NIOSH

A TECHNICAL REPORT

An EVALUATION of OCCUPATIONAL HEALTH HAZARD CONTROL TECHNOLOGY for the FOUNDRY INDUSTRY

AN EVALUATION OF OCCUPATIONAL HEALTH
HAZARD CONTROL TECHNOLOGY
FOR THE FOUNDRY INDUSTRY

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PREFACE

Although many different engineering approaches to the control of chemical
and physical hazards in the workplace environment have been used in
foundries, little documentation exists concerning the effectiveness with
which these measures protect foundrymen from exposure. In particular,
air contaminant control technology, which is well-developed, is in
greatest need of documentation; and noise control technology, although
not widely applied in foundries, is an area receiving increasing attention.
It was largely because of the excellent cooperation of 24 participating
foundries, that an in-depth field evaluation of control measures, in-place
and functioning, was possible. The participating foundries provided
good examples of the application of engineering principles to the control
of hazards.

The present study does not represent all the possible problem solutions
nor do the solutions presented necessarily represent the best possible
approaches. The goal of documenting the best controls will be achieved
only after all of the approaches which have been tried, both successes and
failures, have been evaluated and compared. This goal cannot be achieved
unless foundrymen contribute their ideas by documenting in the literature
the methods which they successfully employ. Many of the methods encountered
during the in-plant studies had already been identified and described in
Volume I of the Foundry Environmental Control Series of the American
Foundrymen's Society (20). The unique contribution of the National Institute
for Occupational Safety and Health (NIOSH) study contained herein is the
indepth evaluation of these and other methods to document the effective
application of engineering principles for hazard control in the foundry
environment.

Because of the many complex factors that affect the extent and controllability
of workplace hazards, it may not be possible for foundrymen to simply plug
in and use one of the methods found in this report. Rather, control
techniques should only be applied after a thorough analysis has been made
of a particular hazardous situation and of the factors which may or may
not permit effective control using the particular method of control.
Understanding is more important than automatic referral to an index of
solutions.

This report has been organized to provide a ready reference to solutions
for foundry hazards. All of the health hazard control information presented
is indexed on process-hazard-control worksheets presented in Section VIII.

ABSTRACT

This report presents the findings of a National Institute for Occupational Safety and Health (NIOSH) study of available technology used to control worker exposure to chemical and physical health hazards in foundries.

The study was performed primarily through an inplant review of functioning control methods in 24 ferrous and nonferrous foundries, supplemented by a review of the literature. The processes selected provide a representative coverage of the industry relative to the number of exposed workers, the severity of the hazards, different control techniques and common operations.

The report is organized to provide a ready reference to control methods for the 26 processes studied. Each of the processes has two worksheets upon which the hazards are identified and the appropriate case history studies or literature references to control methods are listed. Advantages and limitations of each control method are summarized on the worksheets and the control measures are categorized. Deleterious effects of the individual hazards and description of the principles behind each category of control are presented in separate sections. Conclusions concerning the existence and effectiveness of the control measures, as well as recommendations for further research and development, are presented.

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SECTION I
INTRODUCTION

STUDY OBJECTIVE

This report presents the findings of a state-of-the-art study of available technology used to control worker exposure to chemical and physical agents in foundries. The study was undertaken because controls for foundry hazards were known to exist, but their effectiveness was not well documented.

Because of the ever-increasing number of chemical and physical agents in foundries due to the changing technology, detailed technical documentation of the state-of-the-art of control methods is necessary to provide foundries with a resource of applicable methods of control, not only for use in retrofitting existing processes but also for planning process changes.

Another objective of the study was to identify processes for which engineering controls were not available or were ineffective and where further research and development was needed. The study was performed primarily through in-plant review of in-place and functioning controls, supplemented by a review of the literature pertinent to foundry hazards and methods used by the industry to control worker exposures.

PRIORITIES FOR STUDY

NIOSH set up certain guidelines for the selection of foundries in which to conduct inplant studies to assure that sufficient information would be gathered to develop valid conclusions regarding control technology. These were:

1. The inplant study was to be conducted in a minimum of 20 foundries, with a maximum of 30 foundries.

2. The plants selected were to represent the best control technology and work practices in the industry.

3. The selection of plants was to be optimized in a manner which was consistent with obtaining the widest possible coverage of the foundry industry while also obtaining as wide a range of engineering process/control combinations as possible.

It was apparent at the beginning that a study conducted in 20-30 plants would not be able to assess all of the various process-control configurations in use. Thus, it was necessary to establish a list of priorities for study to ensure an investigation of solutions for the most pressing problems facing the foundry industry today.

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The principal factors used as a basis for setting priorities were:

1. The severity of the hazard.
2. The potential for overexposure.
3. The number of workers affected.
4. The use of control methods in existing foundry operations.

The highest priority in the study was placed on evaluation of technology for controlling air contaminants, since these posed a more severe potential health hazard and affected workers in most foundry process areas. It was known that substantial air contaminant control technology was in use in foundries, yet overexposure of workers still occurs. Less emphasis was placed on evaluation of noise controls since noise is less of a hazard to health than air contaminants and control technology for noise has only been applied to a very limited extent in foundries.

Heat stress control in foundries is achieved for the most part through acclimatization programs for workers, and through ventilation of hot processes. This area became an adjunct of the air contaminant control evaluation.

Other potential foundry hazards such as ionizing and nonionizing radiation and vibrations were given lowest priority. Ionizing radiation controls were not pursued because of the very strict regulations which are enforced concerning the use of ionizing sources. This resulted in a very low probability of harmful exposure occurring. Nonionizing radiations such as infrared and ultraviolet are well controlled with proper opaque clothing and dark glass for viewing. Vibrations were excluded from further study because of the lack of standards in this country, incomplete knowledge about the factors resulting in vibrational disorders, and uncertainties about measurement and analytical procedures.

VARIABILITY OF FOUNDRY OPERATIONS

All foundries have one thing in common: they melt metals and cast them into useful shapes. The raw materials for casting are primarily scrap materials, and so foundries may be considered as the great recyclers. There is great variability in the way the melting and casting takes place and many of the variables have a substantial impact on the extent and controllability of hazards. Most foundries employ sand mold methods. A typical foundry operation, if one could be defined, would consist of the elements outlined in the flow chart in Figure I-I.

The truth of the statement "no two foundries are alike" can be quickly realized when the diversity of factors relating to foundry hazards and their control are understood. These factors include, among others:

Type of metal cast.
Cleanliness of scrap.
Process methods employed.
Type of foundry.
Production rate.
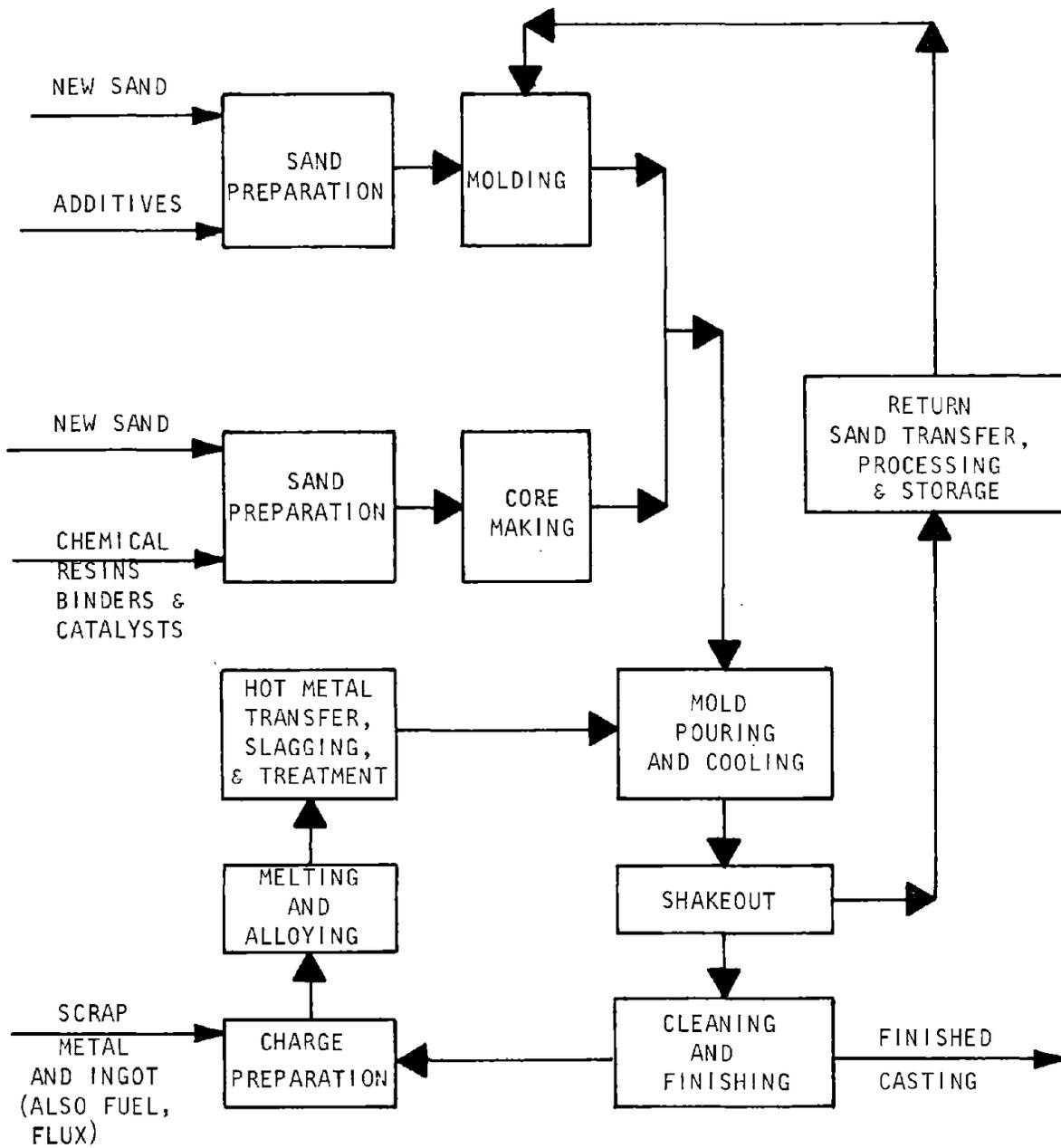
Figure I-1. Typical sand-cast foundry flow sheet.

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Degree of automation.
Casting size.
Age, size and layout of plant.
Climatic differences

Type of Metal Cast

Many metals are contained in varying percentages in the different classes of
ferrous and nonferrous alloys. Toxic properties of the metals vary widely.
For example, iron oxide exposure is limited mainly because of nuisance
effects, whereas copper fume has a standard many times lower than that of
iron because it can cause upper respiratory tract irritation and possibly
metal fume fever. The fume evolution rate for a particular metal is
dependent on the relationship of its boiling point to the melting temperature
of the alloy. Boiling points of the metals vary widely as do the melting
ranges for ferrous and nonferrous alloys. Zinc always fumes when it is
present in either ferrous or nonferrous molten alloys because its boiling
point is lower than the range of melting temperatures employed. Manganese,
on the other hand, has a boiling point higher than any metal in common
use and its presence in the fume is seen more in welding processes than in
furnace operations.

Cleanliness of Scrap

Foundries charge their furnaces with varying types and percentages of scrap
including: ingot, machine shop scrap, automotive drive components, foundry
returns, structural and plate steel, and tubing. Scrap may contain a wide
range of combustible materials, e.g., fabric and oil, and a number of
tramp materials such as lead and zinc. Hazards during furnace operations
are dependent to a large extent on the nature and cleanliness of charge
materials.

Process Methods Employed

Furnaces differ widely in the technique and rate of melting. Induction
melting, on the one hand, is a quiet and nonturbulent method in which
scrap is loaded into a molten bath into which it gradually sinks as it
melts. Fume generation is light to moderate. Arc melting, on the other
hand, is a violent and noisy process in which the temperature at the arc
is higher than the boiling points of all of the metals in the alloy, and
consequently fume generation is high.

Molding methods and materials are even more diverse as are the hazards
involved. The hazards in silica sand molding are far greater than in the
use of permanent molds. Silica sand moldmaking utilizes a closed cycle
reclamation system which creates a severe respirable dust hazard at many
foundry operations. Nor is the hazard isolated to the casting process.
Cleaning and finishing of ferrous castings is rendered extremely hazardous
by a "defect" of the sand casting process whereby mold materials are
imbedded in the surface layer of the metal.

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A variety of organic and inorganic binders and additives are used in molding and coremaking. Products of decomposition released into the air from just-cast molds can vary because of a variety of factors, including:

> Type of metal cast.
> Casting size and configuration.
> Organic materials present in mold and core binders and additives.
> Sand-metal ratio.
> Pouring temperature.
> Production rate.

Type of Foundry

Approximately 80% of foundries are job shops which produce many different castings. A much smaller number are captive foundries (20%) which tend to be high production facilities. Some captive foundries sell a portion of their castings on a jobbing basis. Captive foundries may be very automated, whereas job shops are limited in the degree of automation possible and tend to be labor intensive. In general, automation and mechanization increase the controllability of hazards by permitting isolation of the worker and the elimination of manual operations.

Production Rate

Foundry production varies widely from the production of only a few specialized castings to thousands of production castings per shift. The number of potential hazards may be the same in each case, but the extent of those hazards varies dramatically. At any production level, the degree of hazard can be dependent on how many shifts of operation are utilized. Foundries with three shift operations perform a large portion of their maintenance during production time. In high production, large foundry situations, workers probably have a single assignment, e.g., melter, molder, shakeout operator. In small shops a single worker may be responsible for charge makeup, furnace operation, hot metal transfer, slagging, and pouring.

Degree of Automation

Foundry processes range from nonautomated to fully automated. Shakeout, for example, can be performed in many ways, the following ways representing the extremes on the scale of automation:

> Automated--
> The contents of the flask are automatically dumped onto a vibrating shakeout. The castings are conveyed automatically off of the table and onto a transfer conveyor. Mold materials passing through the table drop onto a return sand transfer conveyor.

> Manual--
> A crane operator hoists a flask to a point near the shakeout. An operator rehooks the chain for dumping the flask on the vibrating table, guiding the flask throughout the dumping process. A second person then leans over or climbs upon the table and hooks out the casting with a hoist and drops it into a hopper.

Casting Size

In the cleaning room small castings are chipped, ground, and welded on benches. The castings may be easily repositioned as necessary to accommodate ventilation control measures. When processing large castings the operator sits, kneels, or stands next to, atop or inside the casting while performing those hazardous operations. The degree of hazard from processing castings depends on the size of the casting.

Age, Size and Layout of Plant

Some old, wooden-framed foundries have low ceilings, whereas new steel trussed buildings have high bay areas entirely serviced by crane systems. General ventilation is very different in these types. An infinite variety of foundry layouts is possible, each with its own unique requirements for methods to transport charge materials, mold and core constituents, hot metal, and castings.

Climatic Conditions

The foundry industry is spread throughout the country, and foundries are subject to the heat extremes of the south and the cold extremes of the north. Some sections of foundries in hot climates may not have walls, whereas foundries in northern climates must be closed up tightly in winter. Ventilation requires substantial seasonal adjustments and the fresh air which is moved at small expense during the summer is moved and tempered at high expense during the winter.

INDUSTRY OVERVIEW

The 1976 Metal Casting Industry Census Guide reported that there were 4,938 foundries in the United States employing 490,000 people with a total capacity for producing 33,700,000 tons/yr (30,300,000 metric tons/yr) of ferrous and nonferrous castings (47). During recent years there has been a continuing trend toward fewer but larger foundries, although over 60% of the foundries in the U.S. and Canada, in 1975, employed fewer than 50 persons. There are, on the average, 75 fewer foundries every year and most of those going out of business have been small operations. The number of large foundries on the other hand is increasing.

From 1960 to 1975, the net production of the industry doubled. The trend toward large, high-producing foundries necessitates more and more mechanization. Metal casting is becoming less labor-intensive as more processes are automated. In 1975, production tonnage was 60%, iron; 13%, steel; and 27%, nonferrous alloys of copper, aluminum, magnesium, and zinc bases. About 45% of foundry employees produced iron castings, 16% produced steel castings, and 39% produced nonferrous castings. Of the large number of foundrymen casting ferrous alloys, almost half of them worked in foundries employing between 100 and 500 people (Table 1-1). On the other hand, the majority of nonferrous foundrymen worked in foundries employing less than 100 people.

Table I-I. Distribution of employees based on foundry size and principal metal cast.

Foundries employing	Mean number of employees	Number of foundries§			Estimated number of employees (x 1000)			Estimated percent of total employment		
		Iron	Steel	Non-ferrous	Iron	Steel	Non-ferrous	Iron	Steel	Non-ferrous
Over 1000	1,000*	42	9	10	42.0	9.0	10.0	18.6	11.0	5.2
500-999	750†	38	23	22	28.5	17.2	16.5	12.6	21.0	8.6
250-499	375†	114	53	65	42.8	19.9	24.2	19.0	24.4	12.7
100-249	175†	307	118	200	53.7	20.6	35.0	23.8	25.2	18.2
50-99	75†	330	87	304	24.8	6.5	22.8	11.0	7.9	11.9
20-49	35†	364	95	650	27.3	7.1	48.8	12.1	8.7	25.4
Under 20	20#	319	72	1,716	6.4	1.4	34.3	2.9	1.8	18.0
Total		1,514	457	2,967	225.5	81.7	191.8	100.0	100.0	100.0

§ United States and Canada, 1975 Metal Casting Industry Census Guide (47).

* The estimate of the mean for this category was set at the low end of the range, thus biasing the estimated number of employees and percent of total employment on the low side.

† The estimate of the mean for this category was set at the midpoint of the range.

The estimate of the mean for this category was set at the high end of the range, thus biasing the estimated number of employees and percent of total employment on the high side.

FOUNDRY AND PROCESS RANKING

A priority ranking of processes was established for the study. The highest priority was placed on processes with inherent problems for which the probability of large numbers of workers being overexposed was high when engineering controls were ineffective or nonexistant. Based on this rationale, the list of priorities in descending order was:

Cleaning and finishing - removal of gates, risers, and sprues, blasting, chipping and grinding, and casting repair.

Sand preparation - transport and processing of recycled sand, addition of new sand, and mixing of mold constituents.

Shakeout and core knockout - vibration or tumbling of molds to separate the cast metal.

Material handling systems - conveying of furnace charge material, raw materials for molds and cores, and finished molds, cores, and castings.

Metal casting - preheating, melting, treatment, transfer, pouring, and cooling of metal.

Maintenance - furnace and ladle repair, and housekeeping.

Coremaking - formation of internal casting forms by bonding of sand using a variety of binders.

Molding - bonding of sand with either clay and water or chemical binders.

Pattern ship - fabrication and/or reworking of patterns for mold and coremaking.

A priority ranking of foundries was also established using the same criterion: steel, iron, copper-base, aluminum, and magnesium. Foundries in the study included only the first four categories. In addition, other specialty metal casting operations including production of beryllium and titanium castings were not included because of the few workers affected. Most foundries in the study employed sand casting methods. In this study sand casting was given priority over permanent molding because of the hazards due to respirable silica and products of mold decomposition.

CATEGORIES OF EXPOSURE CONTROL

Control technology in this study is classified under four headings:

I. Engineering controls - These include methods for elimination or reduction of a hazardous emission into work areas through: substitution of nontoxic or less toxic substances, equipment, or

processes for more hazardous ones; isolation of hazards from the worker, or workers from the hazard; control or elimination of hazards at the source; and general ventilation.

2. Process monitoring - This category includes devices or procedures designed to ensure that process conditions will not occur which could be hazardous and that engineering control systems continue to function properly.

3. Work practices - This category includes operational and maintenance procedures followed by the workers to eliminate or reduce exposure to hazards.

4. Personal protective devices - These devices are worn by workers to protect them from uncontrolled hazards.

CONTROL EFFECTIVENESS

Effectiveness of controls for air contaminants was assessed by comparing the environmental levels to both OSHA Permissable Exposure Limits (PEL's) and the 1977 ACGIH Threshold Limit Values (TLV's). Noise control effectiveness was assessed by comparing noise levels to the OSHA PEL. Effectiveness of heat stress controls was assessed by calculating several heat stress indices fcr various exposure areas.

FOUNDRY SELECTION

Recommendations for potential candidate foundries for inplant studies were elicited from a foundry technical association, foundry professionals, and the literature. This study was performed on a completely voluntary basis and candidate foundries were sent a copy of the study protocol before their decision was requested on whether or not to participate.

Following an affirmative response from the foundry, a telephone inquiry was made and questions asked to determine the type and extent of control measures in operation. Of the 43 foundries consenting, 38 were selected for preliminary visits to further discuss the study scope and procedures, and to tour the foundry. After completion of all of the visits a group of 24 foundries was selected for inplant studies. These foundries included iron, steel, copper-base, and aluminum casting operations, captive and job shops, large and small production of very small to very large castings, all sections of the country, and a wide variety of molding and coremaking processes.

INPLANT STUDY

Evaluation of the information obtained in the preliminary meeting and tour resulted in establishment of a sampling plan which was submitted to the individual foundries for review prior to commencement of the inplant studies. The subsequent field studies were one to five days in duration and involved sampling measurements, process and control system documentation and review of existing foundry data. After completion of the inplant

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studies and analysis of the samples obtained, case histories were prepared for each process studied. The case histories were submitted to the foundries for review of accuracy of the information and deletion of proprietary information prior to being included in this report.

SECTION II
CONCLUSIONS

Conclusions from the study are presented in this section. Conclusions concerning air contaminant and heat stress controls are presented first, organized by foundry area. Conclusions concerning ionizing radiation and noise follow.

AIR CONTAMINANT AND HEAT STRESS CONTROL

Cleaning and Finishing of Ferrous Castings

1. The ferrous cleaning and finishing operation is perhaps the most difficult area in the foundry in which to achieve full breathing zone protection from air contaminants.

2. Control of respirable dust and fume in the breathing zones of all workers manually cleaning ferrous castings is not being achieved with today's ventilation technology. Incomplete control is caused by present limitations of the ventilation techniques used, as well as defects in effectively applying these methods.

3. Dust exposure in cleaning rooms comes from two equally-important sources: background dust and dust from the operation being performed.

4. The main sources of background dust in cleaning room air are processes that take place in the cleaning room; secondary sources are processes that take place elsewhere in the foundry.

5. Overexposures to dust are most likely in the least automated cleaning and finishing operations and are unlikely when the process is fully automatic.

6. The larger the casting, the more difficult the control of dust exposure during cleaning.

7. Metal penetration into mold and core materials (burn-on, burn-in) makes abrasive blasting less efficient in reducing dust exposures later in the process.

8. Loose dust is not being adequately removed from castings prior to chipping and grinding operations and as a result this dust, which freely builds up in cavities, becomes a source of dust exposure during chipping and grinding.

9. Shot blasting and tumbling become sources of background dust when seals on machine enclosures fail and when, as usual, the dumping of debris

into bins or hoppers is not controlled by ventilation.

10. The conditions under which floorstand grinders are capable of controlling dust are not well defined.

11. Improvements to the conventional floorstand grinder hoods are available that may significantly reduce the amount of dust reaching the operator's breathing zone.

12. The electrostatic fog method, as a supplemental method of reducing the amount of dust escaping grinder hoods, shows promise, does not cause over-humidification because of the minor amounts of water used, and is commercially available.

13. Dust control for abrasive grinding and/or cut-off, using swing frame machines, can be achieved with machine-mounted hoods or with booths. Conventional booth hoods can adequately control dust, but present cleanup problems because of heavy particle build-up in the rear of the enclosure.

14. Control of dust from use of portable grinders can be achieved with downdraft benches and with high velocity, low volume (HVLV) exhaust systems. Neither method is suitable under all conditions.

15. Downdraft benches do not control dust well during the cleaning of internal casting cavities, when the grinding swarf is directed away from the bench, when exhausts from portable tools disrupt the flow of control air, when the castings are blown out with air from nozzles, and when exhaust rates are less than the minimum recommended by ACGIH.

16. High velocity-low volume (HVLV) exhaust systems do not control dust well when capture efficiency is sensitive to tool position, when chipping is done, when the hood interferes with operating the tool so greatly that the hooded tool is abandoned for an unhooded one, when castings are blown out with air nozzles, and when the work area is swept after castings have been cleaned. No practical hood for chipping tools was found.

17. Ventilated booths can control fume during arc-air processing and torch cutting of castings, but an important part of that control appears to be work practices.

18. Nonionizing radiation from arc-air, consisting of visible and ultra-violet light, is controlled with welding helmets and proper clothing and opaque or colored transparent drapes.

19. Exhaust ventilation provides some control of heat stress. Heat relief is also provided by air supply directed at workers mainly for purposes of dust control.

Green Sand Systems

1. Effective housekeeping and effective ventilation are both necessary to control respirable silica, whenever green sand is used for molding.

2. An enclosed and ventilated muller can effectively limit dust liberation during filling and mixing of dry recycled sand with binders, additives, and water.

3. Manual bond additions to the muller can be effectively controlled with a hood and proper technique.

4. Unloading and transfer of prepared sand can be done without exhaust ventilation because the sand is moist.

5. Dust exposure of an operator of a stationary sand slinger can be controlled by isolating him in a remote work station. However, no protection is afforded the slinger assistants, unless auxiliary ventilation is applied and adequate distance from the slinger head is maintained. One example of auxiliary ventilation is the use of a downdraft exhaust scheme utilizing a spill pit as a hood.

6. ACGIH recommended ventilation control techniques are effective at controlling dust emissions from shakeout and from dry sand processing and transport operations.

7. The Schumacher Process effectively limits dust emissions from return sand by mixing prepared sand with it, thus reducing the amount of ventilation required.

8. Substitution of nonsilica molding aggregates of olivine, zircon, or chromite sands for silica sand in molding can reduce the silica content of dust by at least 80%. Exhaust systems at the major dust-producing operations are still necessary in foundries using nonsilica sands.

9. Substitute molding sands do not eliminate silica from dust when silica sand is used for cores, or clay is used as a binder. After substitution of another sand for silica sand in molding, about a year is required before equilibrium is attained and the silica content of dust stabilizes.

10. There is not enough known about the chronic inhalation toxicology of the substitute sands to state with certainty that these materials will all be less troublesome to man than is silica. Preliminary data indicates that these materials will probably be less toxic.

Melting and Casting

1. Incomplete control of dust generated during charge bucket filling does not result in overexposure of operators when they are in control booths.

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2. Dust emitted during charge bucket filling usually becomes part of the background dust (can approach allowable levels) on the melting platform. Strong drafts of air induced toward the melting area because of a high volume of exhaust and a lack of makeup air in most foundries is responsible for this problem.

3. In dual cupola arrangements with one cupola on line and an adjacent one down for repair, furnace repairmen may be overexposed to carbon monoxide, as well as respirable silica.

4. An arc furnace with a sidedraft hood, connected only during the melting cycle, usually requires a slag door hood and a spout hood, as well as a roof ventilator as supplemental ventilation for charging and tapping emissions.

5. Emissions from charge preheaters can be controlled effectively by ventilation at the source combined with fresh air supply.

6. Emissions of fume from induction furnaces can be effectively controlled with a close-fitting hood, or, in certain restricted cases, by general ventilation. Close-fitting hoods, which provide fume control over most of the cycle, will usually emit fume during tapping because of the difficulty of sufficiently enshrouding the spout and/or ladle.

7. All furnace operators are subjected to heat stress. Heat stress can be reduced with cooled control rooms. When operators must be close to the furnace, radiant heat shields, aluminized clothing, tinted glasses, and tinted face shields help reduce exposure to heat.

8. Mobile transfer ladle hoods are available and effectively control fume from such ladles, if there are no disruptive crossdrafts.

9. Covers for transfer and pouring ladles help reduce fume emissions and also reduce heat stress on operators.

10. Hot metal crane operators can be well protected from fume and from heat by enclosing and/or air conditioning the crane cab. Mobile fresh air supply systems for enclosed crane cabs are commercially available.

11. Ladle slaggers are protected from heat stress by isolation with barriers to infrared radiation and/or by distance provided by long poles with rests, or by mechanization and remote control of the process.

12. Plunging bell and sandwich inoculation methods allow effective fume control by ventilation at the ladle. Sandwich inoculation in the ladle presents fume control difficulties when performed at the furnace.

13. Ladle slaggers, inoculators, and others who must spend time close to molten metal usually rely on aluminized clothing to protect against heat and metal splashes, tinted glasses to protect against eye injury (development of cataract) from infrared radiation, and tinted face shields to reduce heat effects on the skin.

14. The major inhalation hazard in nonferrous foundries that make alloys containing lead is usually lead fume.

15. To provide adequate control of fume from nonferrous induction furnaces, a roof ventilator and/or a mobile ladle hood is necessary in addition to the usual close-fitting canopy hood on the furnace.

16. The most acutely hazardous air contaminant generated during the pouring of molds is carbon monoxide.

17. The amount of gas emitted from a poured mold increases directly with the weight of metal and decreases exponentially with increasing sand-to-metal ratio.

18. Peak gas emission rates occur shortly after pouring and at shakeout.

19. Mechanized pouring lines can be ventilated effectively with standard, commercially available side-draft exhaust hoods.

20. Mobile exhaust hoods are effective in capturing fume in floor pouring operations.

21. Rapid, mechanized transfer of cooling molds from the pouring area can effectively limit exposure of pourers and others to gases and heat from poured molds.

22. Effective smoke and fume control from cooling molds was not found for a pallet line system.

23. Manual metal pouring is a chronic heat exposure problem in foundries. General and individualized fresh air supply systems have been used to alleviate heat stress on pourers, but discomfort still appeared to be a characteristic of this job.

Molding and Coremaking Using Chemically Bonded Sand

1. Heat and gases from molding and coremaking using chemically bonded sand can be effectively controlled by a combination of ventilation at the molding or coremaking operation, a canopy hood over molded parts, and fresh air directed at the operator.

2. Exhaust from the corebox alone is not sufficient to control catalytic gases from cold box (phenolic urethane) coremaking.

Other

1. Ventilation controls may reduce respirable silica concentrations during furnace and ladle repairs, but adequate control of this process has not been demonstrated.

2. Exhausted enclosures effectively control carbon monoxide and heat during the ladle curing process.

3. Powered sweepers and vacuum cleaners are almost always necessary for adequate cleaning of floors, equipment, and structural members in foundries.

4. Housekeeping problems are minimized by operational and maintenance steps that reduce leakage of sand and other materials.

5. The most successful housekeeping programs are those with established responsibilities and timetables for cleaning.

IONIZING RADIATION CONTROL

1. The main use for ionizing radiation sources in foundries is for the radiography of castings. A secondary use is for level control or other gauging.

2. Radioisotope sources and X-ray machines are licensed and closely regulated by state and federal law. Those foundries that use such sources of ionizing radiation exercise very complete control over exposures to people.

NOISE CONTROL

1. No effective means of controlling noise generated by chipping and grinding was found.

2. Noise levels generated by cupola melting of gray iron and crucible furnace melting of nonferrous alloys generally exceed allowable limits, but the hazards are not severe.

3. Noise levels from tumbling mills were reduced to allowable limits by the use of enclosures. Enclosures could be used to effectively control noise in other processes which can tolerate the restrictive aspects of such a control measure.

4. Substitution of quiet for noisy equipment is growing in popularity as a noise control method and hence, equipment designed to be quiet is becoming more available. Although not the whole solution to foundry noise problems, this method probably has a place in any such solution.

SECTION III
RECOMMENDATIONS

Recommendations from the study are presented in this section. Recommendations concerning air contaminant control are presented first, followed by recommendations for heat stress and noise control, and a general recommendation.

AIR CONTAMINANT CONTROL

1. The focal point for eliminating the respirable silica hazard should center around reduction of burn-on caused by metal penetration into mold and core materials, because of the severe dust hazards created during cleaning and finishing of castings, as well as the present limitations of ventilation methods in protecting the breathing zones of workers using portable tools.

   Unless breathing zone samples for respirable silica show otherwise, cleaning room workers using manual and semi-automatic tools should be assumed to be overexposed. Proper respiratory protective devices, in particular air-supplied respirators or hoods, are recommended for such workers.

2. Further research should be undertaken to accurately identify the mechanisms of metal penetration into mold and core materials. In their recommendations for further research, Draper and Graindhar (18) have suggested that the effect of certain factors which cause penetration be systematically studied, with special emphasis placed on the influence of the different base sand compositions and impurities in mold and core constituents and washes. They recommend further development of mold coatings which resist cracking, and development of some possible ways to control metal penetration through process changes. Their recommendations are seconded.

3. The high-velocity, low-volume (HVLV) control method should be further developed for foundry use because it has good potential for providing breathing zone protection during finishing of certain castings. In particular, hooding methods should be developed for chipping tools and specialized hoods should be developed for unique grinding situations which occur, particularly during finishing of the internal cavities of complex castings.

4. Further research and development should be performed, preferably on a controlled experimental basis, to determine whether a combination of existing and new or improved ventilation methods and work practices might be sufficient to achieve complete exposure control for certain classes of chipping and grinding operations.

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5. Further research should be undertaken to evaluate existing floorstand grinder hood techniques and to establish for certain the conditions under which control can and cannot be achieved.

6. Manufacturers of abrasive cleaning and finishing equipment should be encouraged to help reduce dust levels, by strongly recommending that debris discharge ducts be isolated and/or ventilated at discharge points.

7. Methods should be developed to remove loose dust from casting surfaces and cavities, so that the process of blowing off castings with air nozzles during chipping and grinding can be eliminated.

8. Electrostatic fog should be further investigated as a possible way to augment ventilation in reducing dust exposure.

9. Further study of the arc-air process should be undertaken to identify and evaluate work practices in present use and their effect on capture effectiveness. Guidelines should then be prepared for work practices and worker training.

10. Exposure and background sampling should continue in foundries casting ferrous alloys in molds made from nonsilica aggregates to determine whether state-of-the-art ventilation techniques can achieve dust control below allowable limits with reduced silica content in the dust.

11. Workers who are involved with furnace and ladle repair should wear approved dust respirators. And, especially in cases where repair work is done during production shifts, ventilation control should be applied to reduce the possibility for cross-contamination of dust containing quartz and cristobalite into other worker areas.

12. Foundries should be regularly monitored for carbon monoxide. Frequency of the monitoring should be based on the prevalent concentrations and the potential for concentration peaks which could result in acute exposures. Examples of potential trouble spots are cupola charge decks and repair operations, areas inside and around enclosed mold cooling rooms, ladle curing, and floor pouring and cooling.

13. Hoods for furnaces melting alloys containing lead should be improved to permit complete capture of tapping fume. These hoods are presently limited in cases where interferences occur from ladle hangers.

HEAT STRESS CONTROL

1. Heat relief in the foundry should be achieved without the use of man-cooler fans. They are an unacceptable substitute for distributed fresh air supply. They unnecessarily recirculate contaminant-laden air, promoting cross-contamination from operator to operator and from process to process. They also disrupt local exhaust hoods, many times nullifying their effectiveness.

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NOISE CONTROL

1. A project should be initiated to investigate and document partial solutions to foundry noise problems. After a strong base is obtained, recommendations could be made for further work to identify and reduce the noise levels.

2. A separate project should be initiated to identify the source(s) of chipping, grinding and arc-air noise.

OTHER

1. This study should be regarded only as a preliminary look at hazard control technology; it is not and could not be exhaustive. This kind of approach should be either continuing or periodic by some organization to keep records of problems and their solutions immediately available to all concerned.

SECTION IV
DISCUSSION

In this section some of the major findings of the field studies and litera-
ture review concerning control technology are summarized and discussed. Air
contaminant and heat stress control is presented first, followed by noise
and ionizing radiation control. Some new control techniques, as well as
new uses for existing techniques are presented at the end of this section.

AIR CONTAMINANT AND HEAT STRESS CONTROL

Cleaning and Finishing of Ferrous Castings

A Problem Area--
The ferrous cleaning room is perhaps the most difficult area in the foundry
in which to protect workers from dust exposure. In foundries using silica
sand for mold and/or coremaking, respirable dust is always found in the
cleaning room. In many foundries the hazard is made worse by the presence
of metal fume from torch cutting and casting repair using arc-air and
welding, which take place in the same general area as the dust producing
finishing operations.

The concentration of quartz found in the breathing zones of workers
performing manual operations, such as stand grinding, gate, riser and
sprue removal, and chipping and grinding with portable tools, varied from 4-23%
of respirable dust in foundries employing available ventilation control
technology. Variability in the silica concentration of the dust occurred
among the different cleaning rooms, processes, and workers, and from
day to day. As can be seen in the graph of allowable dust exposures
(Figure IV-1), the limit for respirable dust containing quartz varies from
0.1 - 1.6 mg/m3 in cleaning rooms experiencing the above range of silica
percentages. Control of respirable dust in the breathing zones of all
workers performing manual cleaning operations to meet allowable limits
at the lower end of that range probably cannot be achieved using today's
ventilation technology.

Modes of Dust Exposure--
There are two modes by which cleaning room workers receive their dust
exposure. The first relates to the degree of worker involvement in dust
producing processes, and the second relates to the extent of contamination
of the background air by the various dust producing sources. The following
is a discussion of each of these two modes.

Four different categories of operations are listed below to provide an
understanding of how cleaning room processes differ in worker involvement.
These four categories are listed in decreasing order of both breathing

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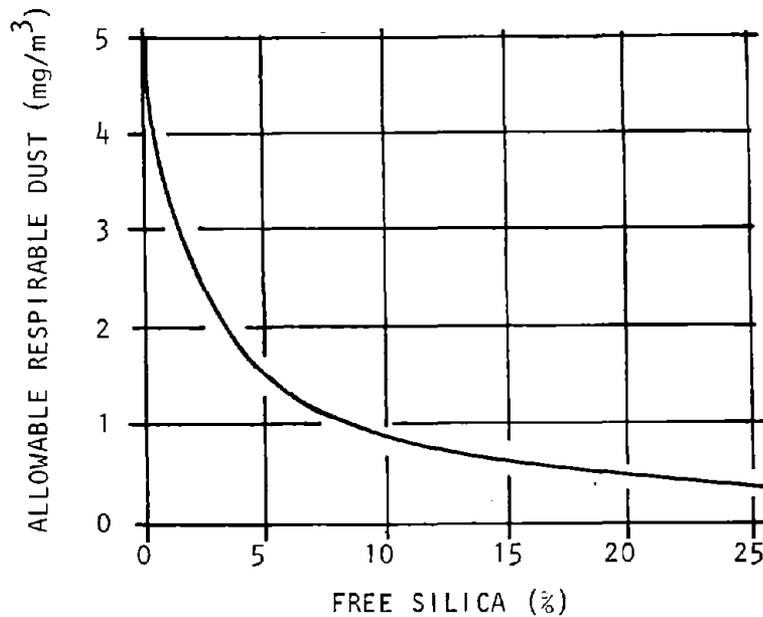
Figure IV-I. Allowable respirable dust exposure.
[OSHA PEL and ACGIH TLV (1977)]

zone hazard and difficulty in providing breathing zone protection.

Category I--Manual support of a portable tool (chipping and grinding with portable tools, removal of gates, risers and sprues). The worker must support the weight of the tool and, at the same time, apply sufficient force to accomplish the process in a reasonable period of time. A variety of body positions are required and the breathing zone is often very close to the dust generation point [0.5 - 2.5 ft (0.15 - 0.8 m)], as the worker stands, sits or kneels adjacent to, on, or inside the casting.

Category 2--Manual handling of castings and processing with fixed tools (wheel and belt grinders and buffers). The operator feeds the casting by hand against the tool. In some cases the casting receives support from a workrest. Because the elbows are usually flexed and the neck is usually bent, the distance from the breathing zone to the dust generation point may vary from 1 - 2.5 ft (0.3-0.8 m).

Category 3--Mechanically assisted operations (swing grinders and stand grinders with mechanical feed devices). The operator is isolated a short distance [3-6 ft (0.9-1.8 m)] from the dust generation point by mechanical levers, such as the frame of a swing frame grinder or the loading lever of a grinding wheel feeder.

Category 4--Totally automated operations (tumbling, shot blasting, automatic swing grinding). During operation the process is isolated from the worker in a ventilated enclosure.

The second mode of exposure occurs because workers are continuously exposed

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to background air which is contaminated by many dust sources, among them:

1. Partially effective ventilation controls on chipping and grinding operations.

2. Debris chutes from shot-sand separators on blast cabinets.

3. Discharge of debris from casting sorting conveyors.

4. Cleaning castings with air nozzles.

5. Forklift truck traffic.

6. Transfer of castings from hoppers into other hoppers or onto conveyors or benches.

7. Using hammers for gate, riser, and sprue removal from castings with adhered sand.

8. Cleanout of swing grinder booths.

9. Leaky seals on shot blast equipment.

10. Sweeping with brooms.

11. Throwing castings into sorting bins.

The accumulated dust from all of these sources creates a background air concentration that may easily exceed half of the allowable limit.

Metal penetration--A major source of free silica in the dust exposure of ferrous cleaning room workers is generated by the various finishing processes which remove materials from the surfaces of castings. If sand is used as a mold material, the casting will have sand adhered to or imbedded in the metal surface because of penetration of molten metal into mold and core materials. When casting surfaces are cleaned, especially with abrasive equipment, the sand grains are broken down into small, respirable dust particles. A very obvious control for reducing this source of dust exposure is to control metal penetration.

In their review of the literature, Draper and Graindhar have concluded that no single mechanism can explain the phenomenon of metal penetration, and that many conflicting theories exist (18). They listed the many factors which affect the degree of metal penetration, among them:

1. Sand type, grain size distribution, refractoriness, and grain expansion.

2. Mold density, moisture content, permeability.

3. Accumulations of dead clay, oxides, and fines.

4. Mold and core failures, including hot spots.

5. Mold atmosphere - oxidizing and carburizing.

6. Evolution of mold gases.

7. Pouring temperatures and rates, metalstatic and dynamic pressures.

The higher the temperature and metalstatic pressure, the greater the penetration. Thus, large ferrous castings probably present the worst problem, whereas alloys with a low pouring temperature and a high surface tension, such as aluminum, present the least problem.

These investigators have suggested four definitions to describe the various degrees of metal penetration:

1. Rough surface - The clay coating on silica grains fuses and some silica fines are dissolved into the glaze. This material flows into the grain pores but solidifies before reaching the midpoint of the first layer of grains. As a result, the molten metal does not wet the grains and mold materials are easily removed from the rough surfaces of the casting.

2. Sand burn-on - Sand grains are chemically bonded to the casting surface by the reaction produced at the mold metal interface. When the cooling rate is slow, the bonds are weak. This facilitates removal during abrasive cleaning by any process.

3. Sand burn-in - When cooling rates are fast, strong bonds with the sand grains are formed which are difficult to remove and produce very rough surfaces.

4. Metal penetration - In this case some sand grains have been deposited under the surface of the casting because of molten metal entering the pore spaces. If the casting is still useable, it will require substantial cleaning to remove the defective surface material.

It can be seen from the above classifications that the deeper the metal penetration into mold and core materials, the more difficult it is to preclean the casting surface using abrasive blasting, requiring that more sand material be removed by manual grinding processes.

The problem of casting size--Casting size is a predominant factor in the controllability of hazards, particularly during manual processing with portable abrasive tools and while using the arc-air process, cutting torches, and welding equipment. Methods for exhaust ventilation at the source rely on an ability to reposition the casting, as necessary, so that direct capture of air contaminants may take place. The larger the casting, the more difficult repositioning becomes. In the extreme, when cleaning castings weighing many tons, the cleaning and finishing operation is performed on the casting while it is in place.

Manual Gate, Riser, and Sprue Removal, and Casting Sorting--
A mesh belt conveyor, through which downdraft exhaust was applied, was found
to be effective in controlling worker exposure to respirable silica during
processing of small to medium-sized castings. The exhaust system also
incorporated enclosing hoods to capture dust during the loading of castings
onto the conveyor and discharge of debris from the conveyor into a hopper.
No solutions were found for processing large castings on the floor with
sledgehammers.

Distributed fresh air supply can provide comfort ventilation and eliminate
the need for mancooler fans when processing on conveyors. When mancooler
fans are used to reduce heat exposure, they are generally placed very
close to the worker and nullify attempts to capture dust at the source. No
methods were found to reduce heat stress on workers processing hot castings
on the floor with sledgehammers, other than allowing the castings to cool
first.

Shot Blasting and Tumbling--
Because equipment for shot blasting and tumbling is normally in isolated
enclosures, exhaust control can be readily applied and breathing zone
protection can be assured by maintaining the integrity of the enclosures
and providing suitable exhaust rates for the control of dust. Preventive
maintenance, particularly of door seals and the shot-sand separator and
screen, are essential for effective dust control. Exhaust rates are
generally specified by the manufacturer of the equipment. Most exhaust
systems installed on shot blasting operations are incomplete, however,
because they do not include the necessary isolation and ventilation of the
chute or tube through which debris is dumped from the shot-sand separator
and screen into a bin or hopper.

Abrasive Grinding or Cutoff Using Swing Frame Machines

Three different methods were found for controlling dust exposure during
swing grinding:

1. Booths are the most commonly applied exhaust control method.
   Only fine dust particles are exhausted, however, and the heavy
   particle buildup must be manually cleaned from the booth.

2. Machine-mounted hoods can exhaust the entire grinding swarf, but
   the effectiveness of dust capture is dependent on the adjustment
   of the hood chute to accommodate variable positions of the
   grinding swarf, depending on the size of the wheel being used.

3. Automated swing grinding machines can be isolated in an enclosing
   hood. This method is suitable for production foundries.

Floorstand Grinders--
Limitations of conventional hoods--The conventional exhaust hood, in use on
most high speed grinding machines in foundries, does not effectively remove
fine dust particles from the air that is entrained around the wheel and is

discharged out the front of the grinding enclosure toward the worker. In addition to this deficiency are inefficiencies of the capture method, such as deflection of the grinding swarf from the tool rest or incomplete capture of the swarf by the lower chute section of the hood. When grinding sand castings, the amount of silica contained in the dust which escapes because of inherent defects of the capture method may be sufficient to cause exposure problems for the worker.

Analysis of data provided by one ferrous foundry demonstrated that the conventional hood combined with individual fresh air supplies to workers, can control dust exposures under certain conditions during production grinding of castings. However, it is unknown which limiting conditions, e.g., production rate, degree of burn-on, etc., permit that control to be effective in this or any other foundry. The problem is often compounded because this operation is performed side-by-side with manual abrasive operations using portable tools, another process for which complete control has not been achieved.

Modifications to the conventional grinding hood have been attempted to improve its dust capture efficiency. No foundry was found which utilized modified hoods nor were data available on the degree of additional protection which these modifications could provide in actual foundry cleaning room situations.

In his discussion of control of inertials versus fine dust, Hemeon identifies a major drawback to complete dust capture using conventional grinder hoods (21). His illustrations are reproduced in Figure IV-2. As can be seen in the top sketch, an illustration of direct capture, the grinding swarf is emitted tangentially from the wheel, with the inertial particles drawing the fine particles along in the induced airstream. If a receiving hood were located directly under the wheel, it would capture the majority of both fines and inertials together. The wheel entrainment effect, however, may draw a small amount of the fines out of the swarf and re-circulate them around the wheel. The conventional hood, represented in the lower sketch, receives both inertial particles and fine dust particles within the shroud. The entire dusty airstream is in close contact with the wheel until it reaches the exhaust port where a portion of the air is exhausted. The remainder of the dusty air is swept past by the entrainment effect and continues around the wheel to be discharged toward the worker.

Hemeon's analysis does not take into account the presence of the tool rest, which is very disruptive to effective dust capture by the conventional hood. The principal purposes of the tool rest are to provide support for the casting and to prevent the casting from being "pinched" between the wheel and the hood, causing possible wheel breakage and/or physical harm to the operator from crushed or severed fingers and exploding wheels. Unfortunately, the tool rest can deflect the inertial swarf stream, thus dispersing the fines away from the hood. The higher the grinding takes place above the tool rest, and the closer to the wheel the tool rest is adjusted, the greater the defection of swarf. In addition, the tool rest

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WORKPIECE

DIRECT CAPTURE
OF INERTIALS
AND FINE DUST
TOGETHER

WORKPIECE

CONVENTIONAL
CAPTURE
TECHNIQUE
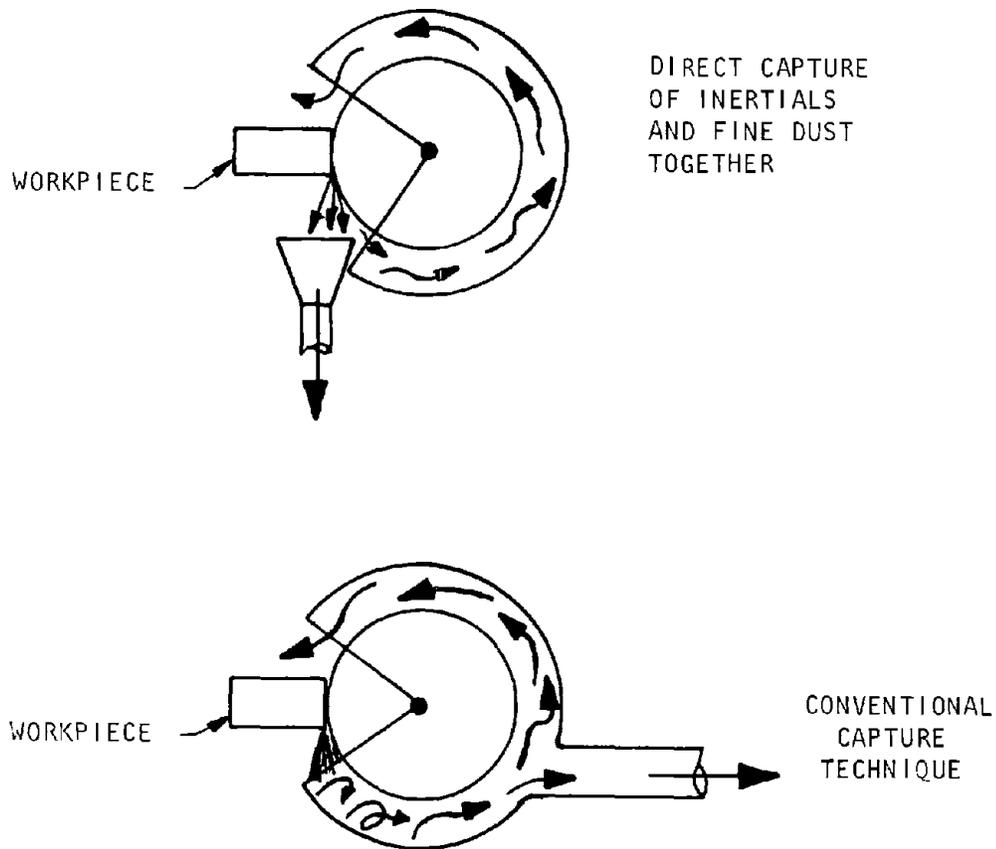
Figure IV-2. Hemeon's illustrations of control of materials and fine dust
(21).

acts as a barrier preventing the hood suction from effectively capturing
the entrained dust as it recirculates around the wheel.

Hood Modifications--Innes, in his attempts to improve the conventional
hood, made two modifications (Figure IV-3) which are described below:

1. An adjustable baffle plate was installed close to the conventional
    exhaust point in an attempt to strip the dusty air from the
    surface of the wheel.

2. The area below the tool rest was enclosed and the bottom chute
    was redesigned to provide a smoother path for the swarf to take
    as it proceeded toward the exhaust duct.

Time exposure photographs showed that swarf capture was much more complete
with the new hood than with the conventional hood. Innes also took air
samples in a location which simulated the breathing zone of the worker.
Data obtained at varying metal removal rates demonstrated the relationship
by which breathing zone exposure increases with increased metal removal
rates. Unfortunately, these experiments with the conventional hood

GUIDES AND VANES

HOPPER EXHAUST

MODIFIED CHUTE
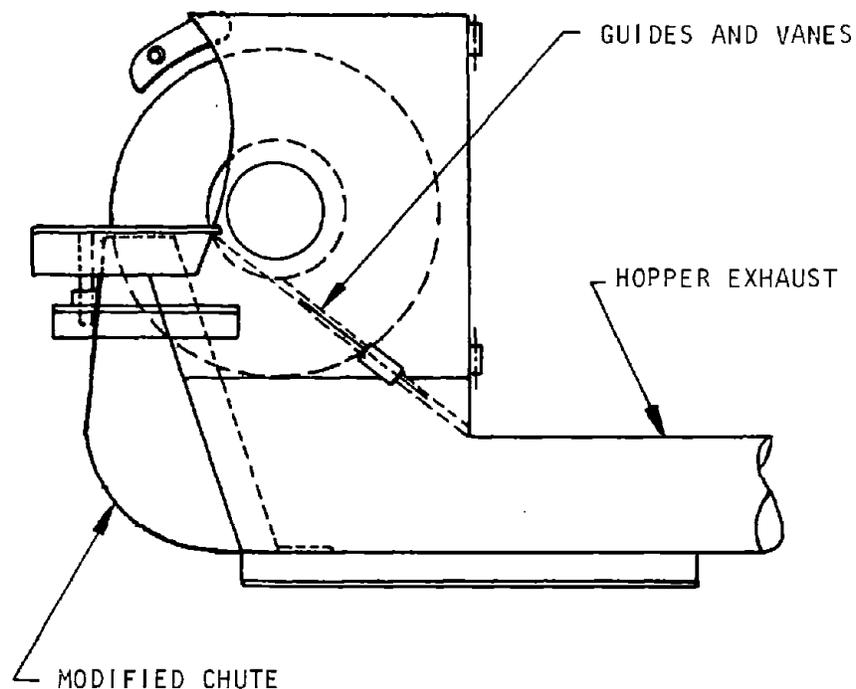
Figure IV-3. New hood design of Innes (22).

were carried out during grinding at a metal removal rate range of 8-16 lb/hr (3.6-7.2 kg/hr), while the new hood was tested through a metal removal rate range of 0-6 lb/hr (0-2.7 kg/hr). Thus, it is difficult to predict the actual improvements in dust capture efficiency the new hood provided over and above the conventional hood.

Another modification to the conventional hood by the British Cast Iron Research Association (BCIRA) attempted to combine the conventional hood exhaust method with an auxiliary exhaust takeoff (FigureIV-4) located at the top front of the hood (35). Photographs of actual grinding on the machine with oil smoke injected into the hood as a tracer demonstrated the effectiveness of this method in recapturing the dusty air which had escaped the hood. The photographs showed how the airstream was stripped from the wheel by the workpiece and deflected outward against the worker's body. After the air slowed in velocity, it was drawn immediately into the auxiliary exhaust without passing through the breathing zone. The control was not dependent on the worker being present to serve as a barrier. If the worker moved back or to the side, the auxiliary ventilation still worked effectively. No data were provided, however, to define the level of breathing zone protection achieved.

Bastress has demonstrated that auxiliary exhausts, such as the BCIRA exhaust, have the potential to achieve higher efficiency of exposure control (31). His experiments consisted of installing a small vacuum cleaner nozzle close to the grinding point of a small, high speed grinder. The additional reduction in breathing zone dust concentration provided by the auxiliary hood ranged from 30-70% over that of the conventional exhaust.

TOP EXHAUST

HOPPER
EXHAUST
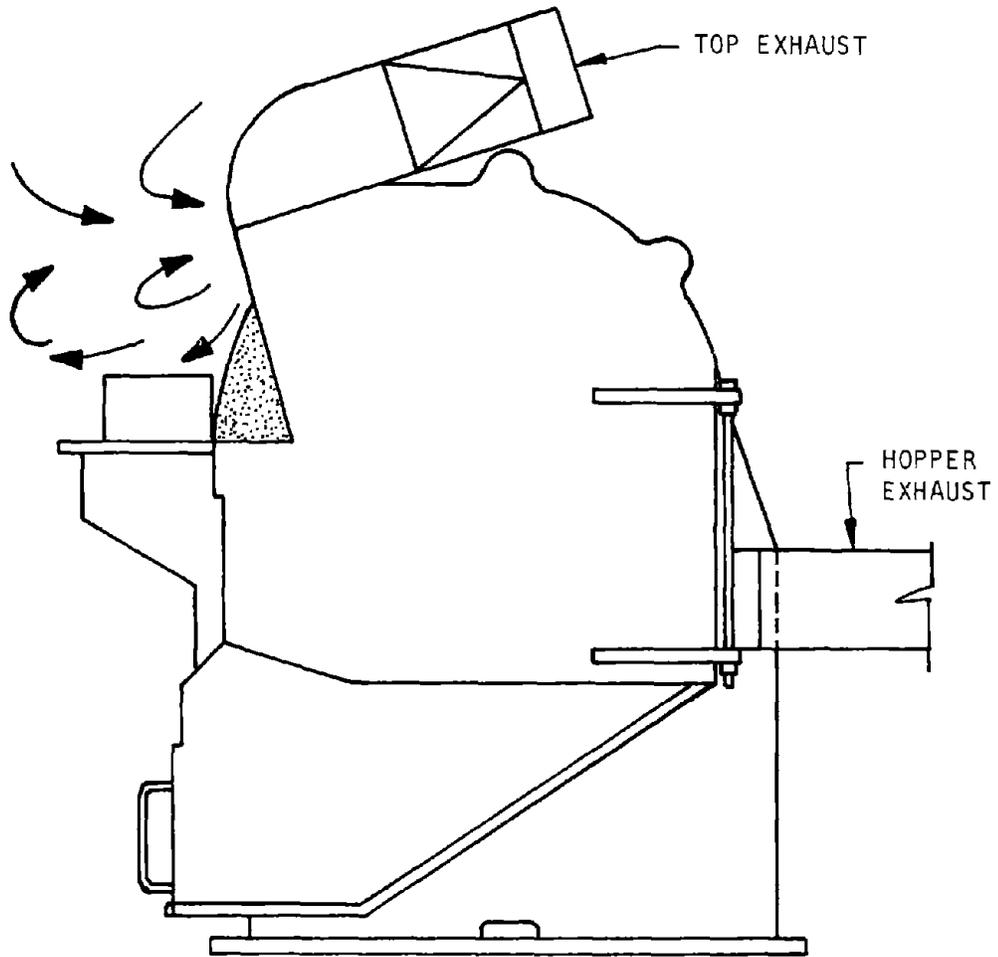
SYMBOL

→ AIR FLOW
PATTERNS

Figure IV-4.   BCIRA hood (35).

Chipping and Grinding Using Portable Tools--
In five foundries using combinations of ventilation at the source and
fresh air supply for processing of small to medium-sized castings, the
breathing zone concentrations of respirable silica were controlled below
the allowable limits for a majority of workers. Incomplete control was
caused by present limitations of the two ventilation techniques used, i.e.,
downdraft benches and high-velocity, low-volume hooded tools (HVLV), as
well as defects in effectively applying these methods. Limitations of the
methods themselves included:

Downdraft benches
1. Ineffectiveness at providing direct capture during processing of
   internal casting cavities.

2. Limited efficiency of capture during external finishing when the
   grinding swarf was directed away from the bench.

HVLV
1. Lack of a practical hooding technique for chipping tools.
2. Interferences of some grinding hoods in certain operations.
3. Sensitivity of capture to tool position.

Defects in application included:

Downdraft benches
1. Disruption of capture by exhausts from portable pneumatic tools.

2. Inability to capture dust blown out of castings with air nozzles.

3. Exhaust rates less than ACGIH minimum recommended flows in some
   cases.

HVLV
1. Use of unhooded abrasive grinding tools.
2. Inability to capture dust blown out of castings with air nozzles.
3. Sweeping the work area after processing of castings.

In many cases this process is performed side-by-side with other abrasive
cleaning processes such as high speed floorstand grinding which may also
be incompletely controlled.

Arc Air Gouging and Torch Cutting

Two types of ventilated booths studied showed that metal fume exposures
during arc-air cleaning of steel castings in exhausted booths can be
controlled but that an important part of the control appears to be
individual worker performance. Necessary aspects of that performance remain
to be investigated and evaluated.

The air jet used with the electrode had a substantial effect on the patterns
of fume dispersion and on the controllability of the emissions. The
airstream caused a rolling of fume within the booth which the exhaust air

was unable to overcome. Thus, direct capture of fume to prevent over-exposure required that the compressed airstream be directed as much as possible at the exhaust opening. The case history showed how a rotating turntable could facilitate movement of the casting into proper position to provide the proper direction.

The foundry field study and a study by Sanderson in a shipyard provide an evaluation of the fume and gaseous contaminant hazard of the arc-air process (24). A summary of exposure results from both studies is presented in Table IV-I.

Table IV-I. Air sampling results - arc-air process.

Test condition	Mean conc. of toxic substances in the breathing zone					
	Metals, mg/m^3				Gases, ppm	
	Cu	Fe2O3	Pb	Mn	CO	O3
Semi-enclosed space # (shipbuilding)	4.0	31.5	0.23	3.3	100	0.6
On bench under canopy hood # (shipbuilding)	0.81	15.2	0.06	0.66	35	-
Open air # (shipbuilding)	0.74	5.1	0.09	0.19	14	BDL§
Ventilated booth (casting repair)	0.04	5.44 *	<0.02§	0.14	-	-
OSHA PEL	0.10†	10.0	0.2	5.0	50	0.10
ACGIH TLV (1977)	0.20†	5.0	0.15	5.9	50	0.10

§ Below detectable limits.
* This is value for iron, iron oxide is probably 29-44% greater in weight.
† Copper fume.
# Data from Reference 24 values are averaged from data presented for various electrode sizes.

Important findings are listed below:

1. Copper fume from melting of electrode coatings was a severe hazard in all the shipyard situations, particularly when the operation was performed in a semi-enclosed space. In the ventilated foundry booth, copper was controlled at about half the TLV.

2. Iron oxide was always present in substantial quantities in both

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controlled and uncontrolled situations. The lowest iron oxide value was measured during shipyard processing outdoors.

3. Other than iron oxide, copper fume, and total dust, no other air contaminant hazards were found during ventilated arc-air work. In the enclosed space, however, other air contaminants, namely lead, carbon monoxide, and ozone, reached hazardous levels.

A careful study of the arc-air process and torch cutting with air lances reveals a possible reason why iron fume exposures were not significantly different during open air processing than they were during processing in a booth ventilated with a high air turnover. The key seems to be the effect of the compressed airflow on fume dispersion. The high velocity air jet creates violent turbulence at the point of fume generation. Hot metal and fume are literally blown away by the air jet. In an open air situation, the turbulence can carry the fume away from the worker. Inside a booth, however, when the airstream strikes a wall or ceiling it rolls off and around the booth. An excessively high ventilation rate would be required to overcome this rolling completely. A good way to prevent air rolling in a booth is to direct the compressed airstream as much as possible at the exhaust opening. Motorized turntables and other mechanized devices can be used to help provide the proper casting orientation. The other critical parameter is to always have the fume generation point between the operator and the exhaust opening.

Green Sand Systems

The Dry Sand Problem--
The predominant problem in green sand systems using silica sand is liberation of dust from dry sand. Sand begins to dry the minute moisture is added to it, because of its elevated temperature acquired by recycling during the casting process. Thus, the respirable silica exposure hazard exists to various degrees throughout the entire system, including molding areas, pouring floors, shakeouts, and return sand systems. Substantial amounts of local and general ventilation are required to abate this hazard. Effective housekeeping is of the utmost importance. Control of dust generated during filling and mixing of dry recycled sand with binders, additives, and water was demonstrated during the use of an enclosed muller. The manual bond addition process was also effectively controlled. Unloading and transfer of prepared sand did not require control because the sand was moist.

If sand moisture is properly maintained, molding does not usually pose a dust problem except in certain unique cases such as slinging. The dust exposure of a slinger operator can be controlled by isolating him to a remote control station. However, this leaves the other flask operators unprotected. If the slinging operation takes place at a fixed location some exhaust may be applied close to the flask filling station to cause an air turnover which reduces dust levels and protects the nearby flask operators. If the slinger is mobile, however, exhaust ventilation may not be practical and the flask operators may be unprotected from exposure.

Shakeout of sand castings is a dust-producing source that required ventila-

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tion at the source to prevent overexposure of the workers involved, and buildup of dust in the background air. This study demonstrated that the ACGIH recommended control techniques are effective at controlling respirable free silica dust from this source. Selection of an exhaust technique is dependent on the nature of the shakeout operation and the extent of worker involvement required. Generally, the more mechanized the process, the more complete the enclosure can be.

Exposure problems occur when shaking out castings from flasks much larger than the shakeout deck. This practice handicaps effective capture of dust by a conventional sidedraft hood and impedes the efficient flow of sand into the sand handling system. Sand spillage, in turn, contributes to silica exposure.

The Schumacher Process--
ACGIH control techniques were found to be effective at controlling respirable silica when all dry sand processing and transport operations were enclosed and exhausted. An alternative approach, the Schumacher Process, controlled the moisture content of the dry sand, thus effectively controlling dust exposure.

Nonsilica Aggregates--
Nonsilica molding aggregates reduce the potential exposure to respirable silica dust. Tubich has reported a five year study conducted on the use of olivine in nonferrous foundries (25). Olivine is also used in ferrous foundries especially those casting high manganese steels. The use of olivine in the study was limited to molding; cores consisted of silica sand. Although the level of airborne dust in foundries using olivine appeared no different than in other foundries, the percent by weight of free silica was found to be 80% less in foundries using olivine than in foundries using silica sand.

The study found that the pattern of contamination of the olivine sand by clays and silica cores was such that a steady state condition, i.e., a fixed level of silica sand in the system, did not occur until a year after the olivine mold sand was first installed in the sand system. The airborne free silica levels also rose during this period following the same pattern.

The above study was conducted in foundries with poor, as well as good ventilation control. It was concluded that exhaust ventilation at the major dust producing operations is still required when nonsilica molding aggregates are used.

At present there does not appear to be a practical method to separate the silica core material from the olivine mold sand during recycle, although substitution of nonsilica for silica cores is becoming more widespread and would appear to be a good method for deriving the highest amount of environmental benefit from the use of nonsilica molding aggregates. One problem is that the chronic inhalation toxicity of these substitutes is not completely known. None has been used as long as has quartz, nor

have so many people been exposed and therefore, presently unsuspected effects may possibly surface in the future following prolonged exposure of many people over many years. Preliminary indications, however, are that these materials will be less toxic than quartz.

Metal Casting

Charge Bucket Filling--
The control of air contaminants at the source during charge bucket filling was incomplete in the foundries studied. Incomplete control at the source did not result in worker exposure problems, however, because the operations studied were automated and operators were isolated in control booths. Because of the strong draft of air directed toward the melting area in most foundries, charge bucket filling dust was generally drawn into the melting area where it contributed to the exposure of melters.

Cupola Melting of Gray Iron--
Unlike tilting electric furnaces, exhaust throughout the charging, melting and tapping cycles of a cupola can be accomplished without the use of mobile duct systems. A case history showed such an effective exhaust control system. Two separate exhaust hoods are necessary - an exhaust from the top or near the top of the vertical combustion chamber and a canopy over the tapping spout. Emissions from the top of the cupola are quite variable in temperature and air contaminant loading and the exhaust system must be designed to provide sufficient indraft at the charge door to prevent escape of emissions under widely varying conditions. Hood inefficiency or puffing can occur, especially during charging when the falling charge causes turbulence in the blast region below. Puffing can also occur if the cupola is not being charged at the proper rate. Puffing will usually not result in an exposure problem unless there are operators located at the charge door level or if the top of the cupola is indoors and the escaping emissions are being drawn downward into foundry areas by prevailing air currents.

In dual cupola arrangements (one cupola on line and an adjacent one down for repair) carbon monoxide concentrations can be rapidly fatal. This problem is further discussed by Tubich (36). Special precautions must be taken.

Both the charge door level and the tapping spout areas are hot places. If an operator is located on the charge door level, he is usually in a crane cab which can be enclosed and air conditioned. This study showed how alloy operators stationed at the forehearth can also be isolated in an enclosure that shields off the workers exposed to infrared radiation from the continuously flowing metal stream.

Charge Preheating and Induction Melting of Ferrous Alloys--
Control of preheater emissions using ventilation at the source has been shown to be effective. A bonus is the possibility of reclaiming heat in an air-to-air heat exchanger to temper makeup air.

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Control of emissions from an induction furnace can be accomplished with either a close-fitting furnace hood or by general ventilation. Close fitting hoods are appropriate where:

1. The scrap contains lead, zinc, oil, and other contaminants.

2. The exhaust gases must be collected and cleaned before being discharged outdoors.

General ventilation can be applied where:

1. The scrap is very clean and free from lead, zinc, and organic materials including oils.

2. The area above the furnaces may be isolated by baffles and exhausted.

3. There are no disruptions to the thermal draft above the furnaces such as crossdrafts through open doorways.

Close-fitting hoods are not completely effective at capturing emissions throughout the furnace cycle and thus, are generally used in conjunction with roof exhausters above the furnaces to provide general ventilation. Because of interferences caused by ladle hangers and crane cables, the portion of the close-fitting hood that shrouds the pouring spout cannot be extended far enough to be in a position to receive the fume in the thermal draft above the hot ladle during furnace tapping. In addition, when charge buckets are used for furnace charging they act as chimneys above the furnace which permit fume to escape the furnace hood.

Direct Arc Melting of Ferrous Alloys--
Many existing arc furnaces employ sidedraft hoods with duct systems that are only connected during the melting cycle. This study showed that protection of workers from exposure when using such systems required the use of roof ventilators above each furnace in conjunction with distributed fresh air and/or enclosed and ventilated control rooms to protect the furnace operators from exposure to metal fume.

Some available furnace hoods utilize mobile duct systems that provide exhaust during all furnace operations. However, even with the use of these, interferences occur from the ladle hanger or overhead crane during the tapping process, so that a sufficient amount of shrouding may not be available over the ladle to capture the fume carried in the thermal draft.

Use of auxiliary canopy hoods to capture emissions during charging and tapping is very difficult, because of the high bridge cranes used in melting shops and because of the crossdrafts which are present (33).

Melting of Nonferrous Alloys--
The major hazard of copper-base foundries alloying with substantial amounts of lead (6-8% or more) was found to be lead fume. Air sampling

data resulting from the field study showed that fume exposure to the metals varied inversely with the boiling points of the metals present. Thus, the workers breathed in descending order of magnitude: zinc, lead, copper, and nickel fume. Zinc oxide has a high allowable limit whereas the other three have low limits and, therefore, the indicator of good fume control would usually be lead.

Defects of close-fitting induction furnace hoods represent a common cause of fume exposure, especially during furnace tapping. Both the furnace operator at the controls and the pouring operator steadying the ladle under the furnace spout are subject to fume exposure. In many cases the furnace operator, located on a raised melting deck, receives the greater exposure. To provide adequate breathing zone protection during tapping, an overhead fan or mobile ladle hood was found to be required in addition to the furnace hood. Several types of close-fitting induction furnace hoods are available and in use on furnaces melting nonferrous alloys. The design that draws exhaust air into the furnace shell and across the hot metal requires flow modulation during the melting cycle to prevent chilling of the furnace spout and the molten metal.

Heat Stress on Furnace Operators--
Heat control for operators of many types of furnaces is facilitated because these operators are required to be stationed directly at the furnace for only about one quarter to one third of the total cycle. The remainder of the time the operator can be isolated in a booth. Heat exposure during operations at the furnace can be reduced through radient heat shields, aluminized clothing, and tinted glasses or face shields.

Hot Metal Transfer--
Ladle monorails--Mobile ladle transfer hoods are effective at capturing fume from alloys containing toxic metals, such as lead, provided no disruptive crossdrafts are present. Ladle covers can help to reduce oxidation and facilitate fume capture by these hoods.

Powered transport devices--Hot metal transfer operators, stationed in crane and monorail cabs, can be isolated in enclosures that effectively provide protection from air contaminants, especially during furnace tapping and pouring into ladles and holding furnaces. The protection provided by enclosed cabs using standard industrial air conditioners is dependent on the degree of sealing of the cab, since the filter on the air conditioner is not efficient enough to clean air for the cab. High efficiency filtering systems and mobile air supply systems are commercially available and can be used when the protection offered by an enclosed cab is not sufficient.

The heat problem is most severe during hot metal transfer using ladles which are manually pushed along a monorail, especially when the operator performs both the hot metal transfer and metal pouring operations. Ladle covers and side baffles on ladle hangers, as well as fresh, tempered air distributed along metal transfer routes, can help to reduce the heat load.

Ladle Slagging--
The slagging process, whether of furnaces or ladles, is one of the greatest sources of heat exposure in the foundry. Several effective means can be used to reduce exposure; the most important is isolation by shields. In the case of very large ladles, isolation by distance using long poles with rests or mechanization and remote process control may be effective and efficient. Where necessary, exhaust and supply air ventilation can be incorporated into the heat control measures. Tinted glasses to protect the eyes are a necessity during slagging. And, depending on the size and temperature of the ladle, the closeness of the operator, and the degree of shielding utilized, face shields and aluminized clothing may be necessary to protect the operator from exposure to infrared radiation and metal splashing.

Ductile Iron Treatment--
Studies of the plunging bell and sandwich ladle inoculation methods demonstrated that these processes can be effectively controlled through ventilation at the source. Sandwich inoculation in the ladle is the more difficult to exhaust because of the interferences present at the furnace.

Metal splashing and bright visible light are uncontrolled hazards during inoculation at the furnace. Tinted lenses and splash-proof clothing are generally necessary for furnace and ladle operators who must remain close to the process.

Pouring and Cooling--
Nature and composition of pouring and cooling emissions--A wide range of air contaminants is produced during thermal decomposition of mold and core materials after pouring. The types and quantities of these products are dependent on a number of variables such as pouring temperature, sand-to-metal ratio, chemical binder levels, and production rate. Scott et al., performed a study of emissions from 12 common molding systems which included clay binders, as well as hot and cold set chemical binders (49). They found that in every case, carbon monoxide was produced in sufficient amounts to be a health hazard. Most of the other contaminants of hygienic concern were present in much lower concentrations and there- fore, were considered to be only potential hazards. A notable exception was ammonia which, in certain hot box molding processes, was found to be a definite hazard. Based on these results they concluded that proper control of the carbon monoxide level through ventilation would dilute most of the other chemical contaminants to below threshold limit values. They also concluded that, because of the relatively high levels of carbon monoxide produced, this compound should be regularly monitored regardless of the sand binder used. Both fixed and portable monitoring devices are commercially available for this purpose.

Another report by this group defined the effects of casting weight and sand-to-metal ratio on the volume of effluent gas emitted from the cooling mold. The volume of effluent gas increased linearly with casting weight, and decreased exponentially with increasing sand-to-metal ratio (48). The casting is a heat source which uses its stored energy to raise and maintain the temperature of mold constituents for an extended

period during which continuous decomposition takes place.

Measurements were also made of the time-nature of emissions. It was found that the time of peak emissions occurred shortly after mold pouring (within 10 minutes for small green sand molds, Figure IV-5) (48). After this time the emission rate decreased gradually until shakeout when it suddenly rose again to a new peak. Other air contaminants followed the same general pattern as carbon monoxide.
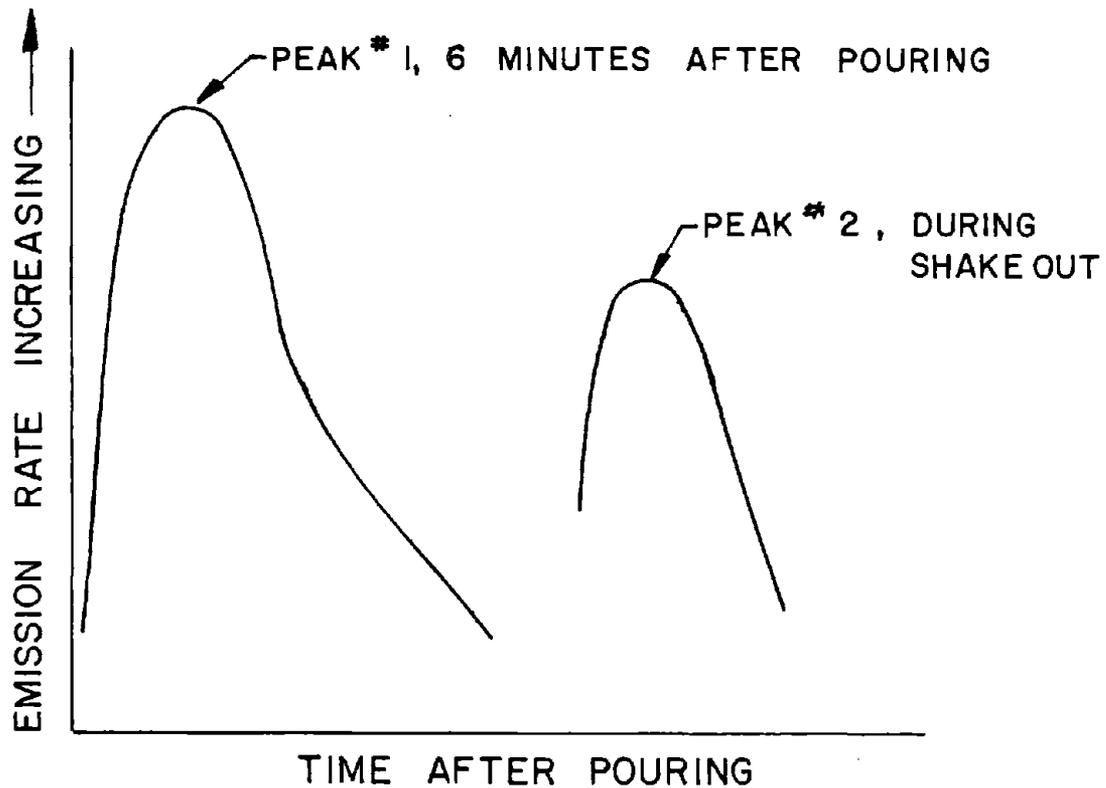
Figure IV-5. Emission rate of carbon monoxide during mold cooling and shakeout.

Mechanized mold pouring systems--The mold cars or monorails used on most new mold pouring systems facilitate the control of emissions. They are, by nature, mobile devices and no extra transport equipment is necessary to provide for separation of pouring and cooling areas. Mechanized pouring lines can be effectively ventilated by standard, commercially available sidedraft exhaust hoods. Cooling areas on automatic mold lines can be isolated in compact tunnels and rooms and auxiliary cooling can be applied in the ventilation design of these rooms. In many operations there is continuous exhaust control throughout pouring, cooling, and shakeout.

Flour pouring operations--Control of metal fume, at the source, during
floor pouring operations is rarely attempted in the case of iron, steel,
and aluminum casting, but it is generally required when pouring copper-
base alloys containing lead, and other toxic metals. Mobile exhaust hood
techniques, demonstrated in the field studies, are effective in capturing
pouring fume in floor pouring operations.

In production foundries, particularly in ferrous foundries, pouring floor
operators must be protected from products of mold decomposition. Floor
pouring is sometimes done with the mold on some sort of mobile device,
e.g., on a roller conveyor, or on tracks. Existing transport devices can
be modified to provide a mechanized means for transport of just-cast molds
out of the pouring area. However, if isolation of cooling molds is to
be successful, the just-cast molds must be moved as soon as possible,
since products of mold decomposition begin to be emitted as soon as the
first hot metal touches the mold, and build to high levels within only
a few minutes. Provision for moving the mold while the metal is in the
molten state must be carefully designed to prevent the possibility of
molten metal run out, a safety hazard.

Once molds are moved from the pouring area they can be isolated to a
separate cooling area, which does not have to be entered by workers,
provided that a mechanized means is available for transporting molds out
of the isolated area. In the case of molds on roller conveyors or
tracks, this is usually feasible.

A pallet line system is a difficult floor pouring line for which to provide
isolation of the cooling area. Most of the mechanisms used to tip molds
onto a conveyor dump-off, either manual or automatic, are operated from a
position immediately adjacent to the dump-off conveyor. Workers are
required to spend substantial periods of time on the cooling deck, where
they are continuously exposed to potentially high concentrations of mold
decomposition products.

General ventilation is often applied to open pouring floors. As a dilution
method, it is not effective at the high emission rates which result from
high production. Since foundries are producing more and becoming more
mechanized, general ventilation will have decreased application as a
primary control for pouring and cooling processes. However, the need
will always exist for general ventilation approaches where mechanization
is impractical, e.g., extra large casting operations and job shops pouring
small runs in a variety of sizes and casting techniques. In general,
only control at the source will be effective in the pouring of toxic
metals with low allowable limits, e.g., lead, nickel, copper. The need
to control mold decomposition products at the source during cooling will
depend on the organic materials present as well as variables such as
pouring temperature, mold material-to-metal ratio, cooling time, and
production rate.

Heat stress on pouring operators--The manual pouring operation is one of
the most severe chronic heat exposure hazards in foundries. In mechanized
systems, worker cooling can be provided along pouring lines by properly

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distributing fresh air supply to the metal pourers. It is very difficult on the other hand, to provide sufficient general ventilation of a large floor pouring area to cool the workers. Isolating the cooling area from the pouring area by means of mechanized conveyors substantially reduces the problem.

Molding and Coremaking Using Chemically Bonded Sand

Heat and gases from molding and coremaking using chemically bonded sand can be effectively controlled by a combination of ventilation at the molding or coremaking operation, a canopy hood over molded parts, and fresh air directed at the operator.

Residual gases--When thermosetting resins are cured with heat or when catalytic gases are used in the cold box process, the finished mold or core emits gases, especially just after the corebox is opened. A method which has minimal interference with production, and yet offers good protection during the handling and processing of finished molds and cores, is the ventilated set-off bench. Using this method, the mold or core is removed from the corebox and immediately placed on the set-off bench, where it is left to cool for one to two minutes under a hood. Several finished molds or cores will be on the set-off bench at any one time. The only change in the process is that the mold or core which is handled and processed during the period between corebox openings is not the one just released from the corebox, but rather one that has had one to two minutes of time in which residual gases are released.

Evacuation of the corebox--Exhaust from the phenolic urethane corebox alone does not provide control of gases escaping because of seal leakage. Auxiliary exhaust, adjacent to the corebox and perhaps also at the core conveyor, can provide continued protection for workers. A properly distributed air supply is also desirable to ensure sufficient dilution ventilation. Heat relief for coremakers working on hot curing operations is usually achieved by individual fresh air supplies directed at the workers and by flow of air induced by exhaust hoods.

Other

Furnace and Ladle Repair--
Although ventilation controls have reduced respirable dust emissions during removal of refractory linings, they have not been shown to be effective in protecting the breathing zones of repairmen. Three methods have been applied to reduce dust: a flexible exhaust duct placed inside the furnace or ladle being chipped out; a slotted hood adjacent to hoppers in which the debris from chipping is dumped; and air exhausts on portable chipping tools to prevent turbulence and dust dispersion. It appears that the above combination of controls should be sufficiently effective to control dust, but there have been negative results even in the case of small ladle repair. Although the chipping out time is short (a worker may only chip out a few ladles during the course of a day), the quartz and cristobalite content of the dust may be high enough to exceed the allowable limit.

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Ladle curing produces a carbon monoxide hazard which can be effectively controlled with exhausted enclosures. Heat from ladle curing can be effectively contained and exhausted. Heat recovery is both possible and practical.

Housekeeping--
Suitable equipment is available to provide effective housekeeping in foundries. During the field studies, powered sweepers were seen in use in almost all of the foundries, and vacuum cleaners were seen in use at several. Through the use of a manifold pipe system one foundry had provided a series of vacuum hose connection points for effectively cleaning at various levels in and around a sand system.

Housekeeping problems are minimized by any operational and maintenance steps that reduce leakage and spillage of sand and other materials. It is documented in the literature how pneumatic conveying of new mold materials from outdoor silos eliminated a housekeeping problem caused by bag breakage during fork lift transport in one foundry (32).

Out of the foundries studies those that had the most successful housekeeping programs were those with established responsibilities and timetables for housekeeping. Several successful programs, especially in foundries with three shift operations, required operators to clean up their work areas at the end of the shift. The one drawback to this practice is that the operators receive some additional dust exposure during housekeeping; this program would only be advisable in foundry areas where the dust exposures were controlled below allowable limits by a suitable safety factor.

NOISE CONTROL

Problem Areas

Effective engineering controls were sought but not found for the following processes which caused noise levels to be above the allowable limits for eight hours of exposure:

1. Manual gate, riser, and sprue removal, and casting sorting.
2. Grinding and abrasive cutoff.
3. Floorstand grinding.
4. Chipping and grinding using portable tools.
5. Arc-air gouging and cutting.
6. Torch cutoff (air assisted).
7. Charge bucket filling.
8. Furnaces melting nonferrous alloys.
9. Cupola melting of gray iron.
10. Furnace and ladle repair.

Although several partial solutions were pointed out, none were evaluated. For example, enclosures have been used which isolate process noise from other workers in the area, however, the process operator is not protected. Many such booths are used in the cleaning room.

Cleaning and Finishing of Ferrous Castings--
Nearly all of the foundries surveyed performed some type of chipping and/or
grinding operation; usually with floorstand and portable tools. Noise
levels generated during chipping and grinding were excessive.

Many foundries have attempted to reduce the noise, but with little or no
success. They have found that the noise is composed of two main parts:
tool noise and the noise generated by the action of the tool on the casting.
For most tools, the noise generated by the tool running free (tool noise)
is equal to or less than the noise generated by the action of the tool on
the casting. Therefore, no matter how much the tool noise is reduced,
a significant reduction in the overall level would not be expected. This
is because when a noise is subtracted from one equally loud the result is
only a 3 dB reduction in the level and a reduction that small is not usually
significant.

Some ways of controlling noise in ferrous cleaning and finishing areas were
air exhaust mufflers, enclosures, and sand boxes and wooden tables to damp
vibrations and reduce ringing. Mufflers only reduced tool noise. Enclosures
reduced noise levels in the vicinity but did not significantly reduce
operator exposure. Sand boxes and wooden tables helped reduce ringing of
the castings, but did not eliminate the problem. Even chipping on a
casting while it was submerged in a tank of water was tried. The noise
level was greatly reduced, but the process was messy and the worker could
not see the casting under water. Neither the sand box nor water was judged
to be practical.

Chipping and grinding do not appear to be completely controllable by
engineering methods at present. Research is being directed along several
lines in attempts to solve this problem. Ways are being sought to
remove the material with less noise and to cast metal in such a way that
there will be much less material to remove, although fin-free castings
might be impossible. Finally, if chipping or grinding could be automated,
the equipment and casting(s) could be confined to an enclosure, thereby
reducing noise in the operating environment.

Furnace Operations--
Noise levels generated by cupola melting of gray iron and melting of non-
ferrous alloys were generally above the allowable limits for 8 hours of
exposure, but the hazards were not severe. Neither partial nor complete
engineering controls were found to reduce the operator exposure to within
allowable limits.

Non-Problem Areas

Processes that did not generate excessive noise levels were:

    1. Sand preparation.
    2. Return sand transfer, processing, and storage.
    3. Hot metal transfer.
    4. Slagging of ladles.
    5. Ductile iron treatment.

6. Housekeeping.
7. Pouring and cooling.

In these areas, when excessive noise was found the cause was either malfunctioning equipment or one of the other processes known to be or found to be noisy.

Solutions

Enclosure--
When a barrier is established between a person and a noise source, that barrier can be regarded as either isolating the man or the equipment depending on its configuration. In either case, the efficiency of the barrier will depend both on its integrity and on its materials of construction. Only when the barrier has sufficient mass and few openings through which the noise may penetrate will it be successful.

Operator exposure to electric arc furnace noise was reduced from above to below the allowable limit, as a result of a control room that reduced the effective exposure about 16 dBA. The control room was constructed of standard factory/office components.

Noise levels generated by some types of shakeout can be reduced to within the allowable limit by engineering controls. A foundry reduced the noise level of one shakeout approximately 20 dBA with a total enclosure.

Noise levels generated by tumbling mills can be reduced to within the allowable limit by engineering controls. At two foundries, enclosures were used to reduce the noise by approximately 15 dBA. Although not investigated during the field studies, rubber lined tumbling mills are purported to be effective in reducing tumbling mill noises. Enclosures for noise control were found to be in general use for a wide variety of noise problems. The noise level reduction achieved was usually substantially less than desired or expected. In many cases, the ineffectiveness of the enclosure was due either to improper design or to an inability to construct a proper enclosure in the existing space.

The enclosures documented in this work were well engineered, and the noise reduction was substantial. Therefore, it is judged that properly engineered enclosures could be used to reduce the noise level of a large number of currently uncontrolled processes.

Equipment Substitution--
Some kinds of equipment appear to be noisy because no one has undertaken the task of designing equipment that makes less noise. Fortunately, as the emphasis on reducing noise hazards has increased, many equipment manufacturers have found that providing quiet equipment can be profitable Many kinds of quiet equipment can be used in foundries and, while the overall noise level may not be reduced drastically by this means alone, if quiet equipment were to be adopted as it becomes available, then the

remaining problems would decrease in number, be more identifiable, and be confined mainly to uncontrolled sources for which no solutions have been found.

The significance of the noise solutions that were found is that they have widespread applicability because the equipment is present in almost all foundries, and in each foundry may be found in many different places. For example, at one foundry, the noise levels in the coreroom were reduced to within the allowable limit by controlling the individual sources of noise such as air nozzles, air discharges from pneumatic equipment, and pattern vibrations. In each case the piece of equipment that made less noise was commercially available. The same kinds of quiet equipment along with a hopper vibrator and a quieter squeeze machine were used to reduce excessive molding machine noise about 8 dBA, to below the allowable limit in another foundry area.

Noise from recirculation fans was reduced about 15 dBA by changing from high-speed/low-pitch fan blades to slow speed/high-pitch blades. This solution can be readily applied to the many propeller-type roof and wall exhausters commonly used in foundries.

Partial Solutions--
Solutions to only 6 noisy processes were found. For this study, solutions were defined as some form of control that reduced the noise of an area and/or process to within the 90 dBA for an eight hour limit (OSHA criteria). Although partial or incomplete solutions were not examined, a significant number of them were observed which either significantly reduced the noise level or reduced the number of workers exposed to the levels; these were not documented. To better understand the scope of the noise problem and provide a strong base for further research, it is recommended that a project be initiated to investigate and document partial solutions to foundry noise problems. After a strong base is obtained, recommendations could be made for further work to identify and reduce the noise levels.

A few processes present noise problems so severe that solutions are not presently foreseen. Therefore, it is further recommended that a separate project be initiated to identify and further study the source(s) of grinding, chipping, and arc-air noise.

IONIZING RADIATION CONTROL

Some foundries are equipped with sealed radioisotope sources of gamma radiation and/or with X-ray machines. Very few foundries work with "loose" (unsealed) radioactive isotopes of any nature and therefore, hazard control methods are essentially restricted to those applicable to sealed sources and machines.

Some licensing agencies distinguish between isotopic and machine sources for jurisdiction purposes, but the hazards and control methods are similar as are the people in charge at the foundry, so there is little or no differentiation at the working level. In all cases, a governmental (federal

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or state) body promulgates rules, issues licenses, inspects and/or certifies equipment, and otherwise regulates the use of ionizing radiation.

Comparison of Radioisotopes and X-ray Machines

Ionizing radiation is used in foundries almost exclusively to radiograph castings, producing an image of the casting and of many kinds of flaws on photographic film. For this purpose, the gamma-emitting isotopes cobalt-60, cesium-137, and iridium-192 are the ones normally found, although other isotopes may be used for special purposes. A secondary use of radioisotopes is for level control or other gauging. In all cases, the radioactive element is sealed inside a container that is periodically checked by wipe-testing for evidence of leakage. X-ray machines are also used to radiograph castings, especially when such castings are physically small, have relatively thin cross-sections and/or are of a low density metal such as aluminum. Machines have the advantage of emitting no radiation when turned off or not connected to a voltage source, making transportation and set-up relatively easy. They emit radiation that is highly directional and less penetrating than that of the radioisotopes used, usually they have smaller equivalent source strengths, and usually are less rigorously regulated than isotopes. Machines, thus, tend to be used whenever practical but nevertheless, radioisotopes dominate in foundries.

Radioisotope sources have many advantages when compared with X-ray machines. They are close to being "point" sources and therefore easily produce good photographic images. Their radiation is emitted throughout a spherical volume (this may be a disadvantage on occasion), is more penetrating than X-rays, and thus can produce radiographs of thicker and larger castings, or of many castings at once. Large amounts of ionizing radiation are easy to obtain from radioisotope sources but difficult and expensive from machine sources; isotopic sources thus can produce radiographs with much less exposure time than required for machines. In many cases, radioisotope sources are used to produce photographic images easily that would be completely impossible for any X-ray machine commercially available.

Licensing

Provisions embodied in Title 10, Parts 20 and 30 of the Code of Federal Regulations regarding protection against and licensing of radioisotopes control use of these materials unless states adopt even stricter regulations. Although 10CFR20 and 10CFR30 refer only to artifically produced ("by-product") isotopes, many states have adopted these regulations in a form that covers all radioactive material from whatever source and that also regulates machines that produce ionizing radiation. In order to receive a license to posses and use radioisotopes, an individual (or company) must show that:

1. The applicant's equipment and facilities are adequate to protect health and minimize danger to life or property.

2. The application is for an authorized purpose.

3. The applicant is qualified by training and experience to use the material in such a manner as to protect health and minimize danger to life and property.

4. The applicant satisfies any special requirements.

In practice, an applicant must describe the radiation detection instruments in use and tell when and by whom they are routinely calibrated. Wipe testing procedures must be described in detail, including who is to obtain the samples and how they are to be analyzed. The facilities must be described, including remote handling equipment, storage containers, shielding, etc., and methods for controlling, handling, servicing, using, and storing the sealed radioisotopes. Personal monitoring devices must be on hand and in use, such as dosimeters, film badges, and/or thermoluminescent devices. The background and experience of people who will handle the materials must be described in detail and their continuing training and education, as well as medical surveillance must be provided for.

In all cases, a single person is designated as responsible for carrying out provisions of the license. This person and an alternate who can be contacted in case of an emergency usually have responsible positions within the foundry organization and must be intimately aware of all details concerning how the radioactive materials are handled and used.

Operating instructions, including those for personal monitoring, radiation surveys, warning signs, instruction of personnel, source security, and emergency procedures in addition to standard operating instructions are written in detail. The instructions will include step-by-step procedures for obtaining radiographs, for transfer of sources from shipping containers to storage containers or "cameras" (exposure devices), and for the reverse operations. Any differences between "field" and "central facility" operation will be spelled out in detail.

Radiography

Foundries casting easily-transportable parts usually do most radiography at a central facility. This is normally an isolated building or a portion of a larger building that can be and is isolated (shielded) from other operations. Radioactive sources are stored in massive containers, and are usually removed completely by a remote handling device of some kind for the actual exposure. Prior to the exposure, castings to be examined are positioned properly and X-ray film taped to a side opposite the source location. Castings, source(s), and container(s) are in a room shielded from inhabited areas with concrete block or other construction material; viewing is by mirror or rarely, periscope or television from a shielded location. The exposure duration may range from a few minutes to many hours, depending on the source type and strength, as well as on parameters relating to the casting and its distance from the source.

In cases where the casting is too large to be transported easily to the central facility, "field" radiography will be used. For this, the source in its shipping container or "camera" is taken to the casting. Here,

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distance and time are used to limit exposure rather than shielding as in the central facility. The source is again handled remotely (some very ingenious devices are used) or the "camera" is used to provide a directional beam upon activation of a "shutter". When the source is exposed, the area is guarded; signs and barriers are used as well to warn of distance limits corresponding to negligible exposure as measured by monitoring instruments. Often field radiography is done when people other than the operator(s) are not likely to be in the vicinity--on weekends, for instance, or empty shifts.

X-ray machines may be portable or confined to a central facility. In use, the precautions taken with them are similar to those used with radioisotopes, taking into account differences in source strength, penetrating ability and directivity of the radiation.

Education

A most necessary component of hazard control in the handling of ionizing radiation sources is education. Control is achieved mainly by engineering and procedure; monitors and other detection devices are used mainly to make sure that proper procedures have been followed and/or to assure that engineering controls (mainly shielding or one sort or another) are intact. Both formal and "on the job" training are used to cover all aspects of radiation from physics and health physics to calculations pertaining to radiation and radiography to actual use and handling of radioisotopes. The training is intensive and normally the trainee is required to pass one or more tests before having free access to and use of isotope or machine sources.

Part of the education program is concerned with the necessity for complete records of source use, radiation monitoring, dosimeter readings, etc. Records are required to be available to qualified inspectors who, however, rarely are seen (in most cases). The records provide a continually updated history from which any person's exposures can be determined and compared with accepted standards and, in addition may give clues to the timing and seriousness of a breakdown of engineering or procedural controls.

NEW AND IMPROVED TECHNIQUES

Electrostatic Fog

The electrostatic fog method to reduce airborne respirable dust levels takes advantage of the fact that many dusts acquire an electrostatic charge during their production in industrial environments. Hoenig, et al., measured the charge on a variety of dusts produced by grinding and found most, including quartz dust, to be negatively charged in the respirable range of particle sizes (26). Experiments were undertaken using positively charged fog to wet and agglomerate the dust, promoting settling or, if inhaled, removal of the dust in the nose or trachea rather than in the lungs. These experiments demonstrated that levels of respirable dust could be substantially reduced by the fog method. It was concluded that this method could be

used to augment foundry ventilation systems, or even possibly replace the need for ventilation in certain instances. As a result of this research and development work the method has now become commercially available, affording foundrymen a chance to try it under a variety of circumstances.

During the process of research and development, the fogging method was used in a swing grinding operation. In performing these tests the fog was aimed at the grinding swarf as it was emitted from the wheel. Measurements of dust concentration were made in the path of the swarf further downstream. Charged fog reduced the respirable dust level 39% at less than one micron, 47% at 1.6 microns, and 20% at 2.2 microns. However, the reduction of the respirable silica content of the dust, which is the item of hygienic concern in most finishing operations (except for toxic metals), was not determined.

The fog method uses very little water so that neither over-humidification nor excessive water usuage should be problems. A commercially available unit employs 0.5 gal./hr (0.03 l/min). The major operating cost is the need for 15 cfm (0.007 m^3/sec) of compressed air for each fogger. One of the unknowns concerning the use of fog in foundries is the effective range of the fog before evaporation occurs. This will significantly affect the number of foggers required and, as a result, the economic feasibility of the method.

As the fog is generated and emitted from the fogging head, the velocity of the air jet produced causes an air induction effect to occur. For example, airflow of 8 cfm (0.003 m^3/sec) from the fogger enlarges to a flow of 400 cfm (0.18 m^3/sec) at a distance of 1.5 ft (0.4 m) in front of the fogger. Induction of air with the resulting mixing which occurs should enhance the ability of the fine water droplets to contact the dust particles. This induction effect should prove especially applicable for use in abrasive cleaning operations. The free silica content in background air is a contributing factor to overexposure of workers to respirable dust. Thus, it would appear that the fogger, in the process of attempting to control dust at the source, would also clean background air in the process. This feature may enhance its desirability for use in combination with devices such as the downdraft bench and HVLV.

Crane Interferences with Ductwork

The use of overhead bridge cranes in foundries complicates the use of local exhaust hoods in the areas served by these cranes. The vertical pathways above hoods for running ductwork to the roof are effectively cut off by the crane. The alternative is to run lengthy horizontal ductwork out of the area at a height below crane level, or to run underground ductwork. Neither of these two options may be practical in many cases.

A third alternative, which may be both feasible and practical is achieved by use of the "push-pull" principle (17) to permit vertical exhaust straight out the top of the hood. An example of this approach used to exhaust a mold cooling tunnel is presented in Figure IV-6. A gap in the ductwork permits clearance space for the crane. A fan in each lower duct

OVERHEAD CRANE TRACK

POURING AREA

COOLING TUNNEL

CUPOLA

CRANE

OVERHEAD CRANE TRACK

OSCILLATING SHAKE-OUT

TOP VIEW

CRANE TRACK

ADJUST SPACE FOR CRANE HEIGHT

COOLING TUNNEL
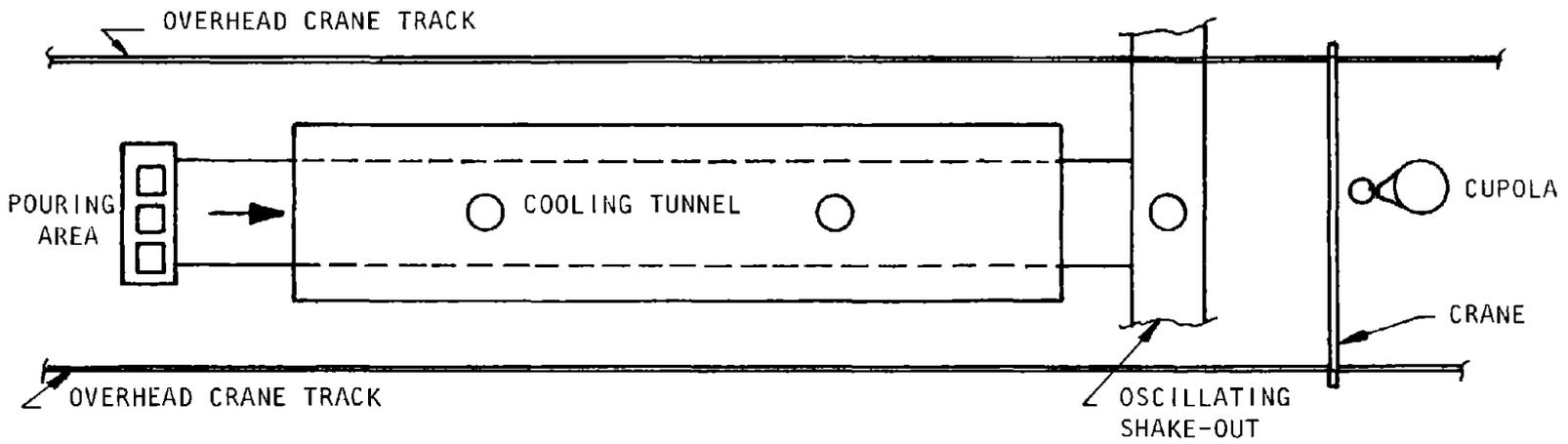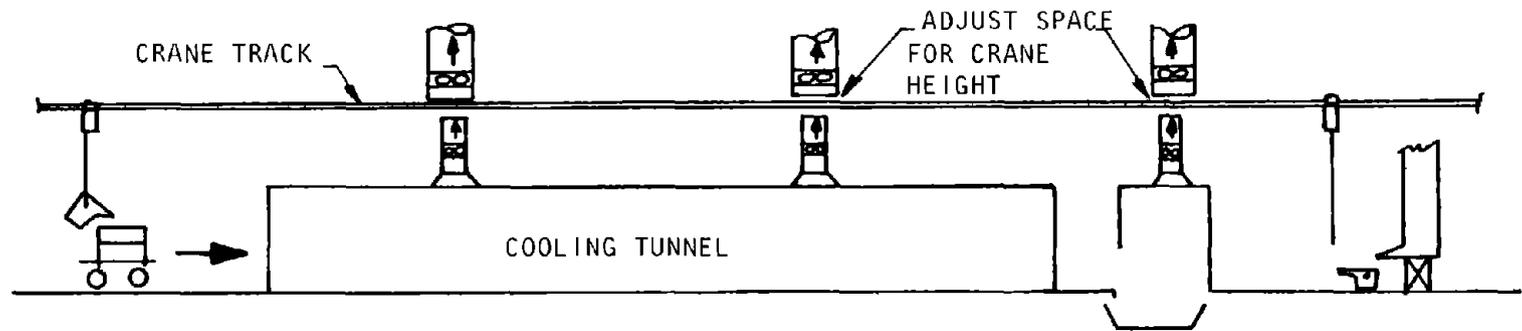
SIDE VIEW

SYMBOLS

= EXHAUST FANS

Figure IV-6. Push-pull ventilation to eliminate crane interferences with ductwork.

section blows air into a receiving duct with its own blower, above the crane. The flow rate of the upper fan is greater than the lower by an amount sufficient to prevent loss of the contaminated air. If the clearance space is reasonably short, the additional air necessary to assure complete capture need not be substantial.

Chemically Bonding Systems

There has been a tremendous increase in the use of chemicals to bond molds and cores which resulted in the need for reclamation of sands from these systems. Accordingly, the manufacturers increased the speed of ribbon flow or continuous mixers and developed new reclamation systems.

When chemically bonded sands are reclaimed, a certain amount of the resin is retained on the sand, resulting in lower additions of new resin required. As a result, the prepared sand is drier and with the increase in mixer speeds there is the potential for increased dust exposures. Typical local exhaust hoods which may be used to control dust emissions are shown in Figure IV-7. These hoods may also control gaseous emissions that may be liberated from the processes. The efficiency of dust exposure control, however, will be limited using these methods where the worker is required to bend over a deep flash to install rods in the mold after certain portions of the flask are filled.

During the past several years some of the chemical binder manufacturers have been investigating the use of inorganic binders to reduce the potential health hazards. Sodium silicate is now the most common inorganic binder in use, however, phosphate-base binders are also now being tried in the industry.

Shot Blast

At one time water or compressed air was used as the propellant for the abrasive, however, there are virtually none of these units in existence today. Several European manufacturers are trying to promote a new approach referred to as the "electrohydraulic" method of cleaning castings. The castings are immersed in a water filled tank and a high voltage discharge is applied between the casting and a submerged electrode; a shock wave is produced which breaks up cores and molding sand, leaving clean castings. No exhaust ventilation is required for the cleaning operation and the casting surface is said to be free of adhering dust. The potential of a water pollution problem exists with this method, however.

A major manufacturer has undertaken a study of all phases of the present cleaning process. It is anticipated that this study will develop improved procedures for producing cleaner castings.

Welding

Modifications to the plasma - MIG automatic arc-welding process have resulted in significant reductions in the levels of ozone, metal fume, and ultra-violet radiation. Basically, this modified welding process makes possible

FLEXIBLE DUCTS

FLEXIBLE DUCT

TELESCOPING DUCT.
ADJUSTS TO FLASK
HEIGHT

FLASK

FLASK

50
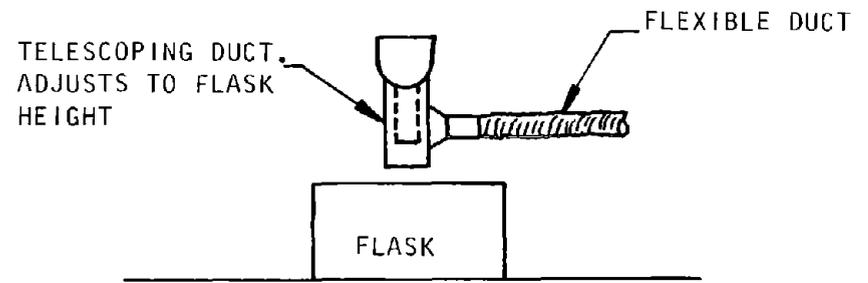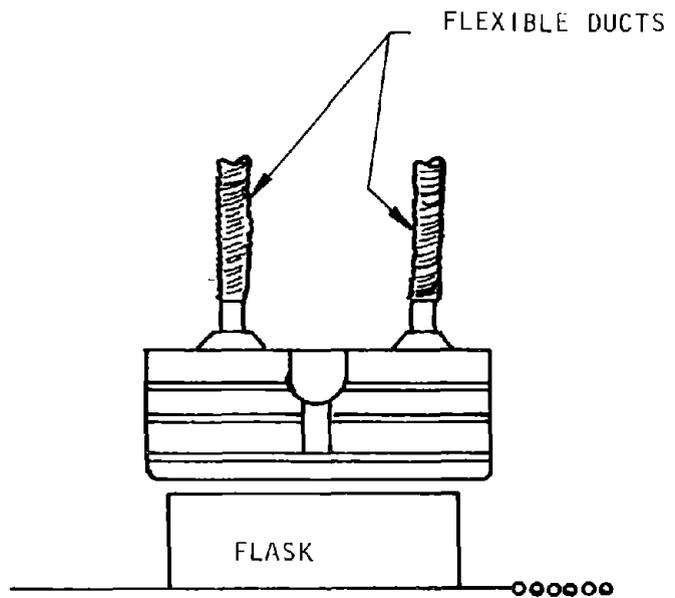
Figure IV-7. Two examples of local exhaust methods for ribbon flow mixers.

better control of mass and heat transport. The welding wire is heated and protected by a sheath of hot, thermally ionized gas.

SECTION V
FOUNDRY HAZARDS

In this section the chemical and physical hazards most commonly encountered
in foundries are described. At the end of the section a summary is presented
of the allowable limits for exposure to these hazards.

AIR CONTAMINANTS

Air contaminants that present a potential health hazard to workers within a
foundry can be classed as either particulate or gaseous. Particulate con-
taminants include various types of dusts and fume. Dust is an aerosol
composed of solid inanimate particles formed during the handling, crushing
and grinding of materials. Fume is an aerosol of solid particles formed
by condensation, often accompanied by some oxidation. Dusts usually have
a size range of 1 to 100 μm and fume 0.001 μm to 1 μm. "Gas" and "vapor"
are used interchangeably when referring to any material in the gaseous
state whether or not it is condensible at room temperature (1).

The contaminants addressed in this section do not represent all contaminants
that could be found in foundries. Rather, they represent those contaminants
that current literature indicates to be of high hazard potential, and the
contaminants that were evaluated during the field sampling phase of this
study.

Particulate contaminants are discussed first followed by gaseous contaminants.
These discussions cover inhalation hazards and some of the major foundry
sources of each contaminant.

Tables V-1 and V-2 at the conclusion of this section give the present, as
well as recommended, hygienic standards for air contaminants and noise.

Particulate Contaminants

Silica (Free Crystalline Silica, Silicon Dioxide)--
Inhalation hazard--The disease associated with chronic (long term) pulmonary
exposure to free crystalline silica is termed silicosis. Silicosis is one
form of pneumoconiosis (a word that means "dust in lungs") and is
characterized by the formation of nodules of scar tissue (fibrosis) through-
out the lungs. Scar tissue results when lacerations or other disruptions
of tissue heal but silica does not lacerate or disrupt lung tissue and
why fibrotic nodules should form around particles of silica is still
somewhat of a mystery. Even people who are not occupationally exposed to
free crystalline silica usually can be found to have some of these nodules
in their lungs probably as a result of inhaling normal ambient air dust (2).
Until the nodules become very numerous and quite large they have little
effect except, perhaps, they may be visible in an X-ray of the chest. Scar

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tissue in the lungs is too thick and heavy to allow transfer of gases to and from the blood and if enough accumulates to noticeably block gas transfer, the first symptoms of silicosis appear.

The disease silicosis can cause difficult or labored breathing (dyspnea) especially on exertion, difficulty in emptying the lungs characteristic of pulmonary emphysema, decreased physical work capacity, and sometimes an enlarged chest (3). Intensity of these signs and symptoms depend on the severity of the disease and that, in turn depends on the duration of exposure and the concentrations of free crystalline silica that reached the lungs during the exposures. When dusty air is breathed, only the very smallest particles get into the lungs; those above an aerodynamic diameter (characterized by settling velocity in still air) of about 10 μm are filtered out by the nose and throat to be coughed up and swallowed (or spit out) or appear in the handkerchief when the nose is blown.

Silicosis uncomplicated by other diseases is rarely fatal even though the severely affected person may be unable to live a normal life. Silicosis makes the lungs more susceptible to attack by other diseases, however, and silicotuberculosis can be an extremely severe complication (3, 4).

Another complication of silicosis (with or without any other disease) is the possibility of right heart failure or cor pulmonale. Blood is pumped from the right ventricle of the heart to the lungs to be oxygenated and to release accumulated carbon dioxide. When there is interference with gas transfer within the lungs from silicosis or emphysema, for instance, the heart must work harder to push more blood through more restricted passages (the nodules press against blood vessels) to achieve adequate oxygenation. But, the right side of the heart is not designed for this kind of work and consequently may become overly large and/or may fail to do the job adequately.

Silicon dioxide can exist in either crystalline or amorphous (noncrystalline) forms. The most common amorphous form is glass; others include diatomaceous (or fuller's) earth and opal. Amorphous silica does not cause silicosis. Many minerals including such common ones as talc, mica, zircon, and topaz contain silicon dioxide in a chemically combined form that also is not capable of causing silicosis. Free (not chemically combined) crystalline (not amorphous) silica exists in three main forms; quartz, tridymite, and cristobalite. Beach sand and the sand used in most foundries is largely quartz.

Even though "free crystalline silica" is the phrase that most closely describes the material most often found in foundries and "quartz" is perhaps next best, the word silica (which to the chemist means silicon dioxide in any form) is heard most often. In this report, "silica" is used as it is in foundries to mean mainly quartz except where another variety of free crystalline silica is specified.

Different forms of crystalline silica produce varying response intensities; tridymite and cristobalite are more conducive to the production of fibrous nodules within the lung than is quartz by a factor of about two.

Exposure sources--In foundries using silica sand for mold and coremaking, crystalline silica (quartz) becomes virtually ubiquitous. Siliceous dust can be found in significant concentrations in many areas of the foundry. Areas of particular interest are: casting cleaning, shakeout, coremaking, sand mulling, dry sand transport, and ladle and furnace repair. Dust concentrations within any of the above areas are influenced by foundry type, production capacity, and housekeeping practices.

