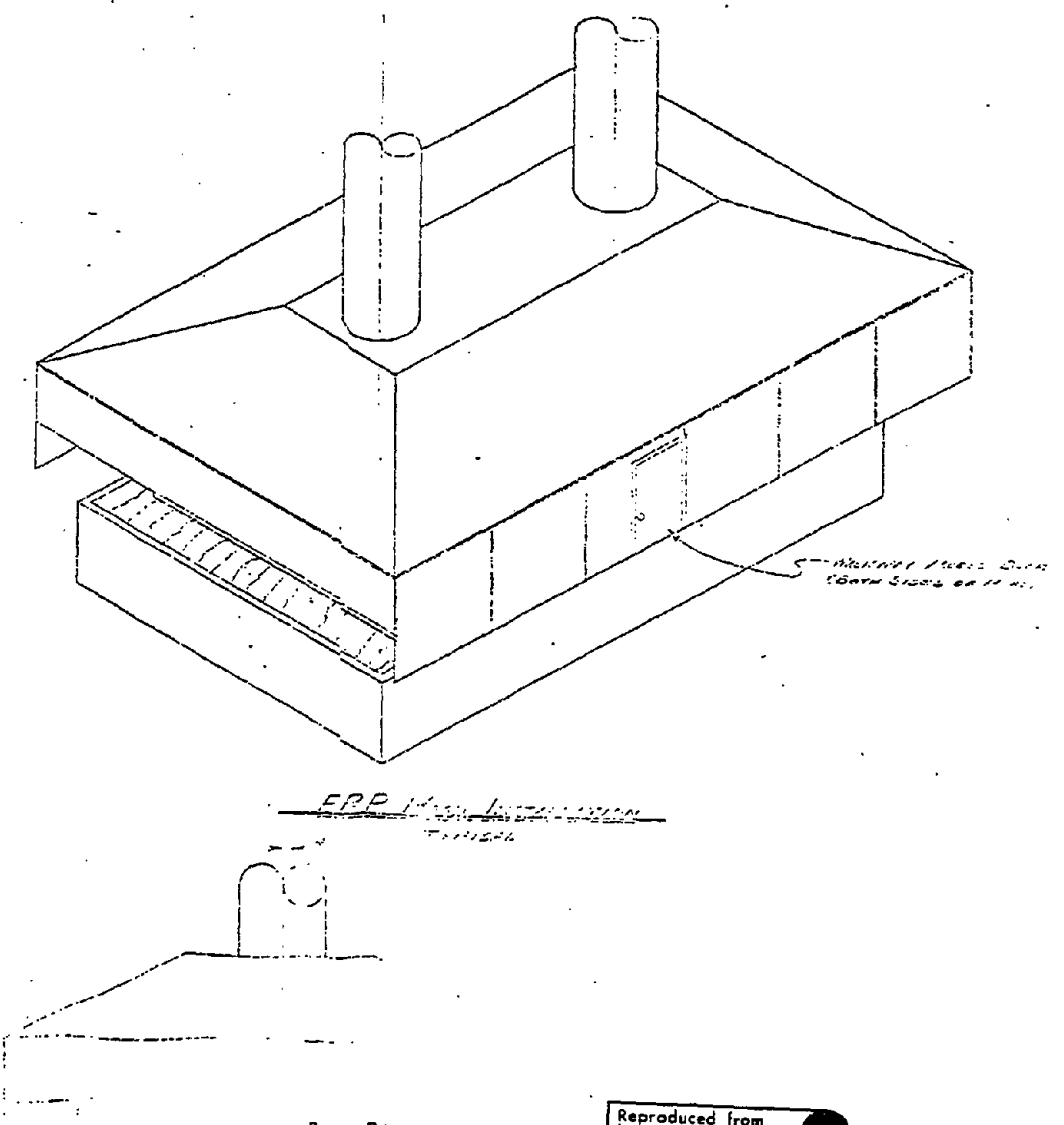
Control Room

Control room ventilation is based on a system with 100 percent recirculation; there is no fresh air makeup. Workplace contaminants enter the control room through the door and, more importantly, through leaks in the return air ductwork (on the suction side). It is interesting to note that, although contaminant levels in the workplace are continually being diluted and dispersed by natural ventilation, there are essentially no such clearance mechanisms for the control room and the test shack. Therefore, contaminants are likely to accumulate in these spaces and cause significant concentrations over relatively long periods of time. If workplace concentration is primarily due to infiltration, contaminant concentration build up and decay would follow similar time curves.

Preventive Maintenance

Mill 26 has an active preventive maintenance program which should have a positive impact on potential worker exposures. If there are no maintenance emergencies, a total of eight day-shift employees are assigned to conduct preventive maintenance inspections based on established checklists. There are over 300 established routes, with daily, weekly, or monthly inspection frequencies. In addition to these employees, the pulp mill operator and assistant operator conduct frequent equipment inspections (every two hours) of the pulp mill.

FIGURE 26-1 Brown Stock Washer Hood



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Equally important is the selection and maintenance of gaskets, packing material, and other seals. Mill 26 has reported effective use of the following materials:

Packing Material

- Garlock graphite fiber formulation (730, 733, and 2580) for pumps and other equipment downstream of the blow unit.
- Chesterton teflon-impregnated packing for the top separators on the Kamyr continuous digesters.
- Lantern rings atop the top separator ring (it is reported that the frequency of repacking has been significantly reduced).

Gaskets

- Asbestos used for green and white liquor lines, and for the evaporators.
- Flexitellic metal gaskets are used for high pressure service.

Tank and Confined Space Entry Procedures

Mill 26 uses a strictly enforced permit system for worker entry into tanks or other confined spaces. As shown on Figure 26-2, an entry permit must be filled out and signed by the operating and maintenance foreman. The permit addresses the following required precautions:

- Equipment isolation - if possible, all lines into or out of the tank or vessel should be broken; blanks must be placed into lines which cannot be disconnected. All sewer and catch basins must also be properly isolated.
- Purging - depending on the contents, the tank must be purged to remove all residual process liquids or gases. The foremen must also ensure that the area is clean and free of oil and other combustible materials.
- Tag-out - all mechanical, pneumatic, and electrical systems must be locked and tagged-out to prevent activation during the task.

VESSEL ENTRY PERMIT

Date _____

DEPARTMENT _____

LOCATION _____

Description of Work _____

Have the following precautions been taken?	CHECK Yes	No
1. Have all lines leading to and from vessles or equipment been properly isolated?	( )	( )
2. Has the vessel or equipment been properly purged?	( )	( )
3. Has electrical tag out been completed and agitator immobilized?	( )	( )
4. Nature of work: Flame ( ) Repair( ) Spark producing( ) Cleaning( )	( )	( )
5. Is combustable-explosive gas present by test? Instrument reading ( )	( )	( )
6. Is oxygen deficiency present by test? Reading ( ) 19½% MINIMUM	( )	( )
7. Is H2S or other gas present by test? READING ( )	( )	( )
8. All sewer and catch basins in vicinity properly isolated?	( )	( )
9. Is area clean and free of oil and other combustable materials?	( )	( )
10. Has forced ventilation been supplied on job?	( )	( )

A.M.
_____ P.M. on _____

Foreman - Operating

Time expired:
_____ A.M.
_____ P.M.

Foreman in charge-Crew

Tester

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FIGURE 26-2

- Air testing - prior to entry, the vessels must be tested for explosive gases (combustible gas indicator), oxygen content (19.5 percent minimum), and toxic materials (reduced sulfur compounds by detector tubes). These investigations are generally conducted by trained testers, who must also sign the permit certifying that the tank or confined space is safe for entry. The tests must be repeated for each time that re-entry is required.

- Forced ventilation - for the entire period that workers remain in the tank or other confined space, forced fresh air must be provided.

Although not specified on the permit, there are also requirements for stand-by workers, safety harnesses and lifelines.

Personal Protective Equipment

A variety of respiratory protective devices are provided to workers in various areas of the mill (Figures 25-3). These units are checked monthly to ensure proper operation.

Except for certain jobs (tank entry, etc.) the use of respiratory protective devices is at the discretion of the worker. Cannister-type respirators are available throughout the pulp mill for use during minor chlorine leaks or process upsets, or for egress during emergencies. Nine self-contained breathing apparatus are also available in the mill (two in the control room; one in the first aid room; one in the evaporator area; two in the safety storage area; and three in the power plant). These units are designed to be used for entry into highly contaminated areas during major leaks or other such situations. The operators can remain in the control room during such periods because of the supply-air manifolds previously mentioned.

FIGURE 26-3

MILL RESPIRATORY PROTECTION PROGRAM

RESPIRATORS AND GAS MASKS:

The Company provides all of the breathing protection equipment you might need, and requires that it be used on certain jobs. Many chemicals are in daily use in the mill, some of which are highly dangerous without proper breathing protection. Check with your foreman before entering any area where you suspect a dangerous concentration of gases may be present.

The following list will familiarize you with the types of equipment available and its use.

Legend: 1 - Light duty dust respirator
2 - Heavy duty dust and mist respirator
3 - Air-Line breathing apparatus
4 - Gas Mask
5 - Scott Air-Pak

	Type(s) of Protection to use (see Legend)
Fumes and Mist:	
Caustic Soda	2, 3, 4
Green Liquor	2, 3, 4
Muriatic Acid	2, 3, 4
Sulfuric Acid	2, 3, 4
White Liquor	2, 3, 4
Gases, Low Concentration:	
Chlorine	3, 4, 5
Chlorine Dioxide	3, 4, 5
Hydrogen Sulfide	3, 4, 5
Sulfur Dioxide	3, 4, 5
Gases, Over 2% Concentration:	
Chlorine	3, 5
Chlorine Dioxide	3, 5
Hydrogen Sulfide	3, 5
Sulfur Dioxide	3, 5
Some Jobs Requiring Protective Equipment:	
Bark Boilers (inside)	1
Blowing Paper Machine Down	1
Chlorine (working on lines and equipment)	3, 4, 5 (Use only 3 or 5 if concentration is over 2%)
Digesters (working inside)	1, 2
Lime, unloading trucks or working on conveyor or in conveyor pits	1
Painting	1
Power Boilers (inside)	1
Recovery Boilers (inside)	1
Salt Cake Mixing Area	1
Sulfur Dioxide (working on lines and equipment	3, 4, 5 (Use only 3 or 5 if concentration is over 2%)

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MILL 29: KRAFT PULPING PROCESS (Continuous Digesters)

INTRODUCTION

Mill 29 produces 1300 tpd of Kraft pulp in two continuous digesters. The first digester was installed in 1968. It was used for cooking both hardwood and softwood chips until 1978, then a second digester was added. Since 1979, softwood has been run exclusively in the older digester (500 tpd) and hardwood in the newer one (800 tpd). The only significant difference between the two processes is the method of stock washing. Vacuum-drum washers (two-stage) are used for softwood stock, while a Kamyr diffusion washing system (dual-stage) is employed for hardwood stock. Mill 29 is located in the Southern United States.

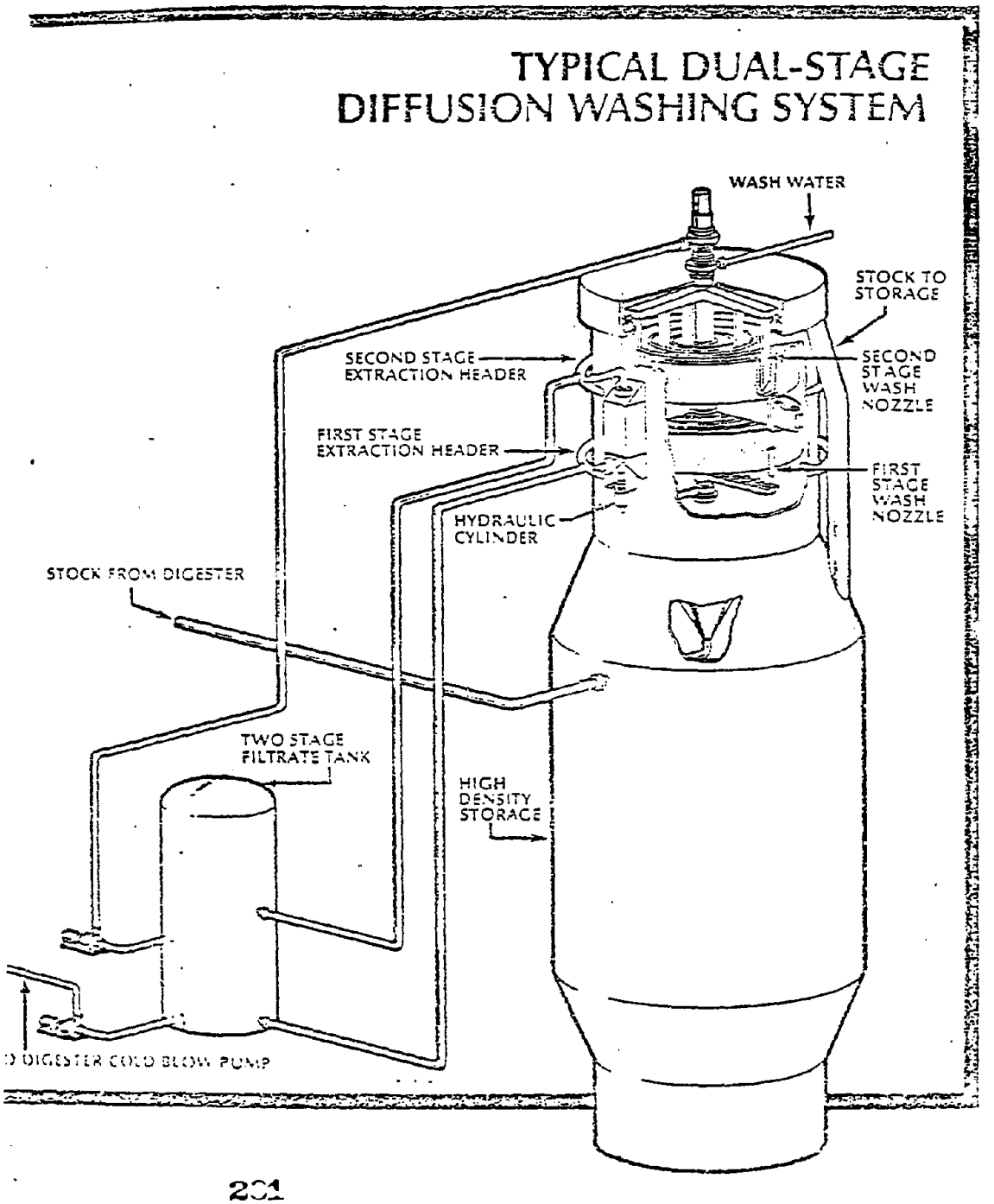
PROCESS SUMMARY (See Mill 8 Report)

Conventional Kamyr technology is used in both process lines from the chip bins to the digesters. Chips are conveyed into a large bin, metered into a low pressure feeder, and dropped into a steaming vessel. From this vessel they are augured into a chip chute, metered into a high pressure feeder, and sluiced to the top of the digester with liquor. The chips move slowly downward through the digester, and are cooked under high temperature and pressure. The bottom section is used to wash the chips before they are ejected to the blow tanks or the diffusion washer.

The similarities between the two processes end at this stage. On the softwood line, the cooked chips exit the digester, and enter one of two agitated blow tanks. The stock is diluted with washer filtrate, and is continuously pumped through two pressure knotters to the brown stock washers. The two washers are operated counter-currently with hot water showers on the second stage, and filtrate showers on the first. From the second stage, the washed stock is stored.

On the hardwood line, the cooked stock is blown directly from the digester to the Kamyr diffusion washer (Figure 29-1). The diffuser tank contains two rows of concrete cylindrical screen rings oriented on a vertical axis. The lower rings form the first washing stage and the upper row, the second stage. Three arms, located between the first and second stages, support the two screen rows and transport extracted filtrate from the screens. These arms radiate from the center of the tank to the outside wall, and are supported by vertical tie rods coupled to hydraulic cylinders. These cylinders provide a vertical stroking cycle to the screen, with a slow upstroke (equal to the upflow rate of the pulp mass) and a very rapid downstroke.

FIGURE 49-1


TYPICAL DUAL-STAGE
DIFFUSION WASHING SYSTEM
WASH WATER
STOCK TO STORAGE
SECOND STAGE EXTRACTION HEADER
SECOND STAGE WASH NOZZLE
FIRST STAGE EXTRACTION HEADER
FIRST STAGE WASH NOZZLE
HYDRAULIC CYLINDER
STOCK FROM DIGESTER
TWO STAGE FILTRATE TANK
HIGH DENSITY STORAGE
DIGESTER COLD BLOW PUMP

During the delay at the top of the diffuser stroke, and also during the downstroke, the extraction flow is shut-off and back flush is introduced to clean the screens.

As the pulp flows upward between the screen rings, wash medium displaces the spent liquor, which is extracted through the screens and gravity fed to the filtrate tanks. Second stage filtrate is returned to the diffuser and used as first stage wash medium. First stage filtrate is pumped back to the washing stage in the digester. Clean, hot water from the turpentine condenser is used as the second stage wash medium.

The washed pulp is removed from the top of the diffuser by a scraper, and falls down a dropleg into the high density storage tank. It is then deknotted, screened, cleaned, thickened and pumped into storage.

In both digester lines, the spent black liquor from the No. 2 flash tank is pumped to a vacuum drum filter. The liquor passes through the filters and drops into a filtrate tank. The pulp fibers and other solids are removed from the filter and sluiced to a solids collection tank. The filter liquor is pumped to the weak black liquor storage tank for subsequent recovery.

The turpentine recovery systems for both lines are also very similar. Both steaming vessels and second flash tanks are vented to cyclone separators, with the entrained liquor collected and piped back to the flash tank. The process gases, vapors, and other condensates pass through the separator to a turpentine condenser. Turpentine gases and other condensates are piped to a decanter, and the non-condensible gases enter the odor control system. The turpentine is drawn off to a storage tank, and the decanter underflow is pumped to the stripper feed tank.

JOB CATEGORIES AND DESCRIPTIONS

The pulp mill is operated by a crew of fourteen employees, including a foreman and two crew leaders. Each of these employees is experienced in all jobs below his current position, and one above. Besides the supervisory personnel, the crew consists of two first assistants (digester operators), two second assistants (bleach plant operators), a kiln operator, a bleach chemical plant operator, a byproducts plant operator (tall oil plant), three pulping assistants, and two reserve employees. There are also three pulp testers working in a laboratory near the main control room.

The first assistants operate the Kamyr digesters and spend most of their time (90%) in the control room monitoring and adjusting process variables. They also collect the following quality control samples:

- o Digester stock samples (every hour) - from a sampling pot adjacent to the digesters.

- o White liquor (every other hour) - from a sampling line just outside the control room.

- o Weak black liquor (once a shift) - from the liquor extraction line.

The hourly samples require about five minutes to collect and deliver to the laboratory. Once a shift all samples are collected, and this takes an additional five minutes. Since we did not sample any of the other crew members, their job descriptions are not necessary.

PERSONAL SAMPLING RESULTS

We collected six 15-minute personal samples for methyl mercaptan on the two digester operators during quality control sampling runs (Table 29-1). Measured ceiling exposures ranged from 0.2 ppm to 0.6 ppm, or less than six percent of the OSHA ceiling PEL of 10 ppm. The results were slightly higher during the long sample runs, and when both digesters were operating. However, the data clearly demonstrate that exposures to methyl mercaptan are usually very low. The area sampling data, discussed below, indicate that exposures to other process gases are also low.

AREA SAMPLING DATA

We collected many area samples to determine typical contaminant concentrations in the control room and on the operating floor. Samples (Table 29-2) were collected for methyl mercaptan (method of Knarr and Rappaport); turpentine, other terpenes, and hydrocarbons (charcoal tubes-gas chromatography); and resin acids, phenols, and alcohols (silica gel-gas chromatography). Detector tube samples were also collected for methyl and ethyl mercaptan, total mercaptan, dimethyl sulfide, and hydrogen sulfide (Table 29-3). During the survey, the odor control system for the softwood digester line was not in operation. Therefore, it is likely that contaminant levels were higher than would normally be expected.

Because control room employees have periodically complained of irritating gases, we collected several samples in this area. Very low levels of methyl mercaptan (0.05 to 0.9 ppm) were measured. Two detector tube samples for dimethyl sulfide[1]

[1]The Gastec detector tubes for dimethyl sulfide are subject to positive interferences of unknown proportions from all reduced sulfur compounds. The data are useful for comparison purposes, but must be viewed strictly in this context.

TABLE 29-1

PERSONAL SAMPLING DATA

Job Category	Day	Shift	Sampling Period (Min.)	Methyl Mercaptan[1] Concentration (ppm)	OSHA Ceiling PEL (ppm)	Activities
First Assistant Operator (Hardwood)	1	2	15	0.4	10	Long Sampling Run[2]
	1	2	15	0.6	10	Long Sampling Run
	3	1	15	0.3	10	Short Sampling Run[3]
First Assistant Operator (Softwood)	2	1	15	0.2	10	Short Sampling Run; Hardwood Line Down
	2	2	15	<0.2	10	Short Sampling Run; Hardwood Line Down
	3	1	15	0.4	10	Long Sampling Run

[1]Method of Knarr and Rappaport, Analytical Chemistry, 1980, vol. 52, pp. 733-736.

[2]Includes digester stock, black liquor (sol[illegible] digester extraction.

[3]Digester stock only.

TABLE 29-2 AREA SAMPLING [illegible]

Location	Day	Shift	Sampling Period (min.)	Concentration (ppm)						
				Methyl Mercaptan[1]	Turpentine[2]	Other Terpenes[2,3]	Other Compounds[2,4]	Resin Acids[5,6]	Phenols[5,7]	Alcohols[5,8]
Control Room	1	1	23	0.7						
	1	2	86		1.0	<0.02	0.40	<0.24	<0.04	0.09
	2	2	111	0.9	0.09	<0.02	<0.03			
	3	2	15	0.9						
	4	1	15	0.05	0.23	<0.007	<0.01			
Outside Control Room (Near Steaming Vessel)	3	1	72	0.8	0.09	<0.03	<0.04	<0.14	<0.02	0.07
	4	1	116	0.16	0.9	<0.007	<0.01			
Pulp Testing Lab	2	2	103	<0.03	0.19	<0.02	0.07			
	4	1	111	0.05	0.59	<0.007	<0.01			
Chip Bin Penthouse	2	1	13	5.6	18	<0.06	0.56	<1.6	<0.21	4.5
	2	1	3	8.5	5	<0.45	2.6	<6.8	<0.93	3.2
(Hardwood Side)	3	1	4	6.6	0.32	<0.18	<0.28			
Knot Washer Platform	3	2	65	2.8	0.9	<0.007	<0.01			
HVAC Fresh-Air Intake	3	1	118	<0.03	0.01	<0.01	<0.01	<0.14	<0.02	0.07
	3	2	107	0.06	0.05	<0.007	0.26			
In HVAC Return Air System:										
Inlet	4	2	47	1.0	0.14	<0.02	<0.04			
Outlet	4	2	47	0.3						

[1] collected by method of Knorr and Rappaport, Analytical Chemistry, 1980, vol. 52, pp 733-736

[2] collected on charcoal

[3] as turpentine

[4] as m-xylene

[5] collected on silica gel

[6] as acetic acid

[7] as phenol

[8] as ethanol

TABLE 29-3

DETECTOR TUBE SAMPLING DATA

Location	Day	Shift	Methyl[1] Mercaptan	Ethyl[2] Mercaptan	Mercaptan[3]	Dimethyl[5] Sulfide	Hydrogen[6] Sulfide	Comments
Control Room	1	1				7		Permafill being replaced
	1	1				5		Permafill being replaced
	1	2	ND[6]					
Outside Control Room (Rear Steaming Vessels).	1	1				4		
	1	1				5		
	2	2				ND		Hardwood Digester down
Pulp Testing Lab	2	1				1		Hardwood Digester down
Hardwood Black Liquor Filter	3	1	ND			7		
	3	2				4		
Chip Bin Penthouse (Rear Softwood Bin)	2	1	40	15	>>100	>>15	20	Hardwood Digester down
Chip Bin Penthouse (Rear Hardwood Bin)	3	2			>>100			

[1] Gastec Detector Tube
[2] Gastec Detector Tube
[3] Dräger Detector Tube
[4] Dräger Detector Tube
[5] Gastec Detector Tube
[6] Not detected

resulted in concentrations of 7 ppm and 5 ppm. However, these samples were collected while the Purafil filters in the control room HVAC systems were being replaced, and the recirculated air was not being cleaned. The charcoal tube and silica gel samples revealed very low or non-detectible levels of terpenes, resin acids, phenols, alcohols, and hydrocarbons. The complaints of irritating gases began when the Purafil filters are depleted, virtually two weeks after replacement. Since our samples were collected shortly after replacement, we cannot identify the irritant gases, nor estimate control room concentrations during problem periods.

Area samples were also collected outside of the control room, near the softwood steaming vessel, and in the pulp testing lab. The results, including four detector tube samples for dimethyl sulfide, are low and essentially equivalent to levels in the control room.

The samples collected on the knot drainer platform resulted in a higher methyl mercaptan concentration (2.8 ppm), but terpene and hydrocarbon levels were not exceptional. We attribute the high level of methyl mercaptan to an upset at the hardwood pressure knotters which resulted in extensive spillage of weak black liquor. This sample is therefore not indicative of normal contaminant levels in this area.

Detector tube samples for methyl mercaptan and dimethyl sulfide were collected at the hardwood black liquor filter, near the quality control sample port. We measured 7 ppm and 4 ppm of dimethyl sulfide, which appears to be the background level throughout the operating floor. No methyl mercaptan was detected.

The most interesting samples were collected in the chip bin penthouse which is located on the roof of the pulp mill building. Three samples for methyl mercaptan resulted in concentrations of 5.6, 5.5, and 6.6 ppm. Turpentine levels ranged from less than 1 ppm near the hardwood bin, to 13 ppm at the softwood bin. Several parts per million of hydrocarbons (as m-xylene) and alcohols (as ethanol) were also detected. Detector tube samples near the softwood bin resulted in 40 ppm methyl mercaptan, 15 ppm ethyl mercaptan, and 20 ppm hydrogen sulfide. Additional detector tube samples for total mercaptans and dimethyl sulfide resulted in concentrations far in excess of the upper limit of detection (100 ppm and 15 ppm, respectively). Last fall, mill personnel collected air samples in the penthouse and reported total reduced sulfur concentrations (as total sulfur) of 30 and 71 ppm, and total hydrocarbon concentrations of 171 and 195 ppm. An additional sample in the softwood chip bin revealed very high concentrations of methyl mercaptan (104 ppm), dimethyl sulfide (594 ppm), and dimethyl disulfide (22 ppm). Although our detector tube data are highly suspect because of mutual

interferences, it is apparent that contaminant levels in the penthouse are excessive. Although employees enter the area infrequently and for relatively short periods, we recommended that respirators be worn until chip bin emissions can be effectively contained. The reasons for this problem are discussed in more detail in a following section.

Additional area samples were taken at the fresh-air intake for the control room HVAC system. Last year, the intake was moved away from the pulp mill building, to a conveyor feed tower over the chip storage piles. We measured considerably lower levels of methyl mercaptan (0.03 ppm, and 0.06 ppm), turpentine (0.01 ppm, .05 ppm), and alcohol (0.07 ppm). No hydrocarbons, resin acids, phenols, or terpenes (other than turpentine) were detected. Although contaminant concentrations at the intake are a function of weather conditions, we conclude that re-entry through this source is normallly not a serious problem.

Methyl mercaptan and charcoal tube samples were also collected in the control room HVAC ductwork. One set of samples was inserted in the return air line; the other in the supply air line downstream of the filter was broken in shipment to the laboratory. These data show that there are low levels of contaminants in the HVAC system, most likely from infiltration into the control room through the door leading to the workplace. The fresh Purafil reduced the methyl mercaptan concentration by seventy percent.

CONTROL OF WORKPLACE EXPOSURE

Worker exposures to reduced sulfur compounds and other contaminants are low primarily because the process is almost totally closed. The softwood knot drainer and brown stock washers are partially open, but are hooded and exhausted to the atmosphere. A computer controls many components of both digester lines, and although we could not evaluate the effect on potential worker exposure, it is likely that the frequency of upsets are reduced.

The chip bin penthouse was the only area where we noted a significant exposure. The low pressure feeders are relieved to the bottom of each chip bin. Some of the relief gases and vapors are absorbed by the chips, but a significant amount enters the penthouse. A 500 cfm blower is designed to ventilate the hardwood chip bin, and transport these non-condensible gases to an incinerator. The take-off duct for this blower was filled with chips, and the chip bin was provided with little or no exhaust. A larger blower, an improved duct configuration (with dust and chip barriers), and a higher transport velocity are all probably necessary for effective containment. The softwood bin is not currently provided with ventilation. There are, however, plans to

install a blower (1500 acfm @ 176°F) and a cyclone separator, and connect them to the existing odor control system. Mill personnel have been discussing these problems with Kamyr engineers to determine the best solutions.

Only two additional significant emission sources were noted in the digester area, both caused by overpressure in the softwood steaming vessel. When the chip chute high level sensor is activated, an interlock shuts down the steaming vessel augur, the chip meter, and the low pressure steam. However, the steam from the number two flash tank continues to enter the steaming vessel. Since the chips are already saturated, the additional steam cannot be absorbed, and the pressure rises. The steam backs up through the low pressure feeder, and a portion leaks from the chip hopper while the remainder passes into the chip bin and ultimately reaches the penthouse. Excessive pressure also occurs in the steam line from the flash tank to the steaming vessel. A pressure relief valve opened many times during the survey and, although it is piped to the atmosphere, much of the escaping steam leaks into the workplace.

Odor Control System

During the 1979 expansion, the mill installed a sophisticated odor control system to collect and transport non-condensible gases to an incinerator. The system reduces environmental emissions, but also controls workplace exposures by preventing the re-entry of vented gases, and by maintaining a slight negative pressure on process tanks and other vessels.

Separate parts of the odor control system serve the hardwood and the softwood digester lines. The hardwood component (Figure 29-2) collects gases from the following sources:

- 100 acfm (170°F) from both diffusion washer filtrate tanks.
- 1105 acfm (180°F) from the black liquor filter hood, the fiber collection tank, and the filter seal tank.
- 276 acfm (140°F) from the turpentine condenser (gases from the steaming vessel and the number two flash tank).
- 500 acfm (200°F) from the chip bin.

The softwood component (Figure 29-3) collects gases from similar sources:

- 375 acfm (140°F) from the turpentine condenser handling vent.

FIGURE 29-2 HARDWOOD DIGESTER NONCONDENSIBLE GAS COLLECTION SYSTEM

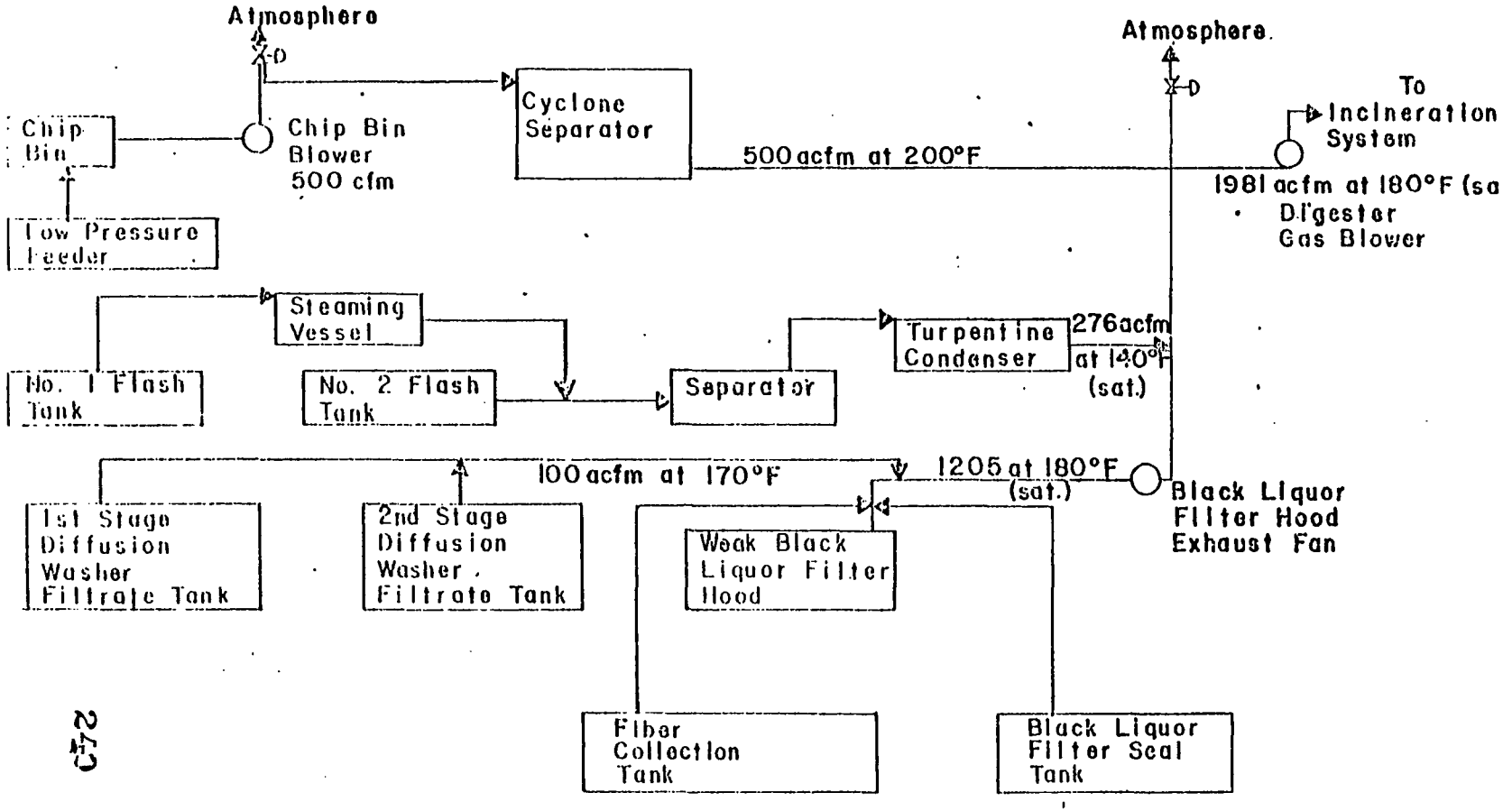
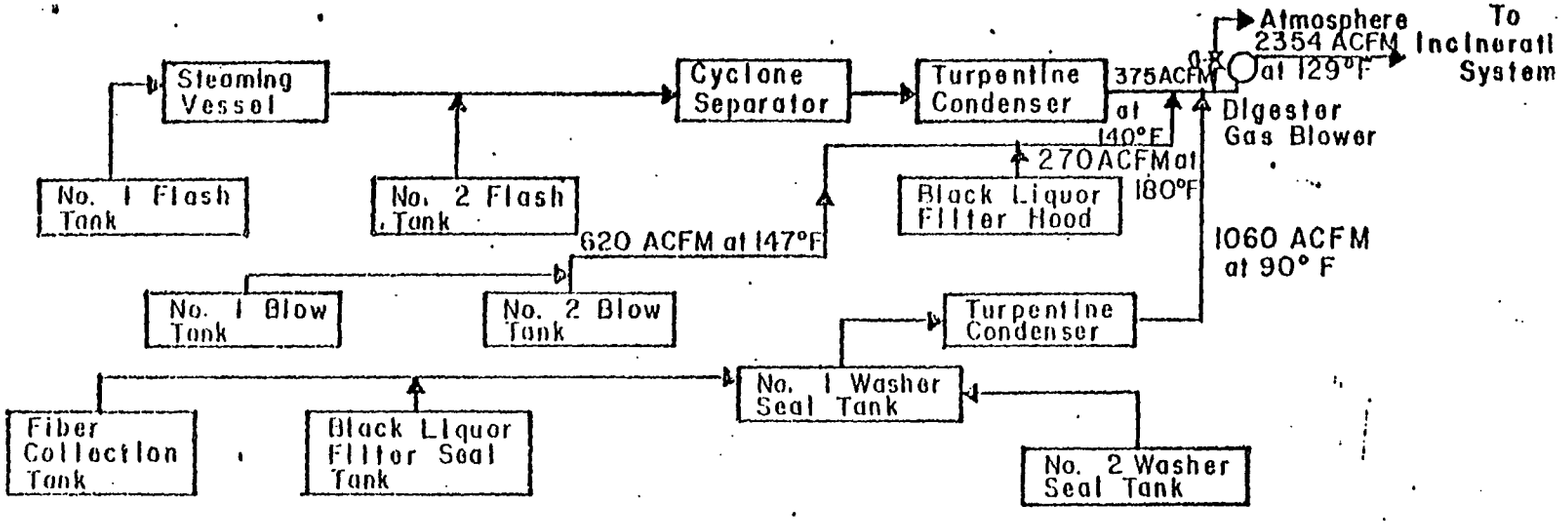


FIGURE 29-3 SOFTWOOD DIGESTER NONCONDENSIBLE GAS COLLECTION SYSTEM



- 270 acfm (180°F) from the black liquor filter hood.
- 620 acfm (147°F) from the two blow tanks.
- 1060 acfm (90°F) from an additional turpentine condenser handling vent gases from the fiber collection tank, the filter seal tank, and the brown stock washer seal tanks.

During our survey, the softwood digester gas blower was out of service and the non-condensible gases were vented directly to the atmosphere. The effects on our sampling data are unclear, but it would appear that workplace contaminant levels may have been higher than normal because of this outage.

Control and Computer Room HVAC Systems

From 1969 to 1979, the computer room and the control room were serviced by the same HVAC system. It was designed to provide 9400 cfm, with 90 percent recirculation and 10 percent fresh air makeup. In 1971, the computer had to be replaced because of corrosion from process gases which had been entering the HVAC system. Because of this problem, the mill installed a spray scrubber in the fresh-air line, and a Purafil filter in the combined supply line. The Purafil filter consists of small pellets of activated alumina impregnated with potassium permanganate. It is designed to oxidize unsaturated hydrocarbons and organic compounds, and retain sulfur as manganese-sulfur compounds. In addition to adding the air cleaners, the mill resealed all of the vacuum-side ductwork to prevent infiltration of contaminants from the workplace. These modifications have thus far prevented further damage to the computers.

In 1979, the control room was enlarged to accomodate the control equipment for the new digester line. A new HVAC system was installed for the combined control room, and the existing system was modified to service the computer room. The new HVAC system is designed for 90 percent recirculation and 10 percent fresh air makeup. A Purafil filter was installed in both the fresh air duct and the combined supply duct. A spray scrubber was also installed in the fresh air makeup duct. Thus the makeup air must pass through the scrubber in addition to the two Purafil filters. The recirculated air passes through one Purafil filter.

In April 1980, control room employees began to complain of lachrymation and upper respiratory irritation. The mill investigated their complaints and determined that the Purafil filters were depleted allowing process gases to circulate through the control room. When the Purafil was replaced, the complaints subsided for about two weeks, and then recurred.

After the Purafil had to be replaced several more times, the mill began an investigation to identify the irritant gases and eliminate the sources of emission. This investigation is still active and the Purafil is still being replaced every several weeks (average cost of $7,000 per month).

The results of the investigation to date are summarized below:

- o A control room air sample was collected on a Tenax trap and analyzed on a GC/MS. Dimethyl sulfide, chloroform, methyl-ethyl ketone, trichlorethane, dimethyl disulfide, 2-formaldehyde, furfural, phenol α-pinene, and ϕ-terpinene were all identified, but it was concluded that none were present in sufficient concentration to cause irritation. An additional sample was collected in chip bin penthouse and similar compounds were identified.

- o Air samples collected at probable sources of contamination proximate to the HVAC system fresh air intakes resulted in very high concentrations of reduced sulfur compounds, particularly dimethyl sulfide. These data (see Table below) demonstrated that contaminant re-entry was highly likely, and corrective action was taken.

Source	Methyl Mercaptan (ppm)	Dimethyl Sulfide (ppm)	Dimethyl Disulfide (ppm)	$\frac{\alpha\text{-pinene}}{\phi\text{-pinene}}$ (ratio)
Softwood Chip Bin	104	594	22	3.2
Filtrate Tank Vent		1641	12	2.7
Turpentine Decanter Vent 20		947	21	0.9
Turpentine Condenser Vent		5		4.6
Control Room Intake		13	6	4.3

- Samples for reduced sulfur compounds and hydrocarbons were collected in the fresh air ducts and the combined supply ducts (both downstream of the Purafil filters) of both HVAC systems. The results are plotted on Figures 29-4 and 29-5, and suggest that: (1) the fresh-air intakes are the source of the problem, and (2) that the supply air Purafil filter is either depleted or totally inefficient.

- The manufacturers of the Purafil filters tested the HVAC systems, and contended that there was a 2000 cfm leak in the control room return air duct. They suggested that workplace contaminants were infiltrating the system through this leak and rapidly depleting the filters. They recommended extending the fresh-air intakes away from the building, and performing sulfur hexa-fluoride ventilation tests. If results are not promising, they suggested that an air-tight mechanical room be installed to hold all air handling units and ductwork.

- Mill personnel challenged the Purafil filters with α-pinene and dimethyl disulfide. (Good collection efficiency was demonstrated until the Purafil was depleted. When this happened, high levels of α-pinene were measured downstream, presumably desorbed from the Purafil.) No new compound formation was detected.

- A new makeup air duct was installed with the intake located remote from the mill (on the chip feed tower above the chip storage piles). A new water seal was installed on one of the black liquor filtrate tanks.

- All ductwork in both HVAC systems were sealed with a special compound. Rubber seals were installed on the control and computer room doors. Both systems were re-balanced to match design air flows.

- Mill received proposal for infiltration ion studies to evaluate infiltration of workplace air, locate leaks, and determine air interchange between both rooms and the workplace.

The Purafil was replaced on the first day of our survey and there were no complaints of irritant gases during the next five days. Air samples in the control room did not reveal significant quantities of methyl mercaptan, terpenes, resin acids, phenols, alcohols, or hydrocarbons (Table 29-2.) Furthermore, the levels did not appear to increase as the survey progressed. We collected additional samples at the fresh air intake and got similarly low results. Methyl mercaptan samples collected in the control room supply air duct before and after the Purafil filter showed a reduction from 1 ppm to

FIGURE 29-4

HYDROCARBON AND TOTAL REDUCED SULFUR CONCENTRATIONS IN THE CONTROL ROOM -- HVAC SYSTEM

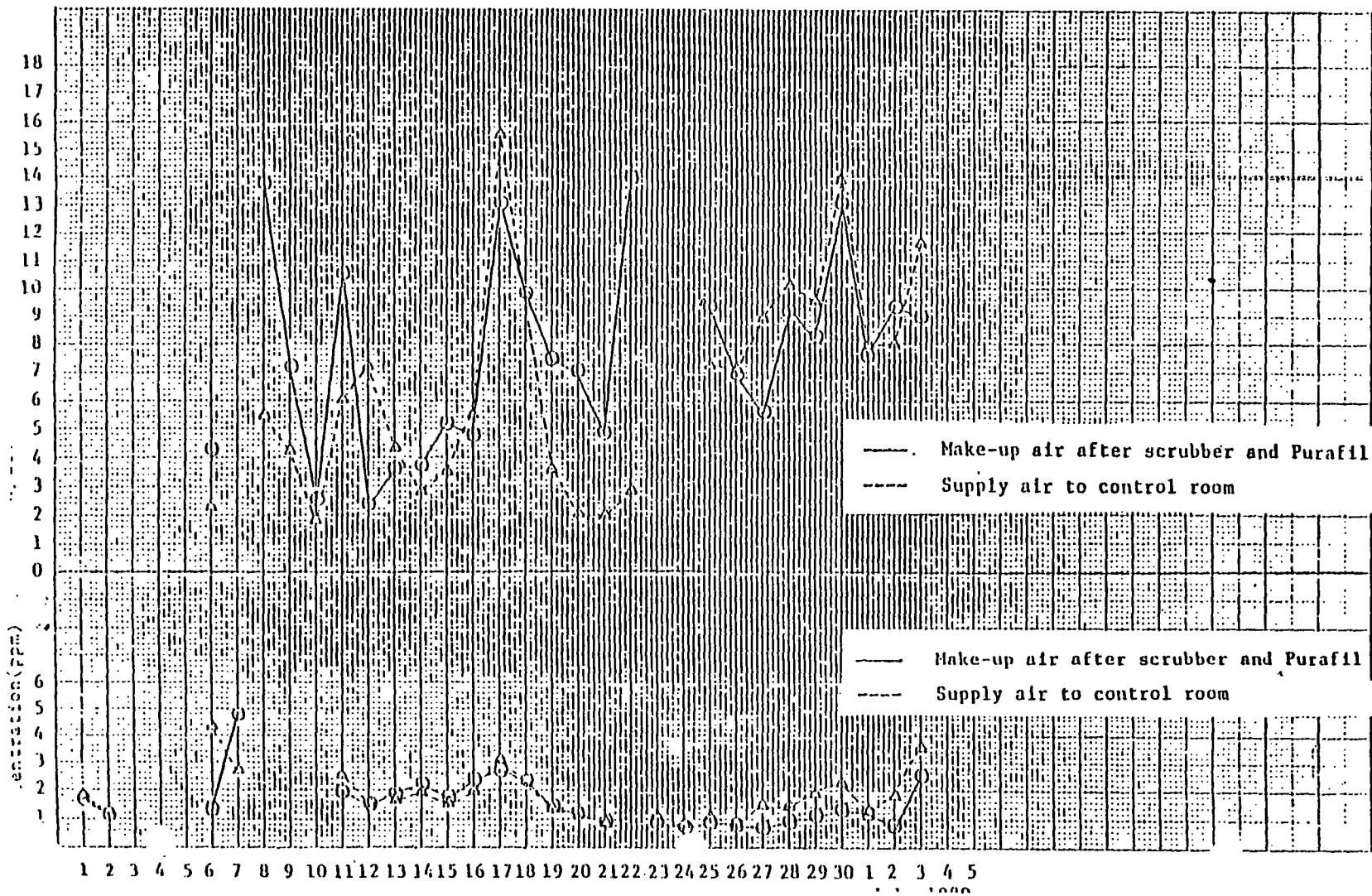
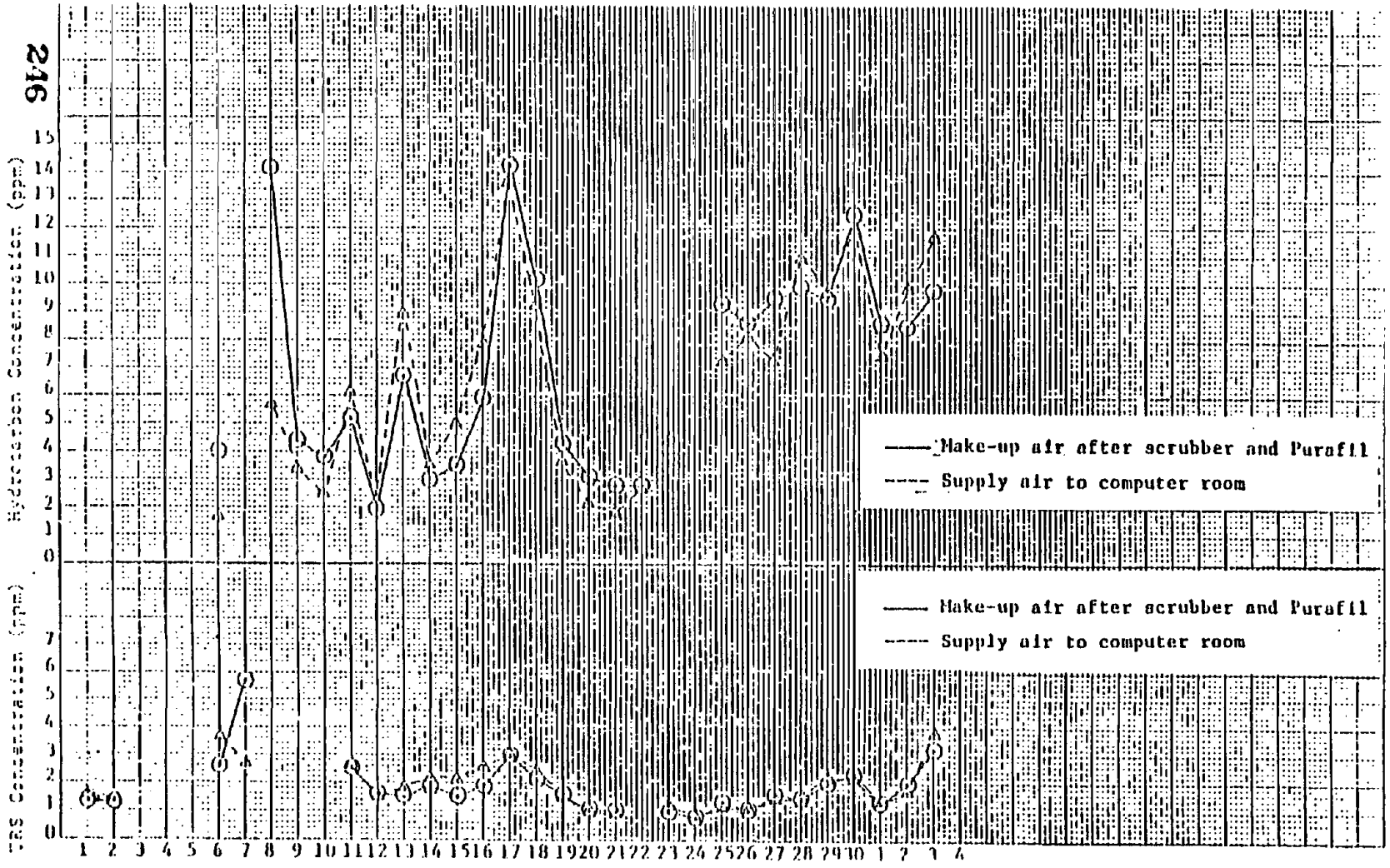


FIGURE 29-5

HYDROCARBON AND TOTAL REDUCED SULFUR CONCENTRATIONS IN THE COMPUTER ROOM--HVAC SYSTEM



0.3 ppm. In summary, none of our data provided any clues on the nature and sources of the problem. However, several observations are indicated:

- Although the control room is under slight negative pressure, employees enter and exit frequently through a number of doors. We believe that this is a significant source of contaminant entry and suggest that double-door air locks be considered.

- The chip bin penthouse is highly contaminated with process gases from the presteaming vessel and corrective action is certainly indicated. However, it is relatively isolated from the control room, the HVAC ductwork, and the fresh air intake, and is probably not the source of the problem.

- Air monitoring should be conducted when the Purafil becomes depleted and the complaints begin. We would not rule out the possibility of new compound formation or rapid contaminant desorption when the Purafil is depleted.

Brown Stock Washers

A large canopy-type hood covers both washer stages, and extends two feet below the top of the vacuum drums (Figure 29-6). The hood is made of 3/16" thick polyester-resin-bonded fiberglass (Atler 382), and is exhausted through two 42" ducts which entend vertically through the roof. Each duct contains an Aerovent fiberglass tubeaxial fan (belt driven) rated at 29,600 cfm against 1/2" static pressure. Based on the hood dimensions and the rated fan capacity, the system is designed to provide about nine complete air changes per minute.

We estimated actual ventilation rates by measuring air velocities in the two ducts (12 point traverse). The first and second stage fans were providing 14,850 cfm and 26,730 cfm respectively, or about 70 percent of total rated capacity. Observations revealed that the hood was very effective in removing steam and process gases emitted from the washer.

Knot Drainer

A separate canopy-type hood covers the knot drainer attached to the front of the first stage washer (Figure 29-7). This hood is also ducted vertically through the roof and exhausted by a roof tubeaxial fan. Although the rated cfm of the fan was not determined, duct velocity measurements indicate that it is providing about 10,000 cfm total air flow. Hood face velocities ranged from 50 fpm to 200 fpm, and observations indicated that most contaminants were being collected.

FIGURE 29-6

BROWN STOCK WASHER

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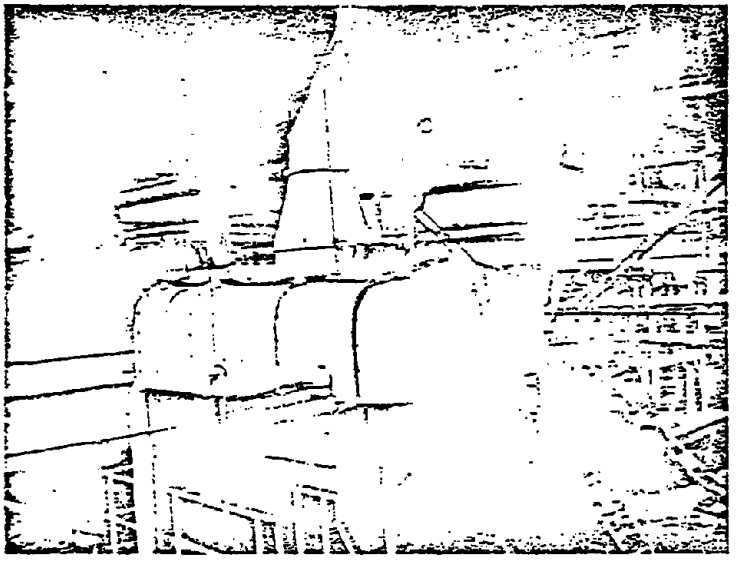
FIGURE 29-7
KNOT DRAINER



Black Liquor Filters

Tight-fitting hoods enclose each of the black liquor filters, and are exhausted through the mill odor control system. The soft-wood filter was not used during the survey, and the hood was not evaluated.

The hardwood filter hood (Figure 29-8) has seven 18" by 12" sliding access doors, which are normally closed. A black liquor sampling port is contained within an open-top metal box attached to one end of the hood. The face velocities through two of the access doors and the top of the sampling box, ranged from 500 fpm to 700 fpm, well above recommended minimum values.

General Ventilation System

Design air volumes and estimated turnover rates for the main pulp mill areas are shown on Table 29-4. On the ground and operating floors, about half of the exhausted air is replaced through mechanical makeup systems; the remainder enters through infiltration and other miscellaneous sources. In the chip bin penthouse, no mechanical makeup air is provided.

The design exhaust and supply air volumes are extremely high, and would provide excellent dispersion and dilution of workplace contaminants. However, it is doubtful that the general ventilation systems are operating at design levels. Two recent inspections by mill engineers revealed that many of the exhaust fans and supply air units were not in service. However, as a result of these inspections, new maintenance priorities were set, and many of the systems were repaired prior to our survey.

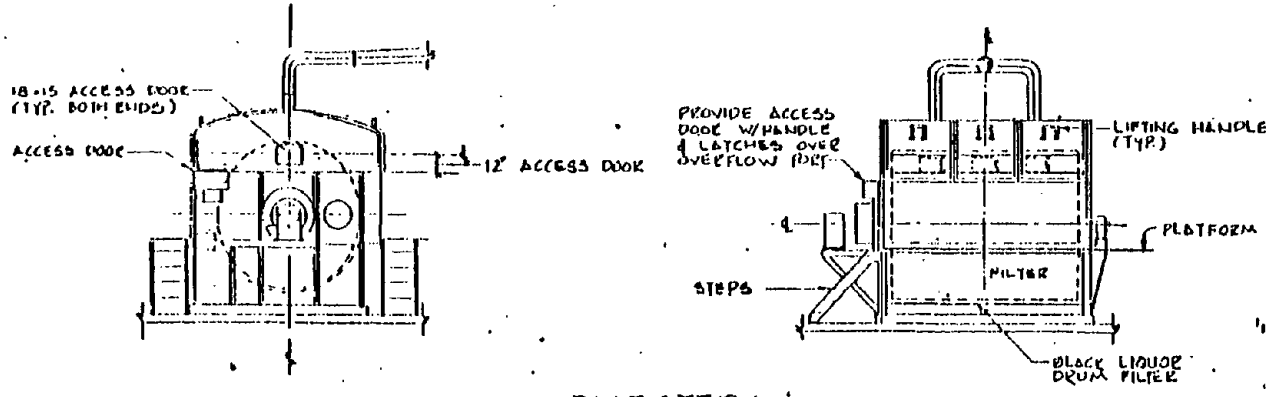
Based on observations and air sampling results, we conclude that the general ventilation systems on the operating and ground floors are very effective. Although we noticed several leaks in the process, contaminants did not appear to accumulate.

Although measurements were not made, the penthouse exhaust fans were definitely not operating effectively. Contaminants from the chip bins appeared to remain in the area, as evidenced by the high area sampling data. We judge that if the exhaust fans were operating at design levels, contaminant concentrations in the penthouse would be significantly reduced.

Vessel Entry Procedures

Mill 29 has a comprehensive policy for vessel entry, establishing uniform procedures for any task, vessel, manhole and sewer, and other confined areas. The overall policy is presented below:

FIGURE 29-8



DIGESTER
BLACK LIQUOR FILTER

A. Preparation for Vessel Entry:

- The vessel must be emptied, cleaned of hazardous materials and purged to place it in a safe condition.

- All lines, including sewer connections and drains that are connected to the vessels must be checked as a source of hazard by operations. If the line carries a hazardous material such as steam, gases, corrosive liquids or flammable solvents, it must comply with one of the following:

  1. It must be equipped with double valves, both of which can be closed and locked out; or

  2. The line must be blanked out with a blank of sufficient thickness and strength to withstand the maximum pressure which might be exerted upon the line; or,

  3. A section of the line must be removed.

  Written permission from the Superintendent of Maintenance or his designated alternate must be obtained to deviate from the above procedure. It is emphasized that a locked out valve cannot be depended upon to provide complete protection. If the line carries only cold water, stock, etc. and is equipped with a valve in good operating condition, the valve must be closed and locked out.

- All agitating equipment and/or power driven equipment of any kind within the vessel being entered must be locked out.

- Until the vessel is made safe for entry, electrical lighting inside the vessel is to be 12 volt or battery powered.

- Atmosphere inside the vessel must be tested and found to have at least 20% oxygen content prior to entry. Oxygen analysis is to be made by J-W O_2 gas analyzer or other approved type. Be sure to test oxygen content at various levels at which personnel may work in the vessel. The need for additional testing to be done after cleaning and before actual entry is to be determined by the responsible supervisor. Determining tests for entry into a vessel will not be an operational function, if entry is for their purpose; if not, Maintenance will assume responsibility for their purposes.

TABLE 29-4

GENERAL VENTILATION SYSTEMS

Location	Total Supply Air (cfm)	Total Exhaust Air (cfm)	Estimated Design Air Changes (per hour)
Operating Floor -			
4 heating and ventilating units	103,000		
1 makeup air unit	33,000		
Infiltration, etc.	87,500		
6 roof fans		149,400	
2 washer hoods		59,100	
1 knot drainer hood		15,000	
	223,500 TOTAL	223,500 TOTAL	48
Chip Bin Penthouse -			
Infiltration, etc.	39,850		
2 roof fans		39,850	
	39,850 TOTAL	39,850 TOTAL	48
Ground Floor and Mezzanine -			
1 heating and ventilating tank	50,000		
Infiltration, etc.	60,000		
5 wall fans		110,000	
	110,000 TOTAL	110,000 TOTAL	12

- o If tests show that it is needed, an independent fresh air ventilating system must be provided and in operation unless self contained breathing equipment is used.

- o Atmosphere inside the vessel to be entered must be tested for explosive and toxic gases by use of approved gas indicators. No entry will be permitted unless tests indicate a safe range, or protective equipment is provided. Continuing checks are to be made as work inside the vessel proceeds if possibility of release of fumes exists. The Department Manager of the operating and maintenance departments will designate personnel who will be responsible for running the necessary tests on each shift. A minimum of two people from each department should be designated this responsibility so that someone is always available to perform these tests.

- o To assist the Operations Supervisor in making the vessel safe for entry, a Vessel Check List will be followed (Figure 29-9).

- o A vessel Entry Permit and Check List is required before vessel entry, and is not valid until the required information is provided on the form and both the responsible Production and Maintenance Supervisors have signed it; except that Maintenance Department approvals are not required when there is no maintenance work involved.

- o When the vessel has been made safe to enter by the Production Department, the supervisor in charge of work being done inside the vessel will assume responsibility for the continuing safety of the men working inside the vessel.

- o Consider the need for special clothing (rubber suits, gloves, goggles, etc.) vessel entrance and exit, footing inside, cooling, fire extinguishers, radiation sources, etc. Proper personal protective equipment to be used as directed by the Supervisor.

B. Vessel Entry:

- o All personnel entering vessels are required to wear a safety body harness with life line attached to permit rapid rescue. When work has begun inside the vessel, the life line(s) may be detached by permission of the supervisor and left where it is immediately accessible, provided the

	Department to Use	Date	Time
.on	Description of Vessel		
. ntents of Vessel	Nature of Work to be Performed		

Probability of Special Hazards Existing:

		Yes	No
..	Toxic Vapors	( )	( )
2.	Flammable or Explosive Gases	( )	( )
3.	Lack of Oxygen	( )	( )
4.	Electric Shock	( )	( )
5.	Injury from Mechanical Equipment	( )	( )
6.	Burns	( )	( )
7.	Falls	( )	( )

Supervisor's Checklist:

	Yes	No	N.A.
essel drained and cleaned as is possible	( )	( )	( )
ll inlets and outlets positively closed	( )	( )	( )
essel flushed with water if practical	( )	( )	( )
urged with steam if necessary	( )	( )	( )
ll lines blanked or valves closed and locked out	( )	( )	( )
ssel thoroughly purged with air and properly ventilated until work completed	( )	( )	( )
ll pumps to vessel shut down and secured in accordance with ock-out procedure	( )	( )	( )
ll mechanical devices within vessel disconnected from power ource in accordance with lock-out procedures	( )	( )	( )
afety shower or water hose (filtered water) available (chemical anks)	( )	( )	( )
rotective equipment - shoes, boots, eye protection, hard hat, loves supplied	( )	( )	( )
roper respiratory equipment provided	( )	( )	( )
escue harness and lifeline available	( )	( )	( )
utside observer trained and properly equipped	( )	( )	( )
dequate low voltage lighting provided	( )	( )	( )
ll portable electrical tools grounded	( )	( )	( )

afety Checklist (Trained Test Equipment Operator):	Test Reading			
ombustible Gas	.....	( )	( )	( )
xygen Deficiency	.....	( )	( )	( )
arbon Monoxide	.....	( )	( )	( )
hlorine or Chlorine Dioxide	.....	( )	( )	( )
ydrogen Sulfide	.....	( )	( )	( )
emperature	.....	( )	( )	( )

PERMIT EXPIRES: Time ___ Date ___

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PERMIT APPROVED BY: ___

Fleet Equip. Supt.

conditions in the vessel have been checked and found to be safe. In the event that the work will continue for an extended period of time, the body harness may be removed if the following conditions are met:

a. It is determined that there is no possibility that toxic fumes could be released from burning or welding on the vessel.

b. No hazardous chemicals were used in the vessel that could release toxic vapors even after the vessel has been cleaned and purged.

- When Maintenance personnel are involved, written permission to remove the body harness must be obtained from the Superintendent of Maintenance or his designated alternate. When Operations personnel are involved, written permission to remove the body harness must be obtained from the Operations Supervisor.

- No employee will enter a vessel without the express permission of his supervisor and completed Vessel Entry Permit and Check List. The operations supervisor will have the responsibility of fully acquainting all employees who will enter the vessel with the operation and hazards involved before the job begins.

- At least one man (stand-by) must be stationed outside the vessel to observe those working inside, a second man must be within hearing distance in order to communicate the need for help to the appropriate people. The second man will be supplied by the Operations Department when the work is being done, when required. It is the responsibility of the stand-by man to: account for personnel working in the vessel; prevent fouling of air lines; be alert for hazards to workers; give normal assistance in handling of materials, tools, messages, etc. that does not require him to leave the immediate work area.

- Extra safety body harnesses and self-contained breathing equipment must be provided outside the vessel for rescue operations.

- All 110-volt circuits used in vessels will be grounded and service outlets must be polarized, three contact types.

C. Emergency:

- o The stand-by man will sound the alarm in the case of emergency.
- o The stand-by man, with whatever assistance is necessary, will remove personnel from the vessel by means of a safety harness, if possible.
- o If necessary, the stand-by man will secure aid to assist in the rescue.
- o <u>The stand-by man should never attempt to enter the vessel, even in an emergency, until help has arrived.</u>

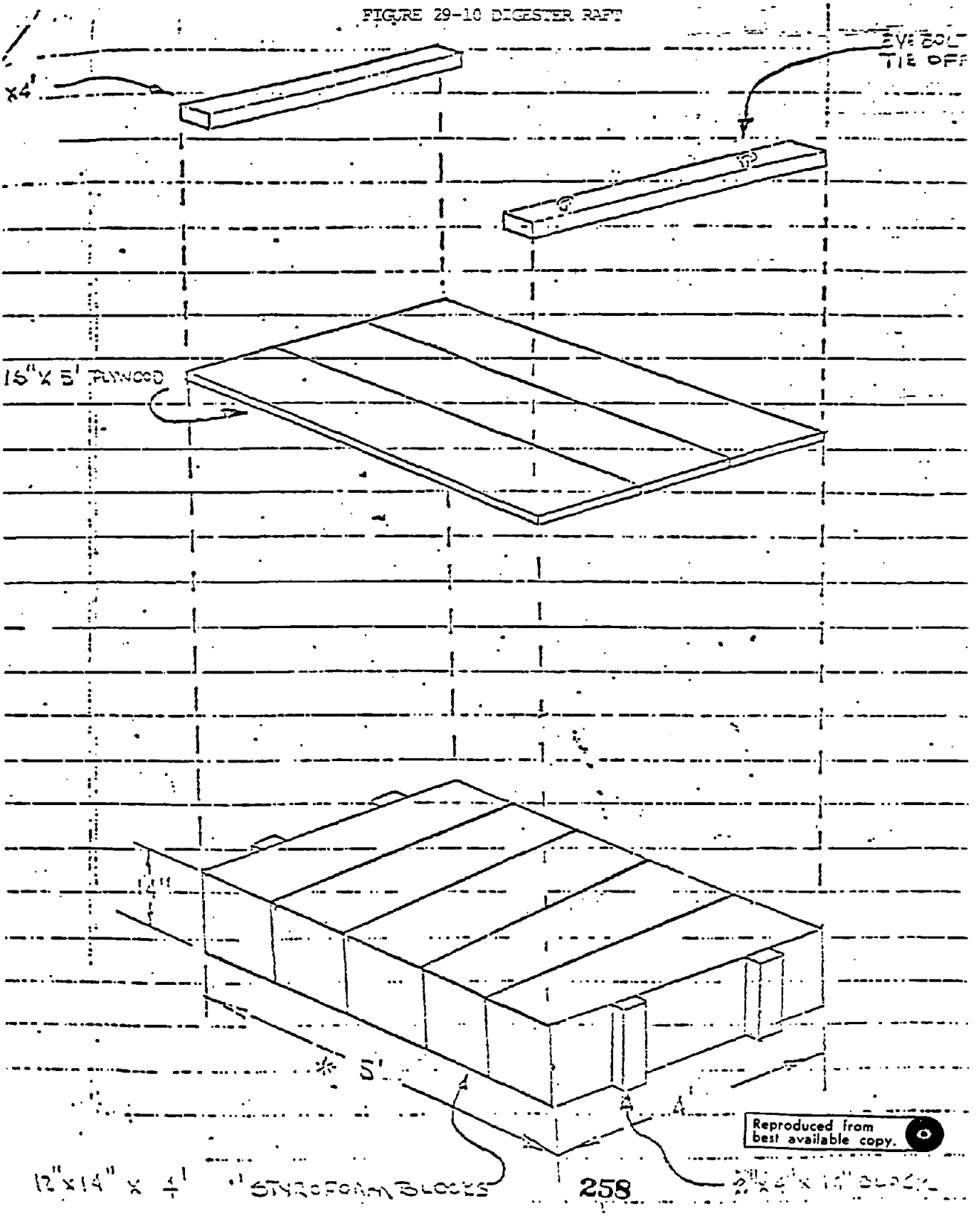
In addition to our normal vessel entry procedure, the following added measures shall be strictly observed when repairs to Digester internals require floating the Digester:

- o At all times when men are inside the Digester, a maintenance mechanic will be stationed at the top manhole to monitor air supplies, welding leads, light cords, and emergency exit equipment. The mechanic will be equipped with two radios, one on the maintenance frequency and one on the operations frequency. The mechanics inside the Digester will be similarly equipped and each will have spare batteries in his possession.
- o At all times when men are inside the Digester, an operator will man the Digester control panel to monitor and adjust water level and to provide an additional safety communications link.
- o During all floats there wil be installed a properly rigged tugger mechanism for immediate use by mechanics at the top manhole to provide emergency exit or entry capabilities to and from Digester internals.
- o There will be two rafts constructed of styrofoam blocks and plywood inside Digester on each float trip (Figure 29-10).
- o The normal crew will be two certified welder maintenance and one operator.

The following is a list of safety equipment required by mechanics inside Digester:

1 ea. - Combustibles/oxygen analyzation meter (2 maximum)

FIGURE 29-10 DIGESTER RAFT



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1 ea. - 7 1/2 volt big beam dry cell lantern (2 maximum)

1 ea. - Scott air pack for each person inside Digester (2 maximum)

1 ea. - Coast Guard approved life jacket for each person inside Digester

1 - Operations frequency radio in good operating order

1 - Maintenance frequency radio in good operating order

1 - Spare battery for each radio

1 - Spare battery for dry cell lantern

1 ea. - Safety harness W/8 ft. lanyard

The following is a list of safety equipment required at top of Digester:

1 ea. - Scott air pack

1 ea. - Maintenance frequency radio in good operating order

1 ea. - Operations frequency radio in good operating order

1 ea. - Spare batteries for above
200' of 3/4" air line to be lowered into vessel
200' of 3/8" nylon rope

1 ea. - 104 tugger mechanism properly rigged

1 ea. - Safety harness

While it is the responsibility of the area scheduler and foreman to provide the materials, it is ultimately the responsibility of the foreman in charge of the Digester repair float to insure that all safety equipment is on hand and in good working order and that all safety procedures are strictly followed.

The following is a list of equipment to be locked out before entry:

1. Top separator drive.
2. Outlet device drive.

Pumps and Valves to be Locked Out:

(Suction and discharge of these pumps to be locked closed with the bleed-off valve open).

PUMPS

1. Lower cooking pump
2. Upper cooking pump
3. Wash circulation pump
4. Make-up liquor pump
5. Spare make-up liquor pump
6. White liquor supply pump (Area 17 for #1 and area 18 for #2).
7. Top circulation pump
8. White liquor purge pump
9. Black liquor filtrate to cold blow pump
10. Acid cleaning pump
11. Quench circulation pump

VALVES

1. White liquor to level tank (2 places)
2. Crossover valve for the spare make-up liquor pump
3. Make-up liquor manual valve (V-53)
4. Steam to the steaming vessel (2 valves)
5. 165 lb. steam to digester vent line (2 valves)
6. Heater discharge valves (6 each)
7. Manual counter wash valves (omit if floating the Digesters)
8. Manual pressure control valve (omit if floating the Digesters)
9. T-C refill valve (V-54)
10. Cooking heater steam valve (3 each)
11. Wash circulation steam valve
12. Black liquor to the level tank
13. Liquor to the bottom of the digester (V-69 for batch cook)
14. Blow steam valve on the blow line.

PREVENTIVE MAINTENANCE PROGRAM

Mill 29 has a highly structured and detailed preventive maintenance program. The equipment lubrication schedule is totally computerized, with sequenced tasks printed out on a regular schedule. The print-out identifies the specific equipment, the lubricant and method, and the frequency.

Mechanical and electrical/instrumentation maintenance are scheduled around planned and unplanned outages. For each process line, there are two planned shutdowns per year. Many of the major preventive maintenance tasks are scheduled for these shutdowns. Additional tasks are scheduled for unplanned outages and minor shutdowns.

Although it is virtually impossible to qualitatively evaluate the beneficial effects of preventive maintenance activities on worker exposure, we did not observe many process leaks during the survey.

MILL 33 KRAFT PULPING PROCESS USING M & D DIGESTER

INTRODUCTION

Mill 33 produces about 100 tpd of Kraft pulp from softwood refuse (sawdust and shavings) in a Bauer M & D digester. The pulp is washed in a single-stage brown stock washer, then transferred to a two-stage washer line located in the main pulp mill. The M & D plant was built in 1966 and is part of a large Kraft pulp mill that also uses both batch and Kamyr continuous digesters. Mill 33 is located in the Southern United States.

PROCESS SUMMARY

The sawdust and shavings are dumped into an unloading pit from both trucks and hopper cars. From the unloading pit, refuse is pneumatically conveyed to a wood refuse silo or to an outside, open top storage pile. As required, a bull-dozer replenishes the digester pit with residuals from the storage pile.

From storage, the residuals are blown to a cyclone separator located atop the M & D plant, and drops into a pre-steaming tower. The tower is used as a surge bin to provide a constant supply of residuals to the Digester. A level device mounted on the side of the tower controls the operation of the reclaim conveyor from the unloading pit. The residuals pass through a metering feeder, and are heated and wetted with blowby steam from the inlet feeder valve. It exits the feeder through a rotary inlet valve - a volumetric feeder with a variable speed drive that can be adjusted manually to set the overall production rate. The inlet valve also serves as a lock to retain steam pressure in the digester. The rotary feed pockets are relieved through a cyclone, and vented to the atmosphere.

The M & D digester is a large, inclined tube with a midfeather and flight conveyor that transports the feed material from the inlet, down the top side, around the lower end, and back up the bottom side to the discharge nozzle. As the refuse enters the digester, it is exposed to steam pressure, and contacts cooking liquor entering just below the inlet valve. As the refuse is conveyed down the top side of the conveyor, live steam is added to maintain the desired cooking temperature. The cooked stock and excess liquor exit the top of the digester through a discharge nozzel into a vertical surge tube. The surge tube is used to maintain a liquid level over the blow valve, thereby preventing live steam from passing to the blow tank. Black liquor is added to the blow line to cool the stock and facilitate blowing.

The stock and excess liquor are discharged under pressure to the blow tank, located just outside the M & D plant. The blow gases pass through a vapor separator and enter a spray-type barometric condenser. The non-condensable gases are collected and burned in the lime kiln. The condensables drop into a dirty hot condensate tank and are pumped to the water accumulator in the main pulp mill.

In the bottom of the blow tank, the cooked stock is further diluted with filtrate from the brown stock washer. It is then pumped to the brown stock washer, located on the operating floor just outside the control room. After vacuum-drum washing, the stock is repulped and pumped to a two-stage brown stock washer in the main pulp mill for additional washing.

JOB CATEGORIES AND DESCRIPTION

The complete pulp mill is operated by a six man crew, but only one of the crew, the First Assistant Operator, is responsible for the M & D plant. This operator controls the process from a closed control room located on the operating floor near the pulp washer. Every hour, he collects a stock sample from the outlet side of the brown stock washer, and a sample of the washer filtrate used for vat dilution. The operator also measures the temperature and specific gravity (Baume scale) of the filtrate. All samples (and an accompanying report) are sent to the main control room for analysis.

The Operator also conducts an hourly inspection tour of the plant, and purges the blow valve with filtrate twice a shift. We estimate that he is in the control room for 90 percent of each shift.

AIR SAMPLING RESULTS

The M & D digester was not operated until the third day of the survey. We collected three personal samples for methyl mercaptan on the operator (Table 33-1), the first two during the start-up, and the last during normal operation. No methyl mercaptan was detected on any of these samples. Since the operator is frequently in the control room, three area samples were collected there for methyl mercaptan. They also resulted in non-detectable levels.

The only significant source of exposure observed during the survey was the counter-weighted blow tank valve, located near an open window leading to the operating floor. Steam and process gases were frequently emitted from this valve. We measured 15 ppm of methyl mercaptan and 17 ppm of ethyl mercaptan using detector tubes. To determine if these gases were entering the workplace, a methyl mercaptan sample was

Worker or Location	Day	Shift	Sampling Period (min.)	Results: Methyl Mercaptan[1] (ppm)	Results: Hydrogen Sulfide[2] (ppm)	Results: Ethyl Mercaptan[3] (ppm)
Operator	3	1	17	<0.07		
			15	<0.08		
	4	1	16	<0.07		
Control Room	3	1	107	<0.01		
			15	<0.08		
	4	1	55	<0.02		
Window Behind Control Room Adjacent to Blow Tank Relief Valve	4	1	14	0.24		
Brown Stock Washer Control Panel	4	1	158	0.05		
Mezzanine Around Top of Digester	4	1	180	0.04		
In Blow Tank Relief Valve Plume	4	1	-	15[4]	ND	17
Above Inlet Vat of Brown Stock Washer	4	1	-	2[4]	ND	1
Beside Brown Stock Washer Control Panel	4	1	-		ND	

[1] Method of Knarr and Rappaport, Analytical Chemistry, 1980, Vol. 52, pp 733-736

[2] Gastec Detector Tube

[3] Gastec Detector Tube

[4] Gastec Detector Tube

Table 33-1: Personal and Area Sampling Data

collected just inside the window. Although little methyl mercaptan was detected (0.24 ppm), these relief gases could periodically contaminate the operating floor and the control room during certain weather conditions. Area samples for methyl mercaptan were also taken at the brown stock washer control panel and on the mezzanine floor above the digester (next to the pre-steaming vessel). Both of these samples resulted in low concentrations (0.5 and 0.4 ppm, respectively), indicating only minor workplace contamination.

Hydrogen sulfide does not appear to be a major constituent in the process gases. Detector tube samples taken above the blow tank relief valve, in the brown stock washer hood (vat side), and at the washer control panel all resulted in non-detectable levels of this gas.

Although based on limited sampling data, we conclude that the M & D plant operator's exposure to methyl mercaptan, hydrogen sulfide, and other process gases is usually low.

CONTROL OF WORKER EXPOSURE

The lack of worker exposure to process gases is attributed to the following factors:

- The pulping process is totally closed.
- Non-condensable gases from the blow tank and the dirty hot condensate tank are piped to the lime kiln and incinerated.
- Except for the pre-steaming vessel and the top of the digester, all process equipment is located outside.
- The equipment is well maintained.
- The operator remains in the control room for 90 percent of each shift.
- The brown stock washer is hooded and ventilated. We measured adequate face velocities of 150 - 250 fpm.

MILL 38: KRAFT PULPING PROCESS (BATCH AND KAMYR CONTINUOUS DIGESTERS)

INTRODUCTION

Mill 38 produces about 950 tpd of Kraft pulp in six batch digesters and one Kamyr continuous digester. The batch digester pulping line was built in the 1950's, cooks hardwood chips, and includes a three-stage brown stock washer. The continuous digester line was added during the 1960's for softwood pulp, and includes a two-stage brown stock washer.

Mill 38 is located in the Southeastern United States.

PROCESS SUMMARY

The chip delivery system for both pulping lines and the charging system for the batch digesters were automated in 1980. The chips are stored in four large silos located outside the mill. Two of these silos hold hardwood chips for the batch digesters; the other two supply softwood chips to the continuous digester.

As needed, the hardwood chips are conveyed to the tripper conveyor, and are automatically charged into the batch digesters through a 20-inch capping valve. Required quantities of black and white liquor are measured, mixed, and added through a pipe located above the capping valve. When the digester is fully loaded with chips and liquor, the capping valve is closed and the cooking cycle is started. All but one of the digesters cook with live steam.

The digesters are automatically relieved to a cyclone and condenser. The condensate and liquor are piped to the knot mix tank for the black liquor charge to the next digester. Excess steam goes to the heat accumulator or atmosphere depending on need for excess heat.

At the end of the cooking cycle, the pulp and spent liquor are discharged under pressure to the blow tank. The stock is diluted with strong filtrate and pumped to the deknotter preceding the first stage brown stock washer. The knots and other oversize material are removed, and dropped into the black liquor knot mix tank. The deknotted stock is then washed countercurrently with recirculated filtrate and mill white water on three rotary vacuum drum washers. The cleaned stock is screened and pumped to storage.

The gases from the blow tank pass through a cyclone separator and enter a jet condenser located on top of the blow heat accumulator. The condensables and hot water drop into the accumulator tank, and the non-condensable gases are piped to the lime kiln for incineration.

The continuous digester process is based on conventional Kamyr technology (See Mill 9 report for a detailed process description). In the bottom of the digester, the cooked chips are washed with weak filtrate and discharged under pressure to a blow tank. The blow gases are piped to a turpentine condenser. The turpentine is separated in a decanter and stored; the non-condensable gases are vented to the atmosphere.

From the blow tank, the stock is pumped through a knotter screen into the inlet vat of a vacuum drum washer. It is washed countercurrently with second stage filtrate. The first stage filtrate is piped to the strong liquor filtrate tank. Air removal and vacuum for the first stage filtrate tank is provided by a blower atop the tank. Liquid carryover is removed in a cyclone, and drops into the tank; gases and vapors are exhausted to the atmosphere.

The second washer (third-stage washing) has a vacuum assist system identical to the first stage washer, except that the blower sits atop the weak liquor filtrate tank. In the third stage, the stock is washed with clean process water. From this final stage, the stock is pumped to one of two stock chests, and then to the screen room.

JOB CATEGORIES AND DESCRIPTIONS

The pulp mill is operated by a six man crew:

Brown Stock Operator - The operator is responsible for the entire brown stock area. He pays particular attention to the Kamyr continuous digester and stays in the control room for a large percent of each shift.

Second Brown Stock Operator - The second operator assists the operator and carefully watches the batch digester line. He also remains in the control room a large percent of each shift.

First Assistant Brown Stock Operator - The first assistant operator is responsible for the M&D digester located in a separate building.

Second Assistant Brown Stock Operator - The second assistant operator is responsible for the brown stock washers and screens on both process lines. He conducts frequent inspections of equipment, responds to process upsets, and takes the following quality control measurements:

- o strong liquor temperature (hourly)
- o strong liquor specific gravity (hourly)
- o soda loss (every two hours)

This employee is in the control room for about 65 percent of each shift.

Third Assistant Brown Stock Operator - The third assistant operator is basically the pulp tester, collecting and analyzing pulp and white liquor samples from both process and lines every hour. He also is responsible for housekeeping duties around the Kamyr continuous digester. We estimate that he spends about 50 percent of each shift in the control room or the test shack.

Batch Digester Helper - This job category has recently been eliminated. However, during our survey, the helper served primarily as a utility man, frequently cleaning the chip feeding floor and the stock washer area. Occasionally the helper checked the temperature and specific gravity of the strong filtrate for the batch digester line brown stock washers.

AIR SAMPLING RESULTS

We collected nine personal samples for methyl mercaptan on the second and third assistant operators, and the batch digester helper (Table 38-1). All samples were collected while these employees were out of the control room for at least ten minutes, and none exceeded 15 percent of the OSHA ceiling PEL of 10 ppm. These data indicate that worker exposures to methyl mercaptan are usually low.

Potential exposures to other process gases were estimated using area samples (Table 38-2). Samples for methyl mercaptan (0.06 ppm; 0.06 ppm), turpentine (0.5 ppm; 0.75 ppm), other terpenes ($<$0.01 ppm; $<$0.01 ppm) and total hydrocarbons ($<$0.02 ppm; $<$0.01 ppm) demonstrate a lack of contamination in the control room. This is attributed to the Purafil filters in the HVAC system, and the double door air locks leading to the control room.

Other area sampling results and conclusions are presented below:

- A single sample collected in the test shack resulted in a 0.2 ppm of methyl mercaptan, higher than in the control room but not excessive.

- Several samples taken directly above the Kamyr digester chip bin resulted in 0.8 ppm methyl mercaptan and 13.9 ppm turpentine. We detected no other terpenes (0.01 ppm), total hydrocarbons ($<$0.02 ppm), hydrogen sulfide, or total mercaptans. These data indicate that the relief gases from the low pressure feeder are effectively absorbed on the chips. .

Job Category	Day	Shift	Sampling Time	Methyl Mercaptan Concentration (ppm)	OSHA Ceiling PEL (ppm)	Comments
Second Assistant Operator	1	1	15	< 0.08	10	Washing down around Kamyr Washers
	2	1	15	0.12	10	Quality Control Samples - Batch Digester Washers
		2	19	0.18	10	Inspection Tour - Stock & Filtrate Pumps
Third Assistant Operator	1	1	15	0.16	10	Standard Sample Collection
		2	16	0.37	10	" " "
		2	15	0.72	10	" " "
		2	15	0.83	10	" " "
Batch Digester Helper	1	2	15	0.08	10	Temperature, Specific Gravity 'A' Line; Housekeeping
	3	1	15	1.1	10	Inspect Batch Digester Tripper Conveyor

1 Method of Knarr and Rappaport, Analytical Chemistry, 1980, Vol. 52, pp 733-736

TABLE 38-1: PERSONAL SAMPLING RESULTS

TABLE 38-2: AREA SAMPLING DATA

Location	Day	Shift	Sampling Time	Methyl[1] Mercaptan	Total[2] Mercaptans	Dimethyl[3] Sulfide	Hydrogen[4] Sulfide	Turpentine[5]	Other[5] Terpenes	Total[5,6] Hydrocarbons	Resin[7,8] Acids	Phenols[7,9]	Alcohols[7,10]
Control Room	2	1	90	0.06				0.5	<0.01	<0.02			
	4	2	60	0.06				0.75	<0.01	<0.01			
Test Shack	2	2	102	0.2									
Kamyr Chip Bin	2	1	60	0.8				13.9	<0.01	<0.02			
	2	2	-		ND		ND						
Batch Digester Chip Loading Floor	3	1	60					1.5	<0.01	<0.02	<0.12	<0.02	<0.12
Kamyr Pre-steaming Vessel	2	1	15	0.33									
Batch Digester Brown Stock Washers	2	2	53								<0.13	0.66	2
	4	2	60	<0.04									
Kamyr Brown Stock Washers	1	2	-		ND	8	ND						
	2	2	180	<0.01									
Make Up Air Duct - Control Room HVAC	4	2	70					0.5	<0.01	<0.02			
Pulp Mill Roof													
Black Liquor Tank Vent	2	2	-		ND		ND						
Batch Digester Turpentine Condenser Vent	2	2	-		<200		ND						
Batch Digester Washer Exhaust Duct					ND								
					~10								

[1] Method of Knarr & Rappaport, Analytical Chemistry, 1980, Vol. 52, pp 733-736

[2] Drager Detector Tube

[3] Gastec Detector Tube

[4] Drager Detector Tube

[5] Collected on Charcoal Tubes

[6] As M-xylene

[7] Collected on Silica Gel

[8] As Acetic Acid

[9] As Phenol

[10] As Ethanol

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- The samples taken on the batch digester chip loading floor resulted in 1.5 ppm turpentine, and non-detectable levels of other terpenes (<0.01 ppm), phenols (<0.12 ppm) and alcohols (<0.12). No area samples for reduced sulfur compounds were collected, but a personal sample for methyl mercaptan collected while the digester helper was inspecting the tripper conveyor (Table 38-1) resulted in a concentration (1.1 ppm) below the OSHA ceiling PEL of 10 ppm.

- A sample taken near a leak in the pre-steaming vessel resulted in a relatively low level of methyl mercaptan (0.33 ppm).

- No methyl mercaptan was detected near either brown stock washer line (<0.04 ppm and <0.01 ppm). A silica gel sample near the batch digester washers resulted in 0.66 ppm phenols (as phenol) and 2 ppm alcohols (as ethanol); no resin acids were detected (<0.013 ppm). Detector tube samples near the Kamyr digester washers resulted in 8 ppm dimethyl sulfide; no hydrogen sulfide or mercaptans were detected.

- Detector tube samples[1] taken in the batch digester washer exhaust stacks resulted in a non-detectable level of mercaptan in the third stage vent and about 10 ppm in the first stage vent.

- A charcoal tube sample taken inside the control room HVAC make-up air duct (upstream of the Purafil filters) resulted in 0.5 ppm turpentine and non-detectable levels of other terpenes and total hydrocarbons.

- Detector tube samples for total mercaptans were taken in the black liquor tank vent (not detected) and the batch digester turpentine condenser vent (>200 ppm). The relative high concentration in the condenser vent is not surprising, but there were no indications during the survey that these vented gases are re-entering the pulp mill building.

CONTROL OF WORKER EXPOSURE

Batch Digesters - The chip and liquor charging system was automated in 1980 and has undoubtedly reduced worker exposure to process gases and other airborne contaminants. Prior to this improvement, the digesters were manually uncapped, loaded,

[1]All of the detector tube samples are subject to positive interferences of unknown proportions from all reduced sulfur compounds. The data are interesting for comparison purposes, but must be viewed strictly within this context.

and resealed. Contaminants could also be released when the digesters were first uncapped. Also, the connection between the chip hopper and the charging nozzel was not totally closed, and process gases could be displaced from the digester, through the openings, and into the workplace. The circular exhaust hood (Figure 38-1) contained and removed a portion of the emissions, but some contaminants likely entered the workplace. The automated chip and liquor charging system consists of a 20 inch capping valve and solid connection between the chip hopper and the digester charging nozzel. The loading cycle is now totally controlled by an Accurary 4200 Micro Systems Computer and a Honeywell TDC-2000 Analog controller. The potential for worker exposure is significantly reduced in two important ways:

- Worker isolation - employees no longer are required to be on the chip loading floor during the charging cycle

- Containment - since the connection between the chip hopper and the charging nozzel is totally closed, steam and process contaminants displaced from the digester exit through the hopper to the chip conveyor mezzanine. Some of the contaminants are absorbed on the chips, and most of the rest are diluted and removed by natural and forced general ventilation.

The remainder of the cooking process is totally closed, and there are no continuous sources of contaminant emission. The digesters are automatically relieved to a turpentine condenser, and the non-condensable gases are vented to the atmosphere above the digester building. During the survey, there was no indication that these vented gases were re-entering the workplace. However, since this is a function of weather conditions, the overall significance of re-entry could not be completely assessed.

The blow gases are also condensed, but the non-condensables are piped to the lime kilns for incineration. However, some of the gases are discharged to the atmosphere through a combination pressure/vacuum relief valve atop the blow tank. As before, the potential for contaminant re-entry could not be adequately assessed.

Kamyr Digester - The Kamyr continuous digester and auxiliary equipment are totally closed, and do not appear to be a source of extensive employee exposure. The process is computer controlled, and employees are only in the area infrequently to collect quality control samples or for maintenance operations. The third assistant operator's ceiling exposure to methyl mercaptan during sample collection runs ranged from 0.15 ppm to 0.83 ppm (Table 38-1), less than 10 percent of the OSHA PEL.

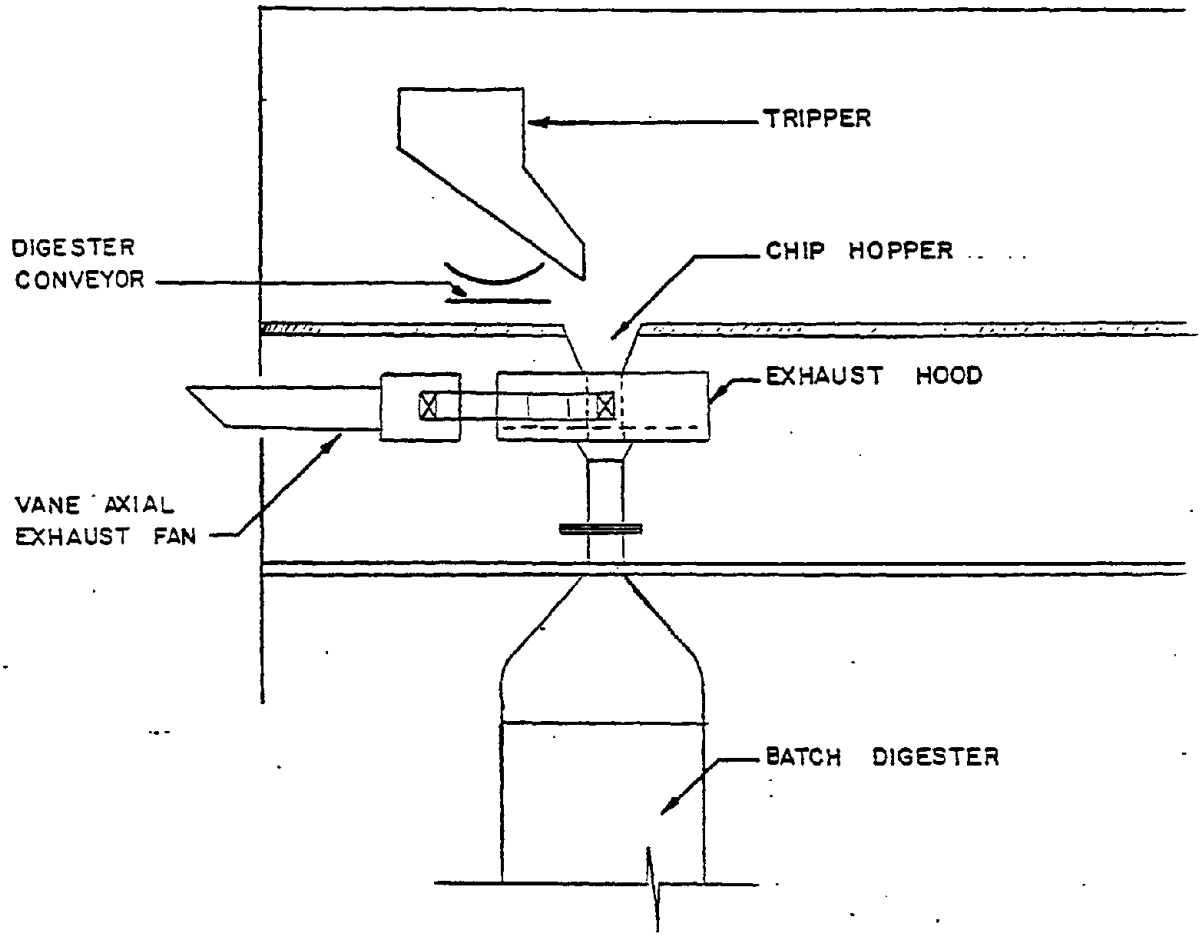


FIGURE 38-1

OLD BATCH DIGESTER EXHAUST SYSTEM

BROWN STOCK WASHER EXHAUSTS

Both brown stock washer lines are provided with canopy hoods and exhaust fans to remove steam and process gases from the workplace. The hood for the batch digester washer line has three exhaust fans, each rated at 25,000 CFM. Given the dimensions of the hood (~11,000 cubic feet), this corresponds to approximately 7.5 air changes per minute. The actual operating level of each fan could not be measured, but inward velocities around the perimeter of the hood ranged from 100 fpm to over 250 fpm. Both area and personal sampling data (Tables 38-1 and 38-2) demonstrate that the hood exhaust system is very effective. Also, two detector tube samples taken in the first and third stage exhaust outlets resulted in relatively low levels of total mercaptans (10 ppm and not detected, respectively). Evidently, the stock washers do not emit large quantities of reduced sulfur compounds.

The Kamyr digester line hood has two exhaust fans of unknown rating. However, perimeter velocity measurements (100 fpm to 200 fpm), observations, and area/personal sampling data indicate that the hood is also effective in controlling workplace contaminant emissions.

Control Room Ventilation

When the process computer was installed in 1980, the control room was modified and expanded, and equipped with a new ventilation system. The system is designed to provide 5600 CFM of tempered air to the control room, or an estimated 30 air changes per hour. Of the total 5600 CFM, about 80 percent is return or recirculated air and the remainder is fresh air make-up. The system has two separate Purafil filters; one in the fresh air make-up duct (100 pounds), the other in the combination return air/fresh air make-up duct (300 pounds). In the past year, the Purafil has been replaced twice. When the system was first installed, there were complaints of objectionable odors and eye irritation. An investigation revealed that the source of the problem was infiltration into the combined return air/fresh air make-up duct downstream of the Purafil filter. The ductwork has since been sealed, and the complaints have not recurred. Air samples collected in the control room (Table 38-2) confirm a lack of contamination in this area.

Because only about 80 percent of the supply air is exhausted and returned, the control room is under a relatively strong positive pressure. This significantly reduces infiltration of process contaminants through the control room doors. This protection is enhanced by double-door air locks installed for each entrance into the control room.

Finally, the fresh air make-up system is provided with two separate intakes, which can be changed by a damper depending on the direction of the wind and other meteorological conditions. This dual intake system reduces contamination of the fresh-air and thus lessens the burden on the Purafil filters.

In conclusion, we believe that the control room ventilation system is extremely well designed and effective.

Personal Protective Equipment - Four full-face, canister type respirators (Willson Type N) are stored in the control room, for use at the discretion of the employees. There is also a Scott Air Pak stored in the control room in the basement of the pulp mill. All of these units are inspected on a monthly basis.

Workplace Air Monitors - During the survey, a four-channel, Texas Analytical Control Model 404A Hydrogen Sulfide monitor was being installed in the control room. Three of the sensors will be positioned in the batch digester and bleach plant basements, near the Kamyr digester; the location of the fourth sensor has not been determined. The Texas Instrument unit replaces a four-channel Bacharach J-W Automatic H_2S Monitor which was reported to be unreliable. The instrument is calibrated monthly using a dynamic gas generator and permeation tube.

Vessel Entry Procedures - Mill 38 has a very thorough vessel entry procedure (Appendix 38-A) including a vigorous entry permit system (Figure 38-2).

PERMIT FOR ENTERING VESSEL

Vessel #_____ Date of Issue:_____ Time_____

Date Expires:_____ Time_____

IMPORTANT
Lines are not to be unlocked or connected while vessel is under this permit.

Department_____ Location of Vessel_____

Last Material in Vessel_____

Work To Be Done_____

_____

SPECIAL PRECAUTIONS:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

ENTRY APPROVAL:

Atmosphere
Checked by:_____

Dept.
Supervisor_____

Mech.
Supervisor_____

CHECK LIST ON OTHER SIDE BEFORE APPROVING

TEAR ALONG PERFORATED LINE

PERMIT FOR ENTERING VESSEL

Vessel #_____ Date of Issue:_____ Time_____

Dept_____ Date Expires:_____ Time_____

Name of Vessel_____

CHECK TYPE WORK:
Operational ☐
Maintenance ☐

Signatures — Atmosphere
Checked by:_____

Dept.
Supervisor_____

Mech.
Supervisor_____

IMPORTANT: THIS PORTION OF THE PERMIT IS TO BE RETURNED TO THE SAFETY SUPERVISOR AFTER THE SAFETY CHECK AND SIGNATURES ARE COMPLETED.

Figure 38-2

VESSEL ENTRY SAFETY CHECK LIST

GENERAL

- A1 ☐ Temperature and atmosphere within vessel are safe
- A2 ☐ Safety observer on hand
- A3 ☐ Depth of material in vessel
- A4 ☐ Stock lines blanked
- A5 ☐ Steam lines blanked
- A6 ☐ Acid or caustic lines blanked
- A7 ☐ Other lines blanked
- A8 ☐ Natural and/or mechanical ventilation provided
- A9 ☐ Isolation transformer or low voltage power provided
- A10 ☐ Electrical connections to agitators, pumps, heaters, etc., disconnected and tagged
- A11 ☐ Other precautions to be taken

PROTECTIVE EQUIPMENT NECESSARY

- B1 ☐ Air line respirator
- B2 ☐ Gas mask
- B3 ☐ Dust respirator
- B4 ☐ Fume respirator
- B5 ☐ Goggles
- B6 ☐ Face shield
- B7 ☐ Special boots or shoes
- B8 ☐ Protective clothes
- B9 ☐ Source of water
- B10 ☐ Rubber blankets
- B11 ☐ Safety belt and line
- B12 ☐ Other precautions to be taken

TANK CHECKS MADE

- C1 ☐ Explosive atmosphere
- C2 ☐ Sufficient oxygen
- C3 ☐ Hydrogen Sulfide
- C4 ☐ Chlorine Dioxide
- C5 ☐ Chlorine
- C6 ☐ Carbon Monoxide
- C7 ☐ Sulphur Dioxide
- C8 ☐ Other toxic material

Figure 38-2 (Continued_

APPENDIX 38-A

ENTRY INTO CONFINED SPACES

ENTRY INTO CONFINED SPACES

A. PROCEDURE

1. This procedure covers entry into any tank, manhole, vessel or confined area, that ordinarily contains materials and is not normally occupied by people.

2. Because of the many different types of equipment in use, this should serve as a minimum policy. Special equipment such as boilers, precipitators and recovery boilers will require a special entering procedure. These procedures should be determined by equipment and condition.

B. PURPOSE

Because confined spaces must be entered for purposes of inspection, cleaning and repairs, this policy is mandatory.

C. RESPONSIBILITY

Entrance into any tank, vessel or any other confined space by an employee will only be made when adequate steps to safeguard the employee have made made.

I. The responsible supervisor of the men entering the tank will implement the vessel entry procedure.

a. Ensure that the employee is fully informed of the conditions he might encounter in the space.

b. Personally ensure that the space is in safe condition for entry.

c. Comply with (a) and (b) above, whether the employee is a member of the maintenance department, production department, or from an outside source.

d. Be responsible to ensure that the employee entering the confined space is properly equipped with protective clothing, hard hat, safety shoes and necessary respiratory devices and is familiar with the operation of this equipment.

II. Permit for entering vessel

a. Gas tests, when necessary, shall be made by the supervisor of the men entering the vessel. Gas tests shall be made only by trained supervisors. Training shall be provided by the Mill Coordinator of Safety.

b. A tank entry permit will be completed accurately in all detail. An authorized signer (supervisor of men entering vessel) must, by personal investigation immediately before entry and before signing the permit, determine that entry and incidental work will be safe. If a pause or stoppage of appreciable duration occurs during the carrying out of the job, the area must be re-investigated and tested before the job can be allowed to recommence. The approved tank Entry Permit shall be attached or displayed at the primary entry point of the vessel. Make sure that the detached portion of the "Permit for Entering Vessel" is returned to the Mill Safety Office.

D. PREPARATION OF SPACE

1. The product in the space shall be drained off, pumped out, floated off or otherwise safely disposed of before entry into the space is permitted.

2. The space shall be made clean (void of residual product) by the best practical method; by washing with hot or cold water, flushing or steaming. If steamed, it should be cooled before entry.

   a. In a space where static electricity is a problem, steam should be introduced at relatively low pressures and low velocity.

   b. Steam lines should be electrically bonded to the metal confining the space to drain away static as it is generated.

3. The space should be thoroughly ventilated by the use of natural ventilation, fans, blowers, or an air mover of the eductor type. It is preferable to exhaust vapors through the roof manholes to facilitate dispersion into the surrounding air, thereby reducing the possibility of gas pockets collecting at ground level. The atmosphere in the space must be tested by the safety coordinator or otherwise qualified person, for contamination or oxygen deficiency to determine its suitability before entry is made.

4. a. All lines including sewer connections which are connected to the confined space must be checked as a source of a hazard. If the line carries only cold water and is equipped with a valve in good operating condition, tagging and locking will suffice.

b. If the line carries a hazardous material such as steam, corrosive liquids or flammable solvents, it should comply with one of the following; (1) it must be equipped with double valves both of which can be locked out; (2) the line shall be blanked off with a blank sufficient thickness and strength to withstand the maximum pressure which might be exerted upon the line, or (3) a section of the line removed.

E. GUARDING AGAINST ACTIVATION OF MECHANICAL APPARATUS IN THE CONFINED SPACE

1. If any mechanical apparatus is installed in the confined space, its activation should be guarded against by the use of the regular tag out procedure with the addition of lock outs of all disconnects, control levers or valves. If the apparatus is air, water or steam operated, the lines supplying power should be disconnected. This includes the supply as well as the exhaust.

2. The keys to all locked out equipment should be kept by the men involved in the work being performed in or on the confined space.

3. There will be cases where it is not practical to break all lines. Written permission should be obtained from the plant engineer to deviate from the above procedure, and he should state the alternate safe procedure.

4. <u>It is emphasized that a locked out valve CANNOT be depended upon to give COMPLETE protection</u>

F. PROCEDURE BEFORE CONFINED SPACE ENTRY

1. All personnel responsible for work in a confined space must be required to read over the "ENTRY INTO CONFINED SPACES" Procedure.

2. All personnel must be informed as to the nature of the material contained in the confined space and about any hazards they may encounter in or outside the confined space in connection with the work they are about to perform.

3. A test of the atmosphere in the confined space must be made by a qualified person immediately prior to anyone being allowed to enter if the confined space has held any flammable or harmful product before flushing, if it contained any sludge or residue, or if oxygen deficiency is suspected.

4. Instruments for this purpose are located in the Instrument Shop. We have a Drager Multi-Gas detector, a Bacharach oxygen indicator and a M.S.A. Explosimeter.

5. Depending on the conditions, the following tests should be performed and in this order:

   a. Flammable vapors (test with explosimeter)

   b. Methane (CH_4) is frequently encountered. Being flammable, it will be detected by the explosimeter. Carbon dioxide (CO_2 is another gas frequently encountered and should be checked for its concentration. Both of these gases are classed as simple asphyxiants and are dangerous because they displace oxygen in the air.

   c. Toxic gases which might be encountered:

      1. Hydrogen Sulfide (H_2S)
      2. Carbon Monoxide (CO)
      3. Chlorine Dioxide (ClO_2)
      4. Ammonia (NH_3)
      5. Sulfur Dioxide (SO_2)
      6. Chlorine (Cl_2)

   d. Oxygen deficiency

6. As gases may leak into the confined space or an oxygen deficiency may be created, forced ventilation should be continued as long as the men are in the confined space. Care must be exercised to ensure that uncontaminated air will be supplied by the forced ventilation. A complete change of air every five minutes should be maintained. Air must be introduced in such a way as to ensure thorough ventilation. The air must be carried to the bottom of the tank by a canvas sleeve on the confined spaces with top manholes only. Tests for atmosphere must be made at predetermined intervals, particularly before re-entering after an interruption. Men entering confined spaces must wear some form of respiratory protection which supplies an independent air supply until atmosphere tests at various points in the confined space prove safe. Men who enter a confined space before the air can be tested should be equipped with a self-contained breathing apparatus.

7. Two or more men will always be assigned to any task involving vessel entry. While men are in the confined space, they shall be under constant observation by a man outside. In any instance where the exposure in

the tank requires an employee to wear respiratory protection or where rescue may be difficult, he must be provided with a body harness with life line attached.

8. Every person entering any confined space must wear a rescue harness. If entry is through a manhole, a life line should be attached to the harness.

G. TOOLS

1. All tools must be in good condition.

2. Where explosive atmospheres may be encountered, only non-sparking tools are to be used.

   If electrical tools are used or welding performed, the atmosphere must be continuously tested for the vapors while the sources of ignition are in use.

3. All electrical tools and lights must be properly grounded. Lights shall be of heavy construction and provided with heavy well insulated cable to stand up under conditions that may be encountered. Only electricians are permitted to make connections and replace burned out bulbs. It is recommended that portable hand lamps have isolated transformers built into the circuitry and operate on 12 volts.

4. When welding is required, the necessary welding permits must be obtained. In electric welding, the men should be provided with, and required to use, rubber blankets and other such protective equipment as needed. Whenever it becomes necessary to cut into a vessel, approval of the Superintendent of Engineering should be obtained and the procedure outlines under F. 3. must be followed to determine whether or not flammable vapors are in the vessel.

5. Fire extinguishing equipment should be on hand at the job site.

6. Paint on any confined spaces should be assumed to have a high lead content. If it is burned, chipped, scraped or sanded, an approved lead fume respirator or an approved dust respirator should be used.

7. Ladders used in confined spaces should be lashed to the top and, if possible, at the bottom. The ladder should never be removed while workers are in the vessel.

a. In confined spaces which are lined, it is recommended that engineering and safety departments approve the ladders to be used.

b. All rope ladders, hoists and life lines should be tested periodically.

H. PERSONAL PROTECTIVE EQUIPMENT

1. PERSONAL PROTECTIVE EQUIPMENT IS NOT AN ADEQUATE SUBSTITUTE FOR SAFE WORKING CONDITIONS, ADEQUATE VENTILATION, AND INTELLIGENT CONDUCT ON THE PART OF SUPERVISORS AND EMPLOYEES.

   Such equipment may protect the individual wearing it, but it will not help others in the area who may be exposed to the danger. The correct use of personal protective equipment requires the education of the worker in the proper employment of the equipment available to him. Its use should be carefully supervised under conditions which are sufficiently hazardous as to require protective equipment. In all cases, the type of protective equipment selected will depend upon the degree of the existing hazard.

2. Employees should be fully covered by clothing at all times and never expose the skin while working in a confined space. Working bareheaded, with shirt sleeves rolled up, or in an undershirt, may be very hazardous in some areas.

3. Eye protection:

   a. Chemical, splash roof, safety goggles, rubber framed or plastic goggles equipped with impact resistant glass or plastic lenses must be used whenever there is a danger of coming in contact with corrosive liquids or vapors.

   b. In addition to chemical safety goggles, face shields, plastic shields (full length 8" minimum), with hard hat protection must be worn where complete face protection is required.

   c. Acid hoods must be used whenever the exposure requires complete face, head and neck protection.

   d. Acid suits must be used whenever the exposure requires complete body protection.

4. Respiratory protection should be approved by the safety department and must be suited specifically to the type and degree of exposure (limitations of equipment should always be known.)

a. Canister type gas masks are safe to wear only under conditions of low concentration of foreign gases (up to 2%) and when an oxygen deficiency does not exist.

b. A self-contained breathing apparatus must be immediately available on entries into a confined space and used whenever high concentrations of gas are present, or if a gas is known to be present. The hose masks supplied with filtered and pressure regulated compressed air are also suitable within a range of 50 feet.

c. Gas masks must not be used where there is inadequate breathing atmosphere.

5. Head Protection

Hard hats must be used to provide protection from liquid leaks, falling tools or other objects.

6. Foot Protection

Rubber shoes or boots with built-in steel toes are recommended for general work in a confined space.

7. Life Lines

a. The employee must be protected with a body harness with life line attached in all instances where the exposure in the confined space requires him to wear respiratory protection, or where the rescue may be difficult.

b. For all work in a confined space, the body harness should be of the "Shoulder Harness" type, have a strong waist belt and shoulder strap, and dee ring which should be located above the worker's head or between his shoulder blades. This allows for raising the victim in an approximately erect position.

c. The free end of the life line must be attended by an observer (helper) who will always keep the man in the vessel within his vision. The observer may pass tools, but he should have no other job which would take his attention away from the man in the confined space. Nothing must interfere with his attempts to withdraw the man by the use of the life line, or require his leaving the location for any time whatsoever.

d. There must be at least one unit of suitable respiratory equipment readily available for use by rescuers.

I. CONCLUSIONS

1. Only after all work inside the confined space has been completed, all equipment removed, all workmen accounted for and approval is given by the supervisor responsible for the area, shall lines be reconnected, the covers replaced, locks removed and power restored and the confined space put back in use.

2. In case of emergency, the outside observer must never take it upon himself to enter the tank until he is relieved at his post. It is his job to summon aid immediately and to attempt to remove the victim by use of the life line. Rescuers entering the tank must be protected with life line and harness, and proper protective equipment. Respiratory equipment with its own supply of air should be available for use by anyone entering the vessel to perform a rescue. Do no overlook the fact that artificial respiration and simple first aid may be required. The first aid department must be notified immediately.

3. The procedure for testing and entry must be repeated in all necessary details before work is resumed whenever confined space operations are interrupted for any period of time which may possibly result in an increase in harmfulness of the exposure within the confined space.

REVISED COPY OF #6 LOCKOUT PROCEDURES

After the repair work or Maintenance has been done, each trade is responsible for the prompt removal of his own lock. The man (or trade) to remove the last lock will notify the Production Supervisor that the equipment is clear and ready to go and the job is finished. The Production Supervisor, after he has satisfied himself that the equipment is clear, will notify the Electrician to energize the equipment.

Any supplemental tags (information) should also be removed. The same policy covering removing of warning tags will prevail for removal of lock and lockout devices.

MILL 18: KRAFT RECOVERY PROCESS

INTRODUCTION

This report summarizes a survey of recovery furnace operations used to burn Kraft black liquor organics thereby recovering the useable chemicals and generating process steam. The mill is located in the Pacific Northwest and produces about 1100 tons per day of Kraft pulp using both batch digesters and a single M & D sawdust digester. Black liquor is oxidized and concentrated, then burned in one of three recovery furnaces. The survey focused largely on the nature of (and controls for) exposure agents in the actual recovery furnace building, rather than the largely outside black liquor oxidation and concentration operations.

PROCESS SUMMARY

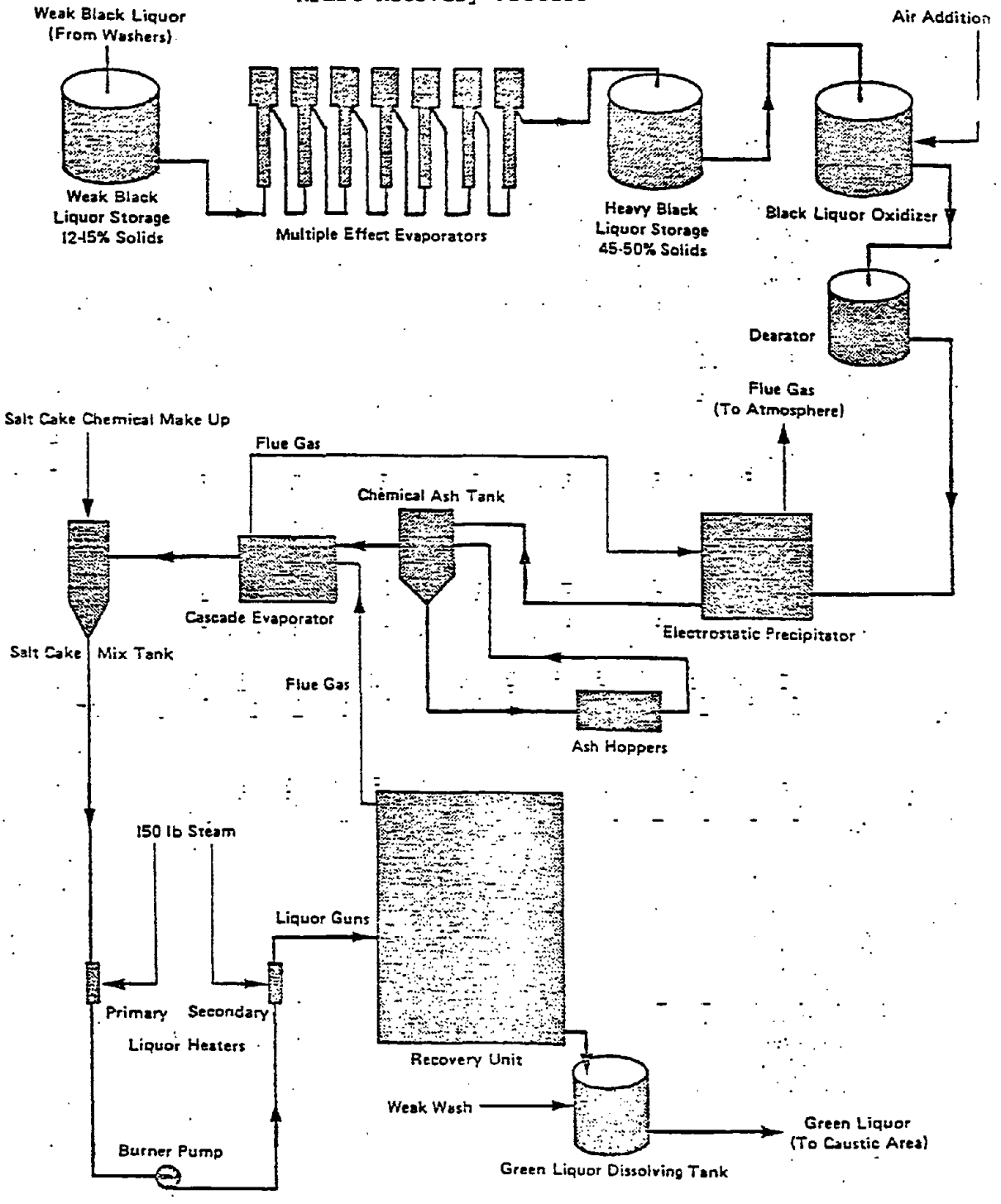
The filtrate from the first-stage brown stock washers is collected and pumped to the weak black liquor storage tank (Figure 18-1). A portion of this liquor is pumped to the blow tanks to dilute the pulp. The remainder is pumped to one of three sets of multiple effect evaporators (sodium hydroxide is added to the stream prior to the evaporators to make-up sodium losses and to minimize scaling in the evaporator tubes). The following sets of evaporators are currently in use:

	Liquor Evaporated (gpm)				
Set	Design	Actual	Year Installed	Bodies	Manufacturer
1	475	650	1957	7	Rosenblad
2	475	650	1959	7	Swenson
3	560	650	1965	7	Chicago Bridge

In the first set of evaportors the liquor is pumped simultanteously to the 7th, 6th, 5th bodies; in the second and third set it is pumped to the 7th and 6th bodies. Steam (60 psig) is injected into the 1st and 2nd bodies of each set (all are of multiple pass design to maximize retention time).

The 7th, 6th, and 5th bodies of each set are operated under vacuum created by a surface condenser, 2 barometric condensers, and two steam ejectors. The vacuum is necessary to vaporize water from the liquor and help remove the noncondensible gases. The combined condensate and the noncondensible gases are piped into a sealed tank (hotwell) -- The condensate is pumped to other Mill areas where contaminated process water can be used; the noncondensible gases are vented to the lime kiln and incinerated. The clean condensate from the 1st and 2nd bodies are pumped to the boilers and used as make-up water for steam generation.

FIGURE 18-1
Kraft Recovery Process



LIQUOR FLOW FROM WASHERS TO
DISSOLVING TANK

The heavy black liquor (45-50% solids) is pumped from the 1st effect evaporator to a storage tank. Before it can be burned, the sulfur in the liquor must be converted to more stable compounds (sodium thiosulfate and dimethyl disulfide). This is accomplished in the black liquor oxidation tank by blowing air through the liquor. The oxidized black liquor is then pumped to a deaeration tank where agitation is used to remove the entrapped air.

Several additional operations are required to further raise the solids content of the liquor to the desired 70%. First, it is pumped through the bottom of an electrostatic precipitator to pick up electrostatically collected ash. The liquor is then pumped through a chemical ash tank containing residue from the boiler and economizer tubes. From the ash tank, the liquor is pumped through the two recovery furnace ash hoppers to recover additional solids. The liquor overflows the ash hoppers into a cascade evaporator where it contacts the hot flue gases allowing additional evaporation. Finally, the heavy black liquor (65-68% solids) is pumped through the salt cake mix tank and sodium sulfate is dissolved in it. Besides increasing the solids content to 70%, this operation replenishes two important pulping chemicals (soda and sulfur).

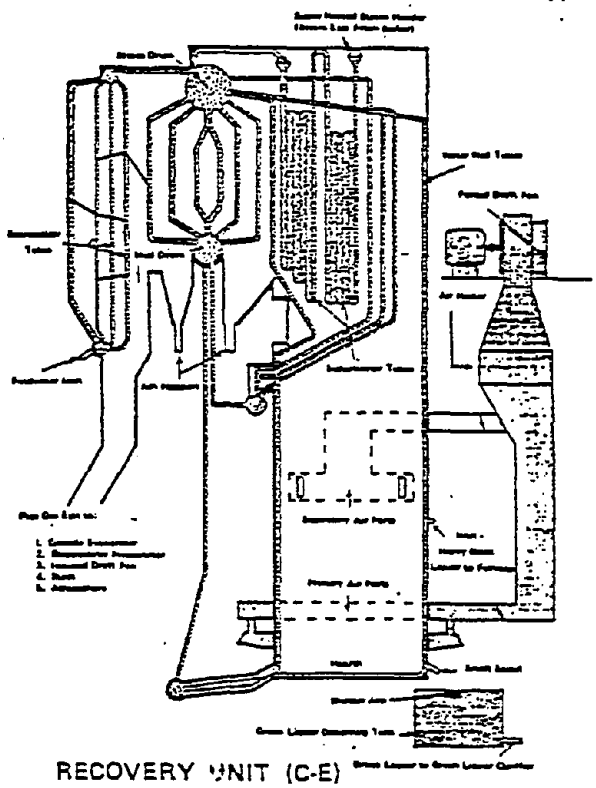
After the salt cake mix tank, the liquor is ready for combustion in the recovery furnace. However, just prior to the recovery boiler, steam (150 psig) is injected into the liquor in the primary and secondary heaters, raising the temperature to 220° - 250° F. The remaining water is instantaneously flashed in the boiler without diminishing the heat content of the liquor.

Figure 18-2 is a cut-away depiction of the Combustion Engineering recovery boiler (housed in a seven story building). Four liquor guns oscillate up and down two opposing sides of the boiler and spray a total of 100-125 gpm of black liquor per furnace toward the center of the hearth. The organics react with the oxygen in the preheated primary air and release great amounts of heat (enough to sustain the combustion process within the furnace). The inorganics are also oxidized yielding the following important reactions:

1) $Na_2S + O_2 \rightarrow Na_2SO_4$
2) $Na_2O + SO_2 + O_2 \rightarrow Na_2SO_4$
3) $Na_2O + CO_2 \rightarrow Na_2CO_3$

These reaction products are relatively sticky at temperatures greater than 1500°F and tend to agglomerate and fall into the char bed or adhere to the boiler tubes (removed by periodic steam cleaning). The char bed is to a large extent shaped by the incoming primary air. Proper shape is very important to prevent collapse of the bed and plugging of the primary air inlets (resulting in incomplete combustion and loss of chemicals entrained in the flue gases).

FIGURE 18-2
Combustion Engineering Recovery Boiler



RECOVERY UNIT (C-E)

Reproduced from best available copy.

The chemical ash and particles slowly migrate down toward the smelt bed, becoming molten at a temperature of 2000-2200°F. The smelt bed extends about five feet above the floor of the boiler where it interfaces with the char bed. Here the molton chemicals are reduced (sodium sulfate to sodium sulfide) and flow out of the bottom of the boiler through two water-jacketed smelt spouts. Before the smelt reaches the dissolving tank, it is broken up into thousands of small particles by steam shatter jets to prevent the possibility of violent reactions or explosions. The dissolving tank is agitated and constantly replenished with weak wash water from the lime mud and dregs washers. The resultant green liquor is continuously pumped from the tank to the raw green liquor mixing tank in the recausticizing area.

Besides combusting the organic materials and reclaiming pulping chemicals from the black liquor, the recovery boiler provides a significant quantity of steam used throughout the mill complex. Clean condensate from the 1st and 2nd evaporator effects and fresh make-up water are pretreated (water softening and deaeration), then pumped into the economizer section of the boiler. The temperature of the water is raised to the boiling point and flashed to steam in a steam drum (450° F). The steam is then piped to the superheater section of the boiler, heated to temperatures well in excess of 700°F, and exits through a header to the main steam header for distribution.

JOB CATEGORIES AND DESCRIPTIONS

Control Room Operator - Under the supervision of the lead fireman, this employee is responsible for the operation of the No. 1 and No. 2 recovery processes. Depending on operating conditions, the operator conducts frequent (every half hour or hour) inspections of the char and smelt beds, the smelt spouts, and the liquor guns. It is estimated that the operator spends 90% of each shift in the control room.

Helper No. 2 - Under the direction of the operator, the helper assures that the two recovery boilers operate properly. Once every hour, this employee performs the following tasks at both of the boilers:

- cleaning the char bed ports (92 per boiler) - opens door and inserts an eight foot rod into the port to remove char buildup.
- clearing the smelt spouts - uses another long metal rod to keep each spout clear of impediments to smelt flow.
- collecting and testing process samples - collects samples of the incoming black liquor and outgoing green liquor and conducts quality control tests.

The helper also cleans the secondary ports (every two hours) and cleans the ash hoppers (every four hours). This employee remains in the recovery boiler area for most of each shift.

POTENTIAL WORKPLACE HAZARDS

The primary hazard to recovery boiler workers is the potential for explosions. Potential workplace air contaminants probably include reduced sulfur compounds and sulfur dioxide. This survey concentrated on air contaminants within the recovery boiler building.

AIR SAMPLING RESULTS

No personal sampling was conducted because the operator essentially remains in the control room and the helper was too busy and physically active to wear a sampling train. It was decided that area samples positioned on several floors of the recovery boiler (Nos. 1 and 2) building would provide data from which to judge the potential for exposure. As shown in Table 18-1, one to two hour area samples for hydrogen sulfide, sulfur dioxide, and methyl mercaptan were collected at four locations on two separate days. The samples on day 1 were collected during start-up of Boiler No. 2 and normal operation of Boiler No. 1; the samples on day 3 were collected with both boilers in normal operation. The following conclusions can be drawn:

- no sulfur dioxide (0.002 ppm) was detected in any of the samples
- hydrogen sulfide concentrations range up to 0.65 ppm
- methyl mercaptan concentrations range between 0.02 ppm and 0.24 ppm
- with the exception of the sulfur dioxide samples, all results obtained on the first day (when Boiler No. 2 was started up) are higher than those obtained on the third day (both boilers in normal operation; however, all results are well below the respective OSHA PELs

Any significant exposures experienced in the recovery boiler building would almost certainly be the result of major leaks or upsets, or infiltration of air contaminants from equipment located outside.

CONTROL OF WORKPLACE EXPOSURES

There are several aspects of the Kraft recovery process that act together to preclude extensive employee exposure to air contaminants during normal operation:

- with the exception of the recovery boiler and the green liquor dissolving tank, the process is totally closed; there are no sources of workplace emissions except during leaks, process upsets, and possibly during certain maintenance activities;

TABLE 18-1. AREA SAMPLING DATA
RECOVERY BOILER BUILDING

Location	Day	Number	Sampling Time (min.)	Concentration (ppm) Hydrogen Sulfide*	Sulfur Dioxide**	Methyl Mercaptan***
Top FLoor	1	1	211	0.05		
		2	72		<0.002	
		3	88			0.17
	3	4	77	<0.01		
		5	84		<0.002	
		6	107			0.02
Control Room Floor	1	7	91	0.02		
		8	70		<0.002	
		9	78			0.11
	3	10	73	0.01		
		11	82		<0.002	
		12	103			0.04
Control Room	1	13	20	0.05		
		14	104		<0.002	
		15	76			0.24
	3	16	73	<0.02		
		17	82		<0.002	
		18	99			0.04
Primary Port Floor	1	19	73	0.65		
		20	78		<0.002	
		21	79			0.08
	3	22	74	0.08		
		23	81		<0.002	
		24	103			0.03

*NIOSH P & CAM 126
**NIOSH P & CAM 160
***Method of Knarr & Rappaport, Analytical Chemistry 52, 1980, 733-736.

- o also, except for the recovery boiler and the dissolving tank, all process tanks and equipment are located outside where natural ventilation can disperse and dilute any emission of contaminants;
- o the recovery boiler is operated at a negative pressure of up to 0.5 inches water, in essence rendering it a 'closed system' (a pressure sensor located before the superheater tubes near the top of the furnace is connected to the induced draft fan to maintain this pressure differential).

As a recovery process is inherently dirty, close attention must be given to maintenance operations for optimum efficiency, and for safety and health reasons. Certain cleaning operations are performed on a scheduled basis:

- o every week one set of evaporators is taken off line and cleaned of scale and other contaminants. If no other major maintenance is required, the evaporators can be boiled out (with water) in about four hours. If other maintenance is required, the boil out is restricted to two hours.
- o the breaching of the cascade evaporators is cleaned annually by the continuous spraying of clean hot water (approx. 19 hours). Unscheduled cleaning is also conducted when a build-up of ash in the breaching causes boiler inefficiency (conducted during the survey).
- o the recovery boiler tubes (economizer and superheater sections) are cleaned using soot blowers on an automatic cycle (once every 50 minutes). A total of 30 soot blowers are located across the height and width of the boiler and consist of a perforated, heavy-gauge pipe with one end sealed. The other end is fitted to a high pressure steam line (400 psig). An air-driven motor provides the pipe with two axes of motion.

MILL 31: MULTIPLE EFFECT EVAPORATORS

INTRODUCTION

Two sets of long tube evaporators concentrate weak black liquor from Kamyr continuous digesters. The older set (1969) has six effects and handles liquor from the softwood pulping line. Soap is recovered from this liquor and used on site to manufacture tall oil. The new set (1979) has seven effects and concentrates liquor from the hardwood pulping line. The hardwood liquor does not contain enough soap to warrant recovery. Both sets of evaporators and auxilliary equipment are located outdoors. This report also covers a black liquor oxidation process and a sophisticated odor control system. Mill 31 is located in the southern United States.

PROCESS SUMMARY

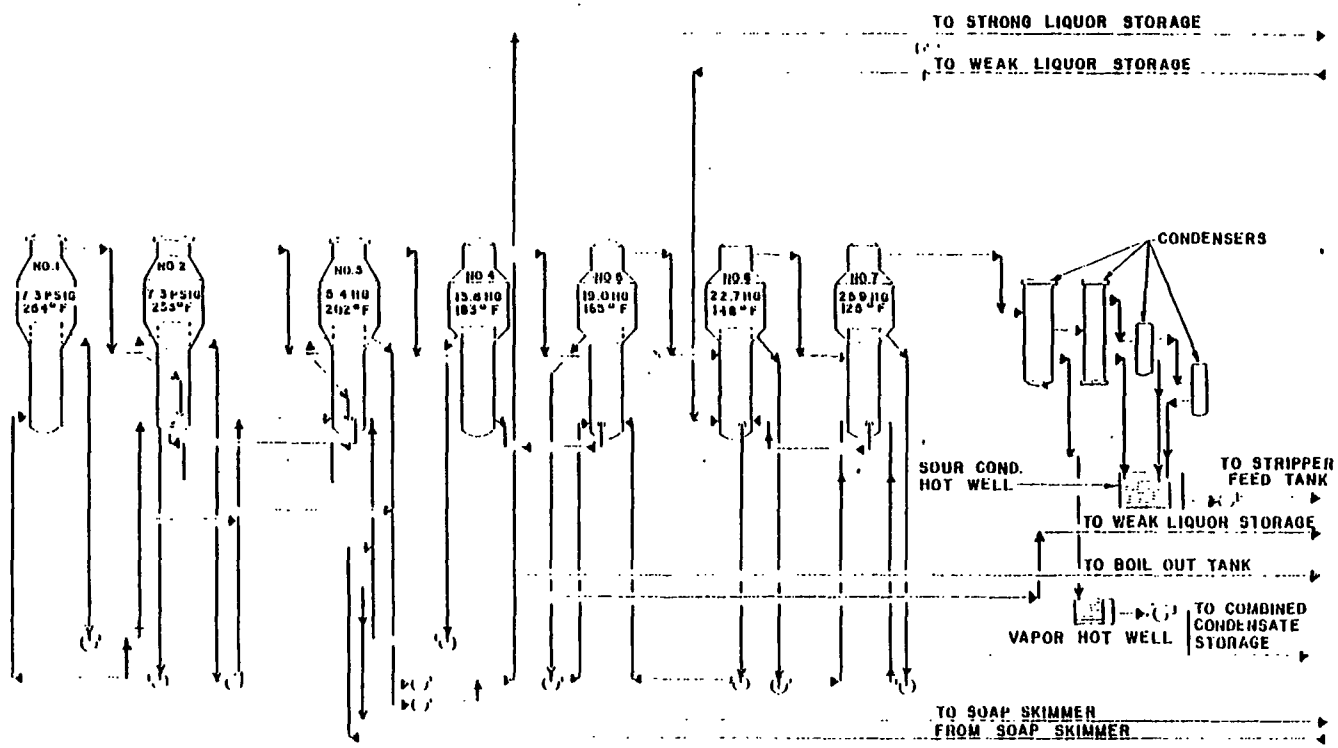
Multiple Effect Evaporators: The hardwood liquor evaporator line is shown on Figure 31-1. Weak black liquor (13 percent solids) is flashed in the sixth effect, collected in a catchall, and pumped to the seventh effect. The liquor is once again flashed and collected, but then recirculated back through the seventh and sixth effects to absorb heat. With minor variations, this sequence is repeated as the liquor passes through the remaining 4 effects and finally exits the third effect at about 50 percent solids.

The first effect is heated with 30 psig steam, and each subsequent effect with vapors from the preceeding evaporator. The vapors from the seventh effect are pulled in series through four condensers by two steam ejectors. The condensate from the first condenser is piped to a sealed hot well, and subsequently pumped to a combined condensate storage tank. The condensate from the other three condensers is collected in a separate hotwell, and pumped to a stripper feed tank.

The condensate from the second through the seventh effects is collected and pumped to the combined condensate storage tank. The condensate from the first effect is therefore collected separately in a receiving tank for subsequent reuse.

The six effect set of evaporators for softwood liquors is operated similarly, except that soap is recovered for tall oil production. The weak black liquor is flashed several times, then pumped to a soap skimming tank. A slowly rotating rake skims the soap from the top of the tank. It is collected in a standpipe and pumped to the tall oil plant. The skimmed liquor is returned to the evaporators for additional concentration.

FIGURE 31-1



HARDWOOD FLOW EVAPORATOR DIAGRAM

Black Liquor Oxidation: The strong black liquor from both sets of evaporators is pumped into several storage tanks. Prior to burning the liquor, it must be stabilized to reduce emissions of maloderous sulfur compounds and to ease problems with foaming. This stabilization process is accomplished in two series-connected black liquor oxidation towers. Each tower is basically a spraying tank, with air sprayed up through the liquor and exhausted through foam breakers and a cyclone separator. The cyclone separator removes entrained liquor, and the gases are piped to a set of condensers (See Figure 31.2). The condensate is collected and pumped to the stripper feed tank. The non-condensible gases are reheated, and burned in a combination boiler.

The stabilized black liquor is pumped from the second tower to a surge tank in the recovery boiler area.

Odor Control System: During a major mill expansion completed in 1979, a sophisticated odor control system was installed to collect and incinerate non-condensible gases from the evaporators, the digesters, and contaminated process water. A very simplified flow diagram of this system is shown on Figure 31-3.

Contaminated process water flows into the stripper feed tank from the sour condensate hotwells, the black liquor oxidation condensers, the softwood evaporator gas cooler, and the turpentine condenser. These liquids are pumped through a rotary strainer, a heat exchanger, and a static mixer, and enter the top of the air stripper column. As they pass down through horizontal plates, the odorous gases are stripped by a stream of air injected at the bottom of the tank. The stripped gases exit the top of the column (through a mesh demister), are combined with vent gases from the stripper feed tank, and are blown into the Total Reduced Sulfur (TRS) condenser.

The non-condensible gases from the digesters, the evaporators, and the air stripper column are combined, and also enter the TRS condenser. The small amount of condensibles are pumped back to the stripper feed tank. The gases (approximately 12,000 cfm at 136°F) are heated to 1300°F, then combusted at 1600°F. The exhaust gases are air-cooled, and exit the incinerator through an economizer for heat recovery. From the incinerator the gases are quenched and then enter a caustic scrubber to remove sulfur dioxide.

JOB CATEGORIES AND DESCRIPTIONS

The evaporators, black liquor oxidation towers, and odor control system are the responsibility of the First Assistant Operator, who is a member of the Recovery Plant and Utilities Crew. The operator remains in the control room (located in the

FIGURE 31-2 BLACK LIQUOR OXIDATION ODOR CONTROL SYSTEM

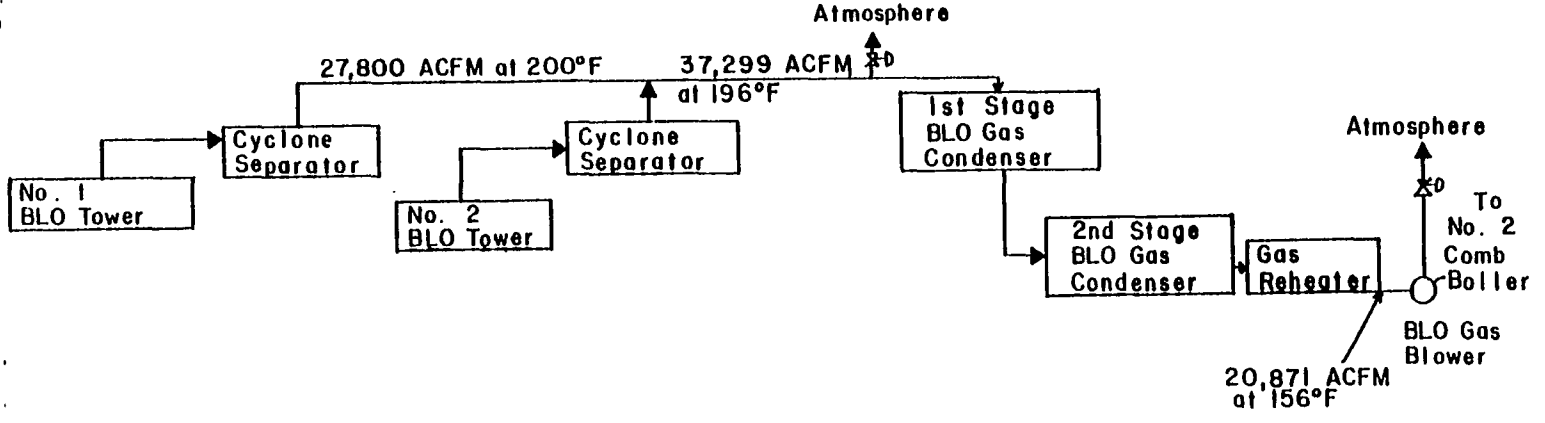
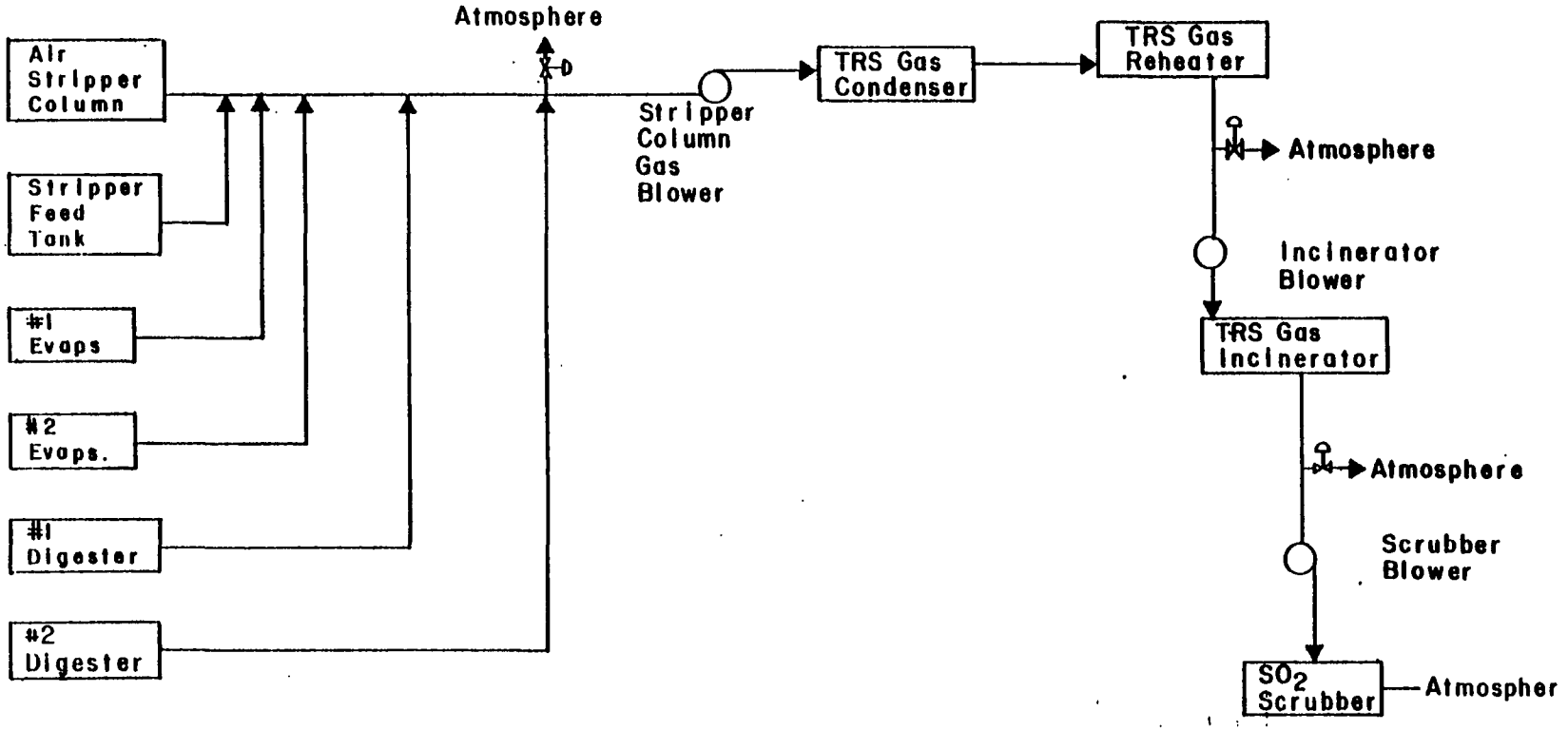


FIGURE 31-3 NONCONDENSIBLE GAS INCINERATION SYSTEM



recovery boiler building) for about 75 to 90% of each shift. Once every two hours, he takes temperature and specific gravity measurements of the strong and weak black liquor from respective pipelines.

In addition, this operator checks the liquid level of the defoamer (added in-line between the oxidation towers), and tests the solids content of the liquid in the scrubber bleed line. These tests require about 15 minutes.

Twice a shift the operator inspects various pumps, blowers, and tanks to insure proper operation. These inspection tours take about 30 minutes or longer.

The operator is also responsible for periodically boiling out the evaporators to remove scale. This operation was conducted during our survey, and consists of the following steps:

- o weak black liquor input is replaced by mill water flowing in parallel through the first three effects; and in series through the remaining effects
- o the temperature and specific gravity of the outlet liquid are constantly monitored
- o as the outlet solids content falls, the liquor is redirected, first to the boil-out storage tank, and then to the process sewer
- o periodically, the shell side of the third effect is 'shocked' with cool water

The evaporators are brought back on line by reversing the above sequence. Weak black liquor is again fed back into the system and, as the solids content increases, the output is diverted from the process sewer to the boil-out tank, then to the weak black liquor storage tank, and finally to the strong black liquor storage tank. During this operation, the operator is near this equipment most of the time.

AIR SAMPLING DATA

We collected ten short-term personal samples for hydrogen sulfide (NIOSH Method ? & CAM 126) on the assistant operator over a three day period (Table 31-1). The samples were taken during routine test and inspection tours, and during a boil out of the hardwood evaporator line. Hydrogen sulfide was not detected on six of the samples, and the highest measured exposure level was only 0.06 ppm. Although the samples were collected during periods of highest potential exposure, none resulted in hydrogen sulfide levels in excess of one percent of the OSHA ceiling PEL of 20 ppm. We conclude that worker exposure during normal operations is very low.

TABLE 31-1: HYDROGEN SULFIDE SAMPLING DATA

Job Category or Location	Day	Shift	Sampling Period (min.)	Concentration[a] (ppm)	Comments
First or Second Assistant Operator	1	2	15	< 0.07	Routine inspection tour
			34	< 0.03	" "
			7	< 0.02	Routine test run
			29	0.06	Inspection and test run
			15	< 0.01	Routine test run
	2	1	14	< 0.01	Test run; prepared hardwood set for boil-out
			20	< 0.07	During boil-out; checked sewer & boil-out tank
			60	0.05	During boil-out; inspection tour, including tall oil plant
		2	60	< 0.02	Inspection tour
	3	1	65	0.05	Put hardwood set back on liquor
Control Room	1	1	186	< 0.02	
		1	180	0.01	
Seventh effect; Hardwood Evaporator Set	1	2	20	< 0.02	

[a]OSHA Ceiling Permissible Exposure Limit is 20 ppm.

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Several area samples were also collected for hydrogen sulfide using NIOSH Method P & CAM 126 (see also Table 31-1). Two of these samples were taken in the control room and resulted in very low levels (0.02 ppm and 0.03 ppm). No hydrogen sulfide was detected in one additional sample at the seventh effect of the hardwood evaporator line.

