

IN THE DISTRICT COURT OF
HARRIS COUNTY, TEXAS



AUGUST GORDON, et al.,

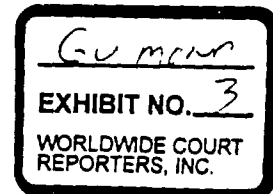
Plaintiffs,

vs.

No. 93-42852

BOB SCHMIDT, INC., et al.,

Defendants.



JOINT AFFIDAVIT OF
JIMMIE D. CHILDRESS AND JOSEPH A. GUIMOND

Before me, the undersigned authority, on this day personally appeared Jimmie D. Childress and Joseph A. Guimond, who being duly sworn, on their oath, did state as follows:

1. I, Jimmie D. Childress, am over the age of 21 and am fully competent to testify as to matters set forth in this affidavit. I am a former Corporate Safety Director of Intermet Corporation, which included nine foundries located in seven states. Before that time, I had worked at various jobs in foundries for approximately 30 years. I have received formal training regarding OSHA requirements applicable to foundries. I currently serve on the American Foundrymen's Society Safety Committee, and have served as Chairman of this Committee. I also serve on the Executive Committee of the National Safety Council's metal section. During the past several years, I have worked as a consultant to various foundries in connection with developing programs and policies to guard against recognized hazards associated with foundry work, including the recognized hazard of silicosis, and to ensure compliance with governmental regulations and standards, as well as industry standards.

2. I, Joseph A. Guimond, am over the age of 21 and am fully competent to testify as to matters set forth in this affidavit. I hold a B.S. degree in Mechanical Engineering and have been the President of Joseph A. Guimond & Associates, an environmental consulting organization, for more than 25 years.

As part of my work during this time, I have provided consulting services to many foundries. As a result of that work, I have become very familiar with foundry processes and procedures, as well as risks and hazards reportedly associated with these procedures, including the reported risk of silicosis. I am also generally familiar with industry guidelines as well as governmental rules and regulations which apply to foundries, particularly regarding the monitoring, control, and prevention of reported hazards. I am a member of various organizations, including the American Foundry Association and the Air Pollution Control Association.

3. Foundries typically must use large quantities of sand in their operations. Among other things, foundries use sand to make molds into which they pour molten metals to form castings. Foundries also use sand to make cores, which they place inside of molds to form the hollow interior of castings. Sand is an essential significant component in foundry operations and has been so for many decades.

4. For many decades, foundries have been concerned about the reported hazards of breathing sand dust, including silicosis. For example, since the early 1900s, various foundry trade organizations, such as the American Foundrymen's Society "AFS", have sponsored and produced numerous conferences, seminars, and symposia specifically aimed at educating foundries about the reported hazards of breathing sand dust and about ways to reduce or eliminate these reported hazards. True and accurate copies of AFS publications describing some of the information presented at these events are attached to this affidavit as Appendix A.

5. For many decades, AFS and other organizations also have distributed and made available to foundries various publications, including the journals entitled "AFS Transactions" and "American Foundryman." These publications have included numerous articles which contained discussions about the reported hazard of breathing sand dust in foundries, including silicosis, and guidelines for reducing or eliminating this hazard. AFS and other organizations sent these types of articles and guidelines to foundries as early as the 1930s. True and accurate copies of some of these articles are attached to this affidavit as Appendix B.

6. Since the 1930s, foundries have been knowledgeable and sophisticated regarding the risk and means of preventing silicosis. As a result of this knowledge, foundries have instituted various protective measures to protect their workers against the risk of silicosis, including ventilation, dust collectors, and the use of respirators.

7. For many years, foundries have been subject to various federal and state laws and regulations that required them to be knowledgeable about the reported hazards of breathing sand dust, including silicosis. Regulations of the Occupational Safety and Health Administration ("OSHA") required foundries, among other things, to keep respirable silica dust levels within certain limits. See 29 C.F.R. section 1910.1000 et seq. For many years, federal and state governments have enacted legislation and regulations applicable to foundries which addressed this reported hazard.

8. Where respirators were necessary to protect the health of the employee, employers such as Central Foundry were required by federal law to establish a "respiratory program," and set forth various requirements of a "minimal acceptable program," including the following:

- (1) establishment of "written standard operating procedures governing the selection and use of respirators";
- (2) selection of respirators "on the basis of hazards to which the worker is exposed";
- (3) instruction and training "in the proper use of respirators and their limitations";
- (4) routine inspection of respirators and replacement of worn or deteriorated parts;
- (5) "appropriate surveillance of work area conditions and degree of employee exposure";
- (6) "regular inspection and evaluation to determine the continued effectiveness of the program"; and
- (7) selection of respirators "from among those jointly approved by the Mine Safety and Health Administration and the National Institute for Occupational Safety and Health under the provisions of 30 C.F.R. part 11."

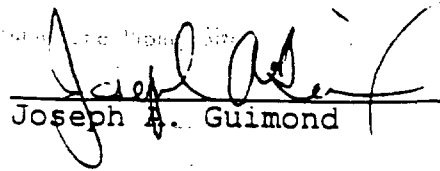
See 29 C.F.R. § 1910.134(b).

Jimmie Childress
Jimmie Childress

SUBSCRIBED AND SWORN TO
BEFORE ME on this
3rd day of April, 1998,
which witness my hand and seal of office.

Betty H. Boyte
My Commission Expires:

November 30 1999.


Joseph A. Guimond

SUBSCRIBED AND SWORN TO
BEFORE ME on this
9 day of APRIL, 1998,
which witness my hand and seal of office.

My Commission Expires:

Marie Anne

AMERICAN FOUNDRY MUSEUM
STREET
LITTON

SYMPOSIUM ON FOUNDRY DUST CONTROL



June, 1947

Published by

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Technical Development Program

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EXHIBIT

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INTRODUCTION

By W. O. Vedder*

MODERN INDUSTRY has substantially increased the overall dust problem with the foundry industry contributing its share as a dust producer. The dust problem in the foundry has become more complex because of accelerated production, new methods and materials, the labor market and scarcity of materials. New methods and materials have resulted in diversification of foundry dusts so that they now include those classified as hazardous down to those which are just plain nuisances.

Generally speaking, the advantages in foundry dust control cannot be measured directly in dollars and cents but usually lie in intangible benefits, such as, elimination of hazards, improved working conditions and reduction of maintenance. The foundry industry does not have the advantage of some of the other dust producing industries that obtain a return from the salvage value of the collected dust which can be credited against investment and operating costs.

Foundry dust control is accomplished by several methods or combination of methods:

1. General or dilution ventilation
2. Isolation or segregation of hazardous operations
3. Substitution of non-hazardous equipment, materials or processes
4. Dust allaying media, such as wetting or oiling
5. General plant housekeeping and cleaning
6. Personal respiratory protective devices, and
7. Exhaust systems.

*Pangborn Corp., Hagerstown, Md

The exhaust system is more widely and effectively applied than any other dust control method. The conventional dust control exhaust system consists of three basic component parts:

1. Exhaust hoods and piping system
2. Dust collecting equipment, and
3. Exhauster and drive.

The exhaust system functions by producing air movement directly at the source of dust production causing the dust-bearing air to flow into the exhaust hood mouth and thence through the piping system to the dust collector. This air movement should, if possible be in the direction of, and thus utilize any motion transmitted to the dust-bearing air as a result of the operation or process. Air flow is maintained through the system by an exhauster driven by a motor.

All of the component parts of the foundry dust collecting system are important and if effective results are to be secured, the design of all parts must be carefully co-ordinated since poor or improper design in any one element will result in poor overall results and unsatisfactory performance. An effective efficient exhaust system constitutes something more than a group of sheet metal hoods and pipes connected to a fan. The design of foundry dust control exhaust systems is a field of engineering requiring special training and experience.

HOODS AND PIPING FOR FOUNDRY DUST CONTROL SYSTEMS

E. A. Carsey
Assistant Chief Engineer
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Cincinnati, Ohio

THE first step in planning a well engineered foundry dust control system is selection and fitting of a proper and correctly designed hood to the source of dust. The source of dust is located and the hood is placed at this point, to reduce the dust concentration to that within safe limits of hygienic standards.

The second step deals with air volume, which is calculated to produce the desired result. This volume determines pipe sizes, actual hood openings and selection of exhaust equipment to produce the desired air flow.

The third step involves details of construction, such as hood and piping gauge, proper clearances, and the safety, comfort and visibility of operator. Adherence to American Foundrymen's Association and State Codes is checked and finally the detailed plan of dust control system is ready for preparation.

Hood for Shakeout

Since the crane operator requires maximum of visibility for unhampered handling of flasks, the use of an overhead hood is sometimes precluded. For this reason the "side" or "cross draft" hood is usually con-

sidered (Fig. 1). The cross draft hood does not have a roof or full extension over shakeout grate and, therefore, it is natural that a much greater volume of air must be handled, resulting in excessive power costs and heat losses.

It is well known that velocity contours of controlling air decrease quite rapidly as the distance from hood intake increases. This means that the foundry operator must increase power consumption approximately 100 per cent to operate the cross draft hood, in comparison to an overhead type or enclosure hood.

The answer to this problem could be a compromise between the straight "cross draft" and totally enclosed hood, as illustrated in Fig. 2.

Perhaps this compromise could be accomplished by means of a pneumatic finger canopy arrangement, having rather closely spaced round

canvas "fingers" possibly 8 or 10 in. in diameter. They would be held in a horizontal position over the grate by means of a small supply blower mounted alongside the shakeout hood or on top. The space between tubes or fingers would afford visibility to the crane operator and the chains would slide and work their way between the tubes, with little or no difficulty.

Such a design would save 50 to 75 per cent of power costs, in comparison to straight shakeout cross draft hood. This is a typical example of the specialized design possible in foundry hoods, which is "step one" in dust control.

Snagging and Cleaning

Snag and cleaning departments in a foundry offer another opportunity to improve hood design (Fig. 3). Here, it is possible to apply pedal operated turntables, built to a convenient height of operator, so that smaller castings are turned and operator grinds into a fixed hood position. Of course, if the castings are larger, the cylindrical type downdraft table arrangement is preferred (Fig. 4).

If floor gratings are used, movable vertical screens or baffles are of assistance in directing the light grinding dust downward. The conveyor transfer points, elevator boot and head connections, shaker screens, mixers, mills, aerators, tailings hoppers, tunnels and the like can be usually handled with direct rectangular to round and overhead hooded connections.

Grinding Operations. Individual grinding stands or groups of wheels are served by heavy duty plate hoods

◆ **Selection and fitting of a properly and correctly designed hood to the dust source is the first step in planning a well engineered foundry dust control system. The required air volume determines pipe sizes, actual hood openings and selection of exhaust equipment to produce the desired air flow for effective dust removal. Hood and piping gauge, proper clearances, and the safety, comfort and visibility of operator must be considered in designing the dust control system.**

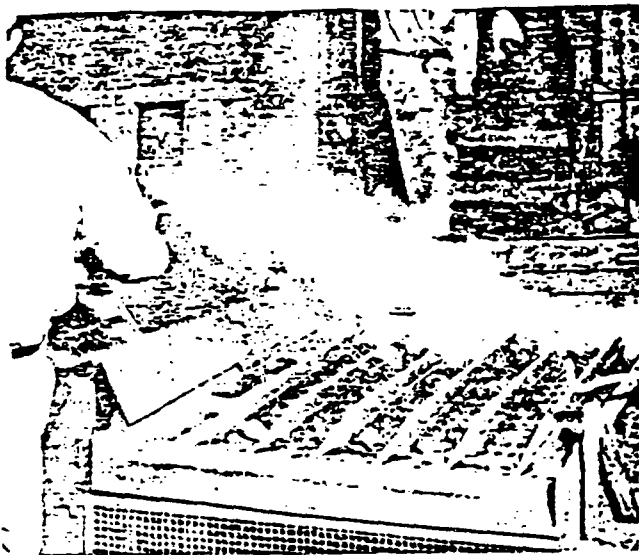
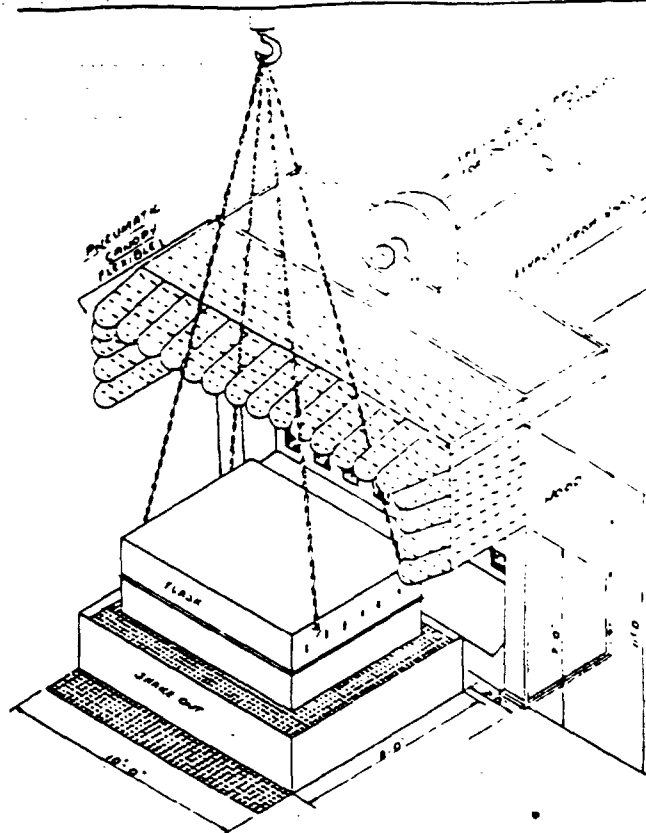
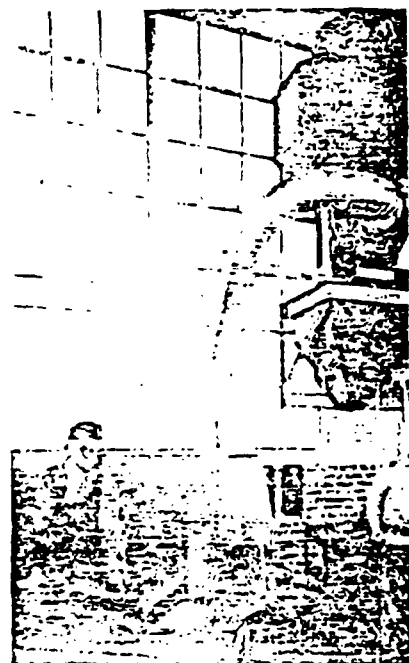


Fig. 1 (Top)—Side or cross draft hood in connection with the mold shakeout operation. Fig. 2 (Right)—Pneumatic finger canopy type of hood, a compromise between the straight cross draft and the totally enclosed hood (Patented).



some with traps built immediately below intake while others have traps in the vertical exhaust to the rear of stands (Fig. 5). Foot rests sometimes are incorporated into design, and sides and tops are hinged for wheel replacement or dressing.