Cristobalite and tridymite may appear in foundry dust in addition to quartz. Both crystalline structures result from the high temperature transformation of quartz (5). Cristobalite and very rarely tridymite are found in ferrous foundries, particularly steel foundries where the metal temperature is high. Cristobalite and tridymite may present significant hazards during cupola relining and ladle and furnace knockout and repair.

Metal Dust and Fume Health Hazards--
Lead--The body organs and systems affected by excessive lead absorption vary depending on the individual, the route of absorption, and the duration of exposure. In most people, the most obvious sign of acute overabsorption by any route (usually by ingestion) is abdominal colic; this is now rarely an industrial problem. Because absorption of lead from the lung is at least an order of magnitude more efficient than absorption from the GI tract, inhalation is usually the most important (but not the only) route of occupational exposure. Both the peripheral nervous system and the blood-forming system may be injured from acute overexposure; chronic overexposure is likely to also result in damage to the kidneys and to the central nervous system (6).

Zinc--Zinc is low in toxicity. Ordinarily it is too poorly absorbed to produce systemic intoxication (6). However, when zinc is heated to a sufficient temperature, it produces a fume consisting mainly of zinc oxide, which can cause metal fume fever. The symptoms of metal fume fever begin four to twelve hours after the overexposure and are typical of "24 hour flu". A bout with metal fume fever confers a temporary immunity to the disease that may be lost in the absence of zinc oxide exposure over a weekend or holiday.

Copper--Metallic copper may cause keratinization of the hands and soles of the feet, but is not commonly associated with industrial dermatitis. Systemically, copper dust and fume cause irritation of the upper respiratory tract, metallic taste in the mouth, nausea, metal fume fever, and in some instances, discoloration of the skin and hair.

Chromium--In some workers, chromium compounds act as allergens to cause dermatitis. They may also produce pulmonary sensitization (7). Chromic acid and chromates have a direct corrosive effect on the skin and the mucous membranes of the upper respiratory tract. Although rare, the possibility of skin and pulmonary sensitization should be considered. Water insoluble chromates have been shown to be the cause of lung cancer in some workers (52).

Iron--The inhalation of iron oxide fume or dust may cause siderosis, a benign pneumoconiosis that is not disabling, but makes x-ray diagnosis of other lung conditions difficult or impossible. Metal fume fever is also possible but unlikely under most circumstances.

Magnesium--The inhalation of freshly sublimed magnesium oxide may cause metal fume fever, similar to that caused by zinc and copper fumes. The metal and its oxide are otherwise low in toxicity. The most serious hazard potential presented by magnesium is the danger of fire.

Manganese--Chronic manganese poisoning is a clearly characterized disease that results from the inhalation of manganese fume or dust. Some individuals may be hypersusceptible to manganese (53). The condition may occur in workers after overexposure for as little as three months, but usually cases develop after one to three years. The central nervous system is the chief site of injury. Chronic manganese poisoning is not a fatal disease although it is extremely disabling. Freshly formed manganese fume has caused fever and chills similar to metal fume fever (54).

Nickel--Generally, nickel and most salts of nickel do not cause systemic poisoning. Nickel, however, has recently become suspect as a carcinogen of the nasal cavity, paranasal sinuses and the lung (29). The most common ailment arising from contact with nickel or its compounds is an allergic dermatitis known as "nickel itch". This usually occurs when the skin is moist (6).

Aluminum--Aluminum and its oxides are low in toxicity. Insoluble forms of aluminum appear to be without demonstrable systemic toxicity by any route provided their administration is not associated with substances that are tissue irritants (6). Particles of aluminum deposited in the eye may cause necrosis of the cornea.

Metal Dust and Fume Exposure Source--
The evolution of metal dust or fume is dependent on the nature of the process. A summary of foundry processes that emit metal dust and fume is presented below:

Process	Dust source	Fume source
Charge preparation.	X	
Furnace operations.	X	X
Hot metal transfer, inoculation, pouring.		X
Abrasive grinding.	X	X
Arc-air, torch cutting, welding.	X	X §

The hazard of each metal depends upon its relative toxicity, percentage used in the alloy, and metal and alloy melting and boiling temperatures. Table V-3 gives typical percentage ranges of alloy metals for the different types

§ The problem of fume generation is not well defined in relationship to cleaning and finishing operations. Copper for instance, has separate standards for dust and fume and the only practical difference between the two aerosol types may be particle size.

Table V-3.   Typical percentage ranges of metals in foundry alloys.

Ferrous alloys	Typical percentage ranges							
	Fe	Ni	Mg	Cu	Pb	Zn	Cr	Mn
Gray iron	97-99	0-1.5	--	--	--	--	0-0.5	0.5-1.0
Ductile iron	97-99	0-3.5	.05-.08	--	--	--	--	0.35-0.80
White, malleable iron	97-99	--	--	--	--	--	0-.03	0.35-0.60
Carbon and low alloy cast steels (< 8% alloy content)	97-99	0-3	0.10-0.30	--	--	--	0.40	0.50-1.20
High alloy cast steels (> 8% alloy content)	-78	8-68	--	--	--	--	12-32	2-20
Nonferrous alloys								
Copper	--	<1	--	$\geq$ 98	--	Trace	Trace	--
Red brass	--	<1	--	80-98	0-10	2-8	--	--
Yellow brass	--	<1	--	83-99	0->	>17	--	--
Leaded bronze	--	<1	--	60-70	>30	<10	--	--
Nickel bronze	--	>10	--	80-90	<.5	<10	--	--
Aluminum bronze	10	<1	--	90	--	--	--	--

of alloys cast in the foundry. Figure V-I shows how the melting and boiling points of each metal compare with furnace tapping temperature ranges for ferrous and nonferrous alloys. Fume is a potential hazard when a base metal contains a high percentage of an alloy metal with a boiling temperature in the same range as the base metal melting and pouring temperatures.

Lead--The boiling point of lead is only 650°F (450°C) above the nonferrous tapping range. This results in large amounts of lead fume from lead-bearing nonferrous alloys during molten metal phases of casting. When lead appears in ferrous scrap as a tramp metal, it is driven off as fume very readily. Any torch cutting or welding process on a lead-bearing alloy can also produce significant amounts of lead fume.

Zinc and magnesium--Zinc and magnesium both boil at or below the tapping temperatures of most nonferrous and ferrous alloys. Zinc fume, therefore, is always emitted at high rates in a nonferrous melt when zinc is present. Magnesium, inoculated into gray iron to produce ductile iron, reacts violently with oxygen and other "impurities" in the iron at the high temperature of molten iron, producing large quantities of fume.

Manganese--Manganese boils just above the ferrous tapping temperature range. In high manganese steel alloys, manganese fume can be emitted in large quantities during melting, as well as during torch cutting and welding operations.

Copper, nickel, chromium, iron, and aluminum--These metals boil at considerably higher temperatures than the melt range of the alloys in which they are found. This results in limited emission of fume during molten metal phases of casting but considerable fume emissions during torch cutting and welding operations.

Coal Tar Pitch Volatiles--
Inhalation hazard--Several organic materials including coal ("sea coal") are used in mold and coremaking and subsequently contact molten metal. Those organic materials which are located close enough to the hot metal to be heated to 300-900°F (150-480°C) then undergo the process of destructive distillation (volatilization when not in contact with air). Insofar as coal is concerned, this process is similar to that used to produce coke; in the coking process particulate material called "coal tar pitch volatiles" (CTPV) has been associated with cancer. A question has then subsequently arisen about the cancer hazards associated with inhaling such materials in foundries.

Gwin et al., identified the presence of benzo(a) pyrene, benzo(e) pyrene and perylene in the benzene-soluble fraction extracted from the condensable effluents from the thermal decomposition products of a green sand foundry mold containing sea coal. Their experiments were performed with the mold inside a sealed container (51).

Although the cancer hazard has been associated only with materials volatilized from coal, many other organic materials may also be destructively distillated
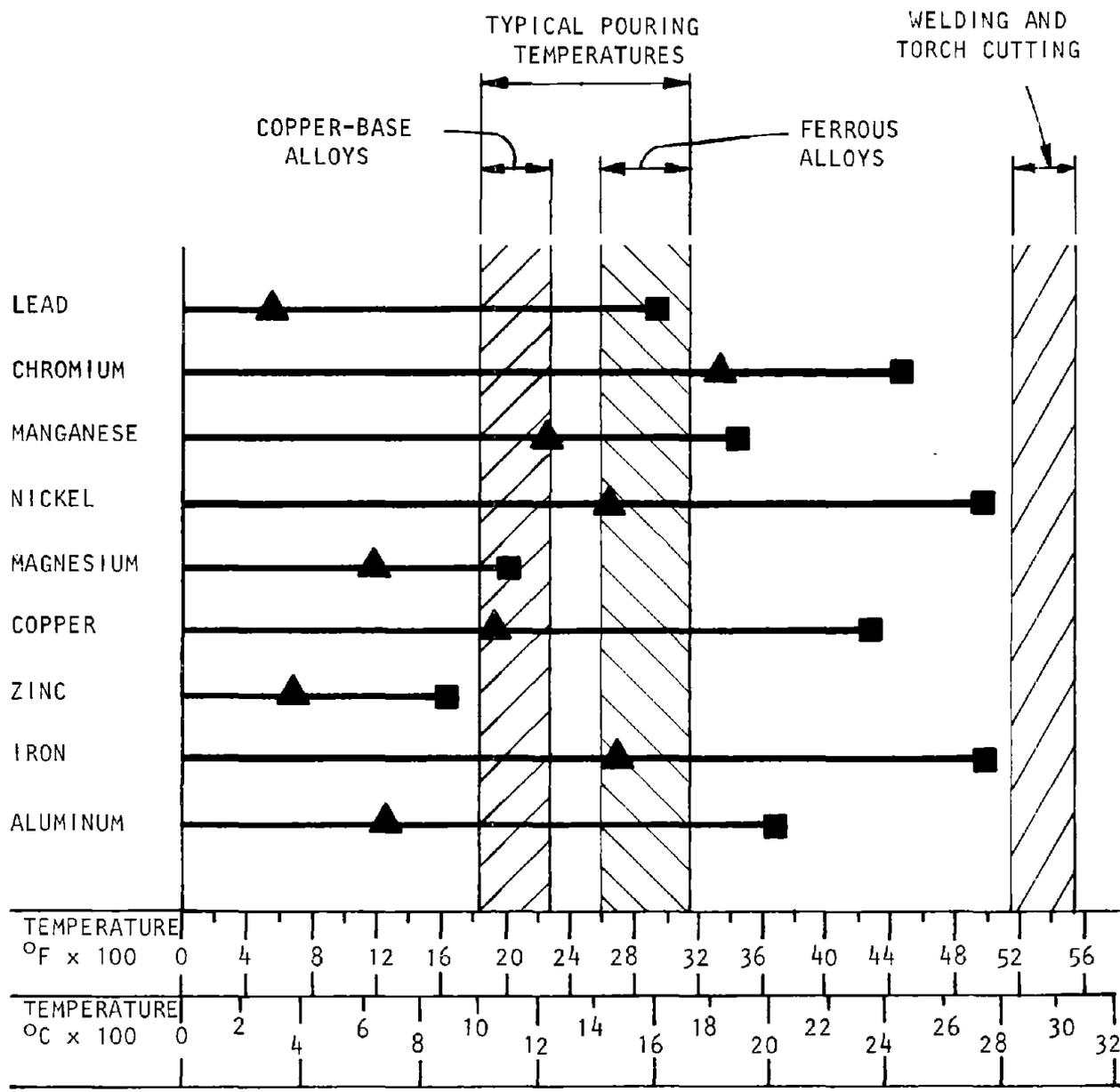
Figure V-I. Melting and boiling points of metals.

during the pouring, cooling, and shakeout processes in foundries. Organic green sand additives in mold and coremaking, such as dextrin, oat hulls, wood flour, pulverized coal, pitch, fuel oil, and asphalt, are commonly used to provide better dimensional stability, accommodation for sand expansion, hot strength, and improved casting surface finish.

The usual analytical method for CTPV is to determine the amount of benzene (or cyclohexane) - extractable material found on filter samples of contaminated air. Even though the products of destructive distillation of organic resins and natural materials such as oat hulls may be as hazardous as the materials from coal, this has not yet been determined.

Gaseous Contaminants

A table of physical properties of the gaseous contaminants is presented in Table V-4.

Carbon Monoxide--
Inhalation hazard--Carbon monoxide (CO) is a chemical asphyxiant that acts by combining with hemoglobin in the blood to exclude oxygen. Symptoms of increasing carboxyhemoglobin concentration in the blood begin at 15-20% blood saturation with euphoria and, perhaps, headache and may progress to nausea, muscular weakness, incoordination, vomiting, paralysis, and death at high (usually >70% carboxyhemoglobin) concentrations. There appear to be no untoward consequences from repeated exposures different from those of acute episodes; the chronic toxicity of CO is low (1).

Foundry source--Carbon monoxide is generated in significant quantities during many foundry processes. CO is produced during charge preheating, melting, pouring, cooling, shakeout, ladle curing, from equipment powered by internal combustion engines and from space and water heaters (36). Furnaces used for annealing, carburizing, and heat-treating metals are also potential sources of CO.

Acrolein--
Inhalation hazard--In liquid or vapor form, acrolein produces intense irritation to the eyes and mucous membranes of the respiratory tract. Skin burns and dermatitis may result from prolonged or repeated exposure. Because of acrolein's offensive odor and irritating properties, severe toxic effects from acute exposure are rare (54).

Exposure sources--Acrolein vapor is formed by the thermal decomposition of glycerine which is present in many core oils. Workers can be exposed to acrolein during core oven unloading and at pouring and/or shakeout operations where oil sand cores are used (5).

Methylene Bisphenyl Diisocyanate (MDI)--
Inhalation hazard--MDI may cause irritation to the eyes, respiratory tract, and skin. The irritation may be severe enough to produce bronchitis and pulmonary edema. Asthmatic sensitization to MDI may occur. The symptoms are wheezing, dyspnea, and cough (55).

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Table V-4. Physical properties of gaseous contaminants.

Common name	Synonym	Odor threshold (ppm)	Vapor pressure mm Hg	Relative density 25° C (Air=1)	Relative concentration 25°C 1 mg/m³= ppm	760 mm Hg 1 ppm= mg/m³
Acrolein	Propenal, acrylic aldehyde, allylaldehyde, acraldehyde	0.21	268 (25°C)	1.93	0.436	2.29
TEA	Triethylamine	0.00021	53.5 (20°C)	3.49	0.24	4.13
DMEA	Dimethylethylamine	--	11.5 (27°C)	2.53	0.33	2.99
Ammonia	Ammonia gas	1-5	--	0.597	1.43	0.696
Carbon monoxide	--	no odor	--	0.97	0.873	1.14
Formaldehyde	Methanal, methyl aldehyde	1.0	--	1.04	0.815	1.22
Furfuryl alcohol	2-furyl carbinol	7.0	1.0 (31.8°C)	3.38	0.249	4.01
Hydrogen sulfide	Sulfuretted hydrogen	0.0047	19.6 (25°C)	1.19	0.717	1.39
MDI	Methylene bisphenyl diisocyanate	2.0	0.00016 (25°C)	--	0.101	9.83
Phenol	Carbolic acid, phenic acid, pherylic acid	0.047	100 (120°C)	3.2	0.260	3.8
Sulfur dioxide	Sulfurous acid anhydride	0.47	2.3	2.2	0.38	2.6

Exposure sources--MDI is formed during the thermal breakdown of urethane polymers. Urethane polymers are formed by the reaction of polyisocyanates with polyhydroxol compounds that are used as sand binders in mold and core-making processes. Urethane cores and molds are made in no-bake processes; they are either the air-set type or gassed type. MDI is generally not considered to be a health hazard during core and moldmaking because of its low vapor pressure. With the addition of heat, however, MDI vapors may evolve during pouring, cooling, and shakeout (56).

Phenol--
Inhalation hazard--Acute phenol poisoning can result from absorption by ingestion or skin contact. Absorption resulting from spilling phenolic solutions on the skin may be very rapid with death occurring within 30 minutes to several hours. Where death is delayed, damage to the kidneys, liver, pancreas, spleen, and edema of the lungs may result. As little as 1.5 grams taken internally has been known to cause death, even when treatment has started within 30 minutes after the ingestion (9).

Concentrations of phenol in air high enough to be acutely hazardous by inhalation (or skin absorption) are irritating to the eyes and mucous membranes; the irritation is intense enough to warn of the impending hazard.

Chronic exposure to low concentrations of the vapor or mist may result in digestive disturbances, nervous disorders, and skin eruptions. Chronic poisoning may be fatal in cases where there has been extensive damage to the kidneys or liver (9). Dermatitis resulting from contact with phenol or phenol-containing compounds is also common in industry.

Exposure sources--Phenol is a principle constituent of phenolic resins. These are synthetic, thermosetting resins used to bond sand in the production of cores and molds. These resins are used in a variety of processes, including baking applications, hot box processes, no-bake binders, the shell sand process and cold box processes. In addition to phenol formaldehyde, urea and furfuryl alcohol are sometimes used to modify the resins. Several catalysts may be used with phenolic resins depending upon the application.

Amines--
Inhalation hazard--Triethylamine (TEA) and dimethylethylamine (DMEA) are irritant gases characterized by a very pungent amine-like fishy odor.

Both are very irritating to the eyes and to the upper respiratory tract. Exposure to high concentrations causes lachrymation and makes normal in-halation difficult. TEA and DMEA are also known to cause corneal edema which results in foggy vision and the appearance of a halo around lights. TEA and DMEA can be absorbed through the skin. Excessive skin contact can cause chemical burns (5).

Hexamethylenetetramine (Hexa) is a powdery crystalline solid at 68°F (20°C) It sublimes at 280°F (130°C). Prolonged contact can cause skin irritations and continued exposure may cause sensitization in some individuals (5). Hexa breaks down in the presence of acids, heat, and water to form formaldehyde and ammonia.

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Exposure sources--Amines, especially TEA, DMEA, and Hexa, are encountered in foundries as catalysts for organic binder systems. TEA and DEMA are used as catalysts for the phenolic-urethane (cold box) binder. Hexa is used as a catalyst and coreactant in the shell sand coating process.

Ammonia--
Inhalation hazard--Ammonia is a strong respiratory irritant. Exposure to high concentrations can cause permanent injury to the cornea, extensive damage to the throat and upper respiratory tract, chronic bronchial inflammation, and edema (6). However, ammonia has excellent warning properties and overexposure is unlikely unless exposures have caused adaptation to the irritation.

Exposure sources--Ammonia is generated as a result of the thermal breakdown of nitrogeneous materials. It is formed in mold and coremaking processes when intense heat is used to accelerate the curing of resinous binders containing nitrogen compounds. Ammonia is also generated as a mold decomposition product during metal pouring and cooling. Resins containing the most significant amounts of nitrogenous materials are furan and phenolic-hot box (shell). However, there is evidence that all cores are a potential source of ammonia to some extent (10).

Hydrogen Sulfide--
Inhalation hazard--The severity of hazard is high for acute exposure and moderate for chronic. Hydrogen sulfide may cause irritation to the eyes at concentrations above 10 ppm (14 mg/m3) and to the lungs and mucous membranes at levels above 20 ppm (28 mg/m3). Its primary physiological effect is respiratory paralysis. Death may occur rapidly with exposure exceeding 600 ppm (834 mg/m3)(6). Since hydrogen sulfide produces rapid olfactory fatigue, its characteristic odor is an unreliable indicator of its presence and/or level of exposure (4).

Exposure sources--Hydrogen sulfide is generated during water quenching of sulphurous slag materials at cupola slag spouts.

Formaldehyde--
Inhalation hazard--The major effect from formaldehyde exposure is local irritation to the eyes, nose, and throat. Mild lachrymation occurs in unacclimated individuals at a concentration of 3-5 ppm (4-6 mg/m3). At a concentration of 10 ppm (12 mg/m3) lachrymation becomes more profuse, even in acclimated indivuduals, and normal voluntary inhalation becomes difficult (8). Formaldehyde concentrations greater than 10 ppm (12 mg/m3) are tolerable for only short periods of time and thus the likelihood for severe respiratory injury is minimized. Human experience indicates that concentrations of formaldehyde vapor in air that are tolerable do not cause persistant eye injury.

Strong formaldehyde solutions cause a hardening effect and primary skin irritation upon direct contact. Contact dermatitis from an acquired sensitivity to formaldehyde solutions of formaldehyde-containing resins is a well recognized dermatologic entity (4).

Exposure sources--The principal sources of formaldehyde vapor are mold and coremaking processes. Both shell and furan resins contain formaldehyde. Formaldehyde also has been measured in significant quantities in mold and core decomposition products (10).

Sulfur Dioxide--
Inhalation hazard--Gaseous sulfur dioxide (SO_2) is particularly irritating to mucous membranes of the upper respiratory tract. Acute overexposure may result in death from asphyxia. Chronic exposure may result in nasopharyngitis, fatigue, altered sense of smell, and chronic bronchitis symptoms such as dyspnea on exertion, cough, and increased mucous excretion (6).

Exposure sources--Sulfur dioxide is generated in cupola melt areas when charge material of a high sulfur content is burned or melted. SO_2 is generated from molds and cores during the casting of magnesium, as well as in other general foundry mold and core practices utilizing sulphurous materials (5, 10). SO_2 is also used to some extent as a catalyst for no-bake binder systems.

Furfuryl Alcohol--
Inhalation hazard--Furfuryl alcohol acts as an eye and respiratory system irritant (6).

Exposure sources--Furfuryl alcohol is used in the production of furan resins and in some modified phenolic resins. These resins are synthetic, thermosetting resins used to bond sand for the production of cores and molds and in hot box, and no-bake furan binders. Furfuryl alcohol can be emitted during mold and coremaking and during pouring, cooling and shakeout of molds and cores using these resins.

FOUNDRY PHYSICAL HAZARDS

Other than the physical hazards usually associated with the field of safety, foundrymen are most likely to encounter the hazards of noise, heat, ionizing radiation, and infrared and ultraviolet radiation. Every foundry is noisy to a certain extent and therefore, noise is a universal problem. Because foundries deal with molten metal, intense heat is always present; whether or not that heat is hazardous depends on several factors, not the least of which is the climate of the area in which the foundry is located. Many foundries use ionizing radiation in the form of X-rays or gamma rays to inspect the internal parts of castings for flaws or for gauging.

Noise

Health Hazard--
Noise is hazardous as the result of possible hearing damage and/or the threat to life and limb by not being able to hear a warning signal. The hazard to hearing can take the form of either temporary or permanent loss. Either type of loss results in an increase in the threshold of hearing or a decrease in sensitivity; i.e., the intensity level at which a person can just detect the presence or absence of sound is increased after an exposure

to noise. If the increase in threshold remains for a relatively short period, it is said to be a temporary threshold shift (TTS). The loss of sensitivity could last from a few minutes to several hours. If after an exposure to noise the increase in threshold or decrease in sensitivity remains, the loss is said to be permanent. Permanent loss is usually gradual over a period of years. However, if the noise is intense enough (140 dB) permanent loss can occur suddenly. Because most losses are gradual, go unnoticed, and generally do not result in any loss of time from work they are often regarded as a nuisance. After a period of years, when the cumulative effect of these small losses adds up to a significant loss, the individual begins to have problems in communication. At this point, he realizes there is a loss, but it is too late. The loss is irreversible and no cure is currently known.

Exposure source--Noise within foundries has been increasing steadily over the last few years. One of the contributing factors has been the increase in production and in the amount of mechanization. Noise is generated by a myriad of processes in a foundry, and in many locations the resultant noise level is above the OSHA limit for 8 hours of exposure. By nature many of the foundry processes are loud, e.g., where heavy hot castings are handled and transported and where surface material is removed by means other than machining. The type and level of noise present can be divided into two classes: 1) annoying and 2) hazardous.

Annoying noise levels are generally below regulated intensities, but are "nuisances". This type of noise presents only a minor problem in terms of work performance. The noise level that results in annoyance is very subjective; i.e., varies from worker to worker. Even though it is not loud, a noise that is intermittent may be annoying. Some examples of annoying noises are warning sirens or bells, air nozzles, and a high ambient noise level in an area requiring a high degree of concentration.

Hazardous noises are ones that result in a noise level greater than the OSHA limit for 8 hours of exposure per day; i.e., the equivalent of 90 dBA for 8 hours. Many foundry processes generate noises above the level. Some typical noise levels in a foundry are recorded in the following table (12).

Process description	Noise level range (Slow response dBA)
Pneumatic hand tools.	93-120
Shakeouts.	94-101
Rattling (pneumatic sand removal).	115-125
Squeezer molding machines.	75-120
Shot blast machines.	99-120
Arc-air gouging.	113-126
Cut-off torches.	98-105
Cupola loading.	118-125
Air blow-offs (open line).	90-110
Core machines.	92-110
Automatic molding machines.	96-110
Tumbling barrels.	90-105

Electric arc furnaces.   92-110
Stand grinders.   89-105

The inability to communicate with fellow employees as the result of
high noise levels can, in certain instances, present a serious hazard to
life and limb. The noise level in many foundries is sufficiently intense
to prevent communication between people at more than a few feet or even
inches. As a result, warning bells, sirens, and instructions between
companion workers may not be heard and a serious injury could occur.

In summary, noise is often regarded as a nuisance. It is only after a
noise induced hearing loss occurs or an accident happens that the problem
is fully realized. Despite such attitudes, noise is a significant health
problem in many foundries and a serious effort to control it is warranted.

Heat

Health hazard--The consequences of overexposures to heat stress range from
minor ones such as prickly heat and fatigue to major ones ranging from
water and electrolyte imbalance to heat exhaustion, heat stroke, and death.

While the most serious consequences are uncommon among foundry workers, the
less serious ones such as fatigue up to and including exhaustion and other
consequences of electrolyte imbalance such as cramps are not. Usually,
the most severe problem in a foundry is experienced in the spring or early
summer when the cool or cold weather of winter is replaced suddenly by hot
weather. During cold weather some or most of the heat acclimation of
certain individual workers will be lost and the advent of warm or hot days
will cause excessive secretion of concentrated (salty) sweat leading to
electrolyte imbalance and/or dehydration unless both water and salt are
replaced in appropriate amounts.

Heat in a foundry is most hazardous to those peripherally exposed who
can lose most or all of their summer acclimation in the winter and who,
therefore, are physiologically unprepared for a sudden spell of really
hot weather. When that heat is added to whatever exposure they receive
in the foundry the consequences can be incapacitating, at least
temporarily. In addition, the ranks of the susceptible include those new
in a foundry who attempt to work in the heat without proper acclimation.
Again, their exposure is rather sudden to heat stress levels above those
to which the body is acclimated. In both cases, the problem is most
severe in those parts of the country where winter is cold enough for people
to lose heat acclimation and where summer heat is not comparable to that
experienced doing a hot job in the foundry.

Exposure sources--Heat sources in foundries are principally associated with
the heating, melting, pouring, and cooling of metal, thermosetting core and
moldmaking processes, ladle preheating, heat treatment of castings, and

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shakeout and degating operations. Because of their nature, heat sources in foundries tend to be relatively intense and hence, quite obvious. Those people with the greatest exposures are almost always those closest to the molten metal, from furnace tenders to slaggers, pourers, and crane operators. Because of their almost constant exposure to heat, they rarely lose a significant portion of their acclimation.

Ionizing Radiation

Health hazards--Today, essentially everyone who works with sources of ionizing radiation has his exposure monitored and controlled to the point where any consequence of the exposure is unlikely in the extreme. This is done because the possible consequences are so severe and because unknowing gross overexposure carries no warning; a person could be exposed to several times the lethal amount of radiation and be unaware of the exposure until hours or days later. Very strict state and federal rules and regulations apply to every phase of ionizing radiation use from procurement to handling and disposal. Compliance with those regulations is usually sufficient to assure adequate control. Further descriptions of the procedures followed by foundries to provide for worker safety and health are presented in the discussion section.

Exposure sources--Radiographic X-ray and radioisotope "cameras" are the main sources of potential exposure to ionizing radiation in foundries. In addition, sealed radioisotopes may be used for level gauging and thickness testing devices. The radiation from such gauges is very small compared to radiographic applications.

Nonionizing Radiation

In foundries, the only types of nonionizing radiation usually encountered are infrared and ultraviolet. Infrared radiation from hot metal and other surfaces is a source of heat stress and also a potential cause of cataracts. Heat stress is discussed elsewhere; the cataract potential is controlled by viewing hot surfaces through glass treated (usually by doping with neodynium) to be opaque to infrared radiation (I). This practice is universally followed in foundries; it is specific and efficiently controls the hazard.

Ultraviolet radiation in foundries is almost always associated with electric arcs, either in conjunction with arc furnaces, with metal removal (arc-air) or with welding. In all cases the skin and eye hazards (sunburn and photokeratitis or "welder's flash") are well controlled by the use of personal protective equipment, from proper opaque clothing to dark glasses for viewing.

People who do not operate the welding or arc-air equipment can be protected from "welder's flash" (and from the intense visible light emanating from the arc) by means of opaque drapes and/or screens that shield the source from them. One of the newer innovations has been the use of special colored (yellow) plastic shields and curtains that are transparent so welders and arc-air operators can be seen by others while at work, thus avoiding a real safety hazard.

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ALLOWABLE EXPOSURE LIMITS

Tables V-I and 2 list OSHA permissable exposure limits (PEL), ACGIH threshold limit values for 1977 (TLV) and NIOSH recommended standards for the air contaminants included in this section, as well as noise. As no OSHA standard exists for heat stress, the following subsection describes several heat stress indices.

HEAT STRESS INDICES

Several methods of heat stress evaluation are available: the wet bulb globe temperature (WBGT) of ACGIH and NIOSH (13), the Heat Stress Index (HSI) of Belding and Hatch (14), and the Predicted Sweat Rate (SRI) of Hatch alone (15) and as modified by Peterson (16).

Wet Bulb Globe Temperature (WBGT)

The wet bulb globe temperature (WBGT) is determined from the "natural" wet-bulb temperature (t_{nwb}) and the (black) globe temperature (t_g) using the equation:

$$WBGT = 0.7\ t_{nwb} + 0.3\ t_g$$

This index is very easy to determine, requiring measurement of only two variables indoors (outdoors the air temperature (t_{db}) is also used). It is complicated somewhat by needing estimates of worker activity for its application because the "TLV" used depends on whether the workload is light, moderate or heavy.

Heat Stress Index (HSI)

Belding and Hatch developed the HSI in 1955, basing it on estimates of the amount of heat transferred between the exposed person and his environment by convection and radiation along with an estimate of the metabolic rate and calculation of the maximum amount of perspiration that could be evaporated into the ambient air. The HSI is actually the ratio of the required evaporative capacity (the sum of the metabolic rate, and the heat gained by convection and radiation) to the maximum evaporative capacity, expressed as a percentage. That is, an HSI of 100 means that the required evaporative capacity and the maximum evaporative capacities are equal; no greater heat stress can be tolerated by the "standard man". (The duration that an excessive amount of heat stress can be tolerated depends on the difference between the required and maximum evaporation rates, not their ratio). The HSI has been used for many years despite its shortcomings (it usually tends to overestimate the heat stress).

One method for causing the HSI to better estimate heat stress is to use a better estimate for the skin temperature than the 35°C usually assumed. Embodied in Hatch's SRI is a method for estimating skin temperatures of heat-stress-exposed people. Calculations based on such estimates are herein used to form another stress index, the HSI2.

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Sweat Rate Index (SRI)

The sweat rate index was developed by Hatch in 1963. It is based on the
idea that the evaporation of sweat can be either free or restricted. "Free"
evaporation implies that all sweat secreted is completely evaporated, while
"restricted" means that some of the sweat formed drips off the skin and
is not used to cool by evaporation. Hatch described each of these regimes
with equations that were used to derive expressions for the skin temperature
in each. At the "boundary" between the regimes the skin temperature
equations were set equal to enable a calculation of a boundary condition,
the maximum vapor pressure of water in air for the free evaporation regime.

The SRI calculated by Hatch's method requires a knowledge about the sweating
behavior of each individual. However, using averages for the appropriate
parameters allows a calculation of an "average" SRI. The SRI is expressed
in heat or energy units per unit of time, such as watts, or kcal/min and
is an estimate of the actual sweat rate of an exposed person. The maximum
sustained sweat rate of a young, fit, acclimated man is about 700 watts or
10 kcal/min.

In experiments subsequent to development of the SRI, Peterson found that
a simple correction to the SRI was necessary to produce the best fit of
his data to measured sweat rates. The predicted sweat rate, S, is found
as:

$$S = -9.8 + 0.8699(SRI) \quad \text{(S and SRI in watts)}$$
$$\text{or}$$
$$S = -0.113 + 0.8699(SRI) \quad \text{(S and SRI in kcal/min)}$$

Table V-I. Hygienic standards and recommended standards, air contaminants.

Substance	OSHA PEL §Ω	ACGIH TLV (1977) §	NIOSH Recommended # Θ
Aluminum	15 mg/m3	10 mg/m3 (as Al$_2$O$_3$), 20 mg/m3 STEL*	——
Chromium	1 mg/m^3, chromium metal and insoluble salts;	0.05 mg/m^3 chromic acid and chromates (as Cr) ψ 0.5 mg/m3 chromium, sol. chromic, chromous salts (as Cr)	0.001 mg/m^3 for carcinogenic hexa-valent chromium 0.025 mg/m3 for other hexa-valent chromium compounds 0.05 mg/m3 (ceiling) (15 min) ∇
Copper	0.1 mg/m^3 fume, 1 mg/m3 dust and mist	0.2 mg/m3 fume, 1 mg/m3 dust and mist, 2 mg/m3 dust and mist STEL*	——
Iron oxide	10 mg/m^3 fume 15 mg/m^3 dust	5 mg/m^3 fume 10 mg/m3 STEL*	——
Lead (inorganic)	0.2 mg/m^3	0.15 mg/m^3 dust and fume (as Pb) 0.45 mg/m^3 STEL*	Less than 0.05 mg/m^3
Magnesium oxide	15 mg/m^3	10 mg/m^3	——
Manganese	5 mg/m^3 dust or fume (ceiling)	5 mg/m^3 manganese compounds (as Mn) (ceiling)	——
Nickel	1 mg/m^3 dust or fume metal and soluble salts (as Ni)	1.0 mg/m^3 nickel metal	0.015 mg/m^3 inorganic and compounds (as Ni)
Zinc oxide	5 mg/m^3	5 mg/m^3 fume 10 mg/m3 fume STEL*	5 mg/m^3 15 mg/m^3 (ceiling), (15 min) ∇

(continued).

Table V-I (continued).

Substance	OSHA PEL §Ω	ACGIH TLV (1977) §	NIOSH Recommended # Θ
Respirable dust <1% crystalline silica	5 mg/m3	5 mg/m3	——
Respirable dust >1% silica, crystalline quartz †	$Mppcf = \dfrac{250}{\% \, SiO_2 + 5}$ $mg/m^3 = \dfrac{10 \ mg/m^3}{\% \, SiO_2 + 2}$	$Mppcf = \dfrac{300}{\% \, SiO_2 + 10}$ $mg/m^3 = \dfrac{10 \ mg/m^3}{\% \, SiO_2 + 2}$	0.05 mg/m3 respirable free silica
Total dust >1% crystalline silica	$mg/m^3 = \dfrac{30 \ mg/m^3}{\% \, SiO_2 + 2}$	$mg/m^3 = \dfrac{30 \ mg/m^3}{\% \, SiO_2 + 3}$	——
Total dust <1% crystalline silica	15 mg/m3	10 mg/m3	——
Gases Acrolein	0.1 ppm	0.1 ppm 0.3 ppm STEL*	——
Ammonia	50 ppm	25 ppm 35 ppm STEL*	50 ppm (ceiling) (5 min) ∇
Carbon monoxide	50 ppm	50 ppm 400 ppm STEL*	35 ppm 200 ppm (ceiling)
Formaldehyde	3 ppm 5 ppm (ceiling) 10 ppm maximum peak above the acceptable ceiling for a maximum duration of 30 minutes	2 ppm (ceiling)	I ppm (ceiling) (30 min) V

(continued).

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Table V-I (continued).

Substance	OSHA PEL § Ω	ACGIH TLV (1977) §	NIOSH Recommended # Θ
Furfuryl alcohol	50 ppm	5 ppm 10 ppm STEL*	——
Hydrogen sulfide	20 ppm 50 ppm acceptable peak above the ceiling to a maximum duration of 10 min once if no other measurable exposure occurs	10 ppm 15 ppm STEL*	10 ppm (ceiling) (10 min) ∇
Methylene bisphenyl isocyanate (MDI)	0.02 ppm (ceiling)	0.2 ppm (ceiling)	——
Phenol	5 ppm	5 ppm 10 ppm STEL*	5 ppm 15 ppm (ceiling) (15 min) ∇
Sulfur dioxide	5 ppm	5 ppm	0.5 ppm
Triethylamine	25 ppm	25 ppm 40 ppm STEL*	——

§ 8 hr. time weighted average except where noted.

* Short term exposure limit (15 minutes) tentative values.

† Tridymite and cristobalite are one-half the limit of quartz.

Based on a time-weighted average of up to 10 hrs., 40 hr. week, except where noted.

Ω Permissible exposure limits; from selected general industry safety and health standards, toxic and hazardous substances - air contaminants; Fed. Reg. Vol. 42, No. 240, p. 62868A, Dec. 14, 1977.

ψ No ACGIH standard directly applies to metallic chromium fume and dust.

Θ From a NIOSH quarterly report, Division of Criteria Documentation and Standards Development, October, 1977.

∇ When "ceiling" and a time period such as "5 min." appear together, the recommended air concentration is an acceptable maximum peak that is not to be exceeded in a sampling period denoted by the time indicated.

Table V-2. Hygienic standards and recommended standards, noise.

OSHA PEL*		ACGIH TLV (1977)		NIOSH Recommended	
Continuous noise-		Continuous noise-		Continuous noise-	
dBA	Duration/	dBA	Duration/	dBA	Duration/
90	8	80	16	85	8
92	6	85	8	90	4
95	4	90	4	95	2
100	2	95	2	100	1
102	1-1/2	100	1	105	1/2
105	1	105	1/2	110	1/4 or less
110	1/2	110	1/4	115	Prohibited
115	1/4 or less	115	1/8		
>115	Prohibited	>115	Prohibited		

Impact or impulse noise §

dB	Permitted number of impact or impulses/day
140	100
130	1,000
120	10,000

§ Exposure to impact or impulsive noise exceeding 140 dB peak sound pressure level is prohibited.
* Permissible Exposure Limit.

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PRINCIPLES OF FOUNDRY
ENVIRONMENTAL CONTROL

Peterson has stated that all occupational hazards can be controlled by use of at least one or a combination of the principles of substitution, isolation, and ventilation (28). Following is a description of each of these classifications of control and their applicability to the foundry environment. These classifications will be used throughout the following sections of the report in defining the type of control used in particular situations.

SUBSTITUTION

Substitution involves the replacement of hazardous materials, processes, or pieces of equipment with less or nonhazardous ones.

Material Substitution

Substitution of nonsilica molding aggregates is a material substitution that could substantially reduce dust inhalation hazards. Substitution of argon for chlorine in the degassing of aluminum can eliminate the dangers of handling chlorine and the production of an air contaminant. Substitution of clean scrap for oily scrap or the elimination from the furnace charge of painted components and mechanical drive components containing nonferrous bearings and bushings, can reduce the lead hazards for metal casting operators.

Process Substitution

Substitution of the Schumacher process for the conventional sand handling system is a method for reducing a respirable dust hazard while reducing the amount of ventilation control required for return sand systems. Precleaning of castings by shot blasting immediately after shakeout is a process modification that not only reduces the hazard of respirable dust in the transporting and handling of castings but also decreases the amount of slag in the furnaces by reducing the amount of sand adhering to foundry return scrap.

Equipment Substitution

Quieter fans, air nozzles, pattern vibrators, jolt-squeeze machines, and air mufflers are examples of equipment substitutions that can substantially reduce the noise emitted from existing components.

ISOLATION

Isolation of hazards is done by interposing a barrier between the worker and the hazard. A barrier consists of either a physical shield, a suitable

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distance between the worker and the hazard, or a time lapse to provide a safety factor against exposure.

Isolation with a Physical Barrier

Heat shielding at a slag station and covering ladles are two ways that metal pourers are isolated from heat and infrared radiation. The mold cooling process in certain cases can be isolated to an area that workers do not have to enter. Operator booth enclosures at control stations (crane cabs, furnaces, charge weighing control stations) isolate the worker from air contaminants, noise, and heat.

Isolation by Distance

Remotely controlled processes can isolate the worker from the hazard generation point by a distance. Sand slinging and slagging of large ladles can be automated, thus moving the operator far enough from the process that respirable dust and heat are no longer problems.

Isolation in Time

Isolation in time may occur in a variety of ways. Dusty maintenance procedures, e.g., housekeeping and furnace repair, can be isolated from production to nonproduction shifts. Allowing castings and hot cores to cool before manual handling reduces heat and gaseous hazards. Dwell cycles in processes at times can be lengthened to reduce the potential for exposure. The period between the end of the shot blast chamber cycle and chamber opening can be lengthened to allow sufficient evacuation of dust.

VENTILATION

There are two major classifications of ventilation: control at the source (local exhaust) and general. Control at the source denotes exhaust capture close enough to the point of generation of air contaminants to prevent the contaminants from entering the breathing zones of workers. These ventilation techniques create air flow patterns that cause the contaminant to move in a direct and predictable manner toward the evacuation point. General ventilation, on the other hand, is a dilution method; it achieves its primary effects by reducing air contaminant concentrations and providing worker comfort by mixing in other less-contaminated air.

Control at the Source

Ventilation control at the source is achieved principally through local exhaust, a method of drawing contaminated air into a duct system through a suction opening. The term "hood" is used in a broad sense to include all suction openings regardless of their shape (21).

Local exhaust methods are classified by the degree of enclosure a hood has. The two main classifications are enclosing hoods and exterior hoods, although it is possible to have a partially enclosing hood. In the following are descriptions of the two major classifications, as well as the factors

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which affect their performance and examples of application of these hood techniques in foundries. A sketch of each type of hood is presented in Figure VI-I.

Enclosing Hood--
In an enclosing hood, the generation point for air contaminants is within the confines of the hood and the worker is outside these confines. The enclosure is formed by any barrier that restricts the flow of air, e.g., the hood itself, the equipment, the wall, ceiling or floor, etc. When exhaust air is withdrawn from the enclosed space it produces an indraft velocity through all of the hood openings to counteract any tendency of air contaminants to escape. Thus, the total required exhaust from the hood is directly proportional to the total open area through which contaminants could escape.

For foundry applications, enclosing hoods are (typically) used for sand system components such as conveyors, transfer points, screens, mullers, shakeouts (Figure VI-I) and for furnaces. Enclosing hoods are quite predictable in performance and ventilation requirements can usually be specified simply be establishing a minimum indraft velocity for the hood. For example, when enclosing hoods are used for sand system applications, the ACGIH recommends a minimum indraft velocity of 150-200 fpm (0.76-1.02 m/sec) (17). Higher indrafts are required either where the contaminant has a high initial velocity which causes extreme turbulence within the hood (blast cabinets) or where the contaminanated air stream is very hot and the hood has openings on top.

The enclosing hood is the most "air-efficient" exhaust method for protecting the breathing zone. Its limitations are that it can interfere with process operation and maintenance. To facilitate access, removable doors and panels and flexible baffles are utilized and when these are removed, they often are not replaced. The result is lower indraft velocities because of larger open area and loss of capture effectiveness.

Special care must be taken in design of enclosing hoods to provide uniform air distribution through all openings. Generally, the larger the hood and the smaller the total open area the easier to achieve uniform distribution.

The booth is a special case of enclosing hood. It typically has only one vertical open access and in many cases the operator works at or just outside this "face". Booths are used for swing grinders and arc-air applications, spray coating of core washes (Figure VI-I) and for chipping and grinding.

Exterior Hood--
An exterior hood is used where processes cannot be enclosed, usually because of operational requirements and/or interferences. The hood is mounted as close to the contaminant generation point as possible and functions by inducing air flow patterns around the process, which draw contaminants toward the hood. For this method to be effective, the worker must not enter the space between the air contaminat generation point and the hood. There are two important subcategories of exterior hoods that relate to the

ABRASIVE
GRINDING
WHEEL

HOOD
TABLE
FEED CONVEYOR
ENCLOSING HOOD

HOOD
WORKPIECE

BOOTH
CORE BE-
ING SPRAYED
BOOTH ENCLOSURE

HOOD

FURNACE
RECEIVING
EXTERIOR HOODS

HOOD
MOLD
VIBRATING
TABLE
EXTERNAL HOOD
(non-receiving)

HOOD
POURING
LADLE
"PUSH-PULL"
EXTERIOR HOOD
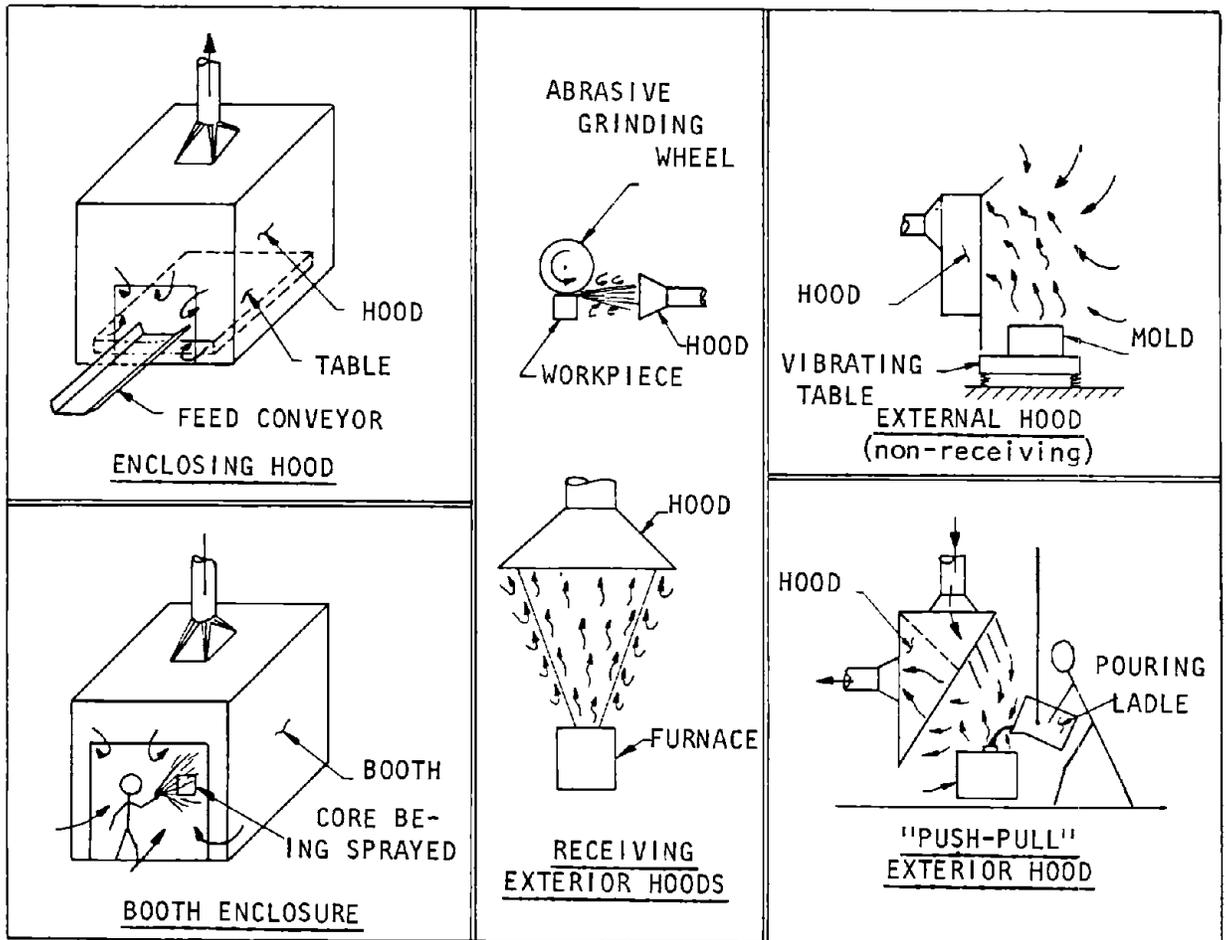
SYMBOL

AIR FLOW
PATTERN

Figure VI-l. Examples of local exhaust hoods (17).

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method by which capture is achieved with the hood: the receiving hood and the nonreceiving hood.

Receiving hoods--The contaminated air is propelled toward the capture hood by some force besides the suction of the hood. The hood must have a sufficient exhaust rate to receive the contaminated air stream.

Two types of propulsion are possible: the process itself may provide the propulsion or an auxiliary air source may provide it.

1. The mode of contaminant generation by the process may result in the propulsion of an air stream. Two notable examples of this in foundries are:

    a. Grinding swarf - When a moving abrasive tool, e.g,, grinding and buffing wheel or belt, contacts a casting during a cleaning and finishing operation, a grinding swarf (stream of particles) is produced which departs from the casting tangential to the tool contact point (Figure VI-I). This swarf contains heavy inertial particles which were removed primarily from the casting, but also from the tool. It also contains very finely divided noninertial type particles, a substantial amount in the respirable range (less than 10 microns). The motion of the heavy particles causes an air flow, called an induced draft, which moves the fine dust along with the inertials. The amount of induced air increases the further the swarf travels.

    If a capture hood is placed in line with the grinding swarf, it will capture the heavy and light particles together. However, the fine dust particles are borne by the induced draft only as long as the swarf is travelling along an uninterrupted path. If the swarf should contact a solid object before being captured, the inertial particles will rebound, whereas the fine particles will follow the prevailing air pattern in the vicinity of the solid object.

    b. Thermal drafts from hot processes - Canopy hoods over hot processes such as furnaces and pouring ladles act to "receive" the thermal draft (Figure VI-I). As in the case of the grinding inertials, the thermal draft also induces air into the mainstream so the total air flow moving in the draft increases as the air rises.

    All receiving hoods have one thing in common: the most effective and air-efficient capture occurs as close as possible to the contaminant generation point. The further away the capture hood is placed, the larger the required exhaust rate to "receive" the ever-increasing flow, and the more susceptible the air stream is to deflection by crossdrafts.

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2. The contaminated air may be given a push toward the receiving hood, either by a mechanical supply air source or by prevailing ventilation patterns. This method is often termed "push-pull" exhaust. Push air induces additional air into the mainstream just as did the grinding swarf and thermal drafts described above, and the larger the spread between the "push" and "pull" points, the higher the ratio must be of "push" to "pull" air volumes. "Push-pull" techniques have been applied to pouring hoods (Figure VI-I), as well as manual casting finishing processes such as arc-air and chipping and grinding.

Nonreceiving hoods--In this case the contaminated air either has no initial velocity or its velocity is, by necessity, directed away from the hood because of the nature of the process. Sidedraft hoods on a shakeout loaded by overhead crane (Figure VI-I) or adjacent to the electrodes above the cover of an arc furnace are good foundry examples. Downdraft chipping and grinding benches also act as nonreceiving hoods when the grinding swarf is directed away from the bench. The velocity of air drawn by the hood must overcome the velocity of the contaminant-laden air before capture can take place. Because there is a rapid velocity decrease with increasing distance from the hood varying almost inversely with the square of the distance, the further the source of contaminated air is from the nonreceiving hood, the less likely the contaminant will be captured (17). To be effective the hood must be placed absolutely as close as possible to the contaminant source.

Design of exterior hoods is much more difficult than the design of enclosing hoods because of the many influencing factors (such as the distance problem discussed above). Thus, recommendations for hood exhaust flows, such as from ACGIH, will usually be drawn from experience and specified in terms of variables such as process size or rate. For example, the recommended flow for a sidedraft shakeout hood is based on grate area, while the flow for a grinding wheel is based on wheel diameter and width (17).

Exterior hoods offer the least disruption to process operation and maintenance, but they accomplish this at a large sacrifice in air efficiency. They are much more sensitive to upset conditions and cross-drafts than are enclosing hoods.

General Ventilation

Dilution ventilation can occur naturally or be provided mechanically. Most foundries employ so much mechanical ventilation that prevailing air currents within the building are dictated primarily by the location and quantities of exhaust and supply air movers, rather than by natural ventilation.

The negative pressure problem--During summer, the net exhaust rate from the foundry is highest because, in addition to the local exhaust hoods, a series of wall and roof ventilators are in use to remove heat from the building. Doors and windows are opened to allow fresh air to be drawn in. During winter the ventilation rate is still high because of the large amount of local exhaust.ventilation and general ventilation required for removal of air contaminants. But doors and windows are closed (especially in the

northern climate) to maintain the heat within the building. The result is a buildup of negative pressure within the building which causes a series of unsatisfactory conditions, among them (17):

Upsetting of air flow patterns.
Cold drafts on workers.
Reduction in low pressure fan exhaust rates.
Reversing the flow through natural ventilation stacks and roof monitors.
Backdrafting of flue stacks from fuel burning systems.
Safety hazard in opening and closing doors.

Significant Air Currents--
In making air velocity measurements in the foundry, the general air is usually found to be in constant circulation, and air patterns are quite complex and variable. Despite that variability, "significant" air currents can be fairly predictable. Hemeon defines significant air currents as, "those air currents having a constant position and direction, and of such a magnitude that they are measurable, and either a) can be exploited in the engineering design for useful pruposes, or b) are a factor deleterious to the desired air conditions and must, therefore, be counteracted (21). In industry, air velocities below 50 fpm (0.2 m/sec) are usually considered insignificant. Three important classifications of significant air currents are local exhaust envelopes, supply air streams, and natural convection above hot surfaces.

The following is a discussion of two of these classifications: local exhaust envelopes and supply air streams. Natural convection above hot surfaces, or thermal draft was discussed briefly under Receiving Hoods above. It is further described in the example of a roof exhauster above a furnace in the Local Exhaust Envelope section below.

Local exhaust envelopes--The zone or envelope around a local exhaust hood or around a roof or wall ventilator in which the velocities are siqnificant, i.e., higher than 50 fpm (0.2 m/sec), is relatively small. For the bench-mounted exhaust hood in Figure VI-2, the described envelope does not extend much past the bench. Thus, air contaminants do not have to move far from their point of generation to escape the envelope. Once they do escape, contaminants are diluted in the background air because of the "air draft" [random velocity patterns less than 50 fpm (0.2 m/sec)]. What this means in effect is that, once outside the exhaust envelope any of the other air in the room has about the same chance of being captured as the air which just escaped the hood's influence.

Understanding this deficiency of the local exhaust envelope provides an explanation of why a huge roof exhauster placed high above a furnace captures so little of the smoke rising during furnace tapping (Figure VI-2). As the hot air rises from the furnaces, it induces a large amount of air in the thermal draft (a significant air current). By the time the thermal draft reaches roof level it has swollen in volume and its velocity is low. Only the portion of this large draft that actually contacts the exhaust envelope of the roof ventilator will be directly discharged. The remainder will drift at insignificant velocities to be further diluted in the room

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EXHAUST HOOD

WORK BENCH

LOCAL EXHAUST ENVELOPE

ROOF EXHAUSTER

FURNACE

THERMAL CONVECTION

ROOF VENTILATOR

DOORWAY

SUPPLY AIR STREAM
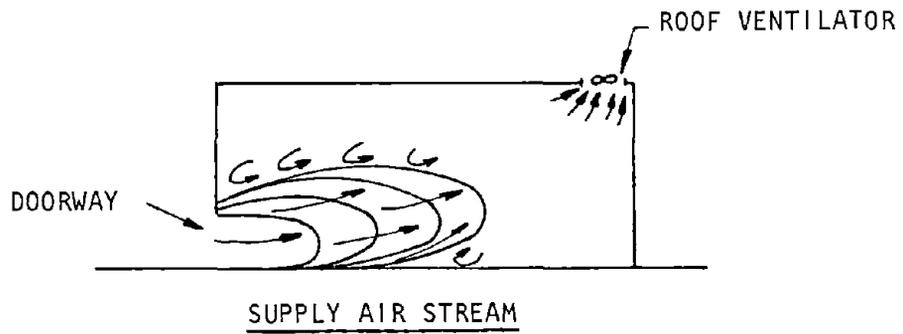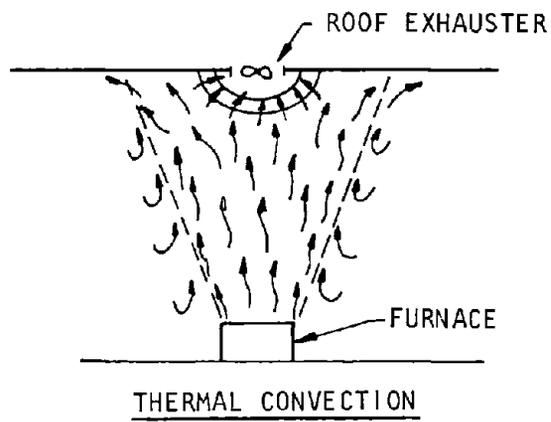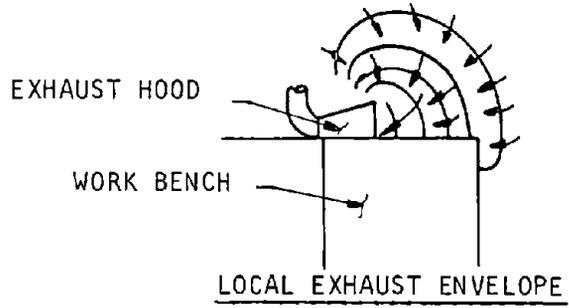
SYMBOL

→ AIR FLOW
  PATTERN

Figure VI-2. Significant air currents.

air and eventually exhausted in the general air turnover. Contaminants which escape direct capture in this manner add to background contaminant levels which are breathed continuously by everyone in the building.

Supply air streams--Unlike exhaust envelopes, supply air streams are usually substantial in size and can travel the full length of a building and still be "significant". A predominant supply air envelope is the draft induced through foundry doors because of "air starvation" which occurs because of a ratio of mechanical exhaust air to mechanical supply air (makeup air units) much greater than one (Figure VI-2). Drafts through doorways often disrupt local exhaust hoods and are also a principal factor in the cross-contamination from one foundry area to another. The highest exhaust rate in a foundry is usually from the melting area, meaning that air streaming through building openings generally causes air patterns that move toward the melting area. By the time it reaches the melting area this air has picked up emissions escaping from all of the upstream foundry areas through which it has passed, a process termed cross contamination. Eliminating cross contamination requires that mechanical air supply (make-up air units) be properly located and distributed to balance off the exhaust and to provide controlled air patterns.

A method of introducing make-up air which has a low potential for cross-contamination is individual fresh air supply. This technique is particularly applicable in areas where a large number of air contaminant sources are present and where the workers are stationed in relatively fixed locations. A good example is the cleaning room.

Certain guidelines must be followed, however, if the fresh air supply is to be an adjunct of, rather than a disruption to, exhaust control at the source. The velocity of air at the air contaminant generation point must be low enough so that the air does not create a disruptive turbulence, nor does it provide a greater "push" than the "pull" of the hood can accept. The need for controlled fresh air supply velocity is particularly essential in the cases of processes producing very fine dust particles such as chipping and grinding or manual appendage removal. The nonpreferred and preferred methods are shown in Figure VI-3.

With a jet air source, the worker receives the best "feel" from the air when he is located directly in the path of the jet. A drawback to the jet is that as air moves from the supply air point to the worker, it induces background air into the jetstream. Thus, the air which enters the breathing zone is composes of a combination of fresh air and background air. A distributed air source, on the other hand, pushes the same amount of air through a large grille area at a lower initial velocity. Near the breathing zone of the worker the air should be rather uniform in velocity so that the worker can move about somewhat without moving away from the fresh air zone. The important result of this method of distribution is that little background air is induced into the airstream and thus the breathing zone is purged with predomonantly fresh air.

Because they are intended for makeup air supply in winter, as well as in summer, individual air supplies should be tempered for use in any season.

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JET AIR SOURCE
(not preferred)

DISTRIBUTED AIR SOURCE
(preferred)
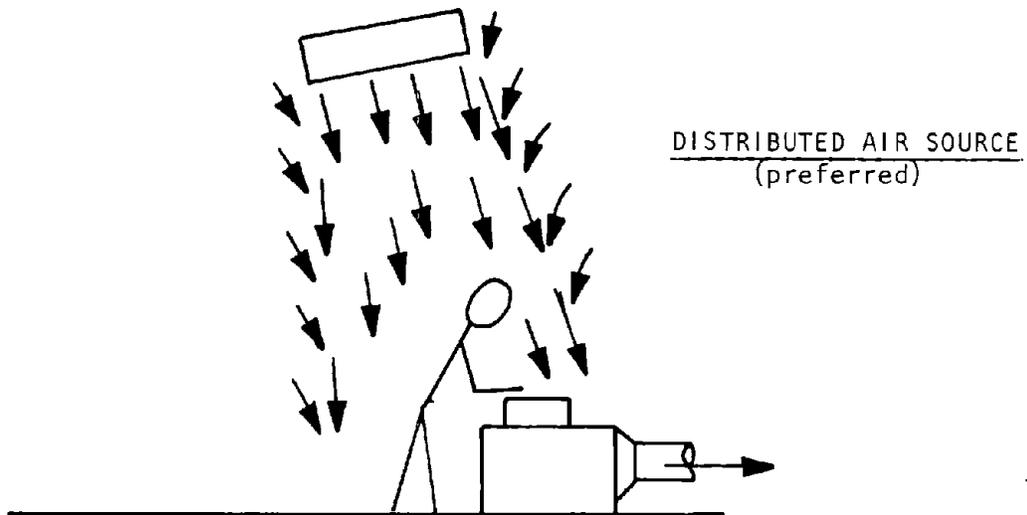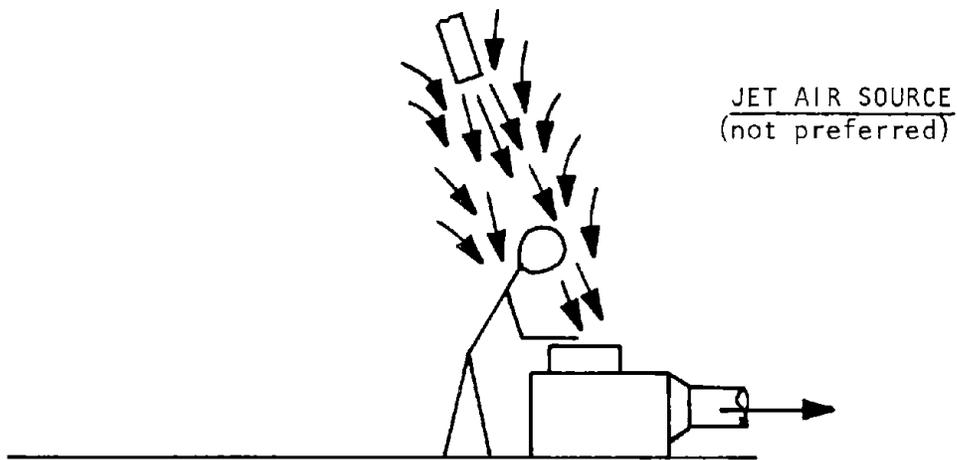
SYMBOLS

→ AIR FLOW PATTERN

Figure VI-3. Comparison of supply air methods for
use with exhausted processes.

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SECTION VII
SAMPLING AND ANALYTICAL PROCEDURES

INTRODUCTION

This section presents the sampling, analytical and engineering evaluation methods used during the course of the technology assessment to measure workplace levels of chemical and physical agents and to assess the effectiveness of control measures. Table VII-1 lists the chemical and physical agents that were measured during the study and the sampling and analytical methods used for each. Table VII-2 presents a list of sampling and analytical equipment used by the contractor during data acquisition.

AIR SAMPLING

General Principles

As a general rule, the purpose of air sampling during the study was to obtain data to lend support to observations and flow measurements about the functioning of a particular control measure. Prior to sampling, a study of the particular process and its control measures, as well as attendant conditions was made to provide an understanding of the variables which could affect the sampling results. The potential for cross-contamination from adjacent as well as remote processes was also considered.

Basically, two different types of samples were taken, each for a specific purpose:

1. Breathing zone samples - This type of sample permitted evaluation of the ultimate goal of control measures - protection of the breathing zones of workers. The results of these 8-hour samples were directly compared to allowable limits. By themselves, however, breathing zone samples did not always give a direct indication of the functioning of a particular control.

2. Fixed area (background) samples - Fixed samples were taken upstream of the process to assess the influence of adjacent processes on contaminant control in a specific area, or downstream to assess the completeness of control. The location of the background sampler was determined with the aid of ventilation mapping and sometimes respirable dust mapping. Ventilation mapping was accomplished with the aid of airflow measuring devices such as thermoaneomometers or smoke tubes. Respirable dust mapping was performed with a respirable dust monitor (RDM).

Sampling duration was based on the applicable TLV or standard, the sensitivity of the analytical procedure, and the estimated airborne

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Table VII-I. Sampling and analytical procedures.

Chemical or physical agent	Sampling procedure	Analytical procedure
Respirable silica	37 mm two piece cassette filter holder/37 mm - 5.0 μm pore size PVC filter preceeded by a 10 mm nylon cyclone at an airflow rate of 1.7 lpm	Respirable dust-gravimetric analysis. Crystalline free silica-(quartz, cristobalite); X-ray diffraction (NIOSH P&CAM 109 method).
Metals/dust and fume	37 mm - three piece cassette filter holder/37 mm - 0.8 μm pore size PVC filter at a flow rate of 2 lpm or 12 lpm	Atomic Absorption Spectrophotometer (NIOSH P&CAM 173 method).
Carbon monoxide	CO analyzer	Ecolyzer series 2000 w and w/o strip chart recorder
Triethylamine	MIRAN gas analyzer	MIRAN gas analyzer wavelength - 9.49 μm Pathlength - 14.25 meters Slit setting - 1
	Gas detector pump w/gas detector tube	Gas detector tube reading

(continued).

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Table VII-I (continued).

Chemical or physical agent	Sampling procedure	Analytical procedure
Phenol	Midget impinger/15 ml 0.1N NaOH at a flow rate of 1 1pm	Gas chromatography, column: 0.1% sp-1000, 80/100 mesh Carbopak - C column Column temp. - 150°C Detector temp. - 160°C Injector port temp. - 100°C Carrier gas - nitrogen 20ml/min Hydrogen flame ionization detector
	Gas detector tube pump w/gas detector tube	Gas detector tube
Methylene Bisphenyl Diisocyanate (MDI)	Midget impinger/15 ml absorbing solution at a flow rate of 1 1pm	Colorimetric (NIOSH P&CAM 142 method)
	Model 4000 Miniature Continuous Monitor	Series 4100 MCM integrating reader/recorder
Furfuryl alcohol	MIRAN gas analyzer	MIRAN gas analyzer wavelength - 9.8 μm pathlength - 9.75 meters slit setting - 1

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(continued).

Table VII-1 (continued).

Chemical or physical agent	Sampling procedure	Analytical procedure
Acrolein	Carbon adsorption	Gas chromatography; Column: 0.1% sp - 1000, 80/100 mesh carbopak - C column column temp. - 100°C injector temp. - 100°C detector tempt. - 160°C carrier gas - nitrogen 30 ml/min hydrogen flame ionization detector
Hydrogen sulfide Formaldehyde Ammonia	Gas detector tube pump w/gas detector tube	Gas detector tube
Heat/radiant heat	Heat stress instrument	Wet bulb, dry bulb, and black globe thermometers.
Noise	Sound level meter, noise dosimeter	Frequency analyzer, Band pass filter set, Level recorder, and Statistical distribution analyzer

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Table VII-2. Equipment list.

1. Atomic Absorption Spectrophotometer--
    Perkin Elmer model 403.

2. Gas Analyzer--
    MIRAN model IA, single beam, variable filter, spectrophotometer, scanning
    the infrared spectral range of 2.5 to 14.5 microns, in conjunction with
    a 5.6 liter capacity cell whose path length is variable from 0.75 to
    20.25 meters.

3. Carbon Monoxide Analyzer--
    Ecolyzer, series 2000.

4. Pumps (Personal Samplers)--
    Bendix model BDX 44 Super Samplers w/BDX99 respirable dust sampler or
    BDX 88 charcoal tube holder.

    MSA model G sampler w/cyclone assembly.

    MSA model S sampler w/cyclone assembly or midget impinger.

5. Pumps (High Volume)--
    Gast 1/3 horsepower rotary vane vacuum pressure pump.

6. Gas Chromatograph--
    Perkin Elmer model 3920B with flame ionization detector and an attendent
    Sigma 10 data handling system.

7. MDI Sampler--
    MDA Scientific, Inc., model 4000 Miniature Continuous Monitor.

8. Gas Detector Pump--
    National Draeger model 31.

9. Gas Detector Tubes--
    National Draeger.

10. Spectrophotometer--
    Bausch and Lamb spectronic 100.

11. Velometer--
    Alnor series 6000-P.

12. Thermoanometers--
    Alnor model 8500 with model 1520-24" probe.

13. Psychrometer--
    Model 566 Bendix Psychron.

Table VII-2 (continued).

14. Heat Stress Instrument--
    Yellow Springs Instrument Company Incorporated, Heat Stress Instrument.

15. Respirable Dust Monitor--
    GCA/Technology Division, RDM 101.

16. Sound Level Meter--
    Brüel and Kjaer model 2209.

17. Noise Dosimeter--
    Brüel and Kjaer model 4425.

18. Frequency Analyzer--
    Brüel and Kjaer model 2121.

19. Band Pass Filter Set--
    Brüel and Kjaer model 1614.

20. Level Recorder--
    Brüel and Kjaer model 2305.

21. Exposure Monitor--
    Brüel and Kjaer model 166

22. Statistical Distribution Analyzer --
    Brüel and Kjaer model 4420

concentration of contaminant to be sampled. Since low contaminant levels were expected, longer sampling times were generally used.

Full-shift samples were normally taken but, when this was not possible or practical, shorter samples were taken. When free silica was measured, the minimum required sample catch was set at 10 micrograms so that subsequent analyses would be significant. There was usually no problem obtaining this amount of free silica during the sampling.

The significance of air sampling results is limited to a certain degree by three factors:

1. Limitation in isolating variables - Many sources of contamination were isolated sufficiently to allow evaluation of the effectiveness with which a particular measure controlled the source hazard under normal operating conditions. However, in some cases, adjacent processes and work practices interfered with an accurate assessment of the function of a particular engineering control. Efforts were not made to eliminate these interferences, for example, by temporarily shutting down adjacent processes. The agreement made with the participating foundries concerning the methods of the study dictated that no special conditions would be placed on the foundry which could disrupt production. Although the effect of each particular contaminant source on breathing zone and background levels could not always be isolated, care was taken to document the existing conditions, listing all potential sources of exposure.

2. Limitation of time - When possible, three replications of each sample were taken. The extent of sampling was limited by the necessity to restrict all of the evaluations within a particular plant to a period of several days at most. Sampling data was supplemented by the plant's own data whenever possible.

3. Limitation of not performing measurements throughout complete weather cycles - Many plants experience variability in worker exposure levels because of changes in general ventilation. The degree of closure of buildings, as well as the magnitude and direction of air currents can cause a range of exposure to occur throughout the year, even with identical process conditions. Repeat sampling was not performed during the hottest and coldest times of the year at each plant. However, the general ventilation was scrutinized during the survey and notation was made if some aspect of general ventilation would probably cause problems at some other time of the year.

Airflow Measurements

The effectiveness of environmental controls was determined principally by assessing the design configuration of control measures, exhaust air volumes, and also ventilation patterns throughout the affected area.

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During the course of the assessment, control configurations were sketched or a photograph was taken to be included in the text. Ventilation patterns within the building which affected the efficiency of the control under observation were carefully noted and measured. Measurements of exhaust and makeup air volumes were also made where possible. When accurate measurements could not be made, with mancooler fans and roof exhaust fans for example, design specifications of the air movers were obtained. When appropriate, these measurements were compared to those recommended by the ACGIH.

Two measuring techniques were used to determine exhaust air flow rates from hoods:

1. Duct traverses - were made to determine total exhaust volumes.

2. Face velocities - were taken to determine the approximate indraft velocities, as well as total exhaust volumes when duct traverses were not possible.

HEAT STRESS SAMPLING

Measurements were made to enable a calculation of the Wet-Bulb Globe Temperature Index (WBGT), as well as other indices such as the Belding and Hatch Heat Stress Index (HSI).

Black Globe Temperature

Black globe temperatures were measured using a globe thermometer, consisting of a 6-inch (15 cm) diameter hollow copper sphere, painted on the outside with a matte black finish.

Air Temperature and Wet Bulb Temperature

Air temperature (dry bulb) was determined with a shielded thermister. Wet-bulb temperatures were determined with a stationary thermister covered by a moist wick.

Air Velocity

Air velocities were measured using a nondirectional thermoanemometer.

NOISE SAMPLING

Dosimeter Measurements

The purpose of these measurements was to determine the employee's cumulative noise exposure from the selected processes. The Noise Dose Meter (dosimeter) was placed on the operator in some convenient location (on the belt, shirt, pocket, etc) and, using the microphone extension cable, the microphone was located as close to the operator's ear as possible. The dosimeter remained on the operator for 6-8 hours and was calibrated immediately before and after each measurement period.

The dosimeter readout was in terms of the percent of the allowable exposure and was adjusted for the exact measurement time. Per agreement with the Project Officer, the exposure was compared to the OSHA standards in existence at the start of the in-plant study.

Sound Level Meter Measurements

The purpose of sound level meter measurements was to determine the range of sound levels generated by the selected processes, to determine true peak levels, and to verify that the levels were such that an exposure as determined by the dosimeter was possible. In addition, the sound was recorded on a precision tape recorder for analysis in the laboratory.

During the 6-8 hour period in which the dosimeter was being worn by the operator of the process, sound level measurements, tape recordings and documentation of the process were made. The following information was recorded on separate data sheets during each measurement:

1. Slow response range dBA.
2. Fast response range dBA.
3. Average slow response dBA.
4. Date, time.
5. Description of operation.
6. Other factors of sources affecting noise level.

The Sound Level Meter (SLM) was hand-held as close to the operator's ear as was practical; his normal operations were not interfered with. After several SLM measurements, a decision was made as to what was a "typical operation" and a tape recording of the noise generated was made (about 10 minutes).

Analysis of Tape Recordings

Tape recordings were used to obtain either octave or 1/3 octave frequency spectrums, and to obtain the percent of times at the various noise levels generated by the specific processes. These spectrums, which were used to more completely document the process, shed some light on other possible controls and helped identify any significant noise sources. The tape recorded signals were played through the analysis equipment after returning to the laboratory. The sound pressure level (unweighted) versus frequency was plotted for each process. In addition, octave band analysis was used in conjunction with the other instruments to obtain the percent of time at the various dBA levels.

SECTION VIII
PROCESS-HAZARD-CONTROL INDEX

INTRODUCTION

The purpose of this section is to summarize the hazards associated with the
26 foundry processes studied and to list and describe the control methods
evaluated during studies in 24 foundries or found in the literature.

Worksheets for each process are presented on two adjacent pages. The format
for the worksheets is described on the example worksheets presented on the
next two pages. The worksheets are organized by foundry area. A listing
of and page references to the processes are provided in the table of contents.

PROCESS/HAZARD/CONTROL INDEX

PROCESS: Process title

PROCESS DESCRIPTION: The purpose and scope of this process.

FOUNDRY AREA: The major foundry operation or system of
which this process is a part.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Chemical agents (air contaminants) and physical agents (noise, heat stress, radiation, etc) that may constitute workplace hazards are identified.	The point of origin of the agent is identified and, where known, the mechanisms for escape of the agent into the workplace environment are described.	A.	Control methods documented during the field studies or in the literature are identified and briefly described. Controls for air contaminant hazards appear first, followed by heat and noise controls. Classification of each control method, as well as its advantages and limitations, are presented on the adjacent page. In addition to the control methods studied or found in the literature, a few other methods are listed in this column. These represent obvious approaches, controls which have been seen but not documented, or techniques which have been evaluated for control of other processes and are worthy of consideration for the process at hand.	Reference to the number of the case history in Appendix A. Page listings for the case histories can be found in the table of contents.	Litera-ture citation found in Refer-ences follow-ing this section.

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CONTROL METHOD EVALUATION

PROCESS: Process title as above

Engineering control			
Item	Type	Advantages	Limitations
A. See oppo- site page for con- trol des- crip- tion.	Classification of control methods according to categories defined in Section VI.	Benefits derived from applying this method. Typical examples are: Multiple hazards can be controlled (air contaminants, noise, and heat). Conserves raw materials. Energy effective method. Reduces human exertion. Facilitates subsequent processing. Constructed of commercially available components. Reduces housekeeping. Rugged design, suitable for foundry use. Provides worker comfort. Basic design has many applications.	Restraints in applying this method. Typical examples are: Can adversely affect the process. Only useful in restricted situations. May encumber the operator or disrupt production. Interferences limit its use. Requires expensive materials or systems. Subject to damage or misuse. Subject to disruptive influences, e.g., crossdrafts. Creates new hazards.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Manual gate, riser, sprue removal, and casting sorting

FOUNDRY AREA: Cleaning and finishing of ferrous castings

PROCESS DESCRIPTION: Sprues, gates and risers are removed from castings using hammers (done on conveyors for small castings and on the floor for large castings). Castings are sorted into hoppers.

Hazard			Engineering control		
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	Residual dust on castings becomes airborne during: Processing on conveyors-- 1. Unloading of castings onto conveyor. 2. Vibratory conveying of castings. 3. Discharge of debris from conveyor into hopper. 4. Hammering castings. 5. Throwing castings into sorting bins. Processing on the floor-- 1. Unloading of castings onto floor. 2. Dust from loose materials on floor re-entrained by workers and fork lift trucks. 3. Hammering casting. 4. Pickup and removal of castings from area.	A. B. C. D. E.	Precleaning of castings by tumbling or shot blasting to remove adhered dust and sand prior to handling and processing. Downdraft mesh belt conveyor to capture dust at the source; used with partially enclosing hoods at casting unloading point and debris discharge point from conveyor. Fresh, tempered air blown directly on workers to provide general ventilation and worker comfort. Substitution of nonsilica sands in molding and coremaking. Allowing castings to cool prior to handling.	1 1, 2, 3	20 25
Heat.	When castings are handled immediately after shakeout, the heat problem can be severe.				
Noise.	Noise is generated by many parts of this process. Impact noises are generated by castings hitting steel conveyors during loading and unloading, castings hitting others as they are thrown into bins, and as the hammers hit the castings during gate, riser and sprue removal. Noise is generated from casting resonances as a result of hammer impacts and from vibratory conveying of castings. Generally these noises are close to or above the allowable and casting resonances are the loudest. In some rare cases, single impacts can be above the allowable limit.				

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CONTROL METHOD EVALUATION

PROCESS: Manual gate, riser, sprue removal, and casting sorting

		Engineering control	
Item	Type	Advantages	Limitations
A.	Process substitution.	Not only can remove dust but also adds to casting cooling time, thus helping to eliminate a source of heat for the workers.	Dry types of precleaning leave residual fine dust particles on the casting which may present a dust hazard. Tangling of castings may occur in tumbling machines. This method may reduce the density of the batch, lowering production, and increasing abrasive wear on machine components.
B.	Equipment substitution and ventilation at source.	Exhaust very close to source of airborne dust; continuous removal of loose sand and dust; sand can possibly be saved and recycled back into system; can reduce conveyor-casting noises; can be inclined.	Large head and tail pulleys may cause problems in layout where one conveyor is transferring to another. Heavy sledging cannot be performed on conveyor.
C.	General ventilation.	Fresh air supplies can cool workers, as well as provide high quality air in the breathing zone.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.
D.	Material substitution.	See sand preparation, Item C.	See sand preparation, Item C.
E.	Isolation in time.	Eliminates severe heat problem.	In many operations, sprue, gate, and riser removal immediately follows shakeout. If cooling time is to be provided, castings must be stored (requiring additional equipment and space).

PROCESS/HAZARD/CONTROL INDEX

PROCESS: Grinding and abrasive cutoff

FOUNDRY AREA: Cleaning and finishing of ferrous castings

PROCESS DESCRIPTION: Abrasive wheels or saws may be suspended from mobile frames which are positioned manually or automatically to remove metal from castings, especially appendage stubs or to cut off gates, risers, and sprues.

Hazard			Engineering control		
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	Residual dust on casting after shakeout or precleaning (if done) becomes airborne during handling and processing.	A.	Precleaning of castings by tumbling or shot blasting to remove loose dust and sand prior to handling and processing.		20
	Dust is generated during the grinding process, containing both free silica (from burn-on) and metals.	B.	Reducing the amount of burn-on caused by metal penetration through improved casting techniques.		18
Noise.	Noise is generated by both the machine and the action of the grinding wheel on the casting. Machine noise is generally below the allowable, but noise generated by the grinding wheel on the casting is sometimes above the allowable limit.	C.	Ventilation control at the source:		
			1. Close-fitting hood attached to swing frame.	4	19
			2. Swing frame grinder booth.		17 (VS-414, 401)
		D.	Fresh, tempered air supply blown directly on workers to provide dilution ventilation and worker comfort.	1, 2, 3	
		E.	Isolation and remote control of the process.		27
		F.	Substitution of nonsilica sands in molding and coremaking.		25

CONTROL METHOD EVALUATION

PROCESS: Grinding and abrasive cutoff

		Engineering control	Limitations
Item	Type	Advantages	
A.	Process substitution.	See manual gate, riser, sprue removal, and casting sorting, Item A.	See manual gate, riser, sprue removal, and casting sorting, Item A.
B.	Process substitution.	Reduction in burn-on reduces the amount of finishing required as well as a source of respirable silica.	Mechanisms for metal penetration into molds and cores are not well understood and difficult to control.
C1.	Ventilation at source.	This commercially available hood can capture dust induced in the grinding swarf immediately after it is generated. The direction of the grinding swarf is quite predictable and there is little interference preventing direct capture. The required air flow is low because the grinding swarf is not given a chance to induce much additional air.	The attachment of mobile ductwork to the frame may increase the effort required by the operator to move the grinder. The adjustable chute of the hood requires periodic adjustment during operation to accommodate changes in grinding wheel sizes.
C2.	Ventilation at source.	Effective in controlling dust when properly designed and with the grinding operation occurring close to the face opening. Provides no additional encumbrance for the operator in terms of weight added to the grinder frame.	This method uses a large amount of exhaust air. Provisions must be made in the booth design for accommodation of hoists and other casting handling methods. Cleaning of accumulated grinding debris from the hood poses a dust hazard.
D.	General ventilation.	Fresh air supplies can cool workers, as well as provide high quality air in the breathing zone.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.
E.	Isolation with a physical barrier and ventilation.	Eliminates human exertion. The noise could be effectively controlled by an enclosure. Can clean curved, as well as flat surfaces, and at considerably higher pressures than can be applied manually.	Is best suited to production facilities; requires different fixturing for each different operation.
F.	Material substitution.	See sand preparation, Item C.	See sand preparation, Item C.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Floorstand grinding

FOUNDRY AREA: Cleaning and finishing of ferrous castings

PROCESS DESCRIPTION: Grinding of castings using abrasive wheels on floorstand grinders for stock removal, surface finish, and production of accurate casting dimensions. Grinding speeds usually vary between 9500-18,000 sfpm (48-92 surface m/sec).

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	Residual dust on casting after shakeout or precleaning (if done) becomes airborne during handling and processing.	A.	Reducing the amount of burn-on caused by metal penetration through improved casting techniques.		18
	Dust is generated during the stand grinding process, containing both free silica (from burn-on) and metals. Grinding dust is entrained by the wheel to be stripped off by the casting. The dust is propelled against the body of the operator and freely enters his breathing zone.	B.	Reducing the amount of required grinding by designing gates to provide the smallest stub area possible; use of breaker cores to notch the point of riser contact with the casting.		
		C.	Precleaning of castings by tumbling or shot blasting to remove adhered dust and sand prior to handling and processing.		20
Noise.	Noise is generated by both the machine and the action of the grinding wheel on the casting. Machine noise is generally below the allowable, but noise generated by the grinding wheel on the casting is sometimes above the allowable limit.	D.	Ventilation control at the source, using:		
			1. Conventional hoods.	3	17
			2. Modifications to conventional hoods.		22, 35
		E.	Fresh, tempered air supply blown directly on workers to provide dilution ventilation and worker comfort.	1, 2, 3	
		F.	Substitution of nonsilica sands in molding and coremaking.		25

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CONTROL METHOD EVALUATION

PROCESS: Floorstand grinding

Engineering control			
Item	Type	Advantages	Limitations
A.	Process change.	Reduction in burn-on reduces the amount of finishing required, as well as a source of respirable silica.	Mechanisms for metal penetration into molds and cores are not well understood and difficult to control.
B.	Process change.	Reduces amount of grinding necessary, thus reducing dust generated.	
C.	Process change.	See manual gate, riser, sprue removal, and casting sorting, Item A.	See manual gate, riser, sprue removal, and casting sorting, Item A.
D.	Ventilation at source.		The conventional hood (without modifications) cannot satisfactorily deal with the problem of dust recycling with the wheel and thus the more free silica present and the higher the production, the less this method is able to provide breathing zone protection.
E.	General ventilation.	Fresh air supplies can cool workers, as well as provide high quality air in the breathing zone.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.
F.	Material substitution.	See sand preparation, Item C.	See sand preparation, Item C.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Chipping and grinding using portable tools

PROCESS DESCRIPTION: Portable chipping hammers, grinders and polishing devices are used to remove excess metal from castings and to finish the casting surface.

FOUNDRY AREA: Cleaning and finishing of ferrous castings

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	Residual dust on casting after shakeout or precleaning (if done) becomes air-borne during handling and processing.	A.	Reducing the amount of burn-on caused by metal penetration through improved casting techniques.		18
	Dust is generated during the chipping and grinding processes, containing both free silica (from burn-on) and metals.	B.	Reducing the amount of required grinding by designing gates to provide the smallest stub area possible; use of breaker cores to notch the point of riser contact with the casting.		
	The nature of the process and the bio-mechanics of body forces causes the worker's breathing zone to be very close to the dust generation point. In many cases the operator kneels, sits or stands very close to the casting, perhaps even on top of or inside it.	C.	Precleaning of castings by tumbling or shot blasting to remove adhered dust and sand prior to handling and processing. Improved removal of materials adhered to casting surfaces after precleaning and during the cleaning process.		20
	Work practices associated with the chipping and grinding process can also be dust-producing:	D.	Ventilation control.		
			1. Downdraft benches.	2	19
	1. Cleaning of castings with air nozzles.		2. High-velocity, low-volume (HVLV) tool hoods.	2	19
	2. Dressing of portable grinding wheels at the work station.		3. Retractable ventilated booth.		27
			4. Mobile extraction hoods.		27
Noise.	Noise is generated by the tools and the action of the tool on the casting. Generally, with newer tools, the noise generated by the tool on the casting is the loudest.	E.	Eliminating the turbulence caused by the compressed air discharge from portable tools through exhaust fittings and hoses.		
		F.	Fresh, tempered air blown directly on workers to provide dilution ventilation and worker comfort.	1, 2, 3	
		G.	Substitution of nonsilica sands in molding and coremaking.		25
		H.	Some tool noise can be reduced or eliminated by mufflers (pneumatic tools) and "quieter designed" tools.		20, 43

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CONTROL METHOD EVALUATION

PROCESS: Chipping and grinding using portable tools

		Engineering control	
Item	Type	Advantages	Limitations
A.	Process change.	Reduction in burn-on reduces the amount of finishing required, as well as a source of respirable silica.	Mechanisms for metal penetration into molds and cores are not well understood.
B.	Process change.	Gating improvements facilitate appendage removal, as well as reducing the amount of grinding to remove stubs.	This technique is generally more practical in iron casting because of lower shrinkage characteristics. Many times it is impossible to accomplish this in a steel foundry.
C.	Process change.	See manual gate, riser, sprue removal and casting sorting, Item A.	See manual gate, riser, sprue removal and casting sorting, Item A.
D.	Ventilation at source.	1. Downdraft benches-- • Produces a minimum of process disruption; especially suited for small to medium-sized castings; commercially available.	Difficulty in protecting breathing zone during all conditions; has problem with internal grinding. Much dust escapes because the variable swarf is directed at the bench only a portion of the time.
		2. HVLV-- Close-fitting hoods on tools have their greatest potential for providing breathing zone control during finishing of large relatively flat castings; can be used with other ventilation methods; is a very air-effective exhaust method.	No practical chipping hoods are presently available; hoods may interfere with some operations; hood capture is sensitive to tool position. Worker cooperation is needed.
		3. Retractable Ventilated Booth-- Designed for castings too large for benches.	Handling of castings is more difficult than with other methods. Power assistance is probably required to move the retractable hood into place.
		4. Mobile Extraction Hoods-- Permit relocation of the hood to be in line to capture the grinding swarf directly.	Constant reorientation of the hood is prohibitive.
E.	Equipment change.	Reduces air noise, as well as eliminating turbulence near the dust generation point. Can be retrofitted to many existing tools; available on some new tools.	
F.	General ventilation.	Fresh air supplies can cool workers as well as provide high quality air in the breathing zone.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood
G.	Material substitution.	See sand preparation, Item C.	See sand preparation, Item C.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Shot blasting and tumbling

FOUNDRY AREA: Cleaning and finishing of ferrous castings

PROCESS DESCRIPTION: Castings are loaded into drums which are rotated to knock off flashing and sharp edges; sometimes tumbling stars are used for additional cleaning. Shot blasting, to remove adhered materials from casting surfaces and provide a suitable surface finish, is done predominantly in enclosed automatic machines, but also in hand-operated enclosed cabinets and hand-operated units within the enclosed rooms.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Dust containing respirable silica and metals.	Residual dust on casting after shakeout is liberated during loading of tumbling and shot blasting machines. Dust can be emitted during process operation if there is insufficient sealing and ventilation of the chamber or of the shot handling and shot-sand separation system (blast equipment). The discharge of debris from the shot-sand separator into hoppers is a dusty process.	A.	Preventive maintenance: 1. Shot-sand separator. 2. Coarse debris screen. 3. Chamber seals. 4. Dust collector pulsing or shaking cycle.		
		B.	Enclosed debris chutes and hoppers from shot-sand separators.		17 (VS-303)
	If the chamber is not properly purged of dusty air during operation, dust can be emitted during chamber opening and unloading.	C.	Substitution of nonsilica sands in molding and coremaking.		
		D.	Noise isolated by total enclosure of a tumbling mill.	30, 31	37, 38, 43
Noise.	As the castings are tumbled, they hit each other and generate noise.				

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CONTROL METHOD EVALUATION

PROCESS: Shot blasting and tumbling

		Engineering control	
Item	Type	Advantages	Limitations
A.	Preventive maintenance.	Eliminates major sources of dust problems with equipment. A properly functioning shot-sand separator will prevent dust from being recycled back into the machine by the shot projecting device.	A well-maintained shot-sand separator reduces maintenance costs and also cleaning time.
B.	Isolation with a physical barrier.	Can contain dust emitted during falling of materials. If chute is sealed to hopper, ventilation is probably not required.	
C.	Material substituion.	See sand preparation, Item C.	See sand preparation, Item C.
D.	Isolation.	Standard building materials can be used in the construction. Some manufacturers have retrofit kits for quieting relatively current machine models.	The operators could still be exposed to the noise if they are required to enter an enclosure. Heat and dust buildup within an enclosure can be a problem. Enclosure could interfere with loading and unloading.

PROCESS/HAZARD/CONTROL INDEX

PROCESS: Arc-air gouging and cutting

FOUNDRY AREA: Cleaning and finishing of ferrous castings

PROCESS DESCRIPTION: The arc-air process utilizes a copper-clad graphite electrode in an arc welding machine with an air lance to remove metal around casting defects in preparation for repair by welding (steel castings).

Hazard			Engineering control		
Agent	Source	Item	Description	Case history	Ref.
Copper and iron oxide fume, (possibly other metals such as manganese, chromium, and nickel depending on alloy percentages).	Copper fume is generated from the copper coating on the electrode. Iron oxide is generated from the base metal. The breathing zone of the arc-air operator is very close to the fume generation point.	A.	Backdraft hood on a bench and air supply behind the worker during processing of small castings.	6	
		B.	A ventilated booth with supply air and a motorized turntable for positioning large castings.	6	
		C.	Booth curtains to shield ultraviolet light and metal splashing from adjacent work areas and operators.	6	
Heat and ultra-violet light.	Created by the arcing process and heat buildup in the casting.				
Noise.	The noise is generated as a result of the combination of air and electric arc. Noise levels are generally significantly above the allowable limit (43).				

CONTROL METHOD EVALUATION

PROCESS: Arc-air gouging and cutting

		Engineering control	
Item	Type	Advantages	Limitations
A. & B.	Ventilation at source	Booth isolates fume from general plant areas. Fresh air supply blown directly on workers provides dilution ventilation and cooling.	The effectiveness of the booths seems to be dependent on work practices, but which practices aid or detract from the effectiveness is not established. Effective use of ventilated booths requires exacting control of: 1. Orientation of fume source between worker and exhaust point. 2. Air blast directed as much as possible toward the exhaust point. Casting loading and unloading must be an integral part of booth design. An upper limit exists as to the casting size which can be handled.
C.	Isolation with a physical barrier.	Cross-drafts are reduced by curtains.	Opaque curtains detract from surveillance of the operation for safety's sake.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Torch cutoff

FOUNDRY AREA: Cleaning and finishing of ferrous castings

PROCESS DESCRIPTION: Torch cutoff involves the use of an oxy-acetylene torch with an air lance to cut large risers off of castings and also to cut scrap castings in half for recharging into melting furnaces.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Iron oxide fume, (possibly other metals such as manganese, chromium, and nickel depending on alloy percentages).	Substantial quantities of fume are generated from the base metal when the metal becomes molten. The air stream aids the oxidation and also acts to violently disperse the fume.	A.	A large exhausted and air supplied booth to control fuming.	5	
		B.	Modified torch nozzles are available to reduce the noise.		37
Heat and intense visible radiation.	Created at the point of cutting and from heat buildup in the casting.				
Noise.	As the gases rush out of the nozzle and burn, noise is generated. The majority of the noise occurs with the addition of oxygen for cutting. Generally, the noise levels are above the allowable.				

CONTROL METHOD EVALUATION

PROCESS: Torch cutoff

		Engineering control	
Item	Type	Advantages	Limitations
A.	Ventilation at source.	Booth isolates fume from general plant areas. Fresh air supply blown directly on workers provides dilution ventilation and cooling.	Effective use of ventilated booths requires exacting control of: 1. Orientation of fume source between worker and exhaust point. 2. Air blast directed as much as possible toward the exhaust point. Casting loading and unloading must be integral part of booth design.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Sand preparation

FOUNDRY AREA: Green sand systems

PROCESS DESCRIPTION: Mixing or mulling of recycled and new sand with clay, water and other additives. Mulling is done in batches or continuously by a rolling, grinding, rubbing, or stirring action.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	Airborne dust is created during the filling of the mixer with sand, binders, and additives and during the mixing process. Many fine dust particles are present in the recycled sand. During mixer emptying there is little dust hazard because the fine dust particles are agglomerated due to the moisture content. Granular particles of sand, consisting of free silica (SiO_2) or combined silica (silicates), comprise 50-90% of the molding material. Sands utilized for molding may be broadly classified as bonded or unbonded silica sands, and nonsilica sands. Bonded silica sands are naturally occurring deposits that contain 5% to 30% AFS Clay Content. In some instances bonded sands are used for molding in the as-mined state, with the addition of water only. Unbonded silica sands are washed and dried sands that contain less than 5% AFS Clay Content. Most unbonded sands have greater than 98.5% silica (SiO_2) Content. Unbonded sands, in many instances, are used as base sands in "synthetic sands", formulated to a desired characteristic by mixing unbonded sand with other materials. Sands such as olivine, zircon, and chromite contain very little free silica in the refined state in the order of 1% or less. Binders and additives are also sources of respirable dust, metal oxides, and even free silica. Some clay binders are composed entirely of clay whereas others contain admixtures of quartz, pyrite, and organic matter.	A. B. C. D. E.	Automatic bond feeding to eliminate a dusty manual process. Control of dust at the source by: 1. Mixer or muller exhaust. 2. Partially enclosing hood around bond chute on muller. 3. Enclosing exhaust hood at bag-breaking and storage hopper. Substitution of olivine, zircon or chromite sand for silica sand to reduce the free silica hazard. Pneumatic conveying of new sand and blending and conveying of additives from outdoor silos to a hopper above the muller. Properly distributed fresh, tempered air for dilution ventilation and cooling.	• 7	17 (VS-107 108,304) 25 32

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CONTROL METHOD EVALUATION

PROCESS: Sand preparation

		Engineering control	
Item	Type	Advantages	Limitations
A.	Equipment substitution.	Eliminates manual operation of transfer from hoppers using a scoop, which produces dust.	
B.	Ventilation at source.	Easily incorporated into enclosed mixing situations, including those where manual bond addition is required.	When weigh hoppers are used to feed muller, ventilation at the source of the muller feeding operation may be difficult without undue interference. Moisture and steam along with clays may cause plugging of ductwork.
C.	Material substitution.	The use of nonsiliceous materials results in low airborne free silica levels and resulting high allowable exposure levels approaching nuisance dust.	Contamination of these sands with silica sand from cores reduces the potential for hazard reduction. Alternate sands are expensive and not as available as silica sand. Toxicity not completely evaluated.
D.	Equipment substitution.	Pneumatic conveying is applicable to many foundry dry material handling operations. Uses only a fraction of the exhaust that conventional dry material handling equipment requires. Exhaust is only required at material transporter unit and destination points. No exhaust is required along the transport path. This can resolve ductwork problems and facilitate foundry layout. Long or short runs all have the same exhaust requirement. Can significantly improve housekeeping, eliminate fork lift operations, reduce waste. Metering of the various bond materials at the proper percentages can be accomplished automatically in a blender.	From experience, several problems may arise during operation which should be given attention: 1. Compressed air must be dry. 2. Augers, rather than air slides are needed to get fireclay out of silos. 3. Backup feed system using a bag breaker may be necessary. 4. Load cells need to be kept warm and clean.
E.	General ventilation.	Can eliminate the need for man-cooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.

PROCESS/HAZARD/CONTROL INDEX

PROCESS: Molding

FOUNDRY AREA: Green sand systems

PROCESS DESCRIPTION: Filling and packing of mold materials against a pattern. Varieties of equipment include: jolt-squeeze machines, automatic mold machines, slingers, and molding and compacting by hand.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	Moist sand emits little dust. The hazard occurs when the sand is allowed to dry. Examples of situations where dry sand would be particularly hazardous include: 1. Flask filling on jolt-squeeze machines-sand discharges from a hopper immediately overhead and in front of the operator, freely falls past his breathing zone. 2. Sand spillage building up around mold machines. 3. Sand slingers - slinging sand at high speed can cause release of fines when the sand impacts the flask and pattern. This hazard is especially high where the operator is immediately adjacent to the slinging head. 4. Portable vibrators - agitation of the sand during manual ramming of mold materials. Silica flour may also present a hazard.	A.	Control of dust emission by monitoring moisture content of sand by: 1. Properly cooling sand before mulling. 2. Restricting storage time of prepared sand.		
		B.	Spill pits under mold machines to collect and remove overspill.	7	
		C.	Isolation of slinger operator from head of slinger through remote controls.	7	
		D.	Exhaust close to flask during sand slinging to remove fugitive dust.	7	
		E.	Substitution of nonsilica sands to reduce toxic hazard.		
		F.	Properly distributed fresh air for dilution ventilation.		
Noise.	Many of the operations or components associated with molding generate noise. Some are: 1. Jolting. 2. Squeeze (ram). 3. Vibrators. 4. Air nozzles.	G.	Noise reduction by substituting quiet tool or piece of equipment for a loud one. Quiet components include: 1. Squeeze (ram) devices. 2. Hopper and pattern vibrators. 3. Air nozzles. 4. Exhaust air mufflers.	35	37, 39

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CONTROL METHOD EVALUATION

PROCESS: Molding

Engineering control			
Item	Type	Advantages	Limitations
A.	Process monitoring.	The cooler the sand during preparation the more consistent will the moisture content be at the molders.	
B.	Equipment substitution.	A spill pit permits the quick removal of sand spillage before the sand has a chance to dry out; reduces housekeeping; facilitates molding machine operation and maintenance.	Spill pit conveyor systems could be a source of dust.
C.	Isolation by distance.	Isolation of a slinger operator to a remote station is feasible whereas ventilation control at the source between the operator and the slinger head may not be. If necessary, the remote operator may be enclosed within a ventilated booth.	While providing a measure of control for the slinger operator, this method does not protect the other mold assembly people who may be working close to the point of slinging.
D.	Ventilation at source.	Provides protection for the other workers in the area, as well as the slinger operator.	It is only practical where the slinger sand filling position is fixed; not feasible for mobile slingers, e.g., on tracks. It is difficult to find a location where dust can be captured and the hood is not susceptible to clogging with sand.
E.	Material substitution.	See sand preparation, Item C.	See sand preparation, Item C.
F.	General ventilation.	Can eliminate the need for mancooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.
G.	Equipment substitution.	Noise reduction can be achieved at the source with commercially available components.	The loudest noise, from jolting, is not reduced using this combination of quiet components. Elastomer pads can reduce jolting noises, however, they also reduce the jolting force and wear out quickly.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Shakeout

FOUNDRY AREA: Green sand systems

PROCESS DESCRIPTION: Castings are separated from mold materials by vibrating or tumbling the mold. The castings, along with large lumps and excess metal remain on top, while fine materials feed through holes in the shakeout and are transported away. Shakeout may be automatic or it may require manual operations of loading and unloading.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	Dust is emitted by the violent action of the shakeout process. Dust and steam are driven upward in the thermal draft. Many fine dust particles are emitted especially from the mold materials which were in direct contact with the casting during pouring and cooling. Besides emissions from the shakeout table, dust can also escape the receiving hopper through the gap between shakeout and hopper. The dust hazard at shakeout relates directly to the dryness of the mold materials. Laboratory studies measuring the concentration of dust emitted from sand samples containing varying percentages of water demonstrated that as the moisture content was lowered below 1.8%, dust emissions during agitation of the sample rose dramatically (23). Sand spillage around shakeout is common. When the flask is too large for the shakeout, an inordinate amount of mold materials are deposited around the shakeout. Even spill pits are usually insufficient to collect this spillage. As a result, the shakeout operator spends substantial amounts of time shovelling sand, a dusty process.	A. B. C. D. E. F.	Control of shakeouts using total enclosures: 1. Air contaminants. 2. Noise. Partial enclosure of a mold dumpoff conveyor on a pallet line. Sidedraft or double sidedraft hood for a shakeout loaded by overhead crane. Enclosing mobile hood for manual loading and unloading across rows of mold conveyor lines. Substitution of nonsilica sands for mold and coremaking. Properly distributed fresh, tempered air for dilution ventilation.	8 33 13 7 15	17 (VS-110, 112) 37,38,43 17 (VS-110, 112) 25
Mold decomposition products.	Mold and core decomposition products are emitted during shakeout of hot molds (See mold pouring and cooling).				
Noise.	Combination of machinery noise and conveyor-part noise.				

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CONTROL METHOD EVALUATION

PROCESS: Shakeout

		Engineering control	
Item	Type	Advantages	Limitations
A1.	Ventilation at source.	Fully automated shakeout enclosures can be ventilated effectively with a minimum of air.	
A2.	Isolation with a physical barrier.	Noise is controlled at the source. Operation not significantly affected. Design concepts could be used for many types of shakeout and other process enclosures.	May not be applicable to shakeouts where hot castings are handled. Some problems might be: a. Temperature inside may get too high for mechanical components. b. Sound absorbing materials may be burned. May be difficult to repair conveyor, if repairs become necessary.
B.	Ventilation at source.	This hood technique can be improved to be more air-effective by providing counterweighted, swinging doors or curtains which are only opened at the point of dumping.	If a partially enclosed hood is used along a long length of conveyor, a substantial amount of exhaust is needed.
C.	Ventilation at source.	This hood can protect operators during loading and unloading operations where the workers are required to work immediately adjacent to the shakeout.	Requires careful flow balancing to assure that indraft is uniform across the hood. This hood is subject to damage from flasks hitting it; subject to cross-drafts; does not provide any noise protection.
D.	Ventilation at source.	Mobility of hood permits shakeout at adjacent conveyor lines using a minimum of exhaust.	Does not provide noise protection.
E.	Material substitution.	See sand preparation, Item C. •	See sand preparation, Item C.
F.	General ventilation.	Can eliminate the need for man-cooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Return sand transfer, processing, and storage

FOUNDRY AREA: Green sand systems

PROCESS DESCRIPTION: Recycled sand is transferred back to the muller for recycle using mechanical conveying equipment (belt and vibrating conveyors, bucket elevators). Storage is usually in sloped-bottom, automatic feed hoppers.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	Dust particles are liberated during the agitation and motion of the materials during transport and processing. The dust hazard from dry sand processing and transport exists throughout the entire system, along conveyors, as well as during sand transfer and processing. Sand spillage may also constitute a secondary, but still major, source of dust. Sand spillage is common around belt conveyors, especially at sand transfer points. Often this spillage occurs on elevated foundry levels directly above the muller. Spillage builds up on equipment and building structures until it reaches the angle of repose. Any further spillage "rains" down, causing a potential over-exposure problem for the muller operator.	A.	Schumacher sand process system to eliminate the necessity for local exhaust of dry sand operations by blending the dry sand with a large amount of moist prepared sand at shakeout.	8	23
		B.	Enclosing hoods on mechanical conveying and processing components to provide dust control for the following sources: 1. Conveyors (oscillating and belt). 2. Conveyor transfer points. 3. Magnetic separating belt conveyor. 4. Bucket elevator. 5. Storage hopper and muller feeding. 6. Flat deck and rotary screens.	7	17, 20 (VS-304, 308)
		C.	Substitution of nonsilica sands for mold and coremaking.		25
Mold decomposition products.	Mold decomposition products may be emitted to a limited extent when conveying and processing takes place immediately following shakeout and the sand is still hot and contains organic materials (see mold pouring and cooling for specific contaminants).	D.	Pneumatic conveying of shakeout sand back to the return sand processing system.		32
		E.	Properly distributed fresh, tempered air for dilution ventilation.		
Noise.	Noise levels above the allowable are generally the result of a malfunction (i.e., rattling guards, loud bearings, etc).				

CONTROL METHOD EVALUATION

PROCESS: Return sand transfer, processing and storage

		Engineering control	
Item	Type	Advantages	Limitations
A.	Process substitution.	Shown to be effective in eliminating the need for enclosure of the sand transfer operation. Thus, it facilitates maintenance while greatly reducing exhaust requirements.	It does not entirely remove the need for local exhaust from the rotary screen and muller chambers to prevent condensation and plugging.
B.	Ventilation at source.	Enclosing hoods are an effective method of controlling dry sand systems. Exhaust hood design parameters are available in the ACGIH Industrial Ventilation Manual for all of the conventional mechanical sand conveying processes, with the exception of oscillating conveyors. The American Foundrymen's Society Foundry Environmental Control Manual provides additional design sketches, as well as photographs illustrating the application of these ventilation parameters in foundry sand system applications. The parameters for belt conveyors probably apply well to control of oscillating conveyors. Design parameters are also available for processes such as magnetic separators and screens, although not for sand cooling units.	Diligence during maintenance is required to assure that removable panels are replaced after machine servicing. Without such a program, assurance of breathing zone protection using enclosing hoods would be doubtful.
C.	Material substitution.	See sand preparation, Item C.	See sand preparation, Item C.
D.	Equipment substitution.	See sand preparation, Item D.	See sand preparation, Item D.
E.	General ventilation.	Can eliminate the need for mancooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Charge bucket filling

FOUNDRY AREA: Melting and casting

PROCESS DESCRIPTION: Charge bucket filling can be done manually or with mechanized equipment such as magnetic cranes. Besides proportioned amounts of various grades of scrap and foundry returns, charge materials may also include coke and limestone (cupola operation) and graphite (arc furnaces melting iron).

Hazard			Engineering control		
Agent	Source	Item	Description	Case history	Ref.
Respirable dust containing respirable silica and metals.	Dust is emitted as charge materials are dropped into the bucket. The amount of dust liberated depends on the cleanliness of the scrap. A major source of free silica is the sand on foundry returns. The potential exposure is usually greatest for the weighing operator or the charge bucket transport operator who may be stationed next to the bucket during filling. Charge bucket filling often occurs outdoors or in a semi-enclosed building adjacent to the melting area. It may also occur indoors, within or next to the melting area. Dust escaping from charge makeup operations is often drawn into melting areas because of the high exhaust rates used at the furnaces.	A.	Ventilated booths to isolate charge make-up operators from dust exposure and noise.		20
		B.	Exhaust hoods to capture dust during charge bucket filling. 1. Semi-enclosing hood above the charge bucket. 2. Exhaust at the lower preheater ports in the bucket.	9	
		C.	Automation of charge bucket filling and isolation of workers from the area.	9	
		D.	Charge bucket liners. 1. "Sandwich" bucket with a rubber liner. 2. Metal liner inside bucket plug welded to bucket.		37, 43
Noise.	Impact noise as the scrap is dropped into the charge bucket is often above the allowable.	E.	Enclosure for the bucket with scrap fed into it on a conveyor to isolate the operator from noise.		43

8—11

CONTROL METHOD EVALUATION

PROCESS: Charge bucket filling

		Engineering control	
Item	Type	Advantages	Limitations
A.	Isolation with a physical barrier.	In many cases, charge makeup operators maintain fixed locations at control stations, and it is possible to enclose these stations into booths.	
B.	Ventilation at source.	Capturing charge bucket filling emissions can reduce cross-contamination of silica-laden dust into the melting areas, as well as protection of charge makeup operators.	Capture of emissions from the bottom of large charge buckets using ventilation is difficult because dusty air is emitted from any gap in the bottom of the bucket, as well as out of the top.
C.	Isolation by distance.	Charge makeup and melting area operators are isolated from the immediate area during charge bucket filling.	Limited to high-production operations.
D.	Equipment modification.		Sandwiching a rubber liner in a charge bucket is often impractical because the charge bucket is placed over or into the melting equipment and heat deterioration is very rapid.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Cupola melting of gray iron

FOUNDRY AREA: Melting and casting

PROCESS DESCRIPTION: A continuous nontilting melting furnace using low sulphur coke for a fuel and limestone as a flux. Material is normally charged in layers with skip buckets or bottom-emptying charge buckets. Combustion is accomplished by forcing blast air (sometimes preheated) through ports called tuyeres.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Metal fume - especially iron, lead, zinc.	Substantial dust and fume is driven off primarily due to the violence of the blast. Typical dust and fume emissions range from 4-27 lbs/ton (2-13.5 kg/ metric ton), depending on the cleanliness of the scrap (30).	A.	Control of charge door emissions using a bifurcated cupola design.	12	
Respirable silica.		B.	Forehearth emission control using a canopy hood.	12	
Carbon monoxide.	Reducing atmosphere in furnace causes high CO levels in exhaust gases (typically 11%). CO has great potential for causing deadly hazards when process and control systems are malfunctioning. The hazard is especially great in duplex cupola arrangements where one cupola is in service while the other is being repaired (36).	C.	Booth to protect alloy and ladle operators at the forehearth from heat and infrared radiation.	12	
		D.	Continuous CO monitoring and alarm system at the charge deck and tender's platform; emergency oxygen supply in the immediate vicinity.		
Sulfur dioxide.	Generated during cupola melting as a result of the oxidation of sulfurous material contained in coke and pig iron.				
Hydrogen sulfide.	Generated at cupola slag quenching channels and tanks.				
Heat and infrared radiation.	Emitted from furnace, especially exposed hot metal at forehearth.				
Noise.	Noise is generated from the roar of the violent burning inside. Generally, only the charging operator is exposed to the noise, and the levels are unknown.				
Ionizing radiation	Level indicators.				