CONTROL OF WORKPLACE EXPOSURES

Worker exposure to hydrogen sulfide is low during normal operations for the following reasons:

- the process is totally closed
- the sour condensate hotwells are tightly sealed and ventilated to the odor control system
- drains are equipped with water traps to prevent emission of gases from the process sewers
- contaminated condensate from all hotwells is pumped to a stripper feed tank, rather than allowed to overflow into the process sewer
- the control room is located in the recovery boiler building, relatively remote from the evaporators
- process equipment is very well maintained, reducing the potential for significant leaks or other upsets

The odor control system is very important to the prevention of workplace emissions. Non-condensible gases are collected and incinerated, rather than vented to atmosphere. In addition, tanks and other equipment are maintained at a slight negative pressure, reducing the potential for leaks.

There are separate non-condensible gas collection systems for each evaporator line (Figure 31-4 and 31-5). Each of these systems is equipped with a blower to collect and transport the gases to the incinerator. Both collection systems provide ventilation for the hotwells, the soap skimmers, the boil out tanks, the weak and strong black liquor storage tanks, and the condensate tanks. The softwood system also removes non-condensible gases from a turpentine decanter (located in the pulp mill) and has a gas cooler to lower the temperature of the gases from 140°F to 100°F.

Another important aspect of the odor control system is the collection and air stripping of contaminated condensate from the hotwells, condensers, and condensate pots of both process lines.

FIGURE 31-4 SOFTWOOD EVAPORATOR ODOR CONTROL SYSTEM

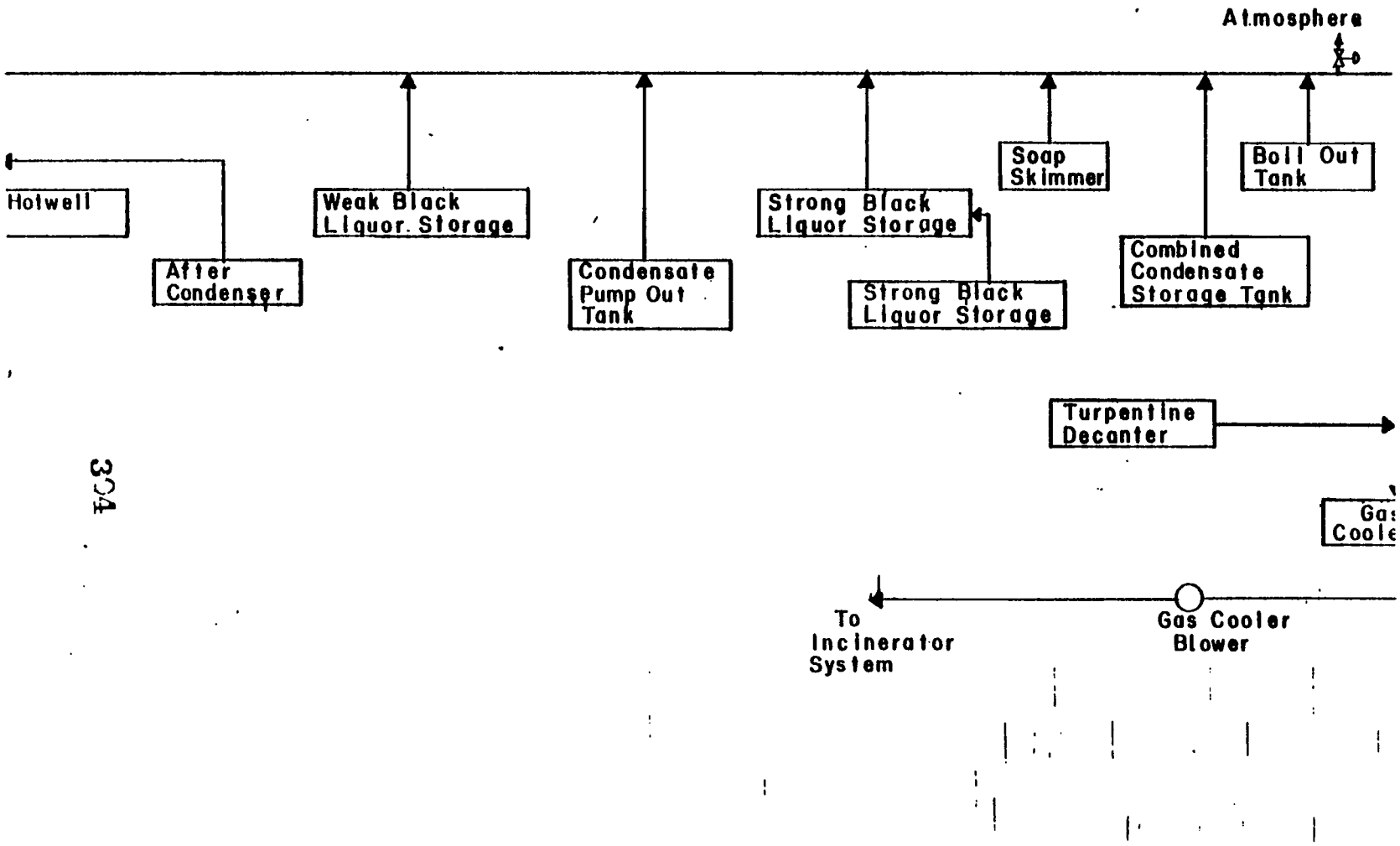
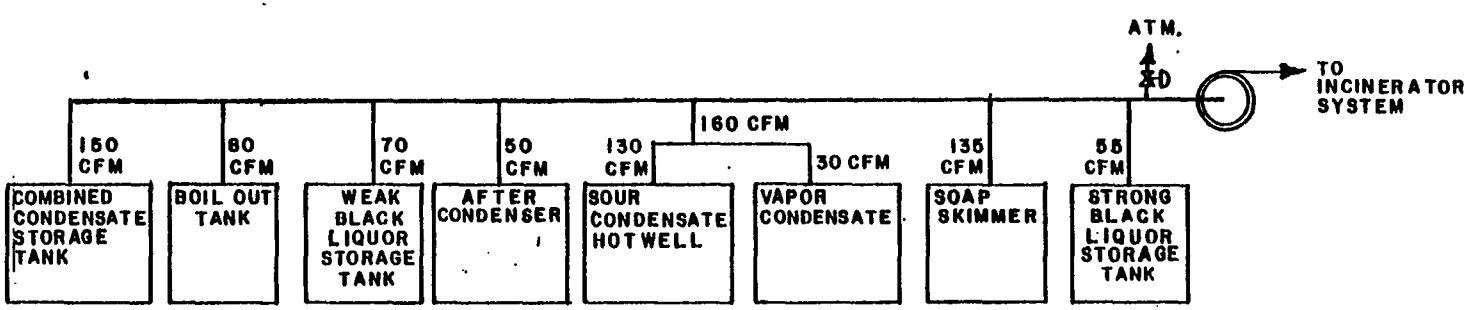


FIGURE 31-5 HARDWOOD EVAPORATOR ODOR CONTROL SYSTEM



The reduced sulfur compounds and other contaminants are stripped from these liquids before they are piped to the process sewer. Since the sewer does not contain large quantities of contaminated effluent, there is less chance of workplace emissions through any sewer drains.

The mill has also recently installed an Ecolyzer Continuous Gas Monitoring System (Series 300) for hydrogen sulfide. The monitor is located betwen the two process lines and is set to give an audible alarm if the concentration of hydrogen sulfide exceeds 20 ppm.

MILL 34: MULTI-EFFECT EVAPORATORS

INTRODUCTION

Mill 34 uses two parallel sets of Swenson long tube evaporators to concentrate weak black liquor before it is burned in the recovery furnaces. One set is used exclusively for softwood liquor and has a capacity of 700 gpm ("A" Evaps). The other set ("B" Evaps) concentrates 1200 gpm of mixed hardwood (85%) and softwood liquor (15%). Both sets are very similar, except that soap is recovered from the softwood set and pumped to a tall oil plant. The mill is located in the South, and all equipment is outdoors. This survey focuses on control measures implemented after an evaporator operator was nearly killed from overexposure to hydrogen sulfide.

PROCESS SUMMARY

Each evaporator consists of a bundle of small tubes encased in a large steel vessel covered by a vapor head. The black liquor is pumped up through the tubes and is heated to its boiling point by either steam (first effect) or vapors from the preceding evaporator. The vapors exit the top of the tubes and are piped to the next effect. Liquor foam is collected by an entrainment separator, falls into a collection ring called a catchall, and is pumped to the bottom of the next evaporator.

The process starts with weak black liquor (17% solids) pumped from the brown stock washer filtrate tanks into storage tanks. From storage it is pumped to the "A" Evap fourth effect, passes through the fifth and sixth, and then is pumped to the soap skimming tank. The soap is collected in a separate tank and pumped to the tall oil plant. The liquor is pumped back to the fifth effect and then in backwards sequence through the remaining effects. In several of the evaporators, the liquor is recirculated several times to further increase the solids content. The concentrated liquor (50% solids) finally exits the system through the first effect into a flash tank, and is pumped to storage. Steam from the flash tank is piped to the second and third effects for heating.

The first effect is steam heated (up to 50 psig); the others are heated with vapors piped from each preceding effect. Vapors from the sixth effect are piped to a barometric condenser where the condensate falls into the hot well, and the non-condensible gases pass to a two-stage steam eductor. The eductor provides the vacuum for the evaporators and forces the gases into the hotwell. A hogging jet is provided should an additional vacuum be required. The hot well is vented to the lime kiln through the non-condensible gas system.

JOB CATEGORIES AND DESCRIPTIONS

One operator controls both evaporator lines and spends up to 80% of each shift in a closed control room located between the two sets of evaporators. His normal duties include:

- monitoring process parameters displayed on the control panels
- taking liquor temperature and specific gravity readings
- Conducting periodic water and acid boil-out of the evaporators
- conducting equipment inspections
- entering process data in the production log.

POTENTIAL WORKPLACE EMISSIONS

Although a variety of reduced sulfur compounds are potentially present, hydrogen sulfide presents the most significant hazard. It may be emitted from the hotwells, the sewer, drains, or any tanks or pipelines containing black liquor. Large quantities of hydrogen sulfide can be generated if black liquor is mixed with acids in the combined sewers or during evaporator cleaning.

AIR SAMPLING RESULTS

We collected six 15-minute personal samples for hydrogen sulfide (NIOSH P&CAM 126). All were collected on the evaporator operator while he was outside the control room. Hydrogen sulfide was not detected on five of the six samples (less than 0.08 ppm); the remaining sample resulted in a concentration of 0.13 ppm (see Table 34-1). These levels are well below the OSHA ceiling PEL of 20 ppm, and indicate that exposures to hydrogen sulfide are usually very low.

Two one-hour area samples were collected in the control room, and no hydrogen sulfide was detected (less than 0.02 ppm). All samples were taken during a water boil-out of the softwood line and include process shutdown and start-up. Throughout the sampling period, the other evaporator line was operating normally.

TABLE 34-

Job Category or Location	Shift	Sampling Duration	Hydrogen Sulfide Concentration	Results (ppm)	OSHA Ceiling PEL	Activities
Evaporator Operator	1	15	0.13		20	Check temperature and specific gravity of weak and heavy black liquor of A and set evaporators.
		16	<0.08		20	Place A set evaporator off liquor to water for boil-out. Check temperature and specific gravity of liquor/water of A & B set evaporators.
		21	<0.06		20	Dump water out of A set first effect. Check temperature and specific gravity of liquor/water of A & B set evaporators
		15	<0.08		20	Flushed scale out of A set 1st effect.
	1 & 2	20	<0.06		20	Check temperature and specific gravity of B set evaporator. Open valve from B set evaporator 6th effect to soap skimming tank. Twice check temperature and specific gravity of B set evaporator. Throttled down black liquor flow to the pond. Pumped weak black liquor from storage tank to soap skimmer.
	2	27	<0.04		20	Re-enter weak black liquor into A set 4th effect. Periodically check temperature and specific gravity of A set. When specific gravity indicated that black liquor of proper specific gravity was exiting the 1st effect, liquor was valved from sewer to the feed tank (weak black liquor) and finally to the heavy black liquor storage tank. Checked A set hotwell, 6th effect, and 5th effect pumps
Evaporator Control Room	1	68	<0.02		20	
Evaporator Control Room	2	56	<0.02		20	

CONTROL OF WORKPLACE EXPOSURES

Inherent process characteristics largely prevent frequent worker exposure to hydrogen sulfide and other process gases. The evaporators and all auxilliary equipment are totally closed; except for infrequent leaks, upsets or certain maintenance operations, there are no sources of gaseous contaminant escape. Also, because the process is located outdoors, natural ventilation usually prevents accumulation of process gases.

Although the probability of worker exposure is inherently low, problems with potential serious consequences can occur. In 1975, an evaporator operator at this mill was overcome by hydrogen sulfide gas in the evaporator area. Only the presence and quick response of a fellow worker prevented serious injury to the unconscious employee. Although he suffered no long-term effects, mill officials initiated a comprehensive investigation into the cause of the accident, and methods of future prevention. It was determined that the hydrogen sulfide probably originated in the hotwell, passed into the sewer, and entered the workplace through the evaporator drains. The gas was able to enter the sewer during a power failure which shut down the mill's non-condensible gas system.

In early 1976, three MSA Tox Guard hydrogen sulfide monitors ($26,000 total cost) were purchased. These units are portable and contain audible and visual alarms based on a pre-selected setpoint. All are still in service - one permanently located in the evaporator control room, the other two stored for use as backup monitors.

Several months later, the mill also installed a Bullard Series 6100 Continuous Hydrogen Sulfide Gas Detector around the hardwood hotwell. The unit is based on a solid state electrolytic cell, and is not subject to extensive interference (20:1 methyl mercaptan). The sensor was connected to a control module in the control room and equipped with a high level alarm. The system cost about $1500 but lasted only two years. Mill personnel calibrated the unit with purchased hydrogen sulfide in air standards.

In late 1978, the mill purchased a four-channel Bacharach Model X0550 hydrogen sulfide monitor as a replacement for the Bullard unit. Its four sensors were located:

- over the softwood line hotwell
- over the hardwood line hotwell
- over the sewer drain for the soap skimming tank
- over the drain near the hardwood line fifth effect.

The control module was again installed in the control room, with alarm setpoints at 10 ppm (warning) and 25 ppm (alarm). The unit lasted about two years, and required frequent sensor repair and replacement. The unit was reported to be very sensitive to high humidity and generally unreliable.

The Bacharach unit was replaced with a Texas Analytical Controls (TAC) Model 404A hydrogen sulfide monitor. The control module was installed in the control room and the sensors at the same locations. After our survey, the TAC alarm output was connected to the existing Control Room Panalarm. The system operates in the scan mode, with the highest sensor reading automatically now displayed at the control module . The sensors are calibrated monthly using a dynamic gas generator and a permeation tube. The mill's limited experience indicates the TAC sensors are both more durable and more humidity resistant than the previous unit. In six months of continuous use, none of these sensors have failed. Recently, the safety department also purchased a portable TAC hydrogen sulfide monitor equipped with an alarm. The monitor is designed to be worn by the operator when outside the control room, but was not used during the survey.

After the accident, a number of engineering controls were implemented to reduce the possibility of hydrogen sulfide escape to the workplace:

- Water seals were installed on all 'U' drains leading to the combined pumping sewer
- All underground sewers were sealed
- An enclosed sewer was installed to pump spent acid from the chemical preparation area to the acid ditch.
- The hotwell manhole covers were sealed and weighted down using 45-gallon drums filled with water.
- Emergency vents and relief valves were connected to the non-condensible gas system
- A steam ejector was installed on the non-condensible gas system to provide an emergency source of vacuum in case of a power loss to the NCG fan.
- H_2S monitors were placed in the brown stock area and the lime kiln firing end.

The mill safety department also developed a training and emergency booklet to acquaint employees with the special hazards of hydrogen sulfide and provide instructions for necessary precautions. The booklet covers the following topics:

- Emission sources - describes how hydrogen sulfide is formed and identifies process areas where it can be emitted
- Characteristics - discusses toxicity and other properties of the gas; explains olfactory fatigues and warns against relying on odor for hazard detection
- Hazard detection - identifies the types and locations of air monitors for hydrogen sulfide
- Emergency response and first aid - outlines emergency and first aid procedures.

The material is clearly and thoroughly presented, and should be an excellent tool for both initial and periodic training.

The operators are not required to (and usually do not) carry a respirator when outside of the control room. However, a full-face cannister respirator is available to allow safe exit during an emergency. Several Scott Air Paks are available in the control room should the operator have to remain in the area.

MILL 16: RECAUSTICIZING AND LIME KILN OPERATIONS

INTRODUCTION

This report summarizes recausticizing and lime kiln operations conducted to supply a Kraft pulp mill with fresh white liquor. The mill commenced operation in the mid-1960's, and currently produces white liquor to produce 900 tons per day of air dried pulp (i.e., 225 tons per day of lime and 648,000 gallons per day of white liquor). This is accomplished using conventional recausticizing unit operations, and a single lime kiln equipped with a computer optimization system. The computer minimizes fuel consumption and maximizes lime quantity and quality.

One worker operates the entire unit operation. Potential chemical exposures were identified as calcuim carbonate and lime dusts, sodium and calcium hydroxide mists, hydrogen sulfide, and other reduced sulfur compounds. Only dust contamination was present at detectable levels. Exposure to the physical agents, noise and heat stress, were judged low.

MILL LAYOUT

The mill layout is reproduced in Figure 16-2.

The mill consists of a large, unenclosed rotary lime kiln and various outside tanks and pumps. These tanks are used for: green liquor clarification and storage, lime storage, recausticizing of lime (slaker), white liquor clarification and storage, and lime mud storage. Small buildings are located at the discharge and the feed ends of the kiln. These contain the process control center, and the lime mud washing/filtering/feeding equipment, respectively. Workers spend the majority of their time in the control center or around the discharge end of the kiln. They only occasionally enter the feed end building.

Other important equipment includes an induced draft fan which draws air through the kiln; and a venturi scrubber and separator, which are elements of the kiln air pollution control system. All are located near the feed/exhaust end of the kiln. New (makeup) lime for the recausticizing operation is delivered to the mill by truck. It is then unloaded into a storage silo and fed by gravity and belt conveyor to the slaker.

PROCESS SUMMARY

The mill uses conventional recausticizing technology and equipment but the lime kiln controls have been computer-optimized. Basically, recausticizing is the production of fresh white liquor (sodium hydroxide and sodium sulfide) from recovered hot, molten Kraft pulping chemicals that have previously been dissolved in water at the recovery

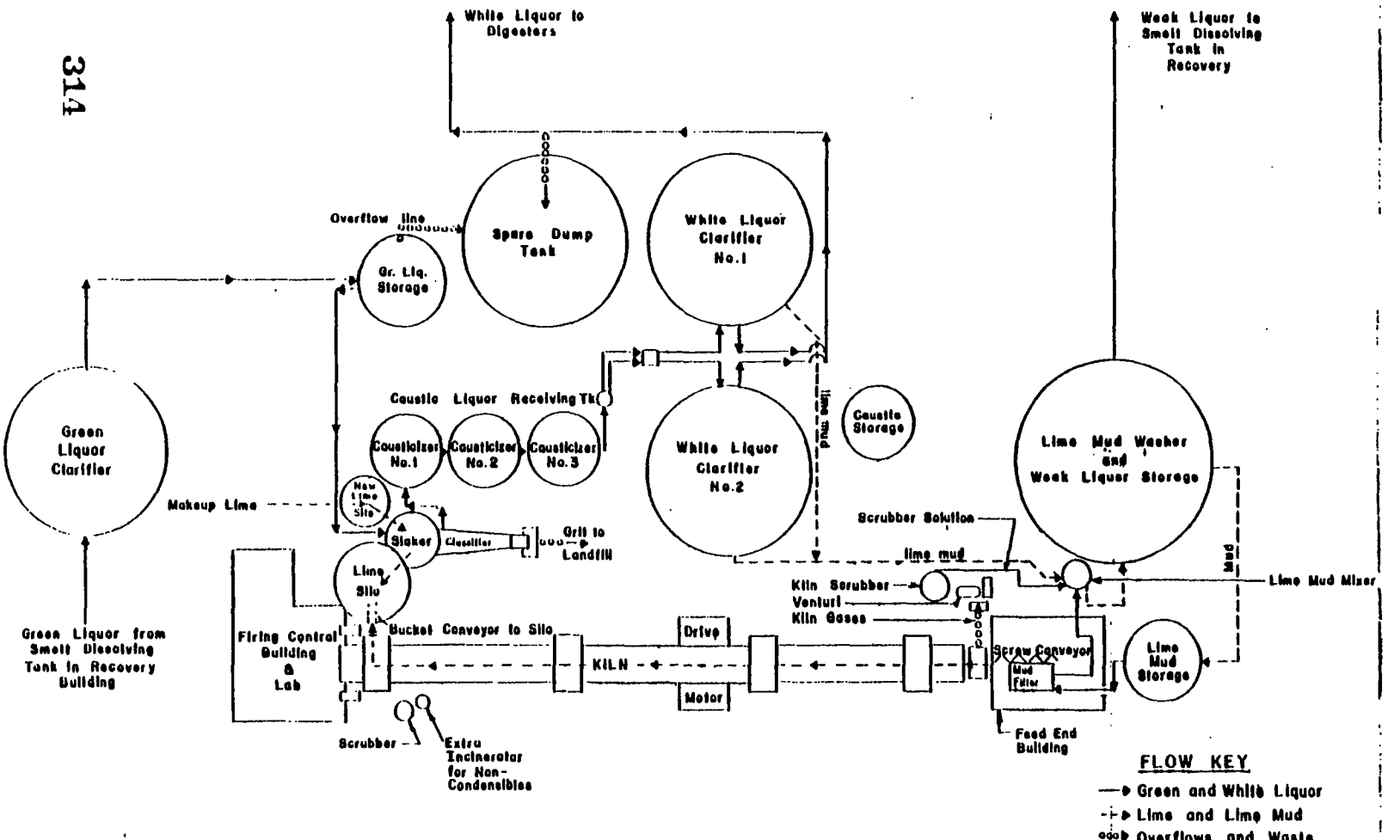
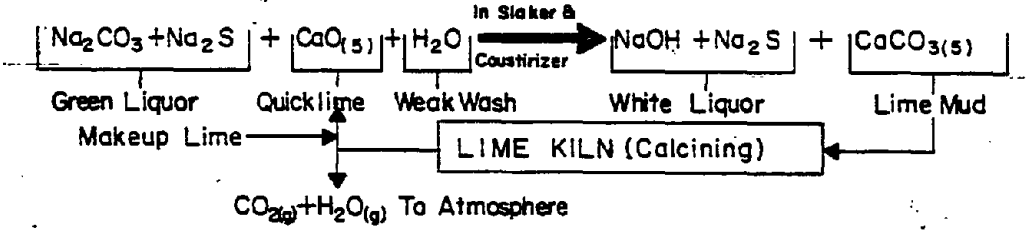


FIGURE 16-2 PLANT LAYOUT WITH SIMPLIFIED PROCESS FLOWS

building (i.e., green liquor, or, principally, a solution of sodium carbonate and sodium sulfide). It is obtained by reacting this green liquor with quicklime (calcium oxide) under controlled conditions. Quicklime, in turn, is obtained principally by burning calcium carbonate (or limestone) which is an insoluble product of the causticizing reaction. Burning is accomplished in a gas or oil-fired rotary kiln, and is known as the calcining step. The entire process involves essentially a closed cycle with only a small amount of new lime required to make up for recovery inefficiencies:



A complete, but simplified, process flow diagram for this particular mill is shown in Figure 16-1.

As shown in Figures 16-1 and 16-2, the recausticizing and lime kiln process in this mill consists of seven distinct steps:

1. Dissolving of recovery furnace smelt to produce green liquor
2. Green liquor clarification
3. Lime slaking with green liquor to produce white liquor
4. Three stages of causticizing to complete the reaction of all green liquor to white liquor
5. White liquor clarification and recovery of lime mud
6. Lime mud washing and filtering/thickening
7. Mud burning in the gas fired rotary kiln to regenerate new lime (calcining).

Step 1 takes place in the recovery/power house building and is not part of the surveyed operations. Steps 2 through 5 essentially involve only balanced, dynamic flows of liquids through large outside tanks. They require little operator service or attention other than periodic quality control testing. Steps 6 and 7 involve automated equipment that remove

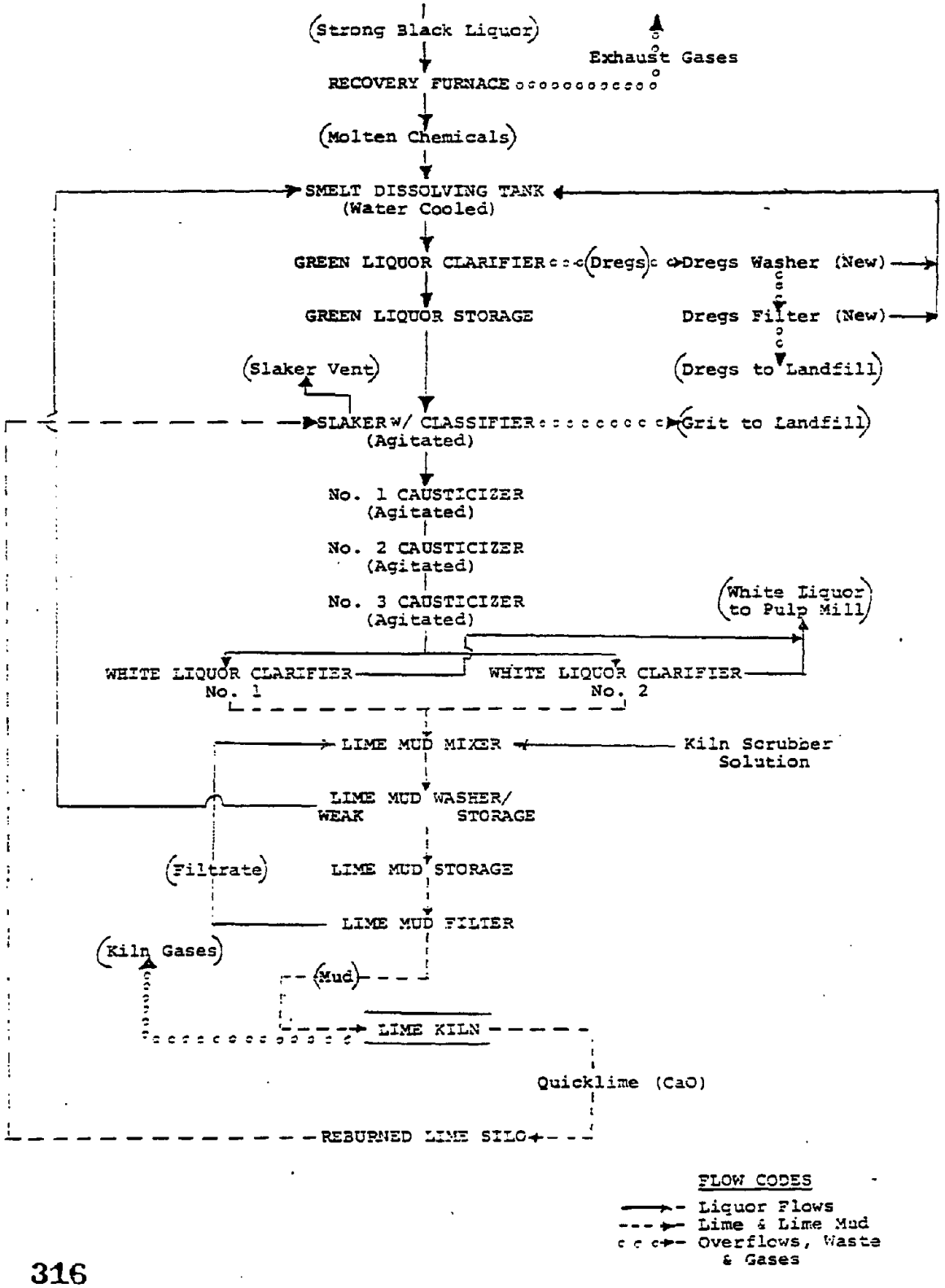


Figure 16-1: SIMPLIFIED PROCESS FLOW

settled mud from the bottom of the clarifiers and then wash and thicken it prior to metering into the feed end of the kiln. These steps also require only periodic inspections to insure that mud is being formed and recovered, and that the filter cloth of the thickener is not clogged. These filters must also be periodically washed - a process which is also highly automated.

The discharge end of the kiln is provided with an observation window (or the service door is kept open) so that the operator can periodically check the desired even movement of lime down the kiln. Hot lime (CaO) then drops through a grate at the firing end down into a rotating lump breaker. It is then screw-conveyed to a bucket conveyor which in turn takes it up to the lime storage silo above the slaker. Fresh lime, delivered by truck, is stored in a silo and fed to the slaker as needed. This lime is used to replace the small amount of lime lost by process ineffiencies.

The lime kiln can be fired with either gas or oil, although oil is normally used. The fuel passes through a flow control valve; is preheated using steam; and then injected into the center of the kiln firing end. Primary combustion air, required to fully atomize and burn the fuel, is introduced at the same location using a damper-controlled forced draft fan. Additional or secondary air is required to complete the reaction of carbonate to carbon dioxide, and to insure stable kiln temperatures. It is provided by an induced draft fan and enters near the primary air through a number of large lime cooling cylinders attached to the kiln firing end.

Foul and non-condensible gases from the pulp mill and chemical recovery area are now added to the kiln hood as additional secondary air flow, and are then burned. Previously, they were diluted and used as primary kiln air, but this resulted in inconsistent quality and quantity of primary air, and combustion problems. This non-condensible gas stream consists of hot, reduced sulfur and other gases from an M&D digester chip feeder, blow gases from the Kraft digesters, foam tank vent gases, and evaporator gases. The first three sources are pre-scrubbed before burning, but the evaporator gases are not.

POTENTIAL AIRBORNE CONTAMINANTS

Lime and Limestone Dusts -

The major chemical exposure agent to which kiln/recausticizing workers are potentially exposed is dust. It is composed of primarily process-derived lime (calcium oxide) or limestone (calcium carbonate), or a combination of both. However, it may also include small amounts of sodium sulfide (from the process) and other environmental dusts from the surrounding areas. Applicable OSHA standards are the 8 hour TWA's for total nuisance dust (15 mg/m^3), and lime dust (5 mg-CaO/m^3).

The recausticizing and lime kiln area of a Kraft mill is easily recognized by its pervasive white lime or limestone coating covering most pieces of equipment. Disturbance and suspension or wind transport of the dry coating can create potential worker exposure situations. Direct emissions of lime or limestone dust from process equipment can also occur at: the kiln discharge end and hot lime bucket conveyor system; the lime feed system to the slaker (lime); the air seal at the kiln exhaust end; or the induced draft fan. (The latter two must have leaks.) None of these were judged to be significant emission sources at this mill.

A small amount of lime dust may also escape during the unloading and transfer of delivered makeup lime. But this operation was not observed during the survey. Lime dust entrained in the kiln exhaust is normally removed by a venturi scrubber, then recycled to the process. It also does not pose a workplace exposure risk.

The greatest potential for exposure to process dust occurs when a worker performs cleanup tasks, or works on or near equipment where it has accumulated.

Other Chemical Exposure Agents -

As mentioned, pulp mill and evaporator non-condensible gases are burned in the lime kiln as part of the secondary air supply. This is both an economical and an efficient means to destroy these malodorous and potentially toxic gases. Closed transport ducts and an injection tee are used to introduce the gases into the kiln hood. No leaks were observed in transport lines, and little potential for exposure exists. Once inside the kiln firing end, there is little potential or escape because all gases (fuel, primary, and secondary air) move rapidly up the kiln creating an induced draft at any firing hood openings. The temperature of the kiln and gas residence time are then sufficient to burn or oxidize most reduced sulfur and other organic compounds. Small amounts of unreacted gases are either removed by the kiln venturi scrubber or exhausted from the stack.

If the kiln should be inoperable, this mill also has a complete standby incinerator system (gas) for burning these non-condensible gases. This incinerator is located outside and adjacent to the kiln near its firing end, and has a separate exhaust stack scrubber.

Lime slaking is the only other identified operation potentially creating chemical exposure agents. As discussed, slaking is the step where quicklime (CaO) is rapidly mixed with green liquor to dissolve it and produce hydrated milk of lime or calcium hydroxide ($Ca(OH)_2$). The calcium hydroxide then

rapidly reacts with sodium carbonate of the green liquor to produce the desired sodium hydroxide or white liquor. The slaking reactions are strongly exothermic and a large amount of steam must be vented from the slaker through a stack. In addition, mills have found that the desired rapid-settling lime mud ($CaCO_3$), produced during causticizing and later recovered, is best obtained if the reacting green liquor is first heated (and/or freshly burned hot lime is used). This is accomplished with a steam heat exchanger on the green liquor feed line to the slaker. Effective lime slaking is obtained with green liquor at 185 to 200° F. If too much lime is added to the slaker or if green liquor is overheated, the slaker contents may start to boil and eventually reach explosive conditions. Under such conditions, a caustic mist of sodium hydroxide and/or lime ($Ca(OH)_2$) may be emitted through the slaker feed system or other openings. Temperature monitors and controls are provided to limit such occurrences and are usually very effective. However, an air sample was collected above the slaker classifier section to investigate the presence of such a mist during normal slaker operation in this mill.

Because the recovery furnaces and lime kiln have essentially destroyed or removed all other volatile and toxic compounds, the green liquor, lime mud, and white liquor, although hot, do not emit such compounds to the workplace. However, skin contact with any of them poses a potential irritation hazard because they are very caustic.

JOB CATEGORIES AND DESCRIPTIONS

The entire recausticizing plant is run by a single operator. A utility person works the swing shift, but performs only housekeeping tasks and has no assigned direct production tasks. These two workers are the only employees normally present in the entire recausticizing area, unless upsets or malfunctions develop.

Operator - The operator is responsible for the entire recausticizing and lime kiln operation. This includes all the equipment shown in Figures 16-1 and 16-2. He normally spends in excess of 80% of his shift inside the control center where he monitors process parameters, interfaces with the computer, and performs various quality control tests. To insure that systems are performing correctly, he must periodically collect and test the following quality control samples:

1. Green liquor for total alkali (once/hour);

2. Slaker, No. 3 causticizer, and final clarified white liquor for total alkali, active alkali, percent sulfidity; and percent causticity (once/two hours);

3. Weak wash (from mud washer), green liquor to clarifier, dregs from green liquor clarifier, and green liquor to slaker for settling tests (once per shift);

4. Reburned lime for available lime test (once/shift);

5. Weak wash for an alkali test (once/shift); and

6. Caustic makeup test (once/shift)

Collection of these samples requires brief trips outside the control center during which he may also inspect equipment. Trips typically require less than 15 minutes to perform.

Periodically, he may make unscheduled, brief trips outside the control room to observe the condition of lime in the kiln, or to break up large lumps in its discharge grate. He is also required to clean the kiln firing hood of accumulated dust once per shift using a compressed air line. However, this operation was not observed. He must also acid-clean the lime mud filter to remove accumulated deposits, once per week. This is usually done on the swing shift, but only requires him to manually valve in a mild acid solution to the filter showers. This can be done from outside the feed end building, and no exposure to acid mist (HCl) likely occurs.

Utility Man - The utility man works only a single shift each day, usually the swing shift (4:00 pm to 12:00 am). His primary duty is to perform housekeeping and cleanup tasks around the entire recausticizing area. As such, his work routine typically involves the following tasks (estimated times shown in parenthesis):

- Hosing down of fine lime dust followed by sweeping and shoveling up of large stones which accumulate below the discharge end of the kiln (30-60 minutes);

- Hosing down of alleyways below the kiln, behind the control building, and around various tanks (4 hours);

- Hosing down the feed end of the kiln and around the mud filter (60 minutes);

- Miscellaneous cleaning and odd jobs (1-2 hours); and

- Break time, usually taken in control center (30-60 minutes).

During rainy periods his routine may vary significantly as there is less need to perform the various area washdowns.

AIR SAMPLING RESULTS

Investigative Area Sampling -

Area sampling was performed to investigate the presence of 1) reduced sulfur compounds at the kiln firing end and in the control room (from the non-condensible gas stream); and 2) mists of sodium or calcium hydroxide from the slaking operations. Single samples each were collected for hydrogen sulfide (by NIOSH Method P & CAM 126) and methyl mercaptan (method of Knarr and Rappaport) in the control room and at the kiln firing end. Total sodium and calcium particulate (or mist) samples were collected above the slaker discharge trough. These used 0.45 mixed cellulose ester collection filters, which were later analyzed by atomic absorption spectroscopy. Results for all investigative area samples are summarized in Table 16-1.

As shown, essentially non-detectable quantities were obtained for all contaminants. Therefore, no leaks in the pulp mill non-condensible gas stream to the kiln were indicated; and no other sources of worker exposure to reduced sulfur compounds were identified. In addition, generation of a caustic mist from the slaking operation is not indicated provided the temperature of this step is properly controlled.

Personal Exposure Sampling -

Four 15-minute ceiling samples were collected to assess the operator's exposure to hydrogen sulfide and to mercaptans during his scheduled sampling tours. Sampling was performed during a single day, and utilized NIOSH Method P & CAM 126 for hydrogen sulfide, and the method of Knarr and Rappaport for mercaptans (Anal. Chem. 1980, 52, 733-736). A single long-term sample was also collected on the utility man (on the same day) to assess his exposure to mercaptans while performing various outside housekeeping tasks. Non-detectable quantities were obtained for all samples, and are summarized in Table 16-2.

The operator and utility man's exposures to process dust (CaO and/or $CaCO_3$) were determined by collecting long-term samples for total particulate matter. Pre-tared 5 u PVC filters were used to collect breathing zone samples, which were later gravimetrically analyzed. Single, full-shift area samples were collected in the control center over two days to estimate the operator's exposure to process dust because he remains in this workspace in excess of 80% of a shift. However, an actual personal exposure sample (254 mins.) was collected on the utility man while he performed outside housekeeping tasks. These tasks included: one hour to wash down the mud filter

TABLE 16-1: AREA SAMPLING RESULTS

Location	Contaminant	Sample No.	Day	(Minutes) Sampling Time	Concentration
Lime Kiln Control	Hydrogen Sulfite[1]	1	3	110	< 0.02 ppm
Room	Mercaptan[2]	2	3	395	0.008 ppm
Kiln Firing End	Hydrogen Sulfide	3	4	60	< 0.04 ppm
	Mercaptan	4	4	68	< 0.008 ppm
Above transfer trough Slaker to No. 1 Causticizer	Total Sodium[3]	5	4	172	0.04* mg/m^3
	Total Calcium	5	4	172	0.001* mg/m^3

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[1]Samples collected and analyzed by NIOSH Method P & CAM 126

[2]Samples collected and analyzed according to method of Knarr and Rappaport, Anal. Chem., 52, 1980

[3]Samples collected on 0.8 um MCE filters and analyzed by NIOSH Method P & CAM 173

*Applicable OSHA standards are 2 mg/m^3 TWA for sodium hydroxide and 5 mg/m^3 TWA for calcium oxide.

TABLE 16-2: PERSONAL SAMPLING RESULTS

OPERATOR

Contaminant	Sample No.	Day	(Minutes) Sampling Time	Concentration
Total Particulates[1]	1	3	440	0.15 mg/m^3
	2	4	404	0.51 mg/m^3
Hydrogen Sulfide[2]	3	3	15	< 0.09 ppm
	4	3	15	< 0.08 ppm
	5	3	15	< 0.10 ppm
	6	3	15	< 0.09 ppm
Mercaptan[3]	7	3	15	< 0.03 ppm
	8	3	15	< 0.04 ppm
	9	3	15	< 0.04 ppm
	10	3	15	< 0.04 ppm
UTILITY MAN				
Total Particulates	11	4	244	< 0.66 mg/m^3
Mercaptan	12	3	260	< 0.01 ppm

[1]Samples collected on pre-tared 5.0 um PVC filters and analyzed gravimetrically

[2]Samples collected and analyzed by NIOSH Method P & CAM 126

[3]Samples collected and analyzed according to method of Knarr and Rappaport, Anal. Chem., 52, 1980, pp. 733-736.

room; two hours to perform washdowns of various outside areas and to cleanup hot lime from below the kiln; and approximately one hour of total break time. Results for all these personal samples were also included in Table 16-2.

As shown, total particulate exposures for the Operator while in the control room (0.15 and 0.51 mg/mg^3) and the Utility Man (0.66 mg/m^3) were all well below the OSHA TWA's for either nuisance dust (15 mg/m^3) or lime dust (5 mg/m^3). Rainy weather the day before may have reduced general dust levels in the recausticizing area, but the utility man's exposure monitoring period did encompass commonly performed outside tasks. Included were his common cleanup tasks involving hot lime material from below the kiln (Task 5). Performing such tasks could potentially result in dust exposure, and require the worker to wear full-protective equipment. We could not evaluate the potential for dust exposure during other housekeeping tasks because of the large amount of rain during the survey.

The single result of 0.51 mg/m^3 indicated some potential contamination of the control rooms with process dust; and, in fact, accumulations of dust were observed on the floor and other horizontal surfaces. These may periodically be disturbed and re-suspended by worker activities and create minor exposures. Workers also frequently transport some dust into the control room on their boots and clothing. Either of these sources may be the cause of the slightly elevated total particulate level of 0.51 mg/m^3 obtained in this workspace. (It was reported that thorough wet cleaning of the room is not possible because water may leak down into the electrical room below the control center.)

Further laboratory analysis to estimate the percentage of lime (CaO or $CaCO_3$) in the total particulate matter of any of the above air samples was unwarranted due to the low results.

CONTROL TECHNOLOGY

Nature of Exposures -

No significant continuous sources of dust emission from the kiln or lime transport systems were observed. Worker exposures, therefore, occur primarily during performance of housekeeping and cleanup tasks. These tasks are performed outside and only by the Utility Man. They involve sweeping or shoveling of lime or limestone spills, and may generate airborne dust. The worker's exposure is dependent on environmental conditions and his own individual work practices. During the survey, considerable periods of rain

probably lowered general dust levels around the recausticizing area. Worker exposures to other process chemicals (reduced sulfur gases burned in the kiln and caustic mists from the slaker), noise, and heat stress were all judged as insignificant.

Types of Controls -

Control of workplace exposure is largely inherent in the nature of the recausticizing and kiln processes and equipment. However, four controls were identified in this mill that contribute to either limiting emissions of dust (and gas) or to protecting workers from exposure: 1) process monitoring and testing; 2) a well-designed control center and HVAC system; 3) good attention to housekeeping and spill cleanup; and 4) use of personal protective equipment. Each of these four controls will be discussed in the following sections.

Process Monitoring and QC Testing -

The most noteworthy process monitoring and control system in the mill is the lime kiln computer optimization-control system. Although detailed discussions of the material and operational efficiencies attained with this system are beyond our capabilities, they were reported to be substantial. This is important for this particular mill because only a single kiln is used, and its efficient and stable performance is vital to maintenace of stable operations in other areas of the pulp and paper plant. Breifly, the computer optimization control (installed in 1979) has the following components and functions:

- A DEC PDP 11/03 microcomputer with dual floppy disks, a printer with keyboard, and a control panel with digital displays and control switches for operator interfacing;
- Seventeen (17) input channels for the continuously monitored variables of: 1) oil flow; 2) gas flow; 3) burning zone temperature; 4) kiln exit gas temperature; 5) excess oxygen; 6) total reduced sulfur in kiln gas; 7) mud flow to filter; 8) primary air flow; 9) firing hood pressure; 10) feed hood pressure; 11) kiln RPM; 12) exit gas scrubber recycle flow; 13) scrubber liquid density; 14) venturi differential pressure; 15) mud density to filter; 16) filter vacuum; and 17) recycle flow to mud mixer;
- Five channels of output to control setpoints on:

  1) Burning zone temperature (cascaded to fuel controller)

2) Kiln exit gas temperature (i.e. controls induced draft fan dampers)
3) Primary air flow
4) Lime mud flow to the mud filter
5) Kiln rotational speed.

The control-optimization strategy (computer software) was developed by an outside specialist after extensive analysis of kiln operating data using a dynamic simulation model. Basically, the system instantly calculates setpoints for the above controlled variables based on the mud flow (to kiln) target. This is inputted by the operator. Outputs to the controllers then maintain or change the controller setpoints accordingly. The optimization feature reduces fuel consumption to a minimum value within the constraints of suitable lime (CaO) quality and other process limitations. Lime (CaO) quality is determined by a manually-performed available CaO chemical test. Results of this test are then inputted to the computer by the operator. The computer then determines the amount by which fuel consumption and other parameters should be changed to achieve the desired target production.

The computer-optimization system indirectly contributes to reduced worker exposures in two related ways. First, it is believed that production workers are now required to spend far less time outside the control center making process adjustments or investigating apparent abnormalties or malfunctions. In fact, only a single worker controls the entire recausticizing and kiln operations, and he spends in excess of 80% of his shift in the control center. Secondly, recausticizing and kiln upsets may occur far less, although the process operates largely trouble-free. (Recausticizing and lime kiln equipment is inherently simplistic, durable, and runs comparatively trouble-free.) With this system, the operator now instantly knows process conditions and the extent to which desired or required products are being achieved. Current operational data can be instantly displayed and evaluated, allowing him to perform his job with far less tension and confusion over effective process operation. This capability also allows for more rapid diagnosis and correction of malfunctions - possibly preventing impending upsets. It may also greatly reduce such upset events (or eliminate them completely), although there is no basis for comparison.

The various quality control tests performed by the operator each hour provide data by which actual process conditions and effectiveness are determined. Little potential for exposure occurs during the brief time (<15 minutes) required to collect the various samples from locations outside the control center.

Chemical tests are performed within the control center, and then all results recorded and evaluated. Incongruous results may require first re-sampling and re-testing for verification, then investigation of the various process monitoring systems. Acceptable data is then inputted to the computer, and existing or new control parameters are established automatically.

Control Center Design -

The well-designed control center in this mill provides an additional measure of protection against worker dust exposure. It is situated, as is typical, at the firing/discharge end of the kiln, and affords the Operator excellent visibility of the access to the important operations and equipment at this end. Within the control center conveniently located are the computer output printer and control panel, other controllers for manual (analog) operation of equipment, a small testing laboratory, and bathroom facilities which include a shower. The Operator can thus readily monitor and control the entire recausticing plant from this control center and continuously see the important lime kiln discharge/firing and operations.

The maintenance of clean, cool, and positive-pressure air within this control center is also important. Cooling is necessary because of the tremendous amount of heat given off by the kiln combustion processes. In its absence, conditions could become unpleasant for the Operator, and possibly lead to overheating of the computer system and other electrical controls. Filtered and positive-pressure air is important to protect against process dust (CaO and/or $CaCO_3$) entering, especially during upset conditions or during dry, windy weather. Entry and subsequent accumulation of such dusts could pose some worker exposure risk, and also damage the various elecrical control systems. The HVAC system for this control center consists of the following components:

- A single air conditioning unit (Trane Model SUW 504) with a 2220 CFM fan and remotely located thermostat;
- An electric heater on the fan discharge duct to heat room air when required;
- A high efficiency air filter unit on the fan intake side (Burke & Co., Roto Aire Sureseal Model No. 312-130 with 2 sets of 20" x 20" x 8" Servodyne Corp. Serv-Aire HI-E-60 Filters and F.W. Dyer A-25 Manometer);
- A wall-mounted 5" exhaust fan (232 CFM) for the bathroom;

- o A wall-mounted 12" fan (920 CFM) for exhausting the duct space above the control room suspended ceiling; and

- o A roof-located make-up air supply duct (500 CFM) with 1/2" mesh screen, cap, and control damper.

For effective operation, the two small exhaust fans are operated continuously, and the air conditioning unit by its remote thermostat. Filtered air (cooled/heated) is supplied to the control room through two diffusers (1100 CFM each) located in the center of its suspended ceiling. Air is then returned through a single register (1700 CFM) located just above and to the left of the front door. It is then combined with fresh outside air (500 CFM); and both are filtered before returning to the AC unit. Although a small amount of air (1152 CFM) is exhausted from the building by the wall fans above the ceiling and in the bathroom, effective positive air pressure is still maintained in the central part of the room. Therefore, when either of the two access doors are opened, air flows mostly outward and reduces possible entry of any air-suspended dust. Air direction readings made at these two doors with smoke tubes confirmed this fact. The noticeable accumulations of settled dust on horizontal surfaces indicates that some dust still enters on workers' boots or clothing (or, perhaps, from collected lime dust samples). However, workers are not significantly exposed if dust accumulations are periodically cleaned in an effective way (i.e. wet cleaning or vacuuming with an absolute filter vacuum).

Housekeeping and Spill Cleanup -

Good housekeeping and prompt cleanup of process material spills around recausticizing and kiln equipment are very important. Ironically, their performance may also result in the most significant worker exposures. However, failure to cleanup spilled process materials could cause significant accumulations of lime. These could then result in airborne dust that could expose more than the recausticizing area workers. In Mill 16, management apparently recognizes this and assigns high priority to timely and effective housekeeping measures. This is evident because a single utility person is assigned for essentially an entire shift to such duties.

As summarized in the job description section, the utility person performs an extensive daily cleanup of the area below the lime kiln and around the various recausticizing tanks and other lime handling equipment. His routine includes both hose-downs of major work areas and walkways, and cleanup of

accumulations of dust and lime material from below the kiln, hot lime transport system (to the storage silo), and the slaker feed system. To accomplish the latter cleanups, he may use a combination of dry sweeping, brushing, shoveling, and/or hosing methods, as appropriate. Usually, large accumulations of material in accessible areas are swept into large piles, shoveled into a wheelbarrel, then dumped into a disposal bin for transport to a landfill.

It was noted that dust emissions and spills probably occur more frequently at the discharge end of the kiln where the process material is primarily quicklime or calcium oxide. However, some dry quicklime and/or limestone (calcium carbonate) may also periodically escape as a dust from the feed end of the kiln. Spills of wet lime mud at this end pose little dust exposure hazard until the mud thoroughly dries.

The utility person may spend in excess of 75% of his time performing cleanup or housekeeping tasks, most of which are at the discharge end of the kiln. He may also periodically sweep or vacuum the control room, and cleanup dust accumulations from around other areas or pieces of equipment anywhere in the mill.

The individual shift operator is responsible for maintaining the kiln firing end platform and hood free of dust accumulations. To do this, he is supposed to use a compressed air line once per shift to blow settled dust off the hood and platform. However, this procedure was not observed, and although a fast and simple one to perform, may so effectively disperse the finer material that subsequent collection becomes impossible. However, failure to keep this area clean could result in significant amounts of process dust getting into the control room.

Personal Protective Equipment -

Observed personal protective equipment available for worker use in this mill include:

- Respirators - 3M Model 8710, half-face piece disposable masks;
- Protective rubber gloves;
- Rubber boots and jackets (with protective head covers); and
- Eye shields.

Each is kept in or near the control center and readily available for worker use. However, interviews with workers indicated that no specific, mandatory requirements are placed on their use, but instead left to the discretion of the worker.

Protective equipment is often used for two common tasks in this mill. First, the operator will often wear rubber gloves when collecting samples of caustic solutions or materials such as slaker, causticizer, or clarifier solutions; green liquor; and occasionally lime samples. Secondly, the utility person will wear full-body protective equipment cleaning up lime spills from below the kiln discharge end. This equipment is necessary to protect against any hot lime or stones dropping from the overhead kiln, and against any lime dust generated by the particular clean-up procedure. Equipment includes a disposable, filtering-type respirator, an eye shield, and rubber head-hood, jacket, pants, and boots. Its use and thoroughness of protection are highly commendable. The particular employee observed using this equipment was also careful to use good work practice to limit dust generation and exposure when handling dry material. Of particular note were attempts to always stand upwind if dust would be generated by a particular operation. He was also very careful about using only clean respirators and thoroughly washing himself after completing cleanup tasks or before eating.

MILL 19 RECAUSTICIZING AND LIME KILN OPERATIONS

INTRODUCTION

This report summarizes a two-day survey of recausticizing and lime kiln operations for two Kraft pulping systems. There are three separate process lines that have conventional recausticizing technology. Total lime output averages about 290 tpd, and white liquor production is for 1100 tpd of Kraft pulp. The mill is located in the Pacific Northwest.

MILL LAYOUT

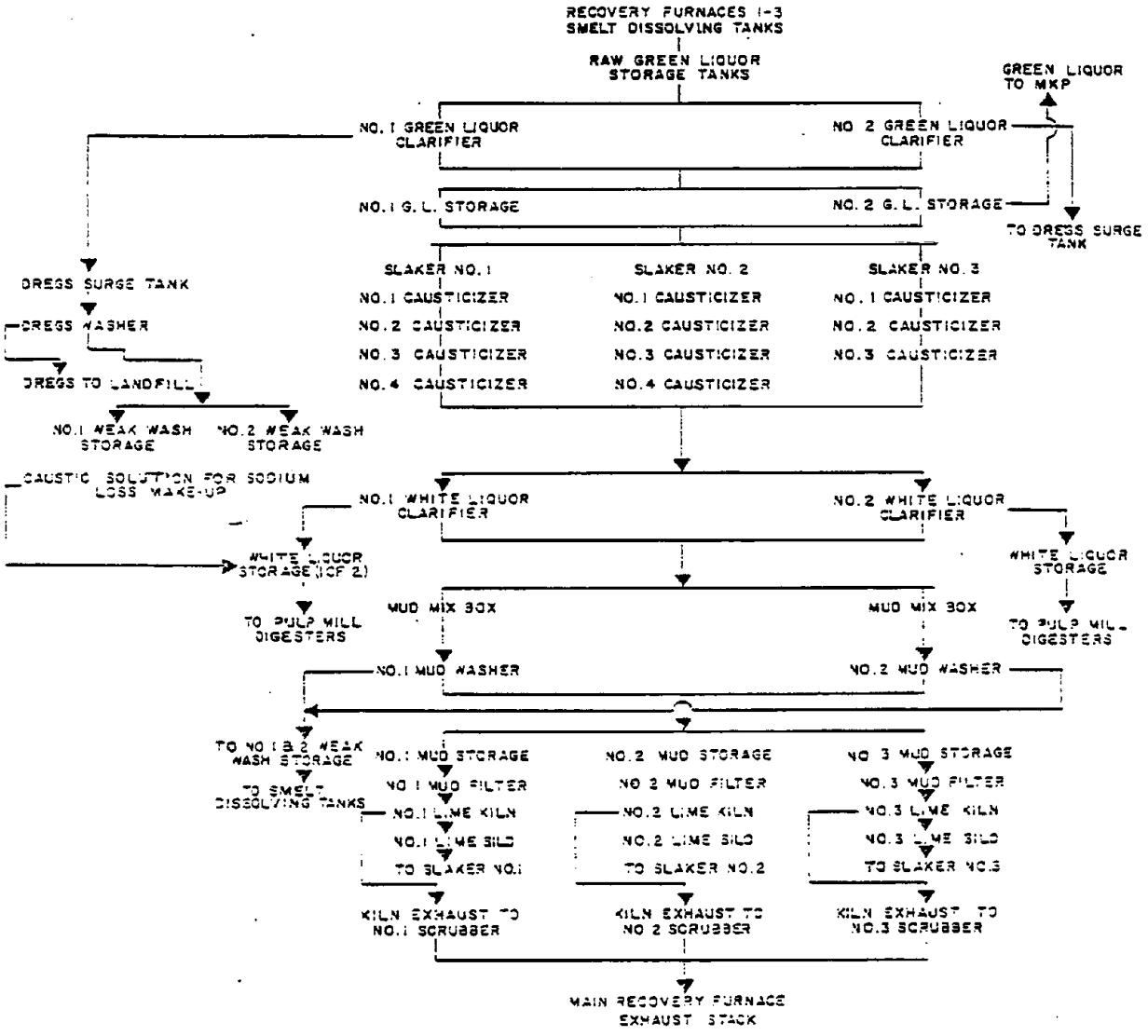
The three lime kilns are located in parallel, with the two oldest and largest (Nos. 1 and 2) sharing a common feed-end building. The newer lime kiln has a separate feed-end building. The buildings contain the lime mud filters and screw-conveyor feed systems for the kilns. Two of the recausticizing lines (lime silo, slaker, and causticizers) are located on the north side of a control center. The other line is located on the south side.

PROCESS DESCRIPTION

A simple process diagram is presented as Figure 19-1. Unique features of the process are:

- Use of three recausticizing systems each with a separate lime storage silo, green liquor heater, slaker (with classifier section to remove grit), and 3 or 4 causticizing tanks.
- Two separate, single-tray white liquor clarifiers, one of which receives recausticized liquor from Lines Nos. 1 and 2; and other from Line No. 3. (Flows can be intermixed.)
- Two separate lime mud washers (one double-tray) which are operated in parallel.
- Two double-tray, green-liquor clarifiers which are operated in parallel (raw green liquor from each recovery furnace's smelt dissolving tank is mixed and stored in a single tank.)
- A single green-liquor dregs washer.
- Three gas-fired rotary lime kilns to convert mud ($CaCO_3$) to quicklime (CaO).

FIGURE 19-1 : SIMPLIFIED PROCESS FLOW DIAGRAM



- Two tanks for storing weak wash water from the mud and dregs washers.

- Diversion of a small part of the clarified green liquor flow (about 5% or 50 gpm) back to the pulp mill for use in a modified Kraft digestion process.

- Makeup of recovery (sodium) loss by adding sodium hydroxide solution (caustic) directly to the white liquor storage tank.

The last of these is particularly significant because it eliminates potential exposures from lime/limestone handling.

JOB DESCRIPTIONS

Recausticizing equipment operation is separated from operation of the lime kilns. One employee operates each, and is the only production worker normally present. Shift foremen and maintenance personnel periodically make equipment inspections and repairs; utility personnel perform cleanups and housekeeping. Although each operator normally works independently, they will assist one another when required (e.g., collection of quality control samples). Their major job responsibilities are as follows:

Causticizing Operator: This operator monitors and controls the three causticizing lines, green liquor storage and clarifying tanks, the lime mud washers, the dregs washer, and the weak wash storage tanks. The majority of the recausticizing process is monitored and adjusted from the control center. The slaker requires considerable attention as problems can cause chain reactions at points farther on in the process. The Operator carefully controls the amount of hot lime fed to the slaker, the green liquor flow and temperature. He must also periodically inspect each slaker and ensure that none of the feed or overflow systems are clogged, and that the classifier section rakes are operating properly. Outside inspections and tests must be made to actually determine the effectiveness of the causticizing, liquor clarification, and mud washing processes. The Operator makes either hourly sample collection or equipment inspection tours throughout his shift. Sample collection points, frequencies, and tests performed are summarized in Table 19-1. The sample collections typically require the Operator to be outside the control center from 3 to 20 minutes, depending on the particular run. The slaker, green liquor, and mud washer samples are all collected during the same run; others are taken either separately or during a complete run. All samples are tested in a small laboratory within the control center. It is estimated that this operator is in the control room for 35 percent of each shift.

TABLE 19-1 SUMMARY OF REGULARLY PERFORMED QUALITY CONTROL TESTS

Job Category	Sampling Location	Frequency	Type of Test Performed
Caustic Operator	o Slaker liquor to causticizers	4 times/shift	
	o Green liquor clarifiers: Top and bottom of tanks (2), plus raw green liquor	4 times/shift plus 1 variable additional	
	o Mud washer overflow	4 times/shift	
	o Dregs washer underflow	variable	
	o Green liquor clarifier underflow	variable	
	o Purchased makeup caustic to white liquor storage	variable	
Lime Kiln Operator	o Mud filters[1]/	2 times/shift	
	1. filter vat slurry 2. filter drum sample		
	o Lime discharged from kiln	Once/shift	
	o Pump test	Once/shift	Performs a manual vibration test for leaks on number of pumps around kiln and recausticizing area.

1/ May also perform inspection and cleaning of filters at time of sampling.

Kiln Operator: The kiln operator remains in the control center (or out on the kiln firing hood platform) well over 50% of each shift. Most of the process monitors and controllers are located within the control center. Outside tasks, mostly unscheduled, include:

- Visually inspecting the kiln interiors to ensure that lime is moving, no rings are developing, and that the kiln lining is intact (may be performed 2 or 3 times per hour for each kiln; operator must wear welding helmet and eye shields when looking into kiln)
- Breaking up large lime lumps in the end of the kiln and discharge chute (performed as required, using long steel rod)
- Inspecting, servicing, and cleaning, mud filters--Operator cleans doctor blades, washer, spray nozzles, mud screw-conveyor mechanism, and building floors; minor maintenance on motor drive systems (all tasks are done largely on an 'as-needed' basis)
- Checking the height of lime in the storage silos (Operator uses a plumb line; task performed only occasionally)

To ensure good lime production, the Operator must also perform regularly scheduled process quality control tests (Table 19-1). All chemical tests are performed in the control center.

During two days of observation, it was noted that the Operator may on occasion be outside the control center for as long as 30 to 40 minutes performing any of these tasks. However, he is rarely outside longer than 15 minutes at any one time. A mud sample collection run typically requires 10 to 12 minutes, and usually includes a quick wash-down of the area. A pump inspection tour of the recausticizing/lime kiln area may require as long as 15 minutes outside. If poor lime is being obtained, more tests and visual inspections of the kiln may be required, hence more time may be spent outside the control center.

POTENTIAL WORKPLACE EXPOSURES

Most process equipment is located outside. However, the lime mud filters and the firing/discharge ends of the kilns are located in a small building made of prefabricated metal to protect equipment against the elements.

Lime mud entering the filters is slurried and becomes a thick cake as the water is removed. Since it is always wet, there is no source of dust generation. The Operator periodically hoses

down the floor area around the filters, thus reducing the likelihood of spilled mud becoming an exposure source. In addition, all filters are hooded and ventilated to remove steam; any acid gas (HCl) emitted when filter fabrics are washed is removed through the hood.

At the firing/discharge end of the kilns, dust is a significant possibility. However, it does not impact directly on any enclosed workspace. Most of the discharge from the kiln to the storage silos exists as small to large lime stones. However, a small amount of fine dust is also discharged and may escape through the kiln discharge chute and screw conveyor system. The dust is composed primarily of quicklime (CaO), although some sodium sulfide (Na_2S) and lesser amounts of calcium carbonate, sodium carbonate, and other minor lime impurities are present. Dry lime is also occasionally spilled onto the firing end platform through the observation doors of the kilns. This usually consists of only small stones (or pebbles), and does not have a tendency to become airborne.

Other sources of potential lime (or process dust) emissions include the lime feeding system to the slakers, and the air seal at the feed/exhaust end of the kilns. Both of these appeared to be constant but minor sources of dust emission, but are located outside. The air seal leak is not typical and has since been repaired. However, it did result in a significant buildup of fine dust immediately below the kiln, as shown. This dust may be a combination of both calcium oxide (quicklime) and calcium carbonate (limestone).

The green liquor from the recovery furnace smelt dissolving tanks potentially contains some reduced sulfur compounds (sulfides and mercaptans) that could be released from the green liquor clarifier or the lime slakers. More importantly, pulp mill non-condensable gases (containing high concentrations of reduced sulfur compounds) are burned in Kilns Nos. 1 and 2. These could potentially be released to the workplace.

The dregs removed from the green liquor clarifier and the grit from the slakers are largely insoluble, inert material that poses little exposure hazard to workers. It is discharged into storage bins for later transport to landfill sites.

AIR SAMPLING RESULTS

During the survey period, personal sampling was conducted to assess potential worker exposure to process dust. Area sampling was conducted to investigate the presence of hydrogen sulfide and mercaptans. Personal samples for total airborne particulates were collected on pre-tared PVC filters contained in three-piece cassettes. Constant flow air pumps (calibrated before and after sampling with a Kurz mass airflow calibrator)

were used. Single samples were collected on the Kiln and Recausticizing Operator for approximately four hours. One hour samples for hydrogen sulfide were collected in the control room and on the kiln firing platform. Drager detector tubes were used to make spot readings for both hydrogen sulfide and mercaptan in the control center, on the kiln firing end platform, and above the green liquor clarifier.

Results for all these samples are summarized in Table 19-2. As shown, all results were either non-detectable (hydrogen sulfide and mercaptans), or well below the OSHA permissable exposure limits. These applicable exposure limits are: 15 mg/m^3 for nuisance dust, 5 mg/m^3 for lime dust, both as 8-hour TWAs; and 20 ppm H_2S and 10 ppm mercaptan, both as ceiling limits.

The absence of any detectable quantities of hydrogen sulfide or mercaptans around the kiln firing end indicates little significant escape of non-condensable gases from the kilns during normal operations. Similarly, few, if any, reduced sulfur gases appear to be given off from the green liquor. It is therefore highly unlikely that OSHA standards for these chemical agents are ever exceeded. Potential exposures during process upsets could not, of course, be accurately assessed.

Worker exposures to total airborne particulates is similarly low, based on the two 4-hour samples that were collected. The sampling periods, although encompassing only half a shift, include most of the common daily tasks performed by the two workers (including equipment inspection and quality control sample collection tours). However, they did not include any outside housekeeping or lime spill cleanup tasks, which may result in more significant process dust exposures. Since all results were less than 5% of the OSHA PEL for nuisance dust and less than 10% of the lime dust limit, no attempt was made to analytically determine the actual percentage of lime dust in the total particulate matter. The measured concentrations, however, do indicate good control over process dust exposures.

CONTROL TECHNOLOGY

The low worker exposure to dust, hydrogen sulfide, and mercaptans is a result of the combined direct and indirect effects of:

- The inherent nature of the equipment and the process;
- Worker isolation and protection afforded by the well-designed and ventilated control center;
- The lack of direct worker involvement with the process other than periodic outside inspections, equipment adjustments, and quality control sample collections; and

TABLE 19-2: SUMMARY OF AIR SAMPLING RESULTS

Personal Samples

Job Classification	Contaminant	Sampling Period	Concentration
Recausticizing Operator	Total Particulates[1/]	14:34-18:37	0.2 mg/m^3
Lime Kiln Operator	Total Particulates	14:30-18:31	0.6 mg/m^3

Area Samples

Location	Contaminant	Sampling Period	Concentration
Kiln Firing End Platform Between Kilns 1 and 2	Hydrogen Sulfide [2/]	16:09-17:09	< 0.02 ppm
Control Room	Hydrogen Sulfide	17:12-18:21	< 0.02 ppm

Draeger Detector Tubes

Location	Contaminant	Concentration, ppm
Lime Kiln Control Room	Hydrogen Sulfide	No reading, est. < 0.25*
	Mercaptan	No reading, est. < 1.0*
Front of Kiln No. 2 Firing End	Hydrogen Sulfide	No reading, est. < 0.5*
	Mercaptan	No reading, est. < 1.0*
Above Green Liquor Clarifier	Hydrogen Sulfide	No reading, est. < 0.5
	Mercaptan	No reading, est. < 1.0

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* Used 20 pump strokes

1/ Samples collected on pre-tared PVC filters (5.0 μ pore size), using 3-piece cassettes and constant fluorate pumps

2/ Samples collected according to NIOSH Method P & CAM 126

- o Good attention to preventive maintenance, housekeeping and spill cleanups.

INHERENT PROCESS CONTROLS

Recausticizing and kiln operations are inherently well-controlled and pose minimum risk of worker exposure to air contaminants. Incoming green liquor, although a hot and concentrated aqueous solution of sodium carbonate and sulfide, contains few volatile, toxic compounds (driven off and destroyed in the recovery boiler). The lime slaking and green liquor recausticizing reactions are exothermic and give off significant quantities of steam and possibly some caustic mists. However, the slakers are all well-vented and off-gases are scrubbed to remove lime dust or caustic mist. In addition, the slaker reactions are continuously monitored for temperature and reactant flows (lime and green liquor). These controls greatly reduce the likelihood of process upsets.

The causticizers are covered, agitated tanks and are not sources of air contaminants. White liquor clarification and lime mud recovery and washing/thickening steps are also accomplished in large covered outside tanks. These operations require little operator attention other than periodic tests to ensure proper efficiency, and inspection of the agitator and mud rake mechanisms.

Lime emission points have previously been discussed, but it should be further pointed out that dust emission directly from the kilns is prevented by two standard systems. First, a large amount of air must be injected into the kilns to combust the primary fuel and the non-condensable gases. This is accomplished with two fan systems (primary and secondary) which direct air into the kiln center near the fuel injection point. To ensure that the air moves quickly and evenly up the kiln, a large induced draft fan is used on the kiln exhaust end. The draft induced by this fan is carefully monitored and regulated within narrow limits to assume proper drying of the incoming lime mud and efficient calcining. However, it also prevents combustion gases from escaping through the air seals at the end of the kilns. (Some of these air seals were leaking during the survey, but most of the emitted lime dust was not becoming airborne.)

The exhaust gas scrubber located on each kiln prior to the induced draft fan removes any entrained lime dust and other combustion products (via a hot water spray). The scrubbed contaminants are then returned to the process at the lime mud washers. The circulation of water through these scrubbers is continuously monitored in the control center and checked by the Operator. After scrubbing, the kiln exhaust gases are discharged to the atmosphere through the main mill exhaust stack, which is 290 feet high.

Spills of lime dust from the kiln discharge end, the transport system to the storage silos, and the slaker feed system are all inevitable at some time. They are controlled by close attention to equipment maintenance and sealing and regularly scheduled housekeeping.

WORKER ISOLATION

Both operators spend the majority of their time within the control center, well isolated from wind-distributed and transported process dust or other direct lime emission sources around the front of the kilns. The Recausticizing Operator spends as much as 75-90% of his shift here; the Kiln Operator in excess of 50%. This is possible because almost all of the process monitors and controllers (plus a small testing laboratory) are located within this building.

As shown in Figure 19-2, the control room contains:

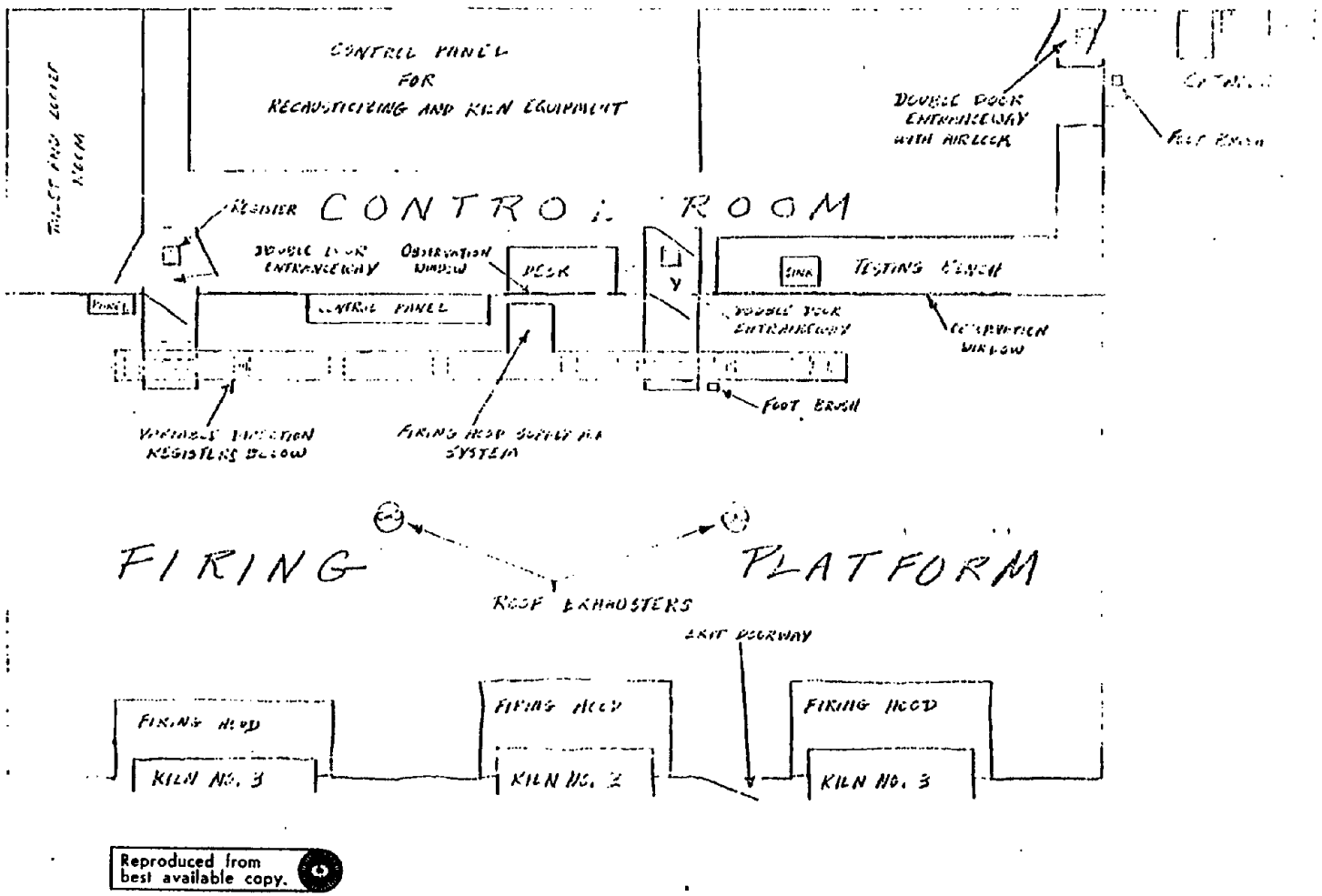
- a small QC testing lab area;
- a main process monitoring and controller panel;
- a work desk; and
- locker/washroom facilities.

The control center is quite new and has an excellent air conditioning system to keep inside conditions comfortable from the excessive amounts of heat given off by the nearby kilns. Unfortunately, no design data were available on the capacity of the HVAC system. A particularly novel aspect of the system are the three air discharge registers located inside each of the double door entrance ways to the room. Since the inside doors would normally be closed whenever someone was entering the room, an air barrier (measuring 50 fpm outward) is established to prevent dust from entering the room. In addition, small brushes are permanently mounted just outside each entrance way so that workers may remove dust adhering to the sides and bottom of their shoes. This greatly reduces the amount of dust tracked into the room and the amount of required cleaning.

The front of the control center is provided with four large observation windows fitted with safety glass. These provide either operator with constant vision over the front of the kilns (firing end platform) and their fuel and air feeding systems, plus the hot lime discharge chutes. They can therefore monitor these important systems from the control center.

When either worker is required to go out onto the enclosed firing end platform, two other ventilation systems provide good control over potential heat and dust exposure. The first is a supply air system located on the control room's wall about 10

FIGURE 19-2 CONTROL CENTER LAYOUT



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to 12 feet above the floor. A fan brings fresh, filtered outside air from the roof and distributes it through eight (8) rectangular distribution registers with variable-direction louvers. By properly adjusting these registers, fresh, cool air can be directed to the front of the kilns, keeping hot and dusty air away from the worker. Since this work space is tightly enclosed (presumably to protect equipment from the elements), two roof fans are provided to exhaust the heat and blast given off by the kilns. No specifications were available, but velometer readings taken at the worker position showed velocities well above 300 fpm towards the kilns. These two systems appeared to be very effective at preventing lime dust from settling and accumulating on the platform (or other horizontal surfaces).

WORKER PROTECTIVE CONTROLS

Protective equipment is provided for workers in the recausticizing/kiln area, but was not required during the survey period. Equipment was stored in the control center and included:

- Half face piece air-filtering type disposable masks (3M Model 8710 Respirators)
- Heat Resistant gloves (for use when working around the hot kilns)
- Rubber gloves (for use when performing lime dust cleanups or handling any of the caustic liquors)
- Safety glasses (for use when outside the control room area.)
- Hardhats (for use when outside the control room area)
- Hearing protectors (for use when outside on the kiln firing platform)

Use of respirators in the pulp and paper mill complex is well planned and carefully supervised. The mill has an excellent program which is summarized in an overall written manual, and includes:

- Detailed informational and educational material on the nature of respiratory hazards;
- Descriptions of the types of respiratory protective equipment provided and available in the mill (i.e., air purifying, supplied air and SCBA), and their principle of operation and manner of use;
- Complete descriptions of the color coding scheme used for respirator canisters;

- o A table summarizing types of contaminants (and TLVs), and the corresponding recommended type of respirator (part number, type, NIOSH approval number, cartridge number, and color code);
- o Detailed training in use, fitting, and care and maintenance of respiratory protective equipment; and
- o Medical considerations of use.

Overall responsibility for the program is assigned to the Mill Safety Supervisor, but daily supervision and enforcement is the responsibility of each department head. The Mill Purchasing Department is given the responsibility of ensuring that only NIOSH or Bureau of Mines approved equipment is purchased. The program clearly states that respirators can be used only as a "temporary" control until feasible engineering controls can be found and installed. It is the responsibility of the Engineering Department to develop and install such controls.

HOUSEKEEPING

Housekeeping is usually performed as needed by the utility personnel. In general, the mill was free of dust-producing accumulations although most equipment was coated with hard limestone deposits. It was reported that the entire area was subject to a semi-annual cleaning for accumulated lime dust. The control room is periodically vacuumed and wet-mopped and was generally very clean.

PREVENTIVE MAINTENANCE

Preventive maintenance is routinely performed on the equipment and is an important factor in the prevention of process upsets, leaks, and spills. Each operator maintains a list of equipment which must be inspected and lubricated each day (Figures 19-3 and 19-4). This procedure provides for the early identification and correction of problems before the impacts are very severe.

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FIGURE 19- 3 CAUSTICIZER OPERATOR'S MAINTENANCE REPORT

CAUSTIC & RECM

EQUIPMENT TO BE CHECKED DAILY

	Oil	Grease
61-001 #1 Green Liq. Clarifier Rake		
61-004 Green Liquor to Slaker		
61-005 Green Liquor to MUF		
61-006 Dregs Mix Tank Agitator		
61-008 Dregs to Dregs Washer		
61-013 Lime Screw		
61-014 Lime Screw		
61-015 Slaker Bowl Agitator		
61-016 Clarifier Rake		
61-020 Causticizer Agitator		
61-021 Causticizer Agitator		
61-022 Causticizer Agitator		
61-025 White Liquor Slurry Pump		
61-026 White Liquor Slurry Pump		
61-028 #1 White Liquor Clarifier Rake		
61-029 #1 White Liquor Clarifier Rake Lift		
61-031 #1 White Liquor Clarifier Surry Pump		
61-032 White Liquor Transfer Pump		
61-033 White Liquor to Digester Pump		
61-034 White Liquor to Digester Pump		
61-035 White Liquor to Digester Pump		
61-037 #1 Mud Washer Rake		
61-038 #1 Mud Washer Rake Lift		
61-040 #2 Mud Washer Slurry Pump		
61-041 #2 Mud Washer Slurry Pump		

	Oil	Grease
63-043 Weak wash to Dissolving Tank Pump		
63-050 Contaminated Hot Water Pump		
63-051 Contaminated Hot Water Pump		
63-201 #2 Green Liquor Clarifier Rake		
63-202 #2 Green Liquor Clarifier Rake Lift		
63-204 Green Liquor to Slaker Pump		
63-205 Green Liquor to Slaker Pump		
63-207 Dregs Washer Rake		
63-208 Dregs Washer Rake Lift		
63-213 Lime Screw		
63-214 Lime Screw		
63-215 Slaker Bowl Agitator		
63-216 Clarifier Rake		
63-220 Causticizer Agitator		
63-221 Causticizer Agitator		
63-222 Causticizer Agitator		
63-223 Causticizer Agitator		
63-225 White Liquor Slurry Pump		
63-226 White Liquor Slurry Pump		
63-227 White Liquor Transfer Pump		
63-228 White Liquor Transfer Pump		
63-237 Mud Washer Rake		
63-238 Mud Washer Rake Lift		
63-239 Mud Pump		
63-240 Mud Pump		

	Oil	Grease
63-243 Weak Wash to Dissolving Pump		
63-250 Contaminated Hot Water Pump		
63-252 #2 White Liquor Clarifier Rake		
63-253 #2 White Liquor Clarifier Rake Lift		
63-254 #2 White Liquor Clarifier Slurry Pump		
63-255 #2 White Liquor Clarifier Slurry Pump		
63-257 White Liquor to Storage Pump		
63-258 White Liquor to Storage Pump		
63-304 Green Liquor to Slaker Pump		
63-313 Lime Screw		
63-315 Slaker Bowl Agitator		
63-316 Clarifier Rake		
63-320 Causticizer Agitator		
63-321 Causticizer Agitator		
63-322 Causticizer Agitator		
63-325 White Liquor Slurry Pump		
63-326 White Liquor Slurry Pump		
63-327 White Liquor Slurry Pump		
63-328 White Liquor Slurry Pump		
63-330 White Liquor Slurry Pump		
63-333 White Liquor to MUD Pump		
63-334 White Liquor to MUD Pump		
63-335 Weak Wash to Storage Pump		
63-350 Contaminated Hot Water Pump		

FIGURE 19-4 LIME KILN OPERATOR'S MAINTENANCE REPORT

	Oil	Grease
64-001 #1 Lime Kiln Drive Parts and Trunion Bearings	_____	_____
64-005 Primary Air Fan		_____
64-010 I.D. Fan		_____
64-021 Cooling Water Recirculation Pump	_____	
64-030 Dynamatic Coupling Cooling Water Pump	_____	
64-032 Sump Clarifier Rake	_____	_____
	_____	_____
64-034 #1 & #2 Sump Pump	_____	
64-036 Sump Clarifier Stand Pipe Pump	_____	
64-037 Sump Clarifier Under Flow Pump	_____	
64-040 Mud Storage Agitator	_____	_____
64-041 Mud Pump to Filters	_____	
	_____	_____
64-045 #1 Mud Filter	_____	_____
64-046 #1 Vacuum Pump	_____	_____
64-051 #1 Sump Recirculating Pump	_____	
64-055 Filtrate Pump	_____	
64-060 Kiln Feed Screw	_____	_____
64-065 Hot Lime Conveyor (top & bottom)	_____	_____
64-068 Lump Crusher	_____	_____
64-071 Hot Lime Elevator (top & bottom)	_____	_____
64-201 #2 Kiln Drive Parts & Trunion Bearings	_____	_____
64-205 Primary Air Fan	_____	_____
64-210 I.D. Fan		_____
64-234 #1 & #2 Sump Pump	_____	
64-240 Mud Storage Agitator	_____	_____
64-241 Mud Pump	_____	

	Oil	Grease
64-245 #2 Mud Filter	_____	_____
64-246 Vacuum Pump	_____	_____
64-251 #2 Sump Recirculating Pump	_____	
64-260 #2 Kiln Feed Screw	_____	_____
64-265 Hot Lime Conveyor (top & bottom)	_____	_____
64-268 Lump Crusher	_____	_____
64-271 Hot Lime Elevator (top & bottom)	_____	_____
64-301 #3 Kiln Drive Parts & Trunion Bearings	_____	_____
64-305 Primary Air Fan		_____
64-310 I.D. Fan		_____
64-341 Mud Pump	_____	
64-342 Mud Pump	_____	
64-343 Mud Pump	_____	
64-344 #3 Mud Filter	_____	_____
64-346 Vacuum Pump	_____	_____
64-349 #3 Sump Pump	_____	
64-351 #3 Sump Recirculation Pump	_____	
64-355 Filtrate Pump	_____	_____
64-359 #3 Mud Filter Discharge Screw	_____	_____
64-360 #3 Kiln Feed Screw	_____	_____
64-365 Hot Lime Conveyor (top & bottom)	_____	_____
64-368 Lump Crusher	_____	_____
64-371 Hot Lime Elevator (top & bottom)	_____	_____

MILL 27 RECAUSTICIZING AND LIME KILN OPERATIONS

INTRODUCTION

This report summarizes a survey of exposure conditions and control technology in the recausticizing/lime kiln area of a Southern Kraft pulp mill. Mill 27 produces approximately 1450 tons per day of Kraft pulp in three continuous Kamyr and one M&D sawdust digesters. Pulping chemicals are reclaimed in two recovery furnaces and reconverted to useable white liquor in a single recausticizing line using two separate slakers and two rotary lime kilns.

MILL LAYOUT

The control center for the recausticizing/kiln area (about 14 x 38 feet) is raised above ground to the same level as the discharge/firing ends of the lime kilns. Immediately in front of it, and accessible through three doors (front and two side) is the kiln firing platform (approximately 40 x 75 feet). This supports the ends of the kilns, their large firing hoods, primary and secondary air fans, and other kiln fuel and air controls. It is partially protected from wind and rain by a roof which extends out from the control center. But, because there are no side or front walls, wind can blow dust from around the front of the kilns directly towards the control center.

Workers usually remain in the control center and have a clear view of all the equipment through large windows along the entire front wall. The center has a large central panel for monitoring and operating all equipment, a small lab testing bench, and an adjoining washroom.

The remaining mill equipment consists mostly of various outside tanks and silos, pumps, and piping systems. These are used for green and white liquor storage, lime slaking, green liquor causticizing, hot lime storage, and lime-mud storage. Most are located behind and to the side of the kilns and their firing platform.

PROCESS DESCRIPTION

Although Mill 27 uses conventional recausticizing equipment, it does utilize some unique equipment and process variations which affect process control and workplace exposure agents. Referring to the complete but simplified process flow shown in Figure 27-1, these include:

1. Two adjacent slakers which discharge hot slaked lime and green liquor to six agitated causticizer tanks arranged in series;

2. Three white liquor vacuum-drum filters (in parallel) to separate and recover the lime mud from the white liquor. These filters replace white liquor clarifiers and mud washers, which would be used in a conventional plant. Each is hooded and ventilated to capture any hydrogen sulfide released from the white liquor, or hydrochloric acid from the required daily cleaning of the filter fabrics;

3. Two conventional vacuum-drum lime mud filters (in parallel) to thicken the lime mud before it is fed to a kiln;

4. Two adjoining, nearly identical (12' diameter by 275' long) rotary lime kilns, each fired with natural gas and rated at 275 tons lime per day;

5. Separate venturi kiln exhaust gas scrubbers, located after a kiln dust collector and before the induced draft fan (scrubber solution is recycled through the dust collector back to the mud discharge conveyor of the white liquor filters);

6. Addition of limestone into the kilns to provide for lime makeup, and to aid in heat retention and formation of good lime pebbles for later slaking. This method of lime addition requires equipment to unload railroad cars, transport the limestone to storage bins, and then feed it into the kilns;

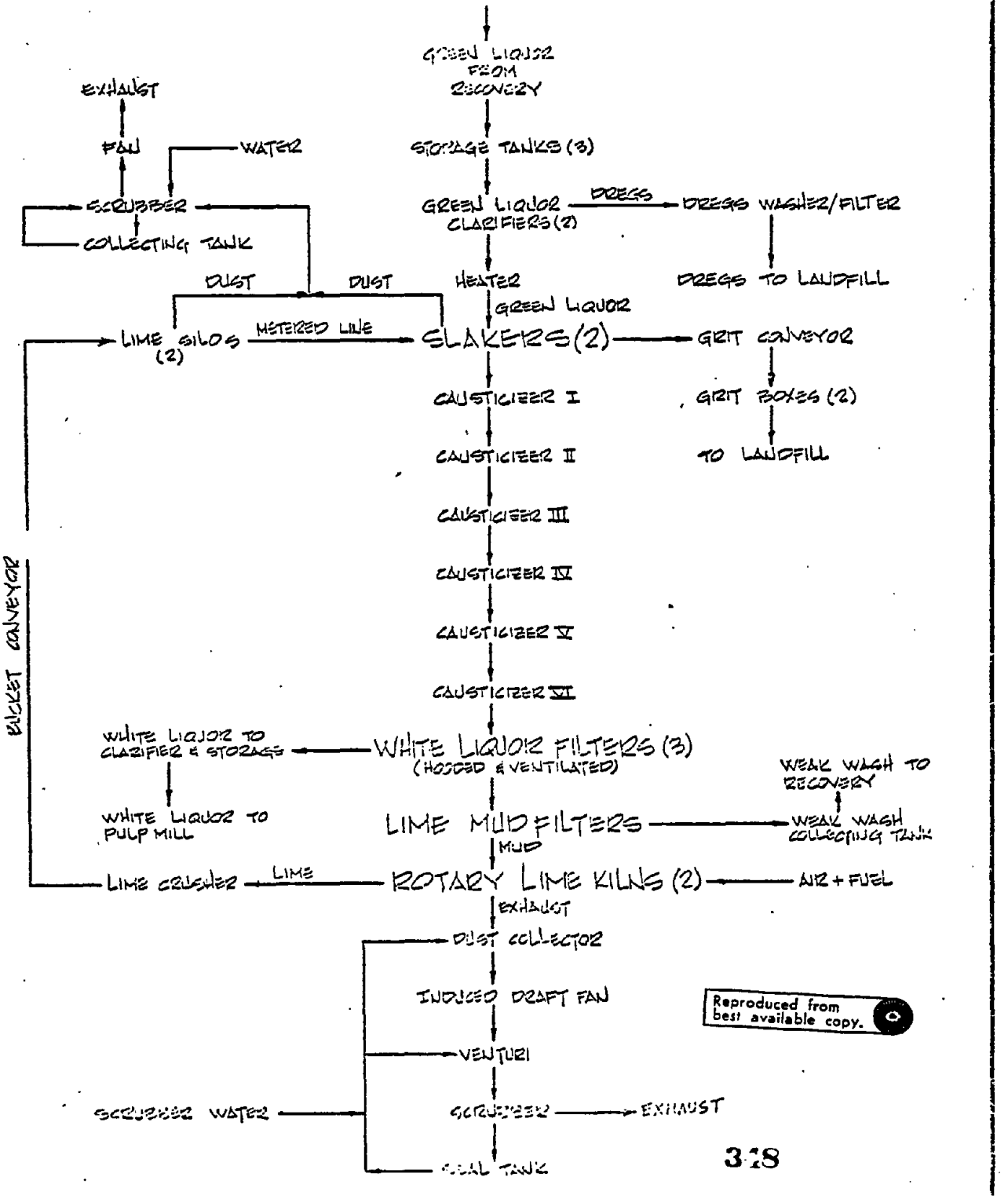
7. An exhaust fan and dust scrubber for the two reburned lime storage silos and the slakers (this replaced an old Peabody scrubber on the slakers); and

8. A secondary air fan which draws air through the hot lime screw conveyor and bucket elevator system. This both effectively pre-heats the air and aids in reducing dust emission from these systems.

With the possible exception of the scrubber for the reburned lime storage silos and shakers, the mill was satisfied with the performance of the above dust control equipment.

The remaining unit operations, equipment, and process flows are all shown in Figure 27-1. They require no further discussion. Pulp mill non-condensible gases are <u>not</u> burned in the kilns so workers are not exposed to them.

FIGURE 27-1 : SIMPLIFIED PROCESS FLOW



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POTENTIAL SOURCES OF WORKPLACE CONTAMINATION

At the time of the survey, the east lime kiln had a major dust leak in its exhaust-end air seal. This leak occurred because the sealing flange was ripped when the kiln slipped forward slightly. Very fine dust, and possibly limestone, continuously falls out of the kiln through this seal and can be blown back into the filter building through small wall openings on its north side. (The mill reported it requires about six months to obtain a replacement seal because this is a customized item.) Dust leaks were also observed at the other kiln's air seal, and at an expansion joint on the east kiln's venturi scrubber (after the induced draft fan). These three leaks created an a-typical dust layer throughout the kiln exhaust ends and in the filter building. Worker exposure to this dust occurs whenever it is blown by the wind or resuspended by worker actions.

A small amount of lime dust was seen coming from the conveyor which takes hot lime from the kilns to storage silos above the slakers, and from the slaker feeding systems. Neither of these were significant exposure sources, and may have been caused by temporary poor performance of the fan and scrubber which exhaust these systems.

Coarse lime dust and large stones spill from the kiln discharge ends, and accumulate below the kilns and on the firing end platform. Any fine dust in this material can cause an exposure risk to personnel working on the firing platform or below the kiln discharge ends. High winds increase this dust exposure risk; periods of rain reduce it.

Workers can also potentially be exposed when cleaning up spilled lime around the kiln firing ends and limestone around the conveyor belts on the filter building roof. Such cleanup tasks, and other housekeeping measures around equipment where dust has accumulated, are regularly performed by the shift utility person, sometimes for up to a full 7-8 hours. The second helper periodically cleans up the spilled limestone below the conveyor belt on the filter building roof. His exposure to dust during these operation is small because the limestone is not particularly dusty, he only shovels it, and the work is performed outside.

JOB CATEGORIES AND DESCRIPTIONS

Five workers per shift are assigned full-time to the recausticizing/kiln area:

- o Chief Operator
- o Assistant Operator
- o First Helper (or Tester)
- o Second Helper (or Filter Operator)
- o Utility Person

Each has distinct job assignments, but also frequently receives some on-the-job training for the next higher job category.

Operator - The Operator has overall responsibility for all unit operations in the plant and supervises the other four workers. Because of this responsibility, he stays in the control center or around the kiln firing ends for most of his shift. He is in the control center watching process monitors and controllers an estimated 65% of the time. Occasionally, he leaves for brief but unpredictable periods to perform various tasks: He may break up large lumps in the kiln discharge grates; inspect the movement of lime down the kilns; or perform other inspections and adjustments of the kilns, slakers, and causticizers. Unless the tasks are particularly complex and he doubts that other workers know enough to perform them safely, he will usually direct other workers to make simple outside inspections or adjustments. If little time away from the control center is involved, he frequently performs jobs himself (conditions permitting). The principle operating rule is that a fully-trained person be in or very near the control center at all times, and that this person know where the operator is at all times.

Assistant Operator - The assistant operator is given direct on-the-job training for the operator's position. The stage of this training determines his work routine, but it is generally similar to the operator's routine. The assistant operator must eventually be able to monitor and operate all plant equipment with a minimum of assistance. When the operator is called away from the control center, the assistant operator covers for him. Overall, he spends about 70% of his time in the control center.

The assistant operator is also assigned the responsibility of operating a sulfite liquor preparation system, which is located behind the control center. It is automated, monitored, and controlled from the control center. Its operation requires a considerable amount of the assistant operator's time.

First Helper - This worker is responsible for performing quality control tests on the various materials to determine overall process and individual unit operation efficiencies. Every hour, samples of white and green liquor, reburned lime, makeup limestone, and lime mud are collected from various process points, then brought back to a testing bench in the control center for analysis. Actual sample collection runs typically require less than ten minutes. Sample collection and other miscellaneous tasks, require this worker to be outside the control center about 35% of the time. While collecting samples, this worker's estimated exposure to process dust is probably low.

Second Helper - This worker stays mostly in the filter building, which is at the kiln feed ends. One particular day shift worker (on whom all samples were collected), remains in the building his entire shift. Mill management reported this is not required and they would prefer he remain there only when necessary because of the potential dust exposure. However, at least three common tasks require significant amounts of time within the building:

1. Acid-cleaning (muriatic acid) and rinsing the fabrics of the white liquor filters and, less frequently, the mud filters --- performed once per shift on all three filters.

2. Changing the fabric on a white liquor filter --- usually performed on each filter once every few weeks, and requiring the assistance of the utility worker.

3. Adjusting the flow of limestone rocks out of the railroad car onto the conveyor belt; and cleaning up spilled rocks from below the cross-conveyor on the roof --- performed as required. (Rock cars have two separate compartments which are emptied one at a time.)

Of these tasks, cleaning the various filters (and making fresh cleaning acid) require the most time. The actual cleaning process occurs automatically after activating an acid shower above the filter fabric (before it returns to the inlet vat).

The filter continues to operate while this cleaning is done, and the entire process requires about one hour. While standing near the filters to observe the process, workers may be exposed to dry dust leaking from the kiln air seals and blown through wall openings in front of the filters, and to wet dust falling off the filter. (The second helper reported wearing a dust respirator for up to thirty minutes while cleaning one filter because of this dust.) Changing a filter fabric is difficult and requires two people and nearly four hours. The limestone unloading and conveyor system is outside. Adjusting the flow of limestone rocks to it is done as required, but may total as much as 30-60 minutes per shift.

The following jobs are performed by this employee as required or when there is free time:

1. General inspections of filter building and other outside equipment, including various pumps and liquor and lime mud storage tanks.

2. Hosing down the floor of the filter building and the area below the kiln feed ends.

3. Making up fresh batches of filter cleaning acid by diluting concentrated muriatic acid in an outside tank (after which it is pumped to the filter shower).

4. Cleaning the white liquor and lime mud oscillating shower nozzles ("punching showers").

Free or break/lunch time usually amounts to one hour or less, and is taken either in the control center or at a small desk in the filter building.

Utility Person - This worker performs lime and liquor spill cleanup tasks and other housekeeping operations as needed throughout the plant. He is outside the control center almost 90% of the time.

Significant dust exposure can occur during these cleanup tasks, but depend on the worker's practices and the particular cleanup technique. He spends a lot of time each day hosing down and shoveling up lime spills around the discharge ends of the kilns. During such cleanups, if the spilled lime is fine and dry, even hosing will cause some dust to become airborne. Careless shoveling techniques also create airborne dusts. Other clean-up practices in use include:

- Hosing down of lime in hard-to-reach places;
- Hand shoveling and use of a payloader to remove large deposits; and occasionally,
- Sweeping and shoveling, or use of a compressed air line.

The last of these, although not directly observed, undoubtedly creates significant airborne dust.

The Utility person is also assigned miscellaneous errands and chores throughout the plant, including trash cleanup, pickup of chemicals from the lab, and personal errands.

DUST EXPOSURE MONITORING RESULTS

Exposure Monitoring Method

Process dust is the major airborne contaminant in the mill. Therefore, exposures of the two highest risk workers to total airborne particulates were determined over nearly full-shifts on three successive days. In addition, a single area sample was collected each day in the control room to assess contamination of this protected workspace. These control room samples also provided a means to assess the remaining three workers' exposures because they spend the majority of their time in this room.

Samples were collected on pre-tared 5.0 uPVC filters by using constant-flow pumps. They were analyzed gravimetrically. Sampling results are summarized in Table 27-1. A brief summary of the estimated time spent performing certain tasks during each sampling period accompanies this as Table 27-2.

Results

As shown, the second helper was significantly exposed to airborne particulate matter while working in the filter building and around the kiln feed ends. All four samples on this worker exceeded the current OSHA 8-hour time-weighted average (TWA) for lime dust (5 mg/m^3); and one sample exceeded the 8-hour TWA limit for nuisance dusts (15 mg/m^3). The unusual kiln dust leaks were thought to be the major cause of these high results.*

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*Because of these high results, we attempted to determine the actual amount of process dust in these four total particulate samples. The reader should see the addendum to Table 27-1 for a discussion of the results of this further analysis.

TABLE 27-1

SUMMARY OF PERSONAL EXPOSURE SAMPLING FOR TOTAL AIRBORNE PARTICULATES

(See Also Accompanying Table 27-2 and Addendum to this Table)

Job Category	Sample I.D.	Day	Sampling Time	Exposure Concentrations As Total Airborne Particulates (mg/m^3)*
Control Room†	1	Tues.	7:17 - 15:00	0.16
	2	Wed.	8:14 - 16.:12	0.28
	3	Thurs.	7:14 - 15:00	0.27
Second Helper	4	Tues.	7:25 - 11:35	11.59**
	5	Tues.	11:36 - 15:06	20.05**
	6	Wed.	8:11 - 16:16	9.64**
	7	Thurs.	7:41 - 14:56	9.38**
Utility Person	8	Tues.	7:16 - 15:00	1.14
	9	Wed.	8:13 - 16:10	2.56
	10	Thurs.	7:19 - 15:00	1.32
	11	Thurs.	15:03 - 17:13	2.81

*All samples were collected on 5.0μ PVC filters (pre-tared) contained in 3-piece cassettes, then analyzed gravimetrically.

**See following addendum to this table.

†Used to simulate exposures of Operator, Assistant Operator, and First Helper.

ADDENDUM TO T. .E 27-1

Because of the high total airborne particulate results for samples Nos. 4-7 on Table 27-1, we attempted to determine the actual amount of process dust in them. The samples were further analyzed by atomic absorption spectroscopy (NIOSH Method P & CAM 173) and by a hydrochloric acid titration procedure (adapted from "Standard Methods for the Examination of Water and Wastewater," 14th ed., 1975, AWWA/APHA/WPCF). The results of these analyses are presented below:

Sample I.D.	Total Airborne Particulates (mg/m^3)	Amount of Calcium (mg/m^3)[1]	Weight Percentage of Calcium[2]	Amount of Titratable Base (as mg-$CaCO_3/m^3$)[3]
4	11.59	4.92	42.5	10.87
5	20.05	8.30	41.4	19.54
6	9.64	4.23	43.9	8.45
7	9.38	4.71	50.2	10.57

[1] By NIOSH Method P & CAM 173

[2] Weight of determined calcium as percentage of the total airborne particulate matter weight

[3] By titrating any water-soluble dust with hypochloric acid to pH of 4.5

Unfortunately, these tests only establish that the particulate matter is composed of primarily calcium-containing process dusts — quicklime (calcium oxide) and limestone (calcium carbonate). This fact was expected based on our observations of the amount of dust leaking from the kiln exhaust ends. The methods could not differentiate between the amount of quicklime present and the amount of limestone. Until more specific analytical procedures are developed for lime ($CaO + Ca(OH)_2$), it will be impossible to accurately determine lime kiln worker exposures to it.*

* Lime has an OSHA PEL designed to protect against its caustic irritation effects, whereas calcium carbonate is considered a less toxic nuisance dust.

TABLE 27-2

MAJOR JOB TASKS PERFORMED DURING PERSONAL EXPOSURE MONITORING
(See accompanying Table 27-1)

Job Category	Sample No.	Total Sampling Time (Min.)	Major Tasks	Estimated Duration (Min.
Second Helper	4	250	o Working in limestone rail car, checking outside pumps preparing acid for cleaning showers (all outside)	35
			o Break time in control center	20
			o Inside filter building -acid washing W.L. filters and cleaning showers.	195
	5	210	o Lunch break in filter building	24
			o Inside filter building -acid washing W.L. filters and cleaning showers.	156
			o Working inside limestone railroad car	30
	6	485	o Inside filter building -acid washing W.L. filters, cleaning showers, and washing mud filters.	410
			o Working inside limestone car	30
			o Other outside tasks and break time	45
	7	435	o Changing white liquor filter fabric	180
			o Acid cleaning W.L. filters	120
			o Miscellaneous time in filter building	105
			o Lunch and break time	30
Utility Person	8	464	o Cleaning up lime below kilns with payloader.	45
			o Lunch and free time in control center	90
			o Hosing down lime spills below kilns and other outside tanks	300
			o Pickup of chemicals from laboratory	30

TABLE 27-2 (Continued)

Job Category	Sample No.	Total Sampling Time (Min.)	Major Tasks	Estimated Duration (Min.)
Utility Person	9	477	(Routine was largely the same as Sample No. 8.)	360-390
	10	461	o Assisted Second Helper in installing new white liquor filter fabric.	255
			o Washing out vat of dregs filter (outside)	60
			o Lunch and free break time in control center	110
			o Miscellaneous time outside	35
	11	130	o Hosing down slaker	45
			o Break time (outside)	40
			o Cleaning out dregs filter and washing down G.L. clarifier	45

The utility worker's exposure was much less and below the OSHA lime and nuisance dust limits. As shown in Table 27-2, the sampling periods for this worker did include common cleanup tasks around the kilns and were representative of normal work routines and exposures.

Results for the three samples collected in the control room were consistent and very low (ave. 0.24 mg/m^3). They indicate little dust contamination of this workspace. Therefore, the other three workers' exposures are likely below OSHA limits when they are inside this room. They are in this room for over half their shift. When outside, they work in areas with much less exposure risk than the areas in which the utility man works. This indicates that their full-shift exposure is also very likely below the OSHA TWA limits for lime dust (5 mg/m^3) and nuisance dust (15 mg/m^3).

CONTROL TECHNOLOGY FOR PROCESS DUST

Overall worker risks of excessive exposure to process dust are low. This is mostly because dry materials are automatically transferred through equipment that is closed and provided with effective dust control systems. However, some material can occasionally spill from equipment, and dust leaks can develop in control systems. As the exposure monitoring results show, these dust leaks can create significant exposure situations.

Other than promptly repairing the leaks, worker exposure is best controlled by quickly cleaning up spills and wearing proper respirators.

In the absence of major dust emissions, four elements provide good overall worker protection to dust exposure in the mill:

1. The scrubber systems on the kiln exhausts and on the slaker/lime silos;

2. The degree of worker isolation and protection provided by the control center;

3. Housekeeping measures (including spill cleanup) and other work practices; and

4. Respiratory protective equipment

Each of these will be further discussed in terms of their role in effective workplace control technology for process dust.

Dust Emissions Controls and Ventilation

When kiln exhaust systems are properly sealed and operating correctly, very little lime dust can escape at the feed end of the kilns. This is because the induced draft (i.d.) fan normally draws all gases and any entrained fine dust out of the kiln and into a dust collector. A good seal between the kiln end and the lime feeder should allow some air into the kiln, but prevent any lime/limestone from escaping. Dust not removed in the collector is then blown by the induced draft fan through a high efficiency venturi scrubber. This scrubber efficiently removes any remaining dust, and recycles it through the dust collector back into the process. Leaks at the kiln air seal and scrubber expansion joint are unusual, but can cause excessive dust emission and potential worker exposure. The measured exposures with a number of such dust leaks occuring emphasize the importance of maintaining this equipment in proper working order. The observed leaks were identified by mill management when they first developed, but replacement parts cannot be routinely stocked and require several months for delivery from specialty suppliers. Each leak was scheduled for attention as soon as new parts arrive.

A ventilation and scrubber system for the slakers and reburned lime silos provides excellent control of dust emission from this equipment. Slakers, because of the violent, exothermic reaction that occurs in them, must be vented. Most mills also install a vent dust scrubber. This mill force-ventilates both slakers and both reburned lime storage silos using only one exhaust system. Some lime and lime dust was observed escaping from the bottom of the silos through the screw conveyor to the slakers.

It was not possible to accurately estimate the effectiveness of the ventilation system to capture this dust, but the amount of exhaust air from both the silos and slakers is probably sufficient. The plant operator noted that the scrubber occasionally clogs up, prevents air from passing through, and causes the fan to short-circuit. He indicated that the system was probably partially clogged during our survey because usually little dust will escape from the slaker feed lines as we observed.

Another effective dust control system uses the suction of one of the kiln secondary combustion air fans. It operates by drawing 8000 CFM of required kiln combustion air directly through the enclosed hot lime chain conveyor which is immediately below the two kilns. In contrast, most mills draw this air directly from the atmosphere. This mill's technique has the beneficial effect of not only pre-heating the air, but also of potentially capturing any fine dust that may escape through conveyor openings.

Portable floor fans are often used by workers in the filter building. Workers will position them to blow dust away from their breathing zones when they are working near the white liquor filters. The fans are an effective control for such brief potential exposures, because dust falling off the filters would be difficult to control by other measures. Workers also occasionally wear respirators when near the filters.

Worker Isolation

In general, workers are isolated from dust exposure sources because only two spend a significant amount of time outside the protective control center. As mentioned, access to the control room is through one of three doors. All of the doors are hinged to automatically swing closed. However, room air is only recirculated, so there is no positive pressure inside it to prevent dust occasionally blowing through any openings or opened doors. Air velocity readings were taken at the three doors while being opened. The readings indicated air momentarily moves outward (50-100 fpm) at the door's upper half, but inward (less than 50 fpm) at the important lower half. This movement occurs because supply registers for the air conditioning system are located in the ceiling near the doors. However, all the return air enters directly at the air conditioning unit which is in one corner of the room. Although samples for total airborne particulate in the control room were low, most horizontal surfaces were coated with process dust. Workers confirmed that it is difficult to keep this dust from entering, especially if it is windy outside. Irrespective, such dust contaminations are probably not significant exposure sources, provided the room is periodically cleaned.

Housekeeping and Work Practices
Housekeeping and prompt cleanup of spills are important elements in control of process dust exposures. The Utility Worker performs such tasks essentially all the time.

Even with the newest and best-designed kiln systems, some lime spills will probably occur at times. If these are not cleaned up, they can be blown into important workspaces throughout the mill. In this mill, workers must routinely clean up accumulations of lime from:

- Below the kiln discharge ends
- The conveyor which transports lime to the storage silo
- The limestone conveyor belt on the filter building roof
- Below the storage silos and around the slakers

No specific instructions are given workers on how to control dust generation during these cleanup operations. We made four significant observations of housekeeping practices:

1. A washdown technique is the more common method of cleaning up lime spills

2. A significant amount of dust (lime) was observed in the control center. This is apparently tracked in by workers on their shoes and clothing, and occasionally blown in through the doors and another small opening behind the control panel. To keep this dust from becoming airborne, once a day workers will apply a layer of oil-treated, dust-absorbing material on the floor. At the beginning of the next day, this is then swept up and a new layer laid down.

3. When a hose is used to wash down lime spills, the force of the water can cause any fine lime to become airborne and, if windy, blown quite far. A more effective technique would be to use an initial fine spray to wet the top layer, then a stronger spray for the washdown.

4. The above procedure for cleaning up lime spills below the kilns is partly responsible for buildup of dust up on the kiln firing platform. This platform must then also be cleaned off every day or so. Workers used a compressed air line to blow the dust off the platform and back down below the kilns. Although fast and convenient, the compressed air causes fine dust to become airborne and then highly dispersed. Water spraying and/or dry vacuuming (preferably with absolute filter vacuums) may be a more effective technique.

Respiratory Protective Equipment

Respirators are not routinely worn although the mill has a written protection plan and provides them for use. Types of respirators available for worker use include:

- Half-face piece air-purifying chemical cartridge types for white liquor tank entry (Norton Model 7501, NIOSH Approval TC-23C-49); and
- Disposable masks for dust exposures (Norton Model 7200/Bantam Respirator for dusts, sprays, and pollens).

Generally, workers were poorly informed of the hazards of lime dust inhalation and the possible need to use respirators during certain tasks or while near certain equipment. This was especially true of dust exposure conditions in the filter building, which were created by the unusual and temporary kiln air seal and venturi scrubber leaks. Workers do not routinely wear dust respirators when in this building. The air sampling results indicate periodic use may be warranted.

Most of the workers keep about half a dozen new dust masks to wear when working in the filter building or other dusty areas. However, one worker reported cleaning and reusing these respirators whenever a clean one is not available. This is a bad practice and should be discontinued.

HYDROGEN SULFIDE EXPOSURE AND CONTROL

Acid cleaning of the white liquor filters potentially generates some hydrogen sulfide gas. It occurs when the white liquor on the filter fabric mixes with the spray of cleaning acid. The mixing potentially causes ionized sulfide species in the liquor to be converted to free hydrogen sulfide gas which could then escape into the workplace. (White liquor is normally alkaline and nearly all hydrogen sulfide is dissolved as hydrosulfide or sulfide ions). Drager detector tubes were used to assess the magnitude of this potential emission source. Three readings were taken at an acid shower (No. 3 filter) during a normal cleaning routine. All readings resulted in levels estimated to be less than 1 ppm. In spite of a faint sulfide odor, it was concluded that this operation did not cause significant workplace emissions. If it did, most of the escaping gas probably would be captured by the exhaust hoods over the filters, and significant worker exposure probably would occur only if a worker was very close to the shower.

NOISE EXPOSURE AND CONTROL

Sound Survey Results

Noise levels around the kiln firing ends were judged high, and a brief sound level survey was performed throughout major work areas in the recausticizing/kiln area. Readings were taken using a slow-response, A-weighted sound level meter. Recorded sound ranges are summarized in Table 27-3.

As expected, the kiln firing end platform was the highest potential exposure area (95-103 dBA). High sound levels result from the kiln fuel guns and nearby combustion air fans. The effect of these sources was demonstrated by momentarily firing the east kiln at its maximum rate and recording the sound in front of it. Levels were 3-4 decibels higher (approx. 103 dBA) than those for the similar west kiln, when it is fired at a more typical rate.

TABLE 27-3

SUMMARY OF SOUND LEVEL READINGS

Location	Sound Level Readings, dBA*
Control Center -	
Center	72-73
West Side	75-76
East Side	71-73
Kiln Firing End Platform -	
Front of West Kiln	95-100
Front of East Kiln	99-103†
Below Kiln Firing Ends	86-89
Westside Pipe Bridge and Walkway, Near West Kiln Firing End	86-87
Front of Sulfur Burner (Behind Control Center)	94-98
Outside West Door of Control Center	91-93
Walkway Above Causticizer No. 6	85-91
Walkway Above Causticizer No. 5	84-87
Walkway Between Causticizers Nos. 2 and 3	83-84
Walkway Above Slakers	83-85
Filter Building (Kiln Feed End) -	
Front of East Lime Mud Filter	89-92
Discharge Side of East W.L. Filter	90-92
Inlet Side of East W.L. Filter	88-89
East Side of Center Lime Mud Filter	89-90
Discharge Side of Center W.L. Filter	90-92
Inlet Side of Center W.L. Filter	88-91
Discharge Side of West W.L. Filter	90-92
Inlet Side of West W.L. Filter	88-89
Between Center and West W.L. Filters	=91
Worker Rest Station, Westside of Building (Near W.L. Filters)	87-88
Between Kiln I.D. Fans (Ground Level)	86-87
Below West Kiln (Feed End) Near Combined Condensate Tank and Pump	88-90

*All readings taken with a Gen Rad Model 1565-C Sound Level Meter using a slow response A-weighted scale. Readings are the measured range of sound values taken in four directions at indicated location.

†Kiln was temporarily fired at its highest rate to obtain the maximum noise level.

Sound levels in general work areas around the firing/discharge end of the kilns ranged from 83 to 91 dBA, but were generally less than 90 dBA - the OSHA 8-hour TWA limit. Exceptions were outside the west control center door (91-93 dBA), and in front of the sulfur burner for the sulfite liquor preparation system (94-98 dBA). Sound decreased slightly farther away from the kiln firing ends, but some pumps and motors can still produce significant local noise.

The filter building also has significant noise-generating equipment. As shown in Table 27-3, high levels were measured in front of the discharge end of all three white liquor filters (90-92 dBA), at the inlet side of the white liquor filters (88-91 dBA), and around the lime mud filters (89-92 dBA). Generally, levels throughout the building were close to the OSHA 90 dBA limit.

Control of Noise

Excessive worker exposure to noise does not occur because of the sound attenuation the control center provides, and the low percentage of time most workers are outside. The control center provides over 20 decibels of sound attenuation (i.e. 95-103 down to 71-76 dBA). Only two workers are out of this room more than half their shift:

Job Category	Percent Time Outside Control Room
Operator	35%
Assistant Operator	30%
First Helper (Tester)	35%
Second Helper	100%
Utility Person	90%

As stated in the "Job Descriptions" section, the second helper works almost entirely in the filter building. He is exposed to sound levels approaching and exceeding 90 dBA in that building, but insufficient data exists to judge compliance to the OSHA standard. He is provided little protection other than brief periods of time outside the building and the opportunity to wear ear protection, which we did not observe him using.

The utility person's time outside the control room is spent performing cleanup and housekeeping tasks throughout the recausticizing/kiln area. Most of these tasks are in areas with sound levels below 90 dBA and over-exposure to noise is therefore unlikely. He occasionally works on the kiln firing end platform, where noise levels are above 90dBA, but rarely for longer than fifteen minutes.

Hearing protection is provide by the mill, but no workers were observed wearing it when outside the control center.

SECTION III SULFITE PULPING

Mill 21	Batch Digesters; Ammonium Sulfite Cooling
Mill 28	Continuous Digesters; Alkaline Sulfite Cooling
Mill 39	Batch Digesters; Acid Sulfite Cooling; Includes Bleach Plant (German Mill)

MILL 21: BATCH SULFITE PULPING PROCESS

INTRODUCTION

Mill 21 is a batch sulfite (ammonium sulfite) mill used to produce 280 tpd of pulp for fine paper manufacture. The mill is located in the Northwest United States.

PROCESS SUMMARY

Wood chips, the majority of which are hemlock (90%), are cooked in one of eight batch digesters. Pertinent parameters on these digesters include:

Digester	Year Initially Employed	Diameter	Height	Capacity
1	1919	12'	65'	12-14 ton
2	1919	12'	65'	12-14 ton
3	1923	12'	65'	12-14 ton
4	1923	12'	65'	12-14 ton
5	1937	12'	65'	12-14 ton
6	1937	12'	65'	12-14 ton
7	1974	13'	65'	15.5 ton
8	1975	13.5'	65'	16.0 ton

Wood chips are transported from storage area to the digesters both pneumatically and by belt conveyors. At the beginning of each cooking cycle, a chip chute is hydraulically lowered into the neck of the digester. As the chips are dropped into the digester, the steam packer is activated. It consists of a perforated tubular ring around the bottom of the digester neck and is used to provide more uniform chip loading and higher yields. About 35 minutes are required to load digesters one through six; the other two digesters require up to 45 minutes. A gamma-ray level sensor, located approximately 15' from the top of each digester, automatically provides the proper amount of chips. The chip chute is then hydraulically raised, and the lid is replaced using a pivoting crane/electric winch and manually bolted with a pneumatic impact wrench.

Once the digester has been loaded and sealed, the vent valve is switched off, and the acid valve and the high pressure relief valve are opened manually. Hot (90° - 100° C) cooking liquor is then pumped through the bottom of the digester until terminated by a differential pressure sensor. The acid valve and the high pressure relief valve are manually closed and the indirect liquor heater is turned on. The liquor is circulated through the indirect heater and returned to the top (75%) and the bottom (25%) of the digester, maintaining a top temperature of about 145° C. Normal operating pressure is 75 psig and is automatically maintained by venting through the high pressure relief system. Occasionally, direct injection of steam through the bottom of the digester is required to accelerate the cooking process.

After about 70 minutes, the chips are fully impregnated, and the excess liquor is blown into the hot acid accumulator, where it is reclaimed. After a cooking period of about 2.5 hours, steam flow to the heater is stopped, but liquor circulation is continued. When digester pressure falls below 60 psig venting is switched from the high pressure to the low pressure system. The digester is vented and cooled for about 50 minutes before the low pressure relief valve is closed. The vacuum relief is then opened and the digester is depressurized further from 30 psig to near atmospheric. The low pressure relief is piped to the low pressure accumulator; the vacuum relief is routed to the weak acid storage tank for SO_2 recovery. Both the high and low pressure relief gases are under sufficient pressure to allow them to reach the accumulators without assistance. An induced draft blower is required, however, to allow the vacuum relief gases to be absorbed at the acid tank. Before the digester is depressurized and pumped out, tests of the cooking liquor for color, smell, and SO_2 residual are performed. When the digester is depressurized, a motorized ball valve beneath the vessel is opened, and the contents are pumped to the stock tank. During the unloading operation, spent cooking liquor is pumped into the digester to lower the consistency of the pulp and facilitate pumping. When the digester is empty, the stock pump is shut off, and the ball valve is closed. Prior to uncapping the digester, a vent valve is opened and the vessel is ventilated to atmosphere with a small blower. Just before the digester is opened, a valve on the top of the lid is opened to relieve the slight negative pressure. From the digester stock tank, the pulp is pumped to one of two EIMCO extraction-type stock washers, both installed in 1976. The washed stock is pumped into a high density tank, then through a rotary knotter, 5 rotary screens, and finally into a vacuum-drum, brown stock washer.

JOB DESCRIPTIONS, CATEGORIES & DESCRIPTIONS

Cook and Assistant Cook

Under the direction of the cook, both of these employees are involved in all phases of the digestion process. Typical tasks include:

- manually capping and uncapping the digesters
- manually opening or closing various valves
- conducting liquor tests (smell, color & residual SO_2)
- automatically operating the chip chutes, pumps, motorized valves, and other equipment
- monitoring the control panel display
- completing the Production Log Sheet

It was judged each employee spends approximately 75% of each shift inside the control room.

Potential Hazards

Both the Cook and the Assistant Cook are potentially exposed to noise, and SO_2.

PERSONAL SAMPLING RESULTS

Personal samples for sulfur dioxide were collected on the cook and the assistant cook using NIOSH P & CAM 160. Since these employees spend a large percentage of each shift in the control room, a sampling strategy designed to allow both calculation of TWA exposures and short term peak exposures was devised and used. To estimate exposure levels in the control room, a series of consecutive area samples were collected and composited during each shift. Each time an employee entered the process area, personal samples were collected. Thus TWA exposures were calculated based on the results of short term personal samples and the sequential area samples in the control room. As shown on Table 21-1, calculated TWAs range from 0.9 ppm to a maximum of 2.2 ppm, and are below the OSHA PEL of 5 ppm. It should be noted that the sampling periods for which the TWA calculations are based are all less than 8 hours (80 minutes to 354 minutes). Although the calculated results are therefore not based on full eight hour shifts, the results are judged to be highly representative of actual 8 hour TWA exposures. For each sample, we have also shown the percentage time that the employee was out of the control room. As would

TABLE 21-1

SUMMARY OF

PERSONAL SAMPLING DATA

(SULFUR DIOXIDE)

Job Category	Sample No.	Shift	Sampling Period (mins)	Calculated TWA (ppm)	OSHA PEL (ppm)	% Time Out of Control Roo
Cook	1	1	220	0.9	5	14%
	2	2	255	0.9	5	13%
	3	2	80	2.2	5	44%
Assistant Cook	4	2	253	0.9	5	22%
	5	1	354	0.9	5	21%

be expected, the highest result (2.2 ppm) occurred when the cook was in the production area for an unusually long period (44%).

The results of the individual, short-term samples from which the TWA exposures were calculated are presented on Tables 21-2 (Cook) and 21-3 (Assistant Cook). The results of the composite control room area samples (0.6 ppm, 0.5 ppm. 0.5 ppm) demonstrate very little variation in sulfur dioxide concentrations of a total sampling period of 30 hours. The results of the short-term personal sample results range from 0.4 ppm to 5 ppm for the cook, and 0.5 ppm to 6.1 ppm for the assistant cook.

These data show a relatively high variability depending on the percentage of time outside of the control room and activities (particularly digester loading) conducted during the sample. Sample No. 2a (Table 21-2) resulted in a sulfur dioxide level of 3.6 ppm over the 10 minute period the cook was in the production area. Much of this exposure occurred when the cook was below the digester operating floor collecting liquor samples. One of the digester test valves was clogged, and liquor was splashed onto the floor.

Sample No. 3a, 3b (Table 21-2) resulted in sulfur dioxide levels of 5.0 and 3.8 respectively. The former was caused by concern over the completeness of a digester pump out. The cook was required to lower a drop light into the digester and visually check for residual stock. During sample 3b (3.8 ppm) the cook participated in the capping of two digesters, a relatively atypical occurrence over such a short period of time (18 minutes).

The Assistant Cook was exposed to a sulfur dioxide concentration of 6.1 ppm over a 20 minute period (Sample 5a, Table 21-3). This high level resulted from a 'dirty' pump out of the #7 digester. Because a significant amount of pulp remained in the digester, weak liquor was added and agitated with live steam to loosen the residual stock. The digester was uncapped throughout this period and the live steam obviously caused significant offgassing.

AREA SAMPLING DATA

Detector tube samples for sulfur dioxide were taken to locate sources of workplace contamination and to assess the relative importance of process variables (i.e, digester cylces). These data are presented on Table 21-4, along with the results of similar samples collected by mill personnel six months earlier.

TABLE 21-2

DETAILED PERSONAL SAMPLING DATA (COOK)

Sample No.	Day	Shift	Sample Duration (mins)	SO_2 Concentration (ppm)	Calculated TWA (ppm)	% Time Out of Control Room	Comments
1a	1	1	44	0.4		9%	
1b			45	1.3		22%	
1c			47	1.0		26%	
1d			34	1.5		12%	
1e			189	0.6			Composite Area Sample in Control Room
		TOTAL	359		0.9		
2a	2	2	10	3.6		100%	
2b			20	1.9		100%	
2c			13	1.4		100%	
2d			222	0.6			Composite Area Sample in Control Room
		TOTAL	265		0.9		
3a	3	2	17	5.0		100%	
3b			18	3.8		100%	
3c			45	0.5			Composite Area Sample in Control Room
		TOTAL	80		2.2		

TAL . 21-3

DETAILED PERSONAL SAMPLING DATA (ASSISTANT COOK)

Sample No.	Day	Shift	Sample Duration (mins)	SO_2 Concentration (ppm)	Calculated TWA (ppm)	% Time Out of Control Room	Comments
4a	1	2	58	1.1		26%	
4b			12	3.0		100%	
4c			61	0.9		26%	
4d			45	0.7		29%	
			77	0.6		Composite Area Sample in Control Room	
		TOTAL	253		0.9		
5a	3	1	20	6.1		100%	Uncapped digester (dirty blow); filled with weak liquor and agitated with steam injection
5b			20	0.5		100%	
5c			35	1.5		100%	
5d			263	0.5		Composite Area Sample in Control Room	
		TOTAL	338		0.9		

TABLE 21-4

AREA SAMPLING DATA (DETECTOR TUBES)

Sample No.	Location/Description	SO_2 Concentrations (ppm)	
		Survey Results (12/80)	Mill Results (6/80)
1	Digester Control Room	2.5	--
2	Digester Control Room	ND	--
3	Digester Control Room	2	--
4	Digester Control Room	--	10
5	Digester Control Room	--	20
6	Digester Control Room	--	5
7	Digester Control Room	--	4
8	Digester Control Room	--	10
9	Outside Control Room -on Blow Pit Roof	1	--
10	Near Digesters (filling)	ND	--
11	Near Digesters (filling)	25	--
12	Near Digesters (filling)	ND	--
13	Near Digesters (filling)	5	--
14	Near Digesters (filling)	15	--
15	Near Digesters (filling)	1	--
16	Near Digesters (filling)	--	30
17	Near Digesters (filling)	--	15
18	Near Digesters (filling)	--	10
19	Near Digesters (filling)	--	15
20	Directly over Digester (filling)	>100	--
21	Directly over Digester (filling)	>25	--
22	Beside Digester (pumping out)	1	--

Although the data are highly variable, several conclusions can be drawn:

- As illustrated by samples 1 through 3, sulfur dioxide can enter the control room from the workplace at certain times. Investigations using smoke tubes demonstrate that, when the control room door is open, air flows from the digester operator floor into the control room. This phenomena is enhanced when the rear door of the control room (leading to the roof of the blow pit building) is open. However, the long term composite samples for sulfur dioxide collected in the control room demonstrate that, although there may be transient peaks of at least 2.5 ppm, average concentrations range below 1 ppm (0.5 to 0.6 ppm).

- Samples 4 through 8 were collected in the control room by mill personnel, and result in considerably higher levels than measured during the survey (4 to 20 ppm). The specific details regarding conditions during these samples were not available, and comparison with the above data is difficult. However, the mill sampling data were collected during problems with the overgas system.

- The samples were taken near the digesters during various cooking cycles. Samples Nos. 10 through 15 were collected adjacent to digesters during chip filling operations and range from non-detectable up to 25 ppm SO_2. Four similar samples (Nos. 16-19) taken by mill personnel ranged from 10 to 30 ppm. These data demonstrate that sulfur dioxide is emitted to the workplace when the digesters are first opened and during the filling cycle. Variations in concentrations can be attributed to the orientation of the detector tube relative to the draft-induced dispersion pattern of the steam and process gases emitted from the digester.

- Sample Nos. 20 and 21 were taken directly above digesters immediately after they were open for filling. Both samples resulted in very high sulfur dioxide concentrations (>100 ppm; >25 ppm), and provide further evidence that significant amounts of sulfur dioxide are emitted from the digesters when they are opened. Although the employees generally stay clear of the escaping steam and gases, it is clear that this emission source contributes significantly to the background concentration and to the exposure levels measured by the personnel samples.

- Sample No. 22 was collected next to a digester while the stock was being pumped to the stock tank and resulted in a concentration of 1 ppm. It is judged that this result is representative of the background concentration and not a function of this operation.

CONTROL OF WORKPLACE EXPOSURES

Although the personal sampling data demonstrate that short-term exposures (< 20 minutes) can range up to 6.1 ppm, calculated TWA exposures were all below the OSHA PEL for sulfur dioxide (5 ppm). Since large amounts of sulfur dioxide are used in the process, it must be concluded that the in-place controls are normally sufficiently effective to prevent excessive exposures. The data are available to assess the effect of leaks or process upsets on TWA exposures.

The primary reasons for the low exposures are the closed nature of the process and the isolation of the workers in the control room. Except when the digesters are opened for the chip loading cycle, the process is totally closed. Digester relief gases are piped to a Jensen tower for recovery, and the stock tanks, blow tanks and liquor tanks are all vented into an overgas system for subsequent recovery in a separate absorption tower. Therefore, the only routine, nonupset-related sources of workplace contamination are the digesters during the chip feeding cycle.

Equally important is the isolation of the employees in the control room, where sulfur dioxide levels average less than 1 ppm. Since the employees average 75 percent of each shift in this relatively protected area, TWA exposures are proportionally reduced. It should be noted that worker isolation is extremely beneficial for reducing TWA exposures, but has a significantly lower influence on the reduction of worker irritation from high short-term exposures.

At one time, the control room was provided with fresh, tempered makeup air. However, the system was corroded and has not been replaced. Currently, the room is periodically vented by opening the rear door leading to the roof of the blow-pit area.

In addition to the above two controls, the overgas system is extremely important to the containment of sulfur dioxide within the closed process. Sulfur dioxide from various process sources is recovered through two different systems. Digester relief gases (both high and low pressure) are directed into Acid Accumulators, and are generally not a source of workplace contamination. Gas streams from the recovery boiler, the BIMCO washers, the evaporators, and various process vessels are directed to a separate absorption tower for sulfur dioxide recovery. The system consists of three components:

- o The exhausts from the two EIMCO washer hoods are forced into the tower by an 8000 cfm fan.

- o the vent gases (overgas system) from the evaporators, the weak and strong liquor tanks, the evaporator feed tanks, the digester stock tank, and the blowpit tanks are transported to the tower by a separate overgas fan.

- o the recovery furnace flue gases are directed to the tower through a separate piping system with no fans required.

In early 1980, it was determined that problems with this system were causing elevated workplace sulfur dioxide concentrations at high production levels. These problems were most apparent when the recovery furnace was fired at a rate in excess of 70 gallons per minute (equivalent to more than 20 cooks per day). It was also determined that the problem was made worse when digester pump-outs were conducted concurrent with recovery furnace soot blowing operations. Apparently, during high production, the capacity of the absorption tower was exceeded and a significant back pressure on the overgas system and the EIMCO washer exhaust system was created. This caused significant amounts of process gases to escape into the workplace, primarily from the digester stock tank, the EIMCO washers, and the liquor tanks. Because of concern over the possible health effects on workers and the obvious disincentive for high production levels, mill personnel placed a high priority on the solution of this problem.

An engineering study was initiated to answer the following questions:

1. can absorption tower pressure be reduced?

2. can amount of gas in overgas system be reduced?

3. contribution of digester blows to system?

4. energy savings available from overgas heat recovery?

5. overall existing equipment capabilities; i.e., fans, ducts, absorption tower?

6. other sources of sulfur dioxide contaminations?

During this investigation, interim corrective measures were instituted: Reduction of Recovery Furnace Firing Rate; and soot cleaning was scheduled in between digester pump outs. In addition, an acid drain system was considered but not installed to minimize sulfur dioxide release when the digesters were being drained. Until definite conclusions could be reached, several other approaches were tested during the summer:

- o the digester pump out dilution was increased (lowering the temperature and gasing rate in the stock tank)
- o the rate of relief from the digesters was slowed (again lowering the gassing rate in the stock tank)
- o the temperature of the wash water in the EIMCO washers was reduced (to lower gassing rate in the washers)
- o the warm-up burner in the recovery furnace was shut down (to reduce flue gases to the absorption tower)
- o the unquenched vents from the evaporators were throttled down (to reduce heat load to the tower).

The first major corrective action involved the relocation of the main overgas line to enter the absorption tower one tray up from its existing location (cost estimate -- $2,500). It was judged that the overgas would still have adequate cooling contact with the lower absorption liquid stream, but the static back pressure against the overgas flow would be reduced by three to four inches of water (since the overgas fan curve is very flat, the reduced back pressure should allow a much higher flow without replacing the fan). The new location had the added advantage of not being directly in line with the entry of the recovery boiler flue gas. It was reported that this modification markedly improved the workplace sulfur dioxide problem at firing rates above 70 gpm; however, the problem still existed during digester pump-outs when the overgas fan cannot handle the increased flow.

The second major action was the installation of a system to reclaim heat from the evaporator vents for hot water to the bleach washers. This system reduces the load on the absorption tower by greatly decreasing the temperature of the inlet gases.

At the time of our survey, these were apparently all of the modifications made to date. Additional options being considered include:

- o removal of the digester stock tank vents from the overgas system and installing separate piping system to the tower (with no fan required; reliance on stock tank pressure during pump out for transfer of off gases).
- o installation of a larger fan for the overgas system.

Based on data and observations during our survey, it is concluded that problems with workplace sulfur dioxide contamination have been reduced with the above improvements. However, it should be noted that workplace sulfur dioxide concentrations will likely be further reduced with the implementation of additional planned actions.

Digester Ventilation

The opening of the digesters for chip filling has been identified as the only routine source of workplace contamination. After the digester's contents have been pumped to the stock tank, the vessel is under a negative pressure caused by displacement of the stock. This slight vacuum is relieved prior to uncapping the digester, and presumably the vessel is at atmospheric pressure when first open. However, the residual amounts of stock and liquor are still very hot and convection currents cause a plume of steam and process gases to exit the digester. To assist in capturing these gases and vapors, the mill has installed a ventilation system (integral to the digester) which is activated just prior to removing the cap. Observations indicated that the system did not generate sufficient inward velocity through the open caps to capture a significant portion of the emissions, particularly just after the digesters are opened.

Personal Protective Equipment

The pulp mill employees are provided with half-face, MSA Confo II respirators with GMC (yellow) cartridges. Full-face respirators with GMC (yellow) cannisters are also available in respirator boxes stored in the control room. For emergencies or prolonged work in high concentration areas 30 minute, self-contained breathing units are also available in the control room.

Respirator usage in the pulp mill is at the discretion of the individual employee. During the survey, no employee was observed using either of the two types of available respirators.

Vessel Entry Procedure

There are apparently detailed vessel entry procedures (written) for each major piece of closed equipment requiring routine entry. The procedures contain the following directives:

- notification procedures for work
- tag and lock-out procedures
- specific directives for closing valves, disconnecting pipes and air lines, etc. (i.e., isolating the vessel)
- notification requirements for operators
- requirements for safety equipment and personnel (safety belts/lines, respirators, stand-by personnel)

MILL 28: ALKALINE SULFITE PULPING (CONTINUOUS) AND WASHING OPERATIONS

INTRODUCTION

This report examines potential worker exposure to sulfur dioxide and noise in a Southern alkaline sulfite (semi-chemical) pulp mill. Sulfur dioxide samples were lost in transit to the laboratory. The survey team's observations, supported by detector tube readings, indicated little potential for significant sulfur dioxide exposure. Noise was similarly well-controlled.

The mill produces about 165-175 tons per day of mixed hardwood corrugating box media using an alkaline sulfite-based digestion liquor and mechanical refining. The chemical pulping stage is accomplished in a modified M & D digester. Pulp is then conveyed to an outside double disk refiner, washed inside a two-stage vacuum-drum washers (hooded), and then further refined.

PROCESS SUMMARY

Mixed hardwood chips are used to produce the desired corrugating box media. Pulping them involves approximately 25% chemical and 75% mechanical (refiners) actions, and results in yields of 75%. The active chemical agent is sodium sulfite dissolved in a buffered alkaline solution (7.5% equivalent Na_2O consisting of 1.0 lbs. Na_2SO_3/gal. + 0.25 lbs. Na_2CO_3/gal. at a pH of 9-10). The combined chemical and mechanical actions are economical and efficient, and result in a pulp of high strength and quality. Equipment is easy to maintain and well-adapted to the intermittent operations which the mill uses.

A mixture of hardwood chips are blown to the building's roof and fall down through a tower and air vibrator to a pre-steamer feeder above the M&D digester. Here steam and hot gases from a flash tank and the digester are injected to heat the chips as they are screw-conveyed over to a rotary feed valve above the continuous digester's inlet. Additional steam (180 psig) is injected at the feeder and the desired amount of chips continuously metered into the digester's top. Here they contact the hot pulping liquor and are digested as they move down and then up the digester on a special conveyor. Liquor level in the digester remains constant, and makeup is heated and added continuously at the top near the chip entry point, as shown. Waste liquor and relief gases exit at the top of the

digester just below the pulp discharge chute. Most of the hot gases are separated from the liquor in a flash tank and separator, then passed to a surface condenser and heat exchanger for heat recovery. Eventually, they are vented to a turpentine decanter (for an adjoining Kraft M&D digester). The waste liquor (and condensed gases) is pumped to a brown liquor transfer tank and then to a storage tank. These both vent to the atmosphere.

The chemically digested chips exit the digester's top and drop through a closed chute to a Bauer 418 refiner located outside on the ground near a blow tank. Steam can be injected into the refiner's feed screw to insure that the refiner core is at a pressure equal to or slightly less than the digester (a balance line between the refiner core and digester top also insures nearly equal pressures). This insures hot pulp continuously flows from the digester to the refiner. In the refiner, the treated chips are broken up into small fiber bundles by mechanical action, and discharged through pressure control valves (digester-refiner differential) to an adjoining blow tank.

In the blow tank, the large pressure (temperature) differential between the digester/refiner and the atmosphere is reduced prior to stock entering the two-stage washers. This is accomplished by relieving gases to the digester flash tank, and quenching some steam with cooler first stage washer filtrate water. Cooled and diluted stock is then pumped back up to the operating floor and into the first stage brown stock washer. Both washers are hooded, and of the vacuum-drum type.

The washers separate the pulp from the used liquor and wash it with second stage filtrate (first washer) and hot (140°F) water (second washer) before it is further refined in an adjacent Bauer 412 refiner. This completes the pulping process, and clean stock is then dropped to a ground level thick stock pump, and pumped to an outside high density storage tank.

Used pulping liquor drains through the filter of the first stage washer and is collected in its outside filtrate tank. It is then pumped to a nearby brown liquor transfer tank, then on to the chemical recovery system.

Of the above unit operations only the digester pre-steamer feeder, digester top, brown stock washers, and 412 refiner are located inside the pulp building. Approximately the same equipment (digester and washers) for a Kraft 'small chips' M&D pulping system are also located in the building and adjacent to the sulfite system. As is customary, the M&D sulfite digester is inclined at a 45° angle from the ground up into the building. As shown, because of small digester movements, an expansion joint is used between it and the feed chute to the 418 refiner.

JOB CATEGORIES AND DESCRIPTIONS

Three employees per shift are responsible for operating the alkaline sulfite and adjoining 'small chips' Kraft pulping systems.

Operator - The operator has overall responsibility for complete operation of both systems and supervision of two assistants. Both systems are automated and can be monitored and controlled using analog sensors and controllers located in a control room near the washers. The operator's work routine can be highly variable depending upon process conditions. During startups or shutdowns he may remain entirely in the control center; during normal operations he may be outside most of the time making adjustments and equipment inspections. However, neither is the rule. Overall, he spends an estimated 30% of his time outside outside the control room. During normal operations, he usually makes an equipment inspection every two hours or so. This may take up to 20 minutes and mainly includes inspections of inside instrumentation and outside flow lines, valves, seals, and pumps.

Assistant Operators - Two other workers assist the operator and are trained in process operations. One of them is usually more experienced and can monitor the process and make necessary adjustments when the operator is away from the control room. Major job tasks for the workers include servicing and adjusting either of the two washer lines, cleaning up stock spills, performing gereral area washdowns, housekeeping, taking tank measurements, and making other equipment adjustments and inspections. Each is outside the control room 25-50% of the time depending on process conditions.

POTENTIAL WORKPLACE EXPOSURES

Chemical Agents

The potential for formation and release of hazardous process gases (and their resulting nature) was briefly discussed with the mill technical staff. Unfortunately, since this pulping process is unique, information concerning process chemistry is scarce. However, because it is based on alkaline sulfite agents acting on mixed hardwood chips at elevated temperatures, the following are potential volatile constituents of the reaction mixture:

- Sulfur dioxide (from the sulfite liquor)
- Tannins (from the hardwood resins)
- Turpenes (from small amounts present in hardwood)

- o Reduced sulfur compounds (formed by reaction of sulfur dioxide with wood compounds)

- o Miscellaneous non-condensible gases (from wood constituents)

There are no specific OSHA standards for tannins and turpenes which have low vapor pressures and probably readily condense. Conditions for formation of significant amounts of reduced sulfurs are probably not present, and no characteristic odors could be detected in the mill. Therefore, all of these are of little exposure significance for this study (as are the other miscellaneous non-condensible gases).

Unlike acid or neutral sulfite pulping, alkaline sulfite liquor has little free sulfur dioxide. However, when it is heated and pressurized and its pH begins to drop as buffer is depleted during the cook, an unknown amount of sulfur dioxide may be freed. Therefore, some gas may potentially be released at:

- o The feeder pre-steamer (this is provided with an outside relief vent);

- o The brown stock washers (these are hooded and ventilated);

- o Refiner leaks (these are usually well-sealed); and

- o Flash, blow, and washer filtrate tank vents (these are outside).

However, none of these sources are thought to create significant workplace exposure conditions. The feeder pre-steamer is vented to the outside; the washers are hooded and ventilated; and the first refiner and the flash blow, and washer filtrate tanks are all outside.

AIR SAMPLING RESULTS FOR SULFUR DIOXIDE

Over a two day period, the survey team collected a number of personal samples to assess worker exposure to sulfur dioxide (NIOSH Method P & CAM 160). Unfortunately, these samples were lost in transit to the laboratory and no results are available. However, during the first day of the survey, the study team used Drager detector tubes to estimate the level of sulfur dioxide in common work areas and to locate potential emission sources. Five readings were taken and are summarized in Table 28-1.

Table 28-1: Summary of Drager Sulfur Dioxide Detector Tube Readings

Location	SO2 Concentration, ppm*	Comments
Control Room	No Reading, est. < 0.5	All three plant workers are in control room for estimated 5 of their shift.
Inlet to First Stage Brown Stock Washer	~ 1	Washer was operating at normal speed.
At Pre-Steamer Feeder	No Reading, est. 0.5	Feeder is located on an isolated mezzanin above digester
Steam Plume from Blow Tank Vent	12	Blow tank is outside
Near No. 1 Washer Filtrate Tank -- Ground Level	~ 0.5	Near leak from outsi filtrate tank

*All readings used 10 pump strokes

As shown, only one of the five indicated an appreciable amount of sulfur dioxide, and this was in a steam plume coming directly out of the blow tank. Therefore, these readings, combined with the survey team's observations and inability to detect characteristic odors, indicates little sulfur dioxide exposures associated with this continuous alkaline sulfite process.*

CONTROL TECHNOLOGY

Although there is little need for workplace controls because little sulfur dioxide escapes from process equipment, workers are well-protected in two ways. First, equipment that potentially emits sulfur dioxide is either outside or vented to the outside, and workers remain most of the time in either the protective control room or outside. Secondly, when not in the control room but on the main operating floor, excellent ventilation is provided by the exhaust hoods over the two sets of brown stock washers.

Both sets of washers are each covered by a canopy hood. These have two central takeoff ducts which extend through the building's roof to vane-axial fans. Each of these fans is rated at 8000 CFM, and result in a total exhaust of 16,000 CFM. Combined with a similar amount of exhaust air from the adjoining 'small chips' washer hoods, they insure excellent air turnover on the washer floor. (This workspace measures only 30' x 80'). Air velocity readings were taken around the four open faces of the sulfite washers' canopy hood. Because the hood extends approximately 1-1.5 feet below the washer's drum, these faces have dimensions of only 3 feet high by 16 feet wide (front and back) by 24 feet long (sides). Velocities in excess of 125 fpm (150-225 fpm for sides; 125-225 fpm for front and back) were measured on all four faces, and indicate that the 16,000 CFM of total exhaust is more than sufficient to capture any gas that may escape from these washers.

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*Plant workers also indicated they rarely smell SO_2 when the process is operating correctly; and if not, most odors are only detected outside.

MILL 39: ACID SULFITE PULPING, BROWN STOCK WASHING, AND BLEACHING (Foreign Technology)

INTRODUCTION

Mill 39 is a chemical pulp mill in southwestern West Germany that was surveyed to provide comparative information on the development of foreign control technology. The mill is old and one of only a few chemical pulp mills in West Germany.* Its equipment and technology contrast with neutral and acid sulfite pulp mills and bleach plants surveyed in the U.S. (See Mills 21, 22, and 28).

