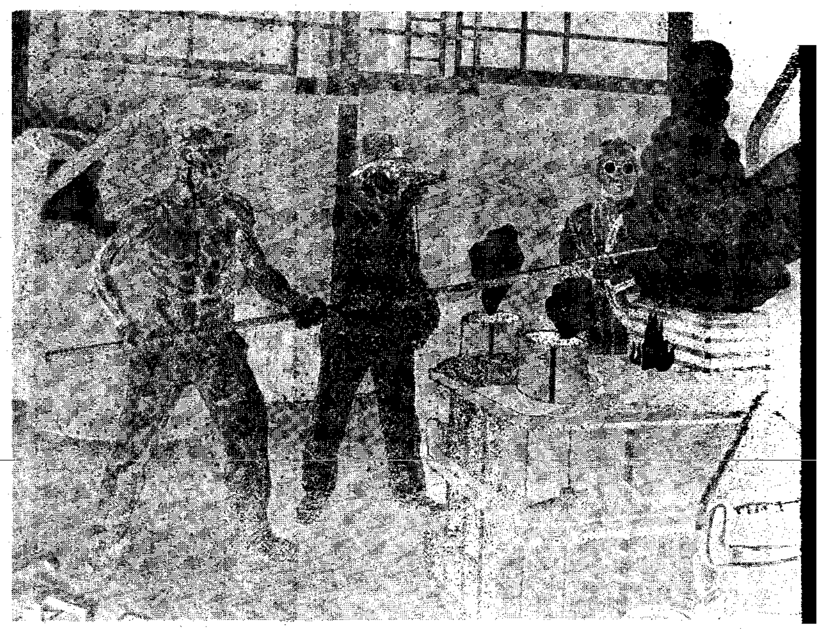
N I O S H

engineering control of occupational health hazards in the **foundry industry**

instructor's guide



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Cover photograph: This mural representing the foundry industry, one of fourteen murals depicting industrial scenes, is now on permanent display at the Greater Cincinnati Airport. The murals, designed by Winold Reiss in the early 1930's, originally adorned the walls of Cincinnati's Union Terminal Railway Station.

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Robert C. Scholz

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This manual contains instructional resource material for a six-hour course module covering the engineering control of occupational health hazards in the foundry industry. The intended primary audience for the course is technical personnel responsible for developing and implementing engineering solutions to occupational health problems. The purpose of the course is to teach the principles and concepts underlying engineering control, through evaluation and discussion of in-place and functioning control measures found in industry. Prior to discussion of control measures, basic foundry processes are briefly described as well as foundry air contaminants and their sources and modes of dispersion. Engineering control measures include material substitution, process isolation, and exhaust ventilation. Maintenance and monitoring of engineering control system performance is also discussed, in addition to housekeeping, and research and development for new and improved engineering control techniques.

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ENGINEERING CONTROL OF OCCUPATIONAL HEALTH HAZARDS IN THE FOUNDRY INDUSTRY

INSTRUCTOR'S GUIDE

Prepared by:

Robert C. Scholz
Rexnord, Inc.
Environmental Research Center
Milwaukee, WI 53214

Division of Training and Manpower Development

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Cincinnati, Ohio 45226

August 1981

DISCLAIMER

PREFACE

The course described in this instructor's manual is different from most courses on health hazard control. It teaches its lessons primarily through evaluation and discussion of in-place and functioning control measures from industry. Such an approach would not have been possible unless a thorough engineering evaluation of such control measures had been made first. During the period from 1976 to 1978, a comprehensive health hazard control technology assessment of the foundry industry was made by NIOSH. Field studies were conducted in 24 foundries and were reported as a series of case histories. After publication of this field study, a two-day symposium was held in Chicago in 1979. New foundry research findings and case studies were reported and documented in the symposium proceedings. The majority of examples used in this instructor's manual were taken from these two sources. As a prospective instructor you should thoroughly familiarize yourself with these resources prior to teaching the course. Imparting knowledge concerning the advantages and disadvantages of a particular control measure requires understanding of the background information and circumstances surrounding the control situation; the case histories from which the examples in the course were taken can provide that understanding.

The subject material has been divided into five units, but the instructor is free to subdivide the material to fit the format in which the course will be used. The sequence of presentation, however, should remain as it is. Discussion questions are presented after each unit for class participation.

The examples presented in this course are organized by classification of control technique rather than by foundry process. Although such an approach results in "skipping around" the foundry in presenting the various examples, this format encourages indepth discussion of the important factors involved in using a particular type of control measure.

On October 22, 1980, a pilot presentation of the course was given at the headquarters of the American Foundrymen's Society in Des Plaines, Illinois. Twenty-six individuals reviewed the course including representatives from the foundry industry, labor unions, a university, the government, foundry design engineering firms, a technical association, and an insurance company. After attending the course, the attendees submitted written critiques. Three of the attendees also reviewed the instructor's manual. Their comments and those of the other attendees and the NIOSH Project Officer have been incorporated into this manual.

The course rated high in technical content, accuracy, and presentation. Relevance and format received a better-than-good rating. Visual aids were received with mixed opinions. The use of the schematics to enhance the understanding of the examples was widely applauded; a few photographs, however, were not of good quality. The overall opinion on the length of the course was good. Those giving course length a lesser rating generally did so with the note that it would not be good if presented in a single day.

The greatest percentage of the discussion concerning the course centered around who should be the target audience. A number of individuals, particularly those from large foundry organizations, indicated that the material was basic and fundamental, and that individuals who have responsibility for, and work from day-to-day on, health-related problems in foundries are often beyond this course. For the course to be relevant to these individuals, it would have to be broadened in scope to include discussion of specific design details and sampling results for in-place control measures. This would add substantially to the length of the course.

There were a number of groups identified who would be good candidates for the course. These groups include:

1. Small and medium-size foundries (all levels). These foundries typically do not employ specialists in health hazard controls. (It should be noted that the industry predominantly consists of small foundries, e.g. 60% have less than 50 employees).

2. Large foundries with safety and health specialists. In large foundries the specialists could teach the course to their own employees.

3. Government employees, e.g. OSHA compliance officers, co-op students, trainees, and NIOSH health hazard and control technology evaluation personnel.

4. New members of foundry plant engineering or safety and health staffs.

5. Students in industrial hygiene engineering.

6. Local union members responsible for safety and health, e.g. safety committee members and stewards.

7. Members of local chapters of American Foundrymen's Society.

8. Students in industry hygiene engineering survey course offered by the National Safety Council.

9. Occupational health physicians.

Some attendees felt that the discussions of particular slides between the instructor and the audience added appreciably to the understanding of the control measures. This emphasizes the need of the instructor to have an in-depth understanding of foundry processes as well as the control methods used.

ABSTRACT

This manual contains instructor's information for a six-hour course module covering the engineering control of occupational health hazards in the foundry industry. The intended primary audience for the course is technical personnel responsible for developing and implementing engineering solutions to occupational health hazard problems. The purpose of this course is to teach the principles and concepts behind engineering control through evaluation and discussion of in-place and functioning control measures from industry. Before control measures are discussed, basic foundry processes are briefly described as well as foundry air contaminant hazards, their sources, and modes of dispersion. Engineering control measures include substitution, isolation, and ventilation. Maintenance and monitoring of control system performance is also discussed in addition to housekeeping and research and development to improve control techniques and develop new ones.

Instructor's materials include this manual, two important literature sources, 35 mm slides, and student outlines. To simplfy preparation, all of the slides have been incorporated into this manual.

CONTENTS

FIGURES

FIGURES (continued)

FIGURES (continued)

TABLES

ACKNOWLEDGEMENTS

The course developer wishes to acknowledge the interest and guidance provided by the NIOSH Project Officer, Mr. John Talty. Before undertaking this course, he directed the activities of the NIOSH foundry occupational health hazard control technology assessment study and the 1979 foundry control technology symposium in Chicago which 500 people attended. With the development of this course, Mr. Talty has attempted to utilize the information gained in the former efforts by teaching it to those with a direct interest and involvement in the health of foundry workers.

The twenty-six professionals who took a day out of their busy lives to attend the pilot course and critique it are to be commended. In particular the additional effort of the three reviewers of the manual is to be acknowledged:

Gary E. Mosher	American Foundrymen's Society
Jane W. Brown	International Molders and Allied Workers Union
Edward R. Hermann, Ph.D.	University of Illinois School of Public Health

Thanks go to the American Foundrymen's Society for hosting the pilot course at their association headquarters in Des Plaines, Illinois.

The additional visual aids provided by several foundries are greatly appreciated for the added insight they provide.

And, of course, the behind-the-scenes people who prepared this manuscript and its visual aids are to be highly commended. Richard Carlson of NIOSH prepared the visual aids and La Donna Leazer of Rexnord typed the manuscript.

UNIT OVERVIEW
UNIT 1 - INTRODUCTION AND DISCUSSION OF POTENTIAL FOUNDRY HAZARDS

METHODS	Lecture LENGTH: 80 Minutes
PURPOSE	To introduce the course and briefly describe the foundry and its potential air contaminant hazards.
OBJECTIVES	Enable the participant to: 1. Understand the sources and modes of dispersion of foundry air contaminant hazards. 2. Be aware of the relationship between the worker and the job and the potential for exposure to air contaminants from the job.
INSTRUCTOR MATERIALS	35 mm slides 35 mm slide projector and screen
TRAINEE MATERIALS	Course outline

INTRODUCTION AND DISCUSSION OF POTENTIAL FOUNDRY HAZARDS

OBJECTIVE AND SCOPE

The purpose of this course is to present the principles of occupational health hazard control technology in the foundry industry. Applied technology is best studied through actual cases and the results of applied research and development. For this reason, the control methods presented are limited to in-place and functioning systems and research findings.

The discussion will include classification of control measures and identification of the principles and constraints which relate to the ultimate effectiveness of engineered control measures. However, this is not a course in engineering design of control systems. Therefore, design calculations and factors will be kept to a minimum. Detailed design information is covered in other available courses and in the literature, especially in the Industrial Ventilation Manual (1).

This course will also cover an area that is seldom addressed - the relationship of the worker to the control measure. This area is greatly misunderstood at present. Many people think of engineering controls as functioning independently of the worker. This is, indeed, a worthy goal because it would eliminate the human variable which is very difficult to control. However, the reality of the situation is that, as long as there are manual operations to be performed (and the foundry industry has a lot of them), the source of air contaminants will often be within arm's length of the breathing zone. The effectiveness of control measures applied to such situations will be dependent on the various aspects of the worker/control system relationship. That relationship will be discussed in this course.

An understanding of the use of the principles of control demands prior knowledge of the modes of generation and dispersion of air contaminants. These modes will be described prior to discussing the application of control measures. Major potential foundry air contaminant hazards will be included in this discussion. However, no attempt will be made to provide a complete list of all potential foundry air contaminant hazards. Toxic effects and permissible exposure limits will not be discussed either. This course will cover all categories of engineering control measures.

Air contaminant control cannot be discusses as a separate and distinct consideration. Air contaminant control in foundries is interrelated with, among other things, control of heat stress, noise, bright visible light, safety hazards such as molten metal splatter and large fast moving particles, fires, explosions, and odors. In some cases, control of these potential hazards will be discussed so that the interrelationships may be better understood.

In many cases, the problem with implementing effective engineering control measures in a foundry is not limited to devising and installing measures which have the potential for effective control; the problem extends to maintaining the performance of these controls over long periods of time. Maintenance and monitoring of control system parameters will be discussed. Specific monitoring instrumentation, however, will not be discussed.

Finally, two other areas of importance will be briefly discussed: housekeeping and the emergence of new control methods through research and development.

The sources of literature upon which the course is based are included in the references. Many of the case history examples may be found in the NIOSH Health Hazard Control Technology Assessment Study of the Foundry Industry (2). Another significant source of information for applied ventilation control in foundries is the Proceedings of the 1979 NIOSH Symposium on Health Hazard Control Technology in the Foundry Industry (3). Other examples were based on the experience of the consulting firm which developed this course.

BASIC CASTING PROCESS

In the most basic terms, foundries melt scrap metal, pour it into molds, allow the molds to cool, remove the castings, and clean and finish them. The process takes many forms depending on the alloy which is cast, and the number, size, and complexity of the castings which are produced. The various unit processes which make up the casting operation will be illustrated throughout this course. The following illustrations from an iron foundry exemplify a common example of the basic aspects of casting.

Figure 1-1. Ferrous scrap pile.

Figure 1-1 shows a pile of ferrous scrap awaiting removal by electromagnetic crane and placement into a bucket which will later be emptied into a melting furnace. The raw metal for casting consists chiefly of waste metal products, the remnants of machining and manufacturing, and foundry returns. Foundry returns are primarily scrap castings and appendages which are removed during the casting finishing process. Casting appendages will be described in one of the coming illustrations.

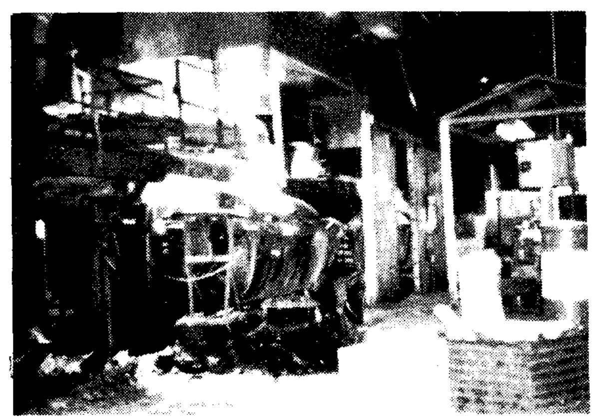

Figure 1-2. Molten metal discharge from the cupola into the forehearth.

Metal is melted in one of a variety of furnaces primarily utilizing electricity, natural gas, or coke for fuel. Figure 1-2 shows the metal discharge point (floor level) of a tall cupola furnace. Metal runs continuously from the cupola into a holding furnace (forehearth), shown in the center of the figure. From the forehearth, the metal is poured into ladles. Usually, these ladles are transported by overhead crane to the area where the mold filling process takes place. Figure 1-3 shows a pouring operator who moves the ladle from mold to mold and fills each mold with metal.

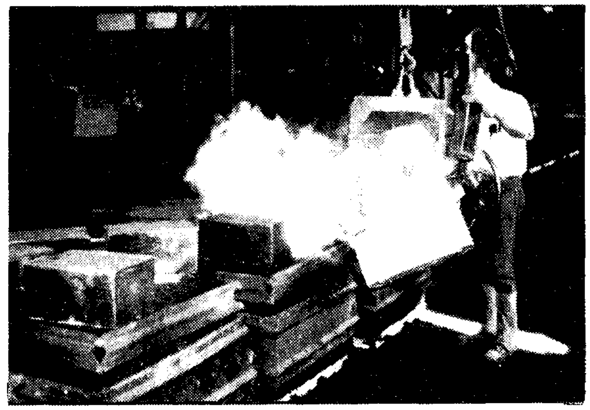

Figure 1-3. Pouring of molds.

Figure 1-4 shows the lower half of a sand mold (drag) with cores in place within the mold. Like the mold itself, the cores are also prepared from sand. A variety of binders are used for molds and cores. A common binder for mold sand (the type shown in Figure 1-4) is clay and water. Molds bound in this fashion are called "green sand" molds. Chemical binders are also used for molds and cores, including, among others, oils and resins.

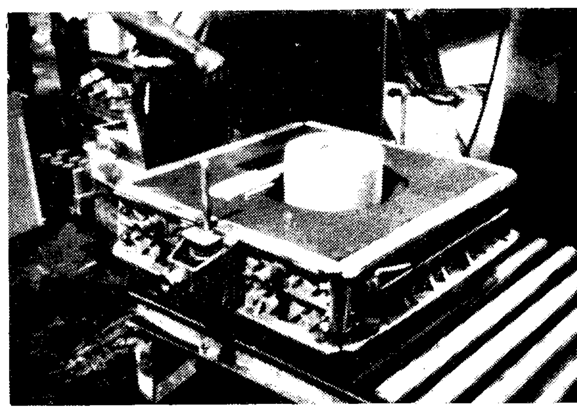

Figure 1-4. Core placement in the mold.

After cooling, castings are shaken out of molds on perforated vibrating tables called shakeouts (Figure 1-5). The mold materials that fall through the shakeout table are processed and recycled; the casting (Figure 1-6) is transported to the cleaning and finishing area. One of the first steps in the cleaning process is the removal of appendages from the casting. Although not a part of the finished casting, these appendages serve as spouts, channels, and reservoirs (sprue, gates, and

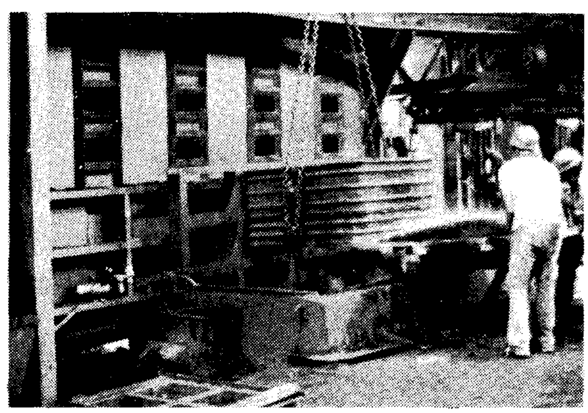

Figure 1-5. Loading the mold on the shakeout table.

risers) which are necessary to fill the mold with metal. Castings are subsequently shot blasted, excess metal is removed, and the defects are repaired before the castings are ready for shipment (Figure 1-7). Torch cutting, welding, abrasive grinding, and cutting are some of the processes used during the cleaning and finishing of castings.

Part of the excess metal to be removed is the flashing — a thin strip of metal which forms around the casting where the mold halves fit together. If one looks closely, one can see the grinding marks around the middle of the casting where the flashing was removed (Figure 1-7).

A typical sand-cast foundry flow sheet is shown in Figure 1-8.

INDUSTRY OVERVIEW

A 1976 census report showed that there were slightly under 5,000 foundries in the United States, employing a little less than half a million workers, and having a total production capacity of about 34,000,000 tons of castings per year (4). The industry profile is continuously changing in a recent trend toward fewer but larger foundries, but 60

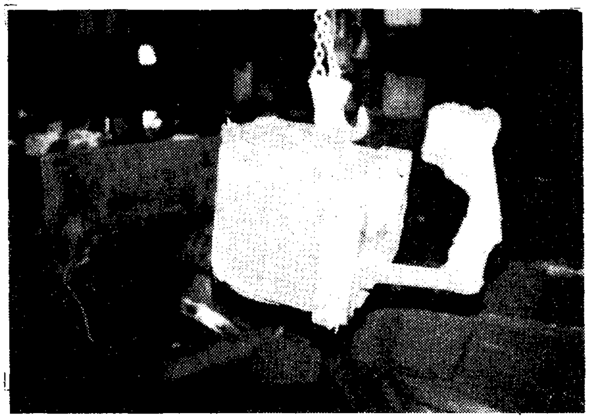

Figure 1-6. Casting after shakeout.

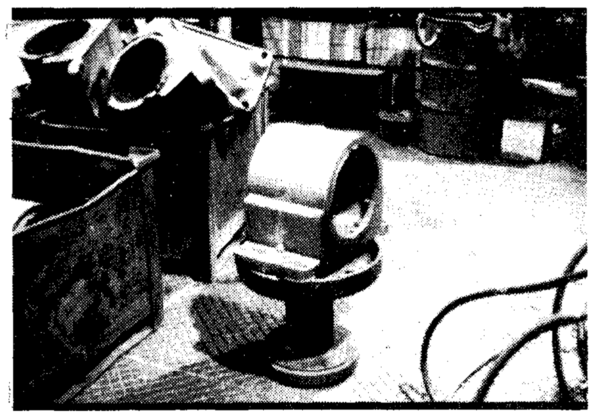

Figure 1-7. Finished casting.

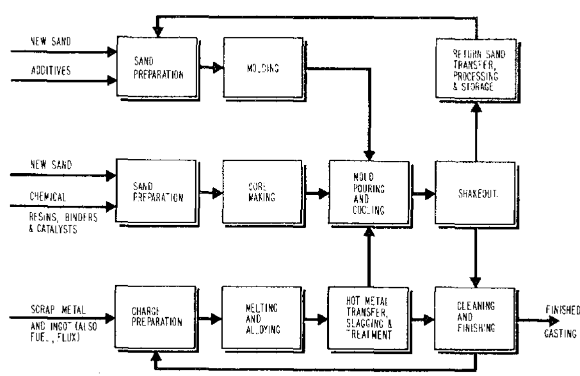

Figure 1-8. Typical sand-cast foundry flow sheet.

percent of the foundries at the time of the census employed fewer than 50 persons.

From 1960-1975, the net production of the industry doubled, and it is still increasing at a significant rate. Higher production has been achieved by the ever-increasing use of mechanization, which is changing the industry from labor intensive to capital intensive. In 1975, production tonnage was divided as follows: 60 percent iron, 13 percent steel, and 27 percent non-ferrous alloys of copper, aluminum, magnesium, and zinc bases.

Approximately 80 percent of foundries may be classified as jobbing shops, which produce many different sizes and shapes of castings for a variety of customers in both large and small quantities. The remaining 20 percent are captive foundries which produce castings for the company's product line as well as for outside orders. Mechanization has spread more rapidly in the captive foundries, where the need for large quantities of identical castings has permitted the use of automated processes.

Casting size and weight are also significant variables, which have an effect on the foundry layout and extent of possible mechanization. Castings range in weight from a few ounces to many tons. The largest castings made are cast in pits under the foundry floor.

The casting industry is spread throughout the country but the highest concentration of foundries is in the Great Lakes region.

The foundry industry is very energy-intensive, using high amounts of energy in the process of making molds, melting and casting metal, and cleaning the castings.

POTENTIAL AIR CONTAMINANT HAZARDS

The discussion in this section is divided into three parts:

1. Identification of the mechanisms of generation and dispersion of various air contaminants which impact on the ability to control these emissions.

2. Worker involvement with the process which is related to the extent of exposure.

3. The additive effects of different air contaminant sources on exposure.

Generation and Dispersion of Air Contaminants

Respirable Crystalline Silica--
The primary foundry mold constituent is silica sand. Clay, water, and organic additives or chemical binders are added to the sand in the process of making molds. After casting, the mold is broken down and the sand is recycled. This cycle is shown in Figure 1-9 for the common case of green sand molding, that is, sand plus clay and water as binders. During the many processing and transporting steps involved in molding and casting, the sand is slowly but constantly broken down into dust particles. Screens are used to control the particle size distribution of the molding sand and to remove unwanted fine particles; however, the removal of a major part of the fine particles from the system occurs through the creation of airborne dust which, unless controlled, can become dispersed throughout the foundry workplace. The system shown in Figure 1-9 is a far-flung system, that is, spread out and involving many pieces of equipment and operations

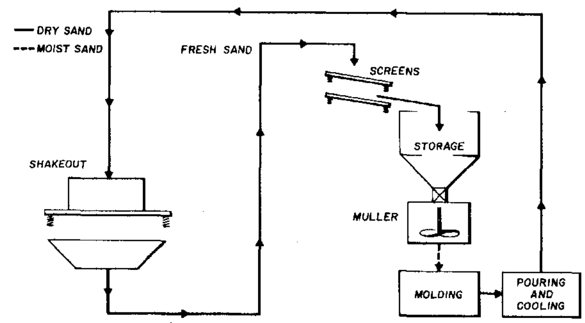

Figure 1-9. Green sand system schematic.

which can produce dust.

The shakeout and screens are usually vibrating tables, but they can be rotary, tumbling drums. The usual methods of conveying sand are vibrating and belt conveyors, and bucket elevators. There are many points in the system where sand falls (for example, as it passes through the shakeout screen to the hopper below, as it is transferred from process to process by conveyor, or as it is put into a storage hopper).

Dust emissions, however, are not a problem throughout the entire green sand system. After the mixing of mold constituents (used in the molding process) the mixture contains sufficient water (typically 3 to 5 percent) to cause fine particles to adhere to the larger particles. A major potential dust hazard occurs after molten metal is poured into the mold. The mold materials rapidly dry out, since the speed and extent of drying is proportional to the temperature of the metal poured, the sand to metal ratio, and the length of time the metal is allowed to cool in the mold before shakeout. Research has shown that the dust problem really begins as the moisture content falls below 3 percent; this problem develops rapidly as the moisture content approaches one percent or less (Figure 1-10)(5).

Although the greatest dust problems are usually associated with shakeout and the subsequent sand recycle steps, the dust hazard is not isolated to the molding materials; the casting itself is not free of silica as it leaves the shakeout. Sand is loosely adhered to exterior casting surfaces and built up in interior pockets. But more than this, sand is tightly adhered to or embedded in the metal surface. During cleaning and finishing of castings with abrasive tools, the embedded sand is broken down into dust particles. The majority of this dust is in the respirable particle size. Two extremes of this embedded sand problem are shown in Figure 1-11 (6). On the one hand, a condition called "rough surface" may result (left sketch, Figure 1-11) in which the metal has not penetrated far enough into the mold to mechanically lock the sand particle (in the way a gem is locked onto a ring). These sand particles are easily removed during the shotblasting cycle. On the other hand (right sketch, Figure 1-11), sand particles

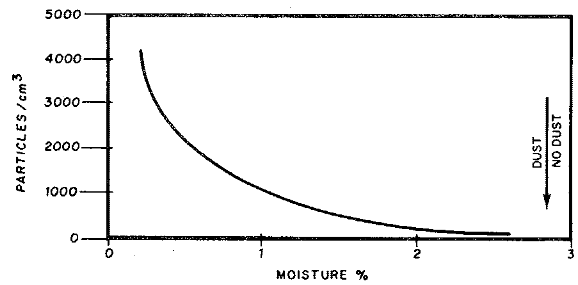

Figure 1-10. Molding material wetness versus dust emissions.

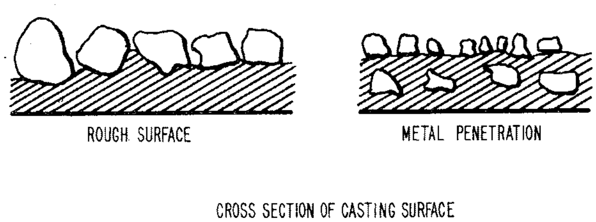

Figure 1-11. Rough surface versus metal penetration.

are fully contained within the metal surface and are not removed during the normal shotblasting cycle. In many ways, this figure is an over-simplification of the real situation because the mold-metal interface is not simply composed of metal and sand grains, but, rather, a whole series of transformation products are also present, including metal oxides, silicates, and fused sand.