CONTROL METHOD EVALUATION

PROCESS: Cupola melting of gray iron

		Engineering control	
Item	Type	Advantages	Limitations
A.	Ventilation at source.	The bifurcated cupola design, with its water cooled exhaust plenums is rugged and has a good service life.	
B.	Ventilation at source.	Where there are no interferences from bridge cranes, canopy hoods can be installed directly above the forehearth to receive the fume in the thermal draft.	Bridge cranes may restrict the use of this hood to elevated levels, at which point it loses its effectiveness and air-efficiency.
C.	Isolation with a physical barrier.	Isolation booth shields infrared radiation and metal splashing and provides a degree of enclosure which facilitates cooling of workers.	
D.	Workplace monitoring.	CO monitors can give early warning of upset conditions. They can be used as fixed or portable monitors to measure levels during furnace operation and repair.	Require calibration and surveillance to assure continued operation in the hot furnace environment.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Direct arc melting of ferrous alloys

FOUNDRY AREA: Melting and casting

PROCESS DESCRIPTION: Tilting furnace charged by buckets with the furnace cover swung out of the way. Electrodes are injected into the charge through the furnace cover. Operators perform furnace functions, e.g., temperature measurement, alloying, slagging, oxygen lancing, through an access door. The furnace is tilted to tap into ladles.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Metal fume - especially iron, lead, and zinc. Respirable silica.	Substantial dust and fume is driven off, especially during the violent initial phases of meltdown; substantial metal fume is liberated during oxygen lancing in steel production. Arc furnaces are capable of melting lower grades of scrap and air contaminants produced can range widely from 6-30 lbs/ton (3-15 kg/metric ton)(30). Very high temperatures are created in the zone of the arc, averaging 6,500 °F (3,540 °C), well above the boiling point of most metals.	A.	Ventilation control of furnaces. 1. Sidedraft hood with door and spout hoods. 2. Direct shell evacuation. 3. Canopy hood. 4. Full roof hood.	11	
		B.	Operator booths to isolate furnace operators from air contaminants, noise, and heat at the furnace control station.	19, 32	37, 38
Carbon monoxide.	Decarburization of steel using air lances. Burnoff of combustibles.	C.	Proper control of charge materials and furnace operations.		
Gases and vapors.	Burnoff of combustibles.	D.	Chain curtains across slag door to reduce infrared radiation.		
Heat and infrared radiation.	Operator exposure is particularly acute when he is working at the slag door, in the direct path of infrared radiation from the exposed metal.				
Ultraviolet light.	From electric arc.				
Noise.	The electric arc from the furnace generates noise during meltdown and heating of the steel.				

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CONTROL METHOD EVALUATION

PROCESS: Direct arc melting of ferrous alloys

		Engineering control	
Item	Type	Advantages	Limitations
A.	Ventilation at source.	1. Sidedraft hood - can be made easily replaceable.	The sidedraft control method requires complete sealing around the periphery of the furnace cover to be effective.
		2. Direct shell evacuation - uses the least amount of exhaust air of the four local control methods.	The direct shell evacuation method can affect the metallurgical process because it draws air from within the furnace.
		3. Canopy hood - does not encumber the furnace operation in any way.	Unless it can be placed close to the furnace it will probably not be effective.
		4. Full roof hood - does not rely on perfect furnace seals.	The weight of the full hood can be a problem.
B.	Isolation with a physical barrier.	Booths reduce operator exposure to noise, heat, and air contaminants. All controls in one location.	In order to be effective, the operators must spend a significant part of their shift inside the room. If their duties prohibit this, their exposure will not be significantly reduced.
C.	Process monitoring.	Limiting of oil and grease in charge prevents excess smoke generation, explosions, and lining wear by distribution of combustibles in the charge.	Availability and cost of clean scrap.
D.	Isolation with a physical barrier.		If they cannot be raised, chain curtains may interfere with slagging, oxygen lancing, or alloy additions.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Charge preheating and induction melting of
        ferrous alloys

FOUNDRY AREA: Melting and casting

PROCESS DESCRIPTION: Loaded charge buckets are preheated at
downblast preheating stations or scrap is preheated on a
conveyor before being fed into a bucket. The bucket is then
emptied into the furnace. After melting, the furnaces are
tilted to tap the molten metal into ladles.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Metal fume - iron and especially lead and zinc depending on their percentages in the scrap.	Fume is emitted during furnace operation. Emission rates are dependent on composition and cleanliness of the scrap.	A.	Exhaust plenum below charge bucket to capture downdraft preheater exhaust.	9	
		B.	Control of furnace emissions using close-fitting hoods and overhead roof exhausters	9	
Respirable silica.	Dust is emitted from the charge during preheating and furnace charging.	C.	Use of a charge bucket cover during unloading of charge materials into furnace		
Smoke and oil vapors, carbon monoxide.	Generated during preheating and/or melting from combustibles in charge.	D.	Control of furnace emissions using a canopy hood above the entire melting area.	9	
Heat and infrared radiation.	Emitted from preheater and furnaces, especially from exposed molten metal surfaces.	E.	Partial operator enclosure at the furnace control station supplied with conditioned air.	9	
Noise.	Induction melting is generally below the allowable. Preheating can be either above or below the allowable limit depending upon the method used.				

CONTROL METHOD EVALUATION

PROCESS: Charge preheating and induction melting of ferrous alloys

		Engineering control	
Item	Type	Advantages	Limitations
A.	Ventilation at source.	Very direct method of emission control; hood is positioned to receive the air forced through the scrap by the combustion device.	
B.	Ventilation at source.	Useful in cases where tramp alloys such as lead and zinc and oils are present in the scrap. Effectively captures emissions during meltdown and during the time the operator is working directly at the furnace.	Requires auxiliary ventilation (overhead canopies or roof exhausters to capture fugitive emissions during tapping and charging. Because of interferences with ladle support devices (ladle hangers, crane cables), the shroud around the pouring spout cannot often be extended far enough to provide capture of tapping fume. During charging, the hood cannot reverse the escape of emissions out the top of the charge bucket.
C.	Control at source.	Prevents escape of emissions by the chimney effect during charging with bottom-unloading buckets into furnaces with close-fitting hoods.	Must swing cover into place before charging furnace and reopen for charge bucket filling.
D.	General ventilation.	In operations where the scrap is clean (free from oil and tramp metals such as lead and zinc) this method can provide sufficient protection without requiring close-fitting furnace hoods.	Limited to applications where the scrap is clean (free from oil and tramp metals such as lead and zinc). Crossdrafts must be controlled and mancooler fans should not be used. Not suitable in cases where isolation baffles cannot be installed, especially where bridge cranes are used.
E. F.	Isolation and ventilation.	The operator is stationed in the booth during the operations which produce emissions, i.e., charge bucket filling, furnace charging and tapping.	Some furnace operations cannot be performed from within the booth, e.g., slagging, clearing scrap from top of furnace, temperature measurement, making additions.

PROCESS/HAZARD/CONTROL INDEX

PROCESS: Hot metal transfer

PROCESS DESCRIPTION: Molten metal is transferred from melting furnaces to holding furnaces and/or pouring lines in ladles. Transfer may be manual, semi-mechanized, or fully mechanized.

FOUNDRY AREA: Melting and casting

Hazard			Engineering control		
Agent	Source	Item	Description	Case history	Ref.
Metal fume – ferrous: iron, manganese, chromium, and nickel.	Metal transfer operators are subjected to metal fume because of their close proximity to the ladle during furnace tapping, ladle transport, slagging and filling of holding furnaces and/or pouring ladles (also during inoculation, see ductile iron treatment).	A.	Isolation of the crane operator in a cab.	16	
		B.	Mobile duct system to provide fresh air supply to the crane cab.		
		C.	Mobile ladle canopy hood for manual transfer of toxic metals along ladle monorail.	14, 15	
nonferrous: lead, zinc, and copper.	Lead and zinc fume are a serious hazard during transfer of copper-base alloys. In many operations, makeup zinc is added to the ladle during furnace tapping. This zinc causes additional fuming to occur during ladle transport.	D.	Motorized monorail drive rather than manual pushing of ladle to isolate the worker further from the fuming ladle.		
		E.	Ladle covers to reduce oxidation of metal and shield infrared radiation.	13, 20, 21	
	Hot metal transfer operators (especially bridge crane operators) are also subject to cross-contamination of contaminants from melting operations and mold pouring and cooling.	F.	Side baffles on ladle hanger to shield infrared radiation.	20	
		G.	Makeup air supply in hot metal transfer areas.	23	
Heat, infrared radiation.	Emitted from hot metal ladle.	H.	Automatic transfer of metal from melting to holding furnaces through a launder, and automatic pouring from the holding furnace.		34

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CONTROL METHOD EVALUATION

PROCESS: Hot metal transfer

		Engineering control	
Item	Type	Advantages	Limitations
A.	Isolation with a physical barrier and ventilation.	Noise, air contaminants, and heat can be controlled in an isolated cab. Where necessary, commercially available, high efficiency filtering units can be installed to place the cab under positive pressure with filtered air to prevent infiltration. Carbon monoxide and other gaseous removal devices are also available.	When an isolated crane cab is employed with a standard industrial air conditioner, the chief mode of air contaminant control is by prevention of infiltration, rather than by cleaning the air. Typical commercially available air conditioners have low efficiency dust filters and no gaseous filters.
B.	Isolation with a physical barrier and ventilation.	Pressurizes the crane cab with fresh air to prevent infiltration; can provide heated or cooled air; the system is commercially available.	Sufficient clearance is needed to run lengths of mobile duct adjacent to the crane cab. Limited to bridge cranes; not developed for monorail cranes with curves in the path.
C.	Ventilation at source.	Uses a minimum of air and provides effective control of fume; very suitable for copper-base alloy transfer; very little process disruption; the system is commercially available; can also capture fume during furnace tapping, slagging, and pouring operations.	Susceptible to cross-drafts; straight mobile ducts using top-entering carriages work much better mechanically than curved duct sections using side-entering carriages. In new applications straight runs should be used whenever possible; in existing systems with complex paths curved sections probably cannot be avoided.
E.	Isolation with a physical barrier.	Improve the performance of mobile ladle hoods.	
F.	Isolation with a physical barrier.	Easy method to reduce heat stress for pourers.	
G.	General ventilation.	This method may be useful where local ventilation techniques are impractical.	Many long and complex transfer operations are not amenable to effective fresh air distribution along the entire path.
H.	Process substitution.	This method could help to reduce the potential for lead exposure in copper-base alloy operations. Covered launders can isolate the fume during transfer from pouring to holding furnaces; oxidation losses are minimized; eliminates the transfer operator.	Limited to foundry lines with high production runs at present.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Slagging of ladles

FOUNDRY AREA: Melting and casting

PROCESS DESCRIPTION: Slagging is done at the furnace, at a slagging station, or at the pouring line by adding a flux to coagulate the slag, and then skimming slag off of the metal surface with a scraper.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Metal fume - iron, manganese, chromium, nickel, lead (ferrous alloys); lead, zinc, copper and nickel (non-ferrous alloys).	Slagging operators are subjected to metal fume because of their close proximity to the slagging process.	A.	Slagging station incorporating:		
			1. Side-draft exhaust of fume.	13,18	
			2. Fresh air supply directed at worker.	18	
			3. Rollers to facilitate movement of long slagging poles used on large ladles. ·	18	
			4. A shield for infrared radiation with an opening only large enough to operate the slag pole.	18	
Heat, infrared radiation.	Slagging of large ladles produces an intense heat exposure for operators.				
		B.	"Robot slagger" to isolate the worker during slagging of large ladles.	17	
		C.	Combination of furnace hood and mobile transfer hood to exhaust fume during slagging of ladles containing copper-base alloys at the furnace.	15	

CONTROL METHOD EVALUATION

PROCESS: Slagging of ladles

		Engineering control		
Item	Type	Advantages	Limitations
A.	Isolation with a physical barrier and ventilation.	The combination of these four controls helps to alleviate heat stress conditions during slagging of large ladles. In the case of small ladles the sidedraft hood (Item AI) may be sufficient.	
B.	Isolation by distance.	Effectively reduces infrared radiation by moving the operator further away from its source; very useful for scraping slag off of ladle walls after pouring is completed. Eliminates the need for additional rest periods because of heat stress.	
C.	Ventilation at source.	Although they generally do not provide adequate capture of slagging fume when used singly, these two methods together allow complete capture of fume.	Effective capture requires that the furnace operator leave the furnace tilted during the slagging operation so that slagging fume can be drawn into the furnace hood.

PROCESS/HAZARD/CONTROL INDEX

PROCESS:　　Ductile iron treatment

FOUNDRY AREA:　　Melting and casting

PROCESS DESCRIPTION: Ductile iron is produced through inoculation with magnesium and post-inoculation with ferrosilicon. Various methods of inoculation are in use; plunging bell, sandwich, porous plug, and in-mold. The molten metal is often stirred during the post-inoculation process.

Hazard			Engineering control		
Agent	Source	Item	Description	Case history	Ref.
Magnesium oxide, iron oxide.	Dense clouds of magnesium oxide fume are produced during the brief period of inoculation with magnesium (one-two minutes).	A.	Custom-built, ventilated treatment station employing the plunging bell method of inoculation.	23	
Intense visible radiation.	Emitted during the brief period of inoculation.	B.	Exhaust control during inoculation at the furnace using the sandwich method.	24	
Heat.	Emitted from hot metal ladle.				

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CONTROL METHOD EVALUATION

PROCESS: Ductile iron treatment

Item	Type	Advantages	Limitations
Engineering control			
A.	Isolation with a physical barrier and ventilation at source.	The plunging bell method isolates the inoculation process from the furnace, thus affording much easier control of emissions.	
B.	Ventilation at source.	Controls furnace tapping and inoculation at the same time; hood is commercially available.	The extent of shrouding of the process will depend on the interferences present, especially from ladle supporting devices, e.g., ladle hangers, crane cables.

PROCESS/HAZARD/CONTROL INDEX

PROCESS: Melting of nonferrous alloys

FOUNDRY AREA: Melting and casting

PROCESS DESCRIPTION: Furnaces include gas-fired crucible, reverberatory, indirect arc and induction. Charge materials consist primarily of ingot, combined with foundry returns and other types of scrap. Tapping usually takes place into small pouring ladles.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Metal fume, particularly lead, zinc, copper, and nickel.	A substantial metal fume hazard exists the entire time the metal is in the molten state, especially from lead fume. Charging, furnace slagging and other furnace operations are performed manually, placing the melter very close to the fume source.	A.	Enclosing hoods (booths) 1. Indirect arc furnace 2. Gas-fired crucible furnace	14 13,14	17 (VS-106)
Heat and infrared radiation. Noise.	Emitted from the furnace, and especially the exposed molten metal. Noise is produced by the arc in electric arc furnaces. When crucible furnaces are used, air and gas under pressure are blown onto the crucible. A roar is created by the combination of the combustion noise and rushing gases. The noise level of this roar is generally above the allowable.	B. C. D.	Close-fitting hood 1. Induction furnace (furnace mounting) 2. Indirect arc furnace (independent mounting) Substitution for chlorine gas: 1. Argon gas 2. Hexachloroethane - inorganic fluoride pill Properly distributed fresh, tempered air for dilution ventilation and cooling.	13,15 13 13,14	17 (VS-104)

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CONTROL METHOD EVALUATION

PROCESS: Melting of nonferrous alloys

		Engineering control	
Item	Type	Advantages	Limitations
A.	Ventilation at source.	The booth is the only hood in use for crucible furnace operations. Booth hoods are most suitable in cases where there are no interferences from ladle monorails and overhead hoists and cranes.	The booth is generally not as air-effective as the close-fitting canopy hood for indirect arc furnace exhaust. When overhead monorails, cranes, and hoists are used the hood top must be slotted and fume could escape.
B.	Ventilation at source.	Close-fitting hoods can capture fume using an exhaust much lower than other methods require.	Furnace mounted hoods have difficulty capturing tapping fumes because of interferences between the ladle hanger and the hood. Were it not for the hanger, the pouring spout shroud could easily be extended forward to a location above the ladle to capture fume rising in the thermal draft.
C.	Material substitution.	Substitution for chlorine eliminates air contaminant hazard, as well as hazard from handling a dangerous material.	
D.	General ventilation.	Can eliminate the need for mancooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Mold pouring and cooling

FOUNDRY AREA: Melting and casting

PROCESS DESCRIPTION: Pouring from ladles is done by top pour or bottom pour, manually or automatically. Pouring is also done automatically from holding furnaces. Pouring and cooling takes place on mechanized conveyors or on the floor.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Metal fume: iron manganese, chromium, nickel, and lead (ferrous alloys); lead, copper, zinc, and nickel (non-ferrous alloys).	Metal fume hazards are present during pouring but are minimal during cooling. The fume is continuously emitted from the molten metal, especially as the metal is poured.	A.	Control of pouring fume at the source using: 1. "Push-pull" hoods on pouring lines. 2. Enclosing hood on mechanized pouring turntable. 3. Mobile sidedraft hood for pallet line pouring deck. 4. Mobile ladle hoods for pouring lines or pouring floors.	20,22 13 13 14,15	
Products of mold decomposition.	Begin to be emitted as soon as hot metal touches the mold and cores. Just-poured molds are a significant source of products for pouring operators.	B.	Automatic pouring to isolate workers from the process.		34
Carbon monoxide.	Organic binders, mold additives (cereals, asphalt, sea coal, graphite. Gilsonite, fuel oil, wood flour, ground pitch, molasses, and dextrin).	C.	Control of mold decomposition products at the source during mold cooling: 1. By isolating mechanized cooling lines into rooms and tunnels.	 20	
Ammonia Formaldehyde Furfuryl alcohol Phenol Isocyanate MDI Acrolein Polynuclear aromatic hydrocarbons.	Furan and phenolic binders. Furan and phenolic binders. Furan binders. Urethane, furan, and phenolic binders. Urethane binders. Oil binders. Organic materials in mold and core. binders and additives.	 D.	2. By isolating floor pouring from cooling areas using mechanized conveyors. Fume reduction and baffling of infrared radiation during pouring with: 1. Ladle covers. 2. Side baffles on ladle hangers as splash guards.	21 13,20	
Respirable silica.	Dust entrained from sand buildup on pouring line from mold crumbling.	E.	Distributed fresh air supply for pouring operators	20	
Heat and infrared radiation.	Emitted during both pouring and cooling, but particularly during pouring.				

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CONTROL METHOD EVALUATION

PROCESS: Mold pouring and cooling

		Engineering control	
Item	Type	Advantages	Limitations
A1 & 2	Control at source.	Versatile methods; do not interfere with high production. Some hoods are commercially available. Distributed push air can be easily incorporated to assist capture and cool workers.	Heat problems may still be severe with several metal pourers on the line at once.
A3 & 4	Control at source.	Mobile hoods permit control at the source over a relatively large area with a minimum of exhaust. Very suitable for nonferrous pouring operations. Item 4 is commercially available.	Fume exposure occurs during the process of installing the flex duct if it is removed during ladle filling (Item 4). These hoods are very susceptible to crossdrafts and must be used under quiescent conditions.
B.	Process substitution.	Eliminates the need for a manual pouring operator, and thus eliminates exposure to air contaminants, and particularly to heat. Requires reduced exhaust. Close-fitting hoods may be employed.	Suitable only for mechanized, high production casting.
C1.	Isolation with a physical barrier and ventilation.	Breathing zone hazards are completely isolated from workers.	When isolated areas are used as cooling chambers, i.e., by adding supply air, automatic controls or warning signals are needed on the ventilation system to prevent positive pressure ventilation conditions from occurring, which would discharge high air contaminant levels into the foundry.
C2.	Isolation by distance and ventilation.	Permits quick removal of just-cast molds out of pouring area into cooling area and then to shakeout. Reduces back strain on pouring floor personnel (usually the flask and weight shifter).	
D1.	Isolation with a physical barrier.	Helps to hold temperature of alloy, while reducing metal oxidation and infrared radiation and containing metal splashing.	
E.	General ventilation.	Can eliminate the need for mancooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Shell molding (phenolic)

FOUNDRY AREA: Molding and coremaking using chemically
bonded sand

PROCESS DESCRIPTION: Molds are formed when sand coated with a
thermosetting resin binder is placed against a heated pattern
plate. After hot curing, a sturdy shell is formed, constituting
half a mold. Mold assembly is done by glueing the mold halves
together.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Carbon monoxide, phenol, formaldehyde, ammonia and respirable silica.	Vaporization is the result of the heat applied during shell curing. Vapors continue to be formed during the mold assembly process and afterward during temporary storage on racks adjacent to the molding station.	A.	Control of dust and vapors at these sources: 1. Molding machine. 2. Cope hanger. 3. Glueing machine. 4. Storage rack.	29	
	The resin materials used include phenol and formaldehyde. They are classed as one-stage and two-stage and differ only in phenol-formaldehyde ratio.	B.	Fresh air supply to cool and ventilate operator area.	29	
	Coating of sand with resin may or may not be performed at the foundry.	C.	The noise generated by the various sources can be reduced by substituting a quiet piece of equipment for a loud one.		
	Dust is created by the sand feed system (gravity or pressurized) and sand spillage around the machine.	D.	Placing the mold on a ventilated set-off bench for a minute or two after it is removed from the molding machine to capture emissions during the first period of mold cooling.		
Heat and infrared radiation.	Emitted by the molding machine and also by the mold during processing and handling.				
Noise.	General molding area noises: air nozzles, air discharges (pneumatic equipment), pattern and/or mold vibrators, miscellaneous (including noise from other areas, rattling guards, and gas jets).				

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CONTROL METHOD EVALUATION

PROCESS: Shell molding (phenolic)

		Engineering control	
Item	Type	Advantages	Limitations
A.	Ventilation at source.	This method effectively controls all of the individual air contaminant process emission points, with the only exception being handling of the cores by the operator.	The canopy hood over the core storage rack can be easily disrupted by cross-drafts.
B.	General ventilation.	Can eliminate the need for mancooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.
C.	Equipment substitution.	See ancillary processes, Item B.	See ancillary processes, Item B.
D.	Process substitution and ventilation.	Requires only a small quantity of exhaust air, the work flow is only slightly changed, and good control is accomplished. This method eliminates much of the emissions which are a problem during the handling and processing of molds.	

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Hot box coremaking (furan)

FOUNDRY AREA: Molding and coremaking using chemically bonded sand

PROCESS DESCRIPTION: Sand is precoated with a thermosetting resin in a mixer. Coated sand is blown into a heated core box where the polymerization reaction takes place.

Hazard			Engineering control			
Agent	Source	Item	Description		Case history	Ref.
Carbon monoxide, phenol, ammonia, formaldehyde, furfuryl alcohol.	Vaporization and/or thermal breakdown occur at the elevated temperatures 400 - 450°F (204 - 232°C) within the core box. Formaldehyde is found in all furan resin mixtures, phenol is only present in some mixtures, and ammonia only generated in mixtures containing urea.	A.	Maintenance of corebox seals to prevent sand leakage.			
		B.	Canopy hood over hot box machine and storage rack.		28	
		C.	Fresh air blown directly on operator to cool him and provide fresh air.		28	
Respirable silica.	Sand leakage past blow seals during core blowing entrains fine dust particles into the background air.	D.	The noise generated by the various sources can be reduced by substituting a quiet piece of equipment for a loud one.			
Heat and infrared radiation.	Emitted by the molding machine and also by the mold during handling and storage.	E.	Placing the core on a ventilated set-off bench for a minute or two after it is removed from the coremaking machine to capture emissions during the first period of core cooling.			
Noise.	General core room noises: air nozzles, air discharges (pneumatic equipment), pattern and/or mold vibrators, miscellaneous (including noise from other areas, rattling guards, and gas jets).					

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CONTROL METHOD EVALUATION

PROCESS: Hot box coremaking (furan)

		Engineering control	
Item	Type	Advantages	Limitations
A.	Maintenance.	A periodic program of inspecting, cleaning, and replacing seals will reduce seal failures and sand leakage.	
B.	Ventilation at source.	The canopy hood takes advantage of the fact that the gases are hot.	
C.	General ventilation.	Can eliminate the need for mancooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.
D.	Equipment substitution.	See ancillary processes, Item B.	See ancillary processes, Item B.
E.	Process substitution and ventilation.	Requires only a small quantity of exhaust air, the work flow is only slightly changed and good control is accomplished. This method eliminates much of the emissions which are a problem during the processing and handling of cores.	

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Cold box coremaking (phenolic urethane)

FOUNDRY AREA: Molding and coremaking using chemically bonded sand

PROCESS DESCRIPTION: A two part binder system (phenolic resin and polyisocyanate) is mixed and coated onto core sand. The coated sand is blown into a corebox and gassed with TEA or DMEA.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Triethylamine (TEA) or dimethylethylamine (DMEA).	Can be leaked past corebox seals (parting line gaskets, blow seals, and stripper pin O-rings) or from gas line leaks; also emitted from the cores during core handling, finishing and storage.	A.	Eliminating sources of backpressure on seals, e.g., excess sand fines, moisture in sand or compressed air, excessive gassing pressures, insufficient gassing vents in pattern.		
Phenol, polymeric isocyanates	Have very low vapor pressures and would generally not be generated in sufficient quantities to produce an environmental hazard. However, where phenolic and polyisocyanate resins are mixed manually, skin and eye contact hazards are present.	B.	Maintenance of corebox seals to prevent sand leakage.		
		C.	Efficient gassing and purging processes.		
		D.	Exhaust of gases from the corebox.	27	
Respirable silica.	Sand leakage past blow seals during core blowing entrains dust into the background air.	E.	Exhaust of gases from the corebox; sidedraft exhaust at the corebox; canopy hood over core discharge conveyor.	26	
Noise.	General core room noises: air nozzles, air discharges (pneumatic equipment), pattern and/or mold vibrators, miscellaneous (including noise from other areas, rattling guards, and gas jets).	F.	Fresh, tempered air supplies at spaced intervals throughout area.	27	
		G.	Fresh, tempered air blown directly on workers to provide dilution ventilation and worker comfort.		
		H.	Placing the core on a ventilated set-off bench for a minute or two after it is removed from the coremaking machine to capture emissions during the first period of coremaking.		
		I.	The noise generated by the various sources can be reduced by substituting a quiet piece of equipment for a loud one.		

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CONTROL METHOD EVALUATION

PROCESS: Cold box coremaking (phenolic urethane)

		Engineering control	
Item	Type	Advantages	Limitations
A.	Process substitution.	Reducing pressure on seals is the most effective way to minimize the gas leakage problem.	
B.	Maintenance.	A periodic program of inspecting, cleaning, and replacing seals will reduce seal failures and gas and sand leakage.	
C.	Process control.	Efficient gassing and purging are accomplished by: 1. Proper location and number of inlet and exhaust gas vents in the pattern. 2. Efficient conversion of TEA liquid to gas to minimize TEA usage.	
D.	Ventilation at source.	The most effective way of capturing the gases.	When this ventilation method represents all the ventilation that is provided, a sufficient air turnover will not exist unless makeup air provisions are installed. Exhaust of gases from the corebox will not contain gas which leaks past seals.
E.	Ventilation at source.	The auxiliary ventilation primarily captures gas which continues to emit from the core after corebox opening. It also provides ventilation for the small leakage which is always occurring. And it promotes air turnover in the area.	
F. & G.	General ventilation	Can eliminate the need for mancooler fans which are disruptive to exhaust control.	Fresh air should be properly distributed, not a jet of air which can disrupt the capture hood.
H	Process substitution and ventilation.	Requires only a small quantity of exhaust air, the work flow is only slightly changed and good control is accomplished. This method eliminates much of the emissions which are a problem during the processing and handling of cores.	
I.	Equipment substitution.	See ancillary processes, Item B.	See ancillary processes, Item B.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Furnace and ladle repair

FOUNDRY AREA: Other

PROCESS DESCRIPTION: Old linings are chipped out using pneumatic chisels. Debris is dumped into hoppers. New linings are applied by pouring and ramming or blowing with air guns. Curing using a heat source is done before the lining is subjected to molten metal.

Hazard		Engineering control			
Agent	Source	Item	Description	Case history	Ref.
Respirable silica.	The principal hazards during relining occur during breakout of old linings, and the dumping of the debris into hoppers. The presence of quartz or cristobalite will depend on its percentage in the lining materials and slag. Cristobalite is particularly present in silica lining materials of ladles used to hold molten steel, due to the higher temperatures involved.	A.	Exhaust on pneumatic tools to prevent turbulence and dispersion of dust.		
		B.	Flex duct exhaust hose installed within the furnace ladle during chip out.		
		C.	Sidedraft hood for hopper exhaust during dumping of debris.		
		D.	Ladle curing hood to remove CO from the building.	25	
Carbon monoxide.	Flames impinging on cold ladles during ladle curing are prematurely cooled, resulting in incomplete combustion of natural gas. Cupola relining can present a serious hazard from CO in duplex cupola arrangements where the damper separating the two exhaust ducts is warped and leaks (35).	E.	Ventilation and monitoring of cupola repair operation: 1. Use of life harnesses and surveillance of operation. 2. CO monitoring before and during relining. 3. Fresh air supply through tuyeres. 4. Emergency oxygen supply. 5. Check to be sure cupola cap is closed.		
Noise.	Noise levels above the allowable limit are often generated during the removal and relining of ladles and furnaces. The noise is a combination of tool noise and tool-on-liner noise. Noise is also generated by the gas fired heaters used to dry refractory liners.	F.	Proper furnace operation and use of clean scrap to prevent excessive burnout and buildup of slag on linings resulting in shortened lining life.		

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CONTROL METHOD EVALUATION

PROCESS: Furnace and ladle repair

DISCUSSION:

		Engineering control	
Item	Type	Advantages	Limitations
A.	Equipment substitution.	Reduces air noise, as well as eliminating turbulence near the dust generation point. Can be retrofitted to existing tools; commercially available on most manufacturers' designs;	
B.	Ventilation at source.	Can reduce respiratory dust levels during the removal of linings in small ladles where the operator does not have to have his head within the ladle and the exhaust on the portable tools is discharged through a vent tube.	For ladle repair the flex duct requires careful positioning to be in a good position to capture the dust. It is doubtful that it can provide sufficient protection so that respirator protection is not required.
C.	Ventilation at source.	A slotted exhaust located along one side of the dump hopper at the top can effectively capture dust during the dumping process. This method is especially suited for ladle repair where the hopper is fixed and the ladles are brought to the hopper for dumping.	Not practical for furnace repair where dumping into the hopper takes place in front of or out the bottom of the furnace. The exhaust provisions for the hopper would have to be mobile in those cases.
D.	Ventilation at source.	Removes a source of heat, as well as CO; the hood could be acoustically lined to reduce noise levels; heat content in the exhaust stream could be reclaimed.	
E.	General ventilation, process surveillance, and safety and health provisions.	A comprehensive health and safety program for cupola repair operations could eliminate the deaths which have occurred while performing this process.	

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Housekeeping

FOUNDRY AREA: Other

PROCESS DESCRIPTION: Housekeeping (as defined here) includes all activities involved with collecting dust and spilled materials from floors, equipment, and building structures. It also includes removal of debris from conveyor discharges, abrasive machines, and dust collectors.

Hazard			Engineering control			
Agent	Source	Item	Description	Case history	Ref.	
Respirable silica.	Lack of housekeeping produces a dust hazard through reentrainment of dust by workers, mobile vehicles, machinery vibrations and compressed air tools.	A.	Powered sweepers with dust filtering mechanisms for cleaning aisleways and unobstructed plant areas.	Most foundries studied		
	Housekeeping itself produces dust:	B.	Vacuum cleaners with dust filtering mechanisms cleaning under machines, in pit areas, on elevated levels, machinery surfaces, etc.	8		
	1. Sweeping (manual) - Depending on sweeping speed and frequency of dust pickup.					
	2. Sweeping (powered) - Depending on efficiency and maintenance of filter; auxiliary side sweeper brush may also cause dust to be generated.	C.	Spill pits using deflector plates and conveyors to catch and transport spilled materials.			
		D.	Use of fine water sprays before and during cleanup of debris containing dry dust to prevent reentrainment.			
	3. Shovelling - Throwing of materials.					
	4. Front end loading - Vehicle movement within dusty area; leakage during transport, dumping.	E.	Properly maintained floor and aisleway surfaces to minimize cracks and holes.			
		F.	Established work practices, responsibilities and timetables for housekeeping.			
	5. Vacuuming - Depending on efficiency and maintenance of filters.	G.	General noise solutions.			
Carbon monoxide.	Fuel-burning engines used for powered sweepers and vacuums.					
Noise.	Many sources, if not properly maintained can generate noise above the allowable. Some are:					
	1. Rattling guards. 2. Floor sweeping machines (no mufflers). 3. Air circulation fans. 4. Air system leaks. 5. Air discharges.					

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CONTROL METHOD EVALUATION

PROCESS: Housekeeping

Item	Type	Advantages	Limitations
		Engineering control	
A.	Process substitution.	Dust picked up by main sweeper brush is filtered before discharge.	Side brush can stir up dust because it generally has no direct ventilation (exhausted shrouds for side brushes are available but they are susceptible to damage).
B.	Process substitution.	Useful in many foundry cleanup operations: 1. Around shakeout. 2. Around molding and coremaking machines. 3. In conveyor pits. 4. Around mullers. 5. Throughout the cleaning room.	If this method is to be used extensively, clearance must be available to transport the mobile cleaner; or a manifold system must be installed to permit use in enclosed places.
C.	Equipment substitution.		Equipment used to transport sand in spill pits requires operators to enter the pit for maintenance. These operators probably require respiratory protection.
F.	Work practices.	Several foundries (especially three shift operations) had successful programs of housekeeping which involved operator responsibility for cleaning his workplace area.	If the dust exposures of operators were close to the allowable limit, additional exposure received from housekeeping could present the possibility of exceeding the allowable limit.
G.	Equipment substitution.	See ancillary processes, Item B.	See ancillary processes, Item B.

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PROCESS/HAZARD/CONTROL INDEX

PROCESS: Ancillary processes

FOUNDRY AREA: Other

PROCESS DESCRIPTION: Equipment and/or systems in common use
throughout the foundry and for which
solutions to hazards may have application
in many different foundry areas.

Hazard			Engineering control		
Agent	Source	Item	Description	Case history	Ref.
Air contaminants.	Emissions into the workplace caused by malfunctioning exhaust systems.	A.	Preventive maintenance to assure proper functioning of exhaust system.	11	
Noise.	General foundry noise sources: Air circulation fans. Air nozzles. Air discharges (pneumatic equipment). Pattern and/or mold vibrators. Dust collector fans. Makeup air units. Compressed air leaks. Hydraulic pumping systems.	B.	Noise reduced by substituting a quiet piece of equipment for a loud one: 1. Low speed high pitch fan blades substituted for high speed low pitch blades. 2. Quiet air nozzles. 3. Quiet vibrators. 4. Exhaust air mufflers.	34, 35, 36	37, 39 44, 43

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CONTROL METHOD EVALUATION

PROCESS: Ancillary processes

		Engineering control	
Item	Type	Advantages	Limitations
A.	Maintenance.	A proper maintenance program can assure continued and efficient operation of hazard control systems.	
B.	Equipment substitution.	Noise reduction is achieved at the source.	
		Quiet pieces of equipment are commercially available in many cases.	If the noise problem originates largely from other sources, then reduction to below the allowable limit cannot be achieved by the equipment substitution method alone. Not all equipment can be controlled by substitution.

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APPENDIX A. CASE HISTORIES

CASE HISTORY #1
DUST CONTROL DURING SPRUE KNOCKOFF AND SORTING OF IRON CASTINGS
DECEMBER, 1977

ABSTRACT

Respirable silica emissions during sprue knockoff and casting sorting were
controlled by a specially designed mesh belt conveyor with downdraft
exhaust. The system was designed for rugged foundry use and has held up
very well after two years of service. Respirable dust samples showed
that worker exposures were controlled below the allowable limits. A fresh
air distribution plenum located behind the workers was available for heat
stress relief in hot weather.

PROCESS DESCRIPTION

Equipment and Operation

This foundry had three automatic molding lines using silica sand for high
production of iron castings. Each of the three lines had its own shakeout
and sprue knockoff and casting sorting conveyor. Figure A1-1 shows a
typical system. The castings were collected in hoppers at the shakeout
and transported by forklift truck to the remote sprue knockoff conveyor.

Several workers stood on one side of the conveyor knocking off sprues with
hammers and sorting the castings into bins or placing them on a blast
monorail. The conveyor discharged sprues and other debris into a hopper.

Materials and Rates

Production on the day of the survey was 84 tons/shift (76 metric tons/shift)
of iron castings in the weight range of 4-35 lbs (1.8-15.9 kg).

WORKPLACE HAZARDS

The major air contaminant from the sprue knockoff and sorting operation
was respirable silica.

CONTROL OF EXPOSURE

Control of respirable silica was achieved through a specially designed mesh
belt conveyor using a downdraft exhaust.

Engineering

A schematic cross-sectional view of the mesh belt conveyor is shown in
Figure A1-2. The belt was suspended between large driver and idler rollers,
supported along the length of the conveyor by small, closely spaced rollers

CASTING FEED CONVEYOR

SPRUE KNOCKOFF AND
SORTING BELT CONVEYOR

PLAN

VIEW

CASTING BINS (4)

OPERATOR PLATFORM

SPRUE BIN

Figure AI-I. Sprue knockoff and casting sorting operation.

WIRE MESH BELT

BELT SUPPORT ROLLERS

TOP SEAL

ROLLER SUPPORT
CHANNELS

SAND HOPPER
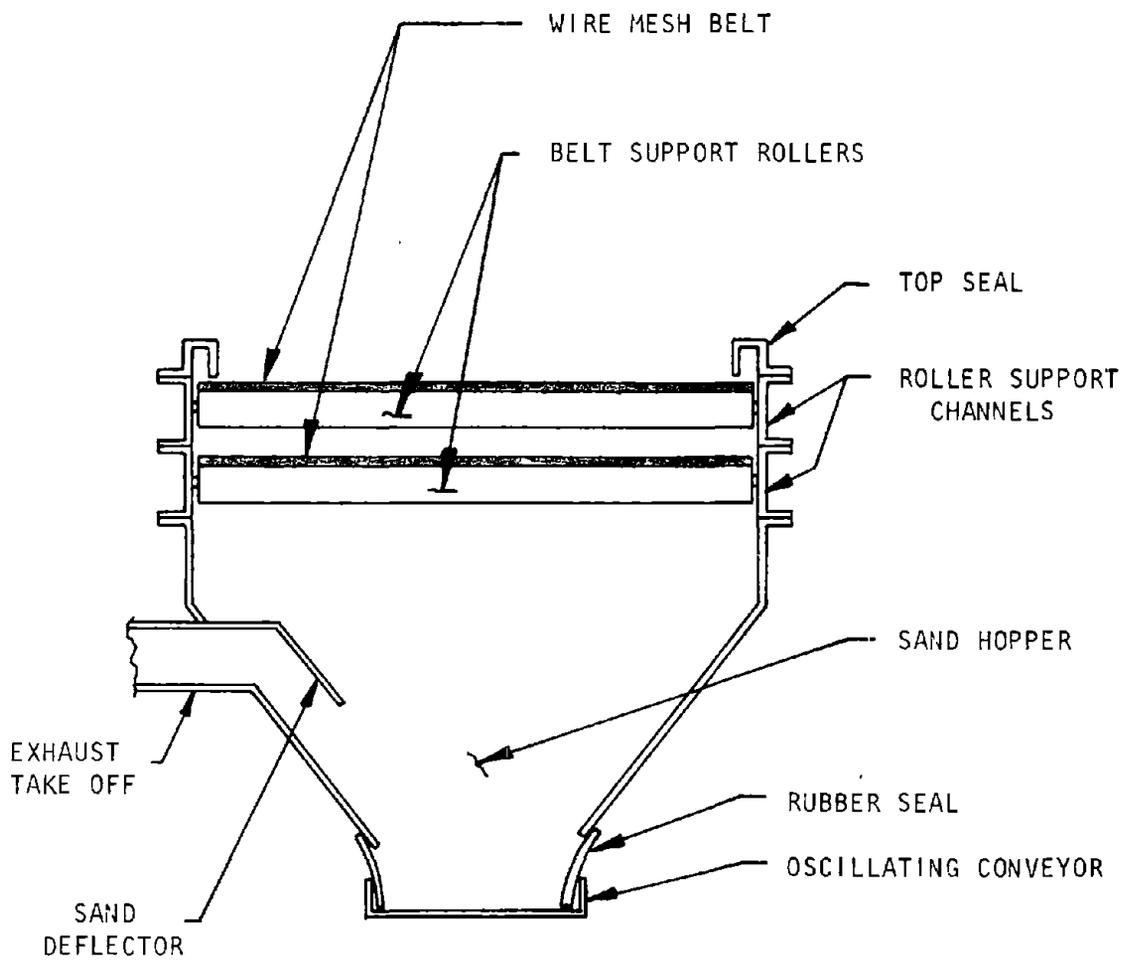
EXHAUST
TAKE OFF

RUBBER SEAL

OSCILLATING CONVEYOR

SAND
DEFLECTOR
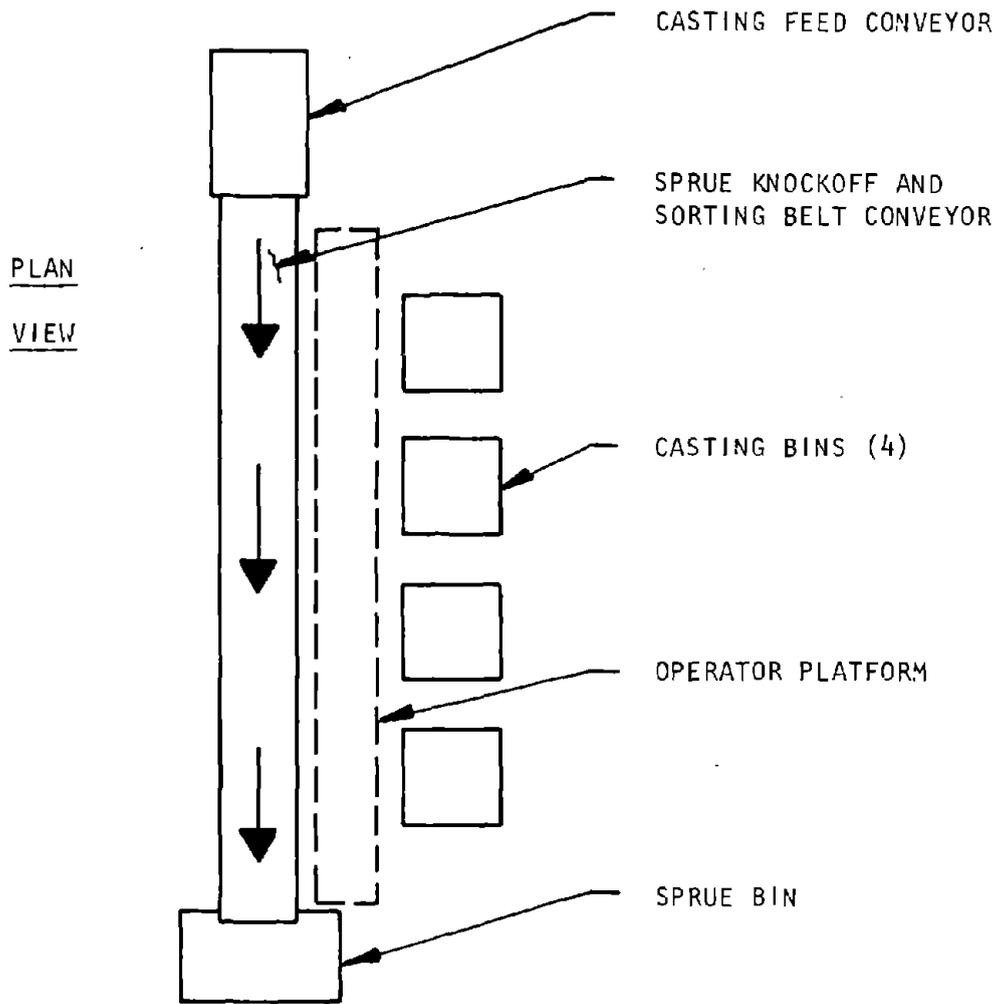
Figure Al-2. Cross-section of wire mesh belt conveyor.

under the top belt, and by small rollers 'at a wider spacing under the return belt.

Both the mesh belt and the support rollers were constructed of heavy gauge metal. The rollers were mounted to a channel frame to provide the necessary structural rigidity for this rugged operation. Special clamps were used to facilitate roller replacement. A metal top seal eliminated a pinch point and prevented damage to the edge of the belt.

Loose sand and dust were drawn downward through the mesh belt and between the support rollers into the sand hopper where the sand was removed by an oscillating conveyor and the dust was drawn into an exhaust takeoff, a slot running 80% of the length of the conveyor. The sand was discharged back into the return sand system and the exhaust air was cleaned by a fabric collector before being discharged outdoors. Additional exhaust ventilation was provided by partially enclosing hoods at both ends of the belt; at the casting loading end and the debris discharge end.

The following is a summary of conveyor design information:

Spiral wound, semi-closed mesh belt

Working length of belt	68 ft (20.7 m)
Width between top seals	2.83 ft (0.86 m)
Coils per unit of width	36/ft (118/m)
Straight connectors per unit of length	18/ft (59/m)
Wire diameter	0.093 inch (0.24 cm)
Belt speed	20 fpm (0.10 m/sec)

Support rollers

Diameter	2.5 inch (6.35 cm)
Centerline spacing (top rollers)	3 inch (7.6 cm)
Centerline spacing (bottom rollers)	12 inch (30.5 cm)

Air flow data

Downdraft velocity through belt (min.)	150 fpm (0.76 m/sec)
Exhaust slot velocity	3500 fpm (17.8 m/sec)
Static pressure in exhaust takeoff	1.3 inch H_2O (2.4 mm Hg)
Total exhaust from conveyor	50,000 cfm (23.6 m^3/sec)

General Ventilation

A tempered air makeup unit was located directly adjacent to the conveyor line providing general ventilation during the survey. A fresh air distribution plenum located just behind the workers was available for heat stress relief during hot weather (not used during survey).

RESULTS

1. Respirable silica was controlled below allowable limits (Table AI-I).
   Other than the field survey data (during winter), plant personnel
   had previously measured a total dust concentration of 0.60 mg/m3
   with 14.2% quartz, which is about one-third of the allowable exposure
   for total dust.

Table AI-I. Air sampling results - respirable silica.

Operator or location	Type of sample	Percent quartz	Respirable dust, mg/m^3	Allowable respirable dust, mg/m3 §
Sprue knockoff and casting sorting operator	Pers.	15	0.27	0.59
	Pers.	16	0.28	0.56
Background above conveyor	Fixed	19	0.20	0.47

§ OSHA PEL and ACGIH TLV (1977)

CASE HISTORY #2
DUST CONTROL DURING CHIPPING AND
GRINDING OF IRON CASTINGS ON BENCHES
JULY, 1977

ABSTRACT

Data on exposures to respirable silica were gathered in the chipping and
grinding areas of five foundries that differed greatly in size of work
force, size of castings, and even in the type of dust control used. The
foundries were similar only in that they all were jobbing foundries and
each of them had cleaning rooms where serious attempts had been made to
control dust. No real differences could be found in the extent of dust
control.

The control method used was either downdraft benches or high-velocity,
low-volume (HVLV) systems. The amount of cleaned air recirculated to the
area varied from zero to 90% of that exhausted, and fresh air was ducted
to several areas (even to individual workers) or was discharged from a
single location in the room. In no case was silica control completely
effective because, in every foundry, concentrations in excess of those
allowable were found for some workers (usually a minority).

Reasons for imperfect control are not obvious. The quartz content of
dust in these cleaning rooms (averaging about 10%) was higher than in any
other area of the foundries surveyed and this undoubtedly was part of the
problem. Much of the airborne quartz probably originated from sand "burn-on"
and was dislodged from castings by the cleaning procedure. Then, because
no control was 100% efficient, the dust that became airborne contributed to
the background (an average of 0.35 mg/m^3 and 39% of the allowable concentra-
tion) and thus to inhaled concentrations. Despite relatively high back-
ground levels, however, some workers were not overexposed to respirable silica.
If such people form an identifiable, continuing group, then perhaps individual
differences between work practices plays a much larger role than has been
realized.

Besides the inefficiencies of ventilation controls, work practices and the
presence of adjacent dust-producing processes also contributed to dust
exposures of chipping and grinding workers. The use of air nozzles to
clean castings during processing, especially the internal cavities of
castings, produced dust clouds that the ventilation controls could not
contain. Housekeeping is a necessary part of dust control; the use of
brooms resulted in increased dust levels in the background air. The close
location of other cleaning operations such as shot blasting and stand
grinding, as well as powered aisle sweepers, were other potential sources
of dust.

One of the major reasons for variance in work station dust levels was
undoubtedly the fact that all of the foundries surveyed were jobbing

foundries. Hundreds of different kinds of castings were cleaned in these foundries, some of the castings contained significant amounts of trapped sand in cavities and/or had unique "burn-on" sand problems.

PROCESS DESCRIPTION

Chipping and grinding of iron castings using portable pneumatic tools was carried out on work benches located in five different finishing areas. A summary of process information for each of the five cases is presented in Table A2-1. All castings were molded in green sand molds.

The cleaning of castings involved both internal and external chipping and grinding.

Castings were delivered to the work bench areas by several methods: fork lift truck, bridge and jib cranes, and roller and belt conveyors. The benches were loaded and unloaded manually when castings were small, and with hoists and jib cranes when castings were large. All of the castings had been shot blasted before being cleaned and finished.

WORKPLACE HAZARDS

The major air contaminant hazard from cleaning and finishing of iron castings was respirable silica. The dust was generated from a variety of sources: the chipping and grinding process; work practices of sweeping the bench area, blowing off castings and dressing of grinding wheels; aisle sweeping; forklift traffic, and adjacent cleaning processes.

CONTROL OF EXPOSURE

Dust generated by the chipping and grinding process was controlled at the source by either downdraft benches or high-velocity, low-volume (HVLV) hoods on the individual tools. A variety of general ventilation methods were used to remove background dust created by numerous sources. A summary of the five different combinations of controls evaluated is presented in Table A2-2.

Engineering

Control at the Source--
Downdraft benches--In cases A-D, four different downdraft bench designs were evaluated. Functionally, they all worked the same but there were some design differences among them that are noteworthy:

   Case A--A small bench was specially designed by foundry engineers to
           be very rugged and compact (Figure A2-1). The workbench
           surface was constructed of replaceable wood slats, spaced
           to permit air flow. Wood was used because it tended to
           deaden the noise. Easily removable dust trays permitted
           fast removal of grinding debris and access for recovery
           of tools. Benches were baffled as far as practical on the
           back and on the side facing the hopper which helped to

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Table A2-1. Summary of process information.

| | Case | | | | |
	A	B	C	D	E
No. of workers	36	4	4	15	5
Production rate					
Tons/shift	80-100	N.A.	N.A.	N.A.	8
Metric tons/shift	73-90				7.2
Casting weight range, lbs	7-10	70-270	N.A.	N.A.	400-5000
kg	3.2-4.5	32.127			182-2270
Manual tools used					
1. Hammers	Yes	Yes	Yes	Yes	Yes
Pneumatic tools used					
1. Chipping hammers	No	Yes	Yes	Yes	Yes
2. Surface grinders	No	No	No	No	Yes
3. Cone grinders	Yes	Yes	Yes	Yes	Yes
4. Radial grinders	Yes	Yes	Yes	Yes	Yes
5. Cut-off saws	No	No	No	No	Yes
Coremaking methods					
1. Oil sand	No		No	Yes	
2. Phenolic urethane	Yes	N.A.	Yes	Yes	N.A.
3. Shell	No		No	Yes	
4. Furan no-bakes	No		No	Yes	
Precleaning method	Shot blast	Spinner-blast, tumbleblast	Shot blasting	Variety of blast devices	N.A.
Duration of precleaning					
min.	12	1.5-5	6	N.A.	N.A.

N.A. = unknown

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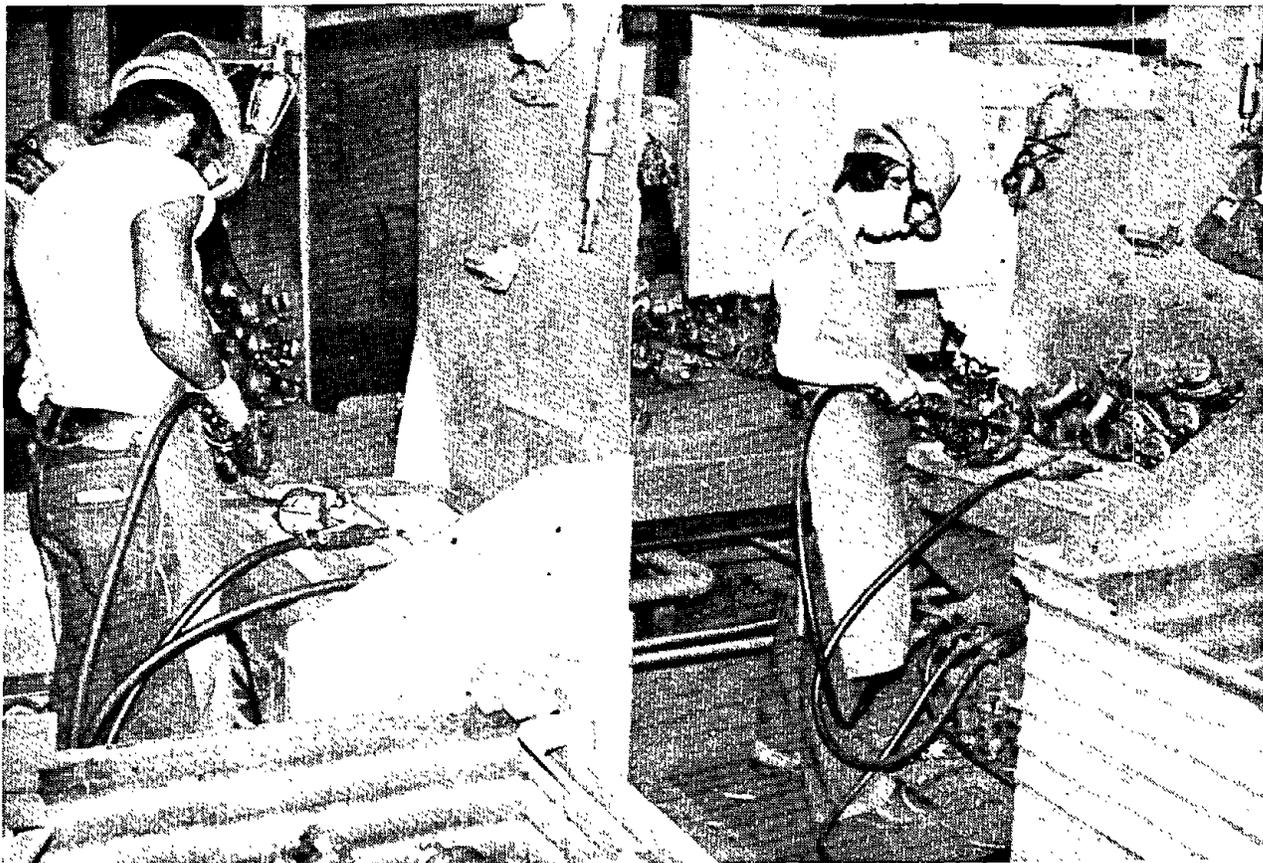
Figure A2-1. Downdraft chipping and grinding bench (Case A).

direct air movement past the process and to provide a shield
between adjacent workers.

Table A2-2. Summary of control methods.

Case	At source	General ventilation
		Control methods
A	Downdraft bench	Louvered fresh air "drops" at spaced intervals throughout area; supply air exceeded exhausted air in the area.
B	Downdraft bench	Louvered individual fresh air supplies for each worker; exhaust air exceeded fresh air supply, causing indraft from adjacent process areas.
C	Downdraft bench	Louvered individual fresh air supplies for each worker; supply air exceeded exhausted air in the area.
D	Downdraft bench	Exhaust air from each bench recirculated to work area from air cleaner at back of bench (90%); single point untempered fresh air supply into room (10%).
E	High-velocity, low-volume hoods (HVLV)	Single point fresh air supply on one end of room; supply air exceeded exhausted air in area.

§ Except as noted, fresh air units had heaters for tempering air during
cold weather.

Exhaust flows through three of the four benches evaluated
were less than the ACGIH recommended flow range (Table A2-3).

Case B—A downdraft bench somewhat larger than in Case A also utilized
wood slats as a work surface (Figure A2-2). This bench was
also custom designed with the same features as Case A. An
additional feature was a distribution duct located under the
bench top providing uniform.velocity distribution over the
surface of the bench. Much of the chipping and grinding was
performed in the front section of the bench nearest the operator,
and thus it was important that adequate downdraft be available
in this section. A partial booth arrangement was created by
two vertical sides above each bench which reduced short-
circuiting of air and shielded the grinding swarf between
workers. In three of the four benches evaluated, flows were

Figure A2-2. Downdraft chipping and grinding bench (Case B).

within the ACGIH recommended flow range (Table A2-3). The fourth was slightly below the minimum recommended flow rate.

The exhaust air in Case A and B was cleaned by fabric filters before being discharged outdoors.

Table A2-3. Downdraft bench exhausts compared to recommended flows.

	A	B	C	D
Bench area, ft^2	4	12	24	9.2
Bench area, m^2	0.37	1.12	2.23	0.85
Exhaust flow, cfm	430-680*	1730-2670*	5000†	1150-1700*
Exhaust flow, m^3/sec	0.20-0.32	0.82-1.26	2.36	0.54
ACGIH recommended exhaust§, cfm	600-1000	1800-3000	3600-6000	1380-2300
ACGIH recommended exhaust §, m^3/sec	0.28-0.47	0.84-1.42	1.69-2.83	0.65-1.08

§ Ref. 17, print no. VS-412.
* Flow measured in 4 benches.
† Flow measured in 1 bench.

Case C--This was a commercially available downdraft bench with a built-in air cleaner section and fan. The metal grating used as a work surface was large in area and the work height was low, specifically to handle large castings (Figure A2-3). Workers could stand on the bench and move around the casting as required. The bench was too low, however, for grinding on smaller castings, causing the operator to work in sitting and kneeling positions. A large rubber mat on which to kneel was located in front of each bench.

The downdraft velocity through this bench was much higher in back than in front of the bench where much of the work was performed.

The bench was baffled on three sides: in the back by the air cleaner, and on the two sides by removable wooden baffles.

The exhaust air from each bench was cleaned by a reusable viscous metallic prefilter, followed by a disposable fiberglass afferfilter. Rated efficiency of the filtering system was 99.7% at 0.5 microns and larger. The air cleaning system was

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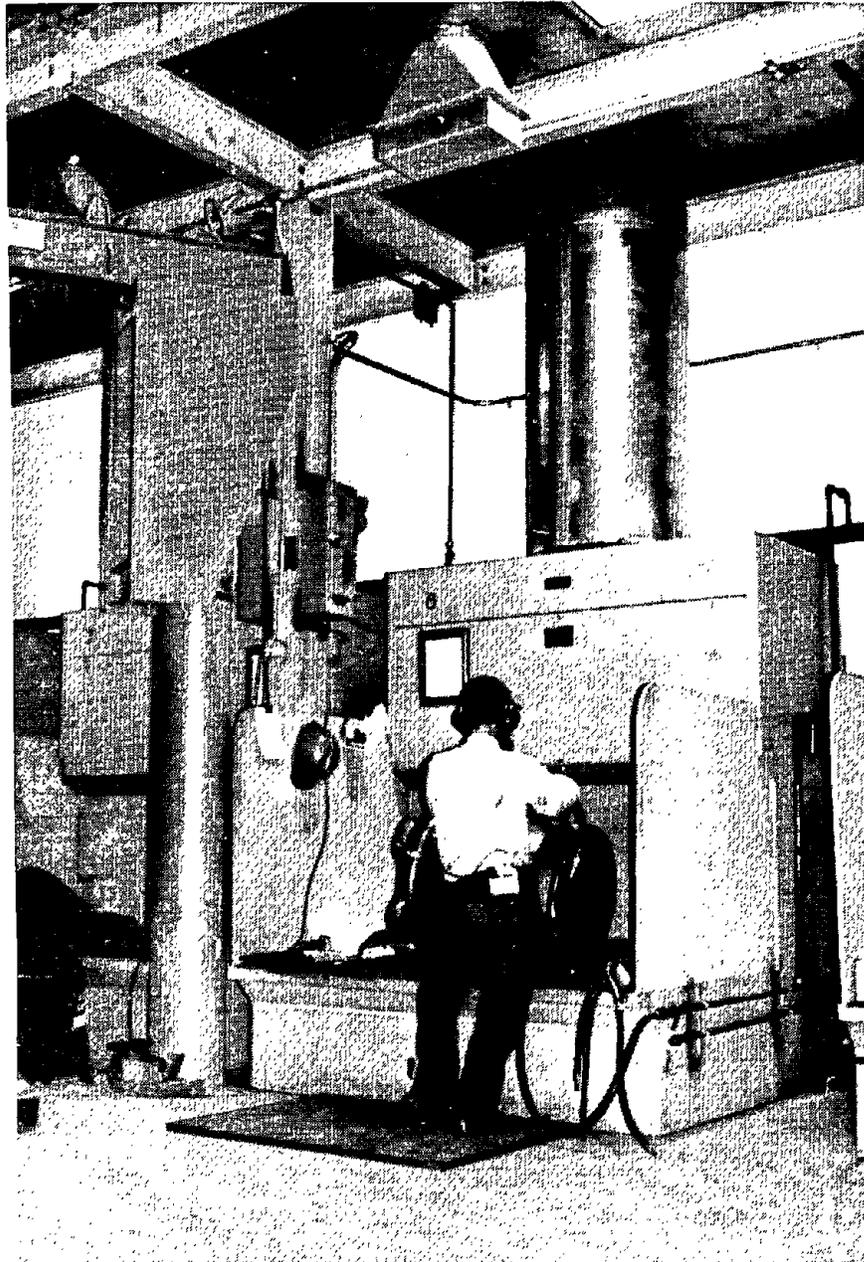
Figure A2-3. Downdraft chipping and grinding bench (Case C).

located in the back of the bench and the exhaust discharge
stack for each bench recirculated the cleaned exhaust air into
the plant air space.

Because clogging of the air cleaning system on each bench could
cause reduction in flow and, therefore, reduction in capture
efficiency of the bench, a manometer was used to monitor the
differential pressure across the filters, with a point on the
scale marked for disposable filter replacement. Since the
equipment had just been installed, required filter replacement
frequency had not yet been established. The downdraft air
flow was well within the ACGIH recommended flow at the bench
measured (Table A2-3).

Case D--Like Case C, this was also a commercially available downdraft
bench with a built-in air cleaner section and fan, but this
bench was smaller, higher, and circular, permitting good
access for working around a casting, as well as rotation
without using a hoist (Figure A2-4). The benches were located
in semi-enclosing booths.

The installation had a history of operation and it had been
found that filters in the air cleaner section of the bench
needed to be replaced every two weeks. Filter changing had
taken place four days before the field survey but downdraft
velocity measurements at the benches showed that some benches
were drawing considerably less air than others. In two of
four benches measured, the flows were at or below the minimum
ACGIH recommended flow range (Table A2-3).

The downdraft benches were most effective in capturing chipping and grinding
dust when the direction of the swarf was toward the bench, and much less
effective when the direction of the swarf was away from the bench. In the
former case, the exhausted bench acted as a receiving hood, directly
capturing the fine dust particles in the induced air stream traveling with
the grinding swarf. In the latter case, the bench acted as an exterior
hood, with the resulting limitation that dust could only be captured when
the induced air traveling with the grinding swarf slowed to below the
capture velocity of the bench. Capture velocity falls rapidly the further
grinding takes place from the bench surface.

In the majority of the cleaning work performed, the direction of the grinding
swarf was, of necessity, variable. The casting configurations were complex,
requiring cleaning at many different angles. The amount of cleaning
necessary and performed also varied significantly from casting to casting.

Body mechanics was also a limiting factor on controllability of grinding
emissions using portable tools, especially with the heavier tools. Applying
necessary pressure against the workpiece required that the operator position
his body so that he could properly support the tool and apply the pressure
with minimum exertion. Whenever possible, the operator used his body
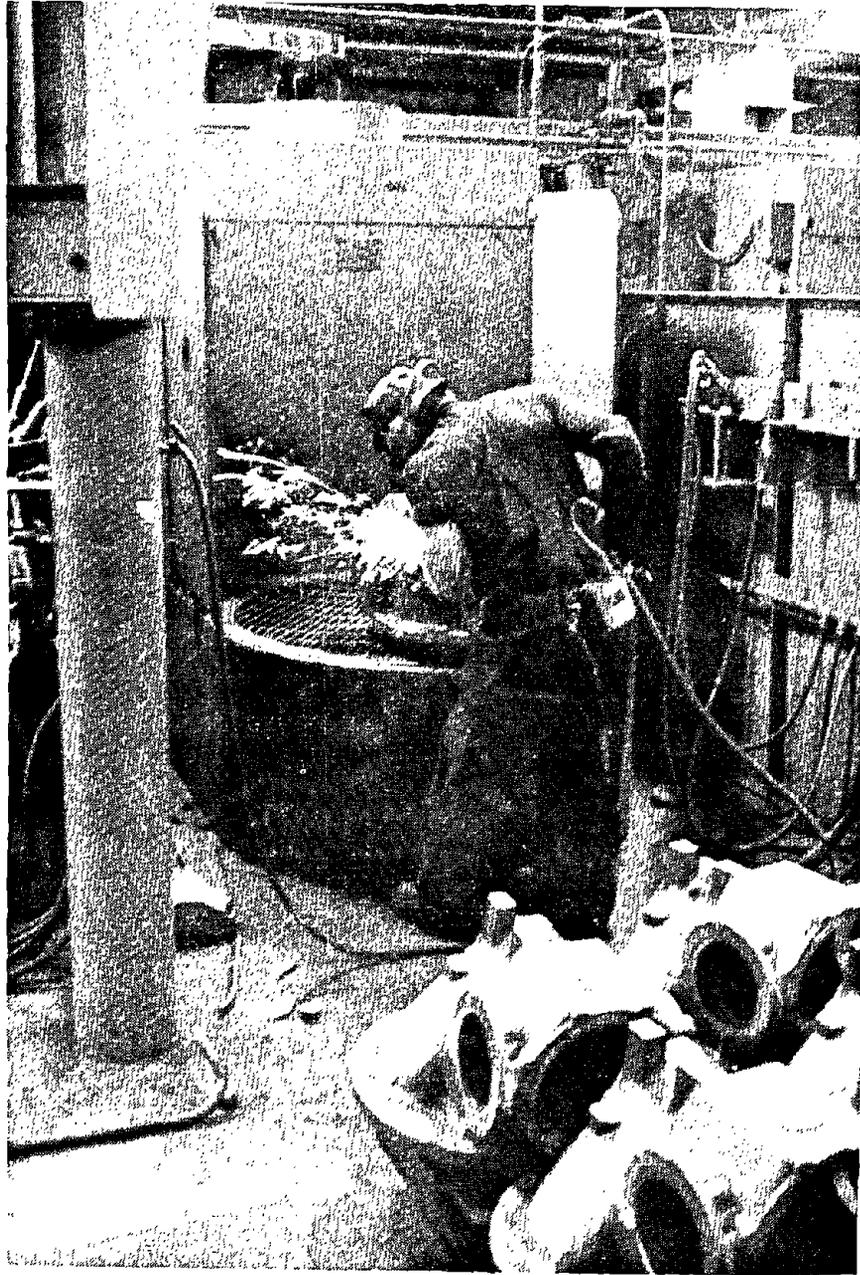to help him apply pressure, with the portable grinding tool pressing

Figure A2-4. Downdraft chipping and grinding bench (Case D).

against his midsection. In this position he was usually bent over the casting with his mouth and nose as close as 0.5-1.5 ft (0.15-0.46 m) from the grinding point. Thus, dust liberated need have travelled only a small distance to enter the breathing zone. In addition to bringing the operator's breathing zone precariously close to the dust generation point, the body position of minimum exertion also blocked most pathways in which supply air could be used to assist dust capture.

The casting itself was a barrier to capture for much of the chipping and grinding work performed on top of or inside it. Internal grinding really complicated the capture process because the pathway for capture was up and out of the casting, then around the casting and down into the bench (Figure A2-5). The dust tended to accumulate within the casting and if the worker's face was located close to the cavity, the confined dust usually ended up in his breathing zone.

SYMBOL

$\longrightarrow$ AIR FLOW PATTERNS
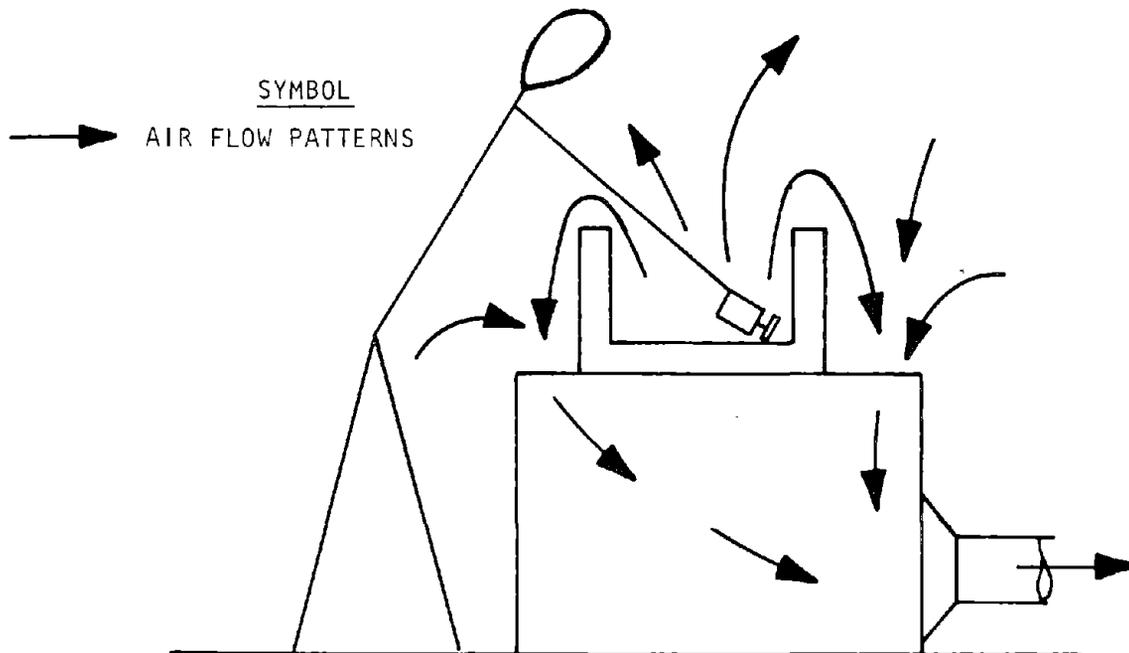
Figure A2-5. Internal grinding on a downdraft bench.

Pneumatic tool discharge air disrupted capture by creating turbulence around the casting which dispersed the dust. In addition, the action of the pressurized air tended to entrain adhered dust from the casting surface.

High Velocity, Low Volume (HVLV) Hooded Tools, Case E--
Close capture hoods were retrofitted to some of the portable grinding tools to capture fines generated by the grinding process using the high velocity, low volume method. The exhaust system functioned by creating an indraft velocity sufficiently in excess of the dust generation velocity to capture

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dust as it was produced. High suction pressure at hood slots could produce
air velocities ranging from 6,000 to 39,000 fpm (30-195 m/sec). A
description of the hoods is presented in Table A2-4.

Table A2-4. Description of HVLV controlled tools, Case E.

Tool name	Diameter, in.	cm	Speed, rpm	Hood description
Cup type surface grinder	6	15.2	6,000	Fitted hood wrapping 3/4 of the way around the wheel § (Figure A2-6).
Abrasive cut-off saw	9	22.8	6,000	Fitted hood enclosing all but work area of saw (Figure A2-7).
Cone wheel grinder	1	2.5	6,000	Slot located on tool shaft adjacent to wheel (Figure A2-8)*.
Radial grinder	2	5.1	6,000 or 12,000	Adjustable extractor head located adjacent to periphery of wheel (Figure A2-9). †.

§ Reference 17, print no. VS-802.
* Reference 17, print no. VS-801.
† Reference 17, print no. VS-804.

The hoods were exhausted through long flexible hoses which were attached to
vacuum inlets located at each of the casting cleaning stations. The vacuum
manifold pipes joined and the entire flow was cleaned by a fabric collector
before being discharged outdoors#.

The HVLV system was designed for 10 vacuum points; but only five were being
used. Exhaust flow measurements for the individual tools were not made
during the survey but rather, system operating conditions were measured
and compared against design values.

Total system exhaust	- actual	1770 cfm	(0.84 m^3/sec)
	- design	1950 cfm	(0.92 m3/sec)
Static pressure	- actual	14 in. Hg	(35.5 cm Hg)
	- design	12 in. Hg	(30.5 cm Hg)

Total tool usage, as well as the use of HVLV controlled tools (Table A2-4,
Figures A2-6 through A2-9) varied significantly among the workers. During

The system was similar to the typical system shown in Print no. VS-807,
  reference 17.

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Figure A2-6. Cup grinding using HVLV controlled tool.
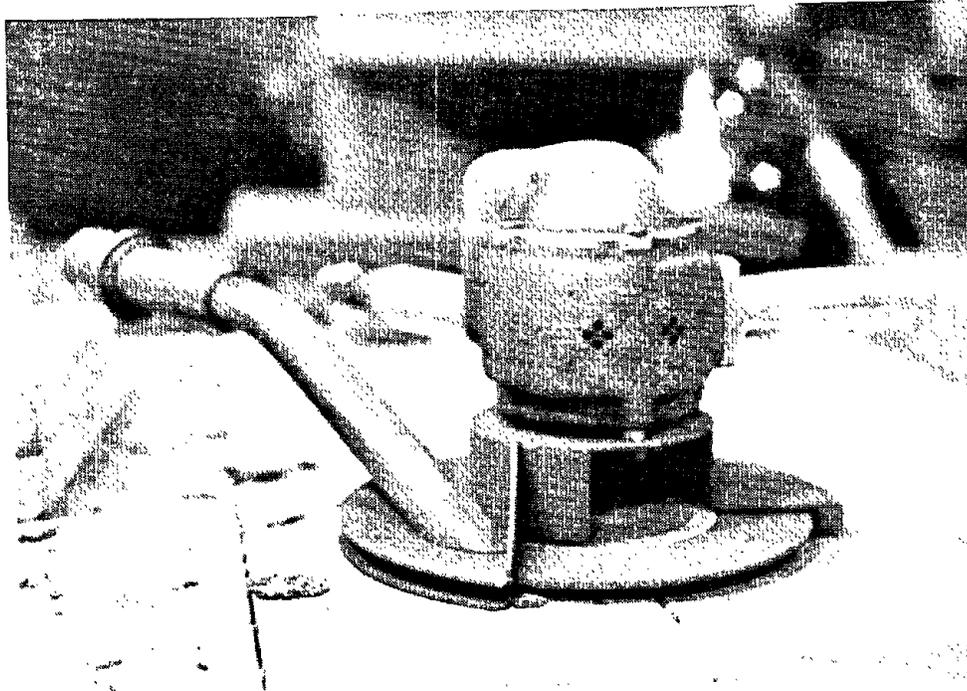
Figure A2-7. Abrasive saw with HVLV hood.
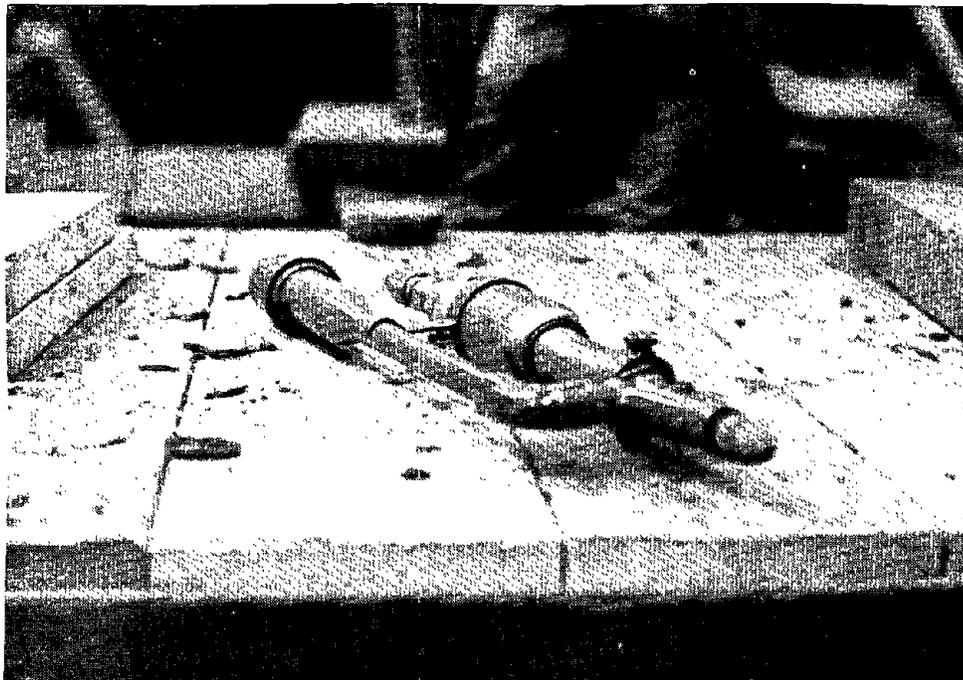
Figure A2-8. Cone grinder with HVLV hood.

Figure A2-9. Radial grinding using HVLV controlled tool.

the survey, hooded tool utilization ranged from 40-90% of the total tool usage time among the workers and averaged 70%. Included in this average was the chipping operation, which was uncontrolled at the source.

Since both hooded and unhooded tools were used, visual observations were made of each to assess the effect of the hoods on dust capture. The hooded tools noticeably reduced dust emissions, especially when grinding on flat surfaces. Dust was seen to escape the hoods particularly when grinding on edges, curved surfaces, and in hard-to-get-at places that required unusual tool angles.

Close-fitting hoods on the cup grinder and cut-off saw seemed to be more effective at removing the dust than the cone wheel and radial grinder hoods which did not enclose the wheel. At times, the radial grinder hood lined up directly with the swarf, but at other times the swarf completely missed the hood due to the angle at which the tool was held in relation to the casting. The cup grinder and cut-off saw were also affected by the angle of tool use.

Interferences restricted controlled tool usage for certain tasks. For example, one worker noted that the hooded cut-off saw could not be used to remove unwanted metal from areas near corners. The extra hooding prevented that tool from removing all of the metal that could be removed by the unhooded tool, thus requiring that a cup grinder be used to finish the grinding. When faced with this situation, the worker always chose to use an unhooded cut-off saw to perform the task. A second example involved the need for a long cone wheel grinder for cleaning hard-to-reach areas within a casting. Because no controlled tool could reach far enough, the worker always used an unhooded cone wheel grinder with an extra long extension.

Although the workers were instructed to use hooded tools whenever possible, they did not like them because they were heavier, bulkier, and required an exhaust hose which interferred with their work. In some instances where controlled tools were not used, partial control was achieved by placing a vacuum hose adjacent to the grinding tool while working.

General Ventilation--
Other than the non-use or inefficiencies of the source controls previously discussed, a number of other sources may have contributed to worker exposure. A summary of these sources is presented in Table A2-5.

Work practices--Castings were precleaned using shot blasting prior to finishing, but this process sometimes left a dust layer on the casting, as well as deposits of dust within the internal cavities. Reentrainment by the tool of dust deposited in internal cavities posed a special hazard because of the limitations of exhaust methods in capturing dust during this operation.

Air nozzles were used in some cases to clean dust from castings before, during or after the finishing process. The local exhaust methods used to control chipping and grinding could not control dust from this air cleaning process. Although good housekeeping certainly must have contributed to better dust control, the use of brooms increased the exposure of operators

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Table A2-5.   Potential sources of dust other than the chipping and grinding processes.

Dust source	A	B	C	D	E
Work practices					
1. Blowing off castings	No	No	Yes	No	Yes
2. Sweeping	At end of shift	No	At end of shift	At end of shift	Often during workshift
3. Dressing grinding wheels	Yes	No	No	No	No
4. Loading and unloading bench	No	Yes, casting tipped over conveyor onto bench	Very little	Very little	Very little
Adjacent dust sources					
1. Stand grinding	Yes	Yes	No	No	No
2. Shot blasting	No	Yes	No	No	Yes
3. Swing grinding	No	Yes	No	No	No
4. Fork lift traffic	Yes	No	Yes	Yes	Yes
5. Powered sweeper (aisles)	Yes	No	Yes	Yes	No
6. Recirculated air cleaners in workbench	No	No	No	Yes	No
Remote sources	No	Sand system	No	No	No

to respirable dust.

Adjacent sources--In only two cases were the chipping and grinding areas isolated from other processes. In the other three cases there were other types of finishing devices present with a potential for respirable silica emissions, such as stand grinders, swing grinders and abrasive blast cabinets. Fork lift trucks and the powered sweepers intended to keep aisles clear for them were also potential sources of silica dust.

Remote sources--As can be seen in Table A2-2, in all but one case (Case B) the supply air exceeded the exhaust air. This greatly assisted in preventing cross-contamination from remote process areas. In Case B air could have entered the cleaning room from the area of the sand system.

Four different methods of general ventilation were employed, each helping to provide thorough air turnover in the areas evaluated (Table A2-2).

1. Individual air supplies were used in two of the cases. In Case B a tempered air supply grille was located above each worker at the 9 ft (2.7 m) level, supplying on the average about half of the exhaust air as push air to assist capture and keep the breathing zones of the workers supplied with fresh air. During the process of designing the fresh air system, the foundry had constructed a prototype booth and tried various combinations of exhaust and fresh air supply. Experiment showed that a low ceiling restricted the amount of "push" air that could be used. Too much supply air caused contaminants to be blown past the capture hood. Three grilles were installed above each worker with a total area of 7.27 ft^2 (0.68 m2) and an average outlet velocity of approximately 770 fpm (3.56 m/sec).

   In Case C fresh air in the amount of 700 cfm (0.33 m3/sec) was supplied 12.5 ft (3.8 m) above floor level at the front center of each bench. As in Case B, partial supply of makeup air would normally result in air being drawn in from other process areas. During the days of the survey, however, all 24 outlets of the fresh air supply ducts were in operation, but only four benches were being exhausted. This put the chipping and grinding area under a positive pressure which prevented cross-contamination from other process areas. The cleaned exhaust air from the benches was discharged in the plant outside the chipping and grinding area.

2. Air drops at closely spaced intervals throughout the area was another method of getting fresh air mixed in the entire cleaning room air space (Case A).

3. In Case D, most of the air turnover was provided by the recirculated exhaust from the bench air cleaners. Only a small amount of fresh untempered supply air was used for dilution. However, the fans used to provide this fresh air interferred with dust capture at several downdraft benches. Fresh air was blown into the room in

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a horizontal direction from a high location at one end of the
room. Since the incoming air was cooler than the indoor air
it "fell" causing a disruptive cross-draft at worker level. At
the far end of the room, an overhead exhaust fan was located
too low, causing a strong disruptive updraft in the area of two
booths.

4. In one case (Case E) single point ventilation was provided by a
makeup air unit located at one end of the room. The air was not
distributed and although it did cause a high rate of air turnover
generally, several workers did not receive the full benefit
because their work stations were partially isolated from the
predominant air flow pattern.

PERSONAL PROTECTIVE DEVICES

A wide variety of practices were observed from no protective devices to
disposable respirators to airline respirators covering the mouth and nose
(TC19C-83). The plant using the airline respirators was in the process
of converting to full face airline respirators (NIOSH No. TC19C-94).
Because goggles and sometimes face shields were needed for eye protection,
it was believed that a single full face mask could serve both protective
needs.

RESULTS

Data on breathing zone exposures to respirable silica had previously been
obtained by foundry personnel in two of the five cleaning rooms (22 samples)
and during the present survey, 28 similar samples were obtained. In addition,
general area samples for background dust levels were obtained at each
foundry during the present survey, bringing the number of samples available
to 63. One of the 63 samples was found to be invalid and was excluded
from further analyses.

The similarity of dust levels in the five foundries was surprising. This is
shown by a log-probability graph, Figure A2-10 in which all 62 (grouped)
data points were plotted. That a single straight line could be drawn
through the data points indicated that all of them could have come from
the same foundry and that the data were log-normally distributed. (The
single "high" point indicating a probability of 4.8% of exceeding 400% of
the allowable concentration is based on too few samples to be particularly
meaningful). Similarity of dust data was further confirmed by the
information in Table A2-6 where background and low and high foundry
geometric means are compared with the overall breathing zone and grand
average for percentage quartz, respirable dust concentration, and fraction
of the allowable concentration. A "t" test at the 0.05 level (on data
transformed to logarithms) was able to distinguish only three of the
averages from "overall" means and none from "grand averages".

PERCENTAGE OF VALUES LESS THAN OR EQUAL TO THE
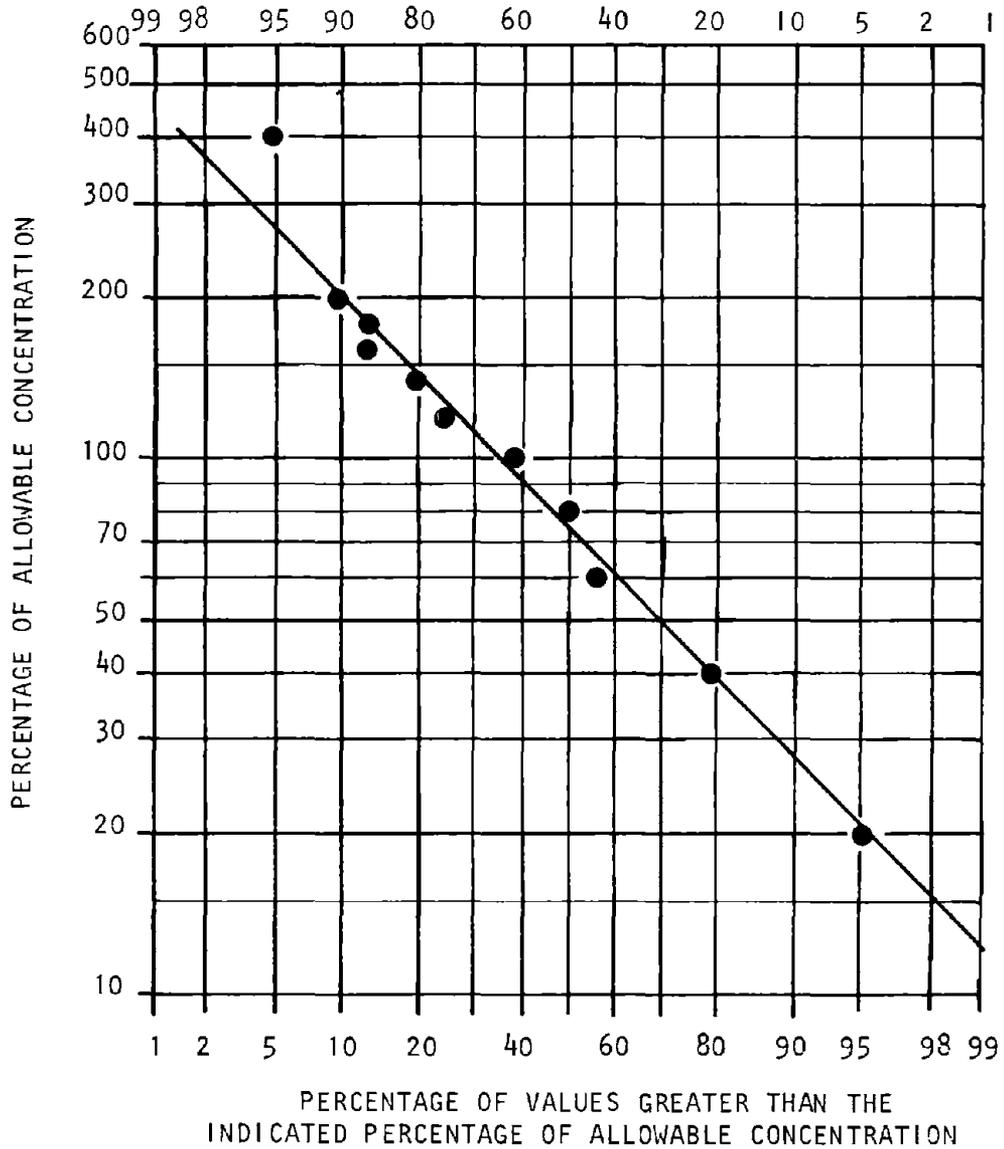INDICATED PERCENTAGE OF ALLOWABLE CONCENTRATION

Figure A2-10. Log probability graph of grouped data on
percentage of allowable exposure during
chipping and grinding.

Table A2-6. Respirable silica in chipping and grinding areas of five foundries.

	Number of samples	Geometric mean	Geometric standard deviation
Percentage quartz			
Background Breathing zone	13	8.79	2.29
Low foundry	15	7.04	2.38
Overall	49	9.93	2.17
High foundry	14	13.81	1.71
Grand average	62	9.68	2.18
Respirable dust, mg/m^3			
Background Breathing zone	13	0.35*	1.82
Low foundry	4	0.32*	2.05
Overall	49	0.69	1.75
High foundry	14	0.82	1.97
Grand average	62	0.60	1.88
Fraction of allowable			
Background Breathing zone	13	0.39*	2.80
Low foundry	4	0.35	6.68
Overall	49	0.85	2.50
High foundry	14	1.31	2.14
Grand average	62	0.72	2.68

*Significantly different from the overall mean (but not from the grand average) at the 0.05 level by a "t" test on the transformed data.

CASE HISTORY #3
DUST CONTROL DURING
STAND GRINDING OF IRON CASTINGS
AUGUST, 1977 - JANUARY, 1978

ABSTRACT

A high production iron foundry made data available on respirable silica ex-
posures of high speed stand grinding operators. All grinders were ventilated
by means of conventional exhaust hoods. The data made it possible to
assess the effects on breathing zone contamination of grinding on castings
of different sizes, as well as of grinding during all three shifts of opera-
tion. Casting size did not make a significant difference in the amount of
airborne dust, but there was a progression and significant reduction in
dust levels from first shift to second to third. The stand grinding process
was performed identically on all three shifts but there were fewer operators
working on each successive shift, fewer stand grinders and fewer workers on
other cleaning room operations such as manual chipping and grinding and shot
blasting. Thus, the breathing zone concentrations were probably related
mostly to variations in cleaning room background dust levels at the different
rates of production. Unfortunately, no background dust level data were
available to substantiate this conclusion.

PROCESS DESCRIPTION

Two sizes of stand grinders were used for two different size ranges of
castings. Data for the two are presented in Table A3-I. All of the castings
processed came directly from shakeout with no additional precleaning such
as shot blasting.

Although all of the cleaning room processes, i.e., stand grinding, manual
chipping and grinding, and shot blasting, were in operation during all
three shifts, the level of production varied from shift to shift. It was
highest during first shift (58 workers) and progressively less during
second shift (50 workers) and third shift (30 workers).

WORKPLACE HAZARDS

The major air contaminant hazard from cleaning and finishing was inhalation
of respirable silica. Respirable dust was generated during stand grinding
primarily by the grinding process, however, transport and handling of
castings could also have resulted in dust exposure, especially since the
castings were not shot blasted prior to handling. Other cleaning room
processes also could have contributed dust to the background air.

CONTROL OF EXPOSURE

Control of respirable dust in the breathing zones of stand grinders was

achieved through the use of conventional grinder hoods and individual fresh air supplies for the workers (which also provided cooling).

Engineering

Control at the Source--
Conventional grinder hoods were utilized on all of the stand grinders. Exhaust flows were about 75% of the ACGIH recommended minimum exhaust flow (Table A3-1).

General Ventilation--
All of the cleaning room processes produced some dust emissions which could build up in the background air. Because the weather was cold during the period of the sampling, the doors and windows leading to the outside were closed. Makeup air to the area was provided by individual fresh air supplies of 400 cfm (0.19 m^3/sec) to each of the stand grinders.

RESULTS

Data on breathing zone exposures were obtained by foundry personnel during all three shifts of the cleaning room operation. During each shift four workers were sampled on two sampling days for a total of 24 samples. However, during the third shift, two samples on one individual were found to be invalid and were excluded.

The breathing zone samples were taken to determine if there was a significant difference between shifts and whether or not the size of the casting being cleaned had any effect on the inhalation hazard. All data are summarized in Figure A3-1 as a plot of the logarithm of fraction of the allowed concentration vs. the percentage of samples exceeding the indicated number. A straight line can be drawn through the data points indicating that a log transformation of the data should be used prior to analysis. This was done and the (retransformed) data summary appears in Table A3-2.

No effect of casting size was evident in any of the categories[§]. There was however, a highly significant difference between shifts for the concentration of respirable dust in the breathing zone and a significant difference for the fraction of the allowable concentration. In each case, highest values were found for the first shift and lowest for the third. Even though the amount of data is limited, this analysis indicates that sampling only on the day shift may well provide a distorted view of the situation. In this case, none of the third shift samples exceeded the allowable concentration and only one of the eight second shift samples did so while half of the first shift samples were in excess of the limit for quartz.

Even though the percentage of quartz in the samples was highest on the first shift, this difference was not significant. That it had little

§ This result also showed that a difference in surface speed of grinding was also not a factor, because the smaller castings were ground at the lower surface speed and the larger castings at the higher speed.

TABLE A3-1. Process and ventilation system data for two different sizes of stand grinders.

Number of machines	5	3
Wheel size range		
(in.)	20-24	24-30
(cm)	51-61	61-76
Surface speed		
(ft/min)	9500	12,500
(m/sec)	48	63
Average exhaust flow		
(cfm)	590	880
(m^3/sec)	0.28	0.42
ACGIH minimum recommended flow[§]		
(cfm)	820	1200
(m^3/sec)	0.39	0.57
Weight range of castings		
(lbs)	0-4	10-40
(kg)	0-1.8	4.5-18.2
Average production rates per shift		
a. No. of castings	2277	442
b. Total weight of castings processed		
(lbs)	3918	10,055
(kg)	1779	4565

§ Reference 17 (VS-411.1).
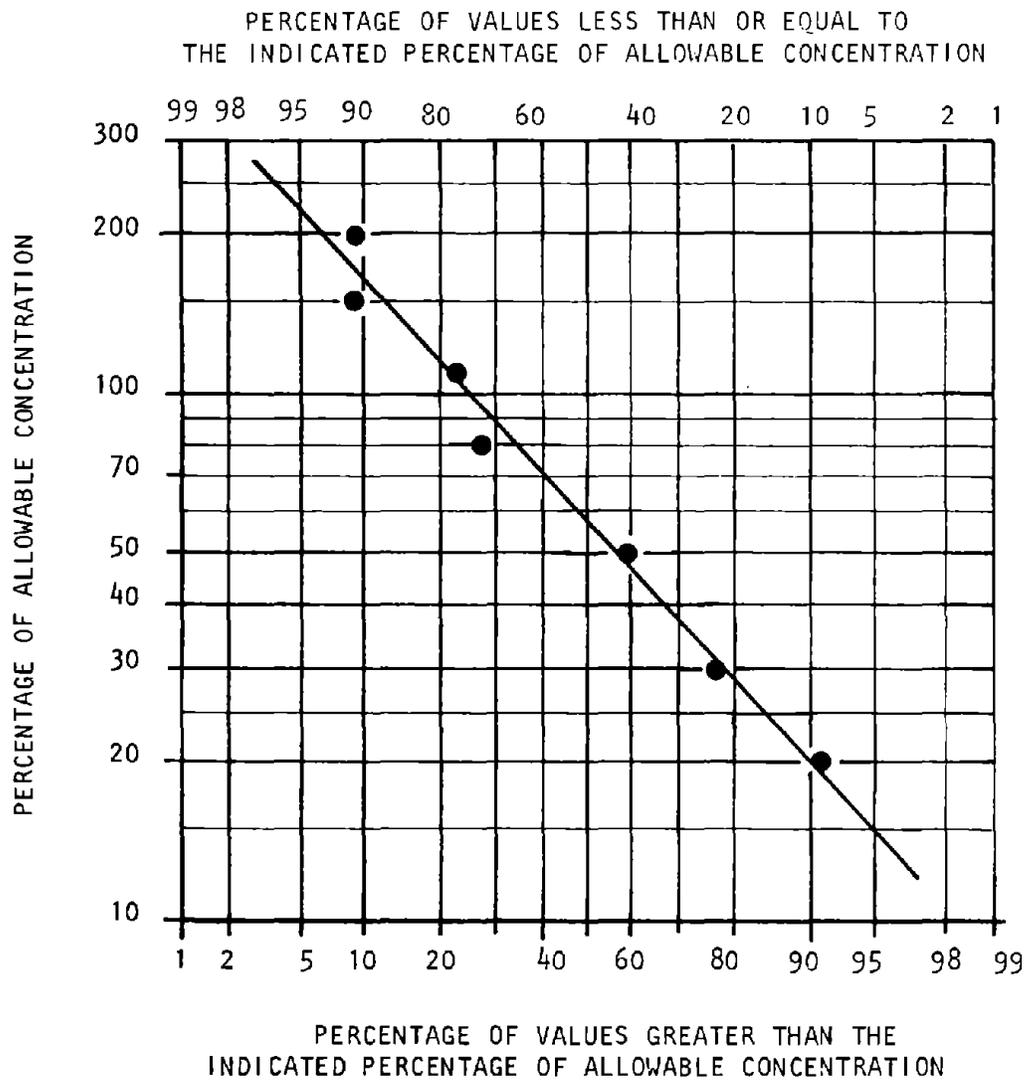
Figure A3-1. Log probability graph of grouped data on percentage of allowable exposure during stand grinding.

Table A3-2.   Respirable silica in the breathing zones of stand grinders.

	No. of samples	Geometric mean	Geometric standard deviation
Percentage quartz			
Shift 1	8	10.6	1.83
Shift 2	8	5.7	1.92
Shift 3	6	6.5	1.57
Small castings	12	8.8	1.59
Large castings	10	6.1	2.12
Grand average	22	7.4	1.87
Respirable dust, mg/m³			
Shift 1*	8	0.71	1.43
Shift 2*	8	0.61	1.36
Shift 3*	6	0.43	1.18
Small castings	12	0.58	1.44
Large castings	10	0.59	1.42
Grand average	22	0.59	1.43
Fraction allowable			
Shift 1§	8	0.92	2.11
Shift 2§	8	0.49	2.03
Shift 3§	6	0.37	1.58
Small castings	12	0.64	1.96
Large castings	10	0.50	2.30
Grand average	22	0.57	2.10

§ Significant differences (at about the 5% level) found between members of this group by means of an analysis of variance performed on transformed data.

* Highly significant differences (0.5% level) found between members of this group by means of an analysis of variance performed on transformed data.

effect is indicated by the fact that the "highly significant" differences in respirable dust concentration became only "significant" when combined with data regarding quartz concentration to form the "fraction allowable".

Differences between shifts could have been caused by differences in the background dust concentration resulting from different levels of cleaning room activity because dust concentrations are generally proportional to production rates or other measures of activity.

CASE HISTORY #4
DUST CONTROL FOR SWING GRINDING OF IRON CASTINGS
SEPTEMBER, 1977

ABSTRACT

Close-fitting hoods exhausted through mobile duct systems permitted capture
of swing grinding dust with a smaller air volume than would have been
required by an exhausted booth. An adjustable bottom chute on the hood was
designed to permit complete dust capture without interference to the grinding
process in the range of grinding wheel sizes used. This adjustment, however,
was not being made and, although the dust generated by a small wheel was
captured, half the dust generated by a large wheel escaped. Fresh air supply
and a wall ventilator reduced worker exposure to dust escaping the hood.

PROCESS DESCRIPTION

Equipment and Operation

Swing grinding was done by two workers, designated A and B, working side-by-
side in a semi-isolated area of a cleaning room. Pictures of the two
operations in progress are shown in Figure A4-1 and 2. Grinder A was
using a 24-inch (61 cm) diameter wheel at 13,200 sfm (722 surface m/sec),
and grinder B was using an 18-inch (45 cm) diameter wheel at 8,000 sfm
(438 surface m/sec).

Castings were delivered to the work stations by forklift trucks that later
removed the castings. Workers used overhead hoists to load and unload a
work support, a pile of wood pallets for the flat castings ground at
Station A, and a wooden frame for the circular castings at Station B. The
swing grinding machine was suspended by a chain-pull hoist to a manually
operated overhead bridge crane permitting the operator to reposition the
wheel as required by the work.

Materials and Rates

Bell and ring-shaped castings, and housings of widely varying dimensions
were finished at the swing grinder stations. A typical ring casting was
2 ft diameter x 1 ft high (0.6 x 0.3 m); a typical housing was 1.5 ft x
1.5 ft x 0.5 ft (0.46 x 0.46 x 0.15 m). Castings were produced by green
sand molding with a variety of cores including phenolic urethane cold
box, furan no-bake, oil sand and shell. Before cleaning and finishing,
castings were precleaned using one of three different devices: cabinet
blast, table blast, or shot blast room.

WORKPLACE HAZARDS

The major air contaminant hazard from swing grinding iron castings was
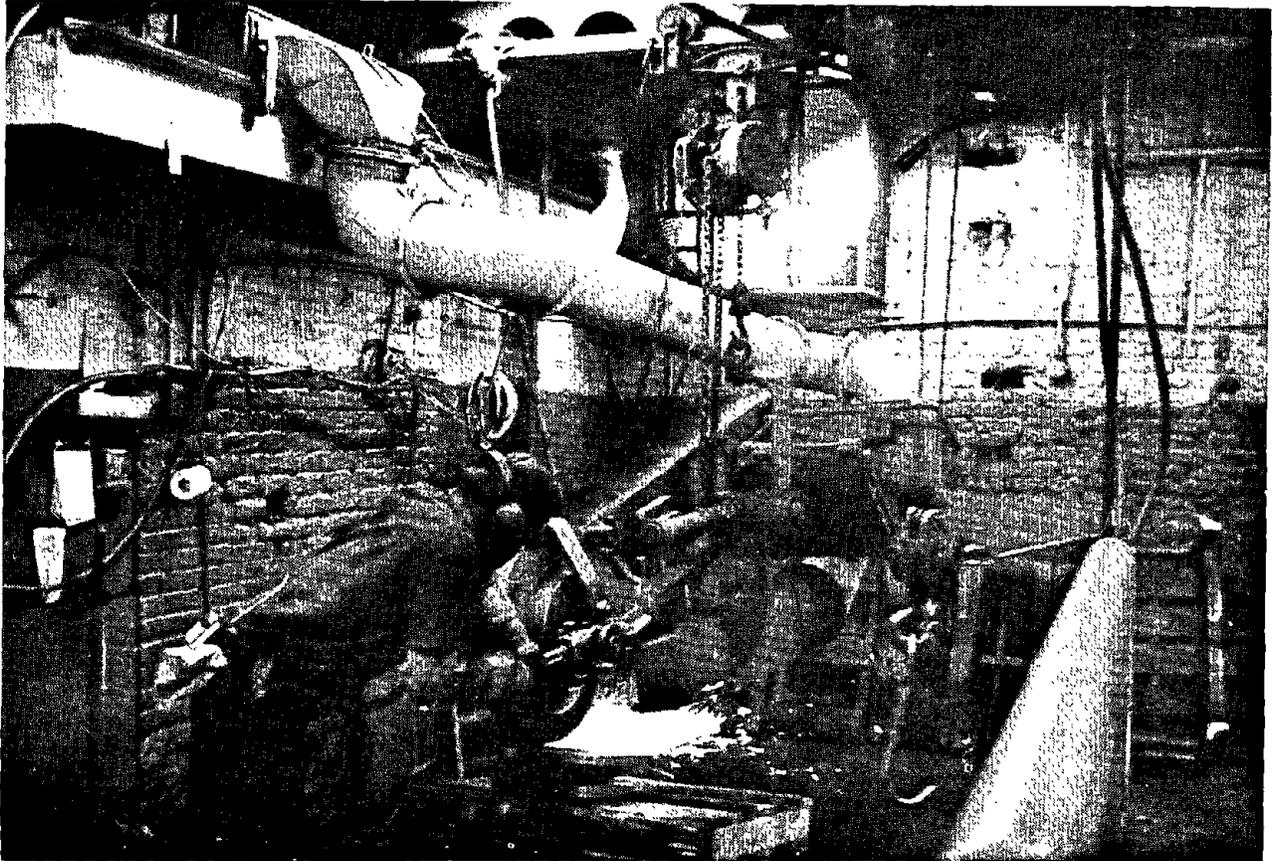
Figure A4-1. Swing grinding operation (Station A) showing mobile
exhaust duct system. The hood chute is not adjusted to capture
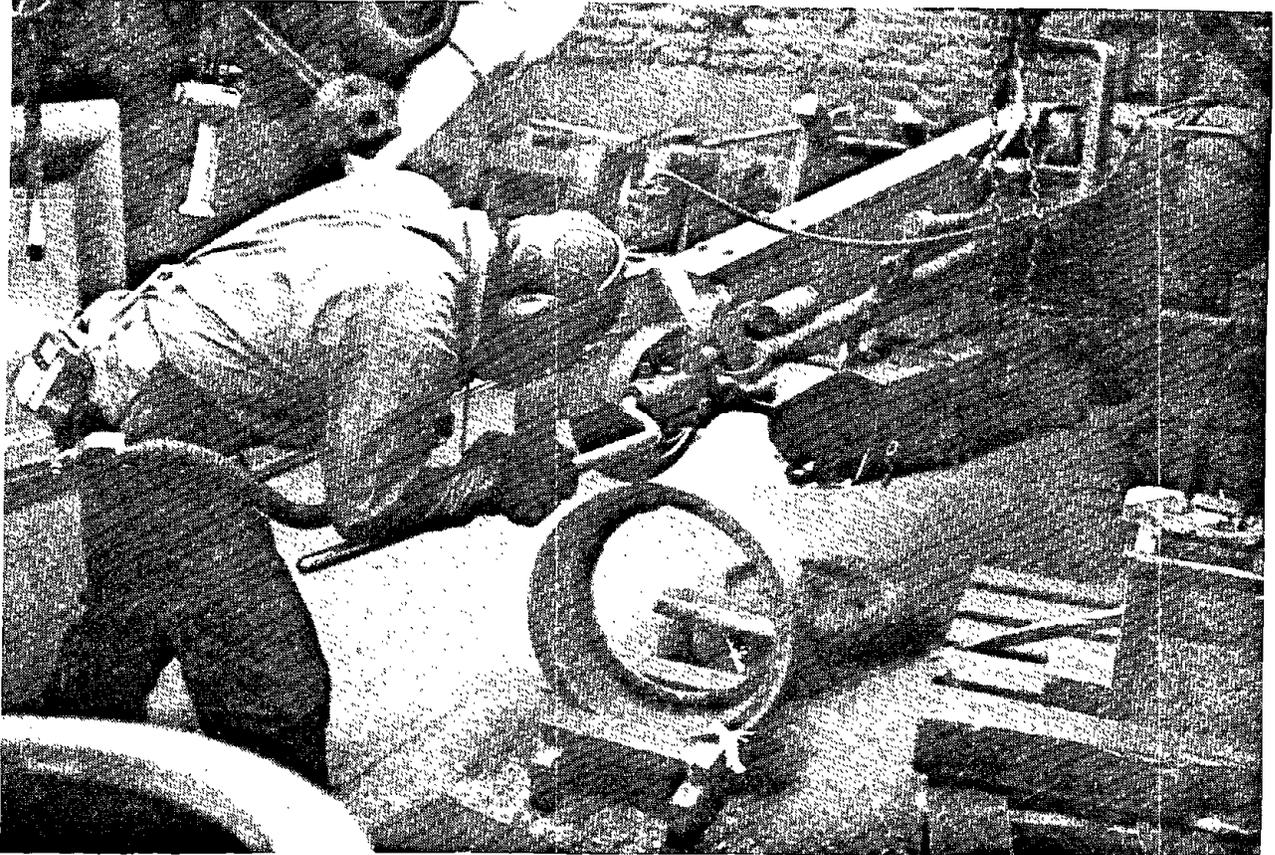the entire grinding swarf.

Figure A4-2. Swing grinding operation (Station B). The hood chute is
adjusted to capture the entire grinding swarf.

respirable silica.

CONTROL OF EXPOSURE

Reduction in exposure to respirable silica was achieved through local control hoods mounted on the swing grinders, a wall ventilator that removed emissions from the swing grinding area and the prevailing fresh air currents.

Engineering

Local Control--
Commercially available close-fitting hoods were attached to a mobile ductwork system that permitted exhaust from swing grinding in any position of the wheel. Ductwork mobility was provided by two mechanisms:

1. A series of freely rotating duct elbows.
2. A carriage moving along an overhead exhaust plenum.

The hood and mobile ductwork connections are shown in Figure A4-1. Movement of the swing grinder back and forth by the investigator was accomplished with some difficulty, although it was hard to determine how much of the resistance was caused by the ductwork system and how much by the overhead crane.

The hood functioned as a receiving hood, positioned to receive the swarf as well as the fine dust carried with it. Exhaust from each swing grinder was measured at 2400 cfm (1.13 m^3/sec). This was low when compared to most exhausted booths that require 100-150 cfm/ft^2 (0.05-0.07 m^3/sec) of booth opening[§]. To capture all of the swarf without interferring with the process, an adjustable bottom chute on the hood allowed repositioning for the various sizes of grinding wheels used. However, the adjustable bottom chutes on both machines were wired in fixed positions. This non-adjusted position was correct for capturing the entire grinding swarf for the small wheel at Station B but it was set too high and only captured half of the swarf at Station A where a larger wheel was used.

General Ventilation--
The primary source of emissions was dust escaping with the uncaptured swarf at Station A. This dust was removed from the room by a 2400 cfm (1.13 m^3/sec) wall ventilator (plan view in Figure A4-3). The prevailing air current entering the semi-enclosed swing grinding area was fresh air drawn through a nearby truck entrance.

Personal Protective Devices

Both workers wore air-line respirators: one using a half-face respirator (NIOSH No. TC19C-83), and the other a full face respirator (NIOSH No. TC19C-94).
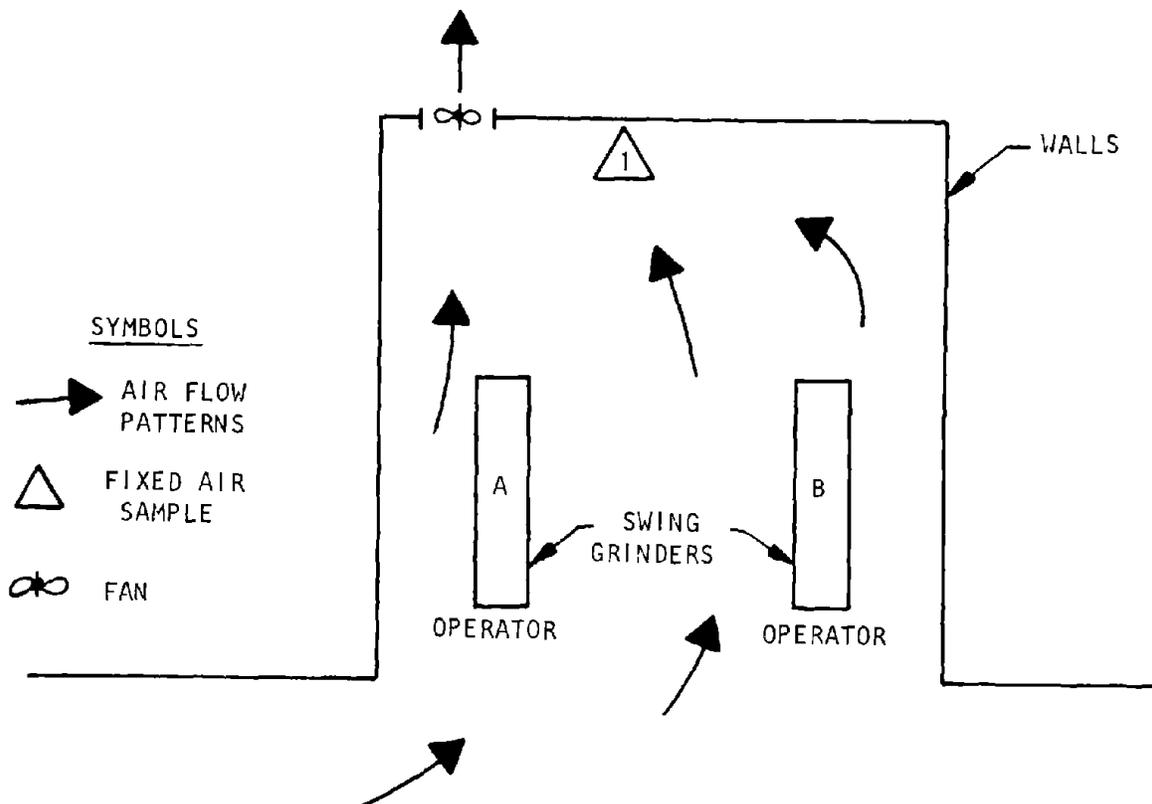

[§]Reference 17 (VS 414).

Figure A4-3. Ventilation patterns at swing grinder stations.

SAMPLING RESULTS

1. Breathing zone dust exposures were very low because of the capture of dust by the hoods and the prevailing air currents of fresh air which prevented dust from entering the breathing zone (Table A4-1).

2. Had any operators been located downstream of the swing grinding process, their exposures would have been significantly affected by the escaping dust from the swing grinder with the improperly adjusted chute.

Table A4-1. Air sampling results - respirable silica.

Worker or location	Type of sample	Percent quartz	Respirable dust, mg/m^3	Allowable respirable dust, mg/m^3 §
Swing grinder A	Pers.	21	0.29	0.43
Swing grinder B	Pers.	12	0.25	0.71
Background (1, Fig. A4-3)	Fixed	15	0.69	0.59

§ OSHA PEL and ACGIH TLV (1977).