The mill produces 80,000 tons per year of softwood pulp (pine and spruce) in five batch digesters by using a calcium-base, acid sulfite cooking process. The pulp is then washed in three, series-connected outside pressurized-drum washers; and brightened in one of two 3-stage (CEH) bleach lines. Air monitoring was conducted for sulfur dioxide and wood dust on the digester operating floor, and for chlorine on the bleach plant washer floor.

MILL LAYOUT

The pulping and bleaching processes are located in adjacent multi-story buildings. The pulp mill has five large digesters arranged in a row, extending from the ground level up through to the top floor. Each holds 250 cubic meters of material. Two are stone-lined steel; the other three are a composite material. Loading hatches, some digester controls, and an overhead chip feeding conveyor are all located on the building's top or operating floor. A control room for the digesters (and the brown stock washers) is located on a lower floor, and one worker remains there full-time to monitor and operate the equipment.

The three pressurized brown stock washers are located above an outward extension of the pulp building, below the floor where the digesters are loaded. The filtrate tanks are outside and below the washers.

*West Germany produces about 15 percent of its pulp, purchasing the rest from North America and Scandanavia.

The multi-story bleach building adjoins the digester building by an enclosed passageway. The bleach towers are outside, but six hooded, vacuum-drum washers are inside on the upper or operating floor of the buidling. Washer filtrate tanks, steam mixers, and stock and filtrate pumps are located below the operating floor. A large, air conditioned control room, containing controllers and monitors for the two bleach lines and a small quality control laboratory, is also located on the washer floor.

PROCESS DESCRIPTION

Pulping

Important steps in Mill 39's pulping process are described below to help the reader understand the nature of contaminant emission and the potential for worker exposure.

Liquor Preparation - Pulping liquor (acidic calcium bisulfite) is prepared by first burning about 20 tons per day of liquid sulfur with air inside a rotary burner to produce sulfur dioxide gas. The gas is then washed with water, cooled, and finally scrubbed of particulate matter in an electrostatic precipitator. Weak sulfuric acid solution from the gas washer and precipitator is collected and sent to the bleach plant for adjusting pulp pH after bleaching. The clean sulfur dioxide gas is converted to the desired calcium bisulfite solution by passing it up through large, limestone-packed towers (See Figure 39-1). Cool water is added to the top of the towers, flows down over the limestone, absorbs and reacts the incoming gas, and becomes acidic calcium bisulfite solution (raw acid) which collects in an adjacent "acid box." This fresh pulping liquor then flows into "acid storage tanks" and is later pumped to two "raw acid tanks."

The fresh acid in these raw acid tanks is too weak for use in pulping. Therefore, it is strengthened with strong, sulfur dioxide-containing gases given off from the waste liquor that is discharged from the digesters through a liquor decompression vessel. These relief gases are drawn into the tanks (after passing through a cooling condenser) by an eductor system which circulates part of the tanks "weak" fresh acid to derive the necessary eductor suction. After this initial strengthening step, the acid is further fortified as it is pumped through low and high pressure acid tanks, and through a final fresh acid storage tank. Strengthening gases are drawn by eductors into the pressure tanks from a three-stage digester pressure relief manifold system, used to relieve the digestors after cooking. However, high "initial" digester relief gas is vented directly to the high pressure acid tank. The "strong" fresh acid (liquor) that results from these fortification steps is then pumped from the final storage tank to the digestors, when required. The various strengthening and storage tanks are vented back to the sulfur dioxide absorption tower in order to maintain a closed system.

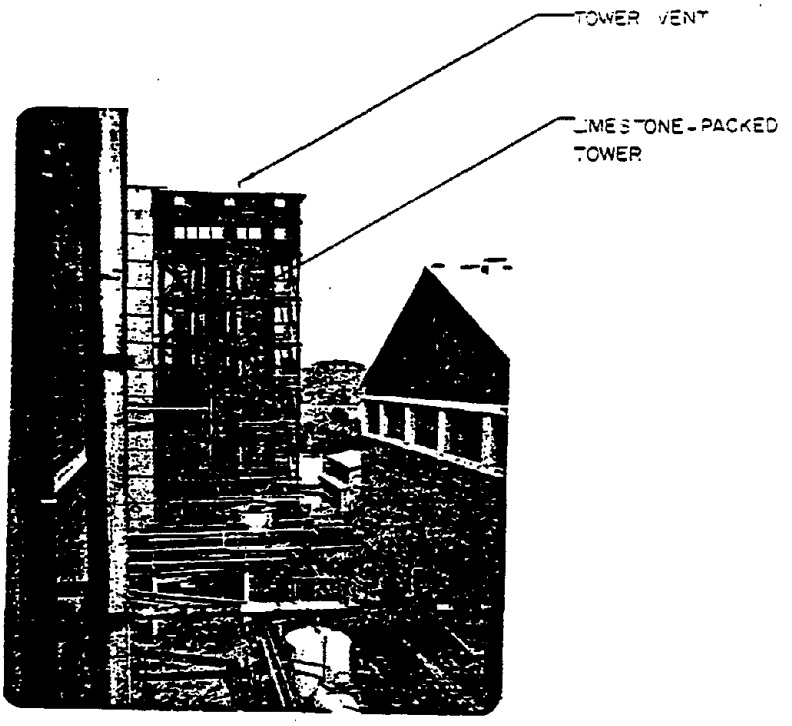

Figure 39-1: Sulfur Dioxide Gas Absorption Towers

Digester Filling - It takes about an hour to fill a digester with chips (spruce and pine). A special loading chute and steam packer must be manually fitted into two of the digesters' loading hatches initially (See Figures 39-2 and 39-3); the other three digesters have permanent loading chutes and steam packers. To keep steam from escaping from a packer (cap pressure is about 10 psi), the workers cover the digester's top with thick blankets (See Figure 39-3). The chips are then delivered from an overhead belt conveyor, and fall down through the chute and packer into the digester. Some chips and dust escape from the conveyor and chute during this loading operation, and collect on the surrounding floor. They must be cleaned-up by a worker after loading is completed. After the digester is full, a worker blows wood dust from the its sealing ring with a compressed air line; applies a sealing paste; and then manually bolts down the cap (See Figure 39-4 A & B). It then takes about 30 minutes to fill the digester with the proper amount of cooking liquor.

Chip Cooking - One of two chip cooking plans is used, depending on desired pulp qualities and quantities. The first has a short liquor impregnation period and a total cooking time of about 6.5 hours at a maximum temperature of 135°C. The other has a longer impregnation time, and about 7 to 7.25 hours of total cooking time. Because one of the five digesters was out of service during the survey, the mill was using a modified cooking cycle with 6.75 hours of total cooking time at 142°C. This shorter cooking time at a higher temperature with only four digesters undoubtedly altered sulfur dioxide emissions and exposures, but in an unknown manner.

Pressure in the digester's top is brought to about 6.5 bars, and then automatically maintained during the required cooking time. Heating is accomplished by continuously circulating liquor through an external heat exchanger. Gas (containing sulfur dioxide) is periodically relieved during cooking to the liquor fortification tanks, or to one of the other digesters.

Digester Emptying - After cooking, the digester is cooled and the pressure is relieved from approximately 6.0 bars down to 1.8 to 2.0 bars (absolute) in three stages over about a one hour period. The pressure is relieved thru a pipeline connected to each digester's loading hatch into a manifold relief line connected to all five digesters. Depending on the pressure, a separate line is opened to this manifold for each relief stage (See Figure 39-5), and the gases are vented to the appropriate liquor fortification tank (see preceeding "Liquor Preparation" discussion).

After relieving the pressure, filtrate water from the brown stock washers is pumped into the digester to briefly wash the pulp. The resulting dirty, hot liquor, containing some pulp, is then pumped out of the digester to a waste liquor decompression tank. The small amount of pulp is separated in a

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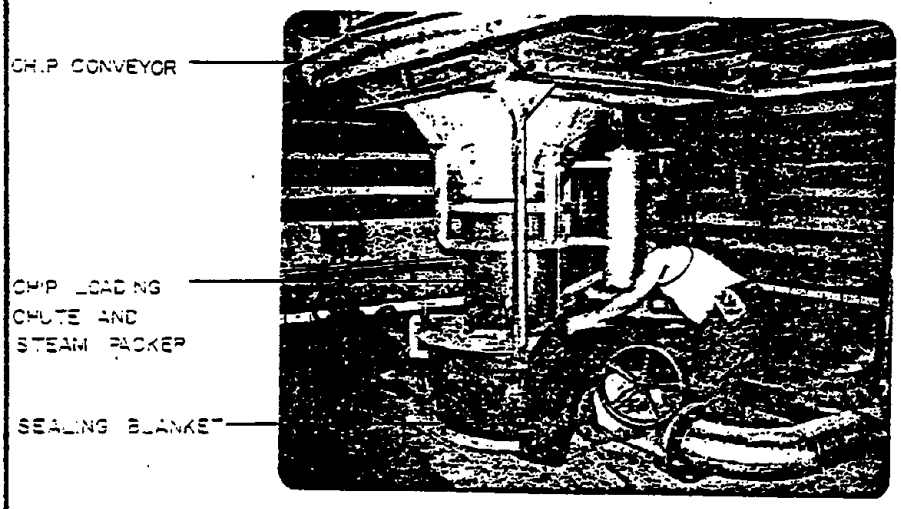

Figure 39-2: Digester Loading Chute
and Steam Packer

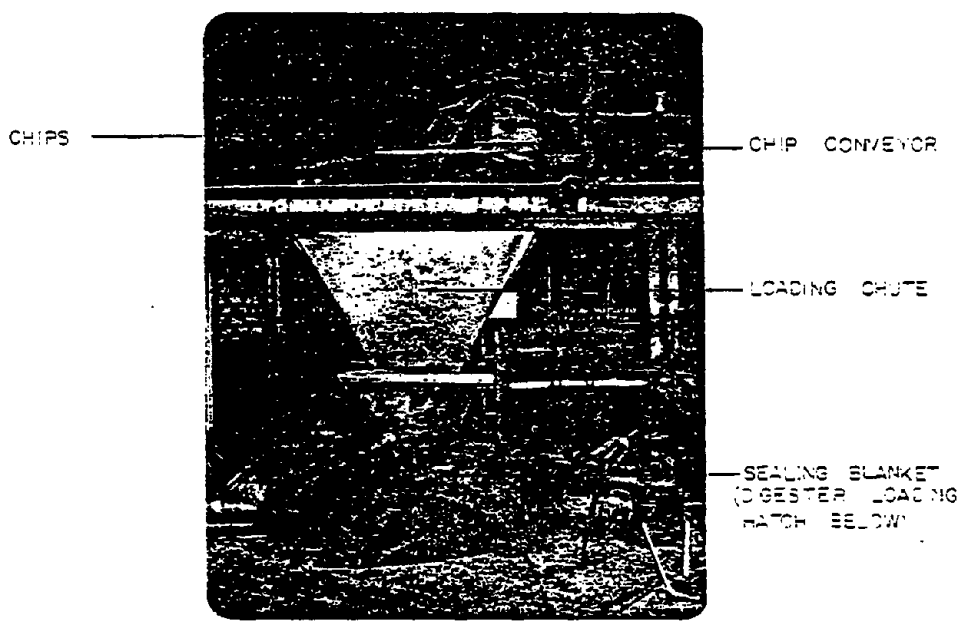

Figure 39-3: Digester Chip Filling Operation

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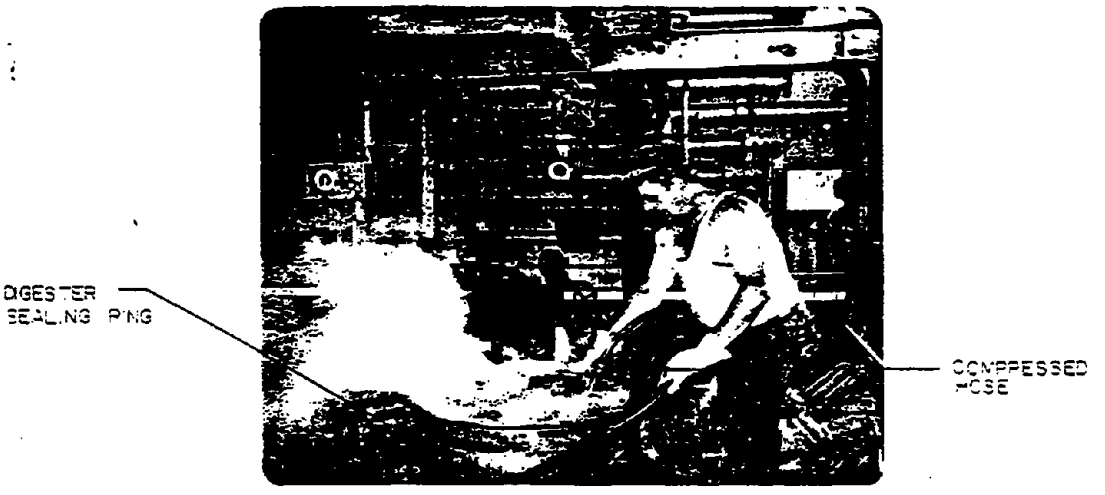

Figure 39-4A: Worker Cleaning Off Digester's Sealing Ring with Compressed Air

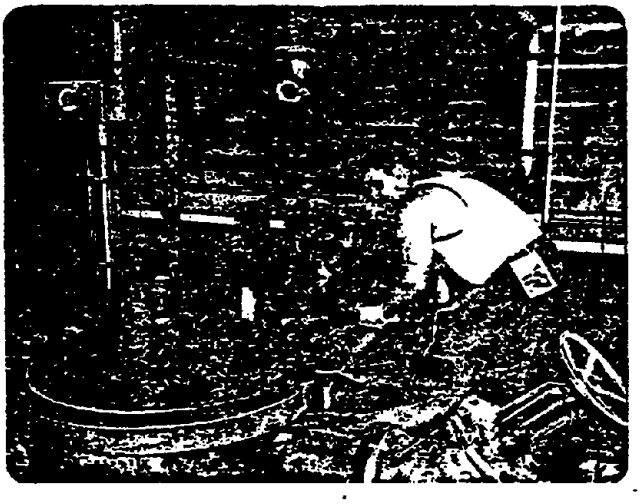

Figure 39-4B: Worker Bolting Down Digester's Cap

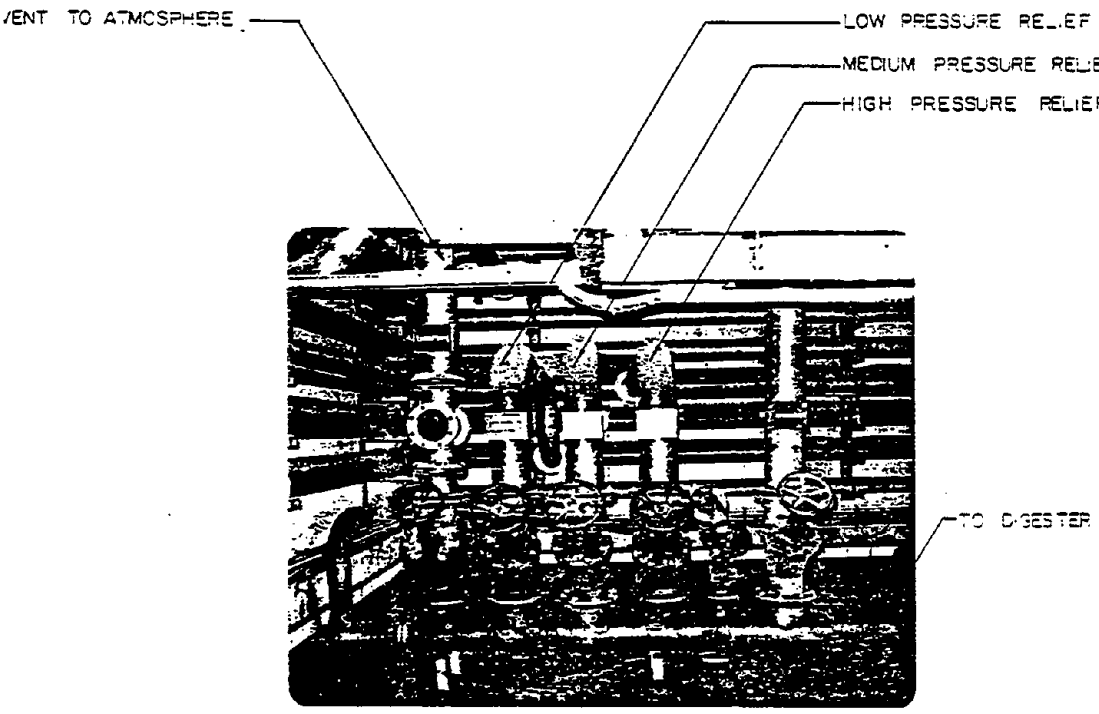

Figure 39-5: Manually-Operated Digester Pressure Relief Manifold System

closed fiber filter, and transferred to the brown stock pit. Liquor is sent to weak waste liquor storage tanks, then pumped to one of two evaporator lines for concentration to heavy liquor by steam heating in either 4 or 6 stages. Evaporator steam and some volatile liquor components (including some sulfur dioxide) are condensed and then cleaned in the mill's biological wastewater treatment plant. The non-condensibles are vented to the atmosphere; the heavy black liquor is transferred to a nearby lignin recovery plant (this plant is independently owned and operated).*

After the pulp has been washed, an aeration safety valve on the digester gas relief line is manually opened to insure the digester is not under vacuum. To actually empty the pulp, workers must first perform the following operations: 1) insure that all steam, relief, and liquor lines are isolated; 2) manually unbolt the digester's cap and place it aside on the floor; 3) startup a loading collar ventilation system that draws gas escaping from the digester into the gas relief manifold system; and 4) insert a special liquor spray line and anchoring harness into the digester's top (See Figure 39-6)

The spray hose is connected to a source of weak filtrate water (from the brown stock washers), and then used to remove pulp that sticks to the digester's inner wall during emptying.

Pumping the pulp out takes about 30 minutes, provided there are no problems. It is accomplished by: 1) opening a large ball valve at the digester's bottom; 2) activating an unloading pump; 3) continuously injecting dilution water to the digester's bottom to facilitate pumping; and 4) applying the spray of wash water down through the digester's top to keep pulp from sticking to the sides. Throughout the latter operation, a worker periodically peers down through the loading hatch to properly position the spray hose (See Figure 39-7.) For exposure protection, workers are required to wear full-face piece, air-filtering respirators during this operation. When the digester is empty, the ball valve is closed, the pump is shutoff, and the digester is prepared for reloading.

*The mill also ferments some liquor in one evaporator line to produce ethanol.

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Figure 39-6: Liquor Spray Nozzle and Positioning Assembly

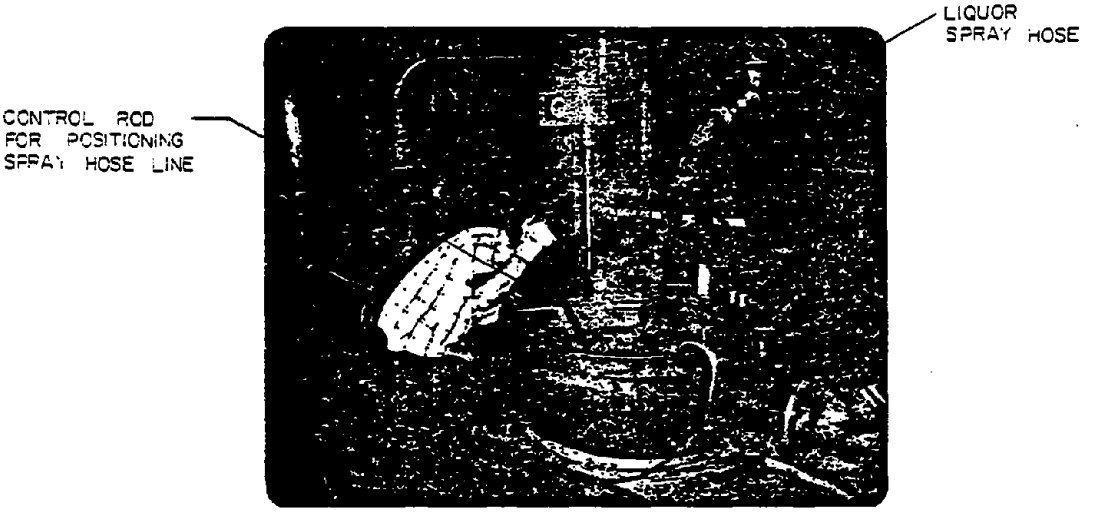

Figure 39-7: Worker While Conducting Digester Emptying Operation

Occasionally, pulp will become too thick and then clog the lowest part of the digester cone during emptying. When this happens, more wash and dilution water must be added to loosen it. Particularly bad cloggings require closing the ball valve, partially refilling the digester with wash filtrate, and blowing pressurized air through the pulp. These upsets and corrective actions increase the time to unload a digester, cause more sulfur dioxide to be released to the workplace, and thereby result in additional worker exposure.

Brown Stock Washing

Pulp is pumped to a brown stock pit which has to be exhausted to the pulp mill roof because large amounts of sulfur dioxide escape. From the pit, it is then pumped to the inlet side of the first of three series-connected 2-stage, pressurized drum washers that have a countercurrent wash water flow system (See Figure 38-8). As shown in the cutaway view (Figure 39-9) and the simplified overall flow diagram (Figure 39-10)*, pulp enters one side of each washer; is picked up on the surface of a rotating screen drum; and then is washed beneath two sets of spray showers as it travels up and over the drum. The first set of washers uses dirty wash water (filtrate) from the next washing stage; and the second uses dirty wash water from the first stage of the final washer. The wash water drains through the filter drum, and is collected below in radial collection trays or in the bottom of the drum. It then flows out of the washer into a 2-compartment filtrate tank, and is pumped to either the showers of the preceding stage, or to the pulp stream (for dilution). Washed pulp is scraped off the drum by a doctor blade on the discharge side, drops into a screw-like repulper trough, and then is pumped to the inlet side of the next washer.

As shown in Figure 39-9, this type of washer must be enclosed with very tight-fitting covers because the space above the drum is pressurized with air to help wash water drain from the pulp and flow through the filter. The pressurizing air is drawn by a fan from inside the drum. If the washers are outside, additional exhaust hoods are apparently unnecessary. If they were inside, some exhaust ventilation may be required.

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*Figure 39-10 shows the simplified flow for only the first two washers.

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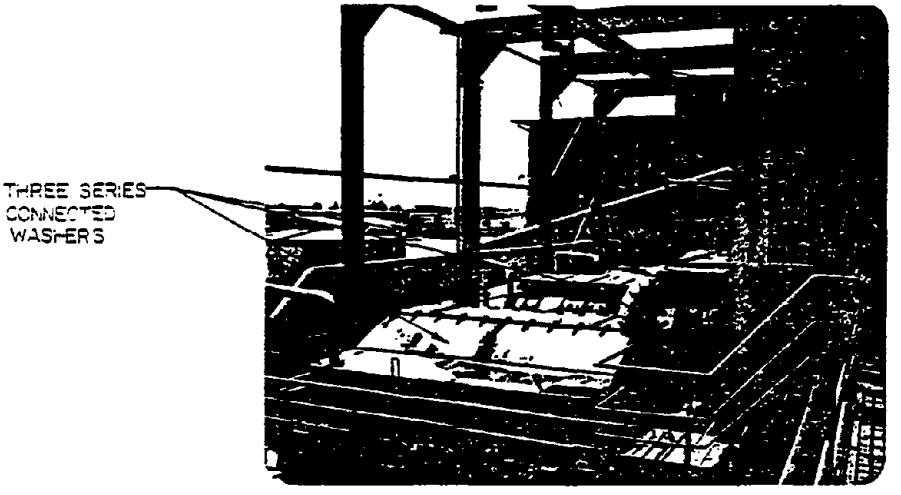


Figure 39-8: Pressurized-Type Brown Stock Washers

Figure 39-9: Cutaway View of Two-Stage Pressurized-Drum Brown Stock Washer

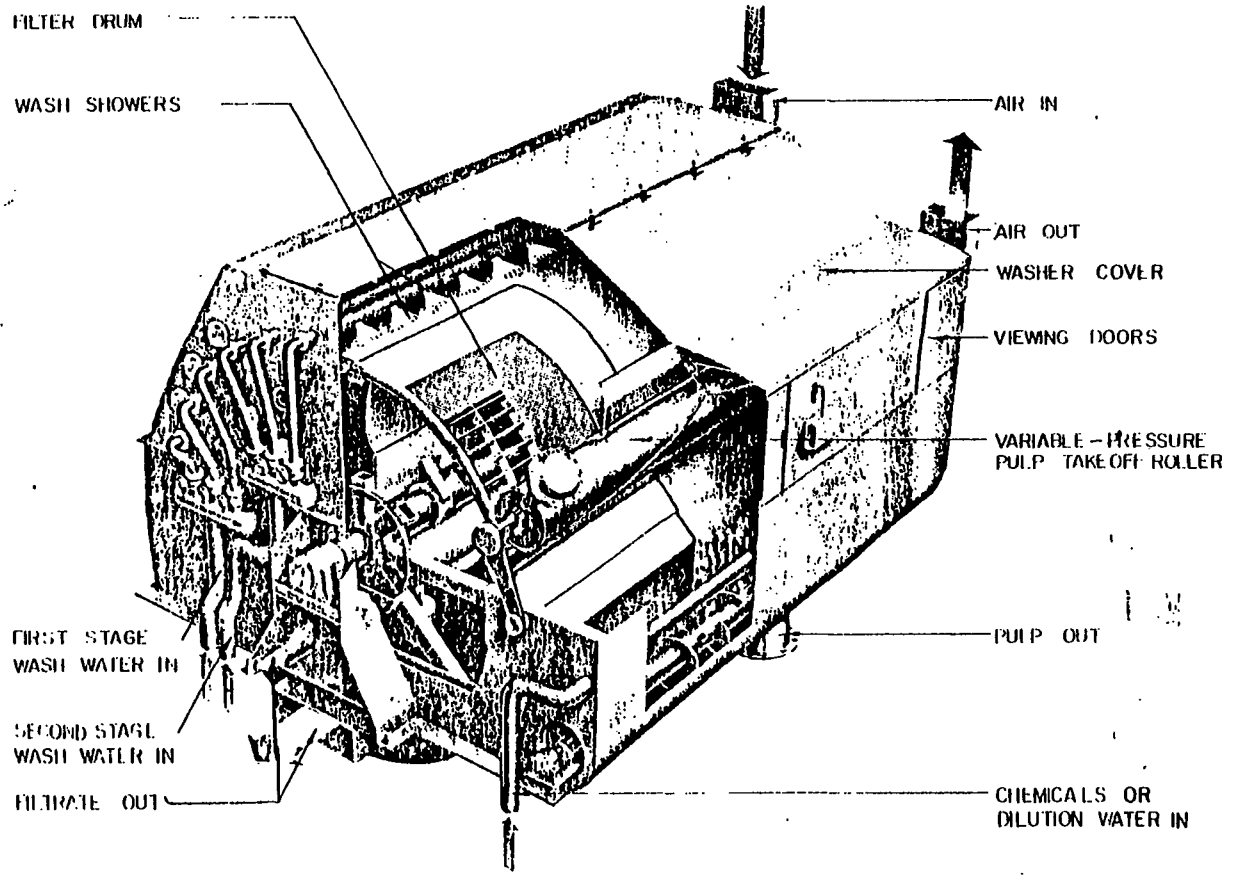
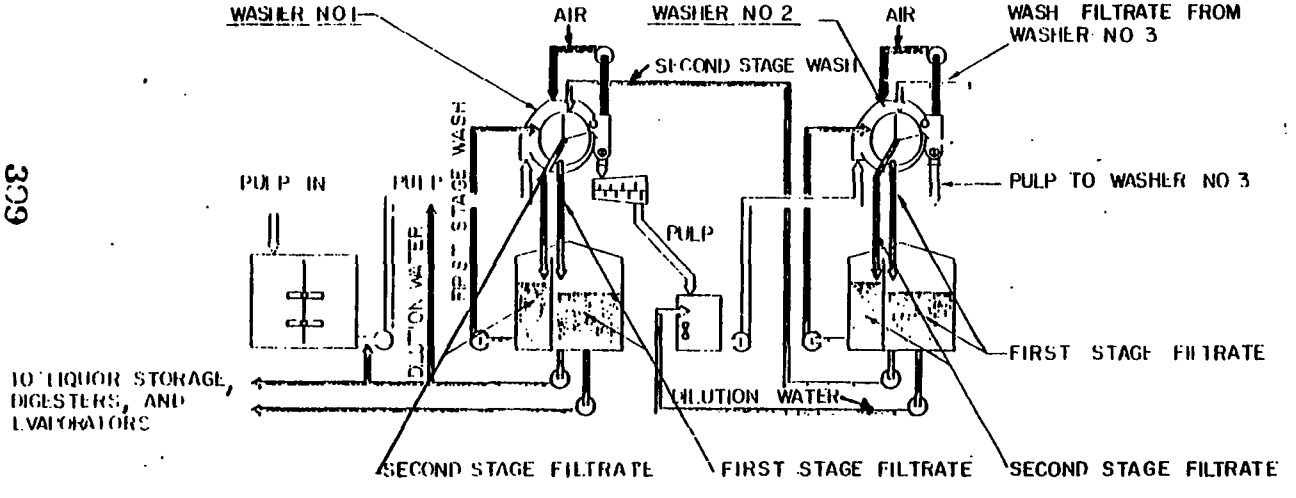


Figure 39-10: Simplified Flow Diagram For Pressurized Brown Stock Washer System
(Only two of three washers shown)



Adapted from Rauma-Repola Sales Literature

Pulp Bleaching

The washed, cleaned, and thickened brown stock from the pulp mill is bleached in one of two three-stage (chlorination, alkaline extraction, and hypochlorite) lines. The lines actually share a common chlorination stage, then the pulp flow is split for the subsequent extraction and hypochlorite stages. This splitting allows pulp of varying quality to be made for either the mill's integrated paper mill or for other mills.

Chlorine gas for the initial bleaching stage is first injected into water, then this solution is immediately injected into the pulp stream and mixed in a dynamic mixer. The pulp and chlorine then react as they are pumped up through a large outside tower and over and down through a smaller tower. The proper chlorine dosage is determined from the brightness and lignin content of the washed brown stock, and is regulated by an automated oxidation-reduction potential (ORP) system. The system's sensor is located in the pulp stream immediately after the dynamic mixer. The system's controller appropriately opens or closes a control valve in the chlorine gas feedline. The dosage system is monitored and operated from the bleach plant control room.

Pulp from the second chlorination tower is split so that about two-thirds flows into the larger of two vacuum-drum washers. Both washers are covered with hoods which are exhausted to a scrubber tower where chlorine is removed by reaction with caustic. The resulting sodium hypochlorite scrubber solution drains to a storage tank containing unbleached pulp.

The remaining two bleaching stages are identical and include the following sequence of steps:

(1) Adding dilute caustic solution at the repulper of the chlorine washers (underneath the washer's hood);

(2) Heating the treated stock with steam in a closed mixer;

(3) Completing the caustic extraction reaction in an outside tower;

(4) Washing the stock in hooded, vacuum-drum washers;

(5) Adding additional caustic at the washer's repulper;

(6) Re-heating the stock in steam mixers while injecting the calcium hypochlorite solution;

(7) Reacting the treated stock in outside towers;

(8) Washing the stock in hooded, vacuum-drum washers; and

(9) Adding weak sulfuric acid at the washer's repulper to lower the pulp's pH prior to storage.

Bleach Chemical Handling and Preparation Operations

Bleach chemical preparation and handling operations were only briefly observed. Liquid chlorine, delivered in rail cars, is unloaded using a chlorine compressor, and converted to the gas in a steam-heated vaporizer. The gas is then regulated for proper pressure, and piped to the bleach plant's first stage injector and the hypochlorite preparation system.

Calcium hypochlorite bleach liquor (30 grams per liter) is prepared in a closed tank by reacting chlorine with calcium hydroxide solution. The resulting solution is pumped to open storage tanks, then to the steam mixers in the pulp lines.

The mill's caustic unloading and dilution system was not observed.

JOB CATEGORIES AND DESCRIPTIONS

There are about a dozen workers (per shift) operating the pulp mill/bleach plant complex. The work force, excluding woodroom and maintenance staffs, consists of:

Work Area	No. of Workers
Digesters	3
Brown Stock Washers, Screens, and Decker	2
Bleach Plant	2
Bleach Chemicals and Pulping Liquor Handling & Preparation	3
Liquor Evaporation & Fermentation	2
Miscellaneous	2

The survey was too short to allow detailed observation of worker activities in the brown stock washing, bleach chemical and liquor preparation, and evaporator areas. Digester workers were extensively observed because understanding their work routines was necessary to interpret sulfur dioxide and wood dust air monitoring in that area. Bleach plant worker activities were only briefly studied.

One of the three digester area workers is the chief operator, and remains in the control room to monitor and adjust the process and direct the other workers. The other workers operate the digesters, and remain on the digester operating floor in excess of 75% of their shift. Their work routines are very similar and include the following tasks:

Task	Estimated Duration (Mins.)
o Installing loading chutes and filling digesters with chips	60
o Cleaning up spilled chips and wood dust	5
o Filling digesters with cooking liquor	30
o Monitoring digester cooking operations	Intermittantly over 7-8 hours
o Relieving digester pressure (after cooking)	45-60
o Washing pulp in digesters	15
o Opening digester caps and installing liquor spray lines	10
o Pumping out digesters	30
o Free or break time, and miscellaneous tasks	30-60

One bleach plant worker remains mostly in that control room to monitor and control the brown stock washing and bleaching processes. He may make brief outside equipment inspections and adjustments, but they are unscheduled. The other worker may be outside the control room 25-50% of the time collecting quality control samples, performing housekeeping duties, and adjusting equipment.

POTENTIAL SOURCES OF WORKPLACE CONTAMINATION

Pulp Mill

Most of the equipment used to prepare or recover pulping chemicals is closed and outside. This includes the liquid sulfur burner, the limestone-packed sulfur dioxide gas absorption towers, and the two liquor evaporation systems. There are potential sulfur dioxide emission sources from this equipment, but no obvious persistent sources of exposure were observed. However, brief acute exposure could conceivably occur during unusual upsets like poor performance or overloading of the absorption towers or evaporators, or a leak in the sulfur burner gas system.

In the pulp building, the three digester workers may be exposed to sulfur dioxide that escapes through the digester loading caps on the operating floor. The greatest potential for exposure occurs during the 90 minutes a digester is open for emptying and reloading. Because the five digesters operate on staggered 11 to 12 hour cycles, one of them is open on the average of 300 minutes out of each 8-hour shift. The workers may also be exposed to wood dust while the overhead chip conveyor is operating.

No persistent sulfur dioxide emissions were observed from the stock pit, the pulping liquor feedlines, or the gas recovery systems. This equipment is closed or vented to the atmosphere, and workers are not normally nearby, although gas leaks sometimes occur.

Mill management recently performed a sulfur balance in order to determine the efficiency of sulfur use in pulping, and the amount lost in heavy black liquor sent to the nearby lignin recovery plant. The balance indicated 92% of the sulfur is accounted for (75% in the black liquor); and 8% or less (< 1.6 tons per day) escapes to the atmosphere through "miscellaneous" vents or to the mill's wastewater. Identified atmospheric vent sources include:

- the gas absorption tower vents;
- the acid box that receives concentrated calcium bisulfite solution from the absorption tower;
- the fresh liquor storage tank vents;
- the exhaust system for the brown stock pit, digester cap, and three brown stock washer tank (this system uses a single exhaust fan);
- the "washed brown stock" storage tank vent;
- the No. II evaporator line vacuum pump exhaust;

- o acid condensate tank vents on both evaporator trains; and
- o vents on the No. I evaporator line and distillation system.

Some of these vents could not be observed or are inaccessible, making it difficult to determine if workplace contamination could result. Sulfur dioxide may be incompletely absorbed in the acid towers,* but the vents on top of the towers are unlikely to affect any workspaces (See Figure 39-1). Concentrated gas may escape at the acid box and fresh acid storage tank, but this equipment is outside and workers are not normally nearby, although they may briefly collect samples there. The exhaust system ventilating the digester caps, the brown stock pit, and the brown stock washers discharges gas near the digester building roof where it is unlikely to infiltrate back into the building's work areas. Atmospheric vent gases for the two essentially outside liquor evaporation systems may contain concentrated amounts of sulfur dioxide, but their potential to contaminate inside workspaces is probably low.

Pulp entering the brown stock washers can contain enough digestion liquor to cause sulfur dioxide offgasing, but the washers are outside and covered to prevent escape of their pressurizing air. No sources of contaminant escape were observed, and worker exposure is unlikely in the absence of process upsets.

With a countercurrent wash water flow system, the first stage washer filtrate may also contain enough sulfur dioxide to cause offgasing and be a source of exposure. However, the filtrate is collected in a tank and then pumped through pipes to the digesters (where it is used to dilute the pulp and wash out the digesters). Gas does not escape from the collection tank or transfer equipment, unless an unusual leak occurs. Workers are not normally near the washers, which are monitored and controlled from the digester control room. Brown stock leaving the washers does not contain enough residual chemical to result in further sulfur dioxide offgasing. Workers are unlikely to be exposed during the subsequent stock screening, deknotting, refining, and cleaning operations.

*The mill reported the towers operate at very high efficiency.

Bleach Plant

The liquid chlorine unloading and vaporization system is totally closed, and gas is unlikely to escape unless a leak occurs. Similarly, the hypochlorite preparation system is closed and exposure to chlorine is unlikely unless an upset or leak occurs and a worker is nearby. The two first stage bleach towers and the chlorine gas injection system are also closed and outside. Chlorine is unlikely to escape at the injector (in the absence of leaks), but excess gas will escape through the vent on top of the last tower. The vent gas is unlikely to infiltrate nearby buildings or the bleach plant. Additional chlorine offgasing occurs as pulp enters the chlorine washers, but the washers are hooded and exhausted (along with the filtrate tanks) to a caustic scrubber on the plant's roof.

After first stage washing, bleach pulp usually does not contain enough free residual chlorine to cause further offgasing. No offgasing will occur during the subsequent caustic extraction and hypochlorite stages because the pulp's high pH keeps any chlorine dissolved and ionized. Brief chlorine exposures (1-2 minutes) may occur when workers collect hourly quality control samples from the chlorination towers and first stage washers.

AIR MONITORING RESULTS

Monitoring Methods

Long-term area monitoring was conducted with an Interscan Sulfur Dioxide Monitor on the digester operating floor in order to estimate worker exposures. No personal samples were collected because impingers restricted worker activities, and proper transport of impinger solutions back to the U.S. for analysis was impractical. Draeger detector tube readings (Table 39-2) were used to augment the area monitoring and to provide estimates of event-related exposures. The Interscan Monitor's recorder tracing is reproduced as Figure 39-11, and discussed below. An overlay on this tracing summarizes the operational status of the four digesters during the 30 continuous hours of monitoring.

Because the digester workers are also exposed to wood dust when the digesters are filled, full-shift personal exposure samples were collected and analyzed for total airborne particulates (5.0 um PVC filters; gravimetric analysis). The results are summarized in Table 39-1.

Potential chlorine exposures for the two bleach plant workers who spend about 50-75% of their time inside the control room were estimated by monitoring area concentrations in the washer room (near the chlorine washers). Exposure to chlorine is

TABLE 39-1: SUMMARY OF PERSONAL SAMPLES FOR WOOD DUST

Job Category	Sampling Time (Mins.)	Wood Dust Exposure* (as mg/m^3 total airborne particulate)	Number of Digesters Loaded During Sampling**
Digester Operator	9:21 - 16:41 (440)	0.93	2
Assistant Digester Operator	9:18 - 16:43 (445)	0.85	2

* Samples were collected on pre-tared 5.0μ PVC filters at 2.0 LPM using constant flow pumps; analyzed gravimetrically.

** All four of the operating digesters were loaded during the sampling period, but usually only one worker is actively involved in this operation. Therefore, each worker was assumed to have loaded only two digesters.

TABLE D 2: SUMMARY OF DRAEGER SULFUR DIOXIDE DETECTOR TUBE READINGS

Location	Day	Sampling Time	SO_2 Concentration, ppm[a]	Comments
Digester No. 9				
o Above Loading Hatch	1	16:10 - 16:19	~12	Started pumping out digester at ~15:55
" " "	1	16:19 - 16:24	~17	" " " " " "
" " "	1	16:30 - 16:36	~25	" " " " " "
" " "	1	16:57 - 16:59	~22	" " " " " "
" " "	1	17:07 - 17:09	~30	Started filling digester at ~17:00
o Above Loading Hatch and Next to Worker	2	13:57 - 14:00	~40	Started pumping out digester at ~13:00
o About 8 Feet in Front of Digester	2	14:12 - 14:14	~24	Started filling digester at ~14:10
"	2	15:02 - 15:06	~5	Completed filling digester at ~15:00
Digester No. 10 -				
o At Loading Hatch Opening	2	15:08 - 15:10	50-90 (est.)	Loading hatch opened for emptying at 15:05
"	2	15:17	50-90 (est.)	Started pumping out digester at 15:14
o Above Loading Hatch and Next to Worker	2	15:22 - 15:24	~6	" " " " " "
"	2	15:41 - 15:41	~22	Finished pumping out digester at 06:06
"	2	16:10 - 16:16	~18	Preparing digester for loading
Digester No. 11				
o Above Loading Hatch and Next to Worker	2	10:48 - 10:54	~0.5	Started pumping out digester at 10:48
"	2	11:06 - 11:12	~2	Near end of pumping out digester
o At Loading Hatch Opening	2	11:16	~55	Reading taken just after digester had been pumped out
o About 8 Feet in Front of Digester	2	11:24 - 11:29	~24	Started filling digester at 11:22
Digester No. 12				
o At Loading Hatch Opening	2	9:38 - 9:43	~30	While pumping out digester
o In Front of Digester	2	10:17 - 10:19	~0.5	At end of digester filling

[a] Concentration range for detector tubes is 1-25 ppm for 10 pump strokes. Readings above 25 ppm were estimated by using less than 10 pump strokes.

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unlikely while the workers are inside the control room because it is closed and kept under positive pressure. The one worker who goes outside each hour (for less than 5 minutes) to collect process quality control samples may be exposed while collecting the first stage pulp samples, but the exposure is probably too brief and too low to measure (less than 1-2 minutes). Other outside tasks (including routine equipment inspections) are unscheduled, and therefore impractical for exposure monitoring. Since the washer room is the most likely workspace when workers are outside the control room, chlorine area concentrations were monitored there over a continuous 28 hour period. A Mast Oxidant Monitor and strip chart recorder were used for this purpose, and results are discussed below.

Monitoring Results

Sulfur Dioxide Exposure - The Interscan Monitor was positioned on the operating floor about 15-20 feet in front of and between the loading hatches for Digesters Nos. 9 and 10. This was about 10-15 feet from an open window. Digesters Nos. 11 and 12 are in an adjoining room, and were probably too far away to affect the instrument directly. There were no known sources of sulfur dioxide emission in the monitored workspace other than the loading hatches of Digesters Nos. 9 and 10, and infiltration of similar emissions from the adjoining digester room. There was no ventilation of the monitored area other than passive ventilation from open windows along the wall behind the instrument. The monitor recorded sulfur dioxide concentrations while workers loaded, operated, and then unloaded four of the five digesters (see operating cycles shown in Figure 39-11).

As shown, sulfur dioxide levels varied widely from about 1.0 ppm to greater than 10 ppm, depending on the operational status of digesters Nos. 9 and 10. Draeger detector tube readings next to the monitor showed concentrations during two offscale periods were as high as 18 ppm (17:00) and 16 ppm (16:00). As expected, the peaks corresponded with a period when Digester No. 9 or 10 was open for either loading or emptying. The data, when interpreted with the detector tube readings, indicate the following conclusions concerning sulfur dioxide exposure in this workspace:

(1) The greatest exposures occur when a digester is first opened after a cook; while it is being pumped out; and during the early period of refilling it with chips.

(2) Brief high exposures, sometimes exceeding 25 ppm, occur when the worker is next to a digester's top to operate valves, open/close the loading cover, or install the chip loading chute. Similar exposures occur throughout a digester's emptying but especially when the worker looks down into the digester to direct the spray of washing liquor.

Because it takes 30-45 minutes to pump out a digester and 50-60 minutes to refill it, each worker may be exposed to these high levels for up to 3 hours each shift (i.e., each worker usually operates at least two digesters and each digester completes one cycle per shift.)*

(3) Baseline sulfur dioxide concentrations on the digester operating floor are about 1-2 ppm, or 20-40% of the OSHA 8-hour TWA PEL*. Such high levels are a reflection of the poor general ventilation of this workspace.

(4) Full-shift TWA exposures may exceed the OSHA PEL because: 1) workers are frequently much closer to the digesters than the monitor was; and 2) they spend very little time in areas with lower concentrations (i.e., the control room or other areas of the pulp mill).

Wood Dust Exposure - Wood dust exposures occur when workers stand near a digester while it is being filled with chips from the overhead conveyor; and while afterwards cleaning up spilled debris. The two full-shift personal samples (0.93 and 0.85 mg/m^3) indicate exposure is well below the OSHA nuisance dust TWA PEL of 15 mg/m^3. Because the dust appeared non-respirable and quickly settled out, partially enclosing the end of the chip conveyor probably would further reduce workplace contamination.

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*Only 4 of 5 digesters were operating during the survey. When all five are operating, overall workplace sulfur dioxide levels and personal exposures may be higher.

Chlorine Exposure - Chlorine concentrations next to the washers were less than the Mast Oxidant Monitor's practical limit of detection (0.05 ppm) throughout twenty eight hours of continuous monitoring (15:25 Monday to 19:42 Tuesday). These low results indicate the chlorination stage is well controlled and the exhaust hoods effectively capture any chlorine offgas. Workers are unlikely to be overexposed in this workspace provided hood observation hatches are kept closed and the chlorine bleach dosage is properly regulated.

CONTROL TECHNOLOGY

Pulp Digesting Operations

The air monitoring results indicate only sulfur dioxide emissions in the digester area are poorly controlled in this mill. Exposures to sulfur dioxide undoubtedly exceed the German standard of 2.0 ppm, and probably exceed the OSHA 8-hour TWA of 5.0 ppm, mainly because of the inability to contain gas that escapes through open digester tops during the loading and unloading stages. Contrary to OSHA requirements, the mill is using respirators as a permanent means to control worker exposure. This is apparently acceptable in West Germany, and each digester worker is provided a full-face canister respirator to reduce the above exposures. Unfortunately, the respirators appeared to be an ineffective control because: 1) they are poorly maintained; and 2) the workers are reluctant to wear them because they are inconvenient, obscure vision, and restrict movements.

The development of effective permanent controls in old chemical pulp mills like Mill 39 is difficult and costly.* A previously surveyed American acid-sulfite mill (Mill 21) has better control of exposures because: 1) digester equipment is more automated; 2) there is some general ventilation of the digester operating floor; and 3) workers obtain exposure relief while inside a contol room located on the digester loading level. It is difficult to determine the suitability and cost of such controls for Mill 39 because it has important process, building layout, and equipment differences.

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*Strict environmental regulations and forest utilization practices make modernization of existing chemical pulp mills, or construction of new ones, difficult.

Improvements in exposure control on the digester operating floor in Mill 39 probably could be obtained by: (1) increasing the local ventilation at each digester's loading collar; (2) installing dilution ventilation; and (3) developing and strictly enforcing a formal respirator program. A combination of these controls probably is necessary because workplace emissions are sporadic and vary in intensity (i.e., major emissions occur only when the digesters are open for emptying or filling). Good local ventilation at each digester's loading hatch should capture and remove most escaping sulfur dioxide; moderate amounts of general ventilation would help remove uncaptured gas during high emission periods or during upset-related gas leaks at liquor lines, gas relief lines, and other equipment on the operating or underlying floors. Unfortunately, design criteria for the ventilation improvements is difficult to recommend because sulfur dioxide emissions are dependent on operational factors like length and extent of chip cooking, liquor strength, length and extent of gas relief during cooking, incomplete relief of digester gases after cooking, a trouble-free digester emptying operation, and lack of upsets and leaks. Furthermore, the improvement of the local exhaust system at the loading hatches is difficult because: (1) contaminant emission rates vary considerably, (2) the hatches must accommodate the chip loading chutes, (3) steam and gas relief lines are connected around the hatches, and (4) the ventilation system should be isolated during the cooking cycle. Completely containing gas that escapes during a digester's loading is probably impossible because chips displace gas inside the digester, and using high velocity local ventilation around a loading collar could capture a large amount of wood dust and small chips. Therefore, augmenting the local ventilation with good general workplace dilution ventilation is probably the best course of action.

Detector tube readings above Digester No. 11's loading hatch (~ 0.5, ~ 2 ppm) indicate its local ventilation is slightly more effective than the other three digesters' (See Table 39-2). Although air flow readings could not be made, the system appeared to capture most gas that escaped during the emptying step. However, high sulfur dioxide levels were still detected above the hatch after emptying (~ 55 ppm) and during loading (~ 25 ppm at 8 feet from the digester's top). The above operational, process, and equipment factors warrant further examination and consideration before making ventilation improvements.

Brown Stock Washing Operations

The brown stock pits are closed, located remote from work areas, and ventilated to remove sulfur dioxide offgases. There is little potential for exposure unless workers are nearby and a leak or upset occurs.

Stock entering the first brown stock washer is hot and may offgas large amounts of sulfur dioxide. However, the washers are closed and outside; no workers are normally nearby; and their covers fit tightly with no apparent sources of gas escape. Worker exposure probably occurs only during an upset like a stock or filtrate spill, or if washer covers have to be removed for inspections or service of the equipment. Stock or filtrate spills are apparently uncommon because the washers are so tightly closed; and windows on the washer sides and ends can be used for routine observations without opening the covers.

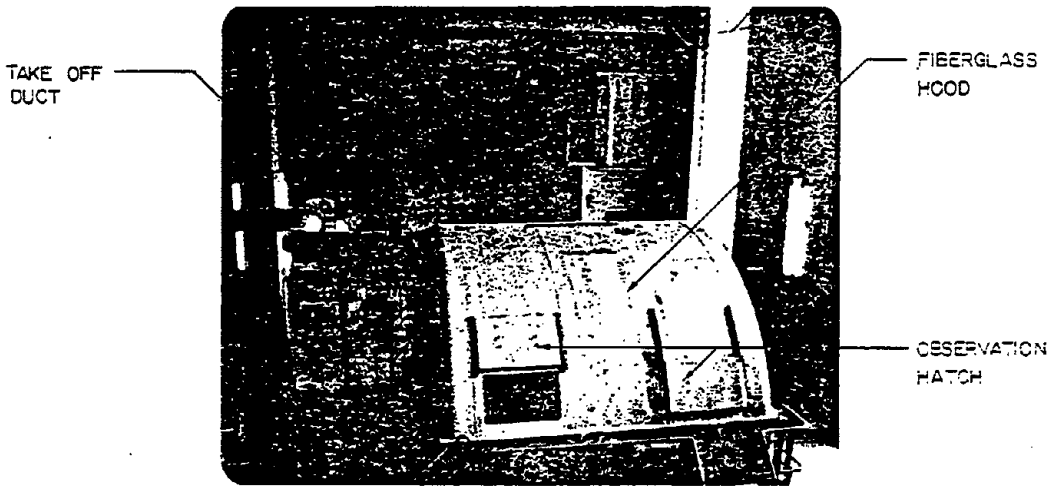
Bleach Plant Operations

Over-exposure of bleach plant workers to chlorine is controlled by: 1) the major potential emission or gas leak sources being outside (towers, chlorine injector, static mixer); 2) the process being closed, automated, and remotely operated; 3) both workers spending the majority of their time inside a protective control room; and 4) exhaust hoods (and the exhaust air scrubber) over the chlorine-stage vacuum-drum washers.

Smoke tube reading at doorways indicated the bleach plant control room is under good positive pressure, and any chlorine emissions in the nearby washer room are unlikely to infiltrate. The good positive pressure is obtained with a recirculating HVAC system that takes in fresh makeup air (unknown volume) through a roof-mounted duct. Respirators are available for worker use when they are outside the room, but they usually are not required.

Of the various process monitoring controls, the oxidation-reduction-potential chlorine dosage system probably has the greatest effect on controlling contaminant release. The system automatically measures chlorine residual about 20 seconds after gas is injected into the pulp, and then accordingly adjusts the chlorine gas rate to maintain the desired dosage concentration. Unreacted chlorine will offgas from pulp entering the washers, but it is prevented from entering the workplace by the tight-fitting hoods (Figure 39-12), which are exhausted through a caustic scrubber by a single fan (unknown capacity). Exhaust air discharges above the building's roof. Workers were particularly careful to keep the sliding hatch covers on the chlorine hoods (two hatches per side) closed. This practice helps reduce the potential for chlorine escaping to the workplace. The lack of detectable chlorine levels in the washer room over 28 hours of monitoring indicate the hoods and dosage control system normally prevent workplace contamination.

Figure 39-12: Typical Bleach Washer Exhaust Hood



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SECTIONS IV & V	PULP BLEACHING AND CHEMICAL PREPARATION OPERATIONS	
	Mill 10	
	Mill 12	
	Mill 22	
	Mill 25	
	Mill 30	
	Mill 32	
	Mill 35	
	Mill 37	Bleach Plant Only

MILL 10: FOUR-STAGE (CEHD) BLEACH PLANT AND BLEACH CHEMICAL PREPARATION SYSTEMS

INTRODUCTION

Mill 10 is a middle-aged, four-stage bleach plant that operates in conjunction with a Kraft continuous Kamyr digester to produce 200-225 tons per day of high-brightness (83-85 units) hardwood or pine pulp for fine printing papers. Pulp (either hardwood or pine) from the pulp mill is mixed and reacted with in sequence : 1) a strong chlorine in water solution; 2) a caustic extraction solution (sodium hydroxide with extra hypochlorite for additional bleaching); 3) alkaline sodium hypochlorite solution; and 4) a final acidic chlorine dioxide solution. All equipment is operated from a central control center within the bleach building. Computer hardware and software are currently being installed and debugged to convert most of the process to a computer-controlled system.

Chlorine dioxide solution is generated on-site in a separate building using a series-connected, two-stage generator (based on the improved Solvay process) and a single-stage, chilled water absorption tower. The chlorine solution is prepared from purchased liquid chlorine using two steam-heated vaporizers, conventional gas pressure and flow regulating equipment, and a gas/water mixing tee. Hypochlorite bleaching liquor is generated on-site by reacting chlorine gas with 6% sodium hydroxide, prepared by diluting purchased concentrated (50%) caustic.

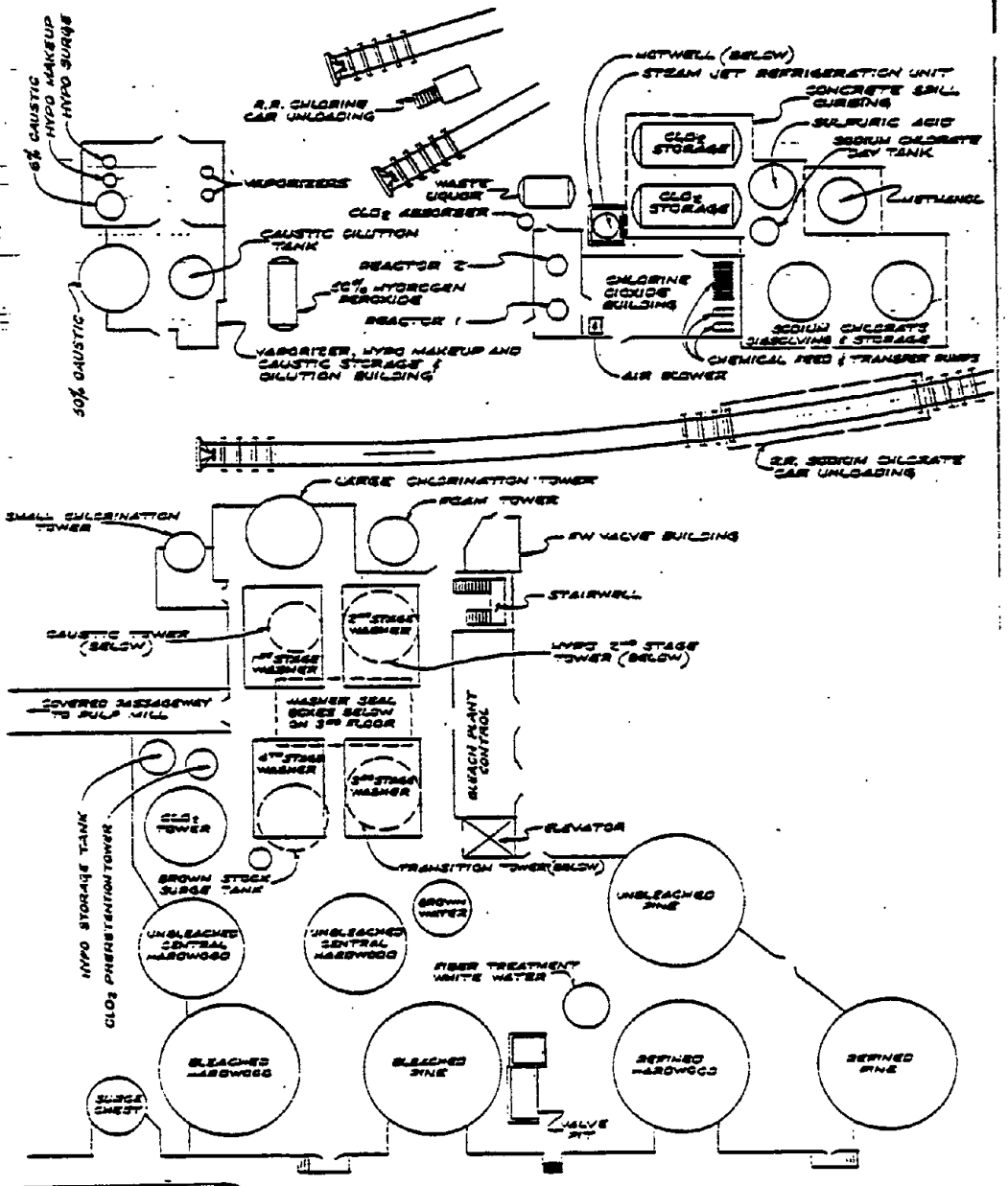
GENERAL MILL AND EQUIPMENT LAYOUT

The overall mill layout and location of major process equipment are shown in Figure 10-1. As shown, the bleach plant contains the control center, stock pumps, steam and chemical mixers, the vacuum washers, stock tanks, and retention towers. It is a large, five-floor building which is separated from the single-story buildings housing the chlorine vaporizers and caustic/hypo makeup systems, and the chlorine dioxide generator. It is connected to the pulp mill building (containing the continuous Kamyr digester, brown stock washers, screens, cleaners, and thickener) by a narrow, enclosed passageway. The control center consists of a closed, positive-pressure, air-conditioned room located on the fifth floor opposite the four vacuum drum washers. Vertical access to the various bleach plant floors is provided by either a stairwell or freight elevator.

FIGURE 10-1 3

FOUR STAGE BLEACH PROCESS
GENERAL LAYOUT

NOT TO SCALE



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Entryways to the bleach plant and vaporizer/hypo makeup buildings are posted with alarms (light and audio) to restrict entry during chlorine leaks or other emergencies. All personnel required to work in or enter the bleach plant must possess an air-purifying (or equivalent) respirator. In addition, full-face air filtering and/or self-contained breathing apparatus are available in closets at or near all access and escape routes, and in the control center.

PROCESS DESCRIPTION (See Figures 10-2 and 10-3)

Pulp Bleaching

Stock Bleaching: Stock bleaching is automated and accomplished in the four stages of chlorine/wash, caustic extraction/wash, alkaline hypochlorite/wash, and acidic chlorine dioxide/wash sequence (CEHD). A small amount of hypochlorite solution is added to the second stage tower to enhance impurity oxidation and extraction. Dilute sulfuric acid was being added on a trial basis prior to the fourth stage to lower pH and reduce the required quantity of chlorine dioxide.

All bleaching operations are controlled from the fifth floor control center[1]. Either softwood (pine) or hardwood is bleached for periods of twenty-four hours or more. Although chemical strengths and stock flows may vary, the process flow is essentially identical for each type of pulp. The permanganate (K) numbers of unbleached hardwood range from 11 to 14, and of unbleached softwood from 17 to about 23. Because the final bleached pulp brightness levels range from 83 to 85, the plant is operating under the challenging conditions of taking difficult to bleach sulfate pulps to very high brightness levels.

Washed, high density brown stock from the pulp mill is stored in one of three tanks located in the bleach plant - two softwood (pine) and one hardwood. Depending on the type of wood being bleached, high density stock is diluted with fresh water, then pumped to a small, agitated surge tank. The stock consistency entering the first stage of chlorination from the surge tank is continuously monitored and regulated to the desired 3-3.5% level by supplying additional fresh water to the stock line.

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1 During the survey, the entire bleach system was in process of being debugged for computer control. The following process description details systems which were or will later be computer controlled.

FIGURE 10-2 .- SIMPLIFIED BLEACH PLANT FLOW DIAGRAM

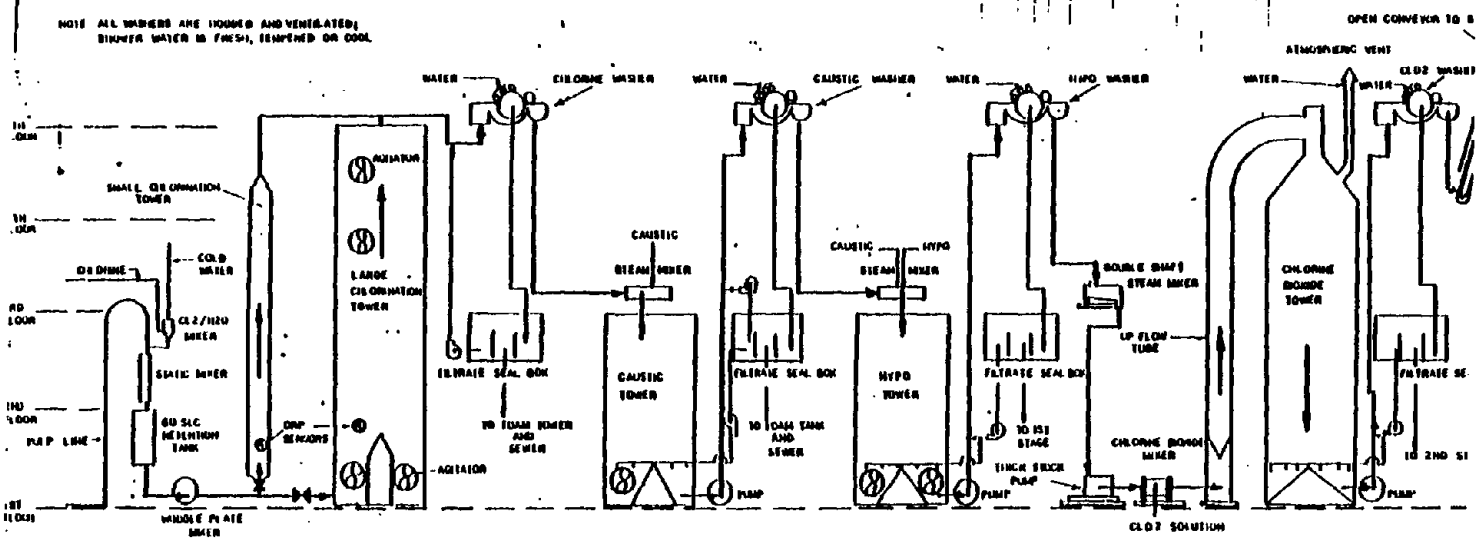
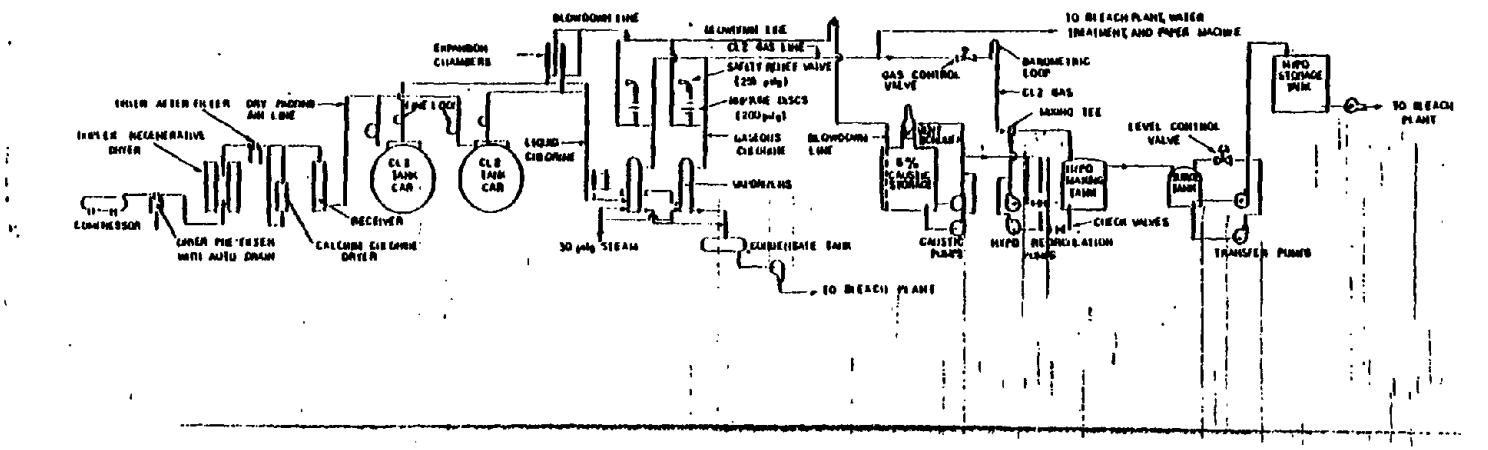


FIGURE 10-3. - SIMPLIFIED CHLORINE UNLOADING & HYPO MAKEUP SYSTEMS



Chlorine gas which has just been mixed with fresh cool water in an adjacent mixing tee is then quickly added to the stock through a high pressure injection line as it flows downward at a high velocity from the third to the first floor of the bleach plant. Complete mixing of the chlorine/water solution and stock mixture is insured by passing it through an in-line 12" Kenics Mixer (a closed, unvented piping element with baffles located on the second floor). The chlorinated stock then passes through a small unvented, fiberglass retention tank (60 second retention time), a wobble plate mixer, and finally upward through either of two agitated first stage chlorination towers. The towers are completely closed and of sufficient capacity to provide about 50 to 75 minutes of 13-15 minutes of retention time respectively. Stock temperatures range from 75-85°F at a pH of 3-4. Stock exiting the top of either tower is diluted to about 1% consistency with water from the seal box of the 1st stage washer. It is then discharged to the inlet vat of the 1st stage washer located on the bleach plant operating floor.

The desired amount of chlorine gas for the first stage of bleaching in this system is controlled (fully automatic with new computer system) by oxidation/reduction potential sensors located both in the large tower and the parallel-piped smaller tower. Either the 70 minute or the 15 minute chlorination tower can be used to vary the retention time in the first bleaching stage as conditions dictate.

The IMPCO washers (rotary, vacuum-drum) are eight feet in diameter and 16 feet long with long droplegs extending to a seal box on the third floor. Chlorinated pulp is displacement washed with hot water (140°F) from the showers, and the dried mat removed at the discharge end with mechanical take-off rolls. The resulting filtrate from this stage (supplemented with filtrate from the third stage hypo filtrate seal box) is used for dilution of stock from the chlorination tower. Excess filtrate goes to a foam tank for the washers. Dropleg vacuum levels are automatically monitored and should they become low, hot water (140°F) from the heat exchanger is stopped. Washed stock drops from the washer discharge to a double-shaft steam and chemical mixer located on the 4th floor.

The mixer mixes stock of high consistency (15%) and caustic (6%) with a small amount of hypo before discharging it to the top of the 2nd stage tower. Stock temperature is automatically controlled by regulating the steam to the mixer based on the temperature of discharged stock. With this mixer, stock temperature is thus raised to 130°F and the pH to the requisite alkaline (pH ~ 11 initially) conditions for efficient extraction of the chlorinated lignin compounds. The caustic feed rate is controlled by differential pH sensors located in the mixer discharge (initial) chamber and the tower (residual pH), and by a caustic flow sensor.

Due to the need for high pulp brightness levels, normal second stage extraction also involves the addition of some hypochlorite through the mixer to achieve additional oxidative removal of colored residues after chlorination and during alkaline extraction. Generated hypo (~45-50 gpl Cl_2 strength) is automatically added to the mixer based on a pre-selected rate for the type of wood being bleached and other process requirements. It reacts with the pulp in the tower during a retention time of about one hour. Stock in the bottom of the tower is then diluted back to a satisfactory pumping consistency (~ 2.5%) by controlled addition of second and fourth stage washer filtrate through a ring header system into the bottom of the tower. Dilution flow is controlled based on a tower level sensing circuit and the discharge pump control valve. To achieve effective washing conditions, the consistency is further lowered to about 1% by injection of additional second and fourth stage washer filtrate.

From the shredder of the 2nd stage washer, stock is discharged at about 13.5% consistency to another double-shaft steam and chemical mixer on the 4th floor below. As with the 2nd stage mixer, a regulated amount of steam (based on temperature) is injected to raise stock temperature back to ~ 100-105°F. Small quantities of sodium hypochlorite (45-50 gpl Cl_2 strength) and caustic solution (~ 6%) are also injected. These chemical feeds are again automatically controlled by in-line differential pH monitors (initial mixer pH ~ 10.5-11.0; final tower pH ~ 8.5-9.5) and a flow control circuit. With this system, chlorine residuals in the mixer are targeted for 0.6-0.8 ppm, and are manually checked every other hour by the bleach plant staff. Third stage (Eypo) tower retention times are typically 2.0 to 2.5 hours. The stock is first diluted to ~ 2.5% pumping consistency in the tower using third stage washer filtrate and fresh tempered water, then down to ~ 1% consistency before being pumped up to the 3rd stage washer.

The final stage of bleaching is accomplished by injecting steam (regulated based on a temperature monitor circuit) into ~ 12% consistency stock through a double-shaft steam mixer. Stock temperature is raised to 170-180°F, and strong chlorine dioxide solution (7-8 gpl ClO_2 strength) is injected through a high pressure, water-sealed mixer located just after a high density stock pump. All equipment is located on the ground floor of the bleach plant, with mixer seal water immediately drained to the sewer system. Chlorine dioxide flow is set based on: plant thruput rate; an in-line pH monitor at the mixer; the bleach chemical flow; the stage III final pulp brightness; and the targeted final brightness.

From the mixer, the stock flows upward through a vertical 6'-6" I.D. (acid brick lined) steel upflow tube and then directly down into and through a (acid brick lined) steel contact tower. The final bleaching is completed in the tower at a

temperature of ~ 170°F with a stock consistency of ~ 10%. Upflow tube stock pH ranges from 4 to 5 units with final pH (as monitored continuously at the washer inlet vat) targeted for 6.5 to 7.5 units. This final pH is controlled by adding a small amount (1 gpm ±) of neutralizing caustic solution to the tower discharge just before the stock pump. Stock temperature monitors and recordings are maintained for the upflow tube and for two heights in the contact tower. The contact tower vent is scrubbed continuously with tempered water flowing back into the tower (~ 10 gpm ±).

Before the stock is pumped to the 4th stage washer, it is diluted to a 2.5% pumping consistency in the agitated tower bottom by adding 4th stage washer filtrate supplemented with additional low pressure tempered water. It is further diluted to ~ 1% consistency after the stock pump with the same water sources. This dilution system (loop) is automatically controlled through a tower level sensing circuit and a control valve after the stock pump. After washing, bleached stock at a consistency of about 12% is shredded and dropped onto a belt conveyor system located on the 4th floor. The conveyor transports the stock to one of three closed storage tanks - (a 85,000 gallon transition (pine and hardwood) tower, a 222,000 gallon pine tower, or a 222,000 gallon hardwood tower).

Bleach Chemical Handling and Preparation Systems

Chlorine Vaporizer and Sodium Hypochlorite Makeup: Mill 10 receives liquid chlorine in railroad tank cars, then steam vaporizes it to produce gaseous chlorine for: first stage bleaching; production of sodium hypochlorite bleaching liquor; water treatment; and papermill disinfection purposes. The two vaporizers and the hypo makeup system are a recent (1977) addition to the existing single-story caustic storage and dilution facility (located behind the bleach plant). Both chlorine vaporization and hypochlorite makeup are now almost entirely automated, and the facility is only periodically entered by the assistant bleach plant operator or a shift foreman for brief inspections or collection of quality control samples. The bleach plant utility man (day shift) occasionally enters the caustic storage/dilution area of the building (separated from the vaporizer/hypo room by a closed door) to monitor or service the dilution system. The vaporizer/hypo makeup area has a separate ceiling supply air system, and manually activated wall (behind the vaporizers) and ceiling exhaust fans. An automated audio/light alarm system is activated by a number of process sensors or a gas monitor within the building (see Control Technology discussion).

The vaporizer and hypo makeup systems are depicted schematically in Figure 10-3. Liquid chlorine flows to the two vaporizers through 1-1/2" steel piping from one of two parallel

piped tank cars which are padded with clean, dry, regulated compressed air to insure a steady flow of liquid chlorine. The piping system is also provided with insulated expansion chambers, pressure gauges, and shut down valves with dry air purges. The vaporizers are the steam-heated type rated at 3000 lbs/hr. maximum, and are operated singly with one off-the-line as standby. Chlorine gas exits the top of each unit through 1-1/2" metal piping with temperature and pressure sensors (and alarms). High pressure in either line is controlled by a rupture disk set at 200 psig, followed by a safety relief valve set at 225 psig. This safety valve, should it open, relieves chlorine gas to the bottom of the 6% caustic storage tank (which is further vented through a caustic scrubber). Both vaporizer lines combine to a single 2" line with pressure regulated (with a low pressure safety alarm) through a control valve. The 2" line is again split into two separate lines - one 1" line supplying a maximum of 9.2 lbs./min. chlorine to the hypo makeup system; and a 2" line which further branches into three separate lines for the bleach plant (2" line, 25 lbs./min., max.), the water treatment plant (1-1/4"), and the paper machines (1", 1 lb./min. max.).

The hypo makeup system is located opposite the chlorine vaporizers, and consists of: fiberglass tanks for 6% caustic storage, hypo making, and hypo surge; corrosion-resistant transfer and mixing pumps; and connecting piping and control valves. Production of fresh hypo is initiated and terminated based on the bleach plant consumption rate as determined by a level sensing circuit on the storage tank located in the bleach building. To produce sodium hypochlorite, a regulated flow of chlorine gas from the vaporizers (max. of 9.2 lbs./min. through 1-1/2" pipe) is slowly injected through a tee into a 4" diameter metal pipe containing recirculated hypo (90 gal./min.). The loop system thus constantly recirculates and mixes the makeup tank contents with fresh 6% caustic added just prior to the pump inlet. The chlorine feed rate (and hence hypo strength) is controlled by an oxidation-reduction sensor and control circuit in the return line to the makeup tank. Caustic flow is controlled by the hypo storage tank level sensing circuit. Hypo overflow from the makeup tank enters an adjacent surge tank from which fresh hypo is pumped to a storage tank or recirculated back to the surge tank through a surge tank level controlling valve. Hypo pumped from both the makeup and surge tanks is protected against backflow by one way valves, check valves (in case of pump failure and chlorine backflow).

As indicated, both the surge and makeup tanks are vented through 4" lines into the 6% caustic storage tank provided with a vent scrubber (using 10 gpm of 6% caustic taken from the tank bottom). The scrubber outlet is provided with a chlorine sensor and alarm system.

Chlorine Dioxide Generation: A two stage generator (based on the improved Solvay process) is used to generate fresh chlorine dioxide gas (in air) at a concentration safely below its explosive limit. Generated gas is absorbed in a single, chilled water absorber and stored in one of two 15,000 gallon tanks for subsequent use in the 4th stage of pulp bleaching. The two reactors, reactant chemical feed and transfer pumps, a compressor for reactor purge air, chlorine dioxide solution transfer pumps, and a small quality control testing bench are all located within a single story building located northeast of the bleach plant (see Figure 10-1). The facility was constructed in the early 60's. The generators are located in a separate room of this building with a two-tiered catwalk accessible by ladder provided for service and inspection of the upper levels of the reactors. Safety relief valves on top of the reactors are ventilated to the roof with a common hood system, and are fitted with permanent, flexible Tygon hoses connected to gas sampling manifolds at the QC testing station for periodic manual sampling of generated chlorine dioxide gas. Chilled water for the absorber is provided by a steam jet refrigeration unit located over the hotwell outside the north wall of the building. The single stage absorber is located within the reactor portion of the building just north of the 2nd reactor and vented to the atmosphere. All other chemical storage tanks are outside the building with concrete spill containment curbs surrounding them.

The improved Solvay process produces chlorine dioxide gas by mixing and reacting solutions of sodium chlorate (46%), cool sulfuric acid (60°Be), and methanol in two steel reactor vessels lined with lead and water jacketed for temperature control (normally connected in series). The reacting solutions are metered by a single, five channel pump at the correct ratios into the bottom of the first reactor through three separate ports along with a controlled flow of air. The metering pump has built-in calibration tubes for each of the five reactant flows which must be carefully regulated to the proper proportions - 1) sulfuric acid to #1 and #2 reactors, 2) sulfuric acid cooling water, 3) sodium chlorate, 4) #1 reactor methanol, and 5) #2 reactor methanol. The reactants are mixed by the air stream, react and flow up the vessel, and are discharged to the second reactor.

Chlorine dioxide gas, plus a small amount of chlorine, is produced by the following reaction and is stripped from the liquor by the air stream exiting the reactor through a 4" diameter pipe on its top:

$$4\ NaClO_3 + 4\ H_2SO_4 + CH_3OH \rightarrow 4\ ClO_2 + 4\ NaHSO_4 + 3\ H_2O + HCOOH$$

In the second reactor, partially reacted liquor from the first stage is fortified with about 10% of the total sulfuric acid flow plus sufficient methanol to complete the reduction of the chlorate. By maintaining the temperature of the first reactor at 135°-140°F and the second at 140°-145°F, carefully maintaining the required ratios of reactants, and controlling the flow of air through both reactors, a chlorine dioxide in air concentration of about 10% and high purity can be maintained. Concentrations above this level can be explosive and difficult to fully absorb in water. The acid overflow from the second reactor containing sulfuric acid, sodium bisulfate, and a very small amount of sodium chlorate (~ 5-15 GPl) is currently diluted and sewered as attempts to use it as salt cake substitute in the pulp mill chemical recovery system were not successful.

The gas stream leaving both reactors is combined and enters the bottom of a single, packed absorption tower. Chilled water (41-42°F, 28-30 gpm) supplied to the top of this tower then absorbs most of the chlorine dioxide gas (and any chlorine) and is discharged from the bottom into one of two 15,000 gallon storage tanks. The strength of the chlorine dioxide solution is thus controlled by the absorption tower water flow rate, tower efficiency, water temperature, and gas flow rate and concentration.

It is then pumped by one of two pumps (31-42 gpm) to the ground level of the bleach plant where it is metered into the pulp stock for the final stage of bleaching.

JOB DESCRIPTIONS

The bleach plant is operated continuously by a two man production staff and a utility man on the day shift. They are assisted and supervised by a mill-wide maintenance staff (as required), the pulp mill management staff, and a shift foreman. The foremen make regular inspection tours throughout the pulp mill, including the bleach plant, chlorine vaporizer/hypo make-up facility, and the chlorine dioxide generator building. The major responsibilities and tasks of the three production workers are as follows:

Operator: The operator has overall responsibility for the entire bleach process including production of bleaching chemicals (except chlorine dioxide), stock bleaching and washing, and quality control monitoring. He directs all bleaching operations, and is responsible for handling all emergencies in his area. He reports to the shift foreman, and prepares and signs the bleach plant production log summary. Since all process monitoring and control instrumentation are in the control room, the operator spends in excess of 90% of his

time in this room. Regular tasks which may require him to leave this room would include:

- Inspection, service or startup/shutdown of washers (wash down of spills, cleaning of stock from drums, adjustment of showers, etc.)
- Collection of stock samples from the washers (usually done by assistant)
- Investigation of a suspected process malfunction (potentially anywhere in the bleach building)
- Supervision of the hookup of new liquid chlorine tank cars (actual connection done by pipefitters)

Bleach Plant Helper: The Helper must communicate closely with the Operator so that each constantly knows the whereabouts of the other and the status of process equipment. Major responsibilities and tasks performed by the Helper include:

- Operation of the chlorine dioxide plant including preparation of the daily production log report, collection and testing of all quality control samples (performed once every other hour during normal generator operation), and overseeing of its startup or shutdown.
- Collection and testing of samples of stock from various bleaching stages for pH, temperature, and residual bleaching agent analysis (performed once every other hour on the odd hour during normal operation).
- Assisting the Operator in the cleanup of major stock spills anywhere in the bleach plant
- Inspection of the chlorine vaporizer and hypo makeup system, and performance of their quality control sampling and testing
- Monitoring of the bleach process whenever the Operator is not available

It is estimated that the Helper spends on the average about 70% of his time in the control room, during normal plant operations. In excess of 75% of his time outside the room is spent performing regularly scheduled equipment inspections, and collecting and testing process quality control samples. These activities are further discussed with the following air monitoring results.

Utility Man: The Utility Man works under the direct supervision of the pulp mill foreman. His work is largely routine and he schedules his activities at his own convenience, unless process upsets occur. Of the three production employees, he spends the greatest amount of time outside the control room. Normal estimated times in various parts of the bleach mill during his eight hour shift are:

In Control Room:	1.0-1.5 hours
Bleach Plant:	5.5-6.0 hours
Outside Bleach Plant:	1.0 hours

While in the bleach plant, he spends his time looking for and cleaning up spilled stock underneath the decker conveyor belts (B4 and B6) and the T2 belt; performing cleaning tasks around the T1 and T3 conveyor belts on the 4th floor, and washing down stock around the bleach washers and stock refiners on the fifth floor of the bleach plant. He also hoses down all floors in the bleach plant and refiner area; and makes up scale and pitch control chemical solutions in the bleach plant. His time spent outside the bleach plant is typically in the caustic dilution area of the vaporizer/hypo makeup building (for very short periods of time); in or outside of the chlorine dioxide building unloading delivered chemicals; or performing errands potentially anywhere in the mill.

Further descriptions of the bleach plant workers' typical tasks are summarized in Table 10:3 of the following section discussing air monitoring results.

AIR MONITORING RESULTS

Methods

Both area and personal samples were collected to assess production workers' exposures to chlorine and/or chlorine dioxide in the bleach plant, chlorine dioxide generator building, and the hypo makeup/vaporizer facility. Because sampled workspaces potentially contain a combination of chlorine and chlorine dioxide and no simple method currently exists to differentiate them, measured exposures and area concentrations were quantified in terms of only the equivalent chlorine concentration. The personal samples were collected for fifteen (15) minutes during selective (or available) periods workers were outside the control room. Sampling flowrates were set at 0.7 to 1.0 LPM with constant flow pumps, and the sampled air was drawn through 15 milliliters of methyl orange solution contained in Liquid Media Samplers. After collection, the solutions were cooled and stored in the dark until analyzed according to NIOSH Method P & CAM 209 for chlorine.

Potentially high exposure areas in certain buildings (and the control room) were monitored for periods ranging from 15 minutes to over 12 hours with a Mast Oxidant Monitor and strip chart recorder. The monitor was field calibrated (3 calibration points) every other day using a Mast Dynamic Calibrator and a Metronics-certified, extended-life permeation tube (30°C). The monitor responds to both chlorine and chlorine dioxide, but preliminary laboratory research by NCASI and other researchers (personal communications) indicate chlorine dioxide may be sensed at about one half its true value based on a chlorine calibration (i.e., 1.0 ppm ClO_2 reads approximately 0.5 ppm as Cl_2). If true, this equals its stoichiometrically predicted response. Unfortunately, verification of these results has not been possible because of difficulties in generating and maintaining accurate chlorine dioxide gas standards.

Air Monitoring Results

Ten personal samples encompassing four work shifts were collected to assess the Helper's exposure, mainly while he operated the chlorine dioxide generator and collected process control samples. These operations were judged to potentially result in his highest exposures. Four samples over two shifts were collected on the Utility Man while he performed various common tasks. Personal samples on the Operator were not collected due to the short, infrequent, and unscheduled periods he is out of the control room. Eleven different areas in the mill were monitored with the Mast Oxidant Monitor. Personal sample results, including a description of specific activities and areas the worker was involved with, are summarized in Table 10:1. The Mast Oxidant Monitor responses are plotted on Figures 10-5 (bleach plant) and 10-6 (chlorine dioxide building) along with certain personal sampling results, although it should be noted that some sampling periods include time spent outside the areas monitored.

The Mast monitor's response in the chlorine dioxide building is probably a result of chlorine dioxide, although the generator does produce some chlorine gas (~10%). Its response in other areas could be a result of both chlorine and chlorine dioxide, although chlorine is the predominant contaminant except around the fourth stage washer.

As Table 10-1 demonstrates, no 15-minute sampling periods exceeded the current OSHA permissable exposure limit (PEL) of 1.0 ppm ceiling for chlorine. Two samples on the Helper (Sample 1 - 0.63 ppm, 15 minutes; Sample 9 - 0.78 ppm, 15 minutes) approached the PEL, but each covered periods while the operator was starting up the generator - a process (either startup or shutdown) which can cause the building to become contaminated wth Cl_2/ClO_2 gas infiltrating from the outside

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Job Classification	Date	Sampling Time	Sample I.D.	Exposure Concentration, as ppm ClO_2 *	Activities Covered
Helper (ClO_2 Generator Operator)	10/14	12:30 - 13:46	1	0.63 †	Startup of ClO_2 Generator - 1.5 mins. transit to ClO_2 building, remainder of time starting up system and checking strength of absorber solution.
	10/14	12:50 - 13:05	2	0.19	Collection of QC samples in bleach plant - 1st floor chlorine residual, mixer samples on 4th floor and washer samples on 5th fl
	10/14	14:15 - 14:27	3	0.08 †	Collection of refiner stock sample 1st floor (1 min.); walk to vaporizer room (2 min.); collection of hypo makeup sample (2 mins.); checking ClO_2 generator (6 mins.); collecting 1st stage tower and 2nd & 3rd stage mixer samples.
	10/14	14:20 - 14:26	4	0.08	While in ClO_2 generator building only (same as Sample 3).
	10/15	10:36 - 10:55	5	0.16	Inspection of ClO_2 generator and collection and testing of QC samples - 2.5 minutes transit to building, collection and testing of #1 reactor waste liquor (=10 mins.); 15 secs. collect 1st stage mixer sample, 3 mins. transit to 4th floor, =1 minute to collect 2 mixer samples, 1.5 minutes transit to control room.
	10/16	8:50 - 9:07	6	0.27 †	QC sampling run - 1.5 mins. to ClO_2 building; 11.5 mins. in ClO_2 building collecting and testing reactor #2 waste liquor sample; 0.5 min. transit to 1st floor bleach plant, 10 sec. to collect 1st stage tower sample, 1 min. transit to 4th floor, =2 mins. to collect 2nd and 3rd stage mixer samples, 1.5 mins. transit back to control room.
	10/16	10:39 - 11:03	7	0.19 †	QC Sampling run - 1.5 mins. transit to ClO_2 building; 19 mins. to collect and test reactor gas sample and absorber sample; 0.35 mins. transit to 1st floor bleach plant, 1 min. transit to 4th floor, 0.5 min. to collect 2nd and 3rd stage mixer samples, 1 min. transit back to control room.
	10/16	12:24 - 12:43	8	0.22 †	QC sampling run - =2 mins. transit to ClO_2 building; 12 mins. to collect and test samples of #1 reactor gas and absorber liquid; 0.5 mins. transit to 1st floor bleach plant, 15 secs. to collect 1st stage tower sample; 2 mins. transit to 4th floor, =1 min. to collect 2nd and 3rd stage mixer samples, 1 min. transit back to control room.
	10/16	16:50 - 17:05	9	0.78 †	Startup of ClO_2 generator - 2 mins. transit to ClO_2 building; 3 mins. monitoring startup of generator including testing of absorber solution strength; 1 min. transit to 1st floor bleach plant; 15 sec. to collect 1st stage tower sample; 1.5 mins. transit to 4th floor; 30 secs. to collect 2nd & 3rd stage mixer samples; 1.5 mins. transit to control room.
	10/16	17:49 - 18:06	10	0.05	QC sampling run - 3 mins. transit to ClO_2 building; 6.5 mins. to collect and test sample of #1 reactor waste liquor; 0.5 mins. transit to 1st floor of bleach plant; 15 secs. to collect 1st stage mixer sample; =1 min. transit to 4th floor; 30 secs. to collect 2nd & 3rd stage mixer samples; 1 min. transit to control room; 1.5 mins. in control room; 2 mins. to collect 3 samples from washer vats (3rd and 4th stage).
Utility Man	10/15	9:02 - 9:17	11	0.20	Checked condition of ClO_2 building floor; on the 4th floor of bleach plant around stock conveyor lines; =1 min. on 5th floor near washers changing drum of pitch dispersant.
	10/15	9:25 - 13:23	12	[illegible]	Long term sample while performed various cleaning tasks in bleach plant - mostly floors 1-4.
	10/16	7:37 - 8:01	13	[illegible]	Inspection tour of 4th and 5th floors of bleach plant.
	10/16	11:08 - 11:24	14	0.18	Checked conveyor belts on 4th floor for stock spills (9 mins.); made up fresh solution of Calgon in caustic shack at vaporizer/ hypo building (=5 mins.).

* Sampling performed according to NIOSH Method P&CAM 209 (methyl orange) for which chlorine dioxide is a positive interferent. OSHA PEL for chlorine is 1.0 ppm as 15 minute ceiling; and 0.1 ppm as an 8-hour TWA for chlorine dioxide.

† Exposures while in ClO_2 building are thought to be primarily to ClO_2; exposures during remaining periods could be to a combination of both

FIGURE 10-3.

BLEACH PLANT AIR MONITORING RESULTS

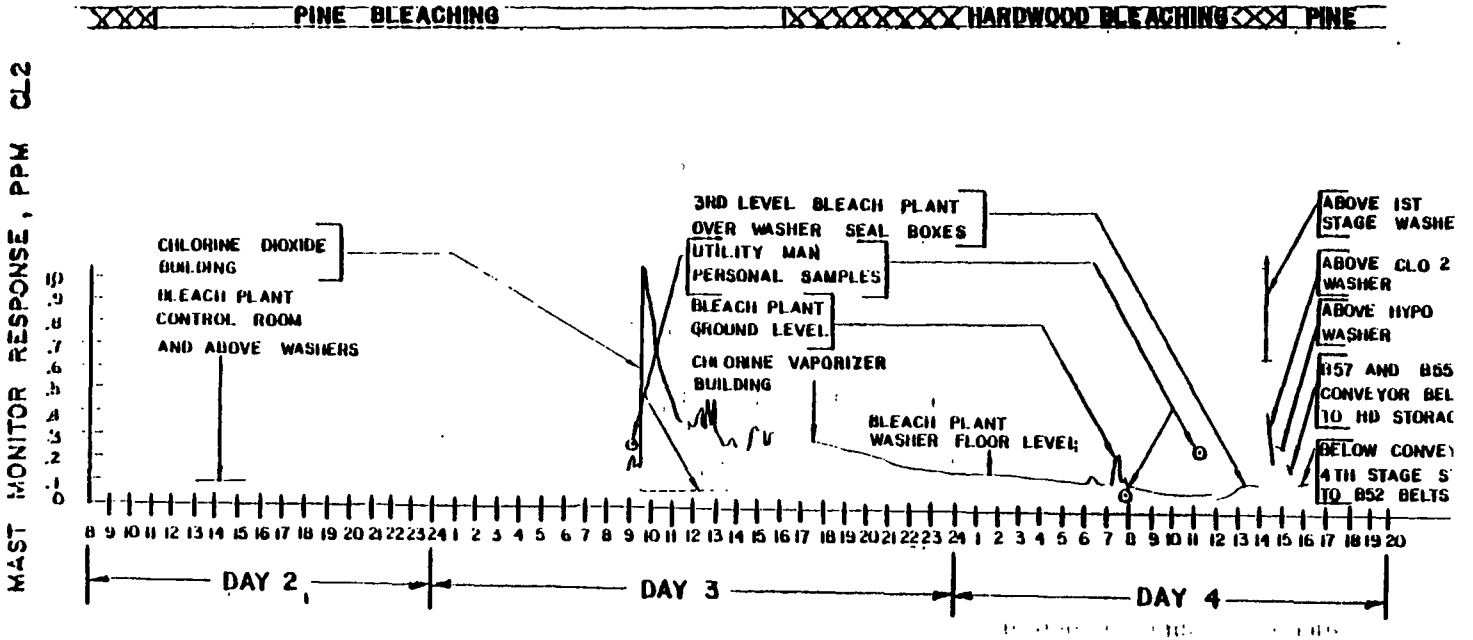

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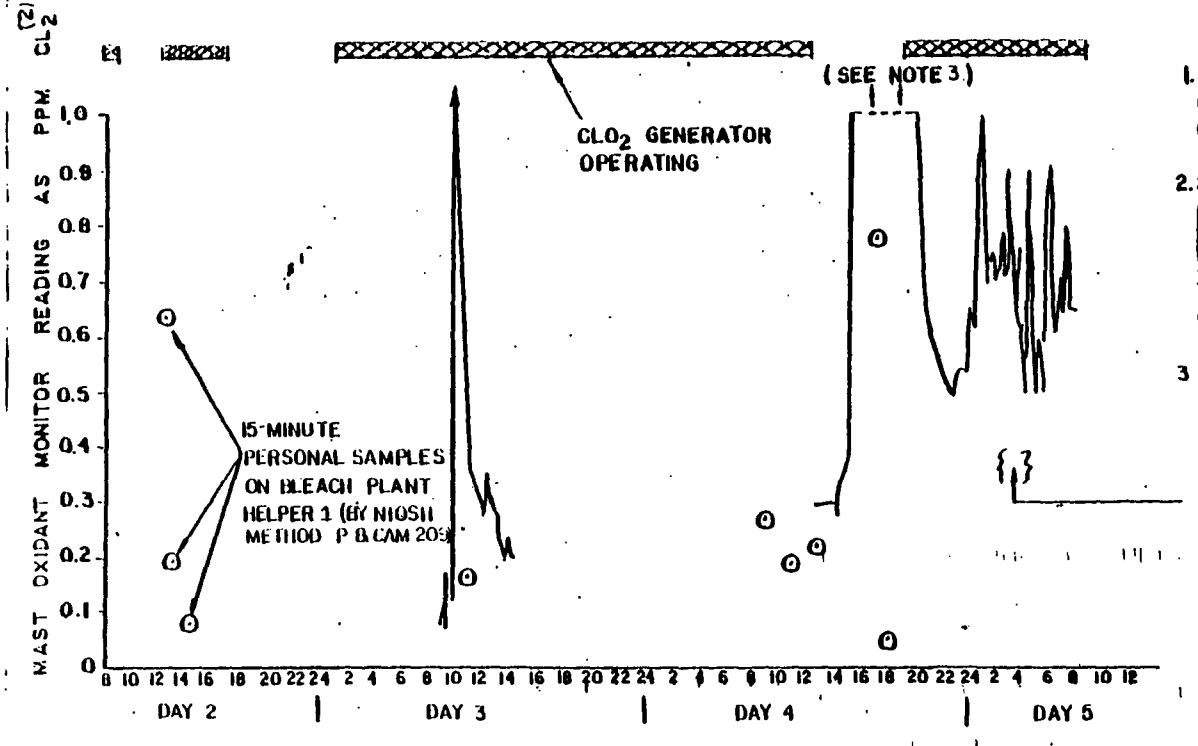
FIGURE 10-6: CHLORINE DIOXIDE BUILDING AIR MONITORING RESULTS



NOTES

1. SAMPLING PERIODS AL COVER EXPOSURES OUTS OF CLO_2 BUILDING

2. MONITOR WAS CALIBRATED FOR CHLORIN BUT AIR CONTAMINANTS ARE PROBABLY A MIXT OF CL_2 AND CLO_2

3 READING WAS OFFSCALE

PLANT OPERATOR BR SAMPLE BOTTLE ON CAUSING POSSIBLE WORKPLACE EMISSION OF CLO2

hotwell to which weak, unuseable absorber solution has been discharged when first starting the system (during sample 1, the Helper spent approximately 12.5 minutes in the building; and 7 minutes during Sample 9). Response of the Mast monitor during one such cycle of generator shutdown and startup on Day 4 indicates that air concentrations of Cl_2/ClO_2 may exceed 1.0 ppm as chlorine. However, workers rarely remain in the building for more than ten minutes during such conditions and the building eventually ventilates. Also the specific monitoring location at the QC testing bench on the operating floor cannot be assumed representative of a resulting worker exposure.

All personal sampling and area profiling in the bleach plant indicate that chlorine/chlorine dioxide levels, under normal operations, rarely exceed 0.4 ppm (as chlorine) in areas of this building typically entered by production workers. The major work areas (washer floor, 1st and 4th floors) were typically below 0.2 ppm, and the conrol room was below 0.05 ppm. The lack of a specific, interference-free personal exposure method for chlorine dioxide precludes the ability to assess extent of compliance to its OSHA PEL of 0.1 ppm as an 8-hour TWA.

Table 10:2 summarizes the job tasks typically performed by each of the three (3) bleach plant workers complete with the estimated frequency and duration of each task and an analysis of the contaminant(s) they are likely exposed to during these periods. Emission sources, their significance, and manner of control are then summarized in Table 10:3 of the following section.

CONTROL TECHNOLOGY

Potential Exposure Hazards - As implied from Table 10:2, during the normal operation of the bleach process, any of the three production workers may be exposed to chemical air contaminants. Two major airborne contaminants are potentially emitted from the process - 1) gaseous chlorine during: preparation of an aqueous solution from liquid chlorine, the 1st stage of bleaching; preparation of sodium hypochlorite bleach liquor; or the 3rd stage of bleaching from the hypo solution; or 2) chlorine dioxide gas during its generation by the Solvay process or from its use as an aqueous solution for the final stage of pulp bleaching.

Sodium hydroxide is used as an aqueous solution and prepared by automatically diluting purchased 50% caustic. It is then metered into either low consistency pulp stock for the 2nd and 3rd stage of bleaching, or an aqueous solution of chlorine for preparation of the sodium hypochlorite bleach liquor. Other process chemicals - sulfuric acid, sodium chlorate, methanol,

TABLE 10:2 - SUMMARY OF NORMAL WORK TASKS FOR BLEACH PLANT PRODUCTION WORKERS

	Task	Frequency	Estimated Duration	Assumed Potentially Exposed To	Comments
Cont:	• In Control Room	Daily	Est. >85% of shift	None-monitoring indicates <0.05 ppm Cl_2/ClO_2	
	• Servicing or operating washers	Daily but unscheduled	Rarely >15 mins.	Cl_2 and/or ClO_2	During upsets may have to be on washer floor for up to 15 mins.
	• Miscellaneous process inspections or investigations	Daily but mostly during upset	Normally <5 mins.	Cl_2 and/or ClO_2 - levels dependent on area and type of upset	Likely will occur less often with new computer control system.
Mr	• In Control Room	Daily	Est. 70% of shift	None-monitoring indicates <0.05 ppm Cl_2/ClO_2	- - - - - - - - - - - - - -
	• Normal, scheduled QC inspection, sampling, and testing of ClO_2 generator:	Daily	Normally <20 mins./ (total) run	ClO_2(and Cl_2 in much lower concn.k pecmential for sulfuric acid, methanol and chlorate	When operating properly, significant exposures occur only during sample collections (and testing).
	Sampling spent liquor	Each reactor twice/ shift	<20 seconds/ sampling	ClO_2 (and pot. Cl_2): sulfuric acid	Liquor has little ClO_2 present when working properly; tests for acidity and chlorate.
	Sampling absorber solution	Every other hour	<20 seconds/ sampling	ClO_2(and Cl_2 in much lower conc.)	Tests only for ClO_2 strength.
	Sampling reactor(s) gas	Reactor 1: twice/ shift Reactor 2: once/ shift	=3-5 minutes/ sampling	" " " " "	Draws gas sample down to gas bench with aspirator vacuum and into absorption solution through hoses connected to reactor taps.
	Analysis of samples	Once/hour	Est. 5-10 mins./run	ClO_2 and Cl_2 ; HCl (for reagent)	Potential for exposure difficult to assess.
	Inspection of equipment and recording data	Once/hour	Est. 2-5 mins./run	ClO_2 and Cl_2	Inspects air blower and chemical metering pump
	• Normal, scheduled collection of QC samples from washer vats, mixers and 1st stage tower	4 times/shift	45 minutes/ sampling	Cl_2 and ClO_2	1st stage before tower and 2nd and 3rd stage mixer samples collected during ClO_2 QC test.
	1st stage before tower	4 times/shift	<20 seconds	Cl_2	Involves 1 while opening valve to collect stock sample containing high conc. of chlorine.
	3rd & 4th stage washers	4 times/shift	<1 minute	Cl_2 and ClO_2	Stock at these stages contains some variable residual of hypo and ClO_2.
	2nd & 3rd stage mixers	4 times/shift	<1 minute	Cl_2 - low levels	Collects stock sample from within mixer through observation port.
	• Startup and shutdown of chlorine dioxide generator (manual operation)	Max. of twice/ day	Est. <15 minutes for startup; shutdown is usually automatic	ClO_2(and Cl_2 in lower conc.)	Startup can result in significant exposure from manner of mixing weak base solution.
	• Regular QC sampling and testing of caustic dilution and hypo makeup systems	Twice/shift	Sampling <2 mins. total/run	Cl_2 and caustic	Chlorine exposure is not likely since hypo solution is very alkaline; caustic is only 3-6% strength.
	• Servicing washers (cleaning, adjusting flows, etc.)	Daily	Rarely >15 mins.	Cl_2 and ClO_2	Only upsets (stock overflows) require operator service times approaching 15 min. periods - usually serviced by Operator.
	• Scheduled equipment inspection tours (ClO_2 generator, bleach building, and vaporizer/ hypo makeup)	Limited inspection each hour	- - - - - -	Cl_2 and ClO_2	Inspections are usually performed concurrently with collection of QC samples.

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TABLE 10:2 CONTINUED

	Task	Frequency	Estimated Duration	Agents Potentially Exposed To	Comments
Helper	o Miscellaneous bleach building tasks	Unpredictable, very low frequency	Typically <5 mins.	Cl_2 and ClO_2	Tasks include special errands and unscheduled equipment inspections.
Utility Man: (Day Shift Only)					
	o In Control Room	Daily	1-1.5 hours/shift	None	- - - - - - - - - - - - - -
	o Cleanup of stock spills on 3rd, 4th, and 5th floors	Daily - unscheduled	30 mins. to 2 hours	Cl_2 and/or ClO_2	Most cleanup time is spent on stock spills below various conveyor belt lines — up to 2 hours for tank overflows; exposure is likely more to ClO_2.
	o Regular washdown of all floors (1st - 5th)	Daily	≈1 hour	Cl_2 and ClO_2	- - - - - - - - - - - - - -
	o Sweeping control room floor and emptying trash	Daily	20-30 minutes	Cl_2 and ClO_2	Exposure is not likely.
	o Changing pitch dispersant drum on 5th floor	Daily - 1 drum/shift	≈30 minutes	Cl_2 and ClO_2	Brings new 55-gallon drum from basement to 5th floor, connects up, and removes old drum.
	o Prepares Calgon water softener for addition to refiners on 4th floor	Daily	10-15 minutes	Cl_2 and ClO_2	Work is done on 4th floor.
	o Preparing H_2SO_4 solution for addition to 4th stage on 4th floor	3 times/day	≈15 minutes/preparation	Cl_2 and ClO_2 , H_2SO_4	Adds 3 carboys/day of 66° Baumé H_2SO_4 to 4th stage, removes empty to 1st floor, and brings up new carboys.
	o Preparation of Calgon solution in caustic shack	Once/day	≈5 minutes	Cl_2	Task is performed in caustic dilution section of vaporizer building and thus under normal operations is isolated from chlorine exposure.
	o Hookup and unloading chlorate railroad cars	One car/6 weeks	≈7 hours/car (total for unloading)	ClO_2 (while in generator area)	Is performed outside by dissolving crystals with water in car; enters ClO_2 building only to activate/shutoff pumps; also performs other normal tasks during operation.

and pitch dispersant - are used as aqueous solutions; automatically metered into closed systems; and do not normally come into contact with the workers or pose a potential airborne exposure hazard. The physical agents - noise and heat stress - were not judged to be significant exposure hazards anywhere in the bleach plant as sound levels and temperatures were judged to be low and workers spend little time within any one area or at any particular task.

Potential Emission Sources (See Table 10:3).

During the normal operation of the bleach plant, only two potential continuous workplace emission sources exist for release of chlorine and/or chlorine dioxide gas in the otherwise primarily closed process:

1. the open top of the 1st, 3rd, and 4th stage washers;

2. the belt conveyor lines for transporting final bleached stock to high density storage tanks.

Both of these emission sources depend on a number of process conditions and systems which will be discussed under process controls. Production worker exposure to these emission sources is effectively controlled by both provided local ventilation in the case of the washers, and normal worker isolation or infrequent need to work nearby to these sources. The only other non-upset (or non-typical process conditions) exposures observed are those resulting to the Helper from his collection of various process quality control samples in both the bleach plant and the chlorine dioxide generator facility - principally collection of the concentrated chlorine dioxide absorber solution, waste liquor sample, 1st stage chlorination tower stock sample, hypo mixer residual, and the 1st, 3rd, and 4th stage stock samples from the washer vats. These exposures are characterized as regularly occurring, short-lived, but potentially very acute and highly variable depending on work practices and design of sampling ports or lines. Finally under the general classification of upset-related and/or infrequent emission sources and potential exposures would be included an assortment of theorized events, accidents, and process leaks - none of which readily avail themselves to any quantitative or failure mode analysis. Their occurrence, duration, and severity are dependent on: type of equipment, their age, and upkeep; complexity of the bleaching process; complexity, type, accuracy, and upkeep of process monitoring equipment; and the general layout, venting and interconnection of equipment and unit operations. The most often cited examples of such infrequent exposure sources are stock spills at the washers or from the conveyor belt system, and startup of the chlorine dioxide generator (i.e. the previously mentioned infiltration of ClO_2 gas to the building from wasted weak absorber

TABLE 10:3 - SUMMARY OF POTENTIAL BLEACH PROCESS EMISSION SOURCES AND ASSOCIATED CONTROLS

LOCATION	POTENTIAL EMISSION SOURCE	NATURE OF EXPOSURE HAZARD	ASSOCIATED CONTROL TECHNOLOGY		
			CHARACTERISTICS OF PROCESS OR EQUIPMENT	ENGINEERED	WORK PRACTICES OR WORKER PROTECTIVE
Bleach and	1. 1st, 3rd, and 4th stage washers	Continuous, 1st stage is most significant due to large amount of chlorine used (see discussion of emission sources)	o Addition of bleach chemicals is automatic and residuals are continuously or regularly monitored o Bleached stock is diluted with wash water o Wash filtrate containing most of the residual bleaching agents is rapidly removed to the seal boxes below o Amount of bleaching agents added is dependent on unbleached stock qualities and desired brightness and strength	o All washers are housed and ventilated o Washers are of vacuum type o Washers are readily visible from control room to detect any upsets o Additional air is supplied to the washer floor thru an overhead system	o Workers normally spend their time in the seal-by two room o Self-face piece filtering respira and self-contains breathing apparat are readily avail in the control ro o Collection of required process control samples from the washer v takes less than 3 minutes typically
	2. 1st, 3rd, and 4th stage washer seal boxes	Continuous emission through overhead vents and loose fitting manhole covers; 1st stage box is likely most significant	o Same as above	o With long dropleg boxes are located on 3rd floor and isolated from the more worker frequented 4th and 5th floors	- - - - - - - - -
	3. Bleached stock open conveyor system from 4th stage washer to high density storage tanks	Continuous potential emission of mainly chlorine dioxide from treatment at final stage	o Careful monitoring and control of the 4th stage bleaching process is designed to minimize the amount of residual chlorine dioxide left in the stock o Stock washing and thickening at the 4th stage washer removes most residual ClO2 o Chlorine dioxide is inherently unstable and decomposes rapidly under certain conditions	o Conveyor system is designed to be operator unattended o Conveyor belts largely run through narrow passageways in the upper levels of the southern wing of the bleach building which contains only the large stock storage tanks	o Workers are requi to enter these passageways only inspect conveyors and cleanup stock spills-exposure periods vary wide o Respirators are available for use but rarely used.
	4. Collection of 1st stage tower, 2nd and 3rd stage mixer, and 1st, 3rd and 4th stage washer stock samples	Variable, short-duration exposures to ClO2 and Cl2 at regular time intervals; collection of 1st stage tower sample is most significant	o Exposures are likely higher if too much bleaching agent has been added in any stage	o Sampling ports are provided on the two (2) mixers o Sampling line at the bottom of the 1st stage tower is provided with a floor drain below it	o All sampling is manually performe o Total required ti to collect all samples is typic <5 minutes. o Suitable respira are readily avail but not commonly used

LOCATION	POTENTIAL EMISSION SOURCE	NATURE OF EXPOSED HAZARD	ASSOCIATED CONTROL TECHNOLOGY		
			CHARACTERISTICS OF PROCESS OR EQUIPMENT	ENGINEERED	WORK PRACTICES OR WORKER PROTECTIVE
	1. Miscellaneous process leaks and vents — bleaching agent piping seals & gaskets, mixer seals, tower vents, sewer spills, etc.	Unscheduled, upset-related, potentially very acute exposures of low frequency and probability	• Process is basically enclosed and leaks can result in significant process inefficiencies	• Good maintenance of equipment and process monitoring and control systems reduces likelihood of significant upsets • Entire bleach system is largely enclosed • Entire bleach system is largely surrounded • Tanks are all vented to atmosphere	• An assortment of effective respirators is available for use when required • Frequent equipment inspection tours are made by shift foremen and operators • Spent spills are usually cleaned by wet hosing as convenient • Both the Operator and his Assistant are both fully knowledgeable about process equipment and control systems with a shift foreman available for further assistance
erizer/Hypo oup Build-	1. Liquid chlorine tank car unloading system	Miscellaneous Leaks-occur infrequently	• Small amounts of moisture entering the system create very corrosive conditions • All equipment is outside and operates un-attended	• Tank cars are padded with dry air to facilitate chlorine flow • Warning alarm systems exist for low padding air pressure, empty tank car, and high ex-pansion chamber pressure	• Chlorine leaks are investigated using an aqua ammonia spray • Suitable respirators are available for → • Tank car hookups and disconnection is supervised by the Operator
	2. Vaporizers and transport piping leaks	High hazard, very rare occurrence	• System must be well maintained and tightly sealed • Vaporizer operate automatically; temperature regulated by controlling steam flow	• Equipment is corrosion resistant-lined • Alarms exist for high vaporizer temperature, and high chlorine gas in vaporizer facility • Vaporizer/hypo makeup room has two exhaust fans and is isolated from rest of mill. Fans operate from outside building	• Vaporizers, ; & and valves are regularly inspected and cleaned • Suitable respirators are available for →

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LOCATION	POTENTIAL EMISSION SOURCE	NATURE OF EXPOSED HAZARD	ASSOCIATED CONTROL TECHNOLOGY		
			CHARACTERISTICS OF PROCESS OR EQUIPMENT	ENGINEERED	WORK PRACTICES OR WORKER PROTECTIVE
	3. Hypo makeup system	Chlorine gas leaks	• System is totally closed and operates automatically from control center • All tanks, piping, and pumps are corrosion-resistant (fiberglass) • Chlorine reacts with strong alkaline solution reducing likelihood of chlorine evaluation	• High pressure chlorine gas, hypo makeup tank and surge tank all vent to 4% caustic storage tank which has a caustic vent scrubber with a sensor and alarm for high chlorine gas. Vent duct goes to roof of building • Hypo makeup system is equipped with one way valves for all liquid flows	• Respirators avail
Chlorine Dioxide Generator Facility	1. Collection and casing of quality control sample-generator gas, absorber, and spent liquor	Short-lived, variable exposure to ClO_2/Cl_2 at scheduled times-most significant exposure results from absorber sample	• Testing must be performed periodically to insure proper functioning	• Sampling tubing is provided from top of generator to test bench for collection of generator gas sample • Floor drain is provided for collection of waste liquor sample; sampling line and cup sink & drain for absorber sample	• Respirators are available, but no regularly used • Length of exposure varies depending on worker's techn for obtaining representative sa
	2. Generator leaks and safety relief valves	Infrequent; potential exposure to ClO_2 and Cl_2	• System is totally closed, generated ClO_2 is purged with air, absorbed in water absorption unit located outside building, and stored in outside storage tanks • System can be separated from control center	• Safety relief valves on top of reactors are headed and ventilated to roof • Piping and valves are corrosion-resistant, Saran-lined • Reactors are insulated in separate room with floor drains provided	• Equipment is regularly inspected by operator and foreman • Respirators are available for eme

LOCATION	POTENTIAL EMISSION SOURCE	NATURE OF EXPOSURE HAZARD	ASSOCIATED CONTROL TECHNOLOGY		
			CHARACTERISTICS OF PROCESS OR EQUIPMENT	ENGINEERED	WORK PRACTICES OR WORKER PROTECTIVE
	3. Wasted liquor and absorber solution drains	Potentially excessive exposures during startups due to ClO_2/Cl_2 gas from wasted absorber solution entering building from nearby outside hotwell	o Recommended operating procedure is to waste weak absorber solution obtained initially on start-up (or shutdown) o Attempts to use waste liquor for tall oil treatment or salt cake makeup were unsuccessful, necessitating the need to sewer o Solvay process is inherently relatively simple to startup and shutdown	o Disposal is to sewers outside building, but gas evolution possible if sewer lines not kept well flushed	o To eliminate infiltration problem, operator at times does not waste initial weak absorber solution o Respirators available during these periods, but were not observed being used
	4. Absorber vent	Potential continuous exposure to ClO_2/Cl_2 at very low level from infiltration of vent gas to building; higher level if absorber is inefficient or overloaded	o Generator can not be started unless chilled water is flowing to absorber o Efficiency of absorber normally precludes venting of significant quantities of ClO_2/Cl_2	o Absorber is located outside and vent is at top	

solution). The protection of the worker during the occurrence of such events is achieved by use of suitable respiratory and other protective equipment during the investigation and subsequent correction of problems, and careful direction of the worker activities when required. However, the best method of control for such events is, of course, to reduce their numbers and/or severity by diligent attention to performance of preventative maintenance, regular equipment inspections, housekeeping, and the accurate calibration and maintenance of process monitoring and control systems.

CONTROL TECHNOLOGY

Control of worker exposures to chlorine and chlorine dioxide gas in this sophisticated bleach plant (which is operated under varying and highly challenging pulp bleaching requirements) is accomplished by the combined application and knowledgeable use of a number of control measures:

- Process monitoring and control systems - for sensitive, accurate, and safe preparation and addition of desired and required amounts and strengths of bleaching agents and maintenance of required process conditions (temperature, pH, retention times, water flows, etc.).

- Ventilation - hooded, local ventilation over the vacuum washers and chlorine dioxide generator top; dilution ventilation of the vaporizer/hypo makeup facility; and general active and passive ventilation of the control center and other areas of the bleach plant.

- Inherent worker and process isolation - the process is almost entirely closed, runs largely unattended, and workers thus spend significant periods of time within the isolated control center.

- Good work practices and housekeeping - timely attention to cleanup of stock or chemical spills and application of good work techniques in sampling process lines or investigating process conditions.

- Personal protective equipment - an assortment of respirators to meet the conditions are available throughout the mill; possession of an air purifying respirator at all times is a requirement throughout the bleach plant.

- Chlorine system upset prevention - a number of engineered safety and ventilation features are provided in the chlorine vaporizer and hypo makeup facility.

Table 10:3 summarizes the various potential emission sources in the mill and the available controls to reduce their occurrence or worker exposure. Each of these control systems will be further discussed.

Process Monitoring and Control Systems - The ability to accurately determine and regulate the progress of the desired pulp bleaching process is judged the most critical element in achieving well controlled workplace conditions in this mill. Efficient, high brightness stage bleaching of difficult-to-moderate-to-bleach pulps as are encountered in this mill is basically based on the conduction of a series of complex chemical reactions carried out under controlled conditions on a dynamically flowing stream of varying pulp. Each of the three bleaching agents (chlorine, hypochlorite, and chlorine dioxide) are added, mixed, and allowed to react with the pulp under specific, controlled conditions and periods of time. Each has specific actions on colored impurities in the wood - chlorine chlorinates the lignin impurities; hypochlorite penetrates and oxidizes to non-colored forms other wood impurities; and chlorine dioxide offers additional selective bleaching of remaining impurities with minimal attack on the fiber cellulose, and provides a small final stock residual to prevent yellowing during storage. Failure to achieve the required increases in brightness in one stage necessitates either rebleaching, wasting, or modifications to the succeeding stages, if possible, - any of which result in significant increased costs and, many times, a reduction in the desired final pulp qualities (namely, strength). Further requirements or challenges placed on this particular bleach plant results from the fact that the pulp mill produces continuous Kraft hard and soft (pine) wood pulp, and the paper mill requires high to very high brightness furnish. A wide range of dynamic conditions and variables must be first attained and then maintained within certain limits for successful bleaching under these conditions. Of these the most significant in terms of potentially affecting bleach plant workplace conditions are thought to be, in descending order:

- 1st stage chlorine dosage (and residual) - a function of mainly incoming pulp bleach requirement (as measured by the K number) and dry weight per unit volume.
- 4th stage chlorine dioxide dosage - a function of primarily required brightness increase from 3rd stage to final target (and stock flow)
- hypochlorite dosage (and residual) - a function mainly of initial pulp K number and effectiveness of 1st stage chlorination.

Effectiveness or variability of brown stock washing, and bleaching temperatures, pH, and retention times are all other important factors effecting the control of bleaching operations but to a lesser extent.

Over-bleaching, defined for our purposes as the excess addition of bleaching agents and resulting high washer residuals, in the 1st and/or 4th stages is the principal action leading to potentially poorly controlled workplace conditions. Because hypochlorite is used in the 2nd and 3rd stages as a strong alkaline solution and added to an alkaline pulp, evolution of gaseous chlorine is thought to be inherently restrictive even though strong solutions are used at high temperatures. Both the 1st (pH 3-4) and 4th (pH 4-5) stages are carried out under acidic conditions which may enhance the evolution of gases. Over-addition of chlorine dioxide is of less significance than chlorine due to its potent reaction potential, long tower retention times, and its natural tendency to decompose quickly. Chlorine has little solubility in water at high temperatures and low pH. In any case, over-additions of bleaching agents result in increased potential of emission of chlorine and/or chlorine dioxide to the workplace primarily from the washers, seal boxes, or the stock conveyor belt system after the final stage. The frequency, duration, and magnitude of such over-bleaching events could not be assessed with the available process monitors and survey time.

At the time of the mill survey, the bleach system was in the process of being debugged for near total computer control - bleaching agents addition; pH, temperature, and flow controlled. Although being largely manually (or semi-manually) controlled during periods of data collection and process observations, the forthcoming further process automations appear to be significant demonstration of even more effective control technology for such a complex and challenged bleach plant. Automated control of this system will be based upon optimized operation of the 1st stage of bleaching (on the full tower basis) by regulated feed of chlorine gas depending on continuously monitored tower residual (by color measurement), stock flow (dry weight/unit time), and inputted brown stock Kappa (permanganate) numbers.

It is projected that this operation will have the following beneficial results: 1) reduce the frequency and duration of 1st, 3rd, and 4th stage over-bleaching events; 2) reduce the consumption of chlorine, hypo, and chlorine dioxide, hence reducing the time and rate at which these generating systems operate; 3) facilitate research on how to further fine-tune or improve the bleaching process; 4) free production workers' time to devote more to equipment inspections and service, housekeeping, and additional process quality control work; 5) reduce the likelihood of major human errors; and 6) indirectly reduce stock spills and leaks.

Figure 10-5 attempts to put the obtained workplace monitoring data into perspective with the unique, mutually dependent process conditions, events, and variables of this mill - namely, type of wood, K number, stock flow (lbs. dry/min.), chlorine and hypo flows, chlorine and hypo residuals, and stock brightness. In short, the approximatly seventy-two (72) hour period available during the mill survey for sampling provided insufficient time to develop sufficient meaningful data to attempt to correlate process conditions and variables to workplace emission sources much less personal exposure dosages. However, similar displays of data (process and workplace) may be of value to other mills experiencing problems in identifying, locating, characterizing, prioritizing, and controlling exposure sources. Although not available for this mill, the most enlightening parameter for assessment of washer/seal box emissions would be actual washer and/or seal box inlet residuals for all stages. However, the following observations and conclusions are warranted for this data and the mill operation: (See Figure 10-5)

1. Generally, for equal flows of either type of wood, pine requires more bleaching agents (i.e. pine has higher K numbers).

2. Changes in one stage of the process, of course, have delayed effects downstream and staggered effects on succeeding stages.

3. The second day change from hardwood to pine results in a gradual increase in K numbers and a concurrent initial reduction of dry stock throughput. Chlorine gas feed is then slowly increased; with hypo addition essentially remaining constant or slightly decreased, and chlorine dioxide flow (not plotted) slowly increasing (both on a staggered basis).

4. Pulp 3rd and final stage brightness levels parallel each other with final values meeting targets - indicating overall proper operation of bleaching.

5. Hypo mixer residuals correspond with hypo addition rates, but 1st stage chlorine residuals (10 minutes contact) appear not to correlate with chlorine feeds.

6. The third day change to hardwood was accompanied by gradual decrease in K numbers and chlorine, hypo, and chlorine dioxide flows; and increases in dry stock throughput.

7. The fourth day change back to pine results in staggered increases in bleaching agent flows for corresponding increased K numbers with reduced dry stock throughput.

8. A ten (10) hour monitoring period for Cl_2/ClO_2 in the center of the washer room indicated essentially constant, low airborne levels (0.15 ppm) of bleach contaminants during bleaching of hardwood.

9. Similar results were obtained for an immediately succeeding five hour period at a location on the ground floor of the bleach plant near the 1st stage tower. A small response peak from 7 to 8 A.M. (0.16 ppm) was thought to be caused by either collection of the nearby 1st stage chlorine residual sample from the bottom of the tower, or contaminated outside air entering the building through a large wall opening behind the small 1st stage retention tank. (This opening was temporary for construction work and is now reported closed).

10. A series of fifteen minute monitoring periods at locations just above the 1st, 3rd and 4th stage washers on the fourth day as the system was just being changed to handle pine again indicated levels above those previously obtained in the center of the washer room. In contrast, spot readings (with the Mast Monitor) taken from 15:10 to 15:20 on the second day at similar points during pine bleaching were all approximately 0.05 ppm. (The readings on the fourth day above the ClO_2 and hypo washers may have been affected by the high levels which just had been measured at the 1st stage washer due to the monitor's low air sampling rate and slow response.) These results indicate that during initial changeover to pine bleaching, 1st stage over-chlorination may occur with, perhaps, concurrent inability of the hood exhaust system to fully capture and remove evolved chlorine gas at the washer. Less significant events of overloading the washer ventilation systems are projected for the probably less-frequently-occurring events of mid-period hardwood to pine over-chlorination or 3rd and 4th stage over-bleaching. Further long-term air monitoring and process data would be required to fully support this contention.

11. The low response of the air monitor (0.05-0.15 ppm as Cl_2) and short monitoring period in two locations near the belt conveyor system transporting final bleached stock to high density storage does not provide conclusive data as to this emission source or exposure hazard. The slight positive response, worker complaints of occasional bad odors, and the desire to maintain a small residual in the bleached stock during high density storage support a contention of potential gas (mainly ClO_2) evolution. Insufficient data is available to judge the variability of this emission or its dependence on 4th stage process control.

The generation rates and storage capacities of the three (3) bleaching agent preparation systems (gaseous chlorine, sodium hypochlorite, and chlorine dioxide solution) are such that the bleaching process is not restricted by their operation. Similarly, the rate of bleaching does not necessitate these systems to operate above rated capacity. Each, however, is a relatively new system.

Hypochlorite production is initiated and regulated based on the continuously monitored storage tank level. As mentioned, once activated, the system runs automatically with only periodic inspections and quality control sampling and testing required. Vaporizers usually run continuously.

Process control and safety features of the vaporizer and hypo makeup systems and building include: 1) the aforementioned tank venting, caustic scrubber, and air monitor/alarm system on the hypo makeup process; 2) standard liquid chlorine line expansion chambers (insulated) vented (along with high vaporizer gas pressure relief lines) to the 6% caustic storage tank bottom; 3) a padding air dryer system on the chlorine tank car consisting of dryer pre-filter with auto drain, Duplex regenerative dryer, dryer after filter and supplementary calcium chloride dryer; 4) one way flow valves on the padding air supply and a differential pressure and alarm system to prevent chlorine backflow; 5) vaporizer output rate control based on regulation of the applied steam pressure, and monitored by the exit gas temperature with a low temperature alarm; 6) pressure regulating valves on the chlorine gas lines with low pressure alarms; 7) high/low sensors and alarms on the 6% caustic storage and hypo surge tanks; 8) an International Sensor Technology Model 3500-7 chlorine gas room air sensor ((0-50 ppm range) alarm, calibration, and operation of sensor was not available); and 9) remote operation of both systems.

Although basically a packaged system, the following are unique features and characteristics of the particular chlorine dioxide system and its installation at this mill.

- Process piping is arranged so that only one or both reactors can be used. This allows for isolating either one for maintenance without interrupting or halting production in the other, albeit, at reduced efficiency and purity of product.

- The reactors and the two storage tanks are sized so that chlorine dioxide production and demand rates are easily balanced. Production rate can easily be expanded by increasing the reactant chemical flows with corresponding purge air and absorption water increases, but with, perhaps, a slight decrease in effectiveness of chlorine dioxide gas absorption. Such capacity flexibility allows the generator to be shutdown for periods up to 6 to ten hours or more -

greatly facilitating the performance of any maintenance or repairs.

- Although, perhaps, not the least costly method for production of chlorine dioxide, the Solvay process is relatively simple to operate and control, and easily automated. If other uses can be made of the acidic waste liquor, costs are usually very competitive.

- With the exception of unloading reactant chemicals and collecting and testing process quality control samples, the process can be largely remotely controlled and monitored from the bleach plant control center. Generally, however, startups (either with reactors still full with liquor or empty) are performed manually in order to insure proper flows and quality of product. The ability to so automate and control the process allows or facilitates:

  1. Locating the system remote from the bleach plant, thereby isolating workers from potential continuous or more importantly upset-related exposures.

  2. Retrofitting the process to existing bleaching facilities requiring additional stages or increased capacity. This can be done apparently with little increase in production staff needs or demands.

  3. Further isolating, containing or ventilating potentially dangerous solutions or significant exposure sources during a process upset - i.e. locating the absorption tower vent outside the building, spill containment curbs around reactant and product storage tanks, and isolating the two reactors in a separate room with a ventilation hood over their tops.

- The process can be easily started up (or shutdown) by merely operating the five (5) channel chemical feed pump after initiating the flow of air to the reactors and chilled water to the tower. The generator is normally shut down for short periods of time with both reactors kept fully filled. Startup then merely involves first starting the desired flow of purging air to both reactors followed by activating the chemical metering pump. Once chlorine dioxide in the absorption water reaches useable strength, flow can then be directed into one of the two storage tanks. However, until this occurs, the weak solution is wasted to the hotwell, and for this particular installation can represent a worker exposure source, as previously discussed.

- This type of generating system apparently requires very little routine maintenance as a result of its inherent design and operation. However, further details of historically-required and preventative maintenance were not discussed or investigated.

- The inability of the pulp mill to use the acidic waste liquor requires that it be disposed of. This is currently done by sewering it without specific and segregated pre-neuralization (other than water dilution) of the acid or residual chlorine and chlorine dioxide. Depending on location, configuration, and flows into the sewer junction, this procedure can constitute an emission source of gaseous chlorine dioxide and chlorine which could be reentrained into workplaces. The plant engineering staff is currently investigating ways to prevent escape of chlorine dioxide gas from the hotwell during wasting of either weak absorber solution or the acidic generator waste liquor. It should be noted, however, that excess chlorine dioxide in both of these streams is of some benefit in that it oxidizes sulfides present in other pulp mill effluents. This then reduces odor in the municipal wastewater collection and treatment system.

Important control and safety features of the ClO_2 generator include: 1) a single shaft, variable drive chemical metering motor with individual piston-type pump channels and graduated separatory-funnel calibration tubes for each of the five reactant feeds to the generator: 2) interlock of the chemical pump motor starter to the reactor #1 and #2 air line differential pressure switches, and the chilled water to absorber flow sensor circuit; 3) high and low gas temperature alarms (and recorder) on the exiting gas of both reactors; 4) liquor temperature sensors, recorders, and high and low alarms on both reactors; 5) air flow recorders and high/low air flow alarms on each reactor's purge air line; 6) storage tank venting to the absorber, and liquid overflow (or flushing water) to the sewer system; 7) a waste liquor stripper (explosion sealed); air purged and vented to the absorber (for both of the reactor waste liquors); 8) dual ClO_2 liquor transfer pumps; and 9) flow and temperature recorders and alarms on the chilled water to the absorber line.

Personal Protective Equipment and Work Practices: Mill 10 has available approved half-face piece filtering (cartridge) respirators for personal use in the bleach plant; and self-contained breathing apparatus (Scott Air Packs) and two supplied air line respirators (one portable) for emergency escape or repair uses. An excellent formal written respiratory protection plan (see Appendix) is established covering the

major items of: program purpose, definitions, hazards, types of respirators available, selection for use criteria, color coding, a guide for selection, training and education, and maintenance and care. Formal presentation and training in this program is provided to each new employee required or potentially required to use a respirator, and repeated semi-annually thereafter. Interviews with the bleach plant production workers indicated a good understanding of this program and the effective use of respirators.

All people required to work in the bleach plant or entering any of the buildings must possess an air purifying or equivalent respirator. Workers are not required to wear respirators, however, for any specific tasks or in any certain areas.

New supplies of personal respirators are readily available in the control center, the mill safety office, and in a number of cabinets throughout the bleach plant and pulp mill.

In addition, the elevator has a four manifold, air line respirator supplied by compressed air cylinders; and the control room has two SCBA for operators during an emergency. Two other SCBA units with full-face masks and compressed air cylinders are also within the bleach plant complex. One is in the chlorine vaporizer building; and the other is mounted on a gas cylinder truck for portability to any required location. For the latter, the manifold is constructed with quick connectors so that an employee can enter/leave a contaminated area with his face mask on and connected to an 8 minute air bottle carried on his person. Thereafter, he can then quickly connect to the truck's tanks for a long-term supply of clean air.

Overall, Mill 10's respiratory protection program was judged to be very effective, clearly defined, well-maintained and administered, and strictly adhered to. Use of other personal protective equipment for chemical hazards by production workers was not observed.

Specific work practices implemented to control or reduce chemical exposures were similarly not observed. Discussion with some production workers, however, did not reveal a recognition and awareness on their part of the importance of not remaining too long in confined areas (even with respirators) where chlorine/chlorine dioxide gas may periodically accumulate as a result of: stock spills, process upsets, collection of QC samples, equipment startups/shutdowns, open stock conveyor belts, near drum washers, at the ClO_2 absorber sampling line, or at the ClO_2 generator hotwell. Diligent attention to prompt cleanup of stock spills (using a water hose to dilute and then wash down the spill), and excellent attention to good general housekeeping measures were also observed. Such tasks typically occupy a large part of the Utility Man's work shift.

Ventilation

Local and general ventilation are important controls in this bleach mill, especially during cold weather when most buildings must be tightly closed. Hoods and local ventilation are used for each of the four vacuum washers, and for the chlorine dioxide reactors. General ventilation is provided for the small vaporizer/hypo makeup room, and for the upper floors of the bleach building. Tempered makeup air is supplied to the ceiling of the fifth floor of the washer room, and the ceiling of the vaporizer/hypo makeup room. The fifth floor control center has its own separate HVAC system with fresh air coming from an intake on the building's north wall. Additional air for cooling purposes is supplied to electrical/transformer rooms on the second and fourth floors of the bleach plant. Air flow ratings for all of these systems are summarized in Table 10:4.

Washer Hoods: The washer exhaust hoods are important to contain and remove any chlorine or chlorine dioxide which may offgas from the pulp stock entering the washers of the first, third, or fourth stages. Their performance, especially the first stage, is vital to protecting the washer operating floor and nearby control room workspaces where production workers spend significant periods of time. Each washer has a tight-fitting quarter-cylinder which extends about one foot above the washer drum from its inlet vat to its top. First and fourth stage hoods are made of fiberglass and have a section covering the washer inlet vat. The second and third stage hoods are of rubber-coated steel and lack an inlet vat cover. Takeoff ducts are connected to the hoods at the top of their far end of the first and third stages; and from the end of the inlet vat cover in the case of the fourth stage hood. Ducts then run directly up to the roof or out through the wall to the corresponding exhaust fan. (The second stage hood fan was inoperative during the survey.) The first stage chlorine exhaust system is also equipped with a caustic scrubber located on the roof after the exhaust fan. Its effectiveness is continuously monitored with a chlorine gas sensor (ITS Model 3500-7, 0 to 50 ppm range) whose control panel, concentration indicator, and alarm are all located on the fifth floor washer room wall. Its performance was reported to be good.

TABLE 10:4 VENTILATION SYSTEM RATINGS

System	Rating in CFM
Bleach Plant	
1st Stage Washer Hood	5,000
3rd Stage Washer Hood	5,000
4th Stage Washer Hood	5,000
4th Floor Wall Exhaust Fan - North	4,750
4th Floor Wall Exhaust Fan - West	3,500 (est.)
4th Floor Wall Exhaust Fan - South	4,750
4th Floor Wall Exhaust Fan - For Conveyor Belt Line	5,000
3rd Floor Fan for Transformer Room Coding	11,000
Vaporizer/Hypo Room	
Roof Exhaust Fan	4,650
Wall Exhaust Fan - North	5,170
Chlorine Dioxide Generator Building	
Hood Exhaust Fan	1,500

The effectiveness of these hoods to contain and ventilate process offgases was estimated by taking air velocity readings across any accesible open faces. For Nos. 1 and 4 hoods, this consisted of four and two, respectively, observation ports with hinged covers located over the inlet vats; and a narrow face between the top of the drum and the bottom of the hood. This face extends the full length of the drum (~9'-3"). No. 3 washer lacked any inlet vat cover, and readings were taken only at the face between the drum top and hood bottom. Due to access problems, readings were taken only at either end of this face for all hoods (i.e., far end or takeoff duct end), or at normally open observation ports. An Alnor Velometer was used, and results are summarized below:

Stage	Duct Takeoff Type		Location	Reading (in fpm)
1st (Chlorine)	Square duct off top of one end	o	Top face (~3"H x 9'3"L) @ takeoff end	1,000
		o	Top face @ far end	350
			Two (2) observation ports (~16" x 11")	150-240 200-270
3rd (Hypo)	Square duct off top of one end	o	Top face (~6"H x 9'3"L) @ takeoff end	225
		o	Top face @ far end	0
4th (Chlorine) Dioxide)	Round 16" duct from vat end	o	Top face (~8-9"H x 9'3"L)	75- 150
		o	One of two observation ports (other one closed) (~10" x 26")	350

The first stage washer has a total estimated open face area of about 5 square feet (after adding an additional 1 square foot of leakage area). An average face velocity in the range of 800-1000 fpm would, therefore, be expected based on a fan rating of 5,000 CFM. Since measured velocities are considerably below this at the major faces, either the exhauster is running below specification; the duct scrubber creates a considerable pressure drop; or partial clogging of the hood and/or ductwork has occured. Since all measured face velocities were still in excess of 150 fpm, effective capture

of any offgased chlorine is still being attained at the hood. Air monitoring around and about this washer, however, indicates that some chlorine gas may escape from the unenclosed discharge end of the washer (see Mast Oxidant Monitor data for the fourth day on Figure 10-5). Such escape may be more significant if first stage over-chlorination is taking place.

Open face areas and associated air velocities are less critical for the third and fourth stage hoods because there is less tendency for chlorine or chlorine dioxide to offgas from these stages. This is because sodium hypochlorite bleach solution remains alkaline throughout the third stage, and because chlorine dioxide is very reactive and tends to decompose. Measured face velocities for these two exhaust hoods are below specification (based on 5,000 total CFM), but still adequate.

General Ventilation: In addition to these local exhausters, some general air turnover and ventilation of the third and fourth floors of the bleach plant is provided by the three (3) fourth floor wall exhaust fans, and the cooling air fan supplying the two electrical transformer rooms (second and fourth floors). These air flows are important for achieving some ventilation of small amounts of chlorine or chlorine dioxide periodically released from process equipment on these floors (such as steam mixers or the open conveyor belt). Such releases occur mainly when high final residuals or overbleaching events occur. A small wall exhaust fan is also provided to draw air from one of the remote fourth floor conveyor belt passageways which workers may occasionally have to enter.

With a maximum of 20,000 CFM of air being exhausted from the fifth floor (i.e. 4 hoods @ 5,000 CFM each) as many as 14 room air changes per hour could be obtained for this approximately 60 feet wide by 64 feet long by 22 feet high workplace (84,480 cubic feet). Similarly, a maximum of 13,000 CFM of air could be exhausted from the fourth floor or approximately 9 air changes per hour.

Passive ventilation of the bleach building can also be important especially during warm weather periods when numerous doors and windows may be open. During the mid-fall survey period, such openings were noted, and for some the relative direction of air flow measured. Results, summarized below, indicate that the upper two floors of the building are under some negative pressure, as is expected.

The mill reported that most doors are usually kept open during warm weather for ventilation; and that the washer room is usually under positive pressure during cold weather when all doors and openings are closed.

Miscellaneous Bleach Plant Openings
(May be either opened or closed depending on weather and season; I = measured air flow direction was into building.)

Floor		Opening Description and Location
5th	o	Two (2) 2'W x 3'H upper wall openings with variable louvers on north and south walls.
	o	Approximately 2'H x 5"W windows (3) on washer floor (I).
	o	Doorway behing 4th stage washer leading to enclosure around top of ClO_2 tower (I).
4th	o	Large double doors on west side (I).
	o	Four (4) windows (4' x 4') on south side of decker room (I).
	o	Passageway to pulp mill.
3rd	o	Door near stairwell on north side
2nd	o	Double door on westside
1st	o	Building entrance doors on north, south, west, and east sides.

Since capacity of the fifth floor makeup air system is not known, the degree of balance between exhaust and supply air cannot be determined. Slight negative building pressure is not thought to be detrimental for this mill because of the effective scrubbing (with caustic solution) of the first stage washer exhaust. This reduces the likelihood of chlorine gas infiltrating to the upper levels of the bleach plant that are under negative pressure. Good vertical distribution of air is also possible for this building through either the stairwell or the elevator shaft.

No information was available on the control center's HVAC system. However, this room is fully enclosed with a slight positive inside air pressure maintained to prevent washer room air contaminants from infiltrating. Fresh air for this system enters through the north wall of the building with the amount controlled by variable intake dampers.

In general, the bleach building air systems were judged to be well-designed and maintained, with the need for general ventilation being noteworthy due to the northern climate and the resulting full enclosures of all equipment.

Vaporizer/Hypo Building Ventilation - The separate vaporizer/hypo makeup facility is provided with an excellent general ventilation system. It consists of two manually controlled exhausters -- a lower wall fan behind the vaporizers (5,170 CFM) and a ceiling fan (4,650 CFM). A makeup air system, drawing outside air from the building's north side and distributing it through a ceiling bag diffuser, was also observed. However, the mill could not provide a capacity for it. As this room is quite small (est. 20'W x 20'L x 20'H or 8,000 cubic feet), the 9,820 CFM of total exhaust capacity could effectively ventilate this facility and minimize damage if leaks in either the hypo makeup or chlorine vaporizer systems should occur. In addition, a chlorine air monitor (solid state detector) is located in front of the wall exhauster. This presumably is used to detect any leaks and sound an alarm so that the ventilation systems can be activated. It should be noted that such leaks occur rarely, however, as equipment is regularly inspected and routinely serviced, and that employees remain in this facility for only short periods of time.

Generator Building Ventilation - The chlorine dioxide generator building consists of primarily two rooms -- a single story room (~35 feet by 20 feet) containing pumps and controllers, an air compressor, and a QC testing bench; and an adjoining multi-story room (~22 feet by 10 feet) containing the two-stage chlorine dioxide reactors. A single ventilated hood with separate shrouds extends down over the safety relief valves on top of these reactors. Its exhaust capacity is rated at 1,500 CFM. This fan is the only source of active ventilation of the entire building, and it is normally kept continuously running. The main purpose of the hood is to contain and remove any gases when the safety pressure relief valve opens due to reactor "puffs" or other upsets. Although such a release has not been observed, the relief setting and configuration of this valve is such that a short-duration, but high velocity (horizontal) release would likely occur (i.e. initial P 50 psi). For such a condition, only a complete-enclosure type hood would be totally effective. The 1,500 CFM of exhaust air, however, should be sufficient to ventilate the upper levels of this building before gas could disperse downward and impact on the operating floor. This system may also provide a small amount of general ventilation of the operating floor where chlorine dioxide (and chlorine) may be periodically released during collection and testing of generator quality control samples.

MILL 12 FIVE STAGE (CEDED) BLEACH PLANT WITH CHEMICAL PREPARATION

INTRODUCTION

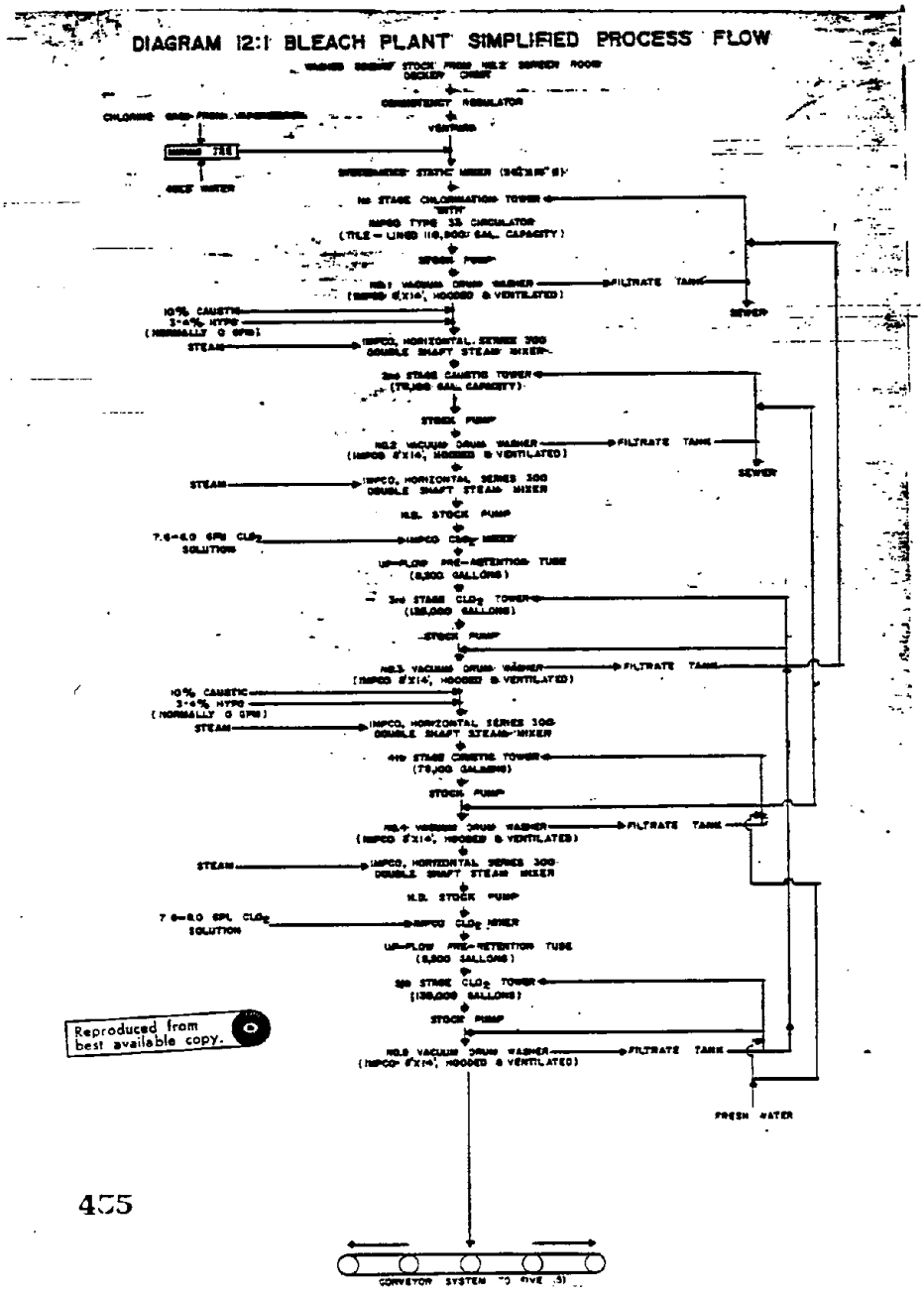
Mill 12 is a five-stage (CEDED) bleach plant operated in conjunction with a batch Kraft pulp mill (hardwood and pine). The mill is located in the southeast region and produces bleached pulp for use in making heavy papers on-site. The bleach plant was constructed in 1954 and, although some process changes have occurred, there have not been major structural changes. Although the CEDED bleaching sequence is most common, the mill can also be operated in a modified C(E-H)D(E-H)D sequence.

