FORMALDEHYDE EXPOSURE CHARACTERIZATION IN GARMENT MANUFACTURING PLANTS: A COMPOSITE SUMMARY OF THREE IN-DEPTH INDUSTRIAL HYGIENE SURVEYS

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ABSTRACT

In-depth industrial hygiene surveys were conducted in three large shirt manufacturing plants to determine airborne concentrations, and personal exposures to formaldehyde as part of a mortality and industrial hygiene study of garment manufacturing workers exposed to formaldehyde. One of the three plants closed in 1982, one plant was closed in 1986; the other plant still manufactures shirts at the writing of this report. Each of these plants produced dress shirts for men using fabric treated with formaldehyde-based resin systems for crease resistance. The pre-cured resin treated fabric was received from a textile finishing mill, cut into shirt parts at the plants and these parts were then sewn together. The workforce, primarily female, of these three plants has been exposed to formaldehyde vapor emitted from the treated fabric since the mid to late 1950's. No historic exposure information exists for this workforce. The only engineering control and exposure reduction efforts consisted of dilution ventilation within the plants and improvements in the resin treatment process to reduce the amount of formaldehyde emitted from the fabric. These in-depth industrial hygiene surveys documented exposures to formaldehyde, nuisance dust, organic vapors, and noise. Personal breathing-zone samples for formaldehyde were collected within each department of each plant. Formaldehyde exposures ranged from non-detectable (<0.02 ppm) to 0.51 ppm and were below the OSHA PEL and ACGIH TLV. NIOSH recommends that exposure to formaldehyde be maintained at the lowest feasible level. Increased dilution ventilation, installation of local exhaust ventilation at specific job operations, and limiting the amount of stored fabric within the plant confines would aid in reducing the exposure levels. The sampling surveys demonstrated that formaldehyde exposure potential was essentially constant (not intermittent peak exposure) and low level for all job operations within all departments, and across all three plants. Cigarette smoking did not appear to influence formaldehyde exposure sample results. Exposure to nuisance dust (lint) was minimal (no measurable amount to 2.28 mg/m^3) and was well below the OSHA PEL, ACGIH TLV, and NIOSH recommended levels. Exposure to organic vapors (cleaning solvents) was not widespread (very few workers were exposed), and concentrations ranged from non-detectable to 20.8 ppm; a level which is considerably lower than the OSHA PELs, ACGIH TLVs, or NIOSH recommended levels. Noise level measurements ranged from 70-95 dBA for various job operations within the three plants. These results indicated the need for a hearing conservation program for workers in the garment manufacturing industry. Recommendations are provided to reduce exposure potential to formaldehyde, cleaning solvent/vapor, and noise.

TABLE OF CONTENTS

INTRODUCTION

Under the Occupational Safety and Health Act of 1970, the National Institute for Occupational Safety and Health (NIOSH) was mandated and authorized to conduct research and health studies. This research is pursuant to the development of health standards applicable to the broad range of occupational environments. In compliance with this mandate, the Industrywide Studies Branch of the Division of Surveillance, Hazard Evaluations and Field Studies, NIOSH, conducted a research study of the extent of exposure and mortality experience of workers exposed to formaldehyde. This research effort was prompted by the results of excess nasal squamous cell carcinomas in two independent studies of rodents exposed to formaldehyde.[1,2] Because of these findings, NIOSH issued a Current Intelligence Bulletin that recommends formaldehyde be handled in the workplace as an occupational carcinogen and that worker exposure to formaldehyde be reduced to the lowest feasible level.[3]

The epidemiologic portion of this research consisted of a proportionate mortality study and a retrospective cohort mortality study.[4,5] The industrial hygiene portion of the study (reported herein) was designed to determine the extent of exposure to formaldehyde across a large general worker population, to aid in the selection of a suitable cohort for the mortality studies, and to fully characterize the environment of the defined population in the epidemiologic study. These were important goals of the overall study because of the paucity of formaldehyde exposure data in the literature. The data that were available did not truly characterize the exposure of individual workers or job operations since it was primarily compliance or hazard evaluation data.

Formaldehyde has been used extensively in various manufacturing processes since the late 1940's. Half of the formaldehyde produced is used to manufacture synthetic resins such as urea- and phenol-formaldehyde resins. These resins are used primarily as adhesives when making particleboard, fiberboard, and plywood. Urea-formaldehyde concentrates are used in various coating processes, in paper products, and in making foams for thermal insulation. The textile industry uses formaldehyde-based resins for producing creaseproof, crushproof, flame resistant, and shrink proof fabrics.

In order to locate a suitable population of workers for a mortality study, eighteen walk-through surveys were conducted to gather information on the number of workers exposed; the frequency, duration, and magnitude of formaldehyde exposure; the extent of confounding exposures; and the existance and quality of personnel records. Based upon these preliminary surveys, the garment manufacturing industry was chosen as the most suitable for the mortality study of workers exposed to formaldehyde. This group was chosen because of the continuous exposure to formaldehyde since the mid 1950's, there was no exposures to other known or potential carcinogenic agents, there were adequate record systems to identify exposed workers and determine vital status, and the group of workers was large enough to satisfy the statistical requirements of the epidemiological study. Nine

walk-through surveys and three in-depth industrial hygiene studies were conducted in garment manufacturing plants. All of these facilities produced garments from fabric which was treated to impart crease resistance and other desirable properties. Garment manufacturing workers, who handled the cloth treated with formaldehyde-based resins, have been exposed since about 1955 to continuous low levels of formaldehyde which evolves from the fabric.

The formaldehyde emitted from the resin treated fabric occurs as the result of non-reacted formaldehyde which is adsorbed onto fabric and/or formaldehyde formed by hydrolysis of the resin.[6] This resin treatment of fabric is called "finishing" in the textile industry.[7] If the finish is applied and chemically bonded (i.e. cured) to the dry fabric by application of heat (>300°F) before the fabric is made into garments, the finish is called a pre-cured finish. When the finishing process is conducted at a low temperature to prevent curing, and the fabric is made into garments before the fabric is fully cured (or the resin is set), the finish is called a post-cured finish. Goldstein (Figure 1) illustrates the difference between the two processes.[7] A post-cure process could feasibly represent higher exposure levels in garment manufacturing plants than would a pre-cure process because less free-formaldehyde is available in the latter.[8] Very few garment manufacturing plants currently employ a post-cure process.

DESCRIPTION OF THE FACILITIES

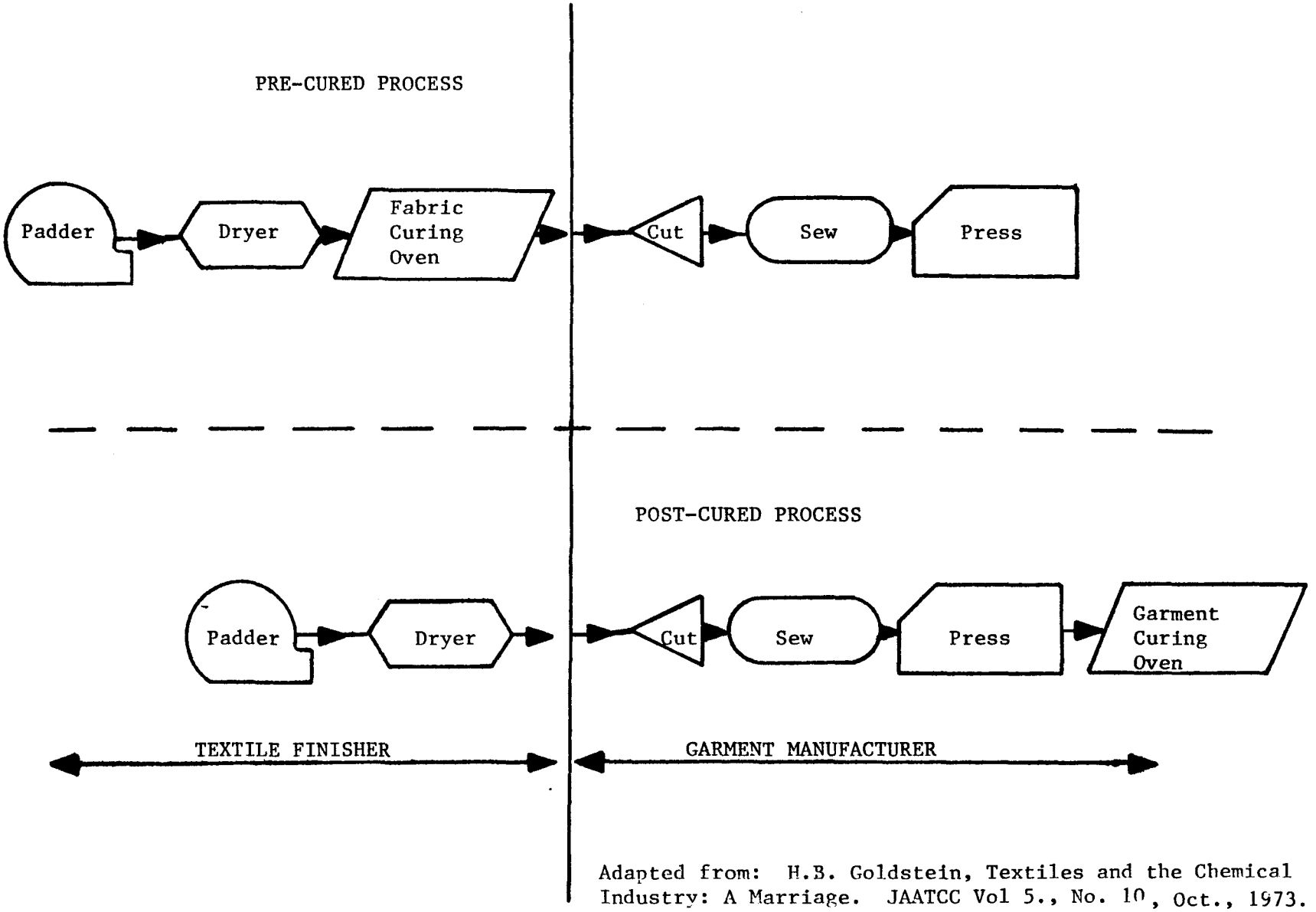
The three facilities selected for the cohort mortality study were men's shirt manufacturing plants, and will henceforth be referred to as plants 1, 2, and 3. Plants 1 and 2 were located in Georgia and plant 3 in Pennsylvania. These facilities produced men's shirts from fabrics which have been treated with methylolated resins in order to impart crease resistance and other desirable properties. The fabric emits unreacted and hydrolyzed formaldehyde from the resin resulting in potential occupational exposure. The use of methylolated treated fabrics began in 1959 at plants 1 and 2, and in 1955 at plant 3. Plant 1 started manufacturing shirts in 1944, plant 2 in 1949, and plant 3 in 1952. Plant 1 closed in 1982, the other two plants were still in operation at the writing of this report. Pre-cured fabrics are the only type of treated (durable-press) fabrics ever used in these three facilities; post-cure processes were never utilized.[6] All raw materials and finished goods were warehoused within the plants for extensive periods of time.