Although many studies have been performed, the exact mechanisms for sand adherence to casting surfaces have not been defined. However, some of the factors which affect it are known (6). Scanning electron microscopy has permitted visual observation of this phenomenon; and measurements have shown that, during ferrous casting, silica at the sand-metal interface transforms from quartz to a more toxic form, crystobalite, in the vicinity of "hot spots" (7). Hot spots occur at locations of heavy cast metal sections and inside confined mold corners.

One study of the modes of generation of crystalline silica dust during cleaning and finishing of castings explored the possibility that some of the silica was created by reaction of the silicon in the metal with oxygen in the air at the point of grinding. The study found that such a reaction was not occurring to any measurable extent (8).

Two basic air-moving mechanisms act to disperse the metallic and silica dust during the abrasive cleaning of castings using rotating grinding wheels. These mechanisms are:

1. The inertia of large particles.
2. The friction of the spinning wheel.

The mechanisms are shown schematically in Figure 1-12. Pressure of the grinding wheel against the casting causes a stream of particles, termed inertial swarf, to be projected tangentially from the wheel. The largest of these are called inertial particles, which can be identified by their glow as they leave the wheel (Figure 1-13). As they move, these large particles drag air (air induction) along with them. Hemeon represents this inertial drag effect as though each of the large particles were a miniature fan (9). The air flow induced by the inertial particles draws the respirable dust with it (Figure 1-14). The

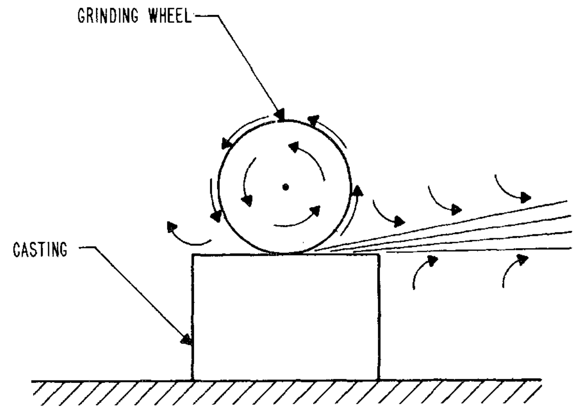

Figure 1-12. Schematic of grinding process.

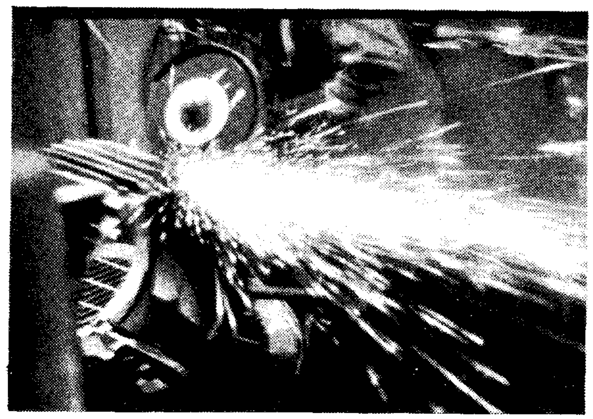

Figure 1-13. Inertial swarf.

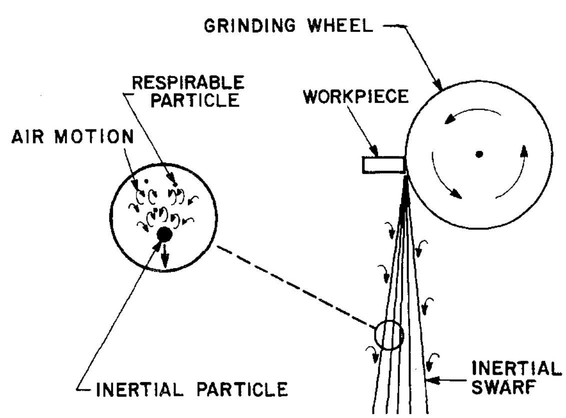

Figure 1-14. Dust transporting mechanism of the inertial swarf.

respirable dust particles move just as the air moves, since they are too small to be subject to inertial forces from the wheel. Thus, both large and small respirable dust particles will travel together for a short distance as long as the inertial swarf is not interrupted.

A second dust dispersion mechanism is the air flow, termed "wheel windage," which is induced around the sides and periphery of the wheel because of the friction forces of the wheel as it moves through the air (Figure 1-12). The air that is induced around the periphery of the wheel and the dust carried with it are both stripped off by the casting at the tool contact point.

In addition, these two air induction mechanisms compete for the dust. When the grinding production rate is high, that is, high pressure of the wheel against the casting, resulting in many large particles in the inertial swarf, the majority of the dust is probably induced along with the inertial swarf. When the production rate is low, the wheel windage mechanism is probably the controlling factor (9). During actual grinding, the pressure is constantly changing, and the proportion of dust drawn by each of the two air induction mechanisms is, no doubt, constantly changing too.

The inertial swarf and the wheel windage are examples of dust dispersion effects which are inherent to the process of grinding itself; they are thus termed primary dispersion modes. Other dust dispersion effects which are not directly related to grinding are called secondary dispersive effects. One such effect is caused by the interruption of the inertial swarf by the workpiece rest which supports the casting and prevents the casting (and possibly fingers) from being wedged between the grinding wheel and the wheel shroud (Figure 1-15). As the inertial swarf rebounds off the workpiece rest, the air induction effect is destroyed and the dust moves freely with prevailing air currents.

Chipping with portable pneumatic tools, a process used side-by-side with abrasive grinding, affords another example of secondary dispersion (Figure 1-16). The chisel causes a primary dispersion of dust in all directions; but, the tool exhaust blows the dust away, causing a secondary dispersion of dust.

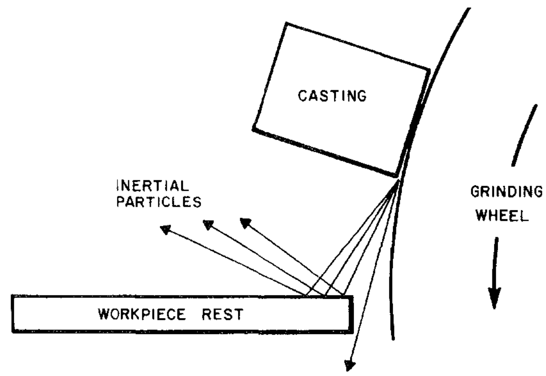

Figure 1-15. Dispersion effect of workpiece rest.

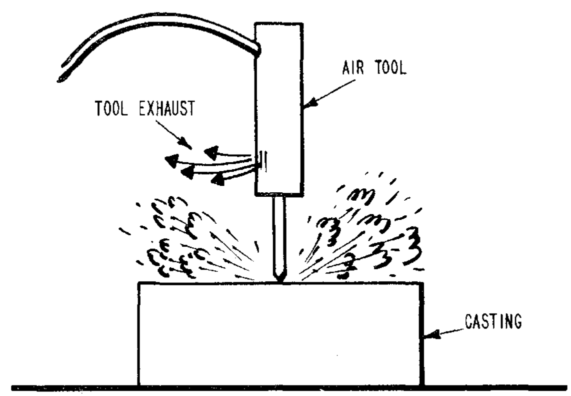

Figure 1-16. Pneumatic chipping of castings.

Dust hazards are not isolated to the process operation itself. Raw material delivery to the foundry can also represent a potential dust hazard. In green sand foundries, substantial amounts of makeup sand and binder are needed to replace materials which are lost to the process through, among other things:

1. Large mold lumps which are not broken down during recycle and are removed.
2. Spillage.
3. Fine particles which are exhausted or removed by screens.
4. Shotblast debris.

Materials are supplied in containers or in bulk. Potential dust hazards during delivery of products in containers could result from spillage from damaged containers, or during the container emptying and disposal operation. Bulk transport, delivery into storage silos, and subsequent transport to hoppers at the point of usage are dust-producing processes.

Transport of sprue, gates and risers, and scrap castings back into the furnace charge system can involve a dust hazard as loosely adhered sand falls from the metal surfaces.

Metal Dust and Fume--
The problem discussed thus far has been dust, that is, an aerosol of solid particles formed by mechanical action. Metallic particles, on the other hand, can be in the form of either dust or fume. Fume is an aerosol consisting of solid particles formed through condensation. Metallic dust is formed primarily through abrasive grinding and blasting operations. Metallic fume is generated primarily during melting and casting operations, during the cutoff of appendages using torches, and during casting repair using a method called gouging, which is followed by welding.

Foundry alloys usually consist of a number of individual metals, all with different boiling and melting points. Figure 1-17 shows the relationship between the melting and boiling points of a number of common cast metals of hygienic significance with the typical processing temperature ranges of these metals (10). Fume begins to be emitted as soon as the metal is melted, but the rate is low

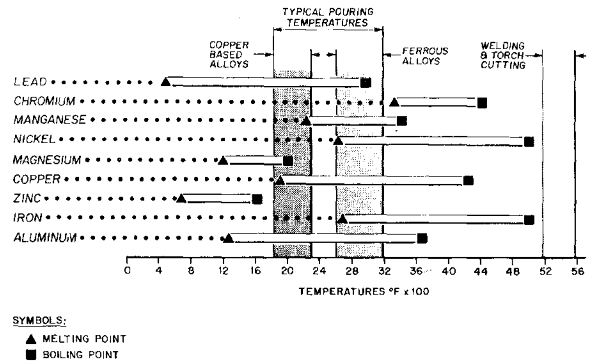

Figure 1-17. Melting and boiling points of metals.

until the metal is further heated. When the temperature reaches the boiling point, all of the metal can freely boil off.

One fact that must be borne in mind when reading this table is that the values presented are the melting and boiling points of the individual metals. After these metals are alloyed together, the melting and boiling points of the resultant alloy may be somewhat different than those of the individual metals. For example, the melting point of chromium is around 3,500 ^{o}F, whereas the melting and pouring temperature range for stainless steels containing substantial amounts of chromium is between 2,600 and 3,150 ^{o}F.

The melting and boiling point table is useful in developing an understanding of the extent of exposure which is received by workers who are close to the molten metal. The following are some observations which can be made from the table of melting and boiling points (Figure 1-17):

1. Although the amount of metal which is molten at

any one time during welding and torch cutting is only a tiny (almost miniscule) fraction of the metal involved in the casting process, the temperature of the metal during welding and torch cutting is above the boiling points of all metals involved, and fume generation is very significant.

2. Zinc, a common metal in copper-base alloys, boils at a very low temperature; zinc loss during casting is thus significant.

3. Lead, which may be found in a significant percent in some copper-base alloys is also present as a tramp metal (an impurity in the scrap) during most ferrous casting. Although the percentage of lead when it appears in ferrous casting may be very low, the metal boils at typical ferrous melting and pouring temperatures.

The effect of metal boiling points on worker exposure (8- hour time weighted averages) can be demonstrated from personal exposure data taken during metal casting (Figure 1-18)(11). Data taken during copper-base alloy casting show that exposure to any particular metal was a function of boiling point, not percentage of the metal in the alloy. The reason this relationship did not hold for ferrous alloys was that the ratio of lead or zinc to iron

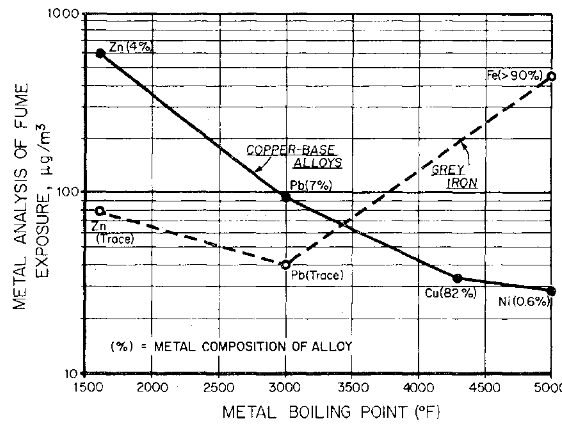

Figure 1-18. Effect of metal boiling points on worker exposure.

was so small that the principal exposure was iron. It is noteworthy, though, that the exposure to zinc and lead during ferrous casting was on the order of one-tenth that of iron, even though the ratios of lead and zinc to iron were many times less than that.

A recent study has shown that automotive scrap containing parts from engines powered by conbustion of leaded gasoline contains substantial amounts of lead salts which were not being removed through the precleaning of these parts in caustic baths (12). Other sources of lead in scrap metal include leaded paints, and bearings and bushings containing lead.

The principal mode of dispersion of fume generated by hot casting processes is one of rising in convection currents of air. These convection currents are also called the thermal draft. As hot air rises above the fume source, cooler air is drawn into the thermal draft by a process of turbulent mixing (left sketch, Figure 1-19). Thus, the volume of the rising air increases with distance above the heat source, while the temperature and velocity of the air

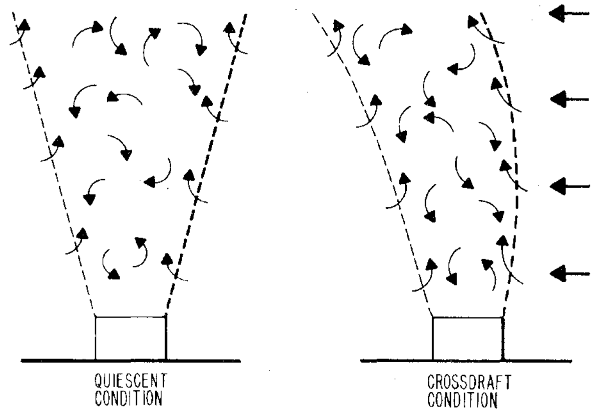

Figure 1-19. Hot air expansion and effect of crossdrafts.

decreases. The right sketch in Figure 1-19 and the photo in Figure 1-20 show the primary, vertical dispersion of the fume with a secondary, horizontal dispersion caused by crosscrafts from mancooler fans.

There are two processes associated with casting repair, which is a manual operation, and they differ in their fume generating and dispersion mechanisms. These two processes follow the same procedure that a dentist uses for filling a cavity: the first involves the removal of decayed tooth from around the cavity and the second involves the filling of the cavity; and so it is with castings. In the process of air carbon-arc gouging, a copper-clad graphite electrode is used to cause localized melting of metal around the vicinity of a casting defect. An adjacent high pressure air nozzle, mounted on the electrode holder, provides air to speed removal of metal through oxidation and by blowing away molten metal droplets (Figure 1-21). The force of the air nozzle, not the thermal draft, is the primary dispersion mechanism. Unlike the air carbon-arc gouging

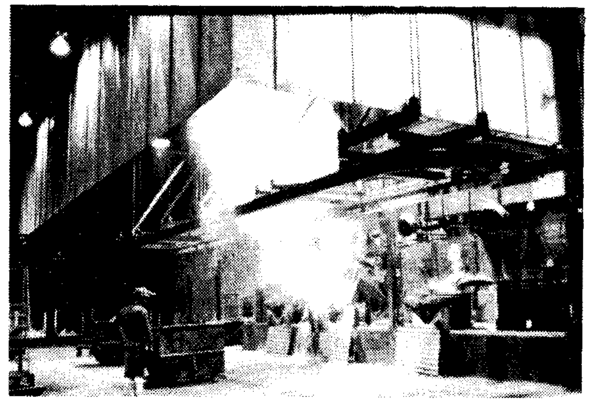

Figure 1-20. Thermal draft affected by a small crossdraft.

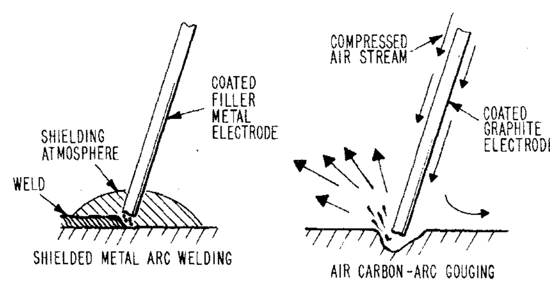

Figure 1-21. Comparison of welding and gouging.

process which attempts to maximize the oxidation of metal, the welding process uses a shielding gas to prevent oxidation which would impair the quality and strength of the weld. The thermal draft is the primary dispersion mechanism for welding.

Carbon Monoxide--

Carbon monoxide is an acute gaseous hazard generated in significant quantities in many foundry processes. Carbon monoxide is generated by combustion of coke in cupola furnaces and during decarburization to produce steel in arc furnaces. It is also generated from combustion of organic materials which are added to green sand molds. The chemical binders used in molds and cores produce carbon monoxide during thermal decomposition. Scott, et.al., measured emission rates of carbon monoxide after mold pouring and found the quantity of emissions to be a function of time after pouring (Figure 1-22) (13). Two emission peaks were measured: one a few minutes after pouring, and the other during and following shakeout when the mold was broken open to the air and when mold materials from the

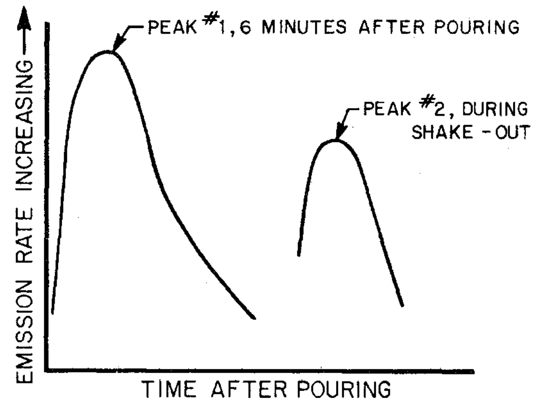

Figure 1-22. Emission rate of carbon monoxide during casting.

outside of the mold came in contact with the still-hot casting.

Carbon dioxide and hydro carbons, including methane and polynuclear aromatics, are also emitted in large quantities during thermal decomposition of mold and core materials during casting. Emissions of these materials follow the same general pattern as those of carbon monoxide.

Gases Evolved During Coremaking--
The principal binders for cores are chemical in nature, and their use results in the escape of gases during both coremaking and casting. Some of these gases of hygienic concern include:

1. Acrolein - Formed by the thermal decomposition of glycerine which is present in many core oils. Oil sand cores are baked in an oven before use in the mold.

2. Methylene bisphenyl isocyanate (MDI) — Formed during the thermal breakdown of urethane binders during casting, not a problem during coremaking because heat is not applied and this material has a low vapor pressure. (If the sand is preheated before coremaking, it still could be a problem).

3. Ammonia - Formed during the thermal breakdown of nitrogeneous materials during

hot coremaking processes as well as during casting.

4. Phenol, formaldehyde, and furfuryl alcohol - Used in a variety of coremaking processes both hot and cold.

In some cases, gaseous amines [triethylamine (TEA) and dimethylethylamine (DMEA)] are used as catalysts in the coremaking process. Figure 1-23 shows how the catalytic gases are applied. Sand coated with chemical binders is blown into a sealed corebox from the top, filling the entire core cavity. After blowing, the sand blow hole is sealed. Catalytic gas is then blown into the core box on one side, passes through supply vent holes in the pattern, through the core, and finally exits through exhaust vent holes in the other half of the pattern. After the catalytic gassing cycle, the gases are purged from the core by pushing air through behind them. To remove the finished core, the corebox is separated at its parting line, and pusher rods separate the core from the pattern.

In theory there should be no exposure from such a process because it is self-contained. But there is

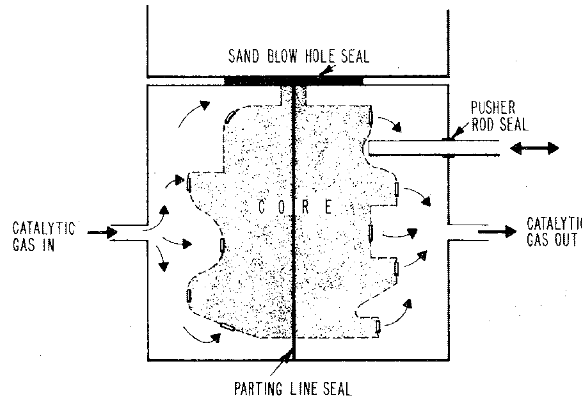

Figure 1-23. Cold box core gassing process.

still a potential exposure from two sources:

1. Seals - Gas contaminant depends on the integrity of the blow hole, pusher rod, and parting line seals which are subject to failure, particularly from abrasive wear due to the sand.

2. Residual gases in the core - To achieve the highest productivity, the purge cycle is set based on removing enough catalytic gas so that the chemical reaction does not continue to the point of disturbing the strength of the chemical bonds. Catalytic gas is also entrained in the pore spaces after ejection of the core from the corebox. This gas slowly seeps from the core during handling and storage.

It should be noted that escape of catalytic gases is not only a problem at the corebox and from the core produced. A leaking gas feed system to the corebox could also pose a potential hazard.

Other Gaseous Contaminants--
Coke combustion results in sulfur dioxide emissions during melting in a cupola and hydrogen sulfide emissions during slag quenching.

Sulfur dioxide is also used for gassing of cores.

Need for Information

In the past several years, many new materials have been added to the foundry process, notably the chemical binder systems for mold and coremaking. When considering new processes involving such materials and when evaluating materials already in use, it is necessary to obtain material safety data sheets from the suppliers to evaluate potential hazards.

Extent of Worker Involvement

Besides being dependent on the type and quantity of air contaminant emissions and the modes of dispersion, worker exposure also depends on the worker's interrelationship with the process. In processes composed partially or entirely of manual operations, the distance between the air contaminant source and the breathing zone is based on the needs of the worker to:

1. Gain safe proximity to the work.
2. Apply force required to do the job.
3. Visually monitor the work.

These three factors determine the ultimate posture the worker will assume.

The pouring process shown in Figure 1-24 requires little force on the part of the worker because the tilting lever is long and the ladle is rotated around its center of gravity. The force must be slowly and carefully applied to produce a constant flow rate of molten metal. The worker's hand is always on the lever during the pouring process, thus maintaining the location of the breathing zone very close to the fume rising from the hot metal ladle.

In the next example, the worker must not only support the grinding tool but also must apply the grinding pressure (Figure 1-25). The worker is bent forward at the waist and the breathing zone is located immediately above the dust generation point.

In a high speed grinding operation, the worker's head is bent downward so that he can see the point of grinding (Figure 1-26).

Finally, in an "ostrich" posture, Figure 1-27, the worker is performing an intricate grinding operation inside the casting.

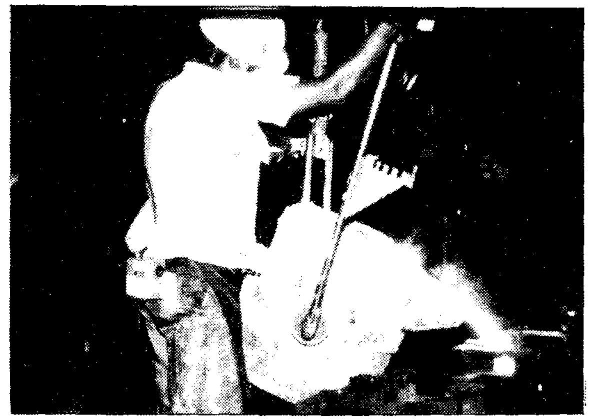

Figure 1-24. Mold pouring process.

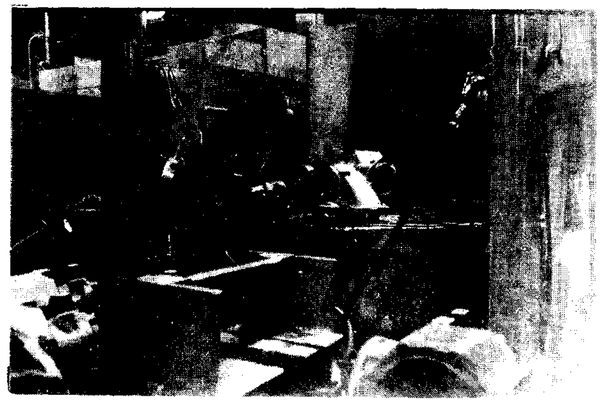

Figure 1-25. Grinding with a portable tool.

Figure 1-26. High speed pedestal grinder.

In all of these cases, the posture assumed by the worker required very little consideration on his part. The body naturally assumes a position which is close enough to apply force and visually monitor the work using the least amount of energy - this is the least energy principle. It is not related to laziness on the part of the worker, rather it is the result of a natural protection mechanism of the body whereby the body acts to conserve and use its energy most effectively to lengthen its period of endurance. All that the body demands of the job is that it not be constrained in selecting the least energy position.

Figure 1-27. Grinding inside of a casting.

The preceding discussion forms one aspect of work practices: the human factors aspect. During the subsequent discussions of engineering control methods, another aspect - the demands that the control measures make on the worker - will be identified.

Additivity of Exposure

A worker may receive exposure to air contaminants emitted from the immediate process, but may also be exposed to air contaminant sources which contribute to background levels which the worker breathes continuously. Metal casting areas are one example. Metal fume is generated during meltdown, hot metal transfer, slagging, holding, metal treatments such as inoculation, pouring, and ladle preheating.

The sand system is an example of multiple and widespread dust sources. Another example of the potential for dust buildup occurs during the cleaning and finishing of castings. Dust sources that contribute to background levels include, among others:

1. Using hammers for removal of casting appendages before shotblasting.
2. Leaky seals on blast equipment.
3. Debris chutes from shot-sand separators on shotblast cabinets.
4. Throwing castings into sorting bins.
5. Discharge of debris off the end of casting sorting conveyors.
6. Partially effective ventilation controls on chipping and grinding operations using portable tools.
7. Cleaning castings off with air nozzles.
8. Forklift truck traffic.

The multiplicity of sources requires that a systems approach, rather than a piecemeal approach, be taken to reduce air contaminant hazards. During the remainder of this course, examples will be given of a variety of control techniques. The individual methods should be seen as components of an overall strategy for exposure control.

DISCUSSION QUESTIONS

1. The trend toward larger, high production foundries brings with it the possibility of reduced health hazards because of mechanization and automation. Agree or disagree? Explain.

2. Why is an understanding of air dispersion mechanisms important in evaluating potential health hazards?

3. Which air contaminant is a potential hazard throughout the entire foundry?

4. Lead is a potential health hazard in all foundries, whether or not it is used as an alloy. Agree or disagree? Explain.

5. If you were to evaluate potential nickel and chromium exposures in foundries casting stainless steel, where would you expect to find the most significant exposures?

ANSWERS

1. Health hazards are not necessarily reduced through automation and mechanization. While these measures can eliminate some of the manual operations which are presently causing the greatest worker exposure problems, they are usually combined with much higher production which can create the potential for higher air contaminant generation rates.

2. The dispersion method by which air contaminants leave their source is important in determining the extent of the hazard as well as the ability to control by engineering means.