The mill, including the chemical preparation systems, is operated continuously for three shifts per day by a production staff of only three people. It produces approximately 550 tons per day of either bleached hardwood or pine pulp at final brightness levels ranging from 80-86. As the brown stock permanganate numbers range from 18-24 for pine and 12-16 for hardwood, the plant would be classified as operating under difficult to intermediate degrees of pulp bleaching conditions.

PROCESS SUMMARY

Bleaching Process - The bleaching process operates in a CEDED sequence, consisting of the following stages: 1) chlorination (with chlorine gas); 2) alkaline extraction (with 25% sodium hydroxide); 3) chlorine dioxide treatment (7.8 - 8.5 gpl strength); 4) alkaline extraction; and 5) chlorine dioxide treatment. Each is followed by a washing step using a rotary, vacuum drum washer. A simplified process flow is presented in Diagram 12:1.

As shown, washed brown stock (typically a 15:1 ratio of hardwood to pine) is pumped to the bleach building and passes through a consistency regulator (set for 4.0%) and a venturi element. The first stage of bleaching is accomplished by injecting a carefully regulated flow of bleaching solution (chlorine gas in water) into a pipe containing a rapid flowing stream of low consistency pulp. The pulp/chlorine mixture is then intimately mixed in a static mixing element (a closed piping segment with baffles). It then passed through an Optichlor brightness sensing element and flows into the bottom on the 1st stage tower. The strength of the chlorine solution is usually fixed at 5% but its flow is continuously regulated based on the output of the Optichlor sensor and the operator-specified setpoint. A permanganate test is manually performed on washed brown stock by the pulp mill staff. The results of this test are immediately communicated to the bleach plant operator to give an indication of the necessary bleach requirements.



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The pulp passes up through the tower in about 28 minutes, is diluted with filtrate, and then pumped into the first stage washer. Here the soluble chlorinated lignin and other colored impurities are displacement washed from the pulp using cold water (80°F). Any chlorine residual remaining in the pulp is removed in the wash filtrate, which drops down into a seal box. The effectiveness of first stage chlorination is determined by periodically measuring the brightness of stock entering the washer. This involves a manual testing procedures, typically performed by the assistant operator every other hour. Poor first stage bleaching results can be corrected somewhat by altering subsequent stages (i.e. increasing ClO_2 dosages); or more commonly, by the use of additional sodium hypochlorite bleaching liquor in the second and fourth alkaline extraction stages. In either case, low or high brightness tests on the above sample would initiate further process investigations, and changes in the Optichlor setpoint and/or chlorine flow. After the washing step, the resulting thick stock (11% consistency) is shredded in the washer discharge trench, and dropped through a close chute down to a steam and chemical mixer.

The remaining four bleaching stages are accomplished in a similar manner, as shown in Diagram 12:1. As shown, only fresh water is used in the washer showers. Cold water is supplied to the first stage washers; hot water to the second, third and fourth washers. Part of the first and second stage washer filtrates are sewered, and all the remaining filtrates are recirculated.

For the CEDED sequence, typical process parameters are:

Stage I: (Chlorination)

Stock Temperature - 95°F
Stock pH - 2.3
Residual Cl_2 at Washer - Range 10-50 ppm, desired above 10 but below 50
Brightness (final) - 18-25 (pine); 28-36 (hardwood)
Stock Consistency - 3.5% (tower)
Chlorine Strength - 5%

Stage II: (Extraction)

Stock Temperature - 160°F - 180°F
Stock pH - 9-11.5 (spec.)
Hypo strength (if used) - 30-42 gpl (at max. flow of 28.6 gpm if in a CEDED sequence)
Caustic strength and flow - 2% NaOH at max. 25 gpm
Stock Consistency - 12% (tower)

Stage III: (Chlorine dioxide)

Stock Temperature - 185F
Stock pH - acidic, 7
ClO_2 Strength - 7.8-8.5 gpl (are attempting to increase to 8.4-8.5)
ClO_2 Flow - 130 gpm (not accurately regulated, are investigating use of magniflow sensor)
Brightness - 73-75 (spec.); 68-76 normal
Stock Consistency - 13% (tower)

Stage IV: (Alkaline extraction)

Stock Temperature - 160°F
Stock pH - 9+
Caustic strength and flow - 10% NaOH at max. 4.2 gpm
Stock Consistency - 15% (tower)
Hypo Strength (if used) - 30-42 gpl

Stage V: (Chlorine dioxide)

Stock Temperature - 165°F (must be above 130°F for effective ClO_2 action)
Stock pH - Neutral, 6-7
ClO_2 Flow - 20-30 gpm (flow is monitored same as Stage III)
Stock Consistency - 13% (tower)
Final Brightness - 82-84 (spec.); 80-86 normal

Chemical Preparation Systems - Chlorine gas is generated on-site by steam vaporization of liquid chlorine delivered in railroad tank cars. The five vaporizers are housed in a small brick building which has a number of wall openings and an open doorway providing constant passive ventilation. Only four of the five vaporizers were operational during the survey. Liquid chlorine is made to flow into their cores through closed, specially-coated piping systems by applying clean, dry padding air into the tank cars. The resulting output of chlorine gas from the vaporizers is regulated for flow and pressure by controlling the amount of steam, and by pressure control valves. From the vaporizers, the chlorine gas is routed to the water/gas mixing tee. The chlorine/water solution is then injected into the stock flow line. All systems are monitored and controlled from the bleach plant control center.

A solution of chlorine dioxide gas in chilled water is used for the third and fifth stages of bleaching. It is produced on-site in an improved-design Solvay system, and stored in one

of two storage tanks. The generator equipment and simplified flows are shown in Diagram 12:2. Total maximum generation rate is about 9 tons/day as chlorine dioxide. As shown, the Solvay generator consists of two closed reactor vessels typically operated in series. Chlorine dioxide gas is generated by the reaction of a sodium chlorate solution with sulfuric acid and methanol under controlled temperatures:

$$4NaClO_3 + 4\ H_2SO_4 + CH_3OH \rightarrow 4\ ClO_2 + 4\ NaHSO_4 + 3\ H_2O + HCOOH$$

When the reactors are operated in series, the solutions overflow from the first reactor to the second. Clean air injected into the bottom of both vessels is used to mix the reacting chemicals. The resulting chlorine dioxide gas is stripped from the solution by this air and removed through the top of the vessel. The air/gas streams from each reactor are then combined, and flow counter-currently through one of two packed absorption towers (Carolina fiberglass) which have chilled water flowing through them. Absorption of the gas results in a chlorine dioxide in water solution, which flows out the tower bottom. The concentration of this solution is determined by the water flowrate, the water temperature, and the concentration of ClO_2 gas in the air stream. As shown in Diagram 12:2, chemical reactants are pumped from large storage tanks, pass through filters and flow control valves, and into four injection ports on the bottom of the primary reactor. Sulfuric acid is received in 78% strength and is injected through two of the ports. Methanol (100%) and sodium chlorate solution are first pre-mixed, and then added through the other two ports. A small amount of additional 100% methanol and sulfuric acid is added to the second reactor to complete the chlorine dioxide reaction.

Although the production rate of chlorine dioxide can be changed by increasing the flows of all reactants, the plant is normally operated at a fixed rate. During periods of low demand, the two storage tanks are filled, and then the generator is usually shutdown until demand increases.

The flow of air to both reactors must be carefully regulated and controlled to maintain the concentration of chlorine dioxide at well below the Lower Explosive Limit (i.e. 10%). In addition, air must always be flowing through the reactors and the absorption towers prior to adding the reactant solutions to insure proper intitial mixing and resultant gas removal on startup. For short-period shutdowns of the generator, the reactors normally remain full with chemicals and with air continuously flowing. Startup then simply involves the resumption of reactant solution flows, and addition of chilled water to the absorbers.

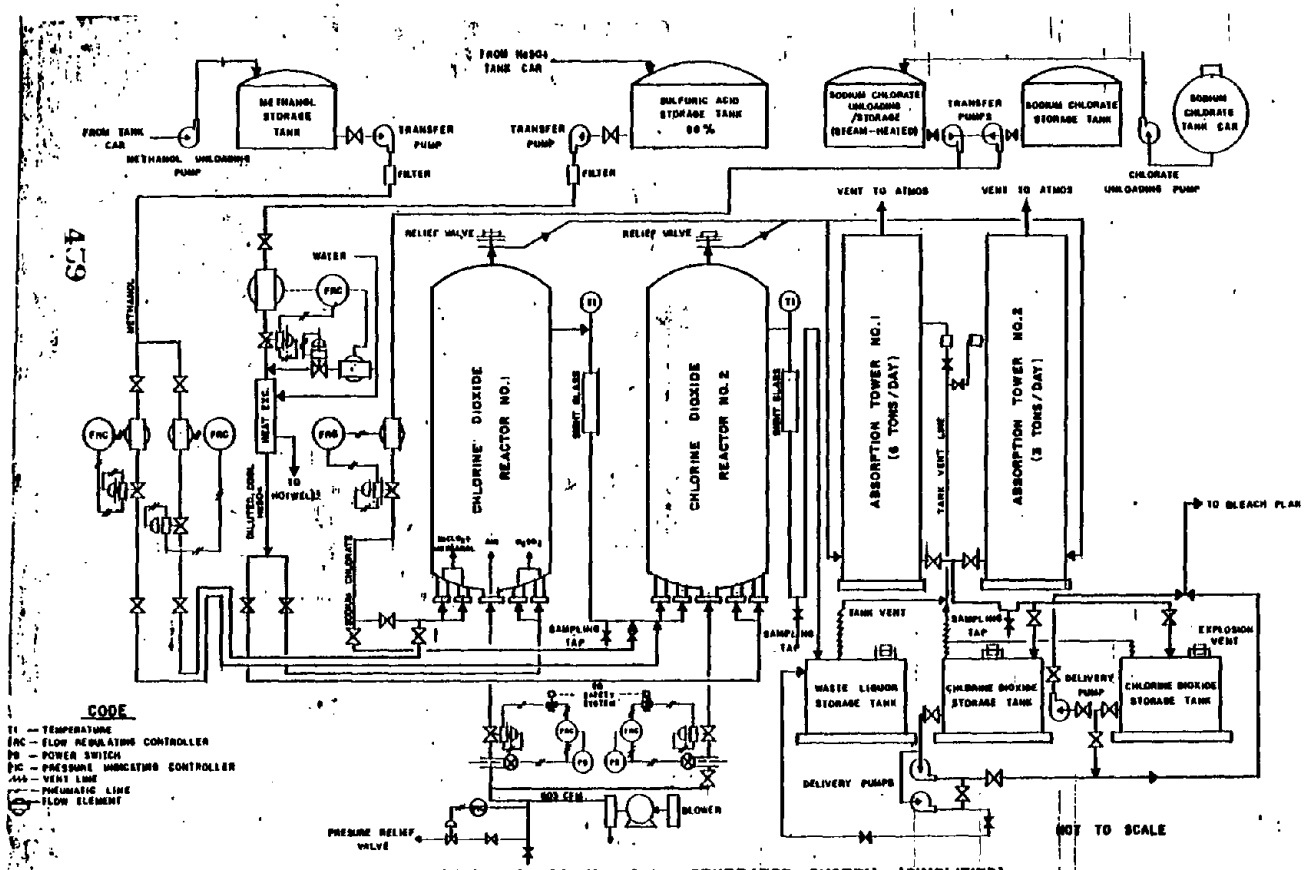

DIAGRAM 12:2 IMPROVED SOLVAY ClO_2 GENERATOR SYSTEM (SIMPLIFIED)

Spent acid from the secondary generator (mainly sulfuric acid, sodium bisulfate, and a very small amount of sodium chlorate) is stored for subsequent use for treatment of black liquor soaps in the tall oil recovery system. This added usage of 'waste' chemicals is mainly responsible for the favorable costs of producing (and using) chlorine dioxide by the Solvay process in this mill. As shown, vents on the spent acid tank (and the two ClO_2 storage tanks) are all ducted back to one of the absorption towers to prevent emitting chlorine dioxide to the atmosphere, or attaining explosive gas concentrations.

The following are typical operating conditions for the chlorine dioxide generating plant:

	Reactor		Absorber
	No. 1	No. 2	
Temperature, °F	135-140	140-145	-
Acidity, gpl H_2SO_4	430-440	450-460	-
Residual Chlorate, gpl $NaClO_3$	80-110	5- 20	-
Gas Concentration, % ClO_2	10	8- 10	-
Gas Purity, %	97-98	95- 98	-
Water Temperature, °F	-	-	35- 45
Solution Strength, gpl ClO_2	-	-	6- 10

The generating plant generally runs with little operator attention and few problems. It is monitored and controlled primarily from the bleach plant control center. Quality control testing and equipment inpsections are normally performed every other hour by the Assistant Operator. At a minimum, they include checks of the air blower flow and pressure and the chemical storage tank levels, and the collection and testing of samples from the following systems:

- Primary and secondary generator spent acids for acidity (H_2SO_4) and residual chlorate (to determine % efficiency of generating process)
- Absorber solutions (for ClO_2 strength and Cl_2 impurity)
- Generator gas to absorbers (for % ClO_2 and Cl_2)
- Chlorate storage tank (test performed once for each delivery of new chlorate to determine strength)

A small amount of sodium hypochlorite is also generated and stored on-site. This is accomplished by mixing chlorine gas (from the vaporizers) with dilutd 25% sodium hydroxide solution in a closed, recirculating piping system. Although further details and flow diagrams of this system were not available, it

apparently operates largely continuously and unattended. The Assistant Operator is responsible for its operation, but during the survey period, he was not observed inspecting or servicing any of its equipment. Control of the amount of chlorine added (hence the strength of the hypo) is accomplished with an oxidation-reduction sensor in the mixing tank. When the setpoint of this sensor is exceeded, chlorine gas flow is reduced, and more of the recirculation flow is automatically diverted to the hypo storage tank. Being outside and atop the storage tank and with chlorine mixed with a strongly alkaline solution, the system poses minimal health risks to workers during normal operation.

Mill Layout - A complete layout of the bleach mill showing all buildings and chemical storage tanks is provided in Diagram 12:3. Pulp bleaching equipment and the mill control center are located in a five story building. Only its top floor (5th) is enclosed (See Figure 12:1). The control center and the vacuum-drum stock washers are located on the fifth floor. The bleach towers (5), injectors or mixers, the storage tanks, the hypochlorite bleach liquor makeup system, and the chlorine dioxide generator are all located outside this building. The chlorine vaporizers are located in a small, single-story brick building. The chlorine dioxide generator control panel and a small quality control testing bench are located in an additional single story brick building.

JOB DESCRIPTIONS

The bleach plant is operated continuously by a three man staff for each shift - Operator, Assistant Operator, and Chemical Unloader. These three workers, under the supervision of a pulp mill shift foreman, are responsible for the efficient operation of the bleach process and various chemical preparation systems. The operator has overall responsibility for the entire plant with the other two people usually reporting directly to him first. Good communication and cooperation amongst all workers is important for the safe and efficient operation of the plant, especially with the number of remote, non-visible pieces of equipment and chemical prep systems as this mill has. The Operator or his Assistant always carry a two-way radio whenever they are outside the control center. This insures instant contact should an emergency or upset occur. Similarly, phones exist in both the main control center and the chlorine dioxide control building.

Operator - The Operator is responsible for the bleaching process, the chlorine dioxide generator, the hypo make-up system, the chlorine dioxide chiller unit, the chlorine car unloading system, the vaporizers, and the high density stock storage towers. As he must remain fully aware of current

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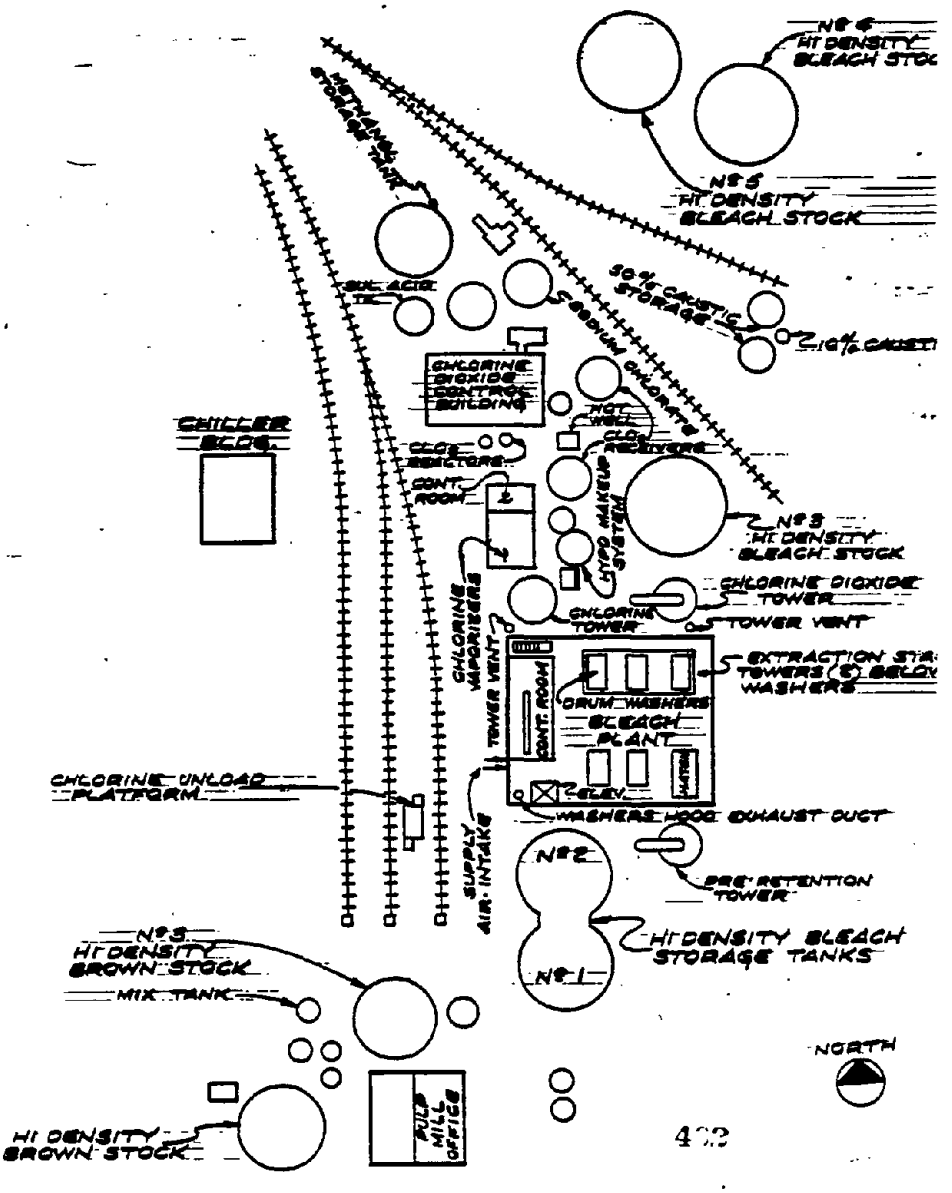
DIAGRAM 1213
GENERAL BLEACH MILL LAYOUT



operating demands, the operator stays close to or in the control center at all times. Tasks or duties that would require him to leave the control center would include:

- Servicing or inspecting the operation of the vacuum drum washers
- Hosing down stock spills from the washers
- Collecting routine or additional investigative samples from the washer vats
- Investigating or inspection process equipment
- Supervising the shutdown, startup, or modification of any process equipment systems
- Changing chlorine tank cars
- Supervising all maintenance operations

The Operator will assign the Assistant Operator to perform any of the above tasks if necessary. If the Operator is ever required to be away from the control center (or operating floor) for longer than a few minutes, he assigns the Assistant Operator (or foreman) to cover for him. The Operator is also responsible for preparing the bleach plant daily log report and verifying the accuracy of all data so entered in it. It is estimated that the operator remains in the control center for at least 90% of each shift.

Assistant Operator - The Assistant Operator assists the Operator in the performance of any tasks - primarily those outside of the control center. He is thus required to be knowledgeable of all bleach and chemical prep systems and controls. His most time consuming function, however, is to assure the efficient and proper operation of the chlorine dioxide generator, hypo makeup system, water chiller, and the chlorine vaporizer and transport lines. This involves hourly inspection and quality control sampling tours of each of these systems. These tours and other non-scheduled tasks result in the Assistant Operator spending about 30-40% of his time each shift outside the control center. Quality control sampling and testing tours of the chlorine dioxide generator are performed every other hour during normal operation. During generator start-ups (and sometimes shutdowns), the Assistant Operator may perform more frequent tests and inspections, or remain in the generator control building throughout the procedure.

Typically, however, inspection/testing tours require 10-25 minutes to perform and may include any or all of the following tasks:

Task Description	Frequency	Est. Time
Transit to ground level from control center	-	1-2 minutes
Inspection of stock pumps, chlorine/water mixing tee, hypo makeup system, vaporizers, and other ground level equipment	Typically every hour	1-3 minutes
Preparation of testing equipment (cleaning containers, pouring out reagents, etc.) in ClO_2 control building, and recording storage tank levels	Every sampling tour	3-5 minutes
Collection of primary reactor waste acid sample and	Every two hours	30 seconds
Collection of secondary reactor waste acid sample and	Every two hours	30 seconds
Collection of absorber solution sample (ClO_2)	Every two hours	15 seconds
Hookup of calibrated gas sampling bulb for collection of generator ClO_2 gas sample	one/shift	1 minute (total collection time)
Performance of testing of samples in ClO_2 control building	Every two hours	7-12 minutes
Calculation of test results and recording of results on ClO_2 generator daily log sheet	Every sampling tour	1-3 minutes
Collecton of hypo samples	Once/Shift	1 minute
Testing of hypo sample for residual Cl_2 and NaOH	Once/Shift	3 minutes
Inspection of water chiller and recording of its operating data on daily log sheet	Twice/Shift	2 minutes

Task Description	Frequency	Est. Time
Inspection of air compressors	Twice/Shift	1 minute
Transit time back to control center	Twice/Shift	2 minutes

As indicated, these tours include different tasks, are performed in varying order, and can vary in duration. Although usually performed at regular scheduled times, they generally are done at the discretion of the employee, depending on the priority of other bleach plant tasks.

Every two hours, the Assistant Operator also collects and tests samples of treated pulp stock from the washers. Only several minutes are required to actually collect the samples, and then they are immediately analyzed at a test bench located in the control centers. Tests are performed for: 1) first stage chlorine residual, pH, brightness, and quality (presence of dirt and shives); 2) second stage pH and alkalinity; 3) third stage stock pH and brightness; 4) fourth stage stock pH and alkalinity; and 5) fifth stage pH and brightness. The stock brightness tests are performed on the first, third, and fifth stages are the only means of judging the effectiveness of the overall bleaching process. If the Assistant Operator is not available to perform these tests, the Operator himself will perform them.

In addition, the Assistant Operator will make unscheduled equipment inspections and adjustments anywhere in the bleach mill. Occasionally, he will also service the stock washers and cleanup stock spills.

Chemical Unloader - The Chemical Unloader works only during the day shift (8 AM to 4PM) He is responsible for unloading and transferring all incoming bleach chemicals to storage; and for loading recovered tall oil (from the pulp mill) into railroad or truck tank cars. This tall oil operation is usually performed continuously and results in the shipment of one or two loads per day. Types of chemicals unloaded include: sodium chlorate crystals, 77% sulfuric acid, methanol, 50% sodium hydroxide (caustic), alum, and 77% resin sizing. (The latter two are used in the paper mill). Unloading of the caustic, sulfuric acid, and methanol from railroad tank cars require hooking up transfer hoses (actual connections made by pipefitters), and then pumping the solution to the appropriate storage tank. (See Diagram 12:3). Unloading the sodium chlorate requires first dissolving the crysals in the tank with hot water, then pumping the solution to storage tanks. This procedure is used because dry sodium chlorate crystals are a fire hazard. None of the above observations require the Chemical Unloader's constant attention and he frequently performs other tasks. He must collect quality control samples

of each new shipment of incoming chemicals and each load of outgoing tall oil (the latter for percent moisture analysis). Actual testing of these samples is usually done by the shift chemist in the main chemistry laboratory. An additional four hours per week is also spent cleaning the tall oil heaters in the pulp mill with caustic solution. This operation, however, was not observed during the survey.

Overall, it is estimated that the Chemical Unloader spends at least 90% of his time outside the bleach plant. The remaining time is spent in the bleach plant control center. He also occasionally accompanies the Assistant Operator in order to train for that position.

Utility Man - A Utility Man is usually assigned to the bleach plant to perform cleanup and housekeeping tasks. However, he may also have similar responsibilities in the pulp mill or the recausticizing area. This employee normally spends in excess of 90% of his shift outdoors or in very 'open' areas of the plant. His work schedule is largely non-routine and variable, depending on process conditions, weather, and the particular work shift.

Workplace Emission Sources and Hazards - The location of this mill in a warm climate largely eliminates the need to enclose process equipment. Only the washer (operating) floor is enclosed; the remaining four stories are all open. Most of the potential exposure sources are outside, and a high degree of worker protection is inherently provided. The primary sources and types of emissions are summarized in Table 12:1. It should be stressed that, except during leaks or major process upsets, there are very few if any sources of workplace contamination. Emissions of gaseous chlorine and/or chlorne dioxide from the washers are the most frequent source of potential exposure. However, workers normally spend only short periods outside the control center on the washer floor, and all five of the washers are provided with exhaust hoods. The potential for workplace emissons from the washers is thus directly related to the efficiency of the exhaust hoods, the residual concentrations of chlorine or chlorine dioxide, stock temperature/pH, and the operating characteristics of the washers (the vacuum being attained within the drum, the efficiency of washing, the shower water temperature, the filter screen condition.)

The only other 'enclosed' workspaces are: the chlorine dioxide control building, and the small vaporizer, water chiller, and air compressor buildings. The latter are only infrequently entered by the Assistant Operator and the shift foreman to make general equipment inspections. Also, with the exception of a chlorine leak from the vaporizers themselves (a very rare event), there are no sources of emission of hazardous agents in these facilities.

TABLE 12:1 - POTENTIAL BLEACH PLANT EXPOSURE HAZARD SOURCES

Exposure Hazard/Source	Location	Hazardous Agent	Nature of Hazard
o Chlorine mixing tee and transport piping/control valves	Ground level of bleach plant	Chlorine gas	Only if leak occurs (rare)
o Chlorine dioxide mixers (2)	Ground level of bleach plant	Chlorine dioxide from solution	Only if leak occurs (rare)
o Steam mixers for 2nd and 4th stages	4th Level of bleach plant	Chlorine gas volatilized from stock containing small residuals or added hypo; potentially occurs because of high temperatures achieved	Continuous, more significant when hypo is used
o Seal boxes of washers (1st, 3rd, and 5th stages)	3rd level of bleach plant	Chlorine and chlorine dioxide gas volatilized from small residual left in stock filtrate after washing	Continuous emission possible, becoming more significant if over-additions of bleaching agents occurs
o Sampling lines on ClO_2 generator system for collection of spent acid and absorber solutions; and the generator gas sample	Below the outside generator	Chlorine dioxide (and lesser amounts of chlorine) gas volatilized from solutions when valves are open; or gas leaking from poorly installed sampling equipment (rare)	Occurs only during actual sample collection when valves are open. (usually <1 min.)
o Stock washers	5th floor of bleach plant	Escaping chlorine and chlorine dioxide gas from residuals left in the stock	Continuous emission related to the concentration of residual agent, stock temperature and pH, and the effectiveness of washer hood ventilation system
o Miscellaneous tower and equipment vents:			
1st stage tower	Above tower southwest side of bleach building	Chlorine off-gassing	Continuous more significant if over-addition of chlorine occurs
3rd and 5th stage ClO_2 towers	Above towers northwest and northeast side of building	Chlorine dioxide off-gassing	Continuous; gas can usually be seen coming from vent; more significant if over-addition of ClO_2 solution occurs
ClO_2 generator gas relief vent	Safety valve above both reactors	ClO_2 gas (and Cl_2) if safety relief occurs	Gas relief usually only occurs during system startups or if chemical feeds to reactors are improper
ClO_2 absorption tower vents	Discharge vent above each tower	ClO_2 gas	Occurs only if tower is not operating properly or absorption water is too warm

The most significant source of worker exposure is the collection of quality control samples. In this case, exposures result at regular times, but are very short-lived, occurring mainly while a sampling valve is open.

The potential for re-entrainment back into the washer floor of chlorine and chlorine dioxide from exhausted or vented equipment is a distinct possibility for this mill. Potential sources of reentrainment gases include the bleach tower vents, the washer exhaust hood duct and, to a lesser extent, the foam tank vent. Of these, reentrainment of te more concentrated first and third stage tower vent gases (chlorine and chlorine dioxide) pose the greatest exposure potential. These vents extend about 5-10 feet above the roof top on two corners of the bleach building (Diagram 12:3). A large intake louver for the supply air system is located close by on the wall of the building just below the roof. This system supplies approximately 42,000 CFM of make-up air to the ceiling area of the operating floor.

PERSONAL SAMPLING RESULTS

Personal samples were not collected for the Operator or for the Chemical Unloader. The Operator remains in the control center for most of each shift, so area samples provide a reasonable estimate of this employee's exposure. The Chemical Unloader typically works outside where exposures would be expected to be very low.

The Assistant Operator, however, makes regularly scheduled inspection and QC sample collection tours, and nine 15-minute ceiling samples for chlorine/chlorine dioxide were taken to assess exposures. Similar samples were collected for the Utility Man and a maintenance worker (while installing a new hypo flow control valve on the washer floor). The results of these samples and short task summaries are presented in Table 12:2. All of these samples were collected and analyzed by NIOSH P & CAM 209, using 15 milliliters of methyl orange reagent in Liquid Media Samplers. Because this procedure responds to both chlorine and chlorine dioxide, we have by necessity expressed all results as the equivalent chlorine response only.

Ceiling exposures for the Assistant Operator range from 0.07 ppm to 0.13 ppm as chlorine. Two of the results (Nos. 3 and 4) could not be quantified because of depletion of the sampling reagent by the high chlorine dioxide levels during the collection of absorber and spent acid quality control samples from the generator.

Job Classification	Date	Sampling Time	Sample Number	Chlorine/Chlorine Dioxide Exposure (as ppm Cl_2)[1]	Activities Performed
Assistant Operator[3]	11/11/80	17:53 - 18:08	1	0.066	Collected 3, 4, & 5th stage stock samples (=1 min.); tested samples in control room (=4 mins.); collected 10% caustic sample and 1st stage stock to washer sample (=55 secs.); and performed testing in control room (6.25 mins.).
	11/11/80	18:44 - 19:09	2	0.095	Full inspection and QC check of ClO_2 Generator - in control room (= 1 min.); checked various outside bleaching equipment (3.5 mins.); inspected vaporiser room (30 secs.); prepared testing equipment in generator control building (=4.75 mins.); collected outside absorber solution and reactor waste liquor samples (=3.25 mins.); and performed testing of samples in control building (=9 mins.).
	11/12/80	9:42 - 10:04	3	>0.12	Full inspection and QC check of ClO_2 Generator - in control building preparing testing equipment (=2.5 mins.); collected primary reactor waste acid sample (10 secs.); measured out aliquot of sample (=30 secs.); collected 2nd reactor waste acid sample (=10 secs.); collected ClO_2 absorber sample (=10 secs.); measured aliquot of sample (=30 secs.); in control building preparing samples (=1 min.); started up hypo system outside (=2.5 mins.); and performed testing of all samples (=9.25 mins.).
	11/12/80	11:30 - 11:48	4	>0.126	Collection and testing of ClO_2 Generator samples - walked to generator (30 secs.); collected and measured aliquot of primary reactor waste acid sample (=5 secs. and =30 secs. respectively); collected and measured aliquot of 2nd reactor waste acid sample (=5 secs. and =15 secs. respectively); collected ClO_2 absorber sample (=15 secs.); collected generator gas sample (=1 min.); and in control building performing testing of the four (4) samples (14.25 mins.).
	11/12/80	11:41 - 11:56	5	0.099	Collection and testing of ClO_2 Generator samples - collected primary reactor waste acid sample and prepared aliquot (=10 secs. collecting; =15 secs. for aliquoting); collected 2nd reactor waste liquor sample and prepared aliquot (=10 secs. collecting; =50 secs. aliquoting); collected absorber sample (=10 secs.); and tested all three (3) samples in control building (10.25 mins.).
	11/13/80	11:37 - 11:42 14:10:30 - 14:20	6	0.07	Simulated inspection of outside bleach equipment as typically performed by assistant operator - inspected outside equipment enroute to generator control building (1.75 mins.); in control building preparing testing equipment (3 mins.); and inspected outside ClO_2 generator equipment, chlorine mixer, and other equipment as returned to bleach plant control center (=5 mins.). (See also above Sample No. 5).

Job Classification	Date	Sampling Time	Sample Number	Chlorine/Chlorine Dioxide Exposure (as ppm Cl_2)	Activities Performed
Assistant Operator[2]	11/13/80	15:53 - 16:08	7	0.098	Collection and testing of ClO_2 generator samples — walked to generator (25 secs.); collected primary reactor waste acid sample and prepared aliquot (10 secs. for collection; ≈15 secs. for aliquoting); collected 2nd reactor waste acid sample and prepared aliquot (≈10 secs.; ≈20 secs. for aliquoting); collected ClO_2 absorber sample (total time sample valve open was ≈50 secs.); collected generator gas sample (done concurrently with absorber sampling); and in control building performing testing of four (4) samples (9.75 mins. for titrations; ≈2 mins. recording data).
	11/13/80	15:49 - 15:58 16:08 - 16:10:30	8	0.11	Simulated exposure of assistant operator while in ClO_2 building preparing testing equipment (≈4 mins.); while collecting four (4) generator samples and initial setup for testing (≈5 mins.); and while in transit back to bleach plant control center (≈2.5 mins.). (See also Sample No. 7).
	11/13/80	10:35 - 10:50	9	0.099	Simulated exposure of assistant operator if spending at least 15 minutes around the outside ClO_2 generator equipment.
Bleach Plant Maintenance Worker	11/13/80	9:12 - 9:27	10	0.073	Simulated maintenance workers' exposure while installing hypo flow valve near 1st stage washer in bleach plant.
Utility Man	11/12/80	10:25 - 10:44:30	11	<0.05	Hosing down 4th floor of bleach plant building (essentially an outside environment).

[1]Sampling and analysis performed according to NIOSH Method P&CAM 209 which is sensitive to both chlorine and chlorine dioxide gas.

[2]Assistant operator's exposure during the listed activities is primarily to chlorine dioxide gas (see also report text).

Although these data are difficult to assess because chlorine and chlorine dioxide can not be distinguished by NIOSH Method P & CAM 209, it is very likely that exposures to either of these contaminants are below their respective OSHA PEL's. The dominant source of exposure during these inspections and QC sampling tours is the actual sample collection procedure itself; specifically the absorber and spent acid sample collections. These involve opening a valve on a sampling line; briefly allowing the line to flush to obtain a representative sample; then collecting a sample in a container. The entire process typically requires less than 30 seconds with exposure being to mostly chlorine dioxide while the valve is open. Also, since all sampling lines are located outside, exposures are affected by environmental conditions in addition to individual worker practices --- time they allow to flush the sampling line and their proximity to the line. Exposures can be greatly reduced by the worker standing upwind and well away from the sampling point during the line flushing step.

The two additional personal samples (Nos. 10 and 11) collected on the Utility Man and a maintenance employee, respectively, demonstrate a similar low level of exposure (0.07 ppm to 0.05 ppm as Cl_2). During these sampling periods, the Utility Man was hosing down the open 4th floor of the bleach plant, and the maintenance employee was installing a new hypochlorite flow control valve on the washer operating floor.

AREA SAMPLING RESULTS

The washer operating floor and the control center were each monitored with a Mast Oxidant Monitor for approximately twelve continuous hours. The results, expressed as the equivalent chlorine response in parts per million, are plotted on Diagram 12:4. Additional detector tube readings taken on the operating floor with Draeger Model 0.2a chlorine tubes are also included in this diagram.

The following conclusions are warranted based on this data:

1. The Mast Oxidant Monitor's response over two twelve hour night time monitoring periods indicate that chlorine/chlorine dioxide levels are highly variable, non-cyclic, and range from less than 0.05 ppm to above 1.0 ppm (as Cl_2)

2. The higher levels may be caused by emissions from the washers (probably during overbleaching events) or from contaminated makeup air (most likely from reentrainment of tower vent gases). The data are insufficient to judge which of these sources are more significant. In fact, both may be important.

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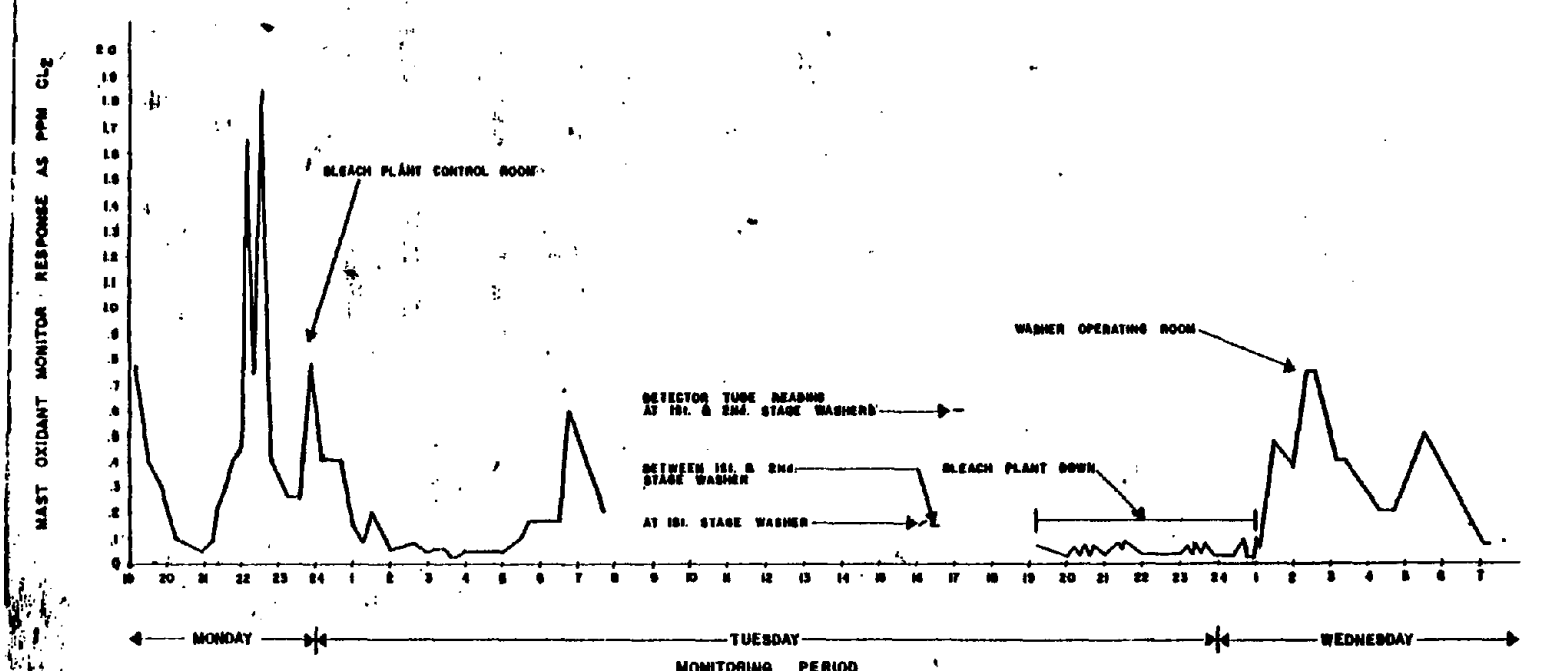
DIAGRAM 12:4
CONTROL AND WASHER ROOM AIR MONITORING



3. The lower concentrations recorded at both locations are thought to be representative of normal bleach plant operation (no overbleaching or other upsets, and no reentrainment of vent gases).

4. The non-cyclic peaks indicate that the bleaching process (either Stages I, III, or V) is occasionally subject to overbleaching events. During the control room monitoring period, at least three such events, representing almost 5 of the 12 hours, were observed. On the washer floor, two overlapping periods, potentially indicative of overbleaching, were observed.

5. The monitoring data also indicate that workplace concentrations (as Cl_2) could occasionally result in worker exposures in excess of the current OSHA PEL of 1.0 ppm ceiling.

6. Spot readings were taken with the Mast Oxidant Monitor in front of the 1st stage washers (0.15 ppm). These data and a single Draeger detector tube reading (0.6 ppm) indicate that some chlorine gas may escape from the washer hood system.

   However, just prior to these readings, flow of chlorine gas to the 1st stage was off for approximately 10 minutes while a new chlorine car was hooked up, and may have prefaced these readings on the low side.

Additionally, 11 short-term area samples were collected on the bleach plant washer floor and in the control room. Results are summarized in Table 12:3. In the control room, five samples were collected over a ten hour period while the bleach process was presumed to be stable and operating normally. Chlorine/chlorine dioxide concentrations ranged from 0.07 to 0.22 ppm, and are thought to be representative of the Operator's exposure under such conditions. Five additional samples were collected near the chlorine, hypochlorite, and chlorine dioxide stage washers; and a single sample on the mezzanine level above the washer floor.

All were collected during the same ten hour period as the above control room samples. Resulting concentrations were less than or equal to 0.11 ppm except a single sample (No. 9) at the chlorine dioxide stage washers of 0.22 ppm (as chlorine). This result, however, correlates with sample No. 4 taken in the control room during the same time period, indicating that conditions at this washer impact on control room contaminant levels. The chlorine dioxide and chlorine stage washers are both adjacent to entranceways to the control room.

TABLE 12:3: SUMMARY OF AREA AIR SAMPLES BLEACH PLANT, VAPORIZER FACILITY, AND CHLORINE DIOXIDE CONTROL BUILDING

Location	Sample No.	Date	Sampling Period	Air Concentration, as ppm Cl_2[1]	Notes
Bleach Plant Control Room	1	11/12/80	6:32 - 8:11	>0.025	Contaminants could be both chlorine and chlorine dioxide.
	2	11/13/80	7:51 - 8:06	0.084	Contaminants could be both chlorine and chlorine dioxide.
	3	11/13/80	9:38 - 9:53	0.099	Contaminants could be both chlorine and chlorine dioxide.
	4	11/13/80	12:41 - 12:56	0.11	Contaminants could be both chlorine and chlorine dioxide.
	5	11/13/80	14:30 - 14:45	0.22	Contaminants could be both chlorine and chlorine dioxide.
	6	11/13/80	18:08 - 18:31	0.069	Contaminants could be both chlorine and chlorine dioxide.
Washer Operating Floor: at 1st Stage Washer	7	11/13/80	7:56 - 8:11	0.092	Most likely contaminant is chlorine gas.
" "	8	11/13/80	18:15 - 18:31:30	0.097	Most likely contaminant is chlorine gas.
at 3rd Stage Washer	9	11/13/80	15:18 - 15:33	0.085	Most likely contaminant is chlorine gas.
at 5th Stage Washer	10	11/13/80	14:31 - 14:46	>0.22	Most likely contaminant is chlorine dioxide gas.
	11	11/13/80	18:37 - 18:52	0.088	Most likely contaminant is chlorine dioxide gas.
Mezzanine Level Above Washer Floor	12	11/13/80	10:00 - 10:15	0.11	Contaminants could be both chlorine and chlorine dioxide.
Vaporizer Facility (On Right Side Wall)	13	11/12/80	18:48 - 19:59	>0.033	Most likely contaminant is chlorine gas.
Chlorine Dioxide Control Building, Above Testing Bench	14	11/12/80	18:51 - 20:00	<0.05	Assistant operator not performing tests during sampling.
	15	11/13/80	10:31 - 10:46	0.064	Assistant operator not performing tests during sampling.
Wet Well Below ClO_2 Absorber (Outside)	16	11/13/80	10:34 - 10:49	>0.22	Contaminant is most likely chlorine dioxide.

[1]Sampling and analysis performed according to NIOSH Method P&CAM 209 which is sensitive to both chlorine and chlorine dioxide.

Three additional short-term area samples were also collected at the chlorine dioxide generation facility (Nos. 12-14). Two samples inside the control building near the sample testing bench resulted in essentially non-detectable concentrations of chlorine dioxide (< 0.05 and 0.06 ppm); and a single sample taken below the outside chlorine dioxide absorber in 0.22 ppm (as Cl_2). All three samples were taken when the Assistant Operator was not collecting QC samples.

CONTROL TECHNOLOGY

Almost all unit operations and process equipment potentially resulting in hazardous emissions are locasted outside in this southern mill. Therefore, process inherent worker isolation and natural ventilation are the most noteworthy control measures. Four general types of controls were observed: process monitoring, ventilation, work practices, and respiratory protective devices.

Process Monitoring Controls - In this particular bleaching system, a high degree of reliance is placed on manual sampling and testing results to provide data with which to regulate the process. These tests include: residual bleaching agent and pH tests on the 1st, 3rd and 5th stages; 2nd and 4th stage pH tests; and 1st, 3rd and 5th stage stock brightness determinations. Since these tests take time to perform, slow diagnosis and correction of process (or stock) changes or upsets can result at times. However, it was not possible for the survey team to actually evaluate the occurance of such changes, or the response of the bleach process or operating personnel to them. Continuous control room recordings are maintained for important parameters such as: chlorine gas flow to the mixing tee; chlorine line pressure from the vaporizers; the Optichlor reading; chlorine dioxide solution low to the 3rd and 5th stage mixers; and of course, various stock flows, temperature, and dilution water flows. These give some forewarning of changing process conditions which are believed more than adequate in most cases.

Careful control of the addition of chlorine in the first stage is very important. Undertreatment necessitates the use of more expensive chlorine dioxide solution (or hypo) in the later stages. Overtreatment can effect pulp qualities but, more importantly, results in significant off-gassing of chlorine from the 1st stage tower or washer. As previously mentioned, an Optichlor system is used to regulate addition of chlorine gas necessary to achieve effective 1st stage pulp chlorination. This sensor is located between the static mixers and the 1st stage tower in the stock flow line. It provides a continuous measurement of the brightness of the flowing stock by measuring the degree of light reflectance from the surface of the pulp. The sensors output is then used to automatically

open or close the chlorine flow control valve until stock brightness balances with the Optichlor setpoint. The Optichlor setpoint is currently determined (for a given pulp) from the permanganate test (manually performed in the pulp mill), the stock flow and consistency, desired final 1st stage brightness, and the tower retention time. Modifications are planned to change to a CEK test to replace the permanganate procedure, but potential improvements were not discussed with mill personnel. The Optichlor control was reported to be generally reliable. However, it can be sluggish in its response; inaccurately calibrated or set; or subject to pulp flow and temperature variations. The frequency or magnitude of such effects was not discussed, although each could potentially impact on emission of chlorine gas to the washer room workspace.

The chlorine dioxide generator is largely a packaged system installed in the mid-1960's to replace original equipment. It is automated, runs largely without operator intervention, and its critical operating parameters are monitored (and recorded from the bleach plant control center. As discussed, the Assistant Operator performs regularly scheduled equipment inspections and quality control tests. Generally, he must directly monitor system startups and shutdowns on-site. Conventional generator control systems that relate to safe and efficient operation are summarized in Table 12-4. Most noteworthy of these are: a safety interlock system which shuts off reactor chemical feeds if the purge air flow drops below a critical level; and safety relief valves for high reactor gas pressures. These (and many of the other controls) are provided mainly to guard against explosive concentrations of chlorine dioxide gas developing inside the reactors or other equipment. Since all generator components are outside in this mill, process upsets would have little impact on workspaces. Worker exposures are, therefore, unlikely to occur unless maintenance or equipment isolation procedures must be performed during or after such events. The liquid chlorine unloading and piping system, the chlorine vaporizers, and the sodium hypochlorite bleach liquor makeup systems were all judged to be largely conventional, and lacking in any noteworthy process control systems. These processes are all located outside, are largely automatic, and thus require little safety control for protection of the worker or property.

The mill was unable to provide any further information concerning the frequency, cost, or nature of any required or preventative maintenance operations on any of the above bleach plant or chemical makeup control systems. Various system accident records or fault diagnosis studies were also apparently not made.

TABLE 12-4: MAJOR SAFETY CONTROL SYSTEMS FOR IMPROVED SOLVAY CHLORINE DIOXIDE GENERATOR

- Flow recording alarms on the methanol, sulfuric acid, and sodium chlorate solution feeds to the reactors
- Indicators for sulfuric acid temperature to the reactors
- Reactor temperature indicating and recording system
- Reactor gas temperature recording
- Safety relief valve (spring-loaded) on top of each reactor for high gas pressure
- Reactor purge air control system (flow and pressure) with low flow safety interlock to chemical feeds to prevent explosive concentrations of chlorine dioxide within the reactors or the gas piping network to the absorbers
- Continuous air purging of the spent acid and the two ClO_2 solution storage tanks back into the absorption tower with a low purge air flow alarm system (mill air)
- Continuous air purging of the spent acid overflow lines into either the 2nd reactor or to the storage tank for waste acid
- Chilled water (to absorbers) temperature indicating and high temperature alarm systems; and water flow indicating and control systems
- Expansion joints on the piping lines into and out of the two absorption towers
- Level indicating and recording systems on reactant, waste acid, and ClO_2 storage tanks

Ventilation - Ventilation is required only for the washer room of the bleach building (5th floor). This constitutes the only enclosed workspace where toxic gas could be released and potentially result in worker exposures if not ventilated. The workspace measures approximately 64 feet long by 76 feet wide by 25 feet high, including the control room, or 121,600 cubic feet of volume. It is isometrically sketched in Diagram 12-5. The HVAC systems for this workspace are also shown and include:

- o A large exhaust fan (32,000 CFM @ 4" S.P.) which ventilates the five washer hoods and the two extraction stage towers;
- o Two axial-type wall exhaust fans (est. 5,000 CFM each);
- o A large makeup air fan and distribution system supplying heated air to the washer room ceiling (rated at 42,000 CFM);
- o A Carrier air conditioning system for the control room (recirculated air only; with cooling coils located on fourth floor).

With a minimum of 42,000 cubic feet per minute of air being moved (i.e., exhaust or supply), approximately 21 air changes per hour could be obtained. Of far greater importance, however, is effective direct containment and ventilation of contaminants as they are emitted from the drum washers. The previously reported area air monitoring results (Diagram 12-4) indicated variable levels of chlorine/chlorine dioxide in this workspace. Variations are thought to be related to process conditions, with higher levels probably indicating poor performance of the washer ventilation system. Other area sampling (and detector tube readings) performed directly at the washer discharge vats indicated escape of small quantities of chlorine and chlorine dioxide even during apparent controlled bleaching operations. The two walls exhaust fans (est. 5,000 cfm each) are thought to be only marginally effective at ventilation of contaminants once they escape capture at the washer hoods. (One fan may even have been rotating backwards; thus supplying air rather than exhausting). After describing the configuration of the washer hoods and the supply air system, diagnostic air flow measurements of the washer hoods will be presented and discussed.

Washer Hood Configurations - All hoods are the half cylinder type and cover the washer drum from its top press roller down to its inlet vat. Each fits snuggly against the side of the washer. The chlorine and two caustic stage hoods are

Diagram 12:5

custom-made from Atlac 711-05A premium-grade polyester resin with fiberglass reinforcement (pigmented white). The two chlorine dioxide stage hoods are made from galvanized steel. To restrict escape of chlorine gas as stock enters the washer, it has a horizontal cover extending out over the washer inlet along its full width. This is then hinged to the main hood to facilitate access to the vat. The two alkaline stage hoods have a similar inlet vat cover but in three-sections. They also have approximately 15 by 15 inch observation doors just above this flat. The two chlorine dioxide stage hoods have no such inlet vat cover. They consist of only 4 sections of galvanized steel hinged together from top to bottom.

The design and fit of the hoods result in a number of open faces common to all washers:

- An approximately 6 to 8 inch high face above the stock in the inlet vat just before the drum
- A number of small holes in the washer sides where shower water pipes enter
- An approximately 1 to 2 inch high face at the washer top and between the press roll

Takeoff ducts for all washers are tangential-type. These takeoffs then lead directly down into an approximately 27 by 27 inch tile duct which in turn extends down through the floor, as shown. A small observation port with a hinged cover (4-6"H x 16"W) is provided at the top of the tile duct presumably to allow checking of the duct condition.

As shown in Diagram 12-5, the chlorine, first extraction, and first chlorine dioxide stage hoods (along with two extraction stage tower vents) then connect to a large trunk duct which is below the washer floor on the east side of the building. A similar duct on the west side collects to the second extraction and second chlorine dioxide stage hoods. Both then combine into a large 4' x 8' brick plenum on the fourth floor (north wall); and a single fan draws from this plenum (54 inch duct) and exhausts to the building roof. It is estimated that this system was initially designed and balanced to exhaust about 6000 CFM of air from each washer hood, and an additional 1000 CFM from each of the two caustic extraction towers.

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Supply Air System - Because of the amount of air exhausted from the washer hoods, makeup air must be supplied back to the washer room. A single supply air fan (rated at 42 CFM) delivers filtered and heated air to the ceiling of the room. It is distributed through nine equally spaced circular diffusers (est. 3450 CFM each), immediately above the washers, and through two additional rectangular registers at either end of the room's ceiling. In the design of the original system, approximately 6,300 CFM of this system's air was also brought down into the bleach plant control room. This was changed sometime in the recent past, and the control room now has its own air conditioning system (Carrier) which only recirculates room air (no fresh air intake). The former 6300 CFM of air is now used as a supplement to the general washer room supply.

In the event that not all this makeup air is required, excess pressure in this room can be relieved through a relief damper (6 feet by 2 feet) located on the south wall about 15 feet above the floor.

Air Flow Measurements - Air velocity measurements were taken at all accessible faces in order to judge the capture effectiveness of the washer hoods. Measurements were also made of air flows through the tile ducts of each washer in order to estimate individual washer hood and total exhaust system CFM's. These latter readings were taken through the hinged observation doors on top of each duct - if the door could be opened. Air flow readings were also made and recorded for any significant miscellaneous air leaks around the washer hoods. These included the aforementioned shower water pipe holes, and miscellaneous leaks where the takeoff duct connects to the hood or to the tile duct. All readings are summarized in Table 12-4 along with a more detailed description of each hood.

In addition to these air velocity measurements, smoke tube tests were performed to determine air flow directions at various doorways and wall openings around the washer room. Results indicate that this room is under considerable positive air pressure rather than a balanced (supply versus exhaust) condition as originally designed (i.e. 32,000 CFM from hoods and 10,000 CFM from wall fans equals 42,000 CFM supply).

Ventilation System Maintenance - Since the original bleach plant construction in 1954, a number of ventilation system repairs and attempted improvements have been made. A partial listing of some of these was prepared by the mill from prior purchasing records, and is summarized in Table 12:5. As noted, most of the repairs were apparently required due to the corrosive effects of chlorine and/or chlorine dioxide on equipment. It should be pointed out that the washer seal box ventilating fan mentioned in this table is no longer operable. The plant also has no formal inspection or preventative maintenance program for ventilation systems.

TABLE 12:4 - WASHER HOOD FACE VELOCITY MEASUREMENTS

Washer No.	Description	Face Air Velocity Readings, fpm
1	One piece fiberglass with bottom flap; three holes in side for shower water pipes; number of leaks where takeoff duct meets hood and where it ties into the tile duct NOTE: Considerable amount of pulp covering inside of hood and likely clogging takeoff duct	Open face above inlet: At takeoff duct side - 100-150 fpm Middle - No reading, <50 Far end from takeoff - no reading, <50 Side holes for shower pipes: (takeoff sid Upper - ≈200 fpm Middle - >2500 fpm Bottom - 400-600 fpm Miscellaneous leaks around tile duct: all >>250 fpm Miscellaneous leaks around takeoff duct 400-800 fpm Tile duct observation door (6"x16", open): Range - 3000-4700 fpm Ave. - 3950 fpm Est. CFM - 2469 CFM
2	Same as No. 1; hinged flap over inlet is in three sections with one section missing; two ≈15"x15" observation doors (always closed)	Open face above inlet vat: Near end at takeoff - No reading Far end - No reading At missing inlet vat flap (≈10"x18"): 250-300 fpm Tile duct observation door (2 1/2"x14"): Range - 2600-2800 fpm Ave. - 2700 fpm Est. CFM - 650 CFM
3	Four section galvanized steel (hinged) with three small holes for shower water pipes; takeoff duct is tightly sealed to hood and tile duct; front face above inlet vat is ≈6"H x ≈14'W; inside of hood is relatively free of pulp buildups	Open face above inlet vat: ≈100-200 fpm along entire width Side holes for shower water pipes: Upper - <200 fpm Middle - ≈200 fpm Lower - 200-400 fpm

Washer No.	Description	Face Air Velocity Readings, fpm
		Tile duct observation door (≈4"x16"): Range - 1600-1800 fpm Ave. - 1675 fpm Est. CFM - 523 CFM
4	Identical to No. 2 except all three bottom sections are in place	Open face above inlet vat: Takeoff end - 100-200 fpm Far end - <100 fpm Tile duct observation door (≈4"x14"): Range - 650-800 fpm Ave. -≈700 fpm Est. CFM -≈200 fpm
5	Identical to No. 3 but with little leakage around shower water pipes or takeoff duct seal; inside of hood is free of pulp buildup; no observation door on top of tile duct	Open face above inlet vat: Takeoff end - 300-350 fpm Middle - ≈150 fpm Far end - 100-200 fpm

At time of above measurements, washer dropleg vacuums were as follows: No. 1 - ≈3" Hg; No. 2 - ≈8.5-9.0" Hg; No. 3 - ≈2.5" Hg; No. 4 - ≈11" Hg; and No. 5 - ≈5" Hg.

TABLE 12:5 - CHRONOLOGY OF MAJOR BLEACH PLANT VENTILATION SYSTEM REPAIRS/IMPROVEMENTS

Date	Repair/Improvement	Approximate Cost
1954	Bleach plant built with five washers hooded and ventilated with rubber-lined fan; supply air system installed	N.A.
1965	New exhaust fan for washer ventilating system (rubber-lined, Buffalo)	$ 4020
1966	Replaced original washer hood ductwork with fiberglass	$ 2500
1966	Installed 24" exhaust fan (fiberglass) on vaporizer facility roof (rated at 5850 CFM at 1/4" s.p.)	$ 842
1967	Installed exhaust system (fan and ductwork) to ventilate seal boxes on 3rd floor of bleach plant (Fan: Advent Type FVD, 6400 CFM)	$ 782
[illegible]4	Replaced or repaired coated steel ductwork on fresh air in-take system	$ 17,516
—	Installed new Carrier A/C unit with 2hp motor in bleach plant control center (recirculating air system only)	N.A.
1978	Encapsulated washer exhaust fan with fiberglass and installed new replacement fiberglass ductwork on supply air system	N.A.

N.A. = Not available

Ventilation System Performance - Based on the previous air monitoring results and the velocity readings in Table 12-4, the following conclusions and comments are warranted concerning the effectiveness of the washer floor air systems:

1. Although the washer ventilation system was originally designed to exhaust approximately 6,000 CFM of air from each hood, much less is now being achieved. Poor fan performance and/or duct clogging with pulp is suspected.

2. Face and, hence, capture velocities at the important face just above the chlorine stage washer inlet are ineffective. No measureable face velocities were obtained along most of the washer width at this face, and chlorine gas could, therefore, easily escape from the hood. This is especially true if excessive amount of steam pressurizes the airspace beneath the hood; or if cross-drafts exist in front of this face.

3. As noted in Table 12-4, a number of air leaks were observed where this hood's takeoff duct connects to the tile duct an to the washer. The inside surface of this hood was also heavily coated with pulp which no doubt contributes to reduce an uneven air flow.

4. The chlorine dioxide stage washer hoods have much better and nearly even velocities across this important face. Total hood CFM's are still considerably below original design rating. These hoods also do not cover the washer inlet vat, and thus may prove less effective at capture of any chlorine dioxide released at this point.

5. The tangential-type, vertical takeoff duct used on all the washer hoods is potentially subject to entrainment of and resulting clogging from wet pulp. Such entrainment likely becomes more pronounced if washer upsets occur that result in stock being thrown off the drum. Once in the exhaust duct, wet pulp would cause considerable reduction in air flow and result in decreased hood effectiveness.

6. Variable levels of chlorine and/or chlorine dioxide exist in the washer room and in the nearby control center. This results primarily from gas escaping from the washers, with levels varying according to process conditions. Once in the workspace, contaminants are only slowly ventilated.

PERSONAL PROTECTIVE EQUIPMENT

Utilized and observed protective equipment in this mill is limited mostly to respirators. Rubber gloves and face shields are provided and occasionally used by the Chemical Unloader or Assistant Operator when they are required to handle potentially irritating or corrosive materials.

The bleach plant resirator program is part of an overall mill program. It includes: a detailed written summary, mill-wide weekly equipment inspection and service tours, and periodic worker instructions in the program. The written summary is contained in the mill's overall "Manual of Practice and Procedures" and covers the subject of:

- Location of general safety and protective equipment
- Department safety rules
- Respiratory hazards identification and location for selection of respirators
- Practices for cleaning and disinfecting air purifying respirators
- Inspection of air purifying respirators
- Selection, use, care, wearing/fitting, and the limitation of disposable-type dust respirators
- Procedure for filling compressed air cylinders
- Procedure for inspecting self-contained breathing apparatus (SCBA)

According to this program, chlorine and chlorine dioxide are specifically identified as the only two respiratory hazards in both the bleach plant and the chlorine dioxide generator area. However, particular conditions and work tasks for required use of respirators are not specified. Each bleach plant employee is assigned at least one half-face piece air purifying respirator for his personal use. It is specified that this respirator must either be cleaned and disinfected by the employee himself after each day's use (or not less than monthly), or exchanged for a new one. General administration of the respiratory program and training of workers is the responsibility of the mill safety department; with daily program enforcement residing with the individual department supervisors. The mill technical services department is

responsibile for performing the mill wide weekly inspections and cleaning/disinfecting procedures for the so-called "emergency respirators" located throughout the mill. Written and signed records are maintanied for these inspections and kept on file in the safety office.

The following number and types of "emergency respirators" are specified for the bleach plant:

Location	SCBA	Portable Air Cylinder, Supply Type Respirator	Full-Face Canister-Type, Air Purifying
Bleach Plant Washer Floor	3	2	4
Bleach Plant Elevator	-	-	4*
ClO_2 Plant	-	2	4

*Is to be replaced with air cylinder to supply 4 people.

Inspection of the bleach plant control room and the chlorine dioxide generator control building revealed the respiratory and other safety equipment summarized in Table 12-6 to be present.

Informal interviews with leach plant personnel indicate that all had been given instructions in the plant respirator program including: criteria for selection and use, care/inspection procedures, and the use of SCBA. However, none of the employees knew if they were medically approved to wear all types of respirators. Later checking with the mill safety director then indicated that the mill has no such formal medical approval requirement.

During the course of the survey, respirators were actually observed being used during two process upset periods. The first was the morning of November 13 when process startup problems required any employee on the washer floor to wear a half-face piece, air purifying respirator. Control room personnel also have briefly worn the same type of respirator. The continuous air monitoring data on the washer operating floor during this time shows that chlorine/chlorine dioxide levels were consistently above 0.1 ppm (as Cl_2). The first shift Operator revealed a late night process shutdown (8:30 pm to 1:00 am) was necessitated because of an apparent loss of fresh water to the bleach plant due to a pump failure.

TABLE 12-6: OBSERVED BLEACH PLANT RESPIRATORY AND OTHER SAFETY EQUIPMENT

BLEACH PLANT CONTROL ROOM:

Equipment	No. on Hand	Comments
o Respirators:		
Type N MSA full-face piece, filtering canister respirator	3	Additional respirators in locked cabinet issued to employees
Half-face piece filtering cartridge respirators	6	Cartridges were unsealed and left exposed to atmosphere; some appeared quite old as outer metal band was corroded
Case of replacement cartridges	3	Sealed in plastic wrappers
MSA SCBA respirators, in case with instructions	2	Cases were sealed with inspection stickers and tanks charged
Fully-charged tanks of air for SCBA	3	These are extra tanks for above two SCBA's
o Fire extinguisher	1	
o Eye & skin neutralizer for acids and alkali	1	

CHLORINE DIOXIDE CONTROL BUILDING:

o Respirators:		
Full face piece, canister type air purifying respirator - Window-Cator, Type N, Model "SW"[1]	6	
Half-face, disposable respirator for dusts and mists, Model Dust Foe 77	1	
Full-face piece, air purifying respirators, MSA Type N	3	Sealed with tape last inspected 11/6/80. May have been additional units in locked personal lockers

TABLE 12-6 (continued)

Equipment	No. on Hand	Comments
Half-face piece, air purifying respirators, MSA Comfo II, with screw-in replacement cartridges, NIOSH Approval TC-23C-47	3	One respirator each was found in three unlocked lockers; were six additional locked personal lockers
o Plastic eye shield	1	Found in locker
o Rubber gloves	1	
o Eyewash station	1	
o Wall-mounted acid/ alkali neutralization solution dispenser	1	Dispenser was full
Fire extinguishers	1	
Posted instructions (18" x 22") for: "Precautions in Handling Chlorine and Procedure in Case of Accidents" and "Precautions in Handling Caustic Soda - Suggestions for Convenient Unloading of Tank Car Shipments" (both by Solvay Co., Sales Div.)	1	

Notes:

[1]Rated for 2% acid gases, CO or organics, and 3% NH_3

The second observed incident of actual respirator use was during the investigation and repair of a major chlorine gas leak at the outside first sage injection tee. This occurred around noontime on November 13. Initial investigation of the leak (indicated by dropping line pressure observed by the Operator on the control panel) was made by the Assistant Operator. This was accomplished without use of a respirator, and involved spraying aqua ammonia around various potential leak sources (tank cars, vaporizers, hypo makeup system). After locating the approximate area of the leak, the Assistant Operator notified the Operator who then in turn assumed responsiblity for all further investigation. He was assisted by a pulp mill shift foreman. Both employees then obtained and wore full-face piece, air purifying respirators (MSA Type N) while first stopping liquid chlorine flow from the tank cars to the vaporizers; and also while establishing the actual location of the gas leak. As the chlorine leak was from the main gas pipe and appeared repairable, the shift foreman obtained a small rubber patch and anchoring clamps. He then proceeded to install the patch. This repair procedure required him to stand in a concentrated plume of chlorine gas for approximately 5 minutes while manually applying the patch. Although a new respirator canister had been installed beforehand, the wearer gave little consideration to the potential limitations of this respirator in such an environment (i.e., O_2 concentration 19%, Cl_2 concentration 2%, or oversaturation of the purifying media). After use, the two respirators were then returned to their normal storage compartments in the chlorine dioxide and bleach control buildings. However, neither worker cleaned or replaced their cartridges or gave instructions to do so.

WORK PRACTICES

Work practices to specifically reduce or control worker exposures were not identified in this mill. However, a number of job performance procedures and inherent isolation techniques are noteworthy:

- o Some workers have recognized the exposure condition when they open sampling lines containing concentrated bleaching agent solutions (ClO_2 absorber and spend acid) to collect quality control samples. They, therefore, attempt to stand upwind during these periods.

2. Some workers consciously do not allow such concentrated solution sampling lines to adequately flush before they collect a sample. This can lead to poor test results, the need to repeat the procedure, and resulting additional exposure.

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3. Operating personnel usually are not required to spend significant periods of time in close proximity to potentially high exposure equipment or materials - directly over washers, below the ClO_2 reactors or absorbers, over washer seal boxes, or at the hypo makeup system.

4. The aforementioned use of aqua ammonia spray to locate chlorine leaks in any systems (aqua ammonia reacts with chlorine to produce a visible white smoke).

Finally, the mill also has established an apparently well-publicized and effective system by which any employee is encouraged to report unsafe workplace conditions. Mandatory, written notification of the employee's supervisor, a plant management safety committee, and the safety department then must take place for this condition. Investigation and correction of a problem is performed either directly by the particular department, or referred to the safety department. In either case, written documentation must be kept of all actions, and the employee must be notified of the results of his complaint. Since other mills have an interest in developing similar programs, a copy of the mill's reporting form has been provided as Figure 12-/.

FIGURE 12: /

EMPLOYEE'S UNSAFE CONDITIONS REPORT

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EMPLOYEE REPORT — (See Instructions) Complete the following report.

Name _____ Clock Number _____

Department _____ Job Classification _____

Describe Unsafe Condition _____

Give Location of Unsafe Condition _____

Supervisor Reported to: _____ Date _____

Employee's Signature _____

Give white copy to your Supervisor and yellow copy to your Labor-Safety Committeeman.

SUPERVISOR — (See Instructions)

Name _____ Date _____

Unsafe Condition Has Been Corrected? Yes _____ No _____

If not, give reasons why not _____

Date Unsafe Condition was Corrected _____

Supervisor's Signature _____

After Completion send this copy to the Safety Department.

MANAGEMENT SAFETY COMMITTEE —

Labor Safety Committeeman Name _____ Date _____

Management Disposition _____

Work Order Number _____ Date _____

Date Corrected _____

INSTRUCTIONS FOR UNSAFE CONDITIONS REPORTING

The purpose of this procedure is to encourage employees to report unsafe conditions to their immediate supervisor so he will have the first opportunity to take corrective action. Also, this procedure provides a means of reporting these conditions and keeping all concerned aware of safety activities.

Unsafe Conditions Report Forms will be distributed to members of the Labor-Safety Committeemen and will be placed in Departmental Offices and Operating Control Rooms for employees to use.

Employees must report unsafe conditions in writing to his supervisor using the Unsafe Condition Report Form. The form is to be made out in duplicate — one is to be given to his supervisor and one to his Labor-Management Safety Committeemen.

The supervisor will try to get the unsafe condition as soon as practical. For most safety jobs the work should be accomplished within two weeks after it has been reported. Once the unsafe condition has been corrected the Supervisor should complete his section of the form and send it to the Safety Department. If the scope of the work is beyond the Departments capability to repair or if there is any question about whether an unsafe condition actually exists this should be noted and the form sent immediately to the Safety Department for disposition.

When an unsafe condition has been corrected the Safety Department will notify the individual initially reporting it.

condition is considered immediately dangerous to life or health, immediate response by the supervisor is to be expected by the employee or the Safety

MILL 22: SULFITE PULP WASHING AND BLEACHING (INCLUDING BLEACH CHEMICAL PREPARATION)

INTRODUCTION

Mill 22 consists of a sulfite bleach plant operating in the CEH sequence and chemical preparation operations including liquid chlorine unloading and vaporization, sodium hydroxide dilution, and sodium hypochlorite preparation. The mill was originally built in the early 1920's, and is located in the Pacific Northwest. Pulp washing operations were included in the survey because they are effectively within the bleach plant and assigned to that production staff.

PROCESS SUMMARY

Brown Stock Washing

Raw, hot sulfite pulp from the batch digesters is pumped to one of two stock storage tanks located in the pulp mill. From these tanks, it is then pumped to the bleach plant and washed counter-currently in one of two parallel EIMCO belt extractor-type washers. The clean stock is then deknotted and screened, and further washed in a vacuum drum washer. The stock is then stored until demanded.

Pulp Bleaching

A chlorine gas-water solution is injected into washed and dilute sulfite pulp, then thoroughly dispersed in a chlorine mixer. From the mixer, the stock is pumped through three upflow chlorine towers where the chlorine reacts with the colored lignin impurities in the pulp. The chlorine injection tee, mixer, and tower are all located outside. The chlorinated pulp enters a vacuum drum washer and the soluble chlorinated lignins and excess chlorine are washed out with mill water. The pulp is then pumped to the caustic mixer, and into a caustic extraction tower. Here the insoluble chlorinated lignin and other colored impurities are dissolved out of the stock and later removed in the caustic washer. From the washer repulper, the stock drops directly down into a steam mixer, with sodium hypochlorite injected directly into the line just prior to a stock pump. Heated, hypo-treated stock is pumped through a distribution system, manually controlled by a pneumatically-operated valve, to one of eight hypo cells on the main operating floor.

Each bleach cell consists of an open-top, tile-lined tank (8 feet diameter and 25 feet high) and holds about four tons of treated stock. In each cell, the stock is constantly mixed by a screw agitator located in the middle of the tank. After a bleaching period of about one hour, the cell contents are drained through a manually-activated valve in the cell bottom, while rinsing and diluting water are added through the top.

The bleached stock is emptied to a stock chest, pumped through a series of centrifugal (vortex) cleaners, and enters the hypo washer on the main operating floor. After washing with fresh water, the stock is repulped, dewatered in a high-density thickener, and stored in a bleached stock high density tower until demanded by the paper mill.

Bleach Chemical Preparation

Bleach chemical preparation includes liquid chlorine unloading and vaporization, sodium hydroxide (caustic) dilution, and bleach liquor (sodium hypochlorite) preparation. Sodium hydroxide (50%) is received in tank trucks and must be diluted prior to use in the bleach liquor makeup process and for the extraction stage (2nd) of pulp bleaching. Several times per shift, the caustic chest is first filled with a quantity of cool water; then 50% sodium hydroxide is slowly added and mixed to yield a 25% solution.

Liquid chlorine is unloaded from rail cars by using dry air to pad the cars and make it flow into the steam-heated vaporizers. Chlorine gas from the vaporizers is then regulated for pressure, and piped to the pulp chlorination tee or to the bleach liquor makeup tank. All of these liquid or gases chlorine handling systems are located outside.

The hypo bleach liquor is formed by the reaction of chlorine gas with sodium hydroxide. Depending on bleach plant consumption, batches of bleach liquor are manually prepared two to four times per shift. Each batch can be prepared in about 65 minutes, but usually requires a worker to be present at all times. To prepare the required strength solution, water and 25% sodium hydroxide are first added to a mixing tank through separate lines. Additional sodium hydroxide is then added until a Baume number 11 specific gravity is attained. Chlorine gas from the vaporizer is then carefully injected into a pipe through which the tank's contents are being continuously circulated by a small pump. The actual chlorine injection point is located just as the circulation line returns to the makeup tank, and the chlorine flow hand control valve is located immediately adjacent to this point for easy operator access.

Initially, chlorine can be added rapidly as the solution pH is high, and it reacts fully with the caustic to produce soluble hypochlorite. However, as the reaction nears its completion, the pH begins to drop and unreacted chlorine gas is potentially emitted to the workplace through the makeup tank's open observation port. To determine the proper rate of chlorine addition and extent of reaction, the makeup operator must frequently check the makeup tank's pH. To do this, he periodically squirts a small amount of pH indicator solution into the tank through the observation port, and then watches the rate at which the color changes. As the desired final strength of hypochlorite is approached, he must repeat this check quite often, and eventually slowly start to reduce the chlorine gas flow rate. When the desired final hypo strength is thought to be reached, the operator will then stop the chlorine flow and withdraw a sample of the tank's contents to test it for pH and chlorine concentration (from which the hypo strength can then be computed). If the proper strength is achieved, the tank's contents are then pumped to one of two nearby storage tanks. Otherwise, more chlorine gas (or caustic) is added as necessary.

As can be seen, the entire preparation operation requires considerable operator attention and skill. Although the makeup tank's observation port is hooded and ventilated, potential worker exposure could result from chlorine gas line leaks; over-additions of chlorine; and the collection of quality control samples. Detailed air sampling was performed to attempt to accurately assess this potential.

MILL LAYOUT

This integrated pulp and paper mill was originally constructed in the middle of an urban center around the turn of the century. As a result, space is now at a premium and the pulp mill complex is rather compact and congested. The batch sulfite digesters, pulp storage tanks, brown stock washers, screens and knotters, and bleach plant are all located within one continuous multi-story building. Basically, the pulp mill occupies the north side of the building and the bleach plant, the south side. A new two-story wing was added off the south side of the building in 1975 to house the two EIMCO extractor-type belt washers. The main bleach plant operating floor includes the main control center, the hypo bleach cells, the hypo washer, a stock thickener (decker), and various other equipment. Below this floor is a low-ceiling basement where various tanks are encased in the floor for storage of washer filtrate, bleach chemicals, hypo makeup, and other process materials. The chlorine and extraction drum washers are located on an isolated mezzanine above the main operating floor. The chlorine vaporizers and stock injection tee are located just outside the west wall of the main operating floor.

JOB CATEGORIES AND DESCRIPTIONS

Three employees per shift are responsible for the operation of the bleach plant and the chemical preparation systems:

Bleach Plant Operator - The bleach plant operator is responsible for monitoring all process indicators and for adjusting setpoints on controllers for bleaching equipment and brown stock washing. All operations in the washing and bleaching process are controlled by this employee, who reports directly to the shift foreman. He is also responsible for maintaining the daily production log report and identifying any process upsets or equipment malfunctions. He remains in the control room about 75% of the time, leaving this workspace primarily to perform periodic process inspections and adjustments.

Assistant Operator - Under the direction of the Operator, this employee will assist in the monitoring and operation of the bleach plant, including the brown stock washers. Many of the manual process adjustments are conducted by the assistant operator, including draining the bleach cells, and collecting pulp samples for chlorine residuals and brightness tests. In addition, when the utility employee is occupied in the chemical preparation area, the assistant operator will conduct equipment checks and perform any housekeeping or cleanup chores. It is estimated that this employee spends only about 60% of each shift in the control room.

Utility Employee - The Utility Employee assumes a dual role at this mill. He is responsible, under the supervision of the Operator, for all the bleach chemical preparation systems, including chlorine unloading and vaporization, caustic dilution, and bleach liquor preparation. However, when not required to perform these tasks, he is also responsible for housekeeping and spill cleanup duties, and equipment inspections in the bleach plant. It is estimated that this employee spends less than 20% of each shift in the control room.

AIR SAMPLING RESULTS

Potential Chemical Workplace Exposures

The most significant potential air contaminants in the bleach plant and brown stock washing area are chlorine and sulfur dioxide. Sources of chlorine gas escape include the chlorine and hypo washers (primarily only during overbleaching events), the open top bleach cells, and leaks from numerous process equipment, (including the chlorine and caustic extraction towers, the gas transport and pressure control lines, and the washer filtrate tanks). Sulfur dioxide may be emitted from either the EIMCO belt-type or vacuum-drum brown stock washers (on the bleach plant operating floor), or may enter the bleach plant from the adjoining pulp mill.

Chlorine is the only significant potential contaminant in the chemical preparation area, which would include the outside chlorine unloading and vaporization systems, and the inside bleach liquor makeup operation. Sodium hydroxide is received and handled only in solution (50% strength), and is thus an unlikely source of airborne exposure.

Chlorine Monitoring

Long-term chlorine monitoring using a Mast Oxidant Monitor was conducted at four bleach plant locations over a 48 hour period. As shown on Figure 22-1, the recorded chlorine concentrations at each of the monitoring locations were as follows:

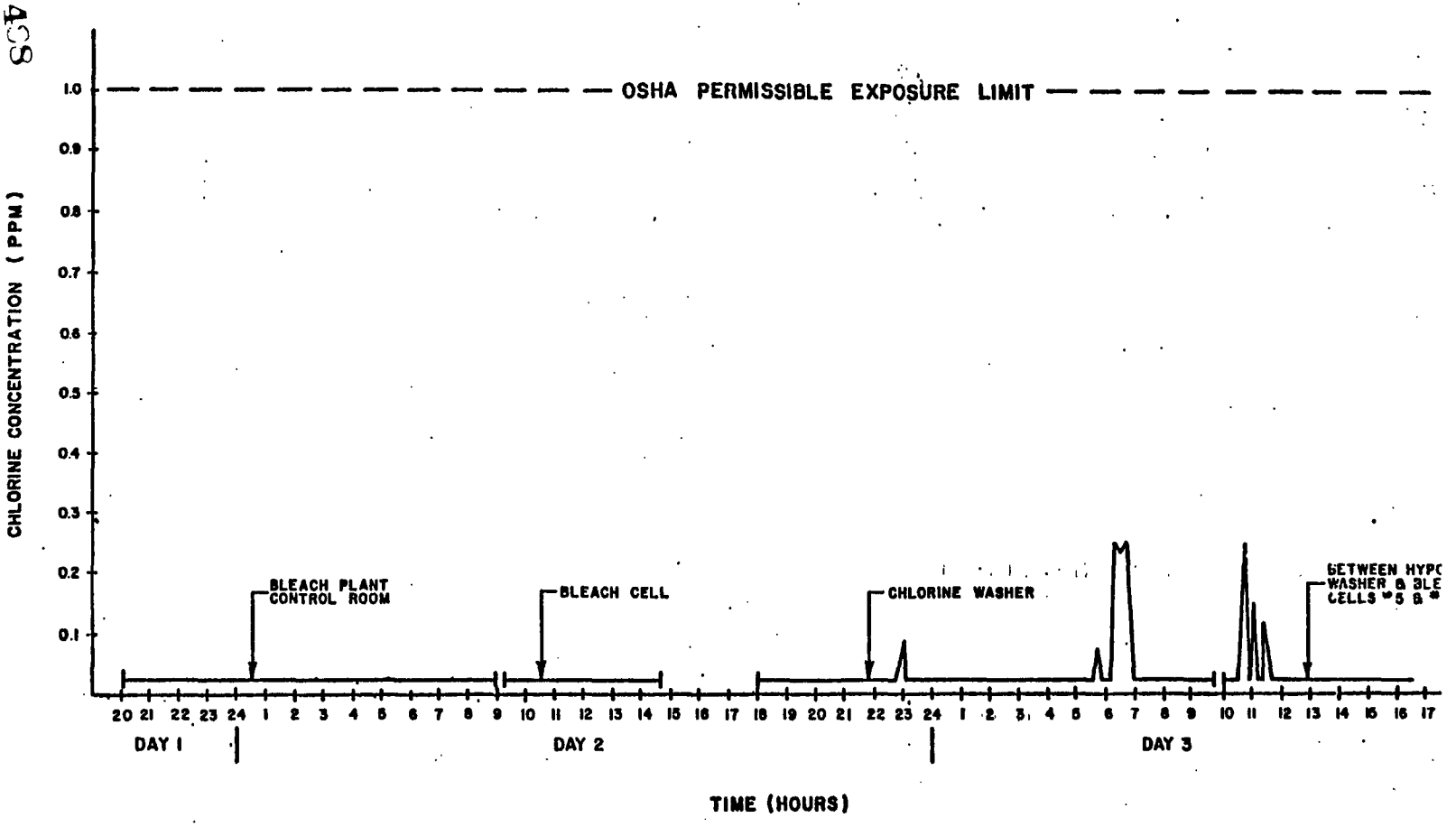
- Bleach plant control room (20:00 day 1 to 9:00 day 2) The monitor was operated for about 13 hours in the control room, with chlorine concentrations essentially non-detectable (0.05 ppm) throughtout the period.

- No. 4 bleach cell (9:15 day 2 to 14:45 day 2) -- chlorine concentrations were also essentially non-detectable directly adjacent to this bleach cell over the 5 1/2 hour monitoring period.

- Chlorine washer (18:00 day 2 to 9:40 day 3) -- Three peaks in chlorine concentration were recorded over this approximate 15 hour period (0.1 ppm at 23:00; 0.08 ppm at 5:40; and 0.3 ppm between 6:00 and 7:00 on day 3). As production logs were not available, it is impossible to correlate these peaks with process or upset conditions. However, since the maximum peak (0.3 ppm) is less than 30% of the OSHA ceiling PEL, it appears that workplace chlorine concentrations around the chlorine washer are generally relatively low. Except for these three peaks, chlorine concentrations remained at or below 0.05 ppm.

- Between hypo washer and No. 5 & No. 6 bleach cells (10:00 day 3 to 16:30 day 3 -- During this monitoring period, there were three consecutive peaks in chlorine concentration (maximum 0.3 ppm) over a one hour period. As before, given the absence of production logs, it is impossible to pinpoint the cause(s) of these peaks. However, since the maximum peak (0.3 ppm) is well below the OSHA ceiling PEL, it is concluded that chlorine concentrations around the bleach cells and the hypo washer are typically very low.

FIGURE 22-1: CHLORINE CONCENTRATIONS IN BLEACH PLANT



The Mast Oxidant Monitor was also used to determine chlorine concentrations at the bleach liquor mixing tank during an entire preparation cycle (Figure 22-2). As shown, chlorine concentrations are very low (<0.1 ppm) during the 40 minutes required to add the chlorine/water solution to the mixing tank (17:00 to 17:50). There was a small peak (0.1 ppm) shortly after the utility employee started draining the tank. These data indicate that, unless there is a leak from a valve or from the injection tee, a significant amount of chlorine is not given off during this operation. There was a significant chlorine peak at about 18:20 (0.7 ppm), or after the bleach liquor makeup cycle was completed. It is believed that this peak was caused by the over-addition of hypo at the hypo cells resulting in high chlorine residuals in the nearby hypo washer filtrate tank.

Area samples for chlorine and sulfur dioxide were also collected, and the results are presented on Table 22-1. Chlorine sample No. 1 and 2 were collected (Drager Tubes) very near the chlorine and hypo washers (inlet side) and resulted in non-detectable concentrations (<0.1 ppm). The next two samples were collected directly over the open tops of two bleach cells, one during the loading cycle and one during the retention cycle. Neither sample resulted in detectable concentrations of chlorine. Sample Nos. 5 through 8 were collected in the bleach liquor makeup area using NIOSH P & CAM 209. The two samples taken near the top of the bleach liquor mixing tank did not result in detectable concentrations of chlorine. The next two samples, collected at the adjacent bleach liquor testing station and in the locker room, resulted in detectable, but very low chlorine levels (0.06 ppm). These data are highly compatible with the Mast Oxidant monitor data and reinforce the conclusion that chlorine concentrations in the bleach plant and at the hypo makeup area are very low except during leaks, overbleaching events, or other periodic upset conditions. A 15 minute area sample was also collected for sodium hydroxide (NIOSH P & CAM 241) during bleach liquor preparation. The sample was collected near the top of the mixing tank, and no sodium hydroxide was detected (<0.01 mg/m^3).

Sulfur Dioxide Monitoring

Area detector tube samples were also collected in the bleach plant for sulfur dioxide (Table 22-1). The bleach plant is attached to the pulp mill and there is the possibility of sulfur dioxide gas from this source. In addition, the EIMCO belt extractor washers and the brown stock washer are located in separate rooms adjacent to the bleach plant operating floor,

Figure 22-2: Chlorine Concentration in bleach liquor make-up area (Most Oxidant Monitor)

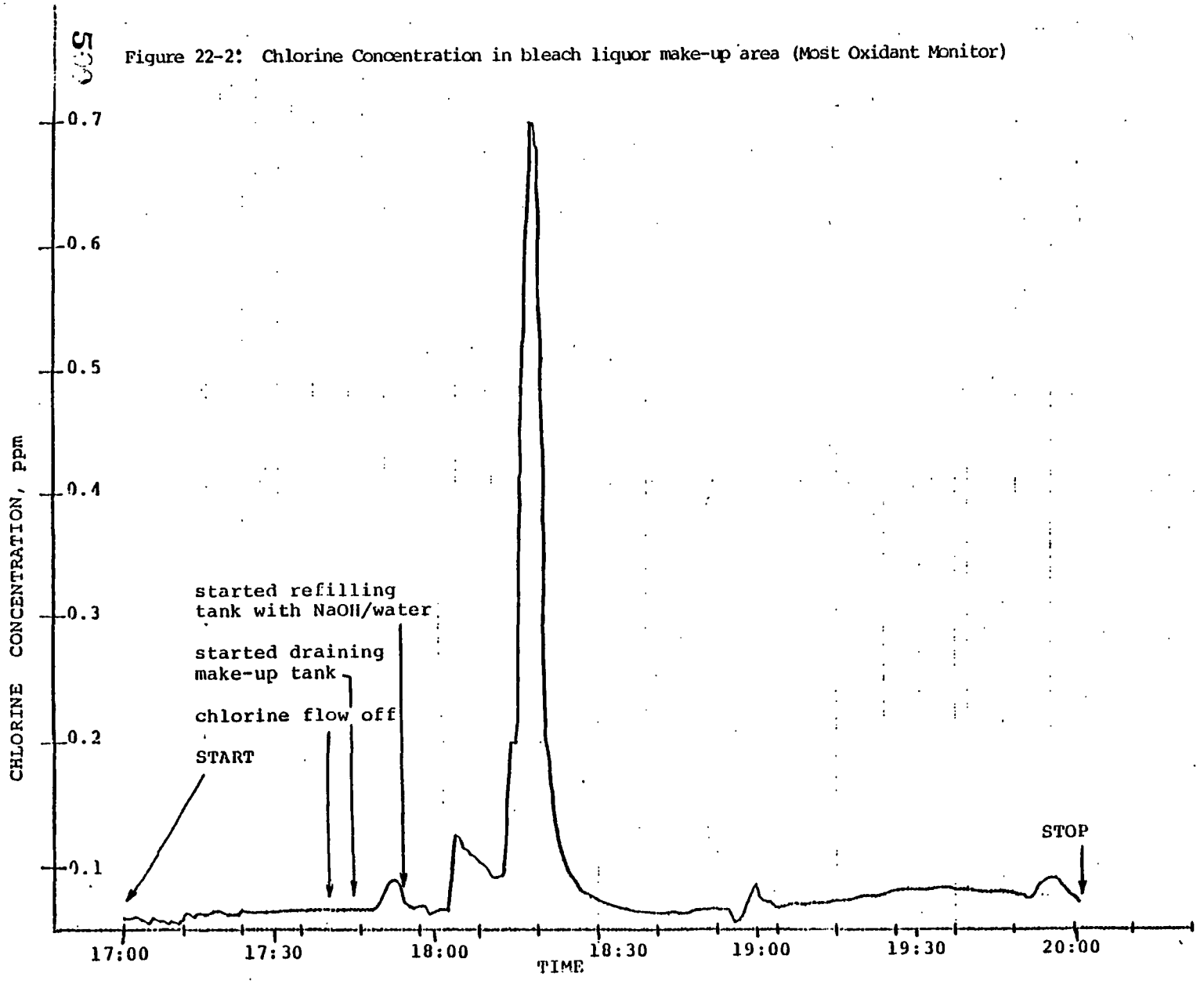


Table 22-1: Area Sample Results

No.	Sample Location	Concentration (ppm) Sulfur Dioxide	Chlorine	OSHA PEL (ppm)	Comments
1.	Beside chlorine washer	---	<0.1	1 ceiling	Draeger Detector Tube
2.	Beside hypo washer	---	<0.1	1 ceiling	Draeger Detector Tube
3.	Directly over No. 4 bleach cell during stock loading	---	<0.1	1 ceiling	Draeger Detector Tube
4.	Directly over No. 6 bleach cell during retention cycle	---	<0.1	1 ceiling	Draeger Detector Tube
5.	Near bleach liquor mixing tank	---	<0.05	1 ceiling	NIOSH P & CAM 209, 20 minute sample
6.	On shelf adjacent to bleach liquor mixing tank	---	<0.05	1 ceiling	NIOSH P & CAM 209, 21 minute sample
7.	In locker room	---	0.06	1 ceiling	NIOSH P & CAM 209, 15 minute sample
8.	At bleach liquor testing station	---	0.06	1 ceiling	NIOSH P & CAM 209, 15 minute sample
9.	Doorway from pulp mill to bleach plant	<0.5	---	5 TWA	Draeger Detector Tube
10.	Outside bleach plant control room	<0.5	---	5 TWA	Draeger Detector Tube
11.	Doorway to brown stock washer from bleach plant	<0.5	---	5 TWA	Draeger Detector Tube
12.	Between EIMCO washers (washer No. 2 not operating)	1.0	---	5 TWA	Draeger Detector Tube
13.	Between EIMCO washers (both operating	<0.5	---	5 TWA	Draeger Detector Tube
14.	Between EIMCO washers (both operating)	<0.5	---	5 TWA	Draeger Detector Tube
15.	Doorway from Bleach Plant to EIMCO Washer Room	<0.5	---	5 TWA	Draeger Detector Tube

and may also be a source of sulfur dioxide exposure. (A small amount of sulfur dioxide is also added to the hypo washer shower to neutralize the hypo; however, the quantity is very small and it is soluble in water). The three area samples indicate that sulfur dioxide concentrations in the bleach plant are generally very low (0.5 ppm). However, its concentrations is highly dependent on pulp mill process variables, meteorological conditions, and numerous other factors; and our limited sampling data are far from definitive.

Based on the results of the detector tube samples for chlorine and the Mast monitoring results, it was determined that detailed personal monitoring for chlorine was not required. The previous samples were collected at positions judged to most likely yield significant results and, since no high levels were recorded, it can be concluded that exposures are very low during normal operating conditions. In addition, the operator and assistant operator spend a good portion of each shift in the control room, away from potential emission sources; and most workplace chlorine emissions result during process upsets or leaks. Short-term personal samples were collected on the utility employee to assess exposure to chlorine during a bleach liquor make-up operation. Three sequential personal samples were collected on this employee over the 50 minute period required for the full cycle. As shown below, no chlorine was detected in any of the three samples.

Job Category	Sampling Period	Sampling Time (mins.)	Chlorine Concentration ppm	OSHA PEL (ppm)
Utility Employee	13:04-13:19	15	< 0.05*	1
Utility Employee	13:20-13:37	17	< 0.05	1
Utility Employee	13:39-13:54	15	< 0.05	1

As with the Mast monitoring results and the area samples, these data indicate that the utility employee's exposure to chlorine is very low except during leaks or other upsets.

*Limit of Detection

CONTROL TECHNOLOGY

Nature of Controls

Effective control of worker exposures to process chemicals in this bleach plant (and brown stock washing area) is largely a result of the inherent nature of the process and its associated equipment. In particular, chlorine is brought into the mill in liquid form and vaporized to the gas systems that must be closed and airtight at all times. Unloading and vaporization systems are located outside. The chlorine is mixed with pulp stock in closed process systems. A significant portion of it then reacts with the pulp or dissolves in the pulp water and is no longer an airborne hazard. When the chlorinated stock reaches the first stage washer, any remaining chlorine may escape through the washer into the workplace; be washed out of the stock and enter the washer filtrate tank; or continue on with the stock. Worker exposure risk from the first two sources is not thought to be significant unless too much chlorine has been used (i.e., over-addition). The frequency and severity of such over-addition were not established, but it is not thought to pose a significant exposure risk to production employees unless the over-addition period is prolonged. This contention is made because of the remoteness of this washer and the degree of worker isolation in this mill. Currently, less than maximum control can be obtained if chlorine should off-gas at this washer because the hood's fan is inoperable. During the survey period, no such periods of over-addition were actually observed, and air flow direction readings indicated that passive ventilation through nearby windows was important in reducing accumulations of chlorine around this washer.

The other use of chlorine in this mill is also inherently well-controlled, but more as a result of process chemistry. Specifically, alkaline sodium hypochlorite solutions will not evolve significant amount of free chlorine gas unless the pH is lowered and/or a significant temperature rise of the solution occurs. The detector tube, Mast monitor, and personal sampling data all confirm that there is little chlorine present in the workplace air around the hypo cells, hypo washer, or the hypo makeup and storage tanks. Some worker exposure may occur during the manual preparation of hypo using chlorine gas and sodium hydroxide. However, the source of release of chlorine, the observation port on top of the makeup tank, is fitted with a small enclosure and local exhaust system. The effectiveness of this engineered control will be discussed below under "Ventilation".

Considerable residual sulfur dioxide gas is probably released when the hot sulfite pulp enters the EIMCO belt extractor washer. For this reason, these washers are hooded and ventilated, with the hood ducts vented to the pulp mill gas recovery system. These washers and their tight-fitting hoods are also discussed below under "Ventilation". After the initial washing step, the brown stock apparently does not contain enough residual sulfur dioxide to pose any additional exposure risk. Therefore, the final washing stage does not require an exhausted hood or other controls. Workers entering the washer area are more likely to be exposed to sulfur dioxide from the adjoining digesters and hot stock tanks than from the washers.

Ventilation

Although chlorine air monitoring results were low, after observing process operations for two days, the survey team was concerned over the condition (and amount) of active ventilation systems, and the ability to ventilate worker-occupied areas should upsets or leaks occur. Of particular concern were:

- the inoperation of the chlorine (and caustic extraction) washer hood fans;
- limited general ventilation of the hypo cell area considering the proximity to the main control center; and
- the possible infiltration of sulfur dioxide gas from adjoining digester areas.

For these reasons, it was decided to perform complete air flow measurements around the bleach plant and brown stock washing areas. Since the washer exhaust fan is inoperable, the only ventilation for the operating and mezzanine levels are the three exhaust wall fans behind hypo cells 6 through 8. Two of these were inoperable, and the discharge from the third was partially boarded over. All ventilation is therefore passive and dependent on existing environmental conditions. Also, the new building wing housing the EIMCO washers is under some negative air pressure because of the washer hood exhaust. This causes some makeup air to move from the operating area into this wing.

Four general conclusions are warranted based on these readings:

(1) Air is entering the main operating floor area through doorways and wall openings. Should significant amounts of chlorine gas be released into this area, it would only slowly be dispersed, diluted and removed.

(2) Air moves from the digester area to the bleach plant operating floor. Sulfur dioxide gas emitted from the pulp mill could therefore easily enter the bleach plant.

(3) There is adequate passive ventilation on the washer mezzanine, primarily caused by drafts through open windows.

(4) The control room affords some protection in the event of a major chlorine or sulfur dioxide leak. However, since the ventilation system is based on 100% recirculation, there is no positive pressure developed to prevent entrance of process gases. Contamination of the control room would therefore be difficult to prevent and handle once it occurred.

EIMCO Brown Stock Washers - The two EIMCO belt extractor-type brown stock washers (Model 4646) were added to the mill in 1975. Originally, these units were developed for the treatment and refining of ores in the mining industry and have not been widely used in the pulp industry. Management in this mill expressed a high degree of satisfaction with their performance; and they do facilitate the installation of tight-fitting, effectively-ventilated hoods to control sulfur dioxide emissions to the workplace. Tight-fitting hoods are possible because the washers consist of a long, narrow, flat-top tray mounted on a large support stand.

In operation, pulp flows up into an inlet vat at one end (covered by the hood and with a hinged access panel on top) and is picked up on a rotating, flexible continuous belt (water-lubricated) fitted with a wire mesh filter fabric (1" thick). A thick layer of pulp is formed on the fabric and is transported down the length of the washer. Along the way, it enters a series of compartments and is sprayed with wash water. Suction is provided from the bottom to remove the wash water. A countercurrent wash water flow (similar to conventional multi-stage drum washing) is used to minimize water consumption and maximum recovery of chemicals. The filtrate collection tray is tightly sealed to the revolving filter by means of teflon seals to maintain the required internal vacuum. After the last washing stage, the pulp is removed with a doctor blade and drops to a surge tank. The filter belt then rotates over a drive roller, is washed with a water spray, and then returns to the inlet vat.

Because the washer is long, narrow, flat and uses a continuous filter belt, a total enclosure-type hood can be fitted. There are few (if any) open faces through which steam or gases can escape, or stock can overflow. Good access and observation of the filter belt is still possible, however, through hinged panels along either side of the hood.

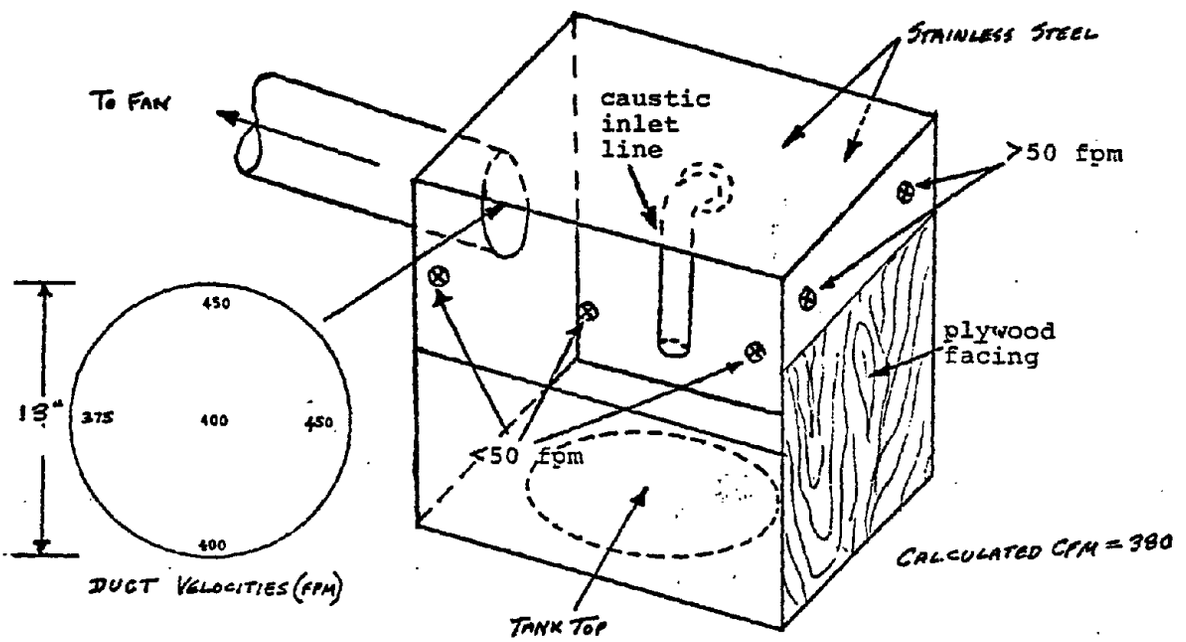
The two hoods are both exhausted by a single fan, rated at 8000 cfm. Exhaust gases and vapors are ducted to an absorption tower to recover the sulfur dioxide. Because the hoods form a relatively full enclosure over the washers, a large air flow is not required to prevent the emission of contaminants. Detector tube readings for sulfur dioxide taken near the washers (Table 22-1, samples 12-15) demonstrate the effectiveness of the hoods. Mill personnel reported that washer emissions occur only when there is very high back pressure in the absorption tower and, since modifications have been made, this is a rare occurrence.

Hypochlorite Makeup Tank Hood - The ventilated hood over the hypochlorite makeup tank is very important to insure that employees are not exposed to excessive chlorine gas during the hypo preparation operation. The hood (Figure 22-3) consists of a stainless steel and plywood box fitted over the observation port on top of the makeup tank. Open faces exist in front and on the right side, where the plywood does not extend up to the top. Face velocities ranges from 50 fpm through the upper right hand opening, to 50 fpm through the front face. The total air exhaust volume was calculated to be about 380 cfm, based on a traverse of the take-off duct. Although 50 fpm is generally not a sufficient face velocity, based on sampling and observations, it was judged to be adequate to capture small amounts of chlorine given off during the hypo preparation. The hood may not be effective if significant over-addition and off-gasing of chlorine occurred, or if a chlorine gas line leak developed.

Miscellaneous Controls

Since no other sources of significant emission or release of chlorine or sulfur dioxide to the workplace could be identified, other controls are not required. The hypo cells (utilized in the final stage of pulp bleaching) do not normally pose chlorine emissions problems but are also not in common use in the industry (and not likely to become so). Similarly, precise control over the amount of first stage chlorine added to the pulp is also not practiced, although an automatic oxidation-reduction probe controller is used and is effective.

FIGURE 22-3: HYPO MAKEUP TANK HOOD



An assortment of personal protective equipment is provided for employees use. This includes respirators (full-face piece air purifying, and self-contained breathing apparatus), rubber boots and gloves, and eye shields. Respirators are kept in the control center, and in the worker station next to the hypo makeup tank. Most appeared to be clean and in good working order. Eye shields are also kept in the hypo area work station for use when handling strong caustic solutions. They were not, however, observed being used when the utility man prepares a batch of 25% caustic from purchased 50%, or when 25% caustic is diluted down in the hypo makeup tank (prior to making hypo).

Formal work practices to limit or avoid exposures are also not established, although workers displayed a good understanding of the process and associated exposure potentials. However, of particular concern was the extent of a single worker's involvement in the caustic dilution and hypo makeup operations, and the remoteness and isolation of these areas should an upset or emergency occur.

MILL 25: KRAFT BLEACH PLANT AND CHEMICAL PREPARATION OPERATIONS

INTRODUCTION:

Mill 25 is a Southern bleach plant with two parallel bleaching lines, one for hardwood (A-line) and one for softwood (B-line.) It bleaches 1200 TPD of Kraft pulp from two continuous Kamyr digesters. The hardwood system has four stages (CEHD), and the softwood five stages (CEHDD). The mill began operation in the early 1960's and few changes have been made since then. Bleach chemical preparation systems include steam-heated vaporizers, an R-2 chlorine dioxide generator, automated caustic dilution equipment, and an automated sodium hypochlorite reactor. Most of these systems are located outside, and pose little exposure to workers. The bleach plant shares a control center with the pulp mill and this is the only enclosed workspace in either process area.

MILL LAYOUT

Bleaching operations are performed in a three-story building that has no walls. Prior to the survey, the mill removed most of the building's roof for repair work and current plans are to put back only a small center section. Therefore, during our survey, the entire building was open. The upper (operating) floor contains the control center and bleach washers, brown stock washers, and deckers and screens for each process line. The steam mixers and the tops of the washer seal boxes (filtrate tanks) are located on the second floor. The ground floor contains the filtrate tanks and a number of stock and water pumps. The chlorine injectors are located on extensions off the second floor near the chlorination towers.

The sodium hypochlorite reactor and the R-2 chlorine dioxide generator are both located on one side of the operating floor in front of the hardwood line's first-stage washer. Neither are enclosed and the generator's absorption tower exhausts through the open roof. The liquid chlorine unloading station and steam vaporizers are located just outside the building, and are also totally open.

PROCESS DESCRIPTION

Pulp Bleaching

The hardwood and softwood bleaching lines are arranged in parallel, use similar equipment, and produce about the same quantity of bleached Kraft pulp (approximately 500 TPD each).

Final pulp brightness is in excess of 83 G.E. units. The softwood line also produces some low brightness (72-74 units) pulp by diverting part of the pulp flow after the fourth stage (i.e. the first ClO_2 stage).

Bleaching is achieved in distinct stages by controlled reactions with chlorine gas, sodium hydroxide (caustic), sodium hypochlorite, and chlorine dioxide. Each stage involves:

- Injection of the required quantity of chemical into the flowing pulp (at the washer outlet or through a specific mixer).
- Mixing of the chemical and the pulp in some type of closed process element (static chlorine mixer, chlorine dioxide mixer, the washer repulper screw, or steam mixer).
- Automatic addition of steam to achieve the desired reaction temperature.
- Completion of the reaction in large, outside towers designed with sufficient retention volume for the required reaction time.
- Dilution and washing of the reacted stock to remove the soluble, color-causing impurities (accomplished in hooded, vacuum-drum washers).

After the last stage in each line, pulp of the proper brightness is pumped to segregated, high density storage tanks until demanded by the papermill.

Physical and operational differences in the two lines are related to the increased difficulty of bleaching softwood pulp (Southern pine) to high brightness levels. Equipment in each stage of both lines is nearly identical, but the softwood line uses more chemicals and has an additional (final) chlorine dioxide stage. As shown in the table below, summarizing and comparing typical operating conditions for each line, much more chlorine gas is used in the first stage of the softwood line (2500-3000 lbs./hr versus 1500-2000 lbs./hr.), and 30-50 gallons per minute of chlorine dioxide are used in a final (5th) stage. This final stage raises pulp brightness from 72-74 (after the first chlorine dioxide stage) up to 83+ units.

TYPICAL OPERATING RANGES

Parameter	Softwood Line	Hardwood Line
Brown Stock Flow	24-28 Tons/hour	18-22 Tons/hour
Consistency	2.8 - 3.0%	2.8 - 3.0%
First Stage Cl_2 Residual (at washer Vat)	0.03-0.05 gpl	0.04-0.06 gpl
Cl_2 Gas to First Stage	1500-2500 lbs./hr.	500-1500 lbs./hr.
Pulp Brightness:		
After Hypo Stage:	64-67 units	72-74 units
First ClO_2 Stage:	72-74 units	83 + units
Second ClO_2 Stage:	83 + units	N.A.
Final ClO_2 Residual	0.01 - 0.03 gpl	0.01 - 0.03 gpl
Hypochlorite Flowrate[1]	20 - 50 gpm	30 - 60 gpm
Chlorine Dioxide Flowrate[2]		
First:	40 - 60 gpm	60 - 100 gpm
Second:	30 - 50 gpm	N.A.

The equipment in each line is conventional for the industry, and is adequately described in other mill reports of this study. Most is outside and little emission of chlorine or chlorine dioxide is possible unless leaks or upsets occur. Additional physical and operational characteristics pertinent to this study include:

- An Optichlor system on the softwood line and a tower oxidation-reduction probe (ORP) system on the hardwood line (to control the amount of chlorine gas injected in the first stage).

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1 At 35-40 grams per liter Cl_2 with 2.5 - 3.5 gpl excess NaOH

2 At 6.5 - 7.0 grams per liter ClO_2

- Totally-closed chlorine mixers (these replace Kamyr impellor-type dynamic mixers which required sealing).
- Upflow first-stage chlorination towers, versus downflow caustic, hypo, and chlorine dioxide towers (chlorine dioxide towers have small upflow pre-retention towers and all towers are agitated).
- Chlorine gas mixing tees which utilize first stage (washer) filtrate water.
- Addition of a small supplemental amount of chlorine dioxide in both first stage towers (15 gpm of 6.5 - 7.0 gpl strength).
- Hypochlorite additions (for third stage) through the extraction stage washer repulper.
- Pulp level and pH transmitters (and recorders) in the inlet vat of the caustic extraction, hypochlorite, and chlorine dioxide stage washers.
- Use of Kamyr-type titanium-lined chlorine dioxide mixers.
- Continuous pulp brightness sensors mounted in the hoods of the hypo and chlorine dioxide stage washers (levels are continuously recorded in control room, but not used to directly control these stages due to suspected inaccuracy).
- Short dropleg washers; chlorine and chlorine dioxide stages vented to separate exhaust scrubber systems.
- Use of fresh (mill supply) or hot water for all washer showers with filtrate water recirculated only to the associated closed tower or to the post-tower stock line (softwood line showers are piped for some filtrate water recirculation, but recirculation is not commonly used).

Bleach Chemical Preparation

Chlorine dioxide and sodium hypochlorite solutions are produced directly on-site in automated systems. Chlorine is purchased in liquid form and vaporized to the gas in conventional, steam-heated vaporizers. Sodium hydroxide (caustic) is purchased as a 50% solution and diluted automatically to three weaker strengths (25%/30%, 5%, and approximately 4.5%.) Therefore, the four observed chemical preparation systems are:

- An R-2 chlorine dioxide generator

- o Steam-heated liquid chlorine vaporizers (3)
- o A sodium hypochlorite reactor
- o Caustic (sodium hydroxide) dilution systems (3)

Each system employs conventional equipment and technology, and simplified process flows for all are shown on Figure 25-1:

R-2 Chlorine Dioxide Generator - In this system, chlorine dioxide (and half a mole of chlorine byproduct) is produced by the controlled reaction of R-2 solution (sodium chlorate and sodium chloride) and sulfuric acid:

$$NaClO_3 + NaCl + 2H_2SO_4 \rightarrow ClO_2 + 1/2\ Cl_2 + 2NaHSO_4 + H_2O$$

As shown, this is accomplished in a lead-lined reactor vessel which is water-jacketed and cooled to maintain proper reaction temperatures. Filtered reactants are fed into the reactor's upper section, and then mixed by pressurized air added through six nozzles in the reactor's bottom. The resulting chlorine dioxide gas in air (plus chlorine and other minor impurities) then exits the reactor's top and is drawn by an induced draft fan through two packed absorption towers. In the first tower, most of the chlorine dioxide (plus approximately 25% of the chlorine) is absorbed in chilled water (45° F) to give a 6.5 - 7.0 grams per liter solution. This is then stored in a large tank (vented back into the absorption tower) until pumped to the bleach plant.

The byproduct chlorine gas is mostly removed in the second absorption tower which uses a weak sodium hypochlorite solution (recirculated from the hypo makeup system.) The more concentrated hypochlorite solution that results is then reused in the bleaching process rather than wasted. Since neither of the two towers are totally efficient, a two-stage vent scrubber is used to remove any remaining chlorine dioxide and chlorine.* The towers use chilled water for chlorine dioxide scrubbing, and weak hypochlorite for chlorine-both then drain back into the process and are reused.

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*This two-stage scrubber had been removed at the time of the survey in order to perform repairs to the bleach plant roof.

The entire generator is automated, and other than collection of periodic quality control samples (absorber solution, reactor gas, and spent acid), it functions with a minimum of operator intervention. The system is monitored from the main control center, and is equipped with a number of safety systems which will be discussed later under "Process Controls".

Liquid Chlorine Vaporizers - The mill uses conventional steam-jacketed vaporizers (3) to heat the liquid chlorine and convert it to a gas. As shown in Figure 25-1, dry air is used to 'pad' the tank car and make the liquid chlorine flow to the vaporizers. These are then heated by automatically regulating steam flow, and the resulting gas flows out through safety piping network to the bleach plant and the hypochlorite preparation system.

Caustic Dilution and Hypochlorite Preparation - These two systems are inter-related; the first producing the dilute sodium hydroxide which later reacts with chlorine gas in the second to form sodium hypochlorite solution (35-40 gpl Cl_2 plus 2.5-3.5 gpl excess NaOH). In addition, they provide a means for safe, economical, and efficient disposal (or blowdown) of chlorine gas from equipment during upsets or leaks. (Residual liquid chlorine in empty railroad tank cars is also evacuated to the blowdown system prior to disconnection.)

As shown in Figure 25-1, automated preparation of caustic is achieved by progressively diluting and mixing delivered, concentrated solution (approximately 50%) with fresh water in a reactor and mixer. The dilution water flow rate, and hence the solution strength, is determined and regulated by means of conductivity sensors after the mixer. Using four such dilution systems, solutions of 30%, 25%, 5% and finally 4.5% are prepared as needed. Each is then stored in separate tanks and becomes the reactant for the next lower dilution system, or is used in the bleach process: the 25% for the caustic extraction stage and the 5% for pH adjustment in the hypochlorite and chlorine dioxide stages. The last caustic dilution system produces a solution of approximately 4.5% concentration which serves as the makeup for the hypochlorite reactor.

To prepare hypochlorite, the caustic reactant (4.5%) is stored in a closed, hypo-blending and blowdown tank (see Figure 25-1). The contents of this tank (actually a weak hypo solution) are continuously pumped out, and then divided for two purposes. A small amount is continuously circulated through an eductor element, then back into the tank. The suction leg of the eductor is used during an emergency or before any repair work to evacuate chlorine gas from the vaporizers, gas lines, or the chlorine tank cars. Gas drawn into the eductor reacts with the caustic to form weak hypochlorite solution.

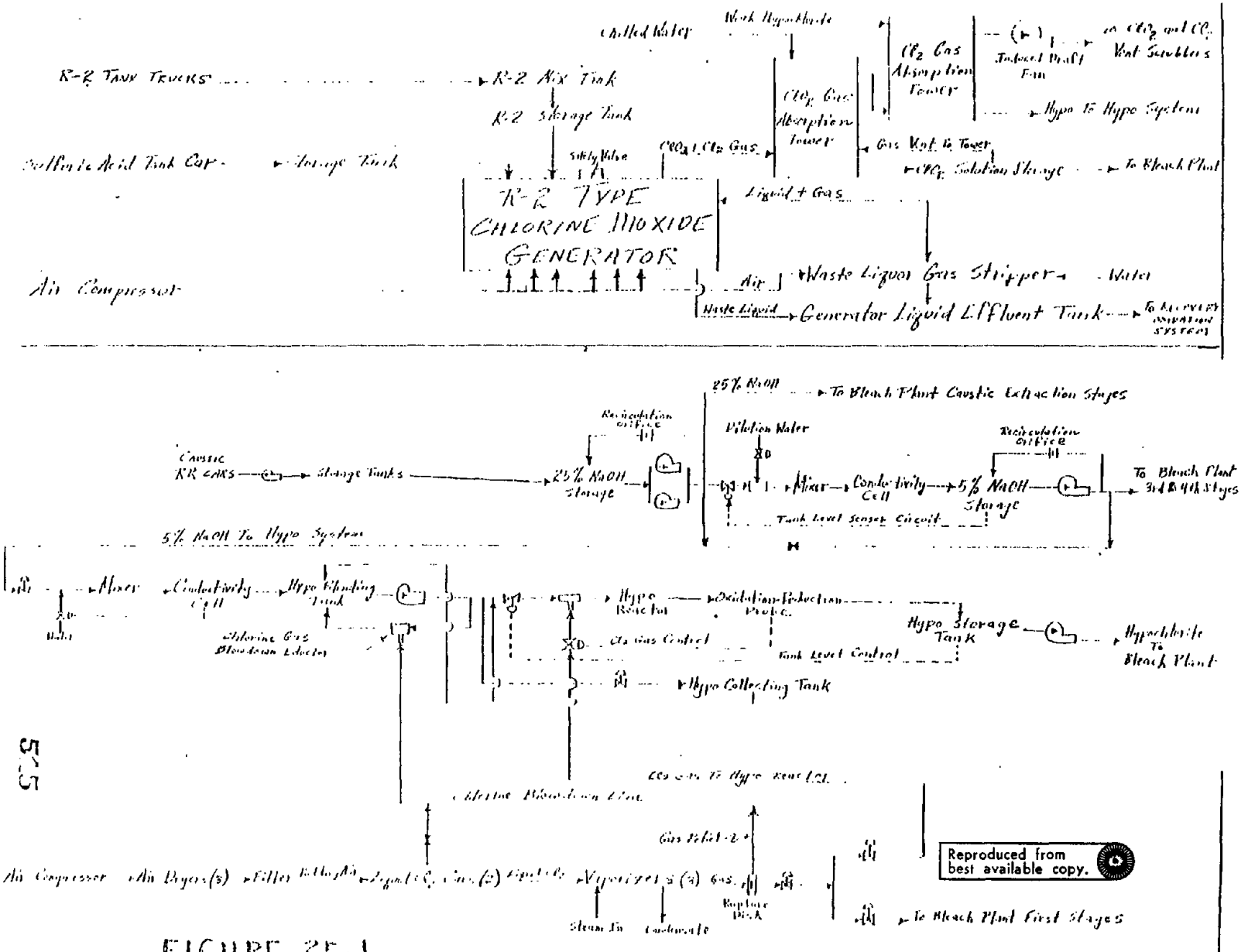

FIGURE P5-1

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The remaining liquid in the hypo blending tank is pumped to the hypo collecting tank then to the hypo reactor. Sodium hypochlorite bleach liquor is prepared by injecting chlorine gas (3.72 tons per day) into a pipeline containing the 4.5% caustic, mixing the caustic and chlorine in a sealed reactor, and then storing the resulting 35-40 gram per liter hypochlorite solution in a tank. Solution strength is continously monitored with an in-line oxidation-reduction probe. The probe's output is interfaced with a controller which operates the chlorine gas flow-control valve, and thereby regulates the solution strength within acceptable limits.

The hypo collecting tank's contents are pumped to the various chlorine gas vent scrubbers (to be discussed later). Here the caustic (or weak hypo) reacts to form more hypochlorite which drains back to the hypo collecting tank.

JOB CATEGORIES AND DESCRIPTIONS

Because the entire pulp mill has a central control center for all operations, the production staff functions as a single, cohesive unit. A total of ten to twelve people are involved in the operation of the mill, including three who are assigned exclusively to the bleach plant. These three production workers have regular assigned tasks, and remain in known areas for most of their shifts:

Bleach Plant Operator: The Bleach Plant Operator is responsible for monitoring and making adjustments to the two bleaching lines, the chlorine vaporizers, the chlorine dioxide generator, the caustic dilution system, and the sodium hypochlorite makeup system. He also has responsibility for operating the evaporator trains of the Kraft chemical recovery system. Since these systems are all automated, he remains mostly in the control center. When necessary, he can call on either of the two pulp mill operators (or the other digester/washer operator) for assistance.

Assistant Bleach Plant Operator: This worker is responsible for any manual adjustments or tasks related to the operation of the two bleaching lines, the drum washers, the chlorine dioxide generator, the hypo makeup and caustic dilution systems, and the chlorine vaporizers and gas controls. He is also responsible for hosing down any stock or chemical spills, and for collecting and testing quality control samples of hypochlorite and chlorine dioxide solutions. Once each shift, he also checks the level of bleached stock in the four high density storage tanks, and inspects the steam mixers and pumps on the first and second floors. It is estimated that he is outside the control center at least half of his shift, and very

frequently all of it, especially if problems occur with certain equipment. By far, the majority of his time is spent servicing and adjusting the washers, or performing other tasks on the operating floor. Of all the bleach plant workers, he is believed to be at the highest risk of exposure.

Bleach Plant Tester: The tester is responsible for collecting and testing samples of stock (and filtrate) to ensure the efficient operation of the two pulp bleaching systems. He is rarely assigned any other tasks because the testing duties require all of his time. It is estimated that the tester is in the control center or the adjoining testing lab for 75% of each shift, with the remaining time used for collecting samples.

Each hour, he conducts one of two sampling runs. The 'short' run takes approximately 8-10 minutes to perform; and the 'long' run about 13-15 minutes. Stock (and filtrate) samples are collected at each of the following points and tested as indicated:

Short Run

- 2nd and 3rd stage steam mixers for alkalinity or hypo residual
- First stage washers for chlorine residual
- Second stage washers for alkalinity
- Hardwood 3rd and 4th stage washers for stock brightness
- Softwood 3rd, 4th, and 5th stage washers for stock brightness.

Long Run

- 2nd and 3rd stage steam mixers for alkalinity or hypo residual
- 1st stage washer vat inlets for residual chlorine
- 2nd stage washer discharges for alkalinity
- 3rd stage washer inlet vats for residual hypochlorite (Softwood also checked for pH and brightness)
- 4th stage washers for filtrate chlorine dioxide residual and pH; and stock for brightness

- o 5th stage Softwood for filtrate chlorine dioxide residual and pH; and stock for brightness

- o Four high density bleached stock storage tanks for stock brightness

The collection of stock and filtrate samples from the first, fourth, and fifth stages (Softwood only) represents the greatest potential for exposure. However, the time required to reach into the washers and collect a sample is less than ten seconds. If the washer hoods are working properly and no chlorine/chlorine dioxide is escaping, overall worker exposure during these runs is very small.

Miscellaneous Job Categories

Three or four additional employees (two supervisory) are periodically involved in bleaching and chemical preparation operations. A Pulp Mill Operator and his Assistant have supervisory responsibilities over all operations and personnel, and report directly to the Shift Foreman. Each makes frequent inspections and checks throughout the mill, and both are available to relieve or assist any of the other three operators in the control center. Generally, if an upset or malfunction occurs somewhere in the process, the mill operator or his assistant will relieve the particular operator responsible for that system so that he may concentrate on correcting the problem.

An Evaporator Man works almost totally outside, and is primarily responsible for the operation of the evaporator lines. However, he is also responsible for unloading incoming chemicals for the bleach plant (caustic, sulfuric acid, R-2, and liquid chlorine). Since the shipments arrive infrequently, these responsiblities are a small part of his work routine. All unloading systems are closed and automated, and he is at little risk of exposure, except during leaks and/or upsets.

Utility personnel may be assigned spill cleanup, minor process and equipment adjustments, and general housekeeping tasks anywhere in the bleaching area of the pulp mill. Their daily work routines, although initially planned by the Pulp Mill Operator, can vary significantly as needs arise. Therefore, documentation of exposure is difficult because it is so highly variable.

AIR SAMPLING RESULTS

Only limited air sampling for chlorine/chlorine dioxide was performed because potential emission sources are located outside, remote from the workers. A total of seven personal

samples were collected during quality control sample collection tours, and two bleach plant maintenance operations. In addition, Drager detector tubes and a portable Mast Oxidant Monitor were used to assess potential chlorine/chlorine dioxide emission sources, and to ensure that the control center was not affected by these potential air contaminants.

The Drager detector tube readings are summarized in Table 25-1. The only locations yielding detectable levels were inside the chlorine washer hood (softwood line), and a leak from the manhole cover on 1A Seal Tank. Chlorine would certainly be expected in the washer, and is well controlled by the exhaust hood. The seal tanks are normally tightly closed and ventilated to the chlorine scrubber system. This leak was unusual.

Chlorine/chlorine dioxide concentrations in the control room were recorded over a 24 hour period using the Mast Oxidant Monitor. No response was observed over the entire period, and the concentration was conservatively estimated at or below 0.05 ppm (as Cl_2). The monitor was then moved downwind of the Softwood chlorine washer. The location was monitored over a four hour period and the results are plotted on Figure 25-2. As shown, concentrations were highly variable, ranging from less than 0.05 ppm to slightly over 1 ppm. These data indicate that chlorine can escape from the observation doors under certain wind conditions. However, the chlorine appears to be quickly diluted and dissipated, and should not typically be a source of significant exposure.

The Mast Monitor was also used to evaluate chlorine concentrations on the building's second floor near the leak from the first stage hardwood seal tank. Its response was highly erratic, with chlorine concentrations ranging from 0.4 ppm to about 1 ppm. A single 15-minute area sample was collected (NIOSH Method P & CAM 209) on the manhole cover of the adjacent softwood seal tank, but less than 0.05 ppm of chlorine was detected. The leak is an unusual occurrence and workers only briefly enter this area to collect process samples or inspect the steam mixers.

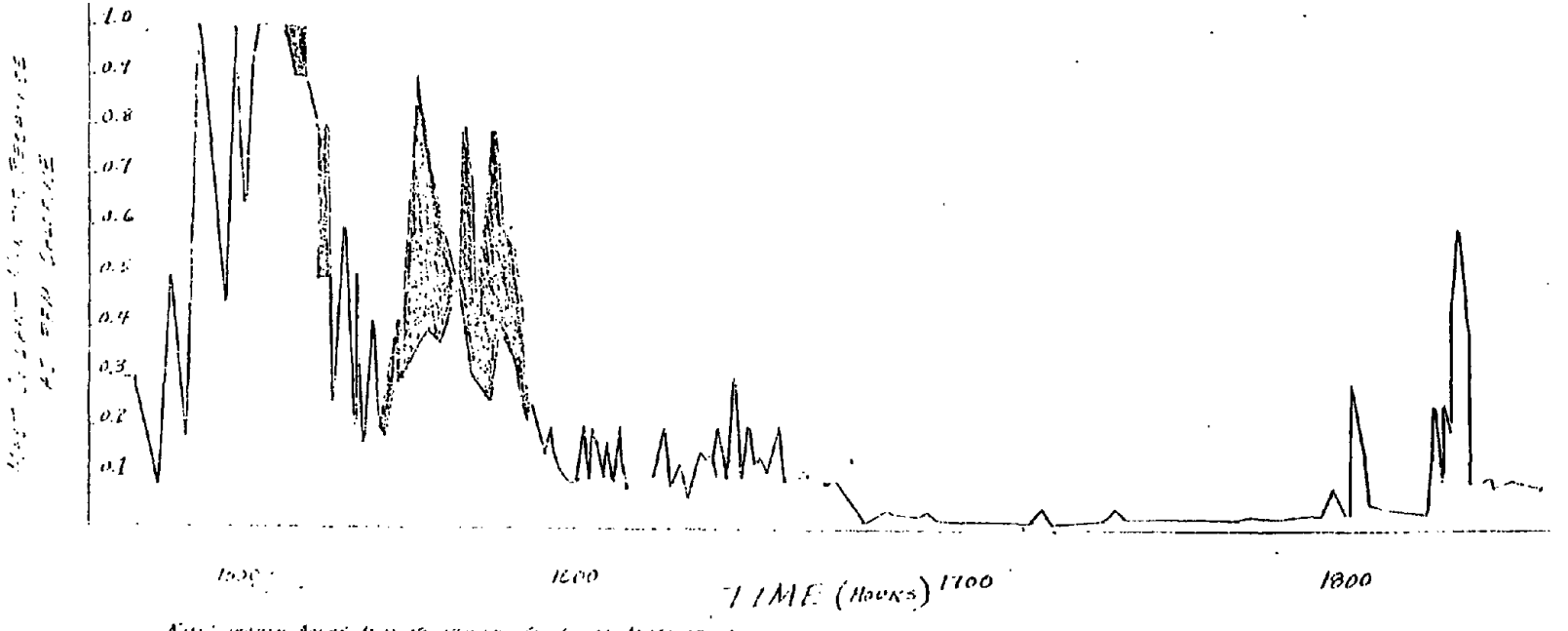
Personal sampling focused on exposures during collection of quality control samples. Samples were collected and analyzed using NIOSH Method P&CAM 209 (methyl orange). The resulting exposures were expressed as the equivalent chlorine concentration in ppm, although during some sampling periods workers may be exposed to a small amount of chlorine dioxide (which responds positively in the method).

As shown in Table 25-2, three short-term impinger samples were collected on the tester during both short and long sample collection runs. Chlorine was detected on only one of the samples (0.11 ppm). An additional sample was collected on the

Table 25-1: Summary of Drager Chlorine Detector Tube Readings

Location	No. Pump Strokes	Concentration, ppm
Inside Control Room	10	No Reading, est. 0. 2
Inside 1st Stage Washer Hood - Line B	5	~6
Front of 1st Stage Washer, Line B (≈10')	10	No Reading, est. <0.2
East Side of 1st Stage Washer (Standing Downwind)	10	No Reading, est. <0.2
West Side of 1st Stage Washer (Standing Downwind)	10	No Reading, est. <0.2
Inside 4th Stage (ClO_2) Washer Hood	10	No Reading, est. <0.2
Air Leak From Manhole Cover on Seal Tank for 1A Washer (2nd Floor)	10	>3

FIGURE [illegible]: CHLORINE AIR MONITORING NEAR FIRST STAGE WASHER
(Softwood Bleach Line)



Note: Shaded Areas Indicate Periods of Lower Evaporation

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Table 25-2: Summary of Personal and Area Air Sampling Results for Chlorine/Chlorine Dioxide

Personal Samples

Sample I.D.	Job Category	Sampling Time	Concentration Cl_2/ClO_2* (as ppm Cl_2)	Comments
1	Bleach Plant Tester	9:59-10:14 (Thur.)	0.11	Short Sampling Run**
2	" " "	15:52-16:07 (Thur.)	<0.066	Short Sampling Run**
3	" " "	15:53-16:02 (Fri.)	<0.081	Long Sampling Run**
4	Utility Man	17:15-17:29 (Thur.)	<0.054	While lighting portable heaters near chlorine injectors
5	Asst. Bleach Plant Operator	18:32-18:40 (Thur.)	<0.096	Collecting hypo and Cl_2 absorber QC samples
6	Maintenance Worker	9:30-9:45 (Wed.)	<0.050	Simulated exposure while cleaning shower nozzles inside washer 3A
7	" "	10:01-10:16 (Wed.)	<0.050	Simulated exposure while cleaning shower nozzles inside washer 4A

Area Sample

8	Manhole Cover of Washer 2B Seal Tank	15:02-15:17 (Fri.)	<0.051	Chlorine gas escaping from nearby 1A seal tank manhole cover

* All samples collected and analyzed according to NIOSH Method P & CAM 209 for chlorine (methyl orange method) using 15.0 ml absorption solution in Liquid Media Samplers. Samples were collected with constant flow Dupont pumps at a flowrate of 0.5-1.0 LPM (determined with a Kurz mass airflow meter both before and after sampling).

** See also discussion of air sampling results

assistant bleach plant operator while collecting hypo and chlorine dioxide absorber samples. No chlorine/chlorine dioxide (0.096 ppm) was detected. These results indicate worker exposures during quality control sample runs are low, except possibly during leaks or other upset conditions. It should be noted that workers are mostly outside and exposures are influenced by weather conditions.

During the survey, the hardwood bleaching line was down for routine maintenance. This allowed two 15-minute personal samples to be collected on maintenance employees cleaning the shower nozzles inside the hypo and chlorine dioxide washers. Neither of these samples resulted in detectable concentrations of chlorine/chlorine dioxide (< .05 ppm). One other personal sample was collected on a utility employee lighting portable heaters at the two chlorine gas injectors on the second floor. Like the other samples, no chlorine/chlorine dioxide was detected (< .054 ppm).

CONTROL OF WORKPLACE EXPOSURES

There are several features of this mill which significantly reduce the potential of worker exposure to chlorine and chlorine dioxde:

- Essentially all work areas are partially or totally open; any minor emissions are quickly dispersed.
- The process is highly automated; most workers are located away from potential emission sources.
- Most of the process is closed, and there are very few persistent sources of workplace emissions.

Specific controls, discussed in detail below, include local and general ventilation, process monitors and safety features, equipment maintenance, and respiratory protection.

Ventilation Systems

There are three distinct ventilation systems which aid in controlling worker exposure in this mill:

- The chlorine washer, seal pit, and tower exhaust system, and a caustic scrubber.
- The chlorine dioxide washer, seal pit, and tower exhaust system, and a chilled water scrubber.
- The induced draft fan and scrubber system on the chlorine dioxide generator's absorption towers.

Originally, each bleach line's washers, towers, and seal pits were equipped with one ventilation system and scrubber. The three chlorine dioxide towers were then vented to a separate, chilled-water scrubber system. However, when these systems required repair a year ago, the original design was simplified and improved (cost of $33,000).

As shown on Figure 25-3, two new but similar systems were installed to separately ventilate and scrub chlorine or chlorine dioxide from washers, seal pits, and towers. Each is designed to exhaust 4000 cfm from the washer hoods, and 1000 cfm from the seal tanks. However, the chlorine system was designed to exhaust 400 cfm from each tower, and the chlorine dioxide system 200 cfm. The chlorine scrubber uses weak caustic solution to react with and remove any chlorine in the exhaust stream. Sodium hypochlorite is formed, drained to the hypo collecting tank, and reused in the process. The chlorine dioxide scrubber employs a recirculated flow of about 50 gallons per minute of chilled water. This then drains to the fourth stage seal pit of the softwood line.

Each washer is fully enclosed by a tight-fitting fiberglass hood, with several small observation ports on each side. One or two of these ports are normally open to allow observation of the washing process. Air flow readings were taken in several open observation ports, and showed face velocities ranging from 150 to over 250 fpm. Unless a large number of these are left open, or there is a high wind (the washers are located in a semi-open area), the exhaust system should effectively prevent chlorine and chlorine dioxide emissions.

The extraction and hypochlorite washers have the same, tight-fitting hoods. Originally, each was exhausted directly through the roof, but now only the hardwood extraction and softwood hypo stages have functioning duct fans. Exhausting these hoods is not considered important because little, if any, chlorine gas is emitted from the washers.

An induced draft fan is used to draw gases safely and efficiently out of the chlorine dioxide generator and through the two gas absorption towers. The fan is located after the chlorine absorption tower. A vacuum control valve before the fan (and interfaced with the generator chemical flow controls) safely regulates the amount of air the fan draws. Generally, the absorption towers operate at high collection efficiency, but a small amount of both chlorine dioxide and chlorine does pass through them. This can pose some exposure risk to workers, and can slowly damage equipment and building materials. To help remove it, the mill has a two-stage vent scrubber* after the induced draft fan. This uses chilled water

*The two-stage vent scrubber was not installed at the time of the survey, because repairs were being made to the bleach plant's roof.

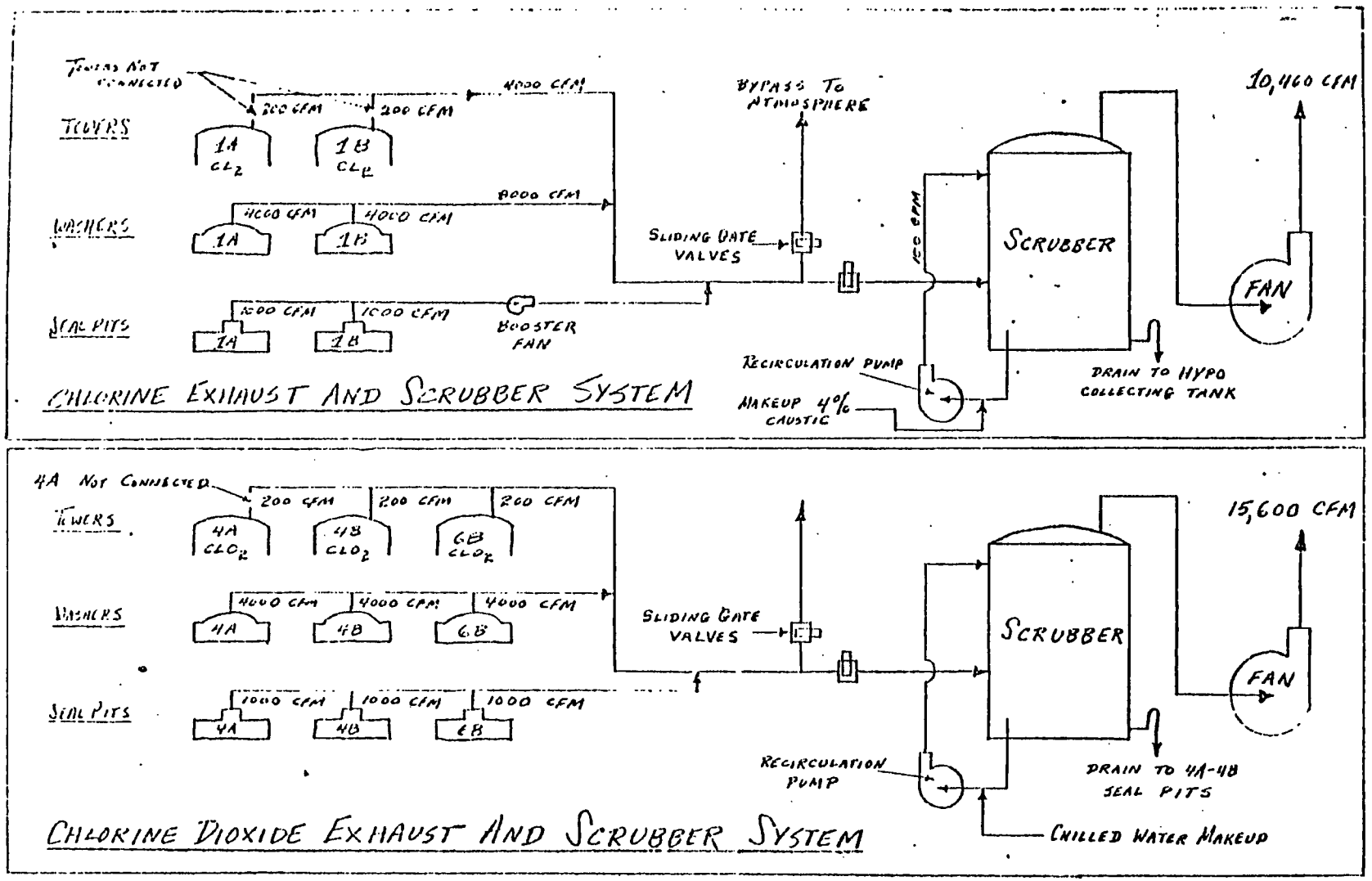

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FIGURE 25-3: PROCESS VENTILATION SYSTEMS

in the first stage to remove chlorine dioxide, then weak (caustic) hypochlorite for chlorine removal. (Residual chlorine dioxide gas is not effectively removed by the large chlorine absorption tower.) Efficiency of this scrubber was not known, but it provides excellent safety should problems develop with the generator and/or its two absorption towers.

The control room HVAC system operates with 100% recirculation. There is no fresh air make-up, and generally, no pressure differential between the control room and process areas. Hence, there is little reduction in air contaminant levels between the two. The low level of chlorine/chlorine dioxide measured in this room (0.05 ppm over a 24 hour period) is an indication of similarly low levels in the immediate process area. However the control center is located closer to the pulping area than to the bleaching equipment. It is therefore effectively isolated from chlorine/chlorine dioxide emissions, unless a major process leak occurs. To allow workers to stay in the control room during a major leak or other upset condition, the mill has installed a supply-air manifold and respirator system inside it. Workers have reportedly never had to use this system, but it is an excellent emergency control.

The small adjoining laboratory where process samples are tested has only a small wall air conditioning unit. Gases and vapors generated during the quality control tests are exhausted by a small canopy hood located over a sink.

Process Control

Although the two bleach lines and chemical preparation systems employ conventional equipment and technology, the mill uses several important process monitoring and safety control systems. The most important of these was the recent installation of a $28,000 Optichlor system and two static mixers to better regulate and control the amount of chlorine gas injected into the softwood first-stage. Previously, an oxidation-reduction probe (ORP) system (similar to the one still used on the hardwood line) was used. However, the ORP system did not respond well to the variable softwood first-stage bleaching demands and conditions. This resulted in excessive chlorine consumption, and/or poor control over the first-stage bleaching process. Therefore, the mill changed to the more responsive Optichlor (or pulp brightness) principle of controlling chlorine addition. To date, its performance has apparently still been poor and future improvements are being investigated. More accurate addition of chlorine and improved control of this bleaching stage will reduce the potential for chlorine off-gasing and employee exposure.

Most of the bleaching operations are monitored and controlled from the control center using analog sensors and controllers. These adjust setpoints on various control valves for stock, steam, water, and chemical solution flows, and activate (and regulate) various pumps and motors. They supply real-time data of process variables. Most signals are continuously recorded so operators and management staff can reference them when diagnosing and correcting operational problems. The recorders are also interfaced with high and low level alarms to warn operators of impending upsets. In some cases, these alarms are interfaced with a process interlock system which effectively halts some unit operations preventing further unsafe conditions. The most notable of these monitoring and control systems include:

Bleaching Lines

- The Optichlor chlorine gas flow control system on the softwood line.
- The oxidation-reduction probe chlorine gas flow control system on the hardwood line.
- Tower and washer inlet vat level control and recording system (these reduce the likelihood of washer overflows and, perhaps, high washer chemical residuals).
- Pulp optical brightness monitors installed on the hypo and chlorine dioxide stage washers of each line (the mill reported these are not very accurate, and operators do not routinely rely on them for process control).

Vaporizers and Chlorine Gas Flow Controls

- Automated heat control (steam) of the vaporizers based on temperature and pressure sensors located in the exit gas line. Sensor signals are continuously monitored, and interfaced to alarms for high (135° F) and low (110° F) temperature, and high (70 psi) and low (50 psi) pressure.
- A safety relief valve (20 psi) for high vaporizer steam pressure.
- An eductor-type blowdown system for chlorine gas, consisting of a large 4.5% caustic tank and recirculating pump. This is used to relieve small amounts of residual chlorine liquid in tank cars before they are disconnected (car is changed every

28-30 hours), and to vent any chlorine gas in lines during an emergency or prior to repair work. Tank provides approximately 1 hour of retention time, with its contents constantly pumped to the hypo makeup system (actually half goes to the hypo reactor and the rest to the hypo-collecting tank).