DESCRIPTION OF THE WORKFORCE

At the time of the in-depth industrial hygiene surveys, plant 1 had approximately 1000 workers operating on a two shift basis, plant 2 had approximately 500 workers operating on a two shift basis, and plant 3 had approximately 600 workers on a single shift basis. Table 1 presents a listing of standardized job categories by department for each plant and the total number of employees assigned to each category. Also, presented in Table 1 are the numbers of employees (within a job title by department and plant) who were sampled for formaldehyde exposure. The workers within these

FIGURE 1

PERMANENT PRESS FINISHING PROCESSES



Adapted from: H.B. Goldstein, Textiles and the Chemical Industry: A Marriage. JAATCC Vol 5., No. 10, Oct., 1973.

TABLE 1
EMPLOYEES SAMPLED PER JOB
GARMENT MANUFACTURING

DEPARTMENT AND JOB CATEGORY	PLANT 1-EMPLOYEES SAMPLED	PLANT 1-EMPLOYEES TOTAL	PLANT 2-EMPLOYEES SAMPLED	PLANT 2-EMPLOYEES TOTAL	PLANT 3-EMPLOYEES SAMPLED	PLANT 3-EMPLOYEES TOTAL	COMBINED TOTAL SAMPLED	COMBINED TOTAL TOTAL
Administration	5	10	30	91	26	72	61	173
Supervision, A001		0	9	28	3	13	12	41
Clerical, A002		0	4	12	3	11	7	23
Warehouse, A003	2	2	1	7	2	9	5	18
Maintenance, A004	1	2	5	12	10	12	16	26
Service/Training, A005	2	6	11	32	8	27	21	65
Cutting		0	12	24	29	37	41	61
Marker, Service, B006		0	2	6	5	10	7	16
Spreader, B007		0	6	7	9	9	15	16
Machine Cut, B008		0	0	2	5	5	5	7
Die Clicker, B009		0	4	4	5	7	9	11
Bundler, B010		0	0	5	5	6	5	11
Collar	32	95	33	87	27	75	92	257
Fuse Collar, Collar Stay, C011	5	11	1	1	3	18	9	30
Turn & Press, Top Stitch, C012	11	31	11	24	3	8	25	63
Run Collar, C013	4	13	4	19	4	17	12	49
Crease Bands, C014	4	12	6	16	3	9	13	37
Stitch Bands, Band End, C015		0	7	16	8	8	15	24
Buttonsew, Buttonhole, Label, C016	8	28	4	11	6	15	18	54
Parts (Cuffs, Pockets, Fronts Back, and Sleeves)	45	92	30	98	40	105	115	295
Turn & Press Cuffs, Adler, D017	3	4	1	7	6	7	10	18
Turn & Top Stitch Cuffs, D018	7	11	8	29	6	10	21	50
Crease Pockets, V Pockets, D019	0	1	2	11	4	18	6	30
Slope Fronts, Match, E020	8	16	0	7	1	3	9	26
Label, Buttonhole Sleeve, E021	4	9	2	9	2	9	8	27
Buttonsew Front, Pocket Set, E022	9	22	4	10	4	16	17	48
Sleeve Facing, Bartack, Blocking, E023	5	12	13	25	7	21	25	58
Concealed Yoke, F024	8	14		0	2	3	10	17
Run-on Sleeve Binding, F025	1	2		0	4	14	5	16
Trim & Stack, F026	0	1		0	4	4	4	5

TABLE 1 (continued)
EMPLOYEES SAMPLED PER JOB
GARMENT MANUFACTURING

DEPARTMENT AND JOB CATEGORY	PLANT 1-EMPLOYEES SAMPLED	PLANT 1-EMPLOYEES TOTAL	PLANT 2-EMPLOYEES SAMPLED	PLANT 2-EMPLOYEES TOTAL	PLANT 3-EMPLOYEES SAMPLED	PLANT 3-EMPLOYEES TOTAL	COMBINED TOTAL SAMPLED	COMBINED TOTAL TOTAL
Assembly	71	155	73	206	66	158	210	519
Yoke & Join, Sarge Yoke, G028	0	2	15	31	10	17	25	50
Folder Join, Folder Yoke, G029	9	24	0	6	5	6	14	36
Run-on Sleeves, Felling, G030		0	29	57	9	22	38	79
Stitch Down Sleeves, G031	4	9	1	14	9	25	14	48
Buttonsew, G032	3	4	1	12	3	6	7	22
Cuff Set, G033	11	14	11	25	7	25	29	64
Hem (Bottom), G034	8	21	3	18	8	20	19	59
Folder Felling, Double Needle, G035	24	58	5	9	6	19	35	86
Collar Set, Service Bands, G036	12	23	8	34	9	18	29	75
Packaging	34	85	45	106	20	50	99	241
Apparel Press, H037	4	8		0	6	6	10	14
Button & Fold, H038	21	49	30	83	10	37	61	169
Examine, Bag, Box, H039	9	28	15	23	4	7	28	58

three plants were predominantly female. All hourly employees at the three plants were represented by the Amalgamated Clothing and Textile Workers Union, AFL-CIO.

DESCRIPTION OF THE PROCESS

The garment manufacturing facilities surveyed during this study receive pre-cured finished fabric from a textile-finishing plant. The fabric is treated at the textile-finishing plant with methylolated (formaldehyde-based) resins to give the fabric crease-resistant characteristics (permanent press). The resin-treated fabric was cured before it was received by the garment plant.

The first step in the process is the cutting of garment parts from the fabric. In order to do this, many layers of fabric must first be spread out, one on top of another, on a long table. All of the layers are then cut simultaneously with hand-held saws ("cutters") or with dies. When a hand-held cutter is used to perform this step, a pattern is first laid over the top layer and the operator cuts according to this pattern.

After cutting, the garment parts are assembled. Individual parts (e.g. cuffs, collars, sleeves, etc.) are assembled into complete pieces, then the major pieces are assembled further into completed garments. Most of the various assembly operations require sewing with sewing machines appropriately modified for each type of operation. Some sewing operations in a plant, such as attaching of pockets to shirt fronts ("pocket setting"), have been "de-skilled". This means that a degree of automation has been utilized in the process. The workers position the parts to be sewn together onto the machines; the machines then hold the parts in the proper positions and make the required stitches without further guidance from the workers. Other sewing tasks are accomplished with more conventional sewing machines. Several assembly operations make use of heat to form or fuse together (in conjunction with a heat-sensitive adhesive) various parts. Conventional hot electric irons are used to press the fabric in some locations. The following assembly operations apply heat to the fabric:

1. Fusing of Lining to Collar: The adhesive-coated lining and the collar are heated to approximately 320°F (160°C) and rolled together, which fuses them.

2. Collar Forming and Pressing: The operator forms the collar with fabric on a specialized machine, and the machine presses the collar at a temperature of 300-350°F (149-176°C) to give it permanent shape.

3. Collar Band Creasing: Prior to the assembly of the (collar) bands, the bands are formed to specific shapes and heat is applied to maintain those shapes.

4. Label Attach: The labels are fused to the shirts by applying heat [about 400°F (204°C)] to the heat-sensitive adhesive which is on the labels. The fusing method of label attach is currently used to a variable extent across garment plants and intermittently in some plants; labels are sewn on in other plants or at other times.

5. Re-do Collar Press: This pressing machine, set for 300-310°F (149-154°C), is often used to re-press collars which are wrinkled.

6. Hand Ironing of Collar Bands ("Re-do"): Conventional irons are used to re-press wrinkled bands.

7. The completed garment may then be pressed (in some facilities) on steam applied apparel presses as the final finishing step.

Finished garments are moved to an area where they are properly folded for packaging. When the cuff will show in the package, it is pressed in this area. The fronts and collars also are pressed with hand irons as necessary. The garments are packaged in boxes or bags and are ready to ship.

These process operations are typical of the garment manufacturing industry. No substantial changes in the garment manufacturing process from 1955 to 1985, other than improved resin systems, were identified which could have affected formaldehyde exposure levels.