Fig. 3—Pedal operated turntable in the foundry snagging and cleaning department. Note cross draft hood arrangement.



A large individual grinding wheel, either vertical or horizontal always proves an interesting problem. It is advisable to consider wheel replacement and locating the point of exhaust as close to a perfect tangent, to material leaving the periphery of wheel, as possible. Sometimes on larger wheels the complete top half of hood is removable for wheel replacement.

The safety of these types of hoods, however, should be the paramount consideration. Accidents have been recorded, where the face opening of hood was too great and castings would become lodged between side of hood and wheel itself.

The horizontal grinder frequently has its own exhaust connections built in bottom. It is then only necessary to utilize a circular header at the bottom of grinder to collect the various points of exhaust.

Figure 6 illustrates a wet grinding application utilizing heavy duty steel plate hoods, with provision for ready removal of the hoods and wheels, by means of an overhead chain fall.

Mold Cooling Tunnels. Special consideration is given to the design of mold cooling tunnels (Fig. 7). These hoods are built from the floor,

having a semi-circular top and served by one or two vertical exhaust stacks with fans built into stacks themselves. Removable sections are provided for applying and removing weights, if desired.

Condensation Traps. Condensation traps are sometimes used in the branch lines for the purpose of reducing moisture content which is always undesirable where accompanied by solids and dust particles in the air stream. Heavy black steel piping with electric welded seams and joined by companion angle connections is used where temperatures

Fig. 4—Cylindrical type down draft table arrangement for snagging and cleaning castings.

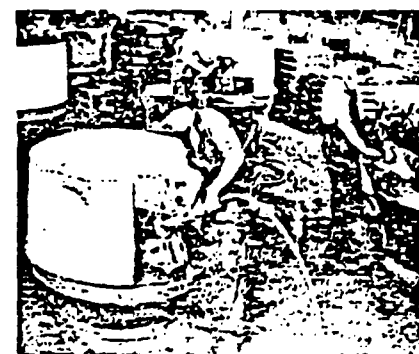




Fig. 5—Dust removing arrangement for individual grinding stands and groups of grinding wheels.



Fig. 6—Dust removing hoods on a wet grinding application.

exceed 100° F. Unusual structural conditions are encountered as illustrated by cross draft fume exhaust system (Fig. 8).

Cleanouts are usually placed at 10 ft. centers along side of header or main pipe for cleaning, inspection and maintenance. Discharge stacks extending vertically through roof may be equipped either with rain cap, 90° elbow, or tapered static regain section.

The most efficient stack termination is, of course, the slightly tapered regain nozzle which converts some of the velocity pressure back into static. The rain cap and elbow offer some protection against weather but incur a slight additional back pressure to air discharge.

Pattern Shop

Pattern shop has its dust control problem. However, here we have woodworking shavings, chips and sawdust rather than foundry abrasives. The hoods and piping can be somewhat lighter in gauge, but nevertheless, require careful planning and expert fitting to the woodworking machines (Fig. 9).

Air Volume and Piping Size

In most instances, in foundry proper, space being at a premium, the hood equipment and piping from the hoods must be built into extremely limited space. This leads us into steps two and three, or the important phase of determining air volume and piping size.

Not until relatively recent years has the problem of pipe design been given its just place of importance in modern foundry dust control systems. We keep rediscovering periodically that piping plays a major role in good foundry practice and although the design and ideas are somewhat different and slightly more advanced in the last quarter

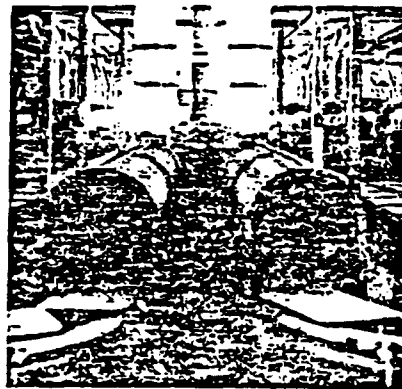


Fig. 7—Mold cooling tunnels.

century, the basic fundamentals are the same.

Fittings and Connections. Fittings and connections are used with branches brought in at very gradual angles and elbows are provided with throat radii resulting in a minimum of friction loss to air and material flow. Since the maximum amount of wear in an elbow takes place at the heel, opposite side from throat, removable plates are provided here which receive the wear of the abrasive materials handled in air stream, and are replaceable making it unnecessary to change elbow itself.

The heavy duty "one piece" elbow is usually seen in modern installations. This elbow, by virtue of being formed from one piece of sheet metal, has but one throat seam and no rivets to wear. The girth seams

are formed from the metal itself providing three thicknesses of metal seam completely around the elbow at each crimp.

The majority of foundry piping installations make use of galvanized iron or steel, riveted and soldered longitudinal and circumferential seams.

Gauges of piping range from No. 18 gauge for small diameter pipes through No. 14 gauge for larger sizes. Elbows are at least two gauges heavier. Often old dust control systems may be modernized by rearranging, balancing and replacing piping, resulting in increased efficiency.

Piping Diameter

Its determination is a study in itself. Present day foundry piping design is customarily based on ve-

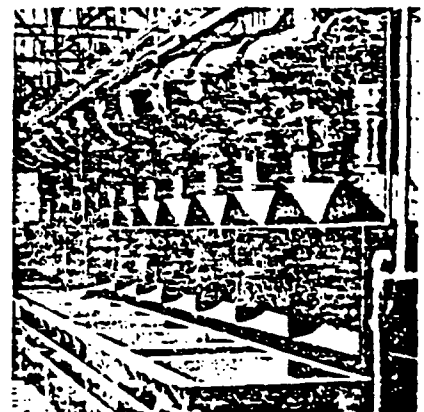


Fig. 8. (Above)—Cross draft fume exhaust system in connection with a condensation trap.



Fig. 9—Dust control system in a wood pattern shop.

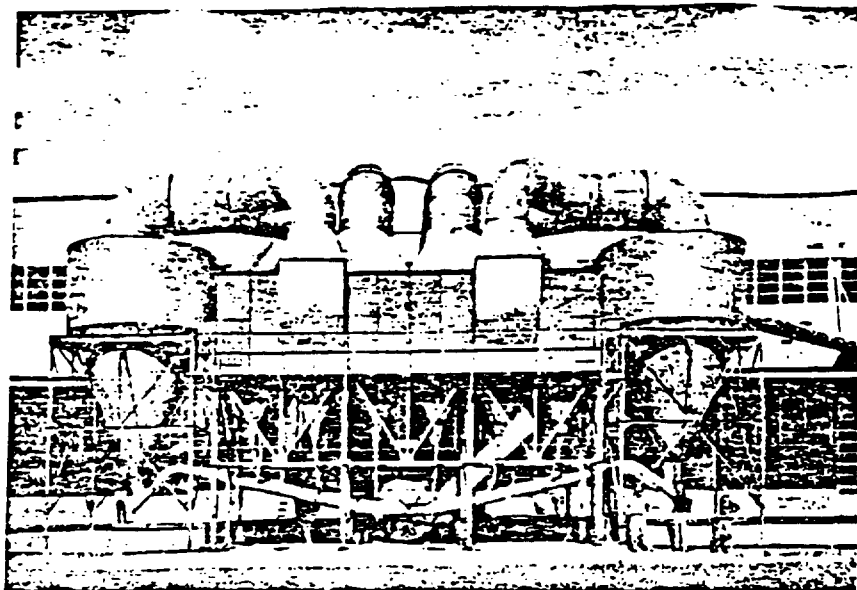


Fig. 10 (Left)—Termination of dust control piping in a large combination collector unit.

locities ranging from 3600 to 4500 fpm. or velocity pressures from 0.8 through 1.3 in. of H_2O . It is desirable to maintain as constant a velocity pressure as possible and sometimes cut-offs are provided and

locked in a fixed position to accomplish this means.

The computation of losses in the entire piping system must be carefully worked out, and a study of hood entrance losses with equiva-

lent loss in percentage of velocity pressure, plus lineal friction loss of pipe in static, branch and elbow losses, plus pressure drop across pre-cleaning and exhausting equipment determine the total pressure at which the systems would operate.

Round piping is usually preferred to oval or elliptical and since the static pressures are quite high, in material handling systems, rectangular and square ducts, if used must necessarily have a good deal of bracing to prevent vibration. Finally, ing of pipe as the smaller sizes used caution should be exerted in the size will incur considerable more power consumption if selected for velocities above 4500 fpm.

Figure 10 shows the termination of dust control piping in a large combination collection unit, the size of which may be approximated by the men in lower right hand corner.

CENTRIFUGAL DUST COLLECTORS

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▶ The writer discusses trap type, common cyclone type, and the volute or spiral type of centrifugal dust collectors. Centrifugal type dust collectors utilize radial acceleration of a gas stream for separating solid particles suspended therein. The fundamental operation is separation of dust particles from the main air flow into a quiescent zone, settling out by gravity into a receiving hopper.

THE basic principle employed in centrifugal type dust collectors is the utilization of radial acceleration of a gas stream for separating solid particles suspended therein. Various designs are in use ranging from the simple trap, in which the particles are thrown out of the gas stream by virtue of a single change in direction, to the high efficiency cyclone wherein the change in direction of the air stream is continuous throughout its passage through the cyclone.

In all such collectors the fundamental operation involved is the separation of the dust particles from the main air flow into a quiescent zone, where they can be settled out by gravity in a receiving hopper.

Dust Particle Separation

This requires that the particles move across the stream, but such motion is opposed by the aerodynamic resistance on the particle, the magnitude of which is a function of the particle size, shape and surface qualities. The velocity of the particle relative to the air stream will depend upon a separating force imposed on the particle against this resistance.

In an ordinary settling chamber (Fig. 1) the separating force is the gravitational force and in the absence of turbulence the horizontal distance of travel required to settle out a particle is directly proportional to both the air velocity and the

height of the particle above the bottom and inversely proportional to the settling velocity of the particle.

It is apparent from a consideration of practical values of the foregoing factors that separation of dust by this means usually involves units of impractical size. In the centrifugal collector the force imposed on the particle is a function of the radius and velocity of rotation and may be of much greater magnitude than the gravity force, so that the distance of travel required for separation of the particle to the collecting surface is reduced.

The maintenance of a minimum radial width of the entering gas stream will also require a minimum length of gas path. In the high efficiency cyclone type centrifugal collector of proper design the downward spiral flow pattern produces the maximum length of gas path in the minimum space.

An analysis of these fundamental factors, will, in general, indicate the relative separating ability of the various types of centrifugal collectors. Actually the problem is more complicated due to velocity requirements in the region of turbulent flow and the presence of secondary flow components. However, consideration of these factors is beyond scope of this paper but it can be stated that various designs have been developed to minimize the effect of these conditions.

Trap Type Collector

Simplest of centrifugal collectors is the trap (Fig. 2). It should be noted that the length of the gas path is extremely short which is a particular reason for its being ineffective

except on particles of large mass. Modifications of this design have been developed using multiple vanes in an attempt to improve the efficiency but the inherent disadvantage of a single change in direction of flow would indicate a rather definite limitation to the gain that might be attained.

Common Cyclone Type Collector

So-called common cyclone (Fig. 3) can be considered next in order, with reference to separating ability. These units are of relatively large dimensions on the basis of gas volume handled as indicated by the large ratio of cyclone diameter to inlet diameter. While the inlet velocity is generally of the order of 50 ft. per sec., the true cyclonic action is not in evidence because of the large gas volume within the cyclone compared to through-put volume.