Hypo Makeup System

- An automated hypochlorite reactor controlled by an in-line oxidation-reduction sensor, and activated based on a level sensing system on the hypo storage tank (with a low level alarm).

Caustic Dilution Systems

- Conductivity cell monitors and controllers to regulate the solution strength.

Chlorine Dioxide Generator

- A flow sensor, controller and recorder for R-2 solution to the generator.
- A flow sensor, controller, and recorder on the generator sulfuric acid line.
- An automatic (or manual) generator shutdown system interlocked to alarms for:

  (a) high reactor exit gas temperature
  (b) low air flow to reactor
  (c) low air pressure in the compressor to reactor line

  The interlock system shuts off flow of R-2, sulfuric acid, and mixing/purge air to the reactor so that generation of chlorine dioxide will eventually stop. However, for added safety, some air continues to purge the reactor, and chilled water and caustic continue to flow through the two absorption towers.

- A vacuum sensor on the reactor gas line; interfaces with a controller for the air flow valve on the induced draft fan. (Fan is used to draw reactor gases and air through the two absorption towers.)
- A chlorine dioxide storage tank level sensing and controlling system with a high tank level alarm.

- Flow and temperature recorders on the chilled water to the absorption tower; with a high temperature alarm (flow controller is interfaced with flow controllers for the R-2, sulfuric acid, and air lines).

- A flow recorder on the discharge from the generator effluent tank to the chemical recovery oxidation system.

- A closed, storage tank gas venting line connected back into the absorption tower.

Most of the above systems are regularly inspected and calibrated by the production and maintenance staffs. They provide a high degree of process control, safety, and gas emission control. However, the actual effectiveness and proper performance of the bleach plant and chemical preparation systems is mainly determined by the various quality control samples collected and tested throughout the day by the production staff.

Maintenance Program

There are two aspects of the mill's preventive maintenance program which may contribute to improved control of workplace emissions. Each week, one of the two process lines is shut down for up to a full shift for maintenance work. This routine permits quick attention to problem conditions which could lead to significant workplace contamination. It also allows for more frequent and detailed equipment inspections and maintenance.

The mill also has a program to test seals, packing materials, and gaskets for corrosive service. This program has assisted in the use of the following materials.

- Packing - A teflon impregnated formulation (Garlock 5880 & 5881) is used in pumps that handle chlorine and chlorine dioxide solutions, and reactor spent acid.

- Gaskets - Garlock teflon gaskets are used in chlorine and chlorine dioxide lines. Tygon is used in acid, caustic, and occasionally in chlorine lines. Lead is used for sulfuric acid lines.

- Mechanical seals - Chesterton mechanical seals are used on certain sulfuric acid and hypochlorite lines (experience has shown that these seals can last up to three years).

Respiratory Protective Equipment and Other Safety Procedures

Mill personnel were knowledgeable in the use and limitations of respiratory protection equipment occasionally required in their job. The mill has developed a written program, and provides employees with a complete assortment of respirators covering most exposure situations. These include:

(1) Light duty dust respirators (disposable masks)
(2) Heavy duty dust and mist respirators
(3) Air-line breathing apparatus (for the control room)
(4) Gas masks (specific, cartridge-type air-purifying)
(5) Scott Air Packs (SCBA)

The written program identifies the types of air contaminants in the mill and corresponding respiratory protection requirements. It also identifies a number of general work areas where protective equipment is more likely to be required. However, specific requirements for wearing equipment is assigned to individual department heads.

To ensure that workers receive proper instruction in respirator usage (and other safety equipment), the mill safety department has developed an excellent "safety instruction checklist" and employee acknowledgement form (see Figure 25-4). Each new employee receives a general overview of the mill safety program and policies, and is instructed to submit the checklist/acknowledgement to his department head. After receiving adequate instructions in the specific department regulations and procedures, the employee must sign the form and return it to the safety department. Refresher training courses are provided informally on an as-needed basis. Department heads and assistants periodically review conditions in their respective areas, consult with the safety department, and devise control or abatement measures as necessary.

Respirators and other protective equipment are not regularly used during any bleach plant tasks, and no exposure situations were observed requiring their use. Half-face piece chemical cartridge respirators were worn briefly by a maintenance worker and the assistant bleach plant operator while they investigated a small leak in the automatic chlorine gas flow control valve (on the second floor of the bleach plant). These respirators appeared in proper condition and provided adequate protection for the observed exposure condition.

FIGURE 25-4

Employee's Name _____ Department _____

The Safety Department has told this new employee about available safety equipment, given him a safety booklet and told him of our insistence that our employees comply with all plant safety regulations and good safety practices. The employee has also been told that additional safety instructions applying specifically to the department to which he is assigned, will be given him by the department supervisor. The Safety Department has also explained to this employee the plant First Aid Rules and Procedures.

SUPERVISORS SAFETY INSTRUCTION CHECK LIST

1. Discuss specific department hazards such as pinch points, dangerous chemicals, eye hazard areas, fall areas or hot surfaces.
2. Show correct method of operating equipment or machinery or the handling of materials as applied to this department. Explain the importance of employee's not operating equipment or handling materials without proper instruction.
3. Explain responsibility for self-protection and the protection of fellow workers such as wearing eye protection or protective clothing or not using defective tools.
4. Explain the values of good housekeeping and how it is done in this department.
5. Discuss formalized systems as applicable. For example tag-out programs, welding and burning permit system, how to report injuries or sickness and where he is permitted to smoke.

Foreman _____ Dept. Head _____

This is to acknowledge that I have been made aware of the policy of to select for employment and for promotion those who are the best qualified, determined by due consideration of such factors as ability, integrity, education, experience, reliability, character, and potential for growth without regard to race, color, creed, or national origin. Also, that plant employee facilities such as drinking fountains, bath house, lockers, and cafeteria are provided without regard to race, color, creed, or national origin.

I also certify that I have had explained to me the various First Aid Rules and Procedures, and the Safety Rules and Procedures of I also certify that I understand these rules and procedures, and I agree to obey these rules, regulations, and procedures and all others that may be placed in effect at a future date.

Date _____ I.D. No. _____ Employee's Signature _____

PLEASE RETURN ALL THREE OF THESE FORMS TO THE SAFETY DEPARTMENT AFTER FOREMAN HAS TALKED TO NEW EMPLOYEE AND THE FOREMAN, DEPARTMENT HEAD, AND THE EMPLOYEE HAVE SIGNED THEM.

MILL 30: HARDWOOD PULP BLEACHING AND BLEACH CHEMICAL PREPARATION OPERATIONS

INTRODUCTION:

This is a report of workplace control technology in a four-stage (CEHD) hardwood bleach plant. Bleaching chemical, unloading and preparation in a separate four-section building are also discussed.

The bleach plant was constructed in the late 1950's, but major modifications were made in the late 1960's and early 1970's. These included installation of a diffusion washer on top of the chlorine dioxide tower (final stage), and a scrubber system for the chlorine stage washer exhaust hoods, towers, and filtrate tanks.

The bleach chemical preparation systems include a modified Mathieson chlorine dioxide generator, liquid chlorine unloading and steam-heated vaporization equipment, an automated sodium hypochlorite reactor, liquid sulfur dioxide unloading and gas vaporization equipment, and systems for unloading and/or diluting deliveries of caustic, sulfuric acid, sodium chloride, and sodium chlorate.

The mill is located in the Northeast and was surveyed during severe winter weather conditions. These conditions require most doors and windows in buildings to be closed, and create some equipment operating difficulties.

MILL LAYOUT

Bleach Plant

Bleaching operations are conducted in a four story building (54' x 159') which adjoins the pulp mill. Nearly all process equipment (including the chlorine tower) is within this building. The upper (or operating) floor (Figure 30-1) contains five valveless washers and one vacuum washer, and a nearby wall-mounted control panel. Small rooms next to the washers are used for a testing lab and worker office, a washroom, general storage, and additional controls. An exhaust gas scrubber for process equipment is located in a small room on the other side of the washers. Two liquid chlorine vaporizers, used to produce gas for the first stage, are also

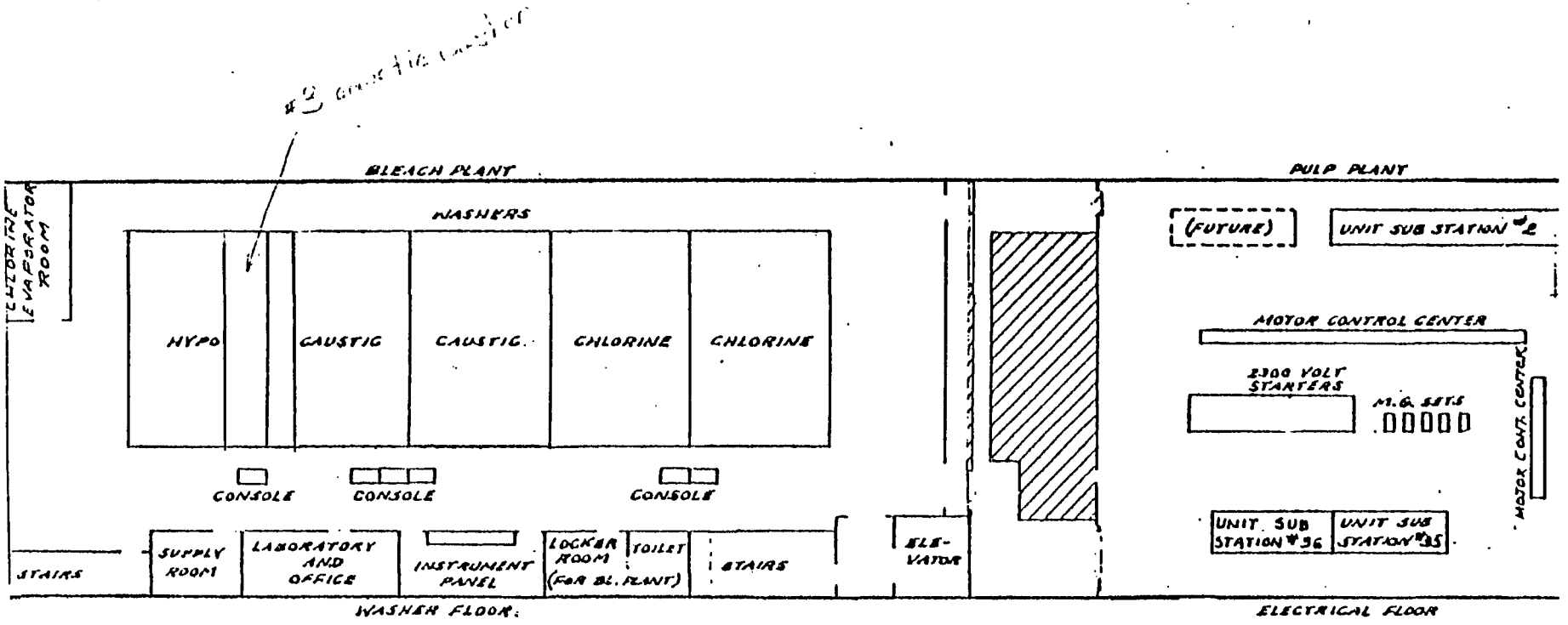

FIGURE 30-1: Bleach Plant Washer Operating Floor Layout

located on the mezzanine off the second floor. The third floor of the building contains steam mixers, a hypo mixer, the various washer filtrate tanks, the top of the first stage chlorination tower, and an electrical room. The second and ground floors contain the remainder of the chlorination tower, the caustic-stage tower, seal and filtrate tanks for the hypo washer, a filtrate tank for the chlorine dioxide diffusion washer, a brown stock chest, and a caustic storage tank. The fourth-stage chlorine dioxide tower, a large new hypo tower, and bleached stock high density storage tanks (3) are all located outside but adjacent to the building.

Chemical Handling

Bleaching chemicals are unloaded and prepared in two separate buildings. One of these has both a one and a four bay shed on either side so that railroad tank cars can be moved inside and unloaded.

The two-story central building contains the main process control panel, and equipment for preparing hypochlorite bleach liquor, antichlor (sulfur dioxide) solution, softened water, and dilute caustic. (New liquid chlorine vaporizers are located in a room off the front of the building, but were not in service). The large 4-bay shed is used for unloading railroad tank cars containing liquid chorine and sulfur dioxide. It also houses the chlorine vaporizers. The single-bay shed is used for unloading railroad tank cars containing liquid sulfur dioxide, suifuric acid, caustic, and sodium chlorate. It also houses two sulfur dioxide gas vaporizers. The narrow four-story building contains the Mathieson chlorine dioxide generator, a ClO_2 solution storage tank, and a steam-jet refrigeration unit (to produce chilled water for the generator absorption tower.) Around the outside of the generator building are tanks for storing sodium chlorate, 50% caustic, concentrated sulfuric acid, and liquid sulfur dioxide.

PROCESS DESCRIPTION

Four-Stage Bleaching

The mill bleaches about 620 tons per day of hardwood brown stock (with a Permanganate number of 10-14) to final brightnesses ranging from 82-85 units (G.E. brightness meter). Bleaching is accomplished by using the selective reactions of five chemicals in four distinct stages: (1) chlorine gas, (2) sodium hydroxide (caustic extraction), (3) sodium hypochlorite (bleach liquor or hypo), and (4) chlorine dioxide solution plus antichlor (a solution of sulfur dioxide). Typical ranges for bleaching parameters are summarized in Table 30-1. We will briefly summarize the major unit operations in narrative form below. (Preparation of bleaching chemicals will be discussed in the following section).

TABLE 30-1: TYPICAL BLEACH PLANT OPERATING DATA

Parameter	Operating Range
Brown Stock Flow	400-700 ADT/D
Brown Stock Number	10-18
Chorination Stage -	
Stock Consistency	≈3%
Chlorine Dosage	100 lbs./ADT
Stock pH	2.0-3.0 units
Stock Temperature	Varies depending on season
Tower Retention Time	30 minutes
Stock Residual (at washer)	1-10 mg./l.
Extraction Stage -	
NaOH strength	≈10%
NaOH Dosage	70 lbs./ADT
Mixer pH	10.2-10.8
Mixer temperature	≈120°F
Tower Retention Time	≈15 minutes
Hypochlorite Stage -	
Hypo Strength	40 gpl
Hypo Flowrate	50-55 gpm (Both mixers)
Hypo Dosage	60 lbs./ADT
Mixer Temperature	110°F
Mixer 5-minute Test-	
Available Cl_2	70-110 mg./l.
pH	10-12 units.
Washer Residual Chlorine	0.3 - 10 mg/l.
Washer pH	7-10 units
Stock Brightness	75-80 (G.E.)
Chlorine Dioxide Stage -	
Solution Strength	≈7 gpl
Chemical Dosage	8-10 lbs./ADT
Stock Temperature	150-155°F
Stock pH	5.5-6.0
Stock Consistency	≈11.5%
Washer ClO_2 Residual	1-20 mg./l.
Washer Stock pH	Variable, 4.5-5.0 units
Antichlor Strength (SO_2)	6 gpl.
Antichlor pH	2.0-2.5
Antichlor Flowrate	19 gpm
SO_2 Residual	<10 mg./l.
Final Pulp Brightness	82-85 (G.E.)

The purpose of the first stage, chlorination, is to change and dissolve the pulp's lignin color-causing impurities. This is done by reacting them with chlorine gas (dispersed in water) in a large ventilated tower. The resulting soluble chlorolignins and excess chlorine are then washed out in one of two ventilated, vacuum-drum washers (11.5' x 20', valveless IMPCO). The amount of chlorine gas added to the pulp (average of 110 lbs. Cl_2 per air dry ton of pulp ADT) is controlled by an optical sensor (Systematics Optichlor), located in the pulp stream just after a chlorine injector and static mixer. This sensor is backed up by an oxidation-reduction probe located in the pulp pipeline just before it enters the tower. The chlorination stage is performed on a regulated and low consistency (3%) blend of unbleached pulp mill brown stock and recycled (bleached) paper mill sludge. Therefore, depending on the amount of recycled sludge (and its quality), first stage bleaching conditions can vary significantly. Stock entering the first stage is usually at a pH of 7.0 - 7.5 units; but, occasionally chlorine dioxide generator spent acid is added, and may lower its pH a small amount, (after chlorine addition, the pH drops to 2.0). The temperature of stock is also variable because the papermill sludge is affected by incoming paper mill clarified water temperature (65°F winter; 85° summer). Each of these variables - amount of chlorine added, and stock pH, consistency, quality, and temperature - affects the rate and extent of chlorine reaction in the first stage. Any unreacted chlorine in the pulp as it exits the tower and comes into the washers, is then either washed out as filtrate, carried along with the discharged pulp, or off-gased above the washer and contained and exhausted by its hood.

An enclosed, but not air-tight, screw conveyor then transports this washed stock from the washers to a caustic-steam mixer on the third floor. Here both steam and 10% sodium hydroxide (70 lbs./ADT) are injected to raise the stock pH and temperature to about 10.5 and 125° F, respectively. These conditions are required to solubilize additional chlorinated lignins. It occurs in a caustic-extraction tower located below the caustic-steam mixer. After a retention time of about 10-15 minutes in this extraction tower, stock is diluted with caustic stage washer filtrate water, and pumped up to the two drum washers (11.5' x 20', IMPCO valveless). In these washers, the water washes out most of the remaining chlorolignins (now soluble), after which the pulp is discharged to two steam-hypo mixers on the third floor. In the third stage, the strong oxidative properties of hypochlorite solution are applied to the remaining color impurities. The steam-hypo mixer injects

about 60 pounds of hypo (per ADT) and steam to the pulp (plus, at times, additional caustic) and raises its pH to about 10.5 and temperature to about 100°F. The hypo is metered and controlled by a means of a magnetic flow meter. It is highly alkaline (pH 12.5), and little free chlorine likely escapes unless too much is added (i.e., because stock flow drops) and the steam rapidly increases its temperature. Treated stock is then conveyed on an open conveyor belt (soon to be replaced by a closed pipe and pump) to a large outside tower where the reaction is completed over a period of about 175 minutes. Stock is then diluted to about 3% consistency with filtrate water, and pumped back to the operating floor to a large hypo washer. After vacuum-drum washing, the 78-80 brightness pulp is discharged to a steam mixer on the third floor to start the final stage.

This last stage uses a chlorine dioxide solution (8 to 10 lbs. per ADT) to efficiently brighten the pulp to a final brightness of 82-85 (G.E.). After the steam mixer raises the pulp's temperature to about 155°F, an 8 grams per liter ClO_2 solution is injected through a Kamyr DM mixer in the bottom of the outside chlorine dioxide tower. Treated pulp reacts as it moves slowly up the tower (pH 5.5-6.0), and then enters a diffusion washer at its top. Here the pulp is washed with either mill, recycled papermill clarifier, or excess pulp press water. Sulfur dioxide antichlor solution is added to the water to reduce any unreacted chlorine dioxide. After washing, pulp with essentially no chlorine dioxide residual, less than 10 ppm of excess sulfur dioxide, and a pH of 4.5-5.0 units is discharged to one of three high density storage tanks.

Chemical Handling Operations

The chemical handling facility is operated by a separate staff. Six chemicals are unloaded there - liquid chlorine, concentrated caustic, sodium chloride and chlorate crystals, concentrated sulfuric acid solution, and liquid sulfur dioxide. Outside tanks are provided for storing some of these, then they are used to prepare the five bleaching agents--chlorine gas, chlorine dioxide solution, 10% caustic, sodium hypochlorite solution, and the antichlor (sulfur dioxide) solution. (Sodium chloride is used to soften mill water).

Liquid chlorine is unloaded from railroad tank cars using dry, pressurized air to make it flow into steam-heated vaporizers. One set of vaporizers is located on the mezzanine off the second floor of the bleach plant. It supplies chlorine gas exclusively for the first stage of pulp bleaching. Another set is adjacent to the tank cars in the four-bay shed, and supplies gas for the hypochlorite reactor and a water filtration plant.

Caustic solution (50%) is unloaded to a storage tank and then automatically diluted to two lower concentrations. A fifteen percent solution is used for the caustic-extraction bleach stage, pulp pH adjustment, and soda makeup in the chemical recovery/recausticizing area of the pulp mill. A five percent solution is used in a reactor, along with chlorine gas, to prepare a 4.2 - 4.5% sodium hypochlorite solution.

The sodium chlorate, sulfuric acid, and sulfur dioxide are all used in the modified Mathieson generator to make a solution of chlorine dioxide.

The Mathieson system for making chlorine dioxide was (and may still be) the most widely used. It is based on the following overall reaction:

$$2NaClO_3 + SO_2\ (g) + H_2SO_4 \rightarrow 2ClO_2 + 2NaHSO_4$$

This reaction is carried out in two lead-lined carbon steel reactors (primary and secondary) which are water-jacketed for cooling and covered by a common exhaust hood. Sulfuric acid (66^{o} Be) solution is unloaded from rail tank cars and stored in a large tank. The chlorate (with a small amount of salt) arrives in crystal form and must first be dissolved in the tank car with hot water. To prevent the solution from crystallizing during storage and use, it is continuously heated to $\sim 140^{o}F$ until it reaches the generator. Both solutions are pumped through filters and then accurately metered through long pipes reaching down into the primary reactor's bottom. Here they are mixed by a stream of sulfur dioxide gas in air ($\sim$6% SO_2), which has been injected through Aloxite diffusers in the reactor's bottom. The entire mixture then reacts to form the desired chlorine dioxide gas, which exits the reactor's top along with the unreacted air stream. The aforementioned dry pressurized air is supplied by a compressor (300 SCFM @ 17 psig), then mixed with sulfur dioxide gas, produced from its liquid by using a steam vaporizer.

In order to more completely react the chlorate, the reactants from the primary reactor overflow to the secondary. Here additional sulfur dioxide gas (in air) is added through this reactor's bottom. The remaining chlorate then reacts with it to form additional chlorine dioxide. The overall two-stage process efficiency is about 90%.

In order for the reaction to proceed efficiently and to full completion, three factors must be well controlled:

(1) reactants must be added in proper proportions and well mixed,

(2) the temperature must be maintained between 30° and 35°F, and

(3) sulfur dioxide gas bubbles must be of proper size to reach the top of the liquid in the primary reactor but not to enter the exiting gas stream.

If the latter occurs, the following undesirable side reaction, causing destruction of some chlorine dioxide, can take place:

$$2ClO_2 + 5SO_2 + 6H_2O \rightarrow 5H_2SO_4 + 2HCl$$

If low reactor temperatures occur, then the acid in the reactors begins to crystallize. High temperatures can increase the risks of gas explosions.

Generator gases pass directly to an absorption tower and are drawn through it by a 270 SCFM induced draft fan. Chlorine dioxide gas is absorbed in the tower in chilled water ($\sim$ 35° F) produced in a nearby Croll-Reynolds steam-jet refrigeration system.

The secondary reactor's liquid effluent (spent acid) pipeline and the tank to which it drains are both continuousiy purged with air to remove any remaining chlorine dioxide. Purging air goes back to the gas absorption tower. Spent acid is then pumped from the storage tank to the mill wastewater treatment plant, but some excess is occasionally added to the bleach plant inlet stock to reduce its pH.

The chlorine dioxide solution from the absorption tower (about 7 Grams per Liter (gpl) in strength) is drained to a large tank which is vented (explosion vent) to the outside. It is then pumped as needed to the bleach plant's fourth-stage tower.

All of the above equipment is located in the tall building at the end of the chemical handling facilities.

Sulfur dioxide gas is used to prepare the antichlor solution. This solution is then used in the pulp bleaching process to reduce chlorine dioxide residual after the final stage. The solution is made in the ground level of the main chemical handling control building. Preparing it involves a closed system which injects the gas into a mill water line (0.05 lbs. SO_2/gal.). The resulting solution is stored in a closed tank until it is pumped to the bleach plant.

JOB CATEGORIES AND DESCRIPTIONS

Bleach Plant

Two workers are assigned full-time to operating the bleach plant - an Operator and a Helper. They are supervised by a pulp mill shift foreman, and assisted by maintenance staff, when needed. A Utility Worker occasionally works in the bleaching area performing housekeeping and cleanup tasks, but his work routine is unpredictable and he oftens performs similar tasks in the entire pulp mill.

Operator - The operator is responsible for controlling the entire pulp bleach system starting from the brown stock surge and storage chests to the final bleached high density storage towers. The bleaching process is monitored and adjusted by means of analog sensors and controllers located on the main panel adjacent to the washers and on a separate panel inside the nearby office. Except for brief equipment inspections/ adjustments potentially anywhere in the building, this worker is on the washer operating floor essentially all the time. Brief breaks are usually taken in the nearby office.

Helper - The helper category is actually a group of pulp mill workers who are under the supervision of the pulp mill foreman. However, one helper is usually assigned full-time to assisting the bleach plant operator. His duties are varied, but mostly consist of collection and testing of process quality control samples each hour. These are collected at the following frequencies and locations:

Sampling Location	Frequency	Type of Test
First Stage Tower Inlet (after mixers)	Hourly	Chlorine Residual
Final ClO_2 Washer Sample	Hourly	Chlorine dioxide residual and final stock brightness (and cleanliness)
Caustic Mixer (3rd Floor)	Hourly	pH to 2nd stage
Hypo Mixers (2)	Hourly	Hypo residual (5 min. test) and pH
Caustic Washer	Every other Hour	PCP
Hypo Washer	Every other Hour	Pulp brightness and residual chlorine
Papermill Saveall Tank	Once Per Shift	General quality and consistency of paper sludge

Because chlorine, hypo, or chlorine dioxide residual tests must be performed after a certain pulp contact time, these samples are collected and then immediately taken back to the bleach plant office for testing. The remainder are collected afterwards, but the longest sampling run typically lasts only 12-15 minutes, including time required to deliver brightness samples to the main pulp mill testing lab (on the second floor).

Other tasks which this employee periodically performs include:

- Preparing and adding (under operator's supervision) secondary chemical additives (defoamers, pitch dispersants, etc.)
- Assisting in opening, closing, and adjusting water and other hand valves as required during startups and shutdowns
- Hosing down process equipment and work areas, and performing other general housekeeping measures
- Learning simple process control routines so that he can assist the operator when needed.

Chemical Handling Area

Only two workers operate the chemical unloading and preparation equipment -- an Operator and a Helper. The Operator reports to the pulp mill foreman, and helps to train the Helper.

Operator - The operator remains mostly in the main building near the monitors and controls for all the chemical unloading and preparation equipment. He is responsible for operating and making adjustments to the ClO_2 generators, chlorine and sulfur dioxide vaporizers, hypo reactor, and the caustic dilution system. He is also responsible for admitting incoming shipments of rail and truck chemicals, connecting the unloading hoses, and recording appropriate inventory data. He prepares a written daily production summary of all operations and chemical inventories, and supervises the performance of all quality control tests by the utility worker. He also occasionally performs simple equipment maintenance tasks including periodic repacking of valves and cleaning of chemical filters.

Helper - The helper assists the operator in the operation of the chemical unloading and preparation equipment. Besides performing routine cleanup and housekeeping tasks anywhere in the chemical handling buildings, his prime responsibilities are to collect and test process quality control samples from the chlorine dioxide generator and hypochlorite makeup systems. Under normal operations, a sample collection run is made every hour. During such a run, various samples are collected at the indicated frequencies:

Sample Location	Type of Test	Frequency Performed
ClO_2 Solution Storage Tank	ClO_2 strength	Hourly (when bleach plant is using it)
Absorption Tower	ClO_2 strength	Every other hour
Primary Reactor Overflow	$NaClO_3$ and acid strength	Every other hour
Hypochlorite Tank (Sample is collected from sampling line at lab sink in main building)	Cl_2 and excess alkali	Every other hour
Antichlor Tank	SO_2 strength	Once/Shift
Caustic dilution system	Density (Strength)	

As later air sampling data will show, some chlorine dioxide exposure results during collection of the first three of these inside the ClO_2 building, but little exposure during the others. In addition, deliveries of chlorate, sulfuric acid, and caustic are tested for their strength when they arrive, but the utility worker only collects the samples. They are tested at another lab.

The above sample collections typically require less than 10 minutes. When completed, the worker usually returns to the main building where he tests the samples at a small lab bench. The bench has a small canopy exhaust hood over it to capture any gases that are released while performing tests. (However, the hood usually is not operated.) The worker will also occasionally make brief equipment inspections and adjustments while collecting the samples.

The helper works under close operator supervision, but is constantly learning about production operations and control systems.

It was observed that the extent of his experience and training can greatly alter the types of tasks he performs -- especially what he does during startups/shutdowns or process upsets.

POTENTIAL SOURCES OF WORKPLACE CONTAMINATION

Bleach Plant

The survey team originally planned to assess workplace emission sources, potential worker exposures, and associated controls for a full four-day operating period. However, a chemical recovery furnace malfunction early in the week resulted in a gradual 48 hour shutdown of the entire pulp mill including the bleach plant and the chemical preparation systems. In addition, because of the shutdown length and the season of the year, a number of cold weather shutdown procedures were implemented in the bleach plant and chemical preparation building. These included isolation and draining of nearly all towers, washers, filtrate tanks, and chemical lines.

The mill shutdown was accomplished slowly, and did not afford time to attempt to document potential exposure conditions, if any existed. Once complete, all emissions and potential exposures essentially stopped. The mill maintenance staff then utilized the shutdown period to perform a number of required equipment repair and service operations. After reviewing a listing of these, the survey team concluded little worker exposure could occur during their performance. No air sampling was therefore performed during the shutdown.

A continuous chlorine monitor was positioned on the washer operating floor to record chlorine/chlorine dioxide levels when the bleach plant resumed normal operation. However, this did not occur until early Thursday morning, so less than 48 hours were available to obtain normal workplace emission and exposure data. Interesting data was recorded as the plant made a brief Wednesday afternoon startup and shutdown, and also when it resumed full operation on Thursday. This data will be discussed in the next section.

The chlorination tower and first stage washers (and their filtrate tanks) are all ventilated to a chlorine scrubber. Therefore, little potential for either emission or exposure is possible, provided the ventilation system operates correctly. Little chlorine gas is emitted during the hypo stage because the hypochlorite solution and the pulp to which it is added, are both very alkaline and remain so throughout the stage. (The pulp pH is monitored and, if necessary, additional caustic is added at the preceding extraction stage to keep it high). Discussions with mill technical staff indicated the only possible emission source of chlorine gas at the hypo stage is the hypo-steam mixer if the hypo flow and steam are left on while pulp flow drops. This apparently can raise the temperature of the hypo to near its boiling point, and the following disassociation reaction goes back towards release of free chlorine gas:

$$Cl_2 + H_2O \rightleftharpoons HOCl + Cl^- + H^+ \rightleftharpoons OCl^- + 2H^+ + Cl^-$$

The chlorine dioxide stage is carried out in an outside tower which has a diffusion washer mounted above it. Unless workers are near this washer (to collect QC samples), there is little potential for exposure. In addition, the tower's top and the washer are both ventilated to the previously mentioned scrubber system.

Therefore, during normal plant operations (i.e., without leaks or upsets), potential worker exposures can result only from:

(1) collection of process quality control samples from the first stage tower and washer vats, and the chlorine dioxide diffusion washer;

(2) the belt conveyor system from the chlorine washers to the caustic-steam mixers on the third floor; and

(3) the open belt conveyor from the hypo-steam mixer to the outside hypo tower (only if hypo is overheated)

The last of these potential exposure sources will be eliminated when this conveyor is replaced by a closed pipe and a thick stock pump. The other two are thought to be minor exposure sources because: (1) a short time is required to collect samples, (2) stock on the conveyor belt usually has a low chlorine residual, and (3) workers are infrequently required to be near the conveyor belt.

Chemical Handling Building

Workplace gas emissions in the chemical handling area are mostly associated with operation of the chlorine dioxide generator. They are not fully understood for a number of reasons. None are thought to be persistent; some may be related to startups, shutdowns, or collection of quality control samples; but none can be accurately measured because no specific sampling method exists for quantifying chlorine dioxide in air. Suspected chlorine dioxide emission sources include:

- Sampling lines for collection of storage tank, absorber, and reactor liquor samples
- Periodic gas puffs from either of the reactor vents (reactors are hooded and ventilated)
- The spent acid tank vent
- Leaking seals on ClO_2 solution transfer pumps (this is not common)
- A constantly-flowing sampling hose from the primary to secondary reactor (this is used to collect a reactor liquor sample; liquor in the hose discharges on the floor in front of the reactors, then drains through the floor)
- Periodic fugitive emissions from process sewer drains

Of these, air monitoring data (to be presented in the next section) indicates collecting process quality control samples not only creates the highest workplace chlorine dioxide levels, but more importantly, results in the most significant risks of worker exposure.

The above-mentioned reactor gas puffs are actually mild explosions. They are caused by decomposition of chlorine dioxide gas, or combustion of some other material in the system by oxygen, which is concurrently released during chlorine dioxide decomposition. There are at least four conditions which may cause a puff:

(1) The presence of an oxidizable material such as dirt, grease, oil; or high concentrations of sulfur dioxide in contact with the chlorine dioxide gas stream.

(2) The presence of considerable quantities of sulfuric acid in contact with the chlorine dioxide gas stream.

(3) Gas temperature above 115°F.

(4) Chlorine dioxide concentrations in the air-gas mixture above 13 percent.

The two reactors, the spent acid tank, and the chlorine dioxide solution storage tank are all designed with explosion lids to withstand such puffs. However, to prevent damage to other systems, release of gas to the workplace, and lost production time, puffs must be avoided. (Procedural and engineering controls for their prevention will be discussed in the "Control Technology" section under "Process Monitoring and Control.") The hypochlorite preparation system is automated and closed except for an open cover on top of the storage tank, which is inside the control building. Little chlorine gas is emitted from the open cover unless too much chlorine or too little caustic flow is used at the reactor. These conditions are unlikely because an oxidation-reduction control system automatically regulates these flows, and it has an alarm to warn of malfunctions.

The remaining chemical unloading systems (chlorine and sulfur dioxide vaporizers, caustic dilution, and acid and chlorate transfer equipment) are also automated. They do not emit airborne contaminants during normal operation, if they are well-maintained and properly sealed.

AIR SAMPLING RESULTS

Area air monitoring for chlorine and/or chlorine dioxide was conducted in both the bleach plant and chemical handling buildings. Actual worker exposures were documented only for certain projected high risk tasks. Two real-time Mast Oxidant Monitors (field-calibrated for chlorine) and Drager detector tubes were used to perform the area monitoring. Short-term

personal exposure samples were collected on the bleach plant's and chemical handling's "testers" during their typical quality control sample collection runs. The personal samples were collected and analyzed according to NIOSH Method P & CAM 209 using 15.0 ml. of methyl orange reagent contained in Liquid Media Samplers. Resulting exposures are expressed as the equivalent-chlorine concentration although chlorine dioxide also responds positively in the method, and some workers may have been exposed to both. Monitoring and exposure results will be discussed separately for each work area.

Bleach Plant Air Sampling Results

A Mast Oxidant Monitor (calibrated for 0-1 ppm Cl_2) was used to monitor air quality on the washer operating floor for a 57 hour period including periods before, during, and after process start-up/shutdowns. The monitor's recorder tracing is reproduced as Figure 30-2 and discussed below. (The monitor was positioned above the washer control panel.)

As shown, while the plant was in a complete cold weather shutdown (19:00 Tuesday to 13:00 Wednesday), washer room chlorine/chlorine dioxide levels were, as expected, essentially non-detectable (0.05 ppm as Cl_2). However, around mid-day on Wednesday, the plant made a brief startup in order to supply the papermill with enough bleached stock to keep running during the forthcoming extended pulp mill shutdown. Over the following six hour monitoring period, three distinct peaks were observed. The first of these (~0.25 ppm) coincided almost perfectly with initial first stage bleaching startup. The second, which began at 14:00 and actually exceeded 1.0 ppm for 10 minutes, could not be attributed to a specific emission source. High first stage stock chlorine levels, perhaps, off-gasing from the post-washer stock conveyor, are the suspected cause because the hypo stage had not been started. The final peak (~0.4 ppm) coincided exactly with the process shutdown, but again could not be attributable to a specific emission source (or to just chlorine gas). Like the initial process startup peak, we believe excessive amounts of chlorine in the first stage pulp, perhaps so high as to pass through the tower/washer scrubber system and infiltrate the building, is the cause.

The bleach plant resumed normal production early Thursday morning (2:15 a.m.). Over the remaining 33 hours of monitoring, three distinct peaks (or group of peaks) were observed and attributable to the following operational problems:*

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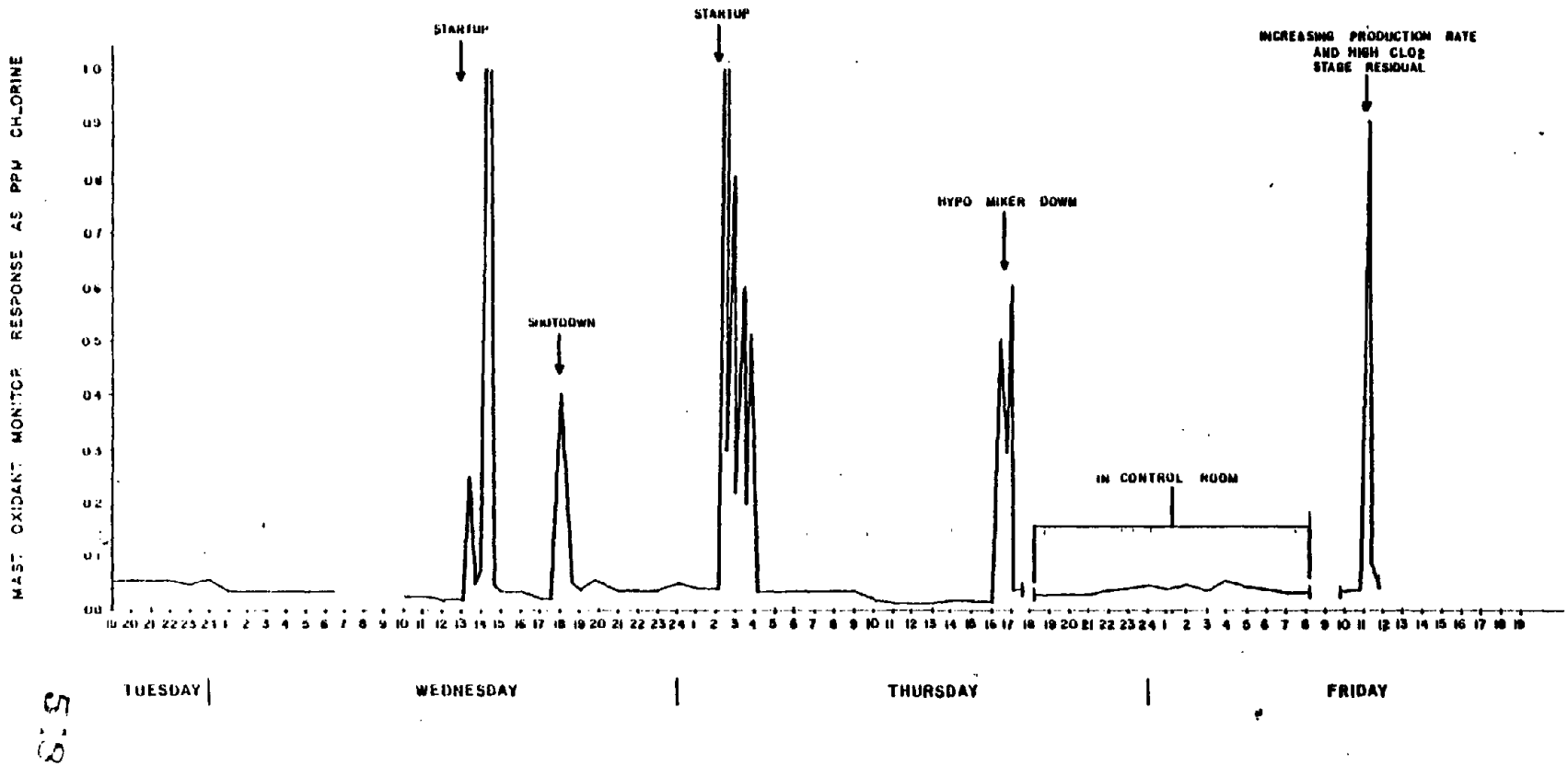
*From 18:00 Thursday to 8:00 Friday, the monitor was actually located in the washer floor office rather than outside next to the washers.

FIGURE 30-2

MAST OXIDANT MONITOR RESPONSE ON BLEACH PLANT OPERATING FLOOR



Time of Peak(s)	Description	Probable Cause(s)
Thursday, 2:00 - 4:00	Four sharp peaks, the first exceeding 1.0 ppm	Chlorination and start-up difficulties
Thursday, 16:00 - 17:00	Two peaks, the highest reading ~0.6 ppm	Hypo mixer difficulties (suspect stock flow to mixer dropped but steam and hypo flow remained high causing overheating and chlorine offgasing)
Friday, 10:45 - 11:30	Single 0.9 ppm peak	Increasing production rate, which caused momentarily high ClO_2 stage washer residuals. Chlorine dioxide infiltrated building from the outside washer.

These short periods of elevated contaminant levels and operational problems are probably not typical, but they do periodically occur.

Four short-term area air samples were also collected in the bleach plant to supplement the Mast monitoring, or to investigate the presence of chlorine emissions. Two were collected near the Mast monitoring location during the brief process startup on Wednesday afternoon (Samples Nos. 6 and 7). Only one of these (No. 7) resulted in detectable levels (1.27 ppm as Cl_2). It coincided with the high Mast reading at the same time, and confirms that chlorine levels did briefly exceed (10 minutes) the OSHA ceiling limit of 1.0 ppm. The other two area samples (Nos. 9 and 10) were taken on Friday morning and directly inside the two chlorine stage washer hood ducts which lead to the scrubber. Surprisingly, they indicated little chlorine gas being emitted from the washers at this time, and are, perhaps, indicative of well-controlled first stage bleaching.

When the mill resumed normal operations on Thursday, four 15-minute personal exposure samples were taken on the bleach plant helper while he collected routine process quality control samples (also see this employee's job description). Results

are summarized in Table 30-2. Three of the four resulted in non-detectable levels of exposure (as chlorine), but the fourth (Sample No. 4) indicated some exposure occurred when the worker entered the enclosure over the chlorine dioxide tower and the diffusion washer. Gas was escaping from the tower because of high stock residuals. Levels inside the enclosure caused the overall 15-minute worker exposure to be 0.25 ppm, but quantified as chlorine rather than as chlorine dioxide.

One additional 15-minute sample was collected on this employee while he hosed down stock spills around the third floor conveyor which transports hypo-treated stock to the outside tower. The non-detectable level (0.05 ppm) confirms that little, if any, chlorine gas normally escapes at this open conveyor line.

Chemical Handling Buildings

In the chemical handling buildings, only the chlorine dioxide generator system was projected to normally pose a worker exposure risk. Therefore, using a Mast Oxidant Monitor, contaminant levels were monitored in the generator building for a continuous 65 hour period. Workers only briefly enter this building to collect process quality control samples or to make equipment inspections and adjustments. This warranted locating the monitor on the reactors' operating floor (3rd level) and near the absorber and the reactor acid sampling points. It was positioned about 15-20 feet away from the reactor's exhaust hood. The monitor's recorder tracing is reproduced as Figure 30-3, and discussed below.

> In evaluating this data, it should be stressed that the monitor was calibrated for chlorine response (0-2 ppm), but the contaminant it was responding to was probably chlorine dioxide. Preliminary work by some industry researchers indicates the monitor responds to about one half of the actual chlorine dioxide present (in the absence of other oxidizing gases). Therefore, a reading of 1.0 ppm as Cl_2 may actually be equivalent to 2.0 ppm of chlorine dioxide.

Recorded contaminant levels during the first 34 hours, while the generator was actually shutoff because of the bleach plant shutdown, were less than 0.2 ppm (as Cl_2) until the last 9 hours (20:00 Wednesday to 5:00 Thursday). During this latter period, the utility worker collected a series of four quality control samples (1 hour apart) from the chlorine dioxide solution storage tank.* Although the actual sample collection

*This solution must be tested for strength whenever the bleach plant starts to use it, even if the generator is not operating.

TABLE 30-2: SUMMARY OF BLEACH PLANT PERSONAL AND AREA SAMPLES

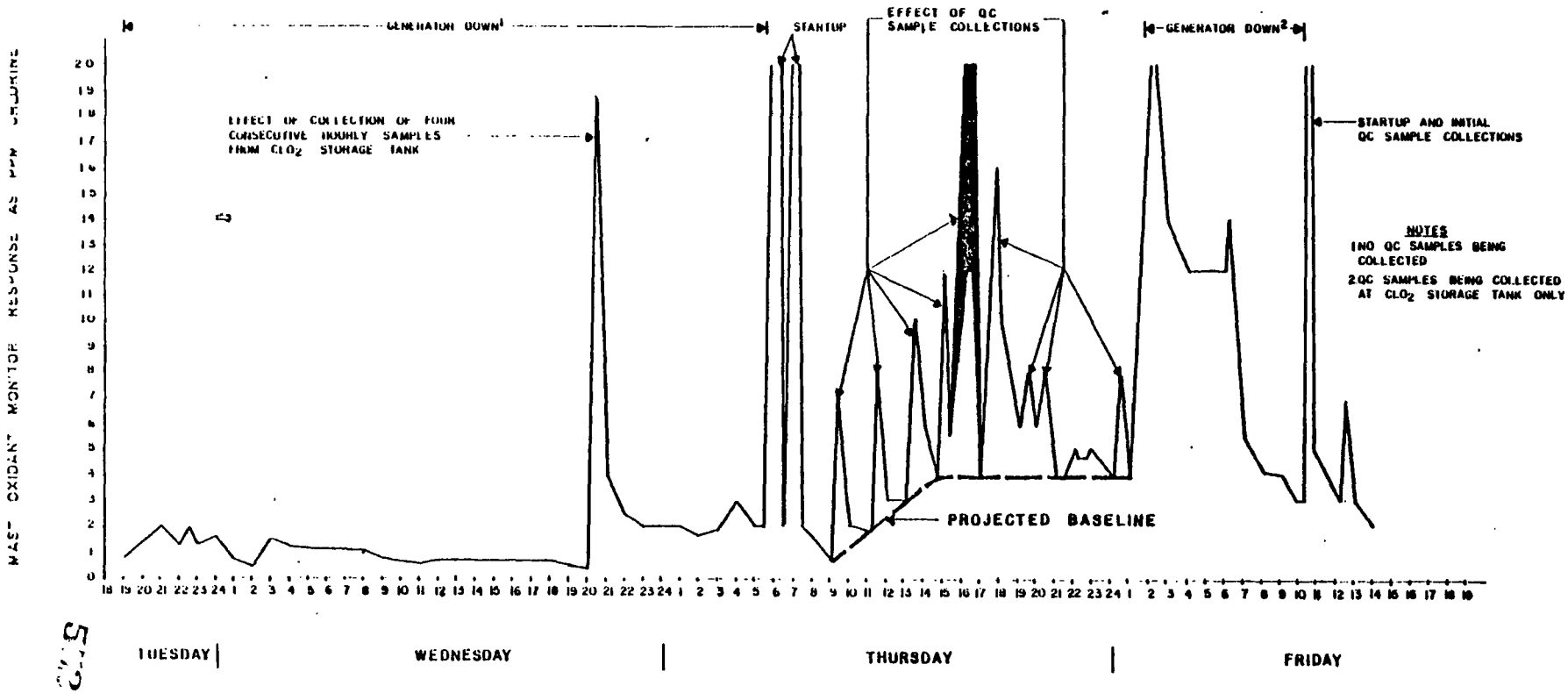
Job Category/Location	Sample I.D.	Day	Sampling Period	Concentration Cl_2/ClO_2* (as ppm Cl_2)	Comments
o Personal Samples -					
Helper	1	Thurs.	7:52-8:07	<0.05	Normal hourly sample collection routine
Helper	2	Thurs.	8:57-9:12	<0.05	Normal hourly sample collection routine (omitted washer samples).
Helper	3	Thurs.	9:19-9:36	<0.05	Hosing down stock spills around hypo conveyor.
Helper	4	Thurs.	10:00-10:15	0.25	Normal hourly sample collection routine (high residual at ClO_2 washer).
Helper	5	Thurs.	19:06-19:23	<0.05	Normal hourly sample collection routine.
o Area Samples -					
Near Control Panel on Washer Floor	6	Wed.	13:55-14:12	<0.05	During start-up of bleach process.
Near Control Panel on Washer Floor	7	Wed.	14:20-14:25	1.27	During start-up of bleach process
No. 1 Chlorine Washer Exhaust Hood Duct	8	Fri.	10:17-10:22	0.09	Not using counter-current wash water flows; water temperature approximately 58°F.
No. 2 Chlorine Washer Exhaust Hood Duct	9	Fri.	10:25-10:40	<0.05	Same as Sample No. 8.

*All samples collected and analyzed according to NIOSH Method P&CAM 209 using 15.0 ml. methyl orange in Liquid Media Samplers. Chlorine dioxide is a positive interferent in collection method, and workers may have been exposed to it and chlorine during the sampling period.

FIGURE 30-3

MAST OXIDANT MONITOR RESPONSE IN CHLORINE DIOXIDE GENERATOR BUILDING*

* MONITOR'S RESPONSE IS LIKELY CAUSED BY ONLY CHLORINE DIOXIDE, BUT NO FIELD METHOD EXISTS FOR CHLORINE DIOXIDE CALIBRATION (SEE ALSO REPORT TEXT)



point was far from the monitor (i.e., on the ground floor of the building), as shown, opening a sampling valve and letting concentrated chlorine dioxide solution drain on the floor caused elevated levels on the operating floor. Although delayed, a sharp initial peak (~1.85 ppm for ~45 minutes) was recorded and then tailed over the next 8 hours (0.5 to 0.2 ppm). These results clearly indicate this procedure of letting the concentrated ClO_2 solution drain on the floor without immediate water dilution and flushing to a process sewer can disperse chlorine dioxide gas throughout the building.

On Thursday morning (~ 6:00), the generator was started up again because the bleach plant required chlorine dioxide. It ran continuously for the next 20 hours. During this period, the utility worker continued to collect quality control samples at the storage tank (every hour), the ClO_2 absorber, and the acid overflow line from the primary to secondary reactor (every two hours). The latter two sampling points are on the generator operating floor near the monitoring station. A series of distinct contaminant peaks were recorded over this 20 hour period. During the first two hours, two separate peaks were recorded. Each exceeded 2.0 ppm (as Cl_2) for about 15 minutes. Collection of quality control samples during this initial startup may have been responsible for the peaks, but their magnitude suggests that generator operating problems (perhaps, a reactor 'puff') may also have occurred and resulted in direct workplace emissions.

Over the next 14 hour monitoring period (7:00 to 21:00 on Thursday), effects of the sample collections are again evident in a series of approximately eight evenly-spaced, sharp peaks. The highest of these only briefly exceeded 2.0 ppm (as Cl_2), but the between peak baseline concentration rose gradually from about 0.1 ppm (9:00) to about 0.45 ppm (at 24:00). These results indicate that collection of quality control samples also has a cumulative impact on air contaminant levels in the building.

Early Friday morning (at 2:30), the generator was shutdown because its chlorine dioxide storage tank was full. An initial sharp peak (2.0 ppm) was recorded, but it tailed pronouncedly down to about 1.25 ppm over the next 4-4.5 hours. During this period, storage tank samples were collected each hour, but the absorber and reactor acid samples were collected only at the start. Therefore, this tailing peak again emphasizes the impact of the poor storage tank sampling procedure on overall building contaminant levels.

The generator was re-started at midday on Friday, and again a sharp peak, briefly exceeding 2.0 ppm (15 mins.), was recorded. As with the previously observed startup peaks, it

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was probably caused by the quality control sampling that is initially required and/or by a direct reactor emission (puff). Before monitoring was stopped, another distinct peak (~0.7 ppm at 12:30) was recorded. It too was probably caused by collection of a quality control sample at the storage tank.

The 67 hours of monitoring indicates some worker exposure to chlorine dioxide occurs when they collect samples in the building. Personal exposure samples collected during these samplings provide some insight into the magnitude of the exposures. Unfortunately, there is no specific sampling method for chlorine dioxide, so samples were collected using NIOSH Method P & CAM 209 for chlorine. During a single day, nine such personal samples were collected on the helper. Results, including brief sampling task descriptions (and times), are summarized in Table 30-3.

Observations during the first sample (0.86 ppm as Cl_2), indicated exposure was most severe during the period the worker opened a sampling valve to flush a line and then withdraw a representative sample. Therefore, some of the later samples (Nos. 3, 6, and 8) used a very short sampling time (2-3 minutes) to assess the magnitude of this specific exposure. All, with the exception of Sample No. 8, resulted in measured exposures in excess of 0.5 ppm regardless of sampling duration. They ranged from 0.77 to 5.53 ppm (as Cl_2). The one low result (No. 8, <0.06 ppm) was a three minute sample collected only while the worker sampled the primary-to-secondary reactor acid and the absorber solution. It confirms that the most severe exposure occurs only during collection of the chlorine dioxide storage tank sample. The other eight samples all included (some exclusively) this specific collection task..

The inability to specifically quantify these exposures in terms of chlorine dioxide makes it difficult to even estimate the extent of compliance to the OSHA TWA standard of 0.1 ppm. The continuous monitoring results in the building indicate chlorine dioxide levels may be above 0.1 ppm during normal generator operation. However, workers are in the building only about 10 minutes or less each hour to collect samples, and their overall 8-hour time weighted average exposures are probably below 0.1 ppm.* Building levels probably never approach the NIOSH IDLH limit of 10 ppm.

To supplement the continuous and personal sampling, a number of Drager detector tube readings were taken in the chlorine dioxide generator building and in other chemical handling areas. They provided information on the possibility

*Workers wore half-face piece air-purifying respirators whenever they collected quality control samples in the building.

TABLE 30-3: SUMMARY OF CHEMICAL HANDLING PERSONAL AND AREA SAMPLES

Job Category/Location	Sample I.D.	Day	Sampling Period	Concentration Cl_2/ClO_2* (as ppm Cl_2)	Tasks Performed**
o Personal Samples -					
Utility Worker	1	Thurs.	9:15-9:30	0.86	Collected ClO_2 Generator Samples: o Storage tank sample- 20 seconds; o Absorber sample- 20 seconds; o Primary to secondary reactor acid sample- 20 seconds (plus ≈9 mins. to unclog sampling line); o Testing samples- 3.25 minutes
Utility Worker	2	Thurs.	11:20-11:29	1.49	Collected ClO_2 Generator Samples: o Storage tank sample- 20 seconds; o Absorber sample- 10 seconds; o Primary to secondary reactor acid sample- ≈ 20 seconds
Utility Worker	3	Thurs.	11:24-11:26	0.83	Collected only absorber sample (sampling valve open for a total of only 20 seconds)
Utility Worker	4	Thurs.	11:31-11:39	0.77	Tested samples in control center.
Utility Worker	5	Thurs.	12:29-12:34	> 2.4	Collected and tested only ClO_2 storage tank sample (sampling valve open for 20 seconds; 3 minutes to test sample)
Utility Worker	6	Thurs.	13:19-13:21	5.53	Collected only ClO_2 storage tank sample (25 seconds)
Utility Worker	7	Thurs.	13:22-13:30	1.36	Collected ClO_2 Generator Samples: o Absorber sample - 7 sec.; o Primary to secondary reactor acid sample- 32 seconds; o Testing samples- 6 minutes
Utility Worker	8	Thurs.	19:33-19:36	<0.06	o Collected primary to secondary reactor sample-30 sec. o Collected absorber sample - 15 sec.
Utility Worker	9	Thurs.	19:36-19:42	0.86	o Collected ClO_2 storage tank sample - ≈11 sec. o Testing samples - ≈4 min.
o Area Sample -					
Near Hypo Makeup Tank	10	Thurs.	18:39-18:57	<0.05	During startup, problems with hypo reactor

*All samples were collected and analyzed according to NIOSH Method P&CAM 209 using 15.0 ml. of methyl orange in Liquid Media Samplers. Method responds positively to chlorine dioxide, but results were quantified only in terms of chlorine.

**Workers wore half-face piece air purifying respirators during all sample collections.

†This worker was exposed only to chlorine dioxide while collecting quality control samples.

of gas leaks from process equipment, and the magnitude of continuous or event-related emissions. The readings are summarized in Table 30-4.

Five readings for chlorine dioxide (using a chlorine tube) were taken in the generator building. Numbers 2, 3, and 4 were taken at the three respective process quality control sampling points, about 30 minutes after samples had been collected. The storage tank (ground floor) and absorber (operating level) locations both resulted in readings of 1.0 ppm (as Cl_2), but the primary-to-secondary reactor acid location resulted only in a reading of 0.1 ppm. This later location is very close to the reactors' exhaust hood, and little chlorine dioxide would be expected to escape there: The other two samples in this building, numbers 5 and 8, both gave slightly positive readings (~0.2 ppm). The latter was taken to see if the continuously running stream of generator acid (where the QC sample is collected) is a constant source of chlorine dioxide. It apparently is not.

Two chlorine detector tube readings were taken in the hypo production area of the main chemical handling building. A reading directly above the hypo storage tank (inside the control building) gave a response of 0.3-0.4 ppm. However, it was taken just after the operating staff had some difficulties getting the reactor started up and operating correctly. It confirms that chlorine gas can be released to the workplace if too much chlorine is used in the reactor. The other reading was taken on the ground floor in order to investigate possible chlorine/chlorine dioxide offgasing from the process sewer. No gas was detected. (The mill reported this rarely occurs, and process sewers are generally well-designed, segregated, and continuously flushed.)

One sulfur dioxide detector tube reading was taken above the sealed antichlor storage tank. However, no gas was detected, and supports our observation that little gas could escape from this system, or from the liquid sulfur vaporization equipment in the adjacent unloading shed.

CONTROL TECHNOLOGY

Nature of Controls

Despite limited time to collect data on normal plant conditions, our observations and air monitoring indicate no constant sources of significant chlorine/chlorine dioxide emission in either the bleach or chemical handling buildings. Workers are generally well-isolated from potential exposure sources (with the exception of collecting QC samples). In addition, a number of process monitoring and control systems guard against situations that could result in exposure like, process upsets, stock and chemical spills, and over-addition of bleaching chemicals. They will be briefly discussed below.

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TABLE 30-4: SUMMARY OF DRAGER DETECTOR TUBE READINGS

Sample No.	Location	Contaminant	Time	Reading (ppm)	Comments
1	Front of Antichlor Preparation Tank	SO_2	9:10-9:13	No Reading, <<.05	Makeup system was operating properly.
2	Above ClO_2 Storage Tank Sampling Point	ClO_2	11:53-11:56	1 *	Quality control sample collected about 30 minutes prior to reading.
3	Above ClO_2 Absorber Sampling Line Drain	ClO_2	12:05-12:09	1 *	Quality control sample collected about 30 minutes prior to reading.
4	Above Primary to Secondary Reactor Acid Sampling Location	ClO_2	12:12-12:15	≈0.1*	Quality control sample collected about 30 minutes prior to reading.
5	Ground Floor of ClO_2 Building-Between Hotwell and Spent Acid Tank	ClO_2	12:19-12:23	0.2*	Quality control samples collect about one hour prior to reading.
6	Ground Floor of Control Building - Above Sump Pump	Cl_2/ClO_2	12:42-12:49	No Reading	Reading taken while sump pump was on.
7	Above Hypo Makeup Tank	Cl_2	19:44-19:49	0.3-0.4	Reading taken just after correcting startup problems with system. (Hypo QC sample results were very high.)
8	ClO_2 Building - Above Reactor Spent Acid Sampling Line Draining to Sewer	ClO_2	19:12-19:17	≈0.2*	Mast Monitor at nearby location read ≈0.7 ppm (as Cl_2).

*Chlorine detector tube was used to estimate ClO_2 concentration; reading is PPM of chlorine.

The survey team had the opportunity to conduct air monitoring in the bleach plant during startup and shutdown conditions under severe winter weather. The monitoring confirmed that poorly controlled chlorine and/or chlorine dioxide usage can occur for brief periods during both operations. We estimated workplace chlorine/chlorine dioxide air levels during these times may approach or slightly exceed existing standards, but attempts to locate, much less reduce emission sources could be a near impossible task. In general, such emissions probably result from the difficulties in filling empty or partially full towers (chlorine and chlorine dioxide stages), and then concurrently adjusting chemical flowrates to balance pulp flowrates. During normal operations, this balancing occurs automatically and is well controlled.

During startups and shutdowns, the bleach process must be operated manually because the controllers are imprecise and are limited in range. Difficulties in stabilizing and balancing chemical and stock flows can result in too much chlorine, hypochlorite, or chlorine dioxide being added to the pulp. This causes off-gassing at the respective towers, washers, and filtrate tanks. Despite an excellent ventilation and scrubber system for the washers, towers, and filtrate tanks, highly contaminated exhaust air can apparently overload the scrubber and infiltrate the washer floor. This occurs because this workplace is under high negative pressure due to all the exhaust air. We believe levels could be controlled if operators did not overuse chemicals during these times in order to insure complete bleaching. Wasting or allowing a small amount of poorly bleached pulp to pass may be a possible solution.

All periods of elevated contaminant levels were short-lived indicating the emission was related to an unusual process condition. We believe emissions are normally well-controlled. Worker exposure is minimized by the combined effects of:

(1) good local and general ventilation

(2) good process monitoring and control

(3) frequent equipment inspections and good maintenance

(4) use of appropriate respirators during process upsets, spills, and collection of quality control samples

(5) Training of workers in recognition and avoidance of potential workplace exposure hazards.

Each of these will be briefly discussed below under the headings of "Ventilation, Process Monitoring and Control, Equipment Maintenance, and Protective Equipment." We believe performance of the ventilation systems in this mill is particularly critical because (1) buildings must be tightly closed during the winter, (2) the chlorination stage equipment and much of the bleach chemical preparation systems are indoors, and (3) control and monitoring panels are not inside protective rooms.

Ventilation

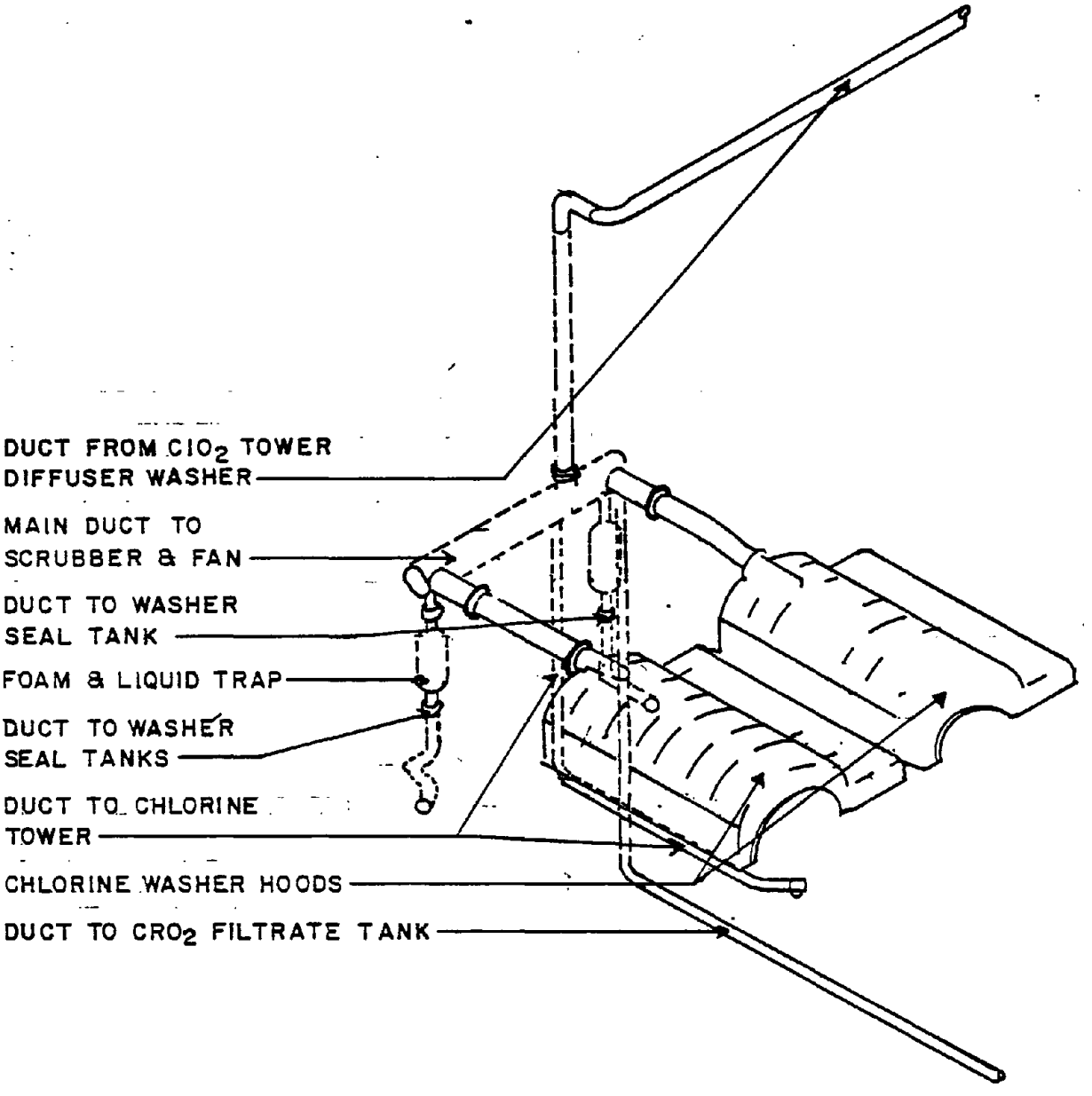
The most noteworthy engineered control in the bleach plant is a local ventilation system for the two chlorine washers and filtrate tanks, and the chlorination tower. It also ventilates the chlorine dioxide diffusion washer. An exhaust hood over the chlorine dioxide reactors in the chemical handling building is similarly important for that workspace. The mill also extensively uses general ventilation, especially during cold weather periods when buildings are tightly closed. This type of ventilation achieves important air turnover in remote, infrequently-entered floors of the bleach plant (ground through third floor) and the upper levels of the chlorine dioxide generator building. Fugitive emissions or small leaks of chlorine and chlorine dioxide may occasionally occur in these areas. If they are not diluted and vented, they could eventually diffuse into more frequented areas like stairways, the elevator, the adjoining building, or equipment operating floors. We will discuss details of all important local and general ventilation systems in the two process areas separately.

Bleach Building

In the bleach plant, the major potential chlorine and chlorine dioxide emission sources are the washers, chlorine and chlorine dioxide towers, and the washer filtrate tanks. They are all exhausted by one fan to a common scrubber system. This exhaust system was installed in the mid-1970's. An isometric sketch of it is shown in Figure 30-4. A detailed description and diagram of the scrubber (Peabody Air Resource Equipment Company) is provided as Figures 30-5, 30-6, and 30-7.

As shown, the system conveniently exhausts all equipment where significant amounts of chlorine or chlorine dioxide gas may evolve from the pulp and filtrate water by using only a 13,000 CFM fan. The exhaust air is then scrubbed before it is discharged near the building's roof. We thought that 13,000 CFM of exhaust air was insufficient to capture all contaminants from these sources, but little exhaust is required for the chlorination tower, the diffusion washer (above the outside ClO_2 tower), or the two washer filtrate tanks. All of this equipment is relatively closed. However, the two chlorine washer hoods must have sufficient exhaust capacity and, more importantly, face velocities to guard against escape of chlorine because at least two production workers regularly work

FIGURE 30-4: ISOMETRIC DRAWING OF BLEACH PLANT LOCAL EQUIPMENT EXHAUST SYSTEM



NOTE:
THIS DRAWING TO BE REDONE FOR FINAL REPORT.

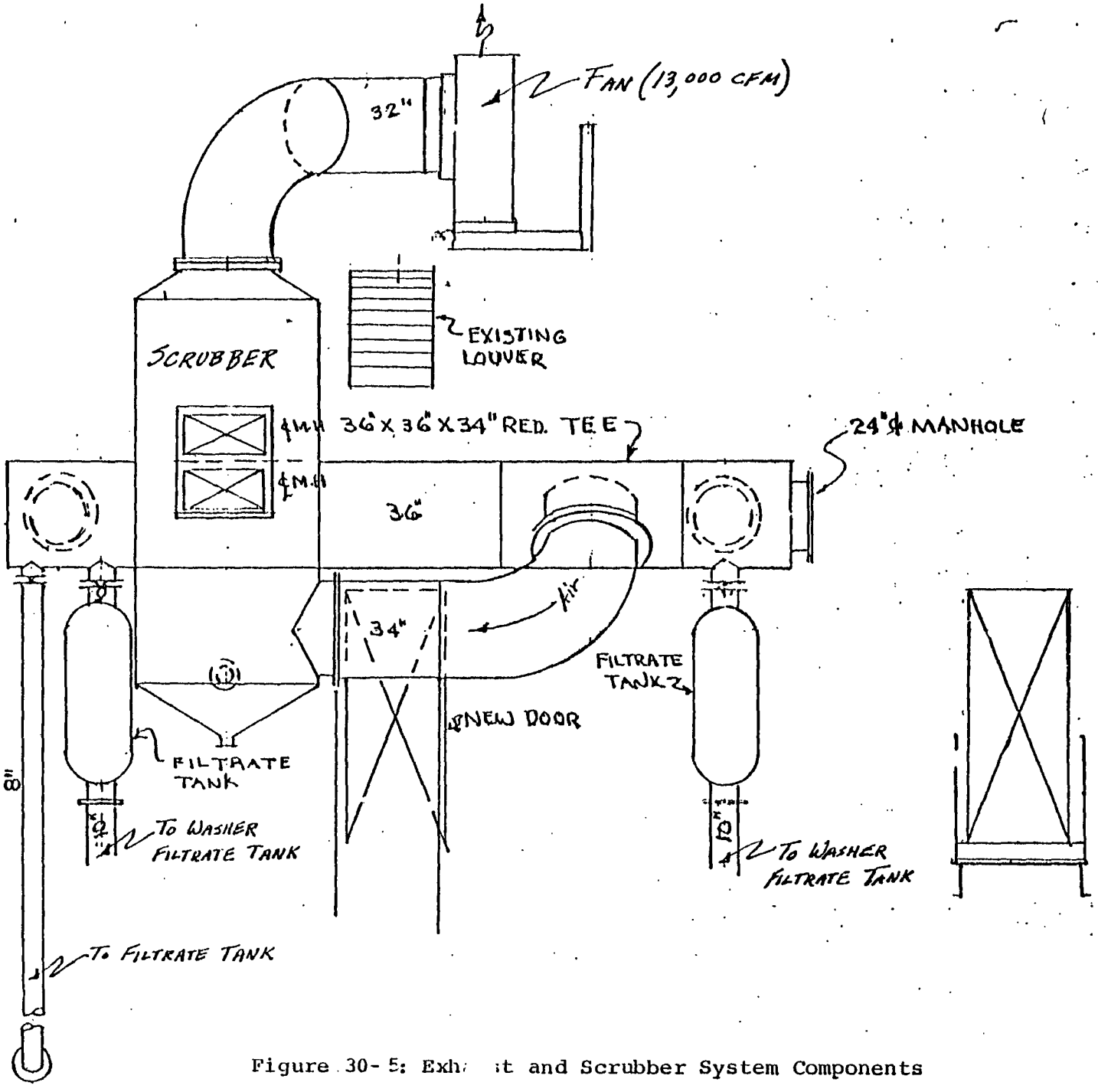


Figure 30-5: Exhaust and Scrubber System Components

Figure 30-6: Scrubber System Operational Diagram

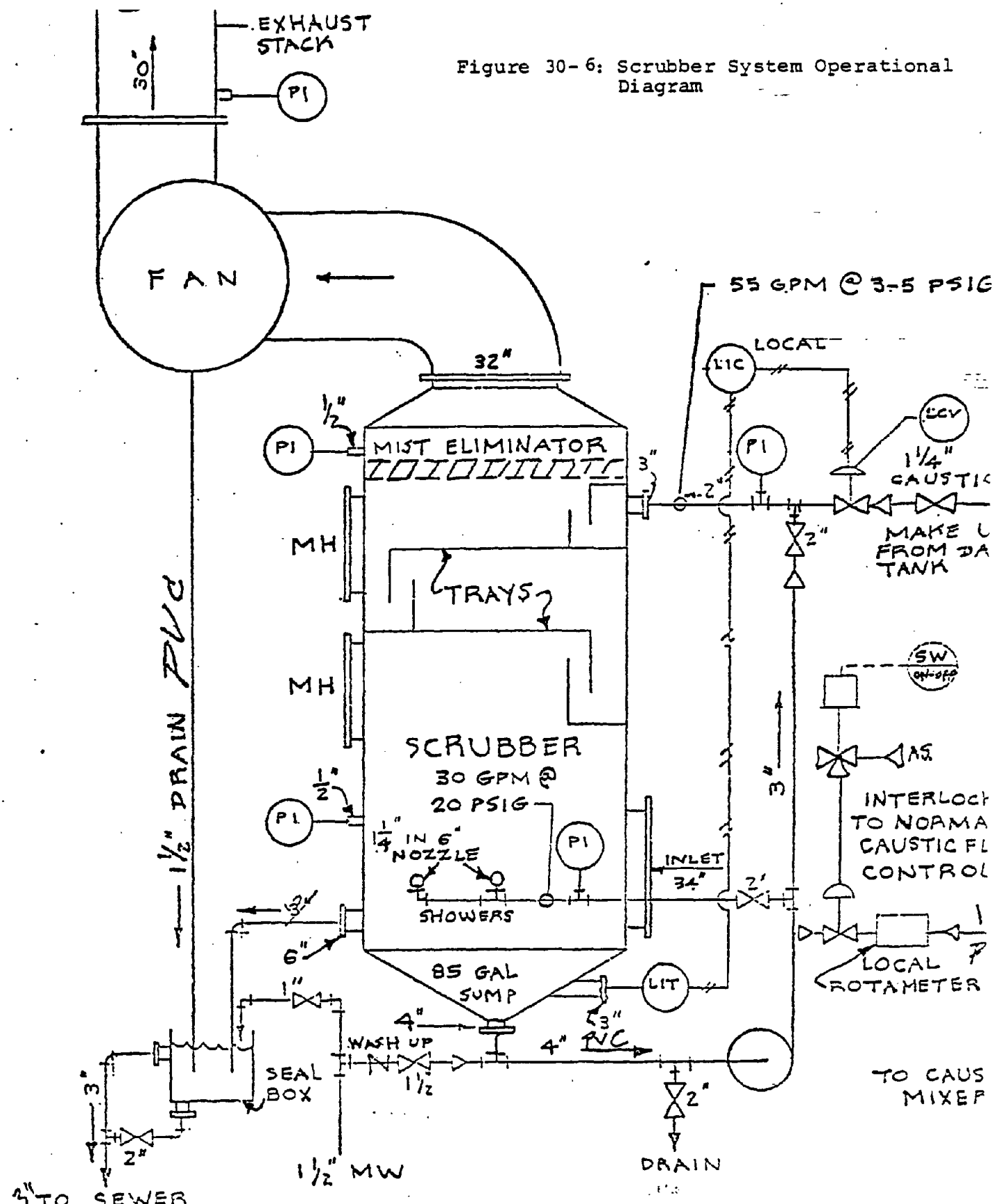


Figure 30-7 Bleach Plant Exhaust and Scrubber System Operational Data

The bleach plant absorber has been designed for the following conditions:

Gas Volume:	13,000 ACFM
Water Vapor:	Unspecified
Inlet Temperature:	80°- 120°F
Inlet Pressure:	-2" W.C.
Inlet Loading	Up to 2 1/2% Cl_2 & ClO_2
Dust/Gas:	Cl_2 to ClO_2
Outlet Temperature:	90° - 110°F
Outlet Pressure:	+0.5 W.C.
Efficiency (design):	97%
Pressure Drop:	6" W.C. Total Unit

The operating requirements include the following:

Air: 13,000 ACFM at 120°F to Absorber
13,000 CFM at 70°F to Fan

Liquid: Absorber N3 55 G.P.M. @ 3-5 P.S.I.G.
N6 A&B 15G.P.M. ea; 30 G.P.M. total @ 20 P.S.I.G.

Knock-Out N7 2-4 G.P.M. @ 20 P.S.I.G.

Operating Description:

Knock-Out Chambers
The two (2) knock-out chambers as shown on G.A. serve as a foam breaker/suppressor (through the action of the liquid spray nozzle) for the filtrate vent.

Absorber
The Bleach Plant Absorber as shown in the General Arrangement drawing consists of two (2) impingement plate stages, spray header, and a mesh type mist eliminator. The water for scrubbing is supplied to the top plate stage and flows across each successive plate stage utilizing a system of down comer and seals. The water eventually falls to the base of the scrubber and is discharged through a water drain. There is an additional supply of water to the spray nozzle in the lower part of the scrubber, forming a spray zone which saturates the hot gas with water vapor and flushes the underside of the bottom plate stage.

The cleaning stages provided are used to mix the gas with large quantities of water and tends to agglomerate the particles, making it easier for the impingement plates to do an efficient cleaning job.

The impingement plate consists of a perforated sheet with individual baffles placed over and at short distances from each hole. Although the baffles are submerged, water cannot flow down through theholes in the perforated sheet while there is sufficient upward gas flow. The scrubbing action that takes place may be described briefly as follows:

Hot dirty gas enters the base of the scrubber and rises up through the impingement plate where the gas is divided into thousands of small jets. These jets, in overcoming the tendency of the water to flow down through the perforations, tear away water droplets from the peripheries of the holes. Impingement occurs between the particles and these droplets and each gas jet itself impinges upon a baffle. The velocity of impact drives the particles into the scrubbing water and breaks the gas jets into innumerable bubbles which pass up through the water layer.

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The scrubbing water which flows cross current to the gas stream is introduced above the top impingement baffle plate stage. The scrubbing water, picking up trapped dust as it flows, travels across the impingement baffle plate stage to a combination drain and liquid seal and passes down to the seal and falls to the base of the unit and finally passes out through the water outlet.

The water eliminator at the top of the unit, which consists of a polypropylene mesh, removes any entrained liquid droplets from the clean saturated gas before it leaves the scrubber.

near the washers. The two chlorination washers have identical tight-fitting, half-drum, fiberglass hoods over them. Each hood has a number of covered hatches over its inlet and discharge ends. The survey team took face velocities at any normally open hatches or other hood openings to see if contaminants could escape. As shown in Figure 30-8, readings in excess of 150 feet per minute (fpm) were obtained for all of them. The readings indicate there is sufficient air flow from both hoods, provided most of the covers remain closed. Contaminants could not typically escape. Detector tube readings taken inside the exhaust duct from these two chlorine washers also indicate little chlorine gas actually escapes from the pulp during effective operation of this bleach stage.

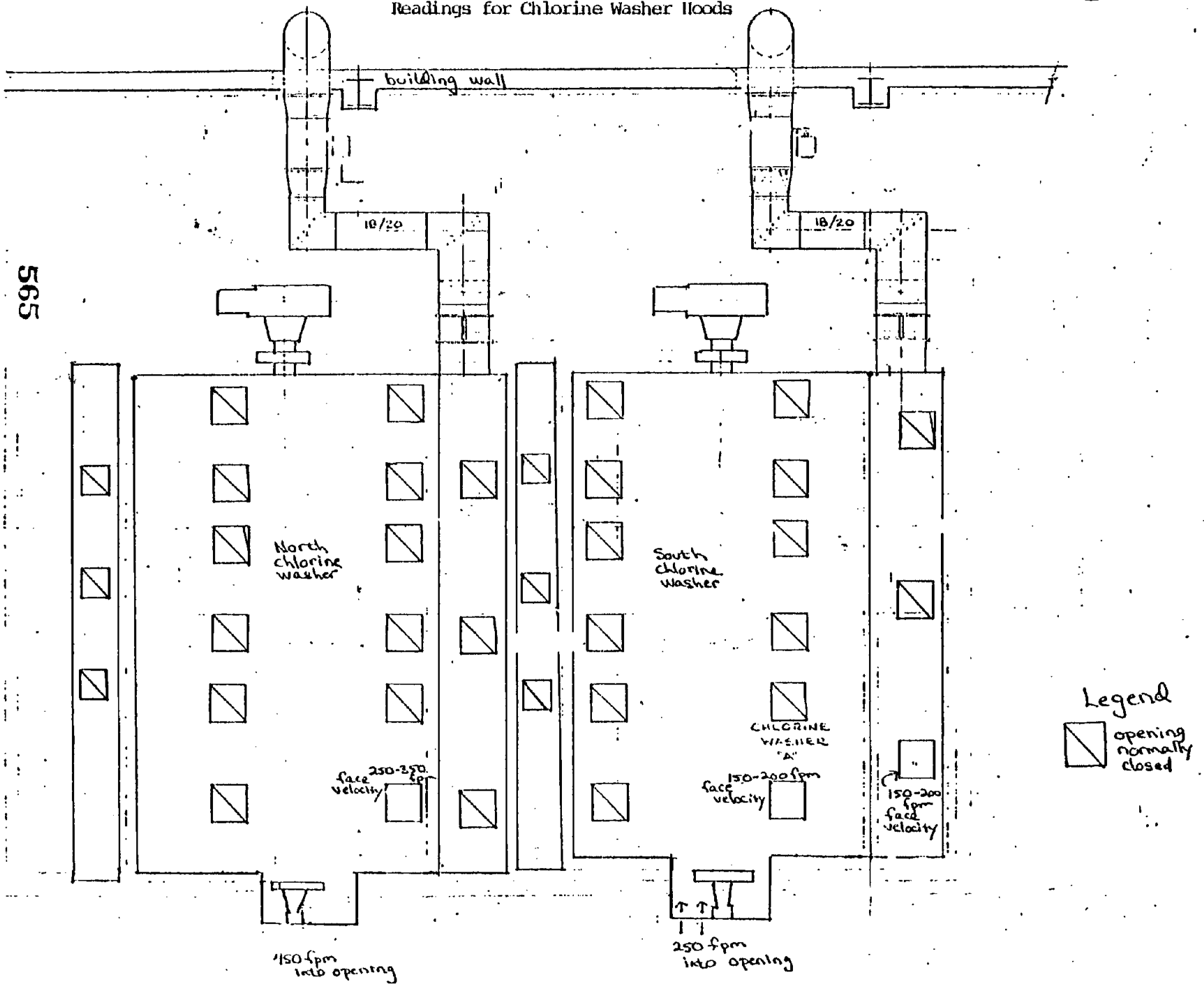
Chlorine gas does not normally escapes from the hypochlorite stage washer either, as it is also provided with a similar, tight-fitting exhaust hood. At the time of the survey, the hood's fan was not operating so no ventilation readings were taken. The fan normally exhausts 7,260 cfm of air from the washer out through the bleach building's east wall.

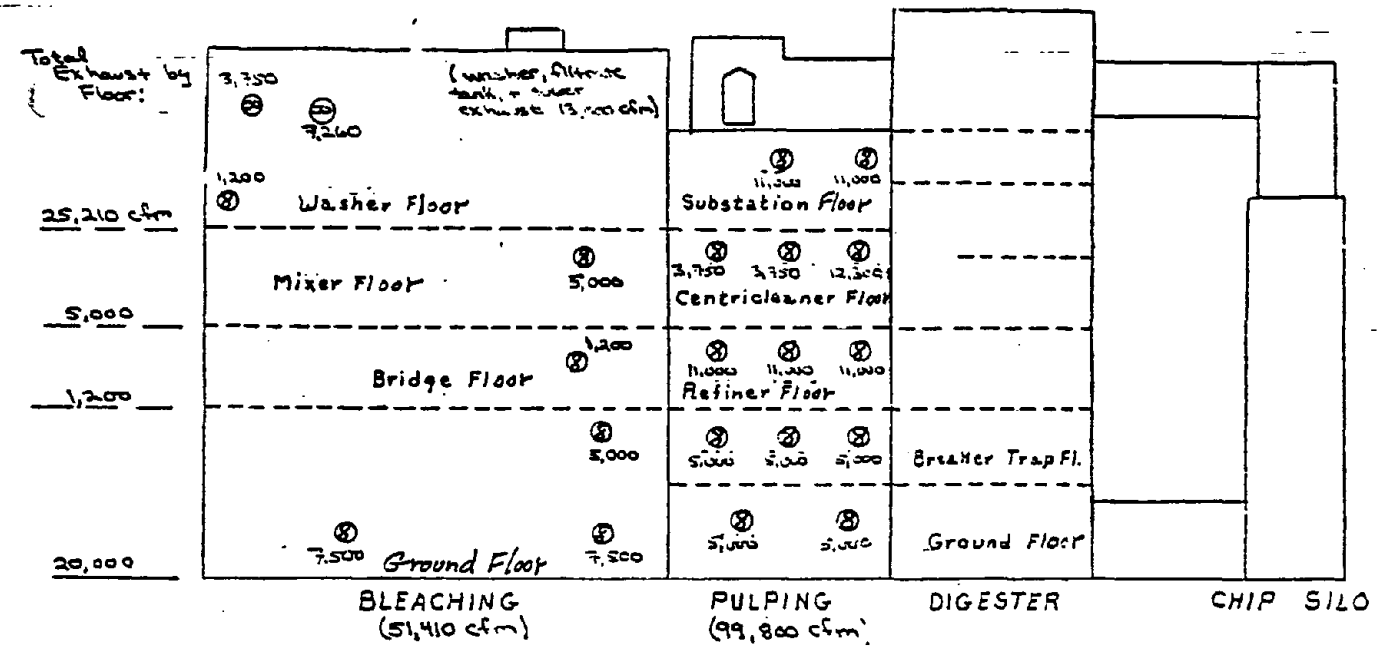
General ventilation of the building's four floors is accomplished with seven wall exhaust fans and six supply air systems (see Figure 30-9). A total of about 51,500 cfm of air is exhausted, and about 104,000 cfm is brought back in (most of the supply air can be pre-heated, when required). The adjoining refiner and cleaner section of the pulp mill exhausts an additional 99,800 cfm of air and returns approximately 60,600 cfm. Therefore, a nearly equal balance of 151,210 cfm of exhaust versus 164,600 cfm of supply results for the entire building.

The important fourth floor washer room was under negative air pressure, despite an indicated small over-supply of air (25,210 cfm exhaust versus 27,000 plus part of a 5,600 cfm system)*. Because of this condition, outside air can infiltrate through openings on the room's east wall near the washer exhaust ducts and near a small 3,750 cfm wall fan. This air may be periodically contaminated with chlorine or chlorine dioxide which the exhaust scrubber cannot fully remove when either chemical is over-added to the pulp. We suggested this explanation for high chlorine/chlorine dioxide levels recorded on the washer floor during process startups and upsets (discussed in the "Air Monitoring Results" section). If this is the cause, little remedy is possible other than: (1) better process control to reduce the amount of chlorine/chlorine dioxide emitted to the exhaust system, (2) extending the scrubber exhaust stack further above the building, or (3) sealing any unnecessary building openings and increasing the amount of air supplied to the floor.

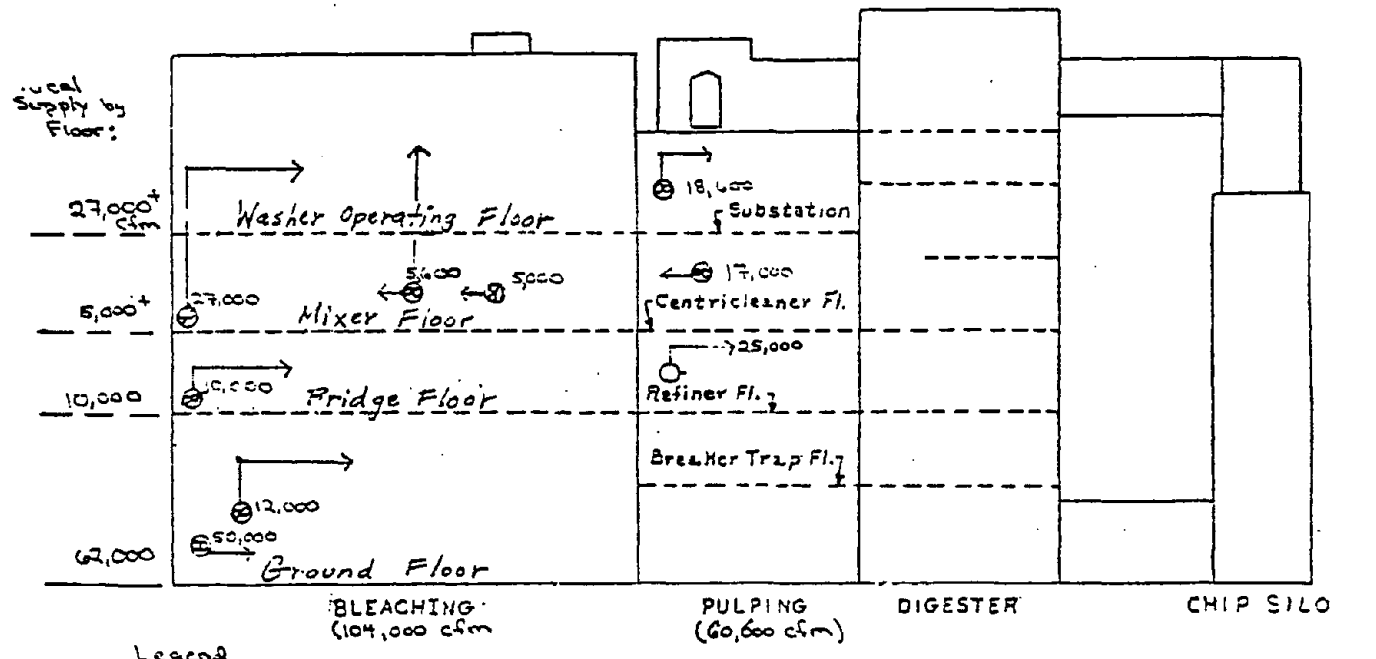
*If the hypochlorite washer hood was operating, this condition would be increased slightly.

Figure 30- 8 Layout and Ventilation Readings for Chlorine Washer Hoods





EXHAUST FAN LOCATION



Legend
- arrows on supply fan indicate distribution (by floor)
- all values are expressed as cfm

SUPPLY FAN LOCATIONS

The amount of exhaust and supply air provided for the other building floors are sufficient to insure good air turnover and the eventual dilution and dissipation of minor gas leaks or emissions there. As shown in Figure 30-9, more air is exhausted and supplied to the ground floor (20,000 cfm exhaust and 52,000 cfm supply). This is a good feature because the chlorine gas controls and injection equipment are located here. However, the mill is also actively pursuing the design and installation of a twelve-channel chlorine air monitoring system for this building to reduce worker concerns over major gas leaks (see "Maintenance" section).

Chemical Handling Building

In the chemical handling area, local ventilation is required only in the chlorine dioxide generator building. The ventilation consists of two canopy hoods; one over the top of the reactors, and the other above the overflow pipe (to the process sewer system) for the generator spent acid tank. Both of these local exhausters are operated continuously. The reactor's hood exhausts 2,000 CFM and the overflow pipe's an unknown amount. They discharge air to the outside through the upper north wall of the building.

The generator's hood is hexagonally-shaped and extends halfway down and over the two reactors. Although hood faces are irregular because of the reactor vessels' shape, velometer readings of less than 50 to 200-250 FPM were obtained at five points around accessible face areas. The two highest readings, 170-220 and 220-250 FPM, were at the front of the reactors. They may have been affected by a heating air fan located above and in front of the reactors (on the generator operating floor). These face readings indicate that the fan is exhausting nearly 2,000 CFM from the hood, and most gas leaks from the reactors can probably be contained and exhausted. However, if either of the reactor explosion vents opened, some high pressure gas may escape into the immediate work area. It would not be of consequence unless workers were nearby.

The other hood is located next to the generator's spent acid tank. It is about two feet above where its overflow pipe enters a sump to the building's process sewer. It was installed in the early 1970's apparently to ventilate any chlorine dioxide which escapes when acid is wasted to the process sewer. The acid is usually pumped to a wastewater treatment plant or the bleach building, so wasting is not always done. Velometer readings at the hood's face (approximately 3'6" x 4') and near the sewer line indicate a total hood CFM of about 3,000, and capture velocities of approximately 50 FPM. Both values demonstrate the hood is effective, but, as a general practice, evolutions of

potentially explosive gases at process sewers are more effectively controlled by direct pipe connections to water-purged sewers with vented or force-ventilated traps and completely closed sumps.

General ventilation in this building is also very important because of periodic, short-duration chlorine dioxide (with some chlorine) emissions and fugitive leak sources that are associated with operation and sampling of the absorber and generator. Contaminants may also occasionally escape from the process sewer and spent acid storage tank. These emissions vary in magnitude and occur throughout the building. They could create elevated air concentrations, but are difficult to ventilate locally. Therefore, three similar wall fans are used to exhaust air from the building's upper levels. They are located on:

- The upper floor north wall (two fans): one behind the head tanks for generator chlorate and sulfuric acid solutions; the other behind the top of the absorption tower.

- The east wall of the stairway to the fourth level (this fan was recently replaced and was not operational at the time of the survey).

The mill did not have actual ratings for the fans, but we estimate 5000-6000 CFM for each. This results in a total of 15,000 to 18,000 CFM of exhaust air for the building. The building's main airspace measures about twenty-five feet wide by thirty feet long by approximately fifty feet high (37,500 cubic feet). Therefore, this amount of exhaust creates an estimated 24 to 29 building air changes per hour. It is judged sufficient to dilute and eventually remove small amounts of air contaminants. A small amount of heated supply air is brought into the building through its ground level south wall (~6600 CFM).

The continuous air monitor recordings (see "Air Sampling Results") indicate any chlorine dioxide gas emitted on the ground floor during collection of the storage tank sample slowly drifts upward through the building. This probably occurs because the exhaust fans are all on the upper floors. The effect of this emission on overall building air quality warrants either its reduction and/or providing more exhaust, possibly by local ventilation.

Based on closing comments to mill management, they have addressed this problem by installing a continuously running flush hose at the storage tank sampling valve. They have also made wearing a respirator during sample collection a mandatory requirement.*

General ventilation is also used in the other three buildings which comprise the chemical handling area of the mill. Air is heated in these buildings by a number of recirculating-type space heaters. Liquid chlorine is unloaded and vaporized in the larger of the two sheds. A wall exhauster with an inverted Y-shaped floor-level intake duct can be used to exhaust the shed if a chlorine leak develops. However, the shed is large and it is doubtful this small exhauster could effectively remove chlorine gas from a large leak. Opening all four of the front doors would probably have an equal or better effect. (The fan for this exhaust system could not be turned on during our survey so no ventilation readings were taken.)

The two chemical handling workers spend most of their shift in the two-story center building, because the main equipment control panel is located there. The only potential sources of gas emission in this building are the hypochlorite reactor (chlorine), and the antichlor preparation system (sulfur dioxide). Two exhaust fans provide some air turnover in the building and may remove small, infrequent fugitive chlorine or sulfur dioxide emissions. Both fans are located on the building's south wall. One is on the upper floor behind the hypochlorite storage tank, the other is on the ground floor. They probably each exhaust about 5,000 to 6,000 CFM, but the mill did not have actual ratings. Neither would be very effective if a major gas leak developed, but design of a ventilation system for such an event is impractical.

The first of these fans may also provide some dilution and exhaust of chlorine gas which occasionally escapes from the hypochlorite storage tank's top. This occurs if too much chlorine gas or too little caustic is added during preparation of the hypochlorite solution. Based on comments made at the survey's conclusion, mill management further evaluated the potential for gas to escape here. As a result, they decided to install a large industrial fan at the hypo tank, and have instructed their engineering department to install an aspirator system to further (directly) exhaust the tank if severe

*Wearing a full-face respirator is also now mandatory during disconnection of liquid chlorine rail tank cars.

chlorine over-addition occurs. If it does occur (as determined by the hypo quality control sample or by smell), the operating staff has been instructed to shutdown the system until the fault can be determined. All three of these measures are excellent process safety and control improvements. Mills having similar inside hypo tanks and reactors may want to evaluate their ability to limit escape of chlorine gas. Tank tops should be kept well-sealed, vented, or exhausted. A local exhaust fan that could be automatically (or manually) activated based on low caustic flow, high Oxidation-Reduction Potential (ORP) levels, or high chlorine gas pressure would also be effective.

Protective Equipment

The mill has a very good overall respirator program. It includes both a detailed written instruction plan and mandatory respirator (escape type) possession requirements for all pulp mill and maintenance employees (and visitors). We observed that the program was strictly enforced. Workers knew how to use respirators and could recognize conditions where they would be required. As previously noted, all chemical handling workers faithfully wore half-face piece, air-purifying respirators when they collected chlorine dioxide generator samples. Pulp mill maintenance workers also always carried an escape respirator.

The written plan is a thorough but concise document for management and worker reference. It is also used to train and educate new employees. It has ten sections. Six of these cover selection, instruction and use, assignment and location, maintenance, storage, and inspection. They may be of interest to other mills, and have been reproduced in their entirety as Appendix A of this report. The mill has two supply-air respirator packs that use bottled air and full-face, pressure demand-type masks (a Cascade System). These are located in the bleach and digester control rooms. The mill also has a number of self-contained breathing apparatus (Scott Air Paks) for emergency use.

The mandatory requirement for all workers to carry an escape respirator (or equivalent) is an excellent safety precaution, but may no t be applicable for other mills. Even small gas leaks in this mill's tightly-closed bleach and chemical handling buildings can create dangerous exposure situations, and large leaks might cutoff escape routes.

Respirators are well-accepted in this mill, and we believe the possession requirement has promoted and encouraged their use during periodic exposure situations where employees should use them but normally may not because of inconvenience or because they are not readily available. The mill spends about $40,000 per year on respirators.

The mill has also developed an excellent set of written hazard identification and safety handling summaries for all its pulp mill and bleach plant chemicals. The summaries include a chemical description, an identification of the chemical's use and location, associated hazards, safety precautions (including use of personal protective equipment), and emergency treatment procedures for both skin and inhalation exposure. Copies of the summaries for all the common chemicals in the bleach plant and chemical handling building are attached as Appendix B. They may be of value to other mills.

Maintenance

During previous mill surveys, we realized good maintenance (frequent equipment inspections, thorough preventive maintenance, and prompt performance of repairs) is important in controlling and limiting workplace exposures. It is very difficult to substantiate maintenance's importance or effectiveness. This mill had an excellent equipment inspection, repair, and preventive maintenance program. Its maintenance staff was very knowledgeable and conscientious about preventing or reducing potential hazardous chemical leaks. They diligently wore respiratory protection whenever there was a potential for exposures, and were actively pursuing the development and installation of a comprehensive chlorine workplace air monitoring and alarm system[1]. In order to gain a better perspective and appreciation of the contribution of their maintenance activities to workplace exposure control, the survey team briefly interviewed the maintenance management staff. The management indicated maintenance workers are particularly thorough and careful about bleach plant and chemical handling maintenance. To assist them, management is developing a computerized maintenance program which they believe will greatly streamline operations, insure work is properly prioritized, and simplify recordkeeping and scheduling. They have also carefully investigated the durability of equipment and various packings, seals, and gaskets. They are constantly striving to make them more durable and less subject to leaks or corrosion. Their analysis has resulted in use of both packings (water-cooled) and

[1]At the time of the survey, the mill had obtained a quotation to supply and install a Devco Series 9000 Chlorine Monitoring System (0-50 ppm, Devco Engineering, Fairfield, NJ). It would have twelve bleach building monitoring locations--four in the basement, and two each on the first, second, third, and fourth levels. Total estimated cost was $25,000-28,000 depending on options.

mechanical seals (mostly where space permits) for corrosive liquids and acids in the bleach plant and chemical handling building. Management was particularly complimentary of a Chesterton graphite tape packing material that they are extensively using on valves and pumps. They are also slowly replacing all PVC piping with specially-lined cast iron pipe because the PVC has failed in places where it had to support any weight.

We also asked to review their records of prior repairs made in the bleach plant and chemical handling area. The mill provided records for nearly the past two months. Unfortunately, review of the records revealed little quantitative data substantiating prevention or limitation of workplace emissions. Generally, the records provided only a simple description of the repair and the work craft responsible for it. Fault diagnosis is investigated informally and no specific records are kept. The types of repairs were highly varied, but the review did support some general pre-conceptions about the nature, frequency, and potential impact of equipment failures and maintenance in bleach plants and chemical handling operations:

- Bleach plant and chemical handling equipment must operate under corrosive conditions because of periodic liquid leaks and gas emissions. Electrical systems must be very well protected.

- There is a high incidence of repair and replacement of flow control valves and process monitoring sensors that handle or contact corrosive and/or concentrated chemicals and treated pulps.

- There is a comparatively higher level of such repair in the chemical handling area versus the bleach plant.

- Process monitoring and control systems are regularly inspected and calibrated (magnetic flow meters, ORP controllers, conductivity cells, etc.)

- There are periodic leaks of concentrated liquids, chlorine gas, and treated pulp at packings, gaskets, and seals. If these are not promptly detected and repaired, they could create potentially significant workplace exposure conditions.

- These leaks reinforce the importance of performing regular inspections and preventive maintenance, which the mill does, separated under the crafts of lubrication, electrical, and instrumentation.

- Repair work must be, and is, prioritized.

- About 65% of the maintenance staff's time and money is spent on bleach plant and chemical handling area maintenance and repairs.

Process Monitoring and Control

Sensitive and accurate process monitoring and control systems with high/low alarms and safety interlocks are extensively used in the bleach process and chemical handling area. Unfortunately, the study team could not fully evaluate them because of the prolonged mid-week plant shutdown. However, we will briefly discuss the functions of important systems.

The amounts of chlorine gas and chlorine dioxide solution continuously added to the pulp at the first and last stages of bleaching, respectively, must be accurately determined and then well controlled. Adding too much can cause gas to be released at the towers, washers, filtrate tanks or other downstream equipment. Extreme over-addition may cause gas to escape to the workplace.* Therefore, it is important to accurately determine how much chemical is required (per unit weight of pulp), and then accurately meter it into the stock stream at a rate proportional to the pulp's flow rate and quality. The first of these (i.e., chemical dosage or percent chlorine applied) is broadly fixed based on overall brown stock quality, the brightness targets for the stage, and to some extent the available equipment. Operators will not deviate from the targets unless directed to, and the sensing elements and analog controllers for process equipment are calibrated for response within a range of these targets. However, equipment such as stock and water pumps or washers never operate trouble-free and the pulp stream may vary in quality and consistency. Such changes and variations require that process systems be continuously monitored and that adjustments be made.

A Systematics Optichlor and an oxidation-reduction sensor (ORP) are used to determine the conditions and chemical requirements for the chlorination stage.

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*The ranges of washer residual tests summarized in Table 30-1 (i.e. Cl_2 stage: 1-10 mg/l; ClO_2 stage: 1-20 mg/l), indicate that there is normally not enough residual chemical left in the stock to create a significant workplace emission at this point. However, the actual amount required to do so is hard to estimate because of the lack of dynamic equilibrium data and knowledge of chemical states, conditions (pH, temperature, etc.), and pulp/water surface areas.

The total amount of required chlorine per unit weight of incoming pulp (or dosage) is determined by the mill technical staff based on the brown stock's lignin content. Lignin content is estimated by a test called the Permanganate (K) number*. The test is routinely performed by the pulp mill staff, and results are quickly transmitted to the bleach plant. It is then used to determine how much chlorine must be applied to meet a certain pulp production level and brightness factor. Once these variables are known (K number, production level, and percent dosage), a controller setpoint for the chlorine flow valve can be established and correlated to the outputs of one of the two chlorination control systems (usually the Optichlor's).

The Optichlor system's sensor is located in the pulp stream after the chlorine injector but before the tower. It determines pulp brightness by continuously measuring the amount of light reflected from the surface of stock flowing through its cell. Its output is connected directly to the analog controller for the chlorine flow control valve. Once the first stage process is started up and is operating correctly, the Optichlor is used to automatically make any chlorine flow corrections. The mill technical staff indicated it generally performs well, although occasionally erratic fluctuations occur because of variations in the amount of already bleached papermill sludge in the stock. A small amount of this sludge is continuously blended with the pulp mill brown stock entering the bleach plant. The fluctuations are a result of the Optichlor "seeing" this already bright pulp. When they occur, operators may change to manual chlorine control, and sometimes they over-add (or under-add) chlorine.

The ORP sensor is located in a small, separate chlorinated pulp line which bypasses the tower and discharges directly to one of the chlorine washer inlet vats. The ORP output is monitored and recorded, and provides a means to check the calibration and sensitivity of the Optichlor system.

*This common test estimates the amount of color-causing lignin left in the digested wood by reacting (oxidizing) a weighted pulp sample with acid permanganate solution.

Operators also review the results of the hourly washer-filtrate residual chlorine and pulp brightness tests. These quality control tests determine: (1) if the correct amount of chlorine is being used, (2) the accuracy of the controller setpoints, and (3) the effectiveness of bleaching. Unfortunately, they provide no real-time data with which to make immediate process adjustments.

The flow of chlorine dioxide solution is largely pre-set based on third stage pulp brightness, stock flow, reaction conditions, and final-stage target brightness. The flow is measured and regulated by means of a magnetic flowmeter and a remotely-operated control valve. Generally, operators do not change the flow unless pulp flow is changing. Equipment for this stage is outside and antichlor (sulfur dioxide) is used to destroy residual chlorine dioxide in the pulp. Therefore, over-addition of this chemical is difficult to detect, other than by the brightness and residual tests. If the amount of chlorine dioxide in the stock as it enters the washer is high enough, our air monitoring results indicate gas may pass through to the exhaust system, scrubber, and then infiltrate to the washer room (see Figure 30-2).

The mill uses a number of additional sensors and control systems to monitor bleaching conditions like temperatures, pH, stock and chemical flows, and pump and agitator status. Most of these are conventional in multi-stage bleach plants, and do not directly contribute to control of workplace emissions. Temperature, pH, and chemical flow monitoring and control systems may indirectly help control workplace emissions by making overall process operations simpler and thereby reducing upsets.

Bleach chemical handling or preparation equipment is closed, and workplace chlorine and chlorine dioxide emissions occur mainly because of upsets or leaks. The most important operational consideration with this equipment is to maintain proper chemical feed rates or ratios in order to prevent upsets or leaks. There are three process monitoring and control systems which warrant comment: (1) sensors and controllers for the chlorine dioxide generator, and associated operational procedures to minimize generator 'puffs'; (2) a hypochlorite reactor (chemical) control system; and (3) the chlorine gas blowdown systems.

The first of these, generator puffs (or mild gas explosions inside equipment), can be prevented if operators pay attention to process details and insure that none of the following conditions occur:

(1) Organic contamination in any of the feed solutions (chlorate, sulfuric acid, and sulfur dioxide).

(2) Sulfur dioxide concentrations (in air feed) above seven percent.

(3) Reaction at any time of the sodium chlorate solution with the sodium chloride present in it, or with sulfur dioxide, without a proper air purge. (This applies to pre-start-up periods during which only sodium chlorate-chloride is being added, and the period after a shutdown when some chloride may remain).

(4) Generator temperatures above about 115°F.

(5) Addition of sulfur dioxide at rates greater than those dictated by the sodium chlorate concentration and feed rate.

(6) The presence of sulfuric acid in the gas stream due to excessive mist carryover from the generator, or from a leak or other external source.

(7) Concentrations of chlorine dioxide above 10 grams per liter in the solution storage tank.

To avoid the above conditions, the following operating procedures must be observed:

(1) Keep the feed and reactor systems free from outside contamination.

(2) Check each rail car of sulfuric acid for oxidizable material.

(3) Keep the SO_2 air mixture at or below 7 percent by proper use of a ratio controller, and check the controller daily for accuracy.

(4) On start-up, start air to reactor (and water to absorption tower) before adding any sodium chlorate to the reactor.

(5) On shutdown, keep air going through reactor until all ClO_2 is removed and no more ClO_2 is detected in the absorption tower discharge.

(6) Keep the sulfur dioxide flow matched to the sodium chlorate feed.

(7) Careful monitoring of the generator temperature; a sudden rise may be a warning of an impending puff.

(8) Insure sufficient chilled water flow through the absorption tower at all times so that the dissolved ClO_2 concentration cannot exceed 10 g/l.

If a puff occurs, the generator is immediately shut down and cooled to 100°F. An immediate effort is made to determine the cause of the puff. On start-up, the chlorate and the acid content of the generator liquor must be checked and brought within specifications. In addition, the chemical feed rates and concentrations must be accurately checked. If repeated puffs occur, the system must be drained and cleaned.

In addition to the above specific discussion of puffs, it should be noted that contamination in the form of oxidizables or acids, or local heating in the sodium chlorate system, can turn a section of pipe or a storage tank into an impromptu ClO_2 generator. This can also potentially lead to damaging local explosions. Allowing sodium chlorate to dry in mixture with oxidizable material can create a severe fire hazard. Spills of any generator chemicals must be promptly washed down.

The periodic chemical quality control tests directly indicate proper performance of the generator, but a number of real-time sensors and monitor/controllers (located on the main control panel) insure its safe and efficient operation and monitoring:

- SO_2 and air flow regulators and indicators; with a low SO_2 flow alarm
- Sodium chlorate and sulfuric acid solution flow indicators and controllers on each reactor; each interfaced to the respective flow control valves
- Temperature indicators and controllers on each reactor; they are interfaced to flow control valves for the respective cooling (mill water) or heating (35 psig steam) supply
- A reactor gas temperature recording controller and low level alarm which automatically controls the flow control valve for air to the waste acid stripping tower.

- o A level indicating controller and low level alarm on the reactor spent acid tank. This tank is continuously purged with air, and heated (to prevent precipitation of chemicals) by means of a steam coil with a temperature indicating controller.

- o A flow recording controller and alarm on the chilled water line to the absorption tower

- o Level indicators and alarms on the chlorate and sulfuric acid storage and head tanks (the chlorate feed line to its head tank also has a temperature indicator and alarm to insure chlorate remains heated and in solution.

Process control of hypochlorite (3.5%) preparation is achieved by means of an automatic oxidation-reduction probe (ORP) system. It functions by sensing the oxidation-reduction potential of the solution that results from the reaction of chlorine gas with 4-5% caustic solution. The probe's output is transmitted to a controller which regulates the setting of a flow control valve on the chlorine gas line. This valve is located on the second floor of the main chemical handling building. Directly after it is a chlorine fail-safe valve. This valve stops chlorine gas flow if anything goes wrong in the hypochlorite preparation system. It is activated by a mercoid switch on the caustic line to the reactor. If caustic line pressure is too high or low, the switch will close the fail-safe valve. If chlorine gas line pressure should drop below the caustic's pressure, caustic could flow back through the chlorine line. But, three ball-type check valves (made of teflon) in the chlorine line after the fail-safe valve (but before the reactor) prevent this from occurring.

For the hypochlorite ORP system to function properly and not over-add chlorine gas, the strength of the reacting caustic (4-5%) must also be well-controlled. Therefore, performance of the hypochlorite reactor is dependent on performance of the automatic 50% to 4-5% caustic dilution system. As is customary in the industry, this caustic dilution system is controlled by means of an in-line mixer and conductivity controller. The controller regulates the amount of dilution water mixed with the 50% caustic to produce 4-5% caustic. Caustic solutions above about 8 percent strength create erratic conductivity and ORP responses; too weak solutions (i.e., less than 4%) may result in incomplete chlorine gas reaction and the potential for gas escape from the inside hypochlorite storage tank. Except for system startups and shutdowns, both of these sensors and controllers were reported to perform well.

When the hypochlorite preparation system is shutdown for any reason (other than very short periods), a chlorine tank car is disconnected, or the chlorine vaporizers and gas lines are isolated for maintenance work, any chlorine in them must be blown down to a tank containing 5% caustic solution. This tank, which is actually part of the hypo system, is always kept full with caustic so that chlorine can be blown down at any time. It is located outside, in front on the chemical handling building.

The mill uses two systems to accomplish such a chlorine blowdown. The first was reported to be the most effective. It is used when there is sufficient time and workers must be assured that all gas or liquid has been removed from a line.

It consists of an eductor pipe-element which is used to create a vacuum in a system of blowdown pipes connected to the liquid and gaseous chlorine supply lines. The 5% caustic is pumped from the blowdown tank through the eductor and back to the tank, thereby, creating a vacuum in the eductor's open leg. The mill technical staff explained that unless vacuum is applied to a chlorine line, small amounts of gas (or liquid) will remain in pipe bends, traps, or other recesses. This eductor blowdown system insures lines are completely purged free of chorine.

The second blowdown system consists of a number of quick disconnect or permanent air lines which can be valved into the chlorine gas lines. A blast of air then blows any chlorine gas or liquid back through the supply line and into the 5% caustic blowdown tank. The system provides a fast method for relieving any chlorine. It can also be effective, if performed long enough.

APPENDIX A

WRITTEN RESPIRATOR PLAN

RESPIRATOR SELECTION

Selection of approved and appropriate respirator is extremely important. Always read instructions to assure you have the correct respirator and are fully aware of its limitations. Supervisors will provide employees with one of the following respirators.

Dusts, Mists
MSA Dustfoe 66

Chlorine, chlorine dioxide, other acid gases, or organic vapors
MSA Canister, Chin Type, GMC
MSA Model 401 and Scott Air Paks SCBA (self-contained breathing apparatus)
Cascade System (supplied air)
MSA Comfo II half facepiece with chemical cartridges

RESPIRATOR INSTRUCTIONS

BEFORE USE

1. Remove top seal and attach canister to mask. (Keep top and bottom seals on spare canisters.)

2. Make certain conditions of exposure are suitable for use of Air Purifying Type canister. Do not use in areas which are not ventilated. If oxygen concentration (less than 19.5%) support life is questionable, use Self-Contained Breathing Apparatus only.

3. Remove bottom seal from canister. Don and adjust harness and facepiece in fresh air only. Check mask operation before entering exposure area.

4. CAUTION: Wear impermeable protective clothing for exposure to gases and vapors which can poison by skin absorption.

5. WARNING: Do not wear for protection against gases or vapors that have poor warning properties or those which generate high heats of reaction with sorbent material in the canister.

DURING USE

Return of the fresh air immediately if (1) leakage is detected by smell, taste, eye, nose or throat irritation; or (2) if high breathing resistance is encountered; or (3) if inhaled air becomes extremely hot or (4) if any feeling of nausea, dizziness or ill being develops.

OPERATING PRINCIPLE

This mask, when properly used, removes harmful gases or vapors, (listed on the canister label) and particulates from the inhaled air in concentrations up to 0.5% by volume of gas or vapor only. Inhaled air is drawn through the canister which contains chemicals that remove or neutralize the contaminants. The air is then drawn through the facepiece, where it passes over the lens (keeping it free of fog) before it is taken into the lungs. Neither a nose clip nor mouthpiece is required. Exhaled air leaves the facepiece through an exhalation valve and consequently is not rebreathed. A check valve prevents the exhaled air from passing out through the canister.

FITTING THE MASK

Don and adjust mask in fresh air only.

Pull out headband straps, expecially the "FRONT" or forehead strap, so that the ends are at the buckle, then grip facepiece between thumb and fingers, insert chin well into lower part of facepiece and pull headbands back over head. To obtain a firm and comfortable fit against the face at all points, adjust the headbands as follows:

(a) See that straps lie flat against head.
(b) Tighten lower or "NECK" straps.
(c) Tighten the "SIDE" temple straps. (Do not touch forehead or "FRONT" strap).
(d) Place both hands on headband pad and push it towards the neck.
(e) Repeat operations (b) and (c).
(f) Tighten forehead or "FRONT" strap a few notches.

WARNING--This device may not provide a satisfactory face seal with certain physical characteristics (such as beards or gross sideburns) as outlined in ANSI Z88.2-1969, resulting in leakage in connection with the facepiece, which voids or limits the protection.

TESTING FOR TIGHTNESS

THE FACEPIECE MUST BE SUBJECTED TO THE FOLLOWING TIGHTNESS TEST BEFORE EACH USE.

Test the mask for tightness by closing air intake and holding the hand tightly over the bottom of the canister. Inhale gently so that the facepiece collapses slightly and hold the breath for ten seconds. The facepiece will remain collapsed while the breath is held providing the assembly is gas tight. If any leakage is detected around the facial seal, readjust head harness straps and repeat test until there is no leakage. If other than facial seal leakage is detected, the condition must be investigated and corrected before another test is made. The facepiece must pass the tightness test before the user should attempt to enter any toxic atmosphere. The mask will not furnish protection unless all inhaled air is drawn through a suitable canister.

REPLACING CANISTERS

The length of time the chemicals in the canister will give protection depends both on the concentration of the gas or vapor, and the rate of breathing. When the mask is properly adjusted, leakage as indicated by odor, taste, or eye, nose or throat irritations is evidence that the canister is exhausted. The wearer should return immediately to fresh air and attach a suitable new canister.

Caution—The bottom seal should be replaced after each use.

CAUTION

Follow the preceding instructions carefully. They were prepared for your protection.

Do not enter any atmosphere with the mask unless you KNOW that:

(a) Canister is the proper type for the contaminant or contaminants present.
(b) Concentration of the contaminants does not exceed 0.5% by volume. (Do not use when concentrations of contaminants are unknown).
(c) Amount of oxygen is sufficient to support life (that is, at least 19.5 percent oxygen by volume at sea level). If oxygen concentration sufficient to support life is questionable, use Self-Contained Breathing Apparatus only.
(d) Mask does not leak (see test for tightness).
(e) Canister does not need replacing.

Discard exhausted canisters.

ASSIGNMENT AND LOCATION OF RESPIRATORS

Listed below are the various respirators used and where they may be obtained or are assigned.

MSA Dustfoe 66 (for portection from dusts and mists) are storeroom items.

MSA Canister, Chin Type GMC masks with Chlorine Canister, (protection from chlorine, chlorine dioxide, acid gases) are assigned to the Pulp Mill, Pulp Mill Personnel and to the Pulp Mill Maintenance Department. They are located in strategic points around the pulping operations and in cabinets outside the Pulp Mill Maintenance Department.

MSA Mouthpiece Escape Mask with Chlorine cartridge (for protection from chlorine, chlorine dioxide, and acid gases to be used by maintenance personnel only) are assigned to some maintenance personnel and must be carried by them whenever they work in the pulping operations.

MSA and Scott Air Paks (for emergency use in any atmosphere above safe limits) are strategically located outside the Pulp Mill Maintenance Office and in Chemical Handling.

Cascade System (supplied air from bottles) is located outside the Pulp Mill Maintenance Office. Masks are kept clean and dry in a cabinet next to the cascade system. Cascade systems will be installed in the Bleach Plant and Digester Control Rooms.

MSA Comfo II respirator half facepiece with chemical cartridge (for protection from all acid gases and organic vapors) are assigned to all Pulp Mill Operations employees and some Maintenance Department employees and must be carried at all times whenever working in the Pulping Operations Areas.

MAINTENANCE OF RESPIRATOR

CLEANING AND SANITIZING

The Facepiece (with the canister removed) should be cleaned and sanitized after every use with MSA Cleaner-Sanitizer, Part No. 34337 (25 - 1 oz. packages per carton).

1. Simply add one package (1 oz.) of powdered MSA Cleaner-Sanitizer to a gallon of warm water (about 120° F.).
2. Immerse soiled equipment in the solution and scrub gently with a soft brush until clean. Take care to clean the exhalation valve in the Facepiece and all other parts that exhaled air contacts.
3. Rinse thoroughly in plain warm water (about 120° F.) and then air dry.

None of the metal, plastic, rubber, leather, cloth, or glass parts will be adversely affected by the cleaning solution.

Pulp Mill Maintenance's respirators will be maintained by the utility crew. All other departments will return used masks to medical for cleaning and sanitizing until cleaning stations are installed in the Pulp Mill and will then be the responsibility of each employee to clean his/her respirator.

Respirators issued for the exclusive use of one worker shall be regularly cleaned and disinfected by the worker. Those used by more than one worker shall be thoroughly cleaned and disinfected by the user after each use.

MAINTENANCE

It is the responsibility of each employee to keep his/her mask in good condition to function properly. Examine mask parts, connections and fittings for leakage and wear. When any part shows evidence of failure, it should be replaced immediately with the proper part. An illustrated Parts List is included with each mask. Extra parts are readily available in the storeroom.

Equipment shall be properly maintained to retain its original effectiveness.

(1). (I) All respirators shall be inspected routinely before and after each use. A respirator that is not routinely used but is kept ready for emergency use shall be inspected after each use and at least monthly to assure that it is in satisfactory working condition.

(II) Self-contained breathing apparatus shall be inspected monthly. Air and oxygen cylinders shall be fully charged according to the manufacturers instructions. It shall be determined that the regulator and warning devices function properly.

(III) Respirator inspection shall include a check of the tightness of connections and the condition of the facepiece, headbands, valves, connecting tube, and canisters. Rubber or elastomer parts shall be inspected for pliability and signs of deterioration. Stretching and manipulating rubber or elastomer parts with a massaging action will keep them pliable and flexible and prevent them from taking a set during storage.

(IV) A record shall be kept of inspection dated and findings for respirators maintained for emergency use. This will be the responsibility of the department using the respirators.

(2). Routinely used respirators shall be collected, cleaned, and disinfected as frequently as necessary to insure that proper protection is provided for the wearer. Each worker should be briefed on the cleaning procedure and be assured that he will always receive a clean and disinfected respirator. Such assurances are of greatest significance when respirators are not individually assigned to workers. Respirators maintained for emergency use shall be cleaned and disinfected after each use.

(3). Replacement or repairs shall be done with parts designed for the respirator. No attempt shall be made to replace components or to make adjustment or repairs beyond the manufacturer's recommendations. Reducing or admission valves or regulators shall be returned to the manufacturer or to a trained technician for adjustment or repair.

SURVEILLANCE

It will be the responsibility of each foreman to make certain his employees comply to the respirator protection program.

Any employee refusing to comply must be disciplined promptly, and a copy of the warning should be sent to the Safety Director.

The effectiveness of the program will periodically evaluated by the Safety Director.

STORAGE

All the care that has gone into cleaning and maintenance of a respirator can be negated by improper storage. Respirators must be stored to protect against:

Dust,

Sunlight,

Heat,

Extreme cold,

Excessive moisture,

Damaging chemicals.

It is strongly recommended that freshly cleaned respirators be placed in heat-sealed or reusable plastic bags until reissue. They should be stored in a clean, dry location away from direct sunlight. They should be stored in a single layer with the facepiece and exhalation valve in a more or less normal position to prevent the rubber or plastic from taking a permanent distorted "set."

INSPECTION PROGRAM

Inspection for Defects

Probably the most important part of a respirator maintenance program is continual inspection of the devices. If conscientiously performed, inspections will identify damaged or malfunctioning respirators before they can be used.

Frequency of Inspection

All respirators are to be inspected by the employee before and after each use and that those not used routinely, i.e. emergency escape and rescue devices, shall be inspected after each use and at least monthly. In one case, the respirator is to be inspected both before and after each use, in the other case, only after use. A trained Pulp Mill employee will check all Production Crew Personnel masks on each third shift tour. All Pulp Mill Production Area gas masks, compressed air mask systems and self-contained breathing appraratus (MSA Model 401) will be checked by a trained Pulp Mill Production employee at least once a month on a day shift.

Specific Items to Check

Air-Purifying Respirators

Routinely used air-purifying respirators should be checked as follows before and after each use.

(a) Examine the facepiece for:

- Excessive dirt,
- Cracks, tears, holes, or distortion from improper storage,
- Inflexibility (stretch and massage to restore flexibility),
- Cracked or badly scratched lenses in full facepieces,
- Incorrectly mounted full facepiece lens or broken or missing mounting clips,
- Cracked or broken air-purifying element holder(s), badly worn threads, or missing gasket(s) (if required).

(b) Examine the headstraps or head harness for:

- Breaks,
- Loss of elasticity,
- Broken or malfunctioning buckles and attachments,
- (Full facepieces only) Excessively worn serrations on the head harness which might permit slippage.

(c) Examine the exhalation valve for the following after removing its cover:

- Foriegn material, such at detergent residue, dust particles, or human hair under the valve seat,
- Cracks, tears, or distortion in the valve material,
- Improper insertion of the valve body in the facepiece,

Cracks, breaks, or ships in the valve body, particularly in the sealing surface,
Missing or defective valve cover,
Improper installation of the valve in the valve body.

(d) Examine the air-purifying elements for:

Incorrect cartridge, canister, or filter for the hazard,
Incorrect installation, loose connections, missing or worn gaskets, or gross-threading in holder,
Expired shelf-life date on cartridge or canister,
Cracks or dents in outside case of filter, cartridge, or canister,

Evidence or prior use of sorbent cartridge or canister, indicated by absence of sealing material, tape, foil, etc., over inlet.

(e) If the device has a corrugated breathing tube, examine it for:

Broken or missing end connectors,
Missing or loose hose clamps,
Deterioration, determined by stretching the tube and looking for cracks.

(f) Examine the harness of a front- or back-mounted gas mask for:

Damage or wear to the canister holder which may prevent its being held securely in place,
Broken harness straps or fastenings.

Atmosphere-Supplying Respirators

For a routinely used atmosphere-supplying device, use the following procedures:

(a) If the device has a tight-fitting facepiece, use the procedures outlined above for air-purifying respirators, except those pertaining to the air purifying elements.

(b) If the device is a hood, helmet, blouse, or full suit, use the following procedures:

Examine the hood, blouse, or full suit for rips and tears, seam integrity, etc.,
Examine the protective headgear, if required, for general condition, with emphasis on the suspension inside the headgear,
Examine the protective faceshield, if any, for cracks or breaks or impaired vision due to rebounding abrasive particles,
Make sure that the protective screen is intact and secure correctly over the faceshield of abrasive blasting hoods and blouses.

(c) Examine the air supply system for:

1. Correct pressure
2. Integrity and good condition of air supply lines and hoses, including attachments and end fittings,
3. Correct operation and condition of all regulators, valves, or other air-flow regulators.

On SCBAs, determine that the high-pressure cylinder of compressed air or oxygen is fully charged (mandatory on an emergency device). On closed-circuit SCBAs, make sure that a fresh canister of CO sorbent is installed before use, or that the total use time on the canister is known. On open-circuit SCBAs, recharge the cylinder if less than 25% of the useful service time remains. All these SCBAs are required to have a warning device that indicated when this point is reached. However, it is much preferred that an open-circuit SCBA be fully charged before use.

When an air-purifying or atmosphere-supplying device is used nonroutinely, all the above procedures should be followed after each use.

If defects are found during any field inspection, the device should be removed from service until it can be repaired and the Pulp Mill office or supervisors should be notified. Under no circumstances should a device that is known to be defective be used.

STANDARD OPERATING PROCEDURE

DISASSEMBLY, CLEANING AND MAINTENANCE OF RESPIRATORS

1. Remove cartridges, canisters of filters and all gaskets that are not affixed to seats.
2. Visually inspect facepieces and parts; discard faulty items.
3. Remove all elastic headbands.
4. Remove exhalation valve cover.
5. Remove speaking diaphragm or speaking diaphragms-exhalation valve assembly; or pressure-demand exhalation valve assembly.
6. Remove inhalation valves.
7. Wash, sanitize and rinse facepieces (see specific procedure for operation of washing equipment). (Maximum water temperature 140°F optimum range 120° to 140°F). Parts removed from respirators may be washed separately as necessary.
8. Dry masks (see specific procedures for drying).
9. Hand wipe facepieces, valves and valve seats with damp, lint-free cloth to remove any soap or water residues, mold release powders or foreign materials not removed by washing.
10. Didassemble and hand clean the pressure-demand and exhalation valve assembly, exercising care to avoid damage to the rubber diaphragm.
11. Visually inspect facepieces and all parts for deterioration, distortion, or other faults that might affect the performance of the respirators.
12. Replace any questionable or obviously faulty parts or assemblies including rubber components that show weather checking when flexed or stretched, and distorted facepiece. Replace only with parts specifically designed for the particular respirator.
13. Reassemble mask and visually inspect completed assembly.
14. Install new or retested filters, cartridges or canister.
15. Clean and apply fogproof to lens per fogproof manufacturers instructions (full facepieces only).
16. Install lens cover.
17. Fogproof outside of lens cover.
18. Quality assurance test each completed unit (see specific procedure for QA test).
19. Individually seal each mask in plastic bag.

GAS MASK INSPECTION

DATE _____

MASK NO.	LOCATION	TYPE			CONDITION			REMARKS
		FULL FACE	MOUTH PIECE		GOOD	FAIR	POOR	

Inspected by _____

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Approved by _____

CHECK LIST FOR COMPRESSED AIR MASKS IN CHEMICAL HANDLING

DATE _____

INSPECTED BY _____

PRESSURE	NAME OF PERSON USING MASK	CONDITION OF MASKS AND HOSES
WEST BAY		
	NAME _____	
EAST BAY		
	TIME ON: _____ TIME OFF: _____ (West Bay)	
	TIME ON: _____ TIME OFF: _____ (East Bay)	

NOTE: THESE MASKS MUST BE INSPECTED TWICE A WEEK PLEASE INSPECT THEM ON TUESDAY AND FRIDAY OF EACH WEEK AND GIVE THEM TO DEBBIE IN THE PULP MILL OFFICE.

ANYONE USING A MASK MUST FILL OUT THIS FORM ALSO-THIS WILL ENABLE US TO KEEP THE CYLINDERS FULL AT ALL TIMES.

APPENDIX B

SUMMARY SHEETS FOR CHEMICAL HAZARDS

CHLORINE

Only authorized employees may work on railroad cars, pipe lines or storage tanks that contain chlorine. If a chlorine leak occurs, only authorized, trained personnel equipped with gas masks should investigate. All others should keep away from the affected area until the cause is discovered and corrected.

If a leak is extensive, all persons in the path or area of the fumes must be warned.

If a person is exposed to chlorine, observe these rules:

1. Carry patient from gas area if unable to walk. Keep patient warm and quiet.
2. If breathing has ceased, start resuscitation.
3. If breathing, place patient on back with head elevated.
4. Call Medical (Ext. 2265) and Plant Protection (Ext. 2202) immediately.
5. Splashes of liquid chlorine and chlorinated water destroy clothing and if such clothing is next to the skin, it will cause irritation and acid burns. In such cases, remove patient's clothes and keep patient warm with blankets.

ACID OR CAUSTIC

Only employees authorized by their supervisor may work with acid or caustic. In doing so, they must wear approved goggles, rubber gloves, and other personal protective equipment.

When diluting acid or caustic, the primary rule is to pour the acid or caustic slowly into the diluting water to prevent splashing.

Splashes of acid or caustic could cause severe skin burns and destroy clothing. In case of acid or caustic splash, the affected areas should be immediately flooded with large quantities of water. Medical treatment should be secured as soon as possible for damaged skin areas.

SODIUM CHLORATE

Have water available to flush body and clothing if contaminated. DO NOT SMOKE IN AREA. Wash with plenty of cold water for ½ hour for burns and then report to Medical.

Know how to handle chlorate without problems. Information is posted where it is used.

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CHEMICALS

We use many other chemicals in our papermaking processes. All containers are labeled with proper handling instructions and first aid procedures. Read label before handling. Ask your supervisor if in doubt. One basic rule - if splashed with any chemical, flush off with plenty of water for at least 15 minutes. Hold eyelids apart to flush them out.

SPENT ACID

SYNONYMS:
Purchased Spent Acid - ClO_2 Generator Spent Acid.

DESCRIPTION:
Yellowish liquid. Clarity and color vary with amount of impurities.

USE AND LOCATION:
The term spent acid is used to refer to two similar chemicals (predominantly H_2SO_4) from two different sources. ClO_2 generator spent acid is waste by-product from the ClO_2 generator. When it is not being sewered, it is used to adjust the ph of the NIC-II brown stock slurry to chlorination. Purchased spent acid is brought in from outside, stored in the outside spent acid tank at Chemical Handling and is used for effluent ph control at JWT sump.

HAZARDS: (See Sulfuric Acid)*
Because of the impurities contained in both spent acids, the breathing of the fumes should be avoided.

SAFETY PROCEDURES: (See Sulfuric Acid)*

SKIN - EMERGENCY TREATMENT (See Sulfuric Acid)*

REMARKS: (See Sulfuric Acid)*

30-B2

CHEMICAL SAFETY DATA

INTRODUCTION

The purpose of these data sheets are to familiarize employees with some of the more hazardous chemicals necessary for use in our mill operations.

Each employee should read these sheets carefully in order to be aware of hazards that might exist in respective work locations.

The information provided is meant to serve as a guide in (1) the recognition of potential hazards, (2) the safeguarding of employees against injuries from these potential hazards, and (3) emergency treatment of these injuries should they occur.

Although it is important to know what emergency steps to take should an accident occur, it is more important to know what precautions to take to prevent accidents. Being able to recognize potential hazards is by far the most important and proceeding in a safe, prescribed manner follows closely behind.

If we remember two very basic things, water and air, we will be equipped to provide the best initial emergency treatment available for any chemical exposure. Such phrases as "wash thoroughly with cold water" and "get fresh air" sound oversimplified and unsophisticated. These are not necessarily the ultimate answer in emergency treatment, but are necessarily the initial step. A thorough washing with water requires a period of fifteen (15) minutes or longer. Modern medical technology has yet to find a more effective emergency treatment for injuries from chemical contact that is more readily available than water. It not only dilutes the chemical, slowing down the chemical reaction with the body tissue, but it also washes the chemical away. The period of time will be dependent not only on the severity of the injury, but the condition of the patient. The statement "report to the medical department" is as much signification of a call for trained medical help as it is an indication of physical movement of the injured.

Phrases such as "required by circumstances" and "if necessary" are not meant to be vague. It would be impossible to cover every situation that might arise. Caution and judgment will always be factors. "Better too much than not enough" is a good rule of thumb for safety.

All incidents of chemical exposure should be reported to supervision.

BLEACH PLANT FILTRATES

SYNONYMS:
Chlorine, Caustic, Hypo and ClO_2 Filtrates.

FORMULA:

DESCRIPTION:
Liquid solutions ranging from light yellow to brownish black.

USE AND LOCATION:
Wash water from each of the four (4) states in the bleach plant.

HAZARDS:

SAFETY PRECAUTIONS:
Neoprene or rubber protection for the body, hands, feet and head plus a full face shield as required by circumstances.

SKIN - EMERGENCY TREATMENT:
After removal of victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the medical department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of a physician.

SODIUM HYPOCHLORITE

SYNONYMS:
Hypo, Bleach Liquor

FORMULA:
NaOCl

DESCRIPTION:
Clear to yellow solution, chlorine odor similar to the odor of household bleach.

USE AND LOCATION:
Manufactured at Chemical Handling. Used in the third stage of the bleach plant. Also used in the Paper Mill to bleach colored broke and on the paper machines for cleaning purposes.

HAZARDS:
Irritation of eyes and mucous membranes. Contact with skin may cause mild chemical burns. Under acidic conditions chlorine gas will be given off. See Safety Precautions for chlorine gas.

SAFETY PRECAUTIONS:
Neoprene or rubber protective clothing and face shields as circumstances require. Eye protection should be worn.

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the medical department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of a physician.

INHALATION - EMERGENCY TREATMENT:
Remove the person from the contaminated atmosphere to a well ventilated area. If breathing is difficult, provide artificial respiration. Place in the hands of a physician.

REMARKS:
Acidic conditions should be avoided when working with sodium hypochlorite because chlorine gas will be given off.

CHLORINE

SYNONYMS:
Chlorine Gas

FORMULA:
Cl_2

DESCRIPTION:
Greenish liquid when supplied under pressure commercially.
Immediately turns to yellow/green gas when released to atmosphere.

USE AND LOCATION:
Used in first stage of Bleach Plant and in bleach making (Sodium Hypo) at Chemical Handling. Also used to treat the mill water supply. Received in rail tank cars.

HAZARDS:
Liquid - causes chemical burns.
Gas - irritation of eyes, nose and throat followed by severe uncontrollable coughing. Concentrated exposure may be fatal! Follow chlorine emergency handbook procedure.

SAFETY PRECAUTIONS:
Exit suspect area immediately upon personal detection of gas or when gas detector alarms are triggered. Report possible danger. Use full face mask to exit suspect areas. Self-contained air supply units are to be used to enter suspect areas. The additional requirement of rubber protective clothing is necessary when exposure to liquid is possible.

Liquid - Wash thoroughly with cold water.

Gas - Exit contaminated area immediately, breathe lightly and get fresh air. Apply artificial respiration if necessary. Summon plant or city emergency squad if oxygen is necessary.

Either - Report to Medical Department if necessary.

CHLORINE - continued

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the Medical Department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of physician.

INHALATION - EMERGENCY TREATMENT:
Remove the person from the contaminated atmosphere to a well ventilated area. If breathing is difficult, provide artificial respiration. Place in the hands of a physician.

CHLORINE DIOXIDE

SYNONYMS:

FORMULA:
ClO_2

DESCRIPTION:
Greenish/yellow gas having an irritating odor.

USE AND LOCATION:
Although not used by itself, it is formed when Chlorine Dioxide Solution used in the Bleach Plant is exposed to the atmosphere. Chlorine Dioxide and Chlorine Dioxide Solution are generated at Chemical Handling.

HAZARDS:
Can be irritating to the eyes and mucous membranes even at low concentrations. Higher concentrations may induce coughing and choking sensations followed by nausea and insensibility. Heavy concentrations or prolonged exposure may be fatal.

SAFETY PRECAUTIONS:
Exit suspect area immediately upon personal detection. Report possible danger. Use full face mask to exit suspect area. Self-contained air supply units should be used to check out suspect areas.

INHALATION - EMERGENCY TREATMENT:
Remove the person from the contaminated atmosphere to a well ventilated area. If breathing is difficult, provide artificial respiration. Place in the hands of a physician.

CHLORINE DIOXIDE SOLUTION

SYNONYMS:
ClO_2 Liquor

DESCRIPTION:
Yellow/green liquid having an irritating odor from the chlorine dioxide gas it emits.

USE AND LOCATION:
Formed in the chlorine dioxide generator at Chemical Handling for use in the fourth stage of the Bleach Plant.

HAZARDS:
Can cause thermal and chemical burns. Exposure to atmosphere will release chlorine dioxide gas which can be irritating to the eyes and mucous membranes at even low concentrations. Higher concentrations may induce coughing and choking sensations followed by nausea and insensibility. Heavy concentrations or prolonged exposure may be fatal.

SAFETY PRECAUTIONS:
Exit suspect areas immediately upon personal detection of gas. Report possible danger. Use full face mask to exit suspect areas. Self-contained air supply units should be used to check out suspect areas. The additional requirement or rubber protective clothing is necessary when exposure to liquid is possible.

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the Medical Department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of a physician.

INHALATION - EMERGENCY TREATMENT:
Remove the person from the contaminated atmosphere to a well ventilated area. If breathing is difficult, provide artificial respiration. Place in the hands of a physician.

GENERATOR SOLUTION

FORMULA:
$H_2SO_4 + NaClO_3 + ClO_2 + Cl_2 + SO_2$ NaCl

DESCRIPTION:
Yellow/green liquid having strong chlorine odor.

USE AND LOCATION:
Used to manufacture chlorine dioxide solution in chlorine dioxide generator located at Chemical Handling.

HAZARDS:
Can cause thermal and chemical burns. Exposure to atmosphere will release chlorine dioxide gas which can be irritating to the eyes and mucuous membranes at even low concentrations. Higher concentrations may induce coughing and choking sensation followed by nausea and insensibility. Heavy concentrations or prolonged exposure may be fatal.

SAFETY PRECAUTIONS:
Exit suspect areas immediately upon personal detection of gas. Report possible danger. Use full face mask to exit suspect areas. Self-contained air supply units should be used to check out suspect areas. The additional requirement of rubber protective clothing is necessary when exposure to liquid is possible.

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the Medical Department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of a physician.

INHALATION - EMERGENCY TREATMENT:
Remove the person from the contaminated atmosphere to a well ventilated area. If breathing is difficult, provide artificial respiration. Place in the hands of a physician.

SODIUM CHLORATE SOLUTION

SYNONYMS:

FORMULA:
$NaClO_3$ + NaCl

DESCRIPTION:
Light yellow, odorless liquid.

USE AND LOCATION:
Used in chlorine dioxide generation at Chemical Handling.

HAZARDS:
Can cause thermal burns. Extremely flammable when dry (white crystaline form).

SAFETY PRECAUTIONS:
Neoprene or rubber protection for body, feet, hands and head including full face shield as required by circumstances.

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the Medical Department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of a physician.

REMARKS:
All contaminated clothing and areas should be thoroughly washed immediately so that no dry material remains. (See Sodium Chlorate)

SODIUM CHLORATE

SYNONYMS:
Chlorate

FORMULA:
$NaClO_3$

DESCRIPTION:
White to pale yellow crystaline material.

USE AND LOCATION:
Mixed with water for use in the chlorine dioxide generator at Chemical Handling.

HAZARDS:
It is an extreme fire hazard if allowed to dry after coming in contact with organic materials such as clothing, leather and wood. Contact with flame, sparks, grease, oil or acid of this dry impregnated organic material will cause violent burning. Can also be irritating to skin and mucous membranes.

SAFETY PRECAUTIONS:
Complete neoprene or rubber protective clothing should be worn at all times when working with this chemical. This is necessary in order to be able to thoroughly rinse any contamination immediately. Employees working with this chemical should shower including washing of hair before leaving work. All contaminated areas should be washed thoroughly with water immediately.

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the Medical Department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of a physician.

SODIUM CHLORATE - continued

INHALATION - EMERGENCY TREATMENT:
Remove the person from the contaminated atmosphere to a well ventilated area. If breathing is difficult, provide artificial respiration. Place in the hands of a physician.

REMARKS:
The fire danger from this chemical is extreme as it is easily ignited and produces its own oxygen by burning. Large volumes of water or complete immersion are the only means of putting the fire out.

SODIUM HYDROXIDE

SYNONYMS:
Caustic Soda, 50% Caustic Soda, 15% Caustic, 5% Caustic.

FORMULA:
NaOH

DESCRIPTION:
Liquid, clear to milky which has no odor and is slippery to touch. Dry, white beads.

USE AND LOCATION:
Liquid 50% caustic soda, as received at the mill, is diluted at Chemical Handling to 5% and 15% solutions. 5% caustic is used in bleach making. 15% caustic is used in the Bleach Plant extraction stage, buffer caustic for hypo stage, Cl_2 and ClO_2 scrubber in Bleach Plant, causticizing white liquor makeup, paper machine boilout solution and ph control in the bleached NTC-II stock, total mill effluent, Paper Mill starch and broke system. The dry beads are used for paper machine cleaning.

HAZARDS:
Can cause chemical burns. Even dilute solutions can erode skin without any warning symptoms. Very damaging to the eyes.

SAFETY PRECAUTIONS:
Neoprene or rubber protection for body, hands, feet and head plus full face shield as required by circumstances. Solution is corrosive to cloth and leather besides skin tissue.

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the Medical Department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of physician.

REMARKS:
Heat increases hazard potential of solution.

SULFUR DIOXIDE

FORMULA:
SO_2

DESCRIPTION:
Colorless gas having biting odor. Supplied commercially as liquid under pressure.

USE AND LOCATION:
Sulfur dioxide in gaseous form used in ClO_2 generation. In liquid form used as anti-chlor in the Bleach Plant.

HAZARDS:
Gas can cause irritation to eyes and respiratory system.
Liquid can cause freezing "BURNS".

SAFETY PRECAUTIONS:
Gas - wear approved breathing apparatus.
Liquid - Neoprene or rubber protection for body, feet, hands, head including full face shield as required by circumstances.

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the Medical Department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of a physician.

INHALATION - EMERGENCY TREATMENT:
Remove the person from the contaminated atmosphere to a well ventilated area. If breathing is difficult, provide artificial respiration. Place in the hands of a physician.

SULFURIC ACID

SYNONYMS:
Generator Acid

FORMULA:
H_2SO_4

DESCRIPTION:
Clear, heavy, oily liquid having sulphur odor.

USE AND LOCATION:
Used at Chemical Handling for chlorine dioxide generation. Used for effluent ph control at the JWT sump. Also used in power plant for regenerating water softeners and for other miscellaneous purposes throughout the mill. Received in rail cars.