3. Respirable crystalline silica dust.

4. The low boiling point of lead makes it a potential hazard even when it is present in minute quantities. Lead is usually present in the casting operation, if not as an alloy, then as a "tramp" metal.

5. They would be found primarily in casting repair operations involving air carbon-arc gouging and welding where temperatures above the boiling points of nickel and chromium are reached. They may also be found in emissions from arc furnaces and in abrasive grinding.

UNIT OVERVIEW
UNIT 2 - CONTROL METHODS:
SUBSTITUTION AND ISOLATION

METHODS	Lecture LENGTH: 50 Minutes
PURPOSE	To categorize and discuss through example different ways to reduce or eliminate air contaminant hazards through substitution and isolation.
OBJECTIVES	Enable the participant to: 1. Understand the considerations that must be made when considering substituting materials, equipment, or processes as a hazard control measure. 2. Be aware of the various ways that isolation can be used as a control measure and the impact that each method has on control of air contaminants.
INSTRUCTOR MATERIALS	35 mm slides 35 mm slide projector and screen
TRAINEE MATERIALS	Course outline

CONTROL METHODS: SUBSTITUTION AND ISOLATION

INTRODUCTION

Peterson has stated that all occupational hazards can be controlled through the use of at least one or a combination of the principles of substitution, isolation, and ventilation (Table 2-1)(14). Substitution involves the replacement of hazardous materials, processes, or pieces of equipment with less hazardous or non-hazardous ones. Isolation of hazards is achieved by interposing a barrier between the worker and the hazard. A barrier consists of a physical shield or enclosure, a suitable distance between the worker and the hazard, or a time lapse to provide a safety factor against exposure. There are two general techniques of removing air contaminants through ventilation: control at the source (local exhaust) and general ventilation.

SUBSTITUTION

Substitution is a category of control which is broader than the word would imply. It can involve modifying the operation and its materials and components in whole or in part to reduce or eliminate hazards, but it

Table 2-1. Classifications of control measures.

METHODS OF EXPOSURE CONTROL

SUBSTITUTION:
- **OF MATERIALS**
- **OF EQUIPMENT**
- **OF PROCESSES**

ISOLATION:
- **BY PHYSICAL BARRIER**
- **BY DISTANCE**
- **BY TIME**

VENTILATION:
- **LOCALIZED**
- **GENERAL**

can also imply initial design considerations during foundry process, material, and equipment selection to minimize potential hazards.

Material Substitution

Substitution of Molding Sands--Substitution of non-silica sands for molding and coremaking is a material substitution that has been found to substantially reduce silica dust inhalation in both ferrous and non-ferrous foundries (15, 16). Non-silica sands include aluminum silicate, chromite, olivine, and zircon. Major limitations to this substitution are the limited production and very high cost of these alternate sands. In 1979, the total production of all non-silica aggregates was reported to be less than one-half million tons per year, in contrast to 10 million tons of silica sand. The cost of non-silica sands was 4 to 6 times the cost of silica sand (17).

A second limitation is that, although these sands can be readily substituted for silica sand in green sand molding, they cannot be as easily substituted in coremaking where chemical binders are used.

Cores continue to be made of new silica sand.

When olivine is introduced into the foundry, its free silica content is usually less than one percent. The use of silica cores in the same sand system results in a gradual buildup of silica in the system over time. The extent of buildup is dependent on the relative amounts of silica and non-silica sands used for molding and core-making, and on the rate of new non-silica sand addition. Silica dust exposure follows the same pattern of buildup over time. To date there is no practical method for separating silica and non-silica sands. The contamination of a non-silica sand system with silica diminishes the benefits of using non-silica sand to reduce exposure to silica.

After completing his study of nine nonferrous foundries using olivine, Tubich concluded that, even using non-silica molding sands, ventilation is still required at the major dust-producing sources in the sand system (15). The use of non-silica sands may reduce, but does not eliminate, the need for ventilation of sand system processes.

An area where non-silica aggregates have a definite advantage is the cleaning room where control of silica exposures is very difficult to achieve with today's ventilation technology.

It should be noted that when a potential substitution is being considered, whether of materials, equipment, or processes, care must be taken to insure that one type of hazard is not being substituted for another. For example, asbestos could possibly be present in a substitute molding sand. A substitute clay could possibly contain more quartz and cristobalite than the clay which was replaced.

Other Substitutions of Materials--Other examples of material substitutions are the use of argon rather than chlorine for the degassing of aluminum and the elemination or reduction of lead-based paints, oils and grease, lead salt deposits, and leaded brass and bronze components in ferrous scrap.

Process Substitution

Schumacher Process--

Besides substitution of non-silica sands, there have also been several different process modifications made to reduce the dry sand hazard which occurs during shakeout and sand recycle in silica sand systems. Several of these modifications involve attempts to restore the moisture content of the sand as soon as possible after shakeout. One such process modification is the Schumacher Process, shown schematically in Figure 2-1 (18). In this system, the muller is oversized to produce several times as much sand as is necessary for molding. The excess sand is recycled and blended with the dry return sand in the shakeout hopper. The moist recycle sand causes the fine dry particles to be agglomerated onto the moist ones and also permits cooling of the sand which is important in maintaining moisture content. Addition of the moist recycle sand reduces the need for localized ventilation during sand reprocessing. Some localized ventilation is still required, however, for the rotary screens and the muller to exhaust the steam emissions and prevent

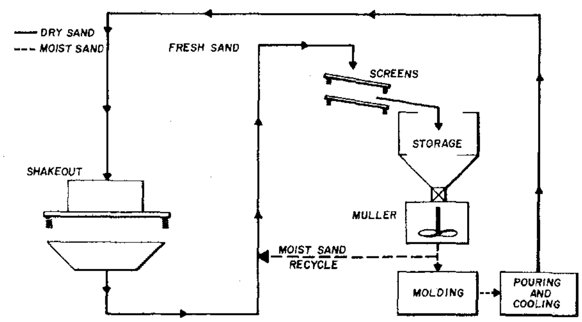

Figure 2-1. Schumacher system.

clogging of these devices. The Schumacher system does not reduce the ventilation requirements at the shakeout.

Casting Design Considerations--
It was seen in the introduction that the casting in the mold includes more metal than does the finished casting. The casting is poured through a pouring spout (sprue), the metal flows into various sections of the mold cavity through channels (gates), and reservoirs of molten metal are maintained during solidification to ensure a completely filled mold (risers). Casting finishing includes removal of these appendages either with hammers, saws, torches, or mechanical presses, and abrasive grinding to remove the remaining traces where the appendages were attached. After removal, the appendages are remelted.

Careful design of appendages can help to reduce the amount of finishing work necessary and, consequently, reduce the potential air contaminant hazards associated with finishing operations. The following illustrations show what one aluminum foundry has done to minimize the amount of the appendages and the finishing work necessary to remove them.

Figure 2-2 shows castings after shakeout. The sprue has already been removed with a hammer. The risers are all located on a single plane and are all removed by a single saw cut. Figure 2-3 shows a casting similar to the one in Figure 2-2, but with the risers removed. No additional abrasive finishing work will be done on this saw cut in the foundry. Later, in the machine shop, milling machines will remove more metal in the plane of the saw cut to provide the necessary dimensional tolerances.

The photograph in Figure 2-4 and the sketch in Figure 2-5 show an aluminum casting poured by this same foundry at an 87 percent yield (appendages are only 13 percent of the casting weight). The sprue and risers are removed with a hammer as one piece and the gates are removed with two saw cuts resulting in two finished castings. The ease of removal of the sprue and risers with a hammer is facilitated through the use of a fibrous glass screen across the plane of separation.

In both of the previous examples the finishing work was not limited to

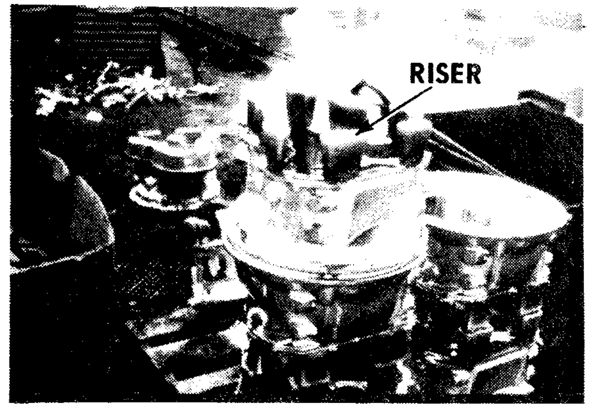

Figure 2-2. Risers all located in a single plane.

Figure 2-3. Risers all removed in a single saw cut.

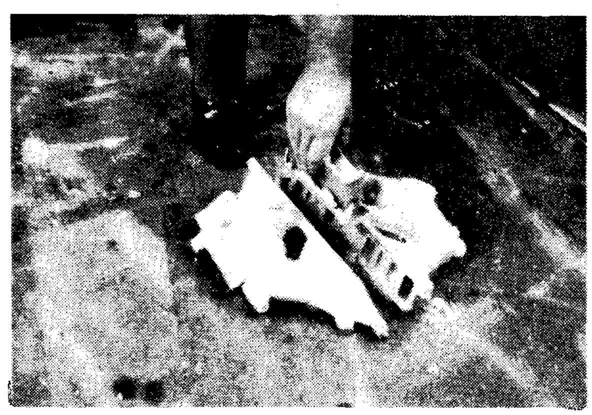

Figure 2-4. Gates between two castings are removed by two saw cuts.

these saw cuts. Portable chipping and abrasive grinding tools were still needed to remove the flashing, which is a thin metal protrusion at the parting line of the mold, and to clean up any other surface defects.

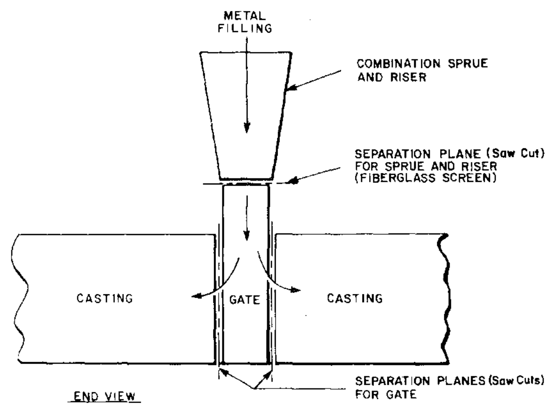

Figure 2-5. Schematic diagram of appendage removal operations.

In some cases, casting gating systems can also be changed to include the use of kiss-gates. This technique employs a reduction of cross-section in the gate at the point where gate removal takes place. As a result, gates can be removed with a hammer rather than a saw.

Careful control of furnace temperature is another process consideration which can result in a reduction in fume generation. In addition, hot metal pouring ladle covers and short distances from furnaces to pouring lines are equipment and layout considerations which can help to reduce the need for superheating of the metal in the furnace to ensure adequate mold pouring temperatures.

Equipment Substitution

Belt Conveyor Design --

Sand spillage is a significant source of airborne dust during dry sand transport. For this reason special consideration should be taken during equipment design to minimize spillage. The following are some important design considerations for the use of conveyor belts (5):

1. Belt conveyors should be designed for the maximum capacity required of them, even if this is only needed for short periods.

2. Because of the construction of belts used in the past, only shallow troughs could be created by angulating the side idlers up to 20° (Figure 2-6). New nylon belts allow steeper angles to be set up to 45°. The steeper the angle, the higher the carrying capacity of the belt and the lower the spillage for a given throughput. This figure also illustrates the use of adjustable rubber seals for use where hoppers discharge onto belts.

3. Where belts are operated flat, e.g., to allow ploughs to be used to transfer materials from the belt into a hopper, the capacities of the belts should be reduced to one-half that of a troughed belt.

4. Belt inclination should be limited to 17° for dry sand carried by troughed belts.

5. Belt cleaners should be used to avoid spillage from the belt after it is turned upside down during the return part of the cycle (Figure 2-6).

6. Self-cleaning pulleys should be used to avoid spillage

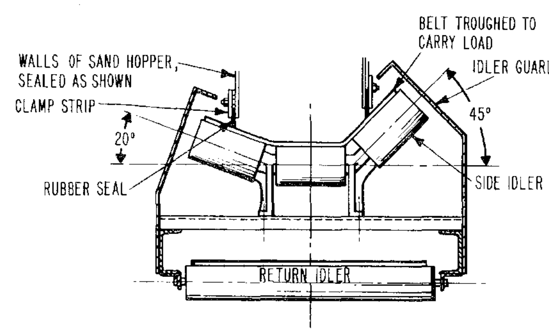

Figure 2-6. Sand conveyor belt design.

that occurs because of the wandering of pulleys built up with sand.

Bond Addition--

Introduction of new sand and bond materials into the foundry has always been a source of substantial spillage and dust emissions. A method to significantly reduce the dust hazard is to transport bulk materials pneumatically from truck to storage silo and from storage silo to feed hoppers at the point of usage. Many bond additives, however, are supplied in bag form, but pneumatic transport can help to reduce the dust hazard here also. Figure 2-7 shows a bond feed hopper for transporting bond materials pneumatically into elevated feed hoppers. The bond feed hopper eliminates the need to use forklift trucks and cranes to raise the bags to a level above the feed hoppers for emptying - a process which is time consuming and can result in bag tears and spillage. The bond feed hopper shown is partially enclosed and ventilated to contain dust. The dust in the transport air is cleaned by a bin filter before exiting the receiving hopper.

Figure 2-7. Bond loading and transport system.

Pneumatic transport systems are also being used to transport both recycle and moist molding sand (5). Disadvantages to their use in sand systems includes high power consumption and wear problems from sand abrasion.

ISOLATION

Isolation of potential air contaminant hazards, whether by physical barrier, distance, or time should always be coupled with ventilation. Isolation by itself does not eliminate air contaminants, it only constrains them from causing worker exposure. Ventilation is still needed to physically remove air contaminants and prevent their buildup. Indeed, enclosing ventilation hoods themselves are a form of isolation of air contaminant sources. The following discussion will be limited to how isolation facilitates control of contaminants. Ventilation and the use of close-fitting hoods will be discussed later under ventilation methods.

Isolation With a Physical Barrier

Any restriction to air flow from an air contaminant source is classified as a barrier. A barrier may be composed of an enclosed hood or booth, or just sheet metal panels. The process equipment itself may act as a barrier. Barriers can be mobile or stationary and can be grouped in three categories:

1. Isolation of the contaminant source from the worker.
2. Isolation of the worker from the contaminant source.
3. Isolation of both worker and contaminant source from the rest of the facility.

The following are examples of each category.

Isolation of the Contaminant Source From the Worker--

Tumbling Machine Enclosure--One method of providing a smooth surface finish on small castings is to tumble a large number of them in a rotating drum. This process produces dust, but noise is even more of a problem. A solution for both air contaminants and noise is to enclose the process during its operation (Figure 2-8)(19). The enclosure is open before and after tumbling for loading and unloading the drum (Figure 2-9). A switch prevents operation of the tumbler unless the doors are closed (Figure 2-10).

Figure 2-8. Enclosed tumbling mill during operation.

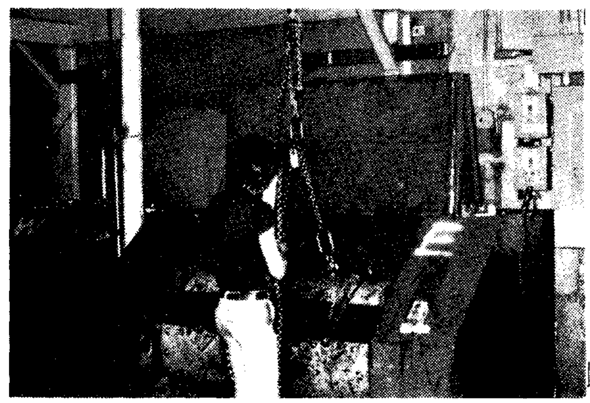

Figure 2-9. Loading the tumbling mill.

Figure 2-10. Closing the door before operation.

Robot Grinder--In some high production foundries, programmable robots are being used for finishing of castings. In the example shown in Figure 2-11, this sprue cutoff process is completely automated and enclosed (20). The worker, located outside the enclosure, removes the casting after processing and installs the next casting to be processed, which is then rotated into position within the booth by a revolving table.

Figure 2-11. Removal of risers on steel castings using an industrial robot.

Melting Platform--The fume rising from one of several furnaces on a melting platform is contained by baffles until the fume can be evacuated (Figure 2-12)(21). The hot metal monorail crane prevents the baffles from being extended downward any further. This figure also shows an example of good work practices. While the ladle is being filled, the worker stands back outside the enclosure to prevent breathing the fume.

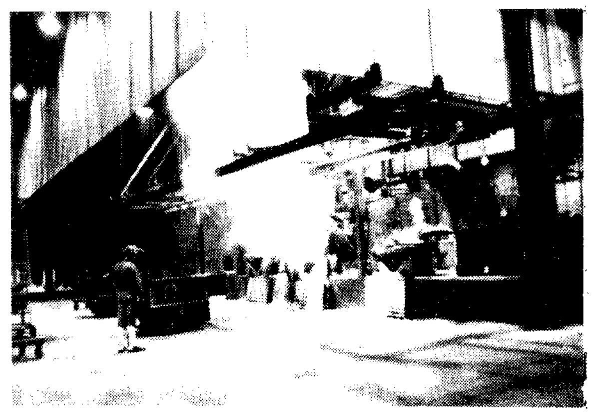

Figure 2-12. Tapping an induction furnace.

Figure 2-13. Ladle cover used during non-ferrous pouring.

Ladle Cover--The worker in Figure 2-13 is pouring copper-base alloys containing lead and zinc. A cover over the ladle reduces the fume-generating potential by restricting the flow of air across the molten metal surface (22). The ladle cover also helps to maintain the temperature of the metal, which is essential to pouring good castings, and it reduces heat stress. The cover is retracted during filling of the ladle.

Separation of Foundry Areas--It has been shown that when one process area of a foundry is separated from another (perhaps placed in a separate building or walled off area), control of air contaminants is facilitated by reducing cross-contamination. One foundry achieved better control of air contaminants in its cleaning and finishing area when this area was isolated into a separate facility (23).

Isolation of the Worker From the Contaminant Source--

Furnace Control Booth Enclosure--In a steel foundry, furnace operators are isolated from fume and noise of a large arc furnace by a work booth located adjacent to the furnace (Figure 2-14)(24). All of the controls for the furnace are located inside the enclosed room and the furnace operation can be observed from there through large, tempered safety glass windows. The operator leaves the booth to operate the charge bucket crane, to add alloys, and to perform other duties at the

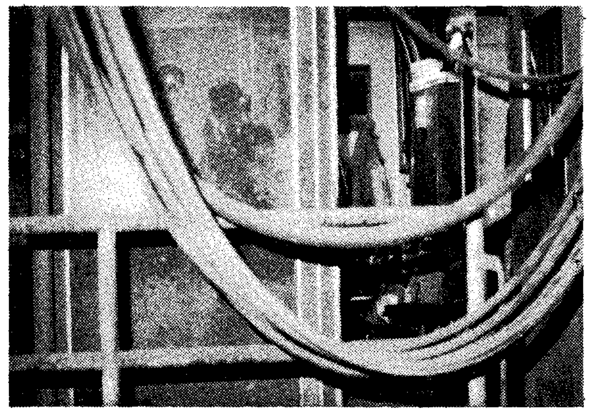

Figure 2-14. Furnace control booth.

furnace. The door is normally closed, although it was left open during the taking of this photograph to show the inside of the booth. The booth is supplied with fresh tempered air under positive pressure to prevent infiltration.

Enclosed Crane Cab--The hot metal crane operator in Figure 2-15 is isolated by a crane cab from the fume rising above the furnaces and from the hot metal ladle being transported by the crane (25).

Cupola Forehearth--Molten metal continuously flows from the cupola furnace into a holding furnace called a forehearth (photograph in Figure 2-16, sketch in Figure 2-17) (26). The forehearth is periodically tilted to tap the metal into transfer ladles. During ladle filling, a small amount of alloy material is added to the ladle. The furnace operator who fills the ladles and adds the alloys is isolated from infrared heat radiation and fume by a wall partition. A sliding door in the partition provides access to the ladle. The partition is low enough so that, as the ladle transfer operator approaches the forehearth, he can operate his remote control switch while being protected by the partition.

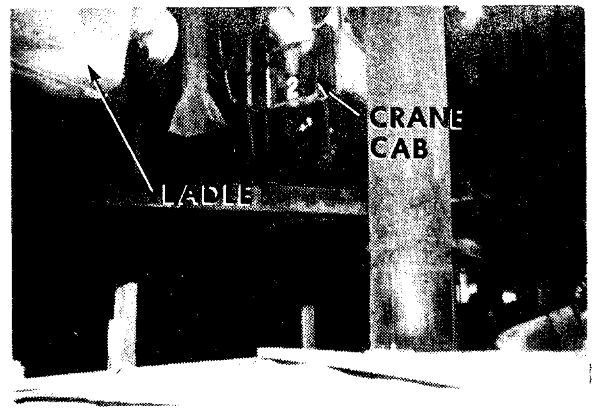

Figure 2-15. Crane cab enclosure.

Figure 2-16. Tapping into the forehearth.

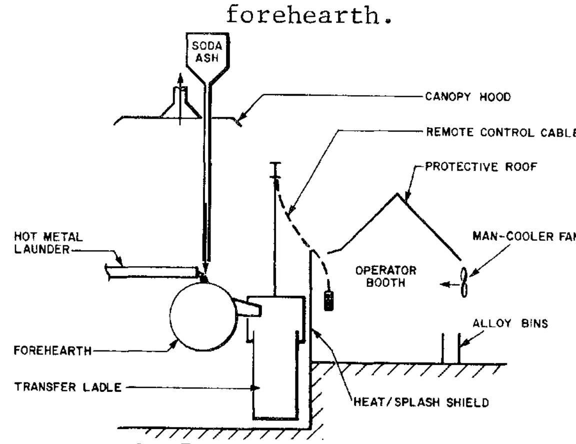

Figure 2-17. Schematic diagram of cupola tapping operation.

While adding alloys or tapping the forehearth, the operator opens the door a small distance and extends no more of his body into the opening than is absolutely necessary. Besides protection from the heat, the wall partition and roof over the forehearth station reduce the hazards from splashing metal.

Isolation of the Worker and the Contaminant Source From the Rest of the Facility--
Simple Partitions--Simple forms of this type of isolation are the baffles which are used between grinding stations to protect the adjacent worker from being struck by the grinding swarf (Figure 2-18). These partitions are acoustically lined to provide a small degree of noise reduction between worker stations.

Enclosed Work Booths--Nearly complete isolation of noisy processes producing dust and fume can be achieved with work booths (Figure 2-19)(23). The primary benefactors of this type of control are the material transfer operators and other workers in the area. The castings are transferred into and out of the booths on roller conveyors. The castings enter one

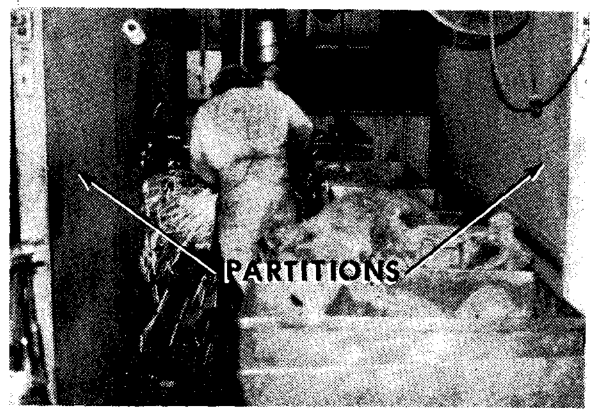

Figure 2-18. Partitions between grinding stations.

Figure 2-19. Row of booths for casting cleaning and repair.

side of the booth and exit the other. The workers performing such jobs as grinding and welding inside the booths are not protected from the noise, however, and require ventilation and hearing protection (Figure 2-20). The rubber flaps which baffle the noise at the casting transfer ports may be seen in this figure.

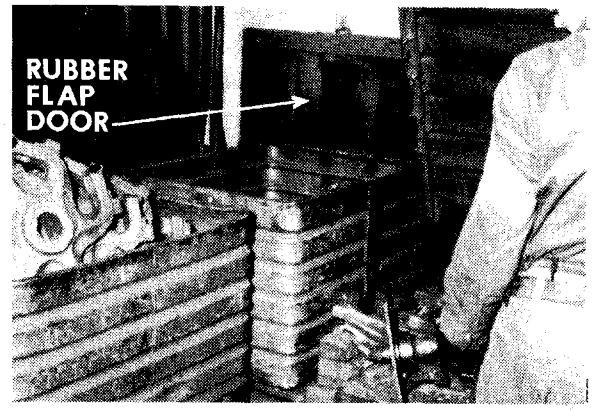

Figure 2-20. Bench grinding in an enclosed booth.

For safety reasons, at least two workers were located in each booth. With individual booths, there is the danger that a serious injury or illness would go unnoticed until the foreman looked in on the worker, or until the end of a shift. Windows also help to relieve the feeling of isolation and facilitate visual monitoring of the worker (Figure 2-19).

Isolation by Distance

Isolation of Cooling Molds--
In the discussion of potential foundry hazards, the thermal decomposition of organic materials in the mold after casting was discussed. Research has shown that these emissions increase after pouring and reach a maximum in several minutes after which time they gradually subside. In floor-

pouring operations, that is, where the molds to be cast are distributed over an area of the floor, the pouring operators are located among the just-cast molds. In one floor - casting operation, the molds are placed on sixteen roller conveyors located side-by-side (27). After pouring, the flasks and weights are removed from the mold by another worker who also moves the molds along the conveyor from the pouring zone to the cooling zone, where the molds are allowed to cool under a hood. Formerly, he pushed the molds by hand and the pushing job was a source of back strain on him besides prolonging the time that just-cast molds remained in the pouring area.

A motorized tow mechanism was installed to eliminate the back strain problem and to hasten the removal of molds from the pouring area. A cable was strung across the top of the roller conveyor in a groove under the base board of the mold (Figure 2-21). A spring-loaded catch on the cable retracts as it passes under a mold and then extends after clearing the mold. The tow motor is then reversed and the mold is pulled along the conveyor to the cooling area. Figure 2-22 shows the cooling area

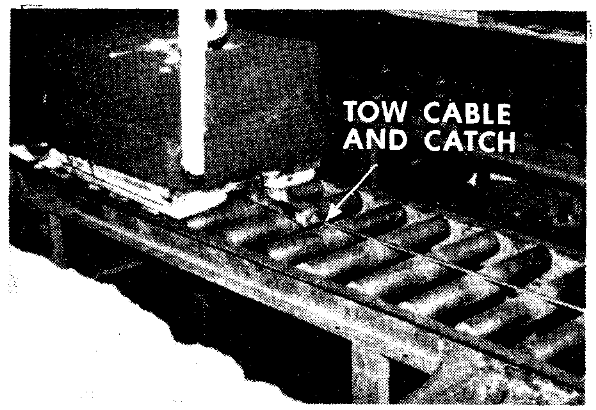

Figure 2-21. Cable transport system using retractable mold catch.