DESCRIPTION OF PAST EXPOSURES

One plant began using fabrics treated for crease resistance with methylolated (formaldehyde-based) resins in 1955; the other two plants began use of these treated fabrics in 1959. Prior to that time, it is unlikely that the workforce was occupationally exposed to formaldehyde. Fabrics treated with permanent-press resins contain residual levels of unreacted or free-formaldehyde. This free-formaldehyde as well as hydrolysis reaction products, has been the source of formaldehyde exposure for garment manufacturing workers. As reported in the trade literature, free formaldehyde levels in fabrics treated with the formaldehyde resin systems have been greatly reduced since the first use of such fabrics in the 1950's.[6,7] It is very likely, therefore, that this workforce was exposed to formaldehyde at higher levels during the years 1955 to 1978 than it is today, and that exposure was reduced gradually to current levels.[8,9]

The chemical manufacturers, textile producers, and the garment manufacturers over the past 15 years have worked together toward reducing formaldehyde emitted from treated fabric. Consumer pressure to eliminate objectionable odors as well as pressure from workers to reduce irritating effects[10,11] prompted the development of new finishing processes to reduce the formaldehyde released from the fabric.[7] The first fabrics finished for permanent-press properties (wash and wear) had formaldehyde release values greater than 4000 ppm.[6,7,12] In 1970 dimethyloldihydroxyethyleneurea (DMDHEU) was introduced as a finishing reactant which reduced

free-fromaldehyde levels to 1500-2000 ppm.[6,12] Improved DMDHEU reactant developed in the mid-1970's further reduced the free-formaldehyde to 800-1000 ppm.[6,12] Partially methylated DMDHEU reactants introduced in the late 1970's allowed free-formaldehyde levels of 250-500 ppm to be obtained.[6,12] Further modifications in DMDHEU have been recently reported to attain levels of 100-200 ppm free-formaldehyde.[13] Engineering controls (i.e. local exhaust ventilation) were not utilized within these plants to specifically reduce formaldehyde exposure. Other than the reduction in free-formaldehyde in resin systems, no concerted attempts have been identified to control or reduce formaldehyde in the work environment of garment manufacturing operations.

This reduction of free-formaldehyde release from treated fabric (via improved resin systems) and the subsequent reduction of formaldehyde exposure in garment workers also is demonstrated by reports in the exposure literature. Bourne and Seferian, in 1959, reported formaldehyde levels of 0.13 and 0.45 parts per million (ppm) in the ambient air of retail dress shops.[10] Formaldehyde air concentrations of 0.9 to 3.3 ppm throughout a retail fabric and garment store were reported in 1966 by Miller and Moore.[11] These sampling results were obtained by both researchers after considerable aeration of the treated fabric had occurred. Also in 1966 Blejer and Miller reported 0.9 to 2.7 ppm formaldehyde air levels in a post-cure garment manufacturing plant.[14] They observed eye and upper respiratory tract irritation, and contact dermatitis throughout the workforce of this particular plant. Shipkovitz in 1966 reported that "10% of the employees in some permanent-press plants in Arkansas sought medical attention for dermatitis, eye and upper airway irritation".[15] Short-term (10 minute) personal exposure samples collected by Shipkovitz in 8 garment plants depicted formaldehyde levels of 0.3 to 2.7 ppm. The air ventilation in these plants was reported to be good (12 to 27 air changes per hour) and "generally more than adequate" as compared to other plants.[15]

Nevertheless, Shipkovitz reported incidence of non-specific respiratory disease and complaints of heavy tearing, wheezing, and excessive thirst to be considerably higher when compared to data of a previous survey. Ten female garment workers were reported (Ahmad and Whitson, 1973) to have lost consciousness during exposure to formaldehyde concentrations of 2 to 10 ppm in the workroom air.[14] Other workers in this plant, who were apparently exposed to the same concentrations did not demonstrate any discomfort "-...indicating that repeated exposure may have diminished their susceptibility to formaldehyde". In 1973, Goldstein estimated that formaldehyde concentrations in the cutting rooms of garment plants were reduced from approximately 10 ppm in 1968 to less than 2 ppm by 1973 as a result of improved resin treating processes.[6] Results from current industrial hygiene surveys (discussed later in this report) indicate that current exposure levels in garment manufacturing plants are considerably lower (<0.50 ppm).

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Plant Ventilation

Plant 2 had a fully-recirculated central air conditioning/heating system since its construction. Over the years, no significant changes have been made to this system. Therefore, any variations in formaldehyde levels occurring through the years in this plant probably were not caused by alterations in this system; rather, they are likely to have been related only to the free-formaldehyde-release levels from the treated fabric.

The other two plants had fully recirculating heating systems but were not equipped with air conditioning. During the hot summer months, windows in these plants were opened and floor or ceiling fans were used in some areas to aid dilution ventilation. There were no significant changes in ventilation design in these two plants from 1955 to 1984.

Historic Exposure Data

The company's insurance carriers had surveyed these facilities for dust and noise levels, but not for formaldehyde levels. The dust levels, as well as the noise levels, reported during these surveys were below Occupational Safety and Health Administration (OSHA) standards, according to company officials.

POTENTIAL EXPOSURES AND CONTROLS USED

Formaldehyde

As stated previously, these three plants use fabrics which have been treated with formaldehyde-based resins for crease resistance, and have been pre-cured. These fabrics contain free-formaldehyde which is released slowly over time.[8,9] This is the primary source of formaldehyde exposure at each facility. Considerable efforts toward reduction of free-formaldehyde levels on treated fabric appear to have effected a reduction in formaldehyde exposure potential. Also, as was stated in the "Process Description" section of this report, heat was applied to the fabric at various steps in the process. Heat can cause a greater rate of formaldehyde vapor emitted; therefore, short-term peak exposures may have been experienced by the workers in these operations.

Another potential airborne exposure to formaldehyde is from the heat-set adhesives, which were used to fuse the collar linings and attach the labels. Local exhaust ventilation (canopy hoods) was limited to areas where heat was applied to fuse the fabric to the lining or where spot cleaning agents were applied. Only a few workers were directly involved with these processes. The two plants which used steam applied apparel presses employed canopy hoods above each press for heat removal.

Dust

A potential for dust exposure from cutting and sewing of fabric existed in each plant. Dust samples collected in these facilities by the companies' insurance carriers have shown low levels of airborne dust, both respirable and total. Therefore, means for controlling or reducing dust exposures had not been implemented by these companies. Housekeeping was very good at

these plants; little accumulation of dust was noticeable on surfaces. Fire safety was the main concern promoting good housekeeping and thus has acted as a dust control measure. Excessive dust on surfaces is a fire hazard, but also it could become airborne and raise the ambient air concentration of dust in the plant.

Other Chemical Compounds

Exposure to other chemical compounds was determined to be minimal in the plants included in this study and is believed to be typical of the garment manufacturing industry as a whole. Exposure to organic solvents was limited to spot cleaning soiled garments with chlorinated dry cleaning agents (e.g. perchloroethylene and methyl chloroform). These spot cleaning operations were conducted in isolated remote areas of each plant and under local exhaust ventilation in plant 1.

Six jobs in plant 3 resulted in potential exposure to ammonia and dimethylthiourea in the pattern copying area of the plant. The pattern copying machines were equipped with exhaust ventilation, but a noticeable ammonia odor was present in the room. This area was on a separate air handling system and was under negative air pressure relative to the main manufacturing area of the plant. Ammonia odor was not noticeable in other portions of the plant.

No other chemical exposures were identified within these plants.

Noise

The potential for exposure to noise existed in these plants. Noise in the garment manufacturing industry is generated by the many specialized and conventional sewing machines that are used. The noise levels can vary depending upon type and mechanical condition of the sewing machines. Continuous level noise is more of a problem than impulse noise in this industry. Shielding of machines to reduce noise levels was not observed in any plants included in this study.

DESCRIPTION OF MEDICAL, INDUSTRIAL HYGIENE AND SAFETY PROGRAMS

Medical

Emergency medical care was provided at each plant by trained and fully qualified individuals. The provision and degree of pre-employment or periodic physical examinations varied between these plants.

Industrial Hygiene

No formal comprehensive industrial hygiene program existed at any of the plants. As noted previously, environmental measurements for dust and noise had been conducted by the company's insurance carriers. These measurements were not conducted on a frequent or scheduled basis.

Safety

A formal safety program existed at each plant site. Each plant had a safety committee composed of management and employee representatives. These

committees met on a scheduled basis, conducted regular safety inspections, and maintained records of safety related actions. Safety equipment provided by the plants consisted of needle guards, eye protection where necessary, and in some situations dust masks.

HEALTH EFFECTS AND RELEVANT STANDARDS OR CRITERIA

Formaldehyde

Formaldehyde is a colorless flammable gas with a strong pungent odor. The first symptoms noticeable upon exposure to formaldehyde (at concentrations ranging from 0.1 to 2.0 ppm) are burning and tearing of the eyes and general irritation of the upper nasal passages. Higher exposures can produce coughing, tightening of the chest, a sense of pressure in the head and palpitations in the heart.[17,18] Dermatitis following exposure to formaldehyde-containing resins is a well recognized problem.[17] Workers may develop redness and swelling of the skin of exposed surfaces.