CASE HISTORY #5
CONTROL OF EMISSIONS DURING
TORCH CUTOFF OF RISERS FROM LARGE STEEL CASTINGS
APRIL, 1978

ABSTRACT

Torch cutting of risers from large castings in a steel foundry was well
controlled by a ventilated booth. Total dust and metal fume were generally
well controlled in the worker's breathing zone. For this control method
to function properly, however, the torch had to be directed toward the
back of the booth. If it were directed at an angle, fume rollback occurred,
some of which entered the operator's breathing zone and some of which
escaped the booth.

PROCESS DESCRIPTION

Equipment and Operation

A torch cutting operation was used to cut risers from very large steel
castings in a specially designed booth. A photograph of the cutting
operation is shown in Figure A5-1 and a schematic view of the booth is shown
in Figure A5-2. Castings were loaded by an overhead crane onto a cart
which was rolled into the booth on tracks. The cart was almost as large
as the booth itself and, after it was installed within the booth, served
as a platform for the worker, as well as the casting. To remove the risers,
a worker held an oxy-acetylene torch in place until the riser was severed
from the casting. The torch contained an oxygen lance to facilitate metal
removal during the cutting. After cutting was completed, the cart was
withdrawn from the booth and the riser was removed. In some cases the
casting was then returned to the booth for cleanup of the cut off section.

Materials and Rates

A 4 ft long (1.2 m) torch was used to cut off 6-8 ft (1.8-2.4 m) diameter
risers. The worker held the torch almost continuously but took breaks
during the cutting process as needed (usually 10-15 minutes per hour).
Depending on the size of the riser, 1 to 3 hours were required to completely
sever it from the casting. The castings were composed of about the same
metal composition listed below:

Constituent	Percent
Manganese	0.7-1.0
Chromium §	0.6-0.9
Nickel §	0.6-0.9
Molybdenum §	0.2-0.4
	(continued)

—————————
§ Not present in all alloys.
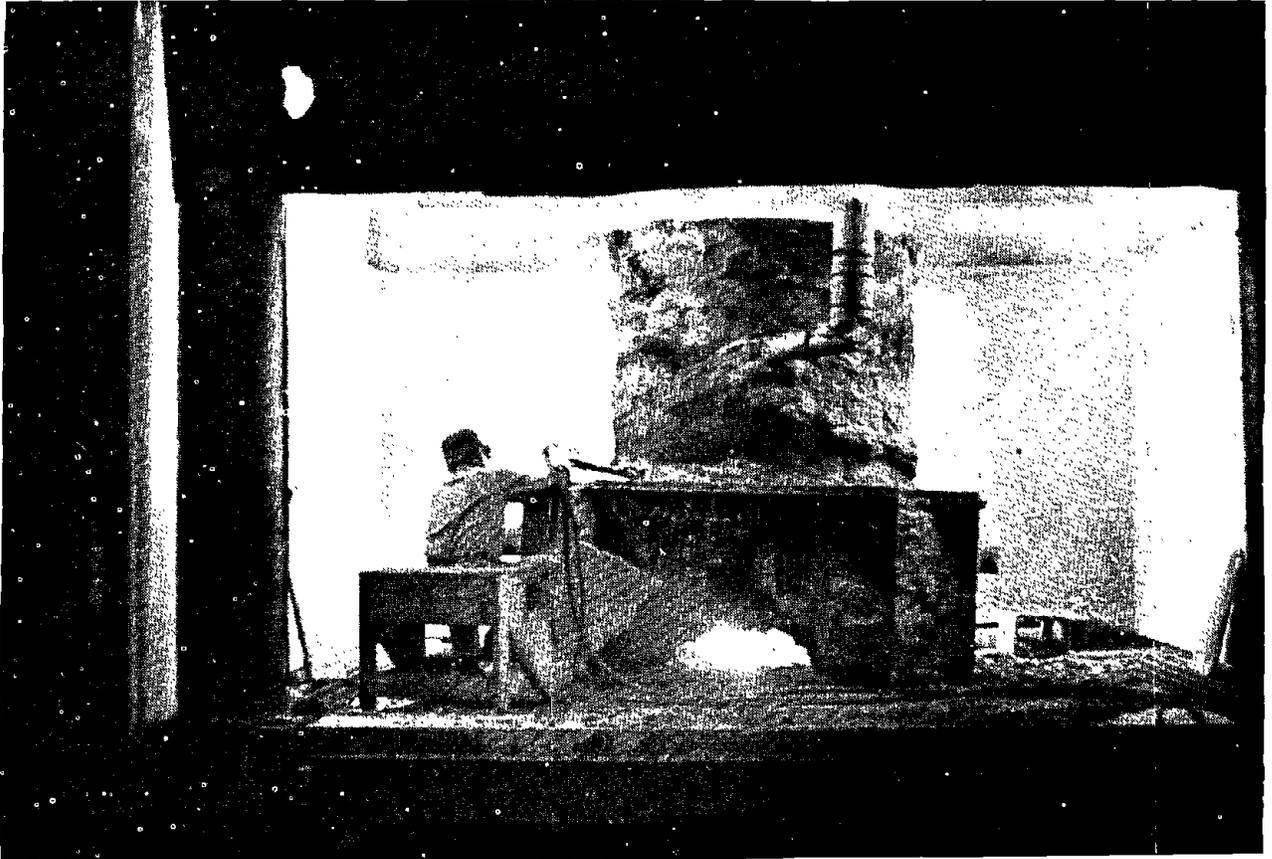
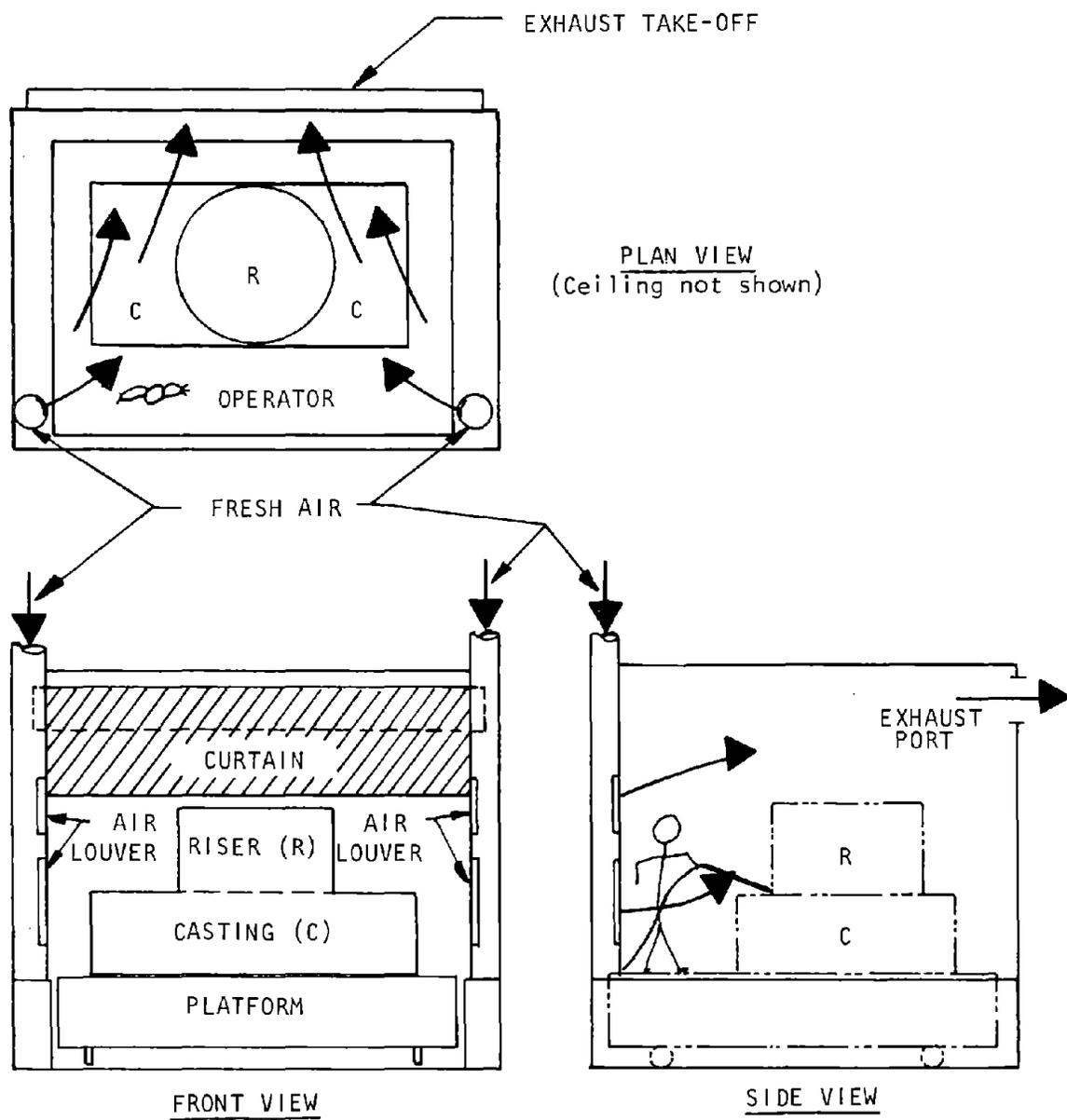Figure A5-1. Front view of environmental booth showing torch cutting operation in progress.

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EXHAUST TAKE-OFF

PLAN VIEW
(Ceiling not shown)

R

C   C

OPERATOR

FRESH AIR

CURTAIN

AIR
LOUVER   RISER (R)   AIR
                         LOUVER

CASTING (C)

PLATFORM

FRONT VIEW

EXHAUST
PORT

R

C

SIDE VIEW

Figure A5-2.   Torch cutting booth.

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Constituent	Percent
Silicon	0.4
Carbon	0.15-0.50
Phosphorus	0.02
Sulfur	0.03
Iron	Remainder

WORKPLACE HAZARDS

The major air contaminant hazard from torch cutting was fume inhalation.
The alloy constituents present in the fume of hygiene significance consisted
of iron, copper, chromium, manganese and nickel. Zinc and lead fumes
could also have been present as tramp metals. Workers were also exposed
to infrared radiation during the torching process.

CONTROL OF EXPOSURE

Fumes generated by the torching process were controlled by a large booth
using both exhaust and fresh supply air.

Engineering

Control at the Source--
A large booth, 18 ft wide x 17 ft deep x 14 ft high (5.5 m x 5.2 m x 4.2 m),
was designed to quickly evacuate fumes generated by the torching process.

A design exhaust flow of 20,000 cfm (9.4 m3/sec) and a supply air flow
of 16,000 cfm (7.6 m^3/sec) maintained an average velocity at the worker
of 100 fpm (0.5 m/sec). The face velocity at the booth entrance was
about 25% higher because of the canvas flap arrangement. The flap helped
to prevent fume escape from the booth.

The exhaust port was located at the upper rear wall of the booth while
the supply air was introduced through slits in two downcomer pipes located
at both sides of the booth face. The direction of the fresh air supply was
adjusted by rotating the supply pipes. This was done several times during
the survey for two reasons: the worker felt chilled and thus directed the
blast away from himself, and during an extended break the air was turned
away from the casting so that the cold air would not crack the casting.

Variability in the fume generation rate seemed to relate to the amount
of metal being removed.

The effect of the air nozzle at the cutting point was to blow the fume
violently away from the casting. The prevailing ventilation pattern
within the booth could not overcome this air blast. Thus, efficient
capture was dependent on the air blast being oriented toward the exhaust
point at the back of the booth, which was the normal mode of operation.
During work on one very large casting on the second day of the survey,
the worker was observed holding the torch on an angle, i.e., not directed
straight toward the back of the booth. In this situation, the air blast
was hitting the side wall of the booth rather than the back of the booth.

Instead of directly proceeding toward the exhaust point, a fume roll-back effect was observed causing some fume to enter the breathing zone of the worker and some fume to escape the booth. When the cut was completed and the casting removed from the booth, the riser was returned to the booth to be cut in two. This was done with the air blast directed toward the booth exhaust and adequate fume control was resumed.

Personal Protective Devices

Workers wore tinted safety glasses to shield their eyes from the infrared radiation.

RESULTS

1. Measurements of metals and total dust and fume in the workers' breathing zones show that air contaminants generated by torching were adequately controlled (Table A5-1). On the second sampling day the total dust measurement exceeded the ACGIH TLV during one period because of fume roll-back during processing of a large casting. In addition, introduction of significant levels of air contaminants into the booth from the background air was partially responsible for the high breathing zone levels measured that day.

2. Background air samples showed that a significant portion of the air contaminant loading in the breathing zone may have been drawn into the booth from the plant ambient air.

3. Most of the total dust was probably iron oxide. Depending on the relative amounts of FeO and Fe_2O_3 present, iron oxide concentrations may have varied from 129-144% of the iron concentration.

Table A5-I. Air sampling results - total dust and fume.

| Worker or location | Sample type | Number of samples | Range, mean | Time weighted average exposure/8-hour workday, mg/m³ | | | | | | | Total dust and fume |
				Fe	Cu	Cr	Mn	Zn	Ni	Pb	
Torching operator	Pers.	3	Hi	4.640	0.026	0.008	0.022	0.012	0.026	<0.001	10.60
			Lo	0.645	0.005	0.006	0.010	0.003	0.015	<0.001	2.02
			M	1.987	0.012	0.007	0.015	0.006	0.020	<0.001	5.26
Background outside of booth	Fixed	3	Hi	1.430	0.022	0.016	0.220	0.014	0.030	<0.001	3.76
			Lo	0.349	0.003	0.002	0.010	<0.001	0.006	<0.001	1.30
			M	0.912	0.011	0.009	0.088	0.006	0.017	<0.001	2.93
OSHA PEL				10.0*	0.10*	1.0 θ	5.0	5.0*	1.0	0.2ψ	15.0
ACGIH TLV (1977)				5.0*	0.20*	0.05∇	5.0†	5.0*	1.0	0.15ψ	10.0

* Fume

† Ceiling value, short term sampling was not undertaken because of the expected low exposure.

ψ Lead, inorganic dust and fume.

θ Metal and insoluble salts.

∇ Chromic acid and chromates.

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CASE HISTORY #6
FUME CONTROL DURING PROCESSING OF STEEL CASTINGS
USING THE ARC-AIR PROCESS
APRIL, 1978

ABSTRACT

This foundry produced steel castings from very small to very large in size.
In the cleaning room specially designed arc-air booths were constructed
for processing different size ranges of castings, the largest being 6 ft
(1.8 m) in diameter. Each of the booths had a localized fume control system
incorporating both exhaust air and a fresh air supply. Two of the three
types of control booths were evaluated in this survey: a bench for small
castings, and a 4 ft (1.2 m) turntable for larger castings.

Comparison of fume control in two different types of booths provided
insights into the requirements of effective capture. Unless fume collection
is very direct, i.e., fumes move directly from the point of generation to
the capture hood, the violence of fume generation caused by the compressed
air stream will cause fumes to "roll" within the booth and enter the
operator's breathing zone.

Previous experience of this and other foundries with arc-air booths has
revealed large variability in exposure.

Many factors could affect the degree of breathing zone protection which
the booth can provide, among them the type of booth, the size of the
casting, work practices, and existing conditions in the cleaning room.

In the process of taking air samples to demonstrate control effectiveness,
attempts were made to isolate some of these factors.

Of all the conditions tested it appeared that work practices was the
greatest factor in determining whether or not breathing zone control
below allowable limits could be achieved in these booths.

PROCESS DESCRIPTION

Equipment and Operation

Two small and one large arc-air booths were studied in the cleaning room
of a steel foundry. Within the room other processes such as chipping and
grinding, welding, shot blasting, and annealing of castings were also
done. Following is a description of each of the arc-air operations:

Small Booth--
The small booths contained work benches on which small castings were processed.
Small castings were of a size which could be processed on a workbench and

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handled with a small overhead hoist. A schematic illustration of a small booth is shown in Figure A6-1 and a photograph taken of the workbench through the curtain is shown in Figure A6-2. Castings were fed into and out of the small booth on roller conveyors which the operator loaded and unloaded himself. The booths were enclosed by metal panels in front of and behind the operators and by curtains on either side. They were open overhead.

Large Booth--
The large booth also had a workbench on which to process the castings, however, in this case the workbench consisted of a custom-designed heavy duty turntable, 4 ft (1.2 m) in diameter. The turntable could support large castings and rotate them into position so that the operator could work on the entire casting from a fixed location in front of the bench. A schematic diagram of this booth is shown in Figure A6-3 and a photograph is shown in Figure A6-4. The castings were loaded onto and unloaded from the workbench by an overhead crane. The booth lid was flipped open during casting transport and lowered during booth operation. Following loading, the arc-air operator pressed a foot pedal to rotate the casting into position for processing. Curtain sections were closed during the operation, shielding the area in front of the bench.

Materials and Rates

The range of casting sizes and weights processed during the days of the survey are listed in Table A6-1. All of the workers used 0.625 inch (1.6 cm) diameter copper-coated carbon electrodes.

The castings were composed of the metal composition listed below:

Constituent	Percent
Manganese	0.7-1.0
Chromium §	0.6-0.9
Nickel §	0.6-0.9
Molybdenum §	0.2-0.4
Silicon	0.4
Carbon	0.15-0.50
Phosphorus	0.02
Sulfur	0.03
Iron	Remainder

WORKPLACE HAZARDS

The major air contaminant hazard from the arc-air process was fume inhalation. The metals of hygienic significance in the fume consisted of:

From the casting: Iron, manganese, chromium and nickel.

From the electrode: Copper and possibly tramp materials such as lead, zinc and carbon.

_____

§ Not present in all alloys.

EXHAUST

PLAN VIEW

SYMBOL

AIR FLOW
PATTERN

FRESH AIR SUPPLY

FRESH AIR
SUPPLY

EXHAUST
TAKE-OFF

FRONT VIEW
(front wall not shown)

SIDE VIEW
(side wall not shown)
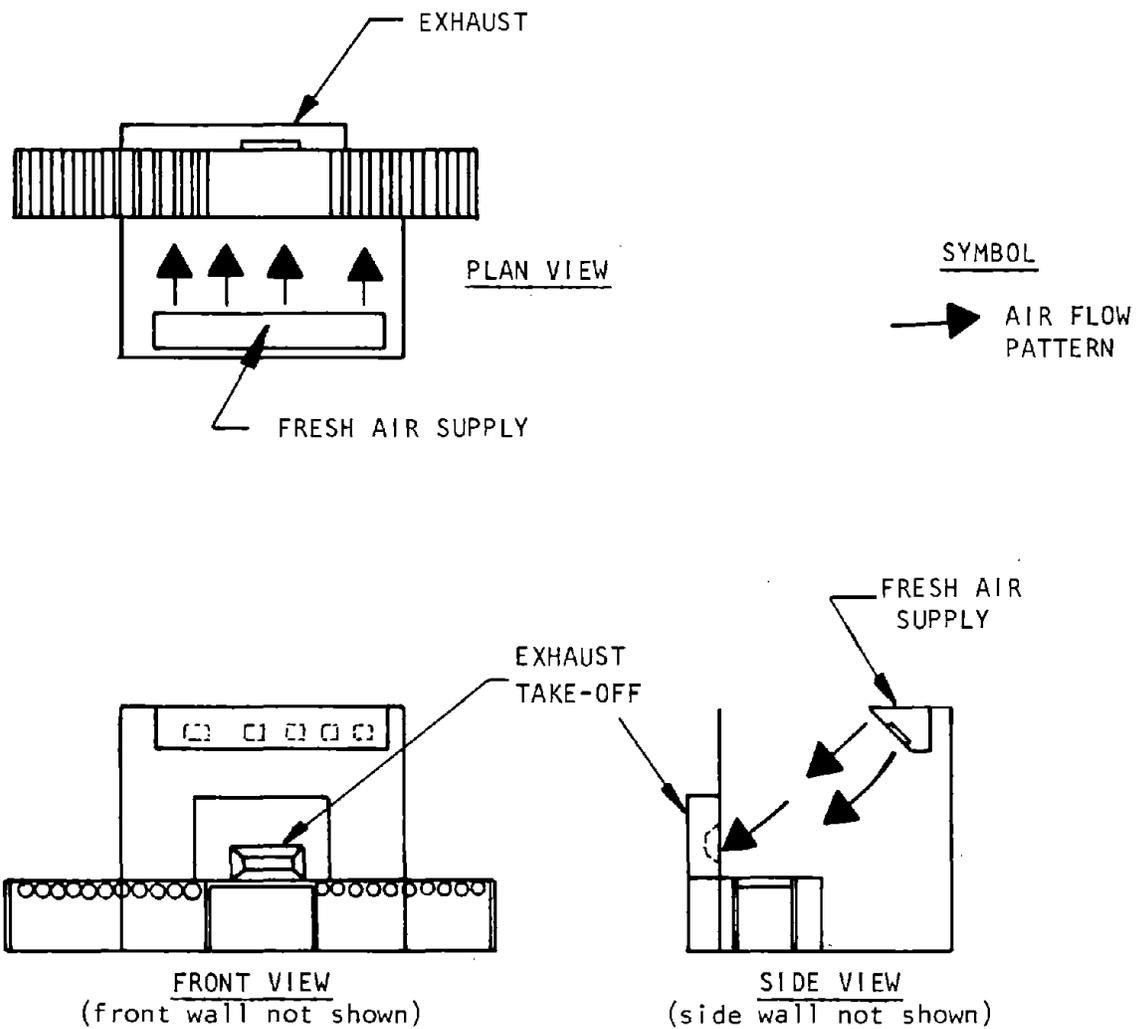
Figure A6-1. Arc-air booth for small castings.
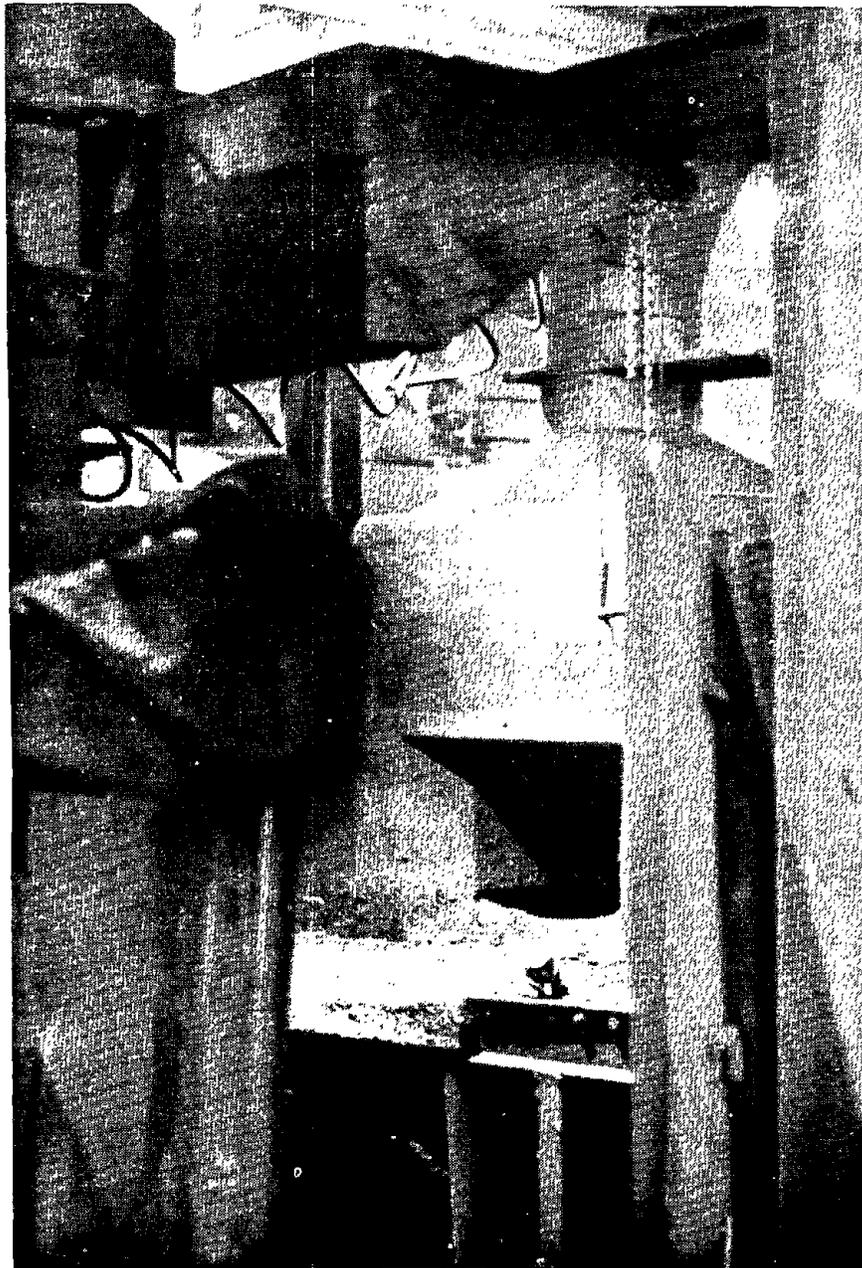
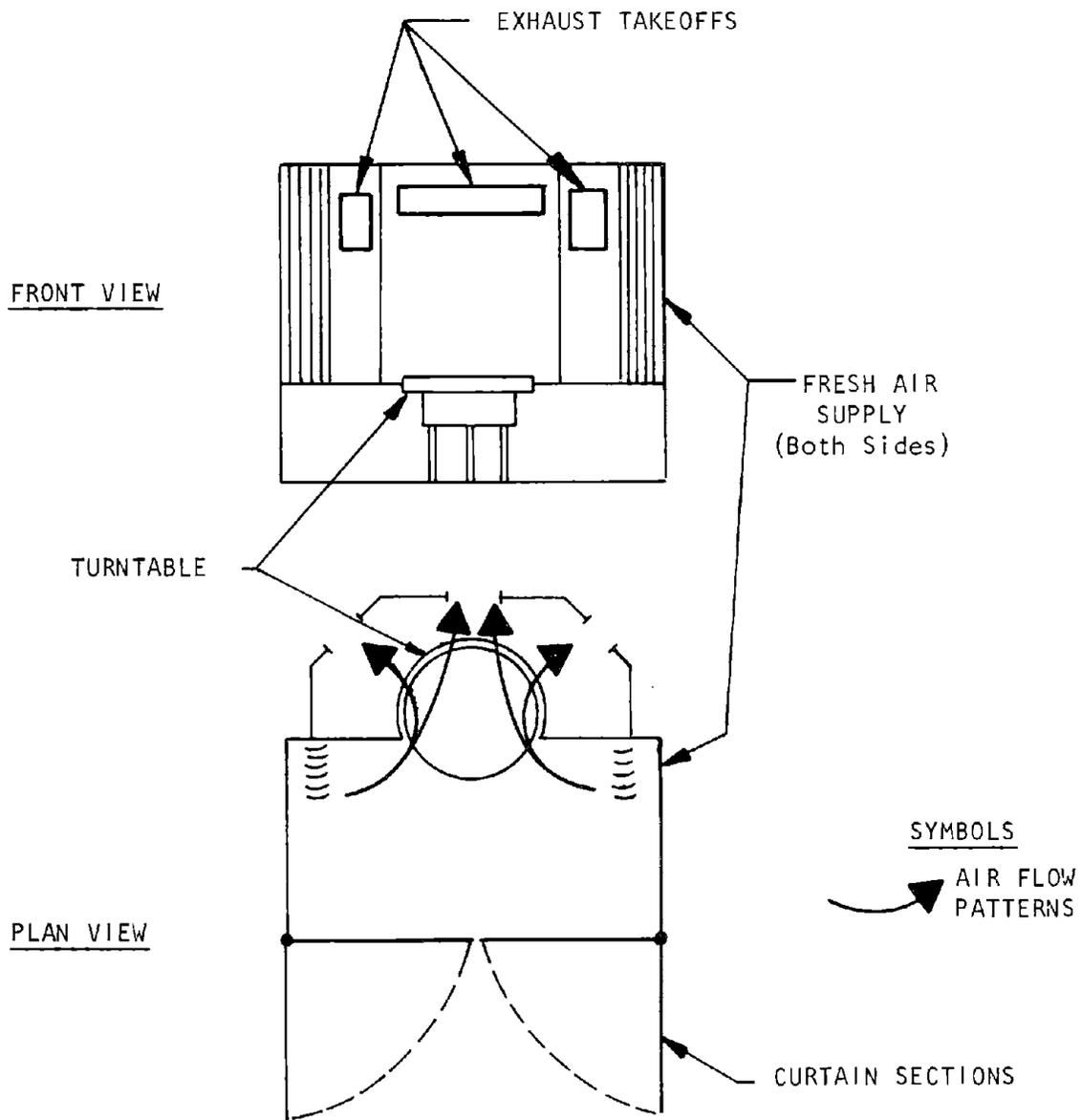Figure A6-2. Small arc air bench and backdraft exhaust as seen through the side curtain of the booth.

EXHAUST TAKEOFFS

FRONT VIEW

FRESH AIR
SUPPLY
(Both Sides)

TURNTABLE

SYMBOLS

AIR FLOW
PATTERNS

PLAN VIEW

CURTAIN SECTIONS

Figure A6-3.   Arc-air booth for large castings.

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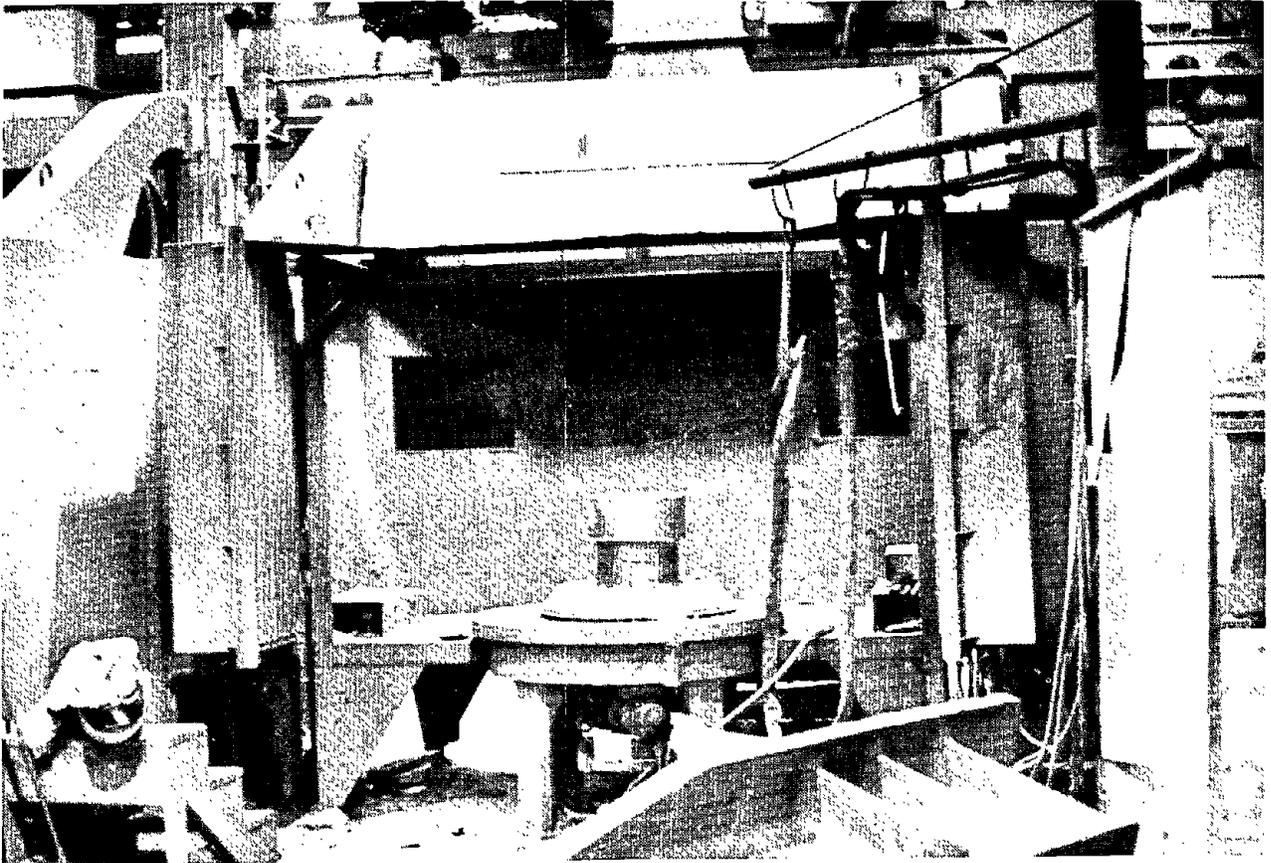
Figure A6-4. Large arc-air booth showing casting on turntable.
Before operation will begin, roof lid will be lowered and curtains will be
shut.

Table A6-I. Castings processed on days of survey,
including sizes and weights.

Booth	Worker	Survey day	No. of castings	Casting description					
				Designation§	Size			Weight	
					ft	m		lbs	kg
Large	I	2	5	Large	5x1x1	1.5x0.30x0.30		350	159
			6	Small	2.5 (dia.)	0.76 (dia.)		1560	708
			I	Small	4 (dia.)	1.22 (dia.)		1640	745
	2	3	3	Large	5x1x1	1.5x0.30x0.30		350	159
			13	Small	2 (dia.)	0.60		1160	526
Small	3	I	50	Small	1x2x1	0.30x0.60x0.30		80-250	36-113
		2	55	Small	1x2x1	0.30x0.60x0.30		200-465	91-211
		3	56	Large	4x1x1	1.22x0.30x0.30		300	136
	4	3	58	Small	1.5 (dia.)	0.46 (dia.)		290	132

§ Designation of large or small was not based on weight, but rather on the size configuration.
Small castings easily fit on the work surface. Large castings are classified as those which
overhung the work surfaces.

Castings processed in both the small and large booths were shot blasted prior to processing.

CONTROL OF EXPOSURE

Control of dust and fume liberated during the arc-air process was achieved by exhaust at the source in combination with fresh air supply in booths.

Engineering

Control at the Source

Small Booth--
Arc air fume was quickly evacuated by a large exhaust opening [5 ft wide x 2 ft high (1.5 m x 0.6 m)] at the back of the bench exhausting 8330 cfm (3.9 m3/sec). The ventilation device is classified as an exterior hood, not a booth enclosure. This is so because of the absence of sufficient enclosure to form a "face" plane behind which the operator stood and in front of which the casting was processed.

Fresh air was supplied above and directly behind the operator at 1500 cfm (0.71 m3/sec). The velocity of the fresh air discharge was low, [230 fpm (1.2 m/sec)], so that its main purpose was supplying a source of fresh air to cool and ventilate the operator. It did little to "push" fume toward the hood.

When the hot metal contained in the compressed air stream was directed at the exhaust opening, fume capture was almost complete. However, when this swarf was directed away from the opening, fume escaped causing "rolling" in the air currents within the booth and fume to rise out of the booth.

Large Booth--
The large booth was truly a "booth" type of hood with a "face" area existing between the man and the casting. Sufficient enclosure to form a booth was provided by vertical sheet metal walls as well as a retractable overhead roof lid and an extended bench top area adjacent to and behind the turntable. The face opening was 46 ft2 (4.3 m2) through which 8500 cfm (4.0 m3/sec) was drawn at an average calculated face velocity of 185 fpm (0.94 m/sec).

The fresh air was supplied at a total rate of 3600 cfm (1.7 m3/sec) from both sides just outside the face of the booth. Adjustable turning vanes in these supply plenums permitted distribution of the air across the entire face of the booth.

The use of the turntable was a critical factor in the design of this booth arrangement since it eliminated the need for the operator to enter past the face of the booth to work on the casting.

Although it was difficult to observe fume patterns within the booth, it was apparent that the large booth was not as sensitive to the variable direction

of the swarf as the small booth was, and less fume rolling and escape was observed.

Work Practices

It was very difficult to make observations of work practices to determine which ones may have enhanced or detracted from the capture of fume. Three practices, however, were noted which probably affected breathing zone control:

1. When castings longer than 4 ft (1.2 m) were processed in the large booth, the casting overhung the table and the operator often left his position directly in front of the turntable to work further to one side or the other. This partially blocked the supply flow changing the ventilation pattern so that fume capture was not as direct.

2. The workers were not always consistent in loading the casting onto the turntable with the entire casting within the booth face, i.e., they sometimes positioned the casting too far forward on the table.

3. To expedite work on small castings, workers in the small booths often lined up a row of castings along the bench and then processed the entire group by going down the line. A drawback to this practice was the fact that castings on both ends of the row were remote from the exhaust opening and capture was not direct, thus producing rolling of fume and escape.

RESULTS

Conventional breathing zone exposure samples taken on the lapel, as well as "in-helmet" and background "fixed" air samples were obtained in both the small and large booths. The "in-helmet" samples were taken by means of a special filter holder affixed to a welding helmet in such a way that the filter was inside the helmet an inch or two (2.5-5 cm) from the worker's mouth. The personal samples were taken only during actual work periods and most averaged two hours in length. Fixed samples were run throughout the workshift and included break times as well as work times.

A total of 28 samples was obtained and all were analyzed for iron (Fe), copper (Cu), chromium (Cr), manganese (Mn), lead (Pb), Zinc (Zn), nickel (Ni) and total dust (TD), with values expressed in mg/m^3. Measureable concentrations were found for all metals except lead.

All data obtained were analyzed to determine the effect of several variables on the airborne dust and metal concentrations. Those parameters considered to be of primary importance were the casting size, the type of arc-air booth, the worker, the type of sample (lapel, in-helmet or fixed), and the day of sampling. Analysis was performed using a one-factor analysis of variance which results in a ratio, "F", characterized by its

value and the "degrees of freedom" associated with the numbers in the numerator and denominator of the ratio--"df/df". High values of the F ratio are associated with increased certainty of an effect (or rather, decreased certainty of no effect).

Regardless of sample type, date, worker, etc., all data for each metal and total dust were combined into discrete histograms that were used to determine the "cumulative probability" of sample values being less than certain stated levels. These data are plotted in Figure A6-5 on log probability graph paper and were found to produce essentially straight lines. This indicated that the choice of a log-normal distribution was correct and that a transformation to logarithms should be used prior to further analyses.

Values of the geometric mean $(\overline{X}_g)$ and standard deviation (S_g) are shown below:

Air contaminant levels of metals and total dust, mg/m^3.

	Fe	Cu	Cr	Mn	Zn	Ni	TD
$\overline{X}_g$	3.32	0.030	0.028	0.093	0.0052	0.00214	9.62
S_g	2.78	2.79	4.51	2.70	2.80	4.18	2.72

The one-factor analysis of variance showed that:

a. The type of booth had no significant effect on airborne concentrations of any metal or of total dust. See Table A6-2.

b. A statistically significant difference in airborne concentrations of iron, copper and zinc was found when sample types (lapel, in-helmet and fixed) were compared (see Table A6-3). Similar analyses (no table) showed that there was no significant difference between lapel and in-helmet samples for any metal or for total dust. The difference shown in Table A6-3 thus, indicates that for iron, copper and zinc the background (fixed samples) concentrations were different from breathing zone concentrations. This may have been caused by differences in proximity to the process between fixed and personal samples, as well as the inclusion of break times in the fixed samples.

c. In-helmet samples (see Table A6-3) were, on the average for all metals, 68.5% of lapel sample values showing that the welding helmet did offer some protection. For total dust, however, the in-helmet concentrations averaged 97% of the lapel sample values.

d. No statistically significant effect of casting size on breathing zone (lapel and in-helmet samples) was found. However, for all except nickel and total dust concentrations, the highest values were associated with the large castings and generally, values for "both" large and small castings fell between values for small and large castings (see Table A6-4).
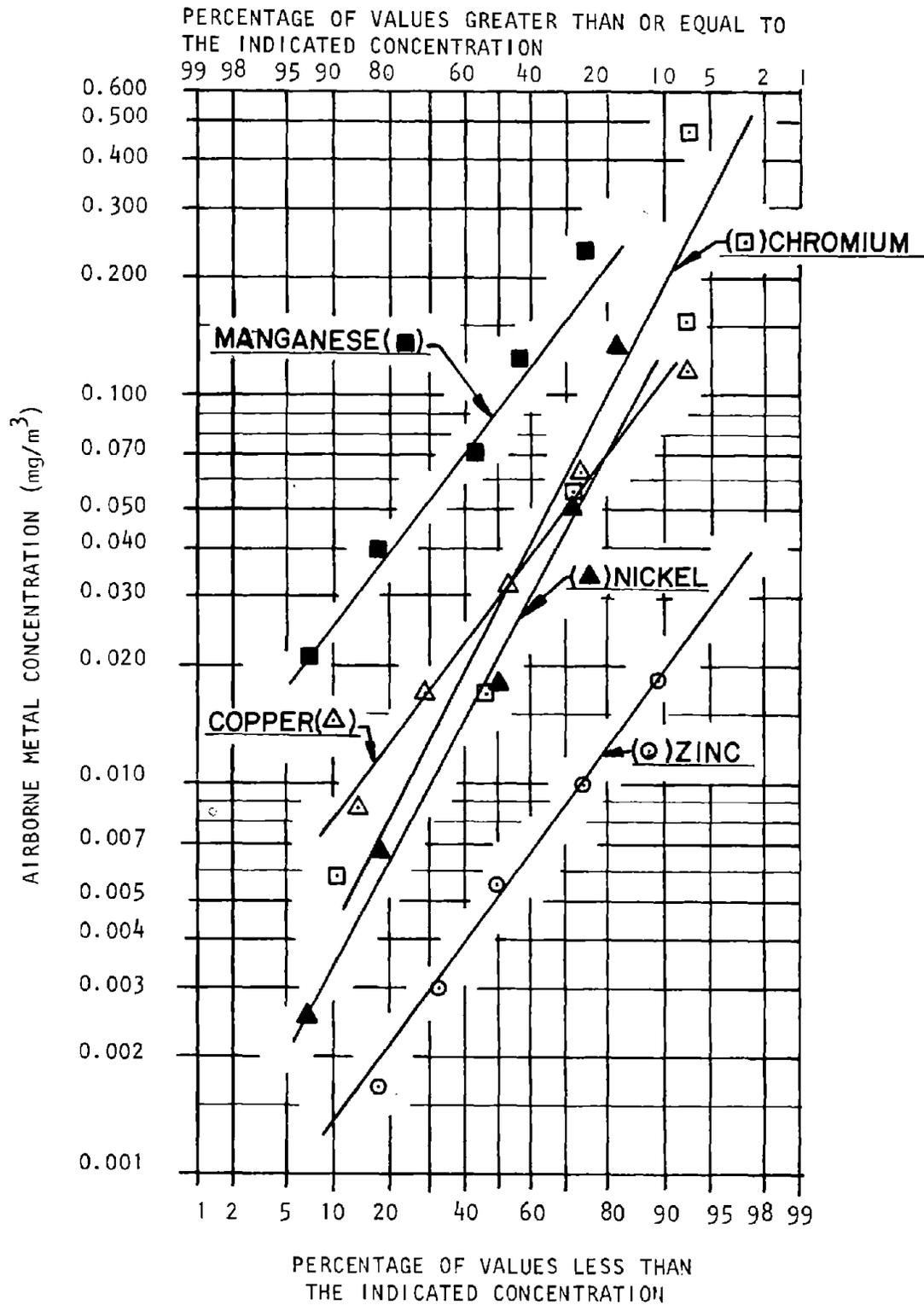
PERCENTAGE OF VALUES GREATER THAN OR EQUAL TO
THE INDICATED CONCENTRATION

PERCENTAGE OF VALUES LESS THAN
THE INDICATED CONCENTRATION

Figure A6-5. (sheet 1 of 2). Log probability graph of grouped
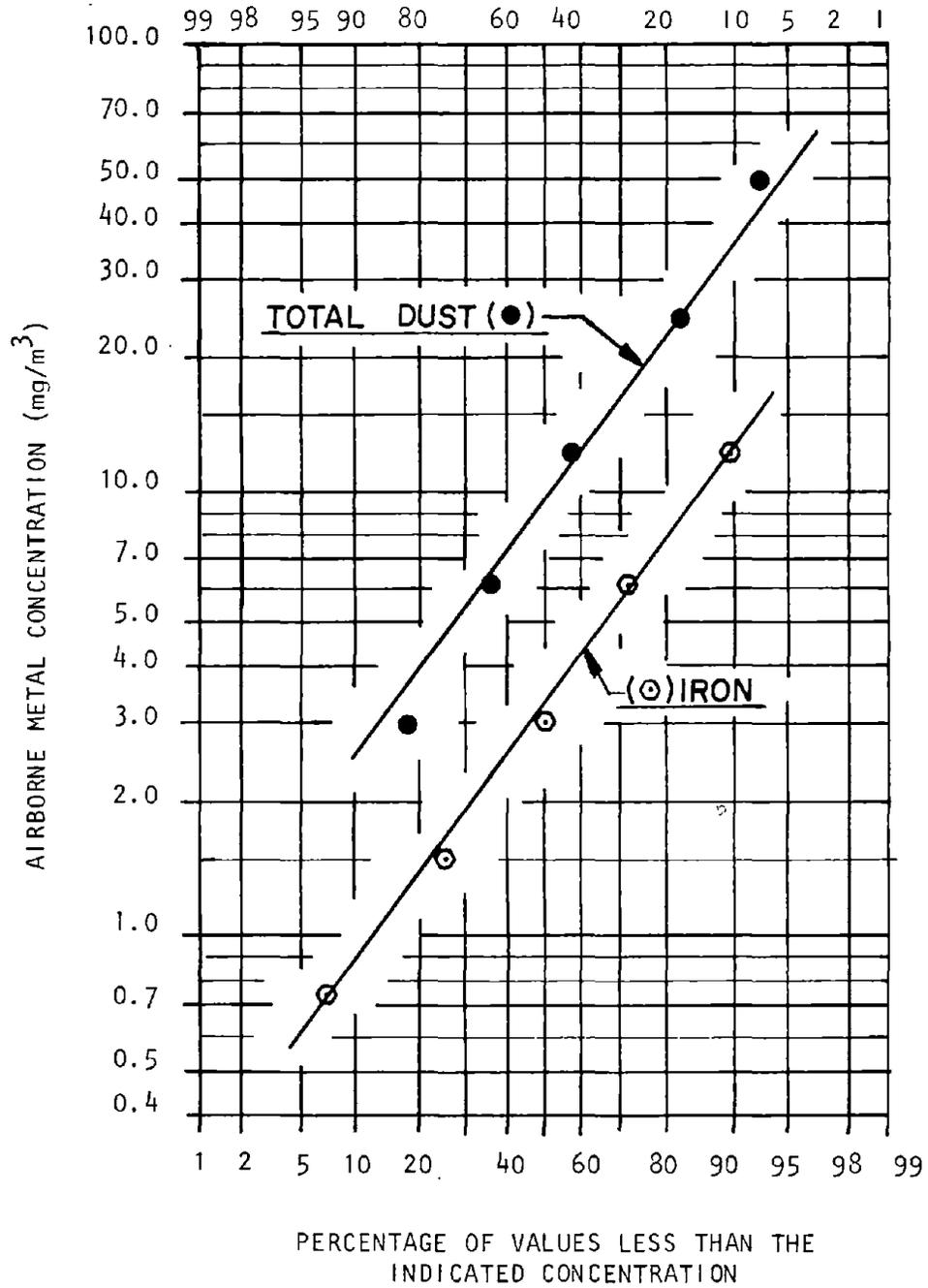data on air concentration of metals during the arc-
air operation.

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Figure A6-5. (sheet 2 of 2). Log probability of grouped
data on air concentration of metals during
the arc-air operation.

Table A6-2. Effect of booth size on airborne concentrations of metal fume and total dust in the arc-air process (all data used).

Parameter	$\overline{X}g$, mg/m³	Sg, mg/m³	df/df	F
Iron				
Small	2.76	2.17		
Large	3.63	2.96	1/26	0.431
Copper				
Small	0.0235	2.29		
Large	0.0335	2.90	1/26	0.726
Chromium				
Small	0.0264	4.36		
Large	0.0247	4.53	1/26	0.011
Manganese				
Small	0.1100	1.95		
Large	0.0855	2.95	1/26	0.385
Zinc				
Small	0.00342	2.16		
Large	0.00625	2.86	1/26	2.187
Nickel				
Small	0.0185	2.18		
Large	0.0230	5.02	1/26	0.138
Total dust				
Small	10.77	2.94		
Large	7.59	1.97	1/26	0.740

Table A6-3. Effect of sample type on airborne concentrations of metal fume and total dust in the arc-air process.

Parameter	$\overline{X}g$, mg/m^3	Sg, mg/m^3	df/df	F
Iron				
Lapel	4.97	2.78		
In-helmet	3.33	2.60		
Fixed	1.30	2.14	2/25	4.59*
Copper				
Lapel	0.0461	2.73		
In-helmet	0.0295	2.69		
Fixed	0.0112	2.07	2/25	5.24*
Chromium				
Lapel	0.0289	2.39		
In-helmet	0.0209	3.65		
Fixed	0.0325	13.06	2/25	0.155
Manganese				
Lapel	0.123	2.60		
In-helmet	0.083	2.63		
Fixed	0.056	2.16	2/25	1.438
Zinc				
Lapel	0.00768	2.12		
In-helmet	0.00488	3.42		
Fixed	0.00218	1.75	2/25	3.82*
Nickel				
Lapel	0.0279	4.33		
In-helmet	0.0214	4.90		
Fixed	0.0117	1.72	2/25	0.764
Total dust				
Lapel	11.97	2.45		
In-helmet	11.61	2.72		
Fixed	4.49	2.10	2/25	2.448

* <5% level of significance.

Table A6-4. Effect of casting size on airborne concentrations of metal fume and total dust in the arc-air process. (In-helmet and lapel samples only).

Parameter	$\overline{X}g$, mg/m3	Sg, mg/m3	df/df	F
Iron				
Small	3.98	2.26		
Large	5.35	2.24		
Both	4.18	2.86	2/19	0.190
Copper				
Small	0.0293	2.21		
Large	0.0602	2.11		
Both	0.0413	2.78	2/19	1.173
Chromium				
Small	0.0178	3.08		
Large	0.0450	1.94		
Both	0.0272	2.74	2/19	1.452
Manganese				
Small	0.0946	2.30		
Large	0.1350	2.73		
Both	0.1020	3.08	2/19	0.225
Zinc				
Small	0.00558	2.80		
Large	0.00854	2.24		
Both	0.00642	2.69	2/19	0.318
Nickel				
Small	0.0251	3.64		
Large	0.0246	5.03		
Both	0.0263	5.72	2/19	0.003
Total dust				
Small	10.15	2.06		
Large	13.34	2.78		
Both	13.58	3.03	2/19	0.218

e. The date that sampling was done significantly affected results
    for all but zinc (see Table A6-5). However, this probably happened
    because data for "dates" could not be separated from that for
    "workers" since no worker's breathing zone was sampled on both
    dates.

f. Table A6-6 shows that, except for zinc, breathing zone concentra-
    tions of all metals and total dust differed significantly among
    workers. Worker #1 consistantly had the highest concentrations
    and worker #2 the lowest. These differences could not be attributed
    to less actual arcing time since worker #2 had a longer total
    arcing time than worker #1 (191 minutes as compared to 146 minutes).
    The "worker" effects are probably real even though observation
    failed to discern differences in work patterns likely to affect
    airborne particulate concentrations.

g. Much of the data for zinc showed no differences while other metals
    and total dust did so (Tables A6-5 and 6). This probably indicates
    that zinc became airborne in some process other than arc-air and
    existed in the arc-air booths as an extraneous contaminant.

Iron, copper, and manganese concentrations were highly correlated with total
dust concentrations (see Table A6-7) and with each other. Although
several other significant correlations were found, none approached these
in magnitude. Significantly, these best correlations were among those
parameters having the highest average concentrations, and the correlations
were sufficiently good so that knowledge of one of the three parameters
could be used to predict concentrations of the other two reasonably well.

Depending on the relative amounts of FeO and Fe_2O_3 present, iron oxide
exposures may have varied from 129-144% of the measured iron exposures
(Table A6-6).

Despite the exhaust controls on the three arc-air booths, allowable concen-
trations for total dust and/or iron were exceeded for every worker if
these short samples were used to estimate whole-shift values. When,
however, actual time-weighted averages were calculated, iron and total
dust concentrations were exceeded only for workers #1 and #4.
Copper fumes were below allowable limits for all four workers although
if all of the copper was in the form of CuO, the concentration of copper
fume would have been 25% higher than the metal concentrations, placing
the exposure of worker #1 right at the allowable limit (Table A6-6).

The main conclusion, then, from this data analysis is that inhalation
exposures during the arc-air cleaning of steel castings in these booths
can be controlled but that an important part of the control appears to
be individual worker performance. Necessary aspects of that performance
should be investigated and evaluated.

Table A6-5. Effect of date on airborne concentrations of metal fume and
total dust in the arc-air process.
(Lapel and in-helmet samples only)

Parameter	$\overline{X}g$, mg/m3	Sg, mg/m3	df/df	F
Iron				
2	7.97	2.25		
3	2.73	2.06	1/18	8.554*
Copper				
2	0.0653	2.55		
3	0.0282	1.99	1/18	4.794§
Chromium				
2	0.0624	2.05		
3	0.0233	1.72	1/18	11.02*
Manganese				
2	0.1861	2.13		
3	0.0702	2.62	1/18	5.219§
Zinc				
2	0.0094	2.88		
3	0.0050	2.43	1/18	1.822
Nickel				
2	0.1173	1.96		
3	0.0082	2.58	1/18	42.42*
Total dust				
2	26.32	2.10		
3	6.68	1.95	1/18	16.70

§   <5% level of significance.

*   <1% level of significance.

Table A6-6. Effect of worker on airborne concentrations of metal fume
and total dust in the arc-air process.
(Only lapel and in-helmet samples used)

Parameter	$\overline{X}_g$, mg/m³	S_g, mg/m³	df/df	F
Iron				
#1	9.62	1.93		
#2	1.92	1.86		
#3	3.38	1.36		
#4	6.84	1.09	3/18	9.47*
Copper				
#1	0.0792	2.28		
#2	0.0204	1.85		
#3	0.0292	1.77		
#4	0.0575	1.25	3/18	4.888§
Chromium				
#1	0.0714	1.78		
#2	0.0101	2.28		
#3	0.0204	1.67		
#4	0.0285	1.02	3/18	10.17*
Manganese				
#1	0.227	1.77		
#2	0.042	2.13		
#3	0.113	1.88		
#4	0.191	1.06	3/18	8.43*
Zinc				
#1	0.0129	1.88		
#2	0.0044	2.80		
#3	0.0037	2.24		
#4	0.0063	1.58	3/18	2.56
Nickel				
#1	0.1155	1.96		
#2	0.0060	2.80		
#3	0.0260	2.46		
#4	0.0170	2.06	3/18	13.75*

-continued-

Table A6-6 (continued):

Parameter	$\overline{X}g$, mg/m^3	Sg, mg/m^3	df/df	F
Total dust				
#1	30.66	1.75		
#2	4.84	1.77		
#3	9.19	1.20		
#4	15.75	1.00	3/18	16.09*

§ <5% level of significance.

* <1% level of significance.

Table A6-7. Regression analysis of metal fume and total dust concentrations for the arc-air process.

(Analyses performed on natural logarithms of the data values. The letters "m" and "b" refer to the constants in the equation: $y = mx + b$ and r refers to the coefficient of correlation).

Parameters x	y	m	b	r
Fe	TD	0.9197	1.1593	0.9394
Cu	TD	0.8533	5.2572	0.8751
Cr	TD	0.3513	3.5166	0.5285
Mn	TD	0.8379	4.2568	0.8310
Zn	TD	0.4249	4.5205	0.4365
Ni	TD	0.0991	2.5226	0.3068
Cr	Zn	0.0173	-5.2062	0.0254
Cr	Ni	0.3846	-2.4730	0.4037
Zn	Ni	0.4457	-1.4950	0.3206
Fe	Cu	0.9708	-4.6743	0.9669
Fe	Mn	0.8426	-3.3903	0.8680

CASE HISTORY #7
DUST CONTROL FOR SAND SYSTEM AND SHAKEOUT
AUGUST AND NOVEMBER, 1977 & JANUARY, 1978

ABSTRACT

Respirable silica from dry sand transfer and processing operations was
controlled at the source with exhaust hoods. Among the processes controlled
were shakeout, return sand system, screens, sand storage and muller. Worker
exposures to respirable silica, as well as to the products of mold decompo-
sition were controlled below allowable limits. However, the lack of makeup
air in the area permitted some cross-contamination from other foundry areas,
particularly the cleaning room.

In the process of designing the present exhaust system the foundry solved
a problem which had plagued it for years. The shakeout hood has been re-
placed annually because of the abuse it had taken during loading by crane.
By adding a guard on the shakeout table, a way had been found to prevent
damage to the shakeout hood from the impacting of flasks.

Dust exposure of an operator of a stationary sand slinger was controlled
by isolating him in a remote work station. The practice of alternating
slinger operators probably helped to prevent overexposure at that station.
Besides the slinger operator the slinger assistants were also located
quite close to the slinger head. An auxiliary exhaust in the spill pit
helped all of the slinger line workers by purging airborne dust from
around the vicinity of the flask.

PROCESS DESCRIPTION

Equipment and Operation

A layout of the sand system is presented in Figure A7-1. A description
of the system follows:

Return Sand Conditioning--
Return sand, stored in an overhead hopper, was fed into a muller and mixed
with clay and water. The prepared sand was then transported by bucket
elevator and conveyor to a hopper located above the nearby sand slinger.

Molding--
After being cleaned, flasks and patterns were assembled and facing sand
was applied to the pattern. The remainder of the flask was filled with
prepared sand by the slinger (FigureA7-2). After filling, the mold half --
was pressed and rolled over. Cores were installed into the drag, the
cope was set in place, and the finished mold was moved to the pouring deck.
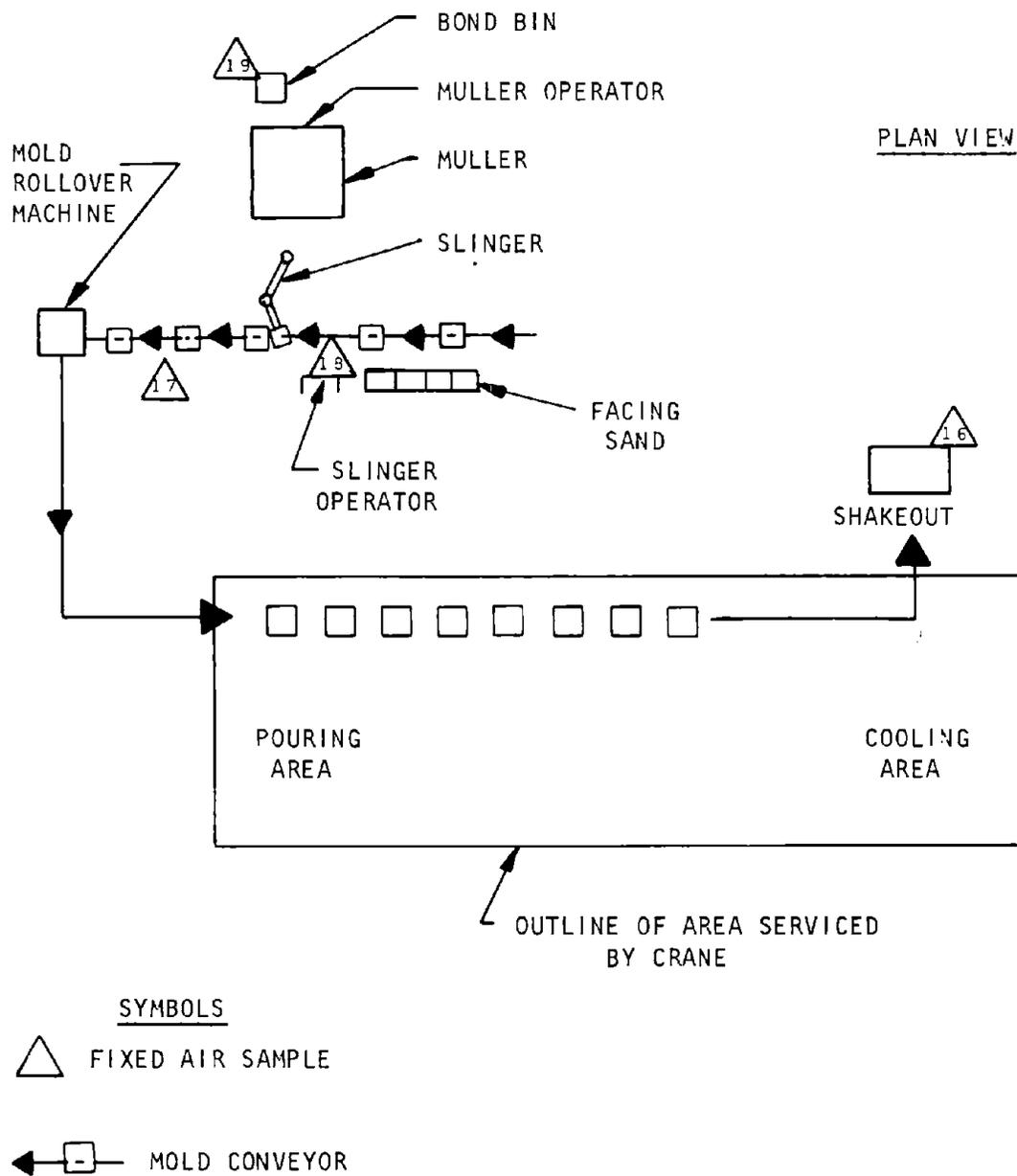
Figure A7-1. Layout of sand system and shakeout.

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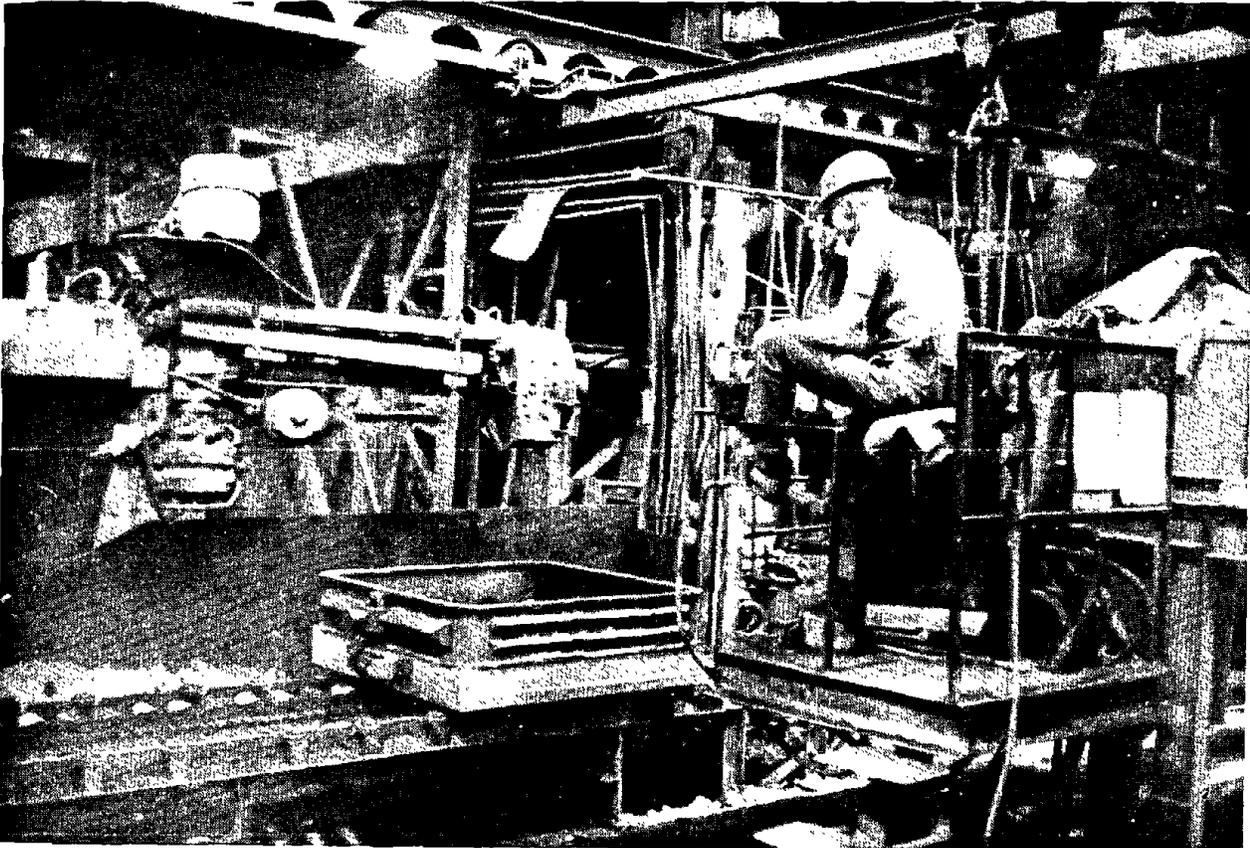
Figure A7-2. Sand slinging operation controlled at remote station.

Shakeout--
Cast molds were lifted by overhead crane onto a vibrating shakeout (Figure A7-3). Flasks and bottom boards were subsequently returned to the molding area. Castings were removed from the shakeout by a hoist and hung on a monorail leading to a shot blast machine. Return sand was transported by conveyor through a pit area to the muller, where it was lifted by bucket elevator and screened before being stored in a hopper for recycling.

The work tasks of operators at the muller, molding area, and shakeout are summarized in Table A7-1.

Materials and Rates

Approximately 62 molds were made during each shift of a two-shift operation. A variety of flasks were used, a typical one being 3.5 ft x 3.5 ft (1.07 x 1.07 m). An average of 168 tons of system sand per shift was used along with a much smaller amount of facing sand. Facing sand was composed of new silica sand, clay, water and small amounts of ground oat hulls, corn flour, and cellulose. Both phenolic urethane and oil sand cores were used. Typical quantities and weights of cores for one shift of operation are given below:

No. of cores	Core type	Range of weights	
		lbs	kg
23	Phenolic urethane	227-294	103-133
62	Oil sand	0.14-30.8	0.1-14

WORKPLACE HAZARDS

The major air contaminant hazard at the muller, molding station, shakeout, and crane cab was respirable silica. Products of thermal decomposition, i.e., MDI, acrolein and phenol were evaluated at the shakeout.

CONTROL OF EXPOSURE

Respirable silica exposure was controlled through localized hoods at all sand processing and transfer points in the return sand system and on the muller and bond feeding system. By the use of remote controls, the slinger operator was isolated from the slinger head. An exhaust hood in the slinger spill pit provided auxiliary ventilation at that station.

Engineering

Control at the Source--
Shakeout--A new sidedraft hood exhausted emissions from a 5.7 x 10 ft (1.7 x 3.1 m) vibrating shakeout. A photograph of the shakeout, hood and flask is shown in Figure A7-3. Prior to the installation of this hood the foundry had rebuilt or replaced the hood every year. Hoods had taken great abuse from being hit with flasks which sometimes occurred accidently, but more often was done purposely to release mold materials hung up in the flask.

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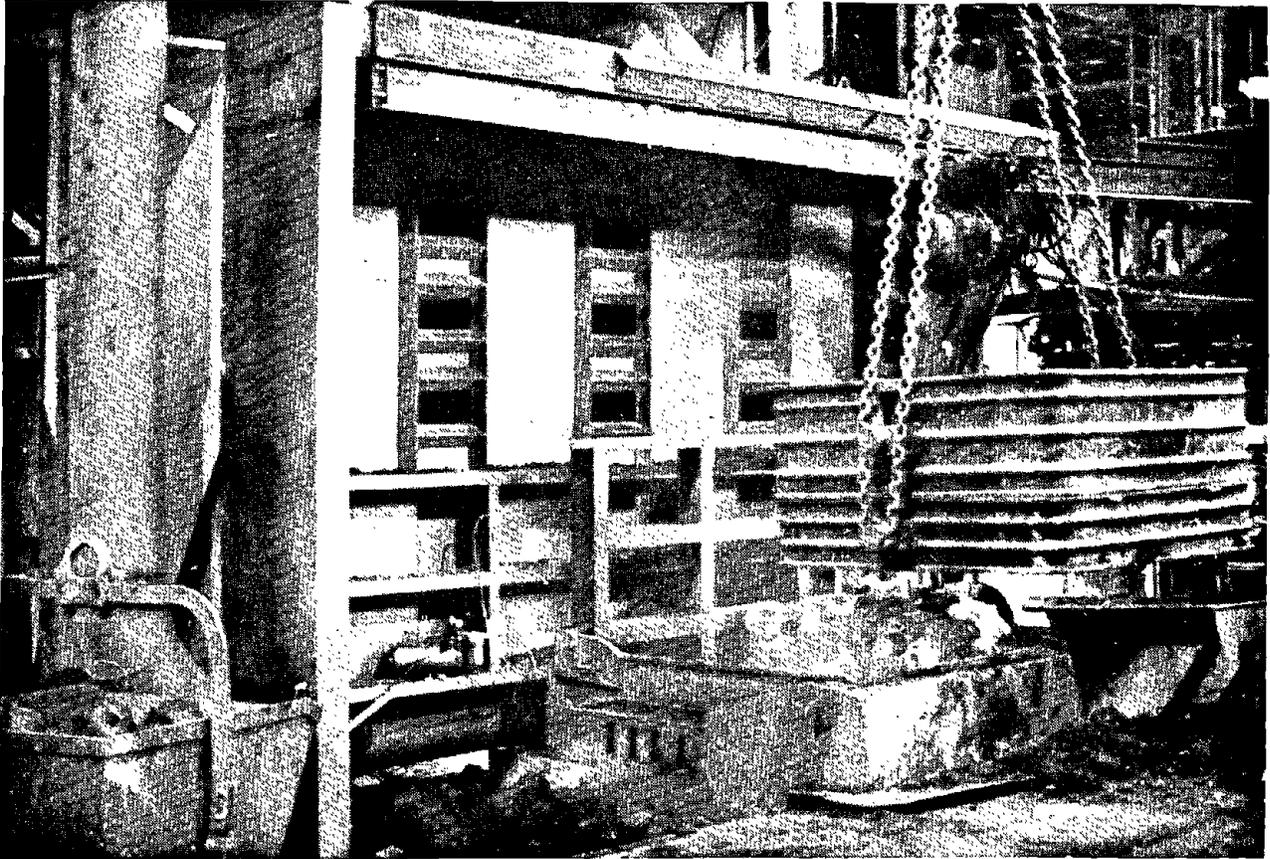
Figure A7-3. Shakeout hood and structure mounted to shakeout to protect hood from damage.

Table A7-I. Summary of work tasks: muller, molding area, and shakeout.

No. of workers	Job title	Task
I	Muller operator	Operated muller controls. Manually added bond materials to bond chute. Filled bentonite bin from bags of clay.
2	Pattern assembly operator	Cleaned pattern. Assembled mold base, pattern and flask. Added facing sand.
I	Slinger operator	Remotely controlled slinger.
I	Press-rollover operator	Controlled press operation. Pushed patterns along return conveyor.
I	Core setter	Installed cores into drag section of mold by hand and with hoist.
2	Mold assembly	Placed cope on drag. Moved mold onto pouring floor.
2	Flask handlers	Fastened chains on mold. Refastened chains at shakeout. Guided mold as crane lifts it onto shakeout. Unfastened chains from flask at return conveyor.
I	Hookout operator	Hooked casting from shakeout and attached it to blast monorail.
I	Crane operator	Pulled castings from pouring to cooling areas. Hoisted molds onto shakeout.

The new hood was much more rugged and was protected from the impact blows by a structure mounted on the shakeout itself. Guide plates were installed to limit the lateral motion of the table and prevent the shakeout from being dislodged from its springs. The added weight of the new structure had no effect on the shakeout operation.

The exhaust flow from the hood was within the ACGIH recommended flow range (Table A7-2) and observations showed capture to be complete. The shakeout hood was extended on one side to provide exhaust above the spill pit. Baffles on top and on the left side of the hood helped to reduce short-circuiting of air and aided the capture flow pattern. The velocities through the 20 slots averaged 2600 fpm (13.2 m/sec) and provided a very uniform velocity pattern across the face of the hood. In front of the shakeout table the indraft velocity was 120 fpm (0.6 m/sec). The shakeout hopper was exhausted with 1550 cfm (0.7 m3/sec), which was below the ACGIH recommended ratio of 10:1 between hood and hopper exhausts.

Effective capture was critical to this shakeout method which required that three operators be located directly adjacent to (and sometimes on top of) the vibrating table and another operator directly above in the crane cab. The shakeout was loaded by either sliding the flask off of the bottom board or by tipping the flask over. In both cases the presence of the flask handlers was required to steady and guide the flask onto and off of the shakeout. After flask removal the hookout operator removed the casting from the shakeout, leaning over or sometimes climbing onto the shakeout to attach the hook. He hung the casting on an adjacent blast monorail for cleaning. He also removed loose sprues and risers from the shakeout by hand.

Return Sand System--
Return sand transfer and processing operations were controlled by hoods at exhaust flows that in most cases exceeded ACGIH recommended minimum flow rates (Table A7-2). Although no workers were stationed immediately adjacent to any of the return sand system hoods, the functioning of these exhaust hoods prevented contamination of the background air at the muller and molding areas in particular, and the general foundry environment.

Special attempts were made to enclose the processes as far as possible without restricting maintenance. For example, in the shakeout pit the oscillating conveyor hood had canvas sides which sealed the hood to the conveyor while permitting easy access. The sand bin above the muller was fed by a belt conveyor with three plows, all enclosed by a single hood. Removable panels on this hood provided access for maintenance of the plow mechanisms.

Muller--
The muller was totally enclosed and automatically controlled with the exception of clay feeding. The muller operator broke open bags of clay and filled a bond bin located next to the muller. The bond bin had a hood enclosure and was exhausted with sufficient air to control dust both during the bin loading process and during the subsequent dipping of clay out of the bin to load into the muller. An exhausted chute controlled dust as the clay was fed into the muller.

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Table A7-2. Hood exhaust flows compared to recommended flows.

Process	Hood type (Ref.)	Exhaust flow		ACGIH recommended flow	
		cfm	m3/sec	cfm	m3/sec
Shakeout	Sidedraft(VS-112)	26,200	12.36	22,800-28,500	10.7-13.4
Hopper	Exhaust takeoff (VS-112)	1550	0.73	2280-2850	1.17-1.34
Muller	Exhaust takeoff (VS-108)	5000	2.36	5000	2.36
Bond chute	Enclosing(VS-108)	1000	0.47	600	0.28
Bond storage hopper	Enclosing (VS-304)	846	0.40	1380	0.65
Slinger	Exhaust plenum in spill pit	6000	2.83	--	--
Return Sand System					
1. Oscillating conveyor	Enclosing (VS-306)	6600	3.12	2100	0.99
2. Conveyor transfer	Enclosing (VS-306)	720	0.34	1050	0.50
3. Magnetic separator	Enclosing (VS-306)	720	0.34	1000	0.47
4. Bucket elevator	Casting takeoff (top)(VS-305)	720	0.34	680	0.32
5. Rotary screen	Enclosing (VS-307)	2640	1.24	1250	0.59
6. Belt conveyor transfer	Enclosing (VS-306)	720	0.34	165-220	0.08-0.10
7. Bin feeder	Enclosing (VS-304)	2880	1.36	1000	0.47
8. Belt conveyor transfer	Enclosing (VS-306)	--	--	700	0.33
9. Muller feeder	Enclosing (VS-304)	720	0.34	800	0.38

Slinger--
Isolation of the worker at a remote control station helped to prevent
contamination of his breathing zone from dust generated by the slinging
process (Figure A7-2). Exhaust in the spill pit below the slinger caused
a low velocity downdraft around the flask. The velocity was not sufficient
to locally capture the dust at its source, but caused a constant turnover
of air around the flask, which helped to evacuate dust from the area. This
auxiliary ventilation was not only important to the slinger operator but
also to other slinger line workers who were also located quite close to
the slinger.

The dust exhausts from shakeout, return sand system, muller and slinger
were collected by a wet scrubber and the exhaust was discharged outdoors.

General Ventilation--
The localized exhaust hoods effected almost complete capture at all of the
dust generation points which reduced dust emissions in the area. In
addition, two large roof exhausters provided additional air turnover in
the area, as well as removal of products of decomposition of cooling molds.

There were no fresh air supply units in the area and as a result makeup
air was induced through a truck entrance and from adjacent plant areas,
particularly the cleaning room.

Personal Protective Devices

Shakeout workers wore disposable dust respirators (NIOSH no. TC-21C-132).

RESULTS

1. All worker exposures were within the allowable limits, however,
    there was a variation in percent-of-allowable exposures among
    workers in the various areas: shakeout, 26%; crane, 46%,
    molding, 84%; and muller, 97% (Table A7-3).

2. Cross-contamination from the cleaning room probably contributed
    to the higher levels measured at the muller and molding area. On
    the first day of sampling the exposure of the muller operator
    exceeded the allowable limit because of the presence of cristobalite
    in the respirable dust. Foundry personnel subsequently corrected
    a dust problem occurring very close to the muller area - the
    refuse hopper from a blast cabinet sand separator. Sand and dust
    were being fed into the hopper through a hose with a free fall
    up to 6 ft (1.8 m). An exhausted shroud was subsequently installed
    on this hopper and no cristobalite was found during subsequent
    sampling at the muller.

3. Although the exposure of the slinger operator was controlled, the
    dust level at the front of his control station was high during
    the second day of testing. The practice of alternating slinger
    operators probably helped to prevent overexposure at that station

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Table A7-3. Air sampling results-respirable silica.

Worker or location §	Date	Sample type	Percent quartz	Respirable dust, mg/m^3	Allowable respirable dust, mg/m^3*
Shakeout					
Mold handler	8/16/77	Pers.	4.6	0.40	1.52
	8/17/77	Pers.	4.6	0.42	1.52
	1/4/78	Pers.	3.8	0.78	1.72
Casting hookout operator	8/16/77	Pers.	4.2	0.29	1.61
	8/17/77	Pers.	3.2	0.27	1.92
Crane cab	8/16/77	Pers.	6.1	0.59	1.23
	8/17/77	Pers.	4.2	0.70	1.61
	1/4/78	Fixed	6.2	1.00	1.22
Background (16)					
Floor level	1/4/78	Pers.	3.6	0.84	1.79
Basement	Prior plant data	Pers.	5.17	0.47	1.39
Moldmaking					
Slinger operator †	10/26/77	Pers.	4.8	1.00	1.40
	1/4/78	Pers.	4.1	1.50	1.64
Other molders #	10/26/77	Pers.	6.7	0.95	1.10
	1/4/78		4.2	1.50	1.61
			6.4	0.92	1.19
Background (17)	10/26/77	Fixed	2.3	0.86	2.30
	1/4/78		2.5	1.40	2.22
(18)	10/26/77	Fixed	3.2	1.00	1.90
	1/4/78		5.6	1.70	1.32
Muller					
Muller operator	10/26/77	Pers.	2.0	1.40	1.47 Ω
	1/4/78	Pers.	2.2	2.30	2.33
Background (19)	10/26/77	Fixed	1.9	1.90	1.60 Ψ
	1/4/78		1.0	2.00	3.33

§ Worker stations and fixed sample locations shown in Figure A7-1.
* OSHA PEL & ACGIH TLV (1977).
† Sample pump worn by three different operatos during course of shift.
# Operators spent portions of shift at process locations 6, 9, and 10.
Ω Sample contained 1.4% cristobalite; limit calculated for cristobalite.
Ψ Sample contained 1.1% cristobalite; limit calculated for cristobalite.

because one area sample indicated an overexposure, although the 8-hour time-weighted averages were less than the allowable level for the slinger operators themselves.

4. The exposure levels of shakeout and crane operators were far lower than the exposures of the muller operator and slinger line molders. The area in which the shakeout and crane operators were located was affected much less by cross-contamination and received a strong fresh air draft through a truck entrance, which was open continually during the October sampling and intermittently during the January sampling for delivery of cores by fork lift truck.

5. The levels of decomposition products from the pouring, cooling and shakeout operations were measured in the crane cab. The results in Table A7-4 show very low levels of contaminants.

Table A7-4. Air sampling results - fixed samples at crane cab for gases and vapors.

	MDI	Acrolein	Phenol	Carbon monoxide
No. of samples	4	4	1	1
Concentration, ppm	0.001 (1) <0.001 (3)	0.02	<5.0 §	5-10
OSHA PEL	0.02 c	0.10	5.0	50
ACGIH TLV	0.02 c	0.10	5.0	50

§ No stain observed on a Dräger 5/a detector tube after ten pump strokes.

CASE HISTORY #8
A PROCESS SUBSTITUTION TO CONTROL DUST FROM
A RETURN SAND SYSTEM
DECEMBER, 1977

ABSTRACT

A patented process, the Schumacher Process, for cooling sand and reducing
dust emissions from a return sand system was studied on a mechanized line
casting gray iron. Dust was controlled by mixing a large amount of moist,
prepared sand into the dry return sand at the shakeout. This technique
greatly reduced the amount of exhaust required for sand transfer and
processing operations. Localized hoods were limited to the shakeout and
bond feed point, and exhaust takeoffs were used on the rotary screen and
muller. A vacuum cleaning system permitted frequent removal of settled
dust from equipment and building structures. Air samples showed that the
background respirable dust levels were controlled below the allowable
limits in all areas where access by workers was required during operation.

PROCESS DESCRIPTION

Equipment and Operation

A fully automated sand system was used for the molding of small iron castings.
A schematic flow diagram of the sand system is shown in Figure A8-1.

Molding sand was prepared at a constant rate in a muller by adding water
to a preblended sand and bond additive mixture. Upon demand, a plow on
the prepared sand belt (location 1) diverted a portion of the sand to
the mold machine hopper. Most of the prepared sand, however, was bypassed
to the spill pit oscillating conveyor (location 2) to provide for return
sand moisture control.

The transfer point at location 2 coincided with the transfer of shakeout
sand onto the spill pit conveyor, permitting a blending of the three sand
streams. At location 3 in the spill pit, the sand mixture was transferred
to a long inclined belt conveyor leading to the rotary screen on the upper
level. A premixed bond additive mixture was metered onto this conveyor
in the spill pit. At four spaced intervals along the inclined conveyor
a series of disks was used to mix the bond with the sand and to further
blend moist and dry sand. After blending, the sand-bond mixture was
screened and then stored in preparation for use.

Because the sand system was fully automated, no full time personnel were
required to be present in the area. The closest operator to the system
was the casting sorting operator located adjacent to the shakeout. The
foreman for the unit spent about half of his time in the area, monitoring
controls.

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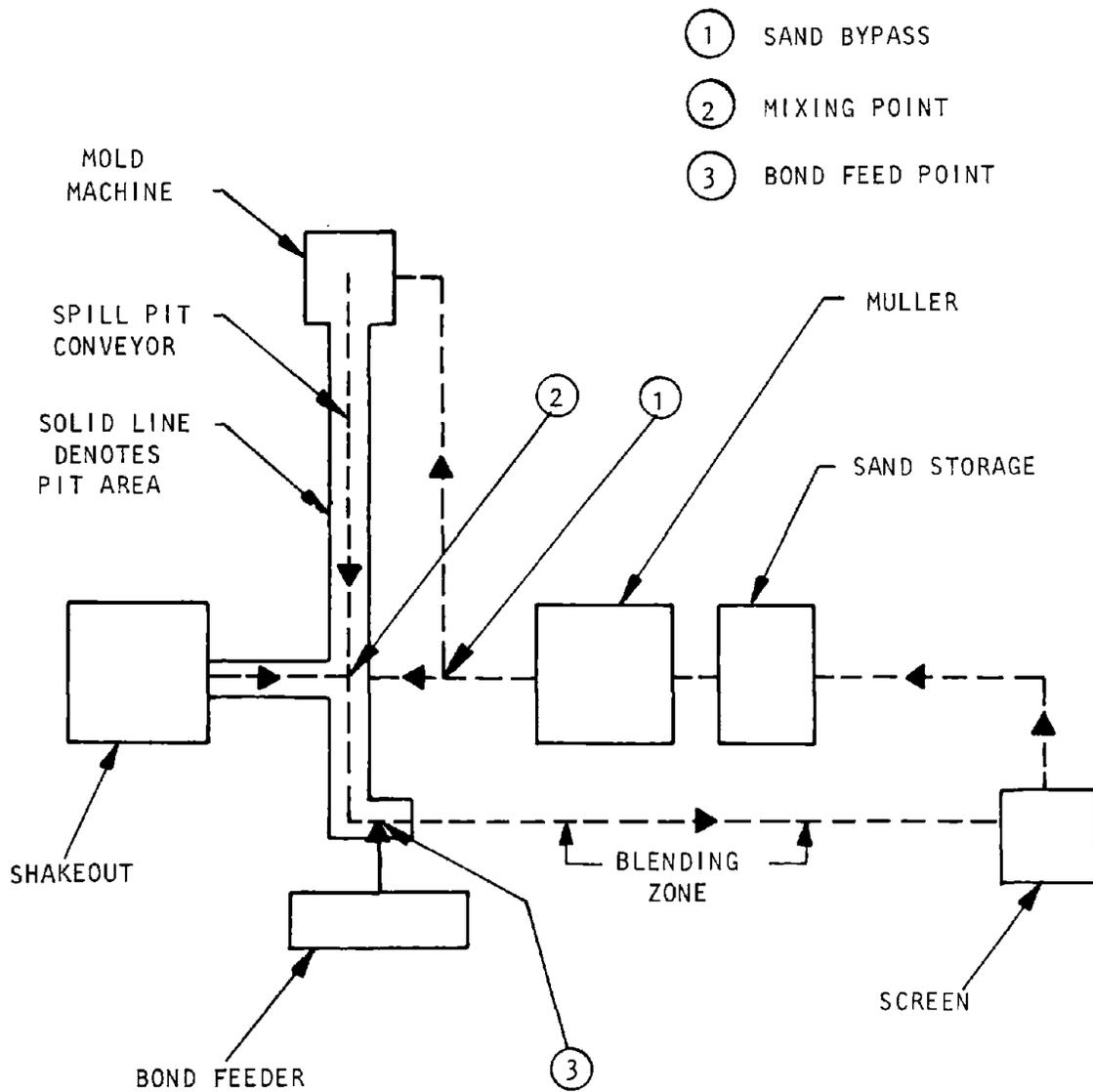
Figure A8-1.   Schumacher process.

Materials and Rates

The following are molding sand constituents and amounts used during the days of the survey:

	Production rate	
	Tons/hour	Metric tons/hour
Molding sand	25	22.8
Recycle sand	75	68.0
Total sand prepared	100	90.8
Bond additives §	0.25	0.23
(70% clay, 30% sea coal)		

A moisture percentage range of 2.9-3.1% was maintained in the prepared sand.

WORKPLACE HAZARDS

The major air contaminant hazard from return sand processing and transport was respirable silica.

CONTROL OF EXPOSURE

Blending a large volume of recycled sand with the dry shakeout and spill pit sand reduced dust emissions from sand transfer and processing operations to the point that a minimum of exhaust was needed. At the time of system installation, exhaust was limited to the shakeout hood and two roof ventilators. Later, it was found necessary to add a bond feed hood and exhaust takeoffs on the muller and rotary screen. Regular housekeeping was performed to remove settled dust from the process equipment and the workplace.

Engineering

Substitution--
The patented sand process system was installed to provide for sand cooling and return sand transfer without exhaust hoods. After the blending of dry and moist sand occurred at location 2 (Figure A8-1), moisture from the recycled sand helped to contain dust from the dry sand during the subsequent transfer processes leading back to the muller.

Control at the Source

Non-exhausted return sand transfer processes included:

1. Spill pit belt conveyor and conveyor transfer to inclined belt conveyor.
2. Oscillating shakeout conveyor and conveyor transfer to spill pit conveyor.

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§ Bond feed rate was based on tons of metal poured, i.e., 5.6 tons/hr (5.1 metric tons/hr) of metal poured x 88 lbs/ton of bond additives (36.3 kg/metric ton).

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3. Inclined belt conveyor and conveyor transfer to magnetic separator.
4. Magnetic separator and transfer into rotary screen.
5. Screen discharge to belt conveyor, conveyor transfer to bucket elevator.
6. Bucket elevator and transfer to hopper feed conveyor (belt).
7. Discharge of hopper feed conveyor into hopper.
8. Muller feed from sand hopper.

Exhausted processes included:

1. Shakeout.
2. Bond feed point.
3. Rotary screen.
4. Muller chamber.

Following is a description of the local controls:

Shakeout--The shakeout was totally enclosed in a hood exhausted with 6900 cfm (3.26 m3/sec). There was only 8 ft^2 (0.74 m^2) openings in the hood, which resulted in a high indraft velocity. A portion of the exhaust was drawn from the spill pit area helping to contain dust emissions from the non-exhausted shakeout hopper and oscillating shakeout sand conveyor.

Bond feed point--Adding bond material onto the top of the sand conveyor in the spill pit produced dust which travelled from the spill pit into the workplace environment. The bond feed point was hooded and a duct takeoff from the hood was connected into the shakeout hood. However, this duct was constantly plugged because of the low transport velocity resulting from inadequate suction. The connection point for the bond duct should have been into the shakeout branch duct, not the shakeout hood.

Rotary screen and muller chamber--Lack of exhaust on the muller and screen led to caking problems with the equipment because of the steam liberated during these processes. Thus, exhaust takeoffs were added and between 500-1000 cfm (0.23-0.46 m3/sec) was drawn from each of these processes to remove the steam.

General Ventilation--
The primary source of dust emissions appeared to be the escaping bond additives rising out of the spill pit. Steam was visibly emitted from the various belt conveyors but little dust was apparent in this steam or in the background air. Two roof exhausters, each drawing a nominal flow of 12,000-15,000 cfm (5.66-7.08 m3/sec), were located in the penthouse section of the foundry above the sand storage hoppers. Because of their location above the sand system at the highest point in the foundry, these fans were ideally positioned to remove heat from the area and provide general ventilation.

Housekeeping

A permanent vacuum manifold system was installed in the area with ports on all levels. Settled dust was removed at frequent intervals from

equipment and building structures.

RESULTS

1. Respirable dust levels in the background air were controlled in all of the areas accessible to workers during system operation (Table A8-1).

Table A8-1. Air sampling results - respirable silica.

Worker or location	Type of sample	Percent quartz	Respirable dust, mg/m^3	Allowable respirable dust, mg/m^3§
Rotary screen	Fixed	7.2	0.31	1.08
		11	0.34	0.77
Storage hopper	Fixed	11	0.21	0.77
		11	0.50	0.77
Muller loading point	Fixed	4.5	0.37	1.54
Muller control area	Fixed	6.7	0.81	1.14
		8.1	0.61	0.99
Sand mixing point (#2, Fig. A8-1)	Fixed	9.7	3.50	0.85
Bond addition point (#3, Fig. A8-1)	Fixed	19	1.90	0.47

§ OSHA PEL & ACGIH TLV (1977).

2. As expected, substantial respirable dust was present in the spill pit (last two samples) because of the dusty processes occurring in a restricted space, i.e., the shakeout conveyor and bond addition. No workers entered this area during operation. However, some of the dust left the pit area and entered the muller area.

CASE HISTORY #9
DUST, FUME, AND SMOKE CONTROL DURING CHARGE PREPARATION, PREHEATING, AND INDUCTION MELTING OF IRON IN HIGH PRODUCTION QUANTITIES

ABSTRACT

Automation of high production gray iron melting operations has permitted isolation of the operators in booths during the majority of the workshift and control of air contaminants at the source. This case history presents two typical operations. In Case A, an evaluation is made of a series of exhaust hoods on charge bucket filling, preheating, and furnace operations. The combination of exhaust controls and worker isolation was sufficient to control dust and metal fume to below the allowable limits.

Although the exhaust hoods removed the major amount of contaminants generated during these operations, emissions occurred during charge bucket filling and furnace charging and tapping because of the limitations of the exhaust methods. Escaping dust, fume, and smoke were removed from the building by roof exhausters. The resultant total exhaust volume from the melting deck was high, which provided rapid air turnover but also had the adverse effect of drawing dusty air into the area from the outdoor charge makeup area. In spite of this, respirable silica was maintained at low levels on the melting deck because of adequate ventilation.

In Case A the charge materials were relatively oil-free. Case B presents a study in a different foundry in which part of the charge consisted of oily materials. A study of the preheater showed that local exhaust ventilation was sufficient to control oil mist, total particulate and carbon monoxide.

CASE A (AUGUST, 1977)

PROCESS DESCRIPTION

Equipment and Operation

Five coreless induction furnaces, each with a capacity of 9 tons (8.2 metric tons) were located side-by-side on an elevated melting deck. Also located on the melting deck were separate charge bucket filling and preheating stations for each furnace and a centralized melting deck office. A layout of a typical section of the melting deck is shown in plan view in Figure A9-1.

The charging operation was completely automated and controlled from the operator booth next to the furnace. Charge buckets were suspended from and moved by a pivoting mechanism to three positions (see Figure A9-1).

TAPPING FUME BAFFLE

HOT METAL CRANE MONORAIL

FURNACE

WALL

OPERATOR BOOTHS

PIVOTS

PREHEATER LOCATION

CHARGE FILL LOCATION

MELTING
DECK OFFICE

PLAN VIEW

SYMBOLS

△ FIXED AIR SAMPLES
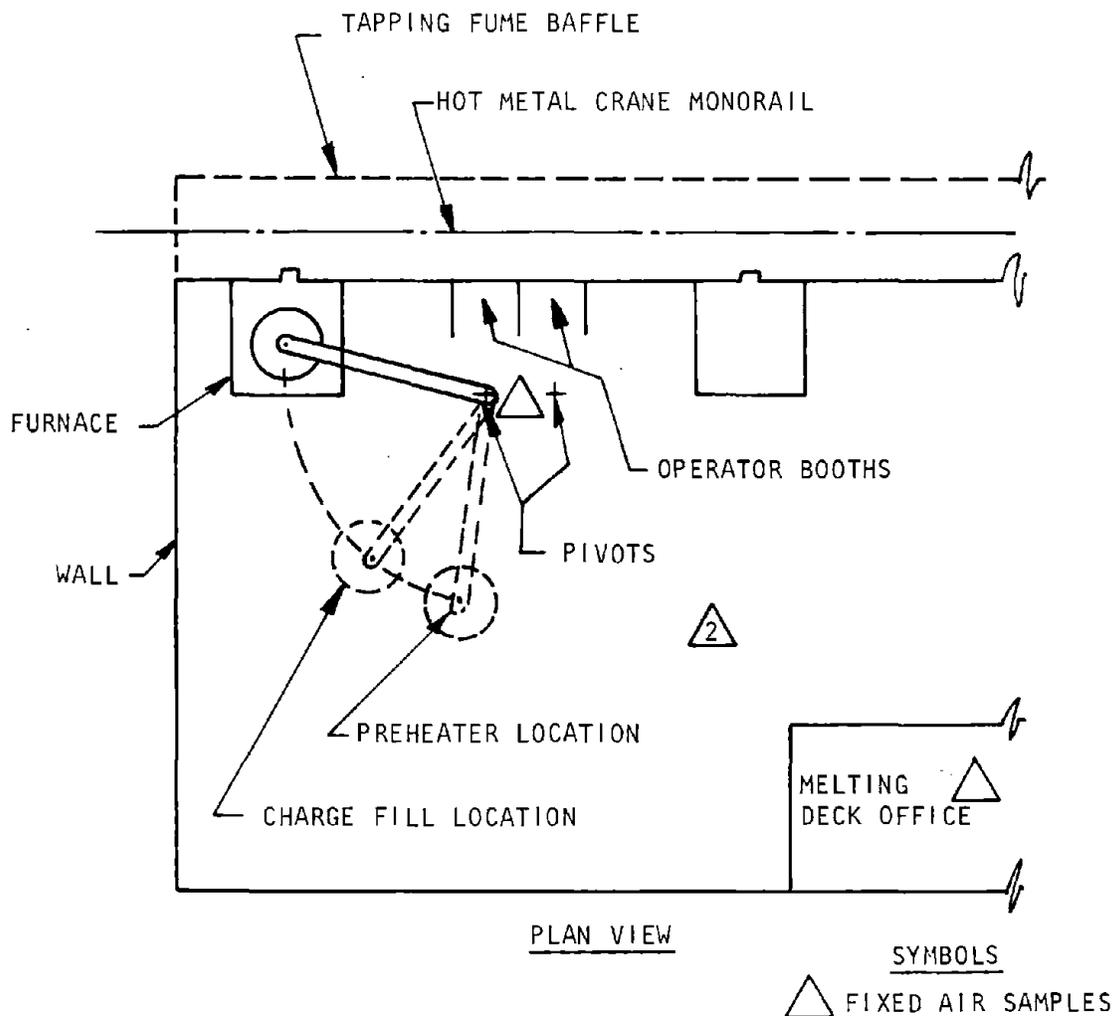
Figure A9-1. Equipment arrangement on melting deck.

1. Charge bucket filling - A skip bucket carrying a preweighed charge of 3200 lbs (1450 kg) automatically dumped its contents into the charge bucket.

2. Preheating - An 8 million BTU/hr (2300 kw) gas-fired downdraft preheater heated the charge to 1000 °F (540 °C).

3. Furnace charging - The segmented, drop leaf bottom doors of the bucket were opened to release the charge into the furnace.

Furnace operations required that the operator perform several tasks at the furnace:

Clearing metal scrap from around the top of the furnace (Figure A9-2). Adding bags of graphite and silicon carbide.

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Figure A9-2. Melter clearing scrap from top of furnace after charging.

Checking temperature of the melt.
Slagging the furnace.

In all, the furnace operator spent only about 25% of his time at the
furnace, spending the remainder in the control booth or in the melting
deck office.

Materials and Rates

During the two days of the survey, the average melting rate per furnace
was 33 tons (30 metric tons) per shift of gray iron heated to 2750 °F
(1510 °C). Charge consisted of clean plate and structural steel, and
foundry returns. A strict scrap specification was intended to minimize
oily scrap, as well as painted metal and mechanical drive components
containing nonferrous bushings, bearings, and gears.

WORKPLACE HAZARDS

The major air contaminant hazards from the three process operations were:

   1. Charge bucket filling - respirable silica.
   2. Charge preheating - dust and products of combustion of oils.
   3. Furnace operations - dust, smoke, and fume including iron, nickel,
       manganese, lead, and zinc.

Charge preheating and furnace operations produced heat and infrared radiation.

CONTROL OF EXPOSURE

Breathing zones of melting deck operators were protected by a combination
of three methods:

   1. Local exhaust hoods for charge bucket filling, preheating, and
       furnace operations.

   2. General ventilation through exhaust fans above the furnaces.

   3. Automation of the charging process permitting partial isolation
       of workers.

A description of each of the three methods of control along with an
explanation of their interworking follows.

Engineering

Control at the Source--
Charge bucket operations--Both the charge bucket filling and preheating
stations were controlled by the same exhaust system, with automatic
dampers used to divert the entire exhaust air flow of 10,000 cfm (4.72
m3/sec) from the charge bucket filling exhaust hood to the preheater hood.

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The hood used to control dust from the charge bucket filling operation was only partially enclosing and was limited in its ability to contain dust emissions as the scrap tumbled and slid out of the skip bucket and fell into the charge bucket (Figure A9-3). It could not prevent the escape of dusty air out the bottom of the charge bucket caused by the air flow induced with the falling charge materials. Dust exited the bottom of the charge bucket through the preheater exhaust ports and clearance spaces between the segmented drop leaves.

Charge bucket filling was a very quick operation and although dust production was high, it was of very short duration. The furnace operator, in his ventilated booth, was not exposed to the dust which was cleared momentarily by the roof exhausters overhead.
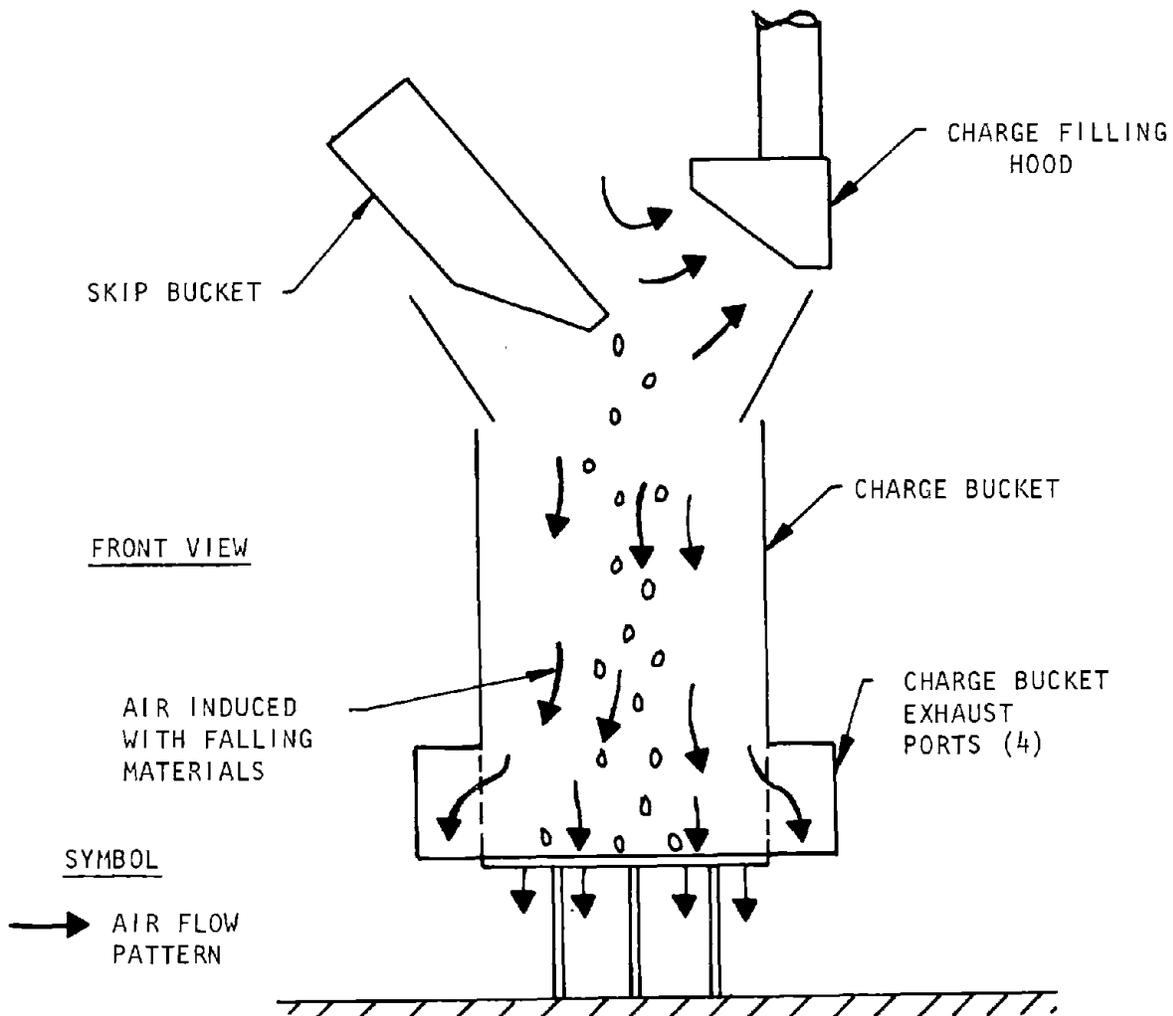
Figure A9-3. Charge bucket during filling.

The downdraft preheater produced smoke and dust which was completely captured by a receiving hood located under the charge bucket (Figure A9-4). The top surface of the hood had openings at each of the four charge bucket exhaust ports, as well as under the charge bucket segmented drop leaves.

Since there was a clearance space between the charge bucket and the hood, the required exhaust air flow rate was greater than the combustion air flow rate by an amount sufficient to cause an indraft through the clearance space with an additional safety factor to accommodate combustion air flow changes due to adjustment of the burner. The preheater exhaust flow passed through a cyclone and an air-to-air heat exchanger, used to temper makeup air for the plant, before being discharged outdoors.

Furnace operation--Furnaces were controlled using commercially available enclosing hoods designed to capture emissions throughout the complete charging, melting, and tapping cycle, and incorporating a telescopic duct takeoff to accommodate furnace tilting. The hood design provided access for furnace operation and maintenance. The furnace cover was removed by swinging it to the side through a hinged door in the hood. The hood cover was mechanically linked to swing with the furnace cover. The hood was short enough to permit access through the openings in the top of the hood (Figure A9-2). When greater accessibility was needed, e.g., during furnace slagging, a door in the back of the hood was opened.

The most complete control occurred during melt down, when the hood was closed. During this time the exhaust flow averaged 7000 cfm (3.3 m^3/sec), sufficient to prevent smoke and fume loss. Control was also adequate when the operator performed his tasks at the furnace with the furnace cover off. Charging and tapping, however, were not fully controlled.

During charging, sparks and fume were emitted because of turbulence caused by scrap falling into the molten bath. The charge bucket, sitting atop the furnace, created a chimney effect, permitting smoke and fume to escape in a thermal draft. Indrafts during charging occurred at the tapping spout and through the open, hinged hood side, but not through the charge bucket.

During tapping, the hood functioned as an exterior hood capturing some of the fume emitted from the metal stream and the transfer ladle. The indraft at the pouring spout of the furnace hood was not sufficient to capture the major portion of this fume. Two problems, however, decreased fume capture efficiency below what might have been possible. One of these involved an interference problem and the other related to loss of efficiency of the hood with time and use. An interference problem between the hood and the hot metal monorail required that the hood be moved back two feet (0.6 m) before tapping. Air cylinders were utilized to provide the movement. Backward motion of the hood detracted from the advantage the tapping spout indraft had of being located in the thermal draft of the fume. With time and use, hood warpage and the destruction and removal of the hinged side panels reduced the efficiency of capture by increasing the open area of the hood, thus lowering the indraft velocity.

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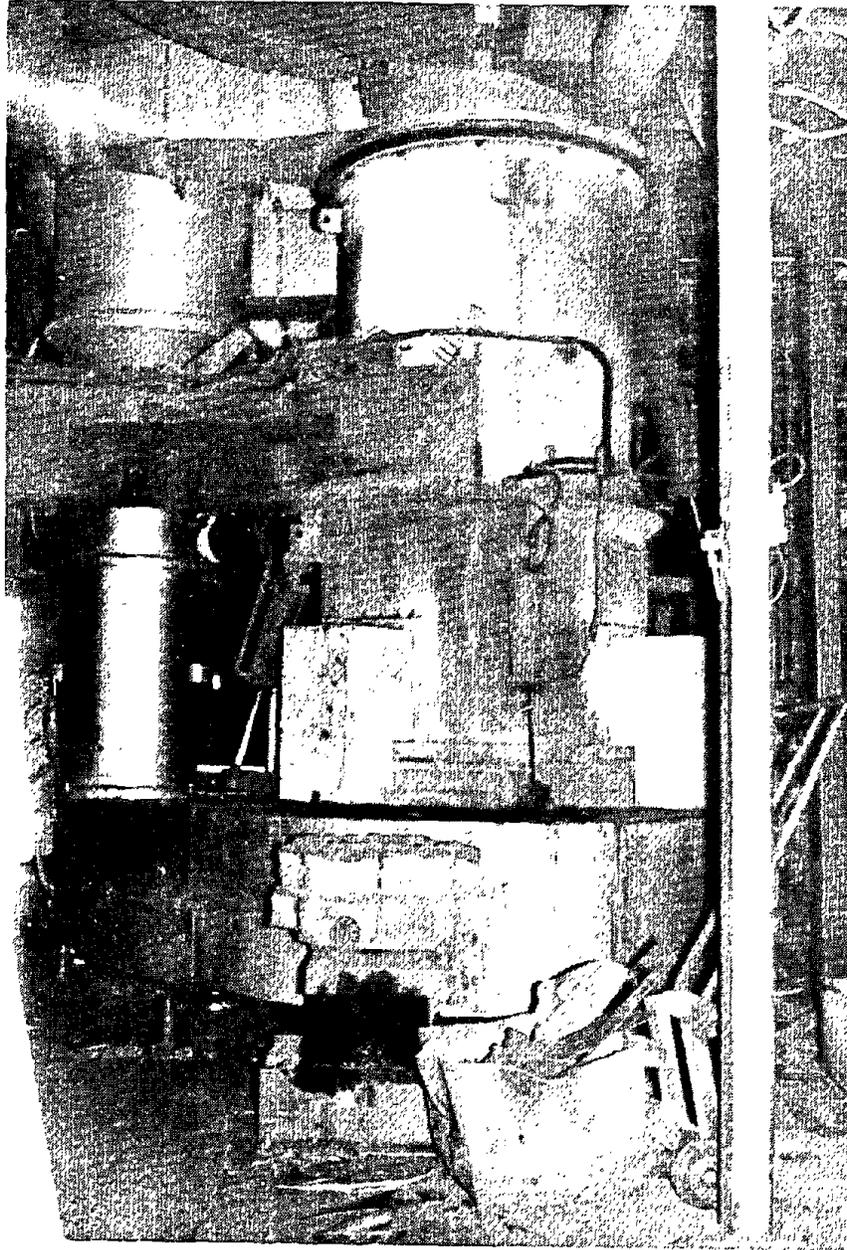
Figure A9-4. Charge bucket station at downblast preheating.

General Ventilation--
In addition to 85,000 cfm (40 m³/sec) of exhaust from the hoods, 185,000 cfm (83 m³/sec) of exhaust was provided by five roof ventilators, one above each furnace. Containment of escaping smoke and fume, especially during tapping, was assisted by a baffle wall located just outside the hot metal transfer monorail. The location of this baffle, as well as the general air flow patterns above the melt deck are shown schematically in Figure A9-5.
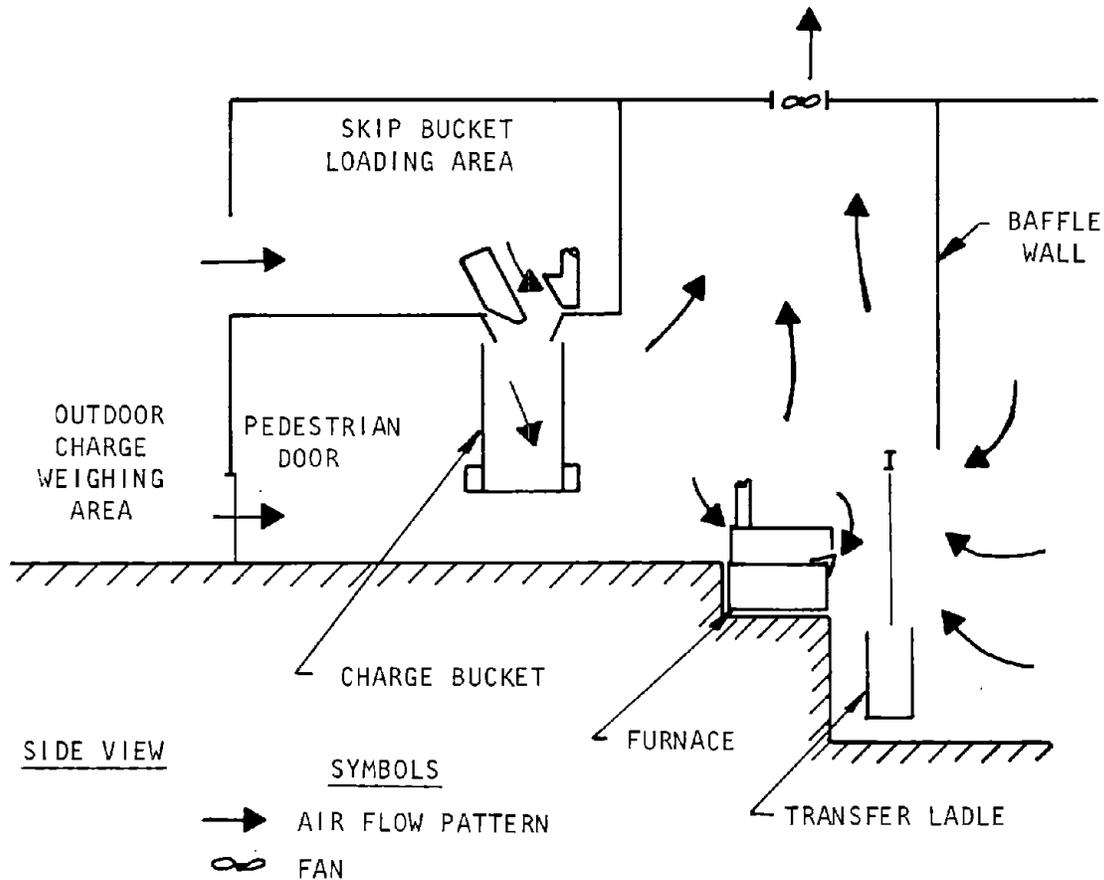
Figure A9-5. General ventilation schematic of melting platform.

An insufficient quantity of makeup air units in the immediate vicinity of the melting area caused most of the supply air to be induced from other plant areas or from outdoors through the skip bucket loading area and a pedestrian door. Each of these sources of supply air had potential problems associated with it:

1. Plant air entering under the baffle wall outside the monorail helped contain fumes on the melting deck, but this air was coming from remote process areas at sufficient volumes to create some

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possibility of cross-contamination. There was, however, no problem during the survey because the weather was warm and most supply air came through an open truck door. The potential for cross-contamination would be greatest during winter months when the building would be closed.