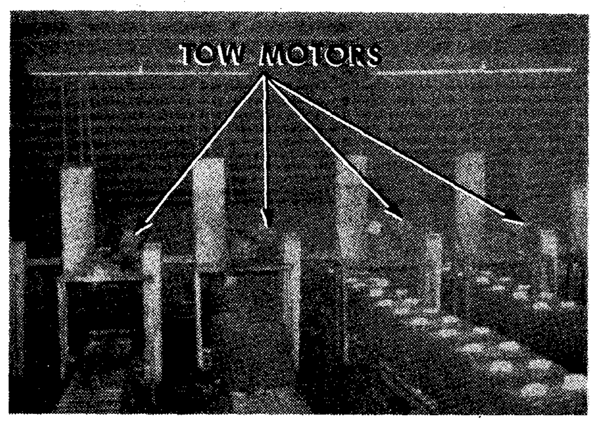

Figure 2-22. Mold cooling area.

and the tow motors for the individual conveyor lines. Care must be taken in moving molds shortly after casting with this or any other method. Accelerative forces can cause unwanted motion of the still-molten metal within the mold.

Remote Controlled Operations--

Sand Slinger--When large molds are cast, a common method for filling molds with sand is the sand slinger (28). The slinging mechanism is attached at the end of a movable, positioning arm (Figure 2-23). In the past, the worker guided the slinger by hand, which placed his breathing zone adjacent to the slinging head. Although the sand contains sufficient moisture to retain the dust, some becomes airborne due to the impact of the sand against the pattern, as well as from the presence of dried out sand which may remain in the flask from the previous molding cycle. Ventilation of this process is simplified and dust exposure of the operator is reduced by isolating him to a work station nearby.

Robot Slagger--In the next example of remote control, a robot slagger is used to move the worker back away from an extremely hot job:

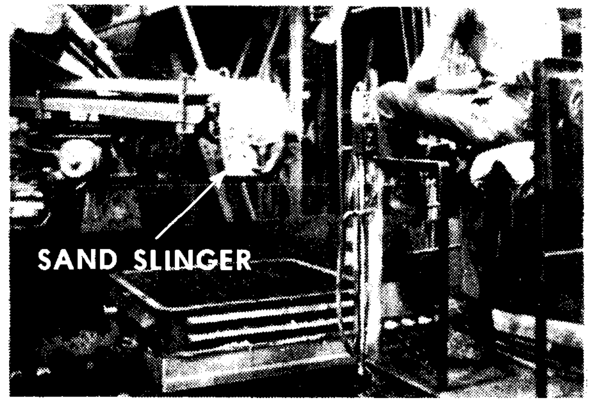

Figure 2-23. Sand slinging operation controlled at remote station.


Figure 2-24. Remote ladle slagging operation.

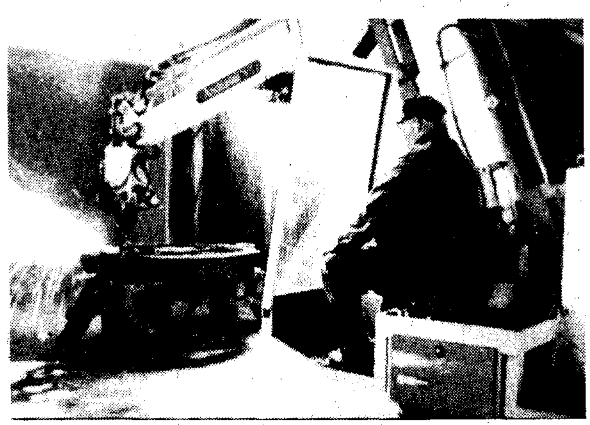
Figure 2-25. Andromat manipulator.

scraping slag from the walls of large pouring ladles (Figure 2-24) (29). Use of the robot slagger has eliminated the previous practice of taking a short break after every slagging operation.

Robots are now also beginning to be used for some finishing operations, primarily on large castings (Figure 2-25)(20).

Isolation in Time

In certain cases, a time lapse can be used to reduce hazards. After hot cores are produced, the exposure of the worker, who must handle the cores, to thermal decomposition products of the chemical binders is reduced by allowing the cores to cool on a ventilated table before handling.

Allowing castings to cool before sprue and riser removal with hammers isolates a heat stress problem.

Isolating furnace relining and other dusty maintenance and housekeeping tasks to a non-production shift helps to prevent unnecessary dust buildup in the general background air.

DISCUSSION QUESTIONS

1. What factors must be evaluated before a material substitution is made?

2. Discuss isolation for control of noise as compared to isolation for control of air contaminants.

3. What are the advantages and disadvantages of using a booth to isolate a work station in the cleaning room?

4. How does a ventilated control station help to decrease worker exposure to air contaminants if the worker spends only part of his workshift in the booth?

5. How does sand spillage result in worker exposure to respirable silica dust?

ANSWERS

1. Suitability for the process, toxicity of the material and its transformation products, safety, availability, cost, effect on energy and material consumption, ease of handling, among other things. Care must be taken so that one hazard is not being substituted for another.

2. When isolation with a physical barrier or distance is used to control noise, the act of isolation by itself removes the hazard from the workers. In the case of air contaminants, isolation must be combined with ventilation to evacuate the air contaminants. It should be noted, of course, that noise

isolation may also be combined with ventilation for heat removal, even when air contaminants are not present.

3. The chief advantage is that noise and air contaminant hazards can be isolated to the booth, thus preventing the additivity of hazards throughout the entire area. The chief disadvantage is that, if the ventilation method used to control worker exposure in the booth is not fully effective, the booth could possibly even exacerbate the air contaminant hazard by permitting the contaminants to build up within the booth.

4. For most contaminants, worker exposure is rated as a time-weighted-average exposure throughout the workshift. The control station, if ventilated in such a way as to be free of contaminants from the process, decreases the average exposure by reducing the total time of exposure to the process. The ventilated work station which is used for only a part of the shift may not prevent instantaneous overexposure to air contaminants which have ceiling value limits.

5. When sand spills and remains on the floor, it dries out and the fine, respirable dust is freed from its bonds to the large sand grains. Any agitation can easily reentrain this dust.

UNIT OVERVIEW
UNIT 3 - CONTROL METHODS:
INTRODUCTION TO VENTILATION,
ENCLOSING AND EXTERIOR HOODS

METHODS	Lecture — LENGTH: 90 Minutes
PURPOSE	To introduce local and general exhaust ventilation, to put the evolution of foundry ventilation into perspective, and through examples, to discuss two categories of local hoods: enclosing and receiving hoods.
OBJECTIVES	Enable the participant to: 1. Understand the need for and uses of localized exhaust ventilation. 2. Be aware of the important factors relating to the effectiveness of enclosing and receiving hoods.
INSTRUCTOR MATERIALS	35 mm slides 35 mm slide projector and screen
TRAINEE MATERIALS	Course outline

CONTROL METHODS:
INTRODUCTION TO VENTILATION, ENCLOSING AND EXTERIOR HOODS

VENTILATION

Introduction

There are two major classifications of ventilation: control at the source (local exhaust) and general ventilation. Control at the source denotes capture of contaminants close enough to the point of generation to prevent the contaminants from directly entering the breathing zones of workers or dispersing throughout the workplace. General ventilation, on the other hand, is primarily a dilution method. It achieves its effects of reducing air contaminant concentrations and of providing worker comfort by mixing cleaner air into the workplace at a suitable temperature and humidity.

Historical Perspective

The present use of ventilation in foundries can be better understood by looking at the way that foundry ventilation has evolved over the years. For many years, general ventilation was the principal method for controlling air contaminants in foundries. The structures of the buildings themselves were designed to take advantage of natural ventilation associated with the convection currents above hot processes. A simplified schematic of the natural ventilation patterns is shown in the top sketch in Figure 3-1. Air entered the building at wall and door openings and was exhausted out roof monitors, which often spanned the entire length of the roof. Original foundry layouts were rather simple and devoid of much of the equipment which was to come later.

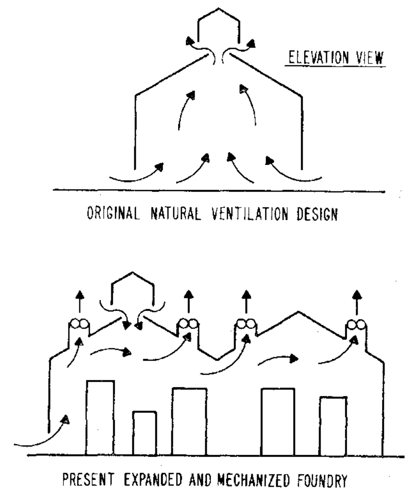

Figure 3-1. Evolution of foundry ventilation.

Mechanization came as a result of a need for higher production and brought with it dramatic changes in the buildings themselves to accommodate the new equipment (lower sketch, Figure 3-1). New buildings were added onto the old, and symmetry began to disappear in the structures. Some equipment components, such as the molding sand mixer (muller) and its feed equipment, were so large that the roof had to be raised in the part of the building in which this equipment was housed. Higher production brought with it higher emission rates of air contaminants which the natural ventilation systems could not purge. Roof exhausters began to appear by the dozens on single roof structures. The proliferation of roof ventilators caused several significant changes in foundry ventilation. Mechanical exhaust now so exceeded natural ventilation that the buildings developed negative pressures which caused air to enter, rather than exit, through the roof monitors. The air entering through building openings increased in volume and velocity as the openings began to be insufficient. Insufficient building openings became a real problem particularly in cold climates where buildings were closed up tight during winter months to reduce cold drafts, which were now more of a problem than ever before.

Thr roof ventilators also dramatically changed air flow patterns within the building. Air entering through building openings moved quickly in the path of least resistance toward these evacuation points. Foundry floor areas were congested with equipment and so the path of least resistance for the air was above the equipment.

The net effect was that, although the theoretical air turnover rate was high, there was no real turnover occurring in the worker areas at floor level.

During the period of proliferation of roof exhausters, local ventilation hoods began to appear. The first processes to be controlled were furnaces such as cupolas and arc furnaces which produced high amounts of particulate and gaseous emissions, and shotblast equipment. The use of local ventilation was then extended to many other processes. The addition of close capture hoods began to change the air patterns within the foundry. The exhaust points for these hoods were typically near floor level. Their effect was to create air turnover in worker areas, something which very high rates of general exhaust had failed to accomplish. At the same time, the need for dilution ventilation began to diminish as more contaminants were removed at the source. Although the need for these devices was on the decline, the use of roof exhausters remained relatively constant, and increased in some cases. The negative pressure in the building began to rise to intolerable levels as the volume of air exhausted from local hoods became a significant portion of the total exhaust rate. The air induced through building openings disrupted many exhaust hoods. Mechanically supplied makeup air began to be used, but only a small portion of the total exhaust rate was usually made up by this method. The high cost and unavailability of fuel to temper outdoor air in winter months has limited the use of heating units. The point has been reached now in which the exhaust rate in many foundries can scarcely be increased. And that brings us up to the present. Throughout the remainder of this course ventilation approaches will be individually discussed. It should be emphasized that a systems approach is needed for a foundry; that is, local and general ventilation approaches should work together to provide the proper protection of workers.

In the remaining sections various classifications of local exhaust techniques will be discussed, followed by approaches to general ventilation.

Control at the Source

There are a number of conditions when control at the source is appropriate; among them are the following:

1. If the contaminant emission rate from a process is high and/or if the contaminant is toxic.

2. If air cleaning devices must be used before discharge of exhaust to the outdoors.

3. If workers must work in close proximity to the process, where they would be subject to high concentrations of contaminants, or to skin and eye contact hazards.

4. If the process releases a substantial amount of heat, humidity, or odor.

5. If uncontrolled emissions would cause safety hazards, such as fire, explosions, or reduced visibility.

6. If uncontrolled emissions would cause a housekeeping problem and reentrainment of settled dust by workers and vehicular traffic.

7. If material or energy recovery is planned.

8. If fouling of process machinery and controls is to be prevented.

Local exhaust functions through the creation of air flow patterns that cause the contaminants to move in a direct and predictable manner toward an evacuation point.

Enclosing Hoods

The most efficient use of local exhaust occurs when the contaminant source is isolated within an enclosing hood. However, not all processes can be enclosed, either because of the size of the process, its mobility, or need for accessibility. In an closing hood, the generation point for air contaminants is partially or totally isolated by physical barriers. Enclosure is rarely complete, due to the need for accessibility to the process. Contaminants are contained within the enclosure and evacuated by exhausting sufficient air to cause indraft into the hood. Enclosing hoods may be generally classified as close-fitting hoods or booths. Close-fitting hoods, as the name implies, fit the process operation quite tightly and allow only sufficient space around the process to perform the needed tasks. The worker dosen't enter a close fitting hood, but may extend his arms through the hood openings.

A ventilated booth, on the other hand, is built larger for operations which require a substantial amount of access by the worker. The booth may have an open face where the worker stands, or both worker and process may be isolated in an enclosure, similar to the grinding operations shown previously.

Close-Fitting Hoods--

The simplest form of the close-fitting hood is the total enclosure, such as the isolated tumbling mill enclosure already discussed. Theoretically, no ventilation is required during operation of this process because there is no open area in the hood; the dust is completely isolated. In actuality, it is very difficult to maintain a complete seal and the doors develop gaps with use. A small amount of exhaust from within the enclosure creates a negative pressure or vacuum condition, that is, the pressure within the hood is less than that outside the hood and air will flow in rather than out. The primary reason to exhaust this enclosure, though, is to evacuate the dust to prevent exposure during unloading of castings from the tumbling mill.

The small amount of exhaust withdrawn during tumbling would be insufficient to prevent dust escape during operation if the doors to the enclosure were left open. The switch, in this case, assures that this will not happen. Not only would dust escape if the doors were open during operation, the noise protection would become almost completely non-functional.

Induction Furnace Hood--In this next example, operator access to the process is also necessary while the process is in operation. During the melting cycle, the enclosure above this induction furnace is complete except for a small clearance around the pouring spout (Figure 3-2). The exhaust requirement at this time is low. But there are times when the cover of the furnace must be removed to provide access for adding alloy, taking temperature or metal samples, or removing slag. A hinged side panel allows the furnace cover to swing to the side and the top of the hood automatically swings with it (Figure 3-3). The worker now may perform the necessary work on the furnace (Figure 3-4)(30). However, the exhaust requirement of the hood has now increased dramatically. There are now three openings in the hood, the one of most concern being located above the furnace in the path of the convection currents.

In order to contain the metal fume, the exhaust air volume must be able to counteract these thermal currents by causing a downward flow of air into the top of the hood. The resultant flow patterns

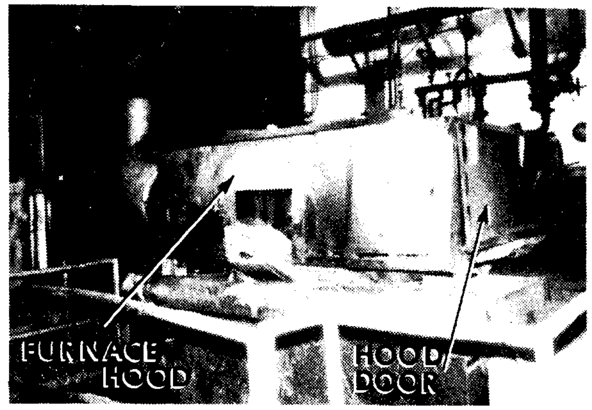

Figure 3-2. Induction furnace hood enclosure.

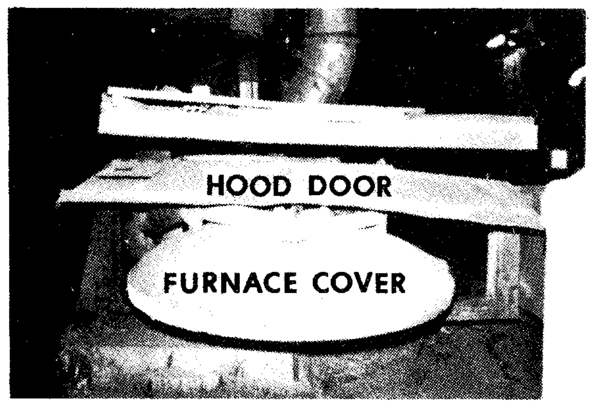

Figure 3-3. Opening of furnace cover.

Figure 3-4. Cleaning scrap from the top of the furnace after charging.

are shown in Figure 3-5. Since the exhaust takeoff is located on one side of the hood only, the greatest potential for escape of fume exists at the opposite side of the hood. The exhaust rate for this hood must be based on providing sufficient downdraft at that far point.

Shell Molding Machine Enclosure--The need to provide sufficient indraft at all points in the open areas of the hood to prevent escape of contaminants can be illustrated through another example. A shell mold machine, which produces thin shell molds through heat curing of sands bonded with phenol-formaldehyde resins, is enclosed with the front of the machine left open so that the operator can remove the finished molds (Figure 3-6)(31). Emissions of gases from the shell core machine rise and are exhausted through a takeoff at the top of the hood. However, the various motions of the core machine can also project some gases outward at the middle of the machine. As can be seen in Figure 3-7, the highest indraft velocities occur at the top of the face opening. Indraft at the middle of the machine is lower due to the greater distance from the exhaust outlet and due to the

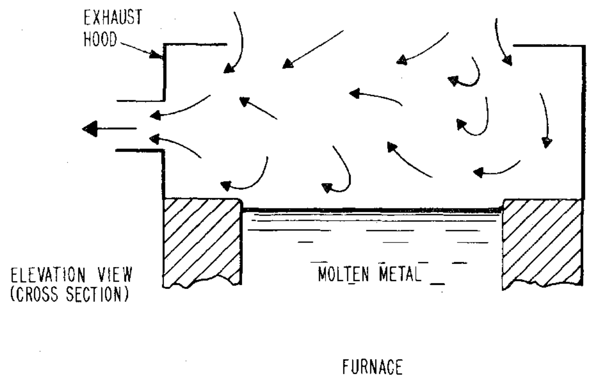

Figure 3-5. Air patterns within a furnace hood.

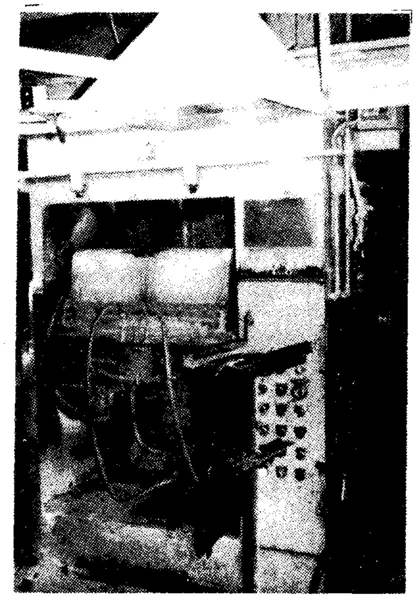

Figure 3-6. Shell mold machine surrounded by enclosing hood.

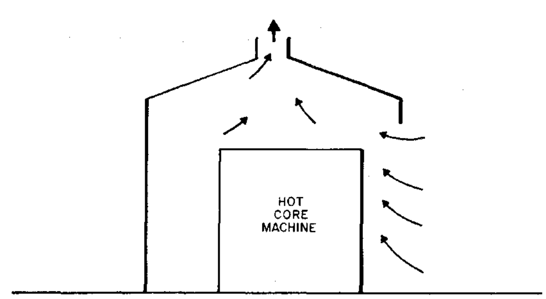

Figure 3-7. Close fitting enclosure.

interference the core machine itself causes to air flow. Thus, the in-draft in the middle part of the face opening where the gases can be projected outward is the controlling factor for establishing a suitable exhaust rate.

Other Uses for Close-fitting Enclosures--Enclosing hoods are also used in other foundry applications which require substantial amounts of worker access to the process. Figure 3-8 shows an enclosure over a small shakeout with an access opening on one side of the hood for loading the molds onto the shakeout and on the other side for hooking out the castings(32).

Figure 3-9 shows a hood for capturing dust during the unloading of bags of clay into a bond hopper. This hood differs from the one shown earlier in that this bond hopper is also the storage hopper from which the muller operator scoop out bond and adds it by hand to the muller. Thus, the pneumatic transport system is not used here to convey the bonding materials to the point of use. The hood enclosure over this process is intended to prevent worker exposure to dust both during bag emptying and during

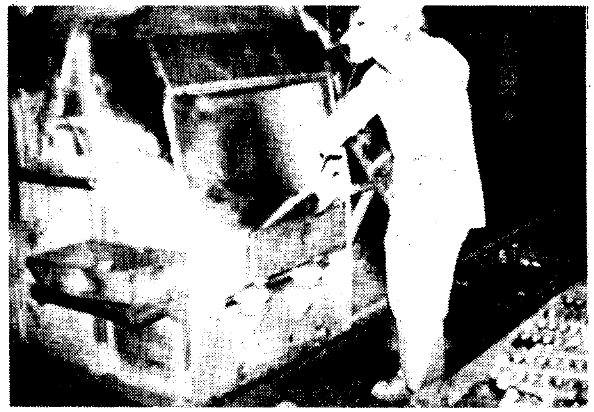

Figure 3-8. Hookout of castings from shakeout.

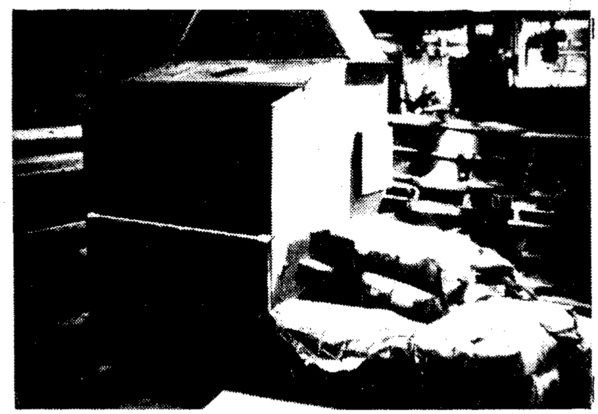

Figure 3-9. Bond hopper enclosure.

scooping out of materials. Work practices are important if this hood is to be effective. After the bag is emptied it must be folded up for disposal. This is a very dusty operation and should be done within the hood.

Dust capture at this same station is also provided at a batch feed hopper into which the worker pours measured amounts of bond (Figure 3-10). The batch hopper is a small chamber mounted in the side of the muller. After filling the batch hopper, the operator energizes a hydraulic cylinder which automatically dumps the bond into the muller (see figure). The small hood which controls dust emitted during batch hopper filling also controls emissions from any gaps around the hopper during batch feeding. The capture velocity at this hood must not be set too high or excessive amounts of the fine bond materials will be drawn from the system.

Material loss is not the only potential waste when using a close-fitting enclosure; a second is energy loss. Figure 3-11 shows an induction furnace used for melting copper-base alloys. The furnace cover is swung aside for charging

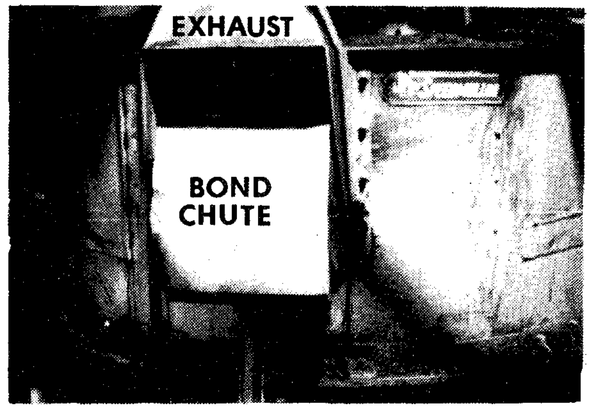

Figure 3-10. Exhaust at bond feed into muller.

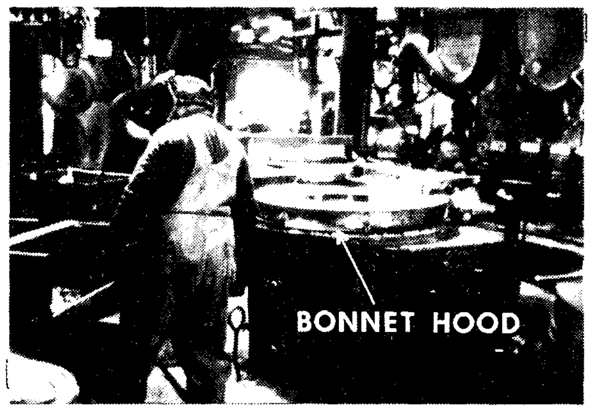

Figure 3-11. Bonnet hood on furnace melting copper-base alloys.

the furnace. Unlike the induction furnace hood shown previously, with this particular hood design the furnace cover does not sit directly on the furnace within the confines of the hood; rather it sits on top of the hood. Thus, the air exhausted passes directly across the molten metal, removing heat and increasing the production of lead and zinc fume. To minimize these detrimental effects, this hood must be operated at a reduced exhaust flow when the furnace cover is in place on the hood. However, the problem with hoods that draw different exhaust rates during different portions of the cycle is that, unless automatic dampers are used, the worker may forget to close and open dampers at the proper time. When the furnace cover is on, the excessive energy loss and fume draw is not visually apparent to the worker.

In both of the induction furnace hood examples already cited, the process is exhausted at the source throughout the entire furnace cycle. Since these hoods are mounted directly on the furnace, they also move with it while it is tilted during furnace emptying or tapping. A duct pivot on the axis of the furnace permits exhaust in any position of the furnace. The common exhaust system used for arc furnaces, on the other hand, does not have this feature of continuous exhaust. During the charging of these furnaces with bottom unloading charge buckets, the furnace cover, which in this case supports the hood, is swung aside and the ductwork is separated (Figure 3-12). Separation also occurs when the furnace is being tilted during tapping (Figure 3-13) (33). Thus, the hood is only effective during the melting cycle. Because of the furnace size, the presence of graphite electrodes which project through the furnace cover, and the complexity of having pivoting ducts for continuous exhaust, it is difficult to design and apply hoods to the arc furnace.

The need for accessibility is one of the greatest constraints to the use of enclosing hoods. Figure 3-14 shows an enclosing hood at a discharge point on a sorting conveyor where forklift access is necessary to remove the debris hopper.