The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) is 3 ppm for an 8-hour time-weighted average (TWA), 5 ppm for a ceiling concentration, and 10 ppm for a maximum peak for no more than 30 minutes during an 8-hour shift.[19] OSHA has proposed to reduce the existing 8-hour TWA PEL of 3 ppm to either 1 ppm or 1.5 ppm, as well as, delete both the ceiling concentration and the peak exposure limits.[20] The issuance of a new formaldehyde exposure regulation by OSHA is slated for September of 1987.[21] The current American Conference of Governmental Industrial Hygienists (ACGIH) (1986) ceiling Threshold Limit Value (TLV) for formaldehyde is 2 ppm.[21] ACGIH also recommends an 8-hour TWA TLV of 1 ppm.[21] In 1976, based upon the irritant effects of formaldehyde, NIOSH recommended that employee exposure to formaldehyde vapor be controlled to a concentration no greater than 1 ppm for any 30-minute (Recommended Exposure Limit - REL) sampling period.[18] This recommendation has since been supplanted by the Current Intelligence Bulletin of April 15, 1981.[3] In this bulletin, based on the chemical's suspected carcinogenicity, NIOSH recommends reducing formaldehyde exposures to the lowest feasible levels.

Nuisance Dust

Airborne dust in the garment manufacturing industry consists of solid particles of fabric (lint) which may be suspended in air and inhaled. The particles may be of various sizes and shapes. Those particles with an equivalent diameter greater than 20 microns are deposited by impingement in the nose and upper respiratory tract. Smaller particles, approximately 10 to 0.5 microns in diameter, are carried into the smaller airways and alveoli of the lung. This range of particle diameters is considered the respirable portion and may represent a potential health hazard. The OSHA standard for respirable dust is 5 mg/m^3, and for total (nuisance) dust is 15 mg/m^3.[17] The ACGIH TLV for total (nuisance) dust is 10 mg/m^3.[22]

Organic Vapors

Cleaning fluids containing perchloroethylene, trichloroethylene, methyl chloroform, or 1,1,2-trichloroethane were used to clean soiled garments.

These organic solvents can affect the body if inhaled, ingested or absorbed through the skin. Short-term exposure to chlorinated solvent vapors may result in irritation of the eyes, respiratory tract, and skin. Continuous exposure may cause fatigue, headaches, weakness, confusion, and drowsiness; at extremely high concentrations these symptoms may be followed by unconsciousness and death. Repeated or prolonged exposure to liquid solvents may cause drying and cracking of the skin. More comprehensive health hazard information, toxicologic data and recommendations for personal protective equipment, first aid procedures and medical surveillance may be found in NIOSH's Occupational Health Guidelines for these solvents.[22] Table 2 lists the OSHA PEL's, the ACGIH TLV's and the NIOSH REL's for these solvents.[19,22,23,24]

TABLE 2

Organic Cleaning Solvent Exposure Criteria
Time-Weighted-Average Levels

	OSHA-PEL (PPM)	ACGIH TLV (PPM)	NIOSH RECOMMENDED EXPOSURE LIMIT (REL)
Perchloroethylene	100	50	*
Trichloroethylene	100	50	25
Methyl Chloroform	350	350	350
1,1,2-Trichloroethane	10	10	*

*Considered to be a potential human carcinogen, reduce exposure to lowest feasible level.[24]

Noise

Hearing damage can result from prolonged exposure to excessive noise. Noise can interfere with communication and be annoying in effect to cause non-auditory effects such as increased blood pressure, fatigue, nervousness, and irritability. The current OSHA PEL for noise is 90 dBA with requirements of a hearing-conservation program for workers exposed to 85 dBA or higher for an 8-hour TWA,[25] while 85 dBA is the recommended ACGIH TLV[22] and the NIOSH REL.[26]

SURVEY METHODS

Formaldehyde

Breathing-zone air samples for formaldehyde were collected in plants 1 and 3 in 1981 using DuPont Model P-200® sampling pumps calibrated to a sampling rate of 200 cc/min, and MDA Accuhaler Model 808® sampling pumps calibrated to 100 cc/min. The samples were collected with glass tubes containing 100 mg of an impregnated-charcoal solid sorbent in the primary section and 50 mg in the backup section. The sampling duration for each tube was approximately 4 hours with the DuPont pumps and 8 hours with the

MDA pumps. All samples were analyzed by ion chromatography in accordance with NIOSH Physical and Chemical Analytical Method (P&CAM) 318[27] with slight modifications.

General area concentrations of formaldehyde were monitored throughout plant 3 using a CEA 555 Ambient Air® sampling instrument, the NIOSH P&CAM #125 (Impinger method)[28] and NIOSH P&CAM #318 (charcoal tubes)[27] in a side-by-side mode. DuPont P-4000 sampling pumps calibrated at 1 liter per minute were used to collect the charcoal tube samples. Table 3 shows the results of this side-by-side general area sampling. These data show the charcoal tube results are consistently lower than the CEA or Impinger results. The variation between the data is probably due to a problem of instability with method P&CAM #318. From other evaluations concerning this method, it was determined that sample loss occurred during shipment of samples as well as temperature and time of sample storage.[29,30]

TABLE 3
GENERAL AREA SAMPLING
PLANT 3
FORMALDEHYDE - CEA 555, IMPINGER AND
CHARCOAL TUBE COMPARISON RESULTS*
AUGUST, 1981

		FORMALDEHYDE CONCENTRATIONS (PPM)		
AREA	TIME	CEA-555	IMPINGER	CHARCOAL TUBE
Assembly	9:00-10:00	0.13	0.18	0.12
Department	10:15-11:16	0.10	0.16	(NA)**
	11:20-12:24	Down	1.99	0.11
	12:31- 1:31	0.22	0.20	0.08
	1:40- 2:40	0.24	0.16	0.08
	2:45- 3:45	0.19	0.29	(NA)
Parts	8:41- 9:44	0.15	0.12	0.09
Department	10:05-11:08	Down	0.15	0.05
	1:24- 2:24	0.09	0.07	0.05
	11:51- 1:00	0.08	0.07	0.05
Fused	8:44- 8:47	0.32	0.21	(NA)
Lining	9:52-10:58	0.38	0.32	(NA)
	11:16-12:17	0.16	0.12	0.09
	1:40- 2:44	Down	0.09	0.20

* Samples were collected utilizing all three methods in a side-by-side sampling mode to evaluate comparability of results. All results reflect a time weighted average (TWA) for the sampling duration in parts of formaldehyde per million parts of air (ppm).

** NA - not analyzed

Limit of Detection for this analysis was:
Impinger - 4 mg per impinger
Charcoal tube - 8 ug per tube

Ambient Sampling Conditions - 28°C, 65% R.H.

It has been estimated that the sample loss when using P&CAM 318 could range from 30 to 70% of the total amount collected. All the charcoal tube results reported using this method in plants 1 and 3 should, therefore, be regarded as minimum values. Because of these findings, NIOSH researchers developed and evaluated a new personal sampling method for formaldehyde.[31] This method was evaluated for use in sampling low levels (<0.1 ppm) of formaldehyde. A second in-depth survey of plant 3 was conducted in January 1984 to repeat the air sampling using the new method (NIOSH P&CAM 354) in order to accurately characterize formaldehyde exposure levels. A re-survey of plant 1 using the new method was not possible because plant 1 closed in 1982.

During the in-depth surveys of January, 1984 (in plant 3) and of February, 1984 (in plant 2) both breathing zone and general area samples were collected using DuPont Model P30A® and SKC Model 224® portable air-sampling pumps calibrated to draw 80 cc/min of air through a Supelco XAD-2 Resin (formaldehyde) Tube®. This tube contains a solid sorbent, XAD-2 Resin®, coated with N-benzylethanolamine. The tube was placed in a metal holder and attached to the worker's collar so that the air inlet was in his/her breathing zone. Plastic (Tygon®) tubing was used to connect the sorbent tube to the pump, and the pump was attached to the worker's belt. The sampling time for each personal sample averaged approximately eight hours. All samples were analyzed using capillary column gas chromatography with flame ionization detection in accordance with NIOSH Method P&CAM #354.[31]

General area concentrations of formaldehyde were monitored throughout all three plants using a CEA Instruments Model 555 Ambient Air® sampling instrument. This instrument is capable of continuously sampling air, analyzing it for formaldehyde by a modified pararosaniline colorimetric method, and providing a concentration reading with a light-emitting diode (LED) display and optional strip-chart recorder. The instrument was calibrated twice daily to the 0 to 1.0 ppm range.

The sampling strategy for collecting formaldehyde exposure samples involved grouping by department and job category because the exposures were felt to be similar. The number of individuals sampled for formaldehyde exposure within each department was based on the total number of employees in that department and reflect a 95% confidence level ($p = 0.05$) that the highest exposed individuals, or job category, were included in the sampling.[32] Ancillary jobs in which exposure to formaldehyde was intermittant, or thought to be non-existent, also were evaluated to the extent possible. The distribution of exposures within each exposure group was initially considered to be lognormal;[32] therefore, the data were summarized by computing the geometric means and geometric confidence limits. In all of the exposure groupings and departments, where more than half of the samples had detectable levels, the statistics were computed assuming that non-detectable concentrations were equal to one half of the calculated lowest detectable concentration.[33]

Information was obtained from each worker sampled regarding smoking status to determine if cigarette smoke contributed to formaldehyde exposure sample results. Each worker sampled was asked if they smoked during the sampling duration. Comparison was made of exposure sample data for smokers relative to data for non-smokers.

Dust

Respirable (nuisance) dust samples were collected for the job categories in each plant thought to have the highest exposure potential. Determination of total dust levels were made in plant 1 but not plants 2 or 3 because levels were felt to be too low to present a confounding exposure problem. Respirable dust samples, however, were collected in all three plants because at the time of these surveys the respirable dust fraction was of concern as a confounder. These samples were obtained with MSA Model G® portable sampling pumps calibrated to 1.7 Lpm in conjunction with tared polyvinyl chloride (PVC) filters in 2-piece cassettes. These cassettes were mounted on 10-millimeter nylon cyclonic size-selective separators for the respirable dust samples. Total dust sampling was conducted in plant 1 using closed-face filter technique and MSA Model G® pumps calibrated to 1.7 Lpm. Total dust samples were not collected in plants 2 and 3 based upon sampling results for plant 1. The sample duration was approximately 7 hours for each sample.