The large dimensions provide a long holding time but the low rotational velocity in these units means a low separating force on the particles. The application of these units is therefore usually limited to rather coarse dust.

Volute or Spiral Type Collector

Next design to be considered is what we might call the volute or spiral collector (Fig. 4). This usually takes the form of a scroll similar to a fan casing except that the flow is in the opposite direction. Usually at about 270° F. from the inlet a slot or slots are provided for passing the dust thrown to the periphery into a hopper or secondary collector.

The gas follows a spiral path

Presented at a Session sponsored by the Safety and Hygiene and the Plant and Plant Equipment Committees at the Fiftieth Annual Meeting of the American Foundrymen's Association at Cleveland, May 6, 1946.

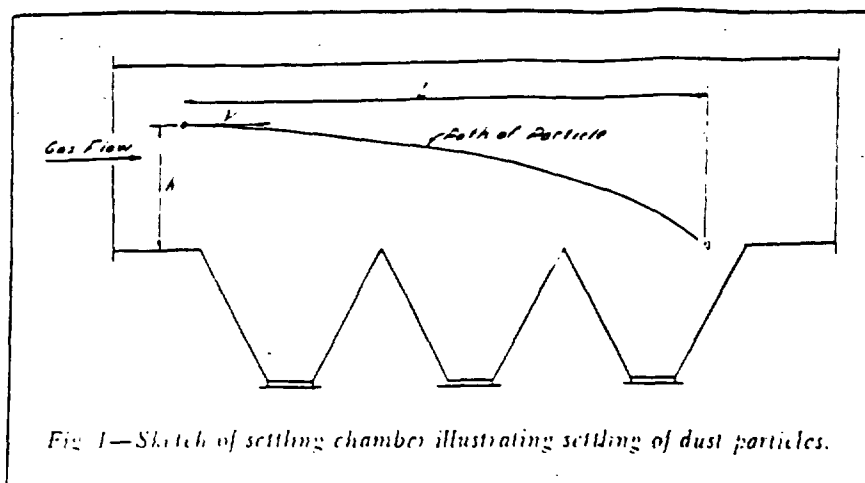


Fig. 1—Sketch of settling chamber illustrating settling of dust particles.

toward the center and leaves through a central opening. Vanes are sometimes provided to form a cylindrical baffle so that the gas is made to reverse its direction before leaving as a means of further improving the separation.

This design has in some cases been used to form the inlet boxes on fans thus incorporating a fan and

collector as an integral unit. It is essential that a proper withdrawal of the separated dust is attained to assure a definite flow through the slot into the collecting hopper or secondary collector. This gas flow must necessarily rejoin the main stream and the required pressure differential may be obtained by connection to a point of low pressure or the use of a small fan capable of handling the shunt flow.

Essentially, the length of path is limited to less than one revolution although some designs are proportioned to provide for recirculation (Fig. 5), in which case the distance is increased with a corresponding increase in efficiency. However, the comparatively large dimensions required means a low separating force so that here again the application is limited to the coarser dust.

High Efficiency Cyclone

At the present stage of the art the high efficiency cyclone (Fig. 6) is the most effective centrifugal collector available. There are many variations of this type but in general they have an inlet at or near the top with the greatest diameter at this point and taper down to a small diameter dust discharge opening at the bottom.

The gas outlet consists of a concentric tube extending down into the cyclone at various distances from the top. The flow pattern takes the form of a descending spiral at the periphery and an ascending spiral in the center.

The gas rotation is achieved either by an inlet tangential to the cyclone body and the outlet tube. In the latter case directing vanes are disposed in the annular space to

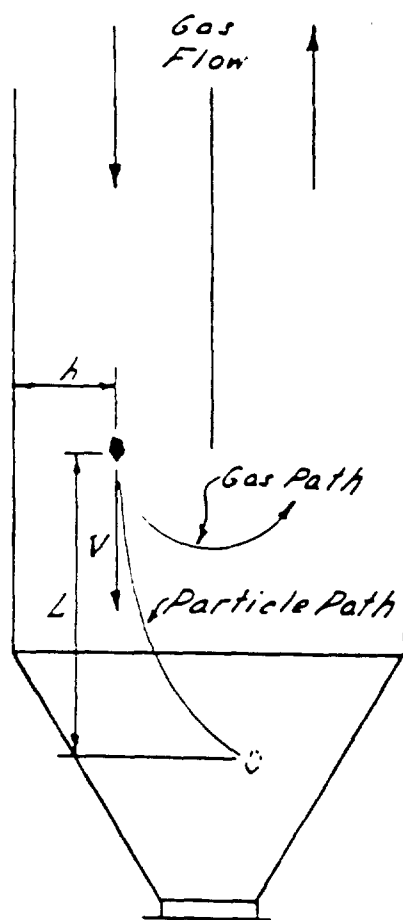


Fig. 2—Sketch of trap type centrifugal collector showing settling of dust particles.

impart a rotational flow to the entering stream.

There have been many attempts toward mathematical analysis of cyclone operation and establishment of basic equations. However, the complexity of the many factors involved has prevented any great degree of success along these lines. At best any equations that have been evolved have been limited to units of particular design proportions.

Most of the work done in the development of high efficiency cyclones has therefore been of an empirical nature. In the case of designs, with which the author is concerned, individual experiments have run into the thousands.

In view of the effect of dimensional proportions on the performance of cyclonic collectors, it is understandable that various investigators have evolved different concepts as to the relative importance of the various factors and have concentrated their efforts on designs in which one in particular is stressed.

Various Factors Considered

However, a proper balance of these proportions is essential since extreme values of one particular factor, while tending to produce higher efficiency may effect other factors to a greater extent in the direction of lower efficiency. By way of illustra-

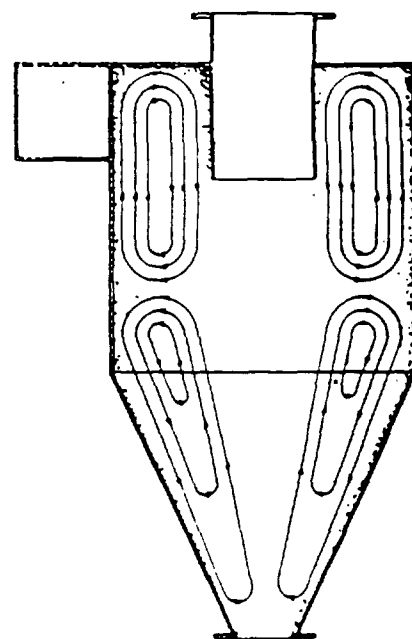
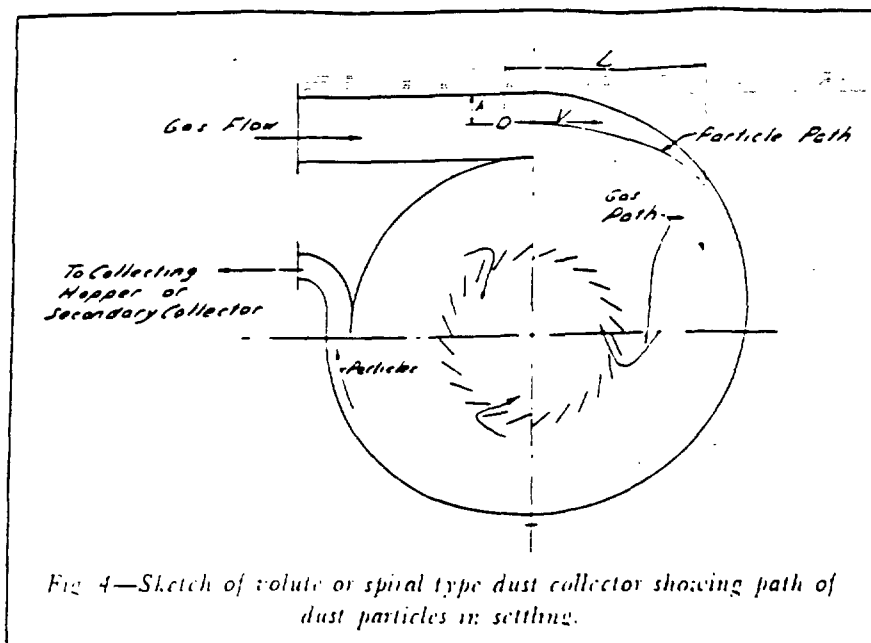


Fig. 3—Sketch of common cyclone type of dust collector.



tion let us consider some of the conditions which promote good performance in a cyclone.

It is fundamental that at a given tangential velocity the separating force on the particle is greater at the smaller radii. However, this does not mean that a small diameter unit is inherently more efficient than one of large diameter, although it does mean that a smaller diameter unit of particular proportions is inherently more efficient than a large diameter unit of the same proportions.

The distinction lies in the fact that in a unit of diameter D tapering down to a dust discharge of $1/2 D$ the separating force at the discharge is about eight times that at the inlet whereas in a unit of diameter $2D$ and dust discharge dia-

meter $1/2 D$, the separating force at the discharge is about 64 times that at the inlet or about eight times that in a unit having a diameter only $1/2$ as large. This would indicate that a small ratio of dust outlet diameter to cyclone diameter is essential.

However, it is also necessary to have a large ratio of overall height to cyclone diameter. It is readily apparent when we consider that if the cyclone tapers too sharply the vertical component of the reaction of the conical wall to the centrifugal force on the particle may prevent its downward motion to the collecting hopper.

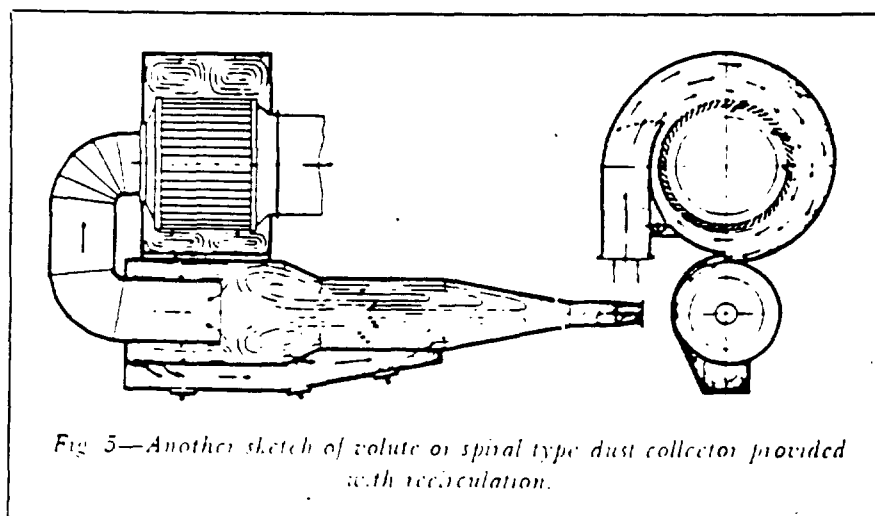
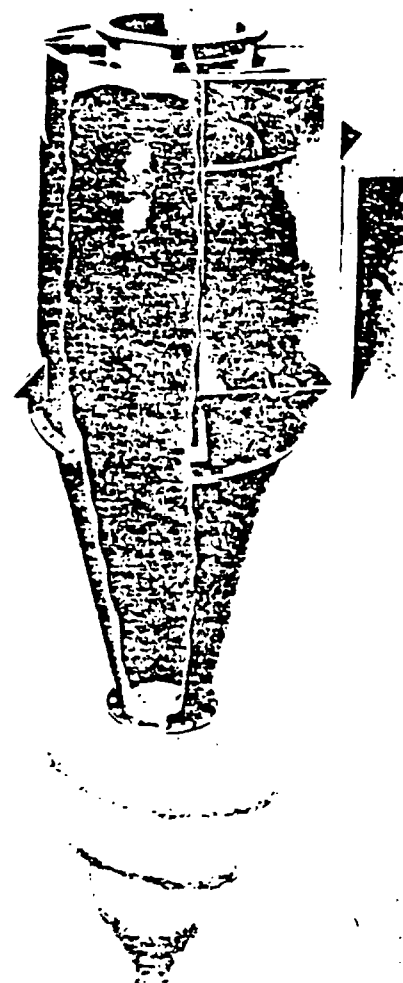
The radial width of the inlet is also an important factor since both theory and practice indicate that with a decrease in width an increase in efficiency can be expected.

There is of course a limit to this decrease where other proportions remain the same since it thus approaches the case of the ordinary cyclone having a large ratio of cyclone volume to through-put volume.

The position and diameter of the gas outlet pipe will effect the efficiency of a given unit. The depth to which these pipes should extend below the top for best performance cannot generally be stated since it is more commonly related to the overall design but a decrease in its diameter will, in general, mean an increase in efficiency as well as increase in pressure drop.

The foregoing discussion has been confined to the design of single elements. In practice, it is generally found expedient to use multiple elements, having common inlets and outlets and discharging to a common hopper. It is essential in such

Fig. 6—Diagram of a high efficiency cyclone type dust collector.



cases that the individual elements equally share the load, since any inequality will result in circulation between elements by way of the hopper, thus reducing efficiency. The design of the inlet and outlet should therefore insure proper distribution to the elements.