2. Indraft through the skip bucket loading area detracted from dust control at the charge bucket filling station.

3. Dust emissions during skip bucket loading (outdoors) on the weigh scale were uncontrolled and this dust was entering through the pedestrian door, blocked open to provide a source of fresh air.

Cooled and filtered fresh air drawn from the roof area was used to ventilate the operator booths. The enclosed melting office was air conditioned.

Personal Protective Devices

Before furnace operators slagged the furnace, they donned heat-resistant aluminized coats and colored face shields to protect them from infrared radiation and metal splashing.

RESULTS

1. Workers were exposed to low concentrations of metal fume and the background air quality was also relatively free of metal contaminants (Table A9-1).

2. Respirable silica was present in low concentrations on the melting deck. The primary source seems to have been cross-contamination from the operation of skip hopper filling occurring outdoors (Table A9-2).

Table A9-1. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average, exposure/ 8 hr. workday, mg/m^3				
				Fe	Ni	Mn	Pb	Zn
Furnace operator	6	Pers.	Hi	0.57	<0.01	0.03	0.10	0.16
			Lo	0.35	<0.01	0.01	0.02	0.03
			M	0.46	<0.01	0.02	0.04	0.08
Near furnace (Figure A9-4)	4	Fixed	Hi	1.05	<0.01	0.04	0.06	0.13
			Lo	0.56	<0.01	0.02	0.02	0.05
			M	0.72	<0.01	0.03	0.04	0.10
Melt deck office (Figure A9-4)	1	Fixed		0.08	<0.01	<0.01	<0.01	0.01
OSHA PEL				10.0§	1.0	5.0†	0.2#	5.0Ω
ACGIH TLV (1977)				5.0§	1.0	5.0†	0.15#	5.0Ω

§ Iron oxide fume.
† Ceiling value, short term sampling was not undertaken because of the expected low exposure.
# Lead dust and fume.
Ω Zinc oxide.

Table A9-2. Air sampling results - respirable silica.

Worker or location	Sample type	Percent quartz	Respirable dust, mg/m^3	Allowable respirable dust exposure, mg/m^3 §
Near furnace (Figure A9-4)	Fixed	2.3	0.88	2.33
Near charge bucket (Figure A9-4)	Fixed	1.3	0.91	3.03
In airstream entering pedestrian door	Fixed	16	0.33	0.56

§ OSHA PEL and ACGIH TLV (1977).

CASE B (JANUARY, 1978)

PROCESS DESCRIPTION

Equipment and Operation

A layout of the induction melting area is presented in Figure A9-6. The entire charge makeup, preheating, and furnace charging cycle was automated and remotely controlled from the melting office. A transport crane system automatically moved the charge bucket from station to station.

INDUCTION FURNACES (5)

CHARGE BUCKET
FILLING STATION (4)

WALL

MELTING AREA
OFFICE

CHARGE PREHEATER
STATION (8)

CHARGE BUCKET
CRANE PATHS

PLAN VIEW
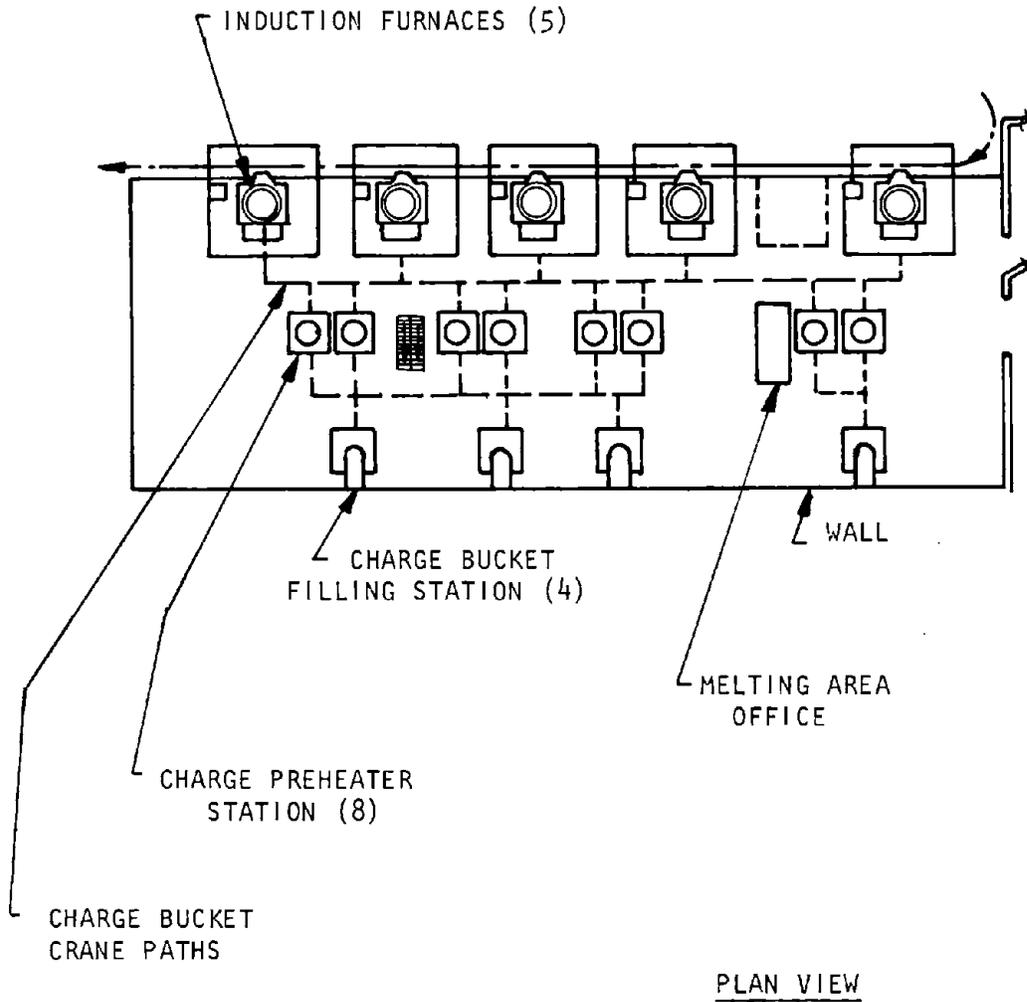
Figure A9-6. Layout of induction melting area.

Charge buckets were filled by a pan conveyor at a charge bucket filling station. Charges were then moved to downdraft preheater stations and

preheated before being transported to the furnaces. No workers were stationed in the charge bucket filling and preheating area.

Materials and Rates

The charge consisted of 7 tons (6.4 metric tons) of metal scrap consisting of 60% sprue and 40% steel. The steel was composed of bundles, ballized, and bushelings (stampings), some of which were oil coated.

WORKPLACE HAZARDS

The major air contaminant hazards from the preheating operation were oil mist, carbon monoxide and particulates. Although no operators were stationed near the preheaters, the ventilation patterns through the area were such that emissions might cause exposure problems for furnace operators. Prevailing air flow patterns drew air through the charge preparation and preheating areas, past the furnaces, and out roof exhausters in front of the furnaces.

CONTROL OF EXPOSURE

Exposure of melting area personnel to emissions produced during charge bucket filling and preheating was prevented by automating the operation, isolating the workers in booths, and by controlling charge bucket filling and ladle preheating emissions using exhaust at the source.

Engineering

Control at the Source--
The downdraft preheaters were controlled by enclosing and exhausting the preheater vent gases. A photograph of the charge bucket within the enclosure is shown in Figure A9-7 and a schematic of the exhaust flow patterns is shown in Figure A9-8. Air was emitted from the bucket through two ports (one on either side) in the wall at the bottom of the charge bucket. It was also emitted through openings in the segmented, drop leaf bottom of the bucket. The enclosure was designed to capture emissions from both sources.

The present design was a modified exhaust approach. Originally the charge bucket was set down on a table with a seal closing the bottom of the charge bucket. Smoke was captured as it was emitted through the side exhaust ports. This method did not prevent smoke escape, nor did it provide uniform charge heating. Trouble was especially encountered when the screens in the side ports became clogged with metal scrap and debris.

In the process of modifying the original hood design to accommodate exhaust out the side ports, as well as from the bottom of the charge bucket, gaps between the segmented drop leaves were widened to encourage more air flow out the bottom of the bucket for better air distribution through the charge materials and thus more complete preheating. This, in turn, introduced a new problem because metal scrap could now protrude out the bottom and possibly wedge tightly against the exhaust hood as the bucket
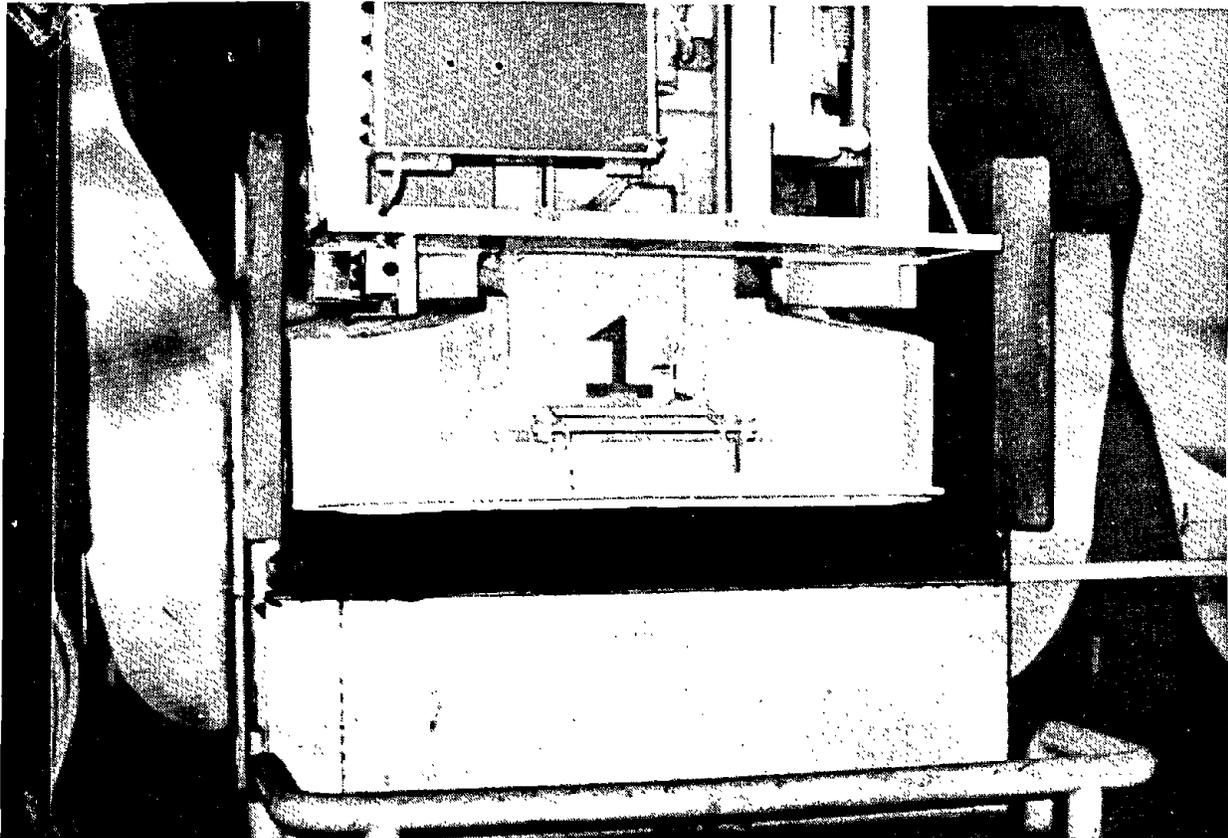
Figure A9-7. Charge bucket at preheater station.

EXHAUST
PLENUM

A

CHARGE
BUCKET

RUBBER
BAFFLE

A

PREHEATER

CHARGE
BUCKET

EXHAUST
PLENUM
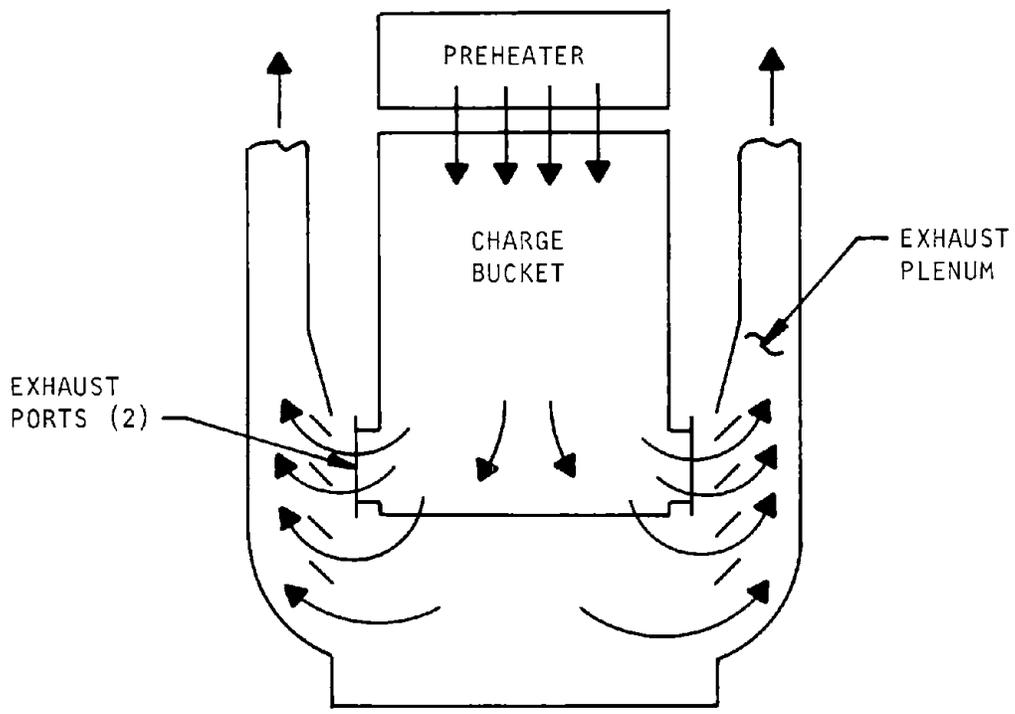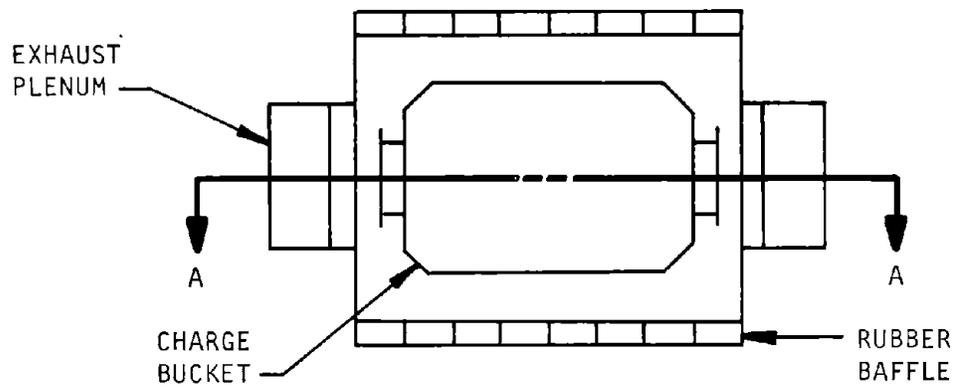
EXHAUST
PORTS (2)

SECTION "A-A"

SYMBOL
AIR FLOW PATTERN

Figure A9-8.   Schematic of preheater exhaust system.

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moved in and out of the preheater. For this reason, retractable rubber baffles were installed on the hood to provide the maximum amount of enclosure and still flex when the charge bucket had scrap protruding from the bottom.

Each preheater enclosure was exhausted with 20,000 cfm (9.5 m³/sec). An additional 20,000 cfm (9.5 m3/sec) was used to inspirate the exhaust through an incinerating afterburner of 8-16 million BTU/hr (2350-4700 kw) capacity. Thus, the total exhaust flow was 40,000 cfm (18.9 m³/sec).

General Ventilation--
Emissions from the charge area consisted primarily of those occurring at the charge bucket filling location. Exhaust was provided at the charge bucket side ports to capture dust during charge bucket filling, but this technique could not prevent dust from escaping through the bottom of the bucket. In addition to dust, a small quantity of smoke was emitted from the charge bucket after filling, with the oily scrap in contact with the hot charge bucket surfaces. These sources made general ventilation necessary.

Tempered makeup air [350,000 cfm (165 m3/sec)] was introduced at the rear of the melt deck area through 7 makeup air units. The fresh air was diluted with air in the charge preparation area before being drawn forward into the furnace area.

RESULTS

1. All contaminants measured were within the allowable limits (Table A9-3). The oil mist and total dust samples were taken previously by foundry personnel. The silica content of the total dust samples was not measured, however, the total dust levels were within the allowable limits on the basis of the typical silica percentage range in this melting area.

Table A9-3. Air sampling results - dust, mist, and gas.

Sample location	Sample type	Oil mist, mg/m³	Total dust, mg/m³	Carbon monoxide, ppm
Charge preheater area	Fixed	0.7	3.16	5-10
		0.8	2.82	
		1.0	3.18	
			2.78	
OSHA PEL		5.0	15.0	50.0
ACGIH TLV (1977)		5.0	10.0	50.0

CASE HISTORY #10
FUME CONTROL USING A CANOPY HOOD
DURING INDUCTION MELTING OF STEEL
AUGUST, 1977

ABSTRACT

A single canopy hood was used to contain and exhaust the metal fume from a bank of five coreless induction furnaces, thus effectively controlling exposures of melting and metal pouring operators. An essential prerequisite for using this general ventilation method was the use of scrap that was free from oil and adhered sand. The canopy utilized a large exhaust flow while drawing its makeup air from the general plant area. Observation of adjacent processes indicated that cross-contamination was not a problem in this case.

PROCESS DESCRIPTION

Equipment and Operation

The induction melting operation consisted of five - 2,000 lb (908 kg) coreless induction furnaces melting about 40 tons (36.3 metric tons) of alloy steel per day in two shifts. A plan view layout of the melting deck area is shown in Figure A10-1 and a photograph is shown in Figure A10-2.

Charge preparation was performed behind the melting deck by one worker who manually filled the charge bucket from scrap bins. A monorail crane transported the charge bucket to the furnaces.

Three workers manned the melting deck: a melter and two helpers. These men monitored the furnace controls and performed various tasks at and around the furnace, including:

    1. Adding alloys to the furnace and pouring ladles.
    2. Measuring metal temperature.
    3. Tapping into pouring ladles.
    4. Adding flux and slagging ladles in front of the furnace.
    5. Removing slag material from floor into hoppers.

Two metal pourers manually pushed the hot metal ladles along a monorail from the melting deck to a nearby shell mold pouring line.

Materials and Rates

On the days of the survey the foundry was adding alloys to bring the metal to the following weight percentages:

OUTLINE OF AREA COVERED BY CANOPY

FURNACES (5)

SCRAP BOXES (9)

COOLING
TUNNEL

MOVABLE WEIGH
PLATFORM

RAISED
MELT DECK

CHARGE
MONORAIL

CROSSDRAFT

POURING LADLE MONORAIL

POURING
LINE

SLAG HOPPERS (2)

POURING
HOOD

PLAN VIEW

SYMBOLS

MAN-COOLER FAN

ROOF EXHAUSTER

FIXED AIR SAMPLES
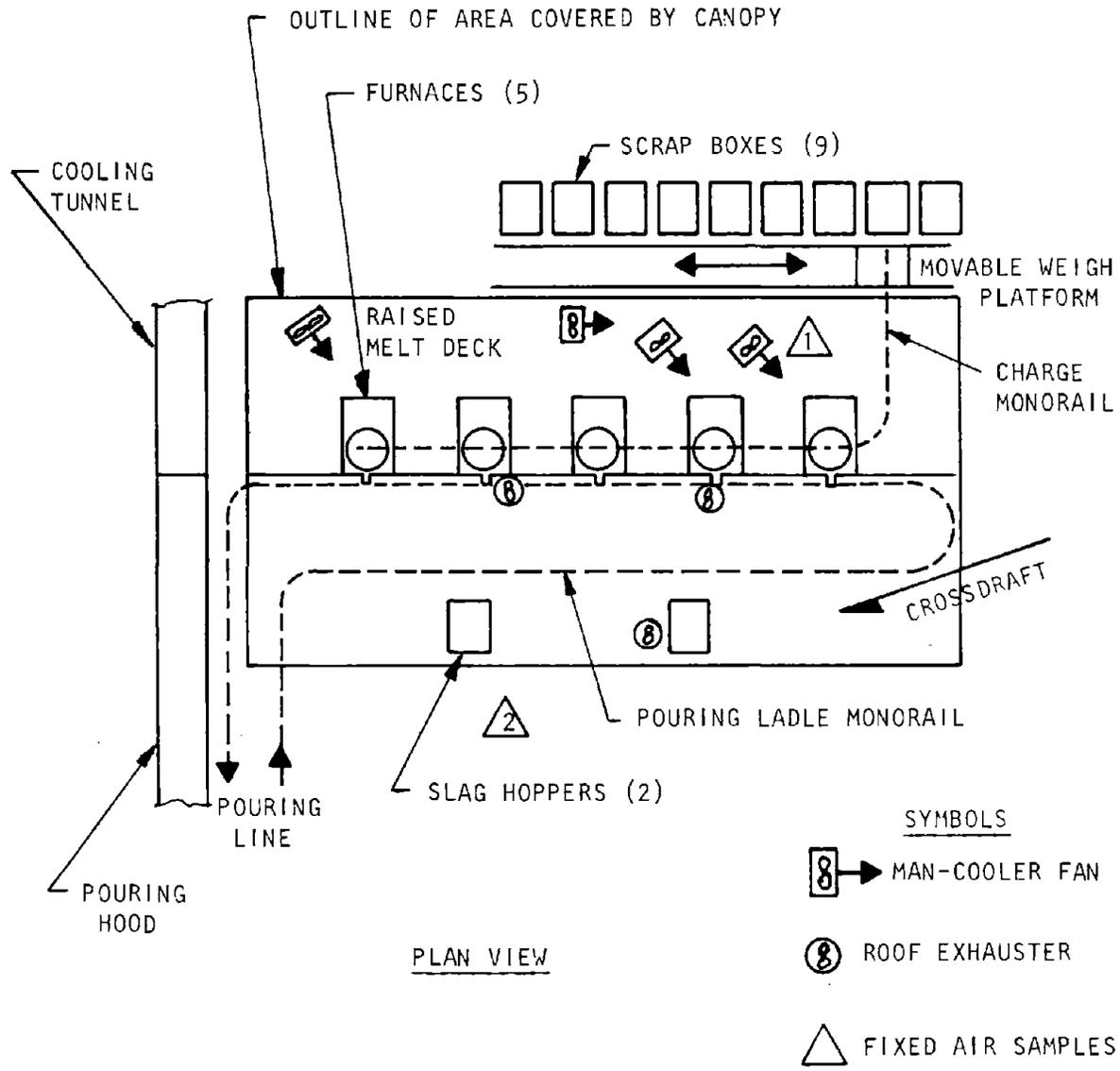
Figure A10-1.   Induction melting area.

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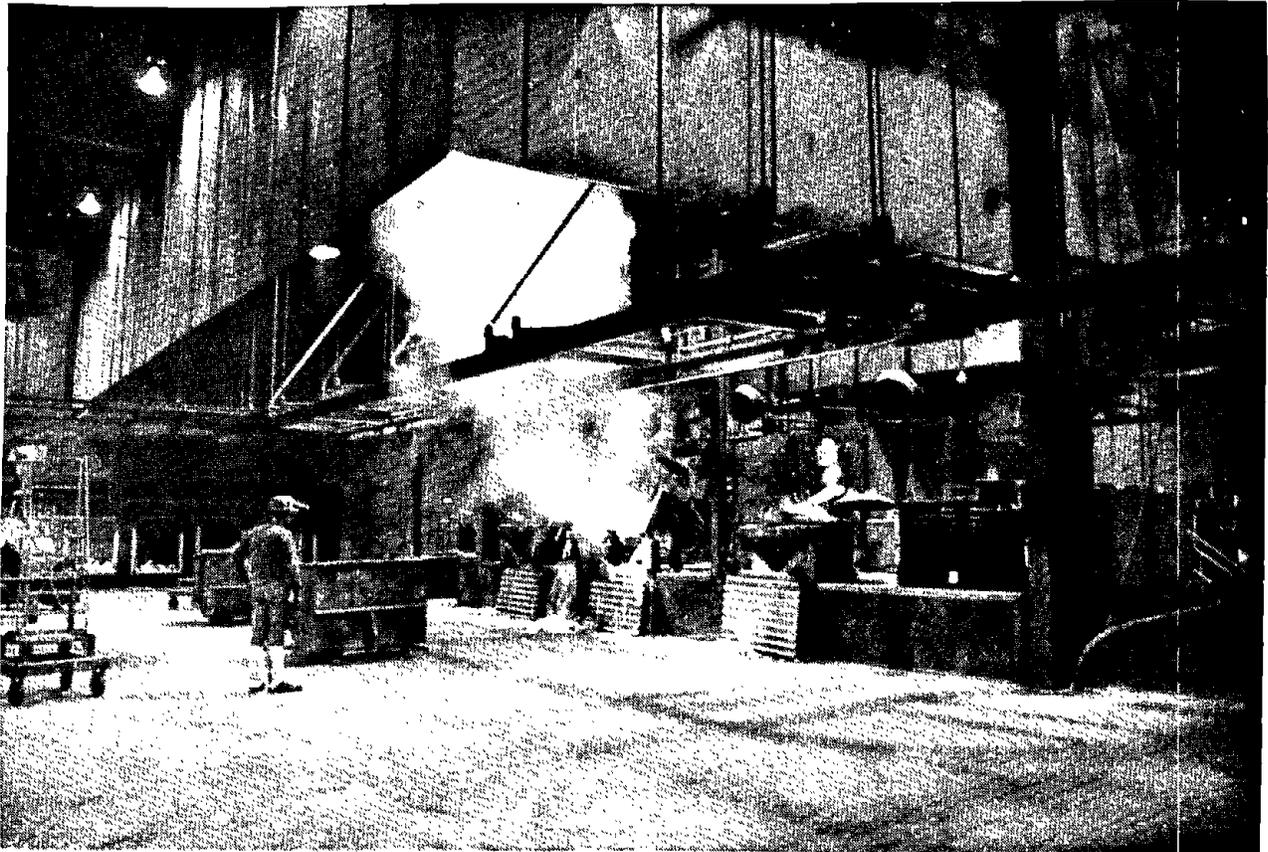
Figure AI0-2. Tapping of induction furnace.

Carbon	0.15-0.20%
Manganese	0.60-0.80
Sulfur	0.04 max.
Phosphorus	0.04 max.
Silicon	0.20-0.50
Nickel	0.40-0.70%
Molybdenum	0.15-0.25
Aluminum	0.06-0.08
Boron	0.0015 min.
Chromium	0.40-0.60
Iron	Balance

Charge material, free from oil and adhered sand, consisted of 665 lbs (302 kg) of ingot, iron punchings, sprue returns, machine shop scrap, stainless steel scrap castings and ductile iron. Alloy additions to the furnace included small amounts of pure nickel, ferromolybdenum, ferrosilicon, and electrolytic manganese. Small amounts of alloy materials were added to the pouring ladle during tapping to adjust the composition of the molten metal.

WORKPLACE HAZARDS

The major air contaminant hazard from this alloy steel melting operation was fume inhalation. The metals of hygienic significance consisted of iron, manganese, nickel, and chromium. Melting and pouring workers were also subjected to infrared radiation from the molten metal.

CONTROL OF EXPOSURE

Melting deck personnel and metal pourers were protected from exposure to metal fume from furnace operations by an overhead canopy hood which contained and evacuated fume rising in the thermal draft. Metal pourers helped to minimize their exposure by withdrawing from the furnace area during tapping.

Engineering

Fume created in the furnace and ladle filling areas was contained by sheet metal barriers extending down from the roof to the level of the top of the hot metal ladle monorail, creating a receiving canopy hood. Thermal drafts from the hot processes carried fume upward into the hood where it was exhausted by three 60-inch (152 cm) roof ventilators, drawing a nominal total flow of 81,000 cfm (38.2 m3/sec). This amount of exhaust caused an average upward air flow into the canopy of 33 fpm (0.17 m/sec).

The worst fuming occurred during furnace tapping and alloy additions to the ladle. As can be seen in Figure A10-2, fuming was well-controlled by the hood. Very little fume drifted into the breathing zones of the furnace operators because of the thermal draft and the presence of mancooler fans blowing on the operators from behind. Although providing a benefit to the

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melting deck operators, these mancoolers caused the fume to move laterally into the ladle filling area as it rose (Figure A10-2).

The canopy hood was not 100% effective in containing fume because of a crossdraft of 50-150 fpm (0.75 m/sec) from air entering the building through a truck entrance some distance away. The crossdraft and the mancooler fans were additive in their effect of pushing small amounts of fume from under the hood.

Makeup air units were located at various points throughout the foundry to provide general ventilation. Since the exhaust canopy was drawing high volumes of general plant air across the melting deck, the possibility of cross-contamination had to be explored. General plant air quality appeared to be very good and only two processes in the area posed any potential for cross-contamination:

1. Charge bucket filling - The scrap was free of adhered sand and little if any dust was emitted from the charge bucket filling operation.

2. Pouring line - The pouring and cooling fume hood was quite effective. Some fume was seen to escape, however, at the point where the pouring line entered the cooling tunnel.

Work Practices

To prevent breathing fume in the ladle filling area during tapping, the metal pourers withdrew from the area during that time (Figure A10-2). However, they did breathe some fume while pushing their ladles along the monorail in front of the furnaces and also while they steadied their ladles during slagging next to the furnace. About two minutes of the 5-8 minute ladle filling and pouring cycle was spent under the canopy hood.

Personal Protective Devices

Melters and metal pourers used tinted lenses, aluminized arm protectors, aprons, and spats to protect themselves from infrared radiation, sparks, and metal splashing.

RESULTS

1. Exposures to metals of hygienic significance were well controlled by the canopy hood (Table A10-1).

2. Comparison of the exposure to metals that the metal pourers received during their entire workshift as compared to their exposure while under the canopy hood indicated that no substantial increase in exposure was occurring because of fume being blown into that area (Table A10-1).

3. Carbon monoxide from the pouring and cooling line did not adversely affect melting deck personnel. No worker spent any appreciable

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time in the corner of the melting deck nearest the pouring and cooling line where the highest exposure was measured (20-40 ppm).

Table A10-1. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average exposure/ 8 hr. workday, mg/m³			
				Fe	Ni	Mn	Cr
Melter and helpers	6	Pers.	Hi	0.180	0.009	0.064	0.005
			Lo	0.042	0.002	0.002	0.002
			M	0.086	0.006	0.022	0.004
Metal pourer	2	Pers.	§	0.107	0.014	0.092	0.012
			*	0.040	0.006	0.025	0.005
Behind furnaces (1 Fig. A10-1)	2	Fixed	Hi	0.032	0.008	0.004	0.001
			Lo	0.019	0.001	0.008	0.001
			M	0.026	0.004	0.006	0.001
In front of canopy (2 Fig. A10-1)	2	Fixed	Hi	0.016	0.008	0.007	0.006
			Lo	0.011	0.004	0.004	0.001
			M	0.014	0.006	0.006	0.004
OSHA PEL				10.0†	1.0	5.0Ω	1.0Ψ
ACGIH TLV (1977)				5.0†	1.0	5.0Ω	0.05Θ

§ Exposure under canopy hood only.
* Exposure during complete work cycle.
† Iron oxide fume.
Ω Ceiling value, short term sampling was not undertaken because of the expected low exposure.
Ψ Metal and insoluble salts.
Θ Chromic acid and chromates as chromium.

CASE HISTORY #11
FUME, DUST AND GAS CONTROL
FROM ARC FURNACE MELTING OF IRON
OCTOBER, 1977

ABSTRACT

Fume, dust, and gases from high production arc furnaces were controlled at
the source by sidedraft exhaust hoods in conjunction with roof exhausters.
The present furnace exhaust hood represented many refinements and improve-
ments over the original hood, resulting in an efficient, durable, and
maintainable control measure. Control was facilitated by an adequate
makeup air system which continuously purged the melting operator stations
with fresh air. Exposure levels of melting operators to dust, metal fume,
and carbon monoxide were controlled below the allowable limits. Continued
proper operation of the exhaust hoods was assured through a continuous
maintenance program involving both the melting operators themselves, and
the maintenance staff.

PROCESS DESCRIPTION

Malleable iron was melted during three shifts using three 30 ton (27 metric
ton) direct arc furnaces at the total melting rate of about 60 tons/hr
(54 metric tons/hr). A furnace charge consisted of 20 tons (18 metric tons)
of malleable iron sprue, low density shredded carbon steel, and grey iron
and steel scrap. After placing a thin layer of metal scrap in the charge
bucket to seal off the bottom openings, 100-400 lbs (45-182 kg) of carbon
graphite was placed in the bucket. The low position of the graphite in
the charge prevented unnecessary burning off of the carbon. Other additions
into the charge bucket included limestone, silicon, manganese, boric acid
(source of boron), and pyrites (source of sulfur). No additions were made
to the furnace, although silicon, carbon, and boric acid were sometimes
added to the tapping ladle to adjust the metallurgy. Slagging was commonly
performed in the tapping ladle at a special slagging station. Slagging was
only performed at the furnace when excessive slag prevented proper inspection
of the melt. Prior to pouring molds the molten metal was held in two
·100 ton (91 metric ton) channel induction furnaces.

One operator was located at each melting furnace performing the following
tasks during the 55-70 minute furnace cycle:

    Clearing scrap from the furnace cover seal area before closing the
    furnace lid.

    Measuring temperature and sampling the melt.

    Shovelling refractory material (as necessary) into the furnace to patch
    the bottom lining after tapping.

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Operating furnace controls.

WORKPLACE HAZARDS

The major air contaminant hazards from arc melting were: metal dust and fume, respirable silica, and carbon monoxide.

Workers were also subjected to ultraviolet light, infrared radiation, and heat, especially when working at the furnace door.

CONTROL OF EXPOSURE

Control of arc furnace emissions was provided by sidedraft hoods on the furnaces, as well as fresh air supplies for furnace operators. Fume escaping the hoods was exhausted by roof ventilators above each furnace. A comprehensive preventive maintenance program kept furnaces and environmental controls in peak operating condition, providing assurance of continued performance and minimum downtime.

Engineering

Control at the Source--
The arc furnace hoods originally supplied with the furnaces seven years ago had since been remodeled to provide better control and longer life. The original hood had had an extension which passed between the close electrodes to capture emissions at the far electrode. This extension received a substantial amount of heat radiation from the two close electrodes and was susceptible to early failure. On one occasion the extension had burned off and shorted out the furnace. The new wraparound hood design is shown schematically in Figure All-1. A cardboard model of the hood is shown in Figure All-2. The far electrode was exhausted by two hood extensions which passed around the outside of the close electrodes. Turning vanes in these extensions helped to prevent hot spots in the hood. The entire hood was constructed of 5/16 inch (0.8 cm) thick Type 309 Stainless Steel. All butt corner joints were eliminated and replaced with overlap joints to prevent the weld failures which had previously been common. The hood was structurally reinforced and its mounting flange was located in such a way so as to facilitate easy hood removal and keep replacement costs down. Before adopting stainless steel material of construction for the hood, the foundry had attempted to use a refractory-lined hood. However, the refractory did not hold up.

A small portion of the exhaust flow from each furnace was used to control emissions at the slag door. This door was opened only when the operator was working on his furnace tasks. The combined exhausts from all three furnaces were filtered through fabric dust collectors before being discharged outdoors.

A drawback of the fume collection system was that the exhaust ductwork from the sidedraft hood was only designed to capture fuming with the furnace upright and the furnace door closed. During charging, the sidedraft hood section swung away with the furnace cover (Figure All-3), and during tapping, the sidedraft hood section and another ductwork section tilted with

HOOD REPLACEMENT FLANGE

CLOSE ELECTRODES (2)

TURNING VANE

FAR ELECTRODE

SYMBOL

→ AIR FLOW PATTERN
INTO HOOD

STUDY PLAN
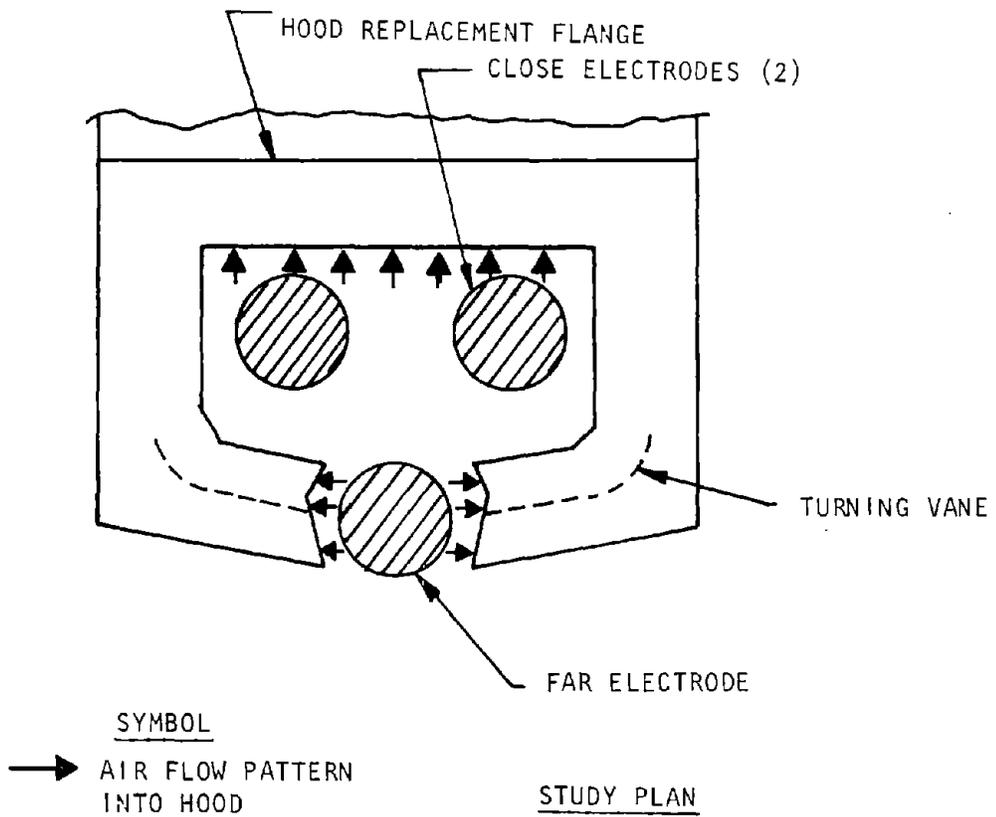
Figure AII-I. Orientation of hood in relation to electrodes.
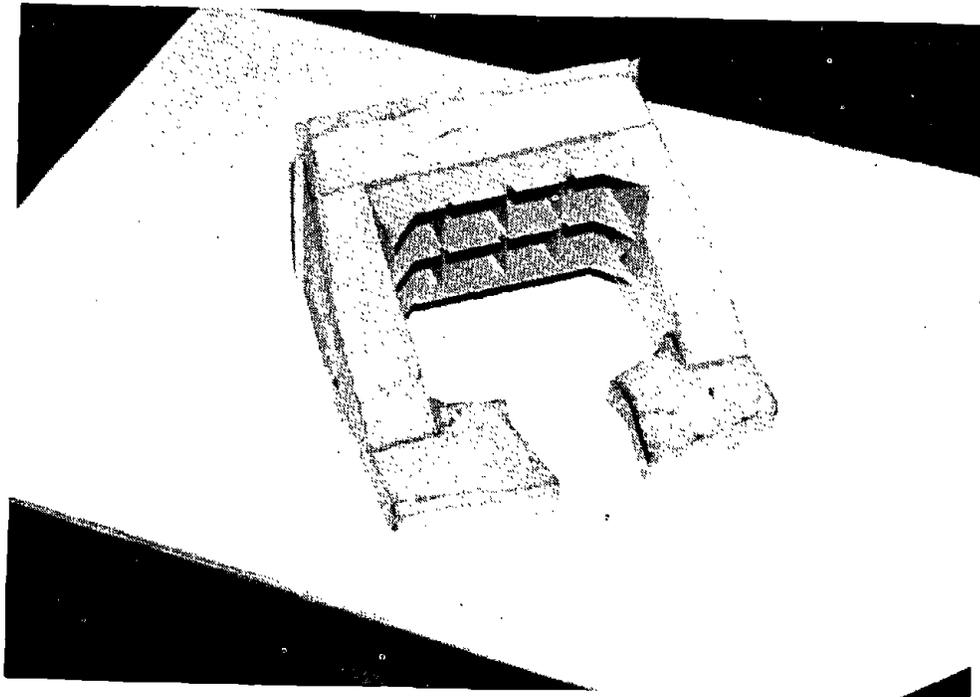
Figure AII-2. Model of sidedraft furnace hood.

254
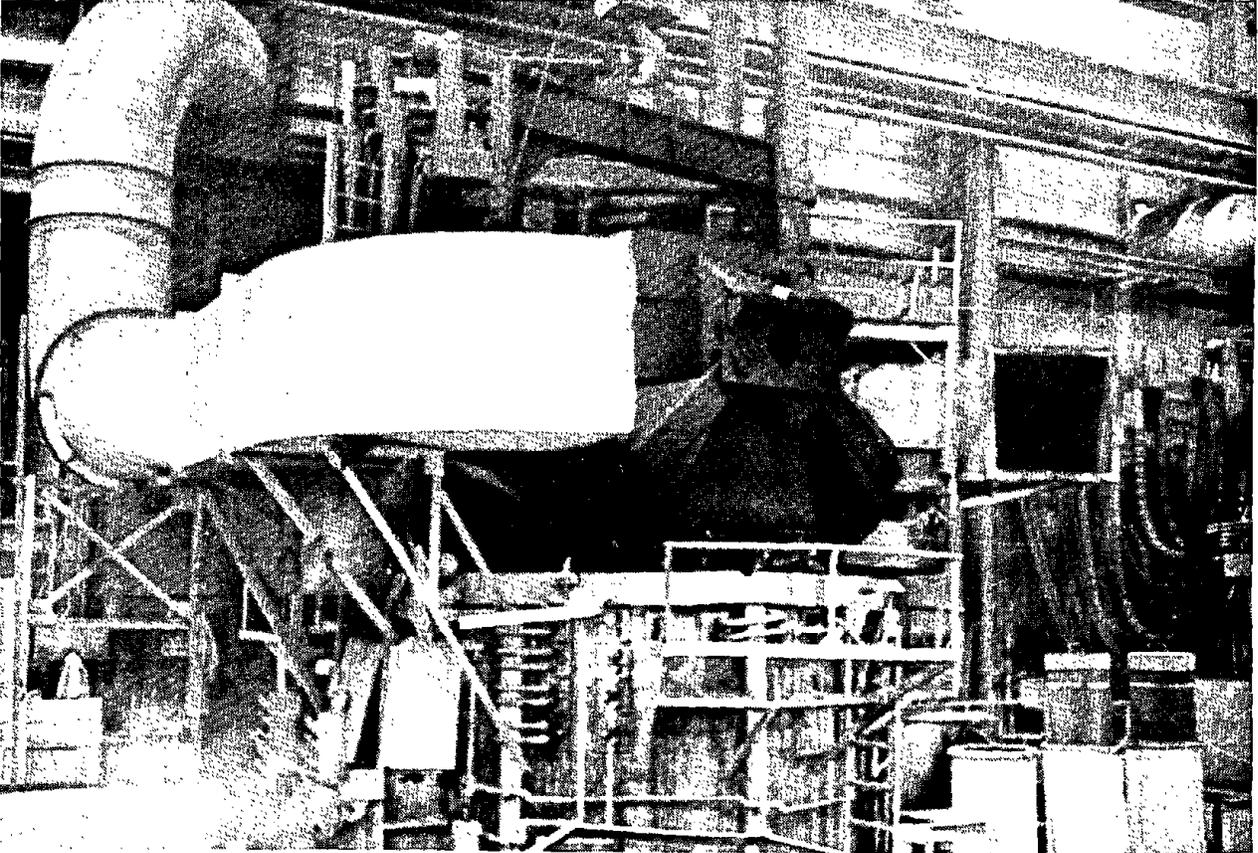
Figure A11-3. Arc furnace showing furnace hood swung out of the way with furnace door during bucket charging.

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the furnace.

An important task performed by furnace operators, affecting the efficiency
of fume capture by the sidedraft hood, was maintenance of furnace cover
seals. The loose aggregate that provided the seat for the seal was
inspected and cleared after each furnace charging.

Preventive Maintenance--
Through experience, foundry personnel discovered that the exhaust control
system for arc furnaces would perform most reliably if a continuous main-
tenance program were implemented. Without continuous maintenance, problems
such as burned bags, plugged baghouse hoppers, and malfunctioning blowers
caused system performance to be unreliable and unpredictable. A summary
of important maintenance tasks is presented in Table AII-I. One person was
assigned to the arc furnace control system on a full time basis and the
effect has been much better than sending in a crew on a weekend basis only.

Table AII-I. Maintenance schedule for arc furnace air pollution control
system.

Task	Frequency
Monitor collector differential pressure and motor amperage (amperage is continuously recorded).	Once per shift.
Check collector augers and fans to be sure they are running.	Once per shift.
Check collector hoppers to be sure material is not building up (pneumatic vibrators permit periodic vibrating of hopper walls to remove clinging materials).	Once per shift.
Check drive components: V-belt and sheaves, bearings, shaker linkages, seals around hanger bearings.	Once per weekend.
Check pneumatic system: solenoid valves, air lines, moisture traps.	Once per weekend.
Check hood for flyash buildup.	Once per weekend.
Check the bags in one compartment per week (excess capacity is available and one module can be taken off line while still providing full flow).	Once per week.
Clean fan impellers with wire brush.	Once per month.

Charge Control--
Since oily scrap caused burn holes in bags, the foundry scrap specification
excluded oily scrap. However, the low density, plain carbon steel scrap
contained some water-base lubricants and so this scrap was allowed to weather
until these materials were removed. The addition of graphite instead of
coke breeze helped the carbon to go into solution more efficiently, with
the resulting effect of causing lower fume emissions.

General Ventilation--
Dust, fume, and gases in the melting area resulted from the following un-
controlled processes: arc furnace charging and tapping, holding furnaces,
ladle slagging, and hot metal transfer. These emissions were carried
upward in thermal drafts and were exhausted by roof ventilators. Nominal
total exhaust from the melting area was 381,000 cfm (180 m3/sec), composed
of three furnace hoods at 67,000 cfm (31.6 m3/sec) each, exhausted to a
fabric collector, and six roof ventilators at 30,000 cfm (14.2 m3/sec)
each, exhausted to the outdoors. Six makeup air units supplied a nominal
342,000 cfm (161 m3/sec), including fresh air supply at each furnace
operator station (Figure All-4). This close balance between exhaust and
supply air prevented dusty air from being drawn into the furnace area from
the outdoor charge preparation area.

Personal Protective Devices

Furnace operators wore tinted safety glasses to protect their eyes from
infrared radiation. When they worked at the furnace door they wore tinted
face shields.

RESULTS

1. Airborne concentrations of metal dust and fume were well below the
   allowable limit (Table All-2).

2. Personal exposure to respirable silica was well below the allowable
   limit for the melting operators who spent the majority of their
   time within the zone of fresh makeup air (Table All-3). A higher
   level of respirable silica existed outside the zone of the fresh
   air.

3. Carbon monoxide was controlled to 5-10 ppm in the melting area.
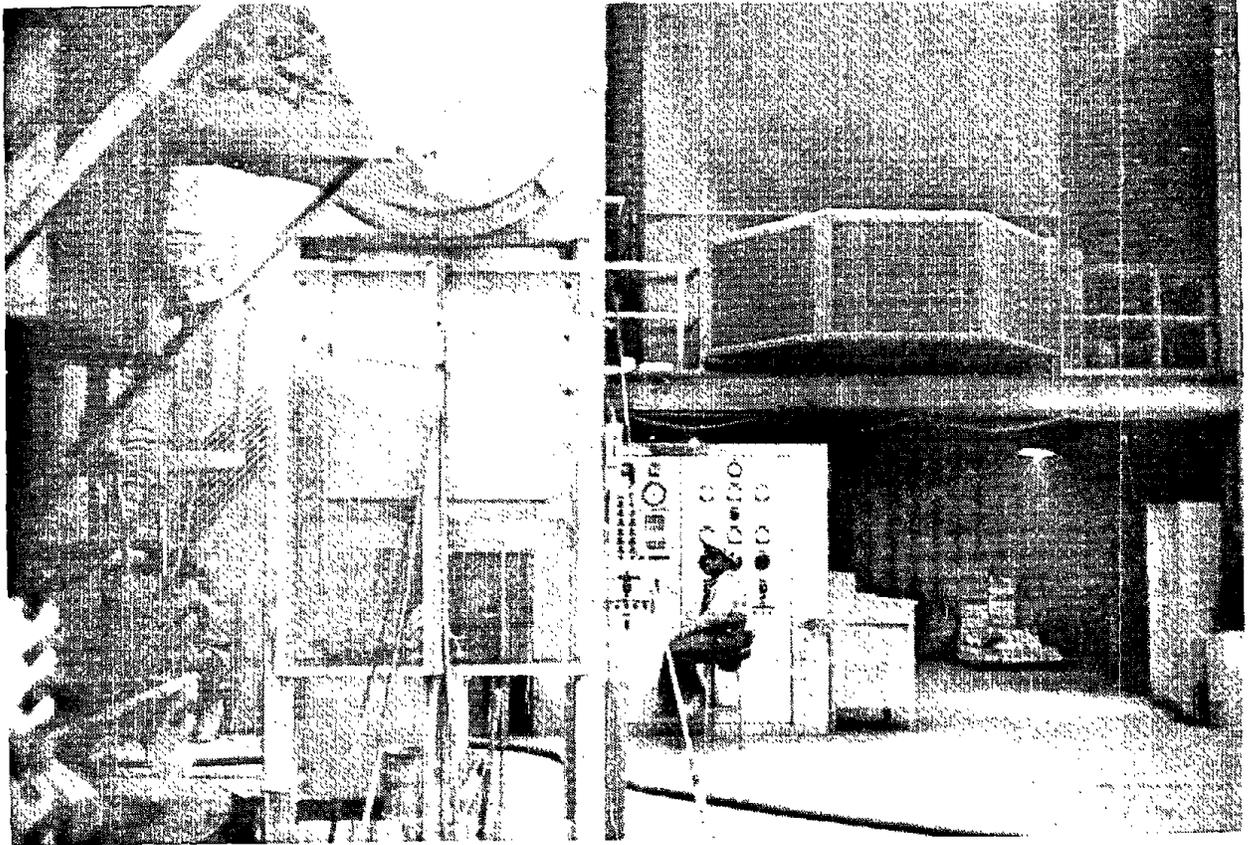
Figure AII-4. Furnace operator station next to furnace showing fresh air supply.

Table AII-2. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average exposure/ 8 hr. workday, mg/m3				
				Fe	Ni	Mn	Pb	Zn
Furnace operator	2	Pers.	Hi	0.74	<0.01	0.03	0.02	0.17
			Lo	0.67	<0.01	0.02	0.02	0.12
			M	0.71	<0.01	0.03	0.02	0.15
Melting deck background	3	Fixed	Hi	1.39	<0.01	0.04	0.02	0.20
			Lo	0.76	<0.01	0.04	0.02	0.14
			M	1.09	<0.01	0.04	0.02	0.17
OSHA PEL				10.0*	1.0	5.0§	0.2#	5.0Ω
ACGIH TLV (1977)				5.0*	1.0	5.0§	0.15#	5.0Ω

§ Ceiling value, short term sampling was not undertaken because of the expected low exposure.
* Iron oxide fume.
# Lead, inorganic fume and dust as Pb.
Ω Zinc oxide fume.

Table AII-3. Air sampling results - respirable silica.

Worker or location	Sample type	Percent quartz	Respirable dust exposure, mg/m3	Allowable respirable dust exposure, mg/m3 §
Melter	Pers.	2.3	1.50	2.33
	Pers.	2.8	1.30	2.08
Background- adjacent to furnace out- side of fresh air zone	Fixed	2.4	1.60	2.27
	Fixed	5.6	1.90	1.32

§ OSHA PEL and ACGIH TLV (1977).

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CASE HISTORY #12
CONTROL OF CUPOLA EMISSIONS
SEPTEMBER, 1977

ABSTRACT

Cupola emissions were exhausted by a unique bifurcation around the charge
door which controlled levels of metal fume and gases to well below allowable
limits. Respirable silica levels, however, were high. In light of the
metal fume and gaseous measurements, as well as evaluation of the degree
of charge opening control and the nature of general ventilation, it is
probable that a major part of the respirable silica was drawn by the
cupola from adjacent foundry areas.

A canopy hood over the tapping spout of the cupola controlled emissions
during continuous flow of metal into the forehearth. A booth at the
tapping spout provided protection for alloy and ladle operators from metal
fume, as well as from heat and infrared radiation.

PROCESS DESCRIPTION

Equipment and Operation

Melting--
Melting was done in two cupola furnaces, with one in service and the other
in the process of being relined. The cupola melted and tapped continuously
into a forehearth which in turn, was tapped in batches into bull ladles.
Furnace operations consisted of alternately charging coke, flux, and
metal into the top of the cupola shaft. The charge bucket was filled
outdoors and transported indoors to the crane pickup point by a motorized
cart. The crane hoisted the bucket up to the charging deck and moved it
on a monorail to the cupola charge opening. The position of the bucket
during charging is shown in the photo in Figure A12-1 and schematically in
Figure A12-2. The crane operator was the only person located on the
charging platform and he was never further than 25 ft (7.6 m) from the
cupola.

Tapping and Alloying--
The tapping and alloying station (Figure A12-3 and 4) was located in a
partially enclosed booth directly in front of the cupola tap spout and
forehearth. The process of filling ladles at the forehearth went as
follows:

    1. A ladle operator moved the ladle to the metal filling position
       in front of the forehearth staying within the booth as he did so.

    2. The alloy operator in the booth manually added alloy constituents
       to the ladle and then filled the ladle with molten metal.
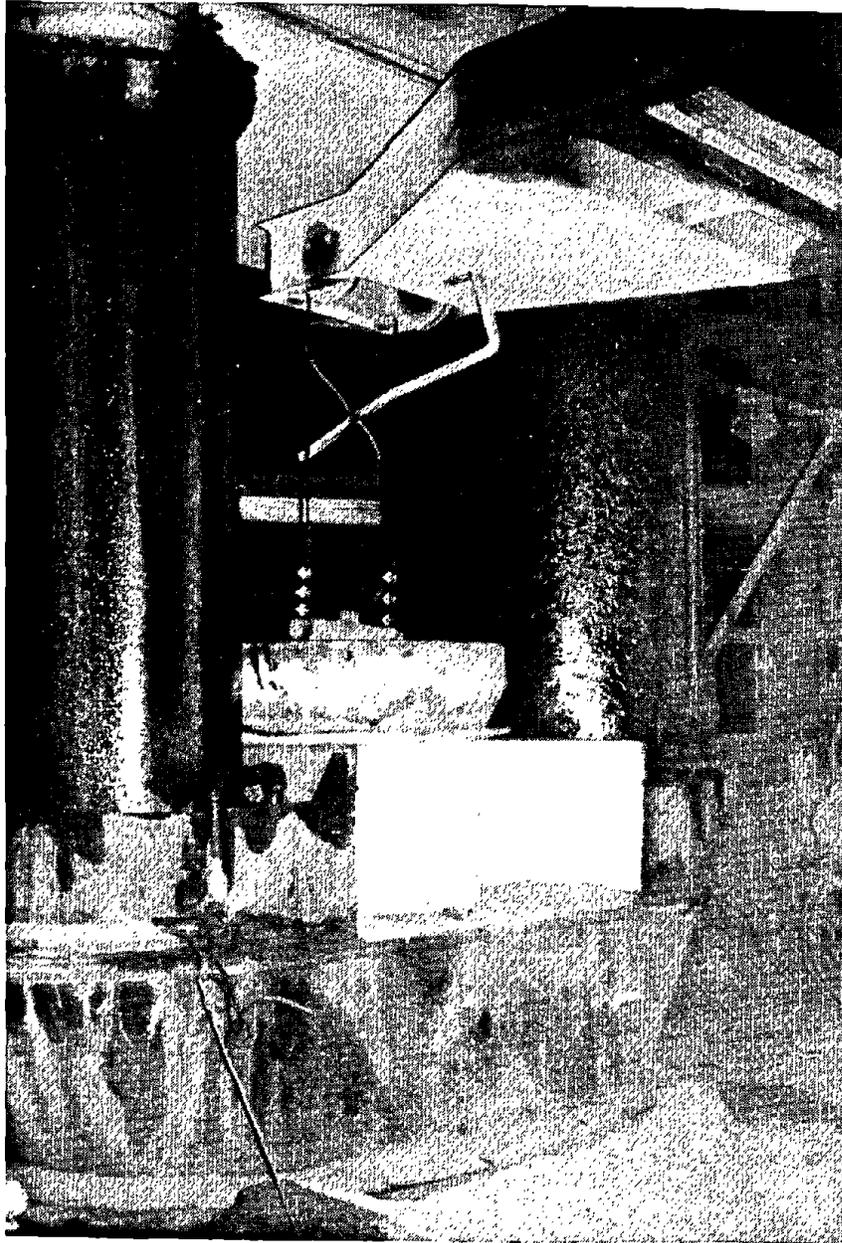
Figure Al2-1. Cupola charge opening during charging with a bucket.

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AFTERBURNER SECTION

BOTTOM DUMPING
CHARGE BUCKET

WATER COOLED DUCTWORK

TRANSITION SECTION

SYMBOL

AIR FLOW
PATTERN

CUPOLA

FRONT VIEW
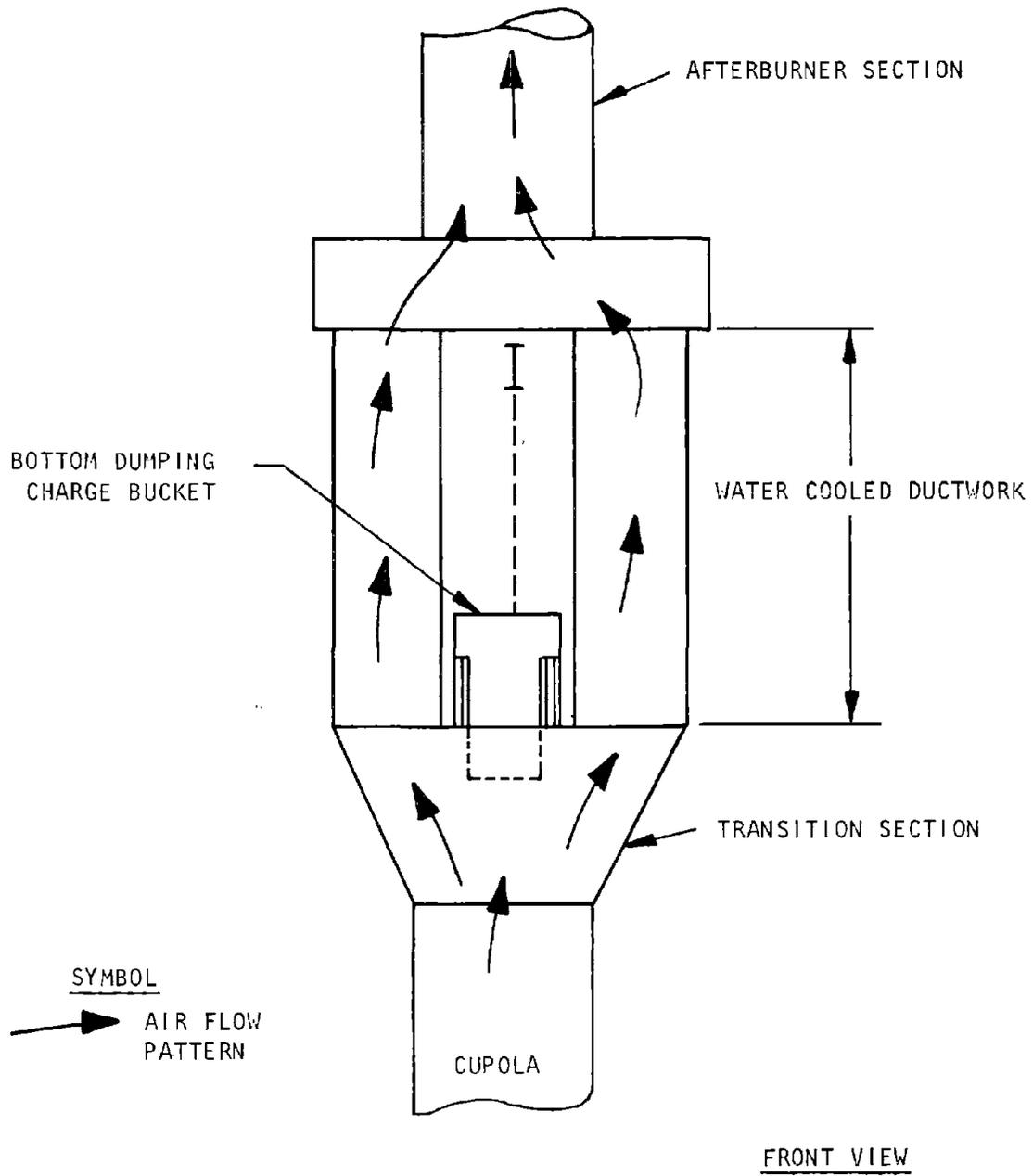
Figure A12-2.   Cupola charge opening-bifurcated hood.

Figure AI2-3. Tapping into the forehearth. The alloy operator booth is shown adjacent to the tapping spout.

SODA
ASH

CANOPY HOOD

REMOTE CONTROL CABLE

PROTECTIVE ROOF

MAN-COOLER FAN

HOT METAL
LAUNDER

OPERATOR
BOOTH

ALLOY BINS

FOREHEARTH

HEAT/SPLASH SHIELD

TRANSFER LADLE
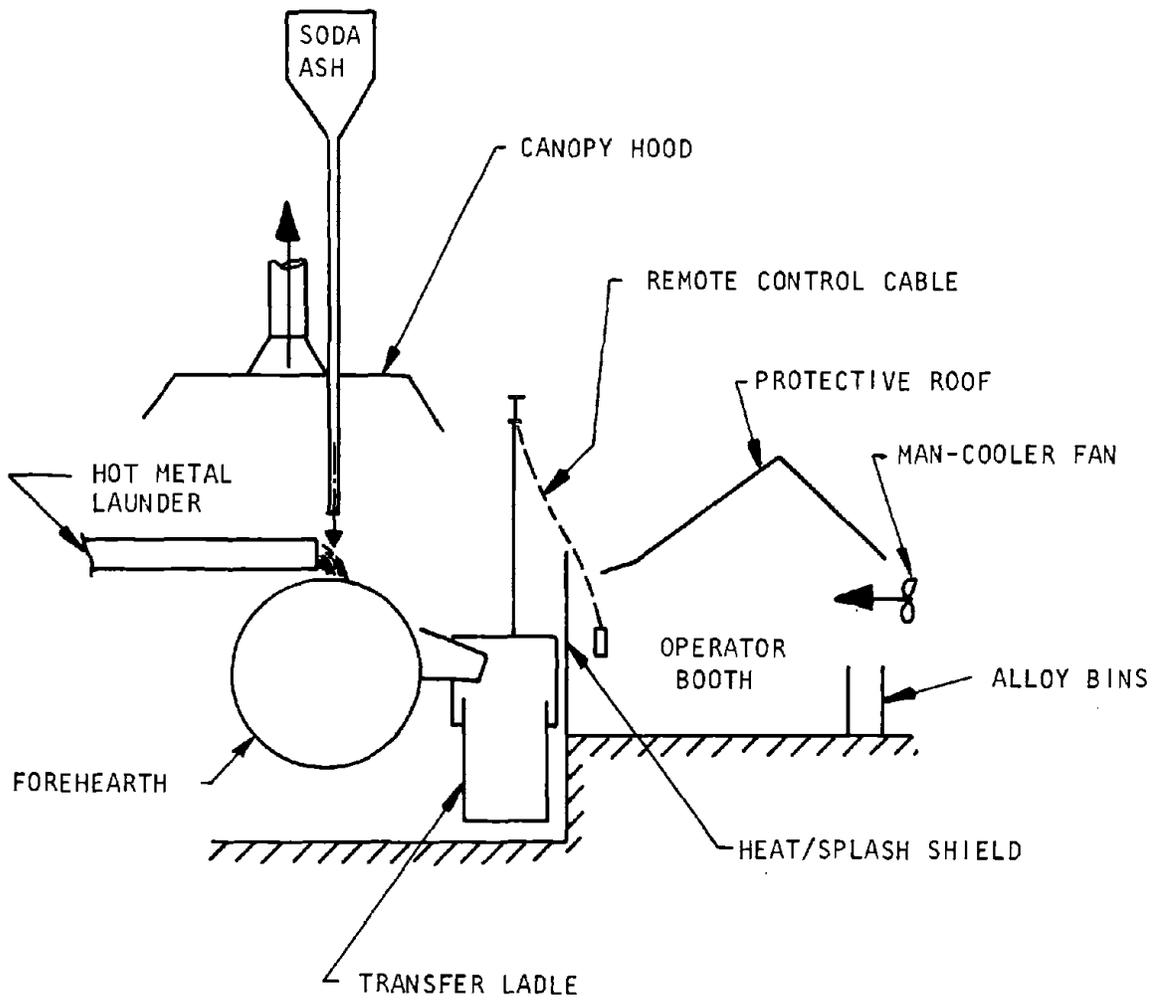
SIDE VIEW

Figure A12-4.   Cupola forehearth area.

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3. The ladle operator moved the ladle to a remote slagging station before proceeding to the pouring line.

Materials and Rates

Melting--
Charge materials consisted of steel scrap, iron returns, pig iron, silvery pig, manganese, carbon briquettes, coke, and limestone. Metal was melted at a rate of 20 tons/hr (18 metric tons/hr) and transported from the forehearth to the pouring line in 5,000 lb (2270 kg) ladles. Soda ash ($Na_2 CO_3$) was continuously injected into the forehearth for desulfurization at the rate of one ton (0.9 metric ton) per 24 hours of operation.

Various alloys were added in small amounts into the ladle before filling, including an inoculant containing 40% chrome, as well as copper, nickel, and molybdenum additions.

WORKPLACE HAZARDS

The major air contaminant hazards from cupola operations consisted of carbon monoxide, respirable silica, sulfur dioxide, hydrogen sulfide, and metal fume.

Infrared radiation and heat were also potential problems for the alloy and bull ladle operators, and heat was a potential problem for the crane operator.

CONTROL OF EXPOSURE

Charge deck emissions were controlled by an exhaust system providing indraft at the cupola charge opening. Emissions during tapping into the forehearth were captured by a receiving canopy hood. Heat was controlled by the above exhausts. In addition, a booth at the tapping spout isolated the operators from infrared radiation and heat.

Engineering

Control at the Source--
Melting--Emissions at the charge opening were controlled by a bifurcation around the charge door specially designed by foundry personnel (Figure A12-1 and 2).

Hot combustion gases, as well as indraft air drawn downward into the charge opening, were exhausted by takeoffs located on either side of the charge opening. Exhaust gases drawn through the two takeoffs were later recombined above the charge monorail. Water cooling was provided on the outside of the two vertical duct sections on either side of the charge opening. The charge bucket was only slightly smaller than the 5 ft (1.5 m) diameter charge opening, thus effectively blocking off the opening during charging and helping to prevent a "puff" from occurring by creating a higher indraft velocity.

The exhaust gases from the cupola were fed through an afterburner and then into a spray quench chamber in which the temperature was dropped to 480°F (249°C). They then flowed through a fabric dust collector rated at 73,000 cfm (34.5 m³/sec) before being discharged outdoors. Cleanout and maintenance of hood transitions and inter-connecting ductwork from the cupola to the quench tank were required on a frequent and regular basis to prevent buildup and subsequent flow reduction.

Tapping and alloying--Emissions during tapping of the cupola into the forehearth were captured by a canopy (receiving) hood. Hood exhaust flow was 19,000 cfm (9 m³/sec) drawn upward into a hood area of 96 ft² (9 m²). The granular soda ash was fed into the metal stream as it entered the forehearth and much of it was lost in the exhaust. The foundry had just installed a briquet feeder to provide more efficient injection into the metal and less emissions.

The booth provided heat relief for the operators during alloying and tapping primarily because of the shielding which it provided. Two sliding doors in the front of the booth permitted complete blocking of the paths of infrared radiation into the booth except during alloy addition and filling of ladles. While adding alloys or tapping the forehearth the operator opened the door a small distance and extended no more of his body into the opening than absolutely necessary. The shielding, as well as the roof of the booth, prevented sparks from hitting the workers.

A mancooler fan at the back of the booth blew air through the booth at 300 fpm (1.5 m/sec). The air passed out the front of the booth to be immediately drawn upward in the thermal draft. Besides helping to cool the workers, this air flow pattern helped to prevent emissions from the cupola tapping and ladle filling area from entering the booth.

General Ventilation--
Emissions in the vicinity of the cupola included:

Escape of cupola emissions from the charge opening.
Fuming from the cupola launder leading to the forehearth.
Fume escape during tapping into bull ladles.

Escaping emissions were carried by the thermal draft into the charging area, which was just below roof level. General ventilation was poor in the charging area because there were no exhaust fans in the roof and only limited openings for natural ventilation. The charging operator spent the majority of his time waiting for the charge bucket at the charge bucket hoisting station. At this station his open cab was immediately adjacent to a wall opening through which outside air was entering the area. Plans were being drawn up for a totally enclosed crane cab using filtered supply air to protect the crane operator from particulate contaminants.

Personal Protective Devices

The alloy and ladle operators wore tinted safety glasses and face shields in addition to their other safety clothing.

RESULTS

1. Metal fume was well controlled below allowable limits both at the charge deck and tapping spout booth (Table A12-1).

Table A12-1. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average exposure/ 8 hour workday, mg/m3				
				Fe	Ni	Mn	Pb	Mg
Cupola tap spout booth	2	Fixed	Hi	0.48	<0.01	0.37	0.04	0.02
			Lo	0.18	<0.01	<0.01	0.01	<0.01
			M	0.33	<0.01	<0.19	0.03	<0.01
Cupola charge deck- next to charge opening	2	Fixed	Hi	0.60	<0.01	0.13	0.05	0.03
			Lo	0.52	<0.01	0.10	0.04	0.03
			M	0.56	<0.01	0.12	0.05	0.03
OSHA PEL				10.0§	1.0	5.0†	0.20‡	15.0Ω
ACGIH TLV (1977)				5.0§	1.0	5.0†	0.15‡	10.0Ω

§ Iron oxide fume.
† Ceiling value, short term exposure sampling was not undertaken because of the low expected exposure.
# Lead, inorganic fume and dust as Pb.
Ω Magnesium oxide fume.

2. Sulfur-containing gases only produced an odor at the slag launder where hydrogen sulfide was perceived. Detector tube measurements showed the level to be less than 1 ppm§.

3. Carbon monoxide was well controlled to less than 20 ppm both at the charging deck and at the tapping spout*.

4. Respirable silica was at the allowable limit at the tapping booth and over 2.5 times the allowable limit in the charging deck background air, and one of the samples contained 3% cristobalite. Although no exposure samples were taken in the crane cab, four minute

§ OSHA PEL 20 ppm; ACGIH TLV (1977) 10 ppm.
* OSHA PEL and ACGIH TLV (1977) 50 ppm.

respirable dust monitor (RDM) samples indicated that the level of dust in the crane cab was 35% of the background air, right at the allowable limit. The exact sources of the dust were not identified, but the results of the metal fume and carbon monoxide sampling, as well as visual observations of emissions from the charge opening indicated that the majority of this dust has not been coming from the cupola. The dust could have been generated in the adjacent sand system areas and drawn up into the charging deck area by thermal drafts and the cupola exhaust. The foundry had only natural roof ventilation, so the cupola exhaust probably acted to draw contaminants from other areas.

CASE HISTORY #13
DUST AND FUME CONTROL DURING METAL CASTING
AND SHAKEOUT AT A NONFERROUS FOUNDRY
NOVEMBER, 1977

ABSTRACT

A nonferrous operation casting both copper-base and aluminum alloys was studied in which melting, pouring, cooling, and shakeout were all performed in a compact area manned by five people. Prior to installing the present ventilation system, exposures to lead fume had exceeded the allowable limit. The new system controlled metal fume below allowable exposure limits by exhausting fume from melting, slagging, metal pouring and ladle preheating at the source. However, several sources of escaping emissions such as hot metal transfer, and furnace charging and tapping still remained which probably accounted for most of the metal concentrations present in the breathing zone. The administrative control of evenly dividing the duties of pouring of aluminum and copper-base alloys between two workers helped to limit exposures to metal fume, particularly lead. Respirable silica exposure was well controlled by hoods on the shakeout, mold dumpoff conveyor, and sand transfer points. Local exhaust ventilation on all of the hot processes also reduced the heat in the building, improving worker comfort during summer months.

PROCESS DESCRIPTION

Equipment and Operation

Melting, pouring, and shakeout operations are located and identified in Figure A13-1. The following is a summary of process and operational information.

Melting--
Copper-base aluminum alloys were melted in six furnaces located at one end of the foundry. A summary of furnace information is presented below:

No. of furnaces	Furnace type	Metals melted	Capacity	
			lbs.	kg
2	Coreless induction	Copper-base	2000	908
1	High frequency pushout (two crucibles)	Copper-base	300	136
2	Gas-fired crucible	Aluminum	600	272
1	Gas-fired crucible	Aluminum	300	136

Coreless induction furnaces--Billets and foundry returns, stored adjacent to the furnaces, were loaded by hand into a 55 gallon (208 l) drum suspended by a hoist with a scale. A drum tilting mechanism on the hoist was used for dumping the charge into the furnace. After melting, the

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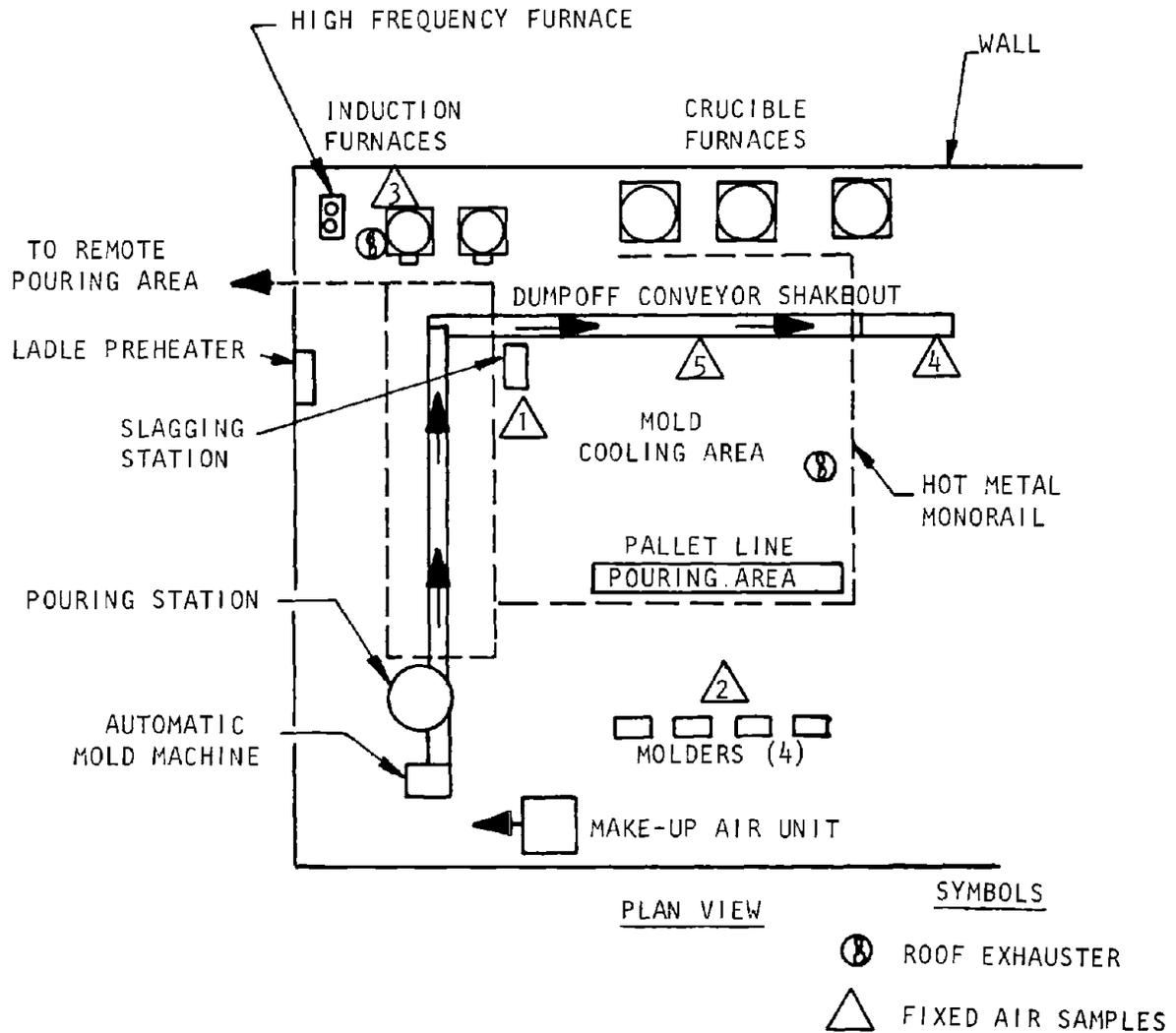
Figure A13-1. Copper-base and aluminum casting operation.

furnaces were tilted during tapping into pouring ladles (Figure A13-2).
Zinc adjustment and flux addition were done during tapping.

High frequency pushout furnaces (Figure A13-3)--Billets and foundry returns
were charged by hand into one of two small crucible pots which were used
alternately. After melting, the pot automatically raised up out of the
furnace, a harness was attached, and the pot was removed for tapping into
pouring ladles. Zinc adjustment and flux addition were done during tapping.

Gas-fired crucible--Billets and foundry returns were loaded into the furnace
by hand and then the burner was lit to melt down the metal (Figure A13-4).
At the end of the heat, the furnaces were tilted to tap the metal into
pouring ladles. Prior to tapping, a degassing "pill", attached to a rod,
was plunged into the melt.
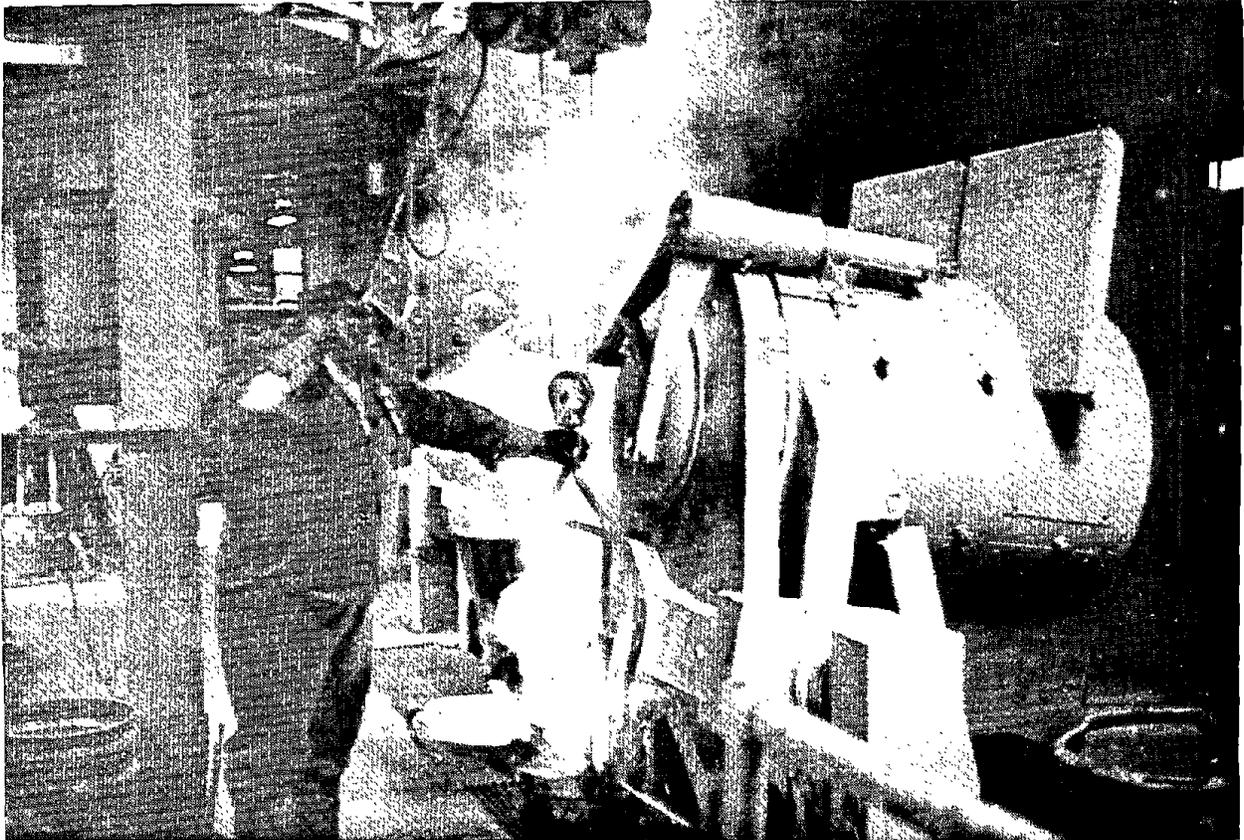
Figure AI3-2. Tapping of induction furnace.

Figure A13-3. Small, retractable hood in place during melting in the high frequency furnace.

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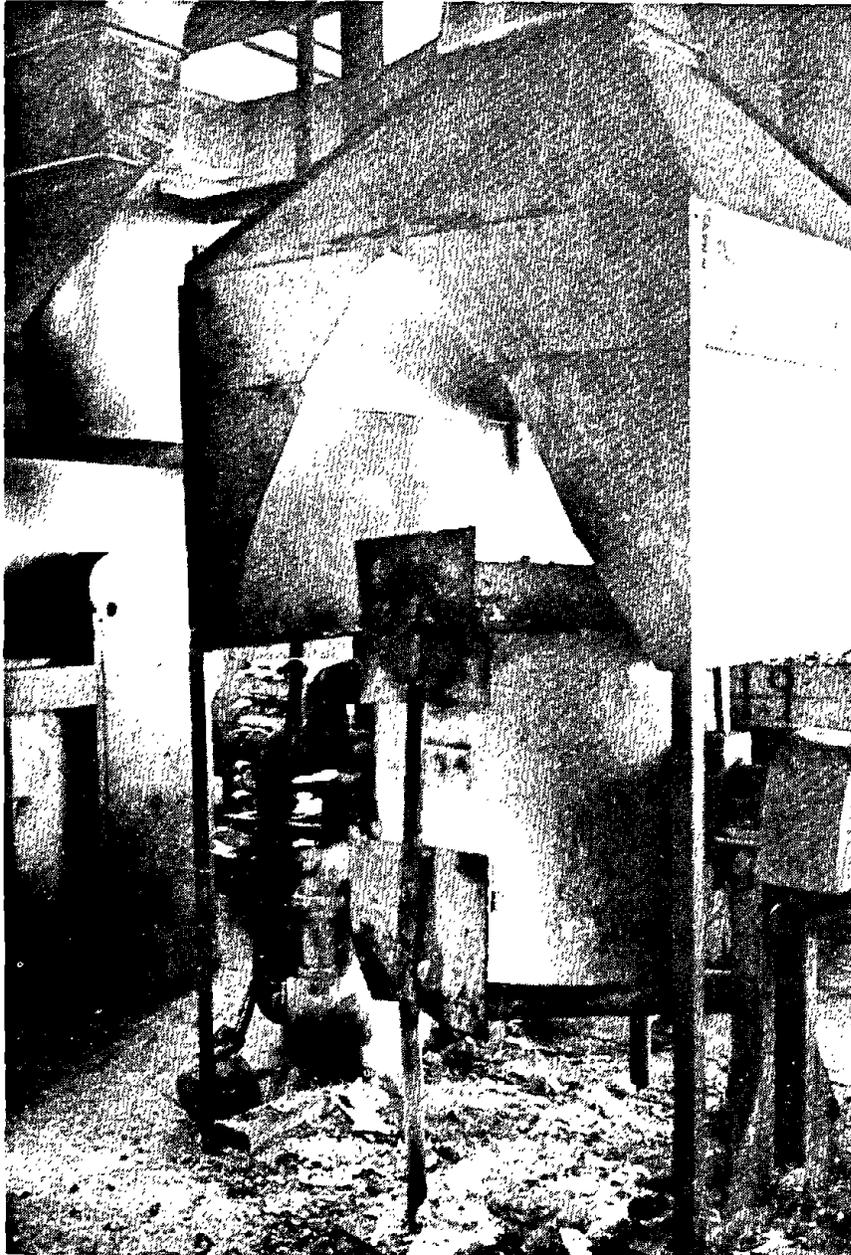
Figure A13-4. Aluminum furnaces - baffle plate deflects flame from openings in front of furnace

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Hot Metal Transfer--
Hot metal ladles were manually pushed along a monorail system to any of
three pouring areas. Ladles of copper-base alloy were first slagged at a
station adjacent to the melting deck area (Figure A13-5). After slagging
a ladle cover was swung into place on the pouring ladle.

Pouring and Cooling--
Automatic molding station--The operator stood and poured molds which
moved past him on a turntable (Figure A13-6). After indexing around,
the just-poured molds were automatically transferred to a pan conveyor
which moved them to shakeout.

Pallet line pouring floor--Pouring of molds on the four pallet lines took
place in the center of the pallet line area (Figure A13-7). After pouring,
mold carts were manually pushed into the area near the dumpoff conveyor
where they were allowed to cool. Finally, the operator activated a
tilting mechanism which dumped them onto the conveyor which transported both
sand and castings to shakeout.

Remote floor pouring area--A small amount of metal was transported to a
remote floor pouring operation.

Shakeout--
Hot castings and loose sand from the mechanized molding station and pallet
line were transported by pan conveyors to the shakeout. The shakeout
operator hooked the castings out and sorted them into receiving bins
(Figure A13-8).

Ladle Preheater--
Pouring ladles were returned to a ladle preheating station to be kept hot
when not in use (Figure A13-9).

The melting, pouring and shakeout operations were performed by five workers.
A summary of work tasks is presented in Table A13-1.

Materials and Rates

During the period of the study, the foundry was producing alloys of the
composition and amounts shown in Table A13-2. On any particular day, the
aluminum alloys were melted and poured before the copper-base.

Copper-Base Alloys--
The coreless induction furnaces were utilized for most of the copper-base
alloys melted during the workshift. Only 300 lbs (136 kg) were melted
in the high frequency furnace and poured in the remote pouring area.

A phosphorus-copper fluxing agent was added to the brass and bronze pouring
ladles prior to tapping, and again after tapping on the metal surface. High
zinc alloys required that 2-3 lbs (1.0-1.4 kg) of pure zinc be added
directly to the ladle during tapping to adjust the metallurgy.
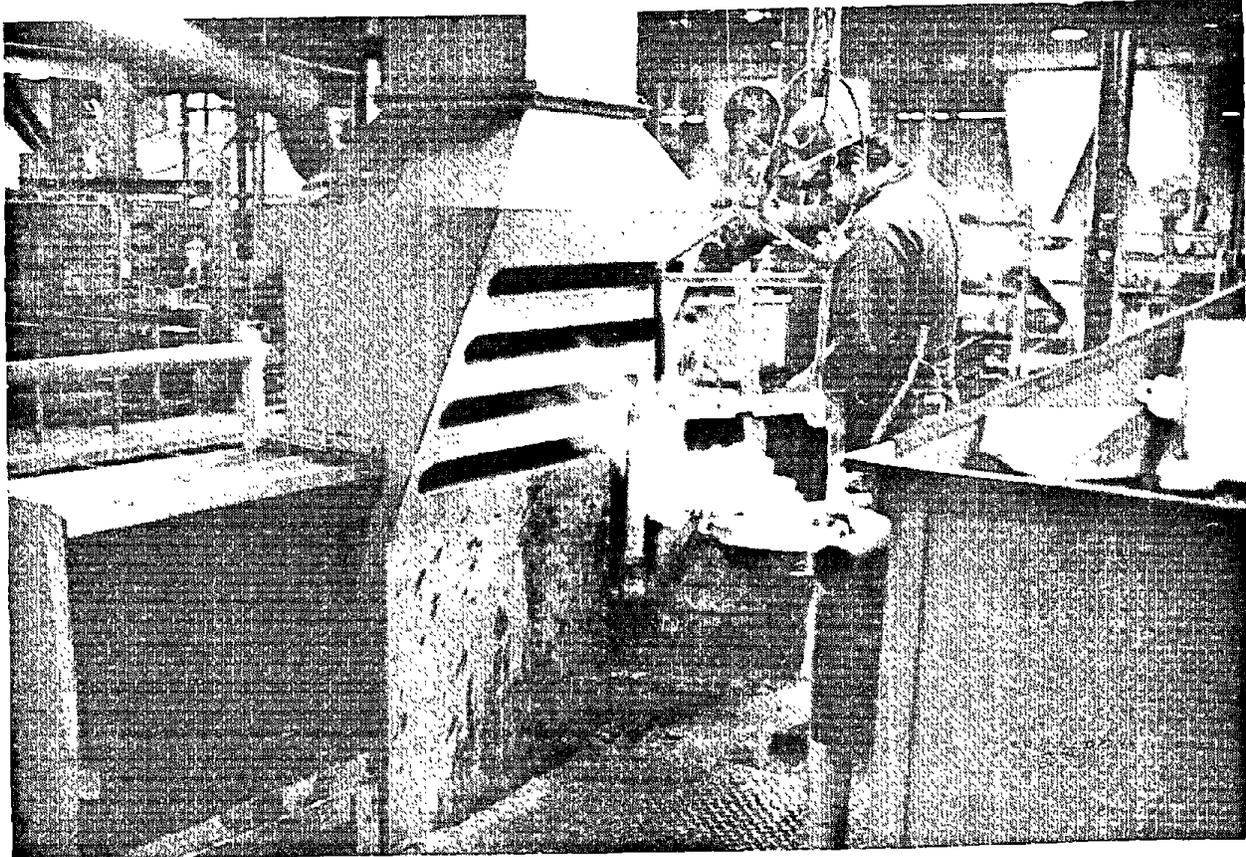
Figure Al3-5. Slagging at the exhausted slagging station.
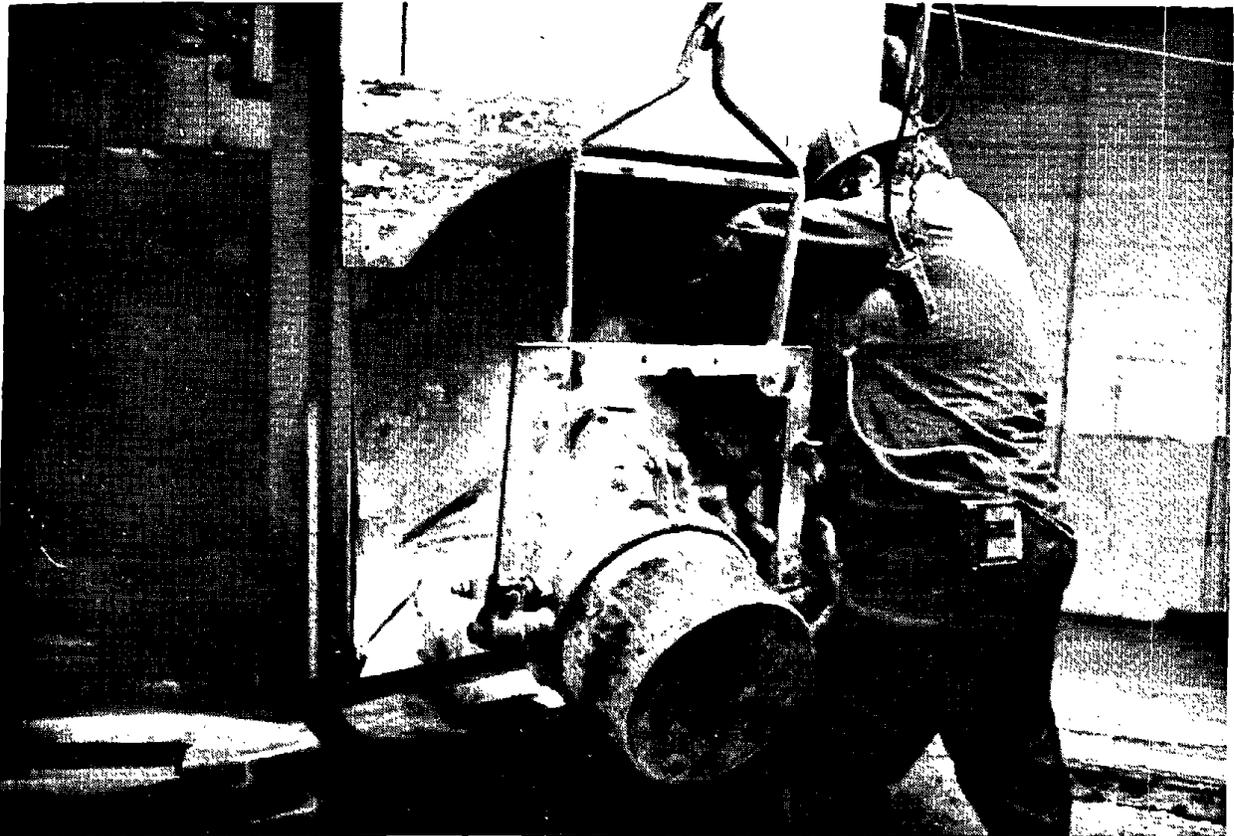
Figure A13-6. Pouring molds at the automatic mold machine turntable.
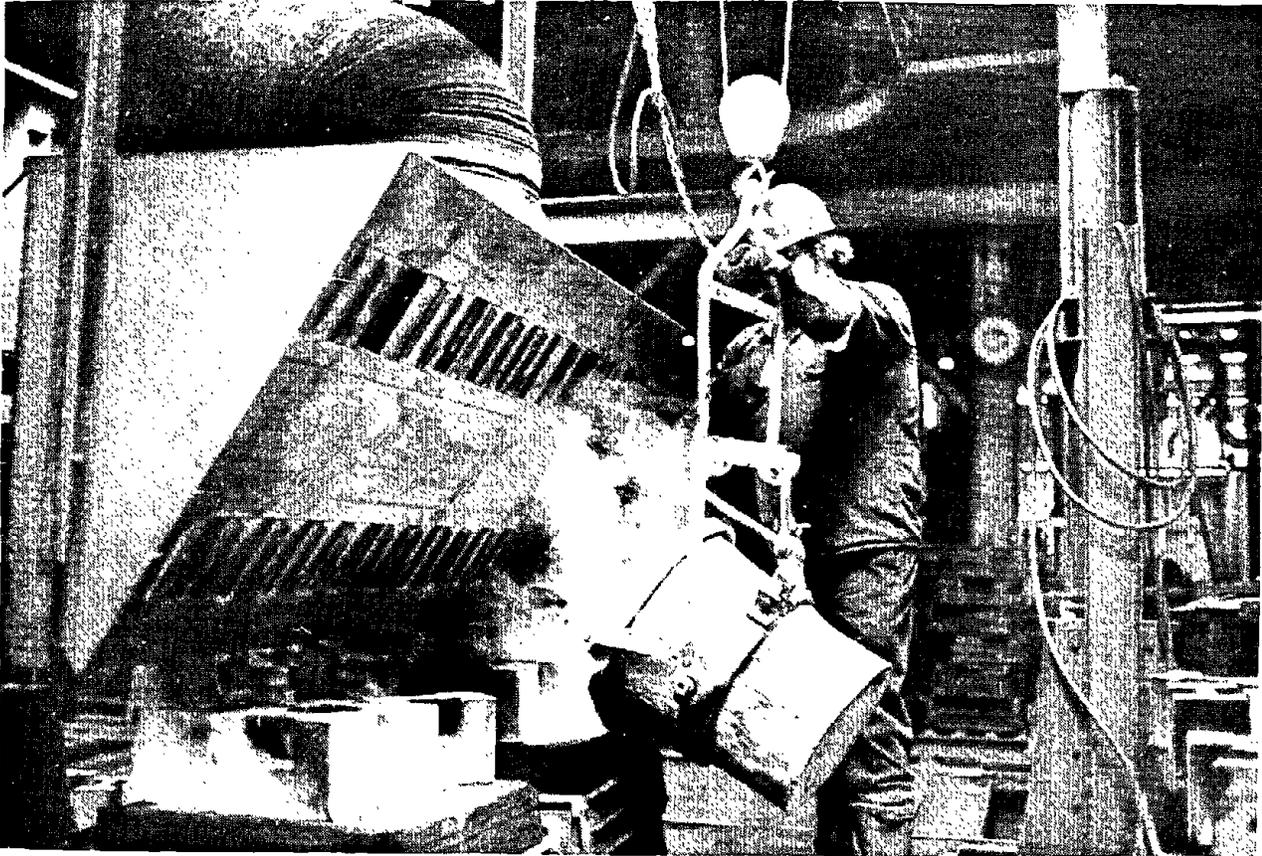
Figure A13-7.   Pouring molds on the pallet line.
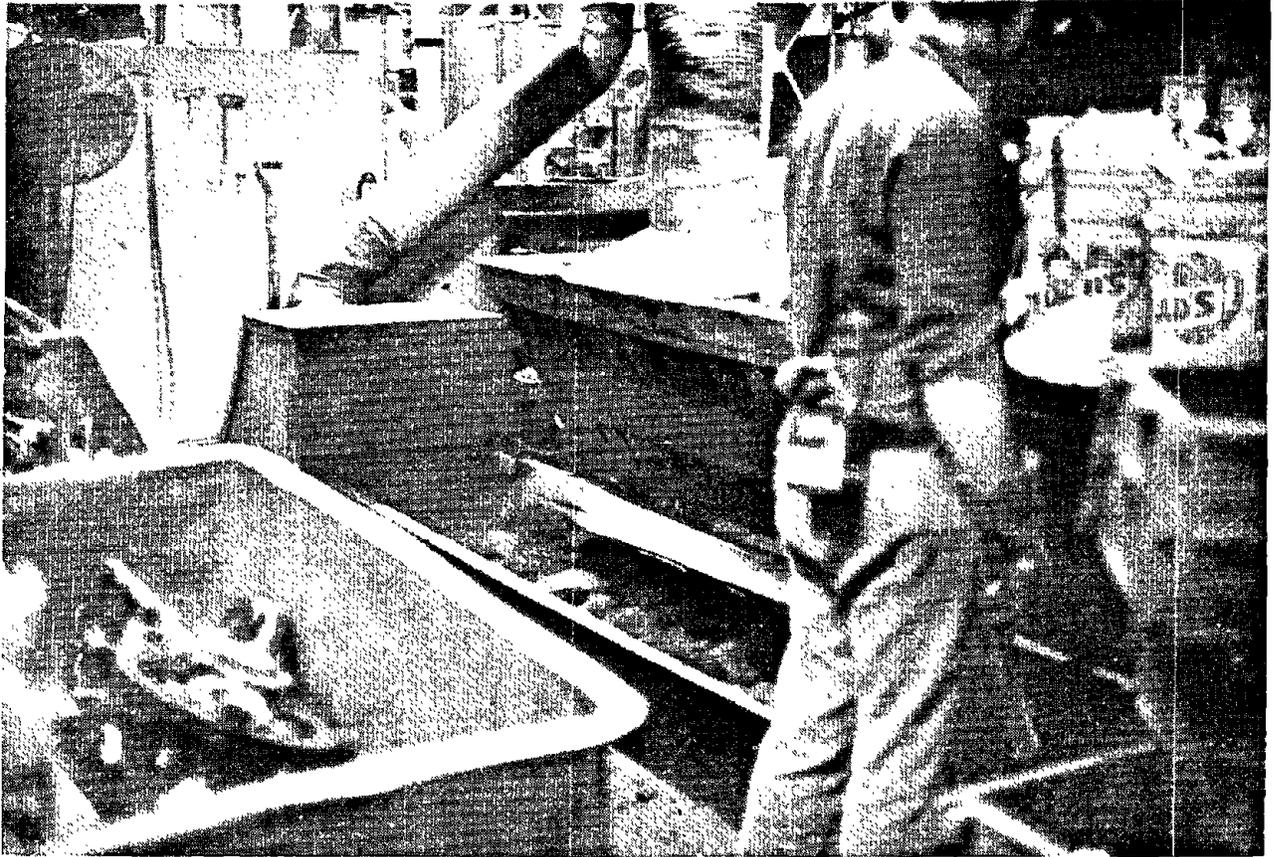
Figure A13-8. Casting hookout at the shakeout.
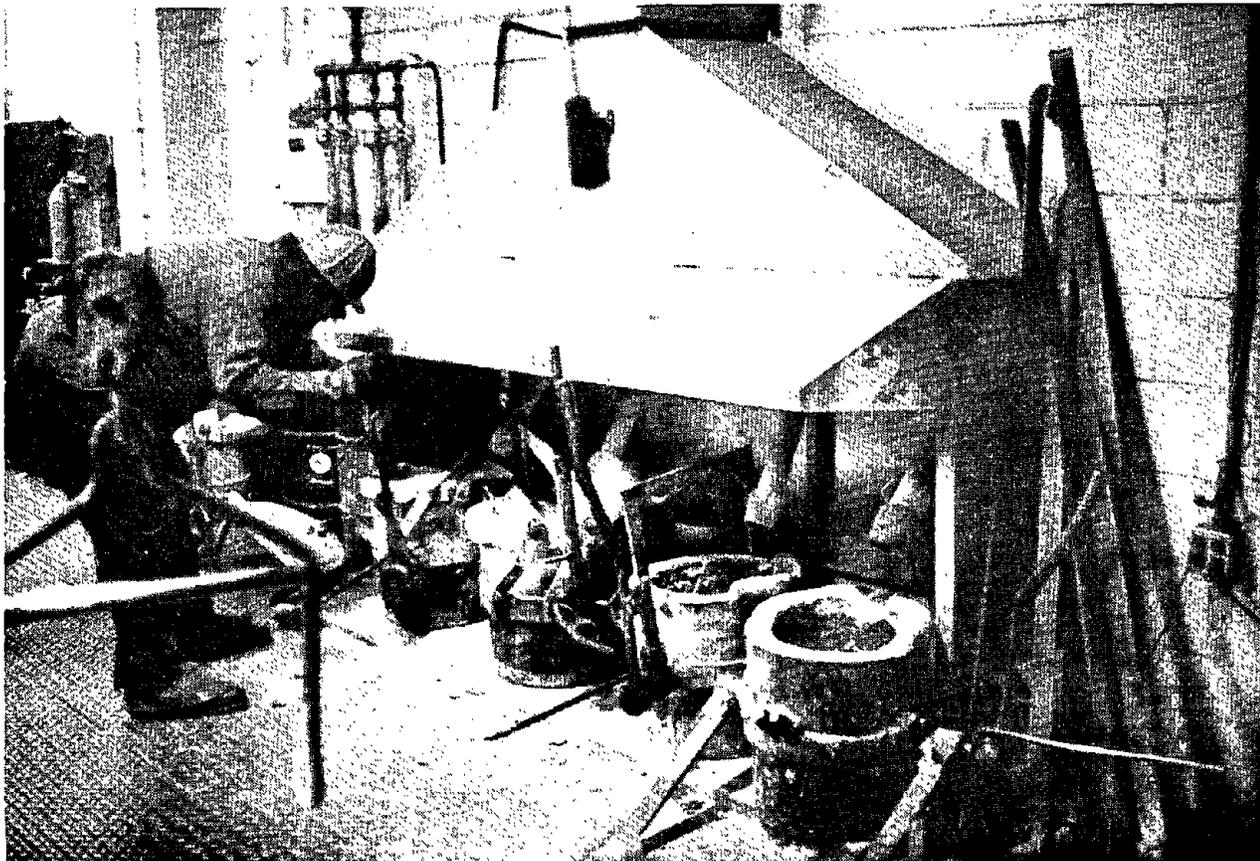
Figure AI3-9. Ladle preheater station.

Table A13-1. Summary of work tasks - pouring, cooling and shakeout.

| Job title | No. of workers | Tasks | |
		Principal duties	Occasional duties
Melt deck foreman	1	Supervised melt deck operation.	Helped charge furnaces. Measured furnace and ladle temperatures. Added fluxes and alloys.
Melter	1	Operated furnace controls. Charged and tapped furnaces. Measured furnace and ladle temperatures. Added metal alloys and fluxes.	Retrieved metal from the tops of molds and dumped molds onto conveyor from pallet line cooling area.
Metal pourer	2	Pushed ladles between furnaces and pouring stations. Skimmed off slag at slagging station. Poured metal.	Measured ladle temperature. Added fluxes and alloys. Helped charge furnaces.
Shakeout operator	1	Manually lifted castings from vibrating conveyor and sorted them into bins.	

Table AI3-2. Composition and amounts of alloys.

Metal type	Production per shift		Percent of alloy constituents §							
	lbs.	kg	Al	Mn	Mg	Cu	Sn	Pb	Zn	Ni
High leaded bronze (SAE 64)	2000	908				78	9.0	8.0	0.75	1.00
Leaded semi-red brass (81-3-7-9)	4000	1816				79	2.5	6.3	7.0	0.8
Red brass (SAE 40)	8000	3632				83-86	4-6	4-6	4-6	1
Gun metal (SAE 62)	300	136				86-89	9-11	0.3	1-3	0.8-1
Navy-G (SAE 620)	2600	1180				86	7.5	0.30	3.0	0.15
Hi-tensile aluminum	6200	2814	91.0	0.60	0.25	0.4			7.0	0.15

§ Some minor alloy metals are not listed.

Aluminum--
The degassing "pill" was composed of 20 - 50% hexachloroethane and >50% inorganic fluoride salts.

Mold Constituents--
Green sand with 6% clay and 1% wood flour was used for molds made by the automatic mold machine and at the pallet line molding stations. At the remote floor pouring area, a small number of furan no-bake molds were used. The number of molds poured at each of the three pouring stations was as follows:

Pouring station	Molds per shift
Turntable pouring	630
Pallet floor area	100
Floor molding area	15

Oil sand and shell cores were commonly used in the molds.

WORKPLACE HAZARDS

The major air contaminant hazard from melting, hot metal transfer and pouring operations was fume inhalation. The metals of hygienic significance included lead, copper, zinc and nickel. Products of decomposition from

cooling molds evaluated included carbon monoxide, ammonia, phenol, and formaldehyde.

The aluminum degassing operation presented a potential air contaminant hazard due to the presence of chlorine, liberated from the breakdown of the hexachloroethane metal treatment.

Respirable silica was generated from dry sand processing operations such as mold dumping, conveying, transferring and shakeout.

CONTROL OF EXPOSURE

Exposure to metal fume was controlled by local exhaust hoods on the furnaces, and at the slagging, metal pouring (with the exception of the remote pouring floor), and ladle preheating stations. A ladle cover helped to reduce fuming during hot metal transfer and pouring. Control of respirable silica was achieved through exhaust hoods at the sand transfer points, pallet line dumpoff, and shakeout.

General ventilation was used to control emissions escaping during furnace charging and tapping, hot metal transfer, mold cooling, and sand conveying.

Engineering

Control at the Source--
A summary of exhaust hood type and flow information is presented in Table Al3-3, along with comparisons with ACGIH recommended flows, where available. The following is a summary of the hood evaluations.

Coreless induction furnaces--Hoods supplied by the furnace manufacturer provided suction all around the furnace top, as well as at the pouring spout. The furnace cover was seated on top of the hood rather than on top of the furnace. Fuming was well controlled during the melt-down cycle, however, fume escaped during charging from drums, as well as during tapping. The spout area of the hood was not large enough nor was the air flow high enough to capture the fume rising in the thermal draft during tapping (Figure Al3-2).

The foundry operated the furnace hoods at a fixed exhaust rate, although the hood was designed to be used at two different flow rates: a low rate during melt-down with the furnace door closed and a higher rate during tapping or during operations in which the furnace cover was open. A low flow rate was desirable with the furnace cover closed because all of the indraft was through the small furnace spout. This air passed across the molten metal surface before being exhausted. Excess air, over and above the amount necessary to maintain indraft through the furnace spout, removed heat from the surface of the melt unnecessarily.

High frequency pushout furnaces--The hoods were in place and effective in controlling worker exposure only during the melting cycle. They were retracted during charging and pushout, the latter process removing the pot

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Table A13-3. Hood exhaust flows compared to recommended flows.

Process	Control hood type	Exhaust temp. °C	Exhaust flow scfm	Exhaust flow m3/sec	ACGIH recommended flow cfm	ACGIH recommended flow m3/sec
Coreless induction furnaces (2)	Close fitting bonnet	65	277	0.13	-	-
High frequency pushout furnaces (2 pots)	Retractible sidedraft §	-	-	-	-	-
Gas fired crucible furnaces (large)(2)	Canopy *	90	9993	4.72	19380	9.15
Gas fired crucible furnaces (small)(1)	Canopy	90	4625	2.18	-	-
Slagging station	Sidedraft †	-	5060	2.39	-	-
Ladle preheater	Canopy	98	2400	1.13	-	-
Turntable pouring station	Partial side enclosure	20	2700	1.27	-	-
Pallet line pouring	Mobile sidedraft †	20	3430	1.62	5000	2.36
Transfer point (2)	Total enclosure	20	2010	0.95	-	-
Dumpoff conveyor	Partial side enclosure	20	3800	1.79	-	-
Shakeout	Partial side enclosure	20	2630	1.24	-	-
Transfer point	Total enclosure	20	2020	0.95	-	-

§ Not measured.
* Reference 17, print no. VS-106.
† Reference 17, print no. VS-107.

from the influence of the hood. The process of tapping the pots into pouring ladles was uncontrolled.

Gas-fired crucible furnaces--The exhaust flow through the canopy hood was sufficient to receive the thermal draft throughout the charging, melting, and tapping cycles. The thermal draft was much stronger in the case of the crucible furnaces than it was for the induction furnaces because of the addition of combustion air. Some of the combustion air was emitted from the furnace out the pouring spout and out another exhaust port in front of the furnace. Baffles at these openings prevented these air streams from pushing fume out from under the hood and also controlled metal splashing (Figure A13-4). The hood exhaust was sufficient to receive the thermal draft even though the flow was only half the ACGIH recommended rate calculated on the basis of open area around the hood.

Slagging hood--The hood was very effective at controlling fume during slagging.

Ladle preheater--Indraft through this hood ranged from 50-150 fpm (0.25-0.75 m/sec), containing the hot thermal draft and the fuming from excess copper-base metal on the ladle walls.

Turntable pouring station--This partially enclosing hood had been retrofitted onto the pouring turntable and was very effective at capturing the pouring fume. After pouring, products of thermal decomposition were exhausted during the short period when the mold was still under the influence of the hood. Once the just-poured mold indexed past the hood, all of subsequent emissions were free to escape.

Pallet line pouring--This mobile sidedraft hood was specially designed to capture pouring fume at all four pallet lines. The hood was supported on a moving overhead monorail (Figure A13-10) and used a long pivoting duct with joints on each end to accommodate movement of the hood from station to station. The pouring operator manually repositioned the hood as he moved across the pallet deck. Indraft was stronger on the right side of the hood than on the left side. When a mold was poured on the left side, a small amount of fume escaped due to a prevailing cross-draft on the pallet line. The pouring hood exhaust volume was less than the ACGIH recommended flow for pouring hoods (Table A13-3).

Sand system--All sand transfer operations were equipped with exhaust hoods, while the vibrating conveyor leading from the pouring turntable was not hooded. The pallet car dumpoff hood and the shakeout hood were of special importance because of the proximity of the worker to these operations.