HAZARDS:
Can cause severe chemical burns by dehydrating (blackening) skin immediately upon contact. When diluting, always add acid to water. Never add water to acid as it will react and splatter, very dangerous to the eyes.

SAFETY PRECAUTIONS:
Neoprene or rubber protection for the body, hands, feet and head including full face shield protection as required by circumstances.

SKIN - EMERGENCY TREATMENT:
After removal of the victim from the exposure to the chemical, remove all contaminated parts and wash all the chemicals from the skin with water. Report to the Medical Department. If eyes have been exposed, flush the eyes with water for at least 15 minutes and place the person in the hands of a physician.

REMARKS:
Large amounts of water are necessary as sulfuric acid and water will generate heat initially.

SODIUM CHLORIDE

SYNONYMS:
Salt, Table Salt, Brine.

FORMULA:
NaCl

DESCRIPTION:
Solid form - white crystals
Liquid form - colorless

USE AND LOCATION:
Used to replenish the sodium zeolite softeners.

HAZARDS:
Poses no known health hazard.

EYE CONTACT:
Flush with clear water.

MILL 32: HARDWOOD AND SOFTWOOD BLEACHING (DIFFUSION WASHERS) AND CHEMICAL HANDLING OPERATIONS

INTRODUCTION

This report evaluates workplace exposure conditions and controls in a Southern bleach plant and its bleach chemical preparation area.* The mill is the newest of all bleach plants surveyed in this study. It has separate, automated hardwood and softwood lines each employing 5-stage (CEHDH) upflow bleach towers with integral diffusion washers. All process equipment is outside, highly-automated, and computer controlled from a main pulp mill control center. The only likely worker exposure to chlorine/chlorine dioxide occurs when process quality control samples are collected from the outside towers and diffusion washers, or when inspections and adjustments of outside equipment are made.

Bleach chemical preparation systems consist of separately-housed chlorine dioxide generators (ERCO and Mathieson Systems); two sodium hypochlorite reactors; steam-heated liquid chlorine vaporizers (located in a small, isolated building); and acid and caustic unloading, storing, and dilution equipment. All of these are operated by a separate two-person production staff.

MILL LAYOUT

The overall mill layout including the dual-line bleach plant and its chemical preparation area is shown in Figure 32-1. It should be stressed that because the mill is located in the South and uses upflows bleach towers with integral diffusion washers, all equipment is outside. The bleach lines are arranged in parallel and extend out from the main pulp mill building. The combined pulp mill/bleach plant control center and a small quality control laboratory are located in this building. It is the only fully enclosed workspace associated with the bleach plant.

As shown in Figure 32-2, which is a model of a similar Kamyr 5-stage bleach tower/diffusion washer system, multi-level catwalks extend around each tower's midpoint, upper levels, and diffusion washer. Workers regularly use these catwalks when

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*Each sub-section of this report presents material for the bleach plant separately from that for the chemical handling operations.

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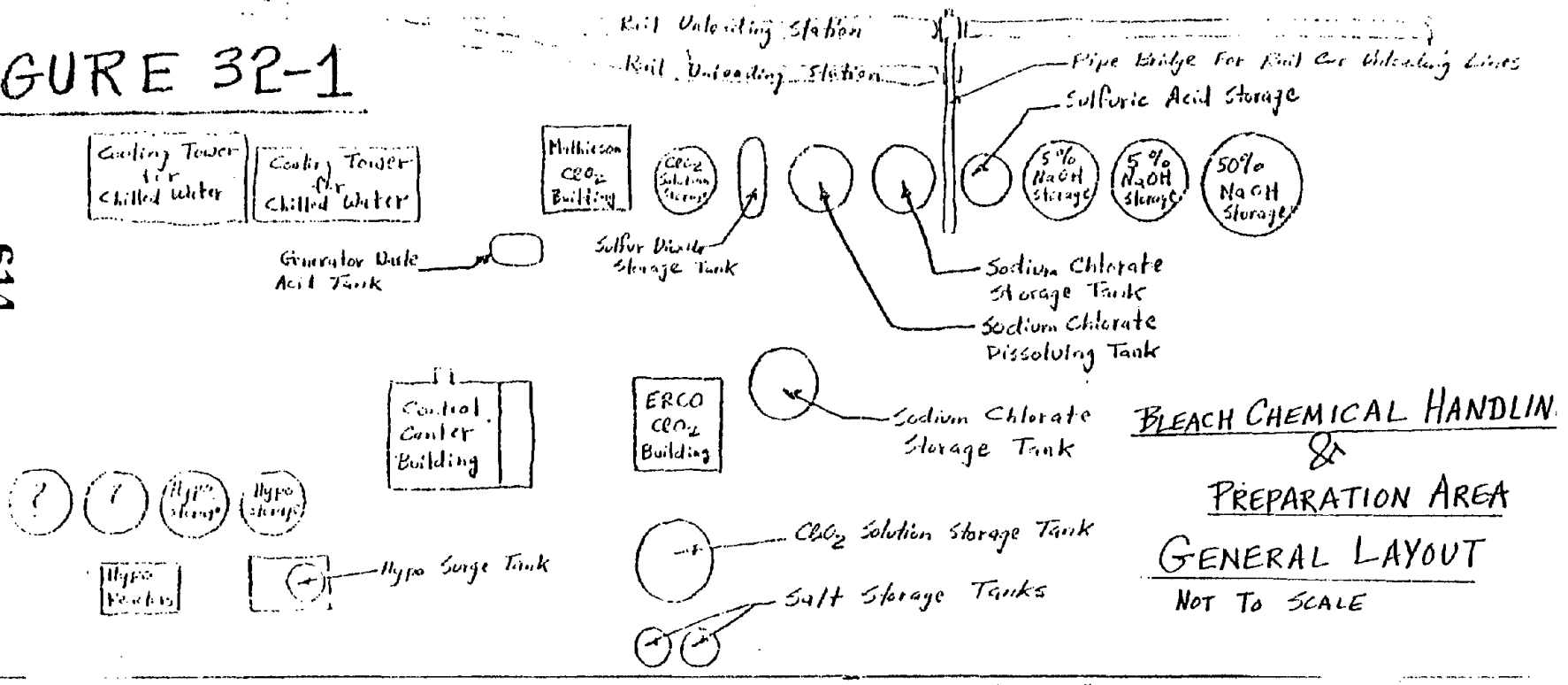
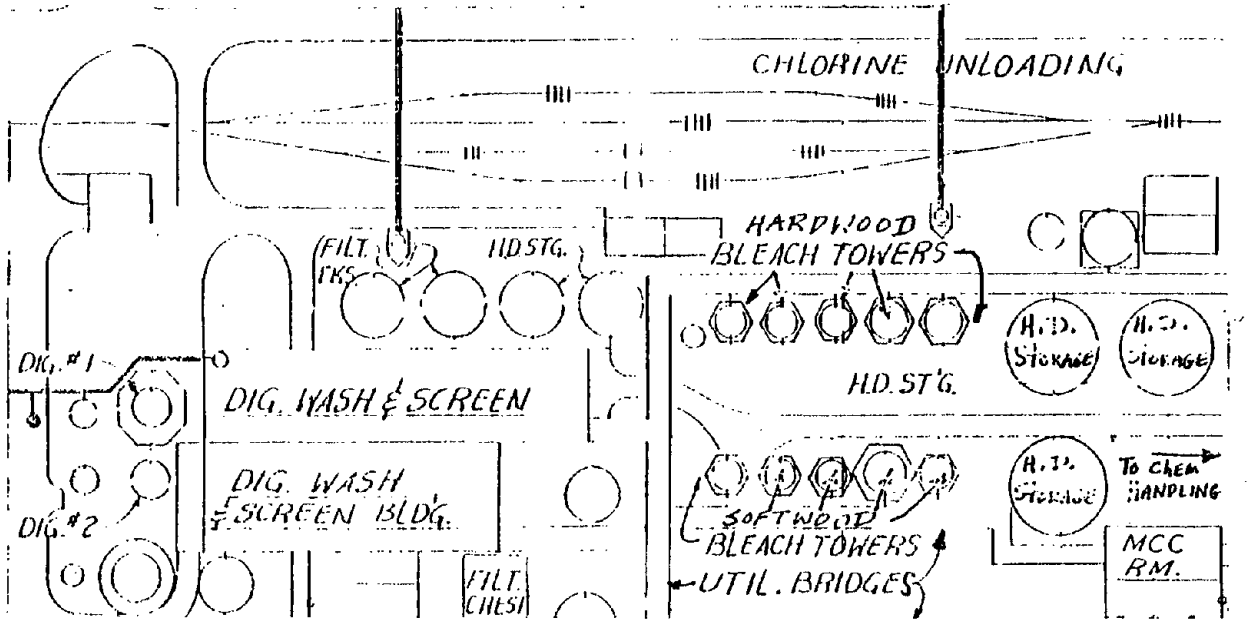
FIGURE 32-1



BLEACH CHEMICAL HANDLIN
&
PREPARATION AREA
GENERAL LAYOUT
NOT TO SCALE



PULP MILL
&
BLEACH PLANT
GENERAL LAYOUT
(NOT TO SCALE)

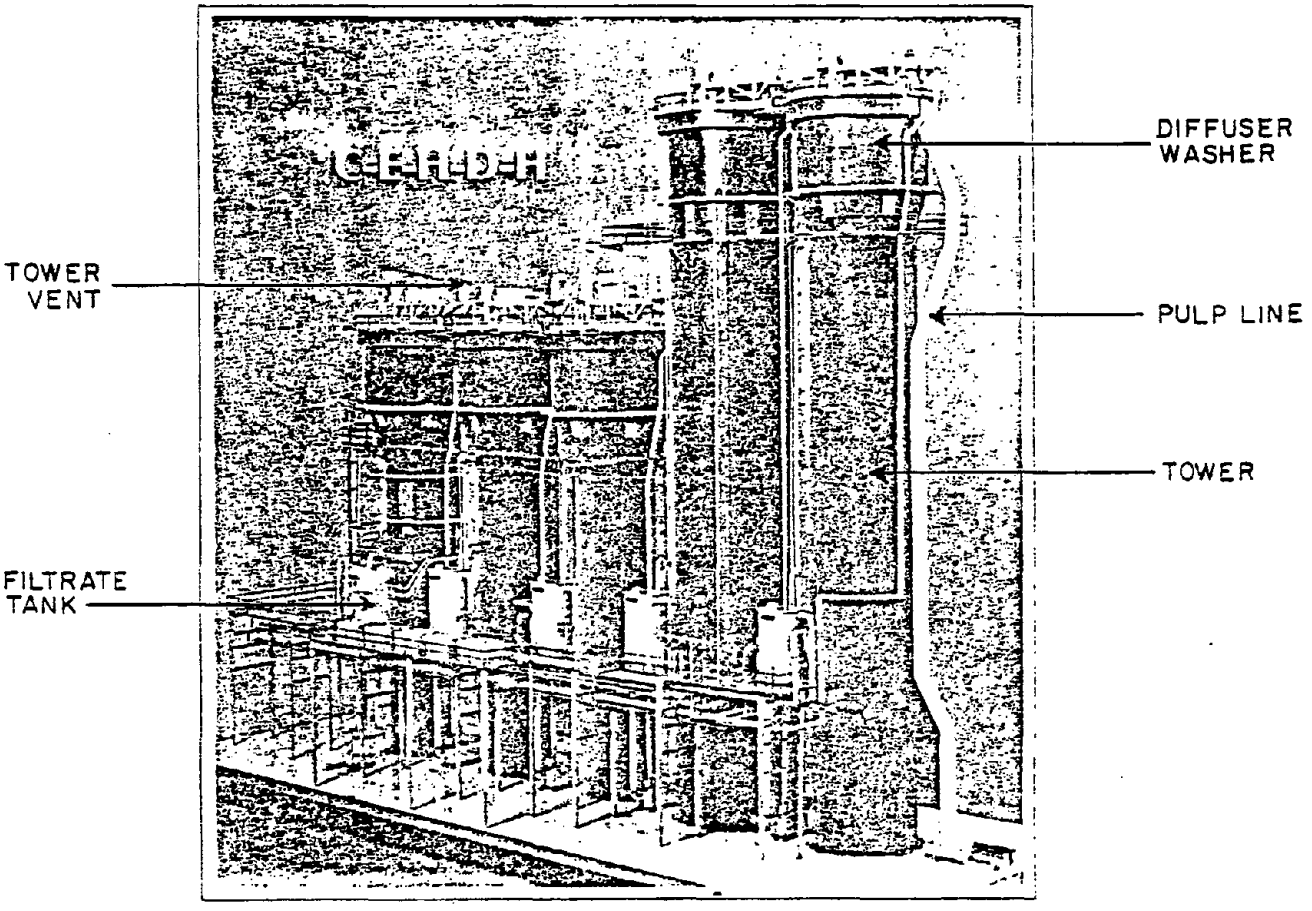


FIGURE 32-2: KAMYR 5-STAGE UPFLOW TOWERS AND DIFFUSION WASHERS

inspecting equipment or collecting quality control samples. Although open to the atmosphere, workers are potentially exposed to chlorine or chlorine dioxide when standing on them. Normally, a worker does not remain on the catwalks very long, and resulting exposures would be highly dependent on environmental factors -- wind speed and direction, temperature, and humidity.

There are three separate buildings within the chemical handling area. The first is a single story central building which houses: the main control and monitoring panel for all process equipment, locker and toilet facilities, and a small testing bench. The other two buildings house the two chlorine dioxide generators, their absorption towers, and other generator equipment. They are very tall and narrow buildings with corrugated metal wall panels. Storage tanks for the generator chlorine dioxide solutions are located outside near storage tanks for a number of other chemicals.

The two hypochlorite reactors are in front of the main control building, and are covered by protective shelter which has no walls.

The liquid chlorine rail car unloading facility is located to the side of the bleach plant near the first stage towers. Four chlorine vaporizers and gas superheaters are located in a nearby single-story, concrete-block building.

PROCESS SUMMARY

Pulp Bleaching

The hardwood and softwood bleaching lines both use upflow towers with integral diffusion washers.* Other than multi-stage displacement bleaching towers (with integral diffusion washers), the technology in this mill probably represents current state-of-the-art for multi-stage pulp bleaching. Each bleach line has five stages -- chlorination, caustic-extraction, first hypochlorite, chlorine dioxide, and second hypochlorite. The hardwood line bleaches about 750 tons per day and the softwood line about 550 tons per day.

Before presenting short process summaries for each line, the operation of an upflow tower/diffusion washer unit should first be described. Both bleach lines consist of a series of five such basic tower/washer units. Other than differences in the size (i.e. residence time), type of reaction, and place at which chemicals are added, all units are basically the same.

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*Towers and washers are manufactured by Kamyr, Inc.

Figures 32-3A & B* show excellent overall and cutaway views of a typical tower/diffusion-washer unit. Pulp at about 10 percent consistency and with the required amount of chemical(s) already added enters the bottom of a tower under the force of a thick stock pump. It then flows up the tower and into the diffusion washer at a rate determined by the desired chemical reaction time. At the bottom of the diffuser, the pulp contacts a series of concentric rings with double-sided perforated plates. Each ring is spaced about 20 inches apart. Pulp moves up and through the rings while any water (added wash water plus any amount already in the pulp) drains through the perforated plates. As shown in the expanded cutaway of Figure 32-3B, between each ring is a slowly rotating nozzel from which wash water is continuously discharged as it moves through the pulp. This stream of water mixes with the pulp and serves to dilute and wash it. It then flows out through the plate perforations and drains through the ring's center to an adjacent filtrate collection tank as shown. The pulp exits the top of the diffuser rings, is pushed outward into a discharge trough by a rotating scraper, then drops through a pipe to a nearby high density stock pump (which is sometimes preceded by a steam mixer). It is then pumped to the next tower/diffuser unit.

In order to keep the pulp in the diffusion washer from clogging the plate's perforations and preventing water from draining, the entire diffuser ring assembly must be kept moving in an up and down cycle. This is accomplished by means of an automatically operated hydraulic cylinder which first lifts the screen assembly at a speed slightly faster than the pulp flow (the upstroke), then abruptly drops it through the pulp wiping off any adhering fibers (the downstroke). The upstroke may take a full minute, whereas the downstroke lasts less than one second. In addition, to insure that all adhering pulp is removed, the diffuser is stopped at completion of the upstroke, and then the drainage water flow is briefly reversed. This causes an instantaneous blast of water to flow at high velocity through the plates' perforations during the diffuser downstroke. The diffuser filtrate water is collected in a vented tank which is on the ground next to the tower. It is then either pumped to the preceding tower to serve as wash filtrate, sewered, or in the case of the first stage filtrate of the hardwood line, used for mixing water for the first-stage chlorine gas injector system.

Nearly complete, but greatly simplified process flow diagrams for each bleach line are presented as Figure 32-4. The softwood line is about 10 years older than the hardwood, which

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*These figures were adapted from a Kamyr, Inc. Sales Bulletin.

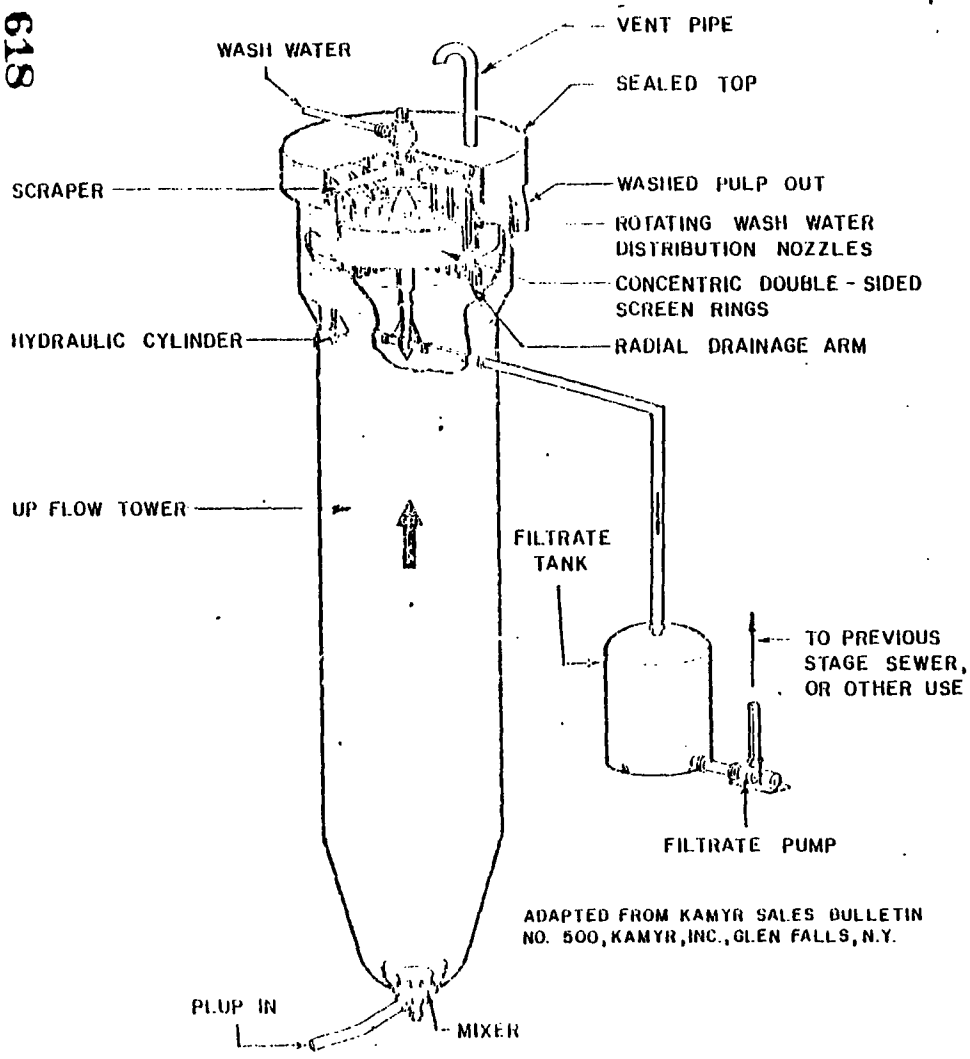

FIGURE 32-3A: TYPICAL SINGLE-STAGE BLEACH PLANT DIFFUSION WASHER IN UP-FLOW TOWER

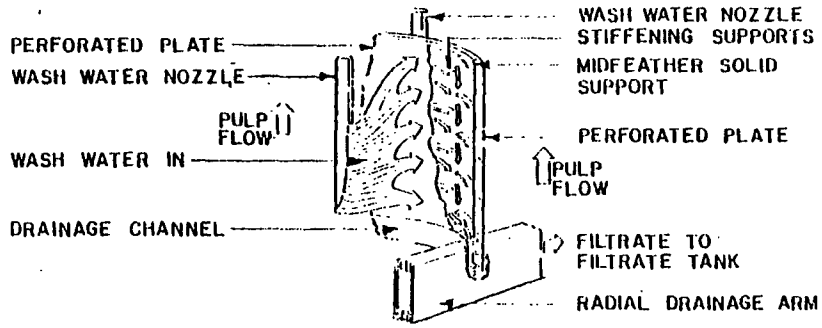

FIGURE 32-3B: CROSS SECTION OF TYPICAL DIFFUSER SCREEN PLUG

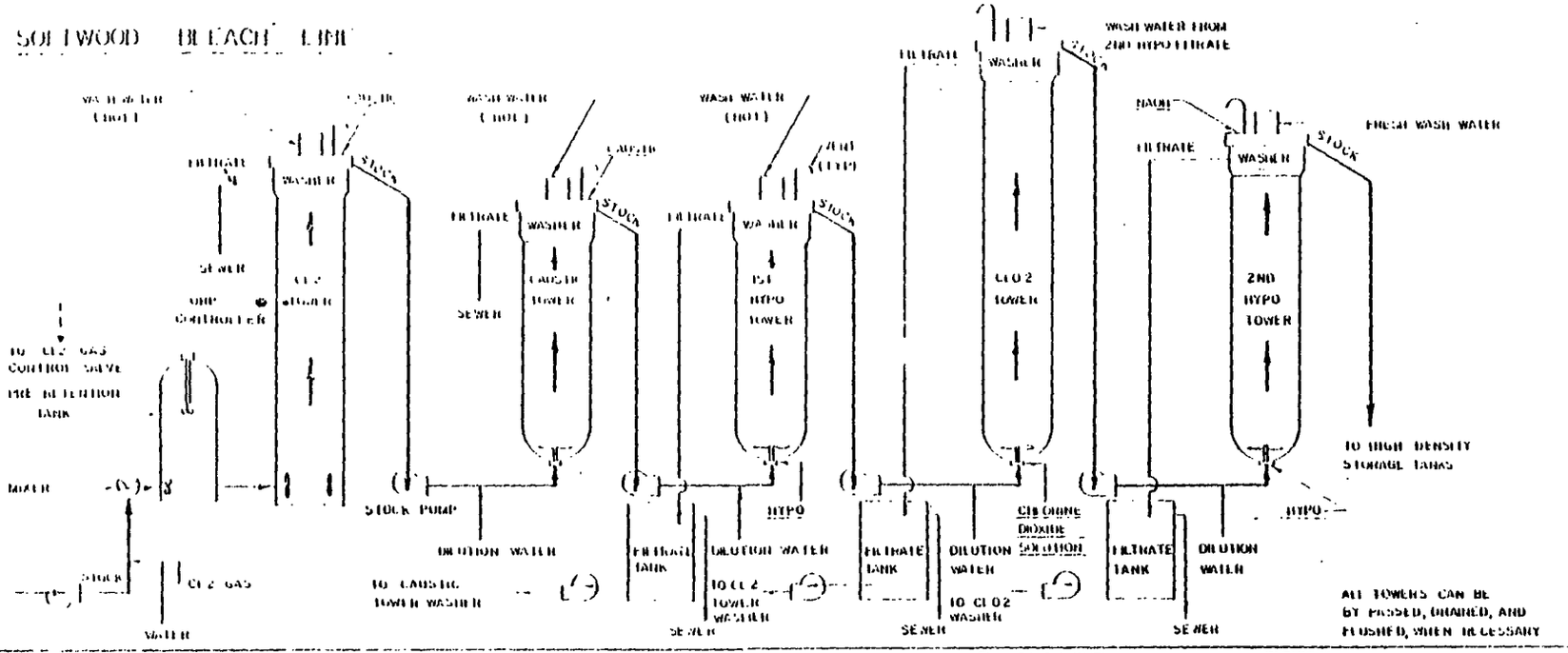

FIGURE 32-4: SIMPLIFIED BLEACHING FLOW DIAGRAMS

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partially explains the small differences in the two. Both are periodically modified depending on pulp market demands in order to produce lower and higher brightness pulps (usually by eliminating the 4th or 5th stages). However, the hardwood line generally bleaches Kraft pulp with Kappa numbers of 10.5 to 13.5 (post decker) to final brightnesses of 81 to 87 (G.E.). The softwood (pine) line bleaches Kraft pulp with Kappa numbers of 19.0 to 22.0 to final brightnesses of 81 to 86.

Description of Chemical Handling Systems

The following chemicals are received, unloaded, stored, and then used to prepare bleaching solutions at the bleach plant's chemical handling and preparation facility:

- Liquid chlorine
- Caustic soda (sodium hydroxide solution)
- Sodium chlorate crystals
- Salt (or brine)
- Concentrated sulfuric acid
- Sulfur dioxide

This facility is separate from the bleach plant and operated by a two-man staff. Most of the incoming chemicals are unloaded by pumping railroad or truck tank cars to outside chemical storage tanks. Additional operations include:

Chlorine Unloading and Vaporization - Liquid chlorine railroad cars are unloaded by pressurizing them with clean, dry air. This allows the liquid to flow to the steam-heated vaporizers where it is carefully heated and converted to the gas. Exit gas line pressure is regulated and then the resulting gas is distributed through a piping network to the two first-stage bleaching towers, the two hypochlorite reactors, and a mill water treatment plant. The gas distribution network is equipped with an air purge system so that it can be cleared of chlorine during a mill shutdown, equipment malfunction, or other emergency. The chlorine gas is purged into an outside tank that contains caustic soda. Chlorine and caustic then safely react to produce hypochlorite, which is used in the bleach plant's third and fifth stage.

Chlorine Dioxide Generation - The mill has both a Matheison and and ERCO chlorine dioxide generator. Each is housed in its own separate building.

The Matheison system produces chlorine dioxide by reacting sulfuric acid, a solution of sodium chlorate, and sulfur dioxide gas:

$$2NaClO_3 + SO_2 + H_2SO_4 \rightarrow 2ClO_2 + 2NaHSO_4$$

The reaction takes place inside a single, homogeneous lead-lined reactor vessel which is jacketed for heating or cooling, as required. Sulfuric acid from the storage tank is filtered and them metered into the reactor's top. The sodium chlorate solution is similarly filtered, then passed through a scrubbing tower before it enters the reactor's top. In the scubbing tower, hydrochloric acid and sulfur trioxide in the chlorine dioxide gas stream from the reactor are removed by dissolving them in the incoming sodium chlorate solution. Sulfur dioxide and air are injected into the bottom of the reactor vessel. The sulfur dioxide, which is about 6%, serves as the reducing agent in the above reaction. The air, in which it is contained, serves to mix the reactants that are inside the reactor and also purges off the produced chlorine dioxide. By carefully controlling the reactant flowrates, the amount of purge air, and the temperature of the reactor, the desired amount of chlorine dioxide gas is continuously produced. The gas is then safely purged out of the reactor vessel by the air stream and into a high efficiency gas absorption tower. (The tower is inside the generator building above the reactor.) Chlorine dioxide gas is absorbed in chilled water added to the top of the tower, and the resulting chlorine dioxide solution drains to an outside storage tank. Used reactants are continuously removed from the generator reactor through a gas stripping tower. This uses air to purge any remaining chlorine dioxide back into the reactor vessel. The used reactor liquid drains to an outside storage tank and is then pumped to another area of the mill for use in recovering tall oil from the pulp mill digester liquor. To guard against chlorine dioxide explosions, the chlorine dioxide solution storage tank is vented back to the absorption tower. Air and any unabsorbed chlorine dioxide in the tower is continuously exhausted to the atmosphere by a 400 SCFM fan.

The ERCO generator is very complex and a complete description of its equipment and manner of operation is beyond the needs of this study. Its basic components are:

- Feed systems for sodium chlorate solution, sulfuric acid, salt brine, catalyst, and purging air
- A large closed, reactor vessel
- A reboiler for heating the reacting liquor

- o A surface condenser for cooling the reactor offgases
- o An absorption tower for chlorine dioxide offgas
- o An absorption tower for chlorine offgas
- o A chlorine dioxide solution storage tank
- o A tail gas scrubber for cleaning the reactor offgases from the two above absorption towers
- o A Dorrclone (cyclone) for separating reactor liquor solids and liquid
- o A hooded and ventilated rotary, vacuum filter for separating reactor liquor solids (salt cake); and
- o A generator liquor recirculation pump

All of the above equipment, except the solution storage tank, is located inside the tall, narrow generator building.

Chlorine dioxide is produced in the reactor vessel by the catalyzed reaction of chlorate with sulfuric acid and salt solutions. Gas is continuously purged from the reactor with air, and passes through the surface condenser for cooling. It then enters the chlorine dioxide tower where primarily chlorine dioxide is absorbed in chilled water. Unabsorbed gas passes on to the chlorine absorption tower where primarily chlorine gas is removed by reaction with weak hypochlorite solution from the tail gas scrubber. The stronger hypochlorite solution that results is pumped to the hypochlorite reactor system for use in making strong hypochlorite bleaching liquor. Any gas which is not absorbed in the chlorine tower is drawn by a steam ejector through a barometric condenser and into the tail gas scrubber. Here any remaining chlorine (and chlorine dioxide) is absorbed in weak hypochlorite from the hypochlorite reactor system. The remaining air is then exhausted by a fan to the atmosphere. The reactor liquor is continuously circulated by a pump through the reboiler (for steam heating) and back into the reactor. Part of this liquor is diverted and pumped to the Dorrclone and salt cake filter where precipitated salt, a reaction by-product ($NaHSO_4$), is separated, then filtered out and washed. Liquid returns to the reactor liquor circulation system. The removed salt is diluted and dissolved in a storage tank before it is pumped to the mill chemical recovery system for use as salt makeup for the Kraft digestion liquor.

Caustic Dilution and Hypochlorite Preparation - These two systems are related because dilute caustic is used in the hypochlorite reactors. Caustic is delivered to the mill in rail tank cars at 50% strength. The car's contents are pumped

to a large outside storage tank. Weaker strength caustic is prepared by mixing the required amount of dilution water with a constant flow of 50% caustic in two closed pipeline mixers. Density sensors in the pipeline after the mixer regulate the water flow and thereby the strength of the dilute caustic ($\sim$7.5%). The dilute caustic is then stored in two large tanks which are equipped with level sensors (and alarms) to automatically activate or stop weak caustic production. The storage tanks can also be heated with steam. Because the unloading, storage, and dilution equipment is closed and automated, there is little potential for worker exposure to caustic mist.

The dilute (7.5%) caustic from either storage tank is pumped to the two bleach lines (second stage) or to one of two automated hypochlorite reactor systems. Both of these produce sodium hypochlorite solution of approximately 35 grams per liter strength (available Cl_2) by reacting $\sim$ 4.3% caustic with chlorine gas* in a closed reactor. The 4.3% caustic is produced by automatically adding the required amount of dilution water to the 7.5% caustic line at a pipeline mixer. The water flow is controlled by a density sensor and controller, similar to the one on the 50% caustic dilution system. The resulting 4.3% caustic is then stored in a surge tank (10,000 gallon) whose level is automatically controlled by regulating the flow of 7.5% caustic to the preceding dilution system. The caustic in the surge tank also serves as reaction media for relief of chlorine gas in the liquid chlorine unloading lines, vaporizers, and gas distribution pipelines. Whenever these lines must be cleared, dry air is used to blow any chlorine into this tank. It then safely reacts to form dilute hypochlorite solution which is later used for pulp bleaching.

Half of the surge tank's contents are pumped to the chlorine absorption tower of the ERCO chlorine dioxide generator. It is used for scrubbing out chlorine gas, then it returns to the surge tank. The other half is pumped through a control valve to a closed reactor where a controlled amount of chlorine gas is injected and mixed to produce sodium hypochlorite solution (35 gpl). The correct amount of injected chlorine is automatically regulated by an oxidation-reduction potential sensor which is located after the reactor. A small amount of hypochlorite solution passes through the sensor and back to the surge tank. If the solution's oxidation-reduction potential is incorrect, then the sensor's controller either opens or closes

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* The mill formerly had one calcium hypochlorite system but this was replaced when the current sodium hypochlorite systems were installed.

the chlorine gas flow control valve. The remaining hypochlorite solution from the reactor passes through a flow measuring element and into one of two outside storage tanks. It is then pumped to the bleach plant when needed.

Other Chemical Handling Systems - Liquid sulfur dioxide for the Matheison chlorine dioxide generator arrives by rail or truck tank cars. They are then unloaded to an outside tank using a compressor. The liquid is vaporized to the gas in a steam-heated vaporizer; then mixed with air prior to being fed to the Matheison reactor vessel. The unloading and vaporization system is totally closed, and largely automated. There is very little potential for worker exposure unless a leak or upset occurs.

Sodium chlorate arrives at the mill as dry crystals inside a railroad tank car. The crystals are unloaded by pumping water from an unloading tank into the car to dissolve them, then back to the unloading tank. This procedure is continued until all the crystals are dissolved. The chlorate solution is then pumped into an adjoining storage tank until it is needed at the two chlorine dioxide reactors.

Salt brine, another of the reactants for the ERCO generator, is delivered to the mill by truck or rail car. It is unloaded pneumatically to two outside tanks, then the salt is dissolved by adding water to the tank. The resulting brine is pumped through filters to a brine head tank in the ERCO building. No worker exposures are associated with these operations.

Sulfuric acid is also delivered by rail or truck. It is unloaded to an outside steel storage tank by applying padding air to the truck or rail tank. The acid is then pumped to the tall oil plant (for emergency use), or filtered and pumped to the two chlorine dioxide generators.

SOURCES OF WORKPLACE CONTAMINATION

Bleach Plant

Locating sources of workplace contamination in the bleach plant is very difficult because all equipment is outside. Because of this, the potential for worker exposure is highly variable. The upflow towers with their integral diffusion washers are largely closed systems, unlike some parts of more conventional bleach towers and drum-washer systems. Pulp transport systems (pumps, control valves, and pipelines) and chemical injection points are also closed and well-sealed. Variable amounts of airborne contaminants do escape from vents provided on top of the tower/washer units, and probably at times from periodic miscellaneous leaks in equipment seals. We also observed some

chlorine and/or chlorine dioxide gas escaping from the acid sewer vents. These vents are in the ground around the towers but some distance away. The acid sewer receives wasted diffuser filtrate water that contains chlorine and chlorine dioxide from the first and fourth stages. If wind conditions are favorable, we determined sewer gas emissions can affect other nearby pulp mill areas - notably the recovery building and the lime kiln control building*.

The severity of the tower vent and sewer emissions is largely determined by the degree of control over application of chlorine gas to pulp in the first stage and chlorine dioxide solution in the fourth stage. Overuse of either chemical causes high stock and filtrate water residuals. This condition can then cause insoluble excess gas to escape at the tower vents or from the washer filtrate water. Workers are potentially exposed to these emissions only if very near them. Such exposure does not occur very often because equipment is automated and remotely-operated. Only the testers regularly go near the towers to collect required stock and filtrate quality control samples. The severity of worker exposure is determined by environmental factors -- principally, wind speed and direction.

Chemical Handling Area

Other than chemical dioxide and chlorine gas which is not fully removed by the chlorine dioxide generator vent scrubbers, there are no consistent sources of contaminant emission from the chemical handling systems. Periodic emissions may occur from: (1) chlorine dioxide generator absorber seal pits, (2) the ClO_2 reactor vessel explosion vents, (3) leaks in ClO_2 solution and other chemical transport pipeline seals, (4) solution transfer pump seals, (5) the ClO_2 solution and spent reactor acid storage tanks. None are thought to be significant sources of potential worker exposure because equipment is (1) outside or inside unoccupied generator buildings, (2) remotely operated, and (3) workers are infrequently near these sources.

Chlorine gas leaks may also occasionally develop in the liquid chlorine unloading lines, the vaporizers, the gas transport piping networks, or the hypochlorite reactor. The potential for worker exposure is small for the same above reasons, but

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* In response to kiln control room employee complaints during one such period of excessive sewer offgassing, we briefly measured chlorine/chlorine dioxide levels of 0.5 ppm (as Cl_2) in the control room and 1.2-1.4 ppm (as Cl_2) just outside the kiln control building.

major gas leaks could potentially cause severe exposures before workers could escape. Gas from major leaks could also infiltrate nearby occupied buildings.

BLEACH PLANT JOB CATEGORIES AND DESCRIPTIONS

The entire pulp mill, including both bleach lines, is staffed on a crew concept. Two workers per shift (plus a shift supervisor) are directly involved in the operation of the two bleaching lines - one Assistant Operator for each bleach line. Three technicians (or Testers) work in the pulp mill laboratory and are responsible for collecting and testing stock and filtrate samples. They rarely operate equipment.

Pulp mill utility workers occasionally perform housekeeping and stock cleanup tasks around the outside bleach equipment. They may be exposed if they go near the diffusion washers and their vents. Job descriptions are presented below only for the two categories actively involved in bleach plant operations -- Operations and Testers.

Bleach Line Operators (or Assistant Operators) - The two operators stay in the main pulp mill control center essentially all the time. From here they can monitor all equipment and interface with a process control computer. Under normal plant operations, this computer controls most stock, chemical, and water flows according to a pre-set program and feedbacks from a number of process monitors -- stock flows to the first stage, oxidation-reduction probe potential, temperatures, pH, etc. The operators input current data on bleaching test results (brightness, chemical residual, pH) and the desired targets for pulp production rate and brightness. The computer then determines and regulates chemical feedrates, stock flowrates, and water balances (dilution and washing). The operational state of pumps and diffuser moving elements are also monitored and displayed on a control panel.

During startups or shutdowns, and often during upsets, the Operator may have to override the computer and manually operate the line using analog controllers. During these periods, they may also have to leave the control center to check a piece of outside equipment, make some adjustments, or perform a simple repair. Examples of such common outside tasks include:

- Unplugging a decker;
- Checking an improperly functioning extraction flow valve;

- Investigating hydraulic oil leaks near the chlorine tower; and
- Investigating common equipment problems - leaking valves and gaskets, bad bearings, etc.

The operators are also responsible for performing a routine equipment inspection 1-2 times per shift. It involves a brief outside tour around the towers and diffusion washers during which the following equipment checks and measurements are made:

- Diffuser back flush tanks
- Extraction tower stock level
- Hydraulic oil levels in diffuser hydraulic system reservoirs
- Automatic chemical valves
- Thick stock pumps
- Other major pumps
- DM mixers in the bottom of chlorination towers
- High density storage tank levels (once per shift)
- Ground level motor inspections and checks for stock spills

Some exposure to chlorine and/or chlorine dioxide may occur during these tours, but it is variable because the worker is always outside. The length of time required to perform the inspections is also variable, but typically less than 15 minutes.

Tester - The three testers comprise a pool of technicians who perform all quality control sampling and testing in the pulp mill and bleach plant.

Two of the three workers usually collect all samples, while the other remains in the pulp mill laboratory to perform tests. The other two will then assist in performing tests when they return from sampling runs. Usually, the samplers are each assigned to collect samples from only one pulp/bleach line. However, during the survey, they frequently alternated and/or assisted each other. This made it difficult to segment their routines and assess the potential for exposure.

A sample collection run is performed every hour and takes approximately 10 minutes for one bleach line. At each tower-diffusion washer, samples of stock and/or wash filtrate may be collected from specially installed sampling taps, sketched as Figure 32-5. As noted, some of the filtrate sampling lines run continuously in order to ensure a representative filtrate sample is collected.

Since the filtrate may contain high levels of residual chlorine, hypochlorite, or chlorine dioxide, those sampling taps are a potential source of worker exposure. The sequence in which the various samples are collected is at the discretion of the worker, but usually he or she first collects stock samples from each tower's upper level, then collects filtrate samples from lower levels. A typical hardwood line collection sequence is as follows:

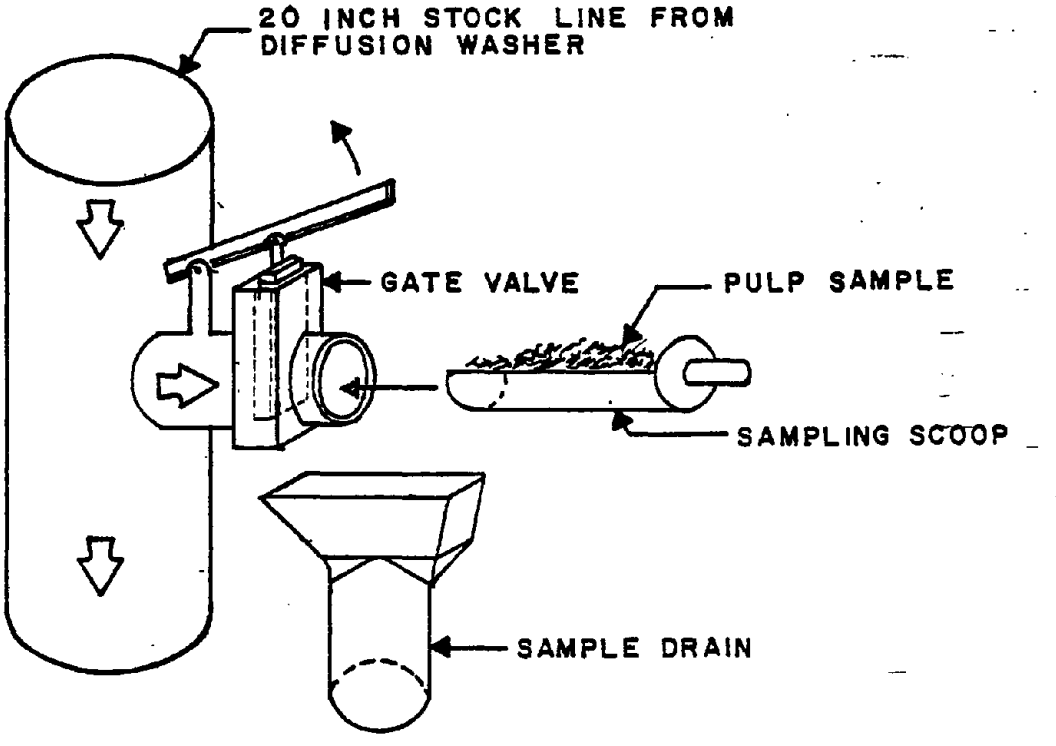
Sample No.	Location	Type of Sample(s)
1	Level 5 - ClO_2 Tower	Stock and filtrate
2	Level 5 - 2nd Hypo Tower	Stock and filtrate
3	Level 3 - 1st Hypo Tower	Filtrate
4	Level 3 - Extraction Tower	Filtrate
5	Level 3 - Chlorine Tower	Stock
6	Level 3 - Extraction Tower	Stock
7	Level 3 - 1st Hypo Tower	Stock
8	Level 2 - Chlorine Tower	Filtrate

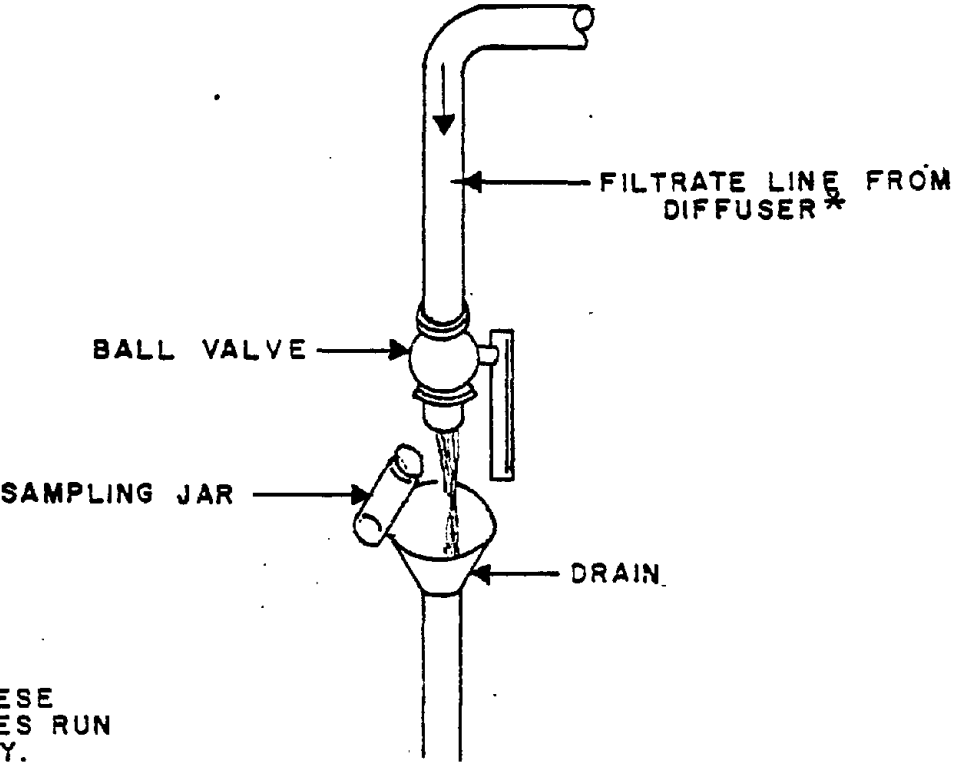
CHEMICAL HANDLING JOB CATEGORIES AND DESCRIPTIONS

Two additional workers operate the bleach chemical handling systems -- an Operator and a Helper.

Operator - The Operator is responsible for operating: (1) the two chlorine dioxide generators, (2) the two hypochlorite preparation systems, (3) the chlorine unloading systems and vaporizers, (4) the liquid sulfur dioxide unloading and vaporization system, and (5) the caustic dilution systems. He is also responsible for receiving and unloading shipments of chemicals, and keeping records of all production operations and

FIGURE 32-5: TOWER SAMPLING TAPS





*SOME OF THESE SAMPLING LINES RUN CONTINUOUSLY.

chemical inventories. If all equipment is operating correctly, his work routine is very simplistic, consisting of remaining in the control building to watch the various process monitors and to make minor adjustments of the analog controller setpoints. Invariably, but unpredictably, there are process upsets, system startups and shutdowns, maintenance operations, and other events which require his attention and for which he may leave the building. Considerable amounts of time are spent in monitoring and adjusting just the ERCO chlorine dioxide generator, much more so than any other chemical handling equipment. Such high level of attention is required because of the complexity of this equipment and the need to maintain a very constant level of liquid inside the main reactor vessel.

Although difficult to accurately quantify the amount of time this worker spends performing any one task or in any one area, we estimate he is in the control building at least fifty percent of the time.

Helper - The Helper's overall function is to assist the Operator in performing any required task. We observed that many Helpers had a limited understanding of process operations and required considerable supervision by the Operator. The worker's main function is to collect and test process quality control samples from: (1) the two chlorine dioxide generators, (2) the two hypochlorite reactors, (3) the caustic dilution system, and (4) incoming shipments of new chemicals. One or more of these samples are collected and tested every hour but the actual time required is very brief -- almost always less than five minutes. Complete summaries of the types of samples, their frequency of collection, and type of test performed on them are presented as Figure 32-6. Of these, the greatest risk of exposure probably occurs when he enters either of the two generator buildings to collect absorber and reactor spent acid samples. Workers are required to have half-face piece, air-purifying respirators whenever they enter these buildings to collect samples or perform other tasks.

The Helper is also responsible for making adjustments to the chlorine unloading and vaporization system, but only under direct Operator supervision. This equipment is located near the bleach plant -- some distance from the chemical handling area. The Helper also performs housekeeping tasks throughout the chemical handling area, but not at any regular times. The worker's free or break time is usually taken inside the chemical handling control building. It is estimated he or she is outside this building about 50 percent of the time.

Figure 32-6: SUMMARY OF QUALITY CONTROL SAMPLES COLLECTED BY CHEMICAL PREPARATION HELPER

Sampling Location	Frequency of Collection	Test Performed
Mathieson ClO_2 Generator Building -		
○ Ground Floor Absorber Sample		ClO_2 strength
○ Upper Level Reactor Spent Acid Sample		Chlorate and Acid Content
ERCO ClO_2 Generator Building -		
○ Ground Floor Absorber Sample*		ClO_2 strength
○ Ground Floor Reactor Spent Acid Sample*		Chlorate and Acid Content
Outside Chlorine Dioxide Solution Storage Tanks (2)		ClO_2 strength
Outside Hypochlorite Reactors (2) Solutions		Available Cl_2 plus Excess Caustic
Outside Hypochlorite Solution Storage Tank		Available Cl_2 plus Excess Caustic
Outside Dilute Caustic Storage Samples		Caustic Strength
Outside Sodium Chlorate, Sulfuric Acid, and Brine Storage Tanks	Each Delivered Shipment of New Chemical	Chemical Strength

* Both samples are collected from same enclosure

AIR MONITORING RESULTS

Methods

A combination of air monitoring techniques were used to develop data with which to assess the potential for workplace contamination and associated worker exposure. They included:

(1) biased personal sampling (using NIOSH Method P & CAM 209),

(2) a continuous real-time chlorine/chlorine dioxide air monitor with strip chart recorder (Mast Oxidant Monitor), and

(3) Drager chlorine detector tubes.

Both chlorine and chlorine dioxide gas are potentially present at the same time in some work areas of the bleach plant and chlorine dioxide generator buildings. None of the above monitoring techniques are specific for one contaminant in the presence of the other. All monitoring techniques respond positively to both, but were only quantified in terms of the equivalent chlorine response because of the current lack of accurate and efficient procedures for generating low-level chlorine dioxide standards.

Approach

Despite these limitations, nine short-term personal samples were collected on the two bleach plant testers while they collected the required quality control samples at the outside towers (see previous Job Descriptions for this labor category). In the chemical handling area, no personal exposure samples were collected because the only inside tasks which are regularly and consistently performed are again the process sampling runs. Specifically, these runs include collection of samples at: (1) the two generator buildings, (2) the outside chlorine dioxide solution storage tanks, (3) the two outside hypochlorite bleach liquor preparation systems and storage tanks, (4) the outside caustic and chlorate storage tanks (periodically). These sampling runs require very little time to perform -- less than one minute for hypo samples; less than five minutes for the chlorine dioxide generator and storage tank samples. When collecting samples from the chlorine dioxide generators and storage tanks, workers primarily are potentially exposed to only chlorine dioxide. No specific quantification methods exists for it.

Airborne levels of combined chlorine dioxide/chlorine were determined and recorded using a Mast Oxidant Monitor. Monitoring station included single locations in both the ERCO and Matheison generator buildings, and in the central control building. The Monitor was field-calibrated only in terms of chlorine.

Drager chlorine detector tubes were used to determine if chlorine gas normally escapes at the hypochlorite reactors; and to determine if chlorine dioxide was well-contained by the unique sampling line enclosure in the ERCO generator building.

Results for air monitoring using these techniques will be discussed separately for the bleach plant and the chemical handling areas:

Bleach Plant Results

Collecting stock and filtrate quality control samples at the bleach towers is probably the task with highest potential for worker exposure. This is because workers (the testers) must walk around the tower catwalks and open lines containing treated stock or washer filtrate which have residual chlorine or chlorine dioxide. Also, it is the only task which is regularly-performed, predictable, and therefore amendable to exposure risk interpretation. A total of nine 15-minute personal samples were collected while workers performed this task. Results are summarized in Table 32-1. For each sample, the sampling time began when the tester left the pulp building laboratory, and ended after 15 minutes had elapsed. In all cases, by the end of this period, the worker had returned to the laboratory and begun analysis of the samples. Therefore, each period included some 5-7 minutes of estimated zero exposure while in the laboratory. Also, little or no exposure probably occurs during the 1-3 minutes of transit time required to reach the bleach towers. Of course, any exposure while working around the outside towers could be highly variable and dependent on environmental conditions.

As shown on Table 32-1, five of the nine collected samples were at or below the practical limits of detection for the analytical method (NIOSH P & CAM 209). Of the remaining four, only two (Nos. 1 and 8) gave appreciable readings (0.21 and 0.19 ppm as Cl_2). While collecting one of these, the survey team member and the worker both could smell chlorine dioxide gas at the fourth stage tower. The tester was undoubtedly exposed to it while collecting stock and filtrate samples at that tower. The data indicates the potential for overexposure to chlorine is very low while performing these tasks, unless very poor control over chemical addition at the tower bottom occurs and a large amount of gas escapes at the chlorine tower's vent. Even then, the wind would have to blow chlorine

TABLE 32-1: SUMMARY OF BLEACH PLANT TESTER PERSONAL SAMPLES

Sample No.	Job Task	Day	Sampling Period	Chlorine/Chlorine Dioxide Exposure [1] (as ppm Cl_2)	Comments
1	Collection of Bleach Plant QC Samples[2]	Tues.	16:25 - 16:40	0.21	Noticeable odor at chlorine dioxide tower.
2	"	Wed.	9:27 - 9:42	0.51	-
3	"	Wed.	11:42 - 11:57	0.076	Noticeable odors at chlorine and chlorine dioxide towers.
4	"	Wed.	13:32 - 13:47	< 0.050*	-
5	"	Wed.	16:24 - 16:39	0.087	-
6	"	Thurs.	10:25 - 10:40	< 0.050*	-
7	"	Thurs.	16:25 - 16:40	< 0.050*	-
8	"	Thurs.	17:30 - 17:45	0.19	-
9	"	Fri.	9:25 - 9:40	< 0.050*	-

[1] Determined by NIOSH Method P & CAM 209. Sampled worker was likely exposed to both chlorine and chlorine dioxide.

[2] Samples were collected from either the hardwood or softwood bleach lines, although the tester occasionally collected samples concurrently from other line.

* Represents limit of detection for the sampling/analysis procedure.

(or chlorine dioxide) downwards and/or towards the tower catwalks before exposure would occur. Exposure to chlorine dioxide is also probably low, but the lack of a specific and interference-free method for it precludes making a definitive analysis of over-exposure potential.

Chemical Handling Area Results

A number of conditions make it difficult to make any specific personal exposure measurements in the chemical handling area, and we therefore did not attempt any:

(1) quality control sampling runs are very brief.

(2) the helper does not collect all the samples at once, but instead collects either one or both sets of generator samples, then the hypo reactor samples, when time permits.

(3) the chlorine dioxide storage tanks are outside and any exposure during collection of their samples is affected by the wind and other environmental conditions.

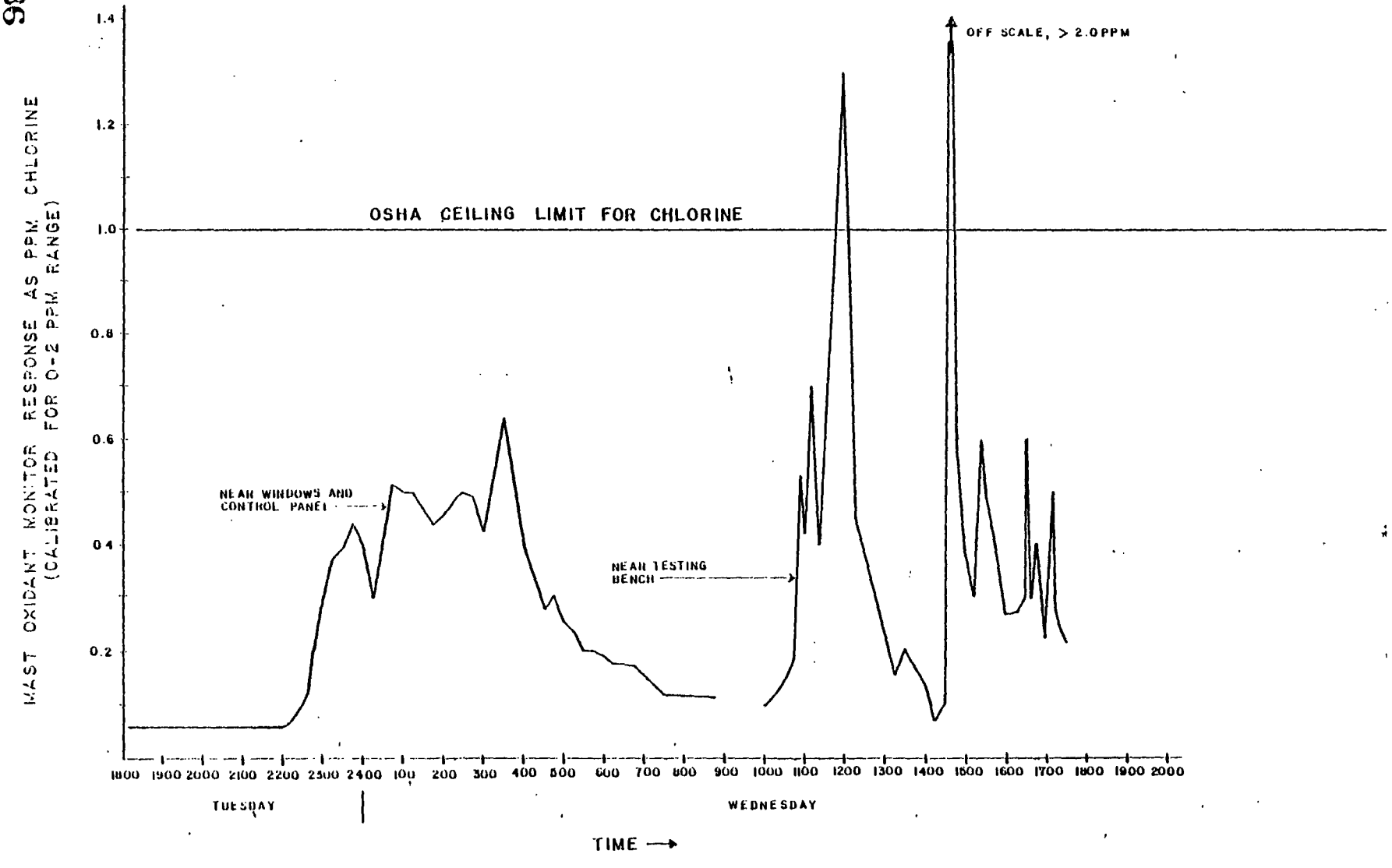
(4) the ERCO generator was shutdown for most of the survey period, an no quality control samples are collected during shutdowns.

(5) performance of other tasks is unpredictable.

As an alternative exposure assessment strategy, the Mast Oxidant Monitor was used to measure and record contaminant levels in both generator buildings and in the main control building. Although the monitor's results cannot be used to directly project potential worker exposure in these areas, it did provide interesting data on the general magnitude, variability, and likely source of airborne contaminants in these three enclosed (but unoccupied) workspaces. For each of these monitoring locations, the Monitor was calibrated for chlorine response in the range of 0-2 parts per million.

In the single-story chemical handling control building, it was first positioned on a bench near the equipment control panel, then on another bench used to test the chemical control samples. It measured air contaminant levels (chlorine dioxide and/or chlorine) over an approximately 23 hour period. The recorder tracing for this time period is reproduced as Figure 32-7.

FIGURE 32-7: CHEMICAL HANDLING CONTROL BUILDING AIR MONITORING



In the Matheison chlorine dioxide generator building, it was positioned on the ground level near a pipe from which the absorber solution sample is collected. This location is near an open doorway and a wall exhaust fan (see Figure 32-10). Inside this tall and narrow building are the generator's reactor vessel, chlorine dioxide absorption tower, spent acid gas stripping tower, and gas stripping tower. (Tanks for the chlorine dioxide solution and spend acid are both located outside). Air contaminant levels (presumably, mostly chlorine dioxide) were monitored at this location for approximately 12 hours. The recorder tracing is reproduced as Figure 32-8.

In the ERCO generator building, the monitor was positioned on the upper level (5th floor) near the top of the generator's absorption towers and a normally-open door, see Figure 32-11. Air movement in the building (determined with smoke tubes) was upward toward this fifth floor, then outwards through the door, another nearby door, and a roof-mounted exhaust fan. The monitor likely detected significant contaminant emissions from almost anywhere in the building. The recorder tracing is reproduced as Figure 32-9.

Air monitoring results for each of the three locations are discussed below.

Control Building - Three periods of surprisingly elevated Cl_2/ClO_2 levels (Tues. 22:30 - Wed. 6:00; Wed. 13:00; and Wed. 14:30 - 17:30) were observed, but contaminants were not thought to be caused by emission from chemical handling operations. With the exception of the hypochlorite reactors, all equipment was downwind from this building during the monitoring. The most likely cause was chlorine and chlorine dioxide offgasing from the main bleach plant process sewer. This sewer was upwind of the control building. It periodically receives excess wash filtrate from the bleach plant diffusion washers. The filtrate occasionally has elevated amounts of residual chlorine and chlorine dioxide, which offgas at a sewer junction, despite the mill's attempts to prevent it. The sewer junction is over 400 feet from the chemical handling control building, but at times offgasing is so severe that gas is blown all the way to the building.*

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* In response to lime kiln worker complaints, we measured air contaminant levels from this source of about 1.0 ppm (as Cl_2) inside the kiln control building. This building is closer to the sewer offgasing point than the chemical handling building is.

FIGURE 32-8:

MATHEISON CHLORINE DIOXIDE GENERATOR BUILDING*
AIR MONITORING

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* MONITOR WAS LOCATED ON GROUND LEVEL OF BUILDING NEAR ITS ENTRANCE DOOR AND THE ABSORBER SAMPLING POINT. A WALL EXHAUST FAN WAS TO ITS IMMEDIATE LEFT LESS THAN 10 FEET AWAY (SEE FIGURE 32-10).

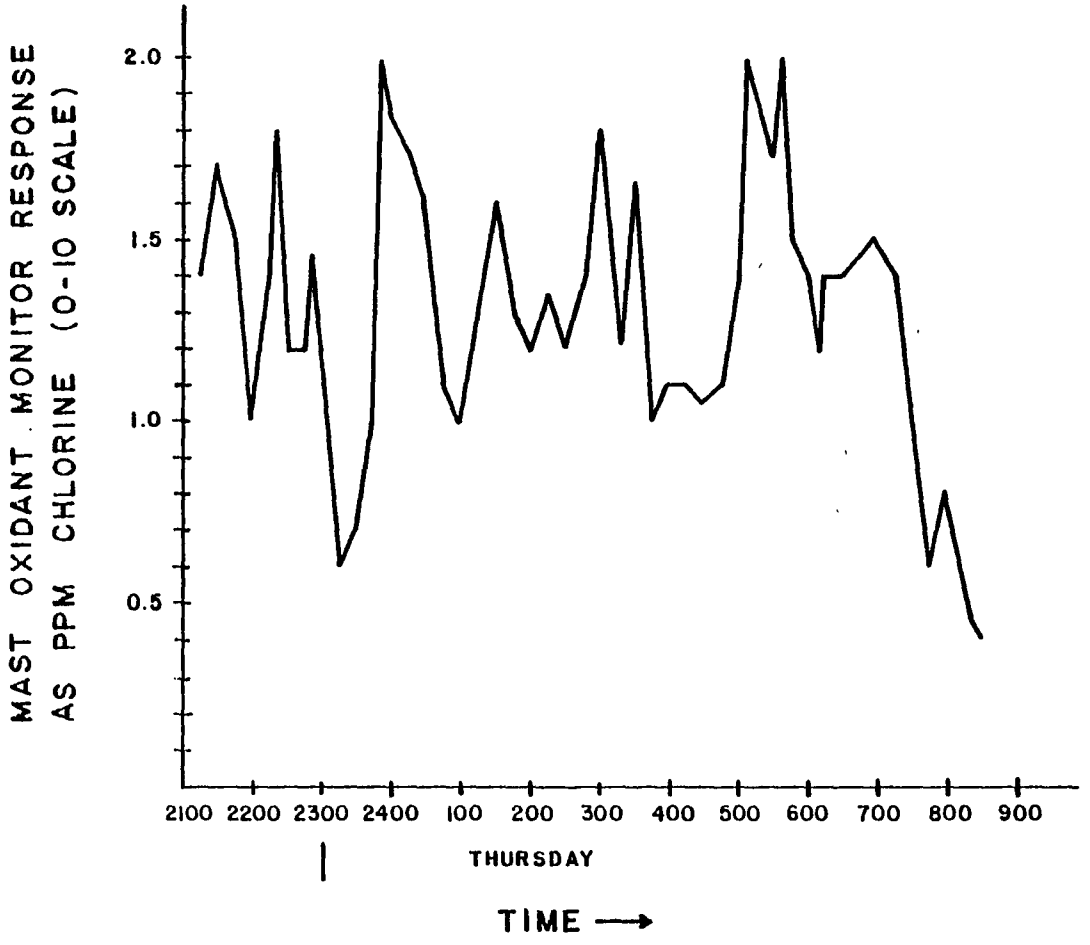
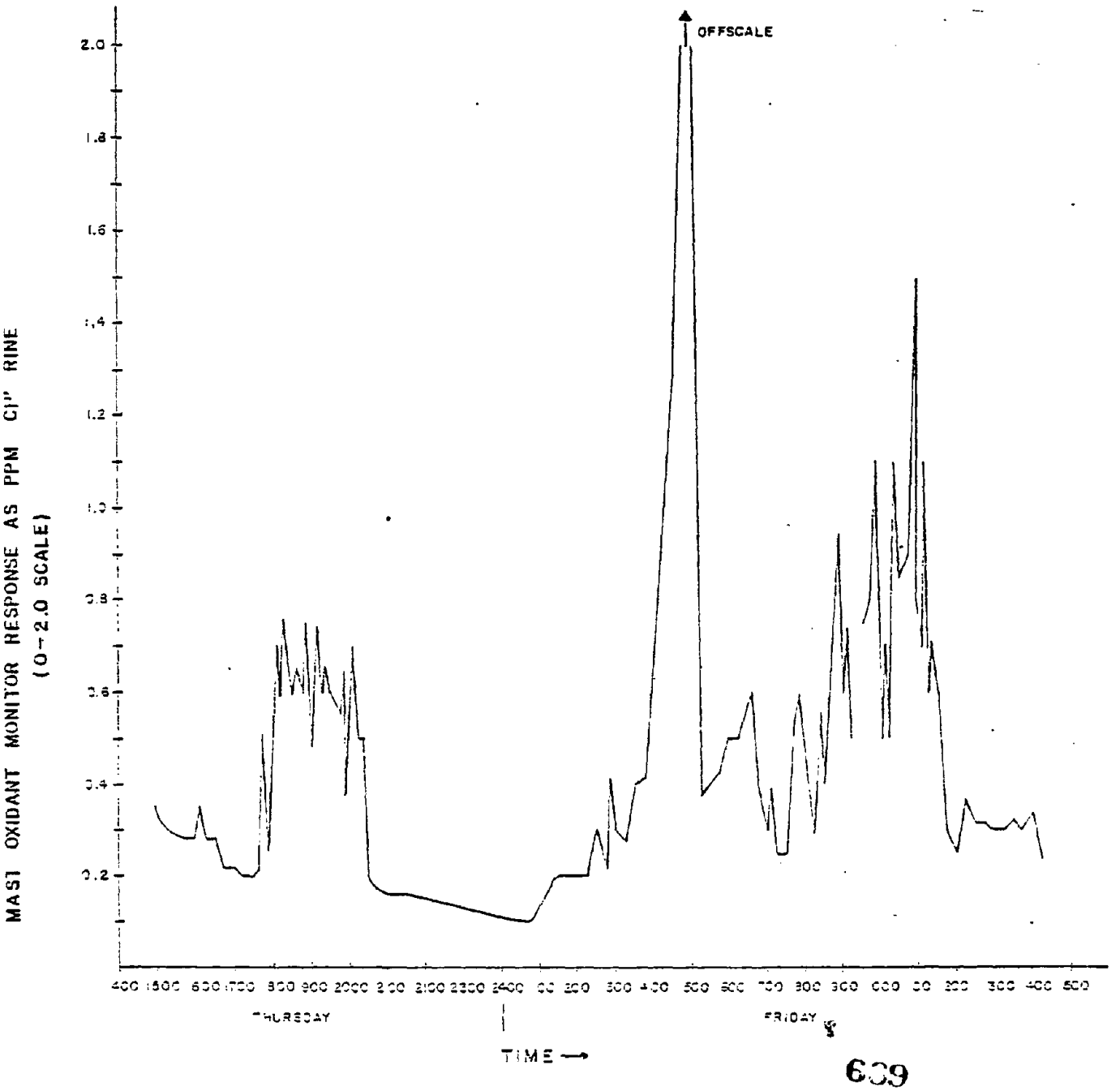


FIGURE 32-9:
UPPER LEVEL OF ERCO CHLORINE DIOXIDE GENERATOR BUILDING



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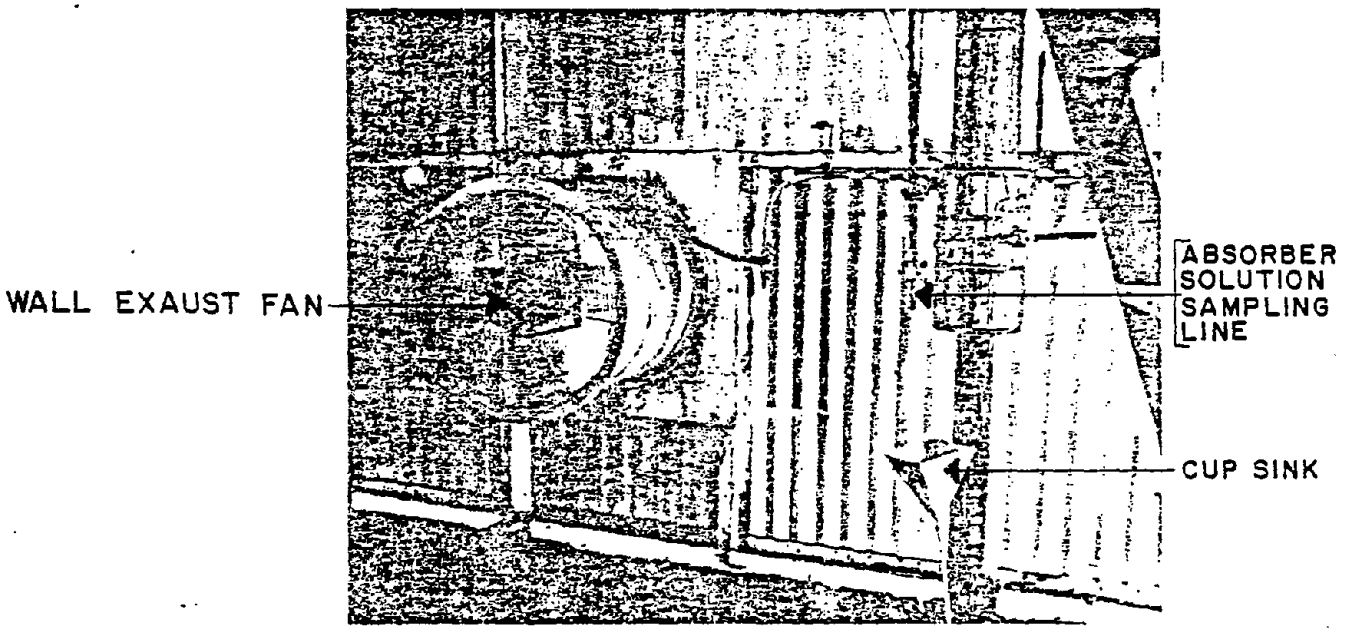
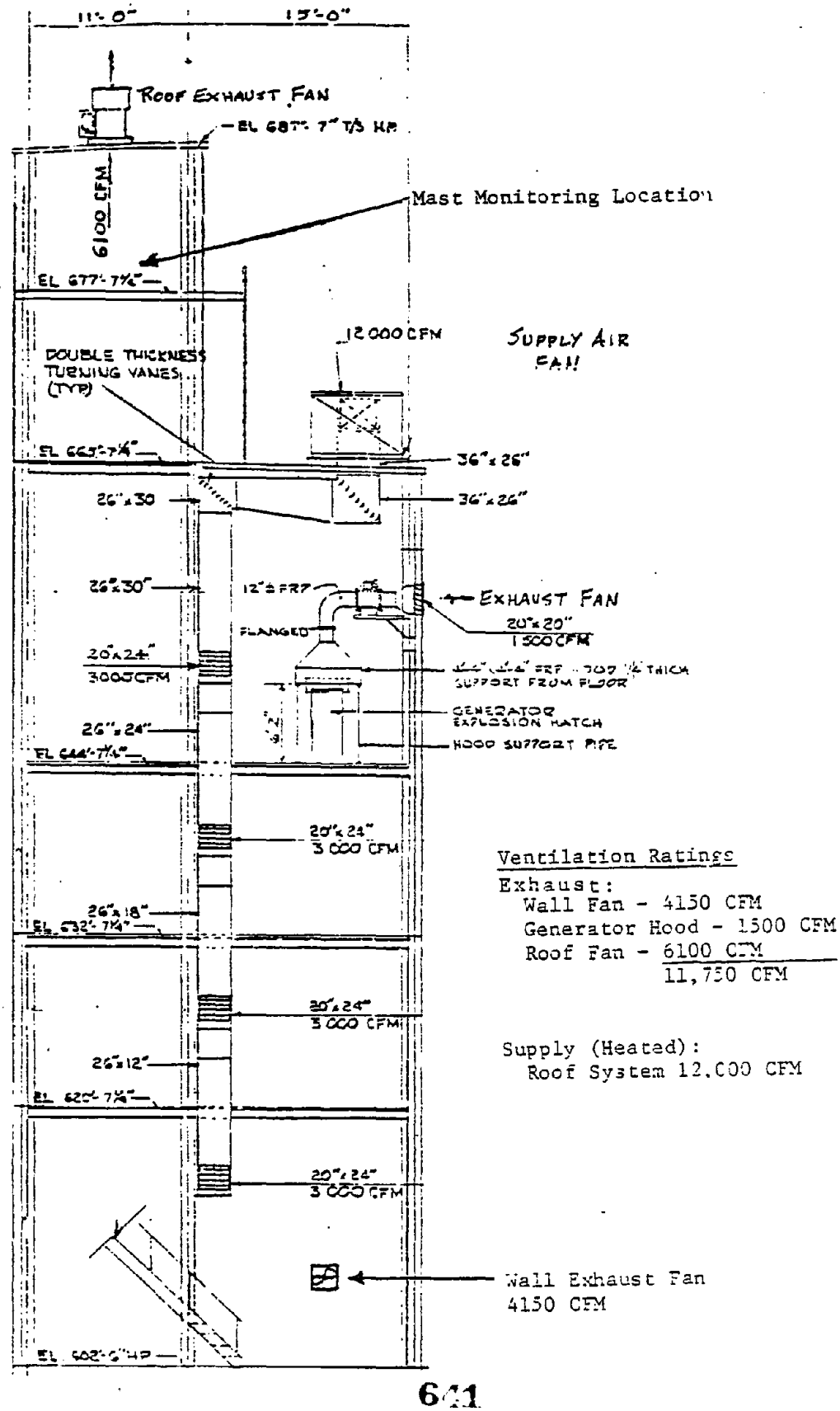


Figure 32-10: Matheison Generator Building Ground Level Monitoring Location

Figure 32-11: ERCO Building Ventilation Systems



Ventilation Ratings

Exhaust:
- Wall Fan - 4150 CFM
- Generator Hood - 1500 CFM
- Roof Fan - 6100 CFM

11,750 CFM

Supply (Heated):
- Roof System 12,000 CFM

Wall Exhaust Fan
4150 CFM

Matheison Building - The Matheison generator equipment is tightly sealed. No consistent sources of gas escape were located other than those that occur during the periodic collection of quality control samples. These samples are collected from the generator's reactor vessel (spent acid), which is on the upper level of the building, and from a sampling line from the chlorine dioxide absorber. The latter location is on the building's ground floor near the monitoring location. The spent reactor acid does not contain enough chlorine dioxide (or chlorine) to be a significant emission source. Therefore, chlorine dioxide gas escaping from the absorber solution when it is sampled is the likely cause of the distinct, although irregularly spaced observed peaks. As shown, recorded levels of chlorine/chlorine dioxide exceeded the OSHA ceiling limit (1.0 ppm chlorine) for all but about two hours. Some thirteen peaks are apparent on the recording. We believe each is attributable to the irregularly-spaced collection of samples from this absorber line. A sample collection involves first opening the sampling line valve, then letting solution in the line flush for a few minutes before quickly collecting a representative sample. During flushing, the solution drains to a cup sink immediately below the pipe, but no water is used to flush the drain. The wall exhaust fan shown in Figure 32-10 is less than 5 feet to the left of the sampling line but it is largely ineffective at containing and exhausting chlorine dioxide gas which escapes from the absorber line and the drain. The magnitude of the measured concentrations clearly indicates collection of this absorber sample can be a major source of workplace contamination. In this building, even the use of a nearby wall exhaust fan still could not remove all the gas that escapes, and therefore between peaks (or between samplings) contaminant levels rarely dropped below 1.0 ppm (as Cl_2). This monitoring data indicates better control over escaping gas from such inside sampling lines is required. Possibly controls would include: (1) better design of the sampling lines and drains including a provision for drain flushing water, (2) locating them outside, (3) use of enclosures*, or (4) better (local) ventilation.

ERCO Building - As shown in Figure 32-9, contaminant levels on the remote upper floor of the ERCO building were much higher than expected. The recorded levels exceed the OSHA ceiling limit for chlorine (1.0 ppm) only briefly (Friday, 4:30 and 11:00), but exceeded half this limit (i.e., 0.5 ppm) for periods totalling over 6.5 hours or almost 30% of the monitoring period. Assuming the monitor responds to about half

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* Such a control is installed on the ground floor in the ERCO generator building (See Figure 32:12).

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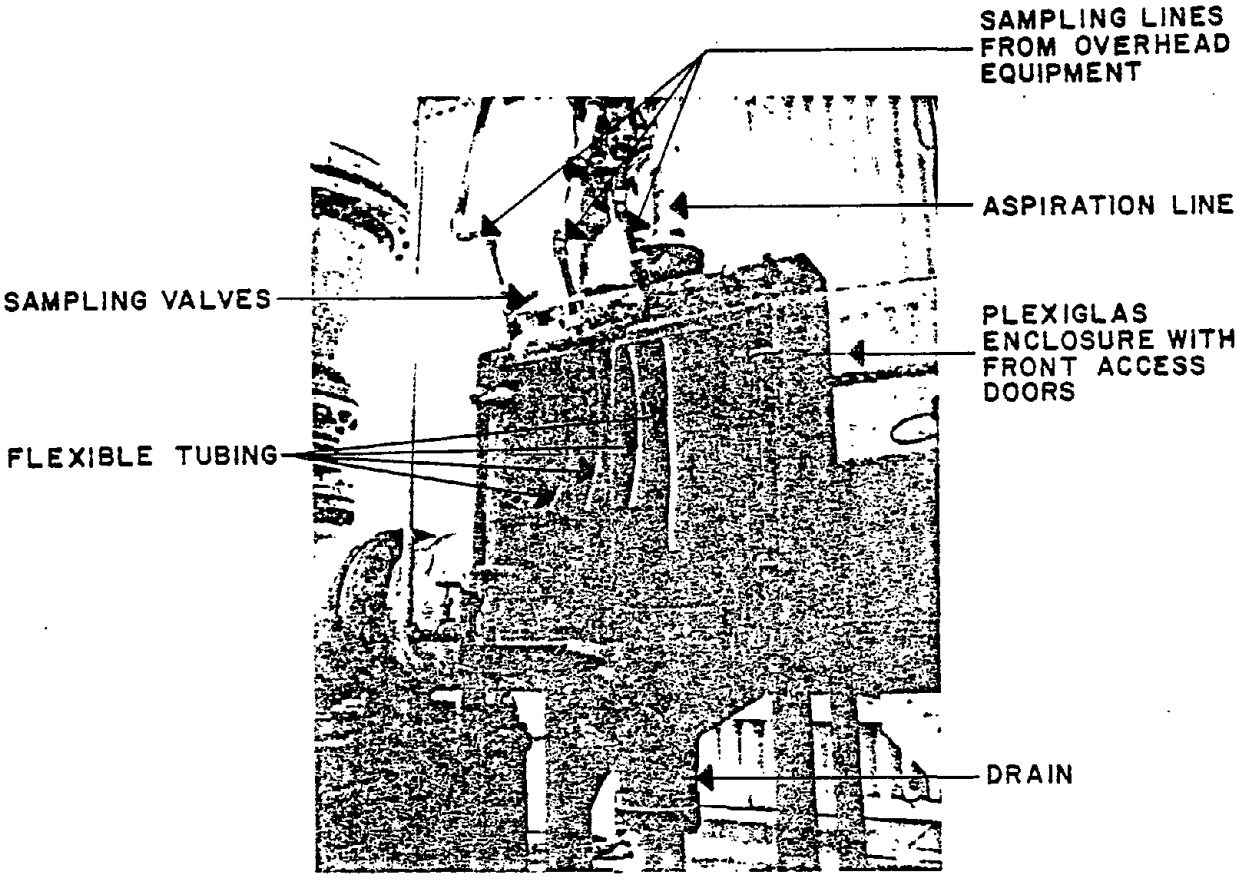

Overall Enclosure Dimensions: 24"W x 11"D x 26"H

Figure 32-12: Enclosure for ERCO ClO_2 Generator QC Sampling Lines

the actual amount of chlorine dioxide present, levels exceeded its OSHA 8-hour TWA limit of 0.1 ppm (0.1 ppm ClO_2 = 0.2 ppm Cl_2) for about 7 hours, or 30% of the monitoring period. It should be stressed that the monitoring location is not representative of a worker's exposure while inside the building.

The two periods of irregular peaks (Thurs. 18:00 - 20:30 and Fri. 2:00 - 11:30) are thought to be caused by one of three sources:

(1) A leak in the process sewer seal pot that receives wasted absorber solution and contaminated seal water

(2) Collection of process quality control samples from a ground level enclosure

(3) Periodic leaks from some unknown generator source like the salt cake filter, absorber, a chlorine dioxide solution line or pump, or the reactor vessel

(4) The aforementioned gas leak from the bleach plant process sewer line

The last two of these, although possible contributors, are not thought to be primary causes of the observed levels because the recorded peaks occurred irregularly and varied greatly in magnitude and shape. Equipment leaks inside the building or at some distance from the building would likely cause elevated but stable contaminant levels, not the observed widely-varying peaks or series of peaks. The most likely cause of these observed levels is periodic emissions from (1) the leaking sewer seal pot for the absorption tower and/or (2) the quality control sampling enclosure on the building's ground level. Mill management knew of the sewer leak and was planning to fix it as soon as possible. Unfortunately, the survey team did not learn of it until just before the survey's conclusion. There was insufficient time to further investigate it.

In order to assess the potential for gas to escape from the quality control sampling line enclosure on the building's ground floor, a Drager chlorine detector tube reading was taken in front of the enclosure while the Helper collected samples (see Table 32-2). A reading of about 1.0 ppm (as Cl_2) was obtained at a distance of about 6-12 inches in front of the enclosure. The worker left one of the enclosure's doors open while he flushed each sampling line. Gas escaping through this open door caused the measured level. Little gas could escape if both doors are always kept closed, except when inserting and removing the sampling container. They can be kept closed because flow control valves for the sampling lines are located outside the enclosure. Poor worker use of this control can therefore contribute to unnecessary release of air contaminants.

TABLE 32-2: Summary of Draeger Detector Tube Readings

Location	Probable Air Contaminant	Readings (as ppm Cl_2)*	Comments
Front of QC Sampling Line Enclosure In ERCO Building	ClO_2	~1.0	Reading taken 6-12 inches in front of enclosure while door was open
Headspace Over Fresh Hypochlorite Sample	Cl_2	~0.2	Reading was taken about 3 inches above liquid
Drain Below Hypochlorite Sampling Tap	Cl_2	~0.5	Reading taken while fresh hypo flowed into the drain

* Used 10 pump strokes for all samples

Two Drager chlorine detector tube readings (Table 32-2) were taken to determine if any chlorine gas normally escapes and causes worker exposure while collecting quality control samples at the hypochlorite reactors. The first reading was taken about 3 inches above the surface of a fresh sample of hypochlorite solution (38-39 gpl). Only a trace of free chlorine was detected (0.2 ppm). The other reading was taken about 3 inches above a drain while fresh hypochlorite solution flowed into it. Again relatively little free chlorine gas could be detected (0.5 ppm). We conclude that there is little potential for worker exposure from the hypochlorite reactors because: (1) both reactors are outside, (2) they are closed systems, and (3) there is no evidence of free chlorine gas escaping from fresh hypo solution when the reactors are operating correctly.

CONTROL TECHNOLOGY

Bleach Plant Control Technology

There is little potential for worker exposure to airborne bleach contaminants because all equipment is outside, highly automated and remotely controlled. These conditions are possible because the mill is located in the south and uses upflow towers with integral diffusion washers. Such technology and climates eliminate the need for any local or general ventilation for control of chlorine or chlorine dioxide process offgases, and reduce the need for precautionary respiratory protective devices (escape masks, self-contained breathing apparatus, supply air systems). Both of these usually must be used in conventional tower and drum washer bleach systems. Extensive process automation is mandatory because of the many parameters which must be accurately controlled. Especially critical is the operation of the diffusion washers, where the amount of applied wash water must be carefully balanced with the amount of extracted filtrate water.

Process monitoring and control for both bleach lines is highly complex and largely computer-controlled. A detailed evaluation of performance of the various control and monitoring systems would be difficult and of limited value, so it will be omitted. However, it should be pointed out that the control systems for both bleach lines (especially the newer hardwood line) are extensively equipped with electrical safety interlocks. These shutdown important stock, chemical, and steam flows if critical process parameters are not met, are exceeded, or if equipment fails (pump does not operate, seal water flow drops, or lubricating oil flows or levels drop).

A number of such interlocks are used for the important chlorination stage. They shutoff or reduce the flow of chlorine gas if injector water flow drops, chlorine line pressure falls, or stock flow changes or stops. This reduces the likelihood of too much chlorine being added to the pulp and then offgasing from the towers and washer filtrate water, potentially causing significant exposure conditions for any nearby workers.

The mill uses oxidation-reduction probe systems on both bleach lines to regulate the amount of chlorine gas for this first stage of bleaching. Magnetic flow meters and remotely-operated valves are used to measure and control the flow of the other bleaching chemicals into the pulp. The mill was satisfied with the performance of these systems, but it appeared that significant amounts of chlorine and chlorine dixoide gas were escaping from the vents on top of the first and fourth stage towers of both lines, particularly the softwood line. This may indicate poor control over proper addition of chlorine and chlorine dioxide to the pulp. With outside equipment, operators have no visual way of judging that too much chemical residual exists in stock entering the washer. In contrast, operators of inside drum washer systems may smell it and make immediate adjustment. This escaping gas is a potential exposure source only if workers are near these outside towers, or if the escaping contaminants infiltrate into nearby buildings. Neither likely occurs.

When workers must go near these towers to collect stock and filtrate quality control samples, the vendor-supplied sampling lines shown in Figure 32-5 provide some protection against exposure. They would also provide good protection for similar sampling tasks from inside chlorine or chlorine dioxide stage towers in other mills. We observe some filtrate lines were left continuously running. If they were inside a building, this could create unnecessary release of chlorine or chlorine dioxide gas.

There is a long, narrow room (12' by 50') near the top of the hardwood line's towers. It contains hydraulic control consoles for the line's diffusion washers. Workers must periodically enter the room to operate or adjust the washers. Because it is near the tower vents and washers, chlorine or chlorine dioxide gas could potentially infiltrate, if wind conditions were favorable. To keep contaminants out of the room and prevent workers from being over-exposed, the mill uses a 10,400 CFM system to ventilate it (estimated 1 to 1.5 air changes per minute).

Chemical Handling Control Technology

In the bleach chemical handling area, workers are also well-protected from exposure to chlorine dioxide and chlorine. This is because equipment is automated and located outside or inside remote buildings provided with effective general ventilation. Respirators are also available for use during process or gas leaks. Each of these controls will be discussed below under the headings of "Process Monitoring and Control," "Ventilation," and "Personal Protective Equipment." The mill also has installed a unique enclosure which isolates and prevents gas from escaping from the ERCO chlorine dioxide generator sampling points. This will be discussed below under "Ventilation."

Process Monitoring and Control Systems - As stated, both generators, the hypochlorite preparation systems, and the liquid chlorine unloading and vaporization systems are all automated and remotely-operated from the main control building. Numerous monitors and controls must be used to insure their safe and efficient operation.

The ERCO generator is a complex system. Workers reported that it is very difficult to operate correctly, sometimes requiring well over 50% of their time. It is newer than the Matheison system, and as stated in the "Process Description" section, constantly recirculates its generator liquid. Only a small amount of this liquid is wasted and replenished. Much of the difficulty in operating the generator relates to the need to keep a constant level of this liquid inside the reactor vessel, and, of course, to the need to accurately regulate chemical feed rates. The systm is equipped with sensors for such important variables as: chemical solution levels, reactor offgas temperature and pressure, chilled water (to chlorine dioxide tower) flow and temperature, reactor liquid temperature, sulfuric acid (to generator) pressure and flow, sodium chlorate solution (to generator) flow, salt brine solution (to generate) flow, and purge air flow to the generator. The outputs of many of these sensors are also recorded, and some are connected to control room alarms and electrical safety interlocks. The most important of these safety interlocks guards against the generator continuing to produce chlorine dioxide if upsets occur. The interlock system will automatically (or manually) shut-off flows of salt brine, sulfuric acid, sodium chlorate, and steam to the generator reactor vessel if any of the following conditions occur:

(1) High generator off-gas pressure

(2) High generator off-gas temperature

(3) Low generator off-gas temperature

(4) Low steam pressure to the process ejector which draws generator gases through the chlorine dioxide and succeeding chlorine gas absorption towers

(5) Low instrument air pressure

(6) Low load on the generator recirculating pump

(7) High inlet gas temperature to the chlorine dioxide absorption tower.

In addition, most of this generator's components where chlorine dioxide or chlorine gas could be released and potentially cause an explosion or workplace emission, are vented to the tailgas scrubber. The scrubber is in the generator offgas line after the chlorine absorption tower. Specific components that are vented to it include: ClO_2 storage tank's scrubber vent, the tailgas scrubber seal-pot vent, the weak hypo tank vent, the ClO_2 absorption tower seal pot vent, the generator dump tank vents, the salt cake slurry tank vent, and the generator's Dorrclone (cyclone) and salt cake filter vents. The outside chlorine dioxide storage tank is fitted with its own vent scrubber, which uses chilled water. This scrubbing water drains to a seal pot then to the chlorine dioxide absorption tower where it combines with that tower's chlorine dioxide solution. This solution is then used for the fourth stage of pulp bleaching.

Ventilation - Four ventilation systems in the chemical handling area contribute to limiting escape of chlorine/chlorine dioxide to the workplace and preventing worker exposure. Three systems are in the ERCO generator building, and the other is the general ventilation system for the chlorine vaporizer facility. Each of these four systems will be discussed below.

The mill has installed a unique ventilated enclosure around the various quality control sampling lines from the ERCO generator. (See Figure 32-12). It is located on the ground floor of the ERCO building to facilitate sample collections and to minimize the amount of worker time spent inside the building. The enclosure (a cabinet) is rectangular and built of Plexiglass panels. PVC sampling lines from overhead generator equipment (absorber, reactor spent acid, chlorate feed, etc.) enter the top of the cabinet and are provided with on/off control valves. The bottom of the cabinet is provided with a grill and a drain which is connected to the building's process sewer. The top is connected to an air aspiration line. This creates a vacuum inside the cabinet to remove any chlorine dioxide or chlorine gas that escapes when a sampling line is opened to collect a quality control sample. Access to the enclosure is through two front doors hinged at either side.

To collect a sample, the worker will open the desired sampling line and let it flush to the drain for about a minute. He will then open one of the doors, place a sampling container inside, and fill it. Observed practice was to leave the door open during this time. It allows some gas to escape to the room as demonstrated by the positive Drager detector tube reading (see Table 32-2). To establish if the enclosure would effectively contain offgasses if both doors always remained closed, we attempted to obtain face air velocity readings. Unfortunately, airflows were too low to measure, even with just one of the front doors partially open. However, a velometer reading of 1700-1800 fpm was obtained in the top aspiration line. This approximate amount of air indicates at least a few CFM are being exhausted from the enclosure, which measures only 2 feet by 1 foot by 2 feet (4 ft^3). We judged that very little gas should escape to the workplace if both doors are kept closed during samplings. The effectiveness of this control is very apparent when contrasted to the amount of gas that escapes to the Matheison generator building when the absorber sample is collected in that building (See Figures 32-8 and 32-10). Similar enclosures may be warranted in other mills with inside generator quality control sampling points.

The ERCO reactor vessel's explosion hatch has an exhausted canopy hood over it in case any gas is ever released as a result of a reactor explosion or "puff" (See Figures 32-13). The exhauster is rated for 1500 CFM and operates continuously. As shown, the bottom of the canopy hood extends down to the top of the explosion vent. Velometer readings taken around this open face area were all less than 50 feet per minute. Although reactor explosions are highly unusual and can vary in severity, the absence of good capture velocities around these faces indicate contaminants could escape to the workplace. Exposure would occur only if workers were nearby.*

General ventilation of the ERCO building may also be important because small gas emissions and equipment leaks can occur at times. As shown in Figure 32-11, single exhausters are installed on the building's roof (6100 CFM) and the east wall of first floor (4150 CFM). Together with the explosion hatch canopy hood, they result in a total building exhaust of 11,750 CFM. Supply air (heated if necessary) is brought in by a single fan system near the building's roof (12,000 CFM). The air is then distributed through registers on the first, second, third, and fourth floors. The building is therefore well-balanced, and an estimated minimum of 14 air changes occur per hour (12,000 CFM for a maximum of 50,760 cubic feet of

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* Better ventilation controls for these vents will be discussed further in the Final CTA Study Report.

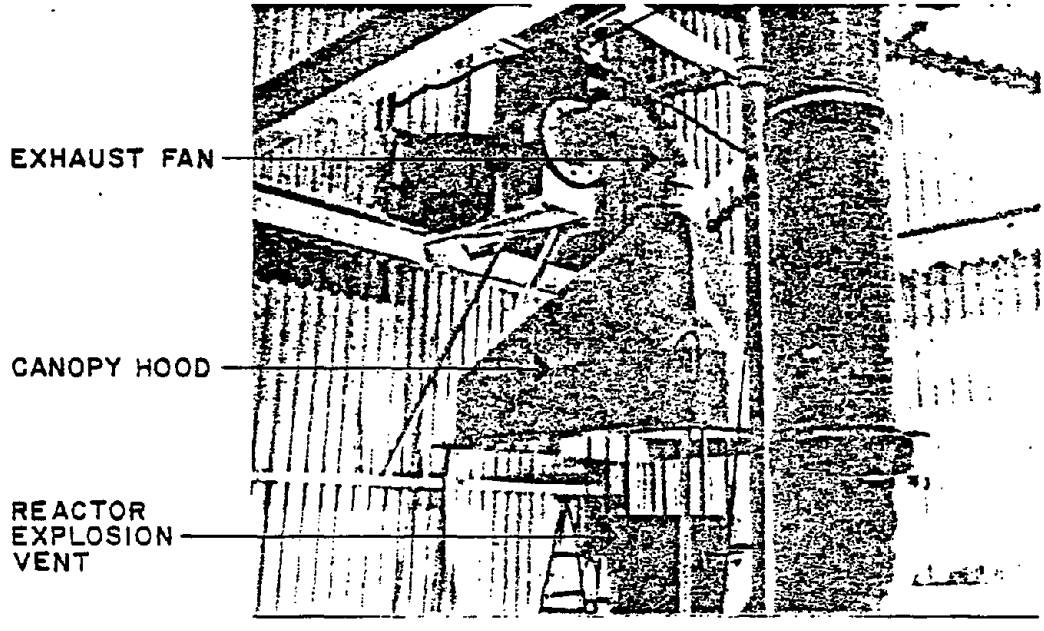

Figure 32-13: Canopy Hood Over ERCO ClO_2 Generator

airspace). Using smoke tubes, we noted building air moves upward towards the roof exhaust fan and away from areas where employees may have to work (reactor vessel, salt cake filter, reactant feed lines, and absorber lines.) Because workers infrequently enter the building*, and then only briefly to collect samples or make equipment inspections or adjustments, we believe this general ventilation system can adequately remove air contaminants from very small gas leaks. In contrast, the older Matheison building only had two wall exhausters (~ 5000 CFM each - one on the ground floor and the other on the second floor), and we noted poor air movement.

The chlorine vaporizer facility consists of three separate but adjoining rooms within a single-level concrete block building. The larger room is original construction, the two equally-sized smaller rooms are expansions to accommodate two new vaporizers and a compressor and air receiver tank, respectively. Workers infrequently enter the rooms, but all three are continuously ventilated by means of wall exhaust fans. The larger room, containing one set of vaporizers and superheaters, measures about 36 feet by 20 feet by 12 feet (high). It is exhausted by a single 3800 CFM wall fan, thereby providing ~26 room air changes per hour. Makeup air enters through two louvers in the opposite side wall. The other two rooms each measure approximately 21 feet by 12 feet and are also exhausted by 3800 CFM wall fans. Makeup air again enters through louvers in the opposite wall. Air changes in these two rooms therefore approach 45 per hour. We believe each of these air flow patterns and rates is sufficient to effectively exhaust small gas leaks. They would be largely ineffective at protecting a worker who entered a room during a major gas leak. However, a ventilation system for such situations is impractical and prevention of exposure is best accomplished by use of air monitoring alarms and respirators.

Respiratory Protective Equipment - The mill has a written respirator plan and provides an excellent assortment of respirators for worker use. Respirators observed in use included:

(1) self-contained breathing apparatus (Scott Air Paks), which are kept in the pulp mill control room and chemical handling control building

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* Workers entering this building must possess a respirator (see next section).

(2) Full-face piece chemical canister (chin or chest style) respirators (MSA Canister, Gas Mask, Type CML-C, NIOSH Approved TC-14G-89); each worker is provided at least one such respirator for his use

(3) Half-face piece respirators (3M Organic Vapor and Acid Gas, No. 8725, NIOSH Approval TC-23C-216)

(4) Mouth-type respirators (MSA Model 461319 for chlorine and hydrochloric acid), which are used only for emergency escapes.

We noted a plentiful supply of all of the above respirator types in the chemical handling control building. Most appeared to be well-maintained. The mill has a mandatory respirator possession requirement for all workers entering both chlorine dioxide generator building and the chlorine vaporizer facility. We also observed that most bleach plant and chemical handling area maintenance workers carried a half-face piece air-filtering respirator.

The mill's written plan includes:

(1) Definitions of types of hazardous atmospheres

(2) Listing of the types of available respirators, their intended uses, and limitations

(3) Instructions for training

(4) Provisions for inspection and cleaning of equipment

The definitions are very thorough and the listings complete. As is common, there is no delineation of which job categories or job tasks may require wearing a respirator. Training in respirator use is provided initially to all new workers and reviewed every six months. It is apparently administered by department managers or supervisors, and includes instructions in:

- Mask fitting and sealing
- Proper selection
- Care and storage
- Limitations of use

Brief interviews with some workers indicated a good understanding of these policies and requirements.

Responsibility for inspecting and cleaning of respirators is assigned to each worker who uses one. An inspection must be performed monthly or after a respirator is used. In order to insure that inspections and proper care are performed, the mill has implemented a mandatory monthly supervisor's inspection procedure. Written records of these inspections are made and forwarded to the Loss Prevention Department. Repair of respirators can only be made by this department. Scott Air Paks are inspected each week by the departments to which they are assigned. The Loss Prevention Department also inspects them each month. A new cylinder must be obtained to replace a used one each time the respirator is used.

Workers in the chemical handling area are also provided with additional protective equipment for use when handling toxic and corrosive chemicals. Observed equipment includes:

- Eyeglasses
- Rubber gloves
- Full-body rubber coveralls
- Full-face splash guards
- Eyewash stations (in control building and nine eyewash and shower stations scattered throughout chemical storage and unloading area).
- Rubber boots

Similar equipment is available for other mill employees.

Maintenance Program - Elements of the mill's maintenance program were not investigated at length because of time limitations and the uniqueness of the bleaching technology. Brief discussions with maintenance management staff did not indicate any unusual elements to their program. The mill has been successfully using mechanical seals for a number of pumps which handle highly-corrosive chemicals in the chemical handling area. These include the chlorine dioxide reactor spent acid, the sodium chlorate, the salt brine, and the chlorine dioxide solution transfer pumps. Although these seals perform well and last up to 6 months (depending on type), they are apparently very difficult and expensive to repair. Replacement of one seal on a ClO_2 solution transfer pump required 4 hours to perform, and the new pump casing cost $3,000 and the seal about $880. Apparently, when the seals fail, damage can be extensive. We observed that two ClO_2 solution transfer pump seals were leaking during the survey. These leaks (and a leak in the Matheison generator spent acid tank) may have affected the continuous air monitoring conducted in the nearby Matheison generator building (see Figure 32-8).

The mill maintenance staff had to develop special procedures for entry into the Kamyr bleach towers. The tops of the towers are often entered because the diffuser washer equipment is complex and often requires servicing. A copy of these procedures are presented in Appendix A so that other mills may use them.

APPENDIX A

Special Instructions for Safe Entry of Kamyr Bleach Towers

The following special instructions apply for entry of Kamyr Bleach Towers:

I. The requirement concerning the use of a safety belt and lifeline as outlined in paragraph B-1 of the general Vessel Entry Procedure is difficult to comply with when entering the top of the five Kamyr bleach towers for the following reasons:

   a. The top of the towers can only be entered at two places so the lifelines have to be handled by a second person outside the tower. The line must be left loose to allow sufficient slack as the employee inside the tower moves around on top of the washer baskets to check the equipment or make repairs.

   b. The lifelines become tangled on the diffuser washer baskets and scraper.

   c. If the employee inside the tower should lose his footing and fall, the lifeline could pull him against the side of the equipment, thereby increasing the possibility of injury.

II. Due to the difficulties discussed above, a lifeline and safety belt will not be required when entering the bleach towers <u>if the following safeguards are followed</u>:

   a. A standby man will remain outside the tower, at the entrance, to observe the employee(s) inside. The standby man should be equipped with a radio so that help can be easily summoned if needed. He can relay messages and pass tools back and forth, but he <u>must</u> observe the employee(s) inside and be aware of their location at all times.

   b. The tower will contain a level of either stock or water to a height within six (6) feet below the bottom of the diffuser baskets.

   c. A life ring with attached lifeline is readily available at the tower entrance.

III. The following lockout procedures must be followed for entry of Kamyr Bleach Towers:

<u>T-11* - T-15 - Chlorine, Caustic, Steam</u>

<u>Chlorine</u> Lock out valve at chlorine injector blocking valve and manual valve on catwalk above pre-mixer.

*See Figure 32-4 for explanation of these equipment designations

Caustic — See note

Steam — Lock out steam valve on T-20 - T-25 steam mixer.

T-20 - T-25 - Caustic - See note

T-25 - T-30 - Hypo, Caustic, Steam

Hypo — Lock out pump, suction and discharge valves in bleach chemical area, with bleed-off valves open.

Caustic — See note

Steam — Lock out steam valve on T-40 - T-45 steam mixer. On T-30 only lock out steam valve to injectors, one valve on catwalk, one valve on platform at windbreak.

T-40 - T-45 - CLO2, Hypo, Caustic

CLO_2 — Lock out pump suction and discharge valves in bleach area, with bleed-off valves open.

Hypo — Lock out pump suction and discharge valves in bleach chemical area, with bleed-off valves open.

Caustic — See note

T-50 - T-55 - Hypo, CLO2, Caustic

Hypo — Lock out pump suction and discharge valve in bleach chemical area, with bleed-off valve open.

CLO_2 — See note

NOTE: All bleach towers have caustic lines to them and therefore when working on any tower, the caustic pump, suction and discharge valves in the bleach chemical area should be locked out with bleed-off valve open.

While working on any given tower, the following items should also be locked out:

1. Thick stock pump to that particular tower

2. DM mixer

3. Scraper drive

4. Hydraulic pumps - If work is being performed on any of the hydraulic components or diffuser, the accumulators should be bled down.

5. Manual back flush valves (note relieve pressure from back flush tank.)

6. Valve to wash nozzles

7. pH sampler - If on Towers T-20, T-40, T-50, T-25, T-35, T-45, T-55.

MILL 35: MULTI-STAGE PULP BLEACHING AND BLEACH CHEMICAL PREPARATION OPERATION

INTRODUCTION

Mill 35 is a 4-stage (CEHD) Southern bleach plant. It bleaches 500 TPD of pine wood pulp.* Sulfur dioxide gas is added after the final chlorine dioxide stage to control pulp pH, remove residual chlorine, and retard pulp yellowing. Bleach chemical handling and preparation operations are conducted separately from the bleach plant. They involve unloading and vaporizing liquid chlorine, generation of chlorine dioxide solution in an outside Hooker R-2 generator, reaction of chlorine gas with caustic to produce hypochlorite bleach liquor, and unloading (and dilution) of caustic, sulfuric acid, and sodium chlorate.

MILL LAYOUT

Bleach Plant

The pulp mill/bleach plant complex was originally constructed in the mid-1960's. Only minor modifications have been made. The bleach plant is within the main pulp mill building. The vacuum-drum bleach washers are within a large L-shaped room that also contains a decker, screens, and two vacuum-drum washers for a Kamyr digester line. The bleach washers occupy one leg of the room's "L". This leg has three levels; the washers occupy the upper level or operating floor. Below this is a narrow mezzanine level containing the washer filtrate tanks, steam mixers, and miscellaneous equipment, including fans for the washer air doctors. The ground floor contains the thick stock pumps, filtrate pumps, and tower stock pumps.

The four bleach towers, the first stage chlorine pre-tower, and the chlorine injector and mixers are all located outside next to this wing. The control center for this pine bleach line is located on the operating floor at the end of the washer line nearest to the pulp mill (i.e., at the "L's" midpoint). It is a narrow room and contains a panel with monitors and controllers for most equipment, a lab bench for testing process quality control samples, and an office.

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*The mill has a similar 4-stage line that is used to bleach hardwood pulp, but it was not studied.

Bleach Chemical Handling Area

The bleach chemical handling facilities are entirely separate from the bleach plant and pulp mill complex. With the exception of the chlorine vaporizers and liquid chlorine storage tanks, all equipment is outside. This includes the Hooker R-2 chlorine dioxide generator, the hypochlorite reactor, equipment to dilute caustic, and storage tanks for sodium chlorate, chlorine dioxide, hypochlorite, sulfuric acid, and sodium hydroxide (caustic) solutions. The operating staff monitors and controls this equipment from a single-story central building. This control building is situated between the chlorine dioxide generator on one side (less than 10 feet from the main entranceway), and the hypochlorite reactor and chlorine gas blowdown tank on the other. The chlorine vaporizers are located in a room off the back of this building. Storage tanks for liquid chlorine are located in a small separate shed just to the side of this room and behind the chlorine dioxide generator. The shed is single-story and is constructed of fiberglass wall and roof panels. It protects the storage tanks from direct sunlight, thereby helping to keep the liquid chlorine at a lower temperature.

PROCESS DESCRIPTION

The bleaching process will be described separately from bleach chemical handling and preparation operations:

Pulp Bleaching

Pine wood pulp is produced in the pulp mill's continuous digester and enters the bleach process with Permanganate numbers ranging from 16 to 25. The bleach plant bleaches it to a final brightness of 81 to 85 (G.E.) using four chemicals in four distinct stages (CEHD):

(1) Chlorination

(2) Caustic extraction

(3) Hypochlorite treatment

(4) Chlorine dioxide treatment with post residual destruction with caustic, reversion treatment with hypochlorite, and pH reduction using sulfur dioxide gas.

Each chemical is added before stock enters the bottom of a large outside retention tower. In the tower, the reaction is completed, then the treated stock is pumped back to the operating floor where it is washed in a rotating vacuum-drum washer. After washing, the stock is pumped to the next stage. Bleaching equipment such as the towers, washers, steam mixers, and pumps are largely conventional. Other pertinent features and operational factors for the process include:

(1) The bleach towers are both the upflow and downflow type. All are outside. Two towers (small and large) can be used for first stage chlorination; they are connected both in series and in parallel.

(2) Stock from each washer drops to a steam mixer (double-shafted) on the mezzanine level, then to a high density pump on the ground level. This then pumps it through the succeeding tower.

(3) Chlorination gas flow to the first stage is regulated by means of an oxidation-reduction potential probe and controller system. The gas is mixed with first stage filtrate water before injection, then the pulp, gas, and water are mixed as they pass through two static pipeline mixers (Systematics 14" Model 14).

(4) There is also an Optichlor (pulp brightness) sensor installed after the above static mixers. It is supposed to aid in regulating chlorine dosage, but does not perform well and is not routinely used. Performance problems are sometimes caused by already-bleached papermill broke that is recirculated into the bleach plant pulp feed. The Optichlor sensor "sees" this bright material as already bleached pulp and then falsely signals its controller to reduce the chlorine gas flow to the pulp.

(5) The bleach plant washers are conventional, hooded, rotary vacuum-drum type, but have short filtrate droplegs that lead to seal tanks on the mezzanine floor. Because of these short droplegs, the washer drums have poor vacuum and must be force ventilated. This is accomplished with a large induction fan, which discharges air above the building's roof.

(6) Each washer has an air doctor to remove washed pulp from the drum. Fans for each doctor are located on the building's mezzanine level. Because the fans draw air from inside the building, they indirectly help ventilate this floor.

(7) Washer shower water comes from the pulp mill accumulator or from the fresh mill supply. Washer filtrate water is recirculated in order to dilute stock in the preceding tower or in the feedline to the washer. Some water is also sewered.

(8) Caustic for the second stage extraction is added to the first stage washer's repulper. Hypochlorite solution for the third stage is added at the caustic washer's repulper. Chlorine dioxide solution for the fourth stage is added at the bottom of the ClO_2 tower (outside).

(9) Sulfur dioxide gas is added to the pulp after the fourth stage to control pH and eliminate residual chlorine. The sulfur dioxide is delivered by truck and stored as a liquid in a tank car. After vaporizing the liquid, gas is added to the pulp through a sealed mechanical mixer (similar to a steam mixer) located on the mezzanine level.

Table 35-3 summarizes other typical process operating conditions.

Bleach Chemical Handling and Preparation Operations

Bleaching chemicals are unloaded, stored, and prepared in facilities that are separate from the bleach plant. Liquid chlorine, sodium chlorate and chloride solution (R-2), sulfuric acid, caustic solution, and occasionally sodium hypochlorite solution are all delivered to the mill by truck or rail. They are then unloaded to outside storage tanks and used to prepare the following bleaching chemicals:

(1) Five percent sodium hydroxide (caustic)
(2) Gaseous chlorine
(3) Sodium hypochlorite solution (35 gpl available Cl_2)
(4) Chlorine dioxide solution (7 gpl)

Operations associated with handling the raw chemicals and preparing the above bleaching chemicals will be briefly described below:

Liquid Chlorine Unloading and Vaporization - Liquid chlorine is delivered to the mill in 90 ton rail tank cars. They are unloaded by applying dry padding air from a compressor and dryer system (or mill air supply) to the tank top. This causes the liquid to flow out and into one of two reserve tanks (4000 lbs. each). Each unloading line (there are four) is equipped with a safety expansion chamber, and can be purged with air to an outside tank that contains caustic solution. The caustic will convert the chlorine gas to hypochlorite. From the reserve tanks, liquid chlorine flows into one of four steam heated vaporizers where it is converted to the gas. This gas

Table 35-3: Typical Softwood Bleach Line Operating Conditions

Parameter	Target	Normal Range
Chlorine Residual at Washer Inlet Vat	0.2 or less	-
pH at Caustic Stage Washer Inlet	10.8	10.5 - 11.0
Caustic Stage Temperature	145 F	-
Chlorine Residual at Hypo Washer Inlet Vat	1.5	0.5 - 3.0
Hypo State Temperature	110 F	-
pH at Hypo Washer Inlet	8.5	8.0 - 9.0
Final Hypo Stage Brightness	75	73 - 77
Chlorine Dioxide Residual at Washer	0.2	0.1 - 0.3
Chlorine Dioxide Stage Temperature	180 F	-
Final Pulp Brightness	83	81 - 85
Sulfur Dioxide Mixer pH	7.0	-

then passes through a steam superheater (above the vaporizer). It is regulated for pressure by a control valve and steam controller; and then distributed through a piping network to the hypochlorite reactor, the mill water treatment plant, and the two first stage pulp bleaching injectors. The vaporizer gas lines are protected from high pressures by a safety head (set at 175 psig) followed by a relief valve. The valve is set to relieve gas pressure above 200 psig to an outside 10% caustic tank*. (The relief valve also has a protector set at 150 psig).

Chlorine Dioxide Generation - Chlorine dioxide gas is produced in a Hooker R-2 generator by reacting purchased R-2 solution (32.5% sodium chlorate and 20% chloride solution) and sulfuric acid in a closed reactor vessel. Compressed air, added through the reactor's bottom, mixes the two reactants and carries off the chlorine dioxide to a packed tower. The gas is then absorbed in chilled water which is added to the top of the tower. The solution (7 gpl ClO_2) drains from the tower's bottom to two nearby storage tanks. It is then pumped to the bleach plant. The storage tanks, and a tank where the used reactor liquid accumulates, are both vented back to this absorption tower to prevent explosive gas concentrations from developing. Because the used reactor liquid potentially contains some chlorine dioxide, on leaving the generator vessel, it first passes through a small stripper tower where air is bubbled through it. It then drains to the storage tank. From the storage tank, it is pumped to both the pulp mill's recovery area for liquor salt cake make-up, and to the mill's tall oil plant.

Sodium Hypochlorite Preparation - Sodium hypochlorite bleaching solution (35 gpl available Cl_2) is prepared by reacting dilute caustic (NaOH) with chlorine gas in a closed, outside piping tee. The resulting solution is then stored in a large tank until pumped to the bleach plant. The strength of the hypochlorite is controlled by regulating the flow of chlorine gas. This is accomplished using a conventional oxidation-reduction potential sensor and controller unit. There is very little potential for worker exposure to either chlorine gas or caustic mist from this operation because equipment is automated, remotely monitored, closed, and outside. The mill also occasionally purchases prepared hypochlorite. It is delivered by truck and unloaded to a separate outside storage tank.

*The liquid chlorine lines and reserve tanks are protected against high pressure by a similar relief valving system.

Caustic Unloading and Dilution - Sodium hydroxide (50%) is delivered to the mill by rail and truck. It is unloaded by pumping to outside storage tanks. Dilute solutions (5% and 10%) are then prepared by diluting the 50% solution with water in sealed pipeline mixing tees. The solutions are stored in tanks, then pumped to the bleach plant caustic extraction stages and the hypochlorite preparation system.* The strength of the caustic is controlled by regulating the amount of dilution water to the mixing tee. This is accomplished by use of conductivity-type sensors and controllers. They are located in the pipeline from the mixing tees. There is little potential for caustic mist generation because equipment is closed, automated, and outside.

R-2 Solution Handling - The R-2 solution for the ClO_2 generator is a solution of sodium chlorate and chloride. It is purchased already prepared and delivered to the mill by rail. Tank cars are unloaded by pumping the solution to closed, outside storage tanks. The solution is then pumped to the top of the Hooker R-2 generator.

SOURCES OF WORKPLACE CONTAMINATION

Bleach Plant

No continuous sources of emission were observed inside the bleach plant. Chlorine gas may potentially escape from the chlorine washer and the hypochlorite washer. Chlorine dioxide may escape from the last stage washer. The washer hoods fit very closely and are well-ventilated to protect against such escapes. We also observed filtrate water overflowing onto the mezzanine and ground level floors from the chlorine and chlorine dioxide stage washer seal tanks. If these filtrates have high chemical residuals, some gas may escape to the workplace. However, workers infrequently go down to these floors except to briefly collect samples and make inspections. In addition, the seal tanks are force-ventilated to the building's roof. A chlorine air monitor, interfaced to a control room alarm, has been installed in the corner of the building's ground level near the outside chlorine tower's gas injector. It would probably detect major gas leaks on this floor or at the outside chlorine gas injector.

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*Dilute caustic is also sometimes used in other parts of the bleach process for buffering and adjusting pulp pH.

Equipment where major chlorine or chlorine dioxide gas leaks could occur are all outside - the chlorine injector, chlorination tower, the chlorine dioxide injector, and the chlorine dioxide tower. If major upsets or gas leaks occurred, it is unlikely that workers would be exposed unless they were outside and near the emission source. The bleach tower tops, and the exhaust duct for the washer hoods, seal tanks, and washer drum vacuum are all well above the building's roof. Contaminants are therefore unlikely to infiltrate back into the building.

Bleach Chemical Handling Operations

Chlorine gas could potentially escape from the liquid unloading and vaporization system, the gas transport piping, the hypochlorite reactor, and the gas blowdown system. Chlorine dioxide could potentially escape from the reactor vessel, the absorption tower, the spent acid stripper and storage tank, the chlorine dioxide storage tank and transport piping, and the chlorine dioxide solution transfer pumps (from leaking seals).

There are no airborne contaminants associated with the other chemical handling systems. However, sulfuric acid, caustic, R-2, and hypochlorite solutions can be hazardous if contacted. R-2 solution, if allowed to dry, is a fire hazard.

No chlorine or chlorine dioxide gas was observed escaping from any of the above equipment, except a small amount of chlorine dioxide from a liquid leak in a hypochlorite tank to which the chlorine dioxide absorber is ventilated. This tank was scheduled to be replaced as soon as a new one arrived. Because all equipment is outside (except the chlorine reserve tanks and vaporizers), automated, and closed, workers are not normally exposed unless an upset or leak occurs and they are near the source. Such upsets and leaks are uncommon.

Some worker exposure can occur during collection of the chlorine dioxide generator's absorber samples. Collections are performed each hour. Exposure can occur because gas will freely escape from the chlorine dioxide solution when a sampling line is opened for flushing and collecting a representative sample.

JOB CATEGORIES

Bleach Plant

Three workers are assigned full-time to operation of the softwood bleach line - an Operator, Assistant Operator, and a Tester. Each has the following responsibilities and assigned tasks:

Operator - The Operator has overall responsibility for correct performance of the bleach process and direction of the other two workers. Equipment is automated and controlled by analog systems. The monitors and controls are located in the control room. The Operator remains in this room most of the time in order to observe these monitors and make any necessary adjustments. During upsets or process startups/shutdowns, he may briefly leave the room to check equipment or make a manual adjustment. However, we rarely observed him outside the room. Either he or the Assistant Operator makes periodic equipment inspection rounds, but these apparently are not regularly scheduled.

Assistant Operator - The Assistant Operator performs nearly all the outside equipment adjustments and inspections. Most of his time is spent adjusting and servicing the drum washers. He is also responsible for cleaning up any chemical or stock spills, and for performing general housekeeping. Free or break time is taken inside the control room, but we could not accurately estimate this amount of time. It probably varies depending on process and equipment conditions. He may potentially spend significant periods of time anywhere in the bleach plant.

Tester - Because quality control samples must be taken every hour in this plant, one worker must be assigned full-time to collecting and testing them. Samples of treated stock, pulp, and bleach chemicals are collected at the washers, stock pumps, and chemical supply lines. Specific sampling points, type of sample collected, frequency of collection, and types of tests performed are all summarized in Table 35-4. The length of time required to collect the samples varies depending on the number and types required. Generally, it takes only 5-10 minutes; the longer time occuring when all the samples must be collected. This 'long run' is performed only twice per shift. Samples are tested both during and after a collection run, depending on the test required. All testing is performed at a bench in the control room. After completing each set of hourly tests, the worker records the results on the daily process log (kept by the Operator). He then cleans up and prepares for the next sampling run. When conditions require, he may assist the Operator and Assistant Operator in servicing equipment, making adjustments, or performing housekeeping tasks. Free or break time is taken inside the control room. We estimate he is in the control room 60-75% of his shift.

Table 35-4

Summary of Bleach Plant Quality Control Tests

Sample Collection Point	Sample Collected	Frequency	Type of Test
Hypo and Chlorine Dioxide Washer Discharge	Pulp	Hourly	Brightness
Thick Stock Pumps -			
• Post ClO_2 Stage	Pulp	Hourly	pH (To Storage)
• To Hypo Tower	Pulp	Hourly	pH and residual
• To Caustic Tower	Pulp	Hourly	pH residual
Washer Inlet Vats-			
• First Stage	Treated Stock	Hourly	Residual Cl_2, temperature, and brightness
• Caustic Stage	Treated Stock	Hourly	pH
• Hypo Stage	Treated Stock	Hourly	Residual Cl_2, pH, and brightness
• ClO_2 Stage	Treated Stock	Hourly	Residual Cl_2, pH, and brightness
Chlorine Dioxide Solution Line to Fourth Stage	ClO_2 Solution	Twice per shift	ClO_2 concentration
Caustic Line (5%) to Second Stage	NaOH Solution	Twice per shift	NaOH concentration
Sulfur Dioxide Mixer	Treated Stock	Twice per shift	pH

Bleach Chemical Handling Area Job Descriptions

Two workers are assigned to operating the bleach chemical handling and preparation equipment - an Operator and Assistant Operator. We also observed a utility person frequently working in the area. The tall oil plant operator may frequently be around some of the chemical handling equipment because that plant is nearby. The utility person works mostly outside performing housekeeping and spill cleanup tasks. He works only the day shift for five days per week. Brief job descriptions will be provided only for the Operator and Assistant.

Operator - This worker is responsible for the proper operation of the chlorine unloading and vaporization equipment, the chlorine dioxide generator, the hypochlorite reactor, and the caustic dilution systems. He is also responsible for insuring that incoming chemical shipments are recorded and then properly unloaded. Most equipment is monitored and controlled from the central control building. The Operator usually remains in this building in order to make any required adjustments, to respond to upsets, answer calls, and direct the workers. We estimate he normally goes outside less than 25% of his shift and then for only very brief inspections or equipment adjustments. He may also make periodic inspections of the chlorine vaporizers, which are in a room in the rear of the control building.

Assistant Operator - This worker performs outside inspections and adjustments of equipment and unloads shipments of new chemicals under the Operator's direction. He also is responsible for collecting and testing quality control samples from the chlorine dioxide generator, the hypochlorite reactor, the caustic dilution system, and the various chemical storage tanks (when new shipments arrive). Performing these sample collections and tests occupy most of his time. A chlorine dioxide absorber sample and a hypochlorite sample are collected and tested every hour. Sulfuric acid, reactor spent acid, and R-2 solution samples for the chlorine dioxide reactor are tested only once per shift. All of these samples are collected and tested separately. They require less than 5 minutes to collect. The greatest potential for exposure occurs when the absorber sample is collected because this is a concentrated chlorine dioxide solution. Chlorine dioxide gas escapes when the sampling line is flushed for about one minute before the sample is collected. The solution drains into an open hotwell below the water chiller near the ClO_2 reactor. The worker stands near this hotwell while collecting the sample. Some exposure may also occur when the worker collects the reactor spent acid sample because this liquid contains some chlorine dioxide. We did not observe the operation.

The Assistant Operator may also occasionally perform cleanup tasks and simple maintenance operations, but usually these are done by utility and maintenance workers, respectively.

AIR SAMPLING RESULTS

Methods

Five 15-minute personal samples for chlorine/chlorine dioxide exposure were collected on the bleach plant tester while he collected and tested process quality control samples (See "Job Descriptions" section). Two short-term personal samples were also collected on the Assistant Chemical Handling Operator while he collected and tested process quality control samples from the ClO_2 generator and the hypochlorite reactor. One of these was a two minute sample while he collected only the generator absorber sample. These two job categories (and tasks) were selected for exposure assessment because they probably have the highest potential for exposure, and are the only group of workers who regularly performed a scheduled task.

All personal samples were collected and analyzed according to NIOSH Method P & CAM 209 (using methyl orange). Sampled workers were potentially exposed to both chlorine and chlorine dioxide. Both contaminants respond positively to the sampling reagent. However, worker exposures were quantified only in terms of the equivalent chlorine response. Personal sampling results are summarized in Table 35-1.

A Mast Oxidant Monitor, connected to a strip chart recorder and field calibrated for chlorine response, was used to monitor air concentrations of chlorine/chlorine dioxide* at the following locations:

(1) in the chemical handling control building

(2) near the chlorine stage washer on the bleach plant operating floor

(3) in the bleach plant control room

Eleven Drager chlorine detector tube readings were taken to assess potential workplace emission sources from the bleach process and chemical preparation systems. Some of these emissions were strictly chlorine dioxide gas. The Drager chlorine detector tube does respond to that contaminant but at about twice the chlorine sensitivity. The eleven readings are summarized in Table 35-2.

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*The monitor also responds to chlorine dioxide gas.

TABLE 35-1: Summary of Personal Exposure Sampling Results

Job Category	Day	Sampling Duration (Mins.)	Exposure Level (as ppm Cl_2)*	Task(s) Performed
Bleach Plant Tester	Tues.	15	<0.05	o Collecting stock and filtrate samples (∿8 mins.) o In control room testing samples (∿7 mins.)
	Wed.	15	<0.05	o Collecting stock and filtrate samples, including ClO_2 solution (∿6 mins.); this is longest sample collection run o In control room testing samples (∿9 mins.)
	Wed.	15	<0.05	o Collecting stock and filtrate samples (∿5.25 mins.) o In control room testing samples (∿9.75 mins
	Wed.	16	<0.05	o Collecting stock and filtrate samples (∿7 mins.) o Collecting ClO_2 solution (∿1 min.) o In control room testing samples(∿8 mins.)
	Wed.	15	<0.05	o Collecting stock and filtrate samples (∿5 mins.) o In control room testing samples (∿10 mins.)
Chem. Prep. Assistant Operator	Tues.	2	1.7	o Collect ClO_2 absorber samples (∿45 secs.) o In control center testing sample (∿1.5 mins
	Wed.	15	<0.05	o Collecting dilute caustic sample (∿45 secs. o Collecting hypo storage tank sample (∿15 secs.) o In control center testing above samples (∿4.25 mins.) o Collecting ClO_2 absorber sample (∿1 min.) o In control center testing samples (∿7 mins.

*Samples were collected and analyzed according to NIOSH Method P&CAM 209. Both workers may have been concurrently exposed to chlorine and chlorine dioxide. The sampling method responds positively to both contaminants.

TABLE 35-2: SUMMARY OF DRAGER CHLORINE DETECTOR TUBE READINGS

Reading No.	Location	Suspected Contaminant	Concentration Reading as (ppm Cl_2)	Comments
1	Near Leak from Caustic Tank for ClO_2 Absorption Tower Eductor	ClO_2	1.2	Tank and eductor are outside; leak was known to plant management and will be repaired.
2	Maintenance Shack Adjoining Chem. Prep. Control Center	Cl_2	No reading, est.< 0.1	Reading was taken to see if above gas leak was entering control building.
3	Inside Chlorination Stage Washer Hood, Near Discharge of ORP Line	Cl_2	10	The ORP cell return line contains freshly-treated chlorinated stock and is the cause of the reading.
4	Face of Chlorination Stage Washer Hood Near Discharge of ORP Line	Cl_2	No reading, est.< 0.1	This reading was taken at hood face less than 6 inches from Reading No. 3; it shows the hood is effective at keeping this contaminant source from entering the workplace.
5	Inside Chlorination Stage Washer Hood - Far End of Inlet Vat	Cl_2	No reading, est. <0.1	Reading indicates stock entering the washer had a very low residual chlorine level at time.
6	Inside Hypo Stage Washer Hood - Above Inlet Vat	Cl_2	No reading, est. <0.1	Reading indicates stock entering the washer had a very low residual hypo level at time.
7	Inside Chlorine Dioxide Stage Washer Hood - Above Inlet Vat	ClO_2	No reading, est. <0.1	Reading indicates stock entering the washer had a very low residual ClO_2 level at time.
8	ClO_2 Solution Collection Point (Sink on Bleach Plant Operating Floor)	ClO_2	No reading, est. <0.1	Sample of the concentrated ClO_2 solution used in final bleach stage is collected every other hour; reading was taken 1-4 minutes after sampling.
9	Directly In ClO_2 Solution Sampling Pipeline	ClO_2	$\sim$ 2	Inserted detector tube directly in sampling line about 4 minutes after it had been closed.
10	Adjacent to Continuous Chlorine Monitor - Ground Floor of Bleach Plant	Cl_2	No reading, est.< 0.05	Chlorine monitor (Interscan) read 0.15 ppm at time of detector tube reading; used 20 pump strokes.
11	Directly Above Floor Drains Receiving Washer Filtrate Overflow - Second Floor of Bleach Plant	Cl_2	No reading, est.< 0.1	Filtrate was overflowing washer seal tanks and draining onto floor.

Results - Bleach Plant

All five of the bleach plant tester samples were below the analytical method's limit of detection (0.05 ppm as Cl_2). We judged that the worker is not exposed to significant amounts of either chlorine or chlorine dioxide while collecting the samples. As summarized in Table 35-1, the sampling tasks do not take very long, typically less than 10 minutes. We believe the highest exposure this worker receives occurs when he collects a sample of the concentrated chlorine dioxide solution used in the last bleach stage. However, he does this only twice per shift and the exposure occurs only during the 30 - 60 seconds that the sampling line is open to flush and then grab a sample. Significant exposure does not typically occur during collection of the other samples or during performance of other bleach plant tasks. This is primarily because the bleach process is closed, equipment is outside, and the washers and filtrate seal tanks are well-ventilated.

The continuous Mast Oxidant Monitor and detector tube readings support this projection that worker exposure is low or non-detectable during normal plant operations. If significant amounts of chlorine escaped into the workplace, they would probably occur around or at the first stage washer. The Mast Oxidant Monitor recorded contaminant levels for nearly 36 hours at a location about 20 feet from this washer on the plant's operating floor. Although levels varied slightly from 0.05 to 0.15 ppm as Cl_2, we do not believe the cause was chlorine gas escaping from the well-ventilated washer hoods.

Contaminant levels (chlorine and chlorine dioxide) inside the bleach plant control room were monitored for approximately 24 hours in order to estimate the likelihood of process exhaust gases contaminating the room's fresh air intake. Depending on wind direction, intake air can be drawn through one of two ducts on the building's roof. One duct is positioned about 20 feet vertically above the roof, and the other horizontally over the building's side. Contaminant levels in the control room were less than 0.05 ppm (as Cl_2) over the entire 24 hour monitoring period indicating this unique fresh air intake duct arrangement reduces the potential for this air supply to be contaminated. Some workers mentioned they occasionally smell chlorine/chlorine dioxide gas inside the room, but varying the fresh air intake duct position usually reduces it.

The Drager chlorine detector tubes were used to judge the potential for worker exposure from the following suspected emission sources: (1) stock in the washers, (2) filtrate water overflowing from the washer seal boxes, and (3) the tap where the bleach plant's chlorine dioxide solution is sampled. As shown by the results in Table 35-2, no chlorine or chlorine

dioxide could be detected above the stock inlet vat under both the hypochlorite and chlorine dioxide stage washer hoods. At the chlorine stage washer hood, chlorine could be detected (10 ppm) only underneath the hood immediately next to the point where freshly-chlorinated pulp stock from the ORP cell flows into the washer's inlet vat through a pipe. No chlorine could be detected escaping from this washer through open hood observation doors, which are over the inlet vat. It also could not be detected directly above the pulp inlet vat inside the hood. This data indicates chlorine and chlorine dioxide gas do not normally escape from pulp entering these washers. The hoods probably would contain and exhaust it if it did.

Despite a faint odor, no chlorine gas could be detected directly above a floor drain to which first-stage washer filtrate was draining after overflowing from the washer seal boxes. This filtrate may contain some residual chlorine from the pulp washing step. The amount apparently is not enough to cause appreciable offgasing. No chlorine gas was detected next to a chlorine air monitor which is near these first stage washer seal boxes. (The monitor was also reading less than 0.1 ppm of chlorine).

A small amount of chlorine dioxide gas (2 ppm as Cl_2) could be detected at the sampling tap used for collection of the chlorine dioxide solution. (This solution is used in the fourth stage of bleaching). However, the reading was obtained by placing the detector tube directly in the solution pipe. The two readings at this location were taken less than 4 minutes after a sample of the chlorine dioxide solution had been collected.

Results - Chemical Handling Area

There is a low potential for worker exposure while collecting quality control samples from the hypochlorite reactor and the chlorine dioxide generator. This is because equipment sampling points are outside, and it takes only a few minutes to collect any particular sample. The greatest potential for exposure probably occurs during collection of the generator's absorber sample. This sample is a concentrated solution of chlorine dioxide, and gas can escape from it. One personal air sample collected on the Assistant Chemical Preparation Operator during the 2 minutes it took him to collect the absorber sample resulted in a exposure concentration of 1.7 ppm, expressed as Cl_2 (see preceding "Methods" sub-section). This result confirms that some brief exposure occurs, but it varies depending on wind conditions and where the worker stands while the sampling line is open. Little exposure would occur if the worker stood well away from the sampling point while initially flushing the sampling line, then used a respirator while actually collecting the sample.

A 15-minute personal air sample was collected while the worker sampled the absorber line, the caustic dilution system, and the hypochlorite reactor. It took only about 2 minutes to collect these three samples (1 minute to collect the absorber sample). The worker's overall exposure was below the limit of detection for the sampling/analytical method (<0.05 ppm as Cl_2) indicating his exposure is probably below the OSHA chlorine ceiling P.E.L. of 1.0 ppm when performing these common tasks.

Contaminant levels inside the chemical handling control center were monitored for a 24 hour period in order to assess the potential for process gases to infiltrate. Recorded levels were less than 0.05 ppm (as Cl_2) throughout this time period.

Possible sources of infiltrating gas would be the ClO_2 generator's absorption tower vent and gas leaks from the chlorine vaporizers, the ClO_2 generator, or hypochlorite reactor. Despite the fact these sources are near the control center, the potential for worker overexposure from them is very low, unless a major chlorine or chlorine dioxide leak occurred. This would be very unusual.

Two Drager detector tube readings were taken near a leak in an outside tank containing weak caustic used to scrub the ClO_2 absorption tower vent gases. Near this leak a reading of 1.2 ppm Cl_2 was obtained, but inside an adjacent maintenance building (attached to the main control building) no gas could be detected. We judged the potential for this gas leak to cause worker exposure was low. The leak in the tank was scheduled for future repair. (The caustic tank is adjacent to the hypochlorite reactor, and workers could be exposed when collecting hypochlorite quality control samples or inspecting the reactor).

CONTROL TECHNOLOGY

Bleach Plant

In the bleach plant, other than process equipment being closed, outside, and automated, we judged the washer ventilation system, use of a chlorine air monitor, control room ventilation, and a good respirator program to be noteworthy controls. Each of these will be briefly described below.

Washer Ventilation System - Stock entering the drum washer may contain enough residual chlorine (chlorine and hypo stage) or chlorine dioxide (last stage) to result in offgasing. Such offgases are prevented from escaping to the workplace by ventilated fiberglass hoods which fit tightly over the top of the washers. The mill also draws a vacuum on the inside of the washer drums in order to provide better suction and water removal. The seal boxes which receive the washer filtrate water are also ventilated. The mill did not know how much air is drawn from inside each washer drum, but 750 CFM is exhausted from each seal box (two per washer). The seal box CFM's could not be confirmed with air flow readings, but they are probably more than sufficient to limit gas escape because there is little, if any, open face area at the boxes. A 15,000 CFM fan exhausts the chlorine stage washer hood, and a 30,000 CFM fan exhausts the other three washer hoods.*

Table 35-5 summarizes face velocity readings taken at hood observation doors that are normally open. There is good airflow, usually equal to or greater than 200 feet per minute (fpm), at faces on the chlorine, hypochlorite, and chlorine dioxide stage hoods. It is very unlikely contaminants could escape from the washers and seal boxes with such amounts of ventilation and small amounts of open face area. We estimate there is 17,150 CFM of total exhaust air from chlorine washer/seal box; and 9,650 from the hypochlorite, caustic, and chlorine dioxide stage washers/seal boxes.**

Chlorine Air Monitor - The mill has installed an Interscan Model LD-34 (0-2/0-10 ppm range) chlorine monitor on the second floor's east wall. It is near the chlorine washer seal boxes and the outside chlorine gas injection system. It is apparently intended to detect chlorine gas leaks from the outside gas injector, the seal boxes, or, perhaps, the overhead washer. The monitor was installed in mid-1980 with the intention to test it for an unspecified period. Its location was determined by the bleach plant management after consulting with the mill safety director. It cost approximately $3,500, and was a replacement for a previous Advance Series 1030 Leak Detector monitor*** which the mill reported did not perform satisfactorily. Apparently, it often gave false or no alarms. Mill management indicated the Interscan LD-34 unit was

*There is a fourth washer which is not in use, but it is still ventilated.

**Because of the amount of air exhausted from the washer operating floor, air is supplied to this room by a number of systems. The actual amount of air and estimated air turnover rates would be difficult to determine and are not vital to control of exposures.

***Made by Capitol Controls Company at a cost of $1200.

performing satisfactorily, although its control room alarm needed repair. The monitor is apparently routinely calibrated, but no one knew how.* Mill management also did not know how often the alarm had gone off, or what response is normally taken to such alarms.**

Mill management is now considering purchase of four additional detectors for the pulp mill area, and four new detectors for the chemical handling area (each to have a flashing light and audible alarm mounted in the vicinity of area entrances). The systems would be used primarily to detect gas leaks. It is estimated these monitors will cost $15,000 - $18,000. Management was very interested in obtaining additional information on good detectors, calibration systems, and how to design a reliable monitoring system.

Control Room Ventilation - An air handling system provides clean, air-conditioned air for the control room. The system previously supplied air to the pulp mill's washer control room, but that room has since been redesigned and has a new system.

Ventilation blueprints for the bleach plant system were not up-to-date, and the current amounts of recirculated versus fresh air could not be determined. Fresh makeup air is supplied through the aforementioned variable-position roof intake duct. The room is therefore under positive pressure and air will quickly flow outward whenever either of the two access doors are opened. This positive pressure and outward air flow reduce the likelihood of chlorine, chlorine dioxide, or other air contaminants entering this important workplace. As stated, the long term air sampling results with the Mast Monitor indicate this system works well, and there is little likelihood of workers being exposed while in the control room.

Respirator Program - The mill has developed a written respirator plan and provides workers with an assortment of equipment. The program includes training in respirator selection, restrictions on respirator use, fitting, and inspection and maintenance of equipment. Brief interviews indicate workers have a good understanding of this program and know how to properly use respirators. As is typical, the written plan does not specify tasks or areas in the mill where respirators must be carried or worn. Most respirators are kept in the control room, and appeared to be in good working

* A recent mill memo indicated it had recently been serviced and calibrated, and is normally serviced every 30 days.

** A mill memo proposed a log system to record when the alarm sounds or whenever there is an odor complaint.

TABLE 35-5: Summary of Washer Exhaust Hood Face Velocity Readings

Washer Hood	Location of Reading	Face Velocity (in fpm)	Rated Hood CFM	Estimated Hood CFM [1]
Chlorine	Inlet Side Observation Hatches*—			
	No. 3	< 200 - 325		
	No. 4	300 - 400		
	No. 8	200 - 350		
	Discharge Side Observation Hatches—			
	No. 1	200 - 325		
	No. 5	< 200 - 275		
	No. 8	200 - 250	15,000	~10,000
Hypochlorite	Inlet Side Observation Hatches—			
	No. 3	< 200 - 210		
	No. 8	200		
	Side Observation Hatch	< 200	7,500	~2,730
Chlorine Dioxide	Inlet Side Observation Hatches—			
	No. 7	280 - 350		
	No. 8	200 - 375		
	Open Face Above Top of Washer Drum (Face is ~4 inches high x 25 feet wide)	~200		
	Side Observation Hatch—	~340	7,500	~5,650
Out-of-Service Washer	Inlet Side Observation Hatch—			
	No. 5	800 - 860		
	Side Observation Window (~12 inches x 12 inches)	> 1,150	7,500	~6,340

[1] Estimated hood CFM's were determined using only face velocity readings shown. They are low because additional air is undoubtedly drawn into the hood through partially-closed hatch doors and other small hood openings.

*Each hood, except the chlorine dioxide stage, has 8 hinged observation hatches along the front of both washer's inlet and discharge sides. These are number 1 - 8 looking left to right on each side. Readings were taken at open hatches using an Alnor velometer. Some washers, as shown, also have small side observation hatches (~8" x 8" or 12" x 12"). The chlorine dioxide stage washer has a half hood which extends from its inlet vat to the drum's top. This fit creates a short space (~1") between the drum's top and the hood. It extends along the washer's entire width (25').

condition. There are three Scott Air Paks in the bleach plant. Two are in the control room and one is on the ground level. Each worker is given at least one full-face piece, air filtering, cartridge respirator (Willson GB Model BD-14F-53, NIOSH Approval No. 14F-53.) He or she is responsible for its maintenance. In addition, a number of new, half-face piece, air filtering cartridge respirators are kept in the control room (MSA Comfo II and Willson).

Once per month, the day shift worker is assigned to conduct a detailed inspection of all respirators. He must then note in writing to the safety department which ones need repair or replacement. Other safety equipment such as eyewashes, showers, alarms, and fire extinguishers are also inspected once a month by a safety committee.

No conditions requiring respirator use were observed during the survey, nor did any workers normally carry a respirator when outside the control room.

Control Technology - Chemical Handling Operations

Extensive workplace controls are largely unnecessary in the chemical handling area because most equipment is closed and outside. Exceptions are the chlorine reserve tanks and vaporizers. They are each in small, isolated, and unoccupied rooms behind the rear of the main control building. Chlorine gas leaks from this equipment are uncommon, but they could occur and possibly cause some worker exposure if workers were nearby and the leaks were severe enough. Mill personnel conduct frequent equipment inspections and there is a good preventive maintenance program (described below). Leaks would therefore probably be quickly detected and repaired.

In addition, both the chlorine reserve tank and vaporizer rooms can be isolated and exhausted by large wall fans. The fan for the reserve tank building is located in the lower left hand corner of the west wall, and discharges air directly outward. The fan capacity was not available, but the room is small and we believe the fan could adequately exhaust it. The fan can be activated from outside the building.

The vaporizer room measures about 36 feet x 29 feet x 12 feet (11,500 cubic feet)* and can be exhausted by a fan on its north wall. The fan's capacity was also unknown, but it was probably sized to achieve 30-60 room air changes per hour. The discharge point of the fan (and the reserve room's fan) may be

*The room's shape is slightly irregular because of a small room (9'x10') near the door to the main control center. This alcove is ventilated by a separate 350 CFM wall fan.

cause for some concern because it is towards a passageway between equipment that workers frequently use when going to or from the control center. It is also only about 50 feet from the main entranceway to the control center, and only slightly above ground. The mill originally used a roof exhaust fan to ventilate this room. Roof discharges provide better contaminant dispersal directed away from work areas and building entrances.

The air in the control center is conditioned but totally recirculated (i.e., there is no fresh makeup air). The AC unit is located in a corner of a large room which adjoins the control room. Supply and return air ducts run from it into the control room and then back. The lack of fresh air keeps the room at equal pressure with outside air, and therefore contaminants could potentially infiltrate to this work area. Air monitoring inside the room indicates this is not normally a problem. However, the control center is very near to potential sources of contaminant emission like the chlorine dioxide generator and hypochlorite reactor. If an upset or major gas leak occurred gas could infiltrate the control building.

To reduce the potential for worker exposure during a gas leak or process upset, the mill is investigating the installation of a number of chlorine/chlorine dioxide air monitors in the chemical handling area. We believe air monitors would be valuable, but the type of sensor, their sensitivity, and monitoring location should all be carefully considered beforehand because of the many outside emission sources and the way contaminants could infiltrate the control center, other buildings, and outside work areas.

There are a number of process monitoring, and control, and safety interlock systems which help to prevent or limit process upsets and associated emission of air contaminants. These include indicators and analog controllers for the chlorine vaporizers, the hypochlorite reactor, and the R-2 chlorine dioxide generator. Nearly all of them are conventional and have been adequately described in other mill reports. Their proper use is fundamental to the safe operation of such chemical preparation systems.