In the high efficiency type of collector the action of the vortex wherein high spin velocities obtain at the dust discharge, the static pressure in the hopper is usually lower than the static pressure in the gas outlet. This means that even with the collector on the discharge side of the fan a negative pressure can exist in the collecting hopper.

It is therefore essential that the hopper be properly sealed at all times against any leakage since admission of air to the hopper creates an upflow into the cyclones which has the effect of materially reducing the efficiency.

With regard to applications in the foundry the centrifugal type collector has a definite place on various operations. They have been successfully used on knock-out and shake-out screens, on sand blast and shot blast machines, as well as grinding and polishing operations.

It must be borne in mind however that in view of its inability to

separate completely all the dust from the air stream the exhaust air should not be returned to the working area but should be exhausted outside the building.

In conclusion, it may be stated that progress is still being made in improvements in design and performance of centrifugal type collectors and while gains can be made to improve the inherent characteristic of decreasing efficiency with decrease in particle size, it is believed that complete collection of the very small particle sizes of the order of five microns will have to be achieved by some other means.

CLOTH TYPE DUST COLLECTORS

George A. Boesger
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◆ Cloth type filters collect finely divided dry dust at economical cost. Two general designs are available—the tube or bag type and the screen type. Mechanical members which support the cloth envelopes are connected to a rapping device for dislodging the dust pack from the cloth surfaces. Hoppers are provided below the screens into which the collected dust is deposited.

CLOTH-TYPE filters remove dust from the conveying air by flowing the air through specially designed filter fabric. Several variations in design are available, but the operating principle remains the same. The cloth-type filter is in general use primarily for the collection of finely divided, dry dusts, and accomplishes high recovery at economical cost. With the exception of the far more costly electrostatic precipitator, no dust collecting device can equal the cloth collector in efficiency.

Collecting only the larger particles of dust gives the appearance of being effective because it does eliminate a larger part of the visible nuisance. However, there are three reasons for collecting the fine dust:

1. Coarse dust particles settle near the point where the dust is created, but the finer particles float in the air and become a nuisance and create damage at considerable distance from the source.

2. Heavy dust particles may settle on a piece of machinery, but only the very fine particles work their way into bearings to cause irreparable damage.

3. It has been scientifically determined that larger particles of dust are stopped in the nose and throat of an exposed person and that only the finest particles find their way into the lungs.

The cloth-type collector is most adaptable as it will handle dust of

any size. No dust is too coarse or too fine for the cloth collector. A cloth filter consists of a tight casing enclosing the filter fabric, and so arranged that all incoming air must pass through the fabric to the collector outlet.

Dust Particles Filtered

Upon entering the case of the collector a reduction in air velocity occurs, serving to drop the coarser particles of material from the air stream. The remaining finer dust is conveyed to the cloth surfaces where it is filtered from the air stream, the cleaned air continuing on through the cloth to the collector outlet. The dust pack, or mat, thus formed on the cloth surfaces assists materially in improving the over-all recovery efficiency.

The collector casing is provided with hoppers into which the collected dust is deposited. The filter is fitted with a shaking device designed to dislodge periodically the dust from the cloth surfaces. This shaking operation occurs with air flow shut off, since the air pressure would otherwise tend to hold the dust pack against the fabric.

Installation Types

A connection may be made from the collector to the discharge side of the exhaustor as a "blow through," or pressure-type installation; or to the inlet side, designated as a "draw through," or suction-type installation. The latter arrangement is most generally adopted because in this case the exhaustor, or fan, handles only clean air and is not subject to abrasion by the dust particles.

Cloth Filter Designs

Two general designs of cloth filters are available—the tube or bag type, and the screen type. In the cloth tube or bag type, the filter fabric takes the form of a series of tubes or bags, open at one end and closed at the other.

These tubes, or bags, are suspended vertically in the casing with the bottom, or open end, tightly sealed to thimbles in a plate located near the bottom of the casing. The dust-laden air enters the casing below the seal, or thimble plate, and passes upward through the cloth inlets (Fig. 1).

Dust is precipitated on the inner surfaces of the tubes, or bags, and the cleaned air continues on to the outlet at the side, or top of the casing. The tubes, or bags, are attached to a shaking device, usually connected at the top of the tubes, which is operated periodically to remove the dust pack from the inner surfaces of the fabric, from which it drops to hoppers which form a part of the collector casing.

Cloth Screen Collector

The cloth screen type collector is of more recent development. In this type of filter the cloth appears in the form of comparatively flat envelopes suspended horizontally and side by side in the metal casing, in a manner which permits installing a maximum cloth area in a minimum size of casing.

Open ends of the cloth envelopes are sealed to each other or to the casing, definitely dividing the casing into a dust chamber and a clean air chamber. The dust-laden air enters the dust side of the casing and must

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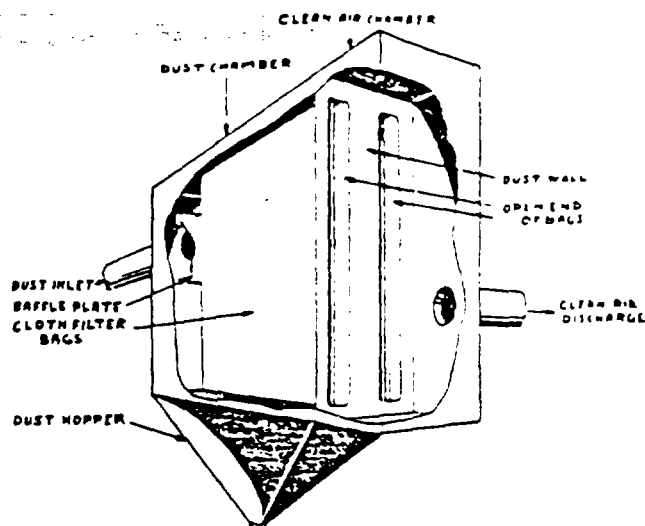
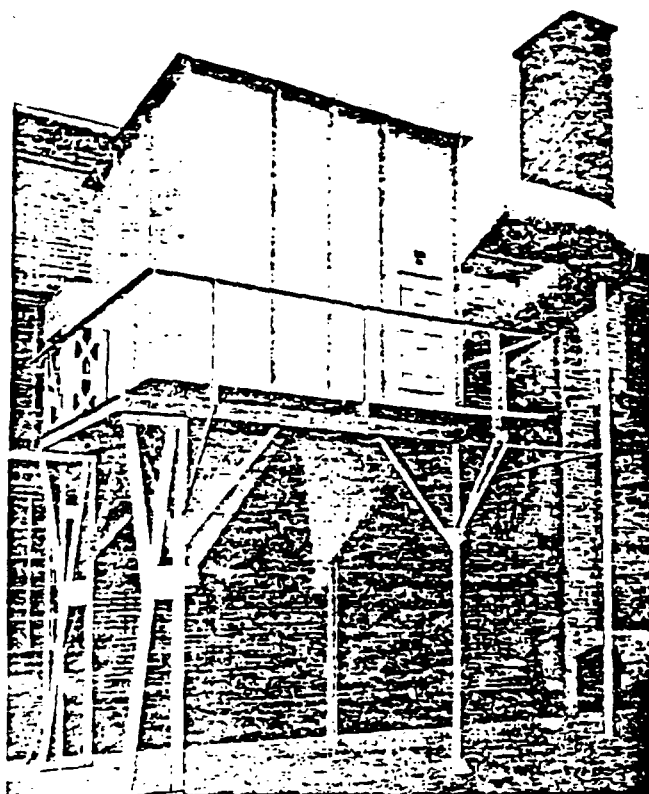


Fig. 1 (Left)—Typical cloth type dust collector installed outside of a foundry. Collected dust is withdrawn from the hoppers. Fig. 2 (Above)—Diagram shows passage of air through a cloth type dust collector.

pass through the cloth from the outside to the inside of the envelopes. The dust is collected on the outside of the envelopes.

Mechanical members which support the cloth envelopes are connected to a shaking or rapping device for dislodging the dust pack from the cloth surfaces. Hoppers are provided below the screens into which collected dust is deposited.

Many refinements in cloth collector design have resulted from

extensive operating experience. They have brought about longer life; greater capacity per unit of space occupied; ease of access; reduced maintenance and repairs; and more effective cloth cleaning.

As the building up of the dust mat on the cloth surfaces results in a gradual increase in collector resistance, it is necessary periodically to vibrate the cloth surfaces to reduce the dust pack and the resistance to air flow. With the more

common collector arrangement, known as the intermittent type, the cloth is cleaned by periodic operation of the shaking device, with the exhauster shut down.

Frequency and duration of these cleaning periods is determined by specific conditions. For average problems with average dust loading, these cleaning periods of 5 to 10 min. may take place after each 4 to 5 hours' operation. The cleaning period frequently can be decreased

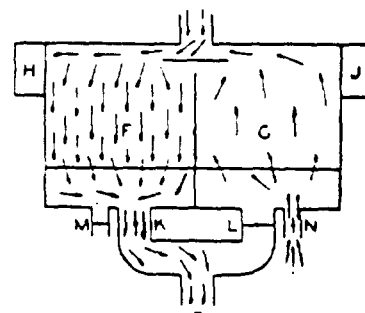
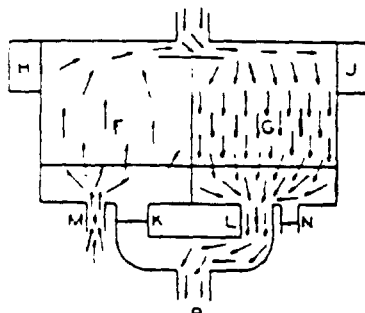
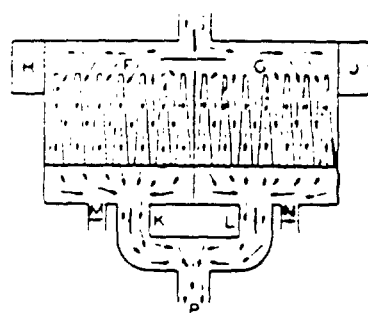


Fig. 3 (Left)—Diagram of air passage in an automatic-continuous dust filter. In this diagram both filter sections F and G handle the dust-laden air. Fig. 4 (Center)—In this diagram main damper K is closed, small damper M is open for reverse air-flow through filter F,

to assist shaker drive H in removal of dust from bags. Fig. 5 (Right)—In this diagram main damper L is closed, small damper N is open for reverse air-flow through filter G, to assist shaker drive J in removal of dust from bags.

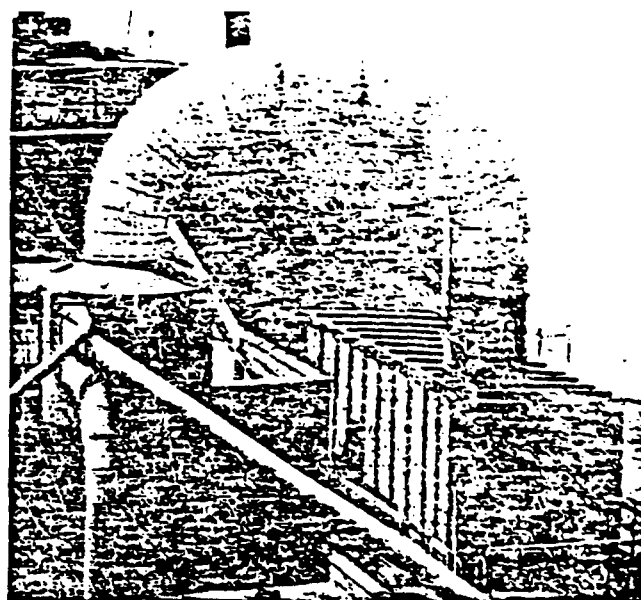
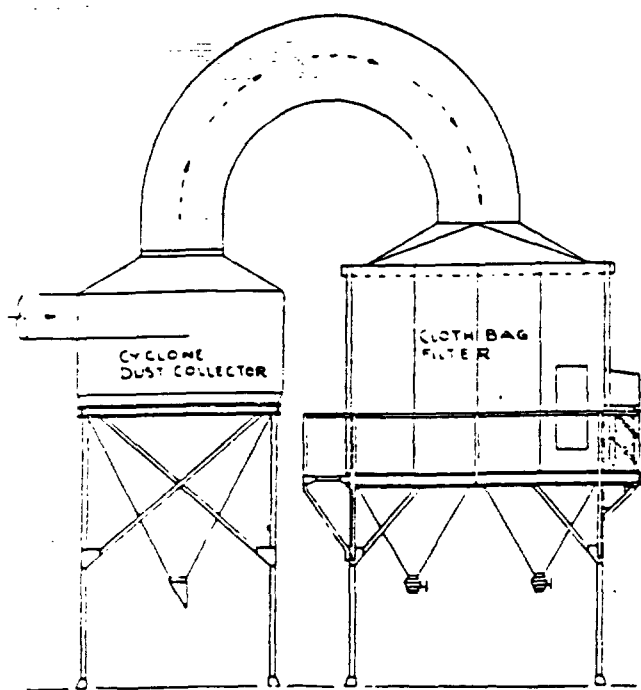


Fig. 6 (Left) with Fig. 7 (Right) show a cloth type dust filter with cyclone type "precleaner".

by installing additional presettling means ahead of the cloth collector to reduce the dust loading on the cloth.