General Ventilation

Sources of dust, fume, and gases not otherwise controlled included:
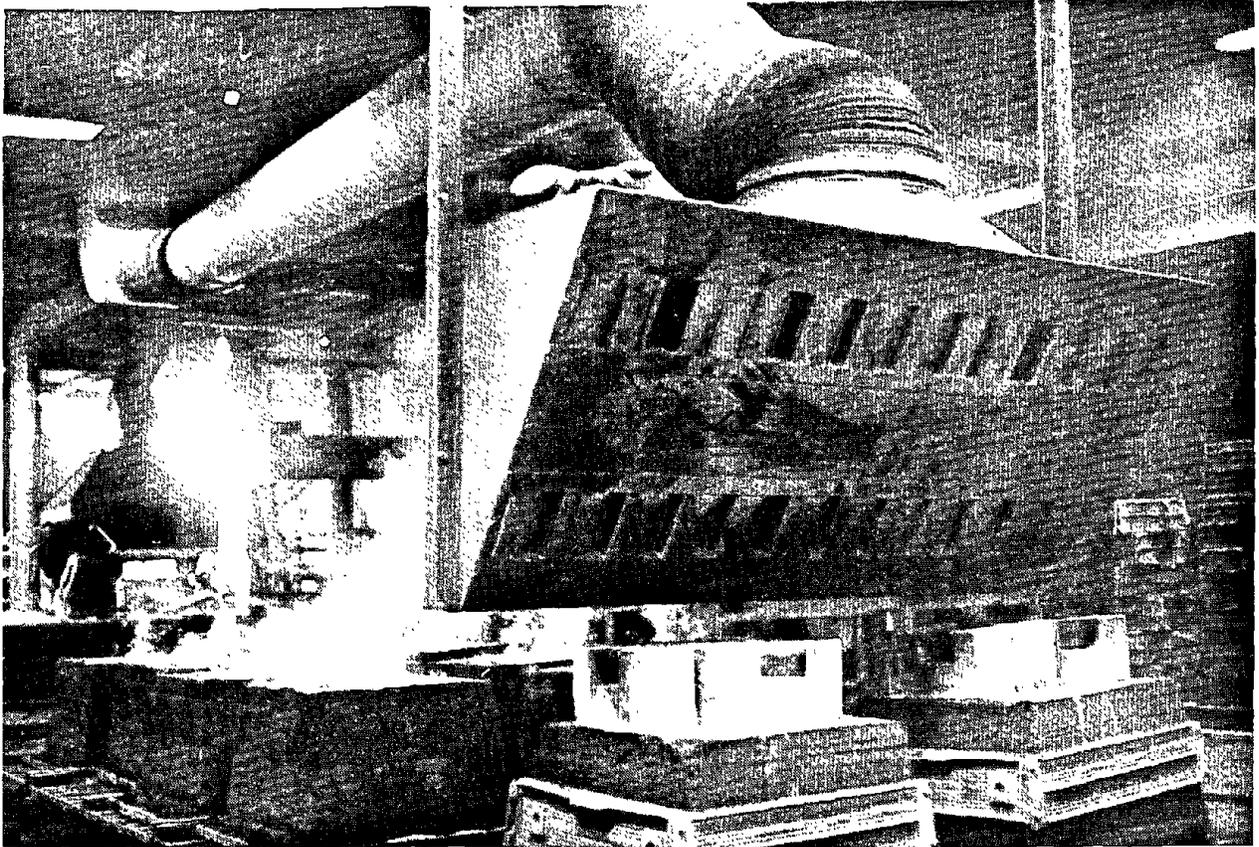
Figure A13-10. Pallet line mobile pouring hood showing the pivoting duct and flexible duct ends.

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Copper-base alloys:

1. Fume escaping capture by furnace hoods during charging and tapping.
2. Fuming during hot metal transfer.
3. Slight leakage of fume past the pallet line pouring hood.

Products of mold decomposition:

1. Gases escaping the automatic mold machine turntable and the unhooded section of vibratory transfer conveyors leading to the shakeout.

2. Gases escaping the cooling molds on the pallet deck.

Respirable silica:

1. Sections of vibratory transfer conveyors leading to shakeout.
2. Slight leakage past the conveyor transfer hood.

Additional emissions of metal fume and mold decomposition products during the small amount of uncontrolled pouring in the remote pouring area did not affect general ventilation in the foundry area surveyed but it did affect exposures of metal pourers to some small degree.

General ventilation was provided by a 60,000 cfm (28 m^3/sec) air makeup unit shown schematically in plan view in Figure A13-1. Makeup air was discharged in one corner of the foundry area and then swept across the whole area before being exhausted through the control hoods and roof exhausters. Single point makeup air discharge caused ample air turnover in many areas but it did not prevent stagnation at the pallet line molder stations and at one corner of the induction melt deck.

Two roof exhausters were used, each rated at 18,000 cfm (8.5 m^3/sec). One was located above the coreless induction furnaces to capture escaping fume, and the other was located above the pallet line cooling area to exhaust products of mold decomposition. The roof exhauster above the furnaces efficiently captured fume escaping from the furnace close to it. However, some fume escaping the coreless induction furnace hood further from the fan drifted in the prevailing air currents toward the crucible furnace hoods.

Work Practices

Exposures of metal pourers to metal fume were limited through three work practices:

1. Pouring duties of copper-base and aluminum alloys were equally divided between the workers.

2. Workers withdrew a little to avoid breathing tapping fume and generally kept their heads out of escaping fume whenever possible.

3. Ladle covers were used faithfully during hot metal transport.

RESULTS

1. Metal fume exposures during casting of copper-base alloys were below the allowable limits. The highest percentage of the allowable limit occurred in the case of lead [66% of OSHA PEL and 88% of the ACGIH TLV (1977)]. Air sampling was performed only during the period when copper-base alloys were melted and poured, which amounted to 64% of the shift for the melter and 75% for the metal pourers. Metal concentrations presented in Table A13-4 are therefore not full-shift, time-weighted averages, but rather are samples that represent exposures only to contaminants from the copper-base alloy portion of the operation. When calculated on a full-shift basis, the 8-hour time-weighted exposures to lead were: 0.085 mg/m3 for the melter and 0.072 and 0.096 mg/m3 for the metal pourers.

Table A13-4. Air sampling results - metal fume.

Worker or location §	Sample type	Exposures during period of melting and pouring copper-base alloys, mg/m3			
		Cu	Pb	Zn	Ni
Metal pourer	Pers.	0.029	0.130	1.640	0.011
Metal pourer	Pers.	0.037	0.096	0.927	0.005
Melter	Pers.	0.039	0.133	1.290	0.012
Melt deck (location 3)	Fixed	0.010	0.030	0.260	0.020
Slagging station (location 1)	Fixed	0.020	0.040	0.300	0.010
OSHA PEL		0.100*	0.200†	5.000#	1.000
ACGIH TLV (1977)		0.200*	0.150†	5.000#	1.0

§ Fixed sample locations are shown in Figure A13-10.
* Copper fume.
† Lead, inorganic dust and fume.
# Zinc oxide fume.

2. Background air samples for metals showed low concentrations, indicating that the workers received the major share of their exposure during their close contact with the fuming metal especially during operations in which fume escaped the hoods during melting, tapping,

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hot metal transfer, and pouring tasks.

3. Respirable silica results in Figure AI3-5 show that dust exposures were well controlled.

4. Carbon monoxide was controlled below allowable limits throughout the foundry area surveyed. The highest levels measured, 20-38 ppm, occurred in the pallet line cooling area. Levels of 13-16 ppm were measured at the periphery of this area. Workers were only intermittently in the cooling area to dump molds. Ammonia, phenol, and formaldehyde were below detectable limits in the mold cooling areas.

Table AI3-5. Air sampling results - respirable silica.

Worker or location §	Sample type	Percent silica	Respirable dust exposure, mg/m³	Allowable exposure limit, mg/m3*
Melter	Pers.	4.70	0.65	1.49
Metal pourer	Pers.	0.72	1.50	2.12
Metal pourer	Pers.	0.61	2.00	3.83
Shakeout operator	Pers.	5.40	0.31	1.35
		6.80	0.32	1.14
		4.30	0.66	1.59
Slagging station (location 1)	Fixed	5.50	0.36	1.33
Molders, (location 2)	Fixed	<1.00	0.33	5.00
Melt deck, (location 3)	Fixed	2.80	0.38	2.08
Shakeout (location 4)	Fixed	3.00	0.39	2.00
Area pallet dumpoff, (location 5)	Fixed	2.70	0.73	2.13

§ Fixed sample locations are shown in Figure AI3-10.
* OSHA PEL and ACGIH TLV (1977).

CASE HISTORY #14
FUME CONTROL DURING CASTING OF BRONZE
FEBRUARY, 1978

ABSTRACT

Furnace hoods and a mobile transfer ladle hood controlled metal fume at the source during melting and pouring of bronze.

The combined effect of the exhaust hoods and a high rate of general ventilation resulted in control of worker exposures below allowable limits. However, the system was subject to cross-drafts which blew fumes past the control hoods during furnace tapping and metal pouring. When the cross-drafts were removed, capture of fume by the hoods was virtually complete during furnace operations and pouring, but incomplete during slagging.

PROCESS DESCRIPTION

Equipment and Operation

Melting and pouring operations are located and identified in Figure A14-1. The following is a summary of process and operational information:

Melting--
Copper-base alloys were melted in an indirect arc furnace and two gas-fired crucible furnaces, located at one end of the foundry. Furnace capacities are listed below:

Number of furnaces	Furnace type	Capacity lbs/hr.	kg/hr.
1	Indirect arc	1000	455
2	Gas-fired crucible	600	273

Furnaces were charged by hand with billets and foundry returns stored directly in front of the furnaces. Prior to tapping the furnace, the hot metal ladle was set down on a small trolley cart in front of the furnace and the ladle was unhooked from the hoist. The cart with the ladle was then pushed on tracks to a position directly under the tapping spout. During tapping a worker manually steadied the ladle (Figure A14-2). One of the casting methods employed (centrifugal casting) required that a fixed amount of metal be tapped into the ladle. This was accomplished by visually monitoring the metal level in the ladle using an air nozzle to blow away the fume (Figure A14-2).

PATTERN
STORAGE
AREA

DOORWAY
PRODUCING
CROSS DRAFTS

INDIRECT
ARC
FURNACE

CRUCIBLE
FURNACES

LADLE
PREHEATER

SLAGGING
AREA

MAKE-UP
AIR
UNIT

MONORAIL
AND
EXHAUST
PLENUM

MOLDER STATIONS(4)

PALLET
LINE
CASTING

MAKE-UP
AIR
UNIT

CENTRIFUGAL
CASTING

SYMBOLS

△ FIXED AIR SAMPLE

⊕ ROOF EXHAUSTER
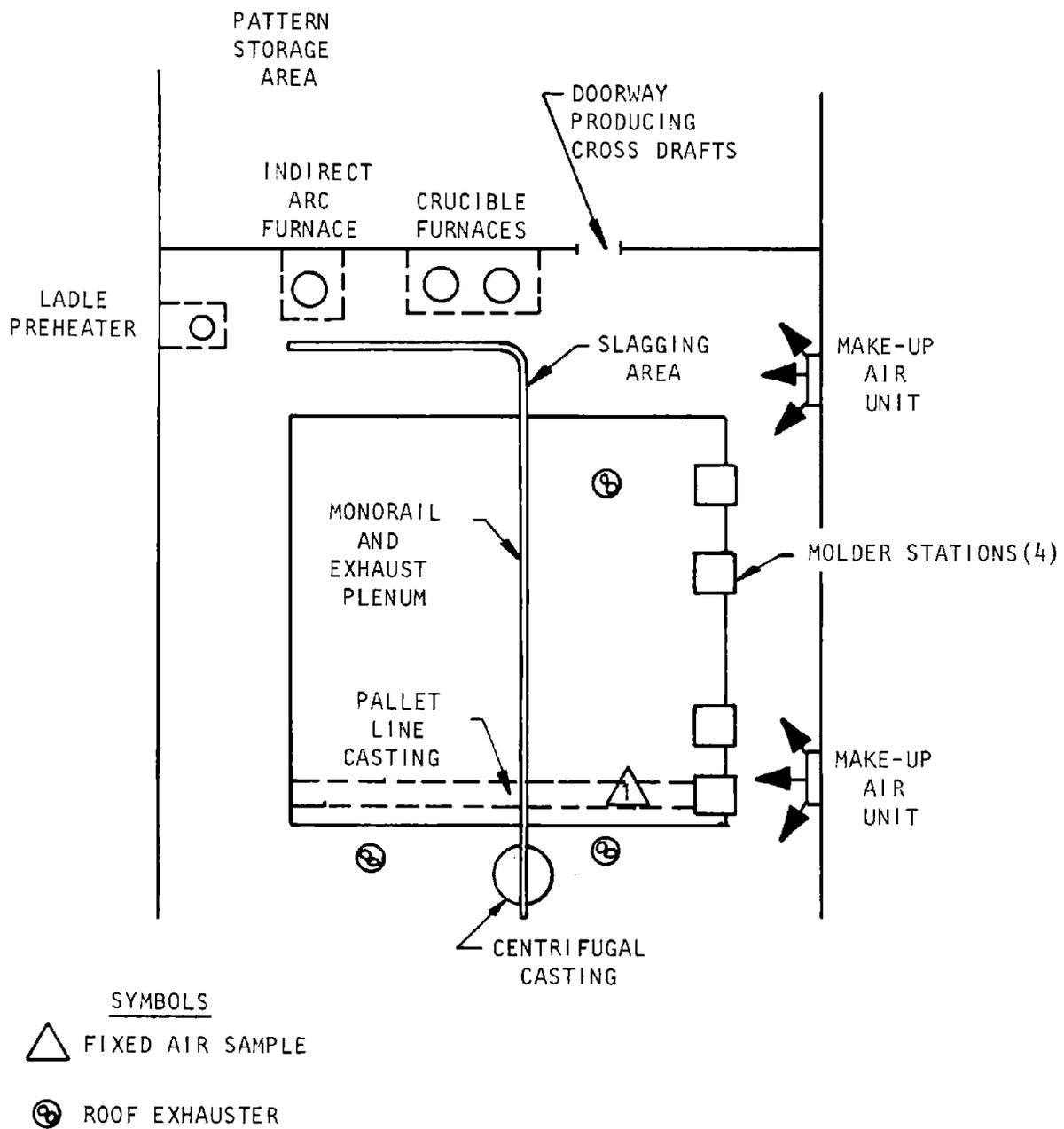
Figure A14-1. Bronze casting system layout.

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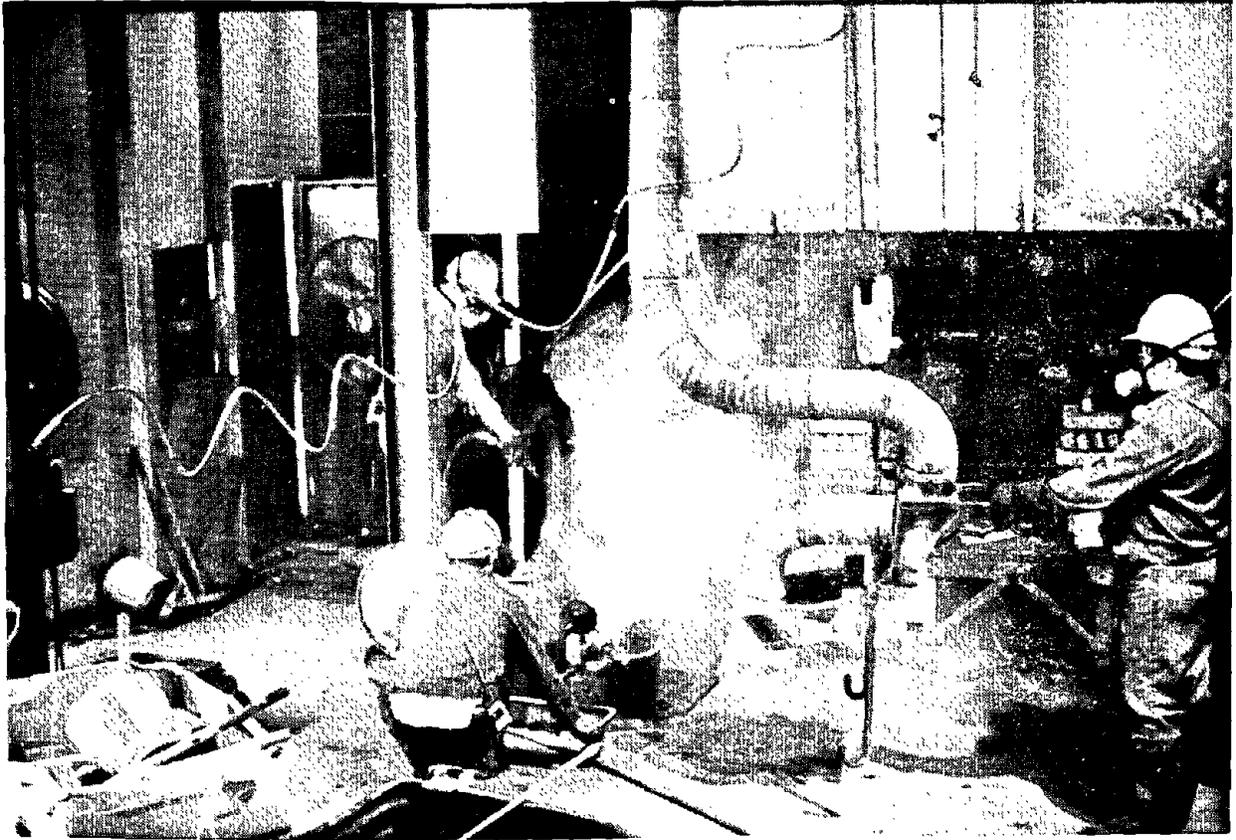
Figure A14-2. Crucible furnace tapping.

Hot Metal Transfer and Pouring

After tapping into the ladle, the trolley cart was pulled back from the furnace and the hoist reattached to the ladle. The ladle was then hoisted and manually pushed by two workers along a monorail system, first to a slagging station (Figure AI4-3), and then to one of two pouring stations: the pallet line or the centrifugal molding station (Figure AI4-4). In many instances, small amounts of metal were poured into sample containers before casting was done.

Ladle preheating--The pouring ladles were returned to a ladle preheating station to be kept hot when they were not in use.

The melting and pouring operations were performed by a three man team. A summary of work tasks is presented below:

Job title	No. of workers	Principal duties	Occasional duties
Melter	1	Charged and tapped furnaces. Measured metal temperatures in ladle. Slagged.	Assisted in mold pouring.
Metal pourer	2	Transferred hot metal. Poured molds. Steadied ladles during tapping.	Moved molds from pouring to cooling area. Operated shakeout.

Materials and Rates

During the period of the study the foundry was casting bearing bronze (SAE 660) of the following composition and amounts:

Copper 82%
Tin 6.5-7%
Lead 7%
Nickel 0.5-0.7%
Zinc 3.5-4.5%

Total metal poured.

	Centrifugal		Green sand		Total	
Day	lbs.	kg	lbs.	kg	lbs.	kg
1	2465	1120	4900	2225	7365	3344
2	2720	1235	3090	1403	5810	2638
Total	5185	2355	7990	3628	13175	5982

A phosphorus-copper shot addition was made during tapping and a flux was added prior to slagging.
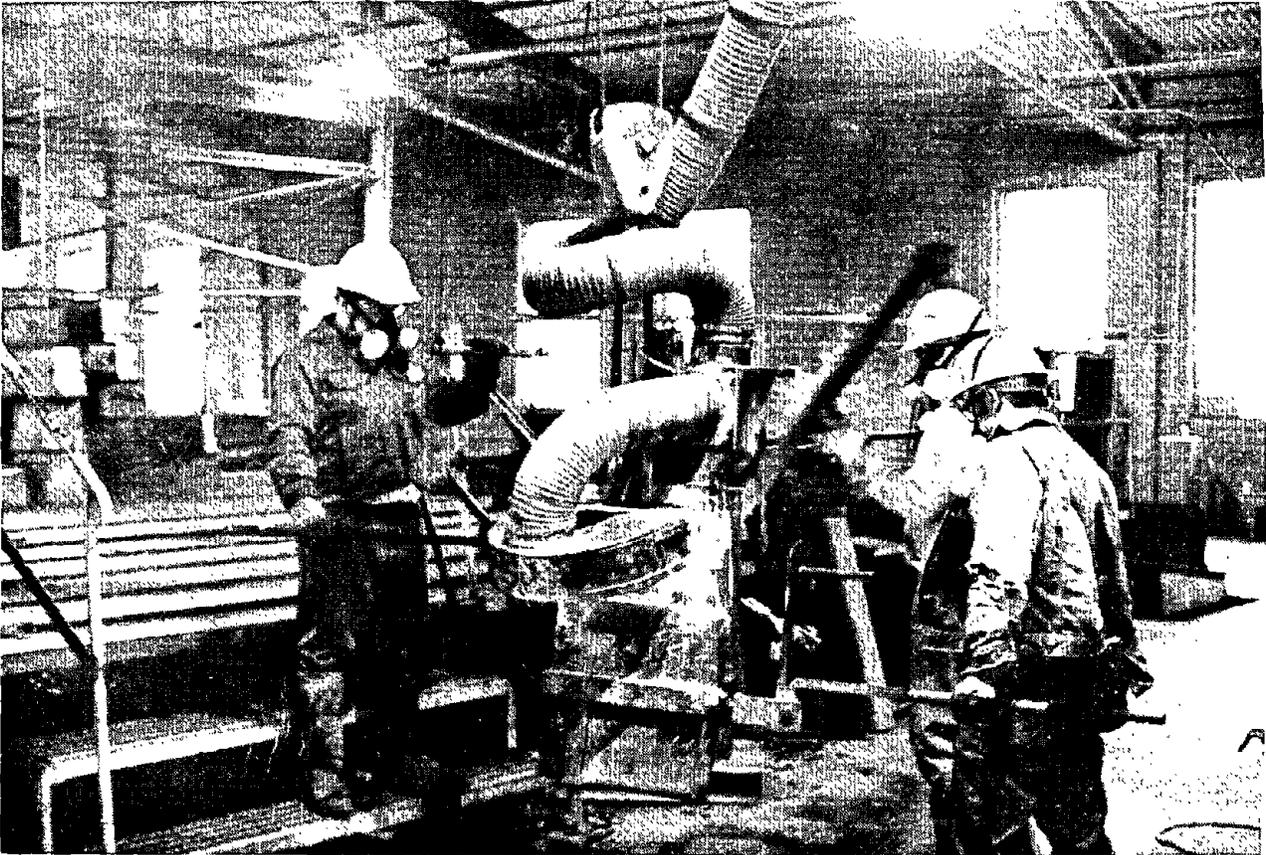
Figure Al4-3.   Ladle slagging.
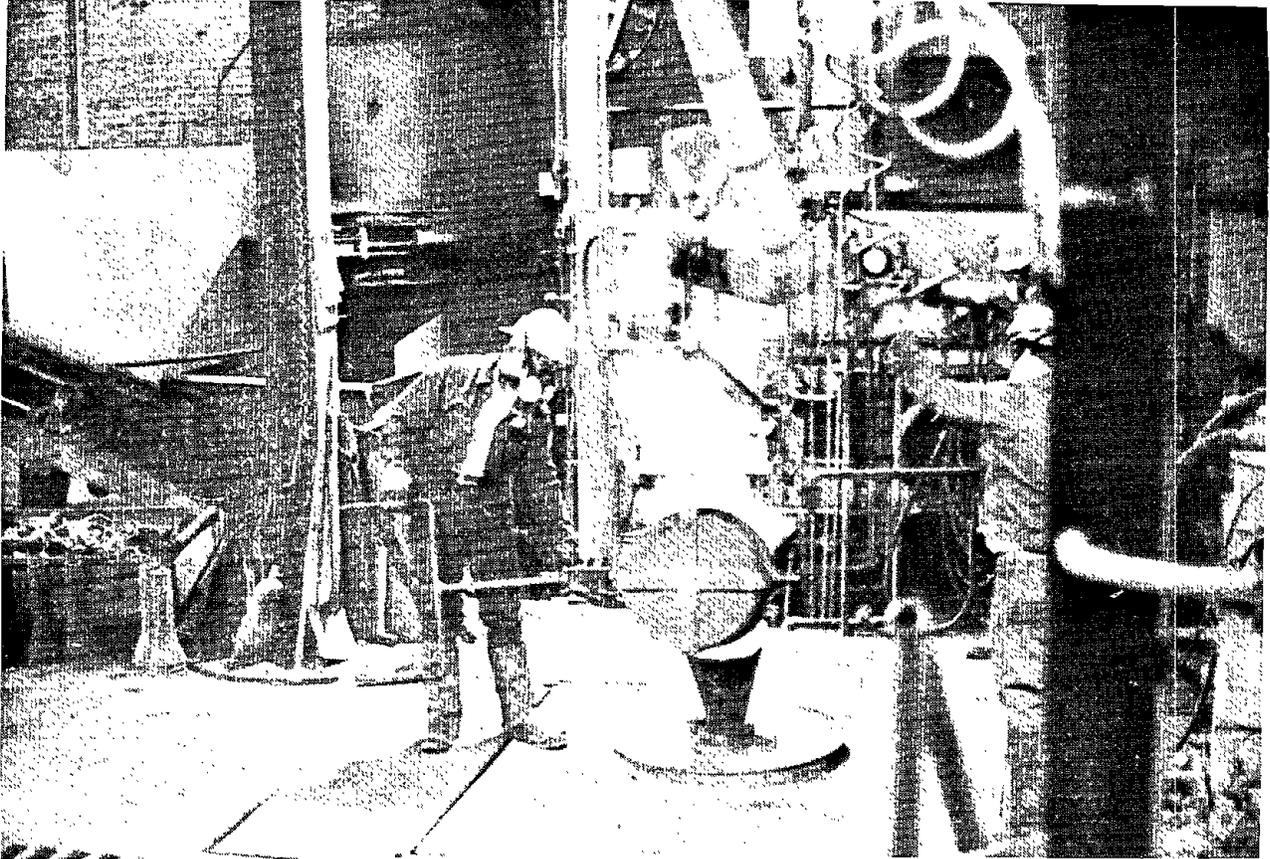
Figure AI4-4. Metal pouring at the centrifugal casting station.

WORKPLACE HAZARDS

The major air contaminant hazard from the casting process was fume inhalation.
Metal fume of hygienic significance included lead, copper, zinc and nickel.
Melters and metal pourers were also exposed to infrared radiation from the
molten metal.

CONTROL OF EXPOSURE

Exposure to metal fume was controlled at the source by:

  1. Exhaust hood enclosures around the furnaces.
  2. Mobile hood on the pouring ladle.
  3. Enclosing hood around the ladle preheaters.

Two makeup air units provided fresh air turnover in the area.

Engineering

Control at the Source--
A summary of exhaust hood type and flow information is presented below
along with a comparison of the furnace exhaust flows with the ACGIH
recommended flows.

Process	Control hood type	Exhaust flow		ACGIH recommended flow	
		cfm	m3/sec	cfm	m3/sec
Indirect arc furnace	Enclosing hood §	12,000	5.66	15,600	7.36
Crucible furnace	Enclosing hood *	15,000	7.08	26,800	12.64
Ladle preheater	Enclosing hood	6,000	2.83	-	-
Pouring ladle hood	Canopy -	537	0.25	-	-

§ Reference 17, print no. VS-106.
* Reference 17, print no. VS-106.

The following is a summary of the hood evaluation.

Furnace Hoods--
The indraft velocities into these enclosing hoods (Figures A14-2 and 5),
particularly the crucible furnace hood, were less than recommended and the
hoods were susceptible to the prevailing cross-drafts of 70-100 fpm
(0.35-0.50 m/sec) through a nearby doorway. The disruptive effect of these
cross-drafts sometimes dispersed fume into the operator's breathing zone.

Ladle preheater--The ladle was preheated in a totally enclosing hood. The
ladle was moved into the enclosed room with a hoist. The door of the
preheating enclosure was closed during preheating.

Mobile ladle hood--A commercially available mobile ladle hood exhausted
the pouring ladle at the source during the entire hot metal transfer,
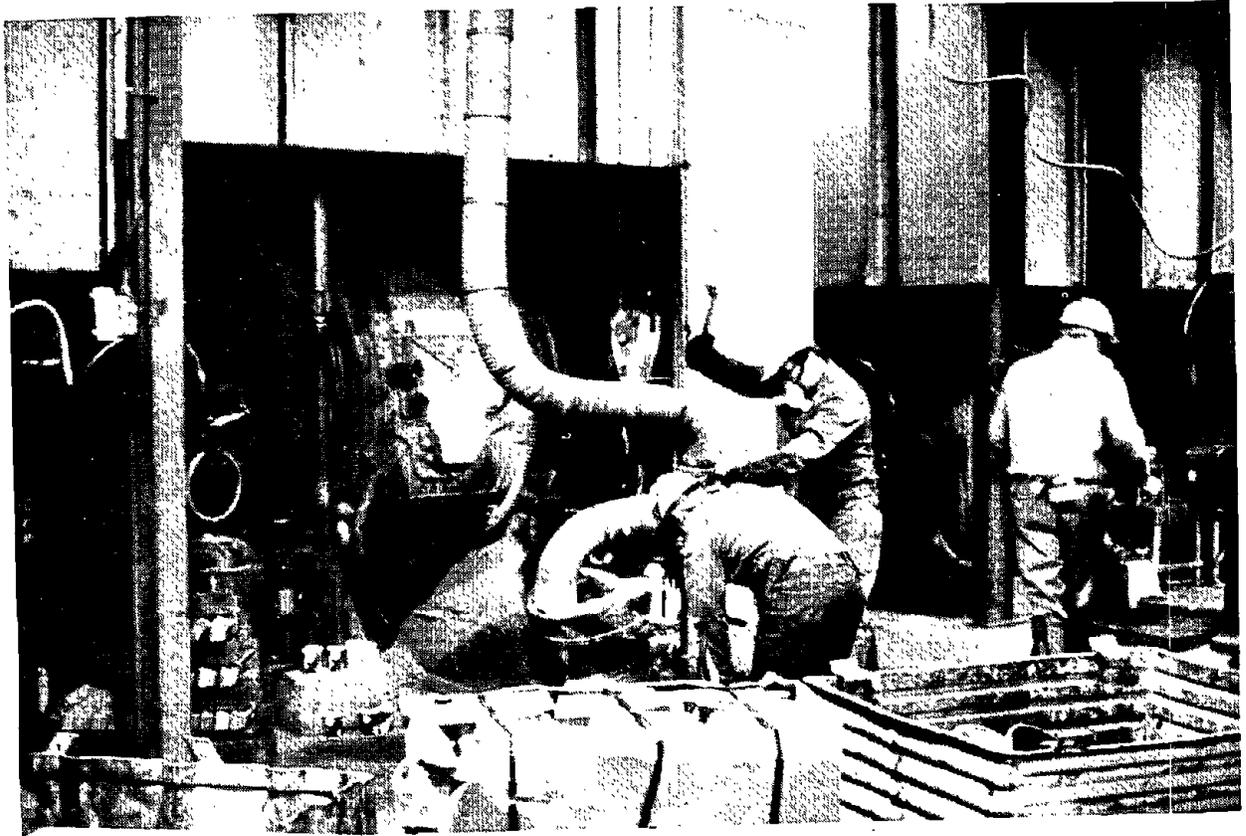
Figure A14-5. Preparing for tapping at the indirect arc furnace.

slagging, and pouring operation, except for a very few seconds after tapping when the hot metal cart was being rolled back from the furnace and the hoist attached to the ladle. The hood was permanently mounted on the ladle hanger and moved with it along the entire length of the monorail providing continuous exhaust above the ladle. The mobile hood can be seen in Figures A14-3 and 4 and a schematic view is shown in Figure A14-6.
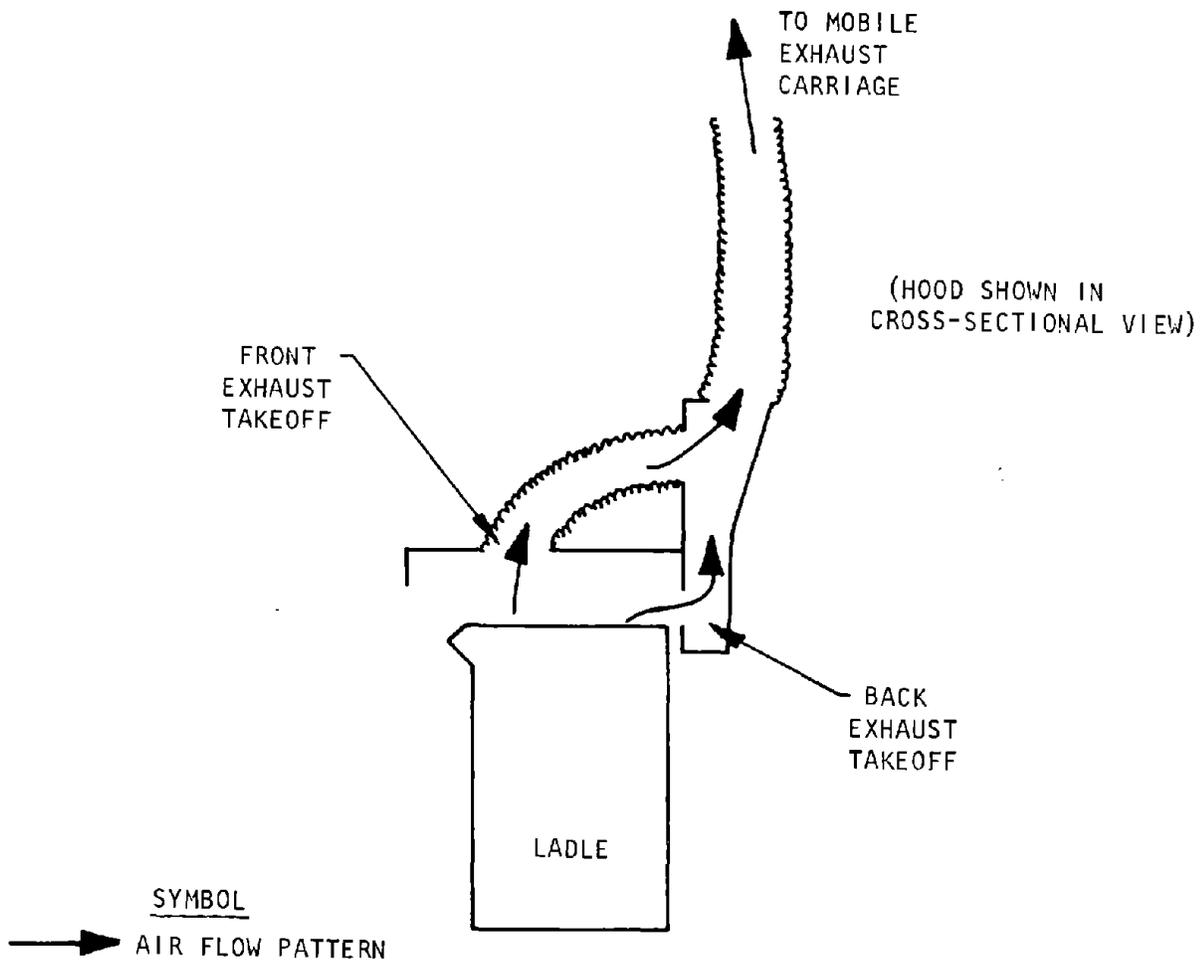
Figure A14-6. Mobile ladle hood.

The hood was connected by flexible ducting to a travelling exhaust carriage which freely moved on rollers on the side of a stationary plenum extending the entire length of the hot metal transfer monorail. The exhaust plenum had a special belt seal which was lifted by the carriage to permit exhaust air to flow into the plenum only at the point of carriage attachment. This technique permitted continuous exhaust anywhere along the monorail using a small amount of air.

Although the hood was quite adequate to capture fume emitting from the ladle it was very susceptible to cross-drafts and as a result some fume escaped past the front of the hood while the ladle was tipped forward during pouring, and past the back of the hood while the ladle was tipped backward during slagging. Cross-drafts did not seem to affect fume capture during ladle transfer between furnace and pouring line. Cross-draft velocity ranged from 100-150 fpm (0.50 - 0.75 m/sec) at the pouring stations and about 70 fpm (0.35 m/sec) at the slagging station.

To demonstrate the adequacy of the hood in the absence of cross-drafts, the door through which the cross-drafts were occurring was temporarily closed ' and the roof exhausters were shut off for an hour, producing much more quiescent conditions. As a result, fume capture was nearly complete during pouring and transfer. Some fume still escaped during slagging, however.

General Ventilation

Two makeup air units provided supply air to the area in addition to the air drawn from the pattern storage area by the roof exhausters and hoods.

Personal Protective Devices

All of the operators wore cartridge-type metal fume respirators (NIOSH no. TC-21C-160) covering the mouth and nose during the entire time they worked at the furnaces or handled the hot metal ladles. The melter wore tinted glasses to protect his eyes from infrared radiation while working on the furnaces.

RESULTS

The metal fume evaluated, i.e., copper, lead, zinc, and nickel was controlled below the allowable limits in the breathing zones of workers, as well as in the background air (Table A14-1).

Table AI4-I. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average exposure/ 8 hr. workday, mg/m^3			
				Cu	Pb	Zn	Ni
Melter	2	Pers.	Hi	0.050	0.140	0.780	0.005
			Lo	0.030	0.100	0.530	0.010
			M	0.040	0.120	0.655	0.008
Metal pourer	4	Pers.	Hi	0.040	0.100	0.950	0.110
			Lo	0.030	0.052	0.230	0.005
			M	0.032	0.080	0.580	0.040
Background-pallet line pouring area (location I, Figure AI4-I)	2	Fixed	Hi	0.030	0.070	2.600	0.006
			Lo	0.030	0.060	0.340	0.006
			M	0.030	0.065	1.470	0.006
OSHA PEL				0.100§	0.200*	5.000†	1.000
ACGIH TLV (1977)				0.200§	0.150	5.000†	1.000

§ Copper fume.
* Lead, inorganic dust and fume.
† Zinc oxide fume.

CASE HISTORY #15
EXPOSURE CONTROL DURING METAL
CASTING AND SHAKEOUT AT A NONFERROUS FOUNDRY
NOVEMBER, 1977

ABSTRACT

A copper-base casting operation was surveyed for metal fume control and control of dust from shakeout. The foundry had not yet completed the installation of the fume control system, and although effective capture of fume was occurring during melting operations, pouring of molds, and ladle preheating because of new exhaust systems, controls were not yet installed for hot metal transfer and a high frequency furnace. A feature of the fume control system was its ability to completely capture the furnace tapping process, a very difficult achievement for close-fitting hoods. A mobile hood on the manual shakeout operation provided effective control of respirable silica during shakeout at any of eight conveyor lines.

PROCESS DESCRIPTION

Melting and Pouring Operations

Copper-base alloys were melted in either of two 3000 lb (1362 kg) coreless induction furnaces and one high frequency (960 Hz) induction furnace with a capacity of 550 lbs (250 kg). The metal was poured into green sand molds in a pouring area consisting of eight conveyor lines supplied with molds by four ram-jolt molders. A plan view of the melting and pouring areas is shown in Figure A15-1.

Three workers were responsible for melting and pouring functions, a furnace operator and two metal pourers. The furnace operator manually charged the furnaces and monitored furnace controls. No alloying was done in the furnaces. Two metal pourers tapped the furnace, slagged the ladles, and together manually pushed the hot metal ladles along a monorail from the melting area to the pouring area where they poured the molds. On the days of the study, both red and yellow brass were cast. Production rate varied from 5-8 tons (4.5-7.2 metric tons) per shift. Charge material was very clean and consisted chiefly of gates, risers, and ingot. A small piece of aluminum was added to the pouring ladle during tapping as a flux.

Shakeout

An oscillating shakeout was mobilized on a set of tracks for shakeout at the end of any of the five mold conveyor lines. Three workers operated the shakeout, two to dump the molds from the pouring conveyor onto the shakeout and at the same time to retrieve the bottom board, and the other to hook the casting off the conveyor (Figure A15-2). Green sand molds were composed of bank sand containing clay, with water added in the muller. Small cores were used, predominantly shell cores.

IN DRAFT

HIGH
FREQUENCY
FURNACE

LOW
FREQUENCY
FURNACE

HOT METAL
MONORAILS
(MOBILE DUCTS
PLANNED)

LADLE
PREHEATERS

WALL

MOBILE
SHAKEOUT
AND HOOD
ON TRACKS

POURING AND
COOLING AREA

MOBILE
COLLECTING
DUCT FOR
POURING HOOD

MOLDING MACHINES (4)

STATIONARY COLLECTING DUCT
FOR POURING HOOD

SYMBOLS

ROOF VENTILATOR

FIXED AIR SAMPLE
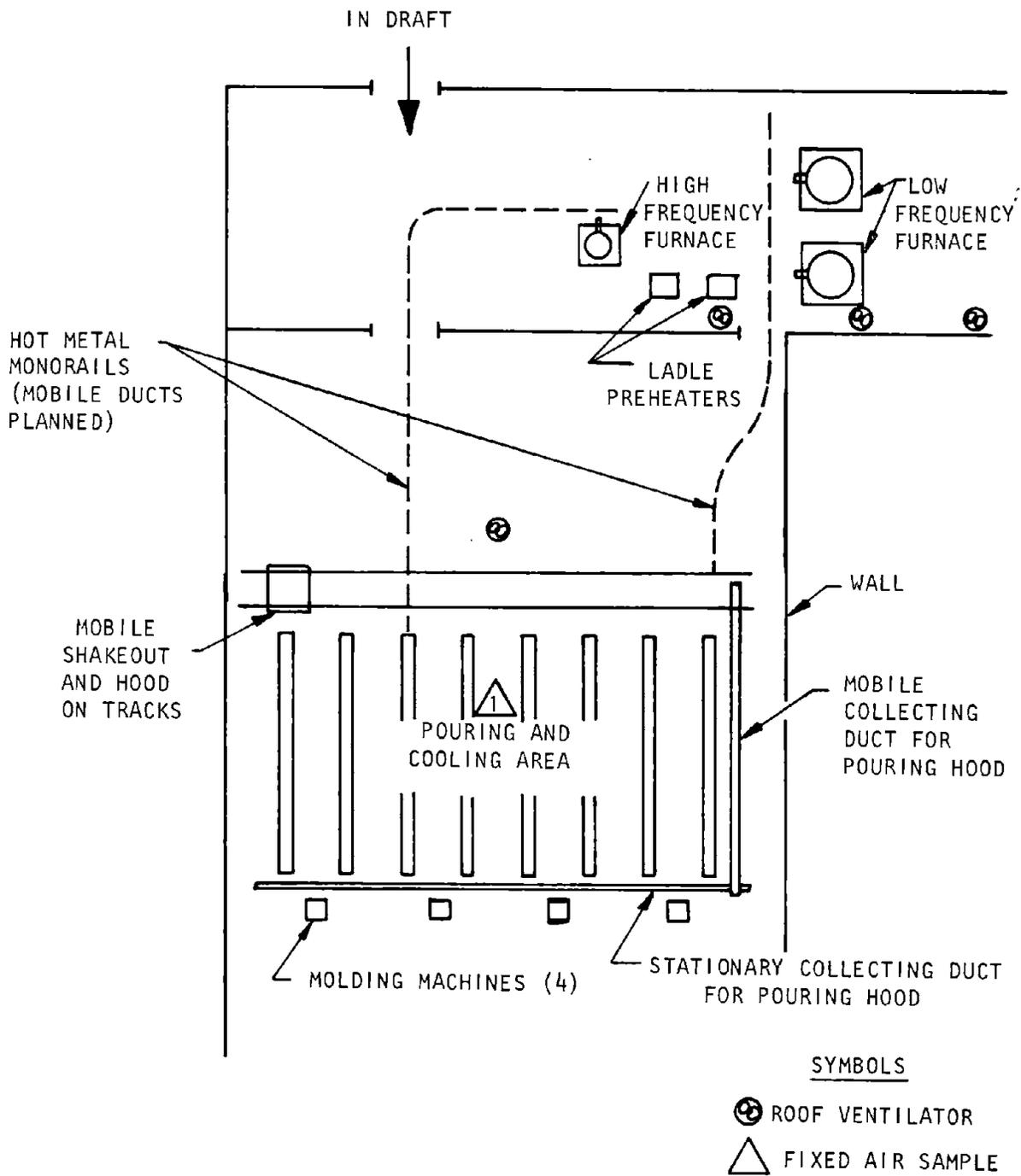
Figure A15-1.   Layout of metal casting area.

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Figure AI5-2. Hookout of castings from shakeout.

WORKPLACE HAZARDS

The major air contaminant hazard during the metal casting process was fume
inhalation. The metals of hygienic significance in the fume consisted of
lead, copper, zinc, tin, and possibly nickel. Fume was produced the entire
time the metal was in the molten state. Fuming ceased rapidly after the
molds were poured. Fume was also produced during ladle preheating, as
well as chipping out the excess metal and slag from the ladle.

Respirable silica in the metal casting and shakeout area was produced by
the shakeout operation and return sand conveyors. Potential products of
mold decomposition included carbon monoxide and phenol, although these
were not expected to be problems because of the lack of organic mold
binders and the small size of the cores.

CONTROL OF EXPOSURE

Exposure to metal fume was controlled by exhausting furnace operations,
metal pouring and ladle preheating at the source. Control of respirable
silica was achieved through a specially designed mobile hood enclosing
the shakeout.

Engineering

Control at the Source

Large Induction Furnaces--
Furnace fume was controlled using a commercially available close-fitting
hood (Figure A15-3). A telescopic duct takeoff permitted exhaust throughout
the melting cycle of 4600 cfm (2.2 m3/sec). Fume control was very effective
during charging, melting and tapping. During charging the melter swung
the furnace cover out to the side and opened an access door in the back of
the hood. The hood cover was mechanically linked to swing with the furnace
cover. Sufficient indraft was available to capture fume during manual
charging; however, during the infrequent drum charging a puff of fume was
produced which escaped the hood. After charging the furnace, the cover
was left open during the early stage of meltdown, until the stacked charge
materials melted down below the top of the furnace. Fume capture during
meltdown was virtually complete. With the furnace cover in place, the
majority of hood indraft was at the pouring spout, sufficient to capture
both the meltdown and tapping emissions.

The mobile pouring hood was in place on the ladle during tapping and slagging
at the furnace and assisted in capturing fume, especially from the part
of the ladle farthest from the furnace (Figure A15-3). However, much of
the fume from slagging, which took place at the furnace immediately after
tapping escaped past the furnace hood. At the suggestion of the study
team, the furnace operator left the furnace in a tilted position during
slagging, a position which kept the furnace hood indraft above the ladle.
This technique resulted in almost complete capture of the slagging fume.

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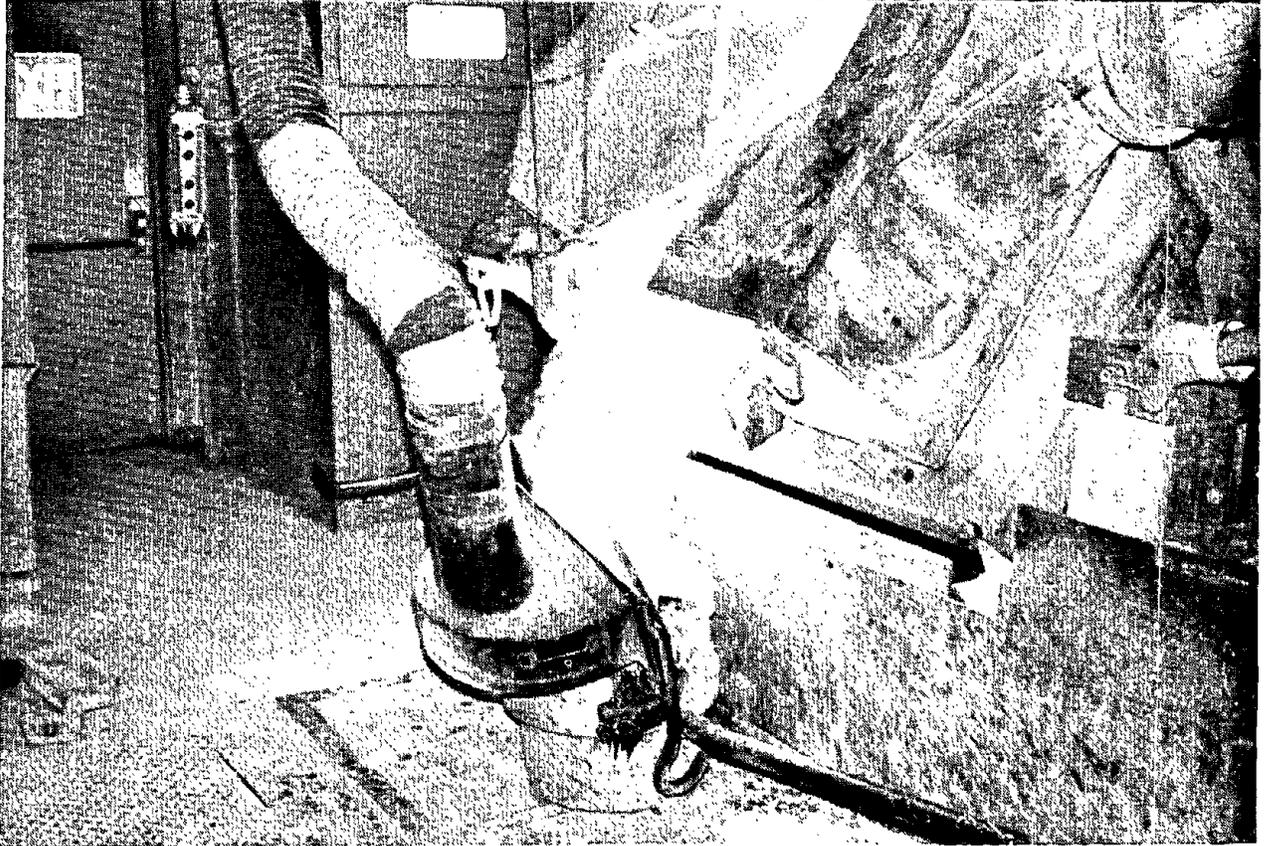
Figure AI5-3. Fume capture by furnace hood and mobile ladle hood during furnace tapping.

Mobile Pouring Hood--
The mobile pouring hood was capable of controlling fume during the entire
pouring operation including transport from the furnaces to the pouring area
(Figure Al5-4). The ladle-mounted hood had an exhaust fitting which was
connected to either of two mobile duct systems, one for ladle transport
and the other for pouring. The operator manually shifted between mobile
duct systems at the point where the transport monorail joined the pouring
line. During the days of the study only the pouring area mobile duct system
was operational because construction of the new transport line mobile duct
system had not yet been completed. Although fume during the 15 second
transport time was thus uncontrolled, the duct system still was available
for fume removal during tapping and slagging at the furnace.

The chief advantage of the mobile ladle hood system was its ability to
exhaust pouring of metal anywhere on the pouring floor using only 1200
cfm (0.57 m³/sec) per pouring ladle. As the metal pourers pushed the hot
metal ladle along the various conveyor lines using an overhead bridge
crane, the mobile duct system freely moved with it. The universal movements
of the mobile duct system were accomplished with two special collection
ducts, located at right angles to each other, one of which was stationary
and the other mobile and mechanically connected to the bridge crane which
supported the ladle hanger.

Use of the mobile hood system did not noticeably slow the metal pouring
operation. Speed in emptying the contents of the ladle was critical because
as the molten metal cooled, the chance of pouring defective castings increased.

High frequency induction furnace--Canopy hood control of nonferrous
furnace emissions made good use of the thermal draft above the furnace to
capture fume during meltdown (Figure Al5-5). However, the hood was swung
aside during tapping to permit tilting of the furnace, and it was at this
time that the pouring operators got their greatest exposure. As part of
the ongoing ventilation system changes, the canopy hood was to be replaced
with a close-fitting, furnace-mounted exhaust hood which could capture
the tapping fume.

Ladle preheater canopy hoods--Excess metal remaining on the walls of the
pouring ladle after pouring caused fuming to occur during preheating of
the ladles. During preheating the ladles were set on their sides on a
small table adjacent to the burner (Figure Al5-5, background). The flame
pattern drove the fume outward and upward and thus the preheater canopy
was only partially effective.

Shakeout Hood

The shakeout hood enclosed the process leaving sufficient room for access
by the workers on both sides. The exhaust flow of 2200 cfm (1.04 m³/sec)
was slightly less than the ACGIH minimum recommended flow of 2430 cfm
(1.15 m³/sec) based on the amount of open area in the hood[§]. Although
capture appeared to be adequate, the hood was susceptible to cross-drafts

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[§] Reference 17 (VS-112).

Figure A15-4. Two man pouroff operation using mobile ladle hood to capture fume.
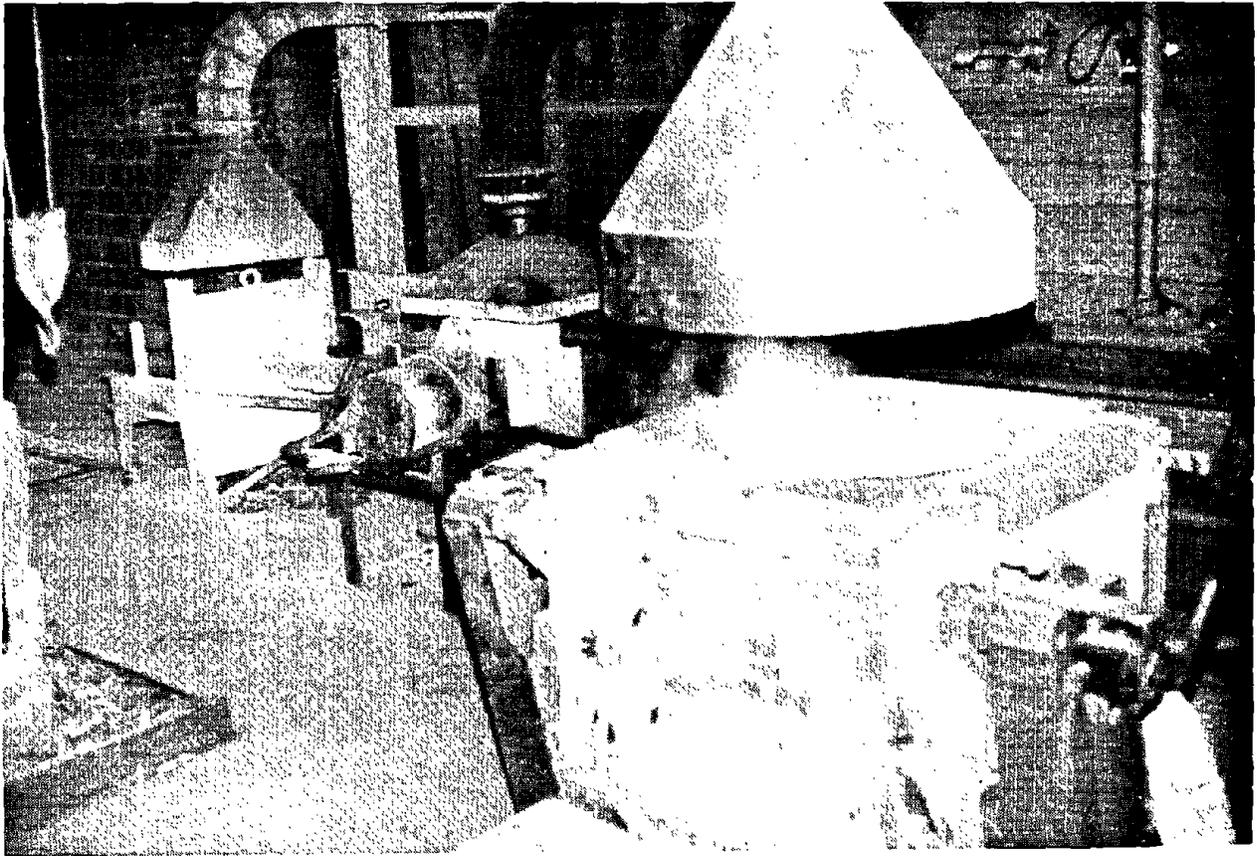
Figure A15-5. High frequency furnace during melt-down cycle with canopy hood in place (will be replaced with furnace-mounted hood). Ladle preheaters and their canopy hoods are in the background.

which occurred when the hood was located directly in line with the fresh air stream entering the area through an open door in the melting department.

A unique feature of the hood was its ability to exhaust the shakeout process at any of the eight pouring lines. The exhaust takeoff section from the hood had a sliding joint which permitted connecting it up to any of the eight inlets to the exhaust plenum below the floor. In the photo of Figure A15-2, the duct connection can just be seen behind the hookout man. Cover plates blocked off the exhaust openings of takeoffs not in use (7 at any one time).

Sand falling through the shakeout was discharged onto a belt conveyor in the pit area. No exhaust was provided on the conveyor but exhaust was present in the pit at the conveyor transfer point.

General ventilation--Three roof exhausters in the melting area and near the pouring area provided general ventilation. The weather varied drastically between the two days during which air samples were taken. On the first day, the weather was warm, the foundry was open, and a draft varying between 13,000 - 26,000 cfm (6.13 - 12.27 m3/sec) was blowing in through the open door in the melting area. On the second day the weather turned colder and the foundry doors were closed. No makeup air units were available to provide supply air when the building was closed up.

Personal Protective Devices

On the second day of the survey, when the foundry was closed, fume escape during transport of the pouring ladle and tapping of the small furnace caused one operator to put on a respirator.

RESULTS

    1.   Attempts to measure the effectiveness of the large induction furnace hood and the pouring hood on metal fume capture were futile because of the presence of substantial amounts of fume from the uncontrolled metal transfer process and tapping of the high frequency furnace.

    2.   Control of respirable silica by the shakeout hood was found to be effective (Table A15-1).

Table AI5-I. Air sampling results - respirable silica.

Worker or location	Sample type	Percent quartz	Respirable dust exposure, mg/m3	Allowable respirable dust exposure §, mg/m3
Shakeout operator	Pers.	1.0	2.0	3.3
		2.2	1.1	2.3
		1.2	0.84	3.1
		1.5	0.88	2.9
Shakeout hood (fixed to top of hood)	Fixed	<1	0.82	5.0
		<1	2.30	5.0
		1.0	2.00	3.3
Background in pouring and cooling area (location I, Figure AI5-I)	Fixed	<1	2.00	5.0
		1.4	0.61	2.9

§ OSHA PEL and ACGIH TLV (1977).

CASE HISTORY #16
FUME CONTROL BY ISOLATION OF A HOT METAL
CRANE OPERATOR IN AN ENCLOSED CAB
JULY, 1977

ABSTRACT

A hot metal crane operator in a high production iron foundry transported
ladles between a melting deck and holding furnace while working inside an
air-conditioned, enclosed cab. Air samples taken inside and outside
the cab indicate that the average concentrations of fume to which the
operator was exposed were below allowable limits and less than 1% of the
concentrations outside the cab. Fume concentrations inside the cab could
vary according to the amount of fume that leaked into the cab. The air
samples taken indicated that the degree of enclosure provided by the cab
adequately controlled fume infiltration.

PROCESS DESCRIPTION

Equipment and Operation

Molten metal was transported from a melting deck to either of two holding
furnaces by an overhead monorail crane. The hot metal crane was operated
by one worker positioned inside an air conditioned cab. The operator
remained within his cab during his entire shift and only came out during
two breaks and a lunch period, a total of a little under one hour.

The hot metal transfer operation consisted of the following sequence of
events:

1. The crane set the transfer ladle in front of the furnace to
    be tapped.

2. During tapping the crane remained above the transfer ladle until
    the furnace was fully tapped.

3. The crane then picked up the full ladle and carried it to the
    holding furnace area.

4. At the holding furnace the ladle was tipped to allow molten metal
    to flow into a water-cooled spout (launder) at the inlet to the
    channel furnace.

Materials and Rates

During the workshift in which air samples were taken the crane made 47 trips
carrying a total of 107 tons (97 metric tons) of iron in a ladle with a
capacity of 2.5 tons (2.3 metric tons).

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WORKPLACE HAZARDS

The major air contaminant hazard from transporting hot metal was fume
inhalation. External to the cab environment metal fume rising in the
thermal draft consituted a significant health hazard to the crane operator.
The metals of hygienic significance in the fume consisted of iron, nickel,
zinc, lead, manganese, magnesium and copper.

CONTROL OF EXPOSURE

Breathing zone control for the hot metal crane operator was achieved by the
isolation of the worker within an air-conditioned cab. Although the cab
was not completely air-tight, fume leakage was minimal and an acceptable
air quality was achieved.

Engineering

The crane cab was air conditioned with a self-contained air conditioning
unit rated at 10,000 BTU/hours (2.93 kw). About 500 cfm (0.236 m^3/sec) of
air was continuously filtered and cooled as it recirculated through the
crane cab. The low efficiency filter used was designed to prevent dust
buildup on the cooling coils of the air conditioner unit. It was not
capable of effectively removing fume from the atmosphere in the cab. The
filter was replaced weekly as part of the plant's maintenance program.

The crane cab was fairly air-tight, although some small amount of air did
leak into the cab. Although this small indraft of air probably helped to
maintain adequate CO_2 and oxygen levels within the cab, it also carried
some fume with it. Fume infiltration had the greatest chance of occurring
as each furnace was tapped since the crane cab was located near the
rising thermal draft of dense fume moving upward toward the roof exhausters.
Although furnace tapping probably accounted for the greatest potential for
exposure because of the very high concentrations and close proximity, the
exposure time was brief. Some contaminants could also have entered the
cab as the worker came and went at the beginning and end of the workday
and at breaks and lunchtime. The access area was located at the far end
of the melting deck in an area with good general ventilation.

RESULTS

Two air samples were taken to assess the degree of control achieved by
isolating the crane cab. Fixed samplers were located inside and outside
the cab for the duration of a workshift. Table A16-I presents the results
of these measurements, as well as the results of a previous sample taken
by foundry personnel inside the cab. The results of the sampling are as
follows:

   1. The measured concentrations indicate that sufficient control was
      achieved by the enclosure method to prevent over exposure of the
      crane operator.

2. The total dust concentrations inside the cab were less than 1% of the total dust levels measured outside the cab.

3. The breathing zone sample taken by the plant indicates that the rate of infiltration probably varies from day to day and that higher levels of contaminants can be present in the cab than those measured during the study.

Table A16-1. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Time weighted average exposure/8 hr. workday, mg/m³							
			Fe	Ni	Zn	Pb	Mn	Mg	Cu	Total dust
Outside cab	1	Fixed	39.9	0.02	2.39	0.30	0.40	0.13	0.05	90.4
Inside cab	1	Fixed	0.10	0.01	0.12	0.03	<0.01	<0.01	<0.01	0.89
Previous plant data (inside cab)	1	Fixed	0.66	0.003	0.29	-	-	-	-	3.70
OSHA PEL			10.0§	1.0	5.0†	0.20#	5.0Ω	15.0Ψ	0.10Θ	15.0∇
ACGIH TLV (1977)			5.0§	1.0	5.0†	0.15#	5.0Ω	10.0Ψ	0.20Θ	10.0∇

§ Iron oxide fume.
† Zinc oxide fume.
# Lead dust and fume.
Ω Ceiling value, short term sampling was not undertaken because of the expected low exposure.
Ψ Magnesium oxide.
Θ Copper fume.
∇ Limits for silica-free dust; respirable silica measurements were not taken.

CASE HISTORY #17
HEAT STRESS CONTROL WITH
A REMOTELY-CONTROLLED SLAGGER
MARCH, 1978

ABSTRACT

Heat stress levels were reduced and worker comfort improved by the use of a
remotely-controlled mechanism for slagging of large ladles. This method
isolated the worker a distance from the heat source and shortened the time
to complete the process.

The duration of the process was too short to obtain accurate measurements
of the reduction in wet bulb-globe temperature which resulted from use of
the remotely controlled device. However, the readings did indicate that
a dramatic decrease had occurred.

Workers reported that the new method was a great improvement over the old.

PROCESS DESCRIPTION

The removal of residual metal and slag from large pouring ladles was done
by first pouring excess metal and slag from the ladle into a slag pot,
and then scraping the ladle walls and dragging the material out into the
same pot. About 5 or 6 ladles of 6.5 ton (5.9 metric ton) capacity were
processed per workshift at the slagging station.

WORKPLACE HAZARDS

The slagging worker was exposed to high levels of infrared radiation,
especially during the task of scraping out the ladle.

CONTROL OF EXPOSURE

Engineering

Heat stress on the worker was reduced by the use of a remotely controlled
device called a "robot slagger". A photograph of the slagger in use is
shown in Figure A17-1. The slagging mechanism consisted of a hydraulically
operated "arm" that was controlled by a worker standing at a control
station nearby. The operator could raise or lower the arm, make it move
either right or left, and extend or retract it as necessary in the process
of scraping the ladle walls and dragging the material into the slag pot.

Use of the slagger enabled the worker to stand farther away from the
heat source, and this constituted the major aspect of the control technique.
Prior to the installation of this equipment, a worker stood about 6 ft
(1.83 m) from the ladle and manually scraped the slag using a long rod
resting on a sliding support. Using the new robot slagger, the operator

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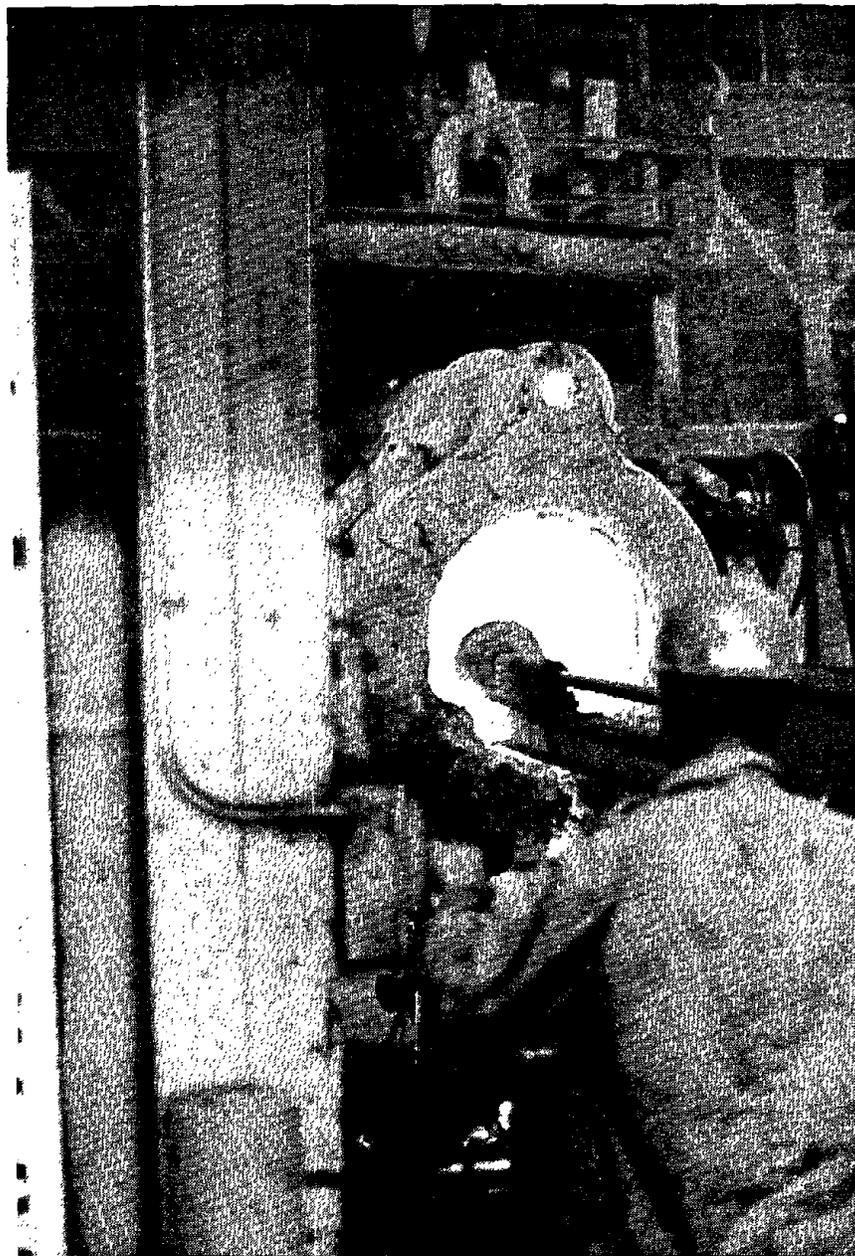
Figure A17-1. View of ladle slagging operation from behind the slagging operator station.

was moved back to a work station about 15 ft (4.5 m) from the ladle. The old versus new worker locations are identified on the plan view sketch in Figure A17-2 as the locations where the heat stress measurements were taken. Some shielding from radiant heat was also achieved because the worker operated the controls while standing behind a 3.5 ft (1.07 m) control console.
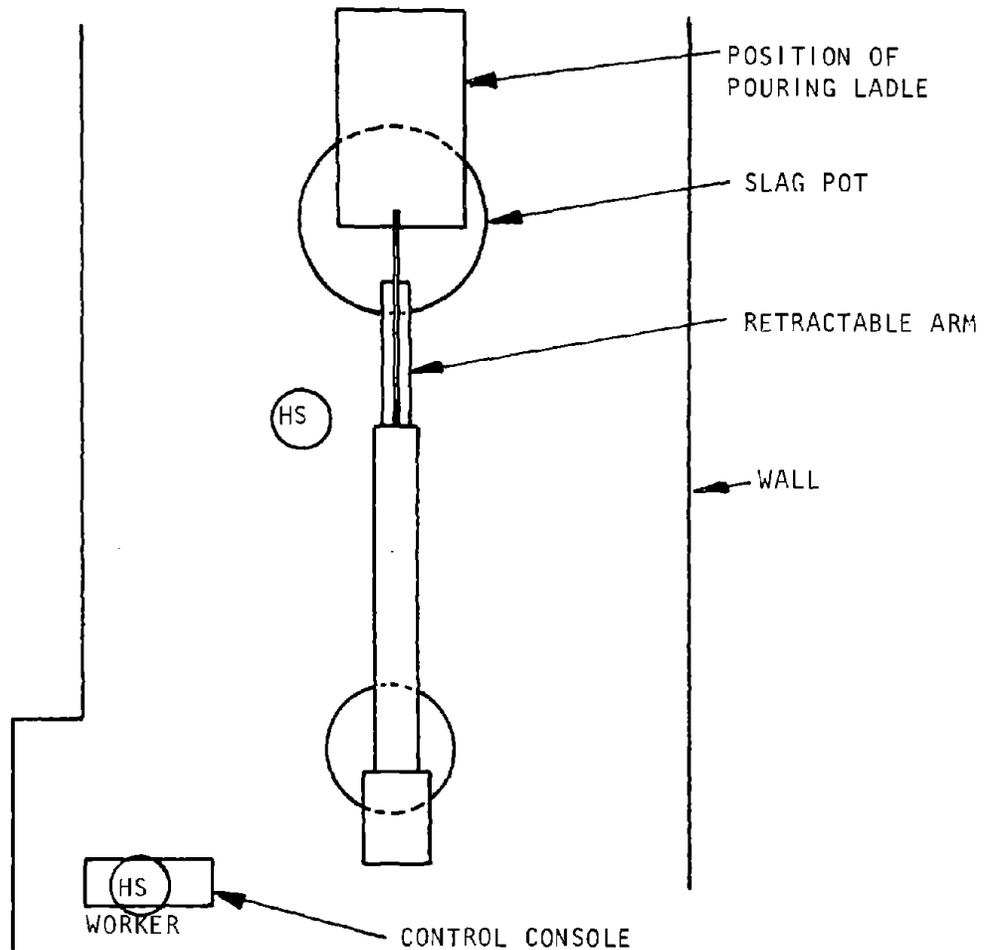
SYMBOL

(HS) HEAT STRESS
MEASUREMENT

Figure A17-2.   Robot slagging operation.

Substantial reduction in heat stress exposure was achieved because the entire slagging process could be performed in less than a third of the time compared to the previous method of slagging. The slagging cycle took about three minutes and was almost evenly divided between the tasks of pouring out excess material and scraping the ladle walls. Prior to installation of the mechanized slagging device, the slagging cycle required about 10 minutes.

Use of the robot slagger also has eliminated the previous practice of taking a short break after every slagging operation.

Personal Protective Devices.

Workers wore tinted safety glasses to protect their eyes from infrared radiation.

RESULTS

The heat stress measurements below are an indication of the reduction in heat stress levels that was achieved by the robot slagger.

	Temperatures, °C			
Location	Natural wet bulb (NWB)	Dry bulb (DB)	Globe temperature (GT)	Wet bulb globe temperature (WBGT)
At control console	19	26	34	21.1
Simulation of old work station	28	43.5	35	32.6

These results by themselves, however, do not give an accurate prediction of the exact conditions because the operation was already completed before the heat stress instrument stabilized. Workers reported that the new method was far more comfortable than the old.

CASE HISTORY #18
CONTROL OF HEAT AND FUMING
DURING SLAGGING OF LARGE LADLES CONTAINING IRON
JANUARY, 1978

ABSTRACT

A special slagging station was constructed for a high-production melting department. The station was designed to reduce the hazards associated with metal fume and radiant heat. A chute and hopper efficiently collected slag for disposal, providing good housekeeping. Because of the short duration of the process, it was not possible to obtain valid heat stress data, nor were air contaminant data taken.

PROCESS DESCRIPTION

A sketch of the station is shown in Figure A18-1. The crane operator received metal at an induction melting deck and transported it to remote pouring lines and holding furnaces. During transfer he stopped his crane at the elevated slag removal station, exited the air conditioned crane cab, and slagged the ladle.

WORKPLACE HAZARDS

The major air contaminant hazard from slagging was fume inhalation. The large free metal surface and the hot walls of the ladle were also a substantial source of exposure to infrared radiation.

CONTROL OF EXPOSURE

Engineering

Metal fume during slagging was captured by a sidedraft hood. Heat stress was reduced through shielding and fresh air supply. A roller support bar helped to speed the slagging process, thus reducing total exposure time. Following is a description of the controls.

Sidedraft Exhaust Hood--
An exhaust flow of 25,000 cfm (11.8 m³/sec) captured fume emitted during slagging. The hood was as close as possible to the ladle without interfering with the ladle transport process.

Shield--
A sheet metal barrier helped to reduce direct paths for infrared radiation from the hot metal surface to the worker (Figure A18-1). The opening in the shield was 36 in. x 42 in. (0.9 m-1.1 m) to permit just enough space through which to operate. At the lower edge of the open space a roller consisting of a metal rod supported between bearings facilitated moving the bar back and forth during slagging, thus helping to speed up the process.

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FRESH AIR

SHIELD

ROLLER FOR SLAG POLE

SIDEDRAFT EXHAUST HOOD

LADLE

ELEVATED PLATFORM

SLAG CHUTE

CHAIN CURTAINS

SLAG HOPPER

SIDE VIEW

SYMBOL

AIR FLOW PATTERN
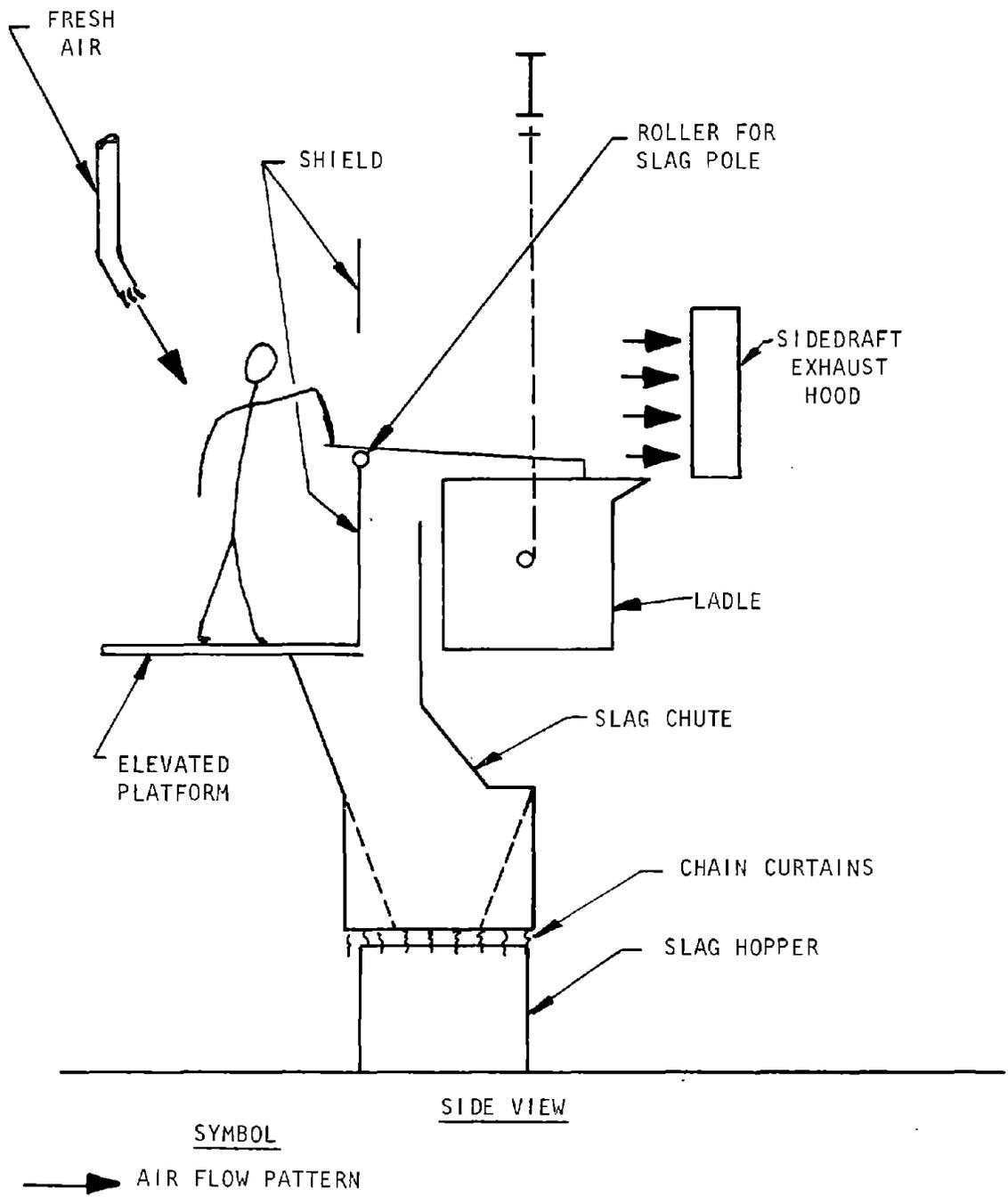
Figure A18-1.   Slagging station.

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Slag Disposal--
As the slag was dragged from the ladle, it fell through a chute and was collected in a hopper for removal. No spillage occurred.

Cooling of Workers--
A fresh air supply with an adjustable damper was located directly behind the operator to cool him. The fresh air could not "blow away" the radiant heat; rather it helped speed up sweat evaporation.

CASE HISTORY #19
HEAT STRESS REDUCTION IN A HIGH PRODUCTION,
AUTOMATED FOUNDRY
AUGUST, 1977

ABSTRACT

No evidence of excessive exposures to heat has been seen since this foundry,
located in a hot climate, instituted a heat stress reduction program four
years ago. Effective methods used to reduce heat stress included:

1. Worker isolation in booths at fixed worker stations.
2. Use of conditioned air.
3. A work-rest regimen tailored for the individual process operations.

Heat stress indices showed the improvement which resulted from the control
measures.

PROCESS DESCRIPTION

Following a heat stress survey of the foundry four years ago, a number
of operations were targeted for heat stress reduction. These areas are
described below:

1. Melting - Five direct arc furnaces were located side-by-side in a
    melting area, providing 48 heats over a three shift operation. A
    furnace operator and a helper were located at each furnace. The
    majority of tasks performed by the operators were involved in
    operation of the furnace controls. However, about 25% of the
    shift was spent performing a variety of work tasks at and around
    the furnace:

    a. Filling ore bins.
    b. Adding alloys to the furnace and ladle.
    c. Taking metal temperature.
    d. Air lancing the melt.
    e. Rebuilding the tap hole.

    Total production from the furnaces averaged 528-672 tons/day
    (479-610 metric tons/day).

2. Metal pouring - Metal from the arc furnaces was poured into molds
    on a mechanized conveyor line at a fixed pouring station
    (Figure A19-1). About 1,000 lbs (454 kg) was poured into each
    mold. Permanent molds were used with a facing of chemically bonded
    sand. A hoist mechanism was used to move the bottom-pour ladle
    above the riser spout. The pouring operator then pushed down on
    a long lever to release the metal into the mold.
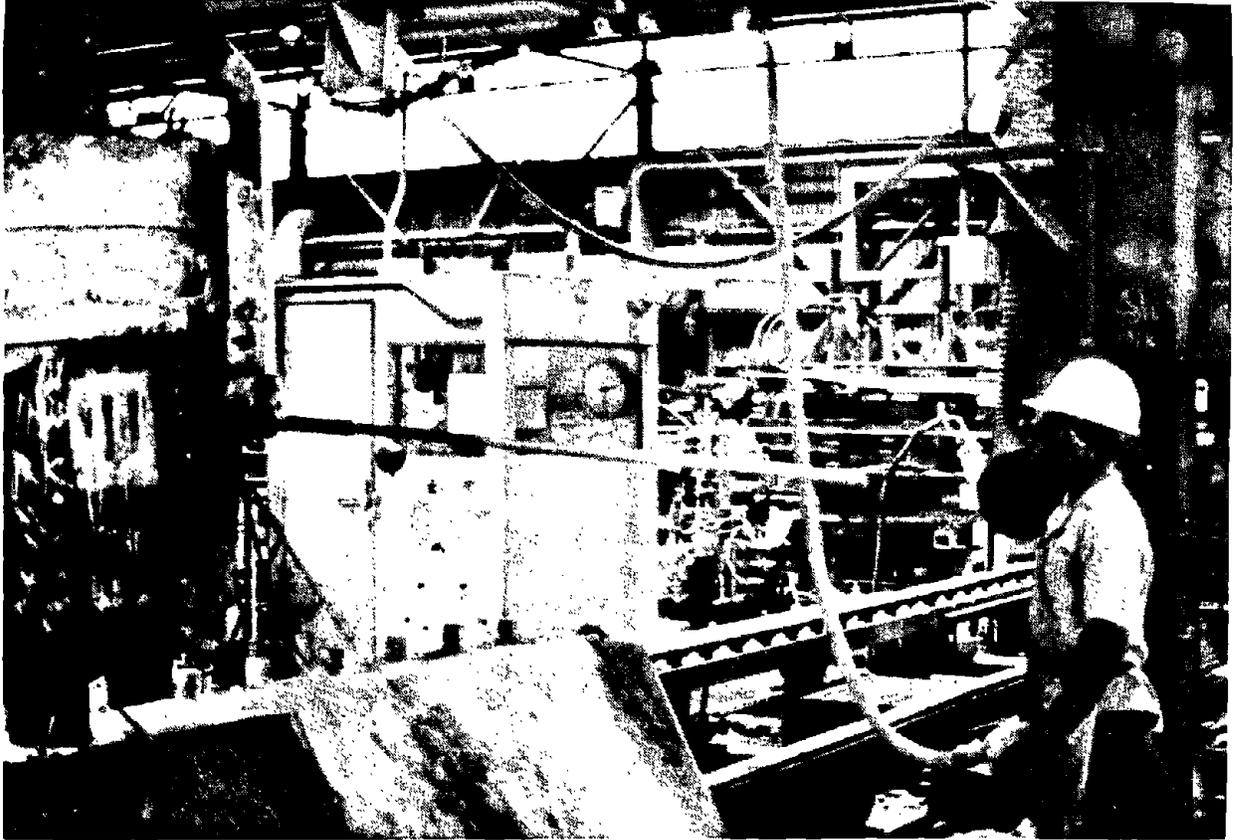
Figure A19-1. Pouring ladle being moved into position before pouring. Pyrometer operator's booth is in background. Fresh air supply duct is shown behind worker.

3. Pyrometer - The pyrometer operator was located at a fixed control station adjacent to the pouring line where he monitored the metal temperature.

4. Shakeout station - The shakeout was automated and involved separating the cope and drag sections of the permanent mold, picking out the casting and setting it on a conveyor. The operator was stationed at a fixed location while he operated the controls.

5. Casting cleaning - Castings were automatically deburred and shot blasted in several machines which were monitored by a worker situated at a nearby control station.

6. Shot peening - Peening was done automatically in a manner similar to casting cleaning.

WORKPLACE HAZARDS

Heat and high ambient temperatures during the summer presented a potential workplace hazard from heat stress. The degree of hazard also was related to worker acclimatization and duration of exposure. Melting and pouring represented the greatest heat stress hazard because of the presence of molten metal. Shakeout was next in severity after the red hot casting was separated from the mold. Casting cleaning and shot peening were not significant heat sources themselves, however, the operators were subjected to heat stress caused by hot adjacent processes.

Because of the three shift operation, foundry temperature remained elevated throughout the day and there was no period when the foundry was allowed to cool.

CONTROL OF EXPOSURE

Three techniques were used to reduce heat stress on workers:

1. Isolation in booths.
2. Cooling with fresh air or air conditioning units.
3. Establishment of work-rest regimens.

Engineering and administrative controls employed for the reduction of heat stress are summarized in Table A19-1.

Engineering

The principal control measure applied was worker isolation in booths that were supplied with conditioned plant air, fresh air, or conditioned fresh air. Because this foundry was so highly automated, many processes were able to be controlled by this method. The construction of the booths

Table A19-1. Heat stress sources and type of control used.

Foundry process	Figure number	Heat source	Workers	Duration of heat exposure during shift	Engineering controls	Air supply #	% Work/ % rest regimen
Melting	A19-2	Furnace, transfer ladle	Furnace operators & helper	2 hours	Isolation booths	CFA	86/14
Pouring	A19-1	Transfer ladle, pouring ladle	Pouring operator	3.4 hours	Cooled air blown on workers; separation wall (shielding other hot processes)	CFA	43/57
			Pyrometer operator	none	Isolation booth †		86/14
Shakeout		Hot castings	Shakeout operator	none	Isolation booths	FA	86/14
Casting cleaning		Adjacent hot processes	Shot blast	none	Isolation booths	FA	86/14
Peening		Adjacent hot processes	Peening operator	none	Isolation booths	CPA	86/14

§ Based on eight-hour workday.

* Pours every other heat, avg. 13-33 minutes per heat.

† Reflective windows facing pouring station.

# FA = Fresh outside air.
  CFA = Conditioned fresh air.
  CPA = Conditioned plant air.

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varied but in general the booths were at least 5 ft (1.5 m) x 10 ft (3.1 m)) x 8 ft (2.4 m) high structures with 3 inch (7.6 cm) thick fiberglass insulation in the walls. The viewing glass was dual pane safety glass on the inside, and the outside was laminated safety plate or plexiglass. A picture of a typical booth (arc furnace) is shown in Figure A19-2.

At the pouring station three of the workers were unprotected from radiation (except for protective clothing) but were bathed in conditioned fresh air supplied to their individual stations. The pyrometer operator was isolated in a booth; the pouring supervisor travelled the entire area and spent some time within the pyrometer operator's booth.

A blast of cooled air (about 6^oC below rooftop ambient) at 1650 ft/min (8.38 m/sec) was used to relieve heat stress on metal pourers. This blast was directed at the pouring work station where the pourer remained stationary and operated the ladle. Since most of the thermal load on pourers came by radiation from molten metal and from the hot ladle, the method of control from radiant heat relied on the ability of the worker to lose large amounts of heat by sweating. Thus, the blast of cooled air did not help control heat stress from thermal radiation, but the air blast on the sweat-soaked worker did achieve a cooling affect.

At the furnace area, about 25% of the worker's time was spent performing tasks (such as tapping) that were uncontrolled with respect to heat stress, but the remainder of the time was spent in the booths or cooled rest areas nearby.

At the remaining work stations (shakeout, cleaning and shot peening), the worker essentially spent the entire workshift inside the booth and came out only during 2 short rest breaks and at lunch time.

Work Practices

Reductions in heat stress exposure were achieved by several administrative controls that governed the employee's work practices. In general, administrative controls consisted of:

1. Enforcement of the amount of break time each employee must take.
2. Water coolers close to the work area [usually within 40 ft (12.2 m)].
3. Enteric-coated salt tablets for workers who felt the need for them.
4. Air conditioned rest areas within 100 ft (30.5 m) of all work areas.

PERSONAL PROTECTIVE DEVICES

In addition to the usual protective devices worn in a foundry, the furnace operators and pourers wore protective clothing to shield radiant heat. The furnace operators wore aluminum coats and asbestos leggings. The pourers wore aluminum aprons, asbestos leggings, and acetate face shields. All wore long sleeves and asbestos gloves. Some wore aluminum coats and pants. The pouring supervisor and ladle operators wore protective clothing similar to the pourer.

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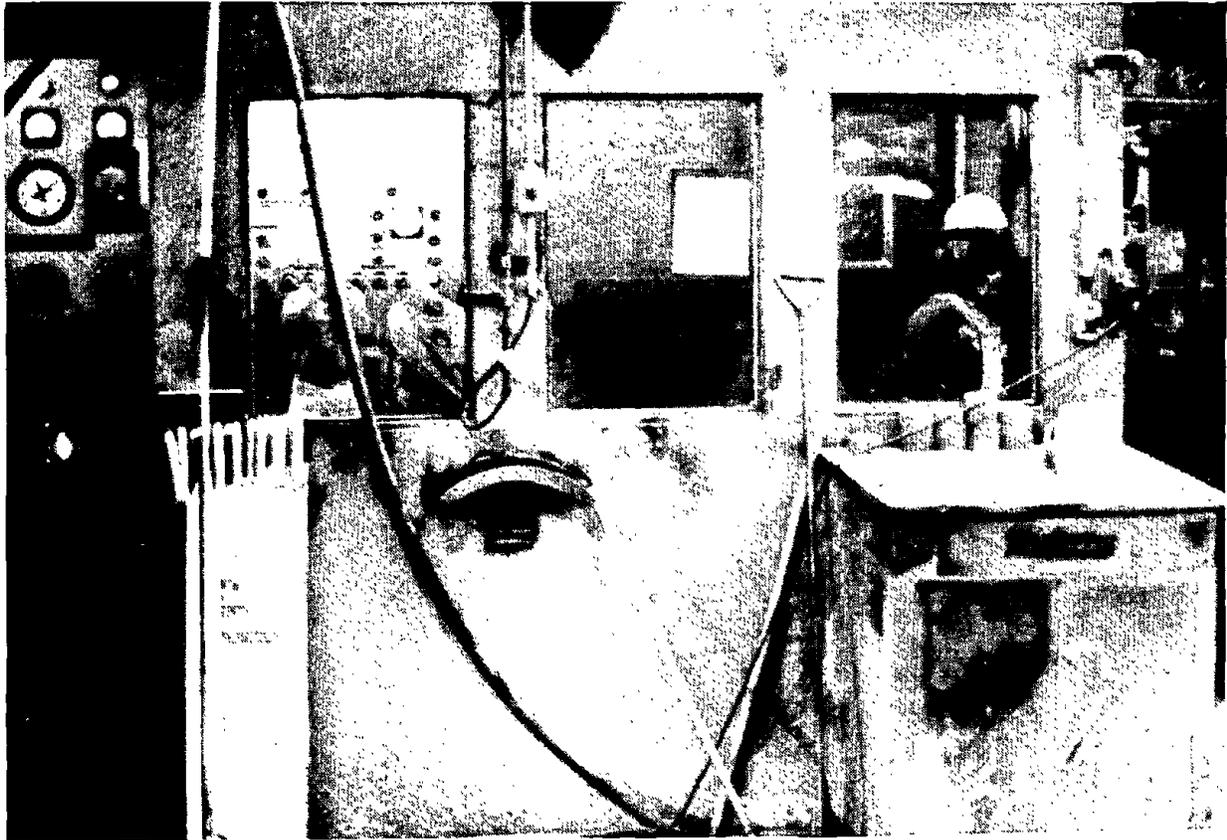
Figure AI9-2.   Arc furnace booth.

RESULTS

Measurements of the variables needed to calculate the heat stress indices are presented in Table A19-2. The calculated indices are presented in Table A19-3.

1. Heat stress indices showed that, in all of the booths but one, the booths provided heat stress relief for workers. This result matched the observations of the investigative team.

2. Heat stress indices for the shakeout booth are very misleading. It is hard to tell from the data (taken on successive days) whether conditions were better inside or outside of the booth. The experience of the investigative team was that infrared radiation from the castings made the outside location much more uncomfortable than inside the booth. The lower calculated indices outside the booth resulted from the cooling effect of fresh air draft through a nearby doorway.

3. The sweat rate required for pourers was significantly higher than that required for all other jobs.

Table A19-2. Heat stress data inside and outside of controlled area.

Process	Natural wet bulb (NWB)		Dry bulb (DB)		Globe temperature (GT)		Air velocity, m/sec		Metabolic rate (estimated), watts
	in	out	in	out	in	out	in	out	
Melting	25	28.2	35	38	36.5	46.2	0.89	0.28	200
Pouring	24.5	29.5	29	45.5	38.5*	52.5*	8.38*	0.38	300
Pyrometer	17.5	28.3	22	38	20	41.8	0.23	0.13	100
Shakeout	27.5	26.6	39.4	39.5	40.7	44.3	0.18	0.61	200
	27.5	23.5	35	33	35	42	0.38	0.84	200
Cleaning	27	29	39	44.5	37.8	45	0.31	0.20	200
Shot peening	23.6	27.6	25	37.5	24.5	40	0.12	0.13	200
Rest area	21.6		27.5		28.5		0.20		100

Temperatures, °C §

§ Vapor pressure of water in the air was about 20.3 mm Hg.

* Globe temperatures were allowed to reach equilibrium (about 20 minutes) before a reading was taken when possible. Since pouring was an intermittent process the highest globe temperature attained at a sampling location was recorded.

Table AI9-3. Heat stress indices inside and outside of controlled areas.

Process	Wet bulb globe temperature (WBGT) °C		Heat stress index (HSI)		Heat stress index (HSI2)		Sweat rate index (SRI), watts,		Predicted sweat rate (S), watts	
	in	out	in	out	in	out	in	out	in	out
Melting	28.4	33.6	46	163	46	149	231	370	191	312
Pouring §	28.7	36.4	18	182	15	160	414	486	350	413
Pyrometer	18.2	32.4	-84	182	-43	174	-113	442	0	375
Shakeout	31.5	31.9	159	102	143	92	358	360	302	304
	29.5	29.0	65	75	68	62	203	329	167	276
Cleaning	30.2	33.8	96	186	94	162	245	448	203	380
Shot peening	23.9	31.3	13	185	35	157	62	424	44	359
Rest area	23.7		-9		3		11		0	

§ Inside and outside of conditioned air stream.

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CASE HISTORY #20
DUST, FUME, AND GAS CONTROL DURING POURING AND
COOLING ON A MECHANIZED CASTING LINE
SEPTEMBER, 1977

ABSTRACT

Metal fume and organic gases and vapors were controlled on a mechanized
casting line during high production of small iron castings. A commercially
available exhaust hood on the pouring line completely contained metal
fume during pouring, as well as products of mold decomposition as the
just-cast molds traversed the pouring line on a conveyor. At the end of
the pouring line the molds entered an enclosed room for a 40 minute cooling
period during which the decomposition products were completely contained
and exhausted. Besides complete control of air contaminants, other control
methods were employed to reduce heat and infrared radiation on the metal
pourers. These included a heat shield on the ladle, a fresh air supply
directed at the workers, a 67%/33% work-rest regimen, and the practice
of pouring prepared sand on the exposed metal of just-cast molds. This
latter practice, however, could have contributed some respirable silica to
the breathing zones of metal pourers.

PROCESS DESCRIPTION

Equipment and Operation

An automatic mold line produced molds continuously which were then automatically
transported on a conveyor line to a 60 ft (18 m) long pouring deck. A
schematic of the casting line is shown in Figure A20-1. At the end of
the pouring line the conveyor entered an enclosed cooling room in which the
conveyor passed back and forth for 40 minutes before exiting to a shakeout.
Several metal pourers manned the pouring line. They moved their ladles
along a monorail in a closed loop and, when on the pouring platform,
they moved in the same direction as the mold line. After leaving the
pouring deck they refilled their ladles from a bull ladle before reentering
the line. A picture of a metal pourer filling molds is shown in
Figure A20-2. One additional operator was located adjacent to the pouring
line. He shovelled sand onto the exposed metal of the just-cast molds.

As can be seen from the schematic view in Figure A20-1 , the hot metal
monorail traversed a very small loop. Thus, ladle filling took place
immediately behind the metal pourers and shields were required to protect
the pourers from sparks and splashing (Figure A20-2).

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POURING HOOD

HOT METAL MONORAIL

MOLD CONVEYOR

EXHAUST

MOLDING AREA

SUPPLY

SHAKEOUT

EXHAUST

COOLING ROOM

PLAN VIEW

SUPPLY

EXHAUST
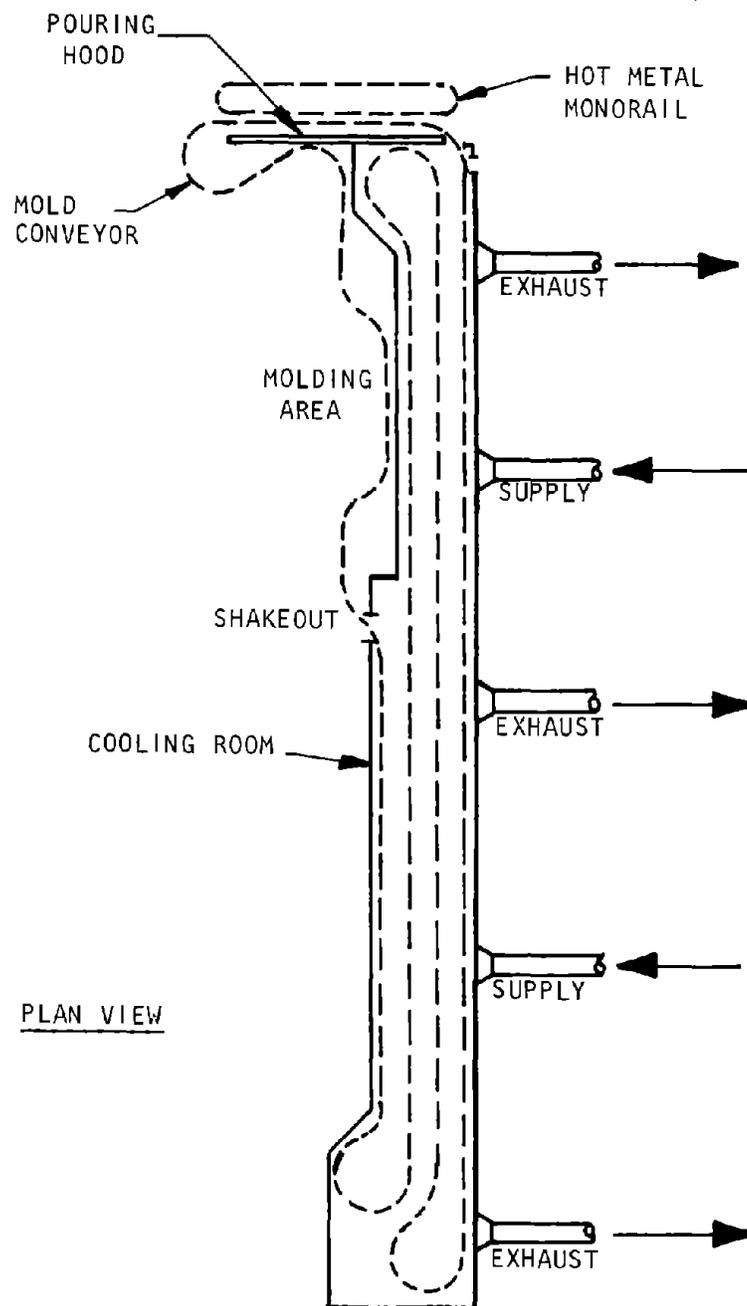
Figure A20-1. Automatic mold line pouring platform and cooling room.
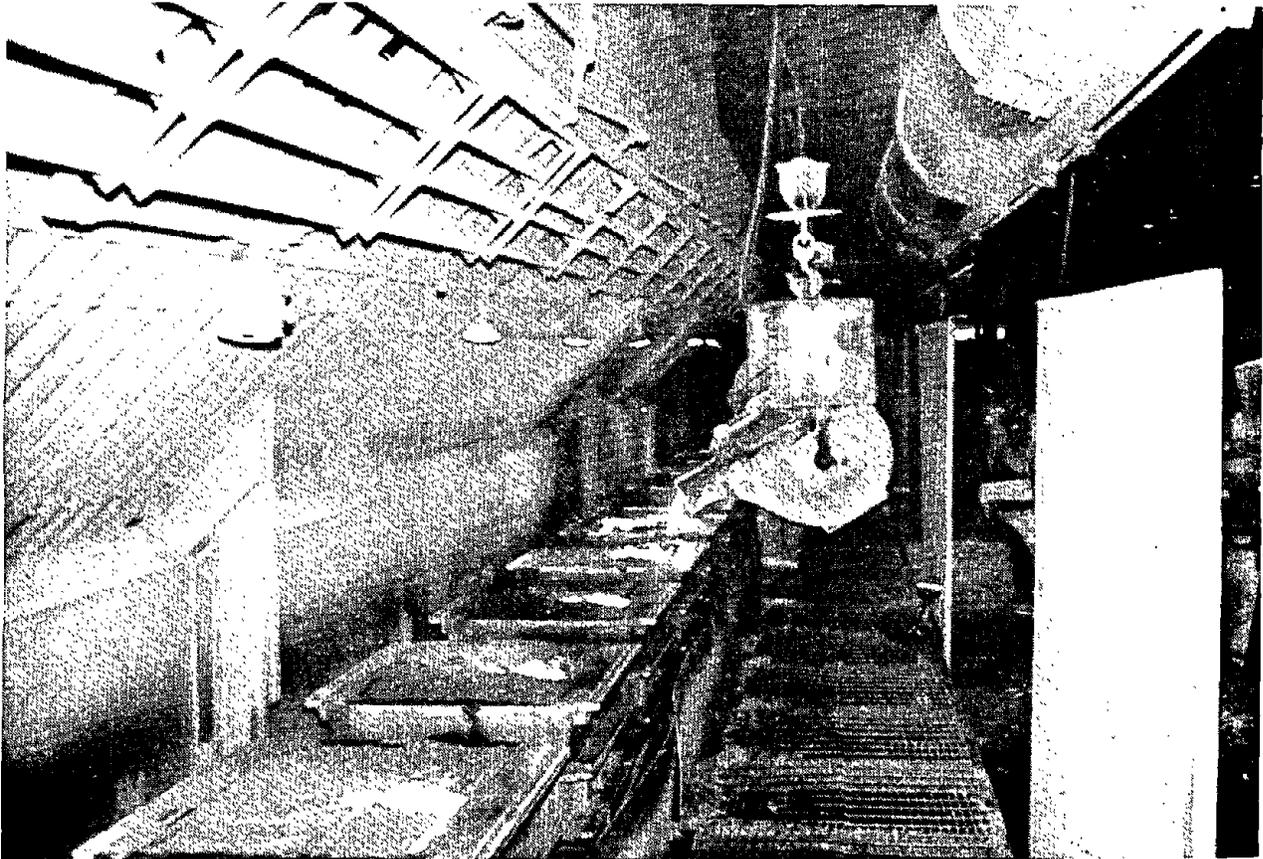
Figure A20-2. View of pouring line from end view showing push-pull pouring hood (on left) and fresh air supply above and behind metal pourer (on right).

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Materials and Rates

Molds were composed of silica sand, clay, water, and Charbo[§]. Cores were phenolic urethane. Metal production rate was 35 tons/hr (31.8 metric tons/hr) of ductile iron.

WORKPLACE HAZARDS

The major air contaminant hazard from the pouring and cooling operation was fume, dust and gas inhalation. The metals of hygienic significance in the fume included iron, nickel, manganese, lead, and zinc. Potential products of mold and core decomposition included carbon monoxide, methylene bisphenyl isocyanate (MDI), and phenol. Respirable silica could have been emitted by the sand shovelling process. Infrared radiation and heat were also potential problems.

CONTROL OF EXPOSURE

Air contaminants were controlled during pouring by a commercially available push-pull pouring hood. The cooling room was totally enclosed, isolated to workers, and ventilated.

Heat relief was provided by several controls:

1. The cooling effect of the fresh air supply on the pouring hood.
2. Fresh air supply along the length of the pouring line directed at the workers from behind.
3. Radiation shields on the sides of the ladle hangers.
4. Shovelling sand onto just-cast molds to cut direct radiation.
5. A 67%-33% work-rest regimen.

Engineering

Control at the Source--
The large plenum extending over the pouring line was composed of two separate air sections. The upper section conveyed fresh air which was aimed downward and outward to help contain the emissions. The lower section provided exhaust drawing the emissions from the molds in the air stream. The resultant air pattern took the form of a loop. This control method was very effective in keeping emissions out of the breathing zone. The supply air feed for the 60 ft (18.3 m) pouring line was 52,000 cfm (24.5 m³/sec) and the exhaust was 78,000 cfm (36.8 m³/sec). The net air exhausted [(26,000 cfm (12.3 m³/sec)] was somewhat higher than the ACGIH recommended flow range of 12,000-18,000 cfm (5.7-8.5 m³/sec) for a 60 ft (18.3 m) conveyor line controlled by exhaust air only[*].

Isolation--
Workers were isolated from breathing the products of mold decomposition emitted during the 40 minute cooling period by enclosing the cooling area

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§ Trade name for a rice hull or oat hull derivative.
* Reference 17, (VS-109).

in a room. The only openings in the enclosure were the conveyor entrance and exit points and an additional opening near the conveyor entrance where a worker sometimes removed metal overspill from the just-cast molds. The total amount of cooling air was not determined. Exhaust exceeded supply by 20,000 cfm (9.4 m³/sec), resulting in a minimum indraft of 150 fpm at all of the openings, fully containing the emissions. The isolated cooling area removed a large heat source from the foundry. Shielding was provided by the side baffles on the pouring ladle and by the ladle cover, isolating infrared radiation from the metal pourers.

The practice of throwing sand onto molds was also an isolation method, because by covering up the exposed hot metal, radiation was cut down. This practice was especially used when two metal pourers were working in close proximity to each other. It was the infrared radiation of the metal from molds just poured by one operator which caused a problem for the adjacent operator. The sand used was prepared sand (containing clay, binders and water) which was contained in a hopper adjacent to the pouring line.

General Ventilation--
Metal fume escaped during transfer of hot metal from the metal transport ladles into the pouring ladles, and during pouring ladle transfer to and from the pouring line. A fresh air plenum located above and behind the workers supplied cooling air on the workers across the entire length of the pouring line. The total volume of cooling air was 30,000 cfm (14.2 m³/sec). The cooling air provided makeup air for the amount exhausted by the pouring hood and in doing this, it helped to reduce cross-contamination from other process areas. However, because of its high velocity, it also induced air from the adjacent melting area which could have contained metal fume and, perhaps, respirable silica.

RESULTS

1. All air contaminants measured were within the allowable exposure limits. Tables A20-1, 2, and 3 present sampling results for metal fume, respirable silica, and vapors and gases, respectively.

Table A20-I. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average exposure/ 8 hour workday, mg/m^3				
				Fe	Ni	Mn	Pb	Mg
Metal pourer	3	Pers.	Hi	0.20	<0.01	<0.01	<0.01	0.10
			Lo	0.16	<0.01	<0.01	<0.01	0.07
			M	0.13	<0.01	<0.01	<0.01	0.04
Background adjacent to pouring line	2	Fixed	Hi	0.26	<0.01	<0.01	0.02	0.12
			Lo	0.24	<0.01	<0.01	<0.01	0.07
			M	0.25	<0.01	<0.01	<0.15	0.10
OSHA PEL				10.0§	1.0	5.0+	0.20#	15.0Ω
ACGIH TLV (1977)				5.0§	1.0	5.0+	0.15#	10.0Ω

§ Iron oxide fume.

+ Ceiling value, short term sampling was not undertaken because of the expected low exposure.

Lead, inorganic fume and dust as Pb.

Ω Magnesium oxide fume.

Table A20-2. Air sampling results - respirable silica.

Worker or location	Sample type	Percent quartz	Respirable dust, mg/m³	Allowable respirable dust, mg/m³ §
Metal pourer	Pers.	5.5	1.10	1.33
		4.9	0.73	1.45
		4.4	0.95	1.56
Background adjacent to pouring line	Fixed	5.2	1.00	1.39

§ OSHA PEL and ACGIH TLV (1977

Table A20-3. Air sampling results - organic vapors and gases.

Worker or location	Sample type	MDI, ppm	Phenol, ppm	Carbon monoxide, ppm
Metal pourer	Pers.	0.0048*		
		0.0050*		
Background pouring line	Fixed		<5.0§	20-40
OSHA PEL		0.02†	5	50
ACGIH TLV (1977)		0.02†	5	50

§ No stain observed on a Dräger 5/a detector tube after ten pump strokes.

* 8-hour time weighted average.

† Ceiling limit.

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CASE HISTORY #21
FUME AND GAS CONTROL BY
ISOLATION OF COOLING MOLDS DURING FLOOR
CASTING OF IRON
JULY, 1977

ABSTRACT

In this floor casting operation, molds were placed on sixteen roller conveyors, located side-by-side, and poured by two workers. After pouring, workers formerly had to manually push the just-poured molds along the conveyors to the opposite end of the pouring floor where the molds were allowed to cool. This task was the source of back strain on workers, as well as exposing them to products of mold decomposition. A motorized tow mechanism was installed to move the molds, eliminating the back strain and isolating the workers from breathing the products of mold decomposition. The tow mechanism, called a "pusher dog system", also transferred molds from the cooling area to a cross-conveyor leading to the shakeout. Thus, no workers were required to enter the cooling area. Better enclosure around this isolated cooling area could have completely contained the smoke, some of which was escaping to other foundry areas. On the pouring end of the floor the combination of a fresh air supply and mancooler fans provided high velocity air patterns to cool the pouring floor operators, a necessity in the hot climate in which this foundry was located. Products of mold decomposition and respirable dust were controlled below the allowable limits for all pouring floor operators.

PROCESS DESCRIPTION

Equipment and Operation

A layout of the pouring line is shown in Figure A21-1. Two jolt-squeeze molders were located at each of four molding stations producing the cope and drag sections of the mold. Other workers moved the finished molds with a powered conveyor onto the pouring conveyors. They also installed jackets and weights on the molds before pouring, and afterward removed them. Two metal pourers transferred the hot metal along a ladle monorail from nearby holding furnaces for malleable iron, or from a post-inoculation station for nodular iron. Once on the pouring deck, they transferred their ladles from the monorail to a bridge crane which permitted free movement over the entire pouring area. Shortly after the molds were poured, the shakeout operator moved them to the cooling area using a remotely controlled motorized system. After the cooling period, he used the same drive system to transfer the molds to a cross-conveyor leading to the shakeout.

A summary of work tasks for casting unit personnel is presented in Table A21-1.
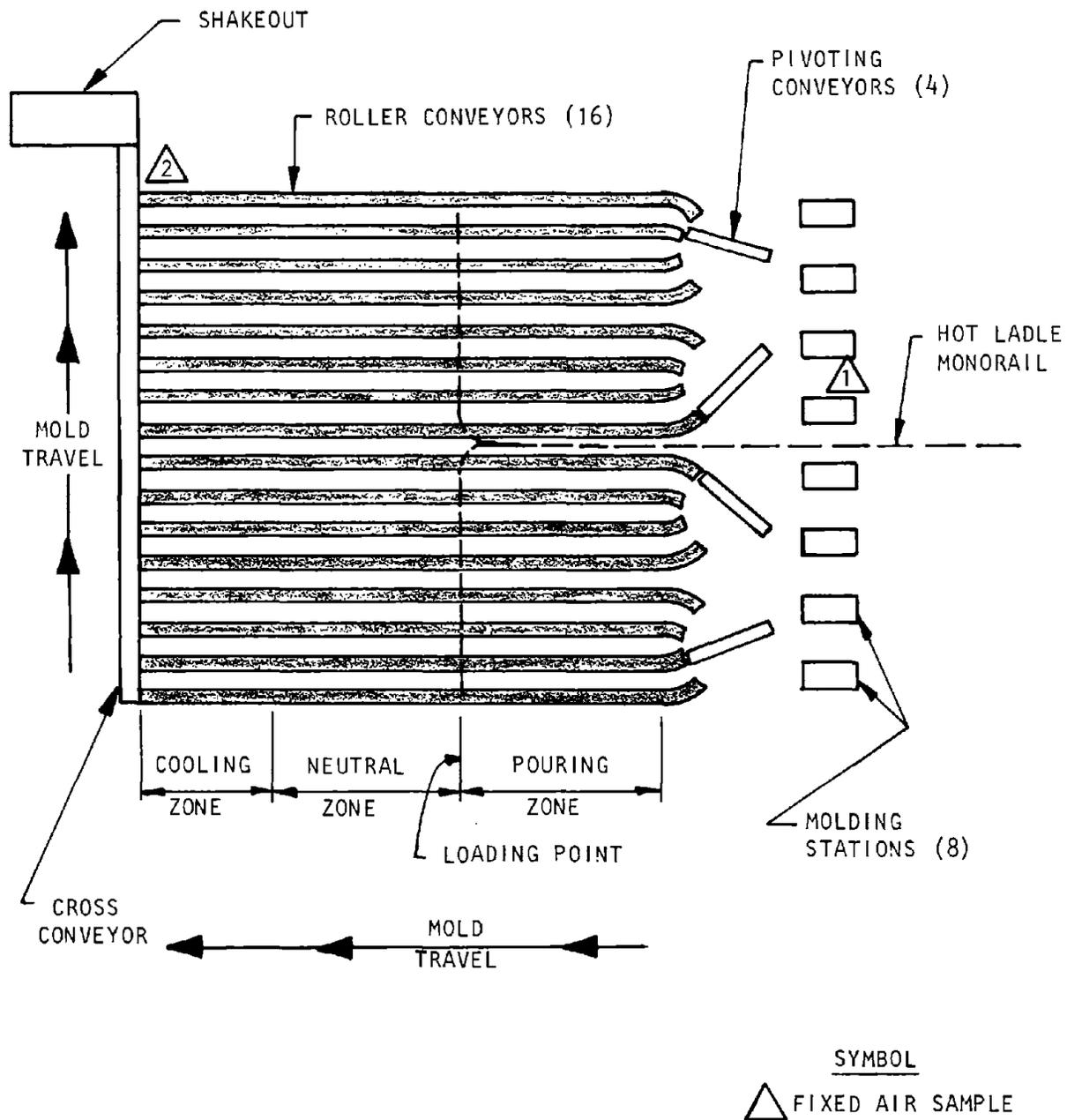
Figure A21-1. Layout of pouring floor.