The chemical handling workers follow the same respirator program as the bleach plant workers (see previous "Control Technology Section"). Each worker is provided a full-face piece, air filtering respirator for his/her use, and is responsible for its maintenance. We did not observe any conditions where respirator use was justified, nor do any workers normally wear or carry their respirators. Most are kept in the control center, and appeared well-maintained. At

least two Scott Air Paks are kept on walls in the control building. They also appeared to be well-maintained, and all workers knew how to properly use them. An adequate assortment of other safety equipment is provided for the workers. It includes eyewash stations, a safety shower, rubber gloves, fire extinguishers, and eye shields. The two rooms where chlorine is handled are each equipped with manually-activated audio alarms to warn workers to evacuate the surrounding area.

Mill management has developed a formal preventive maintenance program for the bleach plant and chemical handling area. It includes three principal elements: (1) regularly scheduled equipment lubrications, (2) a preventive maintenance "Tickler" work order program, and (3) equipment failure prediction and repair. Oiling and greasing are done periodically. Frequencies vary from daily up to every three months, and are indicated on a master lube schedule. The schedule describes the application, the number of lube points, type of lube points, lubricant specifications, and frequency. Oil in reduction gears is checked and changed, if needed, at least annually. Couplings and electric motors are greased every six and three months, respectively. A few oil lubricated motor bearings are checked weekly.

The Preventive Maintenance Engineer surveys each plant area to establish required, regular preventive maintenance inspection needs. This is based on the type of equipment, wear and failure likelihood, and importance to production. From this inspection, he writes work orders, where needed, showing in detail the type of regular inspection required and its frequency of performance. These work orders are carried out at the required frequency, and if the inspection shows a need for preventive repair, the mechanic so notes the need on his inspection record. The Preventive Maintenance (P.M.) Records Clerk notifies the applicable operating department whose supervisors then write the necessary repair work orders. The P.M. Records Clerk keeps permanent records of the P.M. work order issues and completions.

Typical items that are predicted for failure include:

(1) Reaction work orders started by the regular P.M. tickler program

(2) Semi-annual inspection of the low voltage electrical switch gear (an infra-red scanner is used to perform this)

(3) Yearly inspection and cleaning of major electric high voltage circuit breakers

(4) Semi-annual inspection of chemical rail car emergency safety gear

(5) Annual pressure vessel safety valve inspections

(6) Tank inspections and thickness testing (performed on 2 to 4 year cycles).

Mechanical seals are not extensively used in the plant except on two spent acid transfer pumps in the chlorine dioxide generator area.

Through their corporate staff, the mill has developed an excellent written information package on procedures for the safe unloading of liquid chlorine rail cars. Although most of the information is common practice in the industry, this subject has not been previously discussed in detail. The mill's information material is attached as Appendix A to this report. It is provided for those mills that may want to review the adequacy of their practices and equipment, or to develop similar written guidance plans.

The mill also has an excellent data form that is used to solicit detailed hazard and control information from its various chemical suppliers. It requests much more detailed and specific information than is commonly provided from the suppliers, or than is inserted on standard material safety data sheets. The completed information on these forms can serve as excellent reference sources for employees or department supervisors in the event of a spill or potential exposure. A copy of this form is provided as Appendix B so that other mills can use it.

APPENDIX A

UNLOADING CHLORINE FROM SINGLE-UNIT RAILROAD TANK CARS

Handling chlorine in liquified or gaseous form requires very specialized knowledge which goes far beyond what is given here. Engineers and supervisors in operations requiring use of chlorine are qualified in the knowledge necessary to safe design and specification of equipment, and in safe operating procedures. The intent of these instructions is to cover certain details of the unloading facility, and emergency measures, which should be in the hands of the safety coordinator and others involved in handling chlorine, below the engineer level. Areas of safe practice covered herein are:

(1) Unloading facilities,
(2) Safety equipment to be used in event of leakage at the car,
(3) Emergency measures,
(4) History of emergency or equipment problems that have been reported in the industry (as a means of illustrating the types of emergency problems that can occur).

Unloading Facilities

Unloading of chlorine should be under the direct supervision of a trained and responsible supervisor. The location should be restricted to authorized personnel. Following are the general requirements for the unloading location:

(1) Tank car must be spotted on dead end siding used for no other purpose than for unloading chlorine. Tracks must be level. Single or double sidings may be used, as required, with an unloading platform set between the tracks when double sidings are used.

(2) Suitable unloading platforms must be provided (See following section).

(3) Unloading areas should be fenced with Cyclone-type fencing, with gates for car entry at one end and for personnel entry at other end. Gates must be kept locked with keys available only to authorized personnel. (It has been pointed out by several mills that the chlorine unloading area is isolated and usually secure from unauthorized entry. In such cases, provisions for fences are not essential.)

(4) Car brakes must be set, and one wheel chocked with Aldon Type B double block chock.

(5) The attached car and unloading facility must be protected toward the mainline track switch by installation of an attached Aldon Type CS-3 hinged car stop. The stop must be locked in position using the same lock and key number as for the fence gates. It should be installed on the rail about 50 feet ahead of the fence gate. The mainline switch should be kept closed and preferably locked.

(6) A sign worded, "STOP - Tank Car Connected" must be placed on a rail just inside the fence gate. The sign must measure 12x15 inches, and have white letters on a blue background (standard sign).

(7) Suitable lighting must be provided so that car stops, sign, and other parts of the facility can be adequately seen at night.

(8) If the siding is open at both ends, then both ends must be protected as above. If loaded or unloaded chlorine tank cars are also stored in the siding, then the same precautions outlined above must be followed. In addition, there must be another car stop between the last car and the mainline switch. Cars in storage must have brakes set.

(9) A wind sock or weathervane should be installed in a high, prominent location on the platform.

(10) Protection devices must be set and the fence car gate locked before unloading connections are attached to the car. All unloading connections must be removed from the empty car before protection devices are opened for removal of the car.

Unloading Platforms - Some unloading platforms incorporate construction features that do not meet acceptable safety standards. Items such as use of planks to connect platforms to car manway platforms, improper platform heights, use of fixed ladders rather than steps to the platform, and muddy conditions along tracks are unsafe and unapproved. Standards pertinent to unloading platform safety that should be followed are:

(1) Platform and stairway tread surfaces will be constructed of open steel floor grating, such as Globe Grip-Strut (The Globe Company, 4000 South Princeton Avenue, Chicago, Illinois 60609) or Bustin Protecto (Bustin Steel Products Company, P.O. Box 589, Dover, New Jersey 07801 or 2775 Goodrich Avenue, Richmond, California 94802), or equivalent.

(2) Platform handrails will be provided on all sides. Height of rails will be 42 inches. Stairway handrails will be 32 inches.

(3) Stairway access will be provided at both ends of the platform. Stair pitch will not be greater than 50° to horizontal; stair tread will be a minimum of 10 inches; riser height a maximum of 8 inches.

(4) Platform height should conform with the car dome manway platform. The following heights above top of rail dimensions apply to cars of the three common sizes used for transportation of chlorine. The tolerance value given is to adjust for slight variation in car dimensions among various manufacturers:

Car Size	Empty Car	Full Car	Suggested Best Unloading Platform Height
16 ton	9' ± 6"	8 1/2' ± 6"	8-3/4'
30 ton	11' ± 6"	10 1/2' ± 6"	10-3/4'
55 ton	12-3/4' ± 6"	12 1/2' ± 6"	12 1/2'

Dimensions above are for height of car dome manway platform above top of rail. Suggested best height is for unloading platform walk surface above top of rail.

It is obvious from the above dimensions that a platform cannot be efficiently made to accommodate cars of all sizes. Therefore, a mill must determine which size car chlorine is most often delivered in and design based on this size.

(5) Steel, safety-grating drawbridges should be provided for each car unloading location. They should be hinged at the platform so that the platform end is flush with the platform walk surface. The hinge should be of a type which will permit slight lateral movement of the platform to make allowance for car spotting. The bridge must be of proper length to seat securely on the car manway yet permit the car end to vary in height from the platform end by as much as 1 foot. The car end must be free to permit raising of the car by about 4 inches during unloading. The drawbridge length cannot be exactly specified as it depends upon various local factors such as the exact position of platform in relation to the track and the exact platform design. Clearance of 8'-6" from track centerline to nearest point of platform structure is recommended. Drawbridges must have a suitable cable (or other mechanism) which is protected from snow or icing.

(6) Adequate lighting must be provided on the platform and throughout the unloading facility.

(7) Platform must be electrically bonded to rails to provide grounding.

(8) Weather-protected telephones to the supervisor's office must be provided for emergency use.

(9) Unloading lines must be properly suspended and protected from damage by cars or other hazards.

(10) Ground surface in the facility must be even and provided with drains, as by gravel fill, to prevent mudding. Fill should be to top of ties and along the siding where men will walk and work.

Safety Equipment to be used in Event of Leakage at the Car

It is expected that employees working in the facility will wear full clothing, hard hat, safety shoes and gloves (vinyl palm type) at all times. In addition, employees will carry a chlorine escape respirator (this should be described in other mill programs). During the course of all line connecting or disconnecting work, chemical coverall goggles (similar to Mine Safety Appliances Company, Chemical Splash Goggle, No. 03-791079), will be worn.

In event of a leak in the chlorine line, the car, the valves, or the connections, it is necessary to have adequate personal protective equipment available. Equipment to be worn when handling leaks is as follows:

(1) Air supplied breathing apparatus with full-face masks are recommended. Equipment such as canister gas masks or Chemox oxygen breathing apparatus are not recommended because:

(a) Actual use of the equipment will probably be infrequent, thus training and experience in use will be limited. The air-supplied breathing apparatus is best in this situation. Chemox apparatus is especially difficult to use, and requires special training.

(b) Canister gas masks are limited in protection (up to about 1000 parts per million chlorine). It cannot be assured that such concentrations will not be exceeded during the leak emergency.

(c) Air-supplied apparatus allow the most freedom to work because of back mounting.

Recommended apparatus are Surviv-Air breathing apparatus with panoramic face masks (Surviv-Air Division, 3325 West Warner Avenue, Santa Ana, California). Also acceptable, are Scott Air-Paks and MSA Air-Masks.

(2) Body protection - Dynel acid-resistant coveralls (as with MSA Chemklos CF-35922).

(3) Hand protection - Neoprene fully coated gloves (as with Edmont Neox 9-220 gauntlet).

Emergency Measures

Emergency conditions that can occur are:

A. Leaks - in tank valves, manway covers, tank connections, transfer lines, or the tank itself.

B. Fire - exposure of the tank car to heat or fire.

The above equipment should be stored in a properly-sized cabinet just within the employee gate to the unloading facility; or, where winter weather is severe, the cabinet may be located inside a nearby building that is never locked. Break-away latches may be used if necessary. The equipment should be stored in an orderly manner, and should also include towels for wiping.

It is expected that similar equipment will be available in pipe fitter or maintenance shops so that other employees can use it to provide help in emergency situations.

The following measures are suggested for chlorine leaks:

(1) As soon as there is any indication of the presence of chlorine in the air, immediate steps should be taken to correct the situation. Authorized employees, wearing the necessary protective equipment outlined in the previous section, should investigate. Chlorine leaks never get better, they always get worse, if not corrected promptly. Depending upon how serious the leak may be, warnings should be given of possible need for evacuation of people from potentially gas-exposed areas. Investigating employees should keep upwind of the leak. Chlorine will tend to seek low levels in still air.

(2) If the leak location is not obvious, it can be located by use of a detector made by tying a small, cloth wad, soaked with ammonia water, to the end of a stick. When near the leak, a white cloud of ammonium chloride will form. Commercial 26° Be' ammonia solution must be used (it should be kept with the valve Emergency Kit); household ammonia is not strong enough.

(3) When the leak is found, proceed as follows:

(a) For unloading line or tank connection leaks - Shut off the supply at the tank car valve. Make suitable repairs or reseat the connection. Another car valve may be used.

(b) With tank angle valve or tank safety valve leaks - Apply valve covers as supplied in the Chlorine Institute Emergency Kit "C". Each location should have this kit. Orders for kits should be placed through Chlorine Institute" producer or repackager" member companies (the chlorine supplier).

(c) With car manway cover leaks - Tighten manway cover stud nuts with tools supplied in Emergency Kit. If leak is stopped or minimized, try to continue unloading with suitable observation and precaution. If leak is serious, disconnect unloading lines, close all valves, and pull the car to the most isolated location possible. Give alarm to local authorities if necessary. Call the supplier for instructions. A leaking car must be kept under continuous observation.

(d) With the tank leaks - Follow instructions for "c", above.

(e) Never use water on a chlorine leak. Chlorine mixed with water is highly corrosive to metal, and the leak will get rapidly worse. Leaks described in "c" and "d" above will grow progressively worse for this reason. Chlorine combined with natural moisture in the air will corrode the metal near the leak.

The following measures are suggested for fires near chlorine cars that could potentially cause heating of the tank:

(1) Chlorine is not explosive or flammable. However, the tank could burst and release a large quantity of gas if overheated. This would obviously be a very serious situation. In case of a nearby heat source, warning should be given of possible need for evacuation from gas-exposed areas.

(2) Disconnect unloading lines and close all valves.

(3) If no chlorine is escaping, cool the tank by applying a water spray.

(4) Pull the car to a location where there is no longer exposure to heat or fire.

History of Reported Emergency or Equipment Problems

The following is a brief outline of the major reported problems which should never be allowed.

Abuse of angle valves - Cases have been reported where the hand wheels have been bent or broken, Woodruff keys stripped out of the valve stem, or valve stems bent evidently by use of an extension on a wrench. Chlorine valves are sometimes a little more difficult to turn, however, a 12-inch hand wheel wrench should always do the job. Broken hand wheels and battered valve stems also sometimes indicate use of a hammer, probably to unseat a stuck excess flow valve. Hammer blows should never be applied to the angle valve, as the valve body could be cracked and allow a serious leak to develop.

Stuck excess flow valve - If an excess flow valve will not unseat and allow flow of chlorine, after waiting for a minute with the angle valve closed, a slight tapping on the manway cover plate will normally unseat it. Never hammer heavily on the cover plate as this could unseat the safety valve and cause it to leak. As a last resort, it is possible to temporarily pipe up to the gas angle valve and use the car pressure to unseat excess flow valve ball (located below the liquid angle valve).

If the liquid withdrawal rate is too close to the capacity of the excess flow valve, its ball will chatter within the valve, and could damage the seat. If additional unloading capacity is needed, connection should be made to another liquid angle valve.

Improper fittings - Use of nipples with worn threads can cause coupling leaks. Cases have been reported of nipples being broken off in the valves and then returned to the supplier. This is hazardous and illegal under ICC regulations.

Careless disconnection of unloading lines - Valves must be closed and evacuated prior to disconnecting in order to protect employees and minimize any possible complaints from nearby workers. All lines should have plugs or stoppers applied when connections are broken, and should not be left open to become wet or dirty.

Cases have been reported of failure to fully close angle valves on empty cars, and of failure to insert the plugs in the valves. This has caused corrosion on the interior of the dome, and in some cases, serious leaks in transit.

Air Padding - Air driers used for air padding of cars must be maintained to prevent depletion. If the air drier is not operating, moisture can be pumped into the car, thus making the gas highly corrosive. Driers should be checked frequently, and padding should not be started until the regenerating air is up to temperature.

The safety coordinator should review these standards with the various involved management people. If there are questions about recommended procedures for attaching lines or operating valves, additional references should be consulted.

Ton Chlorine Containers

Some locations use chlorine supplied from ton containers. It is obvious that many of the precautions outlined above also apply to them. Emergency kits for ton containers are designated Chlorine Institute Emergency Kit "B". This kit should be kept on hand at locations using such containers for chlorine supply.

APPENDIX B

SUPPLIER:

The attached form is a required part of Company's material control system and must be completed prior to acceptance for use of purchase of a new material.

We believe all of the questions asked are important, but realistically, we know some questions will not pertain to a certain product or the required information will not have been generated to answer them. Hence, your response to the form should be as complete as possible.

Please complete the form in duplicate and return the completed forms to the mill's Technical Department requesting the data. The completed forms should be marked to the attention of the mill's Technical Superintendent.

MATERIAL SAFETY DATA SHEET

I. Product Identification Request No.

A. Trade Name _____
PLEASE ATTACH SAMPLE LABEL FROM DRUM, BAG, ETC.

B. Synonyms _____

C. Manufacturer _____ Mfg's. Telephone# _____

D. Sample Enclosed Yes_____ No_____

E. Dept. of Transportation Classification _____

_____

II. Physical Data (please attach Technical Data sheet)

General Appearance : _____

Odor : _____

Boiling Point (at 760MM Hg) : _____ Melting Point : _____

Specific Gravity (H_2O=1) : _____ Vapor Density: _____

Evaporation Rate (Butyl acetate=1) : _____ Vapor Pressure: _____

Solubility in water (% by wt) : _____ pH as Shipped : _____

% Volatiles by Vol. : _____ pH in 1% Soln : _____

III. Hazardous Property Data

Exposure	Hazard (1) Classification	Basis For Classification	Source
A. Inhalation			
B. Skin Contact (2)			
C. Skin Absorption			
D. Eye Contact			
E. Ingestion			

FOOTNOTES:

1 Please follow definitions listed in Table 1

2 If human patch test data is available, please attach a report covering test. If not available, include an opinion letter from a dermatologist.

IV. Fire and Explosion Hazards:

Hazard Classification (1) _____

Blash Point:_____Auto Ignition Temp._____

Flammable Limits in Air (% by Vol) Lower_____ Upper_____

Extinguishing Media:_____

_____

Unusual Fire and Explosion Hazard:_____

_____

V. Reactivity Hazards:

Condition Contributing to Instability:_____

_____

Incompatibility (1) :_____

_____

Conditions contributing to hazardous polymerization:_____

_____

_____

(1) E.G., hazard gas expelled if mixed with acid.

VI. Ecological Hazards:

Biodegradable: _____

Aquatic Toxicity (E.G., 96 hr. TLM or LC50): _____

Content of known toxic materials or heavy metals: _____

_____

Cadium (Cd) ppm _____

Lead (PB) ppm _____

Zinc (Nz) ppm _____

Mercury (Hg) ppm _____

Antimony (Sb) ppm _____

Arsenic ppm _____

Chromium ppm _____

PCB ppm _____

Other ppm _____

_____

VII. Handling Procedures

A. General Precautions.

B. Protective Equipment Specified:

Respiratory : _____

Eye : _____

Gloves : _____

Other Clothing &Equipment: _____

C. Ventilation Requirements: _____

D. Storage Temp. Requirements: _____

E. Container - Materials of Construction to Avoid: _____

_____

F. Storage Temperatures to Avoid: _____

G. Shelf Life: _____

VIII. Disposal, Spill, or Leak Procedure

Steps to take if spilled _____

_____

Waste Disposal Methods _____

_____

Neutralizing Chemicals _____

_____

IX. First Aid Procedures

Eye: _____

_____

Skin Contact: _____

_____

Inhalation: _____

_____

Ingestion: _____

_____

X. Regulatory Status

A. Is material cleared under "Food Additives Amendment of 1958" of Federal Food, Drug and Cosmetic Act? _____

_____

B. If yes, what regulation covers the material. (Please include section and sub-section of regulation.) _____

_____

D. Please list any limitation or usage in above regulations.

_____

D. List any other Federal, State, or Local regulation that limits use of this material. _____

_____

XI. Person for Regulatory Personnel to contact for additional information or for clarification.

Name: _____

Title: _____

Telephone Number: _____

Address: _____

XII. Person Completing Form:

Name: _____

Title: _____

Company: _____

Address: _____

MSDS INSTRUCTIONS

The trade name listed should be the same as that on the product label. The shipping name is the shipping name as listed in DOT and IATA regulations, references 1 and 2. If the product is not a hazardous material according to these regulations, then it should be so indicated by listing the shipping name as "Not Restricted Article" or "Not Restricted".

Data in this Section II should be for the product as shipped.

Materials listed in Section III shall include those ingredients listed as toxic or hazardous substances in the regulations listed in references 3 to 8 plus any other ingredients which contribute substantially to the hazard(s). Sampling and analytical methods for all ingredients which are likely to become airborne contaminants should be attached or appropriately referenced.

The health hazard information listed in Section VI should be a combined estimate of the hazard of the total product. Specific toxic hazard data should be stated under "Basis for Classification" in terms of concentration, or dose and animal used, i.e., 100 ppm 4 hour LC_{50} rat, 75 ppm LC_{LO} man, 400 mg/kg LD_{50} calculated based upon ingredients. The "Hazard Classification" should then be listed according to the attached hazard definitions.

In Section V it is particularly important to highlight conditions contributing to instability or incompatibility to common substances such as water, acids, alkali, hypochlorite (oxidative bleaching), hydrosulfite (reductive bleaching), etc.

If specific procedures are required for continuous discharge or spills and leaks they should be identified in Section VIII. Note: Ingredients which require specific controls under FPWCA or other regulations should be indicated in Section X.

Specify preferred methods of ventilation in Section VII. Respirator specifications should include type of equipment and limits of protection, e.g. up to 100 ppm.

In section VII precautionary statements should consist of label statements such as those specified in ANSI Standard Z129.1-1976. Storage conditions should include materials of construction, materials or conditions to avoid, shelf life. Other regulatory concerns should indicate applicable regulations (specific section) controlling use of the product or its ingredients. If the cited regulation refers to specific ingredients, please indicate which ingredients.

REFERENCES:

1. 49CFR Part 171 and 172, Sections 171.8 and 172.101; Proper shipping name. List of Hazardous Materials. (DOT)

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2. IATA Restricted Articles Regulations, Section IV. Shipping name according to the International Air Transport Association.

3. 29 CFR Part 1910 Subpart Z - Toxic and Hazardous Substances. Occupational Safety & Health Act of 1970. (OSHA)

4. 40 CFR Part 180 - Tolerances for Pesticide Chemicals. Federal Insecticide, Fungicide and Rodenticide Act. (EPA)

5. 40 CFR Part 129 - Toxic Pollutant Effluent Standards. Federal Water Pollution Control Act, Section 307. (EPA)

6. 40 CFR Part 116 - (Proposed) - Designation of Hazardous Substances. Federal Water Pollution Control Act, Section 311. (EPA)

7. 40 CFR Part 61 - National Emission Standards for Hazardous Air Pollutants. Clean Air Act. (EPA)

8. 40 CFR Part ____ - Identification and Listing of Hazardous Wastes. Resource Conservation & Recovery Act, Section 3001. (EPA)

TABLE I
DEFINITION OF HAZARD TERMS

	HAZARD CLASSIFICATION	DEFINITION	SOURCE
	Flammable Gas	L.E.L. $< 13\%$, or range (U.E.L.-L.E.L. $> 12\%$	ANSI Z 129.1-1976
	Extremely flammable Liquid	F.P. $\leq 20^{\circ}F$	16 CFR 1500.3 29 CFR 1910,106(a)(19)
	Flammable Liquid	$20^{\circ}F < F.P. < 100^{\circ}F$	
	Combustible Liquid	$100^{\circ}F \leq F.P. < 140^{\circ}F$	29 CFR 1910.106(a)(18)(i)
	Moderately Combustible Liquid	$140^{\circ}F \leq F.P. < 200^{\circ}F$	29 CFR 1910.106(a)(18)(ii)(a)
	Flammable Solid		16 CFR 1500.3(c)(6)(iv)
EXPOSURE Inhalation	Highly Toxic Toxic Moderately Toxic	$LC_{50} \leq 200$ ppm 200 ppm $< LC_{50} \leq 2000$ ppm 2000 ppm $< LC_{50} \leq 20{,}000$ ppm	16 CFR 1500.3 ANSI Z 129.1-1976 ------
	Strong Sensitizer		16CFR 1500.3(c)(5)
Skin Contact	Corrosive Irritant Strong Sensitizer		16 CFR 1500.3(b)(7) &(c)(3) 16 CFR 1500.3(c)(4) 16 CFR 1500.3(c)(5)
Skin Absorption	Highly Toxic Toxic Moderately Toxic	$LD_{50} \leq 200$ mb/Kg $200 < LD_{50} \leq 1000$ mg/Kg $1000 < LD_{50} \leq 2000$ mg/Kg	16 CFR 1500.3 ANSI Z 129.1-1976 ------
Eye Contact	Corrosive Severe Irritant Mild Irritant	1/	16 CFR 1500.3(b)(7) & (c)(3) 16 CFR 1500.3(c)(4) ------
Ingestion	Highly Toxic Toxic Moderately Toxic	$LD_{50} \leq 50$ mb/Kg $50 < LD_{50} \leq 500$ mg/Kg $500 < LD_{50} \leq 5000$ mg/Kg	16 CFR 1500.3 ANSI Z 129.1-1976 ------

F.P. = Flash Point, °F L.E.L. = Lower explosion Limit U.E.L. = Upper explosion limit

MILL 37: BLEACHING OPERATIONS FOR KRAFT DISSOLVING PULP

INTRODUCTION

Mill 37 has two separate bleaching lines for Kraft dissolving pulp. Both operate in the CEHDED sequence (chlorine, caustic extraction, hypochlorite, chlorine dioxide, caustic extraction and chlorine dioxide). The vacuum drum bleach washers are located on two large operating floors which also contains the brown stock washers. The bleach towers, mixers, and other miscellaneous equipment are located below the operating floor, and are basically open to the outdoors. Both process lines are operated by a combination of automatic analog controllers and a computer. Within several months, some operations will be controlled by a new electronic system.

This survey also includes the hypochlorite preparation operation, and the chlorine vaporizers. The chlorine dioxide generator is separate from the bleach plant and was not evaluated. Mill 37 is located in the Southern United States.

PROCESS SUMMARY

Most details of the process are proprietary, and little details was obtained. A very basic flow diagram is presented on Figure 37-1, and pertinent process characteristics are described below:

- the bleach washer towers are not operated counter-currently
- sulfur dioxide is injected into the bottom of the downflow chlorine dioxide towers to reduce chlorine dioxide residuals
- chlorination levels are primarily determined by ORP probes located after Cl_2 injection.
- hypochlorite levels are set by the computer or manually by the operators
- chlorine dioxide levels are determined by the operators based on brightness
- there are two chlorine unloading stations; chlorine is forced under pressure from the rail cars into a weigh tank, is vaporized in one of three vaporizers, and is piped to the chlorination mixers and the hypochlorite make-up tank
- hypochlorite is produced in a mix tank located on the ground floor; chlorine is injected into a dilute caustic solution and mixed with weak hypochlorite from the chlorine dioxide scrubbers.

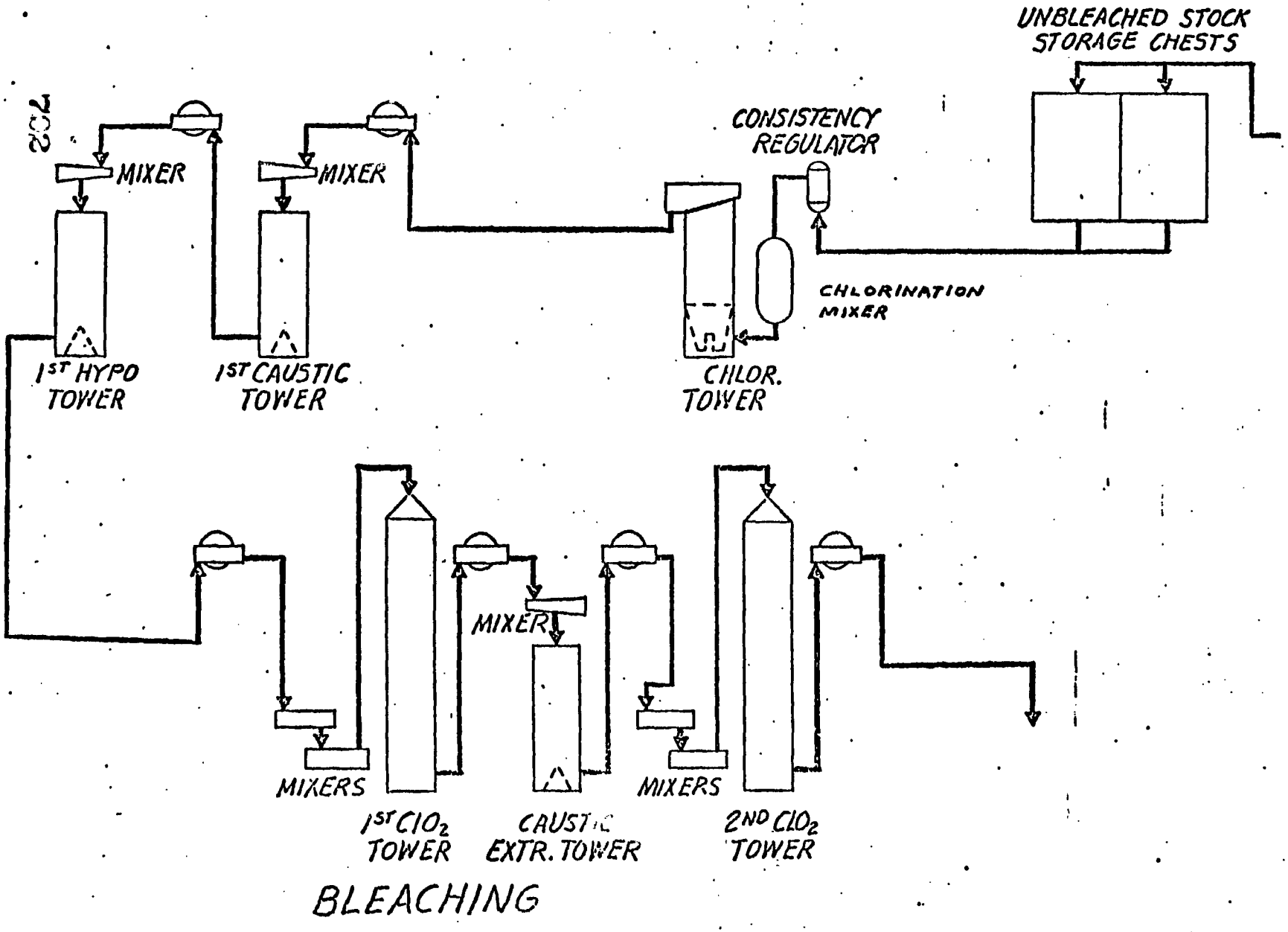

Figure 37-1: Simplified ow Diagram

JOB CATEGORIES AND DESCRIPTIONS

The bleach plant is operated by a five person crew including a crew leader, a Mill No. 2 operator, two Mill No. 1 operators, and a utility relief operator:

Crew Leader - The crew leader supervises all other employees and makes all operating decisions. He is on the operating floor for most of each shift.

Operators - The three operators control the process; conduct start-up, shutdowns, and grade changes; and collect and test quality control samples. One of the two operators for the No. 1 mill is responsible for the chlorination, first extraction, hypochlorite, and last chlorine dioxide stages. The other operator is responsible for the other two stages and hypochlorite making. Each of these employees rotate to collect the following quality control samples:

1) Operating Floor (every hour)
   - A. chlorine washer
   - B. both chlorine dioxide washers
   - C. both chlorine dioxide preretention tubes
   - D. caustic extraction washers

2) Mixer Floor (every hour)
   - A. chlorine tower
   - B. first stage chlorine dioxide tower
   - C. both caustic extraction mixers
   - D. hypochlorite mixer

3. Hypochlorite mixing tank
   - A. mixed hypochlorite solution
   - B. caustic feed

These samples take about five to twelve minutes to collect, and up to five additional minutes to analyze.

Utility Relief Operator - This employee relieves for all four other employees and handles the chlorine car changes as necessary. In addition, he is responsible for housekeeping tasks throughout the bleach plant.

AIR SAMPLING DATA

We collected 16 personal samples for chlorine/chlorine dioxide using P & CAM 209.* As shown on Table 37-1, all of these samples were taken for 15 minute periods while the operators were collecting and analyzing quality control samples on the

*Neither NIOSH P & CAM 209 nor the Mast Oxidant Monitor are specific for chlorine; both sampling techniques also respond to chlorine dioxide.

Location of Quality Control Samples	Day	Shift	Sampling Time (Min.)	Cl_2/ClO_2 Concentration (as ppm Cl_2)	Notes
Operating Floor	1	1	15	<0.05*	
	2	1	15	0.08	
	2	2	15	0.07	
	2	2	15	<0.05	W
Hypochlorite Mixing Tank	1	2	15	<0.05	
	2	1	15	<0.05	
	2	2	15	<0.05	
	2	2	15	<0.05	
Mixer Floor	1	1	15	<0.05	
	1	1	14	<0.05	
	1	2	15	0.12	X
	1	2	15	0.09	Y
	2	1	15	< 0.05	
	2	2	15	< 0.05	
	2	2	15	> 0.86	
	2	1	15	0.06	

W No. 2 Mill Operator - took samples from the No. 2 mill chlorine tower, hypo mixer, caustic mixer, both ClO_2 washers, both ClO_2 preretention tubes

X For Concurrent Mast Monitor Sampling - See Text

Y For Concurrent Mast Monitor Sampling - See Text

* Represents limit of detection for sampling/analysis method

TABLE 37-1: PERSONAL SAMPLING RESULTS

washer and mixer floors, and from the hypochlorite mixing tank. With one exception, the measured exposures are very low (<0.05 ppm to 0.12 ppm) relative to the OSHA ceiling PEL of 1 ppm. We did not notice any unusual occurrences during the collection of the one high sample (>0.86 ppm), and therefore cannot identify the source of this exposure. However, it may be due to a short exposure to a very high chlorine or chlorine dioxide level when the tower samples were collected on the mixer floor.

During the collecting of two sets of mixer floor quality control samples (see notes X and Y on Table 37-1), a Mast Oxidant Monitor was used to estimate chlorine/chlorine dioxide levels* at each sample location:

Quality Control Sample Location	Chlorine/Chlorine Dioxide Levels (as ppm Cl2) (X)	(Y)
Chlorine Tower	0.1	0.1 - 0.15
Chlorine Dioxide Tower	0.2 - 0.5	0.15 - 0.45
Hypochlorite Mixer	0.15 - 0.2	0.1
First Stage Caustic Mixer	0.15	0.1
Second Stage Caustic Mixer	0.1	0.1
Concurrent Personal Sample Results	0.12	0.09

The results are relatively consistent, and indicate that the chlorine dioxide tower is the most significant source of potential exposure (0.15 ppm to 0.45 ppm). The remaining four sample collection locations yielded similar chlorine/chlorine dioxide levels (0.1 ppm to 0.15 ppm), approximately equal to the results of the concurrent personal samples.

The bleach plant employees spend most of their time on the operating floor, at the control panels, the quality control testing area, or a room used for break time. Potential exposures during these periods were estimated by operating the Mast Oxidant Monitor for long periods of time beside the break room. The instrument response (calibrated for chlorine) was recorded over several periods totalling 51 hours. The recorded chlorine/chlorine dioxide concentration was very stable and never exceeded 0.1 ppm. These long-term data illustrate that employees' exposures to chlorine/chlorine dioxide are usually low on the operating floor.

The Mast Monitor was also operated for over two hours on top of the No. 2 Mill chlorine tower. No chlorine/chlorine dioxide

*Neither NIOSH P & CAM 209 nor the Mast Oxidant Monitor are specific for chlorine; both sampling techniques also respond to chlorine dioxide.

was detected (<0.05 ppm), even though the tower hatch was opened twice for the collection of quality control samples.

Finally, the Mast Monitor was used to profile chlorine/chlorine dioxide concentrations in various areas of the bleach plant. Concentrations on the operating floor ranged from < 0.05 ppm to 0.1 ppm, the higher concentrations being recorded directly beside the chlorine, chlorine dioxide, and hypochlorite washers. We did, however, determine that the sampling spout for the chlorine dioxide tower retention tube was a significant source of contaminant release to the workplace (>2 ppm chlorine/chlorine dioxide). It is interesting that the personal samples taken during the collection of these and other quality control samples on the operating floor (<0.05 ppm to 0.08 ppm) do not reflect this potentially high source of exposure. However, since the samples are usually collected in less than 30 seconds, the low results may be attributed to the short exposure times. Regardless, we recommend to mill personnel that the preretention tube sampling sites be partially enclosed and locally exhausted.

Additional area concentrations of chlorine/chlorine dioxide were recorded near the vaporizers (0.09 ppm); at the bottom on the hypochlorite mix tank (0.1 ppm); inside the hypochlorite test shack (0.1 ppm); and at several locations on the mixer floor (0.1 ppm). In general, it appears that chlorine/chlorine dioxide levels throughout the bleach plant remain at 0.1 ppm or below unless there is a significant leak, process upset, or other problem.

CONTROL OF WORKER EXPOSURE

There are several factors which usually prevent excessive exposure to chlorine and chlorine dioxide:

- the process is basically closed and there are therefore few sources of workplace contamination
- except for the operating floor, the bleach plant is basically open to the atmosphere; any emitted contaminants are rapidly dispersed and removed by natural ventilation
- both the bleach plant and the process equipment appear to be very well maintained, reducing the frequency of leaks or other process upsets
- the degree of process control appears to be excellent (i.e., stock exiting the bleach towers has very low chlorine and chlorine dioxide residual)
- as discussed below, the bleach washer and tower ventilation systems are well designed, and operate efficiently; most vent gases are scrubbed prior to atmospheric dispersal

Local Ventilation - The bleach washers are tightly hooded and ventilated. Each hood is made of Hetron No. 197/Antimony resin, and contains four observation ports (2 ft. x 2 ft.), which are normally kept closed.

To evaluate the operating levels of the hood exhaust systems, we measured the face velocities through open observation ports, and traversed each hood exhaust duct to estimate total air flow (cfm). As shown below, face velocities were highly variable, ranging from 100 fpm to 350 fpm. Total air flows for each hood ranged from 400 cfm to 2600 cfm.

Mill	Washer	Face Velocity* fpm	Estimated CFM
No. 1	chlorine	125 - 225	2600
	hypochlorite	150 - 275	1600
		200 - 250	-
	1st stage chlorine dioxide	300 - 350	1100
	2nd stage chlorine dioxide	325 - 350	-
No. 2	chlorine	125 - 200	800
	hypochlorite	125 - 150	400
	1st stage chlorine dioxide	250 - 300	600
	2nd stage chlorine dioxide	100 - 250	1700
		150 - 250	-

All of the measured face velocities are sufficient for adequate containment of process contaminants. In general, however, the No. 2 Mill system is not providing sufficient air flows for effective face velocities should two or more observation ports be open concurrently. Mill personnel indicated that the fans on both ventilation systems are due for replacement within the next year. Both systems are exhausted to the atmosphere through stacks extending well above the top of the bleach plant.

The chlorine and hypochlorite towers in both mills are ventilated to a scrubber system prior to atmospheric discharge. The system uses caustic as the scrubbing medium, and it is reused in the hypochlorite mixing tank. We could not determine the design or operating air flows for this system but both personal and area sampling data indicate that there is little emission from these towers.

The chlorine dioxide towers are provided with ventilation through separate vents, each containing ten feet of packing and a chilled water spray. There is some escape of chlorine dioxide when the Sample Taps are opened for sample collection (0.15 ppm to 0.45 ppm as chlorine on the Mast Monitor).

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*through one or two open observation ports

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The No. 1 mill bleach washers are provided with a vacuum assist system to supplement the vacuum derived from washer filtrate drop legs. The exhaust from the large vacuum assist pump passes through a packed tower and is scrubbed with caustic effluent prior to atmospheric venting. The exhaust from the small vacuum pump is vented to a foam tower stack located atop the bleach plant.

The hypochlorite mixing tank, the acid sewer, and the chlorine system rupture discs are all vented to the foam tower to reduce atmospheric emissions.

General Ventilation - Except for the operating floor, the bleach plant is partially or totally open, and contaminant emissions are quickly dispersed and removed by natural ventilation. Because of the bleach and brown stock washer exhaust hoods, the operating floor is under a severe negative pressure. This causes extensive drafts through all openings to the outside, and an excellent level of general ventilation in the workplace. If there is a major leak or upset, two large wall fans located on the north side of the operating floor can be used to assist the natural drafts in removing the contaminants.

SECTION VI PAPERMAKING OPERATIONS

Mill 02 Off-Machine Coating

Mill 06 Coating Preparation

Mill 09 Coating Preparation

Mill 13 Dry End Paper Machine

Mill 24 Friction Grade Paper Manufacturing

MILL 02 OFF-MACHINE COATING OPERATION

PROCESS SUMMARY

Color Building: The coating operation begins in the color building, where a number of different coating formulations are prepared in a large mixing tank. A typical batch weighs 9,000 pounds and may contain some or all of the following ingredients:

- Clay
- Starch
- Titanium dioxide
- Calcium stearate
- Ammonia
- Wet strength resin
- Dispersant
- Defoamer
- Antimicrobial agent
- Water

The ammonia (13%), the clay slurry, and the starch (cooked on the third level) are metered directly into a steam-heated mixing tank. Required amounts of wet strength resin, titanium dioxide slurry, and latex are measured in a small weigh tank, then dropped into the mixer. The remaining ingredients are measured and added directly by the operator.

When the batch has been thoroughly mixed and homogenized, it is pumped through a vibrating screen, and dropped into a large holding tank. As needed, coating solution is pumped to one of two 500-gallon tanks located in the coating area.

Off-Machine Coating: Paper is coated on a 165 inch Beloit off-machine coater installed in late 1971. In 1980, the process was interfaced with a Memorex computer system.

Rolls of paper (12,000 pounds) are loaded on the front-end of the coater. If no problems are encountered, it takes approximately 25 minutes to unwind, top coat, dry, bottom coat, dry, and rewind a roll of paper. About 3,000 pounds of coating material is typically applied to a roll of paper.

The coating (top or bottom) is applied by passing the paper through a coating trough that is continuously replenished from the holding tanks. A backing drum and a doctor blade are used to effect a very precise coating thickness on the paper. Following each coating stage, the paper is dried in a gas-fired infrared heater and a series of steam heated drums. After passing through the second stage dryer, the paper is rewound into a coated roll of paper.

JOB CATEGORIES AND DESCRIPTION

Color Building:

Operator - The operator is responsible for mixing batches of coating, cleaning the vibrating screens, and providing relief as necessary.

Assistant Operator - The assistant operator's primary responsibility is the starch cooking operation.

Utility Person - The utility person is responsible for unloading and providing a constant supply of raw materials.

Off-Machine Coater:

Operator - During normal operation, the operator is responsible for monitoring and recording process parameters, helping the utility person load or unload rolls of coated paper, and checking the quality of the coated paper. During upsets, his duties include cleaning the dryer section drums and controlling the rethreading operation to get the coater back on line.

Assistant Operator - The assistant operator's responsibilities include removing broke from the coater area and assisting the operator as required. During upsets, he cleans the second-stage backing drum, and replaces the doctor blades.

Splicer - The splicer is responsible for maintaining an adequate supply of uncoated paper, splicing uncoated paper between a spent and new roll, removing broke from the area, and assisting in rethreading the coater following an upset.

Utility Person - The utility person is responsible for removing coated rolls of paper from the line, adding empty rolls, and removing broke from the area. During upsets, the utility person cleans the first-stage backing drum and replaces the doctor blade.

WORKPLACE HAZARDS

Color Building - The major air contaminant hazards in the coating preparation area are formaldehyde and ammonia. Free formaldehyde ($\leq$ 1.5%) is contained in the wet-strength resins, made up of either urea-formaldehyde or melamine-formaldehyde. Ammonia-containing ingredients are used infrequently. The latex is a sytrene-based polymer containing less than 0.05% free styrene.

Potential exposures to nuisance dusts are minimal, as most dry ingredients are handled in slurry form. The dispersing, defoaming, and antimicrobial agents are used in very small quantities, and should not present a problem.

Off-Machine Coater - Potential exposures at the coater should be restricted to formaldehyde and ammonia (when used). Heat stress may be of concern, particularly during process upsets when employees enter the second level.

EVALUATION OF POTENTIAL EXPOSURE SOURCES

In the color building, formaldehyde may be emitted from the weigh tank, the mixing tank, the screens, and the holding tank. At the off-machine coaters, small quantities of formaldehyde can be released from the coating troughs, but the majority would be driven off at the dryer sections. Because the employees are relatively isolated from the coater during normal operation, there is little potential of exposure. However, during upsets (when employees are cleaning dryer and back drums, replacing doctor blades, and rethreading the coater), the potential for exposure is increased.

PERSONAL SAMPLING RESULTS

Long-term personal samples for formaldehyde were collected on color building and off-machine coater employees. The results are presented on Table 02-1, and discussed below for each job category:

- Operator (color building) - Because the operator is responsible for loading the wet strength resin, operating the mixer, and cleaning the screens, his potential for exposure is much greater than the other employees. Thus all personal samples were collected for this job category. As shown on Table 02-1, measure TWA exposures (0.09 ppm and 0.03 ppm) are less than 3% of the OSHA PEL of 3 ppm TWA. It is judged that the TWA exposure of the operator or other color building employees rarely, if ever, exceeds permissable levels for formaldehyde.

- Operator (coater) - Calculated TWA exposures on two consecutive days (0.27 ppm and 0.03 ppm) demonstrate very low exposures for the coater operator. As shown on Table 02-1, there is little variation between the two consecutive samples collected each shift (0.23 and 0.31 ppm; 0.04 and 0.02 ppm). The somewhat higher measured TWA on the first sampling day does not appear to be attributable to a higher number of upsets - the coater was down approximately twice as long during the second day.

TABLE 02-1 PERSONAL SAMPLING RESULTS FOR FORMALDEHYDE

Department	Job Category	Day	Shift	Sampling Period (Minutes)	Concentration (ppm)	TWA (ppm)	OSHA PEL(TWA) (ppm)
Color Building	Operator	2	2	227	0.07	0.09	3.0
				214	0.12		
		3	1	380	0.03	0.03	3.0
Off-Machine Coater	Operator	1	1	267	0.23	0.27	3.0
				205	0.31		
		2	1	243	0.04	0.03	3.0
				20	0.02		
	Assistant Operator	1	1	228	0.25	0.35	3.0
				209	0.47		
		2	1	221	0.17	0.17*	3.0
	Utility Person	2	1	240	0.08	0.08*	3.0

* Because of sampling difficulties, these samples were collected for only 4-5 hours during the shift. Because conditions are somewhat stable during the operation, the exposure concentrations for that period are reported as the TWA exposure.

- o Assistant Operator (coater) - Calculated exposures for the assistant operator reflect very low TWA exposures (0.35 ppm and 0.17 ppm).

- o Utility Person (coater) - Measured TWA exposure for the utility person (0.08 ppm) relfects a similar lack of significant exposure.

AREA SAMPLING RESULTS

Area sampling results, including several samples collected by mill personnel, are presented in Table 02-2. In the color building, two long-term samples were collected near the top of the mixing tank and reflect very low workplace levels of formaldehyde (0.04 ppm and 0.07 ppm).

At the off-machine coater, area samples were collected at the operator and splicer station, on the second level above the second coater head, and in the dryer area. The work station samples (0.02 ppm to 0.28 ppm) demonstrate that, during stable operating conditions, employee exposures will be very low. During upsets, when employees are required to be in and closely around the coater, the potential for significant short-term exposures is increased (0.54 ppm - 2.27 ppm). However, unless there are problems with air circulation and turnover in the dryer hood (creating dead air spots where formaldehyde could accumulate), ceiling exposures should usually remain well below the OSHA PEL of 5 ppm ceiling.

CONTROLS

Color Building - The mixing tank is locally exhausted, providing an average face velocity of 150 fpm through the open dump port (19" x 31"). Except while ingredients are being manually added, the dump port is covered using a cardboard lid.

Off-Machine Coater - The off-machine coater is provided with a large (30' x 96'), open hood covering the first and second stage dryers, coating stations, and infrared heaters. The side and end hood panels extend down to the middle of the top dryer drums.

The hood is exhausted by two vane-axial fans, each rated at 38,000 cfm at 3/4" S.P. The exhaust ducts exit the drive side of the coater, and extend horizontally through a wall to the outside.

TABLE 02-2 AREA SAMPLING RESULTS FOR FORMALDEHYDE

Department	Location	Day	Shift	Sampling Period (Minutes)	Concentration (ppm)	Comments
Color Building	Scale near mixing tank	2	2	434	0.07	
	10' from mixing tank	3	1	379	0.04	
Off-Machine Coater	Over 2nd coating head-2nd level	1	1	67	0.54	
	Over 2nd coating head-2nd level	3	2	217	0.55	
	Over 2nd coating head-2nd level	4	-	60	0.82	Collected by Mill Personnel
	Over 2nd coating head-1st level	4	1	60	0.94	Collected by Mill Personnel.
	Asst. Operator Work Station	1	1	223	0.24	
		1	1	88	0.28	
	Operator Work Station	1	1	130	0.02	
	Splicer Work Station	1	1	125	0.28	
	End of Dryer - 2nd Level	4	-	60	0.94	Collected by Mill Personnel
		4	-	60	2.27	Collected by Mill Personnel

Most of the free formaldehyde remaining in the coating would be released at the dryers and carried by convection into the hood. With an exhaust rate of 76,000 cfm and a volume of approximately 36,000 $ft.^3$, the hood provides an air turnover rate in excess of one air change every 30 seconds. At this turnover rate, formaldehyde should not accumulate in the hood.

General ventilation (estimated at six air changes per hour) for the off-machine coater area is provided by the coater exhaust hood and two separate sources of supply air. One supply system (80,000 cfm) consists of two direct-fired make-up air heaters, discharging at each end of the room. Additional make-up air is provided by two man-coolers, (elevated, floor mounted registers) one on each side of the coater. These units pull air from the basement and redistribute it through diffusers approximately four feet above the floor. This system is run periodically and assists in easing heat stress problems, particularly in the summer months. Air flow measurements indicate that the system can provide about 18,000 cfm of supply air to the coater area.

MILL 06: COATING PREPARATION OPERATIONS

INTRODUCTION

Coating formulations are prepared in two separate buildings: 1) a main mill, consisting of separate production lines for four coaters, and 2) a bulk plant, with a coating preparation line, a wet-end starch operation, and the majority of the bulk raw material handling systems. Four employees per shift are necessary to operate the processes.

PROCESS SUMMARY

Bulk Handling

The main mill and the bulk plant provide coating formulations and wet-end starch for five coaters. Although raw materials vary among production lines, ingredients typically include:

- clay
- starch
- titanium dioxide
- sodium hydroxide
- soda ash
- calcium carbonate
- calcium stearate
- latex

Small quantities of slimicides, tinting agents, defoamers and dispersants may be added to each batch. Delivery and handling procedures for bulk quantity raw materials are summarized in Table 06-1:

TABLE 06-1: RAW MATERIAL DELIVERY AND HANDLING

Raw Material	Mode of Transportation	Frequency	Time to Unload	Method of Unloading
Starch	railroad	1 car/week	8 hours	pneumatic
Clay(dry)	railroad	3 cars/day	8-10 hours	conveyor
Clay (slurried)	railroad	12 cars/week summer	1.5 hours	pump
Titanium dioxide	railroad	1 car/month	2-3 hours	pump
Latex	railroad	1 car/week	4-6 hours	pump

Raw Material	Mode of Transportation	Frequency	Time to Unload	Method of Unloading
Calcium carbonate	tank truck	1 truck/week	2 hours	pump
Sodium hydroxide	tank truck	1 truck/month	2 hours	pump

Each railroad car of dry clay (about 100 tons) is conveyed into one of two agitated make-down tanks in the basement of the bulk plant. Water is then added to achieve the desired percent solids for each particular type of clay (67 to 72 percent). Sodium hydroxide is metered into the tank, and soda ash is added manually. The clay mixture then is recirculated through a Cowles Clay Dissolver for about two hours, and afterwards pumped to one of eight primary storage tanks. Upon demand, it is pumped to one of five agitated, secondary clay storage tanks for subsequent transfer to the coating preparation mixing tanks.

Starch is transferred with a vacuum unloader from railroad cars into a separator. It is then pneumatically conveyed into one of two storage silos located on the roof of the bulk plant. From the silos, it is augered to several slurry tanks, and then mixed with water to attain the desired solids content. As the starch slurry is pumped to the coating preparation line, the slurry tanks are replenished to maintain a constant level and solids content.

Calcium carbonate is similarly transferred from railroad cars into a separator, and pneumatically conveyed to a storage silo. From the silo, it is augered into an agitated make-down tank, slurried with water, and pumped into an agitated storage tank. As needed, the slurry is pumped to the top and/or wire coating mix tank.

Titanium dioxide slurry is pumped from a railroad car into an agitated storage tank. If necessary, a slurry may also be produced from bagged ingredients in an agitated make-down tank. As needed, it is pumped to the starch blend tanks on each coating preparation line. Latex is be pumped into either a transfer tank or a storage tank, then either pumped through measuring tanks or metered directly into the starch cooking tanks. Calcium stearate is pumped to storage, then subsequently transferred to the starch cooking tanks.

Coating Preparation Lines

The five coating preparation lines are very similar, and consist of the following sequential operations: starch blending, clay mixing, cooking, and storage. The major

difference is the blending, mixing and cooking tanks on two lines are used for both top and wire coating formulations.

The starch slurry is pumped into the wire and/or top coating starch blending tanks, and mixed with water and titanium dioxide slurry. The coating line operator adds several buckets of soda ash, a few ladles of defoamer and dispersant, and a very small quantity of tinting agent. If specified, several bags of additional starch are also added to the tanks.

After about 15 minutes, the starch slurry is pumped onto a SWECO vibrating screen and dropped into the top and/or wire coating clay mix tanks. Slurried clay and calcium carbonate also pass through the screen, and are mixed with the starch slurry. From the clay mixing tanks, the coating mixture is pumped through in-line, steam-heated cookers (200°F) into the agitated top and/or wire coating cooking tanks. Caustic is pumped from a day tank into a vented measuring tank, and then dropped into the cooking tank. Latex and calcium stearate are metered into the tank, and small quantities of slimicide are added.

After a cooking cycle of about 15 minutes, the coating formulation is pumped into top and/or wire coating storage tanks for transfer to the papermachine coating lines.

Wet-End Starch

Starch added to the pulp at the wet-end of the paper machines is also prepared in the coating preparation area. Once every shift, the bulk plant operator slits and dumps ten 100-pound bags of starch into a mixing tank. Water is added to yield the desired solids content, and the slurry is thoroughly mixed and diluted with additional water. It then passes through one of two in-line, steam-heated starch cookers and is pumped to a storage tank. A small amount of preservative is added to the storage tanks to prevent spoilage and, the starch is then pumped on demand directly to the paper machines.

JOB CATEGORIES AND DESCRIPTIONS

There are three coating prep operators and one bulk plant operator per shift. Two of the coating prep operators handle the four main plant coating lines; the remaining operator handles the coating line in the bulk plant. Primary duties for each employee classification are listed below:

Bulk Plant Operator

- Unload and transfer dry and slurried clays to the make-down tanks
- Prepare (make-down) slurries from dry clay

- Pump clay slurries from the make-down tanks to the primary and secondary storage tanks
- Unload and transfer starch to the silos
- Make-down of light and medium starches
- Make-down, cook, and store wet-end starch
- Unload and transfer titanium dioxide, latex, calcium stearate, and sodium hydroxide into storage tanks
- Store and transfer bags and drums of minor ingredients
- General clean-up of the bulk handling areas

Coating Preparation Operator

- Monitor and operate the coating preparation lines
- Meter raw materials into the blending, mixing, and cooking tanks
- Manually add minor ingredients to the coating formulation
- General clean-up of the coating line areas

POTENTIAL WORKPLACE CONTAMINANTS

The major potential air contaminants are nuisance dusts like starch, clay, titanium dioxide, and soda ash. There is a much lower potential for exposure to sodium hydroxide mist; and preservatives, tinting agents, defoamers, and other minor ingredients are generally used in too small a quantity to present a problem.

PERSONAL SAMPLING DATA

Full-shift personal samples for nuisance dust and sodium hydroxide were collected on coating preparation employees over two shifts on three consecutive days (Table 06-2). Sodium hydroxide was not detected on any of the eight personal samples, and because the detection limits (0.04 to 0.06 mg/m^3) are well below the OSHA PEL of 2 mg/m^3, it is clear that theses workers are not exposed to excessive quantities of sodium hydroxide.

TABLE 06-2 : PERSONAL SAMPLES FOR NUISANCE DUST AND SODIUM HYDROXIDE

Job Category	Day	Shift	(Minutes) Sampling Period	8-Hour TWA Exposure (mg/m^3) Nuisance Dust	OSHA PEL	Sodium Hydroxide	OSHA PEL
Coating Prep Operator (Bulk Plant)	1	1	324			<0.06	2
	1	2	424	0.6	15	<0.05	2
	2	1	418	0.3	15		
	2	2	450	0.6	15		
	3	1	432	0.2	15		
Coating Prep Operator (Main Mill)	1	2	412			<0.05	2
	2	1	414			<0.06	2
	2	2	423			<0.05	2
	3	1	430	0.4	15		
	3	1	418			<0.04	2
Bulk Plant Operator	1	2	410	4.5	15		
	2	1	414	8.5	15		
	2	2	430	2.4	15	<0.05	2
	3	1	425			<0.06	2

Coating preparation operators' exposures to nuisance dust ranged from 0.2 to only 0.6 mg/m^3, and are therefore well below the OSHA PEL of 15 mg/m^3 for total nuisance dust. Measured TWA exposures for the bulk plant operator were much higher, ranging from 2.4 to 8.5 mg/m^3, but still well below the OSHA PEL. The higher exposures for this worker are attributable to the unloading of dry, bulk-quantity raw materials, and the manual handling of bagged starch at the wet-end starch operation.

CONTROL TECHNOLOGY

Local Ventilation

In 1979, A Torit Dust Collection System was installed to provide exhaust for the bulk plant starch blending tanks. As shown on Figure 06-1, the system includes tank hoods connected to a common exhaust duct, and interconnected duct dampers which always keep one duct closed when the other is open. Exhaust air is recirculated to the workplace after passing through a cyclone and a bag filter, but, in July of 1980, the bag filter was relocated to an isolated area on the first floor because of employee complaints that particulate matter was passing through the system and re-entering the workplace.

Air flow measurements were taken and compared with system design specifications. They are summarized on Table 06-3.

TABLE 06-3: BULK PLANT STARCH BLENDER EXHAUST SYSTEM

	Design		Actual	
Location	Load*	No-Load*	Wire Tank	Top Tank
Take-off Duct	860 cfm	1200 cfm	280 cfm	280 cfm
Hood Face Plane	100 fpm	72 fpm	approximately 100 fpm at bottom of hood near the take-off ducts - essentially zero elsewhere	

*load means the bag filter is fully loaded - 7.9 inches static pressure; no-load means a 'clean' bag filter - 4.6 inches static pressure

As shown, the exhaust system was providing less than one third of the design air flow for either blending tank. It was thought that the bag filter was overloaded and, more importantly, that the duct connecting both hoods was partially clogged with settled particulate matter. However, based on the personal sampling data, the system was operating sufficiently to prevent significant nuisance dust exposures.

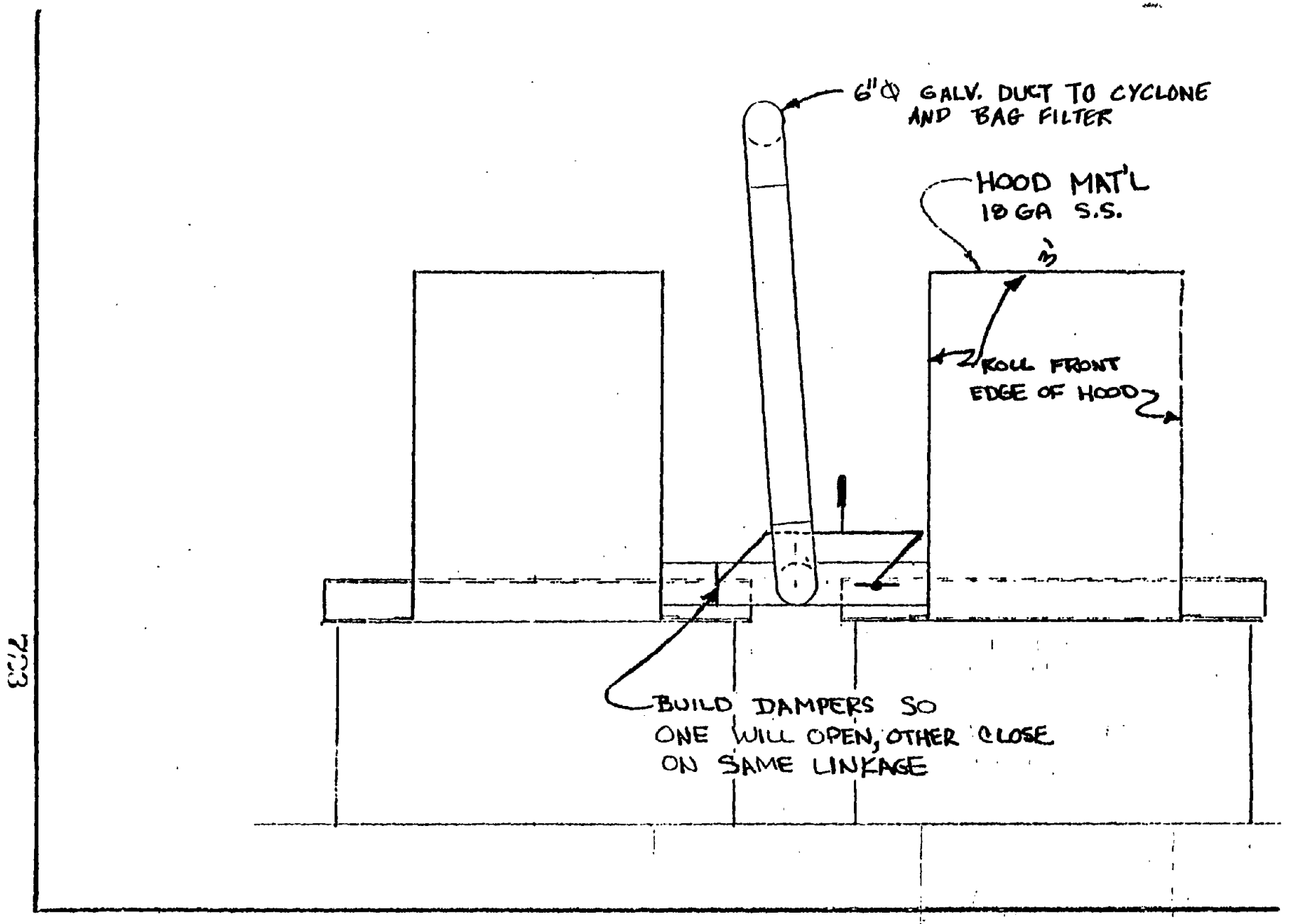

FIGURE 06-1: Starch Blending Tank Exhaust System

In 1979, the wet-end starch mixing tank was also provided with a Torit Dust Collection System. The hood is of the same design as the starch blending tanks, but, there are take-off ducts, at opposing ends of the hood (Figure 06-2). Air flow measurements (Table 06-4) showed:

TABLE 06-4: WET-END STARCH MIXING TANK EXHAUST SYSTEM

	Design		Actual	
Location	Load	No-Load	Left Side	Right Side
Take-off Duct	860 cfm	1200 cfm	120 cfm	130 cfm
Hood Face Plane	100 fpm	72 fpm	50 to 80 fpm at bottom of hood - essentially zero elsewhere	

The system was providing less than one third of the design air flow to the mixing tank hood, undoubtedly because of clogged ducts and an overloaded bag filter. If this system were operating as designed, the bulk plant operator's exposure to nuisance dust would be significantly reduced.

The starch blending tanks in the Main Mill are also locally exhausted. Each of the five blenders are exhausted through 6-inch ducts that attach to the top side of the tanks. Air flow measurements in the open hatch of each tank are shown on Table 06-5. The face velocity measurements were made with all hatches open.

TABLE 06-5: MAIN MILL STARCH BLENDER EXHAUST SYSTEM

Location	Hatch Opening	Measured Face Velocity
No. 4 Wire Starch Tank	1 square foot	75 fpm
No. 4 Top Starch Tank	1 square foot	50 fpm
No. 1 Wire & Top Starch Tank	1 square foot	125 fpm
No. 3 Wire & Top Starch Tank	2.5 square feet	100 fpm
No. 9 Wire & Top Starch Tank	2.5 square feet	25 fpm

Additional face measurements taken at selected tanks while all their other hatches were closed, revealed that air flows are increased up to 100 percent. Although personal samples did not indicate significant exposure for employees working in this area, the exhaust system would obviously be more effective if the hatches were kept closed.

General Ventilation

The bulk plant has five general exhaust fans, each rated at 5560 cfm which help reduce background dust levels. Including any local exhaust flows, the building ventilation systems can provide an estimated 6 to 10 air changes per hour. The main mill, containing three roof-mounted exhaust fans (total rated capacity of 48,000 cfm), has a similar forced air turnover rate.

Process Considerations

Two aspects of the coating preparation process which significantly reduce the potential for exposure are:

- titanium dioxide, latex, calcium stearate, and clay (in the summer) are all purchased as slurries.
- Clay and starch are primarily unloaded and handled through closed systems (pneumatic or auger).
- manual handlings of raw materials is minimized
- sodium hydroxide is purchased and used in liquid rather than solid form

Basically, the only excessively dusty operation remaining is the manual addition of bagged starch at the wet-end starch mixing tanks. Within the next six months, at Mill 06 the operation will be modified to allow the starch to be augered from the storage silos directly into the mixing tanks.

MILL 09 COATING PREPARATION PROCESS

PROCESS SUMMARY

Bulk Handling: The "color room" and the clay receiving building provide coating formulations and wet-end additives to two paper machines. Although raw materials vary somewhat among production lines, typical ingredients include:

- clay
- starch
- titanium dioxide
- ammonia
- water
- calcium carbonate
- latex
- melamine formaldehyde resins
- calcium stearate
- optical brightener
- plastic pigment
- carboxylated methyl cellulose

Very small quantities of tinting agents, defoamers, alginate, and dispersants may also be added to each formulation. If a batch is required to be held for a significant period of time, a small amount of slimicide must be added.

Clay is transferred from a railroad car into a receiving vessel using a vacuum unloader. It is then pneumatically conveyed into one of two clay storage silos located outdoors adjacent to the clay receiving building. From the silos, the clay is conveyed to the south turbo mixer where it is slurried down to a 60% solids consistency with water. After homogenization, the slurried clay is pumped to one of four constantly-agitated clay slurry storage tanks, for subsequent transfer to the coating preparation mixing tanks.

A vacuum unloader is similarly used to transfer starch from the railroad cars into a receiving vessel. The starch is then pneumatically conveyed into the starch storage silo located just north of the clay receiving building. From the silo, the starch is pneumatically conveyed to the starch make-down tank, and mixed with water to attain the desired solids content. The starch slurry is pumped through an in-line starch cooker, and flashed into a tank located above the color room. From this tank, the slurry is gravity fed into a storage tank. The make-down tank is automatically replenished to maintain a constant liquid level and solids content.

Titanium dioxide is received as a 70% solids slurry and in 50-pound bags. The slurry is pumped directly to the titanium dioxide slurry storage tank. Bags are used only if slurry is not available and are manually dumped into the south turbo

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mixer to effect a slurry. The slurry is either pumped to the titanium dioxide slurry storage tank for subsequent transfer to the coating preparation mixing tank or to one of two agitated storage tanks located across from pre-coat mix tanks for subsequent delivery to the wet-end of the paper machines.

Calcium carbonate is received in two forms - amorphous and crystalline. The amorphous form (plain ground limestone) is unloaded and transferred to a bucket elevator by a front-end loader. The bucket elevator transports the calcium carbonate to a storage bin, from which it is augered into one of two Kady mixing tanks. The crystalline calcium carbonate is transferred from railroad cars into a receiving tank using a vacuum unloader. It is then pneumatically conveyed into a storage bin located adjacent to the Kady and turbo mixers. From the bin, the calcium carbonate is augered into the north turbo mixer, where it is slurried with water to a 20% solids consistency. After homogenization, the slurry is pumped to one of two constantly-agitated wet-end storage tanks situated near the wet-end of the #4 paper machine. From the storage tanks, calcium carbonate slurry is pumped directly to the wet-end of the paper machines.

Latex, plastic pigments (polystyrene), and ammonia are received in tank trucks and pumped to their respective storage tanks.

The carboxylated methyl cellulose and dispersing agents are received in bags or fiber drums. Resins, defoamers, optical brighteners, and calcium stearate are usually received in 55-gallon drums. Upon demand, these liquids are transferred through spring-closed spigots into 5-gallon plastic buckets for subsequent use in the forumulation of coating compounds.

COATING PREPARATION LINES

An average of 2 batches of wet-end additives are prepared each shift in the north turbo mixer. Crystalline calcium carbonate is augered into the mixer from the storage bins. After homogenization with water, the batch is pumped to one of two wet-end additive holding tanks.

Once every three shifts, two batches of titanium dioxide slurry are prepared in the south turbo mixer. Titanium dioxide slurry is added to the mixer and diluted with water to achieve a 16% solids consistency. After homogenization, the slurry is pumped to the titanium dioxide slurry storage tank for subsequent pumping to the various coating preparation mixing tanks and/or one of two agitated wet-end additive tanks.

An average of nine mixes of precoat formulation are also prepared during each shift in two separate mixers. Starch, alone or in combination with titanium dioxide and/or clay

slurries are pumped into the mixers along with ammonia and latex. Small quantities of dispersant and defoamer are added manually. Both precoat mixers are situated in one room of two called the "color room".

Six to eight mixes of blade coating formulation are prepared each shift in the two Kady mixers located in the color room. Typically, water is first added to the mixers, followed by manual additions of dispersant and defoamer. Specified quantities of ammonia and titanium dioxide, clay and starch slurries are then automatically metered into the mixers.

Amorphous limestone is augered from the overhead storage bin directly into the mixer. Small bucketfuls of alginate, resins, calcium stearate, and optical brightener are added, followed by automatic metering of plastic pigments and latex. Slimicide is not normally used unless the mix is to be held for several shifts before utilization.

The formulation is mixed for about 30 minutes, then dropped into one of two dump tanks located directly beneath each of the Kady mixers. The mixture is then pumped through one of two Sweco screens located on a level above the Kady mixers, and dropped into storage tanks.

JOB CATEGORIES AND DESCRIPTIONS

There are three "color room" operators and two bulk material handlers per shift. The three "color room" operators rotate on a daily basis among the three jobs - the two Kady mixers and the pre-coat mixers. Primary duties for each employee classification are listed below:

Bulk Material Handlers

- Unload and transfer dry clays to the storage silos.
- Make-down clay slurry in the south turbo mixer.
- Unload and transfer starch to the starch silos.
- Unload and transfer crystalline calcium carbonate to storage bins.
- Make-down crystalline calcium carbonate slurry in the north turbo mixer (wet-end additive).

- o Unload and transfer amorphous limestone to the storage bay with a front-end loader.
- o Transfer amorphous limestone to the bucket elevator with a front-end loader.
- o Unload and pump latex to the storage tanks.
- o Unload and pump liquid titanium dioxide to the storage tank.
- o Make-down titanium dioxide slurry in the south turbo mixer.
- o Unload and transfer bags and drums of minor ingredients.
- o Replace bag filters on vacuum unloader receivers.
- o General clean-up of the receiving dock and turbo mixer areas.

Color Room Operators

- o Monitor and operate the coating preparation lines.
- o Meter raw materials into the mixing tanks.
- o Manually add minor ingredients to the coating formulation.

POTENTIAL WORKPLACE HAZARDS

Bulk material handling employees are exposed to nuisance airborne particulate matter including starch, clay, titanium dioxide, and calcium carbonate. The primary air contaminants to which the color room employees are exposed are ammonia (used intermittently) and formaldehyde (melamine-formaldehyde resin contains 1 percent or less free formaldehyde). The preservatives, tinting agents, defoamers, dispersants, and other minor ingredients are used infrequently and in very small quantities.

PERSONAL SAMPLING DATA

Full-period total dust samples were collected for bulk material handling employees over two shifts on three consecutive days. Table 09-1 presents the results of these samples along with primary employee activities during each sampling period. Eight of the ten personal samples resulted in time-weighted average exposures of 0.7 mg/m^3 or less, or well below the OSHA PEL of 15 mg/m^3 for total nuisance dust. There does not appear to

TABLE 09-1: TOTAL DUST SAMPLES, BULK MATERIAL HANDLERS

Job Category	Sample #	Day	Shift	(Minutes) Sampling Time	TWA Total Dust (mg/m^3)	OSHA PEL (mg/m^3)	Comments
Bulk Material Handler	1	1	1	322	3.5	15	Replacing bag filters on vacuum unloader receiver
	2	1	1	277	0.3	15	Unhooked 2nd section, hooded up and unloaded 3rd section of clay hopper; worked on 3rd section of clay hopper; cleaned dock area
	3	1	1,2	477	3.2	15	Made up and pumped 3 batches of wet-end additive formulation in north turbo-mixer; prepared 1 batch of titanium dioxide slurry in south turbo-mixer
	4	2	1	391	0.6	15	Made up and pumped 2 batches of wet-end additive formulation in north turbo-mixer; prepared 1 batch of titanium dioxide solution in south turbo-mixer
	5	2	1	391	0.3	15	Unload plastic pigment tanker; worked on 2nd section of starch car; cleaned dock area
	6	2	2	399	0.6	15	Sampled, hooked up and finished 1st section of clay hopper; worked on 2nd section of starch car; cleaned dock area
	7	2	2	399	0.6	15	Made up and pumped 2 batches of wet-end additives in north turbo-mixer
	8	3	1	185	0.7	15	Unloaded, unhooked and closed out starch car; unload titanium dioxide tanker, finished 2nd section of clay hopper and unhooked car
	9	3	1	392	0.4	15	Made up and pumped 2 batches of wet-end additive formulation in north turbo-mixer; prepared 1 batch of titanium dioxide slurry in south turbo-mixer
	10	3	1,2	581	0.7	15	Made up and pumped 2 batches of wet-end additive formulation in north turbo-mixer

be any significant variation in results among employees preparing wet-end additive formulations and those unloading bulk raw materials on the receiving dock. Two of the TWA exposures (3.5 mg/m^3 and 3.2 mg/m^3), although well within the OSHA PEL, are significantly higher than the others. These elevated data can probably be attributed to abnormal dust generation while the bag filters on the vacuum unloader receiver were being changed.

Full-period consecutive samples for formaldehyde were collected on the three color room employees. Time-weighted average exposures calculated for each set of sample results are presented in Table 09-2, along with corresponding worker activities. The number and content (formaldehyde resin and ammonia) of mixes prepared during each sample period is also shown. Eight of the nine calculated TWA exposures are below 0.15 ppm, or less than 5 percent of the OSHA PEL of 3 ppm TWA. One of the samples (#13) resulted in an integrated formaldehyde concentration of 1.76 ppm. The reason for this higher result cannot be explained relative to either the employee's acitivties or the formulations prepared during the sample period.

Short-term personal samples were also collected for ammonia to estimate exposures when this compound is added to certain formulations. The results of these samples are also presented on Table 09-2, and range from less than 0.5 ppm to 3.5 ppm. From these data, it is judged that employee exposures to ammonia are very low relative to the OSHA PEL of 50 ppm to TWA.

CONTROL OF WORKPLACE HAZARDS

Bulk Material Handling: Clay, starch, and crystalline calcium carbonate are all transferred from railroad cars to receiving vessels via a vacuum unloader. The materials are then pneumatically conveyed into their respective storage silos or bins. The receivers are located on the roof and each is equipped with 24 bag filters. This unloading system is basically closed with very little potential for significant generation of dust in the workplace.

Clay and crystalline calcium carbonate slurries are prepared separately in the turbo mixers. The calcium carbonate is augered from storage bin and the clay is blown from the storage silo directly into the mixers and thoroughly dispersed in water. Although the turbo mixers are not provided with any local ventilation, sampling data demonstrate that exposures at this operation are very low.

Starch is similarly blown from the storage silo directly into the starch make-down tank, and slurried with water. As the slurry is pumped through an in-line cooker, the make-down tank

TABLE 09-2 FORMALDEHYDE AND AMMONIA SAMPLES, COLOR ROOM OPERATOR

Job Category	Sample Number	Day	Shift	(Minutes) Sampling Period	Conc. (ppm)	FORMALDEHYDE TWA (ppm)	FORMALDEHYDE OSHA PEL (ppm)	AMMONIA Conc. (ppm)	AMMONIA OSHA PEL (ppm)	Comments
No. 4 Kady Mixer	1	1	1	170	0.08	0.07	3			Prepared and pumped batch Formulation A*
	2	-	-	214	0.07					
	3	2	1	216	0.06	0.07	3			Prepared 2 batches a pumped 1 batch Formulation A*
	4	-	-	218	0.08					
	5	-	2	205	0.12	0.15	3			Prepared 1 batch and pumped 2 batches Formulation A*
	6	-	-	215	0.17					
	7	3	1	234	0.13	0.10	3			Prepared 2 batches and pumped 1 batch Formulation A*
	8	-	-	177	0.05					
No. 5 Kady Mixer	9	1	1	171	0.16	0.11	3			Prepared and pumped 3 batches Formula-tion B*
	10	-	-	182	0.07					
	11	2	1	251	0.06	0.08	3			Prepared 5 batches and pumped 3 batches Formulation B*
	12	-	-	161	0.12					
	13	-	2	253	1.76	1.76	3			Prepared and pumped batches Formulation
	14	3	1	234	0.12	0.10	3			Prepared 7 batches a pumped 5 batches FormulationC*
	15	-	-	200	0.07					
	16	-	-	15				0.8	50	Pumped 1 batch Formulation C*
	17	-	-	15				0.8	50	Pumped and prepared batch Formulation C*
	18	-	-	15				3.5	50	Prepared 1 batch Formulation C*
	19	-	-	15				0.5	50	Prepared 1 batch Formulation C*
Precoat	20	2	1	247	0.01	0.01	3			Prepared and pumped batches Formulation and 2 batches Formula D*
	21	-	-	225	0.01					
	22	-	2	15				1.3	50	Prepared 1 batch Formulation D*
	23	3	1	15				0.8	50	Prepared 1 batch Formulation D*
	24	-	-	15				0.8	50	Prepared 1 batch Formulation E*
	25	-	-	15				1.1	50	Prepared 1 batch Formulation E*

*Formulation A - 11 gal. melamine formaldehyde resin
*Formulation B - 24 gal. melamine formaldehyde resin
*Formulation C - 17 gal. melamine formaldehyde resin - 1 gal. ammonia
*Formulation D - 1 gal. ammonia
Formulation E - 1 gal. ammonia
Formulation F - 2 gal. ammonia

is automatically replenished with necessary amounts of starch and water to maintain a constant solids content and liquid level. The operation does not require significant employee intervention and thus is not a significant source of exposure. Since the in-line starch cooker was installed, the three batch cooking tanks are used only intermittently in a back-up capacity.

Titanium dioxide is purchased as a slurry, pumped into the turbo mixer, and diluted with water. Obviously, there is no dust exposure associated with this operation. Bagged titanium dioxide is used solely as a backup for the slurry system and is infrequently required. Manual dumping was not performed during the survey.

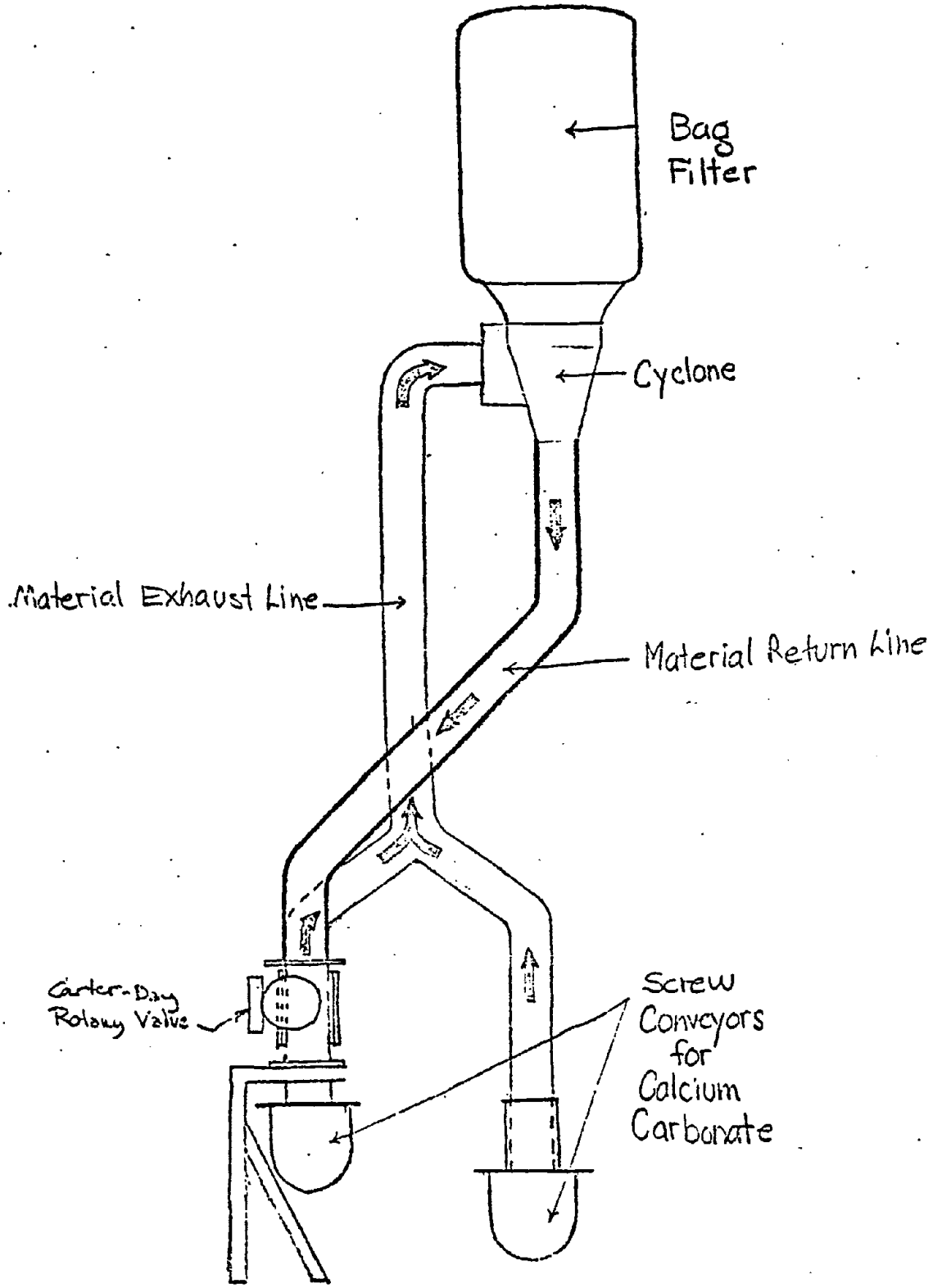
The amorphous calcium carbonate is unloaded and transferred to a bucket elevator using a front end loader. This operation is relatively infrequent and short-lived, and there are essentially no physical controls to prevent dust generation. However, sampling data indicate that it does not significantly increase worker exposures to nuisance dust.

The bulk material handlers clean the unloading dock and turbo mixer area at least once during every shift. This prevents spilled or settled raw materials from accumulating and becoming a significant secondary source of dust generation. The good housekeeping procedures are particularly evident around the amorphous calcium carbonate handling and storage area, and the south turbo mixer.

Color Room: The blade coating formulations are prepared in two Kady mixers. The only significant potential source of airborne dust is the amorphous calcium carbonate and clay which are screw conveyed into the mixers from a storage bin. During the past year, Mill 09 installed a DUSTKOP 800 series recirculating dust collector (Model 8C 50-D1) to recover dust generated in the two screw conveyors (Figure 09-1). The exhaust passes through a cyclone and a bag filter - the filtered air is recirculated back into the room; the calcium carbonate and clay are collected and returned to one of the screw conveyors through a Carter-Day rotary valve. The system induces a relatively strong negative pressure on the screw conveyors and is very effective in preventing dust leaks into the workplace.

Melamine-formaldehyde resin (11 to 17 gallons) is manually dumped into the mixers by the color room employee. Infrequently, 1-2 gallons of aqua ammonia are also metered directly into the mixers. Neither mixer is provided with local exhaust, and the screw conveyor dust collector system is not of sufficient capacity to provide any air flow through the open

FIGURE 09-1



COLOR ROOM DUST RECOVERY SYSTEM

mixer lids. Despite the lack of local ventilation, the sample data confirms that exposure to formaldehyde and ammonia is very low. This may be attributed to the following factors:

- the melamine-formaldehyde resin contains less than 1% free formaldehyde
- the resin dumping operation requires only a few minutes to perform
- the mixer lids are generally kept closed except when batch ingredients are manually added
- the ammonia is added in very small quantities (1-2 gallons) and only to a small percentage of the formulations.

The blade coating formulations are mixed for about 30 minutes and dropped into the dump tanks. It is then pumped through one of two SWECO screens and into the storage tanks. The SWECO screens and the storage tanks are provided with local ventilation via a common system. The screens are exhausted through a large canopy hood with a measured face velocity of 25 fpm or less. Although this air flow is very low compared to recommended values, the system is relatively effective due to low vapor generation rates. The exhaust system for the storage tanks was not functioning during the survey - one duct had been disconnected; the other was very likely clogged. The absence of the storage tank exhaust capability did not, however, appear to adversely affect ammonia or formaldehyde exposure levels.

MILL 13 DRY END PAPER MACHINE OPERATIONS

INTRODUCTION

This survey examines worker exposures to paper dust at dry end operations of three paper machines (P.M.): 1) a 180 inch tissue machine (P.M. #1); 2) a 180 inch tissue towel machine (P.M. #2); and 3) a 258 inch news machine (P.M. #3). During the survey, a two-ply bathroom tissue was being run on P.M. #1, and a single-ply paper tower on P.M. #2.

PROCESS SUMMARY

Dry end operations are similar for each paper machine. The web of paper exits the machine driers at approximately 4400 feet per minute (fpm). They are then calendered and wound onto a steel reel at about 3500 fpm on P.M. #1, 3400 fpm on P.M. #2, depending on the grade. The reels are transferred by an overhead crane to the rewinder station where rolls are slit to size and rewound on cardboard cores at about 6000 fpm. Two or three rolls are combined into the desired number of plies (two during the survey) on a special calender roll prior to rewinding. The sized rolls are then conveyed to the finishing areas where they are wrapped, headed, and weighed.

JOB CATEGORIES AND DESCRIPTIONS

The following production job categories are involved in dry end operations:

Second Hand (Back Tender) - The second hand has primary responsibility for the drying, calendering, and reeling operations.

Third Hand - The third hand's duties are primarily to operate the winder and make the finished rolls ready for the wrapping area. The fourth and fifth hands are under his supervision. Although much of his time is spent at the winder control console overseeing the operation, the third hand conducts most of the area blowdown operation. He also adjusts the slitter blades as necessary.

Fourth Hand - The fourth hand conducts various tasks including removing broke, threading paper, preparing cores, and assisting with the area blowdown.

Fifth Hand - The fifth hand's duties are similar to the fourth hand's, but, because he typically works at two separate machines, they are somewhat more varied.

POTENTIAL WORKPLACE EXPOSURES

Workers at the dry end of the paper machines are potentially exposed to paper dust which is considered to be a nuisance dust with an OSHA 8 hour TWA permissable exposure limit of 15 mg/m^3.

EXPOSURE MEASUREMENT RESULTS

Long-term (and event-related short-term) personal samples to assess full-shift worker exposures to total dust were collected on employees working at the dry end of the paper machines. Samples were collected on 5 um PVC filters using constant flow air pumps and analyzed gravimetrically. As shown on Table 13-1, worker exposures are significantly higher at paper machines Nos. 1 and 2 (0.6 to 9.1 mg/m^3) than those at paper machine No. 3 (0.1 to 1.0 mg/m^3). This is because production and handling of tissue paper and paper towels produces greater quantities of dust than does newsprint. However, the data demonstrate that, despite high variability, measured exposures are well below the OSHA TWA PEL of 15 mg/m^3 for total nuisance dust.

The most significant source of worker exposure is the area blowdown operation which is conducted at least once during each shift by the third hands with the fourth hand assisting. This operation consists of using a compressed air line and hand-held jet nozzle to blow settled dust from all tissue and towel machine equipment and work surfaces. It is required in order to reduce the fire hazard of dust accumulations on rotating or heated equipment. Workers performing this operation wear dust masks, and attempt to blow all dust towards central broke recovery systems. Other dry end employees usually must stop work and stand in unaffected areas during this operation. Two short term samples collected on the third day during one such operation on No. 1 tissue machine (third and fourth hand); samples resulted in dust exposure concentrations of 10.0 mg/m^3 and 8.1 mg/m^3.

Some paper dust is also generated at the slitters of each machine, and whenever the web breaks and must be rethreaded onto a machine.

CONTROL OF WORKPLACE EXPOSURES

There are both local and general ventilation systems in use at the dry end of the paper machines. The general ventilation system (six 36-inch ceiling fans) is obviously not desiged to control paper dust, but may provide some benefit particularly following the blowdown operations. The No. 2 unwinding station is provided with an exhausted, canopy-type hood which, during

TABLE 13-1 PERSONAL EXPOSURE RESULTS

Line	Sample #	Job Classification	Day	Shift	Total Dust* Sampling Time	(Minutes)	(mg/m3)	Comments
Paper Machine #1 (180" Tissue Machine)	1	Third Hand	3	1	8^{37}-15^{33}	416	9.1	Blow down at 11^{00}
	2				11^{00}-11^{24}	24	10.0	During blow down
	3	Fourth Hand	3	1	8^{57}-15^{33}	396	4.4	Blow down at 11^{00}
	4				11^{00}-11^{24}	24	8.1	During blow down
	5			2	16^{22}-22^{56}	394	1.5	Blow down at 22^{30}
	6		4	2	15^{33}-22^{28}	415	1.3	Blow down at 22^{30}
	7	Fifth Hand	3	1	16^{16}-22^{56}	400	0.9	
	8		4	2	15^{55}-22^{38}	403	0.7	
Paper Machine #2 (180" tissue-towel machine)	9	Third Hand	3	1	8^{35}-15^{33}	418	6.0	Blow down at 11^{00}
	10			2	16^{18}-21^{40}	322	1.9	Blow down at 22^{30}
	11		4	2	16^{05}-22^{39}	394	3.3	Blow down at 22^{10}
	12	Fourth Hand	3	1	8^{34}-15^{33}	419	1.5	Blow down at 11^{00}
	13		4	2	16^{03}-22^{41}	398	9.1	Blow down at 22^{30}
	14	Fifth Hand	3	1	8^{34}-15^{33}	419	0.6	Blow down at 10^{40}
Paper Machine #3 (258" news machine)	15	Third Hand	2	2	16^{30}-23^{12}	402	0.3	
	16	Fourth Hand	2	2	16^{30}-23^{00}	390	1.0	
	17	Fifth Hand	2	2	16^{28}-23^{00}	392	0.3	
	18	Core Cutter	2	2	16^{31}-22^{55}	384	0.3	
	19	Back Tender	2	2	16^{27}-22^{58}	391	0.3	
	20	Roll Wrapper	2	2	16^{28}-22^{56}	388	0.4	

*Collected on pre-tared 5 um PVC filters and determined by gravimetric analysis.

normal operation, will effect some dust containment and removal. There are also ventilated floor grates at the take-up station of the No. 2 line, and at the calenders and the back stack station of the No. 1 line. These systems, however, have little influence on dust collection at the primary sources of generation. Finally, the ejector-type twin blower system, which pneumatically conveys trim from the slitters to the repulpers, undoubtedly, captures some of the dust generated at these sources. However, this is not its primary function and it is judged to be only marginally effective.

None of these ventilation systems appreciably assist in controlling secondary dust generation occurring as a result of the area blowdown operations. These are considered the major source of overall worker exposure. However, it was observed that employees generally wear dust respirators during these blowdowns, and at other periods, such as paper breaks when dust levels are visibly high.

MILL 24: ASBESTOS EXPOSURE CONTROLS FOR FRICTION-GRADE PAPER MANUFACTURE

INTRODUCTION

Mill 24 is a specialty paper mill that produces about 15 tpd of filter paper and automotive friction paper. The mill began operations in the early 1970's, but did not produce asbestos friction-grade paper until 1976. Currently, production schedules are based on single orders, and long production runs are infrequent (less than a week for asbestos friction-grade papers). The mill is small and manufacture of asbestos friction grades has never been more than 10 percent of its total output.

This report summarizes controls installed by the mill to reduce potential worker exposure to asbestos fibers to the lowest practical level and to comply with the OSHA standards. The most important of these is a ventilated enclosure in which dry and dusty materials can be safely opened, then automatically fed into the pulp stock. This enclosure may be of interest to other mills.

PROCESS SUMMARY

The mill purchases pulp in dry form, then reslurries it in a large, agitated tank called a hydrapulper. Most raw materials, including the dry pulp and asbestos, are received in covered bales or paper bags, and transported to the hydrapulper area as needed. They are used to prepare papermaking stock or furnish on a batch basis. A number of closed unit operations are involved.

To produce asbestos friction-grades, the hydrapulper is first charged with pulp, asbestos, and other fillers and additives. Most solid ingredients are placed on an inclined conveyor belt which takes them from the production floor up to the hydrapulper top. Here, they are manually opened and then dumped into the hydrapulper. Bags of dry asbestos are now opened in a specially-designed, ventilated enclosure, then screw-conveyed into the hydrapulper tank. Other dusty materials (diatomaceous earth, graphite particles, and other friction particles), which are occasionally used in some grades, are also now opened and added through this enclosure.

As ingredients are added to the hydrapulper, they are slowly blended together in water. Once all have been added, they are thoroughly mixed, then adjusted to the desired consistency. This stock mixture is put in a dump chest and eventually pumped to either of two machine chests. Depending on the particular

grade, it then is either refined (Claflin Model 101), or sent straight to the paper machine mix box. In the mix box, various other liquid and solid ingredients are added, and then blended with the stock to produce the final machine furnish.

The treated stock flows to the headbox of the papermachine (a rotoformer) where it forms a web of wet paper. After forming, excess water is removed by suction, and the paper is transferred to a continuous felt. Additional water is removed as the paper passes through the press section of the machine. Finally, the web enters the dryer section where rotating steam-heated drums drive off the remaining water. The paper exits the drier section, and is collected on a take-up roll. When full, rolls are wrapped and labeled, and then transported to the shipping dock. However, some rolls are transferred to one of three slitter/rewinders where they are cut to customer specifications, rewound, and then wrapped and labeled.

JOB CATEGORIES AND DESCRIPTIONS

The mill employs less than 100 people, but the actual number varies depending on business conditions. During peak friction-grade production, it operated continuously for seven days per week, but recently has reduced production to 5-days per week.

The following job categories are involved in asbestos grade production (numbers of workers per shift in parenthesis):

- Pulper Operator (1)
- Pulper Helper (1)
- Paper Machine Operator (1)
- Paper Machine Back Tender (1)
- Paper Tester (1)
- Rewinder Helper (1)
- Rewinder Helper (1-2)

The Pulper Operator and Helper handle raw, dry asbestos or asbestos-containing paper broke, and are at the highest risk of possible exposure. The Machine Operator, Back Tender, Rewinder Operator, and Tester all occasionally handle the dry asbestos paper, but exposure risks are judged less significant. Forklift drivers, maintenance personnel, and management staff are also periodically in potential asbestos exposure areas, but their work routines are unpredictable and exposure risks are

similarly judged low. While working in high potential exposure areas around the hydrapulper and bag opening station, all employees are required to use protective equipment. Exposure monitoring data has been developed for all the above job categories over the past four years. Extensive data has been developed for the Pulper Operator and Helper -- the two categories at projected highest risk of exposure. Short job descriptions for both follow.

Pulper Operator: The Pulper Operator is responsible for preparing the particular grade of stock (to be 'furnished' to the paper-machine) and for ensuring that all required ingredients are added. He operates the hydrapulper (from a nearby control panel) and other stock treatment equipment such as: the machine chests, refiners, deflaker, and mix box.

Most of these are closed systems and exposure is not possible (unless a spill occurs and dries) because the asbestos has been previously slurried at the hydrapulper. However, either the Operator or the Helper will obtain, open, and add the required raw materials to the hydrapulper, and while performing these operations exposure could potentially occur. The Operator remains on the production floor for essentially his entire shift, minus short break and meal times.

Pulp Helper: The Helper's tasks are similar to the Operator's, and both are thought to be at nearly equal risks of potential exposure. The Helper's main function is to pick up raw materials in the warehouse; deliver them to the hydrapulper; and then open and add them as required to the hydrapulper through either the inclined conveyor or the bag opening station. He also periodically collects paper broke, that is to be repulped, at the papermachine and rewinder areas; and performs housekeeping tasks around the warehouse and pulper room. The latter includes cleaning up any material spills by hosing them down with water into the plant sewer system.

PRE-CONTROL ASBESTOS AIR MONITORING DATA

When production of asbestos friction-grade paper began in 1976, mill management requested assistance from their worker's compensation carrier. During the next several years, three one-day asbestos air monitoring surveys were conducted by the insurance company. Each of these surveys focused on exposures that might occur during the manual method of opening and adding bags of asbestos from the inclined conveyor at the top of the hydrapulper. This procedure was used until the ventilated bag opening enclosure was installed in mid-1979.

As shown in Table 24-1, a total of thirteen personal samples[1] of short or unknown duration were collected during these surveys on the pulper operator (2.26 to 2.50 f/cc), the helper (0.51 to 10.3 f/cc), and the rewinder/slitter operator (0.24 to 2.65 f/cc). In addition, as shown on Table 24-2, two area samples (1.95 and 1.1 f/cc) were collected at a location just below the hydrapulper (at the Pulper Control Panel). These data indicated potential high exposure risks during loading of asbestos to the hydrapulper prior to installation of controls.

In early 1979, OSHA conducted a detailed asbestos compliance survey over a non-consecutive, two-day period. As shown on Table 24-1 and 24-2, a total of 28 personal samples and six area samples were collected. During each survey, a discontinued, three-year-old supply of very dusty African anthophyllite asbestos was used; and the results probably represent 'worse case' situations. Also, on the second day of the survey, the plant was shut down because of a boiler malfunction. Results for the personal samples OSHA collected are summarized below by job categories:

- Pulper Operator - during the first day, nine samples were collected, ranging from 0.82 to 17.11 f/cc. With the process shutdown, three samples were collected (0.04 to 0.4 f/cc).
- Pulper Helper - results ranged from 1.77 to 3.19 f/cc with hydrapulper operating, and 0.13 to 0.96 f/cc with it down.
- Rewinder/Slitter Operator and Helpers - five samples were collected, ranging from 0.09 to 0.66 f/cc.

Four area samples were collected at the hydrapulper control panel. They resulted in concentrations of 1.06 to 2.19 f/cc (hydrapulper running), and 0.2 and 0.03 f/cc (hydrapulper down). Two additional samples collected in the warehouse near the asbestos storage area resulted in concentrations of 1.60 and 1.89 f/cc.

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[1]For total fiber count by NIOSH Method P&CAM 239. Counts are expressed as fibers per cubic centimeter of air (f/cc).

Table 24-1: Summary of Personal Air Samples

Job Category	Collected by	Sampling Time (Mins.)	Asbestos Concentration Fibers/cc**
Pulper Operator	Insurance Company	—	13.6
		—	25.0
		—	13.6
		—	2.26
	OSHA	60	1.39
		10	17.11
		140	0.82
		140	1.10
		60	1.43
		10	3.96
		105	5.39
		15	6.73
		60	3.27
		60	0.4*
		60	0.09
		120	0.04*
	Consultant/Mill	154	0.75
		47	0.63
		120	0.38
		120	2.09
		120	0.44
		27	5.73
		145	0.44
Pulper Helper	Insurance Company	—	4.37
		—	4.6
		—	2.76
		—	10.31
		—	2.76
		—	0.51
	OSHA	15	1.77
		60	2.58
		105	3.19
		75	0.96*
		60	0.13*
		60	0.19*
	Consultant/Mill	157	0.67
		68	0.28
Rewinder & Helpers	Insurance Company	—	0.24
		—	0.73
		—	2.65
	OSHA	405	0.09
		50	0.66
		65	0.26*
		175	0.30*
		240	0.09*
	Consultant/Mill	129	0.04
		68	0.17
		128	0.09
		66.5	0.15
		119	0.72
		74	0.10
Back Tender (Dryer)	OSHA	175	0.06*
		35	0.32*
		35	0.18*
	Consultant/Mill	159	0.06
		44	0.22
Papermachine Operator	Consultant/Mill	158	0.03
		48	0.08
Paper Tester	OSHA	60	<0.03
		255	0.03*
	Consultant/Mill	148	0.03
		55	0.22

* Samples were collected during a period when no asbestos was being furnished to hydrapulper, but papermachine was still operating.

** All samples collected on 0.8 μ MCE filters (open face) and analyzed according to NIOSH Method P & CAM 239.

Note: All employees wore protective respirators during the above sampling periods.

Table 24-2: Summary of Area Air Samples

Location	Collected by	Sampling Time (Mins.)	Asbestos Concentration Fibers/cc**
Pulper Control Panel	Insurance Company	--	1.95
		--	1.1
	OSHA	210	1.06
		210	2.19
		175	0.2**
		105	0.03**
	Consultant/Mill	240	0.016
		240	0.012
		240	0.028
		240	0.325
		263	0.028
		240	0.008
		240	0.138
		240	0.020
		240	0.010
		240	0.014
		240	0.089
		240	0.005
		240	0.049
Bag Opening Station	Consultant/Mill	259	2.002
Storage Warehouse	OSHA	400	1.60
		400	1.89
	Consultant/Mill	240	0.008
		240	0.102
		254	0.043
Offices on Production Floor	Consultant/Mill	180	0.003
		121.5	< 0.0025
Lunchroom	Consultant/Mill	181	0.012
Storage Warehouse Entrance	Consultant/Mill	185	0.035
Loading Dock	Consultant/Mill	250.5	< 0.0014
Conference Room (Second Floor)	Consultant/Mill	254	0.017

* All samples collected on 0.8 μ MCE filters (open face technique), and analyzed according to NIOSH Method P & CAM 239.

** Samples were collected during a period when no asbestos was being furnished to hydrapulper, but the papermachine was still operating.

As a result of these surveys, OSHA issued a citation alleging violations of the asbestos standard. In response, the mill immediately started using cautionary labels on all asbestos-containing materials, improved its packaging procedures for waste, and restricted eating and drinking in the hydrapulper area. In addition, complete medical exams (conducted previously in 1977) were rescheduled on an annual basis. A consulting firm was also retained to:

- o conduct an initial exposure assessment survey;
- o establish an ongoing air monitoring program;
- o provide assistance in developing engineering and administrative controls; and
- o document the effectiveness of installed controls;

CONTROL OF EXPOSURES

When they first began producing asbestos friction-grade paper in 1976, the mill evaluated possible engineering and process controls. They decided to install a separate shower/locker room and a lunchroom which would be used during asbestos production. They also tried to add asbestos directly to the hydrapulper in unopened pulpable bags, but this was unsuccessful because of the pulping rate of the bags. However, by the time of the first OSHA compliance survey, a number of promising controls were in the final stages of development or installation. They included:

- o The ventilated bag-opening station with a filter baghouse for its exhaust air
- o Two new supply air systems
- o An isolated and clearly-designated area in the raw materials warehouse for storage of asbestos-containing materials (this was actually in existence at the time of the OSHA survey)

All of these were installed and ready for use by the next major asbestos run after the compliance survey (with the exception of supply air systems). The mill also developed a number of process and work practice controls in order to reduce the likelihood of exposure and to meet the requirements of the asbestos standard. These included:

- Packaging and sealing of rolls directly at the rotoformer's end (eliminates need to transport and store unprotected rolls);

- An improved paper broke handling procedure -- specifically, baling and covering it with plastic; transporting to the hydrapulper; removing plastic; wetting with a water hose; cutting the baling straps; and dumping into the hydrapulper; and

- Modification of the inclined conveyor belt system (to the hydrapulper) to reduce the amount of material which carries over on the belt (eliminates material falling down to the production floor).

Work Practices/Administrative Controls

- Complete segregation of the asbestos material storage area with curtains, and posting of caution and restricted entry signs;

- Purchase of an asbestos-filter vacuum cleaner for cleanup of asbestos-containing debris;

- Requests to suppliers (written) to improve shipments of asbestos raw materials (incoming shipments are now inspected and damaged containers returned);

- New mandatory procedures for using respirators and other protective clothing, and for disposing of contaminated material;

- Scheduling of annual medical exams, including chest X-rays, for all mill employees;

- Training meetings for all employees to discuss asbestos hazards and new control measures; and

- Restrictions on eating and drinking in production areas during asbestos production.

During the next few asbestos production runs, an extensive air monitoring program was performed by the consultant in order to document the effectiveness of these improvements, especially the ventilated bag opening enclosure.

The initial sampling effort focused on assessing possible interferents in the analysis procedure for asbestos. To do this, nine area samples were collected during a non-asbestos friction-grade run, and analyzed by the standard NIOSH/OSHA optical procedure (NIOSH Method P & CAM 239). The results,

summarized in Table 24-3, clearly show that optical methods for determining individual fibrous contaminants in papermill workspace air can be subject to significant positive interferents. Results of the remaining sampling program are discussed in the following section.

EFFECTIVENESS OF ENGINEERING CONTROLS

During the next major asbestos run, extensive personal and area monitoring was conducted, mainly to establish the effectiveness of the bag opening enclosure. Over a seventeen day period, 22 area and 21 personal samples were collected and analyzed. Results are also summarized in Tables 24-1 and 24-2.***

The magnitude of exposure reduction is best seen by comparing the averages of exposures by job categories and by locations with the previous insurance carrier and OSHA results. (This comparison is somewhat inaccurate because different grades of paper, using a number of asbestos varieties, were being made at each time.) As shown in the table below, Pulper Operator's and Helper's exposures were reduced by factors of approximately nine and eight, respectively; and the Rewinder's (or Helper's exposure by approximately three. Area concentrations showed even more pronounced reductions, dropping by a factor of 28 at the pulper control panel monitoring station, and by 34 times in the storage warehouse area.

	Before		After		
Job Category	Number Samples	Avg. Conc. Fibers/cc	Number Samples	Av. Conc. Fibers/cc	% Reduction
Pulper Operator	13*	7.36	6**	0.789	89.0
Pulper Helper	9*	3.65	2	0.452	87.6
Rewinder/Helpers	8	0.628	6	0.21	66.6
Pulper Control Panel	4	1.58	13	0.057	96.4
Storage Warehouse	2	1.75	3	0.051	97.0

* Excludes samples collected on second day of OSHA survey when process was down because of a boiler failure.

** Excludes one sample of 5.728 fibers/cc (27 mins.), because filter was inserted into a pile of raw asbestos fibers.

***Some samples were collected by the mill after the consultant trained one of their lab workers.

Table 24-3: Summary of Background Air Sampling Results

The following area samples were collected during production of a non-asbestos-containing grade of paper. Samples were analyzed according to NIOSH Method P & CAM 239 by an AIHA-accredited laboratory and by an analyst with over ten years experience in the procedure.

Sample Location	Sampling Time (Mins.)	Fibers/cc*
Pulper Control Panel	128	2.55**
" " "	132	1.92
Storage Warehouse Below Bag Opening Station	238	0.28
Storage Warehouse at South Entranceway	223	0.13
Plant Lunchroom	239	0.037
Technical Supertendant's Office on Production Floor	241	0.006
Plant Manager's Office	241	0.032
Loading Dock	265	0.006
Outside Air (from Research Lab Window)	218	< 0.001

* Optical counting procedure eliminated any fibers positively identified to be non-asbestos

** Exceeds OSHA 8-hour TWA standard for asbestos of 2.0 fibers/cc.

Referring back to Tables 24-1 and 24-2, two personal (5.7 and 2.1 f/cc) and one area (2.0 f/cc) samples actually exceeded the OSHA TWA standard (2.0 f/cc), but each was attributable to initial startup and procedural problems with the bag opening enclosure (workers failing to open bags inside the enclosure, and spills from the conveyor system.) During one sample (5.7 f/cc for 27 minutes), the employee inadvertently inserted the sampling cassette in a pile of asbestos he was cleaning up.

Although these results were very encouraging, on the consultant's recommendation, the mill continued to collect long-term personal and area samples in order to establish a sound statistical data base. Results of this continued effort are summarized for the past two years in Table 24-4. They clearly demonstrate the effectiveness of the ventilated bag opening enclosure. Most revealing are nine short-term personal samples collected on the particular operator of the bag opening station, and eighteen area samples at the pulper control panel. When operating the bag opening station, measured exposures ranged from less than 0.02 to only 0.47 fibers/cc, but the average of nine samples was only 0.14 fibers/cc. At the pulper control panel (where OSHA and the insurance carrier had detected levels from 1.06 to 2.19 f/cc), results now ranged from less than 0.0026 to 0.14 fibers/cc, with an average of only 0.0199 fibers/cc.

In addition, three personal samples were collected on maintenance workers performing cleanup tasks after asbestos production runs. They show there is also little exposure during these common tasks.

Because of the demonstrated effectiveness of the bag opening enclosure, detailed sketches and a more complete description of it are provided in the appendix of this report. It may have applications in other papermills using similar, dry and dusty materials. We have also included a sketch of the special shower/locker room layout for possible use by other mills.

ADMINISTRATIVE CONTROLS

To assure full compliance with the requirements of the asbestos standard, the consultant also developed six administrative programs:

- worker education and training
- written respirator program
- medical monitoring
- personal hygiene
- housekeeping (including inspection outline for ventilation systems)
- air monitoring

Table 24-4: Summary of Mill's Air Monitoring Program Results

(July 1979 - October 1980)

Job Classification/Location	Sampling Time (Mins.)	Asbestos Concentration Fibers/cc
Pulper Operator	240	0.0223
	120	0.078
	120	0.058
	180	0.071
	23	0.233
	180	0.050
	185	0.027
	60	0.076
	180	0.0403
Pulper Helper	180	0.067
	240	0.0095
	240	0.11
	195	0.064
Operator of Bag Opening Station	20	0.29
	16	0.15
	36	<0.0212
	31	0.092
	22	0.062
	21	0.056
	15	0.47
	15	0.064
	15	<0.025
Back Tender	480	<0.0159
	240	0.033
Rewinder	90	0.017
Maintenance/Cleanup	240	0.0151
	200	0.0488
	54	0.079
Bag Opening Station	120	0.042
	122	0.025
	240	0.035
	10	<0.038
	120	0.019
	120	0.053
	124	0.019
	120	0.017
	120	0.017
Pulper Control Panel	240	0.009
	265	0.032
	240	0.029
	240	0.012
	240	0.013
	240	0.009
	255	0.004
	240	0.0014
	245	0.016
	480	0.0103
	480	0.0143
	240	0.14
	240	0.023
	250	0.013
	420	0.0077
	240	<0.0032
	240	0.0024
	240	<0.0016
Storage Warehouse	146	<0.0026
Shower Room (Dirty Side)	266	<0.005
Asbestos Storage Area	248	<0.0015
	240	<0.0016

These were subsequently refined by the mill (parts of the program were already in use by the mill), and are now part of its standard operating procedure. A seventh program established a permanent asbestos policy committee to audit and enforce the other control programs. Summaries of the training, respirator, personal hygiene, and housekeeping programs may be of use to other companies, and are included at the end of this report in original form.

COST OF CONTROLS

In relation to the sporadic nature of asbestos friction-grade production and the mill's total sales (approximately $6 million in 1979), the costs of control measures, summarized in Table 24-5, are particularly high. Also, in the case of some of the engineering controls, the mill performed much of the installation work itself, and actual costs could not be accurately estimated. The mill estimates the total continued yearly cost of all controls is $12,000-15,000 beyond the initial equipment costs of $133,700.

Table 24-5: Summary of Costs of Asbestos Controls

		Estimated Cost ($)
Engineered Controls		
o Bag Opening Enclosure with Baghouse		70,000 + installation
o Modification to Hydropulper Feed Conveyor		10,000 + labor
o Shower/Locker Room		20,000
o Supply Air Systems (2)		~23,000
o Lunchroom		~ 5,200
o Nilfisk Vacuum Cleaner (absolute filter)		~ 4,500
o Asbestos Storage Area		~ 500
o Air Sampling Equipment		~ 500
	Subtotal	$133,700
Administrative Controls		
o Respirators and Protective Clothing		3,500-4,000 per year[1]
o Medical Monitoring (70-100 workers)		1,800-2,600 per year[1]
o Air Monitoring (Analytical + Estimated labor for sampling)		2,000-2,500 per year[1]
o Recordkeeping (Labor estimate)		~ 3,000 per year[1]
	Subtotal	$ 10,100-12,100 per year
Miscellaneous		
o Consultant Fees (1979-80)		~ 4,000

[1] Based on 1980 costs

APPENDICES

APPENDIX A

VENTILATED ASBESTOS BAG OPENING STATION AND BAGHOUSE

The mill's ventilated bag opening station is based on a design similar to that developed by workers at John Mansville Company and shown in Figure 24-1 (Refs: Industrial Ventilation: A Manual of Recommended Practice, American Conference of Governmental Industries Hygienists, 1978, p 5-122, Specific Hood Design VS-1001; and Goldfield, J. and Brandt, F.E., "Dust Control Techniques in the Asbestos Industry," a paper presented at the AIHA Conference, Miami Beach, FL, May 12-17, 1974).

The mill's system is similar, but a 9 inch diameter horizontal screw conveyor has been fitted in the enclosure's bottom to transport dumped material to the nearby hydrapulper. The enclosure was fabricated from fiberglass, and has a 30 inch high by 42 inch wide Plexiglas access door in front. This is hinged at the top and will normally swing closed unless held up by a worker. A small shelf has also been provided in front on which to place unopened bags.

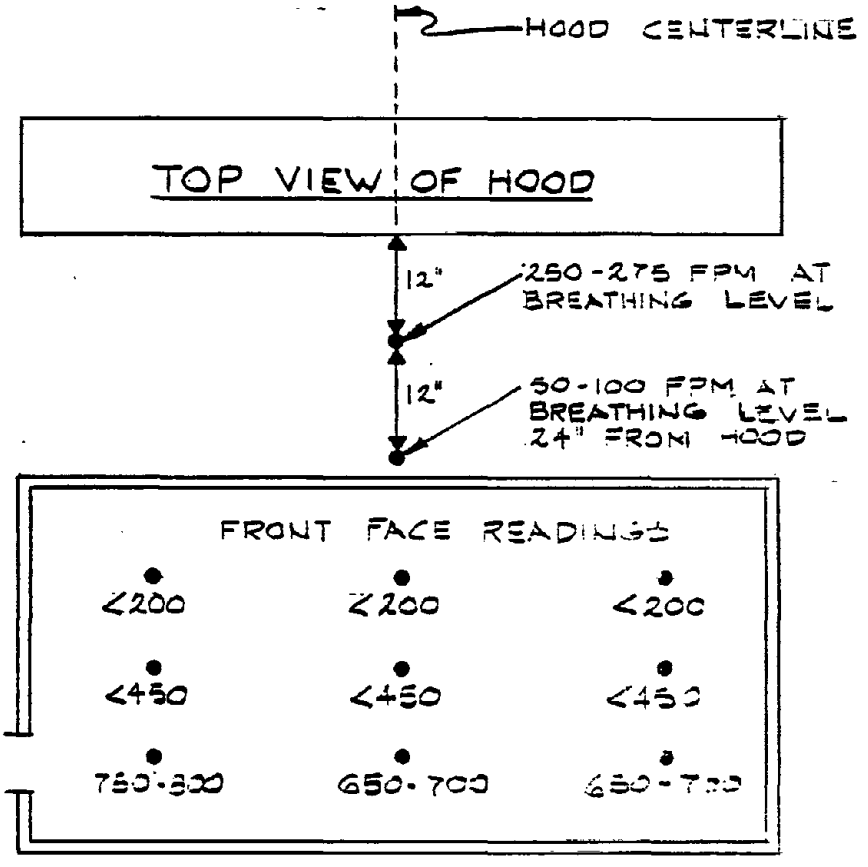
In operation, bags of asbestos (and other dusty materials) are placed inside the enclosure by the worker, then slit open with a knife. The bag's contents are then dumped through the bottom grate and into the screw conveyor. The empty bag can then be conveniently disposed of through a duct in the enclosure's wall into a clean plastic disposal bag. This eliminates the potential for dust generation associated with handling empty asbestos bags. In addition, the screw conveyor is convered and tilted slightly back towards the hydrapulper to facilitate washing with water. Access covers are provided to service it should jams or leaks develop, and a damper is fitted at its outlet for isolation when not in use.

The exhaust duct takeoff for the enclosure is from the top and leads directly into an exhaust fan rated at 3000 CFM. It then drops down into a baghous directly below on the warehouse floor. A sliding gate valve is provided in the duct near the enclosure in order to control air flow and to isolate the enclosure from back pressure created by the pulsating baghouse air cleaner.

The baghouse is a Carborundum Pulseflo Model 81-S-8. It is designed to accommodate 6,000 CFM of contaminated air so that the mill can add another complete bag opening enclosure in the future. The filter bag has 738 square feet of cloth area or a 4:1 air to cloth ratio at 3000 CFM. Captured asbestos fibers are continuously cleared from the bag by means of timed blasts of 100 psig air at 12 CFM. They then drop into a hopper in the baghouse bottom. From here, they are discharged through a

magnetic vibrator and Kopper rotary valve, and are collected in a plastic bag. They can then either be reused in the process, or sealed and labeled for proper disposal.

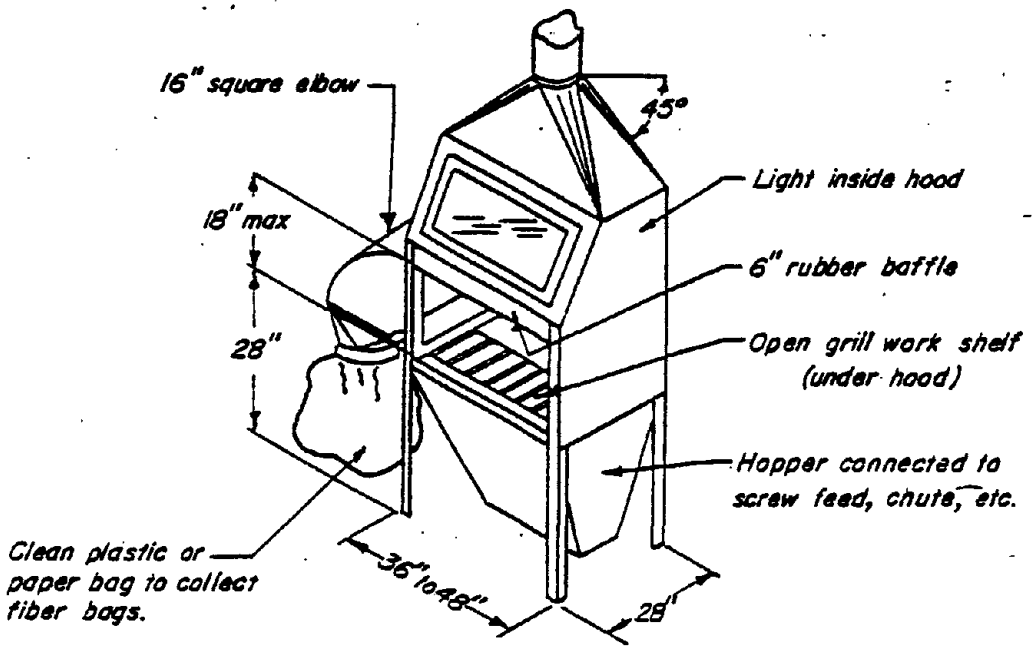
The bag opening enclosure is designed to provide face velocities between 250 and 400 FPM. This is controlled by the position of the Plexiglas door and the duct damper. Velometer readings were taken at the front face and at horizontal distances in front of the hood with this door at 35-40° angle from vertical and the damper fully open. Results indicate excellent capture velocities for asbestos fibers, even with a worker creating air flow turbulence by standing directly in front of the hood.



FRONT VIEW OF HOOD

READINGS IN FEET PER MINUTE WITH HOOD ACCESS DOOR AT 35-40° ANGLE FROM VERTICAL AND DUCT DAMPER FULLY OPEN

FIGURE 24-1



Q = minimum 250 cfm/sq ft of open area
Duct velocity = 3500 fpm minimum
Entry loss = 0.25 duct VP

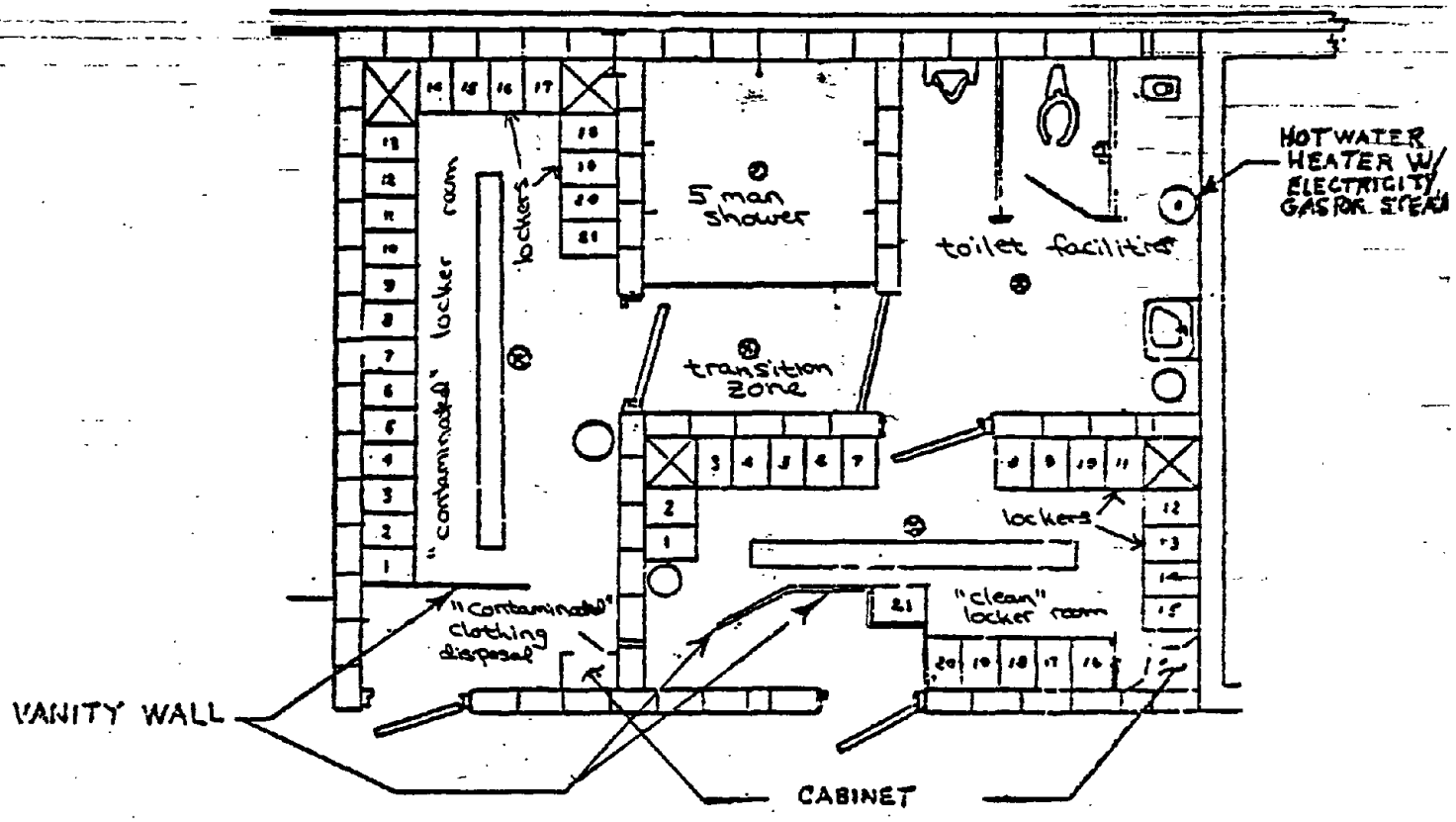
Ref: Industrial Ventilation, 1978, American Conference of Governmental Industrial Hygienists.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	
ASBESTOS FIBER BAG-OPENING	
DATE 1-78	VS-1001

Reference 125

APPENDIX B

FIGURE 24-2: ASBESTOS SHOWER/LOCKER ROOM



NOTES

1- ALL WALLS CEMENT BLOCK, EAST WALL INSULATED
2- INSIDE WALL SURFACE EPOXY HIGH FINISH PAINT
3- FLOOR SCUPPERS 6"ϕ - DRAIN PIPE 4"ϕ PITCH ¼" TO 1'
4- 4" CEMENT SLAB ON EXISTING FLOOR AFTER PIPE LAYED
5- LOCKER 12"X18"X66" - SIT ON 2" CEMENT BASE
6- BENCHES 8' WIDE 17" HIGH - WOOD W/ METAL LEGS
7- STEEL DOORS 2'-10" X 6'-5" INSIDE DOORS W/ WINDOW
8- SLOPING LOCKER TOPS; CORNERS WITH SLOPE TOP
9- SHOWER STALL WITH 2"x4" CURB, ROUNDED TOP; SAME SIZE CURB BETWEEN SHOWER AND TOILET ROOMS
10- STORAGE CABINETS INSTALLED AS INDICATED IF NEEDED - 2" HIGH BASE
11- SUMP PUMP CAPACITY 30 GPM (Lunch Space)
12- CEILING STRUCTURE W/ FLOOR TO SUPPORT 50 LBS. PER SQ FT.
13- LIGHTS 2'X4' FIXTURE; 5½' APART LENGTH TO ROOM WIDTH - SOUTH & NORTH ROOMS - TWO FOR SHOWER AREA; TWO FOR TOILET AREA
14- CEILING EXHAUST FANS 500 CFM EA ROOM
15- DIMENSIONS NOT FIRM FOR EQUIPMENT INSTALL.

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APPENDIX C

RESPIRATOR PROGRAM

(For exposure to asbestos and other fibers only)

Person(s) Responsible -

Overall: Asbestos Policy Committee
Daily Inspections: Shift Foreman

Type of Respirator -

Normal exposure: (i.e. for up to 20 fibers/cc as 8 hour TWA). A single-use purifying respirator (mask) of NIOSH approval No. TC-21C-132 (3M Co. 08710 or equivalent)

Emergency cleanup: (i.e. cleanup of large dry asbestos spills under supervision of policy committee only). For fiber levels expected to exceed 100 fibers/cc use a powered air-purifying respirator and full facepiece or type "C" supplied-air respirators.

Standard Operating Procedure

- Respirators are stored in the cabinet near the pulper control panel and the asbestos locker room.
- A clean respirator should be obtained by each employee required to wear one prior to commencement of work.
- Employees required to wear respirators for their work tasks but unapproved medically for such must be rotated to other tasks until so approved.
- It is the responsibility of the shift foreman to ensure that all assigned employees have been instructed in the proper fitting and seal testing of the respirator. The shift foreman has the responsibility to see that such instructions are repeated at the commencement of each new asbestos production run for any new employees. (Instructions for fitting and leak testing are given on the 3M 08710 package box).
- Employee failing to properly wear respirators will be subject to disciplinary action.

- Respirators should be disposed of in designated asbestos disposal containers at the commencement of a work shift. Badly soiled or contaminated masks should be replaced during shifts as needed.

- Day-to-Day enforcement of the respirator program is the responsibility of the particular shift foreman. Inspections should be made each shift. Violations should be reported to the asbestos policy committee for action.

- Employees required to cleanup dry asbestos-containing spills or debris should consult the shift foreman as to the need and type of respirator protection required.

Coverage - (During asbestos use)

- All production and maintenance personnel while engaged in the operation, servicing and cleanup of the:

  - Bag opening station and transport system (including dust collector cleaning)

  - Pulper tank and feed system

  - Other plant areas where dry asbestos was stored or spilled or used (also changing of vacuum cleaner bags)

  - All other employees required to perform tasks in the above areas for more than four (4) hours per shift, or who are reasonably expected to be exposed to fiber concentrations in excess of 0.1 fibers/cc for an eight (8) hour TWA or as determined by the asbestos policy committee.

  - These levels and policies shall be reviewed and adjusted as more data is collected on each grade of asbestos paper produced.

Disposal Respirators for Protection against Air Borne Asbestos
Standard Procedure for use of the 3 M No. 09710
Permissible Respirator for Dust

Approval No. TC-21-C-132

I. Areas of Use

This disposable respirator must be worn whenever grades of paper being run contain asbestos fiber in the following areas:

760

A. Pulper room
B. Raw material warehouse - asbestos storage area
C. Rewinder area, when baling trim and stacking coils
D. Fork truck drivers - whenever transporting asbestos and/or driving in the pulper room and raw material warehouse during above-mentioned runs.

II. Standard Procedure for Use.

A. Storage location - respirator will be stored in dust proof cabinet located on outside wall of the shower/locker room.
B. Upon entering pulper room disposable respirator masks can be immediately obtained and put on.
C. Follow exact procedure, clearly written and pictured on box to properly fit and wear respirator. Proper fitting and wear is mandatory so that proper filtration efficiency will result. Use both straps, etc.
D. Disposal - after use, end of shift period or other reason. Respirator masks should be removed and placed in impermeable plastic designated for asbestos contaminated waste.

APPENDIX D
HOUSEKEEPING PROGRAM

Person(s) Responsible -

Overall: Asbestos Policy Committee
Daily Enforcement: Shift foreman

Elements -

1. Spill Prevention, Labeling, and Storage

- Raw asbestos and asbestos-containing material should only be transported in fully enclosed containers, labelled and the following readily visible and legible warning:

CAUTION

Contains Asbestos Fibers
Avoid Creating Dust
Breathing Asbestos Dust May Cause
Serious Bodily Harm

This requirement pertains to all raw materials, mixtures, scrap, waste, debris and other products containing asbestos fibers that could reasonably be expected to be released to the atmosphere during handling, storage, processing, transportation or disposing. Such label should remain on the material or its container throughout its use.

- Readily visible and legible warning signs should be placed near the bag opening station, the asbestos storage area, and the pulper control panel. Signs should contain the following specified warning in a 20" x 14" vertical format:

CAUTION

Legend	Notation
Asbestos	1" Sans Serif, Gothic or Block
Dust Hazard	3/4" Sans Serif, Gothic or Block

Legend	Notation
Avoid Breathing Dust	1/4" Gothic
Wear Assigned Protective Equipment	1/4" Gothic
Do Not Remain in Area Unless Your Work Requires It.	1/4" Gothic
Breathing Asbestos Dust May be Hazardous to Your Health	14 Point Gothic

Spacing between lines shall be at least equal to the height of the upper of any two lines.

The asbestos storage area sign should also specify "Authorized Personnel Only".

o All raw asbestos and asbestos-containing waste or material scraps must be properly labelled and stored only within the curtained area at the raw material warehouse in the northwest corner of the plant.

Raw asbestos bags should be inspected by the shift foreman when delivered to the plant. Improperly packaged, broken or unlabeled containers should not be accepted and returned to supplier. Material should be stored on wooden pallets and preferably be covered.

During production runs requiring the use of asbestos, the shift foreman should make daily inspections of the storage area. Broken, torn or damaged containers and bags should be transferred (using respirator, gloves, and coveralls) to a labeled 6 mil plastic bag or other acceptable container. Any spilled material should be reported and cleaned up as directed in the following sections.

Only production and maintenance personnel verbally authorized by the shift foreman are allowed in the asbestos storage area.

2. Spill and Plant Cleanup

- All incidents of spills of asbestos or asbestos containing materials in a dry or drying state must be reported to the shift foreman immediately. The shift foreman will make daily inspections of the asbestos storage and use areas for the presence of spills which could cause airborne asbestos fibers.

- All spills will be cleaned up using the following procedure:

  a. The shift foreman will verbally appoint the person(s) responsible for cleanup. He will then diectly supervise the operation and insure compliance to the following procdures.

  b. No broom or other device that could cause fibers to become airborne should ever be used on dry materials.

  c. The cleanup personnel must wear an approved respirator, full protective coveralls, and disposable gloves.

  d. Material should be carefully placed in a 6 mil plastic trash bag, tightly sealed and clearly labeled as containing asbestos. Spills should not be wet vacuumed. The labeled waste should be recylced or stored in the asbestos storage area until disposal in an approved landfill can be arranged.

  e. The spilled material should be slowly wetted using a fine spray of water while being aggregated together for collection with a trowel or dust pan.

  f. The spill area should then be wet mopped or sprayed down and flushed with water, allowing the wastewater to flow into the plant waste stream. In the case of particularly severe spills, the area should additionally be dry vacuumed afterward using the absolute filter vacuum.

  g. At the conclusion of cleanup the site should be inspected by the shift foreman.

- At the conclusion of an asbestos-using production run, a plant cleanup program should be undertaken. The procedure should include:

a. Assignment by the asbestos policy committee and shift foreman of a cleanup crew.

b. Use of full protective equipment by each member - respirator, coveralls, and gloves.

c. The wet mopping and hosing down of the floors in the bag opening, dust collection, and hydropulper tank areas. Dry vacuuming using the approved absolute filter cleaner of the horizontal and vertical areas around the bag opening and dust collection (baghouse) areas and the locker/washrooms.

d. Disposal of all liquid and dry wastes (including vacuum cleaner bags) in a clearly labeled plastic disposal waste bag. All wastes should be stored in the asbestos storage area until transport to an approved landfill can be arranged.

e. Periodic inspection of the cleanup operation by the shift foireman for compliance to the above requirements, and a signed record of completion to the asbestos policy committee.

3. Ventilation System Inspection

Before commencement of each new asbestos-using production run, the plant maintenance staff, Production Superintendent, or Technical Superintendent must thoroughly inspect the asbestos bag opening station, its ventilation system, and dust collector. The ventilation system and dust collector must run continuously while in asbestos-using production irregardless of whether the bag opening station is in use. This inspection should include:

- Confirmation of sufficient face velocity across the bag opening hood for asbestos dust containment by performance of a simple smoke capture test or use of an accurate air velocity measuring instrument.

- Visual inspection and evaluation of the raw asbestos transport system for proper functioning and tight sealing.

- Inspection and evaluation of the dust collector system for proper installation and operation of the filter or bag, and performance of the exhauster.

The shift foreman should regularly check all ventilation systems to insure that they are on and operating properly.

On a yearly basis, the entire plant ventilation system and each component should be thoroughly inspected by a competent ventilation person. Such inspection should include a check for physical damage (broken, corroded, coated, or partially blocked ducts and fan blades) and proper operation of components (fan rotation, damper positions, air cleaner condition, temperature and alarm controls, etc.). Additionally, face velocities across all inlets of hoods and transport velocities in critical ducts and connectors for exhausting hazardous materials should be measured and compared to initial recommended or design requirements. Any identified deficiencies should be reported to the asbestos policy committee and plant engineering for corrective action.

A ventilation system quality control logbook should be maintained by the policy committee for recording of all inspection data. Components showing high incidence of failure and wear, or decreased efficiency should be placed on a regularly performed maintenance schedule.

APPENDIX E

PERSONNEL HYGIENE PROGRAM

Person(s) Responsible -

Overall: Asbestos Policy Committee
Daily: Shift Foreman

Requirements

1. No smoking is allowed at any time by any production, maintenance or supervisory personnel while in or performing tasks in the following areas during asbestos production runs:

   - o Bag opening station including servicing of dust collector
   - o Asbestos storage area.
   - o Area around hydropulper tank including feed system.
   - o Production personnel while performing tasks of pulper operation and charging.
   - o Maintenance men while servicing equipment and machinery in any of the above areas or while performing "asbestos cleanup" operations, as defined in the Housekeeping Program (including spill cleanup).
   - o Smoking while performing other production activities such as paper machine tending, backtending, slitting and rewinding, and packaging and shipping should be strongly discouraged.

   Requirements of this item must be strictly enforced by the asbestos policy committee through the individual shift foremen. Smoking is allowed in the plant lunchroom, washrooms, plant floor level offices, and any non-designated areas. However, any employees working in areas or performing tasks indentified in the preceding section must wash his or her hands before commencing to smoke anywhere within the plant.

2. Personnel protective equipment

The following personnel must wear full-body coverage protective coveralls throughout performance of their eight (8) hour or longer assigned work tasks. Such protection includes company supplied disposable (cloth) full-body coveralls, disposable booties or washable (rubber) boots, and, preferably, a head hood and disposable or washable gloves.

- o Pulper operator and helper
- o Maintenance and spill cleanup crew while performing work in areas in which asbestos is contained or used.

Use of protective coveralls by paper machine operator, testmen, backtender, rewinders, forklift operator and others is optional, but recommended.

Reuseable shirts, pants, and boots are acceptable for outer protection for any personnel other than the pulper operator and helper provided that:

- o Clothing is changed and stored between work shifts only in the "dirty" side of the locker room.
- o Dirty clothing is placed in a plastic bag at the conclusion of each work week by all employees and washed by a person authorized by the asbestos policy committee.
- o No amount of excessive (visible) dust remains on the clothing while a worker is on break or lunch time and then moves from his assigned work area to other plant locations. Such dusts should be removed with the approved asbestos vacuum cleaner.

Workers using disposable coveralls (and other protective equipment) should remove and/or fully vacuum off such whenever leaving their work area or the plant. Rubber boots should also be washed off before moving about the plant. Badly soiled coveralls should be changed and disposed in a 6 mil plastic waste bag clearly labeled with an asbestos hazard warning.

3. Locker/Washroom Use

The locker room should be completely cleaned and outfitted with supplies before each asbestos production run (coveralls, booties, respirators, hoods, and towels, and disposal bags).

All employees assigned to wear protective equipment (respirators, coveralls, etc.) during asbestos production runs must use the locker/washroom for post-shift personal cleanup and storage of reusable equipment and garments. The locker/washroom should be operated on a single direction basis only - contaminated employees entering from the locker side; uncontaminated from the (clean) washroom side. Employes wearing protective coveralls and soiled shoes needing to use the toilet facilities during a production shift must use only this facility. Entry must be through the "dirty" side of the locker room with removal of vacuuming of contaminated clothing before entering the washroom.

Contaminated clothing and respirators to be discarded must be disposed of in a sealed and labeled plastic waste bag placed in a container in the "dirty" side of the locker room. Unsoiled and untorn clothing may be stored in lockers and reused on the following shifts. Respirators may only be used for single shifts.

Company supplied new coveralls and respirators should be stored and disposed of in the locker room. Employees entering the "dirty" side of the locker room must wash or wipe off the soles of their shoes outside beforehand. Employees not exposed to asbestos fibers or not wearing protective equipment should use other plant facilities during asbestos production runs.

All production, maintenance, and supervisory plant personnel who have come in surface contact with asbestos materials must thoroughly wash their hands and faces after each asbestos production shift before leaving the plant. Pulper operators and helpers should ideally take showers after each shift. Street clothes should be kept only in the "clean" side of the locker rooms.

4. Eating and Drinking

No eating or drinking is allowed in the pulp room, loading dock area, or outside the plant. Production workers, during asbestos operations, currently

required to eat while at their work stations should be relieved to eat in an approved area, or the production process should be scheduled and operated so as to allow workers a sufficient eating period. All potentially exposed employes must thoroughly wash their hands before eating and remove any protective equipment.

APPENDIX F

ASBESTOS TRAINING PROGRAM

Objective - To make employees aware and conscious of the hazards of asbestos handling and inhalation; and the specific engineering, work practices, process, and administrative controls which the plant has developed to insure their protection. Also to clearly inform all employees of their obligations and rights under the OSHA asbestos standard and the developed programs, and to provide a vehicle by which their questions and concerns can be dealt with.

Coverage - All protective and maintenance personnel.

Program Responsibility - Asbestos Policy Committee and Consultants

Frequency - Initially a thorough verbal or written presentation upon commencement of employment for all new production and maintenance personnel. Yearly refresher presentations at the annual plant meeting.

Curriculum - (Initially and for all new employees)

- Complete description of what asbestos is; how it is stored, used and handled in the plant; and what the hazards of its inhalation are.
- A thorough presentation of what the OSHA asbestos standard is; the rights and responsibilities of both the employee and employer under the Act and Standard; and the specific engineering, process, and work practices controls that he plant has installed and implemented for asbestos control (and also their operation and performance).
- A thorough explanation of the elements and requirements of the medical, air monitoring, respirator, personal hygiene, housekeeping, QC/inspection/auditing and training administrative programs.
- Presentation of the normal level of exposure which each employee can reasonably expect to encounter in this job.

Additional Elements

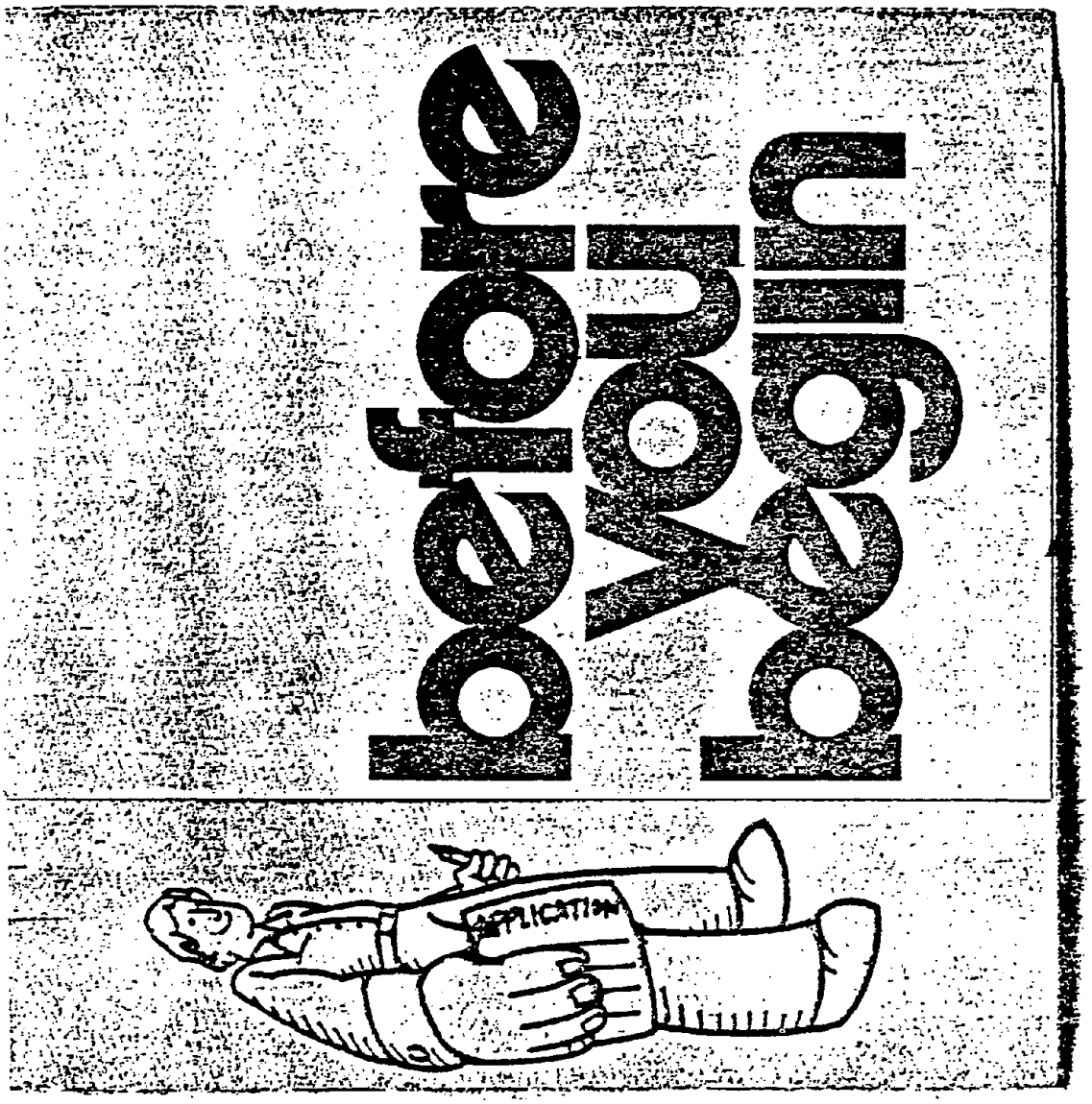
- o A standard employee-signed Letter of Acknowledgement of completion of the program to be kept in the employee's personal file.