Intermittent type of collector is economical in first cost and maintenance for use with operations and processes where short shutdowns for cloth cleaning are not detrimental. These cleaning periods ordinarily are arranged to coincide with the lunch periods or shift changes.

Continuous Type Collectors

Continuous type cloth collectors are used for process applications where these shutdown periods for cloth cleaning cannot be permitted, and continuous operation is essential (Fig. 2). The continuous type collector consists of two or more cloth filter compartments, or sections, each fitted with an individual shaking device and arranged with gates or dampers to permit alternately isolating each compartment from air flow to permit cloth cleaning.

This control of air flow and shaking of the respective compartments may be accomplished in regular cycle through manual operation, or by automatic control apparatus. In some instances, involving the handling of high dust concentrations, an extra cloth filter compartment, or

section, is provided over and above those required, with the control so arranged that one compartment is constantly shut off for cleaning.

Continuous type collectors are substantially more expensive from the standpoint of first cost, operation and maintenance than the intermittent type collector. This is particularly true when the installation is of the automatic type, necessitating electrical control and timing apparatus.

Properly applied and maintained, cloth filters will provide effective suppression of finely divided as well as coarse industrial dusts, but several factors must be given consideration in their application. The more important limiting factors are temperature, moisture, and chemical qualities of both the dust and the conveying air or gas.

Maximum Operating Temperature

The limiting temperature for cotton filter fabric is approximately 175° F. This limit may be somewhat extended through the use of wool filter fabric. The use of asbestos, glass cloth or plastics does not appear to be satisfactory at this stage of development, because proper physical qualities have not been developed to withstand the requirements of this service.

When containing moisture, the conveying air and collector temperature must be maintained above the dew point to prevent condensation within the collector, which might otherwise result in sludging the dust on the cloth surfaces. The chemical properties of the air, or gas, and the materials being handled, must be analyzed to determine if a deleterious reaction on the fabric or the collector parts is likely.

Cloth Filter Factors

Other factors governing the cloth filter recommendation for each application are the air volume handled; nature, characteristics and amount of material to be collected; and range of dust particle size and specific gravity. The size of a cloth filter, i.e., the filtering area, is governed by consideration of these factors. Filtration velocity used with intermittent type collectors will vary with specific problems of average nature in the range of from one to four lineal ft. per min. This is more commonly termed "ratio," meaning one to four cu. ft. of air per min. passing through each sq. ft. of filtering area. With continuous type collectors, the "ratio," or filtration velocity, frequently is increased.

High dust loadings are reduced by presettling devices installed ahead

of the cloth filter. This presettling may be accomplished by a centrifugal or cyclone collector, settling or baffle chamber, or other devices effective for partial precipitation.

Wire Mesh Spark Screen

When connected to systems where there is a possibility of sparks or incandescent particles being drawn into the system, a wire mesh spark screen is installed in a compartment ahead of the cloth filter section for trapping and extinguishing these particles.

This device is also useful for removing or trapping nominal quantities of lint or fibrous material from various classes of operation. The wire spark screen frequently is fitted with a rapping device operated from outside the casing for shaking down accumulated dirt and lint. As a further protection in applications where sparks may occur, the filter fabric may be treated with a special flame-proofing solution.

When handling dusts of explosive or combustible nature, cloth filters should be fitted with vents, or stacks, arranged automatically to open and

relieve pressure, should an explosion occur.

Discharge of dust from collector hoppers should be given careful consideration to prevent dispersing fine dust to the working room or the surrounding territory during the emptying operation. Standard cloth collectors are provided with hoppers having dust-tight discharge gates fitted with canvas tubes. By proper manipulation of the canvas tube the dust emitted during the emptying operation can be kept at a minimum.

This is accomplished by twisting the tube before opening the hopper gate, then gradually untwisting it and allowing the dust to slide slowly through the tube to the receptacle or truck. The hopper gates are, in some instances, fitted with clamps for the attachment of bags to which the collected dust is discharged directly. Receptacles, trucks, etc., with tight covers connected to the hopper gates by removable spouts are sometimes used.

A practice of considerable merit is to enclose entirely the space below the collector casing surrounding the hoppers. This prevents air currents from distributing dust which may

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be emitted during the hopper emptying operation. Access to the hopper enclosure is had through a tight door in the end or side. As a further step, the enclosure can be provided with an exhaust connection to maintain a slight negative pressure therein and thus prevent emission of dust.

When mechanical or continuous dust discharge is desirable, the collector hoppers are fitted with rotary air-lock type valves, which permit dust discharge but prevent air leakage, although the collector may be in operation. The rotary valves ordinarily discharge into a tight conveyor for returning the material to the process or to a central disposal point. In some instances the dust is discharged from the hoppers into a water sluicing system and discharged as sludge into settling pits, lowlands or sewer.

Acknowledgment

The writer wishes to acknowledge assistance from Mr. Andrus, of the American Foundry Equipment Co., and from Mr. Vedder, of the Pangborn Corp., in the preparation of this paper.

WET TYPE DUST COLLECTORS

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► Dust particles, in wet type dust collectors, are entrapped in a liquid, usually water, and conveyed by the liquid to a settling tank. Four general types of wet type dust collectors, namely, spray or water curtain type, dynamic precipitator type, impingement type, and the combination types of collectors are discussed.

WET type dust collectors have a common basic operating principle. Dust particles are entrapped in a liquid, usually water, and conveyed by the liquid to a settling tank or disposal area.

General Types

The method of entrapping the dust particles varies with the design of the collector. The desired water patterns for collection are obtained by using a fresh water supply, recirculating pump, rotor, or the air stream itself. The types of wet collectors are as follows:

- 1—Spray or water curtain type.
- 2—Dynamic precipitator type.
- 3—Impingement type.
- 4—Combination of the above types.

Spray or water curtain type collector. In the spray or water curtain type dust laden air is drawn through one or more stages. The water pattern is produced by nozzles, high air velocity, or a rotor. A considerable amount of water is carried upward in the air stream to the moisture eliminators where it is separated from the air and drains downward flushing the surfaces.

Usually the liquid is recirculated after a settling period in an integral tank. A small amount of make-up is required to compensate for evaporation and sludge handling.

Dynamic precipitator type collector. In the wet type dynamic precipitator (Fig. 1) the collecting unit

also serves as the exhaust fan for the system. Sprays are located in a pre-cleaner section and in the impeller unit.

The entrained liquid and dust are thrown against the impeller blades and the dust and water precipitated through a by-pass into a sludge hopper or tank. Usually the liquid is not recirculated but runs off through an overflow pipe from the settling tank. Ordinarily a fresh water supply is required.

Impingement Type Collector

Impingement type collector (Fig. 2) is usually designed to direct air flow so as to create the desired water pattern and impinge the dust particles against wetted surfaces in one or more stages. The water is admitted near the top of the collector, just below the moisture eliminators. It descends against the air stream washing all the surfaces and carrying the dust downward.

A settling tank may be used or the effluent may be pumped or drained to the disposal area. Usually the liquid is recirculated unless the effluent is taken directly to the disposal site. A small amount of make-up is required to compensate for evaporation and sludge handling.

Combination Types of Collectors

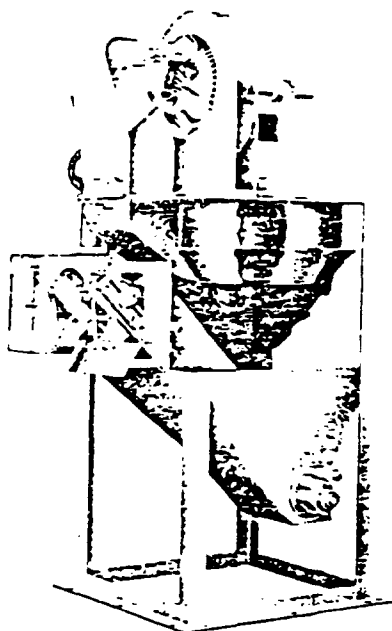
In combination type collectors (Fig. 3), the dust laden air is usually first subjected to a spray and then forced through nozzles or bubble caps so that the air passes through the liquid. Sometimes the liquid is treated with a wetting agent to form a foam bed through which the air passes. The dust then

settles to a sludge tank. In some designs the liquid is recirculated and in others drained off. Make-up is required for evaporative and sludge handling losses.

Foundry Applications. Most wet collectors have a relatively high efficiency and are used for dust control of all foundry operations requiring collection including grinding and cleaning room equipment. They are especially well adapted for handling air at a wide range of temperatures and moisture content as in the case of shakeout and sand conditioning operations. Collectors have the additional operating features:

- 1—No fire hazard present.
- 2—No health hazard in handling the collected dust since it is in the form of sludge.
- 3—Constant resistance for a given system eliminating fluctuations in air volume.
- 4—Continuous operation is possible since the collected dust is washed down constantly to the settling tank.

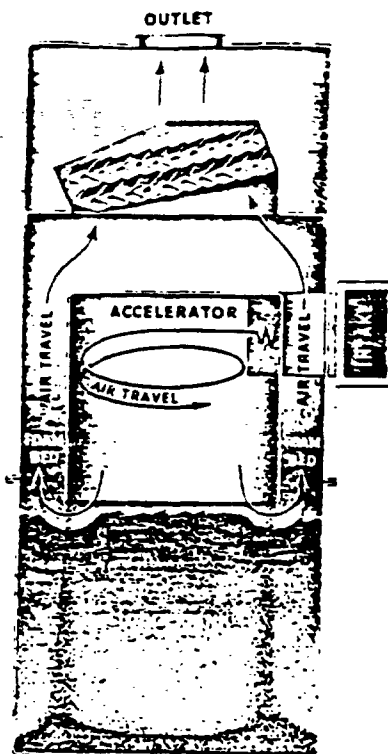
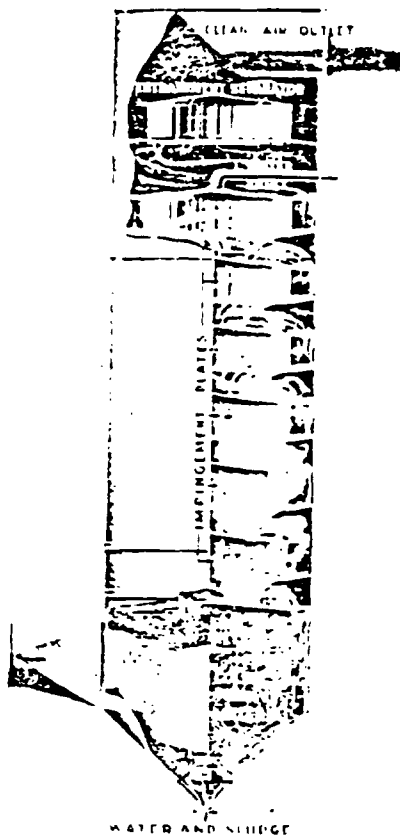
Collector installations. Collector installations are varied to suit requirements (Fig. 4 and 5). They range from a small completely self-contained unit for an isolated operation to a complete foundry system involving a number of collectors. In larger projects a study should be made to determine the most economical arrangement consistent with flexibility of foundry operations, satisfactory performance, and ease of maintenance. The tendency in our company has been to locate the collectors as close to the dust pick-up points as practical and to use a central dewatering system.



(Courtesy, American Air Filter Co., Inc.)

Fig. 1 (Above)—Dynamic precipitator type collector with settling tank and sludge ejector.

Fig. 2 (Below)—Cut away view of an impingement type collector. Water descends against the air stream reaching all the surfaces and carrying the dust downward.



(Courtesy, The R. C. Mahon Co.)

Fig. 3 (Above)—View of a combination type collector where dust-laden air is subjected to a spray treated with a wetting agent forming a foam through which the air passes (Patented).

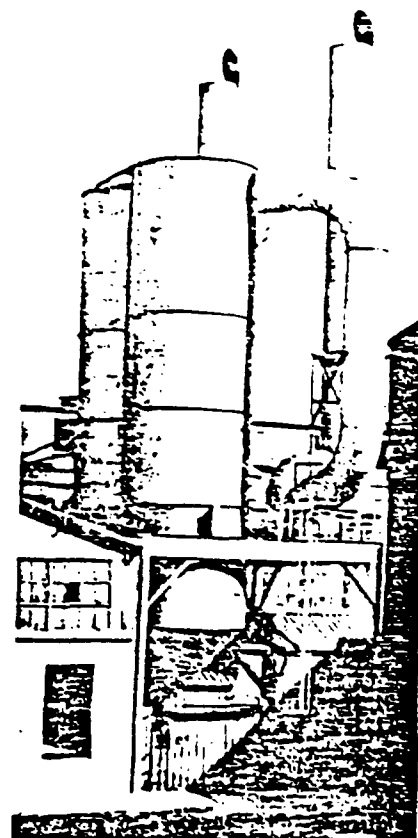
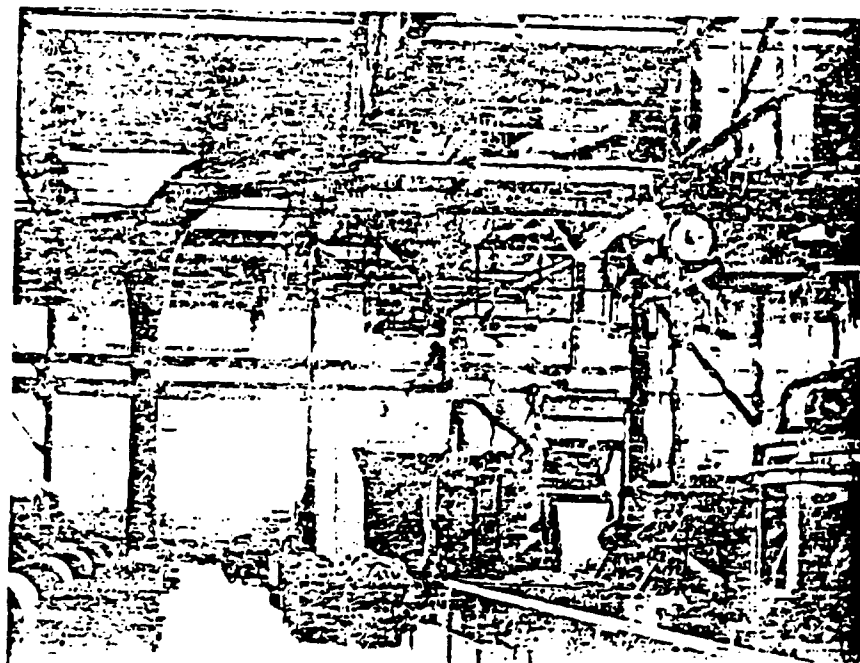


Fig. 5 (Above)—Collector outside of building to avoid loss of working space.