Table A21-1. Summary of work tasks, floor casting unit.

No. of workers	Job title	Location	Task	Percent of time
8	Molders (green sand).	Adjacent to pouring area.	Made green sand molds, installed cores, closed molds.	100%
4	Weight and jacket shifters.	Pouring area.	Distributed molds equally among conveyor lines.	50%
			Moved weights and jackets from previously cast molds to new molds prior to casting.	
2	Metal pourers.	To and from holding furnaces and inoculation station.	Transported metal to pouring line.	25%
		Pouring area.	Poured metal into molds.	75%
I	Shakeout operator.	Shakeout station.	Moved poured molds into cooling area and from cooling area to shakeout using "pusher dog" system. Manually dumped molds onto shakeout.	50%
			Transported bottom boards back to molder stations.	50%

Materials and Rates

The foundry was a job shop and several different castings were poured on the days of the investigation. The common flask size was 20 inches (0.2 m) x 24 inches (0.6 m).

On the first day, malleable iron was poured on one side of the floor and ductile iron on the other. On the second day, only malleable iron was poured. The cores used were small [0.5 - 5.0 lbs (0.2 - 2.3 kg)]; the majority were shell cores with a few oil sand cores. Casting weights ranged from 9-82 lbs (4-37 kg). Sand bonding additives to the mold included 6% western bentonite, 3% low sulfur sea coal, and small amounts of corn flour.

WORKPLACE HAZARDS

The major air contaminant hazard to pourers and jacket and weight shifters was primarily due to metal fume and products of thermal decomposition of mold constituents. The pouring operators were also subjected to metal fume during the transport of hot metal ladles to and from the holding furnaces and the post-inoculation ladle. Metal fume of hygienic significance included iron, lead, zinc, magnesium and manganese. Potential mold and core decomposition products included carbon monoxide, ammonia, phenol, formaldehyde, and hydrogen cyanide. Metal pourers were also exposed to infrared radiation from the molten metal.

CONTROL OF EXPOSURE

Air contaminants were controlled in the pouring area by the immediate removal of poured molds to the cooling area and through dilution ventilation. Fuming from molds in the isolated cooling area was partially controlled by a sidedraft hood.

Engineering

Isolation of Cooling Molds--
Remote control of mold transfer from the pouring to the cooling area and from the cooling area to the shakeout isolated workers from the cooling area.

The remotely controlled system, consisting of a chain driven "pusher dog" and a cross-conveyor belt, is shown schematically in Figure A21-2. A 1.5 hp (1.12 kw) gearmotor drove a chain sprocket which, in turn, moved a retractable "pusher dog" along the top of the roller conveyor under the bottom boards of the molds. When moving from the cooling area to the pouring area to pick up molds, the spring loaded dog would retract as it passed under the bottom boards. After clearing the last mold, the dog would again extend upward, so that when the gearmotor was reversed it would catch on the bottom board and push all of the molds ahead of it into the cooling area (Figure A21-3). With this type of system, tension was only applied in the section of chain between the drive sprocket and the "pusher dog". Therefore, cable was used on the return section because of the expense of chain.

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BUMPER GUIDE

MOLDS

SHORT ROLLERS

DRIVE SPROCKET

TRANSFERRING MOLD

TAIL PULLEY

CROSS-CONVEYOR

CHAIN

PUSHER DOG

TAIL PULLEY WITH TAKE-UP

CABLE

DRIVE SPROCKET

LIMIT SWITCH

ROLLER CONVEYOR

LIMIT SWITCH

ELEVATION VIEW
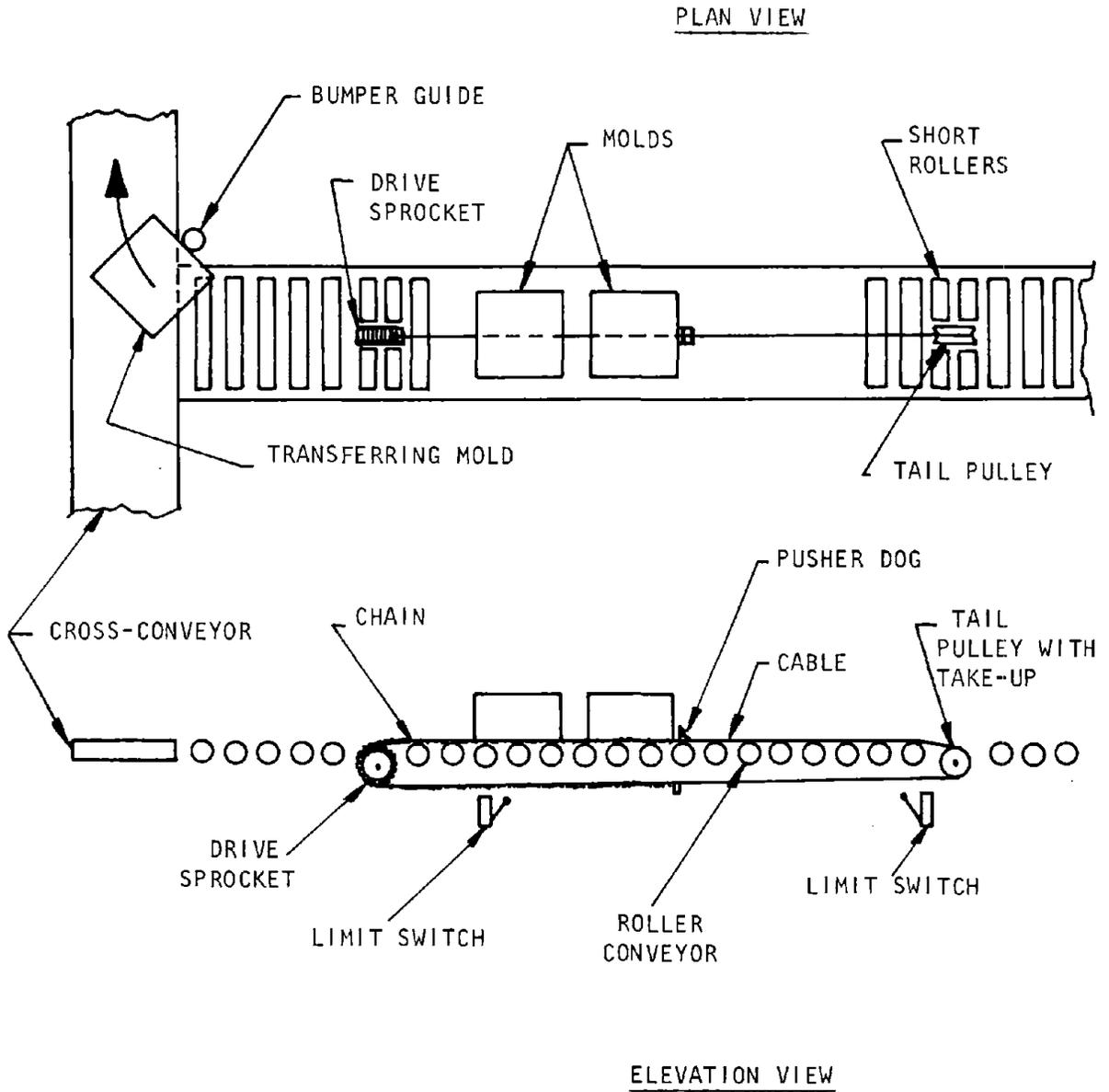
Figure A21-2. Mold transport system.

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Limit switches constrained the movement of the "pusher dog" on top of the roller conveyor.

As can be seen in the schematic view in Figure A21-2, the mold pull-down system did not extend the entire length of the cooling area. Rather, it terminated somewhat short of the cross-conveyor, requiring that four molds fill this section of conveyor before the "pusher dog" would move the first mold onto the cross-conveyor.

Localized Control of Cooling Area--
The isolated cooling area was exhausted by a sidedraft hood located directly behind the cross-conveyor (Figure A21-3). Cooling fume was pushed toward the hood by the prevailing air flow pattern created predominantly by a series of large fans located in the pouring area (Figure A21-4).
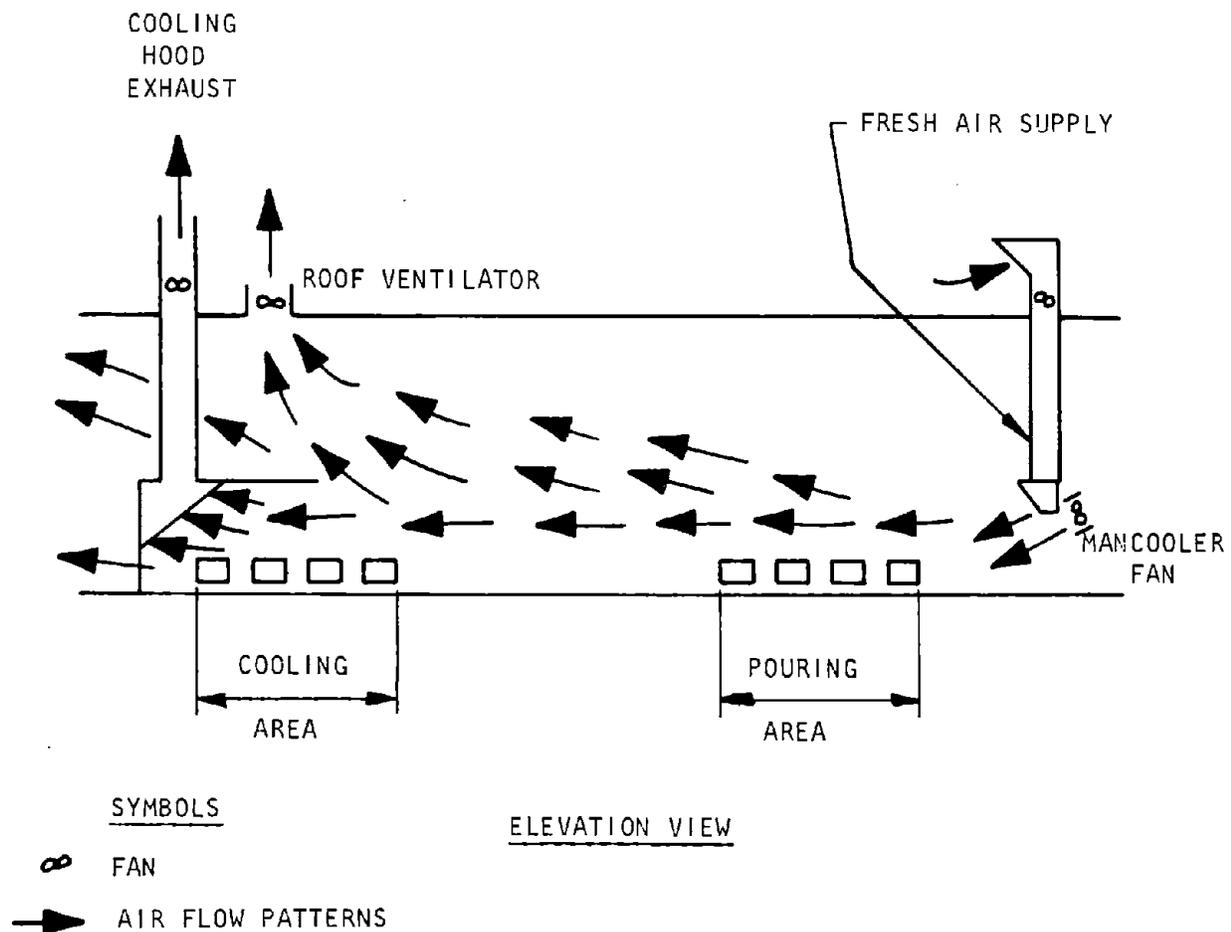
Figure A21-4. Ventilation patterns on pouring deck.

Thus, the hood removed cooling fume, as well as a portion of the pouring fume. Although the cooling area could have been enclosed except for the side

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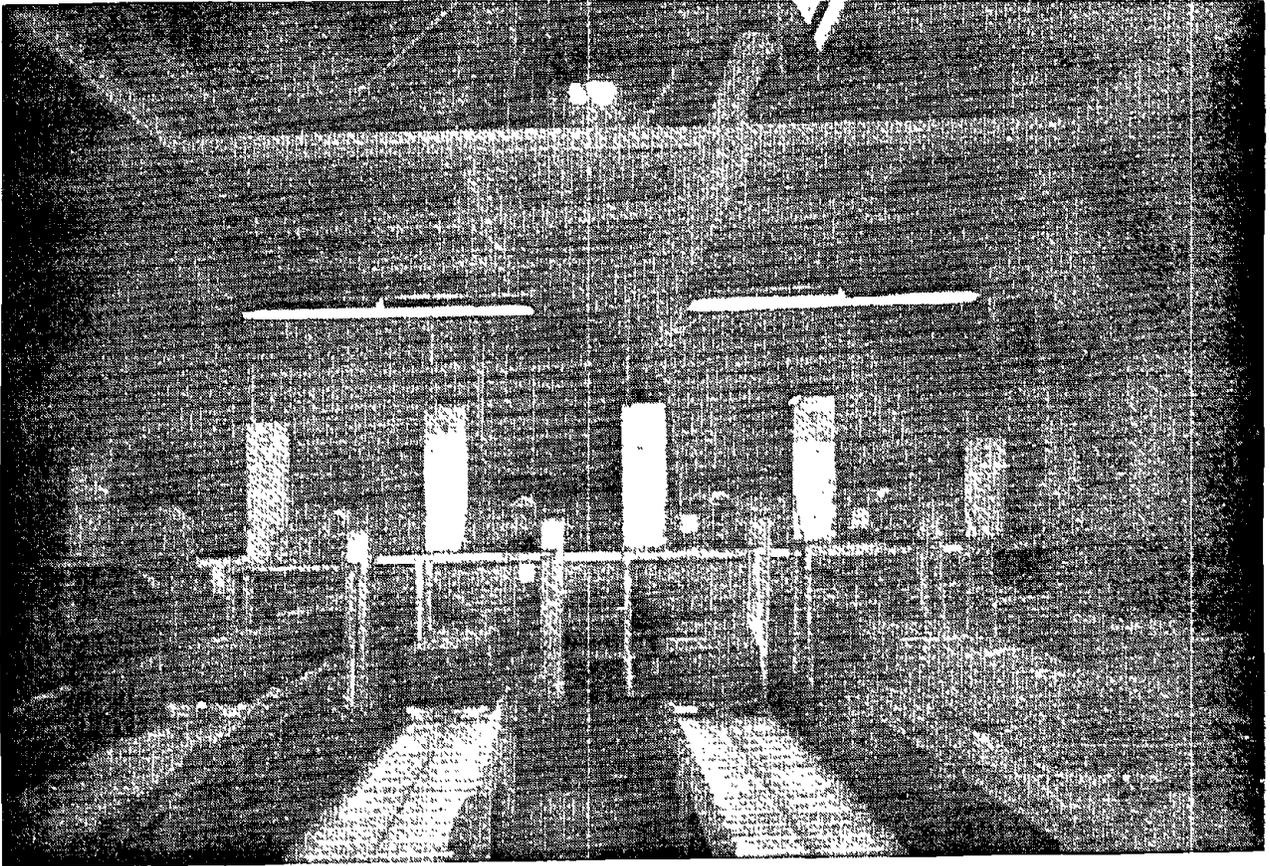
Figure A21-3. Mold cooling area.

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facing the pouring line and a small opening on one side for the cross-conveyor, only a section of roof baffling had been installed to help contain the cooling fumes. With this limited amount of enclosure and the low exhaust flow of the sidedraft hood [25,000 cfm (11.8 m3/sec)], cooling fume escaped over and around the hood.

General Ventilation of Pouring Area--
A large volume of air was introduced into the pouring area, blowing smoke away as soon as it was produced (Figure A21-4) and providing heat relief for workers on the pouring deck. Air velocities on the pouring deck ranged from 300-410 fpm (1.5-2.1 m/sec) on the downwind and upwind ends, respectively. However, because two-thirds of the air used to achieve dilution [110,000 cfm (52 m3/sec)] was recirculated plant air, the pouring deck operators were subjected to cross contamination from upwind processes such as the holding furnaces, molding stations, or other nearby casting units.

The roof area was inspected by the investigative team to assure that exhaust air was not contaminating the supply air. While supply and exhaust were at the same level, the supply air was filtered and there was sufficient distance between its inlet and any other emission points on the roof to prevent short-circuiting.

Personal Protective Devices

Metal pourers wore tinted glasses to protect their eyes from infrared radiation.

RESULTS

1. Metal fume concentrations were consistently low in the breathing zones of pouring floor operators, as well as upwind and downwind of the pouring area (Table A21-2).

2. Exposures to respirable silica were below the allowable limits (Table A21-3).

3. Products of decomposition were not a problem for pouring floor operators. Carbon monoxide levels in the pouring area ranged from 15-20 ppm upstream to 20-25 ppm downstream. The highest level measured in the area, 40 ppm, occurred directly in front of the cooling hood, where no workers were located. Detector tube measurements of hydrogen cyanide, formaldehyde, and ammonia in the pouring area were below detectable limits. One detector tube measurement taken directly downwind of smoking molds showed a value for phenol of 2.5 ppm (9.8 mg/m3) or half of the OSHA exposure limit. To further explore this potential problem one of the investigators wore an impinger sampler simulating the exposure of the weight-and-jacket shifter for one hour by following in his footsteps. The impinger sample was below detectable limits [<0.003 ppm (<0.01 mg/m3)].

Table A21-2. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average exposure 8 hr. workday, mg/m^3				
				Fe	Mn	Zn	Pb	Mg
Metal pourer	3	Pers.	Hi	0.440	0.044	0.250	0.043	0.018
			Lo	0.370	0.029	0.140	0.029	0.012
			M	0.400	0.034	0.195	0.033	0.014
Weight and flask shifter	3	Pers.	Hi	0.540	0.031	0.196	0.029	0.023
			Lo	0.230	0.012	0.044	0.012	0.015
			M	0.360	0.027	0.080	0.027	0.018
Molder stations (1, Fig. A21-1)	6	Fixed	Hi	0.580	0.032	0.145	0.033	0.025
			Lo	0.200	0.010	0.066	0.014	0.011
			M	0.358	0.016	0.085	0.020	0.014
Adjacent to cooling (2, Fig. A21-1)	3	Fixed	Hi	0.500	0.032	0.208	0.034	0.019
			Lo	0.380	0.015	0.118	0.026	0.012
			M	0.413	0.023	0.157	0.029	0.015
OSHA PEL				10.0§	5.0*	5.0†	0.20#	15.0Ω
ACGIH TLV (1977)				5.0§	5.0*	5.0†	0.15#	10.0Ω

§ Iron oxide fume.
* Ceiling value, short term sampling was not undertaken because of the expected low exposure.
† Zinc oxide fume.
# Lead, inorganic fume and dust as Pb.
Ω Magnesium oxide fume.

Table A21-3. Air sampling results - respirable silica.

Worker or location	Sample type	Percent quartz	Respirable dust exposure, mg/m^3	Allowable respirable dust exposure, mg/m^3 §
Molder stations (#1, Fig. A21-1)	Fixed	1.8 3.5	1.30 0.93	2.63 1.82
Weight and jacket shifter	Pers.	8.2	0.77	0.98
Previous sampling data				
Molders	Pers.	-- 1.8	0.80 0.90	5.00 2.60
Shakeout operator	Pers.	--	1.20	5.00

§ OSHA PEL and ACGIH TLV (1977).

CASE HISTORY #22
CONTROL OF SMOKE AND FUME DURING POURING OF
SHELL MOLDS
NOVEMBER, 1977

ABSTRACT

Pouring of shell molds created substantial smoke and fume which was controlled by a push-pull ventilation technique. The technique employed a partially enclosing hood around the pouring conveyor and a fresh air supply overhead to push the smoke into the hood. The exhaust hood by itself would not have captured the emissions because the pouring point was by necessity, very close to the front of the enclosure. Smoke and fume were well controlled by the hood except in one small section of the line where the push air distribution was inadequate and smoke escaped. Metal fume and products of thermal decomposition of molds were controlled below allowable limits. In addition to assisting capture of smoke, the fresh air helped to cool workers.

PROCESS DESCRIPTION

Equipment and Operation

Shell molds were poured on a mechanized pouring line by several metal pourers (Figure A22-1). They filled their hot metal ladles from a large metal transport ladle at a location adjacent to the pouring line, and then manually pushed them along the moving, pouring conveyor as they poured. Several metal pourers were on the 48 ft (14.6 m) long pouring line at any one time. After their ladles were emptied, they exited at the opposite end of the pouring line and completed the loop back to the ladle filling point. After the molds left the pouring line they entered a long enclosed cooling tunnel.

Materials and Rates

During the survey the foundry was pouring iron with the following controlled alloy amounts:

Amount of metal poured/shift		Alloy composition, %				
lbs.	kg	Mn	Ni	Cr	Cu	Fe
23,200	10,533	0.75	0.15-0.50	0.27-0.50	0.08	92.2
7,350	3,337	0.40	3.50	2.10	0.12	89.4
2,450	1,112	1.25	14.00	1.85	6.00	71.7
Total 33,000	14,982					

A total of 1,342 shell molds were poured during the shift with an average cast weight of 24.6 lbs (11.2 kg). Sand/metal ratio varied from 1.25-1.5

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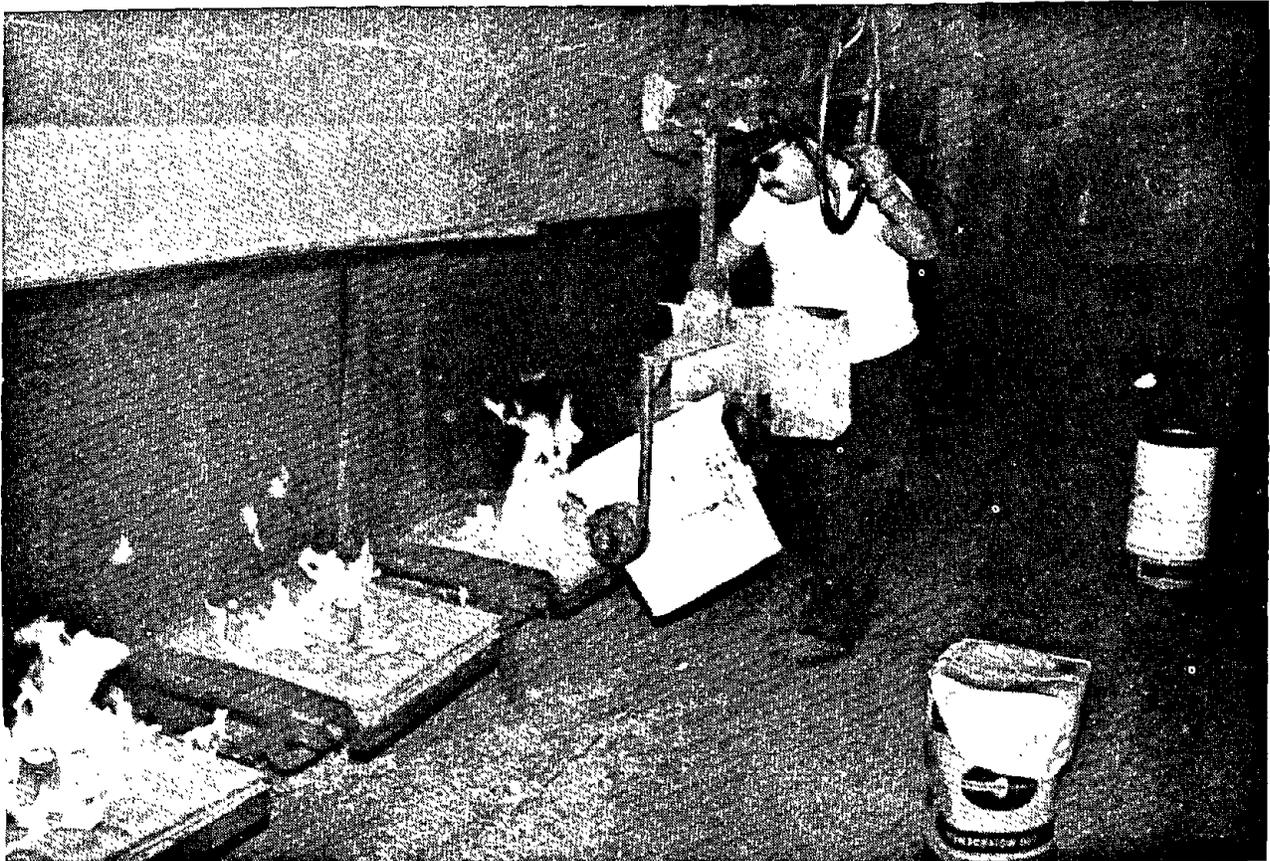
Figure A22-1. Pouring of shell molds.

WORKPLACE HAZARDS

The major air contaminant hazard from the pouring operation was fume inhala-
tion. The metals of hygienic significance in the fume consisted of iron,
manganese, nickel, chrome, copper, lead, and zinc. Products of thermal
decomposition of shell molds included carbon monoxide, phenol, ammonia,
and formaldehyde. Metal pourers were also subject to infrared radiation
from the hot metal.

CONTROL OF EXPOSURE

Shell mold pouring was controlled by a "push-pull" localized control system
which incorporated a partially enclosing pouring hood and a fresh air
supply located above and behind the metal pourers.

Engineering

The pouring hood enclosed the entire mold conveyor leaving only a 4.3 ft
(1.3 m) high opening for pouring the molds (Figure A22-2). A slotted
takeoff at the upper back of the hood provided 500 cfm/linear ft (0.77
m³/sec-m) of exhaust along the entire length of the pouring line at a
slot velocity of 1500-2000 fpm (7.62-10.16 m/sec). This amount of exhaust
was substantially higher than the ACGIH recommended range of 200-300
cfm/linear ft (0.31-0.46 m3/sec-m) for partially enclosed pouring stations[§].
Even though the exhaust flow was higher than recommended, the pouring hood
required the push air to capture all of the smoke from the burning molds.
The smoke was generated just below the front edge of the hood and the
rising thermal draft needed to be deflected toward the back of the hood
for complete capture.

The total exhaust flow from the pouring line [23,800 cfm (11.2 m³/sec)] was
cleaned by a fabric collector before being discharged to the outdoors.

The untempered fresh air supply was distributed at a rate of 775 cfm/linear
ft (1.2 m3/sec-m) from grilles located 11.2 ft (3.4 m) above the foundry
floor. The fresh air provided an average of 160 fpm (0.8 m/sec) of down-
draft velocity at the front lower edge of the hood, which helped to contain
the billowing smoke within the hood. However, when the molds passed a
certain short section of the pouring line where the fresh air was not
distributed properly, the downdraft velocity dropped below 100 fpm
(0.50 m/sec) and smoke escaped.

General Ventilation

The amount of fresh air supplied to the pouring area [37,180 cfm (17.5
m3/sec)] was higher than the amount exhausted [23,800 cfm (11.2 m3/sec)],
thus helping to prevent cross contamination from other process areas.

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§ Reference no. 17, print no. VS-109.

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FRESH
AIR
SUPPLY

LADLE
MONORAIL

SLOTTED
EXHAUST

MOLD
HANGER

POURING LADLE

SHELL MOLD
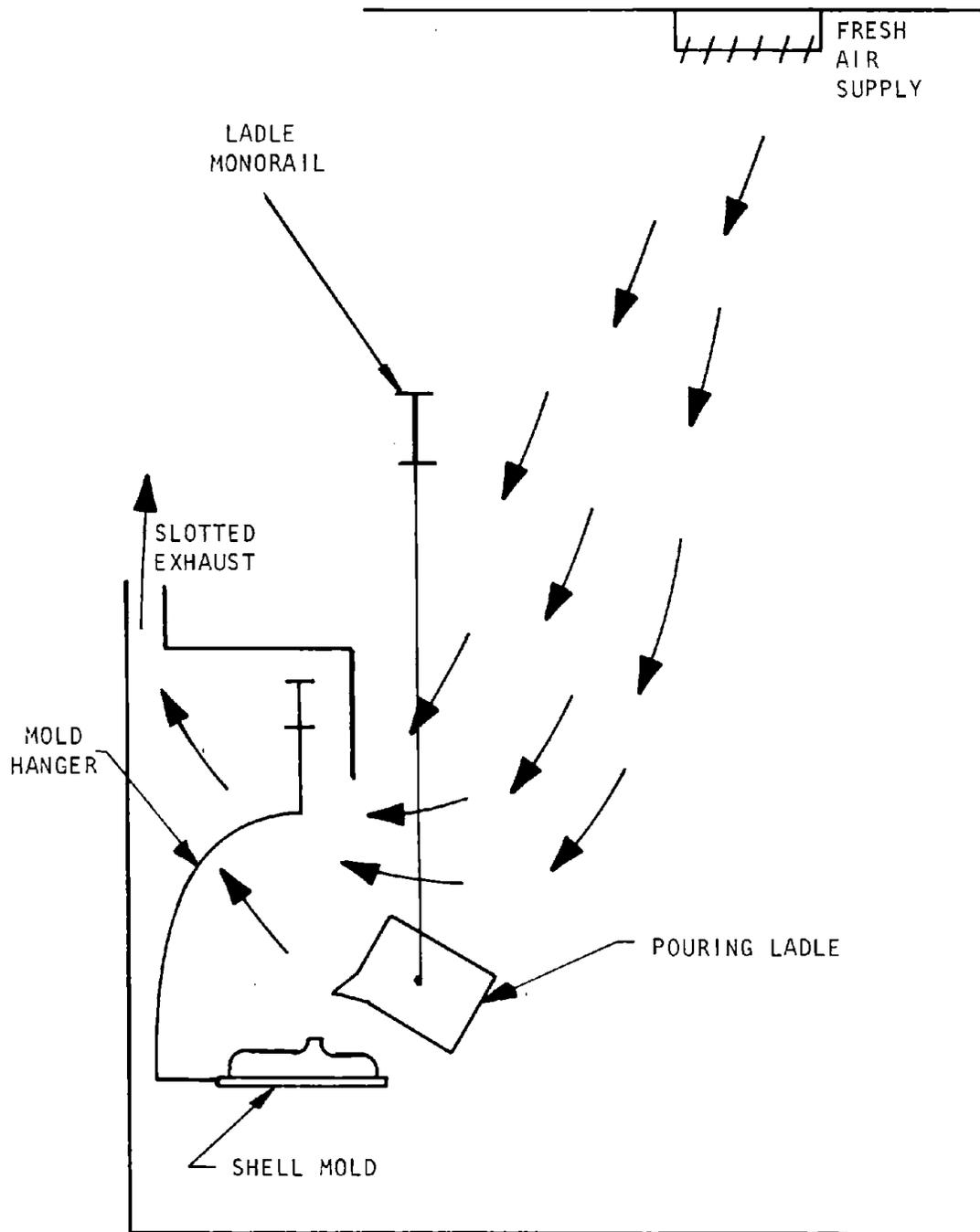
SYMBOLS

AIR FLOW PATTERNS

Figure A22-2. Shell pouring operation.

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PERSONAL PROTECTIVE DEVICES

Metal pourers wore tinted safety glasses to protect their eyes from infrared radiation.

RESULTS

1. Metal fume exposures were well controlled below the allowable limits (Table A22-1).

2. Phenol, ammonia, and formaldehyde were below detectable limits. Carbon monoxide ranged from 15-25 ppm on the pouring deck.

Table A22-1. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average exposure/ 8 hr. workday, mg/m^3				
				Fe	Ni	Mn	Cr	Cu
Metal pourers	3	Pers.	Hi	0.52	0.02	0.11	<0.01	0.01
			Lo	0.49	0.01	0.10	-	0.01
			M	0.51	0.02	0.11	-	0.01
Background (between ladle filling area and furnaces)	1	Fixed		0.62	0.03	0.15	<0.01	0.03
OSHA PEL				10.0§	1.0	5.0†	1.0#	0.1Ψ
ACGIH TLV (1977)				5.0§	1.0	5.0†	0.5Ω	0.2Ψ

§ Iron oxide fume.
† Ceiling value, short term sampling was not undertaken because of the expected low exposure.
# Metal and insoluble salts.
Ω Chromium, chromic acid and chromates.
Ψ Copper fume.

CASE HISTORY #23
FUME CONTROL DURING DUCTILE TREATMENT
AUGUST, 1977

ABSTRACT

A special station was constructed for ductile treatment, permitting effective isolation of the process and ease of installation of an enclosing hood. The effectiveness of the hood was demonstrated by the low exposure of the operator to metal fume, as well as the obvious high quality of the general workroom air.

PROCESS DESCRIPTION

Equipment and Operation

The ductile iron melting and pouring process consisted of two-25 ton (22.7 metric ton) coreless induction furnaces supplying hot metal to a mechanized pouring line. A plan view of the melting area is shown in Figure A23-1. Hot metal was transported in a treatment ladle by a monorail crane to the treatment station, where the ladle was placed at position 1 on a rotating platform (Figure A23-1). In rapid succession, the ladle was treated at position 2 and then post-inoculated at position 3. When the turntable completed its cycle to position 1, the ladle was removed and transported first to the slagging station, and then to the pouring line. During normal production, such as during the days of the study, the monorail operator would load a ladle onto the ductile treatment platform and then wait for treatment to be completed before picking up the ladle. During high production times the monorail operator could load position 1 and unload position 3 at the same time.

Ductile treatment was remotely-controlled by an operator from a booth next to the rotating platform. Remotely-controlled operations included: platform indexing; submerging the plunging bell into the metal using a hoist at position 2 and later raising it, and stirring the melt with an up-down motion using a pneumatic cylinder drive at position 3.

Manual tasks included:

1. Fastening and unfastening the monorail carriage from the treatment ladle at position 1.

2. Loading the plunging bell with magnesium alloy at position 2.

3. Adding a bag of inoculant into the ladle before post-inoculation at position 3.

4. Preparing and installing new plunging bell assemblies when needed.

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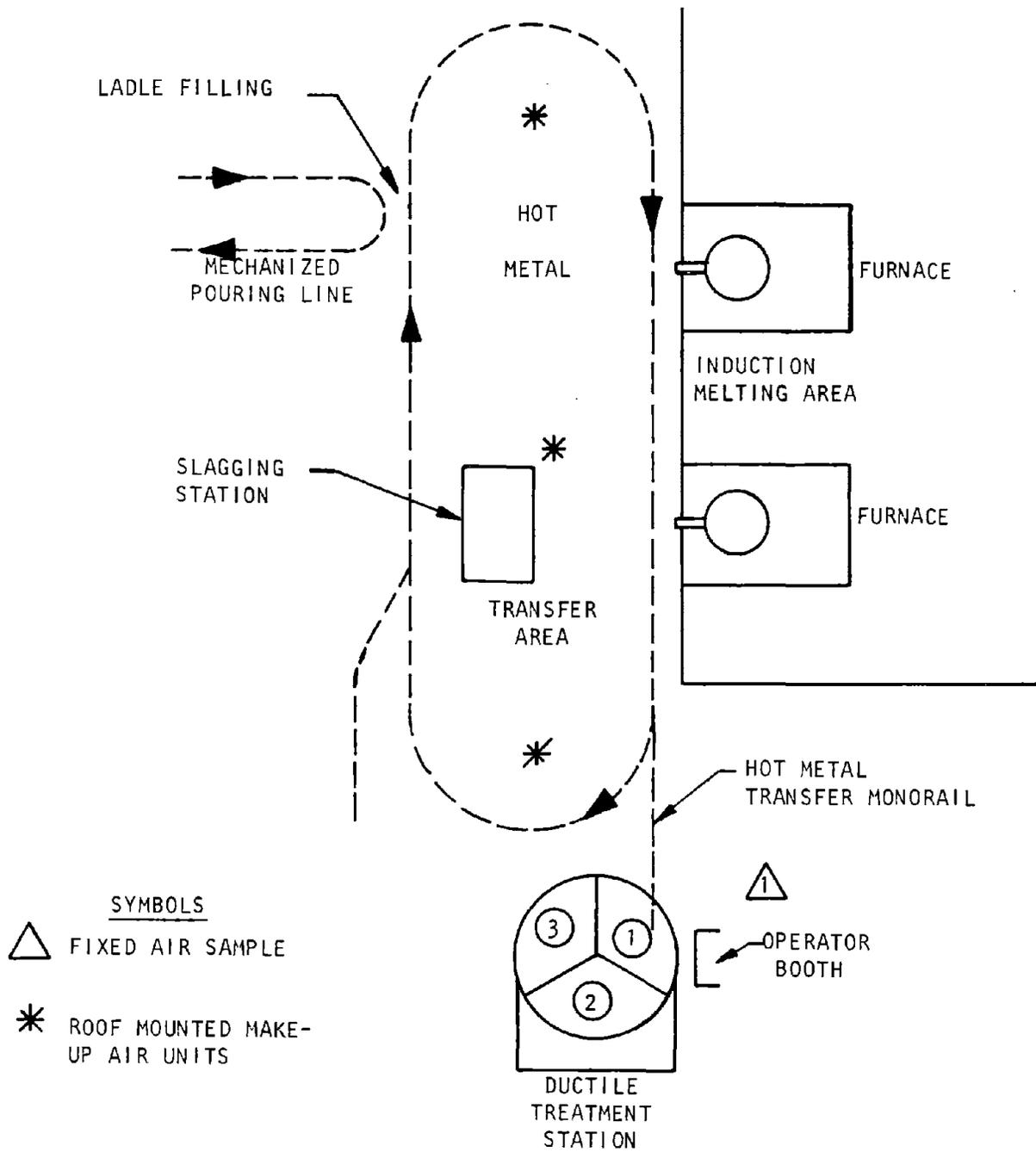
Figure A23-1. Induction melting department.

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Materials and Rates

Ductile treatment was accomplished in 2700 lb (1226 kg) and 3600 lb (1634 kg) batches at the rate of six ladles per hour. The treatment lasted a little over four minutes and was composed of:

1. Inoculation with combinations of magnesium-bearing alloys.
2. Post-inoculation with ferro-silicon.

WORKPLACE HAZARDS

The major air contaminant hazard from inoculation was fume inhalation. The metals of hygienic significance in this ductile treatment operation included iron, magnesium, lead, nickel, and manganese. The major amount of emissions were given off during treatment with magnesium at position 2. The treatment produced a violent reaction with intense visible radiation and metal splashing.

CONTROL OF EXPOSURE

Ductile treatment on the turntable had the advantage of permitting isolation under a hood and operation by remote control. The hood contained the fuming and provided a barrier to shield the bright radiation and metal splashing during treatment with magnesium.

Engineering

Control at the Source--
The exhaust hood enclosed the plunging bell assemblies and jib crane at position 2 (Figure A23-2) and the post-inoculation stirrer at position 3. The four outside vertical sides of the hood (dashed lines in plan view in Figure A23-3) extended down to about two feet (0.6 m) below the top of the ladle (Figure A23-2). Around position 2 the bottom 40 inches (1 m) of these panels were constructed of flexible material to prevent damage by forklift trucks which delivered and removed plunging bell assemblies. The two vertical sides isolating positions 2 and 3 from position 1 were composed of fixed panels extending down to just above the ladle (dashed lines in Figure A23-3), and panels attached to the rotating platform (solid lines on Figure A23-3) extending up to meet the fixed panels.

Two hood exhaust takeoffs were located directly above ladle positions 2 and 3. Total exhaust flow from the hood of 12,200 cfm (5.75 m3/sec) was passed through a fabric filter before being discharged outdoors. The flow caused a calculated average updraft of 65 fpm (0.33 m/sec) into the hood. Blast gate dampers permitted separate control of exhaust at the two treatment positions. Exhaust control during inoculation at position 2 is shown in Figure A23-4.

The enclosing hood captured almost all metal treatment fume and was minimally affected by cross-drafts. Fume containment was enhanced by the metal shroud surrounding the plunging bell. The shroud was seated on top of the ladle during treatment with magnesium to contain the violent

SHEET METAL
HOOD

HOIST

SHROUD

FLEXIBLE
PANEL

PLUNGING BELL

PANELS ATTACHED
TO PLATFORM,
THREE SEPARATE
POSITIONS

HOLE FOR
INOCULANT
RETAINER
PIN

SIDE VIEW
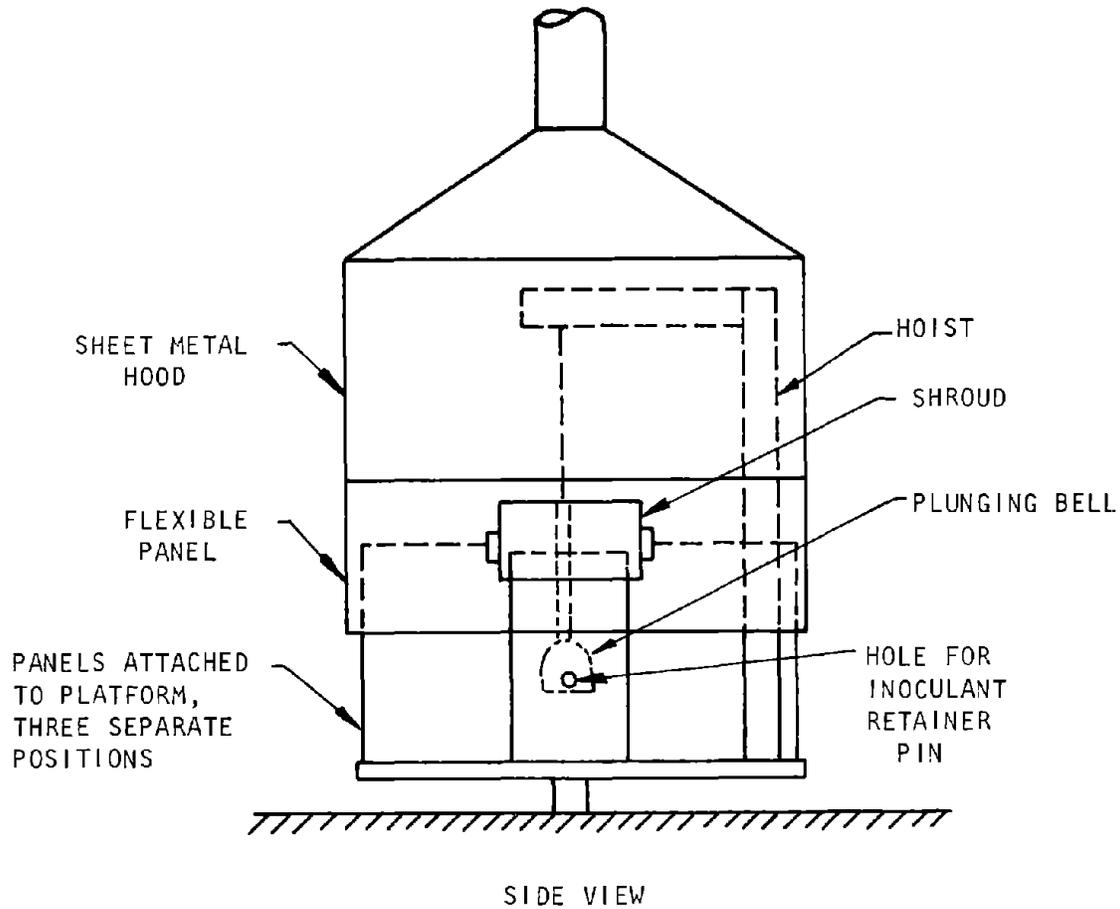
Figure A23-2. Plunging bell assembly at position 2.

reaction. Some fume was seen to escape, however, caused by two preventable
problems with the hood:

1. Fume escaped through slots in the top of the hood where electrical
    conduits fed down to the hoist. These spaces could have been sealed.

2. Clearance space between upper and lower vertical panels isolating
    positions 2 and 3 from position I was too great (several inches)
    and some fume escaped through this space.

General Ventilation--
The hot metal transfer area contained several sources that were controlled
by general ventilation only: hot metal transfer, slagging, and filling of
pouring ladles. General ventilation consisted of three large makeup air
units mounted in the roof within the hot metal transfer area.

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ROTATING PLATFORM

HOT METAL
TRANSFER
MONORAIL

HOT METAL LADLE

BAFFLES ON ROTATING PLATFORM

METAL STIRRER

POSITION
-3-
POST-
INOCULATION

POSITION
-1-
LOADING-
UNLOADING

PLUNGING
BELL WITH
SHROUD

ALTERNATE
PLUNGING BELL
ASSEMBLY

POSITION
-2-
MAGNESIUM
INOCULATION

OUTLINE OF HOOD

PLAN VIEW
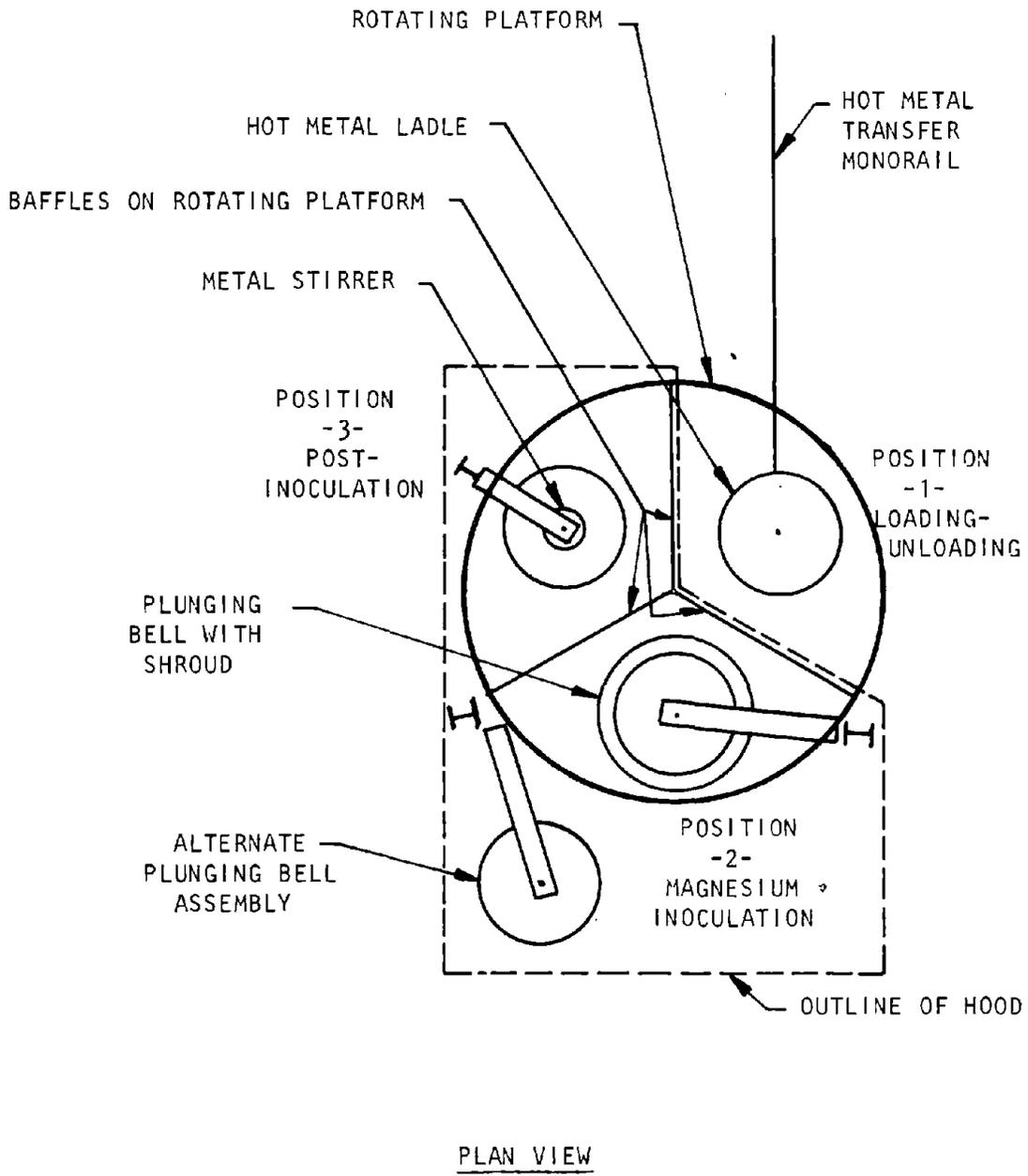
Figure A23-3. Ductile treatment station.

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Figure A23-4.   Plunging bell inoculation in progress.

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Personal Protective Devices

The treatment operator required the protection of an aluminized full arm
protector and a hard hat with face shield during the loading of alloy
into the plunging bell before each ladle was treated.

RESULTS

1. The concentration of metal fume in the breathing zones of the
ductile treatment operator and the hot metal monorail operator
was well below the allowable limits (Table A23-1).

Table A23-1. Air sampling results - metal fume.

Worker or location	Number of samples	Sample type	Range, mean	Time weighted average exposure/ 8 hr. workday, mg/m^3				
				Fe	Ni	Mn	Pb	Mg
Hot metal monorail operator	4	Pers.	Hi	0.42	<0.01	0.01	0.03	0.21
			Lo	0.25	<0.01	0.01	0.01	0.10
			M	0.33	<0.01	0.01	0.02	0.16
Ductile treatment operator	2	Pers.	Hi	0.25	<0.01	0.01	0.02	0.43Ψ
			Lo	0.23	<0.01	<0.01	0.02	-
			M	0.24	<0.01	<0.01	0.02	-
Operator station (1, Fig. A23-1)	3	Fixed	Hi	0.33	<0.01	0.02	0.04	0.17
			Lo	0.21	<0.01	<0.01	0.01	0.13
			M	0.28	<0.01	0.01	0.02	0.15
OSHA PEL				10.0§	1.0	5.0†	0.20#	15.0Ω
ACGIH TLV (1977)				5.0§	1.0	5.0†	0.15#	10.0Ω

§ Iron oxide fume.
† Ceiling value, short term sampling was not undertaken because of the
expected low exposure.
Lead dust and fume.
Ω Magnesium and magnesium oxide.
Ψ Only one sample was analyzed for magnesium.

2. Protection of the ductile treatment operator was an essential
consideration in the design of the ductile treatment hood, however,
background air quality in the hot metal transfer area was also
significantly improved by the control (Table A23-1).

3. In addition to protecting the workers from fume exposures, the hood,
assisted by the shroud covering the plunging bell, shielded the
operator from bright visible radiation and contained hot metal
splashing.

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CASE HISTORY #24
FUME CONTROL OF SANDWICH INOCULATION
FEBRUARY, 1978

ABSTRACT

The combination of a furnace-mounted canopy hood and a roof exhauster effectively removed fume during sandwich inoculation and filling of pouring ladles. A roof exhauster had previously been used to control fuming, assisted by baffles extending downward from roof level to help contain the fume. Crossdrafts, however, had caused fume to escape capture and to contaminate other foundry areas. The new furnace mounted exhaust hood captured virtually all of the inoculation fume at the source eliminating the largest contributor to the emission problem. The ladle filling process was exhausted effectively by the roof exhauster except at the farthest position of ladle tipping when a small amount of fume did escape into operator areas. No air samples were taken in this particular case study.

PROCESS DESCRIPTION

Equipment and Operation

Metal from one of two cupolas continuously flowed into a holding furnace. Inoculation using the sandwich method took place in the treatment ladle as the holding furnace was tapped. After inoculation, iron from the treatment ladle was transferred to two pouring ladles. A photograph of the treatment ladle in front of the holding furnace is shown in Figure A24-1.

Two workers were involved in the inoculation and ladle transfer process, an inoculator and a turnout man. Their duties are listed below:

Inoculator	Turnout man
Weighed and added magnesium inoculant.	Prepared and added steel chips into inoculation ladle.
Operated furnace tilt controls.	Operated inoculation ladle hoist controls.
Activated damper in exhaust duct.	
Prepared and added post-inoculant.	

Materials and Rates

Inoculation occurred at an average interval of 4-1/2 minutes (106 times per workshift). Molten iron was tapped from a 22 ton (20 metric ton) holding furnace into a treatment ladle that held 2400 lbs (1090 kg) of metal. Sandwich inoculant materials consisted of 66 lbs (30 kg) of 5% magnesium

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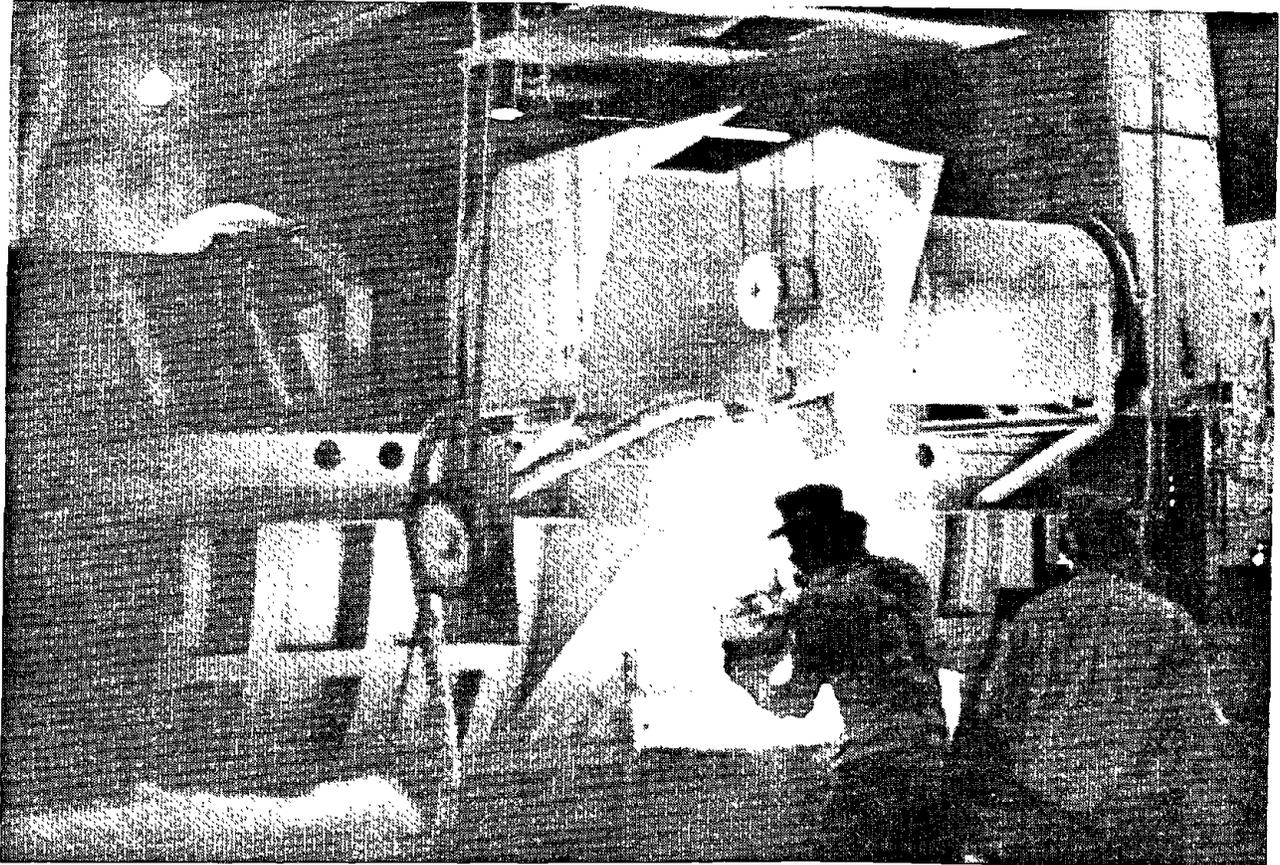
Figure A24-1. Inoculant addition prior to tapping of holding furnace into treatment ladle.

alloy charge covered by 50 lbs (23 kg) of metal chips. Following tapping into pouring ladles, 7 lbs (3.2 kg) of 75% ferro-silicon post inoculant was added to each ladle.

WORKPLACE HAZARDS

The major air contaminant hazard from inoculation and the metal transfer process was from magnesium oxide and iron oxide fume. Workers were also subjected to infrared radiation from the molten metal and hot ladle, and intense visible radiation from inoculation.

CONTROL OF EXPOSURE

Engineering

Control at the Source--
A commercially available canopy hood mounted on the holding furnace controlled fume during the sandwich inoculation process. The fume-laden air was exhausted through a mobile ductwork system and cleaned by a fabric collector before being discharged outdoors. The exhaust hood is shown with the furnace in the upright position in Figure A24-1. As the furnace tilted forward to tap into the treatment ladle the exhaust hood tilted with it and assumed a position directly over the ladle to capture fume carried in the thermal draft. Fume capture during one minute of inoculation was virtually complete at a flow rate of 13,400 cfm (6.31 m3/sec). When the process was completed the furnace was tilted back and the exhaust flow was reduced to 5,000 cfm (2.4 m3/sec) for the remainder of the cycle.

General Ventilation--
Although fume capture was complete during inoculation, escaping emissions did occur during the time the treatment ladle was being moved away from the furnace and emptied into pouring ladles. During this time the ladle was out of the influence of the inoculation exhaust hood. Most escaping fume was carried upward in the thermal draft and was exhausted by a roof exhauster of 15,000 cfm (7.1 m3/sec) capacity, directly overhead. Baffles extending down from roof level helped to contain the fumes. While the second ladle was being filled, the treatment ladle was tipped very far and some of the escaping fume entered worker areas during this short period. The exposure at this time was minimal.

Personal Protective Equipment

Melting area operators wore tinted safety glasses to shield their eyes from infrared radiation.

CASE HISTORY #25
CARBON MONOXIDE CONTROL
DURING LADLE CURING
JANUARY, 1978

ABSTRACT

Carbon monoxide emission during ladle curing was controlled through an exhaust enclosure around the ladle drying station. The station removed heat from the area, controlled carbon monoxide, and reduced noise from the combustion burners.

PROCESS DESCRIPTION

Ladle repair was done in a separate building. After linings were removed and replaced, the ladles were placed under 500,000 BTU/hr (146 kilowatt) ladle curing heaters. A plan view layout of the ladle repair room is shown in Figure A25-1. Approximately eight ladles were cured per shift.

WORKPLACE HAZARDS

The major air contaminant hazard from this process was carbon monoxide. When flames from the burners impinged on cold lining surfaces, premature cooling of the flames resulted causing incomplete combustion.

CONTROL OF EXPOSURE

A custom-built ladle hood permitted easy access for placement and removal of ladles. The hood contained a series of overlapping doors which could be moved to provide access to any of the ladles. A side view of the door arrangement is shown in Figure A25-2, and a front view is shown in the photo in Figure A25-3.

The booth was exhausted by 6-9500 cfm (4.5 m3/sec) wall fans within the hood. The hood doors were 2 inches (5 cm) thick, lined with acoustical material covered by perforated metal.

There were a total of 10 doors mounted on heavy duty metal rollers; they could be rolled by hand. Theoretically, 5 doors could be open at any one time.

The amount of in-draft to the hood was sufficient to exhaust the products of combustion, as well as to prevent escape of gases through gaps around, under, and between the panels.

RESULTS

The concentration of carbon monoxide ranged from 5-8 ppm in the workplace environment and 10 ppm under the hood.
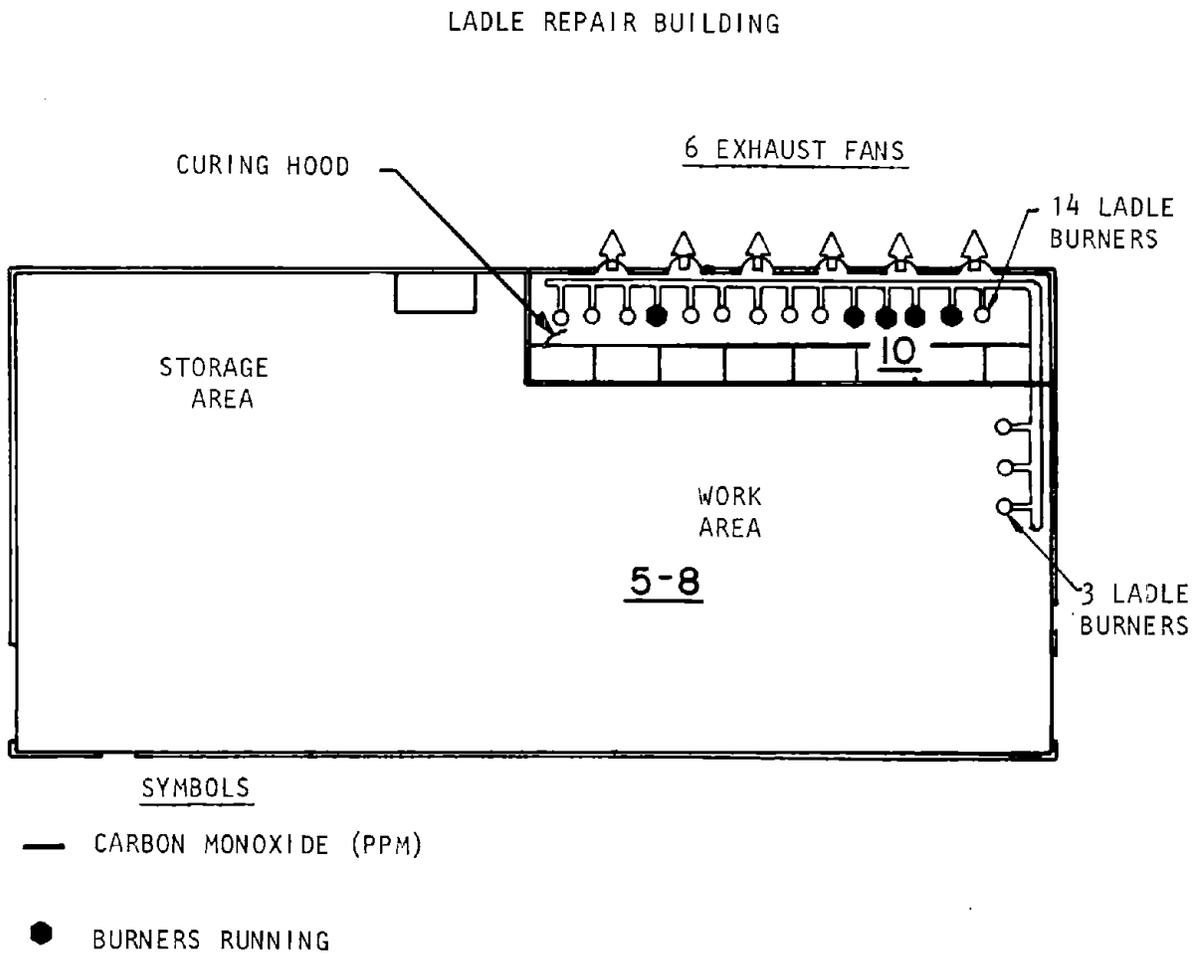
Figure A25-1. Carbon monoxide measurements around
ladle curing process.
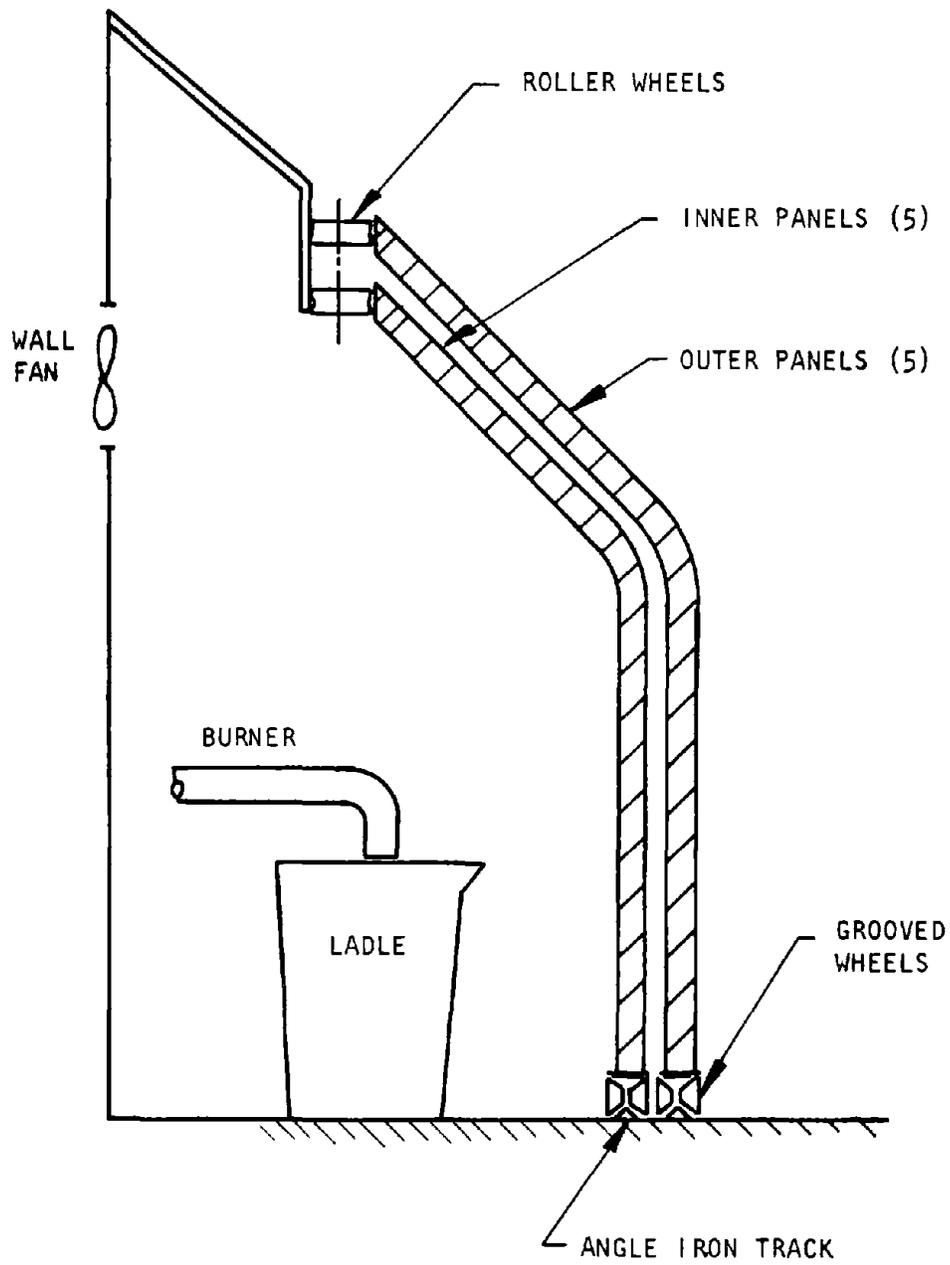
Figure A25-2. Side view of door panel construction.
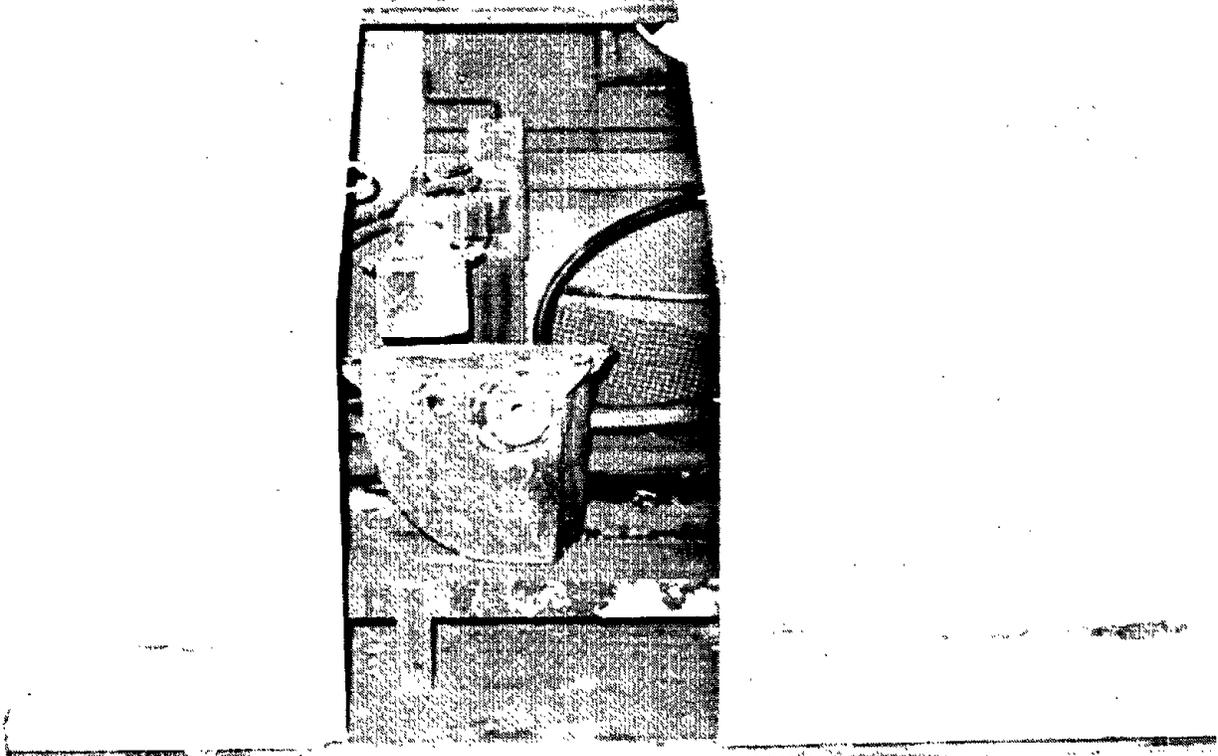
Figure A25-3. Ladle curing hood with the door opened to expose the ladle.

CASE HISTORY #26
DUST AND GAS CONTROL DURING
PHENOLIC URETHANE (COLD BOX) CORE PRODUCTION
JANUARY, 1978

ABSTRACT

Exhausting of the corebox in conjunction with auxiliary exhaust ventilation adjacent to the corebox and above the retrieval rack effectively controlled air contaminants generated during coremaking. Worker exposure to respirable silica, triethylamine, and phenol were well below allowable limits.

PROCESS DESCRIPTION

Equipment and Operation

The core machine was classified as a vertical press type consisting of a stationary sand hopper and attached match-plate, and a vertical piston with match-plate which opened and closed the corebox. A schematic diagram of the machine is shown in Figure A26-1. An automated core lift-out rack was used to retrieve cores from the corebox to the worker position. Coremaking consisted of an automated cycle of blowing, gassing, purging, core ejection, retrieval, and storage on racks.

Materials and Rates

Production rate was 720 lbs (324 kg) per hour. Core constituents consisted of lake sand (silica) and a two-part binder system of phenolic and isocyanate (a MDI polymer) resins, with triethylamine (TEA) gas used as a catalyst.

WORKPLACE HAZARDS

The major air contaminant hazard from this process was from TEA, phenol, and respirable silica.

CONTROL OF EXPOSURE

Environmental controls consisted of direct gas exhaust from the corebox and auxiliary exhaust ventilation adjacent to the corebox and over the retrieval rack.

Engineering

Control at the Source--
Corebox--The corebox exhaust provided a negative pressure at the discharge side of the corebox, and removed gases. Exhaust gases were incinerated by an afterburner before being discharged outdoors.

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CANOPY HOOD

SAND BOX

PARTING LINE
GASKET

CORE RETRIEVAL RACK

CORE BOX

SIDE VIEW

HYDRAULIC
PISTON

TEA
GAS OUT

SAND BOX

SIDE DRAFT
HOOD

CORE BOX

TEA
GAS IN

HYDRAULIC
PISTON

FRONT VIEW
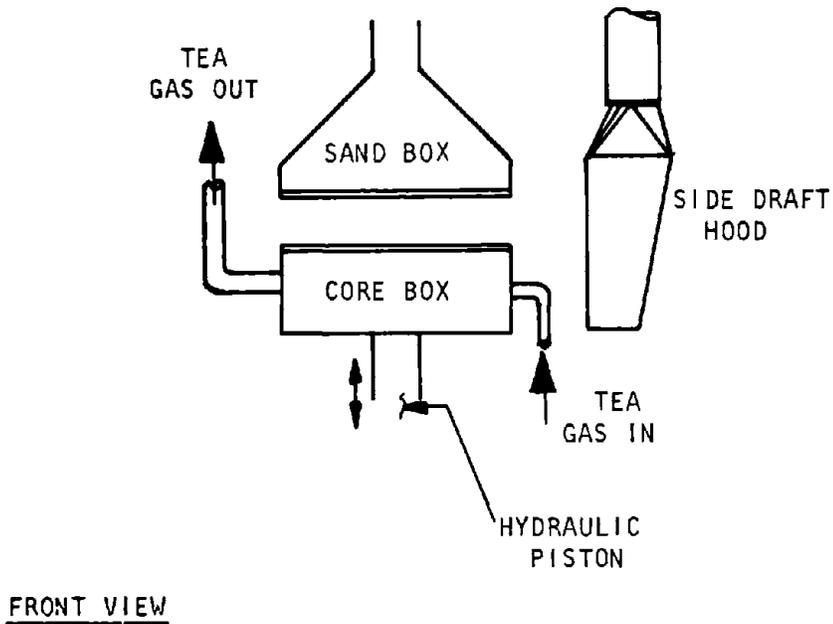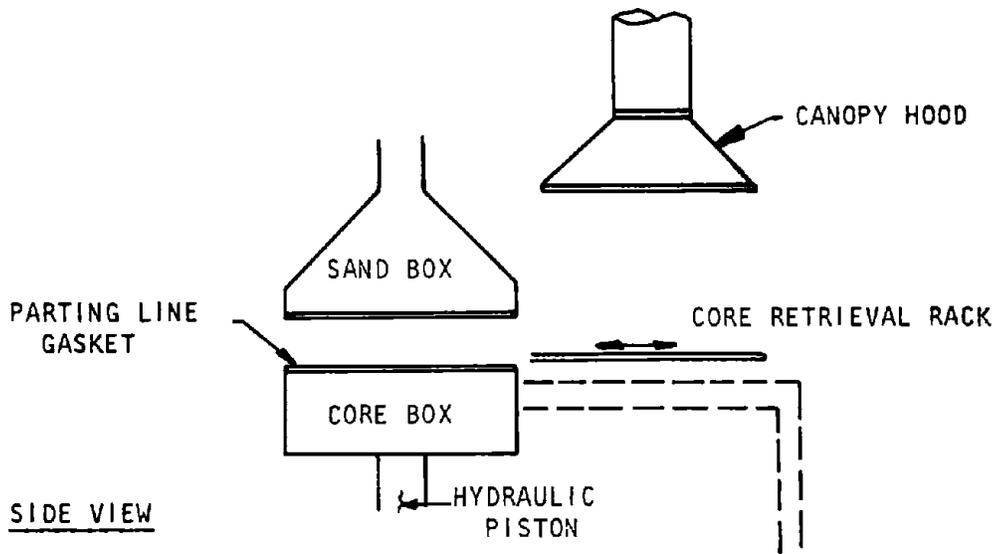
Figure A26-I.   Exhaust of cold box coremaking.

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Auxiliary exhaust--A sidedraft hood at the corebox and a canopy hood over the retrieval rack captured gases escaping during box opening and core removal. The two exterior hoods had a combined exhaust volume of 18,000 cfm (8.5 m3/sec). This amount of exhaust was far in excess of what would be necessary under normal operating conditions to purge the surrounding air of gases or dust leaking from the process. However, if a corebox seal failure or any other gas leakage problem should occur, the auxiliary exhausts would protect the breathing zone of workers.

RESULTS

1. The core machine operator's exposure to gases, vapors, and respirable silica was well below allowable limits (Table A26-1 and 2).

Table A26-1. Air sampling results - vapors and gases.

Worker or location	Sample type	Carbon monoxide, ppm	TEA, ppm	Phenol ppm
Core machine (background sample)	Fixed	5-10	3-5§	<5.0
OSHA PEL		50	25	5
ACGIH TLV (1977)		50	25	5

§ 3.08 hr. duration of sample.

* No stain observed on Dräger 5/a detector tube after ten pump strokes.

Table A26-2. Air sampling results - respirable silica.

Worker or location	Sample type	Percent quartz	Respirable dust exposure, mg/m3	Allowable respirable dust exposure,§ mg/m3
Core machine (background sample)	Fixed	4.6	0.60	1.52
		4.8	0.50	1.48

§ OSHA PEL and ACGIH TLV (1977).

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CASE HISTORY #27
DUST AND GAS EMISSION CONTROL FROM PHENOLIC
URETHANE COLD BOX COREMAKING
SEPTEMBER, 1977

ABSTRACT

Exhaust of the corebox at the source and fresh makeup air were used to control the level of air contaminants generated during the production and final preparation of phenolic urethane cores. Triethylamine (TEA) gas and respirable silica were of major concern during the study. TEA was emitted during coremaking and from cores on the finishing conveyors and storage racks. Respirable silica resulted from inadequate seals between the corebox and the sand hopper during core blowing, and from sawing and scraping of cores during finishing. Levels of TEA were below the allowable limit. However, blow seal leakage on several core machines resulted in exposures to respirable dust at about the allowable limit.

PROCESS DESCRIPTION

Equipment and Operation

The core room contained twelve core machines in two groups of six each, located on either side of the core finishing conveyors (Figure A27-1). Several types of vertical and horizontal press-type core machines were used to make the different cores. The general coremaking procedure always consisted of an automatic sequence of core blowing, gassing, purging, and core ejection. A typical core machine is shown in Figure A27-2.

Core finishers, located along the conveyors, cleaned and repaired (and sometimes coated) cores. After they were finished, cores were removed from the conveyor and placed on storage racks. The coated sand from which the cores were made was prepared on an overhead mezzanine by mixing a measured amount of the two-part resin with a predetermined amount of sand. The mulled sand was then dumped from the muller onto a hand cart (also on the upper level), and manually transported to core machine hoppers. A summary of job tasks for core room operations is presented in Table A27-1.

Materials and Rates

Approximately 22,000 cores were produced in an 8 hour shift, consuming 75 tons (68,102 kg) of sand, 37 gallons (140 liters) of liquid triethylamine, and 2,625 pounds (1193 kg) of resin. The triethylamine was stored outdoors and pumped indoors to tanks on the individual coremaking machines.

WORKPLACE HAZARDS

The major air contaminant hazards included respirable silica and triethylamine.

TEMPORARY CORE
STORAGE

CORE MACHINES

CORE MACHINES

CONVEYOR LINES

SYMBOLS

⊗ = FRESH AIR
SUPPLY POINTS

S = SMALL

M = MEDIUM

L = LARGE

➤ MATERIAL FLOW

PLAN VIEW
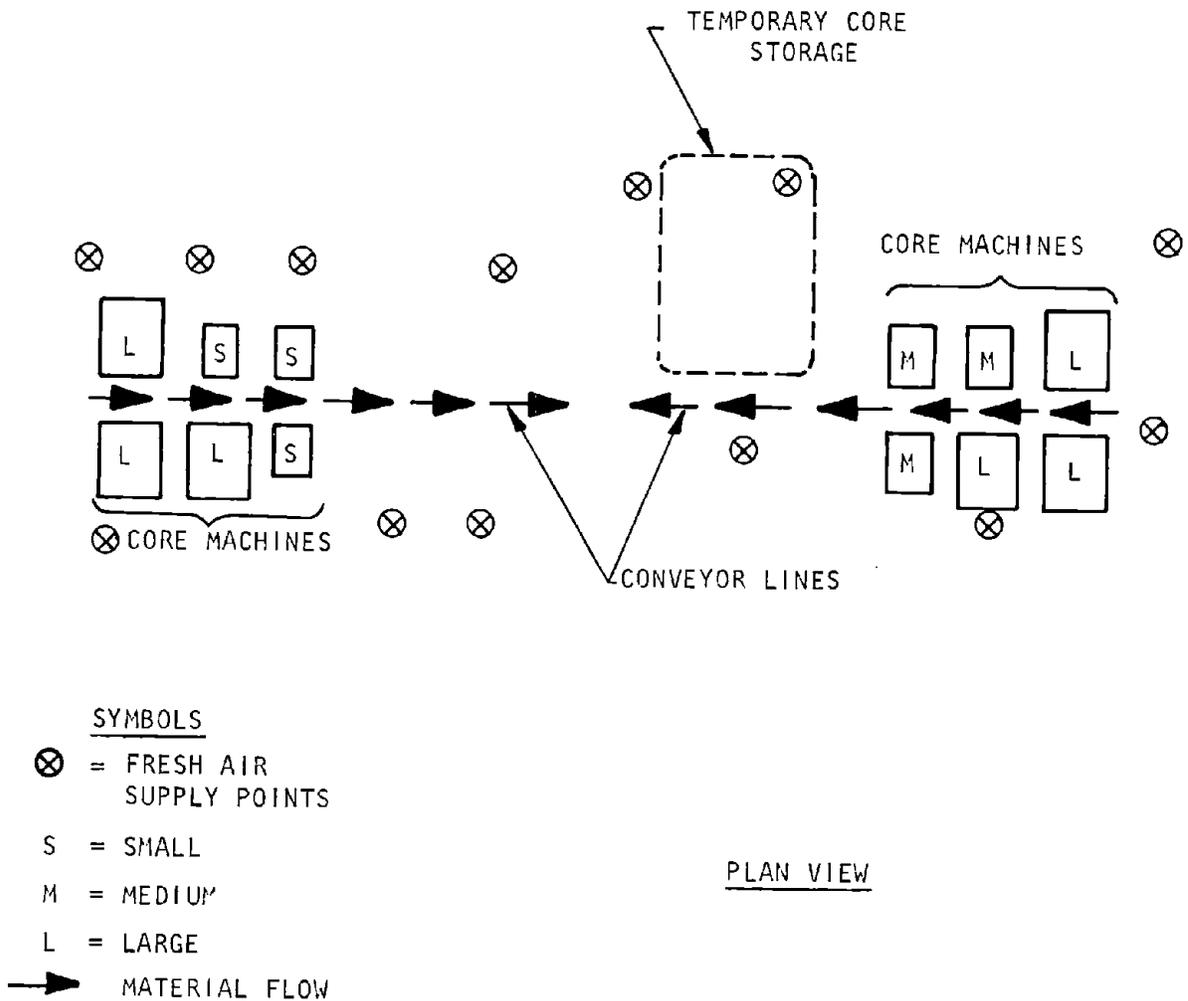
Figure A27-1. General layout of coreroom.

Methylene bisphenyl diisoacyanate (MDI), and phenol were not suspected hazards, but their presence was checked.

CONTROL OF EXPOSURE

Each core machine was equipped with local exhaust in the form of venting of core box gases. General ventilation was provided by fresh air supplies at spaced intervals through the area.

Engineering

Control at the Source--
Coremaking--Local exhaust was provided at the core box by a directly attached flexible duct. An exhaust flow of 125 cfm (0.06 m^3/sec) was used to provide a negative pressure at the core box during gassing and purging, and thus remove the triethylamine gas and other vapors.
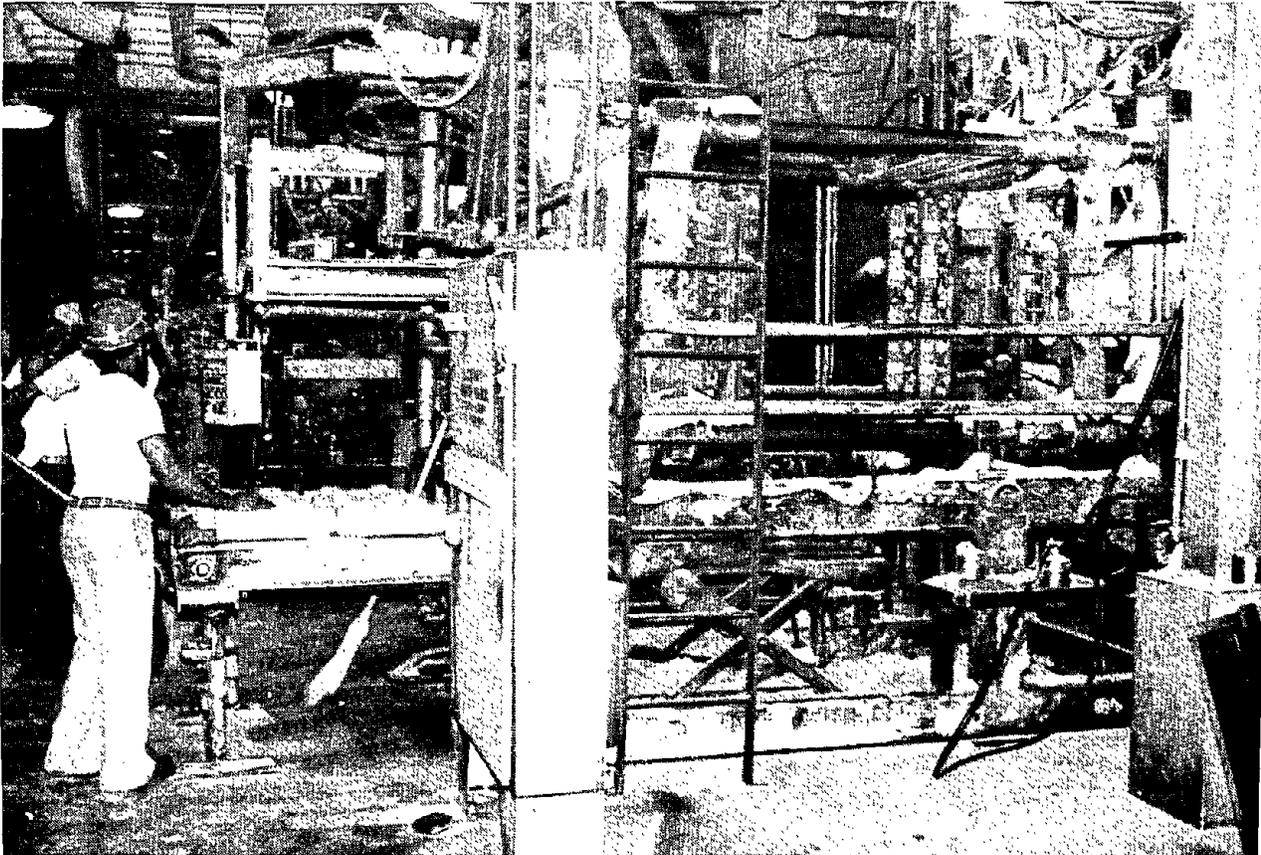
Figure A27-2. Typical coremaking operation showing location of operator.

Table A27-I. Summary of work tasks - core room operation.

Job title	Task
Core machine operators	Removed cores from roll-out conveyor or core lift-out rack and placed them on the conveyor line. Cleaned and sprayed core-box with parting compound.
Core finishers	Removed excess sand from cores and made repairs where necessary.
	Used abrasive saw to remove uneven ends from cores.
	Dipped cores in wash solutions.
Muller operator	Opened hopper damper to fill muller with sand.
	Measured two part resin and added to muller.
	Activated muller for mulling operation.

The effective control of emissions of gases and respirable silica dust depended on three types of seals:

1. Parting line gasket - sealed the two halves of the pattern together during core blowing, gassing, and purging.

2. Blow seal - performed two functions:

    a. Sealed the wear plate around the sand fill ports during core blowing.

    b. Sealed against the gas head plate during gassing and purging.

3. Stripper pin o-rings - sealed around the pins which moved in and out to eject the cores after core box opening.

Foundry personnel performed periodic maintenance to assure the proper functioning of seals and to prevent gas leakage from the coremaking machines. From experience, the following (in descending order of frequency of occurrence) were the major sources of gas leakage:

1. Faulty stripper pin o-rings.

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2. Backpressure on the core box seals created by: 1) too many sand fines, or 2) moisture in sand or moisture carryover from compressed air drier.
3. Faulty gas head plate and seal.
4. Gas line leaks.
5. Parting line gasket leaks - detected almost immediately by sand leakage occurring during core blowing.

Sand Preparation--
Exhaust outlets were provided to capture dust during filling of the sand hopper and the mixer. However, the degree of enclosure was inadequate and some dusty air was escaping. A mancooler fan blew the dust away from the operator and out of the coremaking area.

General Ventilation--
Uncontrolled emission sources in the coremaking area included:

1. Gases leaking past core machine seals and residual gases emitted from cores during handling and finishing.

2. Dust leakage past the blow seal during core blowing.

Sources of TEA emissions could be identified by odor as the core box and the cores on the finishing conveyor. On several machines sand escaping past the blow seals during core blowing was sprayed around the area.

Fresh makeup air was provided at thirteen supply points in the area (Figure A27-1). The air was well circulated at floor level by mancooler fans trained on the workers.

Personal Protective Devices--
Coremakers wore chemical goggles while applying pattern sprays and metal cleaners to the pattern.

RESULTS

1. Triethylamine (TEA) concentrations in the breathing zones of coreroom personnel were well below the allowable limit of 25 ppm (Table A27-2). As expected, TEA concentrations were highest immediately adjacent to the corebox. However, most employees were sufficiently removed from the corebox [minimum of 5 ft (1.5 m)], thus allowing some dilution to occur before exposure. Residual TEA from finished cores also contributed to breathing zone levels of core finishers, who received higher exposures than the coremakers did.

2. Blow seal leakage on several machines caused respirable dust exposure at about the allowable limit (Table A27-3).

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Table A27-2. Air sampling results - vapors and gases.

Operator or location	Sample type	MDI, ppm	Phenol, ppm	Triethylamine, ppm
Core machine operator	Fixed §	-	<5.0*	5-7
Core finisher	Fixed §	-	<5.0*	10-15
Core room area	Fixed	0.002	<5.0*	5-7
Core room area	Fixed	0.002	-	-
Directly adjacent to core box	Fixed	0.001	<5.0*	10-25
OSHA PEL		0.02†	5.0	25.0
ACGIH TLV (1977)		0.02†	5.0	25.0

§ Detector tube sample taken in the breathing zone.
* No stain observed on a Dräger 5/a detector tube after ten pump strokes.
† Ceiling limit.

Table A27-3. Air sampling results - respirable dust and silica.

Worker or location	Sample type	Percent quartz	Respirable dust exposure, mg/m³	Allowable respirable dust exposure, mg/m³ §
Core machine operator	Pers.	22	0.36	0.42
	Pers.	19	0.42	0.48
Core finisher	Pers.	27	0.42	0.34
	Pers.	23	0.40	0.40
Background in coremaking area	Fixed	11	0.69	0.77
	Fixed	16	0.32	0.56

§ OSHA PEL and ACGIH TLV (1977).

CASE HISTORY #28
DUST AND GAS CONTROL DURING
FURAN (HOT BOX) CORE PRODUCTION
JANUARY, 1978

ABSTRACT

A canopy hood was used over each of seven core machines to control emissions from the furan hot-box coremaking process. As a result, breathing zone levels of all air contaminants of hygienic significance were well controlled below allowable limits. The canopies were large enough to provide ventilation of the operator station and core rack, as well as the core machine itself. The (receiving) hoods captured emissions contained in the thermal draft. The process was automated and a sequenced, lift-out rack removed cores from the box, processed them in a surface-finishing device and delivered them to the coremaker. Personal exposure to organic gases and vapors may have been reduced by the extension in time this mechanism provided between core box opening and handling of cores.

PROCESS DESCRIPTION

Equipment and Operation

In addition to other coremaking processes, the core room contained seven high production horizontal-type hot box core machines. The coremaking sequence consisted of: core blowing and curing, core ejection and removal from the box, core finishing, core removal from the rack, inspection, and placement of cores on the storage rack. The operator handled the cores, controlled the coremaking operation, and cleaned excess materials from the core box using an air nozzle after cores were removed from the box.

The operator did not directly remove the core from the box. Rather, the core was ejected onto a lift-out rack which indexed through four positions. After the core box opened, the lift-out rack received the cured cores at the first position. It then indexed to a second position where the cores were given a light finishing. The rack dwelled at the third position and finally the cores were indexed to a fourth position in front of the operator for unloading. The entire indexing cycle took about one minute.

Materials and Rates

Production per machine was 1800 lbs (810 kg) per hour. Core constituents consisted of lake sand (silica), red iron oxide, core oil, and catalysts containing urea and ammonia.

WORKPLACE HAZARDS

The major air contaminant hazards from the hot box coremaking process included furfuryl alcohol, formaldehyde, phenol, carbon monoxide, and respirable

silica. Heat was also generated by the hot box operation, although it was not a problem during this winter study.

CONTROL OF EXPOSURE

Emissions during hot-box coremaking were controlled by an overhead canopy hood and an individual fresh air supply (not operating during study) for each worker.

Engineering

Control at the Source--
A single canopy hood covered the complete coremaking process. The plan view dimensions of the canopy were 12 ft (3.7 m) x 20 ft (6.1 m). The lowest edge of the canopy was 7.6 ft (2.3 m) above floor level. The hood covered the entire core machine, the operator station, and the core storage rack.

A volume of 9500 cfm (4.5 m^3/sec) provided an updraft velocity of 40 fpm (0.2 m/sec) into the hood. A flow splitter baffle within the canopy proportioned the exhaust, drawing the largest amount from above the core box from which the largest emissions were occurring. The baffle, shown by a dashed line in Figure A28-1, helped to control rolling of fume under the canopy which could, in turn, recirculate fume down into the breathing zone.

Most emissions occurred when the box was opened after curing and for a short period afterward. Because of the one-minute period between core box ejection and removal of the cores by the operator (during which cooling and degassing of the cores took place) few air contaminants were emitted during handling.

Cross-drafts were minimal resulting in little interference with capture by the canopy hood.

General Ventilation--
A fresh air supply was located above and just behind each operator for cooling during hot weather and dilution ventilation. Damper control was available for adjustment by the operator. The air supply was used during the study.

RESULTS

1. Airborne concentrations of gases, vapors, and respirable silica were well within the exposure limits (Tables A28-1 and 2).

PLAN VIEW

CANOPY HOOD

FRESH AIR SUPPLY

FLOW SPLITTING BAFFLE

CORE MACHINE

STORAGE RACK

ELEVATION VIEW
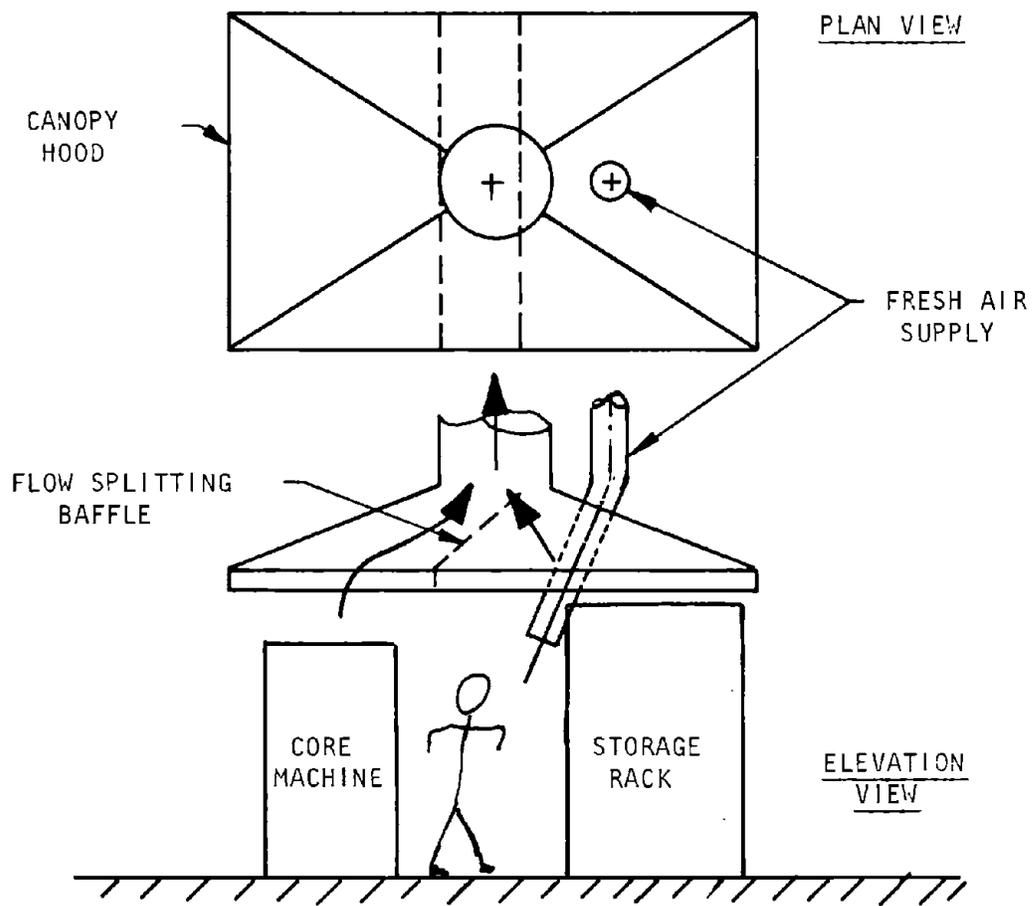
Figure A28-1. Canopy hood and fresh air supply for furan hot box core machine.

Table A28-I. Air sampling results - respirable silica.

Worker or location	Sample type	Percent quartz	Respirable dust exposure, mg/m3	Allowable respirable dust exposure, mg/m3 §
Core machine operator	Personal	1.8	0.41	2.63
		3.4	0.47	1.85
		<1	0.29	5.00
Core room background	Fixed	3.9	0.45	1.69

§ OSHA PEL and ACGIH TLV (1977.

Table A28-2. Air sampling results - vapors and gases.

Worker or location	Sample type	Furfuryl alcohol, ppm	Formaldehyde, ppm	Phenol, ppm	Carbon monoxide, ppm
Core machine operator area	Fixed	5-7	<1	<5.0§	10-15
OSHA PEL		50	3	5	50
ACGIH TLV (1977)		50	2	5	50

§ No stain observed on a Dräger 5/a detector tube after ten pump strokes.

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CASE HISTORY #29
DUST AND GAS EMISSION CONTROL
DURING SHELL MOLD PRODUCTION,
NOVEMBER, 1977

ABSTRACT

Air contaminants emitted during shell mold production were controlled below the allowable limits by the use of exhausts at each major emission point. These included the shell molding machine, cope hanging, mold closure, and mold storage. Fresh make-up air was introduced at each work station to help keep the operator area purged of the gases which escaped during handling and assembly of the mold, and to alleviate the heat.

PROCESS DESCRIPTION

Equipment and Operation

The molding area contained twelve shell molding machines (dump box type). The molding procedure consisted of the following basic steps (see Figure A29-1 for equipment and operator locations):

a. Removal of cured cope section from machine (1) and placement on cope rack (2).

b. Removal of cured drag section from machine (1) and placement on glue applicator (3).

c. Assembly of drag (3) and cope (2) on mold press (4).

d. Placement of completed mold on storage rack (5) or in debris bin (6) (if defective).

e. Spraying and cleaning of pattern and restarting of cycle (1).

Materials and Rates

The average production rate for the single molding machines was 50 molds/hr at 25-30 lbs (11.3 - 13.6 kg) per mold. Several double machines produced about 28 molds/hr of larger size molds.

WORKPLACE HAZARDS

The major air contaminant hazards from the shell moldmaking operation included phenol, ammonia, formaldehyde, carbon monoxide, and respirable silica.

MOLD
MACHINE

①

COPE
HANGER

②

GLUE
APPLICATOR

③

④

⑤

⑥

MOLD
PRESS

STORAGE
RACK

REFUSE
BIN
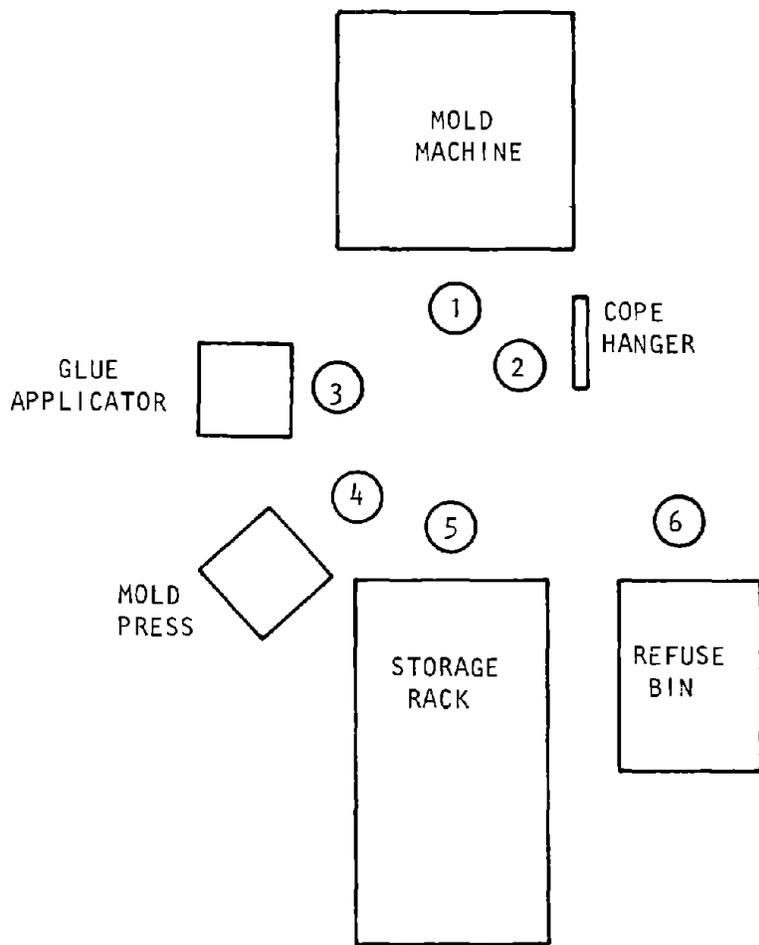
SYMBOLS

◯ OPERATOR
POSITIONS

PLAN VIEW

Figure A29-1. Shell molding station.

CONTROL OF EXPOSURE

Gaseous and particulate contaminants were controlled by local exhaust at each stationary emission point. Individual fresh air supplies helped to cool workers and prevent accumulation of contaminants in the worker areas.

Engineering

Control at the Source--
Molding machines--An enclosing hood around the molding machine used 5,500 cfm (2.6 m3/sec) to exhaust emissions generated during the process (Figure A29-1). Solvent vapors and dust emitted during pattern cleaning were also exhausted by the same hood, as was the mold machine sand feeding system. The sand was conveyed to the hopper above and behind the mold machine in a completely sealed system. A pinch valve in a hose section regulated the supply of sand from the hopper into the mold machine. Thus, no open sand transfer processes occurred outside the hood enclosure. Combustion products of gas-fired curing devices in the mold machines were exhausted to the outdoors in a separate stack. The exhausts from the mold machine hood (as well as the three other hoods) at each work station were joined and discharged outdoors.

Cope rack--A canopy hood suspended above the cope rack (Figures A29-2 and 3) exhausted 1240 cfm (0.6 m3/sec). The hood was too high above the rack to provide adequate capture, and the majority of gaseous emissions were seen to drift into the mold machine hood.

Mold press--A sidedraft hood attached to the press exhausted emissions during the short period when the assembled mold was held in the press [900 cfm (0.4 m3/sec)].

Storage rack--A canopy hood over the storage rack exhausted gases which were still being emitted during storage (Figure A29-3). This hood was very subject to cross-drafts which were present in the area. Exhaust flow from this hood was 5,900 cfm (2.6 m3/sec).

General Ventilation

Shell molding required a substantial amount of handling of the mold in the just-cured condition with the mold halves still smoking. The worker was literally surrounded by process components as he moved around while making and assembling molds. Although all of the process equipment had individual exhausts (with the exception of the debris tote bin), the transfer process produced smoke and gases which passed immediately through the breathing zone. Each worker had an individual fresh air supply to cool him and purge the operator area. The worker could adjust both the volume and direction of the fresh air.

RESULTS

 1. The airborne concentrations of all contaminant samples were well within exposure limits. Tables A29-1 and 2 list results for
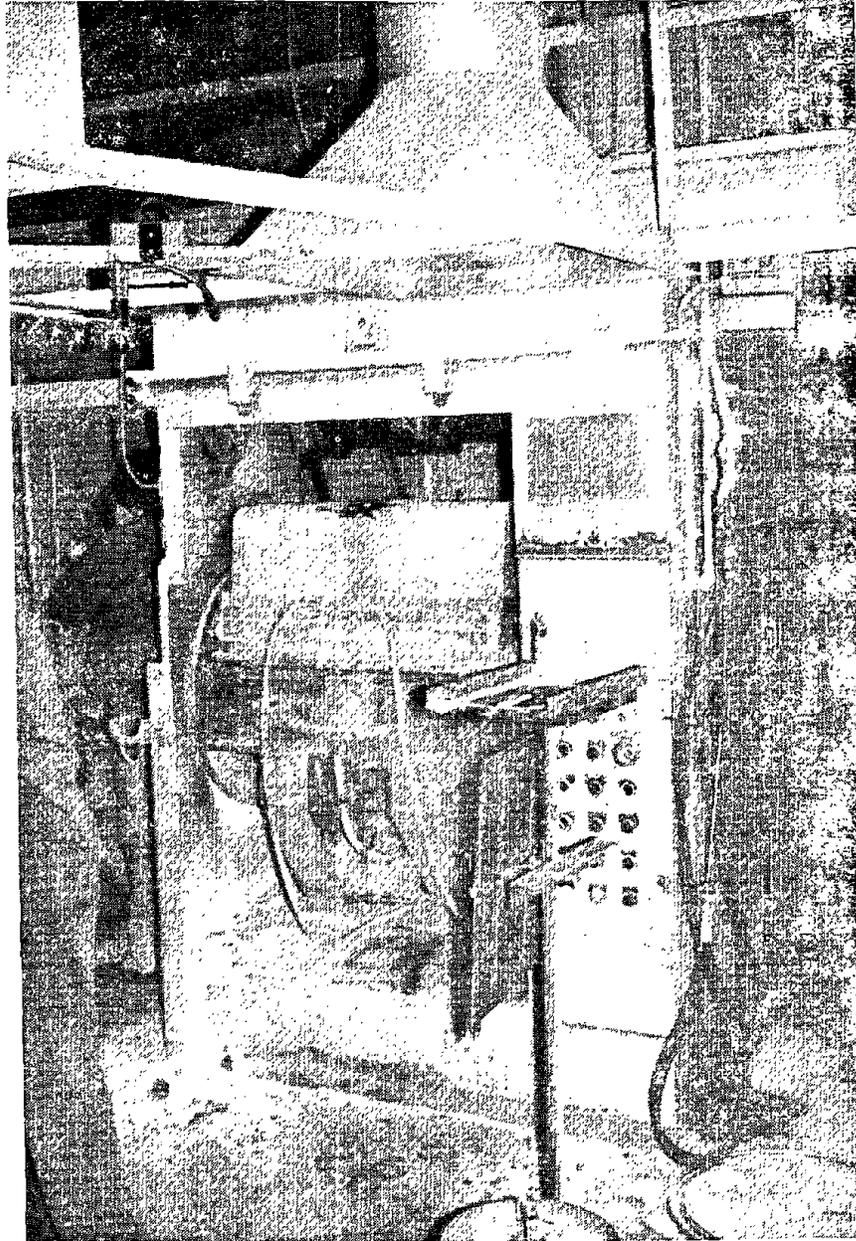
Figure A29-2. Mold machine surrounded by enclosing hood. Cope rack is shown in foreground.
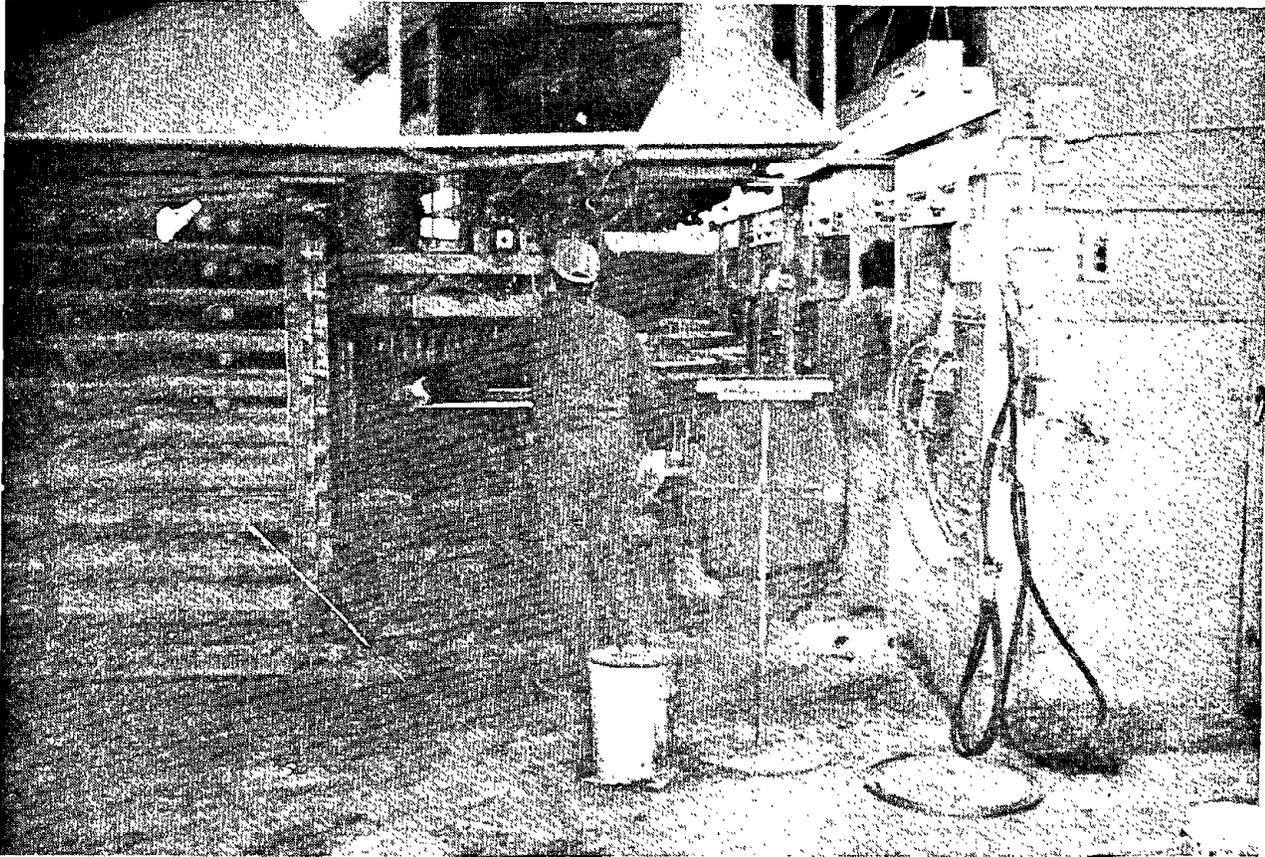
Figure A29-3. Coremaking area showing mold storage rack at left and mold machine at right. Glue applicator and mold press are in background.

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respirable silica and gases, respectively.

Table A29-1. Air sampling results - respirable silica.

Worker or location	Type of sample	Percent quartz	Respirable dust, mg/m3	Allowable respirable dust, mg/m3 §
Molder	Personal	4.7	0.82	1.49
	Personal	3.3	0.87	1.88
	Personal	1.9	0.96	2.56
	Personal	<1	0.83	5.00
	Personal	1.0	1.40	3.33

§ OSHA PEL and ACGIH TLV (1977).

Table A29-2. Air sampling results - fixed samples at molder stations for gases and vapors.

	Phenol	Carbon monoxide	Ammonia	Formaldehyde
No. of samples	8 §	6	3	4
Concentration, ppm	<0.10	15-20	3-10	<2.0*
OSHA PEL, ppm	5	50	50	3
ACGIH TLV (1977), ppm	5	50	25	2

§ Impinger samples and detector tubes.
* No stain observed on a Dräger detector tube after five pump strokes.

CASE HISTORY #30
CONTROL OF TUMBLING MILL NOISE
JUNE, 1977

ABSTRACT

In this large iron and steel foundry, two tumbling mills located in a casting sorting and inspection area generated noise levels greater than the OSHA limits. An enclosure of the two tumbling mills isolated the process and reduced the noise to less than 90 dBA. Tumbling mill noise was reduced 17 dBA in the area.

PROCESS DESCRIPTION

The two tumbling mills were located in a large casting sorting and inspection room. They faced each other and were near one wall in about the middle of the room.