- o An open file of reference material and exposure data to be kept in the personnel office (i.e. the asbestos standard, written copies of all programs, exposure data, pertinent sections of the Occupational Safety and Health Act, and copies of the Revised NIOSH Recommended Asbestos Standard and all past survey reports).

- o A protocol by which employees may submit and receive answers to their questions.

(Based on this program, the mill developed an excellent information booklet which is given to each production employee. Included in the booklet is a tearout card by which the employee can acknowledge his receipt and understanding of the control program. This booklet is reproduced in the following pages.)

COPY OF EMPLOYEE ASBESTOS INFORMATION BOOKLET



There Are Some Things You Should Know

Every person seeking employment at _____ where asbestos fiber is used should know that breathing excessive amounts of asbestos causes certain health problems.

_____ has taken many steps to protect you from exposure to harmful amounts of asbestos fiber. To make these steps effective, you must follow safe working rules on the job.

The health problems

So we can be sure

NOT REPRODUCIBLE

The health probelms that have been connected with exposure to asbestos are these:

- Breathing excessive amounts of asbestos fiber in the air might result in a disease called **asbestosis**—a scarring of the lung tissue—which, when severe, makes it difficult to breathe properly.

- Persons who smoke cigarettes and inhale excessive amounts of asbestos dust are at a greater risk of developing **lung cancer.** Asbestos alone does not appear to cause this disease, but it can make people who smoke cigarettes more likely to develop this cancer. Studies show that if you don't smoke cigarettes, asbestos exposure does not increase your risk of getting lung cancer.

- Persons exposed to excessive amounts of asbestos have a greater risk of developing **mesothelioma,** which is a rare cancer of the lining of the chest or abdomen. There also is some indication from unconfirmed studies that there might be a greater incidence of **cancer of the digestive tract** in persons exposed to excessive amounts of airborne asbestos.

Be concerned, not alarmed

Be concerned, not alarmed about asbestos-related health problems in coming to work for today. Present cases of the health problem we mentioned are related to working conditions that existed many years ago. As we became aware of the risks, began spending thousands of dollars to improve equipment and processes and to upgrade dust control systems to prevent excessive asbestos exposures. We are confident that as long as employees follow safe work rules and equipment is operated properly, no employee will be exposed to hazardous amounts of asbestos fiber in our operation.

To assure continued control of risk, the company will be regularly checking asbestos-using operations with trained industrial hygienists. You must cooperate with these hygienists when they are checking your work areas.

Government inspections are also made of our facilities to make sure you are not being exposed to hazardous levels of asbestos. The government has set standards that limit how much asbestos you can be exposed to, and abides fully with those regulations.

You will be required to do certain things on the job to help us protect you. Some of these are:

1. You **must** do everything you can to prevent dust or getting asbestos fiber into the air where it could be inhaled.

2. Strict rules about how to perform your job **must** be followed at all times.

3. In some areas you may at times be required to wear a respirator temporarily or other forms of personal protective equipment. You **must** wear this equipment properly whenever it is necessary.

4. You **will** be requested not to smoke on the job i you might be exposed to asbestos. You will be urged, for your health's sake, to quit smoking completely.

5. You **will not** be permitted to take any asbestos material home from the plant in order to prevei exposing others. You will be encouraged to use facilities provided to change work clothes and wash before going home.

6. If equipment is not working correctly, you **must** report it to your supervisor immediately.

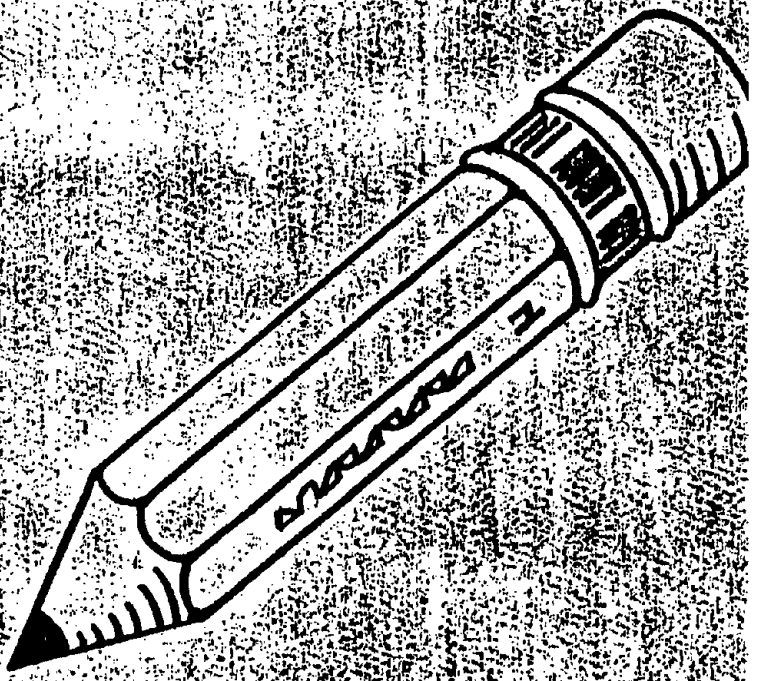
VIOLATION OF HEALTH WORK RULES CAN RESULT IN DISMISSAL.

After you begin work

After you begin work, you will be given an opportunity to learn more about the potential health risks of asbestos and what the company is doing to protect you on the job. You will be taught how to use personal protective equipment and other methods of protecting yourself. Because of the efforts of [illegible] and your own efforts, it is [illegible] as likely that you will be as safe working for [illegible] in any other occupation or endeavor. That is the way we want it. We will not take chances with your health and we won't allow you to take chances with it.

Violation of health work rules can result in dismissal.

REFER TO THIS BOOKLET OFTEN



So we can be sure you have read this booklet and kr
about the potential risks connected with your job an
the strict rules you must follow, we would like you to fi
out the form at the right and return it to us. This sheet
must be forwarded to the personnel office before you
first pay period ends.

Reproduced from best available copy.

Tear Off This Form at the Dotted Line

Hand in the Form. But Keep This booklet and Refer to It Often

Have you read the whole booklet? _____ Yes _____ No

Do you understand the health risks connected with asbestos? _____ Yes _____ No

Do you understand that smoking cigarettes increases the health risks connected with asbestos? _____ Yes _____ No

Do you understand that you will have to follow certain work rules set by the company to protect you? _____ Yes _____ No

Do you have any questions about what you have read in this booklet? _____ Yes _____ No

Please sign your name and put today's date below.

Signed _____ Date _____

SECTION VII MILL MAINTENANCE OPERATIONS

Mill 05 Felt Cleaning

Mill 17 General Maintenance Operations

MILL 05 FELT CLEANING OPERATIONS

PROCESS SUMMARY

The press and drier section felts on the paper machines are washed when necessary, usually once every week. A variety of acids (sulfuric or phosphoric) and alkaline compounds (sodium or potassium hydroxide) are used in three to ten percent solution.

For the press section felts, the 5 percent sulfuric acid cleaning solution is made up in a 'soap' tank and pumped to the two showers as shown on Figure 05-1. For the drier section felts, the 10 percent sodium hydroxide solution is prepared in a portable auxiliary tank, which is then wheeled into position and connected to the two showers.

Both solutions are manually prepared by an all-purpose helper (Sixth Man) for the three paper machines. One additional employee hoses down the felts to remove suds created by the washing action. The entire washing operation is usually completed in less than one hour.

JOB CATEGORIES AND DESCRIPTIONS

Although variable, one or two employees usually perform the felt cleaning operation:

Sixth Man - The sixth man is responsible for preparing all washing solutions and assisting as needed in other tasks.

Helper - The helper regulates the flow and dilution of cleaning solutions to the showers, and manually hoses down the felts.

POTENTIAL WORKPLACE CONTAMINANTS

The primary air contaminants that may be emitted from the washing operation include sulfuric and phosphoric acids, sodium and potassium hydroxides, and possibly butyl cellusolve. There is also a potential for skin contact with these strong acids and/or alkalies, particularly when the cleaning solutions are being prepared.

Washing solutions are prepared manually - buckets of commercial acid or alkali felt cleaning chemicals at strengths up to 45 percent are dispensed from 55-gallon drums and dumped into the cleaning solution tanks containing sufficient water to effect the desired dilution. When these solutions are discharged at the press and drier showers, an airborne mist may escape and contaminate the workplace.

EVALUATION OF POTENTIAL EXPOSURE SOURCES

One personal sample for sulfuric acid (No. 1, Table 05-1) was collected while the sixth man prepared the cleaning solution for the press section felt. No sulfuric acid was detected, but the samples detection limit (2 mg/m^3) was above the OSHA PEL of 1 mg/m^3 because of the short sampling time during this operation.

Area samples for sulfuric acid and sodium hydroxide were collected before, during, and after a felt cleaning operation for the drier and nearby press sections. Sampling devices were positioned at the control panel next to the drier section and on the near side of an adjoining paper machine. As shown on Table 05-1, neither sulfuric acid (< 0.2 to < 0.97 mg/m^3) nor sodium hydroxide (< 0.21 to < 0.75 mg/m^3) were detected on any of the samples.

Press and drier section felts of another paper machine were washed the following day. Area samples at its drier section and at a nearby adjoining paper machine resulted in non-detectable concentrations of sulfuric acid and sodium hydroxide after the washing operation. One area sample, analyzed for total sodium, resulted in a measured concentration of 0.18 mg/m^3.

CONTROL OF EXPOSURES

Personal Protective Equipment - While preparing the washing solutions, the sixth man wore rubber boots, goggles, a face shield, a full-body rubber suit, and rubber gloves. During the washing operation, involved employees did not use any personal protective equipment.

Nature of Operation - Extremely small quantities of felt cleaning chemicals are contained in the washing solutions. In almost all instances, the sulfuric acid or sodium hydroxide comprises less than three percent of the prepared washing solution. Hence, the aerosol generated during the washing operation is predominantly water.

Process Modification - Ten or fifteen years ago, the felts were cleaned by hand. Obviously, more employees were required, potential exposure times were greatly increased, and the potential for skin contact with or inhalation of chemicals was higher. Today the operation requires little intervention by mill employees. Once the washing solutions have been prepared, employees only regulate and monitor the flow of solution to the showers and periodically hose down the felts. In effect, the employees are now largely remote from the operation.

TABLE 05-1 FELT CLEANING SAMPLING RESULTS

AIR SAMPLES - SULFURIC ACID1

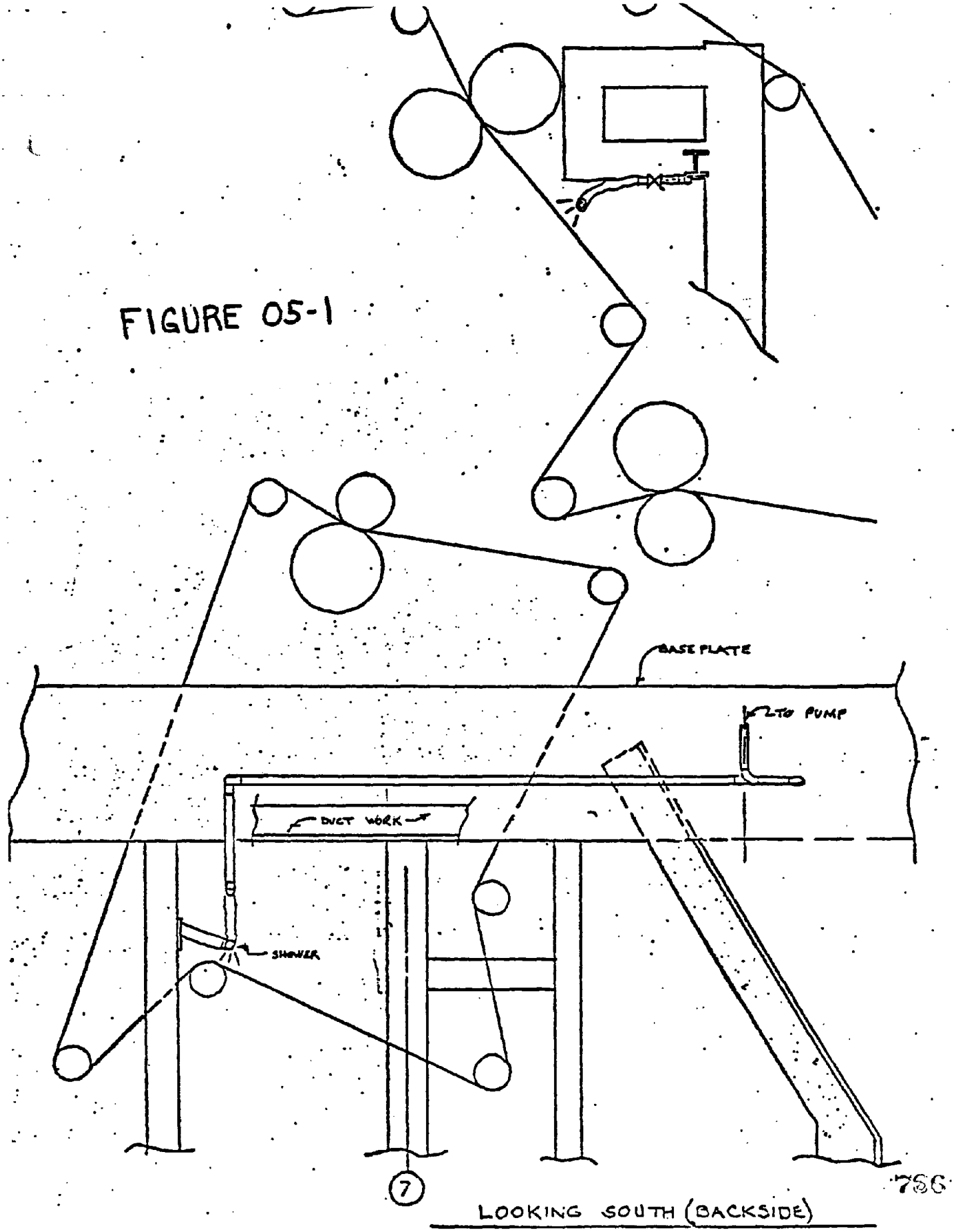
Sample No.	Day	Location	Sampling Time (Minutes)	Result (mg/m3)	OSHA PEL (mg/m3)	Comments
1	1	Personal sample-on Sixth Man	18	< 1.98	1	Making up washing solution
2	1	Control panel-adjacent to dryer Section	119	< 0.27	1	Background Sample before washing
3	1	Control panel-adjacent to dryer section	40	< 0.83	1	During washing operation
4	1	Drier section-of adjoining paper machine	37	< 0.97	1	During washing operation
5	1	Control panel-adjacent to drier section	93	< 0.42	1	After washing operation
6	1	Drier section-of adjoining paper machine	94	< 0.39	1	After washing operation
7	2	Adjoining paper machine	194	< 0.14	1	~1 hour after washing operation
8	2	Near drier section	193	<0.11	1	~1 hour after washing operation

TABLE 05-1 (Continued)
AIR SAMPLES - SODIUM HYDROXIDE2

Sample No.	Day	Location	Sampling Time (Minutes)	Result (mg/m3)	OSHA PEL (mg/m3)	Comments
9	1	Control panel-adjacent to drier section	39	< 0.51	2	During washing operation
10	1	Control panel-adjacent to drier section	98	< 0.21	2	After washing operation
11	1	Drier section-of adjoining paper machine	25	< 0.75	2	After washing operation
12	2	Adjoining paper machine	194	< 0.086	2	~1 hour after washing operation
13	2	Near drier section	207	< 0.07	2	~1 hour after washing operation
14	2	Adjoining paper machine	194	0.18	-	Sample analyzed for total sodium[3]

[1]Analysis by barium perchlorate titration (NIOSH S-174)
[2]Analysis by back-titration (NIOSH S-381)
[3]Analysis by atomic absorption (NIOSH P&CAM 173)

FIGURE 05-1



LOOKING SOUTH (BACKSIDE)

MILL 17: BLEACH PLANT AND KRAFT PULP MILL MAINTENANCE OPERATIONS

INTRODUCTION

Mill 17 is fully integrated pulp and paper mill with an additional paper converting operation and complete woodyard. The two pulping systems are: 1) a refiner groundwood mill (approximately 300 tons per day) and 2) a bleached Kraft pulp mill consisting of a Kamyr continuous digester and a M & D sawdust digester. The Kraft pulp is deknotted, screened, washed, thickened, and then bleached in an automated five-stage bleach system. Chemical preparation and recovery systems for the Kraft pulping process include a conventional recausticizing system with a single, rotary kiln; chlorine vaporizers; sodium hypochlorite makeup equipment, a chlorine dioxide generator (2-stage); chemical unloading and storage tanks; and a single recovery furnace and steam boiler.

SUMMARY OF MAINTENANCE PROGRAMS

Maintenance activities at Mill 17 consist of three interrelated programs:

- scheduled shutdowns
- preventative maintenance
- lubrication maintenance

Scheduled shutdowns fall into two categories. Every year there are major shutdowns coinciding with the Christmas and Fourth of July holidays. During these five to seven day periods, all process systems are brought down for cleaning, inspection, and major repair if necessary. In addition, every thirty days one of the digester systems is shutdown for about 12 hours to allow maintenance personnel to catch up with needed repairs.

Preventative maintenance activities are shared by three separate groups, each responsible for specific areas in the pulp mill:

Area 1: digester, brown stock washers, lime kiln - 12 employees
Area 2: bleach plant, chemical prep - 10 employees
Area 3: woodyard, groundwood mill - 12 employees

Typically, equipment malfunctions are reported via work orders to the appropriate area foreman. If the malfunction is not considered to be an emergency, the work order is forwarded to the maintenance coordinator and filed in one of the punch lists corresponding to the nature of the problem (i.e. mechanical, electrical, or instrumentation).

At the end of the third shift, all punch lists are forwarded to the area maintenance foreman for assignment. As the jobs are completed; the maintenance personnel make inspection tours of mill areas for which they are responsible. Depending on the particular service, the maintenance history, certain equipment must be inspected daily. Other less critical equipment is inspected less frequently. In general, the maintenance employees check for excessive heat, noises, and liquid or gaseous leaks.

The lubrication maintenance staff consists of an additional seven employees who, on a set schedule, grease and oil all equipment in the mill. One of these employees is permanently assigned to the pulp mill and works very closely with the preventative maintenance staff in that area.

POTENTIAL WORKPLACE EXPOSURES

Maintenance employees may periodically be exposed to any of the primary air contaminants emitted from the pulp mill: hydrogen sulfide, methyl mercaptan, dimethyl sulfide, chlorine, and chlorine dioxide. The greatest potential for exposure of these agents occurs during leaks, or when the employees must enter a vessel or break a line previously containing process materials. Maintenance employees must also periodically enter mill areas containing noisy equipment.

AIR SAMPLING RESULTS

Air samples were collected on two employees during routine maintenance operations and equipment inspection tours. The first of these was assigned to the bleach plant, and 16 short-term personal samples for chlorine and/or chlorine dioxide were collected on two consecutive days according to NIOSH Method P & CAM 209. The results of these samples and corresponding activities performed by the worker during each sample period are presented in Table 17-1.

The sampled employee performed three maintenance tasks and conducted inspection tours throughout the bleach plant and the chemical preparation building. During the first day (11^{24} to 15^{50}), a leaking plug valve on one of the liquid chlorine unloading lines were located and replaced. As shown on Table 17-1, the employee was exposed to significant levels of chlorine (0.58 ppm, 0.32 ppm) while locating the leak and purging/valving off the chlorine line. The actual exposure levels could not be quantified because of depletion of the sampling reagent by the high chlorine levels. However, the employee wore a full faced, acid gas, canister respirator for the majority of this period. When the employee returned with a replacement valve (14^{10} -14^{15}), the exposure levels had been reduced to 0.05 ppm chlorine. However, when the chlorine

TABLE 17-1: PERSONAL EXPOSURE RESULTS - BLEACH PLANT MAINTENANCE EMPLOYEE

Day	Sampling Period	Employee Activities	Exposure Concentration (as ppm Cl_2)**
4	10^{20} - 10^{35}	o inspected bleach washers	0.04
	10^{38} - 10^{53}	o checked air compressors, steam mixers, thick stock pumps in bleach plant	0.03
		o inspected superheater, vaporizers and air dryers in chemical prep area	
	11^{24} - 11^{28} 11^{32} - 11^{39}	o investigated chlorine alarm at the railroad car unloading station	>0.58* >0.32*
		o ammonia solution used to located leak (2 inch Durco plug valve)	
		o purged and valved off chlorine line	
		o full-face canister respirator was used during this operation	
	14^{10} - 14^{15}	o checked size of valve to be replaced	0.05
	14^{27} - 14^{42}	o changed valve; full-face canister respirator used	>0.17*
	14^{42} - 14^{52}		<0.01
	15^{15} - 15^{30}	o checked chlorine tank cars and chlorine monitor	<0.01
		o went to control room to determine why alarm was still on (reset button not pushed)	
	15^{40} - 15^{50}	o reset chlorine monitor and silenced the alarm	<0.02
5	9^{02} - 9^{17}	o changed filter on padding air dryer	0.01
	9^{19} - 9^{34}	o inspection tour of second floor chemical prep area (noted valved handle on padding air system was slipping)	<0.01
	10^{18} - 10^{33}	o valve stem tapped and dried; handle refitted on stem	<0.01
	10^{34} - 10^{49}	o check compressors on second floor of chemical prep area	<0.01
	10^{50} - 11^{05}	o inspected bleach washers	<0.01
	11^{06} - 11^{21}	o inspected steam mixers	<0.01
		o hosed down stock pump and floor	
	11^{23} - 11^{51}	o inspected chlorine dioxide and hypo seal tanks	<0.01

* Exposure environment was too high to quantify by the utilized sampling method, collection solution volumes, and air sampling rate (i.e. 15 milliliters of methyl orange at air flowra of ≈0.9 liters per minute).

** Determined by NIOSH Method P & CAM 209

line was broken to remove the leaking valve, sufficient residual chlorine remained to cause a significant additional exposure (>0.17 ppm) to chlorine). As evidenced by the followng sample (14^{42}-14^{52}), the effect of the residual chlorine was short-lived and the exposure was eliminated (< 0.01 ppm).

During the second day, the employee changed an air dryer filter and replaced a valve stem on the padding air line. Since neither of these lines contain chlorine, there was no significant exposure during these operations (0.01 ppm, < 0.01 ppm).

When not repairing or replacing equipment, the employee conducted inspection tours throughout the bleach plant and the chemical prep builidng. Seven short-term personal samples were collected during these tours, with no result exceeding 0.04 ppm as chlorine. During the first day, a Mast Oxidant Monitor was used to monitor chlorine/chlorine dioxide concentrations over a 13 hour period on the bleach washers floor. These data reflect chlorine/chlorine dioxide levels to which maintenance employees may be exposed while conducting tours of the washer floor area. The chlorine concentration on the washer floor did not exceed 0.15 ppm (as chlorine) over the 13 hour sampling period. It is concluded that exposures during routine inspection tours will be very low except during leaks or significant process upsets.

The second maintenance employee whose exposures were evaluated is assigned to the pulp mill. He typically spends much of his shift conducting inspection tours of the Kamyr and M&D digester lines and the brown stock washers. Observations made while accompanying this employee on these tours indicated no apparent leaks in the mill or significant exposure situations, and no exposure samples were collected. On the previous day, another employee (assigned to this same position), conducted a repair operation in the pulp mill, and his exposures to hydrogen sulfide and methyl mercaptan were determined over two 20 minute periods. The operation consisted of replacement of 12 bolts on a 12 inch stock line coming from the blow tank to the brown stock washers, and required less than an hour and a half in total to complete (including cleanup). Since only two of the bolts were removed at a time and replaced immediately, the pipe flange was never apart and little potential for release of gaseous contaminants from this stock line into the workplace existed. No respiratory protection was, therefore, required during this operation. The exposure assessment results are summarized in Table 17-2, and, as shown, non-detectable concentrations of hydrogen sulfide and very low levels of methyl mercaptan were obtained. These results are thought to be related to pulp mill background concentrations of these

TABLE 17-2: PERSONAL EXPOSURE RESULTS - PULP MILL MAINTENANCE EMPLOYEE

Day	Sampling Period	Employee Activities	Exposure Concentration (in ppm) Hydrogen Sulfide[1]	Methyl Mercaptan2
4	10^{30} - 10^{50}	Changing bolts on stock line from blow tank to brown stock washers	0.08	0.13
	11^{28} - 11^{46}	" " " "	0.08	0.25

[1] Determined by NIOSH Method P & CAM 126

[2] Determined by method of Knarr and Rappaport, Anal. Chem., 1980, 52, pp. 733-736

contaminants, rather than local sources related to this maintenance operation. No other pulp mill maintenance/repair operations were conducted during the survey, so no additional exposure evaluations could be made.

CONTROL OF WORKPLACE EXPOSURES

There are two separate but very important facets of control technology relative to mill maintenance operations. First, thorough control procedures must be used to directly protect maintenance workers from process emissions during performance of maintenance, inspection, or repair tasks. Because of the highly variable nature of pulp mill maintenance requirements and the distinct potential for significant exposures, these procedures must be carefully designed and strictly enforced.

Secondly, the effectiveness of the overall preventive maintenance program is a critical factor in the control of workplace exposures for production and other mill workers. Both of these facets of maintenance programs are discussed below.

CONTROL FOR MAINTENANCE WORKERS

Vessel Entry Procedures -

Mill 17 has prepared specific entry procedures for each vessel or other enclosed area in the pulp mill, the bleach plant, and chemical prep building. Because the written procedures are highly specific to conditions at this particular mill, it serves little purpose to present them in this report. However, in general, each procedure includes requirements for the following items:

- equipment that must be shutdown and locked out
- lines that must be valved or blanked off
- purging procedures (water for chlorine dioxide lines; air for chlorine, black liquor, and other lines)
- drains that must be opened
- ventilation that must be provided
- respirator usage and/or availability
- required air sampling
- protective clothing that should be used
- need for standby employees
- safety harnesses

Where specified, air testing is conducted by the technical services staff using an explosive gas analyzer, oxygen meter, and/or detector tubes.

Written Lock-Out Procedures -

Written lock-out procedures has also been developed and are strictly enforced. In general, all machinery and equipment (including pipe lines) must be made inoperative and locked out by the person(s) who will be working on or around the equipment before any work is started. All mechanics are issued personal safety locks to be used as follows:

- o whenever and wherever employees are working on driven machinery, the main switch or prime-motor starting device must be locked out in the stopped or de-energized position separately by all persons working on the job.
- o each employee will be separately responsible for the removal of their lock at the end of the shift or after the job is completed.
- o in no case will an employee go through or remove another employee's lock
- o a green tag is used whenever equipment is to be kept inoperative; however, it is never to be used in lieu of the personal safety locks

In addition, isolation sheets (Figure 17-1) have been successfully used for over 10 years. These are used in the following manner. Once a piece of equipment has been purged, totally isolated, and locked-out as per the written procedure, the sheet is completed and signed by both the mechanic and the area operator. When the task is completed and the equipment de-isolated, the mechanic must again sign the sheet. Throughout the procedure, the isolation sheet remains with the operator to assure knowledge of maintenance operations in their areas of responsibility.

Personal Protective Equipment -

Each maintenance employee is issued a dual-cartridge (acid gas) half-face mask, filtering respirator to be carried at all times while in the pulp mill. These respirators are to be used primarily for mill egress in the event of a major leak or other emergency. For certain maintenance tasks around chlorine, chlorine dioxide, or strong black liquor lines, the employees carry a full-face, acid gas canister respirator, whose use is discretionary. Throughout the pulp mill, there are also numerous Scott and MSA Air Packs to be used by maintenance and operating personnel in emergencies or during certain specified tasks such as vessel entry.

FIGURE 17-1

DATE _____ _____ TIME _____

JOB DESCRIPTION (MECHANIC FILL IN) _____

_____

1. THE FOLLOWING VALVES HAVE BEEN -

CLOSED (OPERATOR ENTRY)	TAGGED (MECHANIC INITIAL)

2. THE FOLLOWING VALVES, DRAINS AND VENTS HAVE BEEN

OPENED (OPERATOR ENTRY)	TAGGED (MECHANIC INITIAL)

3. THE FOLLOWING DRIVES HAVE BEEN TAGGED OUT - (MECHANIC ENTRY) (MECHANIC ENTR

_____

_____

_____

4. FLUSH OR PURGE COMPLETED - (OPERATOR ENTRY) YES ☐ NO ☐

5. ADDITIONAL STEPS TAKEN -

WHAT -	BY WHOM -

ISOLATION COMPLETE AS INDICATED ABOVE..... TIME ☐

_____

_____

JOB COMPLETED, TAGS CLEARED and TURNED BACK TO OPERATIONS -

OPERATOR _____ MECHANIC _____

TIME 731 DATE _____

The vessel entry procedures also specify that during certain tasks, other protective devices and clothing must be used. These include: full rubber suits, goggles, rubber gloves, face shields, and rubber boots.

EFFECTIVENESS OF PREVENTATIVE MAINTENANCE PROGRAM

The preventative maintenance program at Mill 17 undoubtedly results in a reduction of workplace exposures for other mill employees. The daily inspection tours by the preventative maintenance staff enhance early detection and correction of problem areas, frequently before they develop to significant emission sources of workplace contaminants. The maintenance department also maintains a card file on every major piece of equipment in the mill, including a relatively complete service history.

This system not only assists in identifying adverse trends, but, along with trial-and-error experience, has resulted in a continuing improvement in packing and gasketing materials, and valve selection. Examples of such successful improvements for this mill include:

Packing Materials:

- Garlock Paperpak 5000: carbon fiber impregnated with teflon; is used primarily for pumps and agitators on black liquor lines with temperatures less than 600°F and speeds less than 1800 rpm. Examples include: the high pressure feeder, the ESCO valve feeder, the outlet device, the top separator, the low presure feeder, and all black liquor circulation pumps.
- Industrial Packing Style 82: teflon-impregnated with asbestos packing; used in the majority of the pumps in the bleach plant for speeds up to 3600 rpm.
- Industrial Packing 706: teflon-impregnated carbon fiber packing; used for high speed (> 3600 rpm) liquor pumps.

Gasketing Materials:

- Garlock 900: used extensively in pulp mill applications
- Flexitellic: a metal-reinforced gasket highly reliable in high pressure applications

- Gore-Tex: pure teflon gasket with an adhesive backing; used extensively in the bleach plant

Valves:

- Josem-Way: a cast gate valve used extensively as a distribution valve for both brown stock and bleached pulp lines
- Kamyr: ball valves used in the high pressure lines of the Kamyr continuous digester
- DURCO: plug valves (teflon seat) used extensively in the bleach plant
- Garlock: teflon-lined butterfly valve also used in the bleach plant.

SECTION VIII MILL MAINTENANCE OPERATIONS

Mill 04 Supercalenders, Windows & Coaters

Mill 23 Corporate Case Studies

MILL 04 NOISE CONTROLS FOR SUPERCALENDERS, WINDERS AND COATERS

INTRODUCTION

In 1978, Mill 04 contracted with an acoustical engineering consulting firm[1] to conduct a comprehensive noise study of all process areas. Based on a preliminary survey of employee exposures, it was determined that the No. 120 supercalender, No. 120 winder, and the No. 1 coater were the areas of greatest concern. Employee exposures in these areas, by job classification, were as follows (exposure levels in excess of 1.0 are above current OSHA regulations).

No. 120 supercalender operator	3.0
No. 120 supercalender helper	1.8
No. 120 winder operator	1.9
No. 120 winder helper	2.0
No. 1 coater operator	1.5
No. 1 coater assistant operator	1.7
No. 1 coater first helper	1.5
No. 1 coater second helper	1.3

Following the preliminary survey, the consultants conducted a thorough study of the major noise sources and recommended practical methods of control.

EVALUATION OF NOISE SOURCES

Table 04-1 illustrates the relative importance of the noise sources in each area during various operating conditions. At the supercalender, the primary source of noise generation (80-90%) is imperfections in the face-filled rolls impacting against the metallic rolls.

These impacts generate direct airborne noise and also create structure-borne energy in the rolls causing vibrationally induced noise. This noise source accounts for the increased noise levels as the rolls become worn.

Supercalender noise sources contribute up to 80 percent of the acoustic energy at the coater exposure positions, caused primarily by reverberent conditions enhanced by the "hard" acoustic properties of the room. Noise levels are reduced by 5 to 7 dBA when the calender is down. The air jets used to keep the ends of the coating rolls clean, and the take-up wind rolls contribute only 20 to 30 percent of the acoustic energy around the coater.

[1] Donley, Miller & Nowikas, Inc.

TABLE 04-1 EVALUATION OF NOISE SOURCES

Area	Operating Conditions	Source	Contribution to Total Acoustical Energy at Employee Exposure Positions
No. 120 Supercalender	Operating	Stack Roll Imperfections	80 to 90 percent
		Stack Drive Motor	Insignificant
		Stack Gearbox	Insignificant
		Wind Drive System	Insignificant
		Windage	Insignificant
		Bearings	Insignificant
	Not Operating	No. 1 Coater Noise Sources	40 to 60 percent
		No. 5 Winder Noise Sources	20 to 30 percent
		No. 120 Winder Noise Sources	Insignificant
		Other Sources (Other Nearby Equipment)	10 to 20 percent
No. 1 Coater	Supercalender Operating	Supercalender Noise Sources	70 to 80 percent
		Roll Noise	10% at exposure positions at take-up end of coater
		Air Jets on Coating Rolls	10-20% at the coater operator and helper's control console
		Drive Systems	Insignificant
		Gear Boxes	Insignificant
		Blowers	Insignificant
	Supercalender Not Operating	Wind Roll, Drive System, Gears and Air Jets	Significant to take-up end positions
		No. 120 Winder Noise Sources	Insignificant
		No. 5 Winder Noise Sources	10 to 20 percent
		Other Sources	Insignificant
No. 120 Winder	Winder & Supercalender Operating	Chevron grooved rolls	50 percent
		Supercalender Noise Sources	15 to 20 percent
		Trim System	Insignificant
		Blade Passage Noise	Insignificant
		Drive Systems	Insignificant
		No. 1 Coater Noise Sources	Insignificant
	Winder Not Operating Supercalender Operating	Supercalender Noise Sources	75 percent
		No. 1 Coater Noise Sources	Insignificant
	Winder Not Operating Supercalender Not Operating	No. 1 Coater Noise Sources	20 to 40 percent
		Other Sources (nearby paper machines)	60 to 80 percent

When the No. 120 winder is running, supercalender noise sources contribute only about 1 dBA to the noise levels in the area. However, when the winder is down, these sources constitute 75 percent (6 dBA) of the acoustic energy around the winder. Thus near field noise sources (primarily the chevron grooved rolls on the winder) are highly significant sources of employee exposure.

CONTROL MEASURES

Once the noise sources were evaluated, a two-phased cost/benefit analysis of the various control alternatives was completed (Table 04-2). It was predicted that implementation of Phase I controls would sufficiently reduce exposures for all job titles with the possible exception of the No. 120 Supercalender and winder operators. Phase II control procedures were provided should additional noise controls for these job classifications be necessary. Based on individual costs, benefits, and engineering/production feasibilities, the following Phase I control procedures were selected for implementation:

- No. 120 Supercalender Roll Stack Shield - The noise source evaluation demonstrated conclusively that acoustic energy from the supercalender rolls was the primary cause of excessive noise exposure throughout the area. It was concluded that there were no feasible methods of reducing the acoustic energy at the source (replacement of the rolls when surface imperfections occur would be effective but not feasible). The only other effective method of control would be to block the acoustic energy from reaching employee positions. Therefore, it was decided to attach two clear plastic sheets (upper and lower) to the front of the supercalender roll stack, forming a partial barrier between the noise source and nearby employees (see Figure 04-1). The shields were constructed of transparent, 1/2" thick DuPont Lucite "SAR", and were located out from the stack to allow employee passage for paper threading. Each shield was mounted with vibration isolators to reduce the potential for surface radiations. The top barrier extends down to just above the paper sheet before the winding reel; the bottom barrier extends up to the sheet of the unwinding reel. Since top and bottom barriers do not align vertically, noise could pass through the open deck grating above and behind the bottom barrier. To block this potential pathway, a 1/4" thick diamond plate was installed on top of the existing grating. Since moisture was likely to collect on the shielded surfaces, drain channels were

TABLE 04-2

SUMMARY OF NOISE CONTROL PROCEDURES

PHASE I

CONTROL METHODS	COSTS	ADVANTAGES/DISADVANTAGES
1. No. 120 Supercalender Roll Stack Shield	$6,500-$7,000	ADVANTAGES 1. Will reduce roll stack noise significantly at all exposure positions. 2. Less obstruction to production and maintenance than other possibilities. DISADVANTAGES 1. Slight interference to employee duties. 2. Implementation requires machine shutdown.
and	plus $5,000 Design Engineering by outside consultants or in-house designers	
2. No. 1 Coater Room Absorptive Treatments	$42K-$52.2K	ADVANTAGES 1. Effectively reduces reverberant level in No. 1 Coater Room. DISADVANTAGES 1. Cost is substantial.
3A. No. 120 Supercalender Control Console Enclosure (three-sided)	$1,100-$1,300	ADVANTAGES 1. Reduces level to that required to meet current criterion. 2. Less expensive. DISADVANTAGES 1. Will not meet proposed OSHA Criterion. 2. Slight interference to employee duties.
3B. No. 120 Supercalender Control Console Enclosure (four-sided) to meet proposed 1974 regulations	$4,600-$5,400	ADVANTAGES 1. Reduces level to meet proposed criterion. DISADVANTAGES 1. More expensive than three-sided enclosure. 2. More interference than three-sided enclosure.
4A. Replace chevron type rolls with smooth or "Vent-A-Nip" type on No. 120 Winder	$15,000-$20,000	ADVANTAGES 1. Will reduce level required amount. DISADVANTAGES 1. Cost is substantial unless able to be defrayed through routine roll changes.
4B. No. 120 Winder acoustic treatment of wall and ceiling	$1,350-$1,500	ADVANTAGES 1. Effectively reduces level.
	TOTAL $51,000-$84,600 Plus $5,000 Design Engineering	

PHASE II

1. Control Console Enclosures (three-sided)	$1,100-$1,300 ea.	ADVANTAGES 1. Only means of control after Phase I controls have been implemented. 2. Effectively reduces noise levels. DISADVANTAGES 1. Slight interference to employee functions.
	Maximum $6,600-$7,800	

FIGURE 04-1

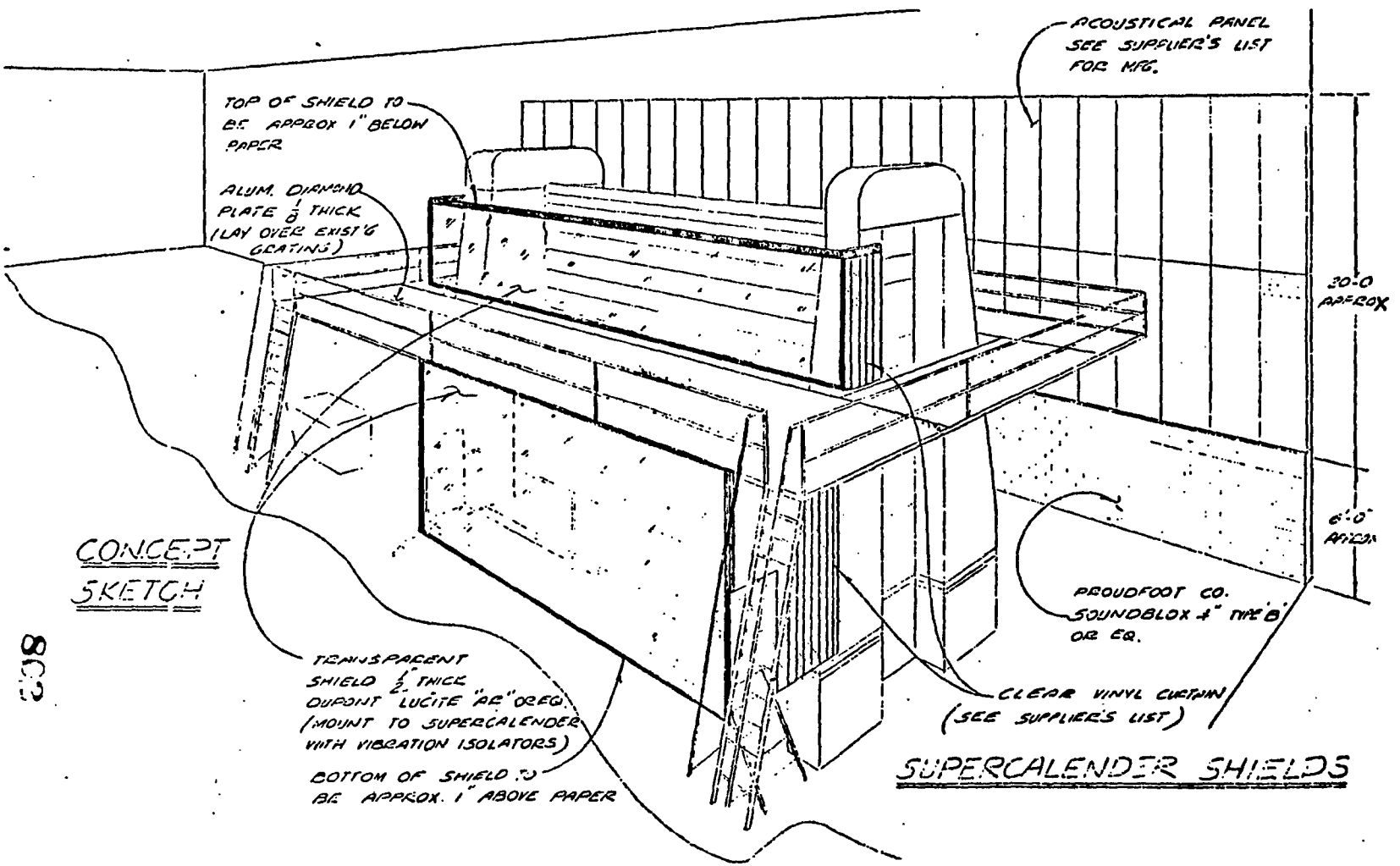


Figure 04-1: Sketch of noise abatement controls around No. 120 Supercalender. Lucite panels outlined in blue.

placed at the bottom of each barrier to prevent condensate from falling on the paper below. To reduce dust build-up, the shields were coated with anti-static spray (Commercial Plastic Cameo - without wax, or equivalent), with provisions for recoating every three months.

Because of frequent threading, maintenance operations, and spacial limitations, the upper barrier consists of three small overlapping shields, each positioned on tracks to facilitate opening and closing. For routine access, the shields can be pushed to one side or the other. For major equipment overhauls, the upper track and all three shields can easily be removed. The barriers substantially reduce direct field noise in front of the supercalender. However, due to reverberant conditions, noise levels would increase behind the supercalender, and the noise reduction effect on the rest of the room would be minimized. Clearly, acoustical conditioning of the walls and the ceiling were necessary to meet noise abatement objectives.

- Control of Reverberant Build-Up - Concrete block sound absorbers were installed on the bottom six feet of the wall behind the supercalender. These slotted concrete blocks can handle far more greater physical abuse than commercially available glass fiber acoustic panels.

  Proudfoot Soundblox 4-inch Type B blocks were selected for installation because of their effectiveness at frequencies around 500 Hz (roll stack noise is most pronounced in the 500 Hz octave band). On the walls above the slotted concrete blocks, and on the walls beside and behind the coater, 2' x 4' glass fiber panels were installed.

  Glass fiber absorbers (2' x 4' panels covered with mylar) were also employed to control reflections from the ceiling. The panels were suspended in rows on four foot centers above the coater and the supercalender.

  The approximate total cost for the absorptive materials and full installation is outlined below.

Sound Absorbing Material	Total Area (ft2)	Cost ($1000)
Acoustic Wall Panels	4455	27-35
Acoustic Blocks	270	1.5
Acoustic Ceiling Panels	1800	7-9

- o No. 120 Supercalender Control Console - Because of spacial limitation, the lower roll stack shield could not be extended far enough to reduce the noise level sufficiently at the operator's control console. Therefore, a two-sided, L-shaped shield was installed at the console to reflect acoustic energy away from the operator.

  The shields (identical to the roll stack shields) extend from the top of the sides of the console to the bottom of an overhead catwalk (but do not touch it).

FOLLOW-UP SURVEY

After the Phase I controls were installed, a follow-up survey was conducted to estimate effectiveness and assess the necessity for Phase II controls. Before and after noise exposure levels for each job classification are shown below (exposure levels above 1.0 are in excess of the current OSHA noise standard):

Job Classification	Before Controls	After Controls
No. 120 Supercalender Operator	3.0	1.2
No. 120 Supercalender Helper	1.8	1.0
No. 1 Coater Operator	1.9	.7
No. 1 Coater Assistant Operator	2.0	.7
No. 1 Coater First Helper	1.5	.6
No. 1 Coater Second Helper	1.7	.7
No. 120 Winder Operator	1.5	1.2
No. 120 Winder Helper	1.3	.9

As predicted, the No. 120 supercalender and winder operators' average exposure levels are slightly in excess of the current OSHA standard. The following additional control procedures are currently being considered for implementation:

- o No. 120 Supercalender Operator - A one dBA reduction at the control console is needed to lower the operator's exposure below current regulation. This can be achieved by placing an absorptive ceiling on the existing, two-sided enclosure. Glass fiber acoustic panels can be used backed with either sheet steel of half-inch plywood for support and to effect a barrier. The absorptive side would be face down towards the console.

- o No. 120 Winder Operator - To meet current and proposed OSHA regulations for the winder operator, the ceiling above the winder will require about 100 square feet of absorption. Glass fiber acoustic panels should be

laid flat against the ceiling. In addition, the wall behind the operator console and the helpers bench will require a similar treatment covering approximately 200 square feet. An alternative solution would be to place a 1/2 inch, clear plastic shield directly in front of the console. Construction would be of vertical lengths of angle with the shield attached and resting on the top of the console. As above, absorption would be required on the wall behind the console.

Also during the follow-up survey, the effectiveness of the upper shields on the supercalender roll stack was evaluated. This was undertaken because of problems with condensation build-up and threading difficulties.

Measurements indicated that the upper shields can be left open without significantly increasing noise levels in the area. Apparently the paper roll affords enough of a barrier for the majority of the time. It was thus recommended that, if the upper roll stack shields still create problems, they can be removed without noticeably increasing noise exposures of the employees.

MILL 23: CORPORATE NOISE CONTROL CASE STUDIES

This report presents a comprehensive summary of noise control projects and studies conducted in a number of pulp and paper mills operated by a large corporation. Each case study includes a detailed description of the noise sources and resulting employee exposure levels, alternate control strategies, the control measures implemented, and the estimates of the resulting effectiveness. The following is a list of the noise problems addressed in these studies:

- o 23-A Caterpillar D7-E Tractor
- o 23-B Lamson Air Compressor
- o 23-C Chip Blower
- o 23-D Power Boilerhouse
- o 23-E Jordan Refiners
- o 23-F ASEA Motors
- o 23-G Wide Supercalendar Motors
- o 23-H Rewinder Trim Blower
- o 23-I Rewinder
- o 23-J Vacuum Pumps
- o 23-K Paper Machine Wet-Ends
- o 23-L Winders
- o 23-M Jagenberg Two Drum Machine Winder
- o 23-N Personnel Enclosures

These summaries contain a wealth of practical information developed by experienced professionals over a number of years. However, it should be stressed that there are a number of possible solutions for each noise problem, dependent on conditions at the individual location or mill, the economics of the control, and the ultimate acceptance by operating or maintenance personnel. The following case studies are not intended to represent the 'best' or most efficient control technologies. They should, however, provide much useful information to mill personnel confronted with the challenge of solving a similar noise problem.

23-A CATERPILLAR D7-E TRACTOR

Noise measurements inside the cab of this tractor operating in the chip area resulted in noise levels of 91 dBA to 94 dBA. Acoustical analysis revealed that the majority of the cab noise was due to direct transmission through the cab walls, door, and glass. Door weatherstripping was worn and in need of replacement, and the flexible coupling between the exhaust manifold pipe and the muffler was missing. Air leaks into the cab from the engine were also a problem.

ACTION: The old thermal insulation was removed and replaced with an acoustical composite material (alternate layers of mass-loaded plastic, polyurethane

foam, and heavy rubber mat on the cab floor). Acoustical material (perforated vinyl-faced foam) was added to the cab interior to reduce reverberant noise. A hydraulic tank cover (12 gauge steel, foam, and mass-loaded plastic) was installed to both reduce noise and also heat radiation (access provided for oil filter change). The average noise reduction under various operating conditions (full RPM forward and reverse; engine idle) was reported to be 16.5 dBA.

23-B LAMSON AIR COMPRESSOR (Cat. No. 20-SG-100; 10 hp; 830 cfm; 2 lb. vacuum)

The air compressor is used as a supply for the pneumatic tube transport system in the paper mill, and is located in a passageway outside the paper quality control laboratory. The noise level in the aisle opposite the compressor was 92 dBA with an annoying pure tone near 500 Hz. Important noise sources were determined to be (in order of importance): the exhaust ducting, the drive motor (partially due to a bad bearing), and the main housing. RPM reduction for noise control was ruled out due to the tube vacuum requirements. Case lagging was similarly discarded because of the irregular shape and motor location.

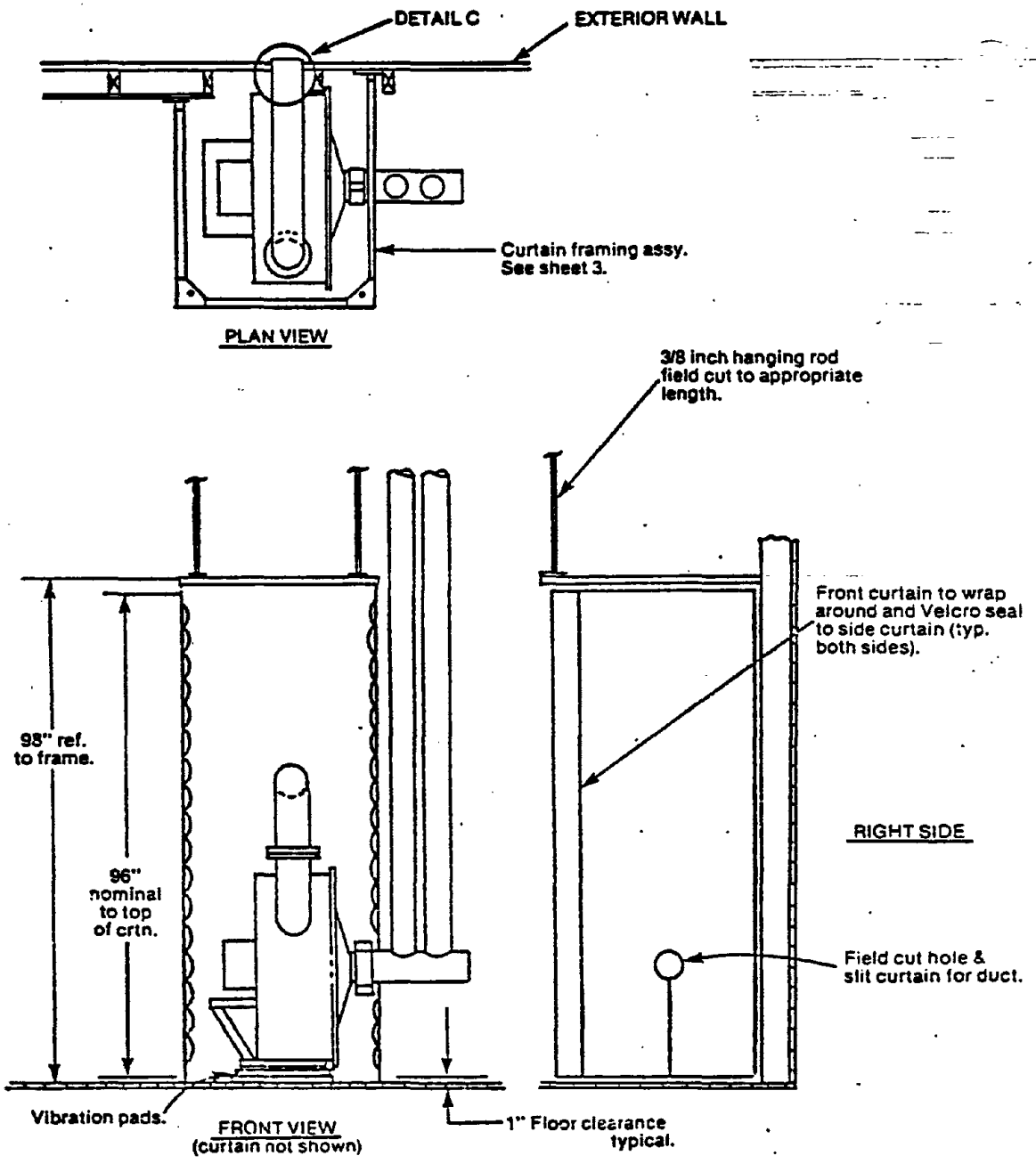
ACTION: It was decided that a three-sided suspended curtain would effect adequate attenuation without interfering with maintenance operations (Figure 23-B1). The curtain is 1 pound mass-loaded, fiberglass-reinforced plastic with a quilted fiberglass blanket on the interior side. Velcro strip seals were included at each front corner to assure a tight seat and easy access. The suspension hardware was a standard Unistrut framework attached to the floor and the wall exhaust hole, and four - 1/2 inch 40 durameter neoprene vibration pads were placed under each compressor routing point. The noise level in the aisle opposite the compressor was reduced from 92 dBA to 83 dBA.

23-C Rader 3200 Rotary Vase Chip Blower

The chip blow station, located adjacent to the chip truck unloader, was the source of both mill personnel and community complaints. Noise levels ranged from 96 dBA ten feet from the blower, to 107 dBA at maintenance positions near the unit. The blower came with inlet and outlet silencers, but investigations found that they radiated as much noise as the blower itself. The exhaust surge tab was coated with 2" of a cellulose fiber compound, but this treatment provided negligible noise reduction. Surface lagging was thought to be uneconomical because of the large surface area of the blowers and silencers.

Figure 23-B1

LAMSON COMPRESSOR CURTAIN NOISE BARRIER



ACTION: A four-sided, open top partial enclosure (Figure 23-C1) was erected around the chip blower. The enclosure was constructed of concrete block due to its ruggedness and capability as a noise barrier. To reduce reverberant buildup, the top three courses of the enclosure were constructed of "Sound Blox," a specially designed hollow masonry block.

To provide additional noise reduction for personnel performing maintenance working on the blower, the receiver surge tank was further isolated. A removable wall of acoustical panels (4" with mineral wool sandwiched between solid and perforated steel) was installed between the blower and receiver tank. The perforated side was positioned on the tank side and the mineral wool was sealed in a polypropylene log. A removable concrete slab roof was installed over the receiver tank to provide full isolation and increased attenuation. The masonry structure was painted inside and out, and internal lighting was added. Steel doors were added on two sides to allow easy access for maintenance personnel. The receiver surge tank can be replaced by removing the concrete slab room and steel support panels. All other equipment can be lifted through the open top with a cherry-picker crane. As shown on Figure 23-C1, noise levels outside the enclosure were reduced from 73-107 dBA to 58-80 dBA.

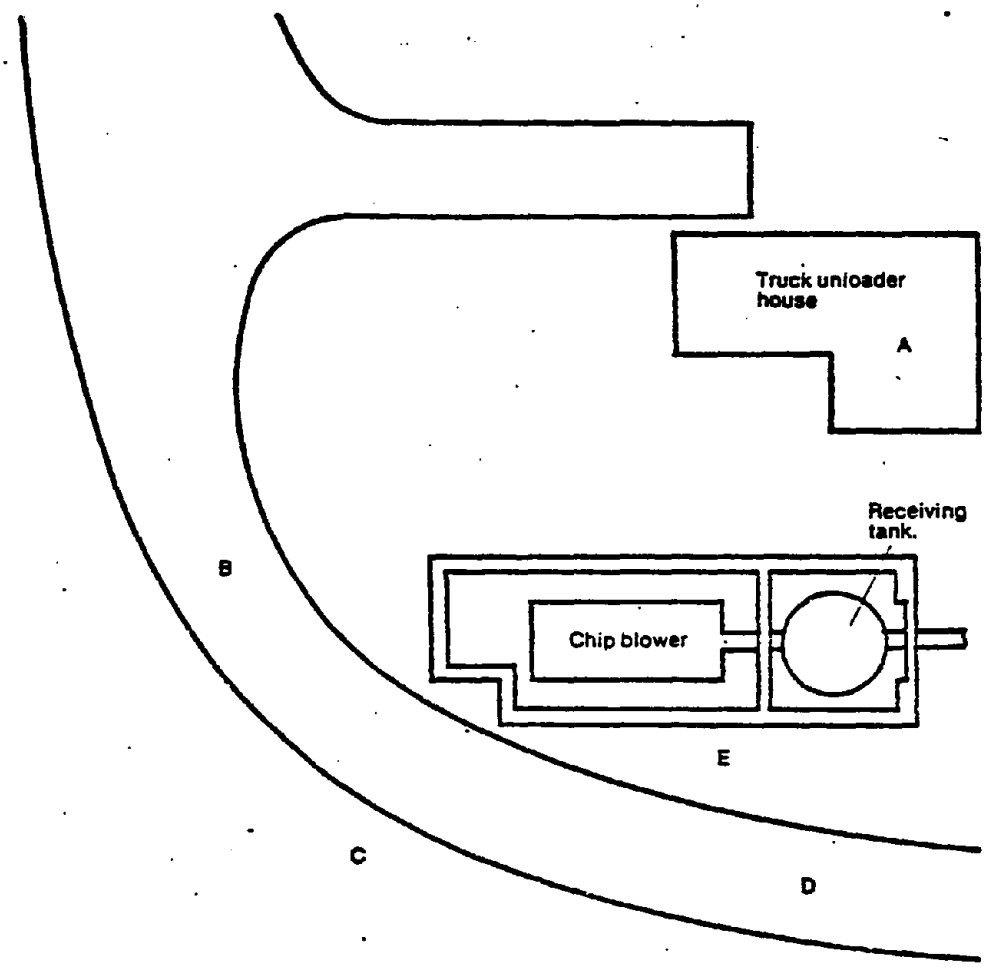
23-D POWER BOILERHOUSE

The boilerhouse at this mill consisted of three power boilers, main air compressors and associated piping, valves, and other control equipment. The building was constructed of acoustically hard and reflective steel and concrete. Main levels ranged from 88 to 95 dBA around the boilers, and averaged 98 dBA at the air compressor aisle. The most important noise sources were determined to be a severe steam leak at a main header control valve, the air compressors, and three boiler forced draft (F.D.) fans located on top of the power boilers. The fans had been previously provided with plywood fan inlet air silencers, but the wood structures were deteriorating and additional noise abatement was necessary.

ACTION: As a temporary solution, a thermosetting plastic compound (Fursnamite), available from a firm of the same name, was injected into the valve leak during full operation. Subsequently, during a scheduled boiler-house shutdown, the defective valve was replaced.

Figure 23-C1

CHIP PUMP NOISE ENCLOSURE PLAN



LOCATION	DISTANCE FROM SOURCE	NOISE LEVEL BEFORE, dBA	NOISE LEVEL AFTER, dBA
A	35'	73	58
B	10'	90	72
C	10'	96	74
D	10'	96	80
E	1'	107	80

There was not sufficient space for a conventional inlet silencer on the F.D. fan for one on the boilers. A partial enclosure was constructed of 4" metal sandwich panels cut to fit fan dimensions (Figures 23-D1 and 2). The three sides and top of the enclosure cause all inlet air to be drawn from the motor side of the fan unit. A 4" absorbent surface was positioned directly opposite the inlet opening, and maximizes noise reduction of the design. Fan noise was reduced from 100 dBA to 88 dBA at the inlet.

Two additional F.D. fans were modified by replacing the existing plywood inlet baffles with commercial inlet air silencers. A detailed performance specification was prepared which dictated noise insertion loss (in decibels over 7 octave bands), total pressure drop, length, and minimum construction materials. It was determined that one of the F.D. fans had a secondary noise source caused by housing radiation. The fan housing was lagged with about 51 s.f. of one pound, flexible plastic sheeting, with 1" of accoustical foam laminated to the surface next to the fan. Fan noise at each inlet was reduced from 100 dBA to 85 dBA and 84 dBA respectively.

Five noisy compressors were located in one corner of the power boilerhouse. Although the boiler tenders spend very little time in the area, the compressors contributed considerable sound power to nearby instrument and boiler inspection stations. Because of the complexity, costs, and probable maintenance interference, individual compressor treatment was ruled out as a possible control option. Instead, an enclosure (26 ft. by 34 ft. by 21 ft. in height) was erected around all five compressors. The sides were constructed of pre-manufactured metal sandwich panels; the top was assembled with Texturn[1] acoustical planks laid over steel purlins. After installation, the roof planks were hot sopped and covered with 30 lb. roofing felt. An existing fire sprinkler system was relocated within the enclosure, lighting fixtures relocated, and hard nails modified. Penetrations for ceiling pipes and conduits were sealed with fiberglass packing and caulking. The new enclosure entrance, without a door, was constructed of a right-angle vestibule from modular panels. Average boiler noise levels on the operating level were reduced from 93 dBA to 84 dBA.Boilerhouse personnel are no longer required to wear hearing protection.

1. Texturn is composed of chemically treated wood fibers bound in moisture resistant Portland cement.

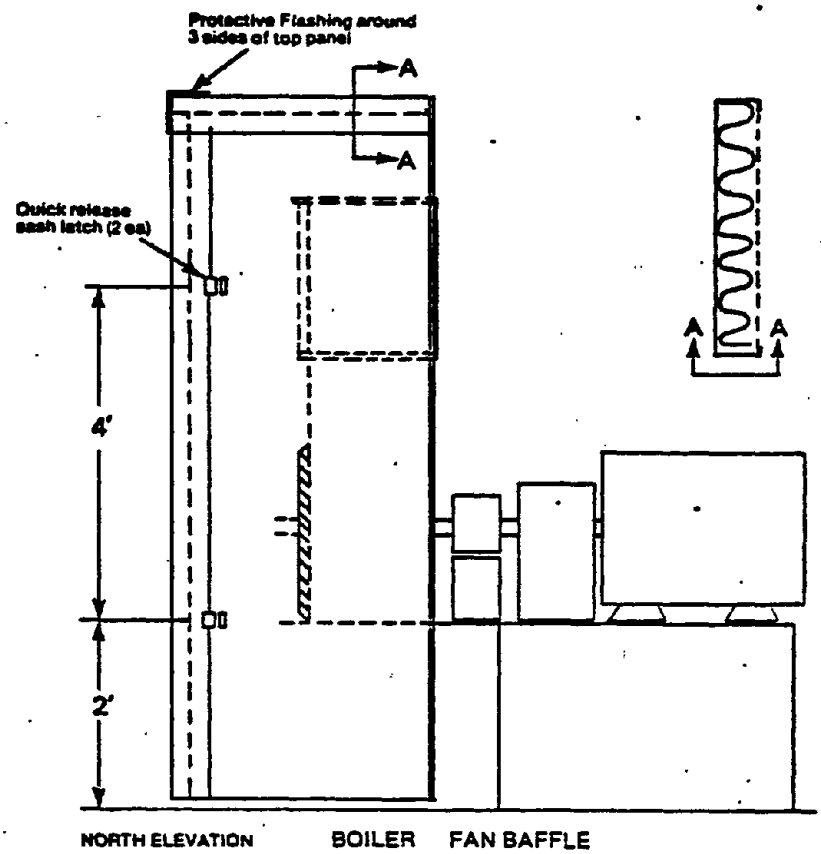
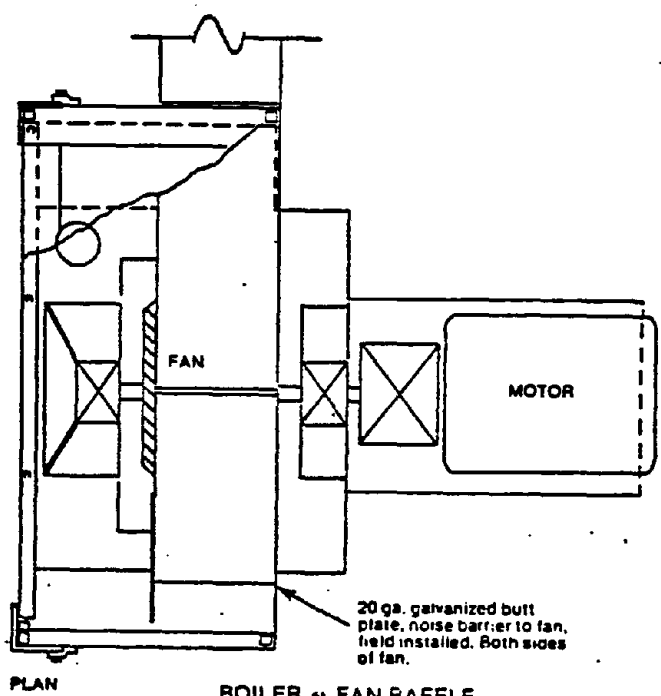


Figure 23-D1

Figure 23-D2



23-E JORDAN - TYPE REFINERS

Although Jordan refiners are covered in this study, it is reported that the principles set forth may be extended to high consistency or disk refiners, and TMP refiners.

Noise levels produced by refiners vary according to type, stock consistency, RPM, and plate pattern:

- Jordan type refiners are generally low RPM machines powered by relatively quiet, direct-coupled electric motors.

- Disc refiners are direct-coupled to high RPM electric motors, and noise levels are generally higher.

- TMP refiners are large, double-disc, high horsepower units driven by large, noisy electric motors. They also generate noise from secondary steam. Refiner noise is typically contained by the very thick steel-body construction.

ACTION: Three noise abatement approaches for Jordan conical type refiners are discussed based on extensive study at one paper mill. These approaches are not necessarily endorsed by participating mill personnel, who stress that their application should be carefully reviewed with respect to each particular need.

1. Lagging: At one paper mill, the refiner was covered with mineral wool and heavy canvas. It was reported that this technique was not particularly successful (3-4 dBA reduction), and it was difficult to fabricate the lagging material to conform to the refiner shell. Also,

Figure 23-E1

JORDAN REFINER SURFACE LAGGING

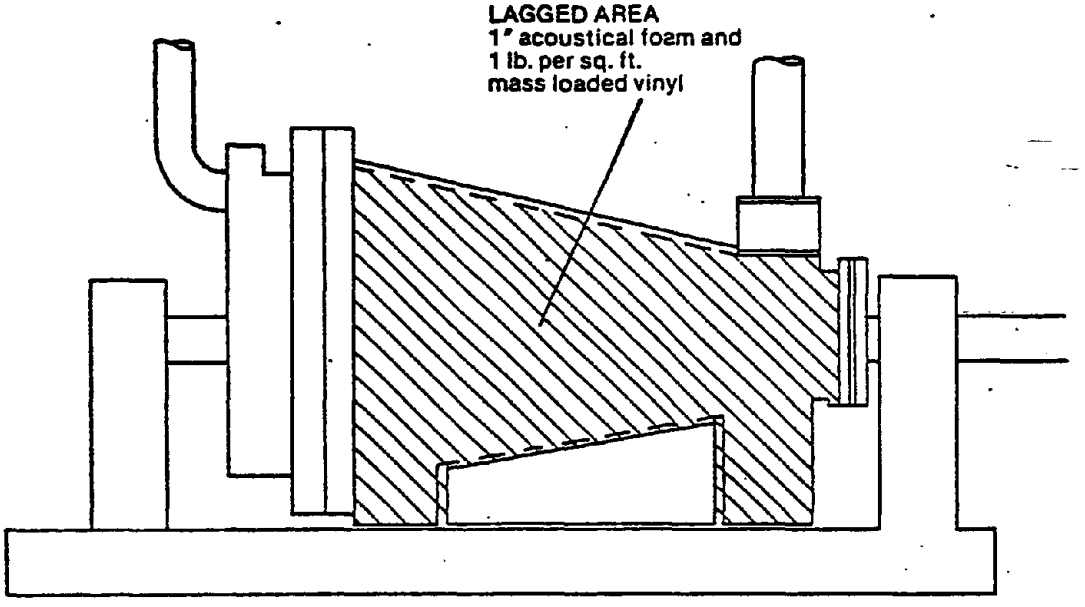
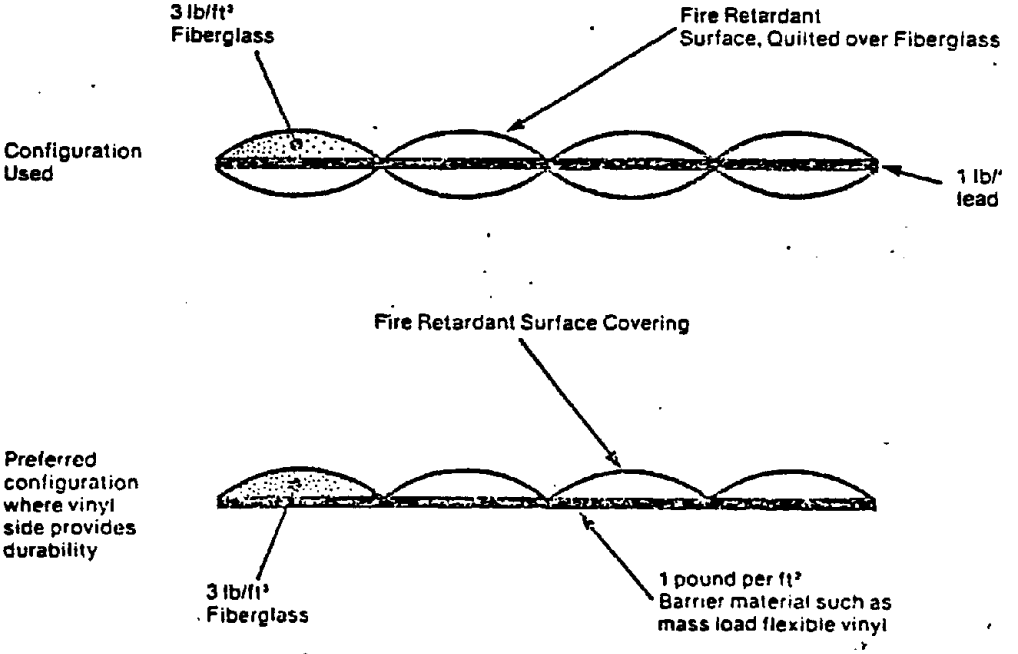


Figure 23-E4

SOUND ATTENUATING CURTAIN COMPOSITION



during wet conditions the acoustical effectiveness of the mineral wool was greatly reduced.

A 4" thick layer of wool, covered by a mastic layer, was also investigated. This lagging technique resulted in an average noise reduction 5-10 dBA, but was not pursued because the material was difficult to work with on odd shapes and the refiner end plates needed to be uncovered.

During a pilot plant investigation, one refiner was lagged with 1" thick acoustical foam and 1 lb. per s.f. mass-loaded vinyl applied to the shell of the refiner core (See Figure 23-E1). Although the characteristic refiner whine could still be heard above the background noise, an average of 7 dBA noise reduction was achieved (98 dBA to 91 dBA). This approach is not applicable to disc refiners as the electric drive motor is a major source as well.

Other study conclusions are:

- bonded foam/mass-loaded vinyls are readily available and generally easiest to work with.

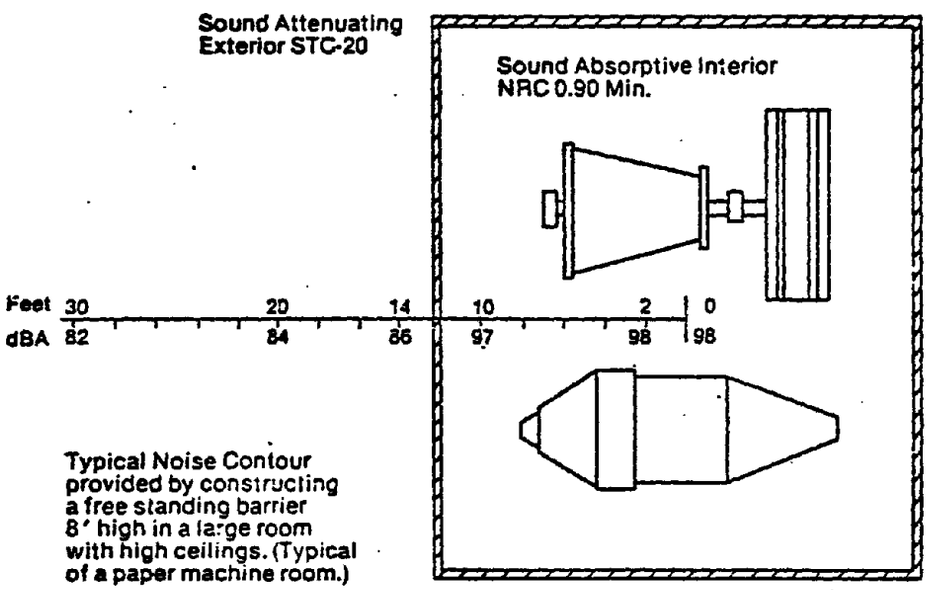
- the sound absorbing material must be sealed watertight as refiners are often subject to water spray (various mastic compounds are available for this).

2. Partial Barrier: Sound attenuating curtains (8 1/2' by 4' lead sheet) were mounted on roller tracks directly in front of the refiner to provide a barrier to noise transmission. It was reported that no noise reductions were realized around the curtain as other sources, primarily an overhead steam valve, dominated. Instead of lead sheet, a mass loaded vinyl (Figure 23-E4) composition material may also be used.

In general, it was concluded that 8' high (or higher) barriers erected around refiners can result in noise reductions of between 7 and 12 dBA (Figure 23-E5). However, there are a number of disadvantages to this approach:

Figure 23-E5

TYPICAL NOISE CONTOUR PROVIDED BY BARRIER



- loss of usable floor space

- interference with walkway clearance and/or equipment maintenance.

- limited effectiveness in highly reverberant low-ceiling rooms (can be improved by treating these surfaces with sound absorbing material, or hanging fire-resistant acoustical baffles.

3. Full Enclosures: Two types of full enclosures for refiners were built and tested at the mill; one was a metal sandwich panel system. The wood enclosure consisted of a steel frame covered with marine plywood sheets. The inside surfaces were lined with 1" thick acoustical foam. The enclosure resulted in noise level reductions of 10 to 15 dBA, but several problems existed:

- it was expensive to design, build, and install.

- it did not last long; in wet conditions, the marine plywood wavered and separated.

- the interior acoustical foam became saturated with water (could be avoided by using a film-faced foam (film 1/2 to 1 mil. thick).

- it was difficult to dismantle for maintenance operations (changes in operational procedures often increase time for a particular task, and are not welcome by operators or maintenance personnel.

Several enclosures of metal sandwich panel construction were built and tested (typical panel cross-section shown in Figures 23-E6 and 23-E7). Gradually, the steel panels were found to be superior to wood in both durability and ease of handling, but still deteriorated after one year's use. Although quick disconnect hardwood was used for ease of assembly and disassembly, maintenance personnel frequently neglected to reassemble the enclosures after repairing a refiner (the extreme importance of maintenance compatability was emphasized). The metal enclosures provided roughly the same noise reduction (10 to 15 dBA) as the wood (refer to Table 23-E1 for additional information about the metal enclosures).

METAL SANDWICH PANEL ENCLOSURES

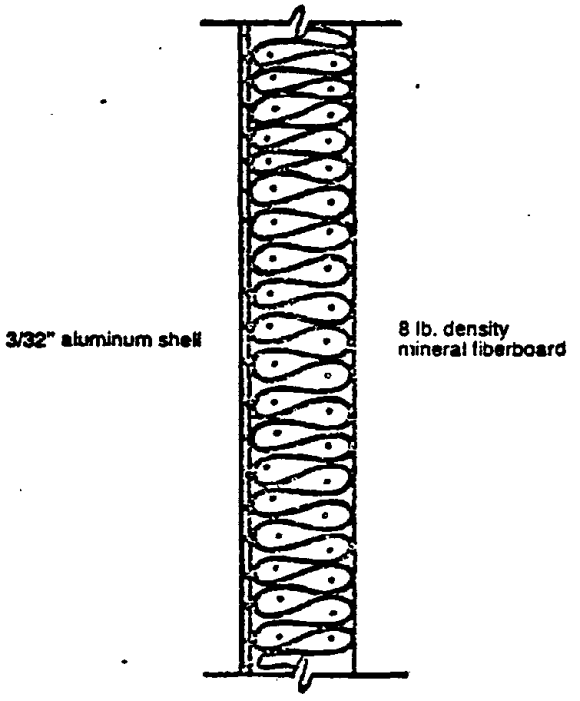


Figure 23-E6

Figure 23-E7

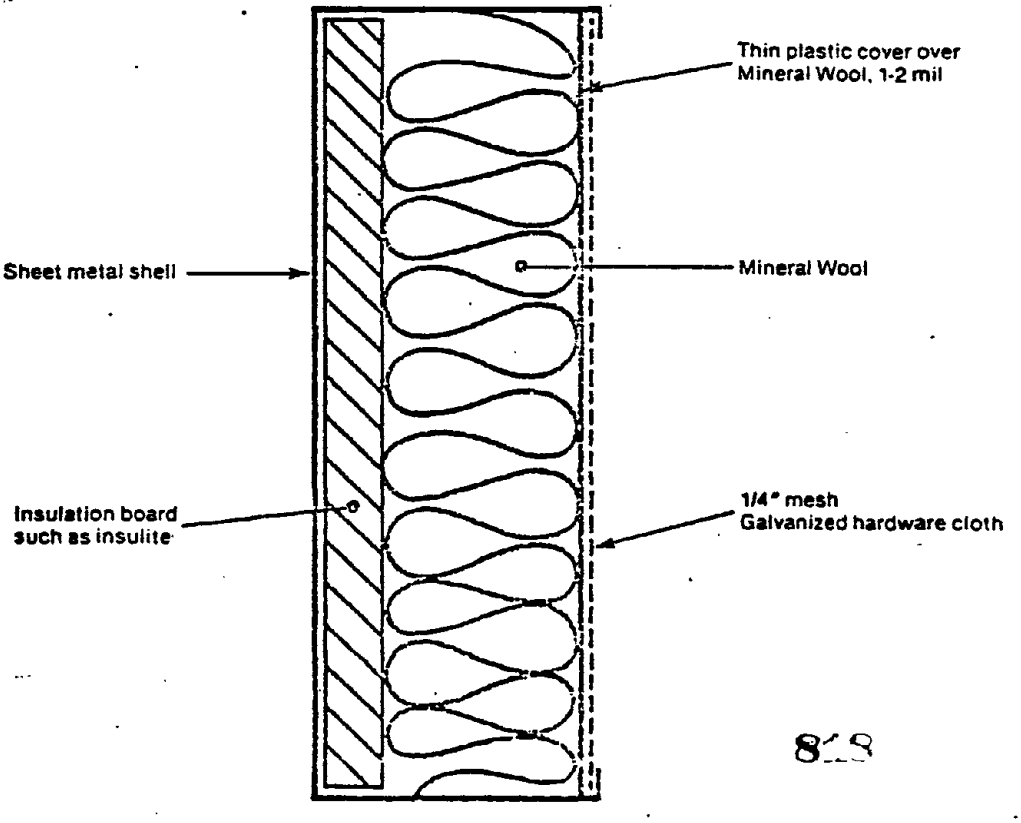


TABLE 23-E1: Metal Sandwich Panel Refiner Enclosures

REFINER TYPE:	Jordan No. 8 HWK	Claflin No. 12 HWK or SWK	Jordan No. 11 Broke	Jordan No. 12 Broke
DATE INSTALLED:	November, 1975	August, 1976	August, 1976	August, 1976
BEFORE NOISE LEVELS:	99-106 dBA	97-100 dBA	101-103 dBA[2]	95-98 dBA[2]
AFTER NOISE LEVELS:	87-88 dBA[1]	93-95 dBA[2]	93-95 dBA	94-96 dBA

REFINER TYPE:	Jordan No. 6 HWK	Jordan No. 5 Beater	Claflin No. 7,8 & 9 GWF Broke
DATE INSTALLED:	February, 1977	February, 1977	April, 1977
BEFORE NOISE LEVELS:	93-99 dBA[2]	93-98 dBA	91-94 dBA
AFTER NOISE LEVELS:	91-94 dBA	88-92 dBA[2]	81-85 dBA[3]

REFINER TYPE:	Jordan No. 8 HWK	Claflin No. 7 HWK	Jordan No. 7 HWK
DATE INSTALLED:	April, 1977	April, 1977	April, 1977
BEFORE NOISE LEVELS:	89-103 dBA	91-94 dBA	92-98 dBA
AFTER NOISE LEVELS:	84-89 dBA[3]	86-88 dBA[3]	86-89 dBA[3]

1. Area noise levels were in compliance at the time of installation; however, the equipment has brought noise levels back up.
2. High residual noise levels are caused by other equipment.
3. Area in compliance.

It was noted that the requirements for a successful refiner enclosure are as follows:

- Adequate sound transmission loss of materials; STC-30 minimum.

- Proper acoustical seals on all mating components.

- Water repellent sound absorbent live material (1/2 mil vinyl-faced fiberglass or Mylar on tedlar-faced fire-retardant acoustical foam).

- Quick release hardware so the enclosures can be dismantled for refiner maintenance.

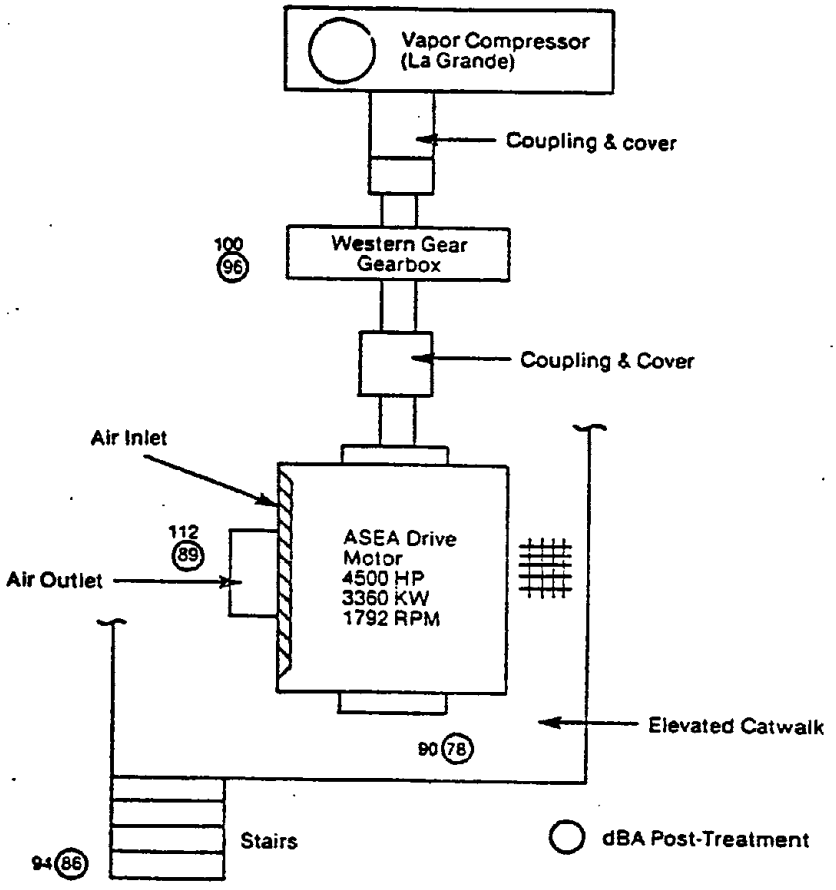
23-F ASEA MOTOR SILENCER

A 4500 horsepower ASEA drive motor for the vapor compressor fan (recovery boiler system) contributed to both personnel exposure and general annoyance at the mill. Noise levels were 94 dBA at ground level, and 95-99 dBA on the elevated steel catwalk around the motor (Figure 23-F1). The annoyance factor was probably caused by a pure tone noise component (112 dBA in the 2000 HZ octave band. Although the ASEA company offers a noise absorbing treatment for the motor outlet cover on new units, a field retrofit system was not available.

ACTION: A 14 gauge sheet metal (stainless steel) duct was designed to fit the motor cooling air outlet. All internal surfaces of the duct were lined with 2" fiberglass duct linear board. Neoprene tape strips were used as gaskets to seal the new duct to the old motor housing. The duct was installed to exhaust air to the ground level (Figure 23-F2). It was reported that no regular maintenance is required for the new silencer and the estimated life is 10 years (the fiber-glass duct was designed for high velocity air streams).

A comparison of pre- and post-construction noise levels are shown on Figures 23-F1 and 23-F3. A net 9 dBA noise reduction was achieved. This pure tone noise component was rendered inaudible.

Figure 23-F1
TYPICAL NOISE LEVELS AROUND ASEA DRIVE MOTOR



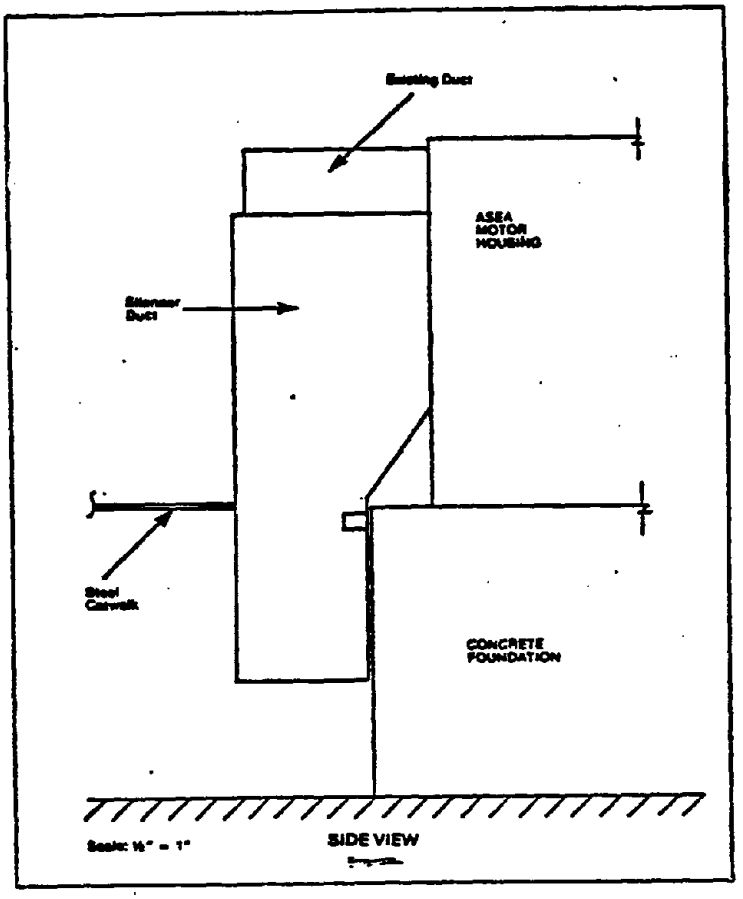


Figure 23-F2

DUCT SILENCER DESIGN CONFIGURATIO

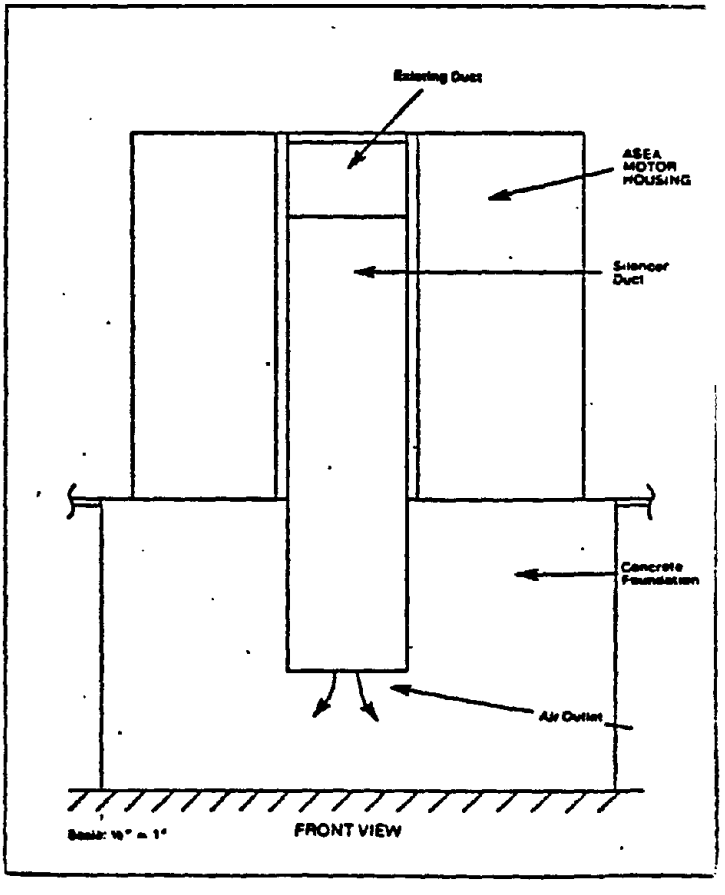
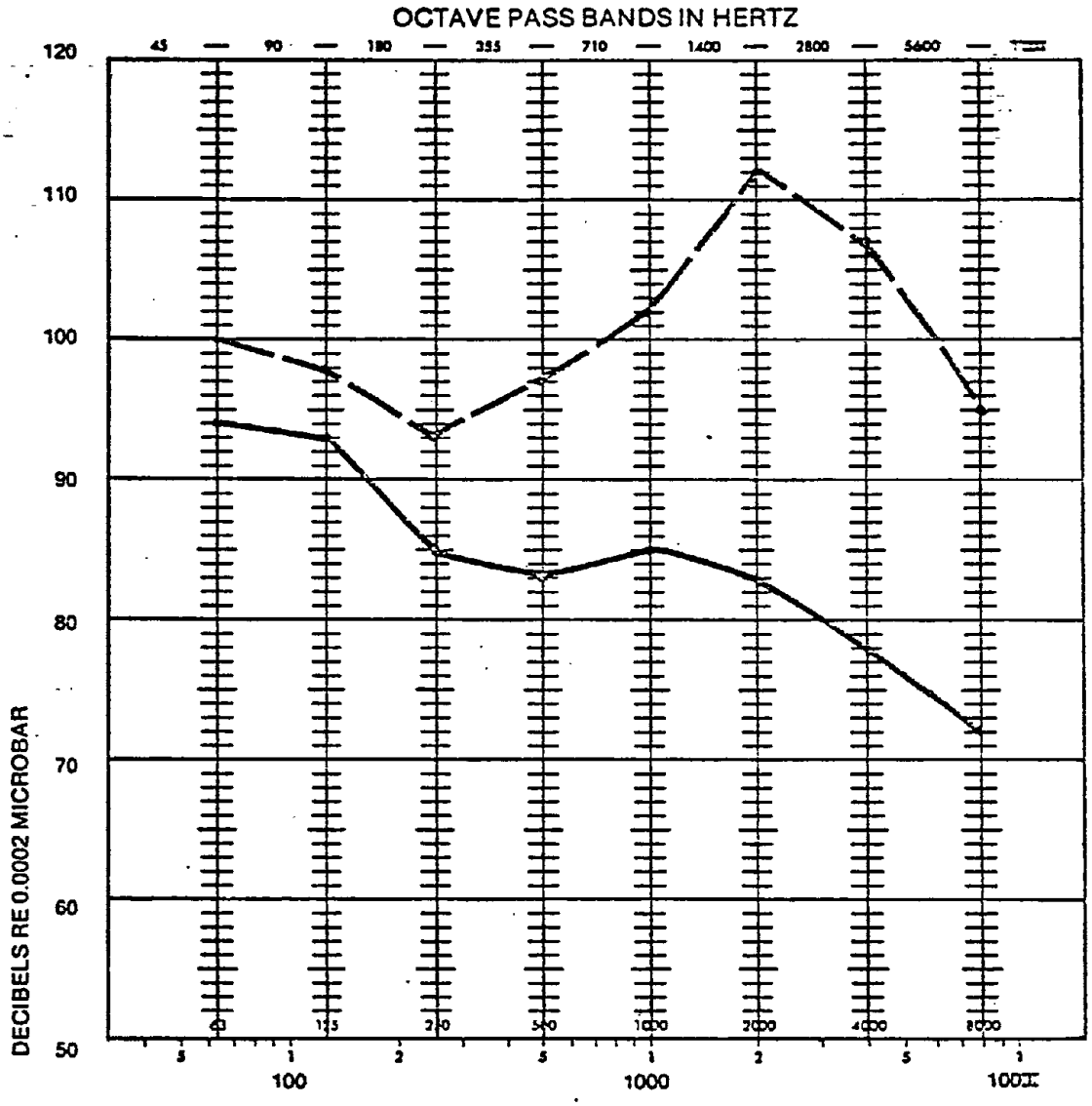


Figure 23-F3



PRE- AND POST-TREATMENT NOISE LEVELS

23-G WIDE SUPERCALENDAR MOTOR ENCLOSURES

In the finishing room of the papermill, thirty-five employees were exposed to excessive noise, primarily from the supercalendars. Noise levels around the supercalendars drive motors ranged from 89 to 99dBA. The following examples are intended to relate experiences by mill personnel in using full enclosures to reduce electric motor noise. Extension of these approaches should be carefully reviewed for system compatibility (i.e. to insure adequate motor cooling).

ACTION: All motor enclosures described in this study were constructed of metal sandwich panels of the type shown in Figure 23-E6 & 7. Even though an insulation board was used behind the sheet metal skin, it is optional based on noise reduction requirements. All enclosures were designated for easy access to the motor, with entrance doors and removable panels provided for maintenance, oiling, and greasing. Ventilation panels were incorporated for heat dissipation (the requirements for adequate ventilation must be examined on a case-by-case basis). The enclosures for the No. 24 and No. 25 supercalendars also incorporated special interior baffles to separate fresh intake cooling air from the hot exhaust air (found necessary to prevent the motors from locking out). In total, five enclosures were constructed (Table 23-G1) with average noise reductions ranging from 5 to 9 dBA.

23-H SILENCER FOR PAPER MACHINE REWINDER TRIM BLOWER

The paper mill has many rewinders feeding a massive trim handling system. Noise levels produced by the trim fan and duct network were causing high exposures at the winder operator's console and in areas where the trim duct passed. This study describes one such trim removal system which caused excessive noise exposure to personnel working a metal core cutting station on floor below the winder. Noise levels in this area caused by the trim blower and duct network ranged from 91-110 dBA (Figure 23-H1).

ACTION: Trim blower noise was successfully reduced by the installation of a pressure blower silencer (straight-through design which allowed both trim and air to pass). A Venturi was installed on the silencer inlet to minimize entrance losses. Noise levels after the installation of the silencer are shown on Figure 23-H2.

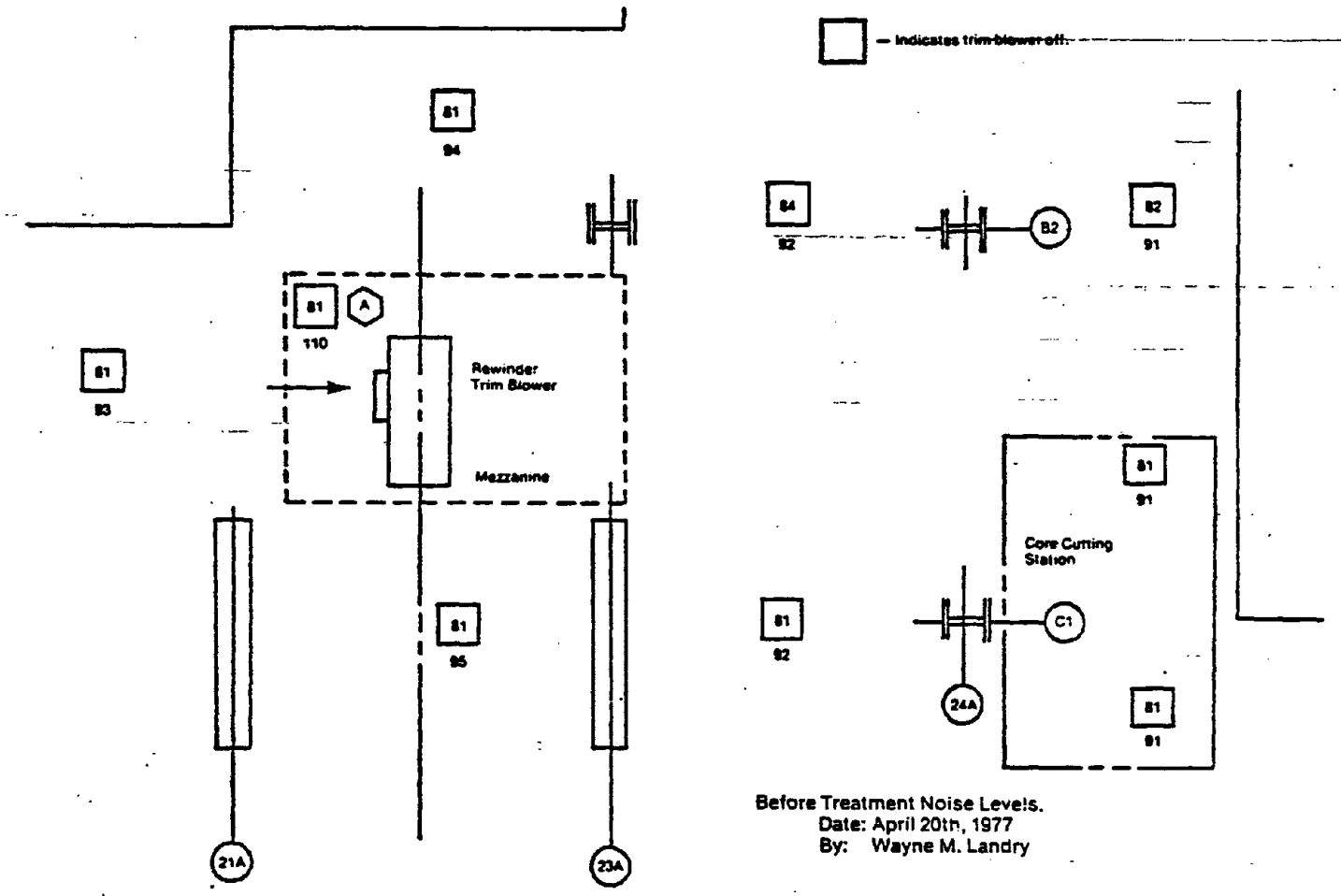
TABLE 23-G1: Wide Calender Motor Enclosures[1]

MOTOR TYPE:	Twin 350 HP Electric Motors for No. 25 Supercalender	Twin 350 HP Electric Motors for No. 24 Supercalender	400 HP Electric[2] Motor for No. 22 Supercalender	500 HP Electric Motor with 5:1 Gear Reducer for No. 21 Supercalender	400 HP Electric[2] Motor for No. 20 Supercalender
DATE INSTALLED:	September, 1976	August, 1976	January, 1977	May, 1978	May, 1978
BEFORE NOISE LEVELS:	94-95 dBA	98-99 dBA	89-92 dBA	91-92 dBA	90-92 dBA
AFTER NOISE LEVELS:	87-89 dBA	88-90 dBA	85-86 dBA	85-88 dBA	83-87 dBA

1. All were vented full enclosures with metal sandwich panel construction.
2. The electric motor was not a major noise source; enclosure was used on the main drive gear reducer.

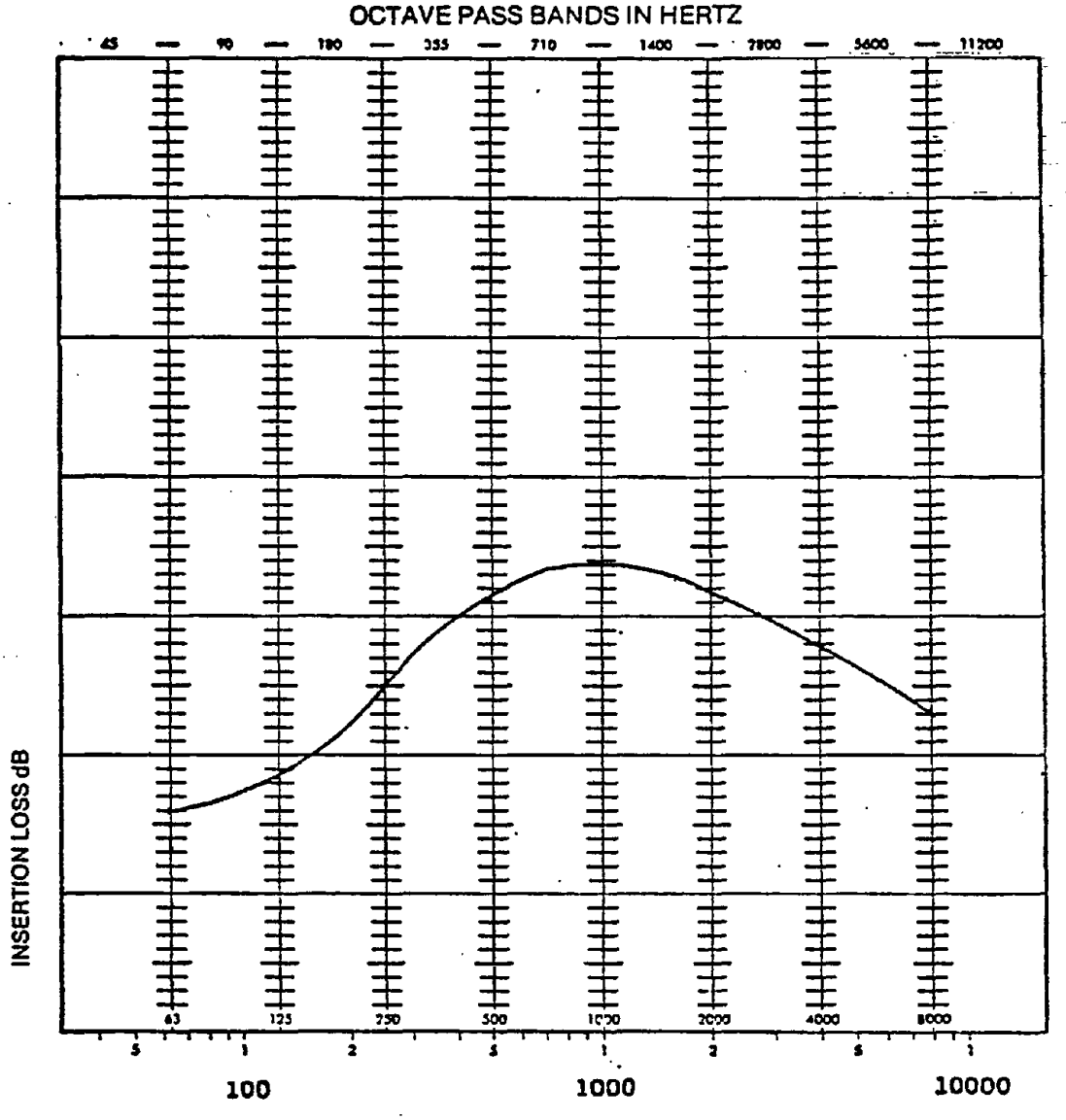
Figure 23-H1

PAPER MACHINE WINDER NOISE LEVELS



Before Treatment Noise Levels.
Date: April 20th, 1977
By: Wayne M. Landry

Figure 23-H2



FREQUENCY IN HERTZ
TYPICAL PRESSURE BLOWER SILENCER
NOISE REDUCTION CHARACTERISTIC

Several important factors had to be incorporated into the selection and specification of the silencer:

- An assessment was made of the allowable static pressure drop in the system relative to the trim blower capacity. It was determined that a Venturi on the silencer inlet was necessary to minimize entry losses.

- Since most silencers are constructed of steel, weight becomes an important design parameter. It was necessary to determine if certain structural elements needed to be strengthened to carry the weight of the silencer.

- An octave band analysis of the source had to be conducted to compare with the insertion loss (reduction in noise level) values supplied in the manufacturer's data sheets to assume adequate reduction, without overdesigning (which can be very expensive).

- The importance of casing radiation (amount of noise radiating from a silencer shell) to the overall noise source. Under certain conditions, casing radiation can be as high as the unsilenced blower.

23-I PAPER MACHINE REWINDER

Employees working at or near the No. 2 paper machine rewinder were exposed to levels in excess of OSHA limits (92-96 dBA at the operator's console). The motor drive was determined to be of primary importance with respect to the overall noise level.

ACTION: Full enclosure of the motor was selected as the optional approach because of the ease of application. The enclosure was constructed of a 3/32" aluminum shell with an inside lining of 8 lb. density mineral fiberboard (Figure 23-E6). Air intake and exhaust louvers were provided at the top and bottom to maintain proper motor cooling. The enclosure is of bolted construction for dismantling and handles were provided on each side so that it can be lifted off when maintenance is required. The post-treatment noise level at the operator's console was 86 dBA or a reduction of 5 to 10 dBA.

23-J VACUUM PUMPS

All paper machines employ vacuum pumps to supply vacuum to pull moisture out of the paper web as it

passes over a suction roll. The vacuum pumps are usually located in the basement beneath the paper machines somewhere near the suction rolls they supply. They require large horsepower drive motors and both units (pumps and motor) cause high noise levels (95 to 120 dBA in the basement).

Normally, paper mill employees do not work on a continuous basis in the vicinity of the vacuum pumps. Maintenance personnel, others, and utility employees must periodically enter these areas but exposure times are extremely variable. In some cases the vacuum pumps are located in aisles connecting various areas of the mill and pedestrian traffic is present. It is reported that noise dosimetry studies have shown various degrees of over-exposure for basement personnel. Job positions constantly exposed to some degree of vacuum pump and motor noise are:

Maintenance Personnel:
- Millwrights
- Electricians
- Pipefitters
- Pointers
- Carpenters

Oilers
Swipers
Clothingmen
Backtenders
2nd or 3rd Refiner Operators
Utility Employees
Truck Drivers
Broke Pit or Hydropulper Operators
Core Cutters

Vacuum pumps used in paper mill applications are primarily the rotary compressor types (Figure 23-J2) with a liquid ring seal. Units are limited to capacities of 8500 m^3/hr at a pressure of 5 kg/cm^2 and vacuums to 635 mm Hg single stage, or 737 mm two stage.

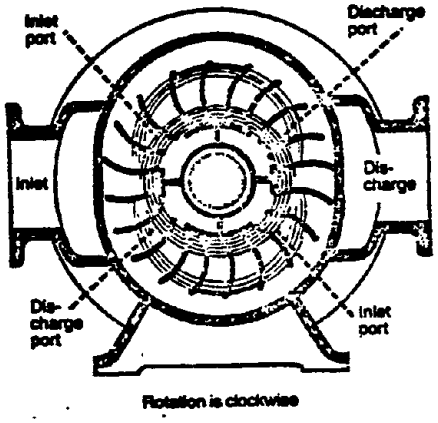
Commonly used vaccum pumps and operating characteristics are listed on Table 23-J1.

TABLE 23-J1

MFG	DRIVE	RPM	MOTOR	HP	RPM
Nash	Belt	-	Syn	60	1175
Nash	Belt	-	Syn	250	900
Roots-Cornersville	Direct	600	Syn	350	600
Nash	Gear	293	Syn	500	1781

Figure 23-J2

ROTARY COMPRESSOR WITH LIQUID-RING SEAL (NASH®)



Commonly served suction devices include the couch, second press section, top and bottom press rolls, breast rolls (tissue machines), washers, flat boxes (fourdrinier) and mud filters. Electric drive motor manufacturers include Reliance, Westinghouse, General Electric, and Allis-Chalmers.

The level of intensity of the various vacuum system noise sources vary, but a typical rank order would be:

Motor	101 dBA
Vacuum Inlet Pipe Radiation	100 dBA
Outlet Exhaust (Silencer Shell and Exhaust Port)	98 dBA
Vacuum Pump Body	95 dBA

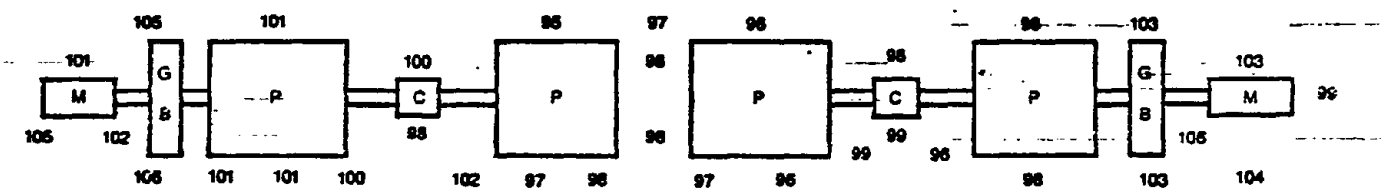
Figure 23-J3 shows a quad-vacuum pump system with noise levels taken at 12 inches from the radiating components. In this case, the drive motor exhibits higher noise levels than the pump, probably due to the cooling fans used in these motors. Recently, quieter motors have been developed by the manufacturers, and new mill installations are not as likely to have this problem.

Vacuum pumps exhibit strong low frequency pure tones which are related to the shaft speed and the number of rotating or reciprocating internal elements (typically 125 or 250 HZ). Occasionally, fourdrinier flat boxes served by vacuum pumps radiate high level low frequency tone at the paper machine wet-end.

DISCUSSION OF POSSIBLE ACTIONS: Noise control measures in vacuum pump areas should be related to the estimated or measured noise exposure, the feasibility, and the cost. Once the measured exposure has justified the work, a thorough noise survey should be conducted to classify the sources.

For Roots type installations (where necessary), the vacuum supply piping, pump casing, and silencer (surge tank/water separator) can be lagged with a fiberglass or acoustical foam decoupling layer covered by a mass layer (one to two pound per square foot. It is important that the fiberglass or foam be dense enough not to collapse under the mass layer yet pliable enough to wrap the pipe (one to two inch pre-molded pipe insulation can also be used). Mass layer coverings can be barium or lead loaded, plain lead sheet, or multiple layers of tin or galvanized steel. If necessary, two stacked layers of lagging can be used. All joints should be tight-butted or overlapped with liberal use of tape to close any cracks.

Figure 23-J3



Near field sound pressure level , dBA at 12" from surface

M — Motor

GB — Gearbox

P — Pump

C — Coupling

Occasionally, the vacuum pump exhaust silencers supplied by the manufacturer will perform poorly. Successful approaches include replacement with a better unit, piping the silencer exhaust port elsewhere, or routing the exhaust port into a floor sump or water silencer. If too much piping is used to connect the pump exhaust to the silencer, the silencer performance may be degraded acoustically. To minimize coupling and pipe noise radiation, silencers should be located as close to the vacuum pump exhaust as possible.

Figure 23-J5 shows a water silencer design which can be used in conjunction with a regular silencer, or installed on unsilenced exhaust (if designed properly). The use of the 6" concrete and 2" fiberglass will increase noise reduction of this device over metal tank silencer types with the same area and volume.

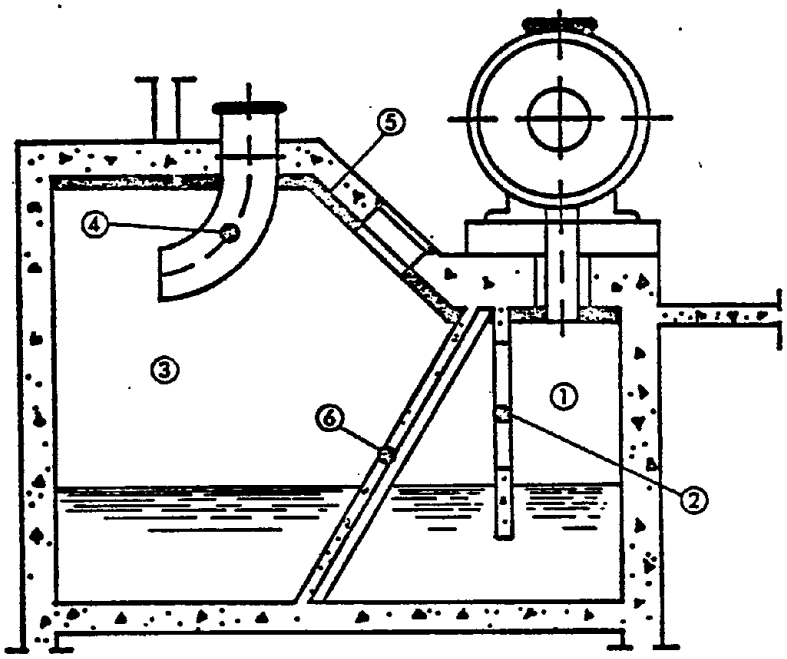
Gearboxes should be checked for badly worn gears in need of a rebuild. Substantial noise reductions have been achieved after a good rebuild. Lagging (as described for pipes and pumps) can also be successfully applied to gearbox covers.

Occassionally, the age or condition of a motor can justify a replacement unit. Many manufactures now offer quiet motor lines with test reports or data that follow the IEEE Test Procedure No. 85. At least one line of quiet TEFC Motors is now available for which noise has been effectively designed out. Air noise was controlled by employing a more efficient fan in the air baffle configuration. The fan housing was designed for a smooth, clean air flow path with no noise-producing sharp edges or obstructions. Electrical systems were designed to suppress magnetic noise and the heavy rigid frame suppresses vibration.

Where aerodynamic noise can be identified as a major noise component, the addition of a motor air silencer can be very effective. TEFC motors, where the fan belt is located on the tail end, can usually be filled with a bolt-on tubular silencer (similar to those manufactured by Spencer Turbine Company of Windsor, CT). Motors with rectangular sides or bottom slots for air flow will need custom designed 16 to 18 gauge steel duct silencers lined with 1" fiberglass ductliner. The resultant attenuation will be proportional to the duct length and elbow dimensions. In severe cases, drive motors can be totally enclosed

Figure 23-J5

WATER SILENCER



1. Pump channel
2. Openings. Calculated to give max attenuation at the pump frequency
3. Sump
4. Outlet pipes
5. Mineral Wool absorbers
6. A concrete wall put across the airstream to separate drops of water

if care is given to controlling temperature rise. An optional and perhaps superior solution would be to cover the motor with a fiberglass lined tunnel with open ends (the length of the tunnel determines the amount of noise reduction).

23-K PAPER MACHINE WET ENDS

At the wet end of a typical paper machine, a suspension of pulp stock (1%) and water (99%) is pumped to a headbox and returned onto the wire (a fine mesh, plastic moving belt) to form the beginning of the paper web. Water is gradually removed from the web via vacuum flat boxes (located under the web) and the couch roll until the paper web is almost 10% pulp stock. The web is then transformed to a web felt and fed into the suction press and smoothing rolls. Refer to Figure 23-K1 for a schematic of a wet end configuration and average noise levels.

At this mill, the only employee exposed to wet end noise on a continuous basis is the machine operator, who receives about 105% of the daily allowable exposure. Other exployees who are exposed periodically include the back-tender, the stock preparation and beater room personnel, and supervisory and maintenance personnel. In some cases, the daily noise dose for these employees exceeds 100%, but this is highly variable.

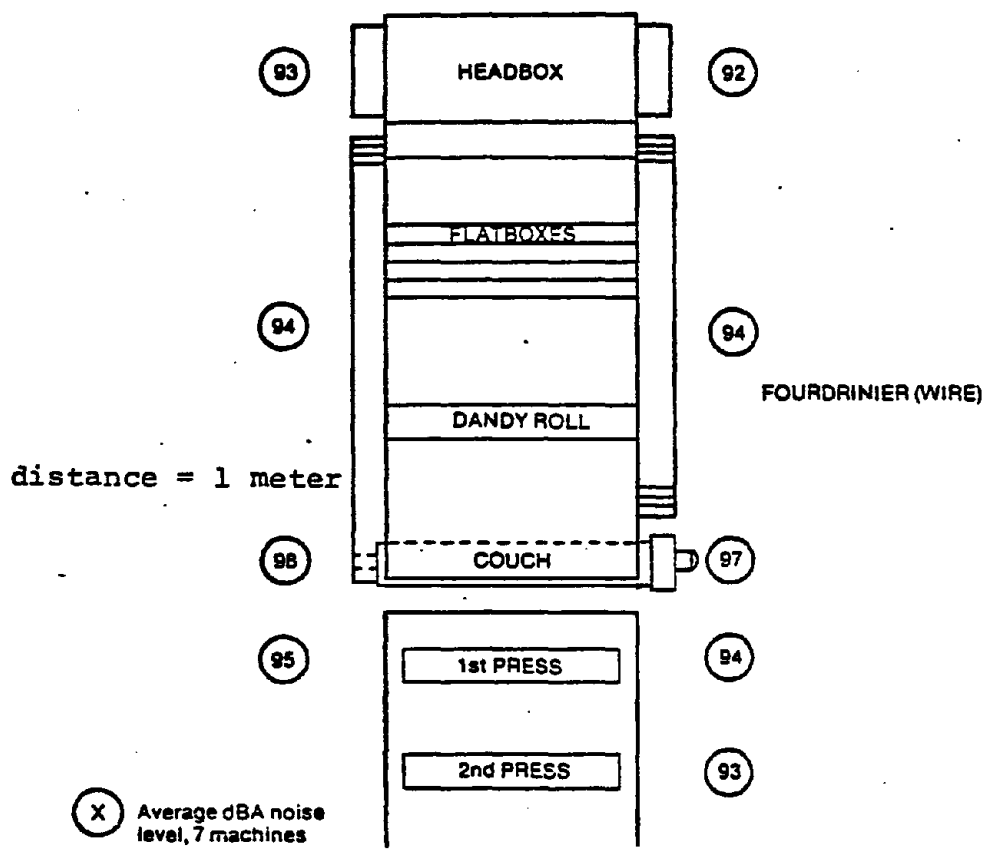
Wet end noise sources (in decreasing order of severity) are typically the couch and suction press rolls, water flows and jets, air jets, flat boxes, vacuum pumps (below the machine), and backside drive equipment. In some mills, refiners also contribute significantly to wet end noise.

A summary discussion of the various noise sources is provided:

- Suction roll noise is produced by the rush of air into roll holes as they rotate over the edge of the suction box from the vacuum to the atmospheric side.

- Breast rolls, located under the headbox, are noisy only on tissue machines where vacuum is supplied and generate a high, pure-tone frequency proportional to rim speed and hole pattern.

Figure 23-K1



TYPICAL PM WET END CONFIGURATION

- Vacuum pump noise was sometimes found to propagate through piping and radiate from press suction rolls (can create aisle noise levels up to 98 dBA). Some flat boxes also radiate vacuum pump noise.

- Backside wet end noise is similar in nature to front side with the addition of electric motors and gear drive units. Some surveyed electric motors exhibited a high pitch whine proportional to the RPM, and the number and position of commutator and stator segments. Primary movers are usually secondary in importance to suction rolls and water noise.

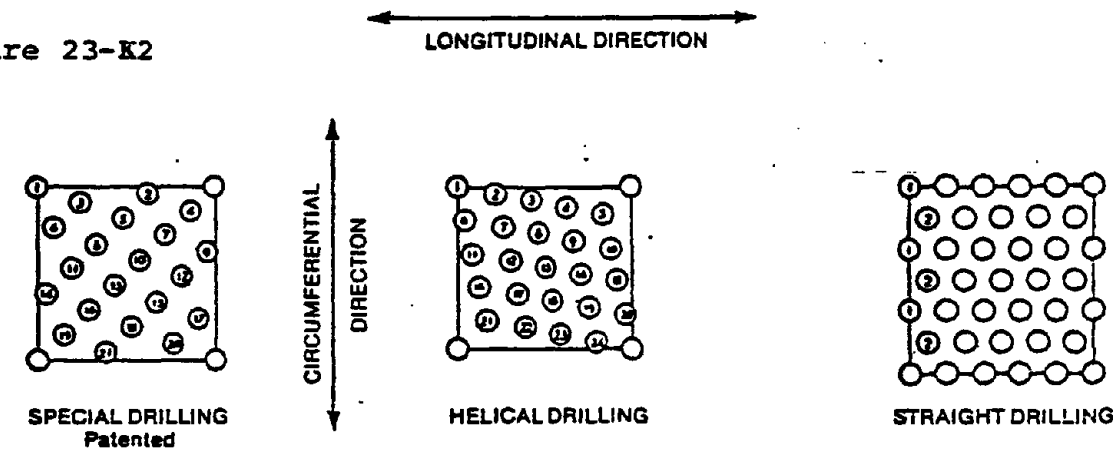
- Water spray noise is generated by two or three rows of water spray nozzles located under the fourdrinier section and one row over the dandy roll. These units spray water streams onto the roll where it crosses the idler roller. Wet end noise generated by water along is approximately 87 dBA at one meter and 91 dBA under the wet end catwalk (Figure 23-K2).

DISCUSSION OF POSSIBLE NOISE ACTION:
Substitution of silent drilling pattern couch or suction rolls for older rolls is the most efficient treatment from an acoustical point of view. However, these rolls typically are very expensive and economics may preclude their use. The silent drilling patterns on these rolls can reduce noise output by as much as 30 dB at some frequencies through an acoustical interference technique (Figure 23-K2).

These silent-type suction rolls should not be standard on all new machines. Replacement may be most efficient during machine rebuild. Where vacuum pump or flat box vacuum noise is a problem, the suction side pipe may be fitted with a conical, stainless steel moisture proof silencer.

Air nozzles may be fitted with inexpensive threaded silencers providing up to 6 dBA noise reduction (depending on line pressure and type). Water jets used to trim the web edge on the wire are not a major problem. However, spray nozzles under the wire should be shielded from the machine operator aisle via lower skirt, stainless steel barrier panels (removable for maintenance).

Figure 23-K2



Various drilling patterns on suction roll shells, special drilling is best for sound abatement.

As motors and gearboxes wear out, they can be gradually replaced with quieter units (noise reduction in excess of 10 dBA). Immediate noise abatement will require full or partial enclosures of modular metal acoustical sandwich panels with sound-trapped cooling air supplies (forced or convection). As with refiners, lagging can be used on gearboxes if sealing and temperature rise are considered. Generally, 1" acoustical foam and one pound mass-loaded plastic barriers are required.

Noise exposure compliance can also be achieved by the use of personnel enclosures, provided the employees spend sufficient time in the protected environment. Enclosure conceptual designs must be tailored for each paper machine location, and may be directly usable at other mills without additional work. All designs should include easy movement where necessary, sufficient interior lighting, adequate air supply, and good process visability.

Wet end enclosures could be 2" metal sandwich panel type with single pane glazing of tempered safety glass. Other constructions with minimum performance of STC 30 for noise isolation are acceptable. In most cases, air conditioning will not be used, but liberal air circulation (with proper sound trapping) is required. Each mill location has stressed the need for quick and easy access to personnel enclosures. This can be accomplished with a two way swinging metal door or, more conveniently, with hanging, overlapping strips of 1/4" PVC (allows full visability through the door). All personnel enclosures should be mounted on hard rubber stainless steel casters to provide access to the paper machines for roll and drum removal.

Operating consoles require only a partial enclosure (three sides and top) on castors to slide over the top of the console. It may be necessary to make minor modifications to accommodate warning lights and horns mounted on the top of the console cabinets. Ceiling lighting for the enclosure should be on a wall switch so that the space can be darkened for console light monitoring.

23-L PAPER WINDERS

This study includes winders, which process large rolls of paper into the desired widths and diameters, and rewinders, which are of the same configuration but process coated papers. As illustrated on Figure 23-L1, winders and unwinders usually consist of an unwind stand, guide rolls, slitters, a front and rear

drum, a lowering device roll kicker, and trim chutes. Most winder operations require three employees - the windman and two helpers, normally within two to three meters of the machine during operation. Despite the fact that winders contain similar parts, three are wide variations in dimensions, drum types, trim evacuations systems, and unloading methods. These variables, including the age of the system, result in significant differences in noise levels and worker exposures, and must be carefully considered in any noise assessment.

Winder employee noise exposures are difficult to assess as the units are not operated continuously, and there are numerous secondary noise sources (paper machines and adjacent winding stations). Noise dosimetry data result in employee exposures ranging from 162 to 200 percent of the allowable limit. Noise levels at winder consoles were found to be in excess of 90 dBA with the winder off for 60 percent of the winders studied. With the winder operating at full speed, increases in noise levels at the console (above background) averaged 3 to 8 dBA. Table 23-L1 presents a comparison of area noise levels for a number of different winders.

Noise measurements reveal that the major winder noise sources (in decreasing order of importance) are the drums, the slitters, and the trim chute blowers. Each of these primary noise sources are discussed below:

- Drums - All winder drums are chevroned (grooved) to aid in winding a tight, uniform paper roll. The chevron angle and depth varies considerably but, with the exception of radial drums, angles are usually 12 degrees or less. Peaks in the frequency spectra are a function of the drum RPM and the chevron angle and spacing (Larger chevron angles result in higher noise levels.)

  New winders use a radial or circumferential drum grooving in a right or left hand threaded spiral arrangement. During winding, trapped air can escape resulting in lower noise levels. On some machines, both drums are radially grooved; on others the rear drum is grooved and the front drum is smooth. Although only one machine was available for study, the latter configuration appears to result in lower noise levels. One manufacturer recommends grooving both drums when 90 lb. or higher paper weights are used.

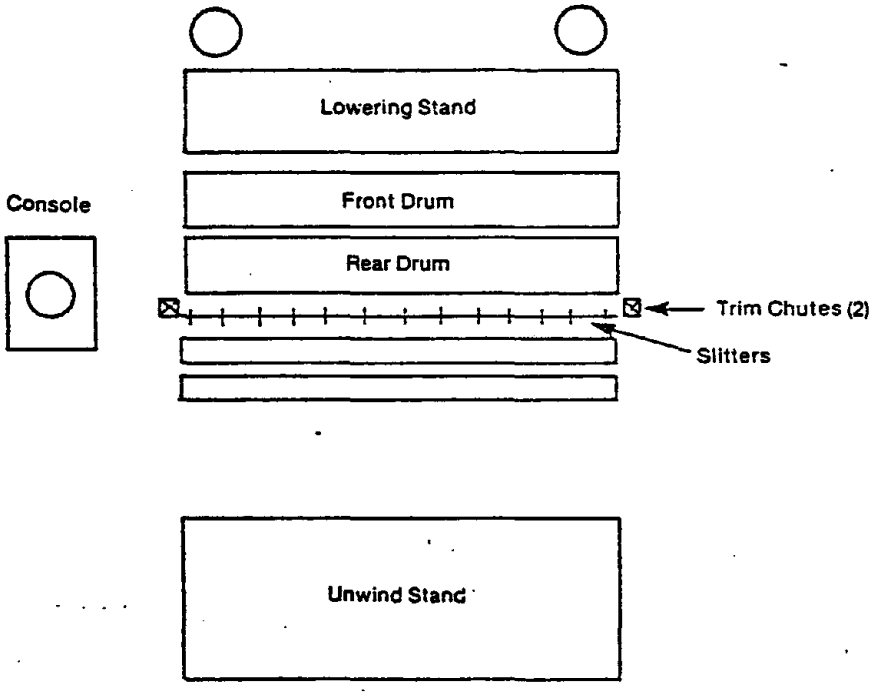
Table 23-L1

WINDER #	LOCATION	PAPER WGT	SPEED FPM	DRUM TYPES FRONT	DRUM TYPES REAR	CONSOLE dBA	CONSOLE AMBIENT	DRUMS NEAR FIELD	TRIM CHUTE EFFECT	NOTES
1	St. Helens	125	3500	LC	LLC	95	84	109	1	
2	St. Helens	34.5	5000	RG	RG	94	91	103	2	
4	St. Helens	41.5	5400	S	RG	91	86	104	1	
1	Salem	20	2900	LC	S	98	90	104	0	
2	Salem	20	—	LC	L	96	91	106	0	
3	Salem	30	3000	LC	LC	94	79	102	0	PM down
4	Salem	20	2500	LC	LC	96	90 (84)*	100	2	*PM down
6	Rumford					96				
7	Rumford	34.5	4000	S	RC	94				
8	Rumford	38	4000	S	RC	92				
9	Rumford	30.5	4000	LC	LLC	96				
31 (RW)	Rumford	40	3500	LC	LC	97				
34 (RW)	Rumford	40	3000	S	RC	93				
5	Ft. Francis	—	6400	S	RG	95	90	99		New Beloit

LC - Longitudinal Chevrons RG - Radial Groove L - Longitudinal
LLC - Longitudinal & Lateral RC - Radial Chevron S - Smooth

WINDER COMPARISON CHART

Figure 23-L1



TYPICAL WINDER CONFIGURATION ◯ Circle denotes measurement points.

- Slitters - The most common slitter arrangement consists of a sharp-edged metal disc driven either by the web or by edge contact with a second motor driven backup disc. Noise is generated by edge-to-edge, high RPM scissors action between the slitters. Radiated noise ranges up to 102 dBA at 1 ft., with spectrum peaks in the high frequency bands (4000 to 8000 Hz). Most control consoles are directly opposite the slitters, which contribute a 2 to 3 dBA increase in employee noise exposure. Web driven slitters are now supplied as standard equipment on new winders, and are usually not detectable above the winder noise sources.

- Trim Chute Blowers - Trimmer paper is transported away from the winder in trim ducts and reconverted to pulp. Suction is created by a large centrifugal fan driving high velocity air through an injector (inverted T-shaped device with the trim paper travelling down the vertical section). The device works through the Venturi effect (Figure 23-L2). Wide variations were found in trim fan and duct arrangements. Duct air velocities varied by a 4 to 1 ratio.

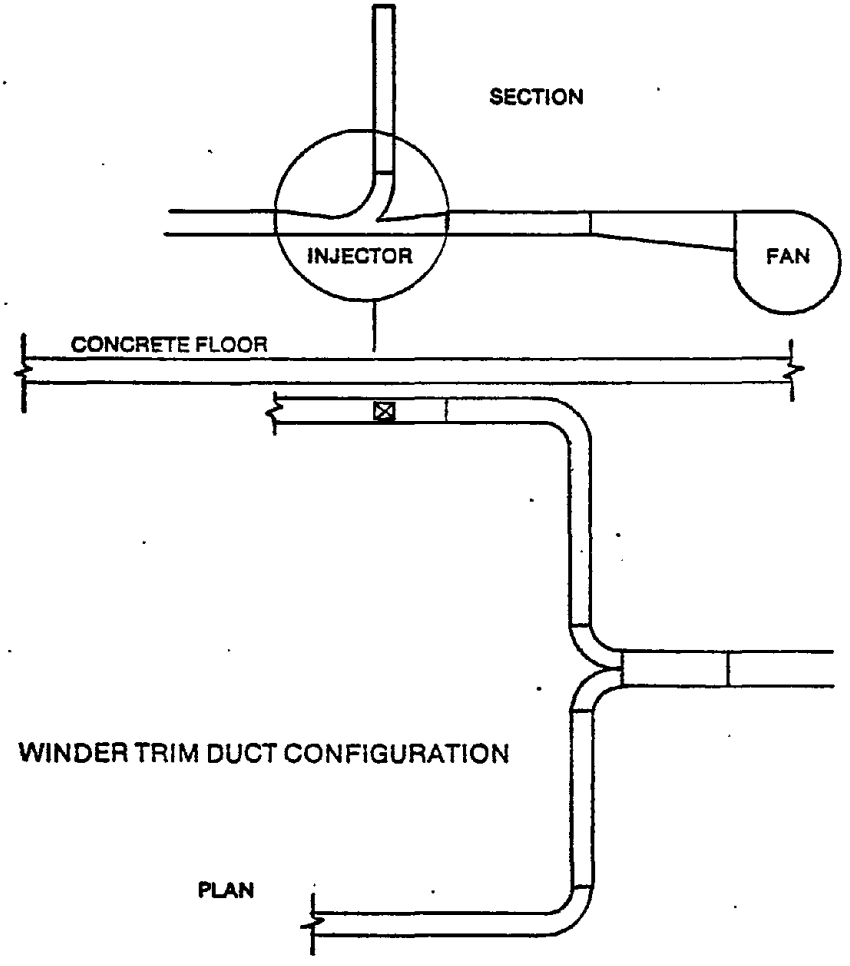
DISCUSSION OF POSSIBLE ACTION

- Drum Noise - From purely an acoustical point of view, replacement or resurfacing/regrooving of old winder drums is the best choice for engineering noise control. However, the cost must be carefully considered.

  The study recommends that new machines be purchased with the quiet drum configuration.

  Another possibility is the use of portable noise screens or barriers between the operator and the control console. These should be at least 8' high, long enough to provide line-of-sight shielding, and provided with a sufficient viewing area of glass or clear Lucite. Such a barrier would weigh over 300 lbs. and should roll on castors to facilitate easy machine access. It should be possible to achieve a noise reduction of 5 to 8 dBA with this control, depending on the ceiling height, reflecting surfaces, and distance between the machine, barrier and console. A major disadvantage of noise barriers is the interference with personnel movement about the machine.

Figure 23-L2


SECTION
INJECTOR
FAN
CONCRETE FLOOR
WINDER TRIM DUCT CONFIGURATION
PLAN

Another option would be the installation of a winder control personnel enclosure. This would probably bring the operator into compliance, but the helpers would likely remain overexposed.

Winder control enclosure studies have shown that each unit must be custom-designed to be compatible with production work flow. For some winders,; enclosures are simply not possible due to interference with paper log transfer movements or maintenance operation. It is also necessary to examine each case separately to determine if the operator can remain inside the enclosure for sufficient time. For those winders found to be over 90 dBA with the winder off, it is also necessary to attack the other noise sources.

- Slitters - Possible engineering solutions include replacement of motor drive slitters with web driven types, or installation of plexiglass barriers near the source. Although replacement with web driven slitters would result in less noise and some electrical power savings, slitter conversion is reportedly very expensive.

  Slitter disc damping has been ruled out as a possible solution because of the mass and thickness of the disc. A Lucite barrier located close to the slitter line could result in sufficient noise reduction for the operator.

- Trim Chute Blowers - Noise radiation is caused by fan noise propagation down the ductwork and up the trim chutes. Some mill personnel believe that lower transport velocities could be tolerated and still convey trim paper. If this is possible, very significant noise reduction can be achieved (noise varies approximately as the 6th power of velocity). A calculation with a 1/3 rpm change at a winder resulted in a predicted noise reduction of 9 dB in each octave band. Changes in the blower RPM can usually be accomplished through a single pulley modification.

  A less desirable and more expensive treatment involves the installation of a through-type sound trap in each duct leg. Another possibility (not investigated) is the use of fiberglass-lined ductwork instead of sound traps (same effect). Either of these designs must be preceded by a thorough study for each individual case.

It was found that some trim blowers (usually located below the winder flow) contributed to the noise exposure of employees working below. Off the shelf inlet air silencers may solve this problem, but enclosure of the fan or duct lagging may also occasionally be necessary.

23-M JAGENBERG VIN-DUR MODEL 45-15 TWO-DRUM MACHINE WINDER

The Jagenberg winder was installed at the dry end of a paper machine in June of 1975. Noise surveys in 1977 and 1979 demonstrated that noise levels one meter from the operating machine average 89 dBA. Since many existing winders average well over 90 dBA, this was documented as an example of a quieted product. Other companies now offer large winders which produce noise levels of 90 dBA or less at speeds up to 6000 fpm (Beloit-Downington Div., Dominion Engineering, Manchester Machine, and others).

SOLUTION: Figure 23-M1 is a specification list for the Jagenberg winder. Although nothing is noted specific to noise control, a combination of factors cause this winder to meet the OSHA noise standards for eight hour exposure.

FIGURE 23-M1
JAGENBERG WINDER MODEL 45-15 SPECIFICATION LIST

Top Web Speed	4000 fpm for material up to 110 g.s.m. 1600 fpm for heavier grades
Max Unwind Diameter	72 inches
Max Rewind Diameter	60 inches
Nominal Trim Width	84 inches
Minimum Slitting Width	4 inches
No. of Top Slitters	14
Width Adjustment Range at the Rewind	55 inches
Main Drive	2 drum electric, 60hp G.,E. motors with Falk reducers

Accessories

"Constamat" automatic web tension control Progressive counterloading of ridex roll Winder drum radial grooving Solenoid braking of tension control rolls Mt. Hope roll

A plan detail of the Jagenberg winder showing area noise levels is shown on Figure 23-M2. These readings were made with the winder operating at 4000 fpm with 38 lb. paper. The bracketed reading (74 dBA) was made with the winder down, and shows that the noise contribution from nearby sources is negligible. It must be noted that conclusions relative to employee exposures around the Jagenberg winder are not valid if background noise is equal to or above the OSHA standard.

Past investigations have shown that the major winder noise sources are the drums, slitters and trim chute blowers. The original trim blower was reconnected to fit the new winder and did not present a noise problem. The winder drums are of the type currently recommended by the manufacturers for noise control (rear drum with radial grooving, forward drum with smooth surface).

The winder also employs shear cut top slitters which are non-tumbling without springs. Operation of the unit is remote from a console via an air charged slitter bushing. Grooving of other metal or plastic web guide rolls may also contribute to noise reduction, but this was not verified.

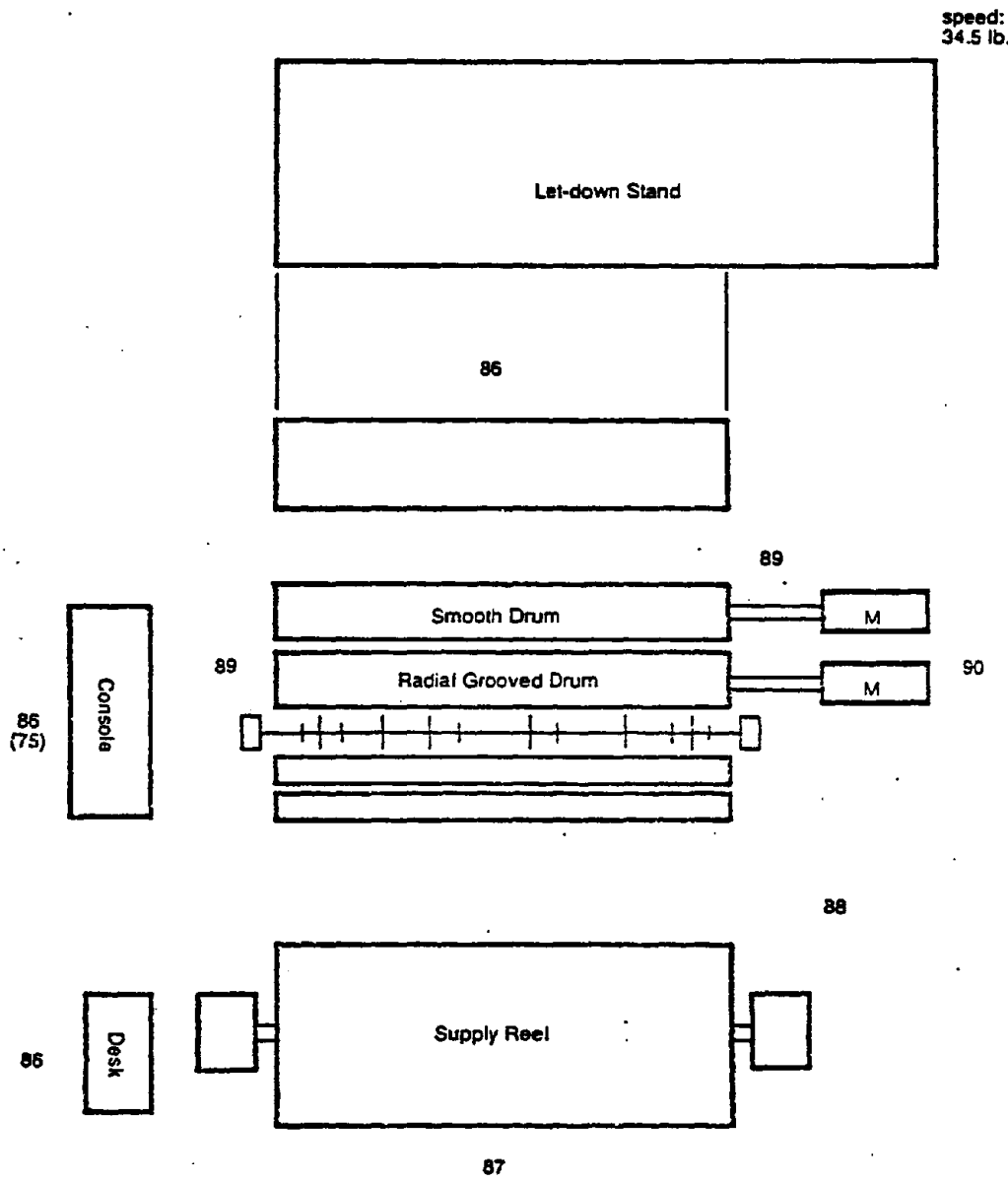
Another unverified but probable noise control factor is the mounting of the winder over two large concrete piers extending below grade. The 2' wide piers with 11' x 2' x 2' foundations used a total of 39 cubic yards of concrete over steel rebars on 1' centers.

23-N PERSONNEL NOISE SHELTERS

Many new paper machines are provided with built-in control rooms which limit noise exposure by employee location. Older mills, however, employ control and instrument consoles in open areas or against a wall near the wet end of the paper machine. Noise levels are usually between 92 and 98 dBA on the attending side of the machine. After an intensive, two-year study of paper machine noise sources and possible engineering controls, a task force determined that the installation of personnel enclosures represented the most cost effective exposure abatement technique in many mill locations.

Figure 23-M2

Jagenberg Winder



Few employees are present at the wet-end and the dry-end (calendar stock and reel) of the paper machines. The back-tender attends the dry-end area, but may occasionally visit the wet-end and other noise areas. Paper winders at the dry-end have one operator who stands at a control console for most of a windup. This employee is assisted by two hands (4th and 5th) who may be near the winder but away from the console.

A detailed noise source and personnel exposure analysis showed that enclosures could be effective controls depending on the time that exposed workers could inhabit them. Time and motion observations, together with workplace noise levels, pointed to excellent probability for success at some locations, but marginal in others. It was surmised that, if adequate time were allowed for affected employees to adjust and become familiar with the enclosures, and if front-line supervision issued and enforced firm usage guidelines, then the chances of success would be greatly increased:

To increase the chances for acceptance and success, the enclosures were designed with the following features:

- control consoles and instruments relocated into two enclosures
- adequate internal lighting (later dropped at the request of employees)
- air conditioning, or volume air flow
- easy access doors
- wrap around windows
- roll-away castors

Personnel enclosures offer a low-maintenance approach as easy access can be achieved by using castors and electrical umbilical cords. Units which require less frequent access can be provided with fork lift channels under the floors.

The task force contacted many enclosure manufacturers for suggestions and input regarding state-of-the-art materials and technique. After interviewing potential enclosure users (machine tenders, backtenders), it was decided that the task force would sponsor an enclosure technique research project. The objective of the project was to develop "linear-noise-reduction" enclosures to counter operator complaints that they could not effectively monitor the paper machine from inside an enclosure. The results of the research project were successful and are described in this report.

Mill Location	Location	NR dBA	63	125	250	500	1000	2000	4000	Remarks
Salem	PM 1 Wet End	10	8	7	8	12	12	13	12	Partial
Salem	PM 2, 4 Wet End	21	8	8	14	23	24	22	22	
Salem	PM 3 Wet End	13	3	4	10	14	15	15	16	Partial
Salem	PM 3 Winder	20	3	7	13	17	21	18	17	
Salem	PM 2 Backtender	23	6	9	18	22	24	23	22	
Salem	PM 4 Manifest Booth	11	1	1	13	11	10	10	13	Partial, Strip Doors
Rumford	PM 9 Wet End	31	6	17	25	33	34	33	37	Supplier Specified

TABLE 23-N2: A-Weighted & Octave Band Noise Levels

- enclosures on castors are equipped with foot locks to prevent movement
- all enclosures use tempered safety glass for all windows (Lucite plastic windows tend to scratch with age and cleaning)
- all enclosures have built-up floors and thus require a step-up entry door (4 inches or less and thus should not constitute a trip hazard)
- hearing protection is not required within the enclosures, but remains mandatory elsewhere.

Other possible enclosure locations are for beater engineers, coater operators and more backtenders and winder consoles.

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