Fig. 4 (Below)—Cleaning room collector supported overhead to avoid loss of working space.



This has the advantage of saving power and reducing duct maintenance. Collectors should be located to avoid using valuable working space. They may be located above the floor or those types having a separate settling tank may be placed outside without danger of freezing provided the inlet air is well above a freezing temperature.

Collector operation. In operating wet type collectors care should be taken to follow the manufacturer's instructions. Otherwise, inefficient performance and increased wear may result. There should be an adequate supply of water (Fig. 6). Ordinarily the water supply should be interlocked with the fan motor to prevent the collector from being operated dry.

It often is advantageous to run water through the collector a short time after the exhaust system has been shut off to flush the collector and effluent lines when used. The collector should be inspected periodically, perhaps once a month. Moisture eliminators should be given es-

pecial attention, as more build-up usually occurs there than in other portions of the collector. A small amount of preventative maintenance will save a lot of time later on (Fig. 7).

Sludge Handling. In general the collected dust has little value and can be readily transported to the disposal area. The method of handling is influenced by sludge quantity, relative location of settling tank to dump, and transportation facilities available. The solids are removed from the tank by hand, gravity, or conveyor or other mechanical means.

Equipment used for carrying the solids to the disposal site may range from a wheelbarrow to a railroad car. However, dump buckets are most frequently used. It is sometimes possible to eliminate most of the sludge handling by pumping the sludge from the settling tank to the dump. Such a method should be laid out carefully to avoid plugging the pipe.

Equipment Selection. Dust col-

lecting equipment should be selected that will give required results with minimum initial and upkeep costs. Due to variations in installations and present conditions, no reliable cost information can be given for complete systems.

The cost may run from a few hundred dollars per thousand cfm of air handled in large systems to several hundred dollars per thousand for small systems. For this reason dust pick-up points should be combined in as large a system as possible without sacrificing flexibility of foundry operations.

Summary

General types of wet collectors and their application and operation have been briefly discussed. There are several variations from those mentioned and their installation and operation may have to be modified accordingly. However, most wet type dust collecting equipment can be installed with a minimum of interference with foundry operations and will give satisfactory results.

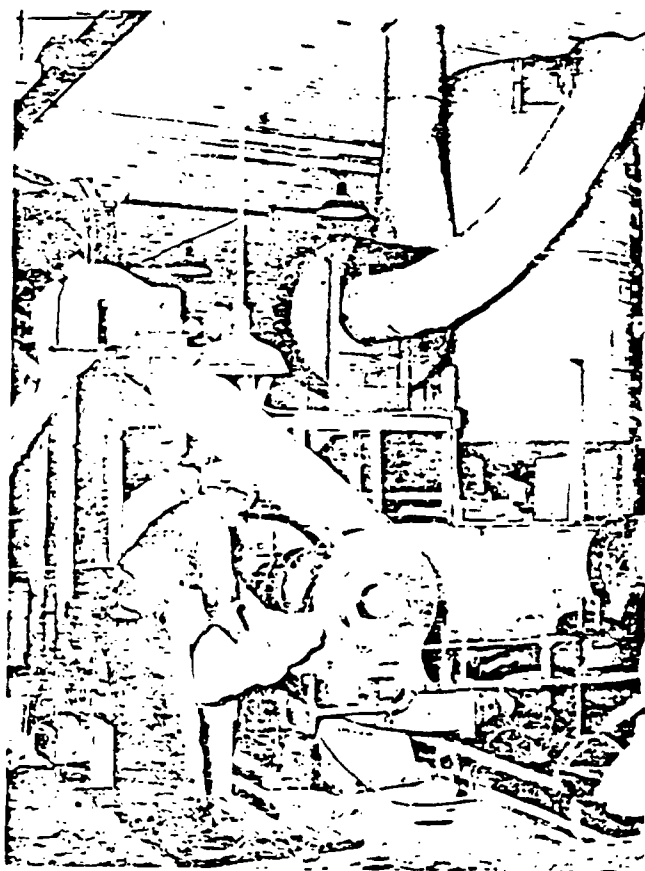
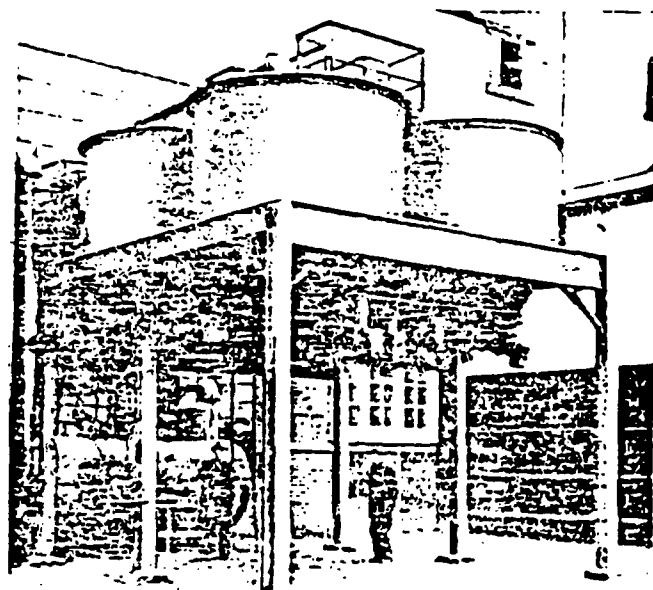


Fig. 6 (Left)—Conveyor type recirculating tank. Fig. 7 (Below)—Bottom dump recirculating tanks for loading directly into truck or railroad car.



FANS AND EXHAUSTERS

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► The author defines fans and blowers. He discusses the centrifugal fan, squirrel cage type fan, radial blade or paddle wheel type fan and the non-overloading type fans. Design and selection of hoods and piping, dust collectors, and fans are interdependent.

RESearch and development which have brought fume and dust hoods, piping systems, dust collection and disposal, important component parts of an air handling system to their present high efficiencies involve much in the way of time and expense. Full benefit of these developments cannot be realized without the use along with them, of an equally efficient device which, figuratively speaking, gives them life—just as the heart does to the human machine with its veins or ducts and its dust and waste collectors. A well built human machine is helpless without a good heart or pump. Similarly, a well designed air handling system cannot produce its potential benefits without it too having a good "heart" which we have come to know in the foundry industry as a fan or blower.

The first use of a fan for collecting and conveying dust was in 1866. The writer quotes from an article by Mr. F. Burnham McLeary in the March, 1914, issue of the *World Work*, referring to this application as follows:

"Now this man Sturtevant was a Yankee and brimful of Yankee brains. One industry, it appears, did not satisfy him. And so when his workmen complained that a shoe buffer he had made, stirred up a fearful cloud of dust, Mr. Sturtevant made a study of the blower problem. The result was a little exhaust fan which seated itself close to the buff-

ing wheel and sucked away every particle of leather. The air was left clean as a whistle. Thus came into being the first satisfactory exhaust fan, and the father of all modern fans and blowers in use today."

Fans Defined

The NAFM (National Association of Fan Manufacturers) has recently issued Bulletin No. 105 entitled "Standards, Definitions and Terms in use by the Fan and Blower Industry." The author quotes from it as follows:

"The term *fans and blowers* has come into general use by custom. Within the industry, the terms *fans*, *blowers* and *exhausters* convey the following ideas:

1. Fans refer to the complete assembly of a machine comprising the rotor and housing and includes both blowers and exhausters.

2. Blowers are fans used to *force* air under pressure.

3. Exhausters are fans used to *withdraw* air under suction. A centrifugal fan consists of a fan rotor or wheel within a scroll (or spiral) type of housing, including driving mechanism supports either for belt drive or direct connection."

A centrifugal fan is a centrifugal pump. It imparts energy to the air passing through it by the action of centrifugal force, drawing air in at the center and discharging it at the periphery of the wheel into the housing from which it passes out through the discharge opening or outlet.

Despite being invisible when clean, air has definite weight or mass; 13.33 cu. ft. of air measured at 70° F. and 29.92 in. Hg. (normal atmospheric pressure at sea level)

weigh 1 lb. This means that a fan handling 13,333 cfm. is actually working with a mass of 1000 lb. per min. or one ton every 2 min. A mass equal to 1 ton of sand or 1 ton of iron passes through 30 times an hour in that particular size of fan. It is obvious, therefore, that a fan for use in a foundry must be a rugged piece of equipment.

The measure of the total energy imparted to a quantity of air flowing through a fan, is the total pressure which it develops. When that quantity of air, or volume in cfm., passes through a fixed fan outlet opening, it must do so at a definite velocity since Velocity is $\frac{Q}{A}$, Quantity divided by Area. This velocity represents kinetic energy, the energy of motion, and is measured by the velocity pressure which creates that motion.

The difference between this velocity pressure and the total pressure generated by the fan is known as the static pressure. Velocity pressure acts only in the direction of air flow. Static pressure acts in all directions: at right angles to, and in the direction of, the air flow. It is the pressure which tends to burst or collapse a pipe or chamber. It represents potential energy.

The writer likes to think of velocity and static pressures in a less technical sense. He likes to think of velocity pressure as the vehicle which speeds the air along. He likes to think of static pressure, because it also acts in the direction of air flow, as the advance guard, the motorcycle squad, which moves ahead of the speeding vehicle, brushing aside all obstructions to give clear passage to the vehicle.

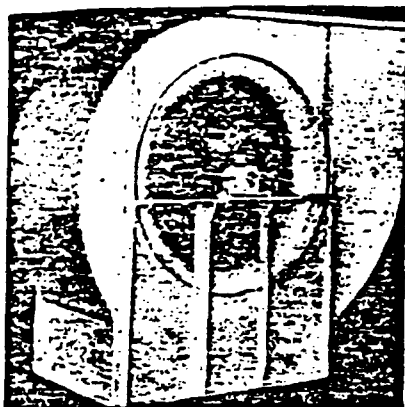


Fig. 1—Squirrel cage or multiblade type fan.

Imagine, if you will, that the inside surfaces of your air piping are not smooth but instead covered with bumps and projections, bristles and obstructions. Imagine further that our invisible motorcycle squad moves ahead smoothing out these obstructions. The measure of the energy with which this is done is the static pressure. *In short, it is the force which overcomes resistance to the flow of air.*

It takes horsepower to develop pressure. Obviously, the slower the air has to move, the less velocity pressure is required. The less resistance there is to overcome, the less static pressure is required. Keeping these component parts of the total pressure to a minimum, keeps the horsepower required to a minimum. Low air velocity also means less abrasion or erosion on elbows and ducts. Lower total pressure means lower fan speeds and longer life.

If the true resistance of a system is no more than the static pressure for which a fan connected to it is selected, the cfm. rating of that fan at that static pressure will actually flow through the system provided:

1. That the manufacturer's tables are rated on NAFM and ASHVE Standards

2. That restrictions or bends at the inlet or outlet, especially the former, do not change the fan characteristic which is determined by test with 10 diameters of straight pipe on the inlet or outlet or both.

3. That additional connections from additional grinding wheels, fume hoods and dust collectors over and above the original design are

not added ad infinitum without increasing the original speed and possibly the size of motor.

The writer cannot emphasize too strongly that a definite relationship exists between the fan and the system to which it is connected. Many engineers have the impression that when a fan is selected from the fan tables for a certain cfm. and static pressure and the fan is operated at the speed indicated, the fan will automatically deliver that amount of air. That is not necessarily so.