One of the real advantages of the new mechanized molding and casting lines is the potential for isolation of contaminant sources to within

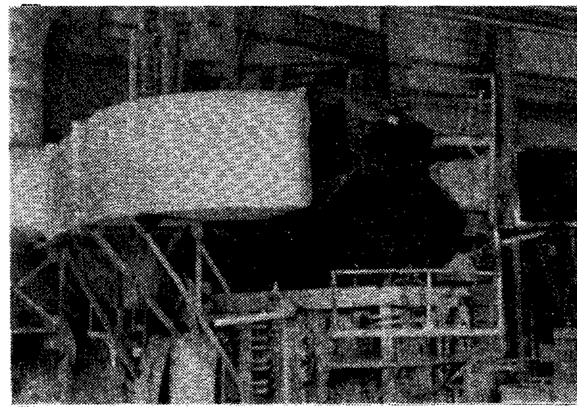

Figure 3-12. Arc furnace during charging using a bucket.

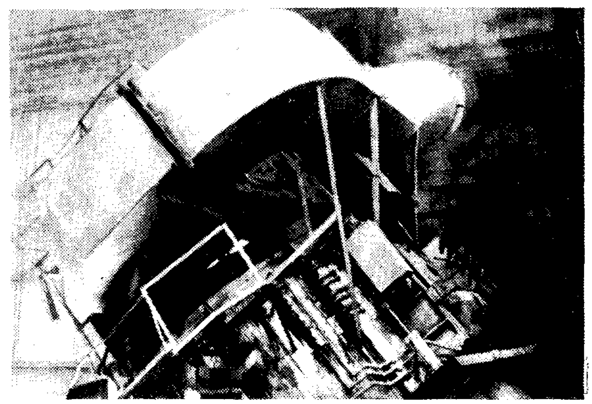

Figure 3-13. Arc furnace during tapping into the transfer ladle.

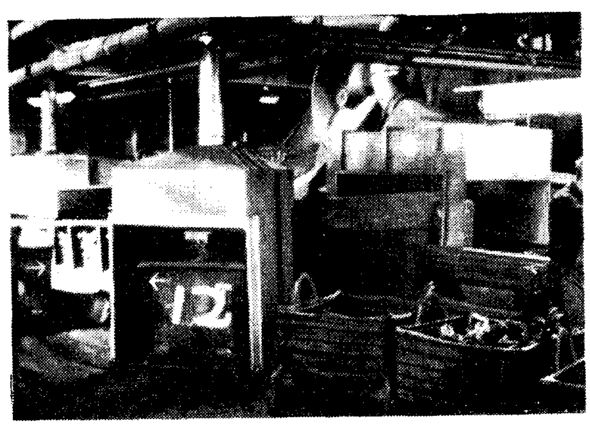

Figure 3-14. Enclosure of conveyor discharge point.

enclosures. Figure 3-15 shows a plan view schematic of a continuous molding and casting process (34). The dashed lines show the path of the molds during the operation. After pouring, the molds move back and forth within an enclosed room in which the molds cool. Outdoor air is blown into the cooling room to speed up the cooling process. To prevent mold pyrolysis products from entering the workplace, the exhaust rate from this cooling room must be sufficient to remove the supply air (which, after it is heated by the molds, is expanded in volume) and to provide an indraft where molds enter and exit the room. An interlock must be provided with this system to prevent the supply air from being used if the exhaust fan is not operating.

Ventilated Booths--

The simplest type of ventilated booth is no more than a scaled-up version of the close-fitting hood. Figures 3-16 and 3-17 show a booth on a swing grinding operation. All sides are enclosed except for the front. The contaminant source should be located within the confines of the hood. (One can see in Figure 3-17 that the contaminant source is improperly located just outside the booth. The

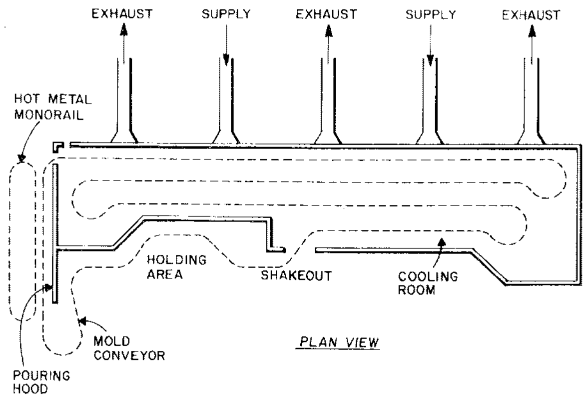

Figure 3-15. Mold cooling room.

Figure 3-16. Swing grinding booth.

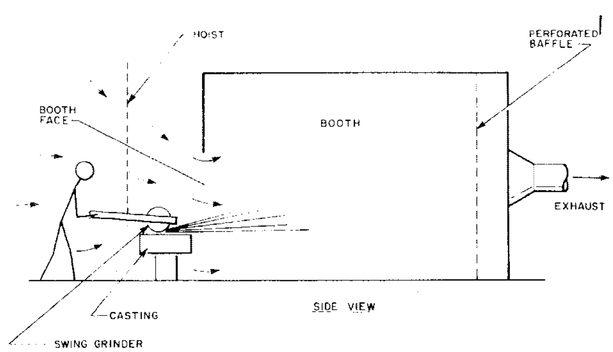

Figure 3-17. Grinding outside of booth face (incorrect procedure).

worker is located completely outside the booth. Air exhausted from the back of the booth causes a uniform indraft into the booth which prevents the escape of contaminants.

Unidirectional Flow Booths--Another type of ventilated booth, the unidirectional flow booth, is a unique type of enclosing hood. Both the air contaminant source and the worker are located inside the booth. In the unidirectional flow booth, the air at any point in the booth has a velocity which is uniform both in velocity and in direction. In this open face booth, air flow is caused by exhaust air distribution at the back of the booth (bottom sketch, Figure 3-18). Distribution is achieved either with slots or, as is shown in Figure 3-18, with a perforated wall. The worker can work anywhere in the booth as long as this orientation is maintained.

The top portion of Figure 3-18 shows a ventilating hood in use within a booth. In this case, unidirectional air flow patterns have not been provided for and random patterns exist. Adequate air

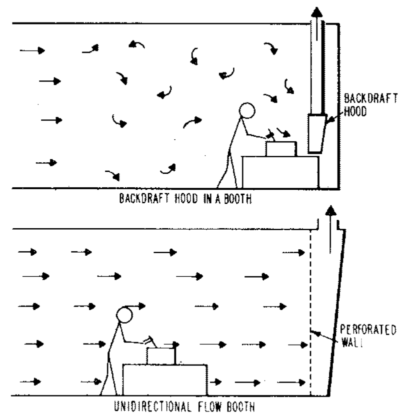

Figure 3-18. Differences in booth methods.

contaminant control in a booth of this type is only achieved when the work is performed on the bench.

Torch-cutting and air carbon-arc gouging are perhaps the most difficult foundry processes to control. Fume dispersion is caused by and varies with changes in the direction of the air nozzle used to promote oxidation. When bench mounted hoods are applied to this process, fume capture is complete only when the air jet is directed at the hood. When it is not, the fume is not directly captured but instead rolls within the booth and past the worker's breathing zone (Figure 3-19). The use of a unidirectional flow booth for this process also has its limitations. The high air velocities which are required to prevent the rolling of fume create another problem - the eddy current effect (Figure 3-20). As air flows around the worker's body, it creates eddy currents in front of the worker. The currents can actually draw contaminants from the source directly back at the worker. The higher the velocity in the booth, the greater will be the eddy current effect (35). The eddy current

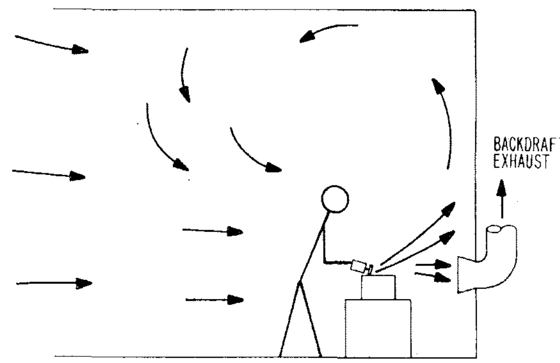

Figure 3-19. Fume rolling during torch cutting.

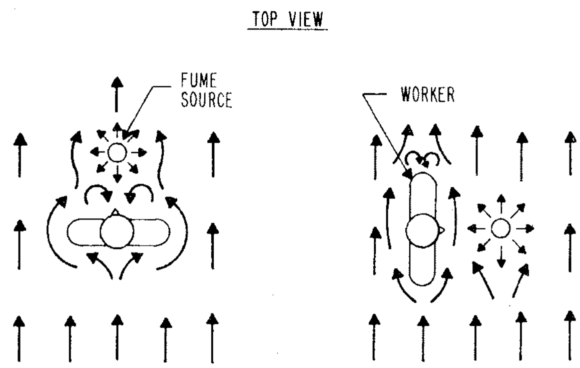

Figure 3-20. Unidirectional flow booth-eddy current effect.

effect can be minimized by having the worker stand to the side of the contaminant source in the airstream; however, in this position, the air jet would have to be directed to the side, which would not be safe and would bring the fume source closer to the breathing zone.

Figure 3-21 shown a semi-enclosed, air carbon-arc gouging booth which uses a power, rotating table to position the casting so that the air jet is directed as much as possible at the exhaust inlets (36). This booth makes use of supply air ducts which are located behind and to either side of the worker. The air ducts create air patterns which will minimize the eddy current effect (plan view, Figure 3-22). The effectiveness of this method is very dependent on the worker rotating the turntable as required and always maintaining a position near the front of the bench.

The torch-cutting and air carbon-arc booth just described can handle castings up to about 1.2 m (4 ft) in major dimension. Castings this size are normally transported to and from the work-bench by overhead crane. The lid

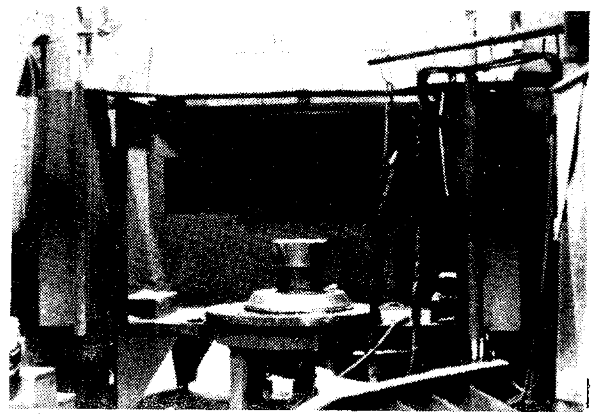

Figure 3-21. Air carbon-arc gouging booth.

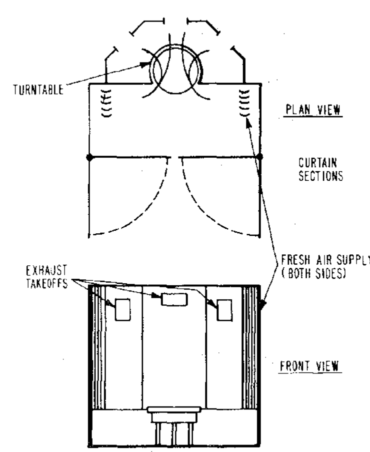

Figure 3-22. Air flow patterns within air carbon-arc gouging booth.

on this booth retracts as the casting is lifted into the booth.

Figure 3-23 shows a ventilated booth used to cut the sprues off of much larger castings (37). The plan view sketch in Figure 3-24 shows that the same basic air flow patterns are applied in this case. The effectiveness of this booth is again very dependent on work practices. The lid of the booth is not retractable; castings are loaded onto a mobile platform which is then pushed into the booth on tracks.

The booths just described are classified as horizontal booths, because air basically flows in a horizontal direction. Vertical air flow booths have also been used in this application but they have been generally unsuccessful.

Exterior Hoods

An exterior hood is used where processes cannot be enclosed, usually because of operational requirements or interferences. The hood is mounted as close to the contaminant source as possible. The hood functions by inducing air flow patterns around the process, which draws contaminants toward the hood. There are two

Figure 3-23. Torch cutting booth.

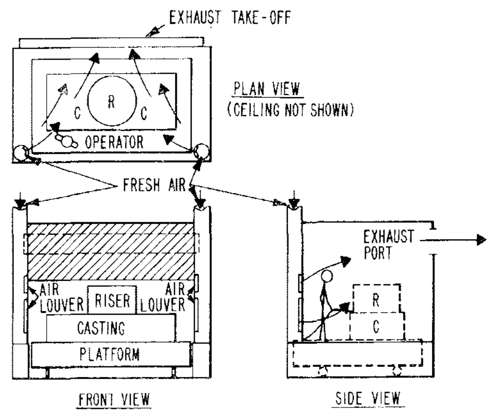

Figure 3-24. Air flow patterns within torch cutting booth.

subcategories of exterior hoods which relate to the method by which capture is achieved: receiving and non-receiving hoods. The receiving hood takes advantage of predictable dispersion forces which propel the contaminants into the face of the hood. In the case of non-receiving hoods, the contaminant either has no initial dispersion velocity or interferences prevent the use of a receiving hood.

Figure 3-25. Close fitting hood on a swing grinder.

Receiving Hoods--

Swing Grinder--An exhaust hood mounted directly on the swing grinder effectively captures dust which is entrained by the inertial swarf of large particles projecting from the wheel (Figure 3-25)(38). Exhaust ductwork must be mobile because the worker manually positions the swing frame, which is supported by a hoist. In this case, the mobile ductwork consisted of a series of swiveling duct elbows (Figure 3-26), which increases the already substantial effort needed to perform the job. Flexible ducts have also been used in place of duct elbows in this application. These offer less resistance during the positioning of the grinder but are subject to rapid wear from abrasive particles.

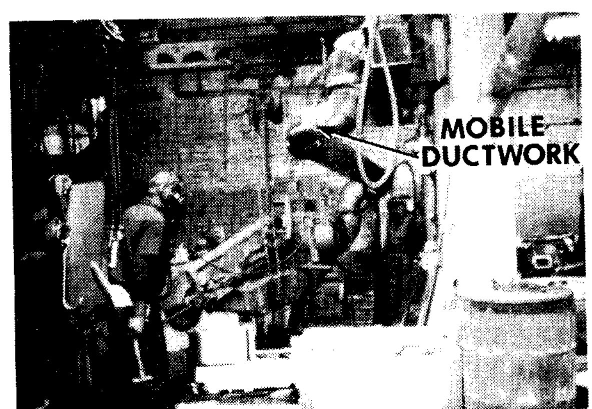

Figure 3-26. Mobile ductwork system exhausting swing grinder hood.

Thus, it can be seen that the transport of exhaust air, in this case, poses more of a problem than the actual capture using a simple receiving hood.

Pedestal Grinder--In Lesson 1, the primary methods by which dust is dispersed away from the point of grinding, that is, inertial swarf and wheel windage, were described. Unfortunately, the conventional grinding wheel hood employed by industry does not take advantage of the dust carrying mechanism of the inertial swarf to capture the dust, rather, it disrupts the inertial swarf, freeing the dust to become entrained in the wheel windage and be circulated around the wheel and out the front of the hood. The deflection of the inertial swarf is shown schematically in Figure 3-27. The hood is designed to contain the swarf; however, the swarf does not enter the exhaust takeoff directly. Instead, it is first deflected by the hood. When deflection occurs, and the air induction effect of the inertial swarf is destroyed, the wheel windage and the exhuast takeoff "compete" for the dust. The speed of the wheel as it passes the exhaust takeoff is two to three times the speed of air entering the duct.

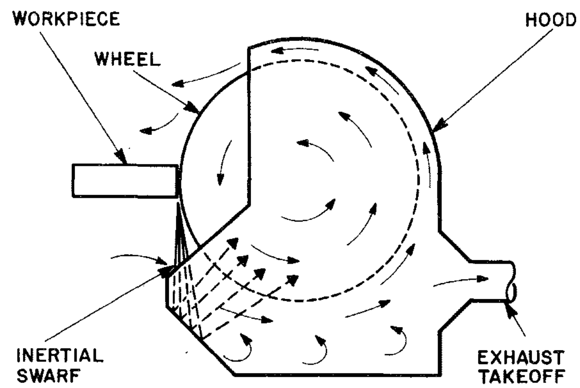

Figure 3-27. Dust capture-grinding wheel.

Thus, the duct suction has little effect in drawing dust out of the wheel windage.

Several attempts have been made to improve the capture of this hood. Figure 3-28 shows an attempt to enclose the wheel as far as possible (39). Figure 3-29 combines in one sketch two separate developments. In one project, the grinding hood chute area which receives the inertial swarf was changed to provide as smooth a path as possible for the swarf in an attempt to direct the swarf into the exhaust opening with the least disruption of the dust entrainment effect (40). As part of this same modification, baffles were placed close to the wheel near the exhaust port in an attempt to strip the wheel windage and divert the dust into the exhaust port. Another attempted improvement involved adding a secondary exhaust at the top of the wheel to recapture the dust which is blown out the front of the hood by the wheel windage (40).

The above research has not been carried far enough, nor has it resulted in the adoption of any of these improvements in industry.

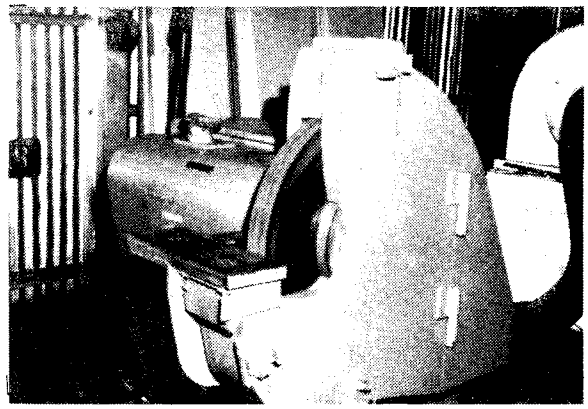

Figure 3-28. Pedestal grinder with well-enclosed wheel.

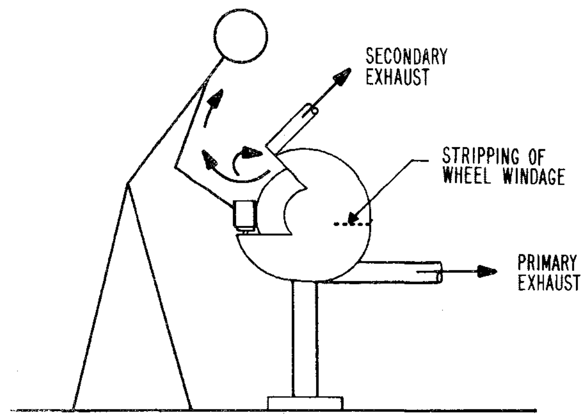

Figure 3-29. Grinder hood improvements.

Ladle Hoods--When toxic metals such as leaded bronze are melted and poured, fume must be captured the entire time the metal is molten if exposures are to be maintained at low levels. The most difficult time to provide capture is during the hot metal transport and pouring process. A lot of the difficulty results from the mobility of these processes. In the case of small ladles pushed by hand along monorails, a mobile ladle canopy hood has been developed to capture fume. Figure 3-30 shows such a hood in use during pouring of molds. The rising fume is received by the canopy hood, a flexible duct then transmits the exhaust to a stationary overhead plenum which extends the entire length of the monorail. The flexible duct connects to a small receiving box which rolls freely along the stationary plenum and injects the fume into it.

The technique for permitting continuous insertion of fume into a long, sealed plenum can be better explained with the aid of Figure 3-31. The receiver box (which moves along the plenum) contains four rollers which lift a belt that seals the plenum. The

Figure 3-30. Mobile ladle canopy hood in use during pouring.

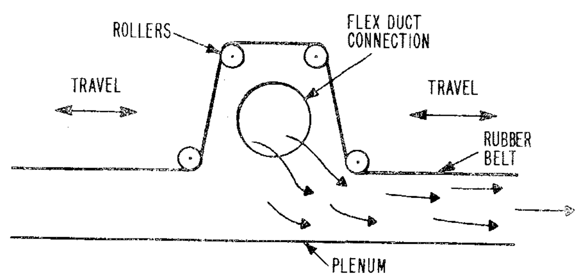

Figure 3-31. Mobile exhaust method.

exhaust is introduced in the section where the belt is lifted. This method uses a very small fraction of the exhaust that would be necessary if conventional hoods were used along the entire route.

The ladle hood is not limited to use with monorail hoists which restrict the use of the exhaust to the path of the monorail. It can also be used with bridge cranes which permit the worker to move freely throughout an entire area with continuous capture at every point. The bridge crane duct arrangement is shown in top view in Figure 3-32.

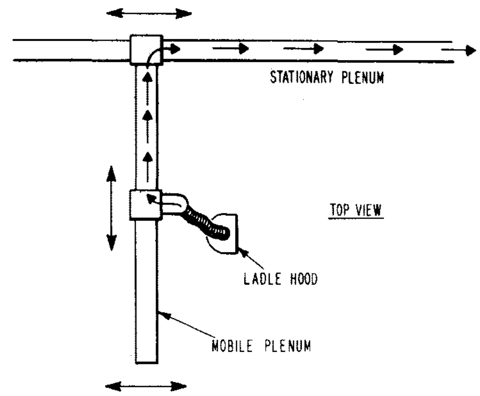

Figure 3-32. Mobile duct-work arrangement.

The system is composed of the same components as before, that is, ladle hood, flexible duct, receiver box, and plenum, but in this case two plenums are used:

1. A mobile plenum which moves with the bridge crane and is attached to it.

2. A stationary plenum mounted near the bridge crane rails.

An additional receiver box is used to transfer the fume from the mobile to the stationary plenum. This receiver box operates on the same principal, that is, localized lifting of a belt seal, as the one which collects the fume from the ladle hood.

The mobile ladle hood is a very versatile method. Its major limitation is that it is usually applied to existing hot metal transport arrangements which often are difficult to retrofit. Figure 3-33 shows a typical monorail switching loop in the vicinity of a furnace. Collecting plenums which can accommodate automatic switching from one plenum system to another are not available.

The mobile ladle hood, when used in conjunction with a close-fitting furnace hood, has been found to effectively control the large amount of fume emitted during the tapping of the furnace. The need for the two above hoods, working in parallel, stems from the physical interference caused by the ladle hanger (Figure 3-34). This interference prevents the use of a canopy hood over the molten metal stream, as well as extension of the furnace hood (Figure 3-35).

Figure 3-33. Ladle monorail system.

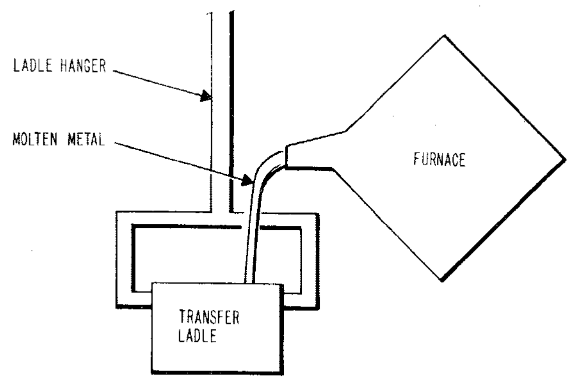

Figure 3-34. Furnace tapping.

Figure 3-35. Ladle hood and furnace hood working together.

Work practices are important when using ladle mounted hoods. These hoods are usually removed while the ladle is being preheated under a burner before the ladle is filled. The worker must reinstall the hood on the ladle before proceeding to the furnace. Workers who have not used this method before must get accustomed to this practice.

Other Uses of Canopy Hoods--A close-fitting canopy hood is shown collecting fume from a gas-fired crucible furnace which melts aluminum (Figure 3-26) (22). The air exhausted by this hood must be high enough to remove the convection currents as well as the products of combustion of the natural gas. The two small metal baffles on the metal post in front of the furnace deflect flames from the side of the furnace which could emit fumes from under the hood.

Figure 3-37 shows a canopy receiving hood at a ladle preheater station (22).

Figure 3-38 shows an improper application of a canopy hood (32). This swing-away hood is only in place during melting. When the furnace is tilted during tapping, no protection is provided for the workers. A

Figure 3-36. Close-fitting canopy hood above crucible furnace.

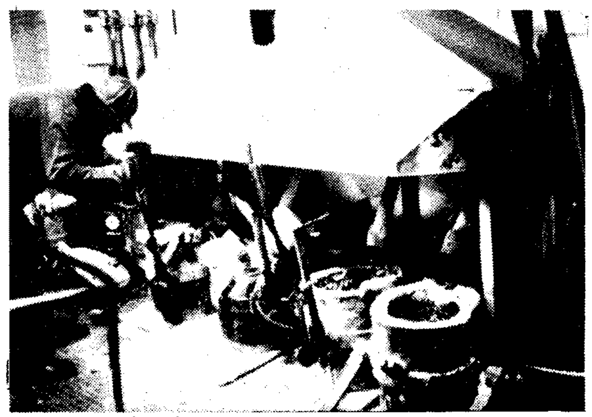

Figure 3-37. Canopy hood at ladle preheating station.

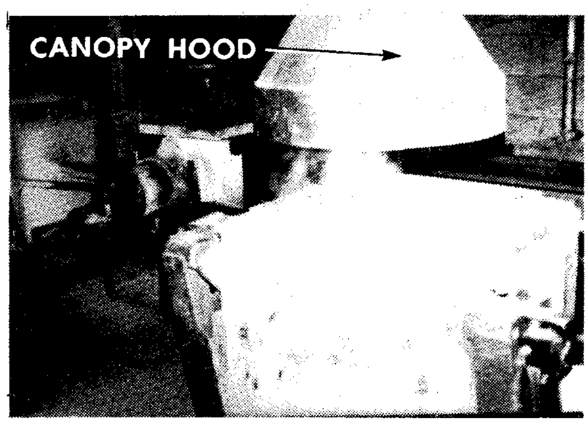

Figure 3-38. Improper application of a canopy hood.

close-fitting enclosing furnace hood is a much better approach because fume is evacuated during the complete furnace cycle.

Combination Deflection/Receiving--In certain cases where a hood cannot be placed directly above a hot process, supply air can be used to purposely deflect the convection currents so that they rise into a receiving hood. The shell pouring operation sketched in Figure 3-39 is a good example (41). The ladle monorail prevents the canopy hood from being extended outward far enough to capture all the rising smoke and fume. A fresh air supply, introduced overhead, deflects air contaminants into the hood. The fresh air, as it reaches the pouring zone, is very low in velocity so that it does not cause disruptive turbulence.