Organic Vapors

The airborne levels of exposure to organic cleaning solvents (e.g. perchloroethylene, trichloroethylene, 1,1,2-trichloroethane, and methyl chloroform) were determined for the spot-cleaning operations. MDA Accuhaler Model 808® sampling pumps calibrated to 100 cc/min in conjunction with charcoal tubes were used to conduct the sampling. Generally, two samples were collected for the operation; a personal sample on the worker and an area sample outside the ventilation hood. The sample duration was approximately 7-1/2 hours for each sample. The charcoal tubes were analyzed for all four compounds according to NIOSH P&CAM 127 (modified) using a gas chromatograph with a flame ionization detector.[34]

Noise

Measurements of noise exposure levels were obtained in areas of each plant felt to have the highest noise levels. These measurements were obtained with a Quest Model 215® portable sound level meter. The meter was set on the A-weighted scale at slow response. These measurements were single-time point determinations.

Temperature and Relative Humidity

During these in-depth surveys, the ambient temperature and relative humidity in areas within each plant were determined using an automatic psychrometer. The average overall temperature and percent relative humidity (%RH) for each survey was recorded and supplied to the analytical laboratory.

Quality Control Procedure

Sampling pumps used during these surveys were checked for significant (greater than $\pm$ 5%) deviation in sampling rate after use. The exposure

sample results were discarded where a significant deviation in pump performance was observed. To assure quality of results, sample blanks and spiked samples were generated, analyzed and reported in accordance with NIOSH Quality Assurance/Quality Control procedures.[35]

ANALYSIS AND DISCUSSION OF SAMPLING RESULTS

Formaldehyde

Tables A-1 through C-11 present summaries of the personal sampling results by department and job category by plant. The industrial hygiene surveys of these three facilities have demonstrated that the concentrations of formaldehyde in these work environments were below the ACGIH TLV and the OSHA PEL. While the formaldehyde exposure levels are low, additional controls to further reduce the exposure potential are presented in the recommendations section of this report.

The results of these surveys indicate that garment manufacturing workers are currently involved in work operations which have similar formaldehyde exposure potential across departments and plants. Figure 2 summarizes the range of formaldehyde exposure within a department by plant and provides a comparison of calculated geometric vs. arithmetic mean-exposure levels for each department by plant. The sample results reported as non-detectable are assigned a value equal to one-half the limit of detection, or 0.02 ppm.

Tables A-1 through C-11 (Appendix A) list the summary statistics used to develop Figure 2. These tables provide statistical descriptions of sampling results for each job category within a department by plant. Specifically the tables include the total number of samples for each job category, the highest and lowest concentration observed in each, and (when feasible) the arithmetic mean, geometric mean, standard deviation, and 95% confidence limits or the arithmetic mean. An overall set of statistics for a department as a whole are also provided according to individual plant.

As shown, the exposure range is narrow (0.51 ppm to < 0.02 ppm) relative to other industrial exposure settings.[3] Detectable formaldehyde exposure levels were identified in each job category sampled and each department of each plant. The range of geometric means across all departments and plants was 0.06 to 0.20 ppm, as compared to the range of arithmetic means of 0.09 to 0.22 ppm. The range of exposures collected in each department of a plant (including non-detectable results) are indicated in Figure 2 for comparison. It must be noted that the large number of non-detectable results for plant 1 and the first survey of plant 3 (see Appendix A, Tables A-1 through A-5 and C-1 through C-5) may be the result of the aforementioned problems with P&CAM 318[25] and not necessarily non-exposure situations. Close evalaution of data collected from plant 3 during the 1981 survey (using P&CAM 318) in comparison to data collected during the 1984 survey (using P&CAM 354) indicates the extent of variation between the methods. Table 4 illustrates this variation as the percent difference in mean exposure levels by job category within departments. This was constructed for job categories where sufficient detectable samples existed to calculate the mean exposure levels.

FIGURE 2

Formaldehyde Exposure by Plant and Department, Garment Manufacturing

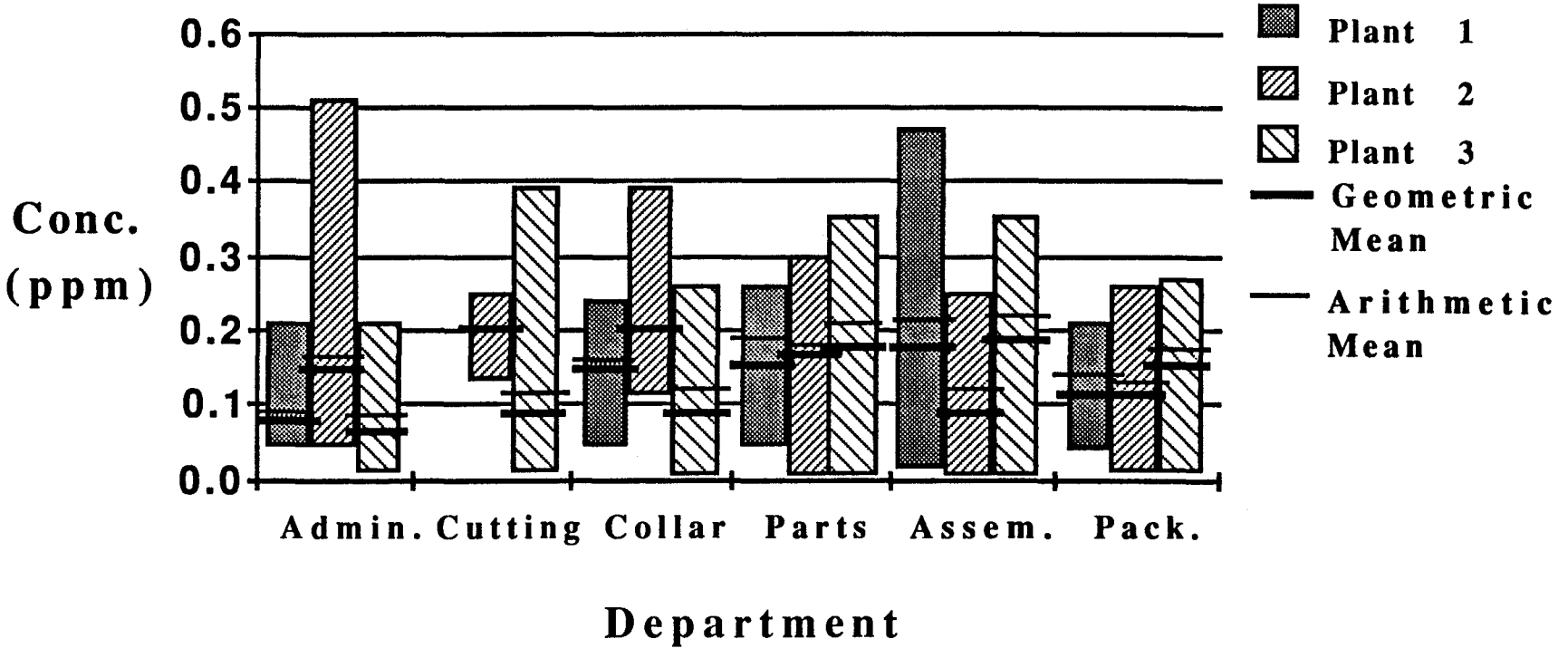

TABLE 4
EXTENT OF VARIATION IN FORMALDEHYDE SAMPLING METHODS
PLANT 3

DEPARTMENT JOB CODE	MEAN EXPOSURE LEVEL(n) AUGUST, 1981 (P&CAM 318)	MEAN EXPOSURE LEVEL(n) JAN., 1984 (P&CAM 354)	% DIFFERENCE
Cutting			
B007	0.14 (3)	0.17 (9)	+12.7
Collar			
C016	0.07 (3)	0.19 (6)	+63.2
Parts			
D018	0.07 (4)	0.15 (4)	+53.3
E020	0.10 (4)	0.26 (3)	+61.5
Assembly			
G034	0.10 (3)	0.18 (8)	+44.4
G036	0.09 (4)	0.20 (9)	+55.0

These percent differences are similar to the projected sample loss of from 30 to 70% for P&CAM 318.[28,29] Based upon evaluation of the operating conditions, production volume, dilution ventilation, and work practices it is reasonable to assume that actual exposure levels within Plant 3 were similar during both surveys. Because of the stability and sensitivity of P&CAM 318 many of the formaldehyde concentrations measured in 1981 at plants 1 and 3 using this method may have underestimated the true concentration by as much as 63%. A follow up sampling survey at plant 1 using P&CAM 354 could not be conducted due to the plant closing in 1982. However, based upon the data in Table 5 in relation to the plant 1 data reported in Tables A-1 through A-5, it is reasonable to assume that the plant 1 mean exposure results (P&CAM 318) may be underestimated by as much as 63%.

Job operations which required the application of heat (C011, C012, C014, E021, and H037) did not appear to result in higher mean formaldehyde exposures when compared to other jobs within the same department or across departments (see Appendix A, Tables B-3, B-4, C-8, C-9, and C-11). These results may indicate heat application processes do not contribute to formaldehyde exposure potential for workers in these processes; or, more likely, the exhaust ventilation where installed to remove heat also effectively removes the formaldehyde and prevents additional exposure within those job operations.