The tumbling mill drums were about 3 ft (1 m) in diameter and 4 ft (1.2 m) long (Figure A30-1). The average "load" was between 1500 and 1800 pounds (680-820 kg) of castings; the cycle time was about 20 minutes.

The tumbling mill operator normally spent only a small part of his time near the machines, i.e., only during loading and unloading. Typically, the operator entered the enclosure, loaded one or both mills, started the cycle timer and left the enclosure. After the cycle was complete and/or when convenient, he returned, unloaded the mill(s), and repeated the cycle. If he started one mill and then loaded the other, he wore hearing protection while in the enclosure.

To load the mill, the operator pushed a tote box of castings along a conveyor and into the enclosure (Figure A30-2). After the box was inside the enclosure, the operator lifted the box with the crane and dumped the castings into the mill. The tumbling mill was unloaded by dumping the castings into a tote box below the mill, and the tote box was pulled out of the enclosure through curtains behind each mill.

WORKPLACE HAZARDS

Tumbling mill noise was greater than 90 dBA, a very disturbing type of noise, and often lasted a long time. The noise levels near the mills were greater than the OSHA limits for 8 hours of exposure. Tumbling mill noise was the loudest continuous noise in the area, but an occasional loud impact from dumping tote boxes, etc., could be louder.

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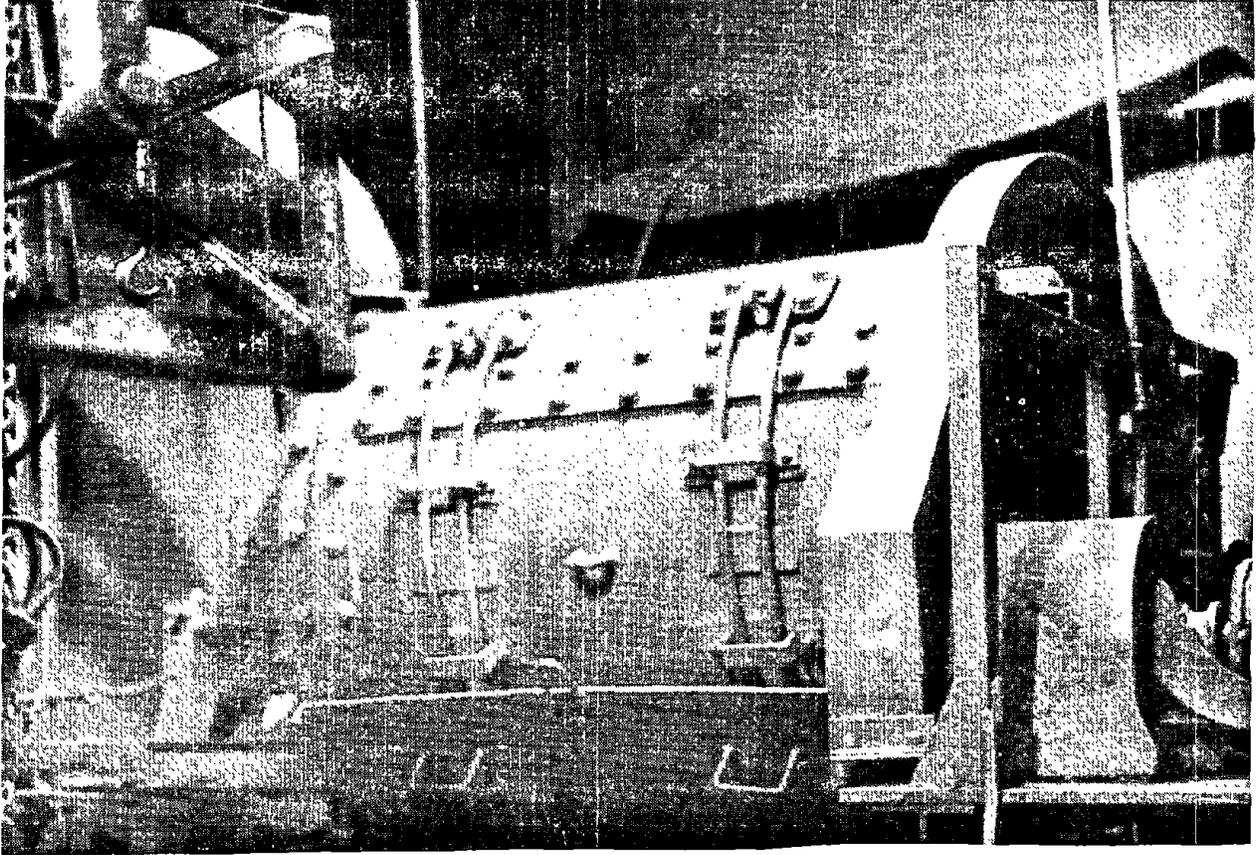
Figure A30-I.   Tumbling mill.
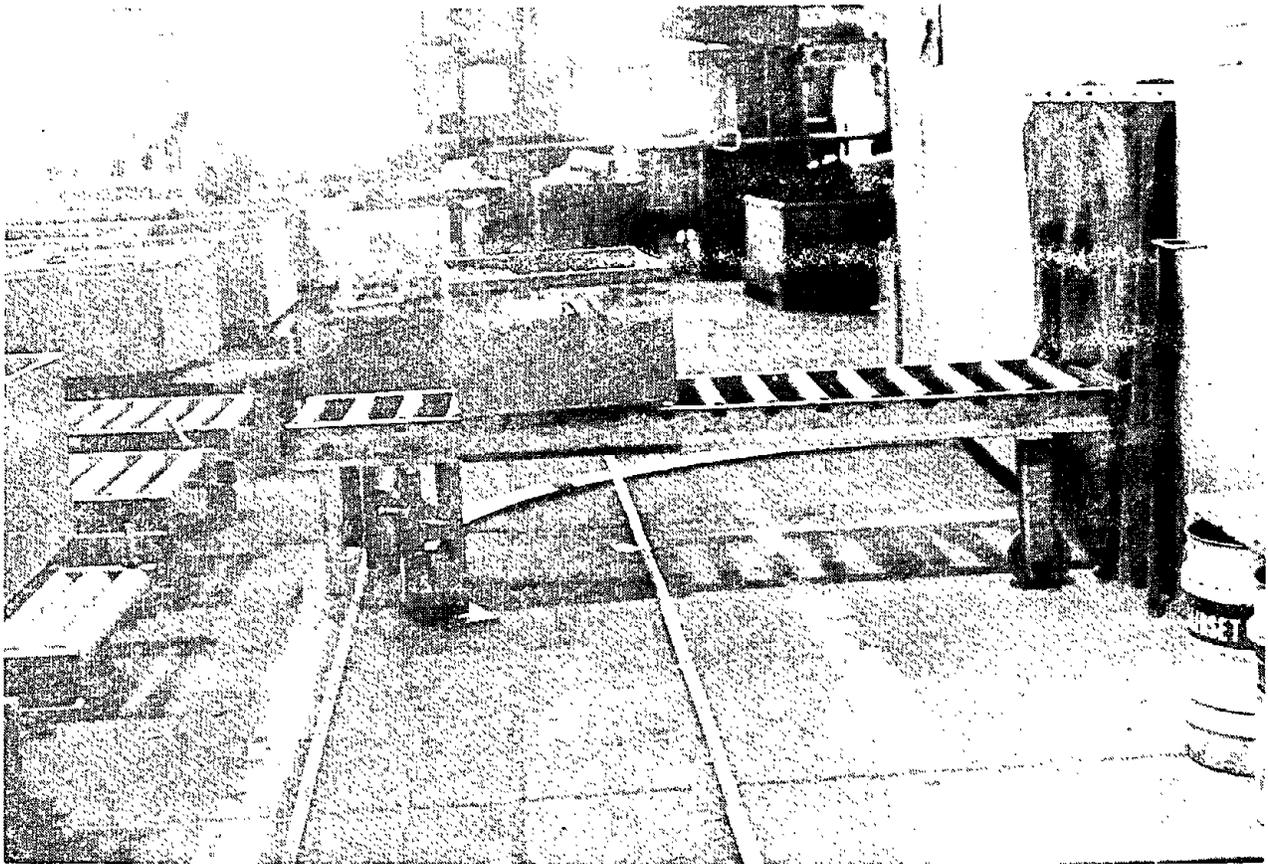
Figure A30-2. "Loading" conveyor.

CONTROL OF EXPOSURE

Engineering

The noise generated by the tumbling mills was isolated from the area by
a total enclosure of both mills; the enclosure was designed by the foundry.
Inside the enclosure there was a jib crane, two tumbling mills and a
platform for the operator to stand on while loading and unloading the mills.

Outside dimensions of the enclosure were 20 ft (6.1 m) long, 13 ft (4 m)
wide, and about 13 ft (4 m) high. The outside of the enclosure was
16 gauge corrugated steel bolted to a steel frame (Figure A30-3). The
surfaces were lined (covered) with two layers of 1/2-inch (1.3 cm) thick
structural fiber-insulation board. The operator's access door into the
booth was of the same construction and did not have any special acoustical
seal; it was 6 ft (1.8 m) high and 30 in. (0.76 m) wide. The tote boxes
were pushed along a roller conveyor and through a "curtain door" to get the
tote boxes into the enclosure. The inlet conveyor provided a good way to
get castings into the enclosure through a small opening. To get the boxes
out of the enclosure they were pulled through large "curtain doors".

The curtains were old carpets (remmants, etc). The inlet door for tote
boxes was 4 ft (1.22 m) high and 4 ft (1.22 m) wide (Figure A30-3).
The doors to remove the tumbled castings were 8.5 ft (2.6 m) high and
5.5 ft (1.7 m) wide (Figure A30-4). Neither the operator door nor the
curtains provided a tight acoustical seal, but they aided substantially
in reducing the noise emitted.

SAMPLING STRATEGY

The objective was to determine if the noise level in the casting sorting
and inspection area was below the OSHA limits and to determine the noise
attenuation of the enclosure.

Measurements were made inside the enclosure at the operator position and
outside the enclosure in front of the inlet and outlet curtains. The
measurements outside were made at 6 ft (1.8 m) from the enclosure and
5 ft (1.5 m) above the floor. Overall level and frequency spectra of
each condition were measured. The contribution from other sources was
minimized by measuring during a quiet period.

RESULTS

1. Noise levels in the casting sorting and inspection area were below
    the OSHA limits. Without the enclosure, the allowable exposure
    was estimated to be only about 5 hours per day.

2. The enclosure reduced the tumbling mill noise in the area by
    17 dBA. The noise level inside the enclosure was about 105 dBA
    compared to 88 dBA outside. The ambient level was about 75 dBA.
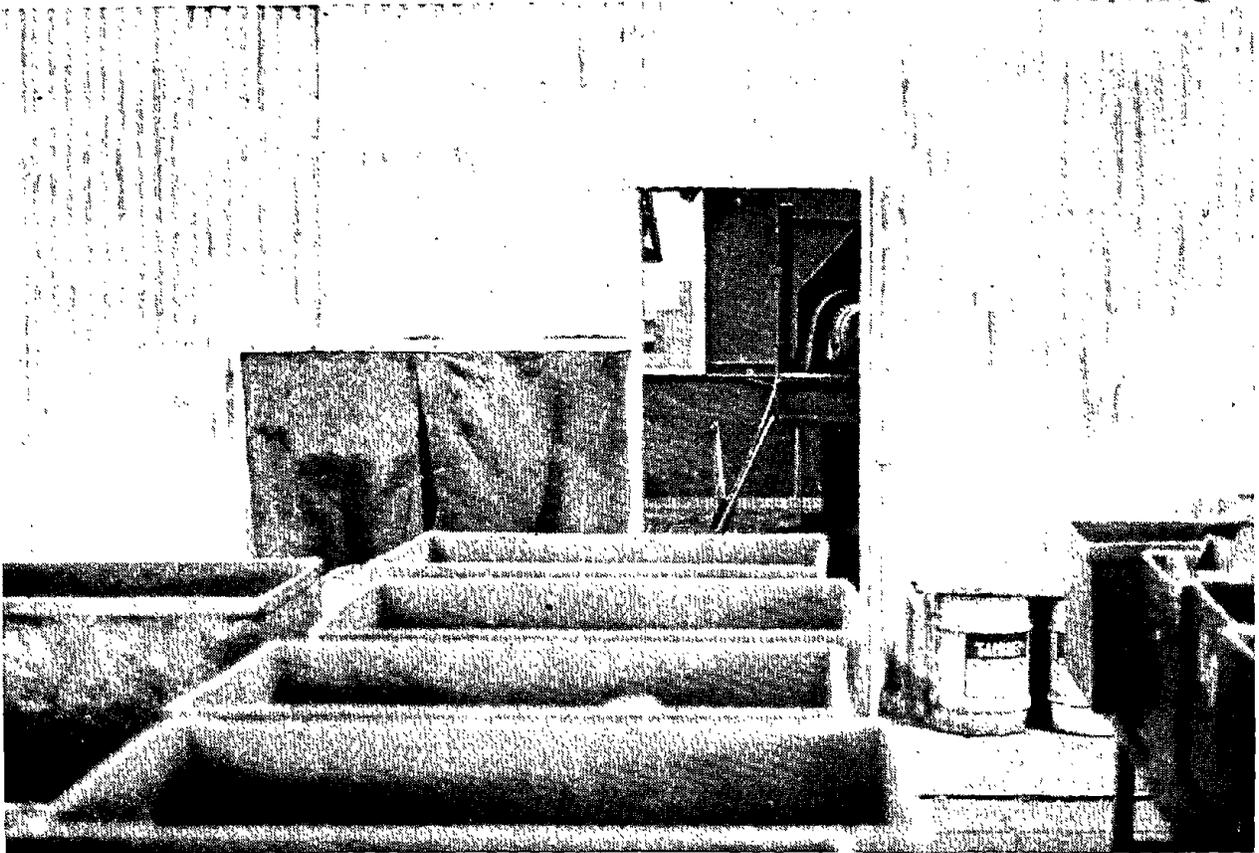
Figure A30-3.   Inlet and operator doors.
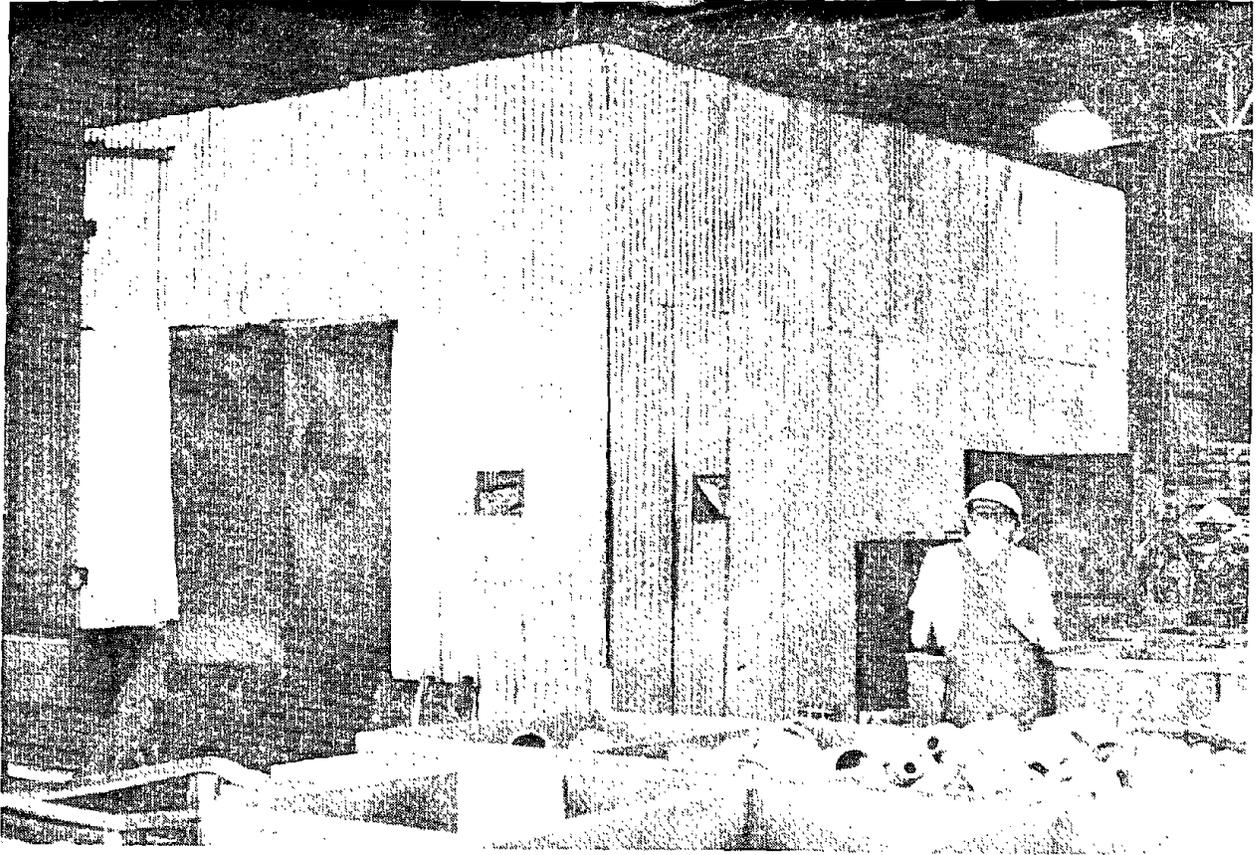
Figure A30-4. Tumbling mill enclosure.

3. The enclosure reduced the noise level of all the frequencies above about 100 Hz; the levels were reduced between 4 and 22 dB. Below 100 Hz, the noise levels were equal to ambient levels; i.e., not a function of the tumbling mill noise (Figure A30-5).
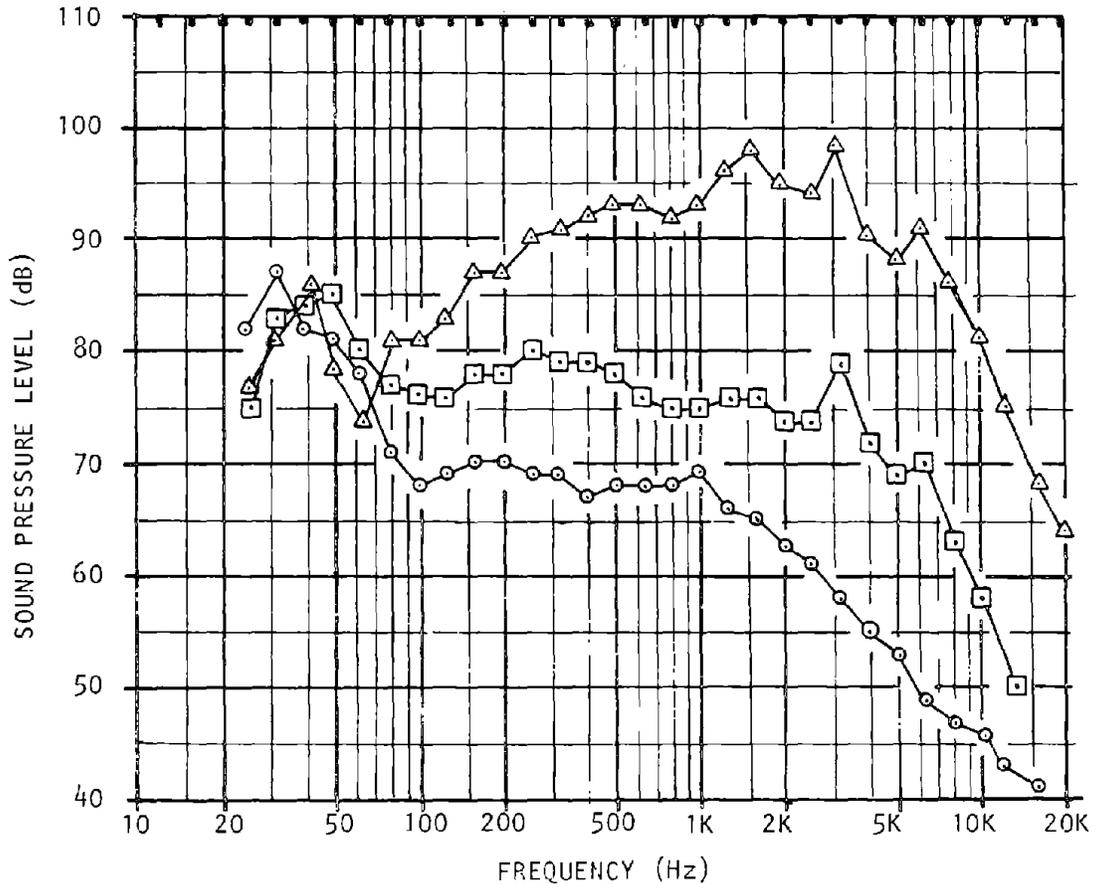
SYMBOLS

△ INSIDE

☐ OUTSIDE

○ AMBIENT

Figure A30-5. Sound pressure level spectrum of tumbling mill enclosure.

CASE HISTORY #31
CONTROL OF TUMBLING MILL NOISE
OCTOBER, 1977

ABSTRACT

In this medium sized iron foundry, two tumbling mills located near the center of the foundry generated excessive and annoying noise levels (above 90 dBA). A well-built, tight fitting enclosure of the tumbling mills isolated the process from the surroundings and reduced the noise level (14 dBA), to less than the ambient level in the area.

PROCESS DESCRIPTION

The two identical tumbling mills were located side-by-side along a wall in about the center of the foundry (Figure A31-1). They were near a sprue knockoff and casting sorting area, and an annealing pot packing and dumping station.

The tumbling mill drums were about 2 ft (0.61 m) in diameter and 4 ft (1.22 m) long. The average load was 1500 to 1800 pounds (680-820 kg) consisting of one or several types of castings. The cycle time was about 20 minutes.

The tumbling mill operator normally spent only a small part of his time near the machines. Typically, the operator loaded one or both mills, added tumbling stars, closed the cover, started the machine, set the cycle timer, and left the area. After the cycle was completed and/or when convenient he returned, unloaded the mill, and repeated the cycle.

WORKPLACE HAZARDS

The tumbling mill was not always the loudest noise source in the area, but the noise was very disturbing. The noise level generated by the tumbling mills was greater than 90 dBA and generally lasted a long time. As a result, the noise level was greater than the OSHA limits for 8 hours of exposure.

CONTROL OF EXPOSURE

Engineering

The noise generated by the two tumbling mills was isolated from the area and reduced as a result of the sheet metal enclosure of each (Figure A31-2). The enclosure was the foundry's own design and evolved out of several less effective designs.
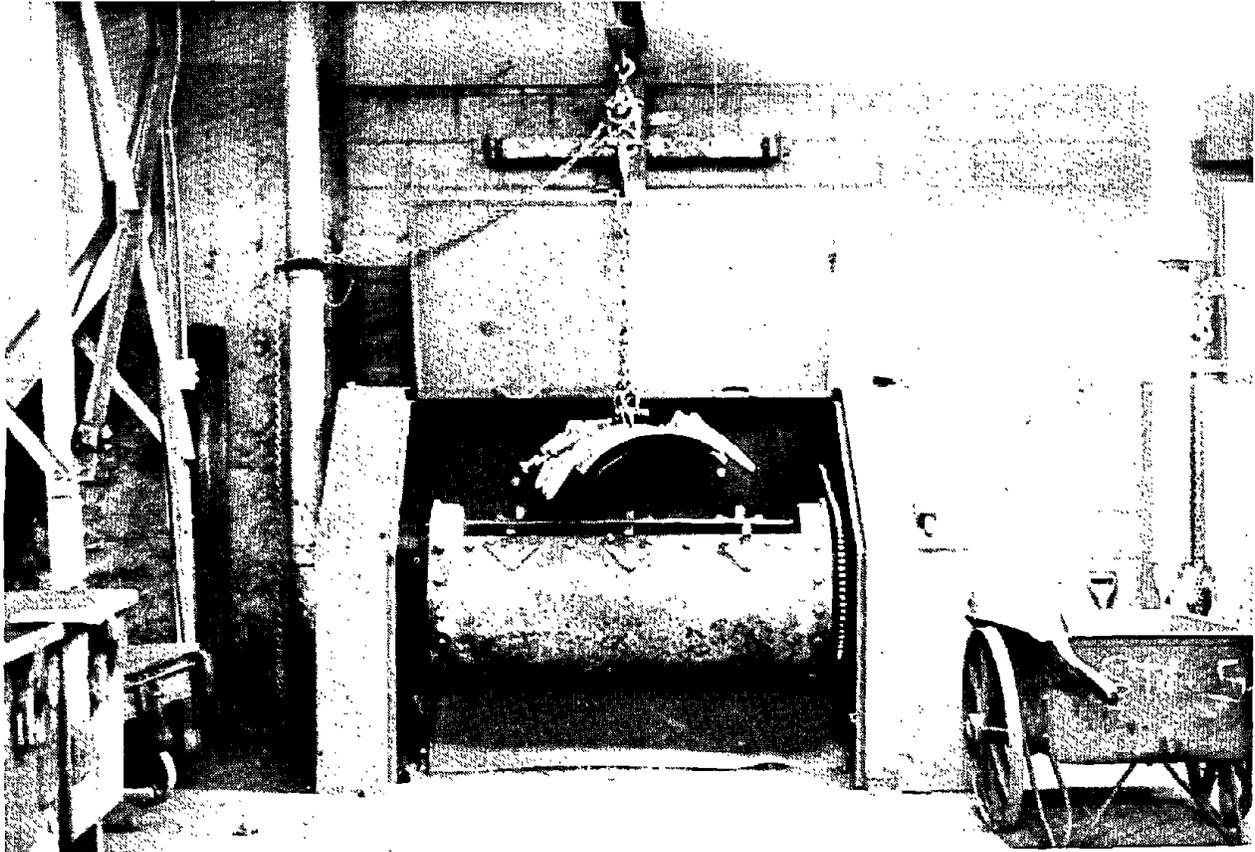
Figure A31-1. Tumbling mill.
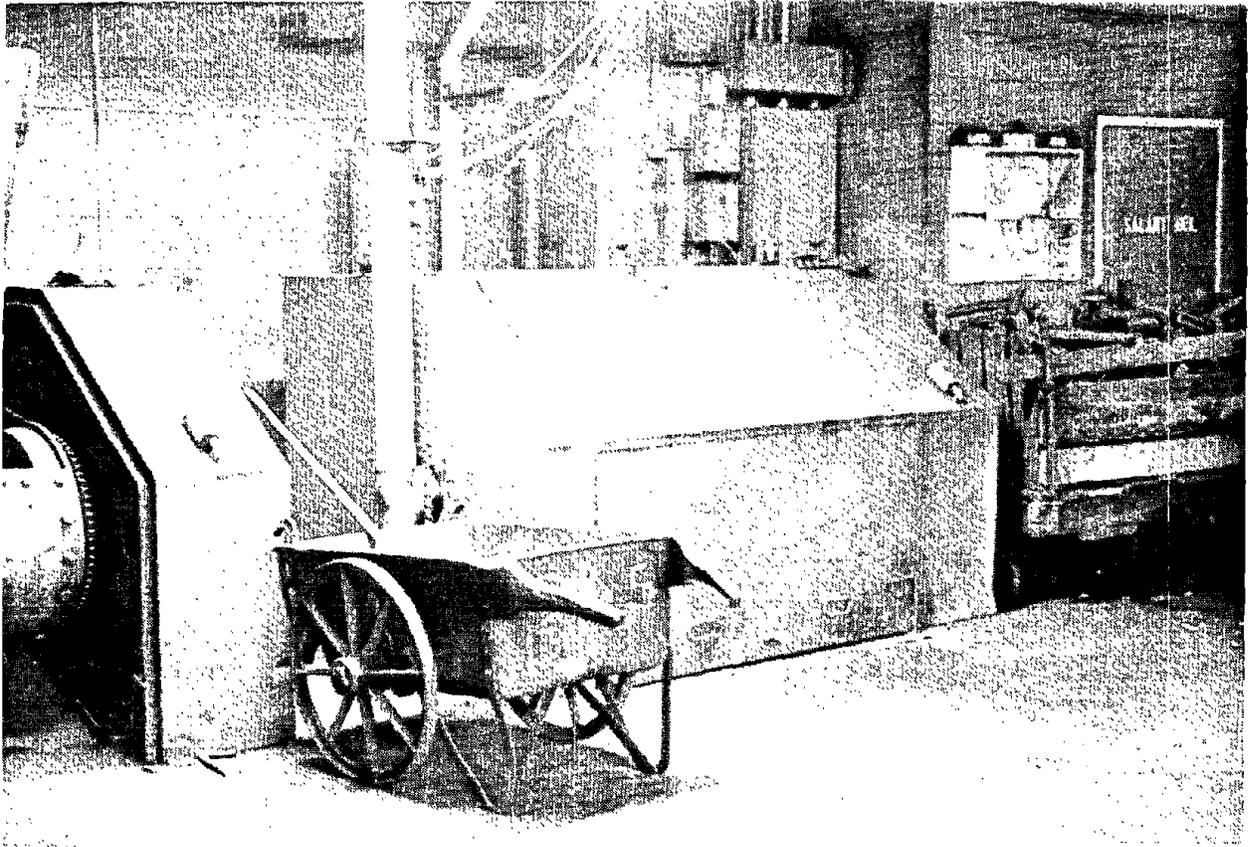
Figure A31-2. Tumbling mill enclosure.

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The outside of the enclosure was 8 ft (2.4 m) long, 6 ft (1.8 m) wide and 4 ft (1.2 m) high, and it was bolted to the floor. Inside, there was about a foot (0.3 m) of clearance between the tumbling mill and the enclosure. The outside of the enclosure was fabricated from 18 gauge steel with support angles at the corners and seams. All of the inside surfaces were covered with 2 inch (5 cm) thick rigid fiberglass. To protect the fiberglass, perforated sheet metal was placed over the fiber-glass (Figure A31-3). As a result, each side became an acoustical panel. The door of the enclosure was hinged in three places and counterweighted so it could be easily lifted out of the way (Figure A31-3). Holes in the enclosure for the electrical connections and exhaust duct were kept to a minimum. An acoustical seal around the door was provided by the flange that the door rested on (Figure A31-4).

The tumbling mill was interlocked with the door closure by a micro-switch positioned near the bottom of the door frame which was activated only if the door was tightly closed (Figure A31-5).

SAMPLING STRATEGY

The objective was to determine if the noise level emitted by the tumbling mill enclosure was less than the OSHA limits (90 dBA) and to determine the noise attenuation of the enclosure. The ambient noise level in the area of the mills was greater than the level generated by the enclosed mills; therefore, measurements were made during a shift change when most of the equipment was shut down and the ambient noise level was as quiet as possible.

Measurements were made at 6 ft (1.83 m) directly in front of the enclosure and 5 ft (1.52 m) from the floor (ear level). The noise level of one mill was evaluated with one load of material for all tests. Noise was evaluated with the enclosure door open, closed, and with the mill not operating (ambient).

RESULTS

1. Noise levels emitted by the tumbling mill enclosures were sub-stantially below the OSHA limits and also below the ambient level in the area (during normal operation). Without the en-closure, allowable operator exposure would have been about 6 hours per day under the OSHA criteria.

2. The tumbling mill enclosure reduced the noise emitted to the area by 14 dBA. The noise level with the enclosure in place was 78 dBA compared to 92 dBA with the enclosure door open (no enclosure).

3. The enclosure reduced the level of all frequencies above about 400 Hz by 2 to 15 dB. Below 400 Hz, noise levels were equal to the ambient levels during the evaluation and were not a function of the tumbling mill noise (Figure A31-6).
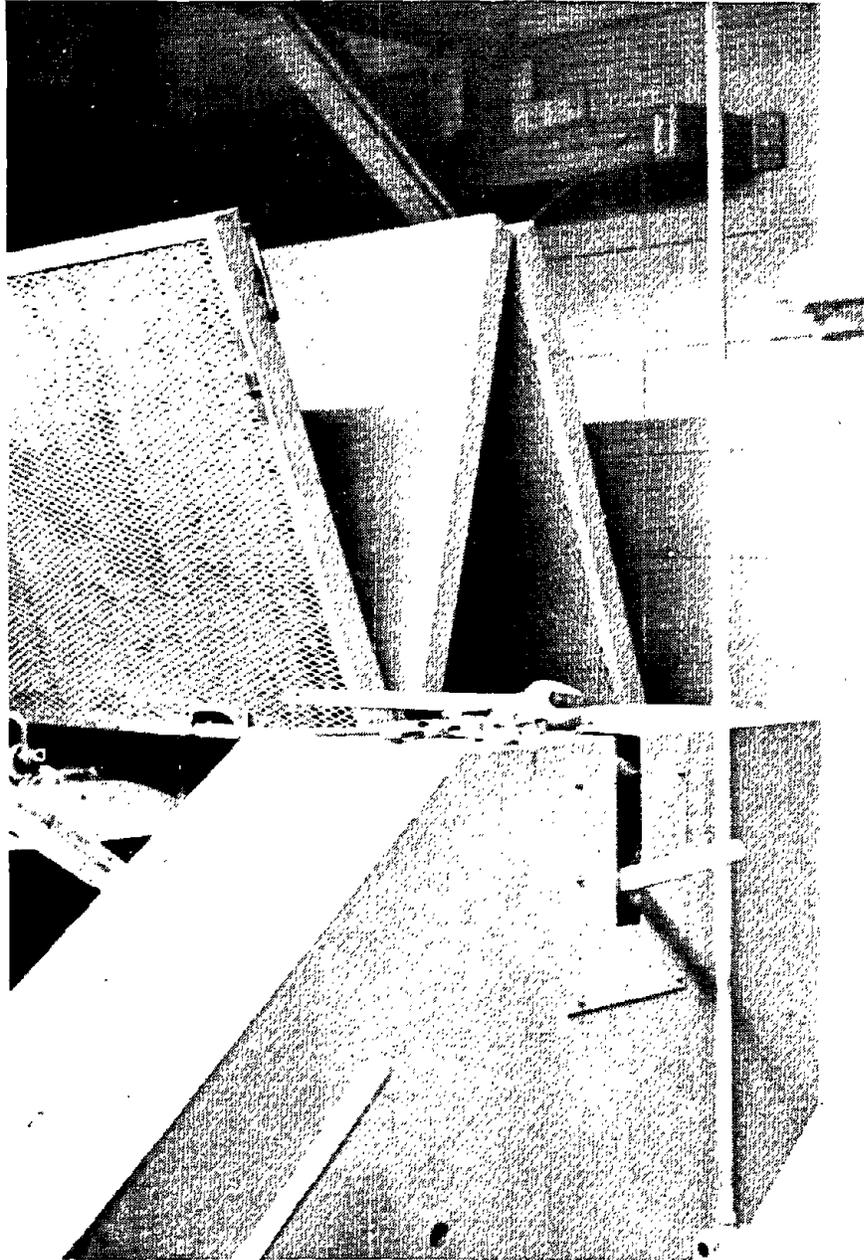
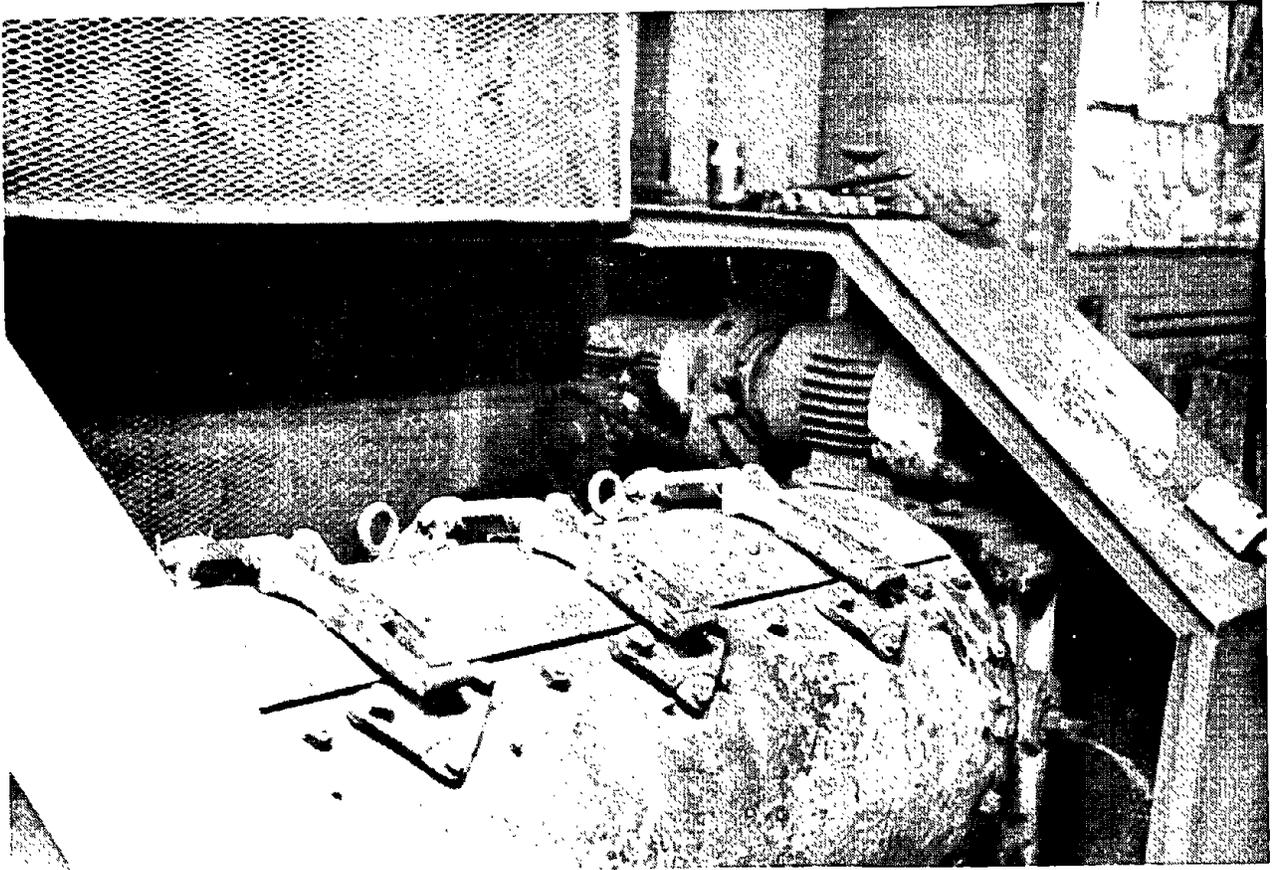Figure A31-3.   Enclosure door and fiberglass covering.

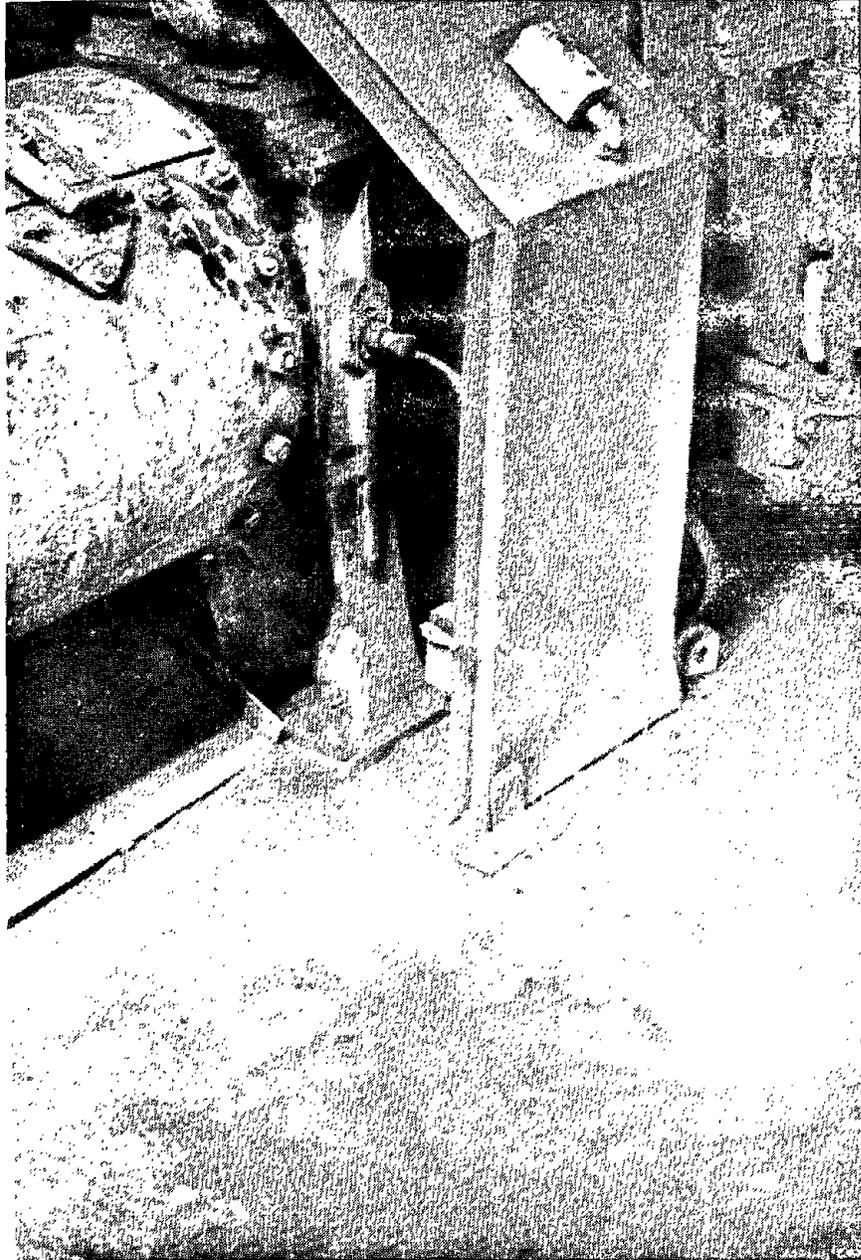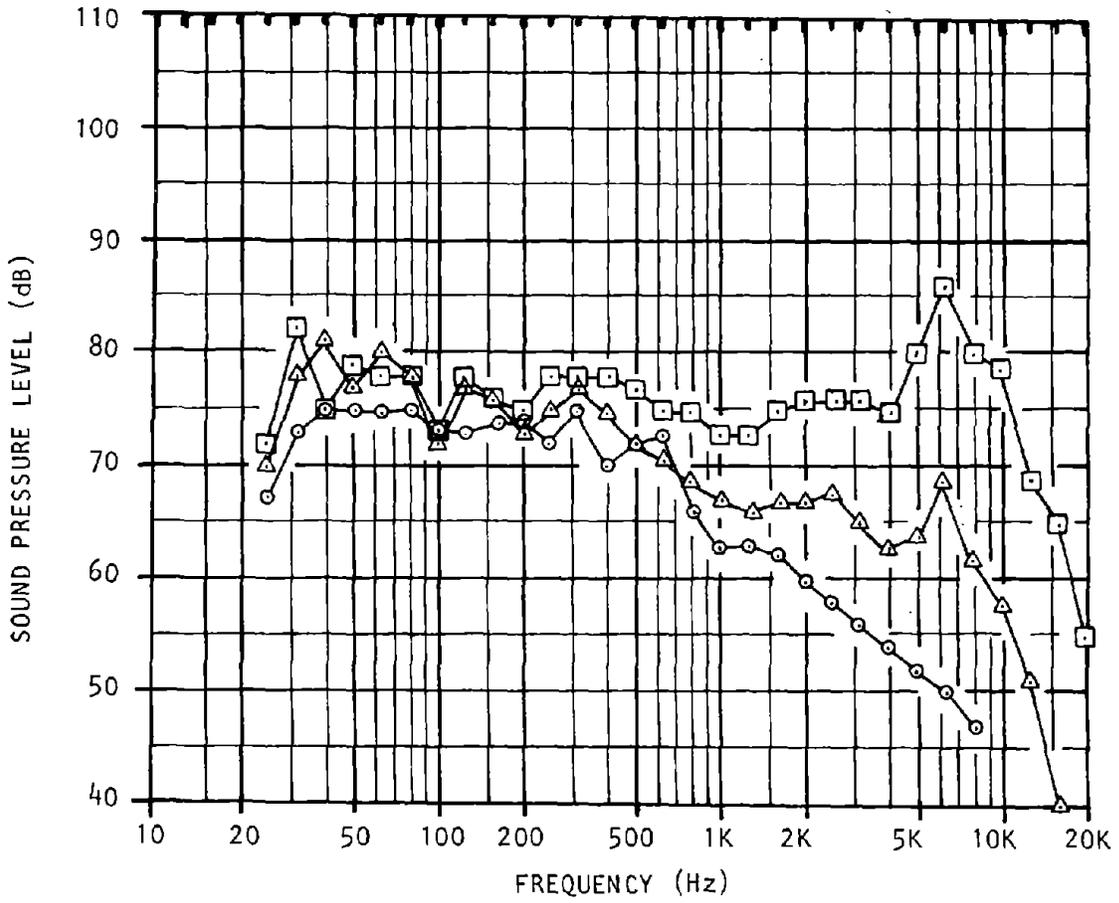Figure A31-4.   Acoustical seal around door.

Figure A31-5. Microswitch to sense door closure.

SYMBOLS

□ ENCLOSURE OPEN

△ ENCLOSURE CLOSED

○ AMBIENT

Figure A31-6.   Sound pressure level spectrum
of tumbling mill.

CASE HISTORY #32
CONTROL OF ARC FURNACE NOISE WITH AN OPERATORS' ROOM
AUGUST, 1977

ABSTRACT

The furnace operators of this large steel foundry were isolated from the
furnace noise by a control room. The room significantly reduced the
operators' noise exposure to about 90 percent of the allowable limit based
on the OSHA criteria. Without a room, the furnace operators' noise exposure
would have been more than twice the allowable limit.

PROCESS DESCRIPTION

The furnace operators' control room was located in one of the foundry's
furnace buildings; the only operation in the building was related to
melting. The room was located against one wall and was about 10 ft
(3.1 m) from the furnace (Figure A32-1). All of the controls for the
electric arc furnace were located inside the room and the overall operation
could be observed from the room. Charging, adding alloying elements, and
other typical operations were performed outside the room. The electric arc
furnace held about 10 tons (9 metric tons) per charge and there were about
3-5 heats per day. The furnace normally heated the steel for only about
30-45 minutes per charge.

The furnace operators (normally 2) were responsible for the entire opera-
tion from charging to tapping the furnace. They added any alloying ele-
ments and performed several other typical arc furnace operations. Whenever
there was a slack period, the operators went into the control room to sit
down. All of the furnace controls and communication equipment were
located in the room.

WORKPLACE HAZARDS

Noise generated by electric arc furnaces was extremely loud and generally
above the OSHA limits for 8 hours of exposure per day. The initial
"melt down" was the loudest operation.

CONTROL OF EXPOSURE

Engineering

The operators' exposure to the electric furnace noise was reduced by
isolating them from the noise by a control room. The room was fabricated
from standard factory office components. It had 3 walls, a door, a
ceiling, and was mounted to a wall and the floor; i.e., the floor and wall
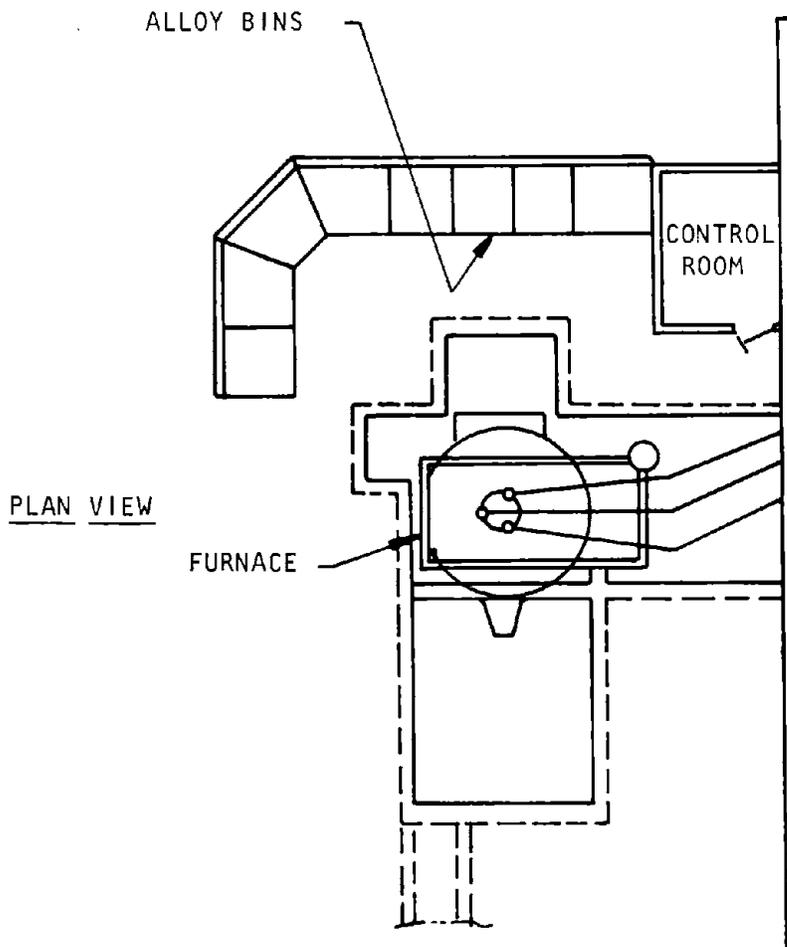
PLAN VIEW

ALLOY BINS

CONTROL ROOM

FURNACE

Figure A32-1. Furnace room layout.

formed two of the six sides (Figures A32-1 and 2). The booth was about 10 ft (3.1 m) long, 7 ft (2.1 m) wide, and 8 ft (2.4 m) high. It had ventilation and air conditioning. There were two large tempered safety glass windows for process observation. The room wall panels were 3 inches (76 mm) thick constructed of two 1/4-inch (6 mm) vinyl clad hardboard faces with a cardboard honeycomb core. The door was not specially sealed against the noise; i.e., there were no baffles along the bottom, etc. In summary, it was typical of what can be made from purchased components supplied by several vendors "off the shelf".

SAMPLING STRATEGY

The objective was to determine if the operators' exposure to the furnace noise was less than the OSHA limits, and to determine the noise attenuation of the room. The noise attenuation of the control room and the operators' noise exposure were evaluated separately. The operator exposure was evaluated by comparing the noise exposure as measured with a noise dosimeter worn by both operators, and the noise exposure as measured by a stationary monitor outside the control room. The attenuation of the room
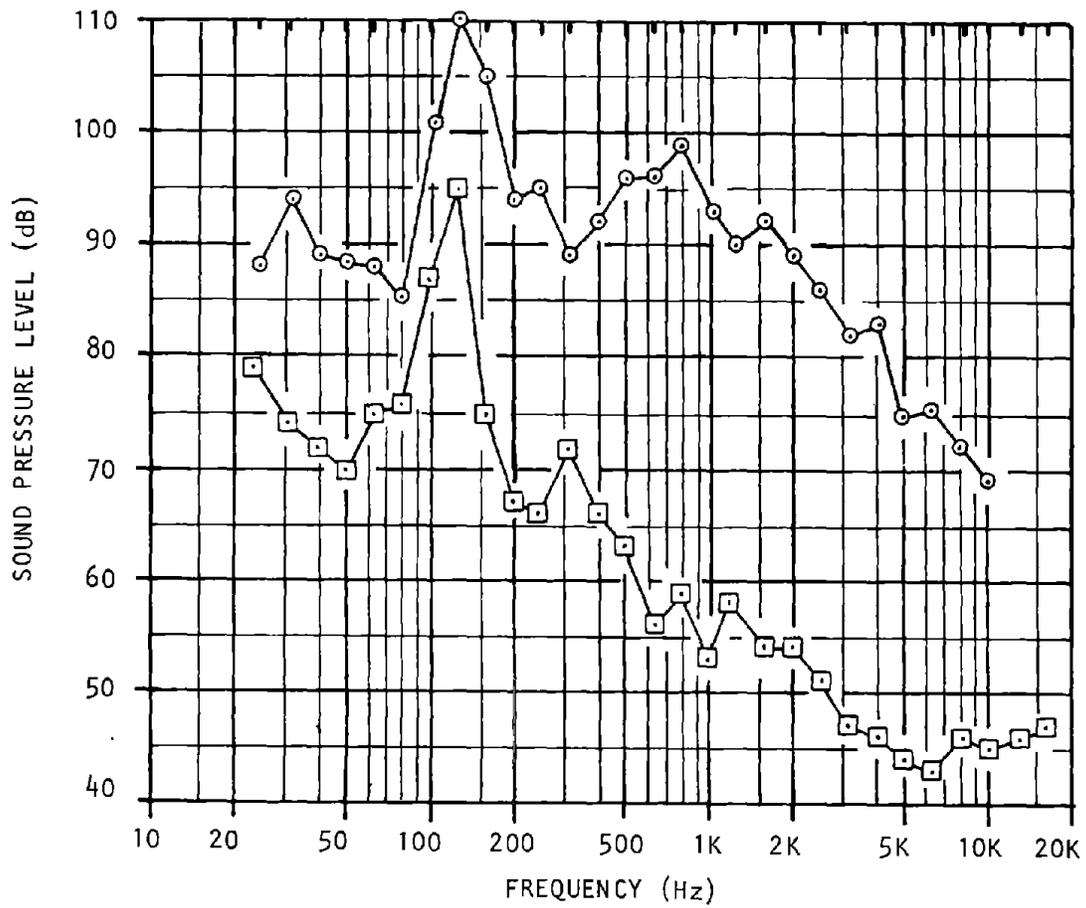
401
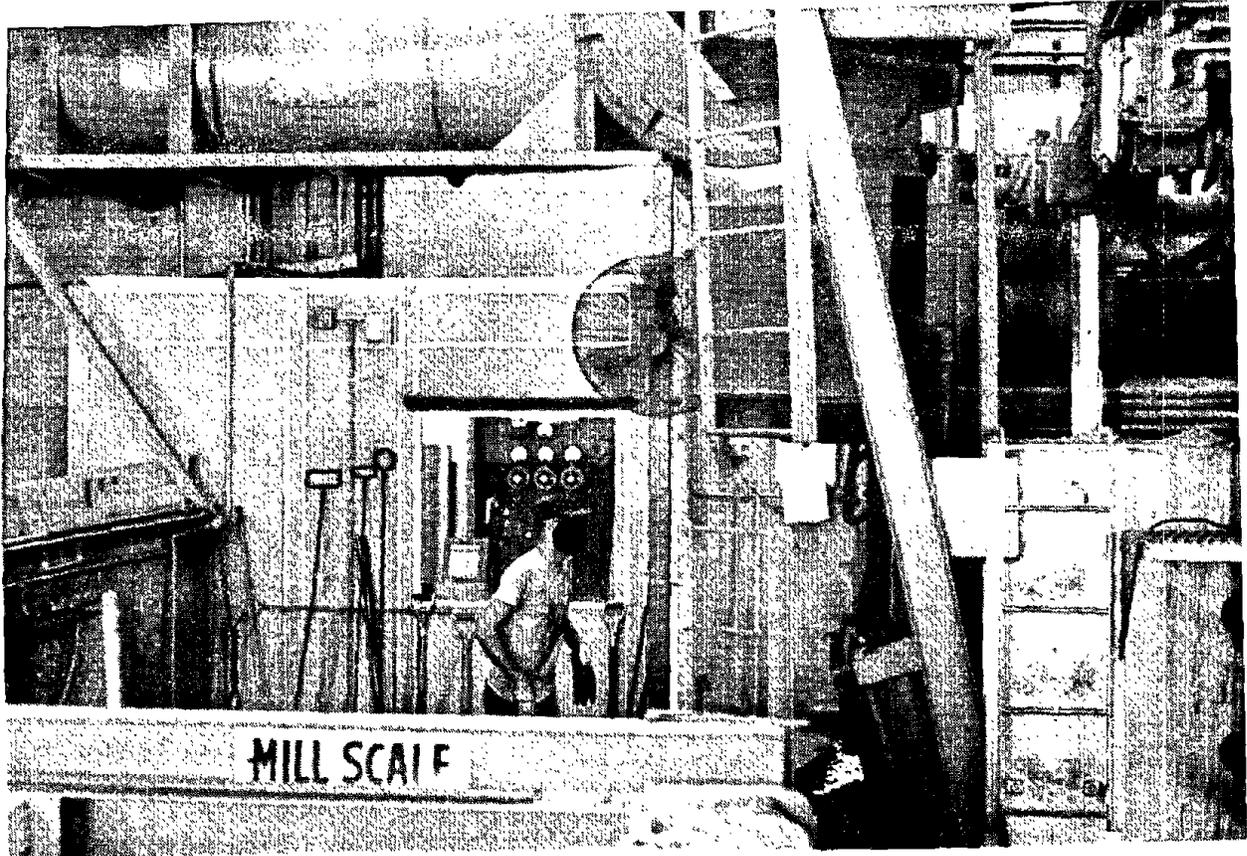
Figure A32-2. Arc furnace control room.

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was evaluated by comparing the overall level and frequency spectra inside and outside the room.

RESULTS

1. The furnace operators' control room significantly reduced the noise exposure. Their exposure was only 88 percent of the allowable OSHA limit for 8 hours of exposure. Without the room (outside), the noise exposure was about 2.5 times the OSHA limit for 8 hours of exposure per day.

2. The noise attenuation of the control room was about 16 dBA. Inside the room the noise level was 82-88 dBA compared to 95-108 dBA outside.

3. The control room reduced the level of all frequencies above 20 Hz; the levels were reduced between 9 and 40 dBA (Figure A32-3).

SYMBOLS

□ INSIDE BOOTH

O OUTSIDE BOOTH

Figure A32-3. Sound pressure level spectrum of operator control room.

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CASE HISTORY #33
CONTROL OF SAND SHAKEOUT NOISE
JUNE, 1977

ABSTRACT

In one area of this large iron and steel foundry, the noise levels generated
by a sand shakeout contributed significantly to the overall noise level.
The shakeout was isolated from the surrounding processes by an enclosure
that reduced the noise level about 20 dBA. The enclosure was constructed
of standard acoustical panels.

PROCESS DESCRIPTION

The foundry had several molding, pouring and shakeout lines. They were
located throughout the foundry and were of varying size. The controlled
shakeout was located among several other foundry operations (spruing,
sorting, etc).

The shakeout was of the vibratory type, about 10 ft (3.05 m) long and
5 ft (1.5 m) wide (Figure A33-1).

In this particular production line, semi-cooled molds were dumped onto a
vibratory conveyor and the hot castings were removed from the conveyor
by hand with the aid of a hoist. The molding sand, core butts, and excess
metal were fed onto the shakeout to separate any metal (sprues, gates,
rods, wires, etc) from the sand. Lumps were broken up and sand fell
through the screen and into the sand system.

POTENTIAL WORKPLACE HAZARDS

The sand shakeout was one of the loudest noise sources in the area and it
was in operation many hours per day. The operator normally worked within
10 ft (3.05 m) of the shakeout.

CONTROL OF EXPOSURE

Engineering

Noise generated by the sand shakeout was isolated from the other processes
by a total enclosure. Outside dimensions of the enclosure were 20 ft
(6.1 m) long, 13 ft (3.9 m) wide, and 18 ft (5.5 m) high. The enclosure
was constructed with standard 4 inch (10.2 cm) thick acoustical panels.
The panels consisted of 16 gauge steel on the outside and about 4 inches
(7.6 cm) of 6 lbs/ft^3 (96.1 kg/m^3) mineral wool with a mylar liner
on the inside surfaces. The mylar liner prevented the mineral wool from
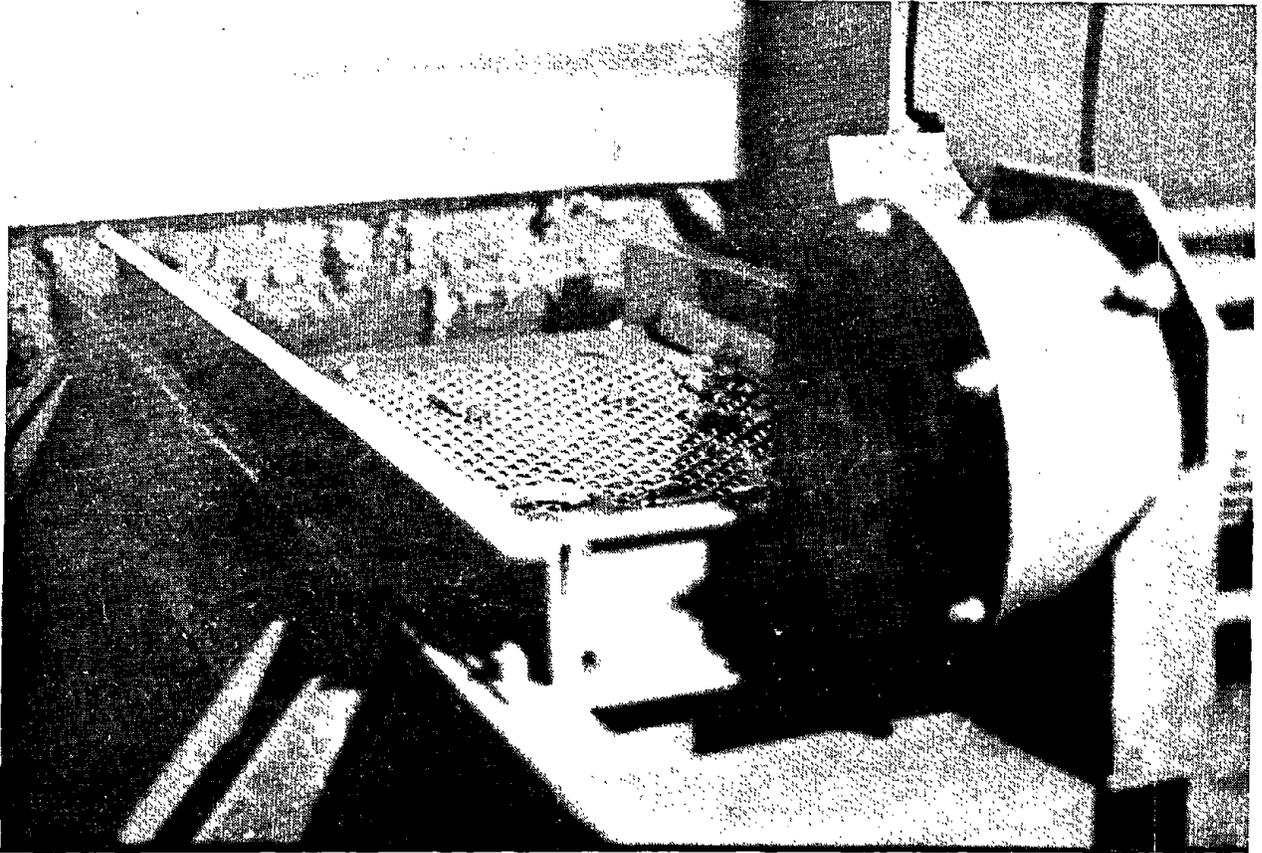plugging up with dust. The inside surface of the mineral wool was also

Figure A33-1. Sand shakeout.

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protected by a 22 gauge perforated steel liner. There was an access door constructed of the same type panels and sealed around the edges. The sand inlet was baffled with three heavy rubber conveyor belts spaced 6 inches (15.2 cm) apart (Figure A33-2).

Personal Protective Devices--
The operator was wearing hearing protection (ear plugs).

SAMPLING STRATEGY

The objective was to determine if the noise level emitted by the shakeout enclosure was less than the OSHA limits (90 dBA) and also to determine the noise attenuation of the enclosure. Measurements were made inside the enclosure and outside at 3 ft (0.9 m) from the enclosure. The overall level and frequency spectra were measured.

RESULTS

1. Noise levels outside the shakeout enclosure were about equal to the OSHA limits for 8 hours of exposure. Without the enclosure, the allowable exposure was about 3 hours per day.

2. The shakeout enclosure reduced the noise level emitted by about 25 dBA. Noise level at the operator position was about 89 dBA with the enclosure compared to about 105 dBA without the enclosure.

3. The enclosure reduced the noise level of all the frequencies above about 100 Hz by 8 to 25 dB. Below 100 Hz, the levels were about equal to the ambient levels (Figure A33-3).
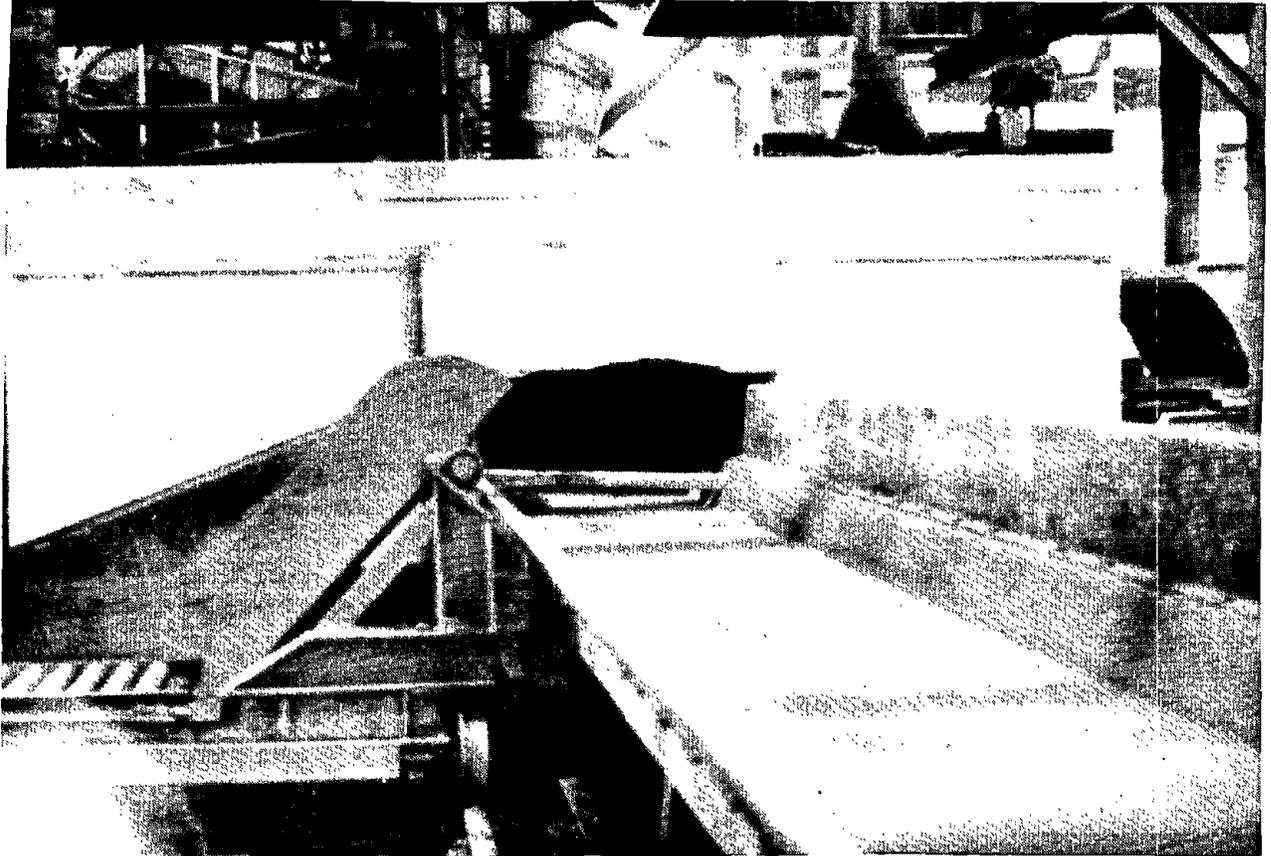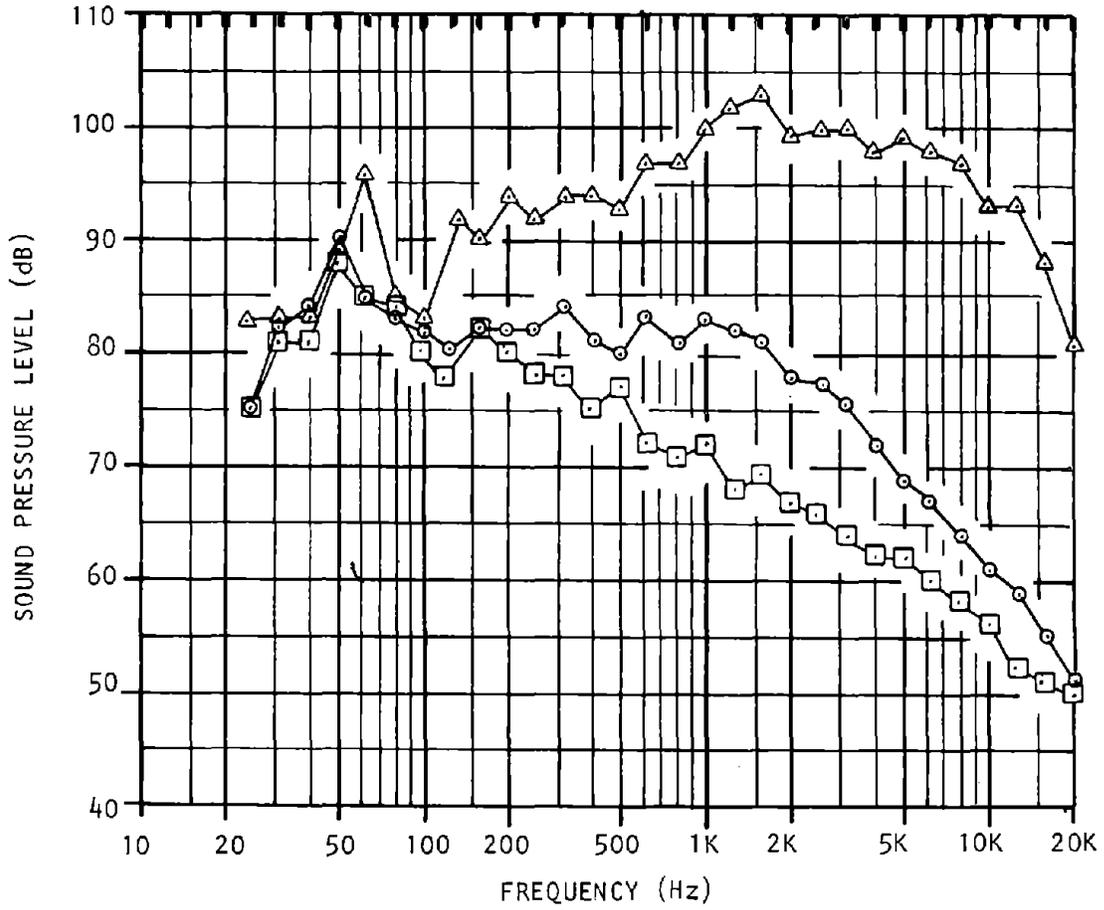
Figure A33-2.   Enclosure inlet.

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Figure A33-3. Sound pressure level spectrum of
shakeout enclosure.

CASE HISTORY #34
CONTROL OF CORE ROOM NOISE
JUNE, 1977

ABSTRACT

The noise level in the core room of this large iron and steel foundry was
above the OSHA limits for 8 hours of exposure per day. The noise was
generated by many sources; some of the sources were fans, air nozzles,
air exhausts and pattern vibrations. Each of the sources was reduced
through equipment substitution, i.e., using a quiet tool instead of a
loud one. The noise level was reduced to less than the OSHA limit for
8 hours of exposure per day.

PROCESS DESCRIPTION

The core room was typical of most green sand foundries and was located
adjacent to a molding and pouring line. Many styles and types of sand
cores were made. The core area was divided into four areas: oil sand,
shell core, some miscellaneous types, and the core ovens.

There were about 30-40 workers in the area, divided approximately as
follows:

    1. Core blowing machines (8-10 workers).
    2. Bench core or hand made (8-10 workers).
    3. Shell core (8-10 workers).
    4. Misc. operations (sand slinger for large cores, no bake, etc).

All the core machines (core blowers and shell) were typical of the type
found in most foundries, and were not specially designed.

WORKPLACE HAZARDS

The noise at each machine and/or work station of the core room was generated
by many similar sources. The most significant noise sources in the core
area are listed below (order of importance was not determined):

    Fan noise.
    Air nozzle noise.
    Air exhaust (from pneumatic equipment).
    Pattern or mold vibrations.
    Gas jets (shell core).
    Ambient from other shop operations.
    Miscellaneous ("clank, rattle, and bang").

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CONTROL OF EXPOSURE

The core area noise was reduced by reducing the noise generated by each of
the sources. In general, the noise reduction was accomplished through
equipment substitution. For each piece of equipment, several manufacturers
of quiet models were available. To determine which items to use, several
different models were purchased, tested and the noise levels compared.
The quietest piece of equipment was selected and substituted for the loud
one unless some other factor prevented its use, e.g., physical size, etc.
A brief discussion of the sources that were reduced follows.

Air Circulation Fans

See Case History #36.

Air Nozzles

At each station, the worker used an air nozzle primarily for cleaning the
pattern. Several quiet air nozzles were found with sufficient force, but
only the Zeph-air[§] safety blow gun did not plug-up with sand and dirt.
The nozzle was a "flowthrough" type (see Case History #35).

Pattern Vibrators

Vibrators were used at most, if not all, work stations to separate the
fragile sand core from the pattern. Piston type vibrators were found to
generate the loudest noises and often generated more force than necessary.
Turbine and rotary vibrators generated much less noise and generally had
sufficient force to separate the sand from the pattern. Generally,
vibrators manufactured by the Cleveland Vibrator Company (1" S-A-M silent)
were used. When mounting the vibrators, the manufacturer's recommendations
were followed (Figure A34-1).

Air Exhaust Noise

On most of the machines, some type of pneumatic equipment was used. As
a result, air was exhausted at high pressure. These high pressure exhausts
generated very loud noises which contributed significantly to the overall
exposure. Many types of commercially available exhaust mufflers were
found that performed adequately. The selection was based on cost, ease
of replacement, and usefulness in the foundry.

Miscellaneous

All other extraneous noises such as rattling guards, etc., were eliminated
where possible.

Personal Protection--
All the workers in the area were wearing hearing protection.
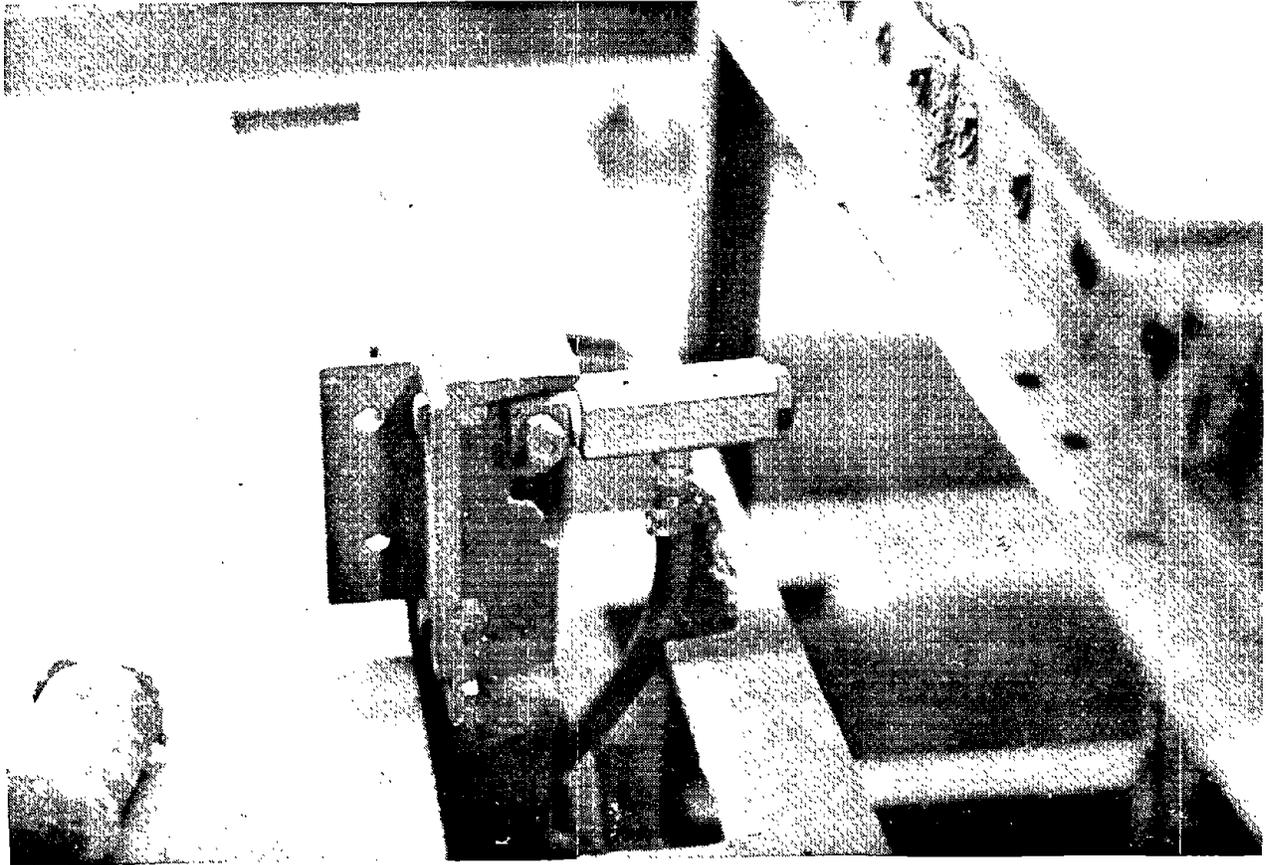
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§ Trade name.

Figure A34-1. Pattern vibrator.

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SAMPLING STRATEGY

The objective was to determine if the noise level in the core room was below the OSHA limits for 8 hours of exposure. Exposure was determined for six different operators in the area and their exposures were compared to the OSHA limits. Each of the operators wore a noise dosimeter for 7 to 8 hours of a normal shift.

RESULTS

1. The noise level in the core room was below the OSHA limits for 8 hours of exposure per day.

2. The noise levels in the core area ranged from 40 to 80 percent of the allowable level.

Core room noise levels.

Description	ENL,§ dBA	Range, dBA	Percent of time*					
			85-87	87-90	90-92	92-95	95-97	97-100
Core blower	88	87-100	0	13	61	20	4	2
Shell core #1	89	85- 92	69	30	1	–	–	–
Shell core #2	87	<85- 95	62	32	4	1	–	–
No bake	82	<85 -97	5	2	1	1	0.5	–
Oil sand (bench)	86	<85-100	19	11	5	3	1	<0.5
Oil sand (bench)	83	<85-100	13	8	4	12	2	<0.5

§ Effective Noise Level (ENL) $= 90 + 16.61 \left[\log \left(\dfrac{\% \text{ count}}{100} \times \dfrac{\text{measure time}}{8 \text{ hrs.}} \right) \right]$

* Based on 8 hours per day.

CASE HISTORY #35
CONTROL OF MOLDING MACHINE NOISE
JUNE, 1977

ABSTRACT

The noise levels generated by the molding machines in this large iron and
steel foundry were greater than the OSHA limits for 8 hours of exposure
per day. A small molding machine was analyzed, and the noise levels of the
various sources were determined. The noise level of each source was reduced
by substituting a quieter operation or tool for the loud one and the
resulting overall noise level was below the OSHA limit. The overall
reduction was about 8 dBA.

PROCESS DESCRIPTION

Although this foundry had several types and sizes of molding machines, the
one evaluated in this work was a small Osborne§. The molding machine was
a jolt-squeeze machine located in a line of about 17 similar machines.
Sand was conveyed to the molding stations by belts and dumped into hoppers
above each station. The completed molds were placed on a roller conveyor
behind the molding machine and rolled into position for pouring (Figure A35-1).
Completed molds were about 18 inches (0.46 m) square. The molding machine
was typical of those used in many green sand foundries.

WORKPLACE HAZARDS

The overall noise level generated during the molding operation was above
the OSHA limit and was the result of many sources. The major noise
sources were found to be (loudest first):

    Jolt.
    Squeeze.
    Pattern vibrators.
    Air nozzle (cleaning).
    Air circulation fans.
    Filling flask with sand (hopper vibrators).

CONTROL OF EXPOSURE

The foundry pursued two paths in reducing the noise. The first was to
contact the molding machine manufacturer and obtain recommendations for
reducing the machine noise. The second was to obtain quiet vibrators, air
nozzles, etc., and determine which were most suitable. The air nozzles,
vibrators, etc., were tested on one molding machine and noise levels were
compared to those from the unmodified machine. In general, the quietest devices
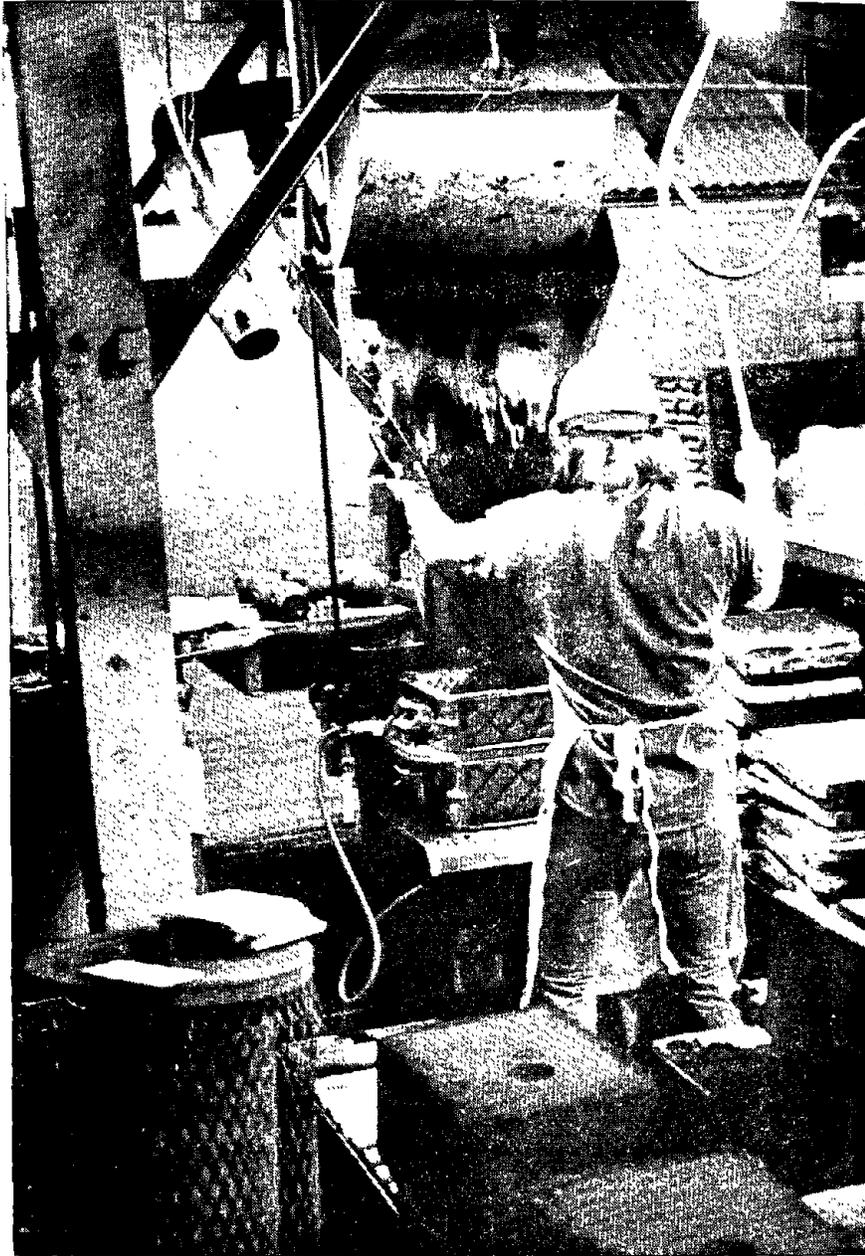
§ Manufacturer's name.

Figure A35-I. Molding machine and operator.

in the foundry's tests were selected. A discussion of the sources that were reduced follows.

Jolting

A significant reduction in the jolting impact noise had not been achieved. Various types of elastomer pads had been tried by this foundry and others. Initially, the pads did reduce peak noise, but they wore out very quickly. Also, the jolting force was reduced as a result of the elastomer, and sometimes mold quality suffered.

Squeeze

The molding machine manufacturer recommended that the machine be retrofitted with a Whisperam[§] to reduce the noise. The Whisperam is a quiet, rapper-type mechanism used to squeeze and compress the pattern into the molding sand; it does a very good job and is substantially quieter. No data were available on the noise level before the installation of the Whisperam.

Vibrator (Pattern and Hopper)

Piston-type vibrators were found to generate the largest forces and the loudest noises, but large forces were not always needed. Turbine and rotary vibrators generated much less noise and produced sufficient force to separate the sand from the pattern or shake the sand loose from the hopper (Figures A35-2 and 3). Generally, Vibco[§] silent air turbine vibrators were used. Lining the sand hoppers with a plastic material allowed the sand to flow more freely, which required less vibration. In each case, the manufacturer's recommendations on mounting the vibrators were followed.

Air Nozzles

The molder used an air nozzle to blow excess sand off the flask, pattern, etc. Several quiet air nozzles were found that had sufficient force to blow the sand away. However, the Zeph-air[§] safety blow gun was the best and did not clog up with sand or dirt (Figures A35-4 and 5). This nozzle had a "flow through" design so that it would not clog and was estimated to be about 10 dBA quieter than the previous nozzle.

Air Circulation Fans

See Case History #36.

Air Exhaust Noise

The molding machine had several pneumatic systems (cylinders, etc) that discharged high pressure air as each mold was made; they contributed significantly to the overall level. Many types of exhaust mufflers from several manufacturers were found that performed adequately. Selection was based on cost, ease of replacement, and usefulness in the foundry.
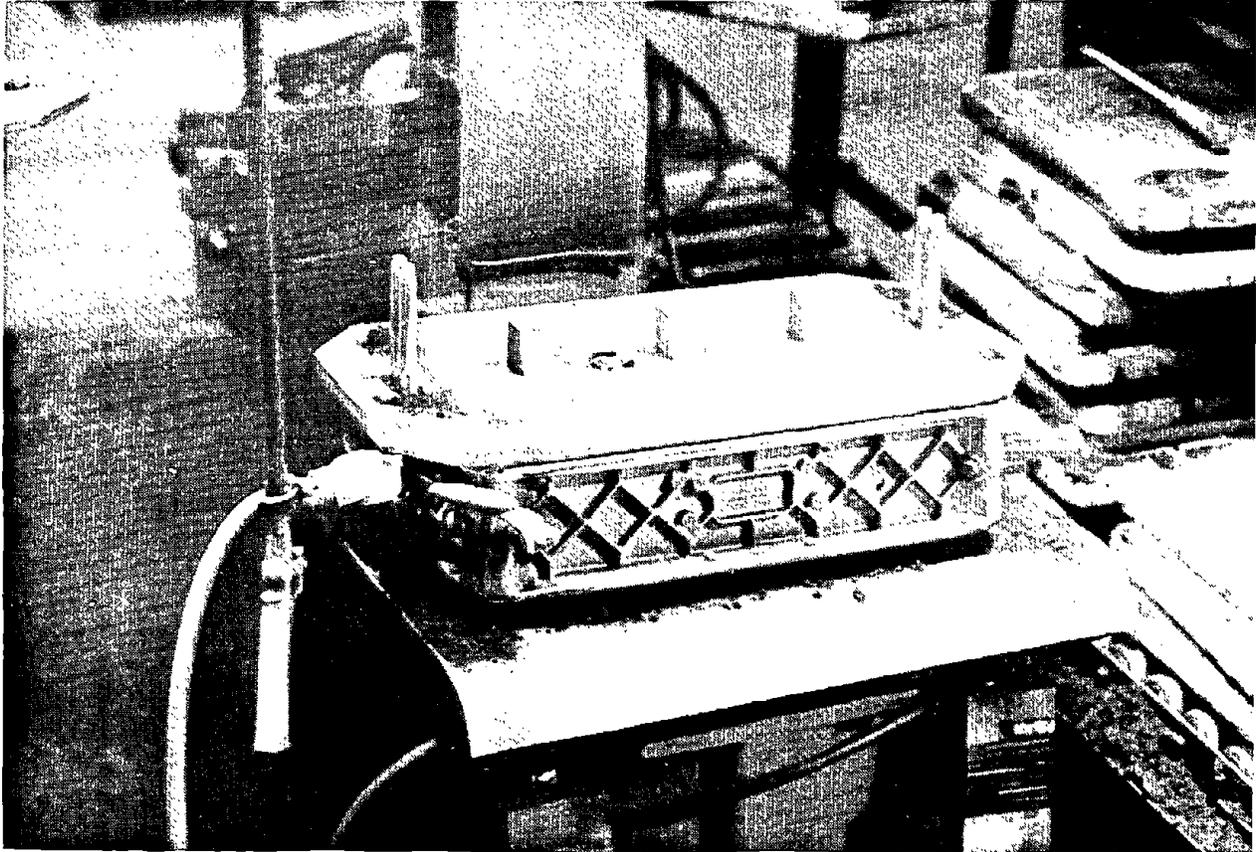

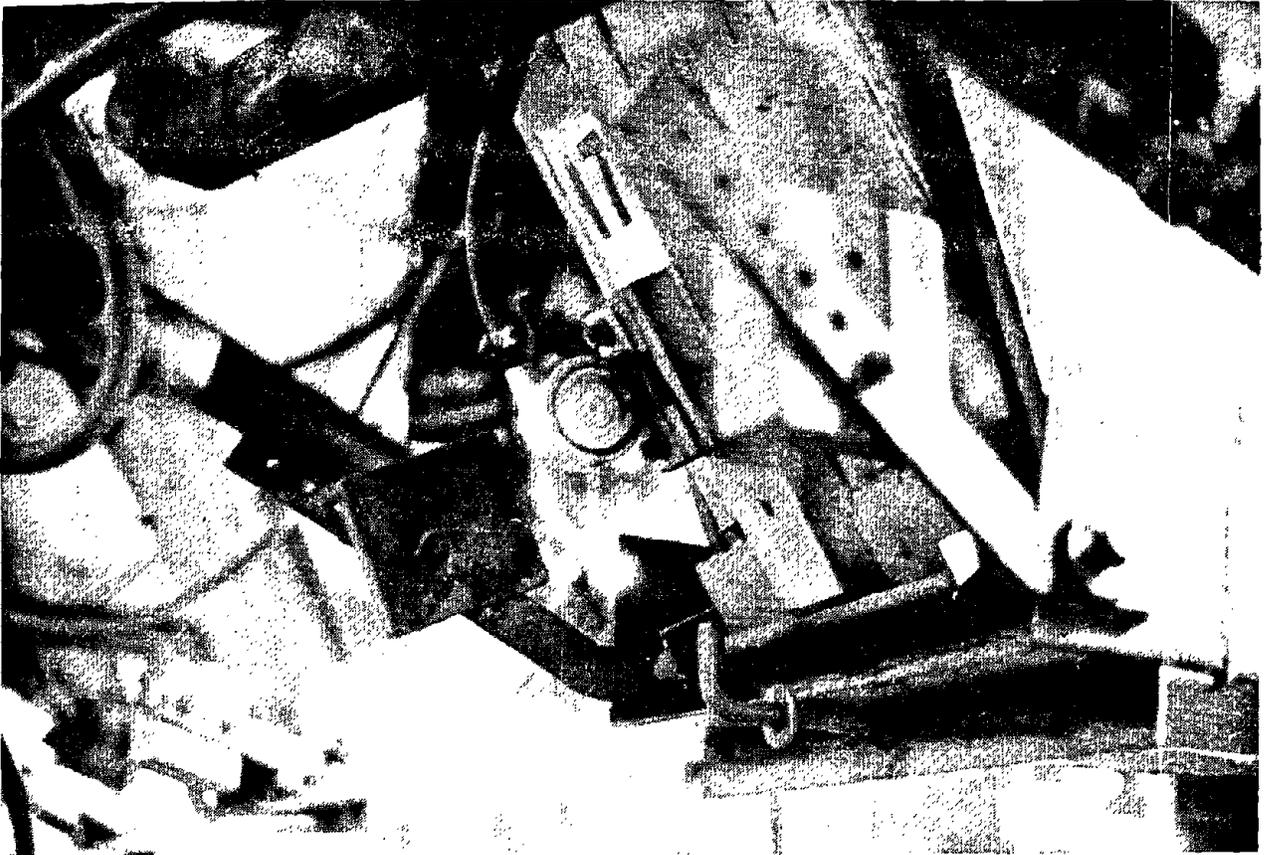§ Trade name.

Figure A35-2. Pattern and pattern vibrator.

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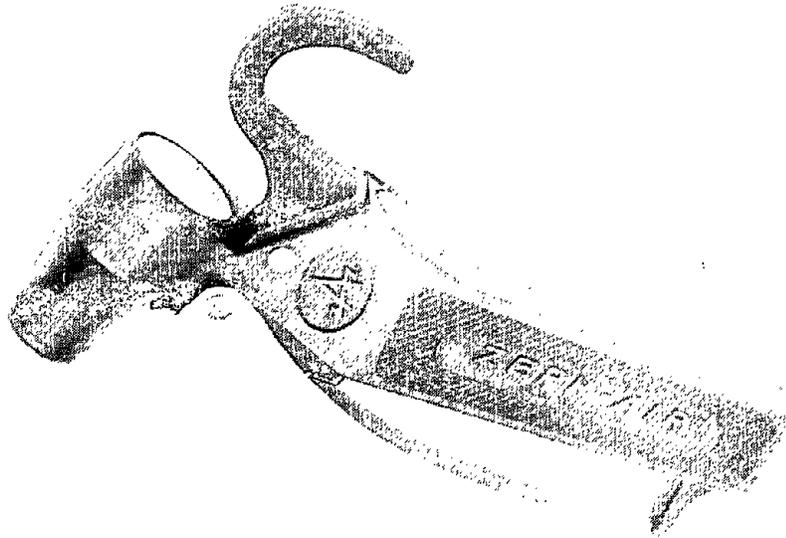
Figure A35-3.   Sand hopper vibrator.

Figure A35-4. Quiet air nozzle.

TWO PARTS
FREE AIR
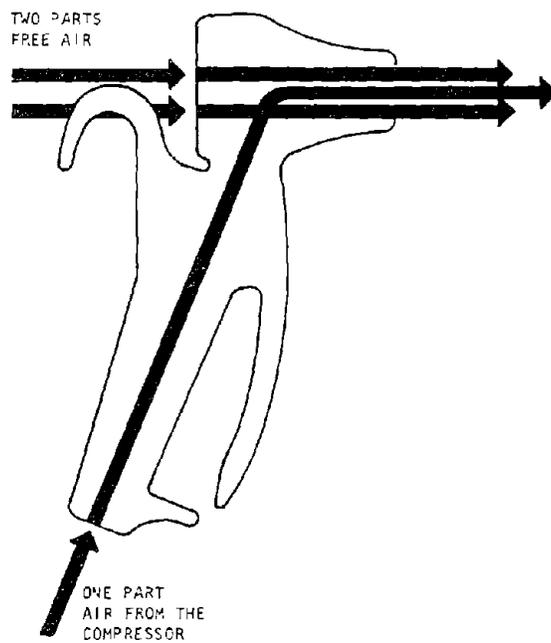
ONE PART
AIR FROM THE
COMPRESSOR

Figure A35-5. Airflow pattern of nozzle.

SAMPLING STRATEGY

The ambient noise level in the area from shakeouts, other louder molding machines, etc., was greater than the level generated by the molding machine. As a result, the operator's noise exposure during a complete shift could not be determined. Instead, his exposure was determined during a 20-minute test with all other machines shut off. During the test, the molder worked exactly as in normal production and the noise level was continuously tape recorded. The tape recording was analyzed to determine the dBA level vs. time. From those measurements operator noise exposure was calculated and extrapolated to a full shift by assuming he worked the same way for 8 hours. In addition, the operator wore a noise dosimeter in the accelerated mode and exposure was also determined in that way. The average of the two methods is reported.

RESULTS

1. Noise generated by a single molding machine was below the OSHA limits for 8 hours of exposure per day. Operator exposure was about 75 percent of the allowable level. Before the noise reduction, operator exposure was about 150 percent of that allowed.

2. The noise level generated by the molding machine ranged from 85-106 dBA. The loudest noise source was still the jolting operation.

Molding machine noise levels.

Method of evaluation	ENL, § dBA	Percent of time								
		85-87	87-90	90-92	92-95	95-97	97-100	100-102	102-105	105-107
Tape recorded	85	35	41	5.4	7.1	1.2	0.6	1.2	1.2	0.6
Noise dosimeter	86	-	-	-	-	-	-	-	-	-

§ Effective Noise Level (ENL) = $90 + 16.61 \left[\left(\frac{\% \text{ count}}{100} \times \frac{\text{measure time}}{8 \text{ hrs.}}\right) \right]$

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CASE HISTORY #36
CONTROL OF AIR CIRCULATION FAN NOISE
JUNE, 1977

ABSTRACT

Part of the background noise level in this large iron and steel foundry was
the result of air circulation fans. The foundry substituted a different
fan blade for the old style and significantly reduced the noise level from
about 90 dBA to about 75 dBA. The original high speed and low pitch fans
were replaced with four blade, low speed, high pitch fans.

PROCESS DESCRIPTION AND WORKPLACE HAZARDS

Throughout the foundry, many fans were used to circulate the air and cool
the workers. Many were old and in need of rapair (Figure A36-1). Noise
levels of the air circulation fans were measured with all other processes
shut down. The noise levels generated by the fans were equal to or
greater than the OSHA limits for 8 hours of exposure (90 dBA). Therefore,
the noise from any other process could only increase the total level in
the area.

CONTROL OF EXPOSURE

Engineering

The noise level generated by the air circulation fans was reduced by
substituting quiet propeller blades for the old noisy types. Each original
fan had a one horsepower (0.75 kw) motor driving a two or four bladed
propeller through a belt. The propellers were designed to operate
at high speed. The old propellers were replaced with four bladed propellers
designed to operate at a lower speed (Figure A36-2).

New lower speed motors were selected. The new propeller speed was selected
to result in about the same air output as the original. The two propellers
are listed below:

| | Diameter | | Number of blades | Blade speed, rpm | Airflow rate | |
Propeller	in.	cm			cfm	m3/sec
New	35-7/8	91.1	4	860	14,500	68.8
Original	36	91.4	2	1750	15,420	72.8

SAMPLING STRATEGY

The objective was to determine the overall noise level and frequency spectrum
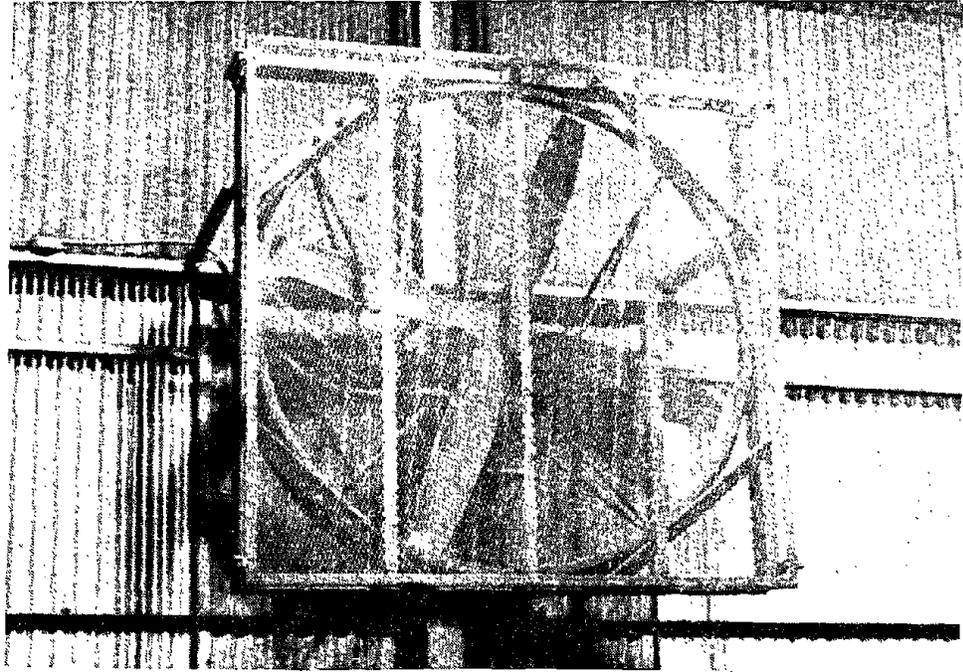
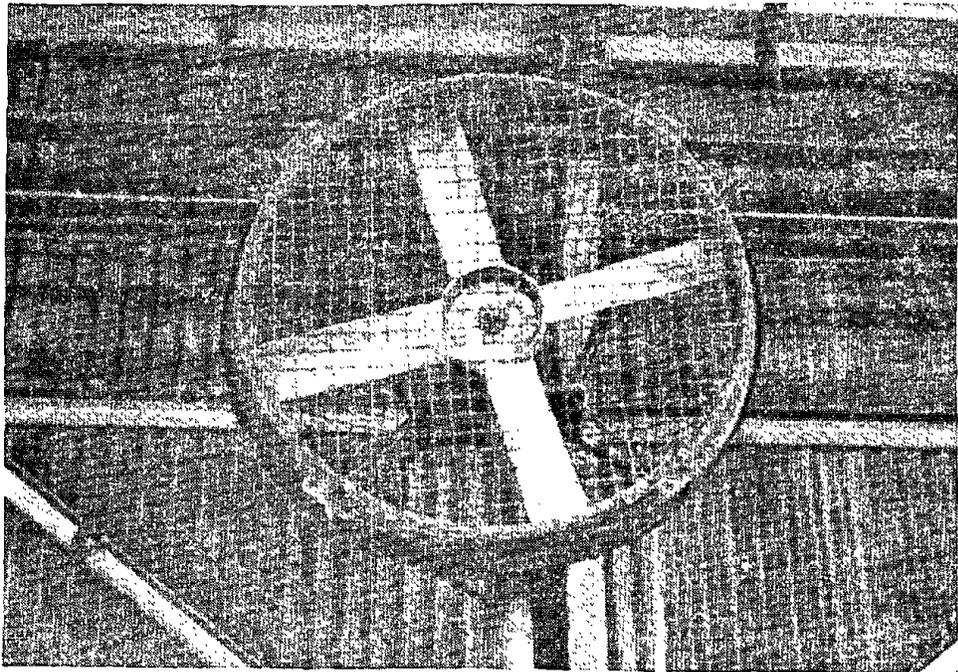421

Figure A36-1. Old style air circulation fan.

Figure A36-2. New style air circulation fan.

of the new fans. The overall level was to be compared to the OSHA limits and to the data gathered by foundry personnel. The measurements were made three ft (0.9 m) in front of the fans with all other processes shut down.

RESULTS

1. Noise levels generated by the new air circulation fans were significantly below the OSHA limits for 8 hours of exposure. In comparison, the old fans generated noise levels equal to the OSHA limit for 8 hours of exposure.

2. Changing the fan propeller reduced the noise generated by about 15 dBA. The noise level of the new fan was 75 dBA compared to 90 dBA for the old fan.

3. The frequency spectrum of the new fan is presented in Figure A36-3. The old fan frequency spectrum was not available.

4. Sound level data collected by the foundry personnel pertaining to the air circulation fans were verified.
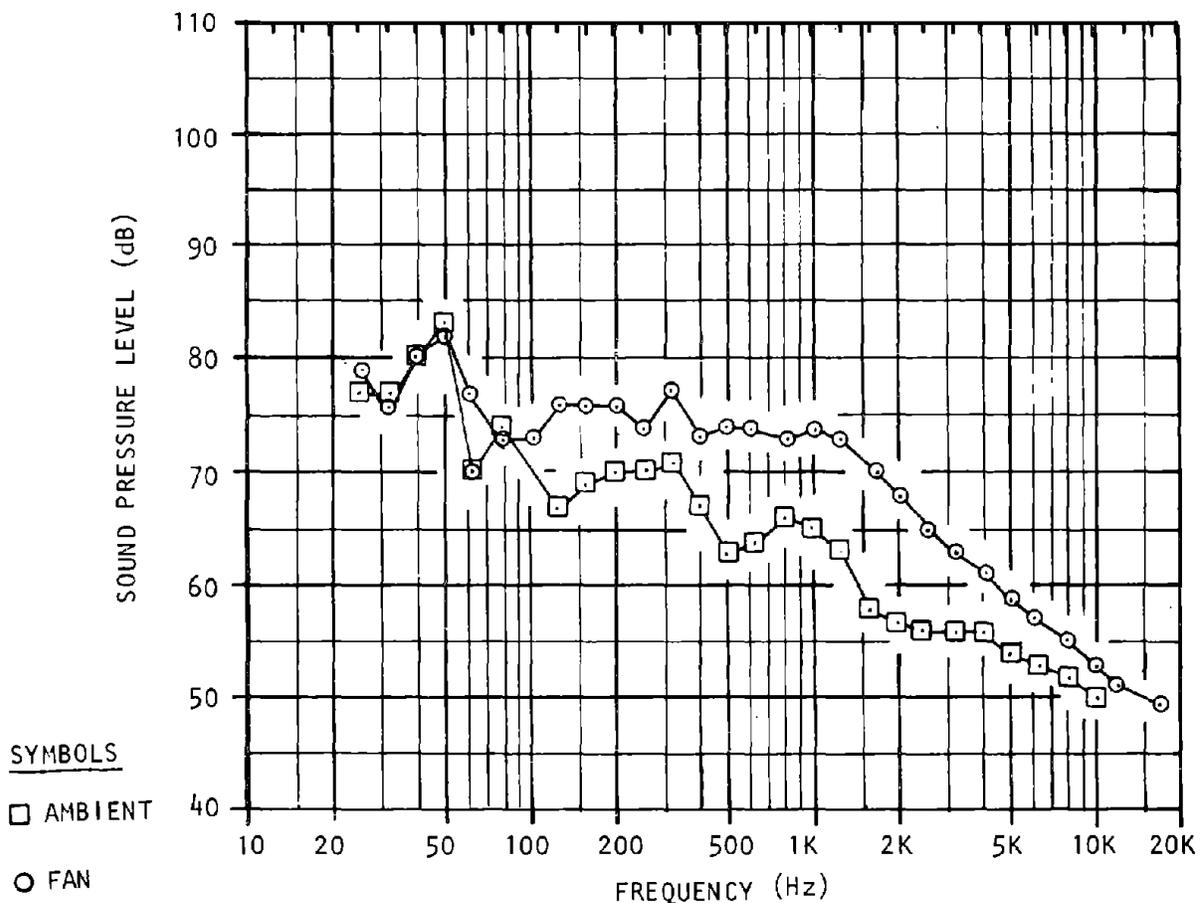

Figure A36-3. New style air circulation fan frequency spectrum.

GLOSSARY OF TERMS

ACCLIMATION
(or ACCLIMATIZATION)
The process of becoming accustomed to new conditions. Also called hardening when used to refer to the body's reaction to chronic exposure to some irritant.

ACGIH
American Conference of Governmental Industrial Hygienists
P.O. Box 1937
Cincinnati, Ohio   45201   for TLV booklets and other information;
P.O. Box 16153
Lansing, Michigan   48902 for Industrial Ventilation.

ACUTE
Short-term or single dose.

AEROSOL
A dispersion of solid or liquid particles in a gaseous medium.

ALLERGEN
A material capable of inducing allergy or hypersensitization.

ASPHYXIANT
A substance capable of causing a lack of oxygen or excess carbon dioxide in the body.

BENIGN
Not malignant.

BRONCHITIS
Inflamation of the bronchi.

CANOPY HOOD
Any suction opening that is located above a source of contamination.

CAPTURE VELOCITY
The air velocity at any point in front of the hood or at the hood opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow toward the hood.

CARCINOGEN
A material or organism capable of causing cancer. Some forms of non-ionizing and ionizing radiation can also be carcinogenic.

CENTRAL NERVOUS
SYSTEM (CNS)
Nervous system consisting of the several sections of the brain and the spinal cord.

CHRONIC	Long-term or duration, repeated dose or exposure.
COLIC	Acute spasmodic pain in the abdomen.
CONTROL AT THE SOURCE	Exhaust capture close enough to the point of generation of air contaminants to prevent the contaminants from entering the breathing zone of workers or the general atmosphere.
CROSS-CONTAMINATION	Contaminants from one process affecting a nearby plant area or process.
CROSSDRAFT	A current of air not flowing in the direction of a hood opening that acts to disrupt or change the direction of streams of air before they can enter an exhaust hood.
DERMATOLOGIC	Pertaining to a branch of medical science that relates to the skin and its diseases.
DERMATITIS	Inflamation of the skin.
DOWNDRAFT HOOD	An exterior hood into which exhaust enters in a downward manner.
DUST	An aerosol of solid particles produced by mechanical action.
DYSPNEA	Difficult or labored breathing.
EDEMA	Presence of abnormally large amounts of fluid in the intercellular tissue spaces of some portion of the body.
ELECTROLYTE	Material capable of ionization in water.
EMPHYZEMA	Pulmonary emphysema is a condition of the lung characterized by an increase above normal in the size of air spaces beyond terminal bronchioles, either from dilitation of the alveoli or from destruction of their walls.
ENCLOSING HOODS	A local exhaust hood where the generation point for air contaminants is within the confines of the hood and the worker is outside those confines.
EXTERNAL HOOD	Any hood that does not confine the process or equipment emitting the contaminant(s) to be controlled. Exterior hoods function by inducing a flow of air from the point(s) of contaminant generation or release toward the hood opening.

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FACE (of a hood)	An opening through which air flows into the hood.
FUME	An aerosol of solid particles produced by condensation.
GENERAL VENTILATION	A dilution method of ventilation which achieves its primary effects by reducing air contaminant concentrations and by supplying fresh, tempered air to the vicinity of workers for comfort ventilation.
HEAT STRESS	The load on the thermo-regulatory system of a person due to an increase above thermally neutral conditions caused by a change in the metabolic rate of the person and/or by a change in the environment.
HOOD	A shaped inlet designed to capture contaminated air and conduct it into the exhaust duct system.
HOOD LEAKAGE (or LOSS)	Refers to contaminants which, due to the energy associated with their dispersal, are carried by air currents past the capture zone of a hood. Note that recapture may occur after the currents dispersing the contaminants lose enough energy to be brought into the influence of exhaust-induced flow patterns.
INDRAFT VELOCITY	Linear flow rate of contaminated air through the face opening of a hood.
IRRITANT	An agent capable of causing a reaction in organic tissue characterized by inflammation, pain, etc.
ISOLATION	Control of a hazard by interposing a barrier between the worker and the hazard (that may be a physical barrier, time or distance).
KERATIONIZATION	Formation of callous or horny tissue, especially on the hands and feet.
KERATITIS	Inflammation of the cornea. Photokeratitis is inflammation of the cornea by light and is also known as welder's flash, flash burn, or welder's eye.
LACHRYMATION (or LACRIMATION)	Tearing of the eyes.

MAC	Maximum (or maximal) allowable (or acceptable) concentration. A set point for control of inhalation exposure.
METAL FUME FEVER	A syndrome induced by exposure to fume, producing a collection of symptoms similar to malaria or influenza.
NECROSIS	Death of tissue, usually as individual cells, groups of cells, or in small localized areas.
OLFACTORY	Pertaining to the sense of smell.
PARANASAL	The region near the nasal cavity.
PERIPHERAL NERVOUS SYSTEM	The part of a living organism's nervous system that lies physically outside the central nervous system.
PNEUMOCONIOSIS	The accumulation of dust in the lungs and the tissue reaction to its presence.
POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)	Hydrocarbons with fused-ring systems, with or without aliphatic side chains.
PROCESS MODIFICATION	An engineering control of a workplace hazard consisting of changing a process to eliminate or reduce a hazardous condition.
PULMONARY	Pertaining to or affecting the lungs.
PUSH-PULL VENTILATION	A type of local exhaust control where a receiving hood induces a flow of air (and contaminants) toward it while the "push" toward the hood is simultaneously achieved by a mechanical supply air source or by prevailing ventilation patterns. Also called blow and exhaust systems.
SENSITIZATION	Process of becoming abnormally reactive to an allergen or a normally stressful condition.
SIDEDRAFT HOOD	A receiving hood into which exhaust enters laterally.
SILICOSIS	Fibrotic disease of the lungs caused by inhaling crystalline silica.
SUBSTITUTION	Replacement of hazardous materials, processes, or pieces of equipment with less or non-hazardous ones.

SWARF	Stream of particles.
SYSTEMIC INTOXICATION	Poisoning of the body induced by toxins, drugs, etc.
TEMPORARY THRESHOLD SHIFT (TTS)	An impermanent increase in the threshold of hearing.
THERMAL DRAFT	Air currents set in vertical motion by heat.
THRESHOLD LIMIT VALUE (TLV)	A concentration in air or an exposure rate or dose rate felt by ACGIH to be safe for repeated exposure to workers. A set point for control of a hazard.
TOXIC HEALTH HAZARD	Likelihood of toxic injury.
TOXICITY	The ability of a material to injure a living organism by other than mechanical means.
TRAMP METAL	A metallic element present (in a casting or scrap, for example) as an impurity, usually in insignificant amounts.
VAPOR	The gaseous phase of any substance which is condensable at room temperature and atmospheric pressure.