Figure 3-40 shows another version of this method in which both supply air and exhaust air are mounted together. The deflecting air flow patterns are shown in Figure 3-41. This latter method is a commercially available hood. To be successful in collecting the fume without causing air turbulence and fume loss to the workplace, this hood first

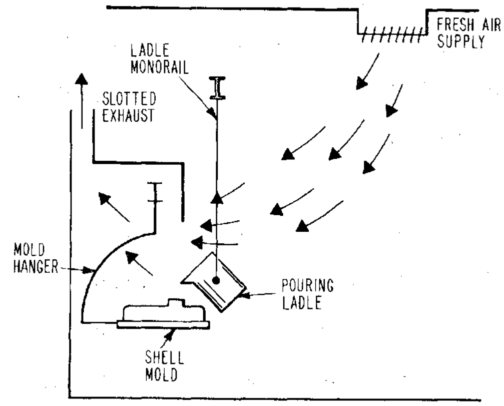

Figure 3-39. Air flow patterns on shell pouring line.

Figure 3-40. Combination air supply and exhaust hood.

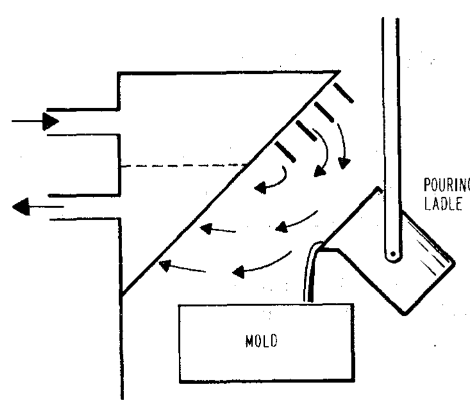

Figure 3-41. Air supplied pouring hood.

went through a research and development program to establish the ultimate configuration and flow patterns.

Canopy Above Process--A canopy hood over a hot coremaking station collects gases and vapors from the coremaking, handling, and storage operations (Figure 3-42)(42). A baffle in the canopy hood assures that most of the exhaust will be from above the major air contaminant source: the coremaking machine. The baffle also ensures that the gases and vapors move upward and are not drawn at an angle toward the exhaust point which would bring them closer to the breathing zone. Fresh air is introduced at the worker station under the hood in such a way that the convection currents above the hot coremaking machine and storage rack are not disrupted.

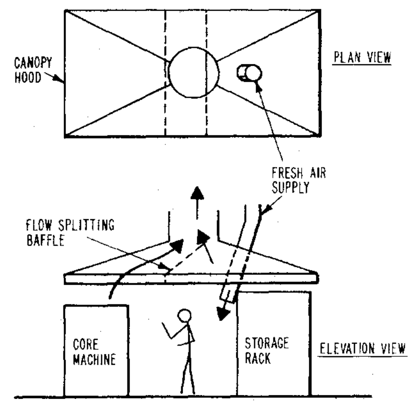

Figure 3-42. Furan hot box coremaking.

DISCUSSION QUESTIONS

1. What steps would you follow in establishing a total exhaust rate for an enclosing hood?

2. What establishes the minimum exhaust flow rate for a receiving hood?

3. What variables affect the dust generation rate for a grinding wheel?

4. When a ventilated booth is used why must the air contaminant source be within the confines of the booth?

5. What is the importance of foundry layout to a mobile ladle exhaust system?

ANSWERS

1. a. Define the limit of the air contaminant source to be enclosed.

   b. Establish a hood configuration which will completely enclose the source.

   c. Determine how much open area will be needed in the hood.

   d. Establish a hood face velocity that will overcome the dispersion forces that would expel contaminants from the hood.

   e. Multiply the hood open area by the face velocity to calculate the total exhaust rate.

2. The flow into the hood must be higher in rate than the contaminant laden air projected at it.

3. Workpiece and wheel materials, grinding speed and pressure, condition of the wheel surface.

4. Outside of the booth face, the capture velocity rapidly diminishes to levels not sufficient to draw the

contaminant into the booth.

5. The feasibility of using a monorail or bridge crane mobile exhaust system will require the absence of interferences such as monorail switches or other obstructions.

UNIT OVERVIEW
UNIT 4 - CONTROL METHODS:
NON-RECEIVING HOODS AND
GENERAL VENTILATION

METHODS	Lecture LENGTH: 90 Minutes
PURPOSE	To discuss through example different uses for non-receiving hoods in foundries and the place of general ventilation in exposure control.
OBJECTIVES	Enable the participant to: 1. Understand the limitations of non-receiveing hoods and the factors which must be taken into account when applying them. 2. Consider the ill effects of negative pressure and discuss ways to alleviate this condition. 3. Understand the ways that present methods of cooling workers disrupt control of worker exposures.
INSTRUCTOR MATERIALS	35 mm slides 35 mm slide projector and screen
TRAINEE MATERIALS	Course outline

CONTROL METHODS: NON-RECEIVING HOODS AND GENERAL VENTILATION

NON-RECEIVING HOODS

Non-receiving hoods differ from enclosures and receiving hoods in that they represent a very inefficient form of capturing contaminants at the source. Although the air velocity at the entrance to a hood may be high, the velocity only a short distance away is greatly reduced. The following examples will discuss this inherent limitation of non-receiving exterior hoods.

Ventilated Workbenches

The worker in Figure 4-1 is cleaning and finishing a casting using portable abrasive grinding tools. During the course of performing this operation, the tool is held in many different positions resulting in the inertial swarf being projected in almost every conceivable direction. The downdraft exhaust through the bench is incapable of directly capturing the dust entrained in the inertial swarf unless the swarf is directed at the bench, which is only the case a small fraction of the time.

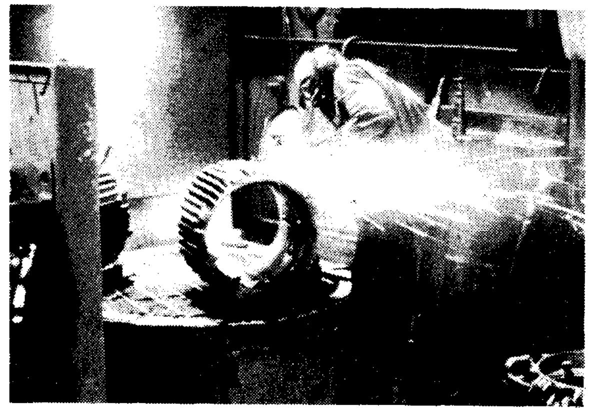

Figure 4-1. Inertial swarf projected away from a ventilated bench.

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A second significant problem is the low capture velocity at the dust generation point. Figure 4-2 can help illustrate this problem.

Each of the curves above the bench represent different levels of velocity. If the velocity into the bench is set at the upper limit of the ACGIH recommended range [(1.25 m/sec (250 ft/min)], the velocity only 60 cm (2 ft) above the bench will be only 0.25 m/sec (50 ft/min), a velocity too low to effectively capture dust (1). Contrast this to the fact that inertial particles are projected from the point of grinding at speeds as high as 63 m/sec (12,500 ft/min). As can be seen in Figure 4-1, grinding on castings is performed at considerable distances above the bench surface.

Many of the inherent problems with the downdraft bench could be resolved if the job could be arranged so that the swarf were always directed at the ventilated workbench.

Figure 4-3 shows a sidedraft grinding bench which employs a fixture mechanism for repositioning of the casting during the grinding process. In this operation the swarf may be directed as much as possible at the suction opening (43). This specially

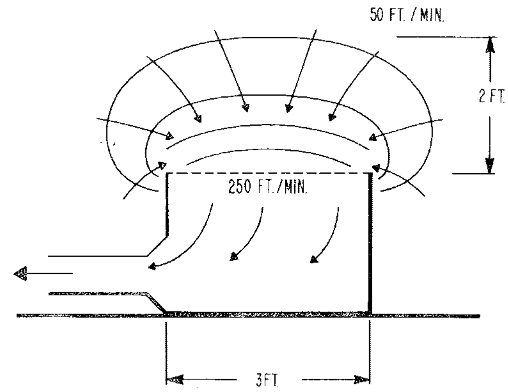

Figure 4-2. Velocity profile above ventilated bench.

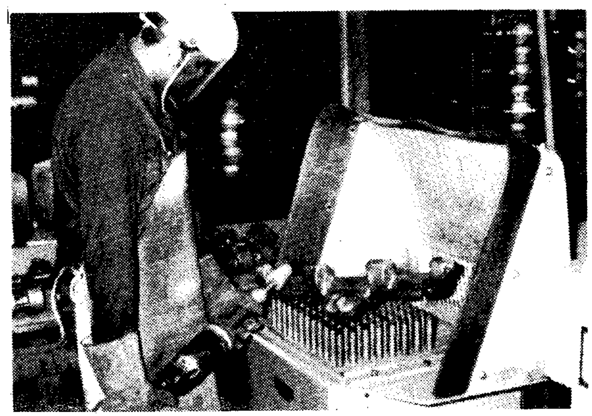

Figure 4-3. "Fetlok" casting support system.

developed fixture is called a Fet-lok system. The casting is placed on a workbench containing a large number of retractable pins; the weight of the casting depresses the pins below it. After placing the casting on the bench, the worker moves a lever which locks the pins in position and supports the casting firmly during grinding. A larger version of a similar holding device which uses a series of retractable pins is shown in Figure 4-4 (44). In this case, the casting is clamped between two such sets of pins.

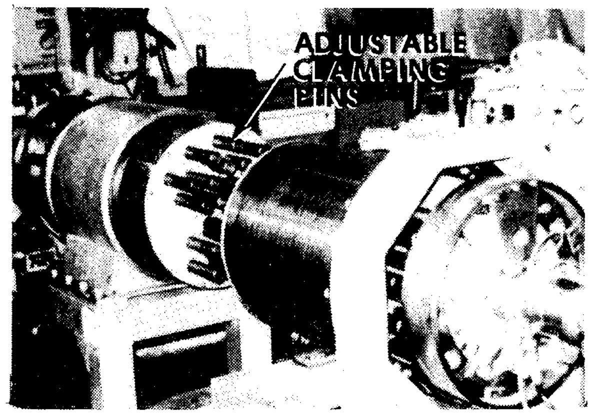

Figure 4-4. Adjustable fixture for casting cleaning.

Besides the problem of receiving the inertial swarf, there is a second problem with the use of ventilated benches-they are in-effective at preventing worker exposure to dust during internal chipping and grinding of castings. During internal cleaning, the casting itself acts as a barrier to a direct movement of dust from the grinding process into the bench (Figure 4-5) (45). The dust must first exit the top of the casting before it can move downward and be exhausted. As it leaves the casting, this dust may first pass through the breathing zone of the worker. Figure 4-6 shows a worker performing an

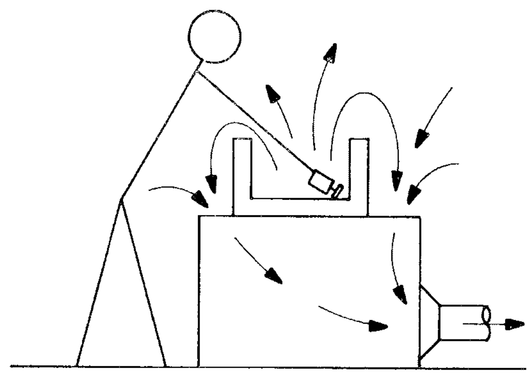

Figure 4-5. Internal grinding on downdraft bench.

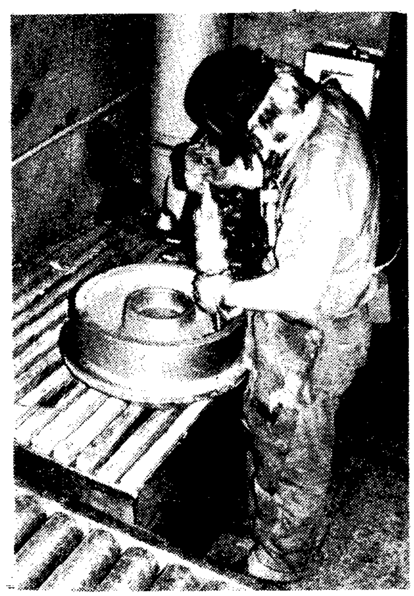

Figure 4-6. Chipping on a downdraft bench.

internal chipping operation on a downdraft bench.

High-Velocity, Low-Volume Exhaust

A method which has potential for exhausting the dust from both internal and external cleaning of castings is the high-velocity, low-volumne (HVLV) method of exhausting the tool itself. This exhaust method functions by creating an indraft velocity close to the point of dust generation, and sufficiently in excess of the dust generation velocity to capture dust as soon as it is generated. Indraft velocities can range from 30 to 195 m/sec (6,000 to 39,000 ft/min).
Figure 4-7 shows a worker using a small radial grinder fitted with a HVLV hood (45). The suction opening is located close above the tool in this picture.

Figure 4-8 shows a cup grinding process in which HVLV is employed. In this case, the hood almost fully encloses the cup grinding wheel. Besides the air supply to operate the portable tool, a second, larger hose is needed for the hood exhaust. Figures 4-9 and 4-10 show HVLV hoods fitted to two other abrasive cleaning tools, a saw and

Figure 4-7. Radial grinding using ventilated tool.


Figure 4-8. Cup grinding using ventilated tool.


Figure 4-9. Exhaust hood on abrasive saw.

a pencil grinder, respectively.

The high-velocity, low-volume exhaust method finds its best application on large castings of relatively simple geometry, such as those just seen. The hoods can interfere with some types of cleaning and the extra hose can be an encumbrance. To be most effective, this method requires that particular grinding tools be used for specific jobs. Normally, because of the many grinding operations performed on a casting, the operator will perform as many operations as possible with a single tool, using the available grinding surfaces on the tool, rather than frequently changing tools.

Another drawback to the use of this method is that, although there are hood methods available for all of the abrasive grinding operations, there are no satisfactory methods for exhausting pneumatic chipping hammers. Probably the best hood method developed to date involves locating a suction hose close to the chipping point without enclosing the process in any way (Figure 4-11) (46). The need to use different chisels in the hammer prohibits the use of a closer fitting hood at present.

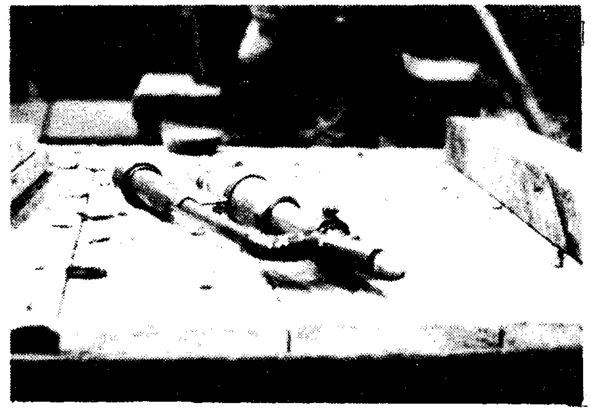

Figure 4-10. Hood on cone grinder.

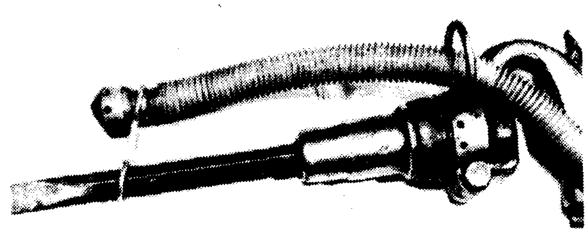

Figure 4-11. Chipping hammer equipped with an exhaust device.

One of the greatest hindrances to the use of HVLV is worker acceptance. There is no question that cleaning and finishing of castings with portable tools is much easier to perform without the nuisance of the hood and the hose. It takes a real concerted effort on the part of both labor and supervision to achieve full application of this method. However, with all its drawbacks HVLV has more potential than other exterior hoods; other exterior hoods do not interfere as much with the work, but they are far more limited in controlling exposure.

Low Velocity Exhaust Hoses

In lieu of using HVLV hoods on tools, large exhaust hoses drawing lower velocities have been used during internal cleaning of large castings (Figure 4-12)(47). This method can only be effective if the worker's head can be kept out of the casting, which is not always possible.

Figure 4-13 shows another good use for the flexible hose method during the chipping out of old refractory lining material from ladles. Again, an important prac-

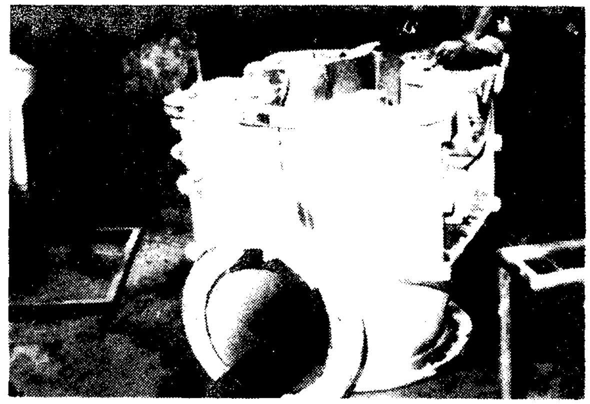

Figure 4-12. Flexible exhaust hose for internal grinding on a large casting.

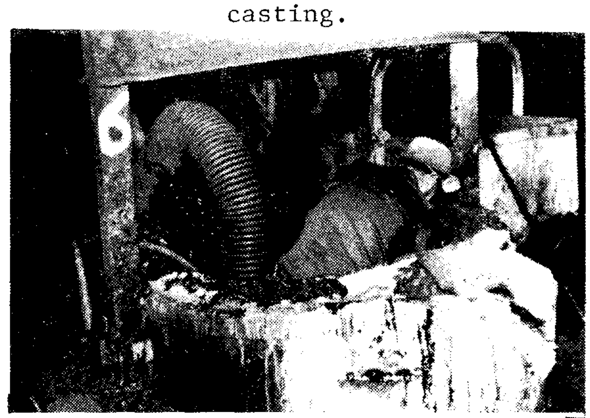

Figure 4-13. Flexible exhaust hose during chipping out of ladle linings.

tice necessary for this control to function is that the worker keep his head out of the ladle while he is chipping. This operation is especially hazardous because exposure measurements have shown that, where silica sand is used in the refractory, a significant portion of the silica dust will be in the form of cristobalite.

Figure 4-14 shows the placement of the hose with respect to the tool during chipping out of the lining.

Figure 4-14. Hose placement during chipping of ladle lining.

In the discussion of the modes of dispersion of contaminants, it was stated that the pneumatic tool exhaust is a secondary source of dispersion from chipping and grinding processes. A method to eliminate the disruptive effects of this dispersion is to vent the tool exhaust through a short length of hose of small diameter which is attached to the air supply hose. This type of tool exhaust not only eliminates the secondary dust dispersion problem, but also substantially reduces the air noise from the tool. In this latter regard, however, it should be noted that there are other significant noise sources associated with the tool besides air noise; this venting method doesn't provide a total noise solution in itself. Some manufacturers are not putting fittings on their tool which can accept the pneumatic exhaust hose. Replacement of hoses, however, has been found to be required on a frequent basis during these rugged foundry operations.

Other Examples of Exterior Hoods

The dumping of the materials chipped out of the ladle described in the previous example is a good example of a process which can be effectively ventilated using an exterior hood (Figure 4-15). In this case, the exhaust is composed of a slot at the back of the debris hopper. The small metal back and side panels shown around the suction point are classified as hood baffles. The baffles help to reduce short-circuiting of air and increase the effectiveness of dust capture. Short-circuiting is a hood defect whereby exhaust air is drawn from around the back and sides of the hood suction rather than across the air contaminant source.

Figure 4-16 shows the effective use of a sidedraft hood during welding of small castings on a bench (23). Figure 4-17 shows an adjustable

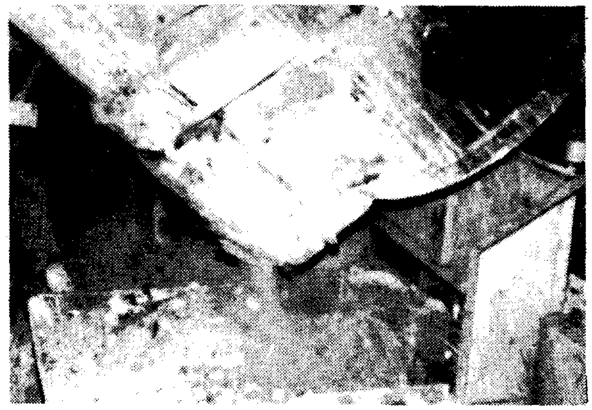

Figure 4-15. Dust capture during dumping of lining materials.

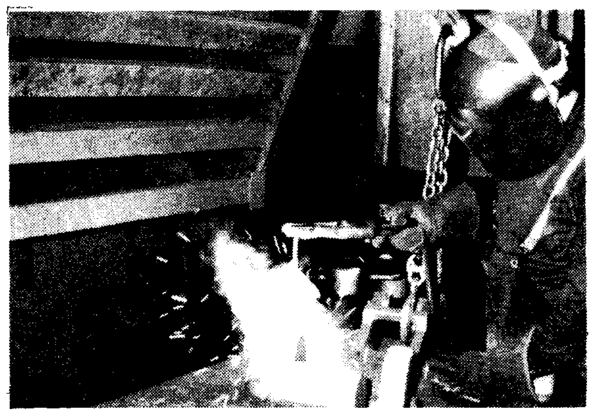

Figure 4-16. Fume control during welding.

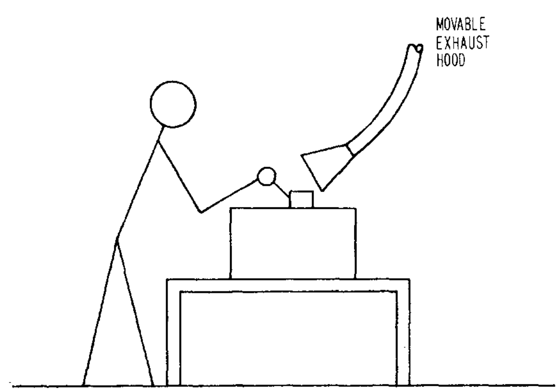

Figure 4-17. Welding exhaust method.

cone-shaped hood which, because of its mobility, has the potential for use during welding of large as well as small castings. To be effective, this method requires that the worker faithfully reposition the hood every time the welding point changes to maintain the exhaust point very close to the contaminant source. Both of the above exhaust methods are limited to use on external welding.

The hazards of welding within enclosed spaces, where the above two methods are not suitable, has led to the development of new welding control methods. These methods more closely approximate the HVLV methods used in foundries to control dust from grinding with portable tools. However, no data is yet available documenting the extent of protection offered by these methods in foundry applications.

Figure 4-18 shows the effective capture of fume with a sidedraft hood during slagging of a ladle full of an alloy containing lead (22).

Figure 4-19 shows how an exterior hood method can be used to ventilate a remotely controlled process. The example presented is the sand slinger discussed earlier (28). This process

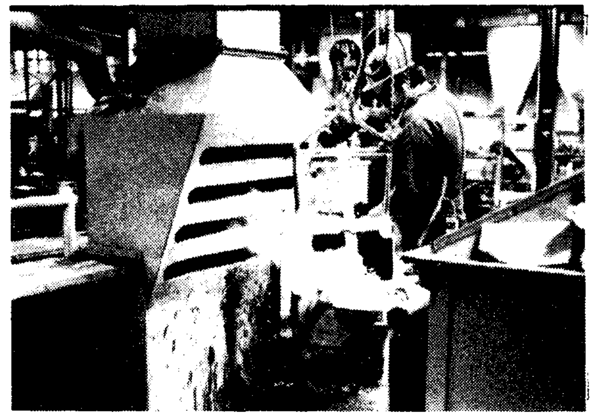

Figure 4-18. Ventilated slagging station.

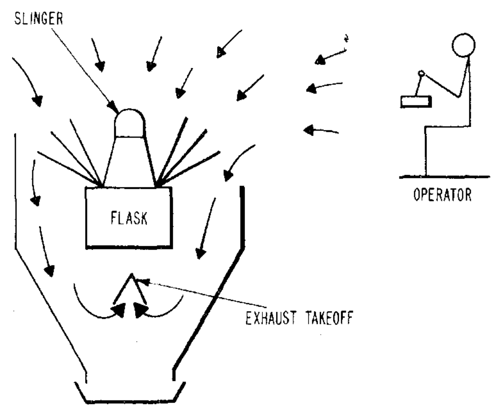

Figure 4-19. Ventilation of a remotely controlled process.

is very difficult to enclose because of the accessibility needed to move flasks in and out and fill them with sand. However, moving the operator back out of the way reduces the need for close enclosure to achieve effective dust control. An exhaust takeoff in the spill pit below the flask can create downward air flow patterns around the flask. An inverted hood is constructed to collect dust without picking up the sand. If the worker were located right at the slinger head, as was once the case, this exterior hood would not offer sufficient protection. The hood creates very low air flow velocities around the flask. This installation allows some dispersion of dust a short distance away from the source because of air turbulence around the slinger. The air currents, however, set up by the exhaust hood are able to prevent escape of the dust to the area of the operation control station.

Control of escaping gases from a coremaking process, using dimethylethylamine (DMEA) as a catalytic gas, is achieved with the use of an exterior bonnet hood around the corebox (Figure 4-20)(48). This hood captures the gases leaking past the seals and the gases emitted during core box opening.

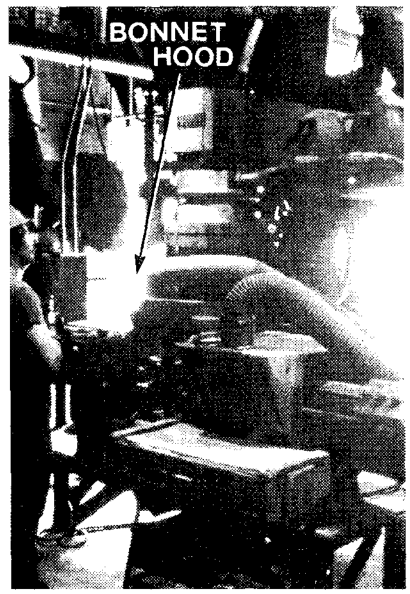

Figure 4-20. Exhaust of catalytic gases around the core box.

during core box opening.

A small sidedraft hood can also be seen in this figure above the table where the cores are handled and finished. Figure 4-21 shows the core finishing process under this hood. This sidedraft hood, as well as all of the other exterior hoods just described, are very sensitive to cross-drafts.