Table 5 illustrates the number of smokers versus non-smokers according to plant. No significant influence from cigarette smoke in the detectable sample results was evident from comparison of group mean exposures.

TABLE 5
SMOKERS VS. NON-SMOKERS
COMPARISON OF FORMALDEHYDE EXPOSURE SAMPLE RESULTS

	# SMOKERS	# NON-SMOKERS	TOTAL	% SMOKERS
PLANT 1	51	141	192	26.6
PLANT 2	53	143	196	27.0
PLANT 3	85	169	234	33.5
TOTAL	189	453	642	29.4
# >LOD for SAMPLING METHOD	127	341		
MEAN EXPOSURE (PPM)	0.16	0.17		

In summary, Figure 2 and Tables A-1 through C-11 illustrate that the formaldehyde 8-hour TWA exposure levels for these plants were similar within job categories across departments and across all three plants. There was formaldehyde exposure evident for all job categories. The formaldehyde exposure is essentially constant with few if any peak exposures.

Dust

The results of nuisance dust concentrations in the breathing zone of workers in these plants are summarized in Tables D-1 through D-3 (Appendix B). Total dust levels in plant 1 ranged from no-measurable-amount (NMA) to 2.28 mg/m^3. These results are below the OSHA PEL (15 mg/m^3) and the ACGIH TLV (10 ug/m^3) for nuisance dust. Respirable dust levels in plant 1 ranged from NMA to 1.35 mg/m^3, NMA to 1.10 mg/m^3 in plant 2, and NMA to 1.48 mg/m^3 in plant 3. All of these results are well below the OSHA standard of 5 mg/m^3 for respirable dust.

Organic Vapor

Table E-1 (Appendix C) summarizes the results of sampling for organic cleaning solvent vapors in these three plants. Personal 8-hour TWA exposures of methyl chloroform (5.0 to 20.8 ppm) were identified in all three plants for the limited number of individuals involved in the spot cleaning operation. An area concentration of 6.2 ppm was detected near the spot cleaning operation in plant 1. A personal 8-hour TWA exposure of 1.0 ppm to 1,1,2-tricloroethane was determined for the spot cleaning operation in plant 3. These concentrations are considerably lower than the OSHA PEL, ACGIH TLV, or NIOSH REL for these solvents. Detectable concentrations of perchloroethylene or trichloroethane were not found in any of the three plants.

Noise

Noise level measurements for the plants are listed in Tables F-1 through F-3 (Appendix D). Noise level measurements obtained ranged from 70-88 dBA in plant 1, 65-94 dBA in plant 2, and 70-95 dBA in plant 3. All results are single-time point measurements and do not represent an 8-hour TWA exposure for those job operations. The results do indicate the potential for overexposure to noise and reflect the need for a hearing conservation program for the employees of these plants.

CONCLUSIONS

These industrial hygiene surveys at three garment manufacturing facilities have demonstrated that the exposure levels to formaldehyde, respirable dust, and organic cleaning solvent vapor were below all the applicable ACGIH TLV's and OSHA PEL's. However, increased dilution ventilation and installation of local exhaust ventilation on specific job operations would aid in reducing the formaldehyde levels in these plants. Such modifications are feasible and appropriate toward achieving NIOSH's current recommendation that all exposures to formaldehyde be reduced to the lowest feasible level.[3]

These surveys demonstrated the potential for continuous low-level (<0.50 ppm as an 8-hour TWA) exposure to formaldehyde in garment manufacturing plants. The formaldehyde exposure range across departments within the plants appears to be narrow; in addition, the exposure among jobs within a department of a plant, across job categories and departments of a plant, and across all three plants is similar.

The homogeneity of exposure is probably a result of the limited dilution ventilation of these plants. Formaldehyde is released from the treated fabric and attains an average plant-wide concentration which is apparently maintained (not reduced any lower) by dilution ventilation. Certainly formaldehyde concentrations vary within the plants depending upon location, air movement, and/or amount of treated fabric in the area. The confines of the plant walls, however, may act as a chamber and the overall range of concentration variation is apparently narrow. This results in homogeneous formaldehyde exposure levels across departments and between plants. Job operations where heat was applied did not represent higher formaldehyde exposure potential when compared to jobs where heat was not utilized. This was probably the result of exhaust ventilation of heat application processes. Cigarette smoking did not appear to influence formaldehyde sampling results of air within the worker's breathing zone for these plants.

These formaldehyde exposure determinations were taken at one point in time in each plant and may not reflect seasonal variations. Factors which could promote fluctuations of exposure levels in individual plants are ambient temperature, humidity, type of fabric or resin system, and volume of stored materials or completed work.

Based on historical information of free-formaldehyde levels in treated fabric and work room concentration levels,[6-16] exposure to formaldehyde in

these plants was probably higher in the past as compared to the current exposures. Further research is needed, however, before historical exposure estimates can be offered.

The noise levels measured at the time of these surveys indicated that some workers may be exposed in excess of the NIOSH REL and ACGIH TLV, as well as the OSHA PEL. Certainly a hearing conversation program is needed in these plants.

RECOMMENDATIONS

The following recommendations were offered to reduce the exposure potential in the facilities surveyed. All recommendations are based on cited references or good industrial hygiene practices and would be appropriate for other typical garment manufacturing facilities.

1. It is recommended that these companies conduct periodic personal monitoring for formaldehyde with a reliable method to determine TWA exposures and peak variations in exposure levels.

2. Local exhaust ventilation hoods should be installed over fused lining machines to capture heat and formaldehyde vapors from this process operation. Such exhaust hoods should be evaluated periodically for efficiency and effectiveness, and should be operational when the fused lining operation is functioning.[36] Areas of a plant should be evaluated for proper dilution ventilation in an attempt to further reduce exposure to formaldehyde.

3. The heating, ventilation, and air conditioning (HVAC) system should not be set up on a fully (100%) recirculated system as is the case during the summer and coldest parts of the winter. Fresh outside air should be introduced to the HVAC system to improve the dilution ventilation of the plant. The higher energy consumption that this would require could be partially offset by the installation of air-to-air heat exchangers which would pre-cool (or pre-heat) incoming air with exhausting air. Such an improvement in dilution ventilation of a plant could reduce the formaldehyde exposure levels in the plant.[36]

4. Local exhaust ventilation should be installed and utilized during the spot cleaning operation and when cleaning stamping devices with organic cleaning solvents.[36] Workers performing these operations should be checked regularly for dry and cracking skin, and treated accordingly by a physician. The extent of worker exposure to cleaning solvents should be determined with a reliable sampling method. NIOSH's Occupational Health Guidelines[23] should be consulted for use of personal protective equipment, first aid procedures, and medical surveillance procedures for this solvent.

5. Noise exposure levels for all jobs in these plants should be characterized. The noise levels determined during these surveys indicate noise exposures for certain job operations may exceed the regulatory standards and recommended limits. This may be due to the mechanical condition of machines and equipment operating in the area of these jobs. A hearing conservation program should be initiated by these companies.[25,26]

6. As a result of the recent epidemiological findings [5,6] of this cohort, there is an interest to determine the free-formaldehyde content of the dust and to fully characterize dust exposures in those plants. More comprehensive dust sampling and analysis is recommended to fully characterize this exposure.

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APPENDIX A

Formaldehyde Exposures Levels
Summary Statistics
Garment Manufacturing Plants

Tables A-1 through C-11

(See Table 1 for Job Code Definition)

TABLE A-1
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #1
MARCH 30-APRIL 2, 1981

SUMMARY STATISTICS - ADMINISTRATION DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	12	0.21	<0.05	0.09	0.08	1.42	0.05	0.19
A004	2	0.09	<0.06	#				
A005	10	0.21	<0.05	0.09	0.08	1.75	0.05	0.19

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 6.0 ug/sample
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 24°C, 55% RH

TABLE A-2
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #1
MARCH 30-APRIL 2, 1981

SUMMARY STATISTICS - COLLAR

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	30	0.30	<0.05	#				
C011	6	0.24	<0.10	#				
C012	7	0.30	<0.05	#				
C013	6	0.16	<0.06	#				
C014	3	0.09	<0.07	#				
C015	3	0.14	<0.08	#				
C016	5	0.14	<0.05	#				

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 6.0 ug/sample
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 24°C, 55% RH

TABLE A-3
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #1
MARCH 30-APRIL 2, 1981

SUMMARY STATISTICS - PARTS DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
A11	37	0.26	<0.05	#				
D017	3	0.15	<0.05	#				
D018	5	0.11	<0.05	#				
E020	5	0.22	<0.06	0.15	0.14	1.94	0.04	0.29
E021	4	0.16	<0.06	#				
E022	9	0.15	<0.06	0.11	0.10	1.56	0.05	0.19
E023	9	0.26	<0.06	#				
F025	1	0.06		#				
F026	1	0.06		#				

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 6.0 ug/sample
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 24°C, 55% RH

TABLE A-4
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #1
MARCH 30-APRIL 2, 1981

SUMMARY STATISTICS - ASSEMBLY DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	73	0.46	<0.03	#				
0028	8	0.46	<0.12	0.20	0.18	1.55	0.12	0.26
0029	9	0.42	<0.06	#				
0030	1	0.08	<0.08	#				
0031	3	0.11	<0.10	#				
0033	11	0.14	<0.05	#				
0034	8	0.14	<0.03	#				
0035	19	0.23	<0.05	#				
0036	14	0.28	<0.06	#				

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 6.0 ug/sample
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 24°C, 55% RH

TABLE A-5
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #1
MARCH 30-APRIL 2, 1981

SUMMARY STATISTICS - PACKAGING DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	28	0.79	<0.04	#				
0037	4	0.12	<0.05	#				
0038	21	0.79	<0.04	#				
0039	3	0.07	<0.05	#				