A fan has an infinite number of capacities at a given speed. Imagine a fan in operation with no duct work on it and with merely a solid plate fastened to a short outlet extension. This is one extreme. We call this "Blocked Tight." The cfm. delivery is zero. The pressure developed is slightly less than the maximum pres-

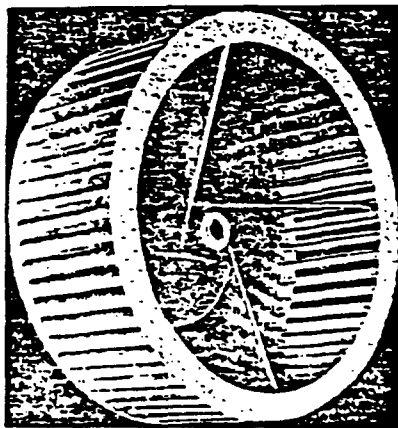


Fig. 2—Multiblade forward curved blade rotor for fan in Fig. 1.

sure the fan can develop at that speed. It is called the Static No Delivery. It has no practical value in the field.

The other extreme is to remove the solid plate and then we have the maximum capacity of the fan at that speed. It is called the Wide Open Volume. Between these two extremes there is an infinite number of capacities, and which one you obtain is wholly dependent upon the nature and magnitude of the restrictions placed on either the inlet side or discharge side of the fan, or both, in the form of hoods, piping, and collectors, rain caps, etc.

A fan will do as much as it is permitted to do. It will operate

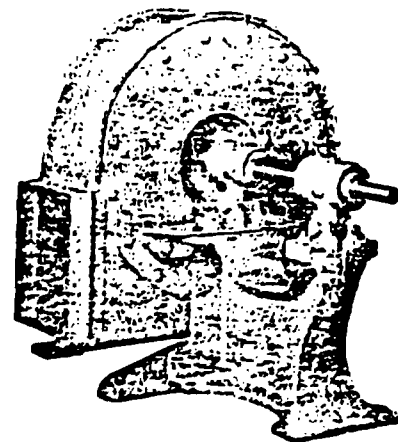
anywhere in its capacity range—subject only and completely to the resistance of the system. In other words, the actual static pressure loss. A fan table merely says in effect: "If the static pressure loss is no more than x inches, then the fan will deliver the specified air quantity and only then."

If the static pressure loss is more, the capacity falls off. If it is less, the capacity increases. In the former case you find insufficient air movement at your hoods and a settling of dust in the ducts due to too low a velocity. In the second case, increased velocity is the result and usually the horsepower increases. With excessive velocity, erosion of elbows and piping is more rapid and collector maintenance may be increased.

Squirrel cage-type fan. There are on the market three distinct types of centrifugal fan. One of the oldest is the multiblade forward curved blade fan, sometimes known as the squirrel cage type (Fig. 1 and 2). It usually has 60-64 blades for single width single inlet, with or without the cup shaped depressions in the blades. It is primarily a ventilating fan for low static pressures, not a fan for dust collecting systems. It occupies a minimum of space for a given duty and runs at the slowest speed.

On the other hand, it has a rapidly rising horsepower characteristic and can easily overload a motor by a reduction in static pressure or by adding additional connections. The curved dished blades make good receptacles for dirt and muck. The

Fig. 3 — Radial blade or paddle wheel type of fan.



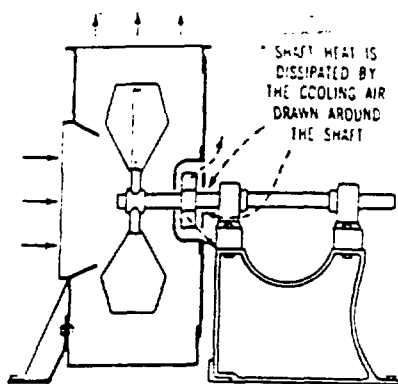
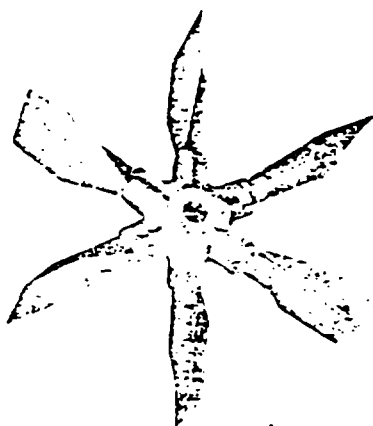


Fig. 5—Diagrammatic sketch of fan in Fig. 3, with provision for cooling shaft.

writer feels this fan has no place in a foundry with the possible exception of the ventilating or air conditioning system for the office section where the pressure requirements are low and the air relatively clean.

Radial blade or paddle wheel type fan. The second type is the radial blade or paddle wheel type (Fig. 3). This is the old reliable of the industry. It is truly an industrial fan. The wheel is made with 6 or 8 simple broad flat blades with or without side plates, depending on the nature of the material in the air stream (Fig. 4). It has been most commonly used for dust collecting work handling exhaust from grinding, buffing and polishing wheels, with or without dust collectors, and before and after dust collectors, usually in capacities up to 25,000 cfm. These fans are obtainable for larger capacities but they become bulky and run at low speeds making for costly

Fig. 4—Radial blade rotor for fan in Fig. 3.



drying equipment.

These fans are also commonly used in core oven work and heat treating for recirculation and exhaust, handling high temperature air. They can be provided with heat radiating devices to protect the bearings without the use of water cooling. (Fig. 5).

The paddle wheel design lends itself very well to fabrication from heat resisting alloy sheet steel or to one piece castings of heat resisting alloy for that application.

The pressure characteristic is more stable than that of the squirrel cage type and the horsepower does not increase so rapidly with a decrease in system resistance. The paddle wheel fan can well be called the

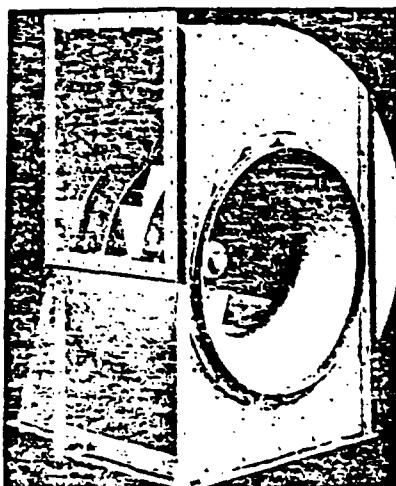


Fig. 6—Non-overloading type fan.

old reliable of the industry.

Non-overloading type fan. The third type is the non-overloading type fan having a wheel with about 12-16 broad blades for single width, single inlet, backwardly inclined away from the direction of rotation (Fig. 6). While this fan is the newest of these three types, the first commercially successful design of backwardly inclined blades was actually made in 1913.

This fan has many desirable features. It has a steep stable pressure characteristic over a wide range of capacity. It is the closest approach to a constant volume centrifugal fan. An increase in system resistance causes less capacity reduction than in other types.

It has a self-limiting horsepower

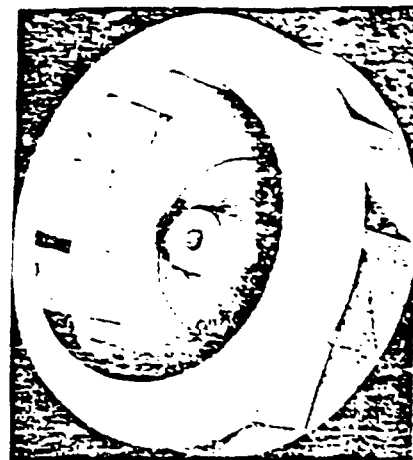


Fig. 7—Rotor with 12 broad backwardly inclined blades for fan in Fig. 6.

characteristic. A decrease in system resistance will not overload the motor since the fan has a predetermined maximum horsepower for every speed. Of the three types, this one has the highest efficiency.

It runs at high rotative speeds which permits the use of smaller diameter V-belt sheaves with a high horsepower rating per belt. It lends to direct connection to standard A. C. motors.

If the non-overloading fan has a wheel with flat, rather than curved, backwardly inclined blades (Fig. 7), it can be used successfully for handling dust laden air, particularly in capacities above 25,000 cfm where it can show an appreciable savings in horsepower.

The flat blade is self-cleaning and the wheel will remain comparatively free from any deposits on the blades. There is no question about its use on the leaving side of an efficient dust collector. Its use without dust collectors for dry shakeout exhaust and fume exhaust cannot be given blanket approval as it is wholly dependent on the possibilities present for erosion and corrosion. However, its favorable characteristics definitely warrant first consideration.

All centrifugal fans can be furnished in NAFM Arrangement No. 1 and No. 2 where the wheel is overhung, with both bearings on the drive side and with a clear inlet. They can also be furnished in NAFM Arrangement No. 3 which has the wheel supported between



Fig. 8—Axial flow type fan.

bearings with one bearing in the fan inlet on a single inlet fan. Generally speaking, ball bearings with dust seals are best suitable for foundry installations.

More thought should be given to the use of Arrangement No. 3 except in the case of heavy dust loadings, dirty or corrosive fumes, and hot gases. In these cases the cantilever Arrangement No. 1 is unavoidable, but careful attention must be given to foundations and setting of the equipment. It is not reasonable to expect that overhung wheel fans and direct connected fans particularly, can be taken from a freight car and placed on a foundation without further examination. This apparatus must be checked for level and alignment.

Since the war, there has been a marked interest in the axial flow fan. During the war 45,000 of these fans were furnished for Navy combat vessels alone and used for hull ventilation, replacing earlier designs of noisier, heavier centrifugal fans. In addition the Navy procured many more for forced draft boiler applications developing pressure up to 60 in. This fan will definitely find a place in foundry work. It can easily be built for the capacities and pressures you require in dust collecting work, although at present commer-

cial offerings are limited largely to 1½ to 5 in. pressure. It is most practical when direct connected to the motor.

The problem of keeping bearings and V-belt drives out of the air stream in belt driven units is not serious and has been worked out. The axial flow fan should not be used indiscriminately, although it is suitable for certain fume exhaust work involving large volume of air. The author used the axial flow fan for that purpose for the past five years and believes it is the fan of the future.

Poor maintenance, addition of more connections without changing speeds and motors, are responsible only in a small measure for unsatisfactory performance of fume and dust collecting systems. By far and large, it is because of divided responsibility for the installation itself.

The writer tried to point out how interdependent the design and selection of hoods and piping, dust collectors, and fans are. The practice of purchasing these items individually at minimum cost, together with the unwillingness of the purchaser to pay for an extremely important intangible, namely, *Engineering Responsibility*, is the reason for unsatisfactory installations even when utilizing the best equipment available.

Do not think in terms of dust and

fume collecting *equipment*. Think in terms of dust and fume collecting *systems*. Place the entire responsibility at one source. Contract for the entire system with one party on an installed and satisfactory operating basis. Whether this contractor be a fabricator, dust collector manufacturer or fan manufacturer, whether he manufactures 10 per cent or 90 per cent of the contract material in his own shops, is not of prime importance. The important thing is that this contractor be financially responsible and, above all, possess an engineering staff with the engineering "know how."

For every cu. ft. of air exhausted from a building another cu. ft. will leak in to replace it. No building can be made airtight. In the winter time this can create a hazardous, cold, drafty condition. Do not install a dust or fume exhaust system without giving equal consideration to the replacement of that air through a properly designed tempered air supply system.

Granted these investments in capital equipment are costly, but the day is gone when they can be avoided. State laws have seen to that. But, in addition, efficient fume and dust collecting systems contribute definitely to increasing morale and production. Obviously, therefore, they merit your most careful consideration.

Fig. 9—Three-blade light duty rotor for fan in Fig. 8.

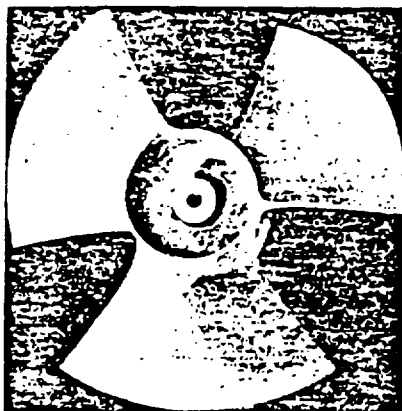
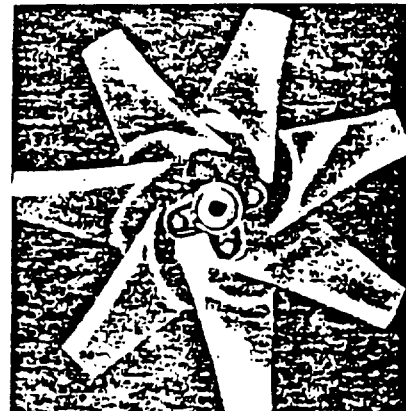


Fig. 10—Multiblade heavy duty rotor for fan in Fig. 8.



MAINTENANCE OF FOUNDRY DUST CONTROL EQUIPMENT

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NO EQUIPMENT is better than the care it receives. The writer says "care" of equipment because maintenance of equipment as commonly understood is too frequently undertaken only when the equipment has failed. Routine preventive maintenance or "care" is necessary if undesirable interruptions of service are to be avoided.

Routine lubrication, cleaning, replacement of worn parts, and general visual checks of all dust control equipment will forestall the major part of equipment breakdowns during production operations. Preventive maintenance pays by eliminating a large part of the losses incurred when workers and equipment cannot be utilized while essential equipment is being repaired.

Exhaust Hood and Duct Maintenance. Foundry dust control starts with the dust hood and ducts. Once a hood and duct system has been set up properly, every effort should be made to keep it in first class condition. Hood inlet adjustments must be maintained, and dirt accumulations must be removed regularly to provide proper ventilation volume.