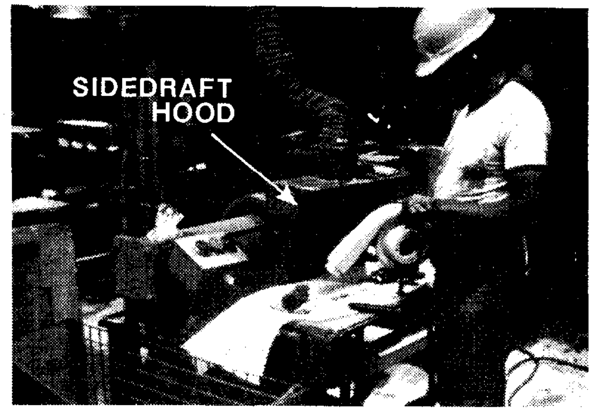

Figure 4-21. Ventilation at core handling station.

GENERAL VENTILATION

In the historical perspective that was presented in Unit 3, it was shown that the total ventilation in foundries has grown to the point where severe negative pressure conditions exist in many foundries. In the following section, some of the serious effects of this situation and methods to abate it are discussed.

Adverse Effects of Negative Pressure

Excessive negative pressure has many detrimental effects, some of which have already been identified. Following are two examples of some serious effects: the first involves cross-contamination of contaminants from one process area to another; the second has resulted in acute exposure of workers to carbon monoxide.

Charge Bucket Filling Area--
Figure 4-22 shows a process, usually performed outdoors, which is typical in many ferrous foundries. Scrap materials are lifted by magnetic crane and dumped into a charge bucket which will later fill the melting furnace. A significant portion of the scrap consists of foundry returns, that is, sprues, gates, risers, and scrap castings, which may have sand loosely adhered to the surfaces and contained within the cavities. Thus, besides metal oxides, dust emitted from the charge bucket filling process may contain respirable silica. The high negative pressure in most melting areas causes this dust to be drawn in through the door through which the charge bucket is transported, which is usually kept open. This dust adds to the exposure of workers in the melting area.

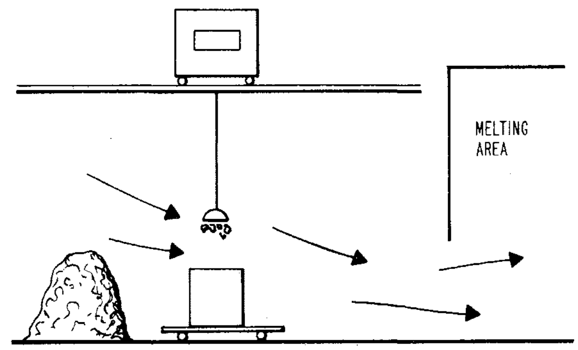

Figure 4-22. Cross-contamination from charge bucket filling operation.

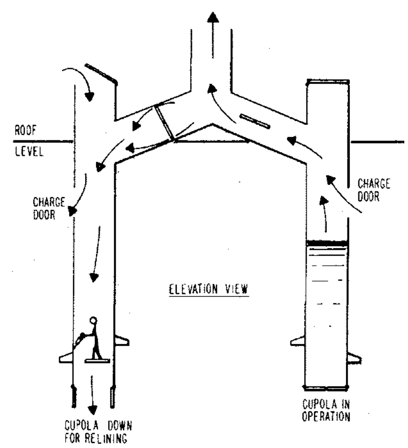

Figure 4-23. Backflow through a cupola.

Cupola Repair Operation--
Figure 4-23 shows a typical operating mode for duplex cupolas: one cupola on line and one out of service for relining. One exhaust system and dampers are used

to draw all of the exhaust from the operating cupola. While one cupola is on line, a maintenance worker relines the adjacent, unused cupola. The cupola cap on the unused cupola is usually raised and the negative pressure in the foundry draws outside air through the opening and downward through the cupola. However, the gap around the damper also permits exhaust from the operating cupola, rich in carbon monoxide, to enter this cupola and to be drawn downward. This action results in gross overexposure of the worker (49).

There is one aspect of this problem that is confusing unless explained further. The question is: If suction from the exhaust system is being applied to the operating cupola, wouldn't the air flow direction through the gap around the closed damper be from the unused cupola to the operating cupola, not vice versa? The answer is that the intense heat of the operating cupola results in a positive pressure at the closed damper, rather than a negative pressure at that point. This positive pressure combined with the negative pressure within the unused cupola acts to draw the exhaust gases into the unused cupola. Although damper fit can be improved, the seriousness of this problem dictates that other preventive measures be taken to prevent acute exposure such as worker surveillance, air supplied respirators, rescue lines, and air quality monitoring.

A better solution to this problem would be to substitute the present Y-joint and dampers with a mobile duct. The duct would swing into place only on the cupola which is in operation and would be completely isolated from the other cupola.

Methods of Reducing Negative Pressure and Providing Dilution Ventilation

Five methods will be discussed:

1. Introduction of fresh tempered air.
2. Introduction of fresh un-tempered air.
3. Reduction in the use of roof ventilators.
4. Indirect heat exchange to temper fresh air.
5. Recirculation of cleaned exhaust air.

Introduction of Fresh Tempered Air--Fuel-fired makeup air units are available which blow air under low pressure into the foundry and which heat the incoming air during winter (Figure 4-24). As far as reducing negative pressure is concerned, it does not matter where the air is brought in. However, in terms of providing good air turnover within the building while avoiding disruptive cross-drafts, it becomes desirable to distribute the air throughout a large area rather than discharging it at one point. Figure 4-25 shows a distribution plenum which is very large in cross-section because air is being conveyed at low pressure and, thus, at low velocity. The distribution plenum is usually mounted high in the building, but the air can be directed outward, downward, or upward by louvered grilles. In summer months, the incoming air is usually directed outward and, because in almost all cases it is cooler than foundry air, it will "fall" in a predictable fashion because of the density gradient between warm and cool air (Figure 4-26). When directed into worker areas, the veolcity of this air as it reaches floor level, while not high enough to disrupt ventilation hoods, is still high

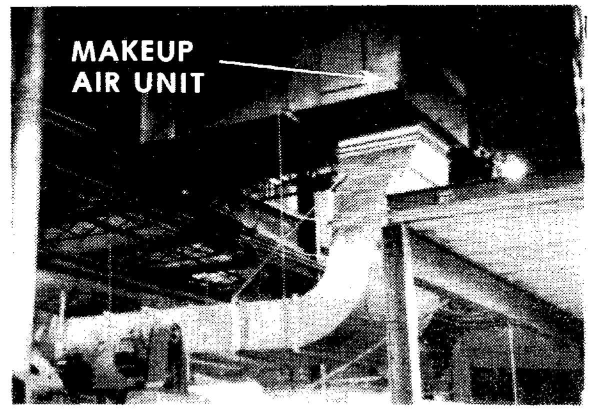

Figure 4-24. Tempered make-up air unit.

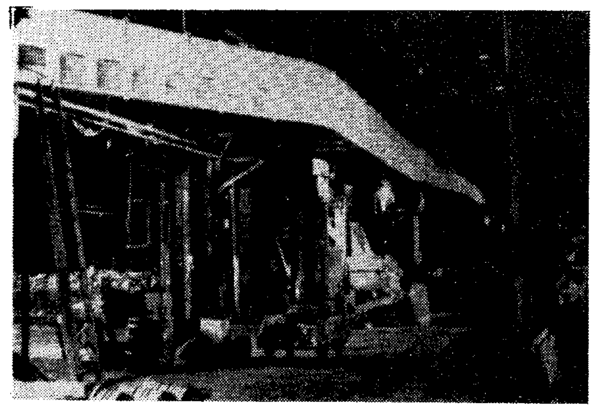

Figure 4-25. Make-up air distribution plenum.

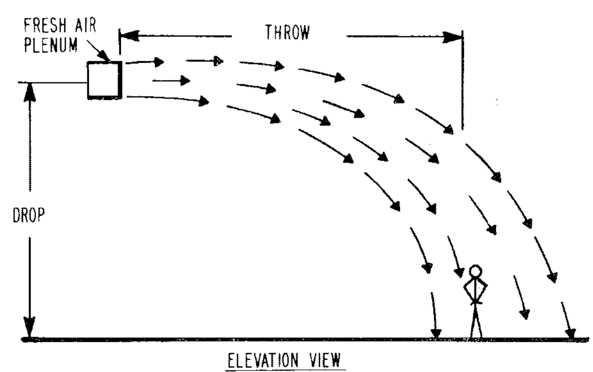

Figure 4-26. Air drop effect.

enough to be an effective aid to evaporation of sweat. In winter, the air is usually maintained in an outward flow or sometimes angled slightly upward. It is not directed downward because, even though the incoming air is tempered in the winter, when it passes through the foundry air, it can still create undesirable drafts on the workers.

The locations of fresh air distribution plenums in relation to the exhaust points should be planned in such a way that the air sweeps as large an area as possible before being exhausted. Fresh tempered air should not be introduced adjacent to large exhaust hoods.

Introduction of Fresh Untempered Air--
There is one fact that must be understood about make-up air entering a building which is under negative pressure: it occurs automatically as air is exhausted. Thus, introduction of make-up air is not a matter of providing air which would not otherwise be provided; rather, it is a matter of choosing where and how the air will be introduced.

It is very difficult to purposely introduce large amounts of untempered outdoor air without causing cold drafts. Air mixing chambers are commercially available which take warm, indoor, roof level air and mix it with cold outdoor air and then project it out a series of air jets (also just below roof level) to become thoroughly mixed with in-plant air. However, these chambers have not been reported to be in use in foundries as yet. One foundry, however, has found a place where air can be introduced without mixing. When this foundry constructed a new melting shop, an underground concrete plenum was installed which permits air to be drawn into the furnace tapping pit area where workers are not located. This air is soon exhausted by the arc furnace hood (Figure 4-27). The net effect is that negative pressure in the building is reduced without the use of the fuel.

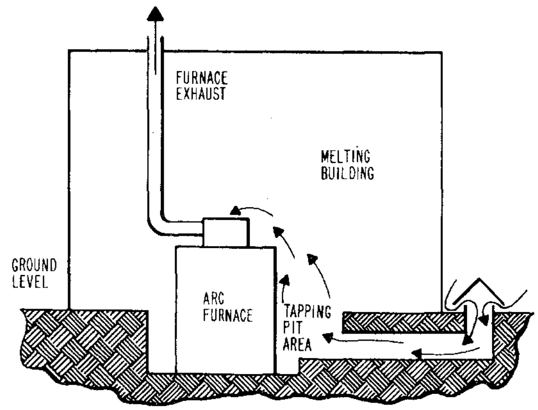

Figure 4-27. Introduction of untempered air.

Reduction in the Use of Roof Ventilators--

Roof ventilators are not as effective at directly removing air contaminants as is sometimes thought. They are typically placed in strategic locations above hot processes, but they are very inefficient at direct removal of contaminants rising in the thermal convection currents unless the roof is close above the process. The cross-sectional area of the thermal convection currents increases with distance above a hot source (Figure 4-28). When the thermal draft impacts the roof, only that portion in the immediate vicinity of the fan is directly evacuated. The greatest majority of the rising air, as it impacts the roof, rolls outward and downward. The spreading effect can only be nullified if baffles are used to contain this air and high exhaust volumes are used to evacuate it. An example of the use of baffles for this purpose was presented in Unit 2 under isolation.

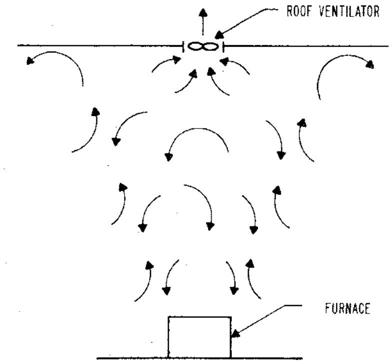

Figure 4-28. Expansion of the thermal draft.

Exhaust very close to the source should be used to remove point sources of air contaminants. Roof ventilators should be restricted to situations where they are absolutely needed. These include heat removal during summer months and dilution ventilation for area air contaminant sources, such as floor pouring areas which are not controllable at the source.

Indirect Heat Exchange to Temper Make-up Air--

A substantial source for energy to temper make-up air is the waste heat from the foundry itself. Indirect heat exchange from hot process exhausts could potentially provide the needed energy. Heat exchangers, however, require a substantial investment and maintenance to keep them operational. Although used in some foundries abroad, they have not been widely adapted in this country. Waste heat is a valuable resource which has yet to be tapped.

Recirculation of Cleaned Exhaust Air--

Recirculation of cleaned exhaust air is another alternative being explored. This method finds its best potential application in the cleaning room where the contaminants consist chiefly of particulate matter. Filtering technology is available to efficiently remove particulate material. However, monitoring systems have yet to be demonstrated which will quickly and reliably sense failures in filtering equipment and take action to prevent exposure of workers to recirculated contaminants. Particle sensors which could be used in such systems are commercially available; they have not yet been developed into systems in foundries.

Cooling of Workers

Besides the exhaust of hot process gases, the principal method of controlling heat stress on workers in hot foundry jobs has been "spot cooling" by blowing fresh air on the worker. Another method in frequent use is the recirculating "mancooler" fan which blows inplant air across the worker at high velocities. In the case of "spot cooling" with fresh air, rarely is the air chilled and so, on the hottest days, the cooling effect is probably negligible. Above 35°C (95°F) the air may be heating the body by convection. The principal cooling mechanism is achieved by the velocity of the air which facilitates sweat removal. Figure 4-29 shows a metal pouring operation with both a fresh air inlet and mancooler fan blowing on the worker from behind.

The unfortunate thing about this approach is that the velocities required to give the worker a cool "feeling" are in the thousands of

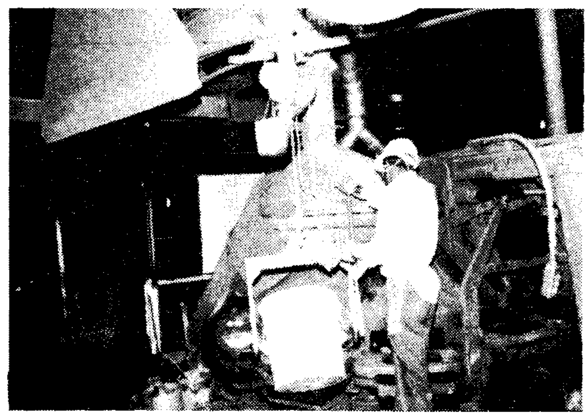

Figure 4-29. Mancooler fan and fresh air inlet to reduce heat stress.

feet per minute, high enough to disrupt any exterior hood such as the sidedraft pouring hood shown, as well as to reentrain dust from floor and equipment. In order not to disrupt the exhaust hood, the same quantity of air should be distributed through a larger area and, thus, at a lower velocity (Figure 4-30). The problem here is that, unless the air is chilled, decreasing the velocity will also decrease sweat removal caused by the air motion. Thus, removing the detrimental effect on exhaust hood operation will also have removed the means for cooling the worker.

Besides preventing the disruption of the exhaust hood, distributed air also prevents another disruptive effect caused by high velocity air: the air entrainment effect. High velocity air, as it moves, draws other air into the air stream because of its momentum. If that air contains contaminants, the net effect is that contaminants can be pushed at the worker. Figure 4-31 shows a pouring operation with a fresh air plenum which blows downward on the worker (upper right hand of figure). Behind this pouring operation, ductile iron was

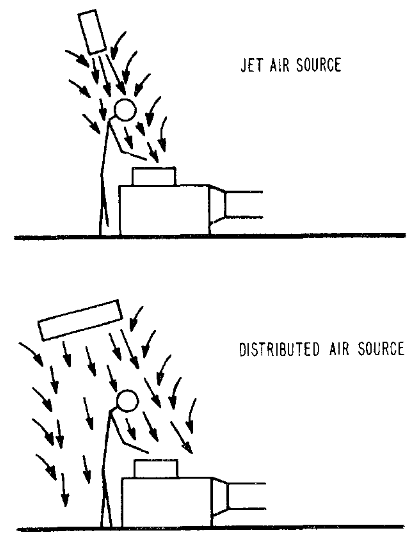

Figure 4-30. Comparison of supply air methods.

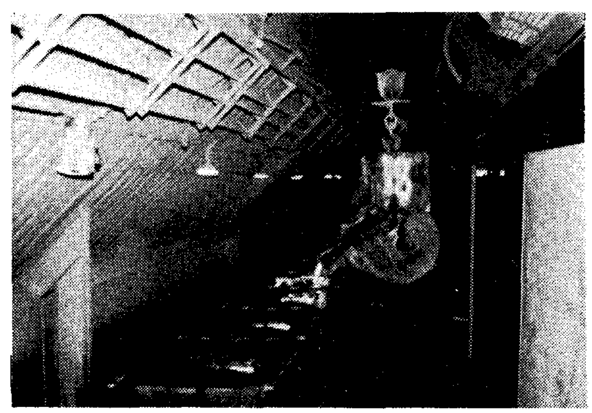

Figure 4-31. Supply air plenum on pouring line.

being periodically transferred to pouring ladles. Figure 4-32 shows that the rising fume from the molten metal transfer operation was being entrained into the fresh air stream and blown onto the pouring line.

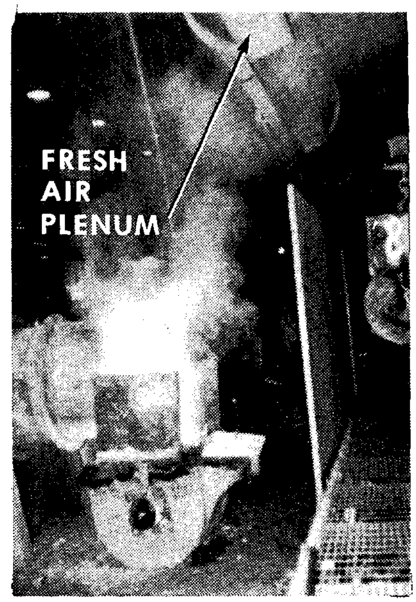

Figure 4-32. Cross-contamination of fume by air induction.

The air entrainment effect must also be considered when areas are being cross-ventilated using supply air at one end and exhaust air at the other end of the area. Figure 4-33 shows the pouring floor described earlier in Unit 2 dealing with isolation. A cable system removes just-cast molds to a semi-enclosed cooling area. A fresh air supply plenum and a series of mancooler fans push air across the area from the pouring area end to the cooling area end. The primary purpose of the air movement is to cool the pouring deck workers, but the air also serves the purpose of blowing fume and smoke away from the pouring process. The problem is that, unless the pouring smoke and fume were captured, the blowing away process would result in the cross-contamination of other foundry areas. For such a "push-pull" system to capture the pouring fume and smoke, the exhaust on the cooling end must be much higher in capacity than the supply air

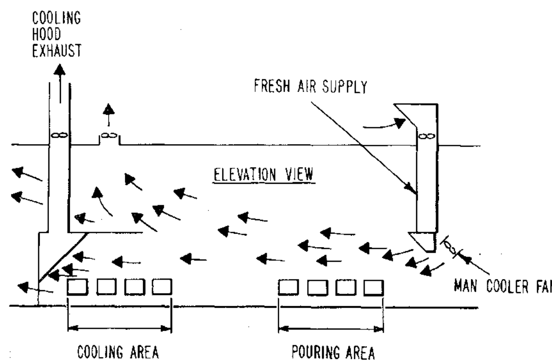

Figure 4-33. Ventilation patterns on pouring deck.

capacity composed of both fresh and plant air, because of additional air entrained. In addition, the cooling area hood shroud needs to extend higher than is shown in Figure 3-33 to contain the expanded air stream. In its present form, this system permits air contaminated with the pouring emissions to escape past the cooling area and to contaminate other areas.

Effect of Localized Hoods on General Ventilation

When reviewing the evolution of foundry ventilation, it was noted that localized exhaust hoods create an air turnover in worker areas because they cause air to move at floor level, which roof ventilators cannot do effectively. Under the discussion of make-up air, it was further stated that fresh air should be distributed into the foundry in such a way that air moves as far as possible before being exhausted, providing the fullest use of the fresh air. There is, however, a limitation to this desirable method of general ventilation that must be understood. If there are uncontrolled emission sources between the supply air point and the exhaust hoods, the air contaminants from the uncontrolled sources will be dispersed into the general air pattern. Before the air reaches the exhaust hood, any contaminants swept with it will first pass through the breathing zones of workers who are located at or near the evacuation hoods. If the number and extent of uncontrolled processes is significant the background air quality in the vicinity of the exhaust hood could be quite poor.

When localized hoods are discussed, no mention is normally made concerning the fate of air contaminants which escape the hood. It is assumed that they are dispersed into the background air which everyone in the foundry, in turn, breathes. In actuality, unless the escaping air contaminants are dispersed away from the air contaminant source through such means as hot thermal drafts or some other dispersion method, they may remain in the vicinty of the process and eventually be drawn back to the hood. This effect can be explained with the help of Figure 4-34. The exhaust hood causes air in the area surrounding the hood (shown in the figure as an imaginary envelope or bubble

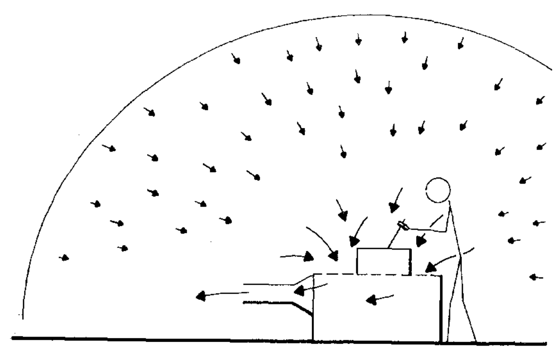

Figure 4-34. Recapture effect around a local hood.

around the worker) to move slowly toward the evacuation point. And so, instead of becoming diluted throughout the entire foundry background air, the escaping contaminants may return to the hood. This recapture effect helps to prevent cross-contamination among process areas, but, at the same time, it represents a secondary mechanism of exposure for the worker.

In summary, for general ventilation to be effective, localized hoods should be as efficient as possible **and should be used to control all of the major air contaminant sources in the workplace.**

DISCUSSION QUESTIONS

1. If a worker must enter a large casting during chipping and grinding with portable tools, what is the principal factor which would limit the effectiveness of using a large exhaust hose to control worker exposure?

2. What factors affect the efficiency of an exterior non-receiving hood?

3. What is the chief advantage of a remotely controlled process with respect to ventilation?

4. Is air turnover rate (expressed as air changes per hour) in the

foundry a useful measure of the adequacy of ventilation? Why or why not?

5. Present methods of cooling foundry workers have a serious defect. What is it?

ANSWERS

1. It would probably not be practical to continuously reposition the suction to always be between the air contaminant source and the breathing zone.

2. Size, mobility, and mode of dispersion of the air contaminant source; size, mobility, exhaust rate, and closeness of the hood to the source; cross drafts; location of the worker in relation to both the source and the hood.

3. The breathing zone is separated further away from the air contaminant source and, as a result, a localized control hood does not have to be as close to the process to be effective in controlling worker exposure.

4. By itself it offers little information about the extent of protection against exposure because:

    a. It does not differentiate between dilution ventilation and control at the source.

    b. It assumes thoroughly mixed air flow patterns exist which is seldom the case. Within a single foundry building, different areas may experience drastically different air turnover rates depending on the methods of ventilation employed.

5. They employ high air velocities which are disruptive to the operation of capture hoods.

UNIT OVERVIEW
UNIT 5 - MAINTENANCE, MONITORING, HOUSEKEEPING, AND THE SEARCH FOR NEW AND IMPROVED CONTROL METHODS

METHODS	Lecture LENGTH: 50 Minutes
PURPOSE	To discuss the need to: 1. Design foundry control systems to be simple, rugged, and as maintenance free as possible. 2. Maintain the performance of control measures. 3. Keep the foundry free of settled or spilled dust.
OBJECTIVES	Enable the participant to: 1. Be sensitive to ways in which control measures can be constructed to provide trouble-free operation. 2. Be aware of the ways in which control systems can fail and ways in which these failures can be detected. 3. Understand the means and difficulties involved in housekeeping. 4. See the need for controlled experiments to improve existing control measures.
INSTRUCTOR MATERIALS	35 mm slides 35 mm slide projector and screens
TRAINEE MATERIALS	Course outline

MAINTENANCE, MONITORING, HOUSEKEEPING, AND THE SEARCH FOR NEW AND IMPROVED CONTROL METHODS

THE RUGGED FOUNDRY ENVIRONMENT

Designing and constructing a control measure that will reduce worker exposure to air contaminants is a challenge, but designing one that will sustain its performance in the foundry environment is doubly so. The following are two examples of how the foundry industry has solved problems which had limited the useful lives of their ventilation hoods.

Protection for Shakeout Hood

Figure 5-1 shows a shakeout operation in a steel foundry (28). Flasks are lifted by overhead crane onto a perforated, vibrating table. After the bottom board of the flask is removed, the contents of the flask (molding material and casting) fall out freely. However, sometimes sand hangs up in the flask, and the crane operator knows from experience that the fastest way to dislodge this sand is to ram the flask against something. The closest object at hand is the sidedraft shakeout hood. The hood

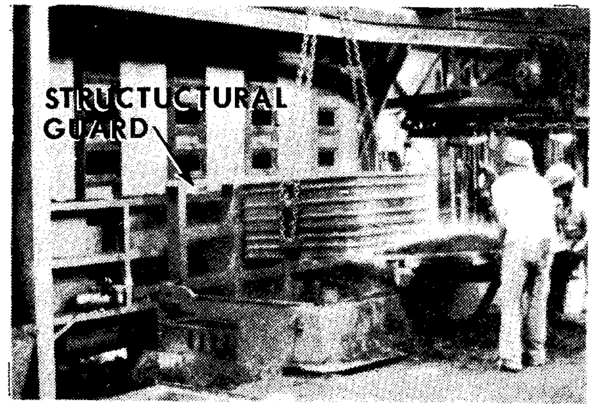

Figure 5-1. Structure protects shakeout hood.

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would have to be built like a battleship to withstand this ramming. The foundry shown here was rebuilding or replacing shakeout hoods on an annual basis before it devised a solution. When they constructed their latest hood, they also built a special structure mounted to the shakeout itself to withstand the ramming. The structure may be seen immediately behind the flask in the picture. The added weight of the structure did not change the vibrational characteristics of the vibrating table, but it did require that guide plates be installed to prevent the shakeout from being knocked off its springs by the ramming.