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 6.0 ug/sample
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 24°C, 55% RH

TABLE B-1
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #2
FEBRUARY 7-9, 1984

SUMMARY STATISTICS - ADMINISTRATION DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
A11	30	0.51	0.05	0.16	0.14	1.53	0.12	0.17
A001	9	0.19	0.05	0.13	0.12	1.52	0.09	0.16
A002	4	0.29	0.12	0.20	0.19	1.49	0.13	0.28
A003	1	0.12	0.12	#				
A004	5	0.18	0.09	0.13	0.13	1.35	0.10	0.17
A005	11	0.51	0.10	0.18	0.16	1.60	0.12	0.21

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 26°C, 50% RH

TABLE B-2
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #2
FEBRUARY 7-9, 1984

SUMMARY STATISTICS - CUTTING DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
A11	12	0.25	0.14	0.20	0.20	1.21	0.17	0.22
B006	2	0.24	0.18	#				
B007	6	0.25	0.15	0.20	0.20	1.22	0.17	0.24
B009	4	0.22	0.14	0.19	0.19	1.25	0.15	0.24

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 26°C, 50% RH

TABLE B-3
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #2
FEBRUARY 7-9, 1984

SUMMARY STATISTICS - COLLAR DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	33	0.39	0.12	0.20	0.20	1.26	0.18	0.22
C011	1	0.20	0.20	#				
C012	11	0.27	0.12	0.21	0.20	1.30	0.17	0.24
C013	4	0.22	0.19	0.20	0.20	1.06	0.19	0.22
C014	6	0.39	0.14	0.21	0.20	1.47	0.14	0.27
C015	7	0.24	0.16	0.20	0.19	1.15	0.17	0.21
C016	4	0.25	0.16	0.21	0.20	1.20	0.17	0.24

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 26°C, 50% RH

TABLE B-4
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #2
FEBRUARY 7-9, 1984

SUMMARY STATISTICS - PARTS DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	30	0.30	0.02	0.18	0.17	1.54	0.15	0.20
D017	1	0.17	0.17	#				
D018	8	0.20	0.02	0.16	0.14	2.08	0.09	0.24
D019	2	0.30	0.11	#				
E021	2	0.22	0.19	#				
E022	4	0.29	0.15	0.19	0.18	1.38	0.13	0.25
E023	13	0.23	0.14	0.19	0.19	1.17	0.17	0.21

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 26°C, 50% RH

TABLE B-5
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #2
FEBRUARY 7-9, 1984

SUMMARY STATISTICS - ASSEMBLY DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	73	0.25	<0.02	0.12	0.09	2.32	0.07	0.14
G028	15	0.23	<0.02	0.12	0.09	3.09	0.05	0.15
G030	29	0.25	<0.02	0.12	0.10	2.13	0.07	0.13
G031	1	0.14	0.14	#				
G032	1	0.15	0.15	#				
G033	11	0.19	<0.06	0.10	0.08	2.06	0.05	0.12
G034	3	0.14	0.13	0.13	0.13	1.02	0.13	0.14
G035	5	0.13	0.09	0.11	0.11	1.15	0.10	0.13
G036	8	0.20	0.13	0.16	0.15	1.15	0.14	0.17

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 26°C, 50% RH

TABLE B-6
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT #2
FEBRUARY 7-9, 1984

SUMMARY STATISTICS - PACKAGING DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	45	0.26	<0.02	0.13	0.11	2.03	0.09	0.13
H038	30	0.26	<0.02	0.13	0.12	1.80	0.10	0.15
H039	15	0.20	<0.02	0.11	0.09	2.43	0.06	0.14

*TWA - Time Weighted Average for 8-Hours
**PPM - Parts Per Million
- Insufficient samples for statistical analyses, or non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Limit of Detection for this analysis was 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 26°C, 50% RH

TABLE C-1
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
AUGUST 11-13, 1981

SUMMARY STATISTICS - ADMINISTRATION DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	20	0.16	<0.04	0.10	0.08	1.92	0.04	0.16
A002	3	0.11	<0.04	#				
A003	4	0.16	0.10	0.10	0.13	1.26	0.08	0.22
A004	4	0.15	<0.04	0.11	0.08	2.73	0.01	0.72
A005	9	0.13	<0.04	#				

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
- Non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 28°C, 65% RH

TABLE C-2
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
AUGUST 11-13, 1981

SUMMARY STATISTICS - CUTTING DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	16	0.16	<0.04	#				
B006	9	0.15	<0.04	#				
B007	3	0.16	<0.11	0.14	0.14	1.25	0.08	0.24
B008	1	0.10	<0.10	#				
B009	1	0.07	<0.07	#				
B010	2	0.13	<0.08	#				

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
- Non-detectable results observed in greater than half of the samples; therefore, statistical analyses were no performed.
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 28°C, 65% RH

TABLE C-3
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
AUGUST 11-13, 1981

SUMMARY STATISTICS - COLLAR DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	19	0.10	<0.04	#				
C011	5	0.10	<0.04	#				
C012	6	0.09	<0.04	#				
C013	3	0.10	<0.04	0.08	0.08	1.65	0.04	0.26
C014	2	0.04	<0.04	#				
C016	3	0.09	<0.04	0.07	0.06	1.52	0.02	0.18

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
- Non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 28°C, 65% RH

TABLE C-4
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
AUGUST 11-13, 1981

SUMMARY STATISTICS - PARTS DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	27	0.16	<0.04	#				
D017	3	0.09	<0.04	#				
D018	4	0.07	<0.06	0.07	0.07	1.10	0.05	0.08
E020	4	0.14	<0.04	0.10	0.08	2.07	0.02	0.39
E021	3	0.12	<0.04	#				
E022	3	0.14	<0.04	#				
F024	4	0.16	<0.04	#				
F025	3	0.11	<0.04	#				
F026	2	0.04	<0.04	#				
F027	1	0.11	<0.11	#				

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
- Non-detectable results observed in greater than half of the samples; therefore, statistical analyses were no performed.
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 28°C, 65% RH

TABLE C-5
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
AUGUST 11-13, 1981

SUMMARY STATISTICS - ASSEMBLY DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	30	0.25	<0.04	#				
G028	2	0.25	0.09	#				
G029	2	0.04	<0.04	#				
G030	8	0.22	<0.04	#				
G033	8	0.08	<0.04	#				
G034	3	0.14	<0.04	0.10	0.08	2.14	0.01	0.55
G035	3	0.06	<0.04	#				
G036	4	0.22	<0.04	0.09	0.07	2.20	0.01	0.37

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
- Non-detectable results observed in greater than half of the samples; therefore, statistical analyses were not performed.
Note: This sampling was conducted using NIOSH P&CAM #318 and the results are of questionable accuracy due to instability problems with the charcoal tubes. This also explains the number of non-detectables.
Ambient Sampling Conditions - 28°C, 65% RH

TABLE C-6
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
JANUARY 24-26, 1984

SUMMARY STATISTICS - ADMINISTRATION DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	26	0.21	<0.02	0.09	0.06	2.82	0.04	0.09
A001	3	0.11	0.05	0.08	0.08	1.53	0.05	0.13
A002	3	0.07	<0.02	0.03	0.02	2.91	0.01	0.07
A003	2	0.05	<0.02	#				
A004	10	0.11	<0.03	0.06	0.05	2.34	0.03	0.09
A005	8	0.21	<0.02	0.15	0.12	2.63	0.06	0.25

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
Limit of Detection for this analysis was - 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 22°C, 30% RH

TABLE C-7
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
JANUARY 24-26, 1984

SUMMARY STATISTICS - CUTTING DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	29	0.39	<0.02	0.12	0.09	2.67	0.06	0.13
B006	5	0.15	<0.02	0.09	0.05	4.11	0.01	0.19
B007	9	0.39	<0.02	0.17	0.13	2.65	0.07	0.25
B008	5	0.20	<0.05	0.10	0.08	2.21	0.04	0.17
B009	5	0.15	0.09	0.12	0.12	1.27	0.09	0.15
B010	5	0.18	<0.02	0.09	0.06	2.95	0.02	0.16

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
Limit of Detection for this analysis was - 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 22°C, 30% RH

TABLE C-8
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
JANUARY 24-26, 1984

SUMMARY STATISTICS - COLLAR DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	27	0.26	<0.04	0.12	0.09	2.19	0.07	0.12
C011	3	0.26	0.02	0.13	0.09	3.27	0.02	0.37
C012	3	0.13	0.08	0.10	0.10	1.25	0.08	0.13
C013	4	0.09	<0.04	0.04	0.03	1.95	0.02	0.06
C014	3	0.13	0.10	0.11	0.11	1.16	0.09	0.13
C015	8	0.23	<0.05	0.10	0.08	1.97	0.05	0.14
C016	6	0.26	0.05	0.19	0.16	1.91	0.09	0.28

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
Limit of Detection for this analysis was - 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 22°C, 30% RH

TABLE C-9
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
JANUARY 24-26, 1984

SUMMARY STATISTICS - PARTS DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	46	0.35	<0.02	0.21	0.18	2.06	0.15	0.22
D017	6	0.35	0.13	0.25	0.24	1.43	0.18	0.32
D018	4	0.20	0.05	0.15	0.13	2.03	0.06	0.25
D019	1	0.26	0.26	#				
E020	3	0.27	0.25	0.26	0.26	1.05	0.24	0.27
E021	2	0.27	0.26	#				
E022	4	0.28	0.19	0.25	0.24	1.17	0.21	0.28
E023	2	0.27	0.25	#				
E024	6	0.29	0.09	0.20	0.19	1.52	0.13	0.26
F025	4	0.27	<0.02	0.15	0.08	4.42	0.02	0.36
F026	4	0.25	0.09	0.17	0.16	1.59	0.10	0.25
F027	10	0.28	<0.02	0.20	0.16	2.60	0.09	0.29