Arc Furnace Hood

In the same manner as the previous example, improvements and refinements to a sidedraft arc furnace hood were necessitated by hood failures that required frequent maintenance and hood replacement (33). Basically, the sidedraft exterior arc furnace hood captures furnace emissions as they rise through the annular space between the three electrodes and the holes through which the electrodes penetrate the furnace cover. Figure 5-2 shows how the new hood

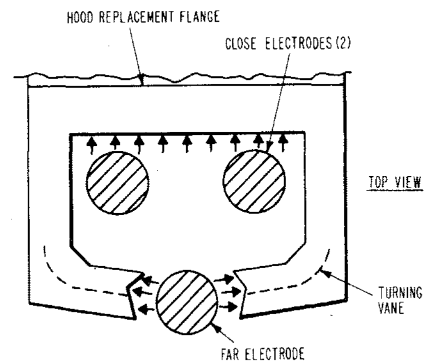

Figure 5-2. Close capture at furnace electrodes.

reaches around the two close electrodes to provide exhaust at the far electrode. Previously, the hood extension to reach the far electrode was projected between the two close electrodes. This hood section would fail rapidly because of the intense heat. A model of the new hood is shown in Figure 5-3. The hood is constructed of heavy sections of stainless steel to provide better resistance to heat oxidation. Turning vanes have been installed within the hood extension at the far electrode to eliminate hot spots. The hood is ruggedly built and flange-mounted for easy removal for repairs.

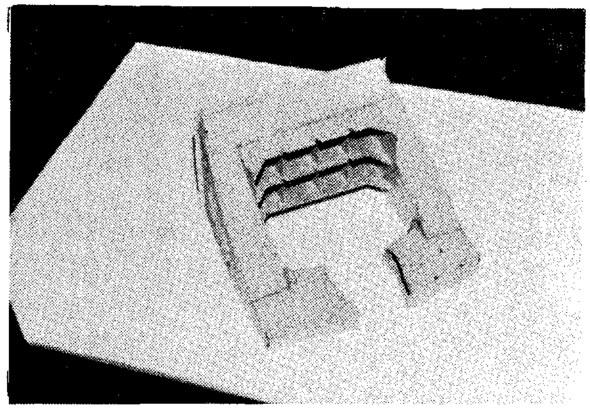

Figure 5-3. Model of sidedraft furnace hood.

Removable Panel Construction

The next example of construction of ventilation systems suitable for the foundry environment is the result of foresight on the part of a heating and ventilating contractor. Realizing that ventilation hoods must be removed for repairs, and that if provisions for hood disassembly are not provided the hood will fall victim to the cutting torch, the contractor constructed this shakeout hood with removable panels (Figure 5-4).

Figure 5-4. Panel construction on shakeout hood.

Duct Blockage

Besides damage to hoods, another problem which interferes with the proper functioning of exhaust systems is duct blockage, especially in the ductwork closely connected to the hood. The large fall-out box on the back of a grinding machine hood (Figure 5-5) permits large particles to be removed, thus reducing the potential for duct blockage as well as abrasive wear of both the ductwork and the fabric in the dust collector. Figure 5-6 shows that the vertical section of ductwork leading from the fall-out box is purposely oversized to facilitate the fall-out process.

Figure 5-5. Grinding wheel hood cleanout.

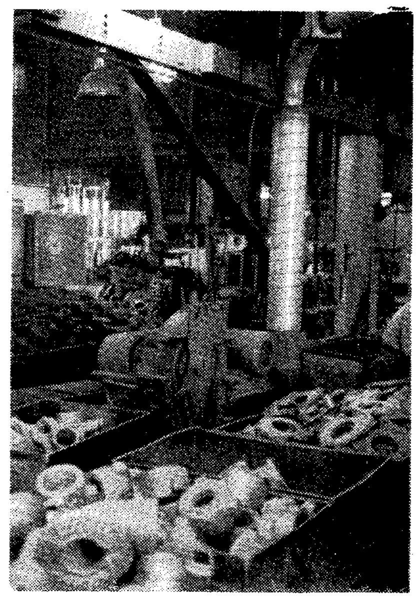

Figure 5-6. Vertical fall-out duct.

Figure 5-7 shows a fall-out box on an aluminum belt grinder. The fall-out box contains a screen to capture large dust particles which are coated with wax used to lubricate the belt. If this wax is not removed in a box such as this, it will coat the walls of the ductwork and cause plugging.

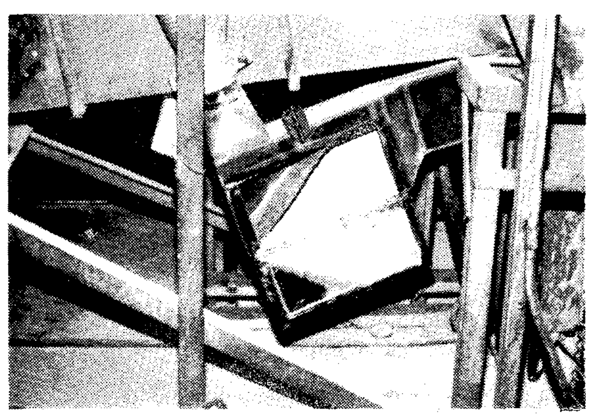

Figure 5-7. Belt grinder cleanout.

GUIDELINES FOR PROPER MAINTANANCE

Just as environmental controls should not be considered as an afterthought to foundry design, maintenance plans for ventilation systems should be establiahed and prepared prior to ventilation system installation. The previous examples have emphasized the need to construct hoods that are suitable for foundry use by virtue of their simplicity, ruggedness, and ease of maintenance. But local exhaust systems are not composed of hoods alone; there are other essential elements such as ductwork, air cleaners, and fans which must also function properly if system effectiveness is to be maintained. Ductwork should have sufficient access openings to permit inspection. It should be installed in flanged sections with separable supports so the ductwork can be removed for cleanout or replacement. Also, remember that an inspection port without access to get to it will never be opened.

With some exceptions, hoods and ductwork are stationary components with few moving parts. Fans and air cleaners, on the other hand, involve moving equipment and replaceable media which require frequent and systematic inspection and maintenance.

The documentation for each ventilation system should be centralized in an operation and maintenance manual. Important sections of that manual are:

A. System objectives.

   1. Hazards to be controlled.
   2. Control method description.

B. Identification and description of system components.

   1. Equipment ID numbers linking equipment to manual.
   2. Reference to system drawings.
   3. Manufacturer's manuals.

C. Design information and performance standards.

   1. Design summary including reference to individuals and copies of correspondence.
   2. Performance test data and documentation.
   3. Modification.

D. Operational and preventive maintenance procedures.

   1. Methods, tools, special procedures, frequency of maintenance.
   2. Seasonal adjustments.
   3. Spare parts list including identification of suppliers.

E. Troubleshooting.

   1. Monitoring data including visual observations, instrument data, employee feedback.
   2. Photographic documentation.

The operation and maintenance manual can serve as a basic tool for instructing operating and maintenance personnel in the proper function and use of the system.

Monitoring Parameters

Hood damage and duct blockage are only two of a large number of failures which can deteriorate the performance of an industrial ventilation system. The term "failure" as used here includes anything which reduces the protection against exposure to air contaminants which the ventilation system offers to the worker. Often in industry, a much less strict criterion is used to define failure of a control measure. Failure is usually defined as deterioration of the control measure to the extent that its performance becomes noticeably poor, for example, air contaminants obviously not being captured, worker complaints, etc. The criterion defined here is one designed to maintain a control measure in steady state by preventing the performance from falling below that level. In the following section, general classes of failure modes will be identified and their effect on measurable system parameters will be discussed. Except for some obvious ones, most failures are not readily apparent, and can disintegrate performance very gradually. For this reason monitoring as well as inspection should be used as a method of identifying and diagnosing problems that detract from system performance.

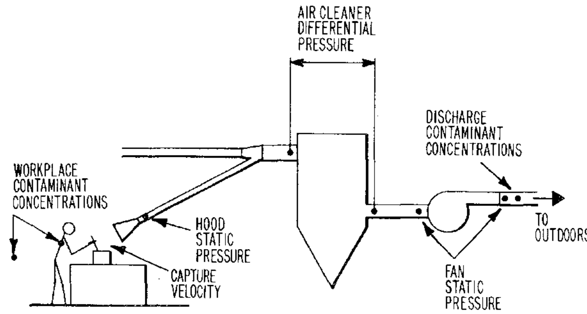

Figure 5-8. Monitoring parameters.

Figure 5-8 shows a simplified schematic of a ventilation system composed of several hoods, only one of which is shown. The branch duct from the hood shown joins a trunk duct which leads to an air cleaner. The blower which draws the air through the system is located on the discharge side of the air cleaner. In this typical case the cleaned air is discharged to the outdoors.

The monitoring variables for which instruments can be used to sense changes in system performance may be generally classified as physical and chemical. Important physical parameters include:

1. Capture velocity - Capture velocity is the minimum velocity necessary to cause the direct evacuation of air

contaminants by the hood. It is measured differently for the different hood types:

a. Enclosures - The capture velocity of an enclosing hood is the face velocity through the openings which prevents contaminants from escaping the hood.

b. Receiving exterior hoods - The capture velocity of a receiving exterior hood is the velocity at the inlet to the hood, which is the point at which the hood receives contaminants which are projected at it by forces other than hood suction.

c. Non-receiving exterior hoods - The capture velocity of non-receiving exterior hoods is the velocity which is induced across the air contaminant source by the hood and which provides the motive force for the air contaminants to move directly into the hood. The capture velocity is usually assessed at that point of the source farthest from the capture hood.

2. <u>Hood static pressure</u> - Hood static pressure is caused by the turbulence losses of air entering the hood and the forces necessary to accelerate the air from rest to the transport velocity of the ductwork. The measurement point for hood static pressure is in the ductwork a short distance downstream of the hood.

3. Air cleaner differential pressure - The difference in pressure from the inlet to the discharge of the air cleaner is related to air turbulence losses through the air cleaner as well as losses associated with the mechanism of contaminant removal for example, the filtering of air through a fabric medium or the mixing of air with finely divided water droplets. Air cleaner differential pressure requires calculation of the difference between two measurements which are made in the ductwork leading to and from the air cleaner.

4. Fan static pressure - Fan static pressure, caused by the sum of all pressure losses in the system both upstream and downstream of the fan, is the static pressure which the fan supplies to cause the needed air flow through the system. Fan static pressure is measured as the differential pressure across the fan less the velocity pressure at the fan inlet.

Static pressure is usually measured through a pressure tap which is oriented perpendicular to air flow in the duct, whereas velocity pressure is measured through a pressure tap which is oriented parallel to flow, facing upstream. Since velocity pressure varies throughout the cross section of the duct it is measured at a variety of points which are averaged over the cross-sectional area to give the total velocity pressure at that point (1).

Important chemical parameters include measurements of air contaminant concentrations in the discharge duct from the air cleaner and in the workplace. Workplace concentrations are measured using either personal samples or general area samples.

Failure Effects Chart

Figure 5-9 shows the effects of various failures on the physical and chemical monitoring parameters. An arrow pointing either upward or downward on the chart denotes an increase or decrease in a particular monitoring variable which occurs as a result of a failure. A dash signifies no change, and two symbols separated by a slash indicate that multiple effects are possible. The first obvious fact that is realized from the chart is that, for any particular failure mode, the effects on the various monitoring parameters are not all in the same direction. For any one monitoring parameter, the various failure modes can cause either increases or decreases in the measurement of that parameter. Thus, no one measurement by itself is capable of predicting all failures.

	CAPTURE VELOCITY	HOOD STATIC PRESSURE	AIR CLEANER DIFFERENTIAL PRESSURE	FAN STATIC PRESSURE	CONTAMINANT CONCENTRATIONS: WORKPLACE	CONTAMINANT CONCENTRATIONS: SYSTEM DISCHARGE
MISSING HOOD SECTIONS	↓	↓	↑	↓	↑	↓
HOOD BLOCKAGE	↓	↑	↓	↑	↑	–/↓
DUCTWORK BLOCKAGE OR FLOW IMBALANCE (REDUCTION)	↓	↓	↓	↑	↑	–/↓
AIR CLEANER FAILURES						
1. BLINDING	↓	↓	↑	↑	↑	↓
2. BREAKTHROUGH	–/↑	–/↑	–/↓	–/↓	–/↓	↑
BLOWER PROBLEMS	↓	↓	↓	↓	↑	–/↓
LEAKAGE INTO SYSTEM	↓	↓	↑/↓	↓	↑	↓

LEGEND: ↓ Parameter Decrease ↑ Parameter Increase – No Change / Multiple Effects

Figure 5-9. Failure effects on monitored parameters.

The two parameters which consistently change in the same direction for all failure modes listed, with one exception, are capture velocity and workplace air contaminant concentrations. Unfortunately, these two are probably the most difficult of the six monitoring parameters to measure. As expected, unless the discharge air is being recirculated into the foundry, the air contaminant concentration in the discharge duct is not a good indicator of failures which effect the capture efficiency of the system. The three in-duct pressure measurements listed, which are relatively easy measurements to make, are not good indicators either. Thus, if the pressure measurements are used to assess system performance, more than one monitoring variable must be measured and the results must be carefully interpreted. One feature of the pressure measurements is that, for all of the failures listed but one, failure always results in some change in the measurement. Only in the case of air cleaner breakthrough could the failure not result in a significant change in one of the pressure variables.

A breakthrough failure would not normally deteriorate workplace air quality unless the discharge air were recirculated back into the workplace.

Failure analysis and monitoring of ventilation systems in foundries, and in industry as a whole, is a very important area which receives inadequate attention.

Housekeeping

The extent of housekeeping is directly related to dust exposure in foundries because proper housekeeping can reduce or eliminate reentrainment of spilled or settled dust.

Housekeeping, like any cleanup problem, is a remedial effort which can be reduced by preventing spillage and controlling airborne dust hazards at their sources. In the case of housekeeping, the prevention is more effective than the cure. In Unit 2 on equipment substitution, it was seen that material handling systems can be designed in such a way as to reduce the potential for sand spillage. Ventilation hoods were than discussed which can evacuate airborne contaminants and prevent them from settling on floors, equipment and building structures. However, because of the nature of the foundry operation, the need for housekeeping cannot be eliminated solely through preventive measures, and so effective housekeeping measures are necessary.

Manual methods for removing material spillage and dust buildup, for example, brooms and shovels, pose significant dust hazards, not only for the people performing these operations, but also for other workers in the general area. One foundry has reduced dust emissions from the part of the shoveling process which produces the most airborne dust — the unloading of the shovel. When maintenance people are removing sand spillage in the pit area shown in Figure 5-10, they are protected from dust emissions from the vibrating sand conveyors by enclosing hoods over these conveyors. But they can still receive substantial dust exposure from the shovelling operation itself. To provide a place to dispose of the shovelled sand, as well as to reduce the dust hazard from shovelling, a hopper was installed in the center

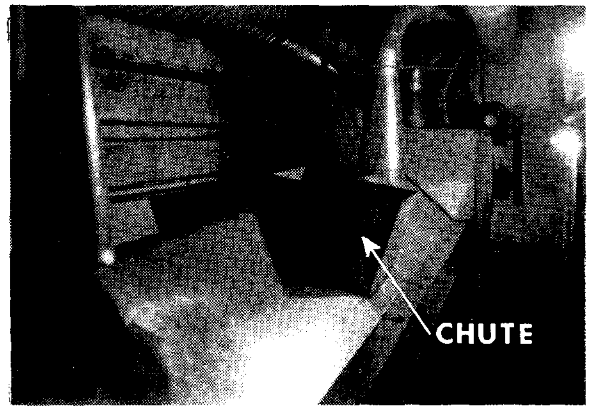

Figure 5-10. Chute for spill sand.

of the enclosing hood into which the worker shovels the sand. This technique is quite effective in reducing dust but does not eliminate the need for housekeeping personnel to wear respirators during cleanup with brooms and shovels.

Portable vacuum sweeping devices are available which can remove sand spillage and dust, and then filter the suction air before it is returned to the workplace. Truck sweepers using the vacuum method are effective at cleaning aisles and open floor areas. Portable hand-operated vacuum cleaners are also available which can clean around machinery (Figure 5-11). The vacuum cleaner can either be moved about as needed or kept at a fixed location and connected to a manifold system which provides suction outlets at all levels of the foundry.

Spillage is inevitable in some processes, such as molding, and in these cases spill pits can be built into the floor to remove the spillage. A spill pit collects sand falling from castings after they are removed from the shakeout table and placed on a monorail hanger leading to a blast cabinet. See Figure 5-12. The spill

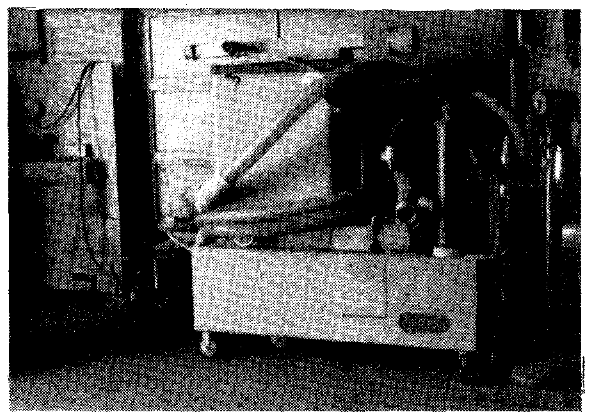

Figure 5-11. Portable industrial vacuum cleaner.

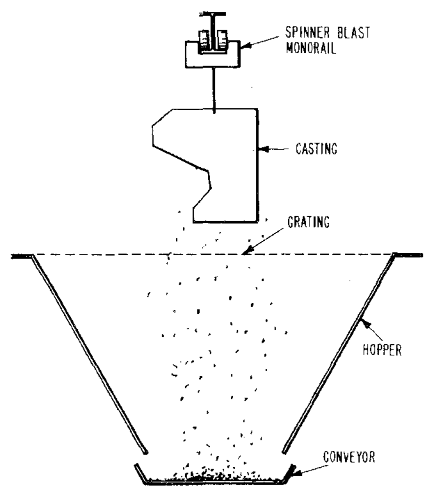

Figure 5-12. Spill pit arrangement.

pit contains a hopper which deflects the spillage onto a moving belt.

Research and Development

From the previous discussion of control methods, it can be seen that the most difficult control measures to apply are those which involve manual operations. In the majority of cases, it is not practical today to automate and isolate these operations; and so, for the present, it is necessary to explore better ways to control contaminants at the source. The local ventilation approaches described in this course manual represent the state-of-the-art of industrial ventilation. Further improvements in ventilation technology will require a scientifically administered program of research and development.

The need for controlled experimentation may be better understood by listing some of the areas which would have to be addressed if, for example, improvements were to be made in the capture of fume from the torch-cutting and air carbon-arc gouging process. Here are some of the questions which would have to be addressed:

1. For particular operations, what orientation between casting and capture hood is required for direct capture of emissions?

2. How can rapid, safe, and non-fouling fixtures be built and used?

3. What is the optimum capture hood configuration and location for specific operations?

4. At what point do increasing air flow rates result in worker exposure through the eddy current effect?

5. What are the impacts of specific work practices on control?

Process Modifications

The difficulty in controlling dust emissions with close capture exhaust during manual abrasive grinding operations emphasizes the need to reduce the amount of finishing work necessary. Of particular importance is the reduction of sand burn-on. In the cleaning room, as elsewhere in the foundry, the reduction in the amount of contaminants generated often goes hand-in-hand with producing better castings.

DISCUSSION QUESTIONS

1. What are the advantages and disadvantages in using physical or chemical measurements to monitor the performance of a ventilation system?

2. What is the most important concern in maintaining foundry sweeping and vacuuming equipment?

3. A fall-out box on a grinding machine exhaust can help to prevent clogging or wear on ductwork and air cleaner wear. However, what potential problems can occur with the use of fall-out boxes?

4. What are the criteria for selection of control measures suitable for the foundry environment?

5. In what ways can air contaminant control go hand-in-hand with producing better castings?

ANSWERS

1. Physical measurements.

   Advantages: Easy to make with inexpensive instrumentation, results directly related to equipment performance.

   Disadvantages: Does not take worker, work practices, process operation, or hood use into account.

   Chemical measurements.

   Advantages: Relate most

closely to the controlled parameter: worker exposure.

Disadvantages: Complex measurements with expensive instrumentation.

2. The effectiveness of filtration devices used to clean the transport air.

3. They can plug and cause loss of air flow; doors can be left open or leak, causing loss of flow at the hood face.

4. Effectiveness, ruggedness, simplicity.

5. A casting surface with fewer defects will require less manual, hazardous, hard-to-control cleaning operations.

   Less scrap will result in a lower percentage of foundry returns which must be recast.

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APPENDIX A
STUDENT COURSE OUTLINE

The attached outline is useful to the students for notetaking during the course sessions. The list of references should be attached to this handout. The references are cited throughout the outline, permitting the student to further explore in the literature the control methods discussed during the course.

NIOSH COURSE MODULE

OCCUPATIONAL HEALTH HAZARD CONTROL TECHNOLOGY
FOR THE FOUNDRY INDUSTRY

I. Introduction and Discussion of Potential Foundry Hazards

A. Purpose - To explore the application of the principles of air contaminant control technology in the foundry industry.

1. Included:

a. Discussion of actual cases and the results of research and development.

b. Classification of control measures.

c. Identification of the modes of generation and dispersion of air contaminants.

d. Identification of the principles and constraints which relate to the ultimate effectiveness of control measures.

2. Excluded:

a. Engineering design details (1).
b. Administrative controls.
c. Respiratory protection.
d. Toxic effects and allowable exposure limits.

3. Principle information sources:

a. Literature sources (1-49, particularly 2 and 3)

B. Industry Overview

1. 1976 census report: slightly under 5,000 foundries in U.S. Production capacity of 34,000,000 T/Yr (4).
2. 60 percent employ less than 50 persons.
3. 80 percent of foundries are job shops; 20 percent are captive.
4. Foundry industry changing from labor-intensive to capital-intensive.
5. Energy-intensive industry.

C. Mechanisms of Generation and Dispersion of Air Contaminants

1. Respirable crystalline silica.

   a. Dry sand hazards during sand casting (5).
   b. Embedded sand hazard during abrasive finishing (6,7,8).
   c. Primary and secondary dust dispersion mechanisms (9).

2. Metal dust and fume.

   a. Differences between dust and fume.
   b. Fume generation is related to the boiling points of metals.
   c. Dispersion of fume in convection currents.

3. Carbon monoxide.

4. Other thermal transformation products during casting (10).

5. Gases evolved during coremaking:

   a. Acrolein - thermal decomposition of glycerine in core oils.

   b. Methylene bisphenyl isocyanate (MDI) - thermal breakdown of urethane binders.

   c. Ammonia - thermal breakdown of nitrogeneous materials.

   d. Phenol, formaldehyde, furfuryl alcohol - used in a variety of coremaking processes, both hot and cold.

   e. Gaseous amines [triethylamine (TEA) and dimethylethylamine (DMEA)] — used as catalysts.

6. Other gaseous contaminants:

   a. Sulfur dioxide - cupola operations and as a catalyst during coremaking.
   b. Hydrogen sulfide - cupola slag quenching.

D. Extent of Worker Involvement

1. Factors which affect relationship of worker to process.
2. Least-energy principle.

E. Additivity of Exposure

II. Control Methods: Substitution and Isolation (14)

A. Substitution

1. Material substitution.

a. Substitution of molding sands (15, 16).

2. Process substitution.

a. Schumacher process (18).
b. Casting design considerations.

3. Equipment substitution.

a. Equipment to minimize sand spillage (5).
b. Bond addition.

B. Isolation

1. Isolation with a physical barrier.

a. Isolation of the contaminant source from the worker.
   1. Tumbling mill enclosure (19).
   2. Robot grinder (20).
   3. Melting platform (21).
   4. Ladle cover (19).

b. Isolation of the worker from the contaminant source.
   1. Furnace control booth enclosure (24).
   2. Enclosed crane cab (25).
   3. Cupola forehearth (26).

c. Isolation of the worker and the contaminant source from the rest of the facility.

   1. Simple partitions.
   2. Enclosed work booths (23).

2. Isolation by distance.

a. Isolation of cooling molds (27).
b. Remote controlled operations.
   1. Sand slinger (28).
   2. Robot slagger (29).

3. Isolation in time.

a. Allowing hot cores or hot castings to cool before handling.
b. Isolating dusty maintenance jobs to non-production shift.

III. Control Methods: Enclosing and Exterior Hoods

A. Reasons for Using Control at the Source

1. High rate or toxic emissions.
2. Where air cleaning is necessary before discharge.
3. Workers close to process.
4. Release of substantial amounts of heat, humidity or odors.
5. Safety hazards (fire, explosive, reduced visibility).
6. Housekeeping.
7. Material or energy recovery.
8. Protect equipment systems.

B. Enclosing Hoods

1. Close-fitting hoods.
   a. Induction furnace hood (30).
   b. Shell molding machine enclosure (31).
   c. Small shakeout (32).
   d. Bond hopper and batch feed hopper.
   e. Material and energy losses due to enclosures.
   f. Hood mobility (33).
   g. The need for accessibility and susceptability to damage.
   h. Mold cooling room (34).
2. Ventilated booths.
   a. Swing grinding.
   b. Laminar flow booths (35).
   c. Torch cutting and air carbon-arc gouging (36, 37).

C. Exterior Hoods

1. Receiving hoods.
   a. Swing grinder (38).
   b. Pedestal grinder (39, 40).
   c. Ladle hoods.
   d. Other uses: gas fired crucible furnace (21) and ladle preheater (21, 32).
   e. Improper use of a canopy hood (32).
   f. Combination deflection/receiving hoods (34, 41).
   g. Coremaking station (42).

IV. Control Methods: Non-Receiving Hoods and General Ventilation

A. Exterior Hoods

1. Non-receiving hoods.

a. Ventilated workbenches (43, 44, 45).
b. High-velocity, low-volume exhaust (45, 46).
c. Low-velocity exhaust hoses (47).
d. Other examples.

i. Dumping of debris during ladle relining.
ii. Welding bench (23).
iii. Slagging hood (22).
iv. Sand slinger (28).
v. Cold box coremaking (48).

B. General Ventilation

1. Adverse effects of negative pressure.

a. Charge bucket filling area.
b. Cupola repair operation (49).

2. Methods of reducing negative pressure.

a. Introduction of fresh tempered air.
b. Introduction of fresh untempered air.
c. Reduction in the use of roof ventilators.
d. Indirect heat exchange to temper fresh air.
e. Recirculation of cleaned exhaust air.

3. Cooling of workers.

a. Disruption of exhaust hoods.
b. Air entrainment effect.

V. Maintenance

A. Designing for the Foundry Environment

1. Protection for shakeout hood (28).
2. Arc furnace hood (33).
3. Removable panel construction.
4. Duct blockage.

B. Monitoring Parameters

1. Physical parameters.

a. Capture and face velocity.
b. Hood static pressure.
c. Air cleaner differential pressure.
d. Fan static pressure.

2. Chemical parameters - concentrations of contaminants in the:

   a. Discharge duct.
   b. Workplace.

C. Failure Effects Chart

D. Housekeeping

E. Research and Development

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