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
Limit of Detection for this analysis was - 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 22°C, 30% RH

TABLE C-10
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
JANUARY 24-26, 1984

SUMMARY STATISTICS - ASSEMBLY DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	66	0.35	<0.02	0.22	0.19	2.08	0.16	0.23
G028	10	0.35	0.17	0.28	0.27	1.25	0.24	0.31
G029	5	0.35	0.27	0.31	0.30	1.11	0.28	0.33
G030	9	0.30	0.18	0.26	0.25	1.16	0.23	0.28
G031	9	0.28	<0.02	0.21	0.17	2.82	0.08	0.33
G032	3	0.23	0.10	0.15	0.14	1.58	0.08	0.23
G033	7	0.20	<0.02	0.10	0.07	3.33	0.03	0.17
G034	8	0.25	0.13	0.18	0.17	1.24	0.15	0.20
G035	6	0.27	0.15	0.22	0.22	1.27	0.18	0.26
G036	9	0.29	0.06	0.20	0.19	1.57	0.10	0.36

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
Limit of Detection for this analysis was - 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 22°C, 30% RH

TABLE C-11
FORMALDEHYDE TWA* EXPOSURE (PPM**)
PLANT 3
JANUARY 24-26, 1984

SUMMARY STATISTICS - PACKAGING DEPARTMENT

JOB CODE	NUMBER OF SAMPLES	RANGE HIGH	RANGE LOW	MEAN	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION	95% LOWER CONFIDENCE LIMIT	95% UPPER CONFIDENCE LIMIT
All	20	0.27	<0.02	0.17	0.15	2.14	0.10	0.21
H037	6	0.27	<0.02	0.15	0.10	3.73	0.03	0.29
H038	10	0.22	0.10	0.18	0.18	1.31	0.15	0.21
H039	4	0.21	0.14	0.17	0.17	1.23	0.13	0.21

*TWA - 8-Hour Time Weighted Average
**PPM - Parts Per Million
Limit of Detection for this analysis was - 1.0 ug/sample
Note: All samples were collected and analyzed according to NIOSH P&CAM #354. These statistics were computed assuming that non-detectable concentrations were equal to one-half the calculated "less-than" concentration.
Ambient Sampling Conditions - 22°C, 30% RH

APPENDIX B

8-Hour TWA
Dust Exposure Levels
Garment Manufacturing Plants

Table D-1 through D-3

TABLE D-1
8-HOUR TWA
NUISANCE DUST CONCENTRATIONS IN THE BREATHING ZONE
PLANT 1
MARCH 30-APRIL 1, 1981

JOB TITLE/DEPARTMENT	DUST CONCENTRATIONS (mg/m^3) TOTAL	RESPIRABLE
Service (B006)/Cutting		0.05
Center Pleat (E021)/Parts		0.15
Center Pleat (E021)/Parts	0.06	NMA
Pocket Attach (E022)/Parts		0.72
Combination (G035)/Assembly		0.22
Combination (G035)/Assembly		0.21
Trim Binding (F026)/Parts	1.88	1.35
Fuse Label (E023)/Parts		NMA*
Yoking (G028)/Assembly	0.11	0.13
Collar Attach (G036)/Assembly	2.28	0.05
Joining (G029)/Assembly		0.06
Bag & Box (H039)/Packaging		0.10
Combination (G035)/Assembly		0.23
Reweaver (A005)/Administration		0.08

*NMA - No-measurable-amount

TABLE D-2
8-HOUR TWA
RESPIRABLE DUST CONCENTRATIONS IN THE BREATHING ZONE
PLANT 2
FEBRUARY 7-9, 1984

JOB TITLE	mg/m^3
Machine Cut	0.85
Die Clicker Operator	1.10
Spreader	0.32
Crease Band Operator	0.48
Exkell Operator	0.35
Stitch Bands	0.23
Run Cuff Adler	0.18
Folder Felling Double Needle	0.21
Hem Bottom	0.15
Buttoner and Folder	0.17
Inspect, Bag and Box	0.10
Quality Control Inspector	NMA*

*NMA - No measurable amount

TABLE D-3
8-HOUR TWA
RESPIRABLE DUST CONCENTRATIONS IN THE BREATHING ZONE
PLANT 3
AUGUST 11-13, 1981

JOB TITLE	mg/m^3
SQC	0.27
Stack After Felling	1.14
Turnpoint	0.56
Service	1.21
Clicker Press	0.14
Insert Bands	0.26
Pin & Ply No.	0.04
Sleeve Binding	NMA*
Concealed Yoke	0.50
Concealed Yoke	1.48

JANUARY 24-26, 1984

JOB TITLE	mg/m^3
Runtops and Trim Points	0.08
Clicker Press	0.11
Machine Cut	0.15
Spreader	0.11
Clicker Press	NMA*
Concealed Join	0.14
Sleeve Binding	0.17
Cutter	0.10
Machine Slit Linings	0.59
Hem Bottom	0.17
Run Cuff Adler	0.17
Folder Felling Double Needle	0.14

*NMA - No measurable amount

APPENDIX C

Organic Vapor Exposure Sampling Results
Garment Manufacturing Plants

Table E-1

Table E-1

ORGANIC VAPOR CONCENTRATIONS - PPM*
GARMENT MANUFACTURING PLANTS
March, 1981; August, 1981; February, 1984

Solvent	Plant 1		Plant 2		Plant 3	
	Personal**	Area***	Personal	Area	Personal	Area
Perchloroethylene	ND#	ND	ND	ND	ND	ND
Trichloroethylene	ND	ND	ND	ND	ND	ND
Methyl Chloroform	20.8	6.2	4.8	ND	5.0	ND
1,1,2-Trichloroethlene	ND	ND		ND	1.0	ND

* Parts of organic vapor per million parts of air

** Personal 8-hour time weighted average exposure levels

*** Area - general area concentration levels in vicinity of organic solvent use.

ND - Non-detectable

Limit of Detection = 0.01 mg per sample.

APPENDIX D

NOISE LEVELS
Garment Manufacturing Plants

Table F-1 through F-3

TABLE F-1
NOISE LEVELS
PLANT 1
MARCH 30-APRIL 1, 1981

AREA	dBA LEVEL
Frankle Operation	85
Frankle Operation	88
Frankle Operation	86
Turn and Press Collar	70
Pocket Setting	80
Run Cuff Adler	82
Button Sew Fronts	78
Turn & Press Collar	76

NOTE: Noise measurements were made using a Quest* #215 Sound Level Meter using the A-weighted scale at slow response. All results are single-time point measurements.

TABLE F-2
NOISE LEVELS
PLANT 2
FEBRUARY 7-9, 1984

AREA	dBA LEVEL
Buttonhole Fronts	85-90
Button Sew Front	82
Pocket Setting	83
Pocket Hem	83
Fuse Lining	75
Run Cuff Adler	85-90
Turn and Press Collar	75
Manual Collar Stitch	80-94
Folder Join	80-85
Sleeving	80-85
Felling Double Needle	75-85
Folding and Buttoning	65-70
Marking Area	70

NOTE: Noise measurements were made using a Quest* #215 Sound Level Meter using the A-weighted scale at slow response. All results are single-time point measurements.

TABLE F-3
NOISE LEVELS
PLANT 3
JANUARY 24-26, 1984

AREA	dBA LEVEL	
Fuse Collars	70	
Insert Top in Band Dress	70	(without background music)
Insert Top in Band Dress	70	(with background music)
Run Top and Trim Points	85	
Turn Points and Press Tops	80	
Crease Band	80	
Spot Removal (Sprayer On)	95	
(Compressed Air On)	75	
(Sprayer and Air Off)	70	
Concealed Join	82	
Apparel Press	75	
Folder Felling Double Needle	83	
Top Stitch Collars	84	
Folder Felling Double Needle	87	
Run on Sleeves	86	
Attach Buttons	86	
Run Cuff Adler	85	
Run Top and Trim Points	93	

NOTE: Noise measurements were made using a Quest* #215 Sound Level Meter using the A-weighted scale at slow response. All results are single-time point measurements.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

The extent of exposure to formaldehyde (50000) was investigated at three garment manufacturing facilities using fabrics pretreated with a formaldehyde based resin system. Two of the facilities (in Georgia) operated on a two shift basis with approximately 1000 and 500 workers; one facility (in Pennsylvania) operated on a one shift basis and had approximately 600 workers. The facilities cut and sewed men°s dress shirts from treated fabric. Measured exposures to formaldehyde, respirable dust, and organic cleaning solvent vapors were all below the applicable American Conference of Governmental Industrial Hygienists Threshold Limit Values and Occupational Safety and Health Administration Permissible Exposure Limits. Formaldehyde exposures ranged from 0.51 parts per million (ppm) down to less than 0.02ppm (undetectable). The potential existed for continuous low level exposure to formaldehyde at these facilities. The authors recommend periodic personal monitoring for formaldehyde with a reliable method to determine time weighted average exposures and peak variations. Local exhaust ventilation hoods should be installed over fused lining machines. The heating, ventilation and air conditioning system should not be set up on a fully recirculated system. Local exhaust ventilation should be installed and utilized during the spot cleaning operation and when cleaning stamping devices with organic cleaning solvents. Noise exposure in these facilities should be lessened and a hearing conservation program initiated.

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