Figure 1 shows a typical dirt accumulation in a hood entrance. Dirt accumulations should also be removed to promote the good house-keeping essential to the modern foundry.

Not only do dirt accumulations in hood entrances and ducts cut down

the volume of ventilation available, but they frequently constitute a dangerous fire hazard especially where core oil fumes condense and soak into the dust accumulations. Where such fire hazards exist, steam jets should be installed in the duct system ahead of the fan for use in smothering a fire.

Opposed steam jets are necessary to prevent the jet acting as a duct inspirator as well as to fill all sections of duct with steam as quickly as possible. The stop button for the fan should be installed by the steam jet valve. The steam jets should be turned on for a few seconds at regular intervals to insure their proper functioning in emergencies.

Liquids which condense in ducts should be continuously drained out into containers which should be emptied frequently. Figure 2 shows a duct drain and collecting container for core oil residues and water from a mold cooling tunnel exhaust

► **Routine preventive maintenance or care of foundry dust control equipment is necessary if undesirable interruptions of service are to be avoided. The writer goes into some detail discussing maintenance of fans, cloth type dust collectors, rotary centrifugal collectors, wet collectors, and air filter type collectors. Proper dust control equipment maintenance consists of good routine care and inspection plus replacement of worn parts before equipment failure occurs.**

duct. Figure 3 shows the fan section of a similar duct which is badly in need of cleaning. Also the duct entrance door needs a drip deflector on its bottom inside edge.

Frequently dust control hoods are severely abused and rendered useless especially at shakeout. Hood face parts must be rugged. Where experience shows that hoods will be abused, construct them of heavy materials.

When long horizontal ducts are used to convey dirty air to a dust collector, they should be made in flanged sections bolted together to permit turning the duct to a new position several times in the life of the duct. Otherwise, the abrasive wear on the bottom of the duct will cause premature duct failure. Bolted flanged elbows in abrasive dust systems are useful for expediting quick replacement of worn out elbows.

All hoods on grinders should be kept clean and in first-class repair for safety and dust control.

Fan Maintenance. Since the maintenance necessary on a fan is very frequently determined by its design, the proper fan for the dust and fumes to be handled must be chosen with care. For exhaust systems on mold pouring and cooling stations, core ovens, or any system handling condensible fumes, radial blade centrifugal fans will give the most satisfactory results since they are relatively self cleaning by centrifugal force. Figure 4 shows an example of a straight radial blade centrifugal fan impellor in contrast to the multiblade type of fan impellor shown in Fig. 5.

If a multiblade type of fan gives

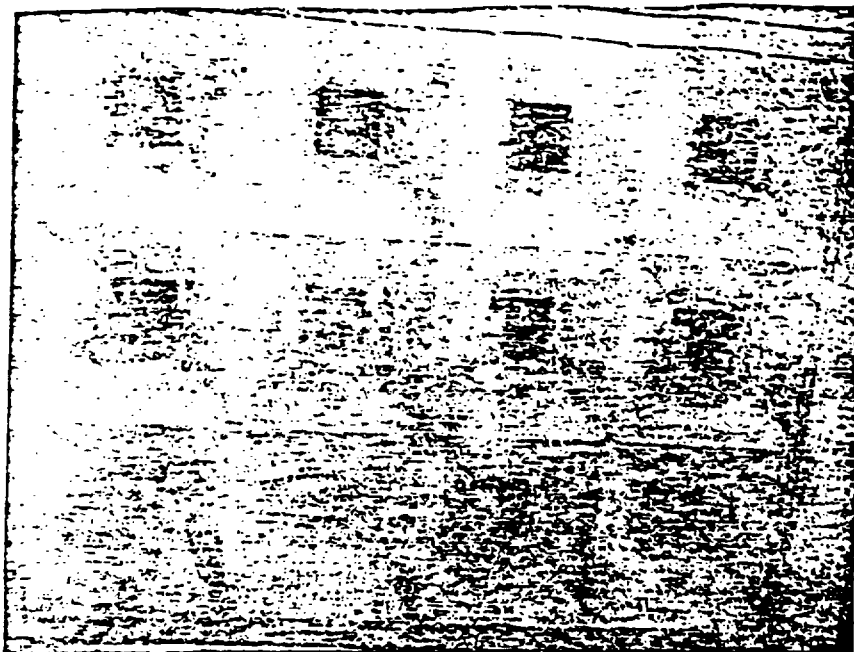


Fig. 1—Typical dirt accumulation at exhaust hood inlets above mold pouring station.

Fig. 2—Duct drain and collecting container for duct handling condensible fumes.



Fig. 3—Duct and fan handling condensible fumes from a mold pouring station showing necessity for periodic cleaning.

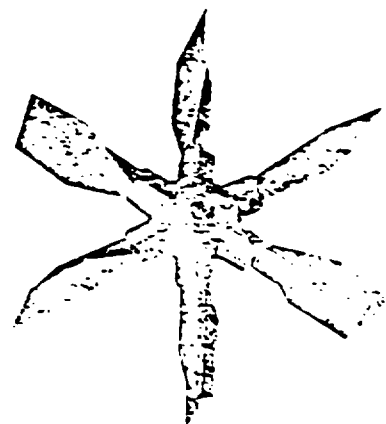
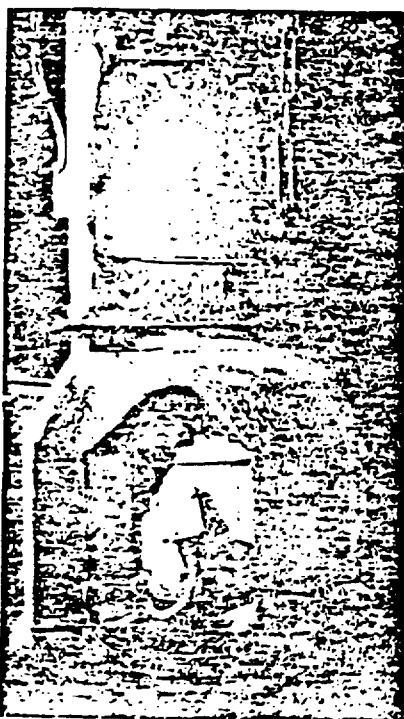


Fig. 4—Straight radial blade fan impeller.

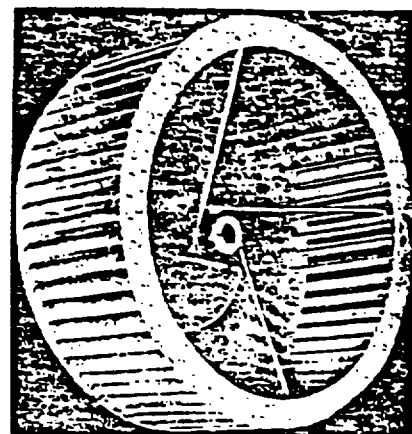


Fig. 5—Multiblade type fan impeller.

Fig. 7—Repaired impeller for centrifugal fan.



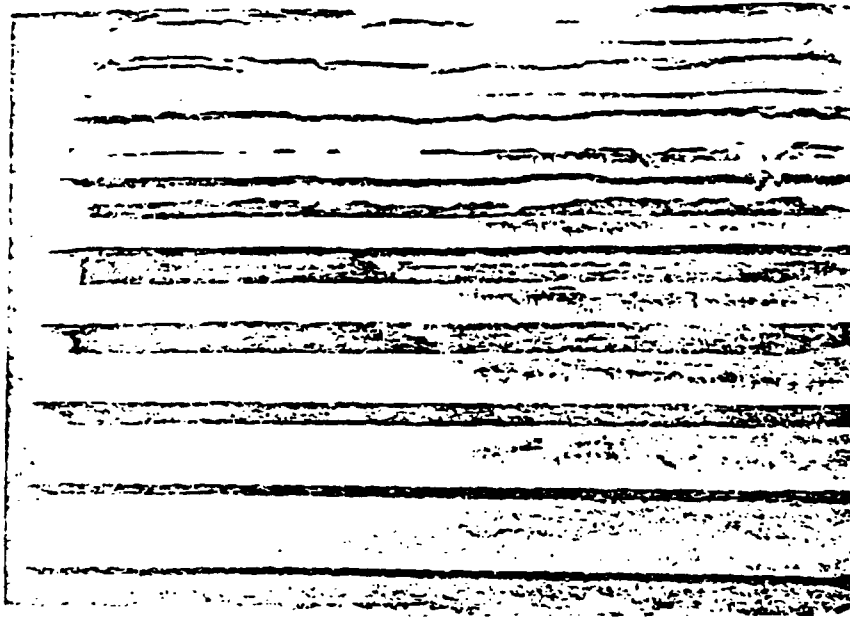


Fig. 6—Multiblade type fan impellor on mold break apart zone exhaust hood showing necessity for regular cleaning.

continual trouble from dirt build up and consequent vibration, it should be replaced with a fan of the radial blade type. Figure 6 shows a multiblade type fan impellor on a large mold break apart exhaust system where regular cleaning of the fan impellor is necessary. Cleaning and checking of such fans can be done more easily if a section of the fan scroll sheet is made removable. Suitable sealing strips must be provided on edges of the removable section.

When vibration is detected in a centrifugal fan, it should be checked for worn or missing impellor blades and for material accumulations on the impellor. Material accumulations should be removed and necessary repairs made. Figure 7 shows a repaired fan impellor. Rebuilt fan impellers should be carefully balanced. Vibration build up in a centrifugal fan can be easily detected when the bearings are given their routine lubrication. Centrifugal fans should not be operated at high speeds unless they are given very good care. Vibration from dirty impellers running at high speed can cause serious damage.

On dust and fume control systems where the dust is not collected, propeller type fans are frequently used. When they are used to handle condensable fumes, they should be of the narrow streamline blade type to cut

down the blade area which can collect dirt. Even so, they should be cleaned regularly. Convenient access doors should be provided in the ducts (Fig. 8) to permit easy cleaning and changing of fan blades.

The belts on external drive duct fans must be kept tight, and the

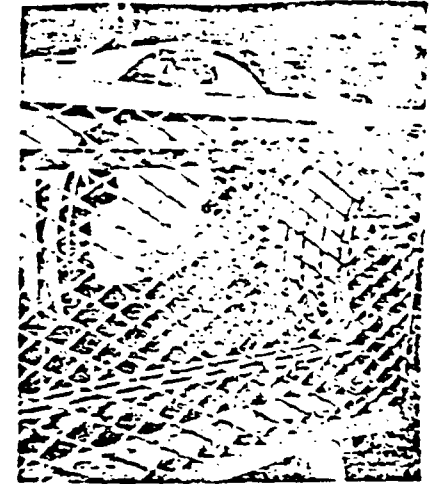
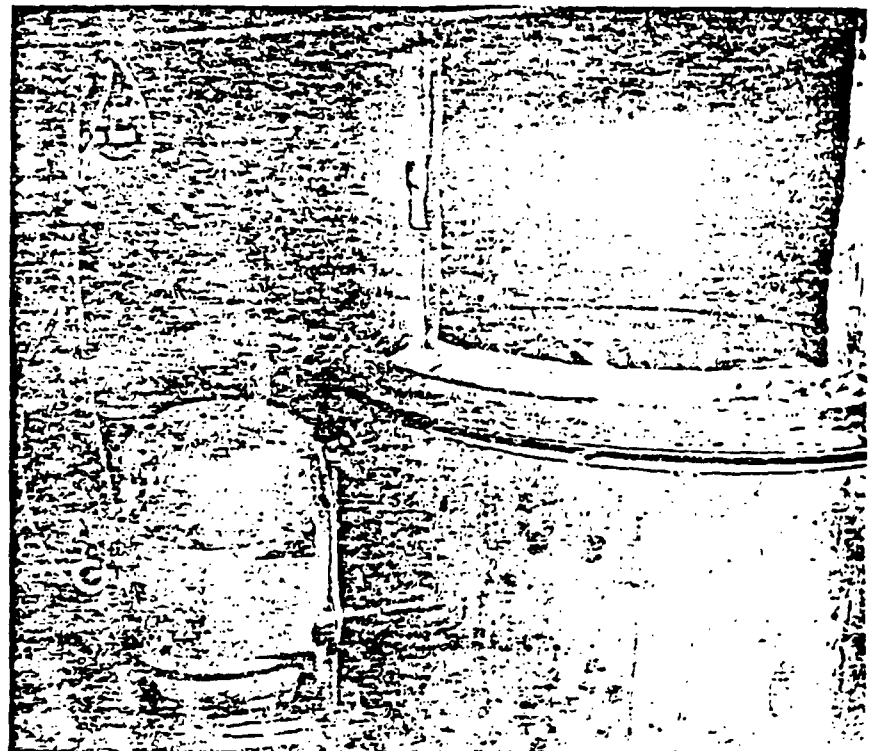


Fig. 9—Fan drive with one belt missing.

bearings should be kept well lubricated especially in ducts from mold pouring exhaust hoods which may carry hot gases. Figure 8 also shows an easily adjusted belt tightener for duct fan drives. The drives for centrifugal fans which use multiple V-belts are often abused. Frequently the individual loose or broken V-belt is not replaced until the overload on the remaining belts has damaged them too. See Fig. 9.

Fig. 8—Propellor type fan with ample duct entrance door and convenient belt tightening arrangement.



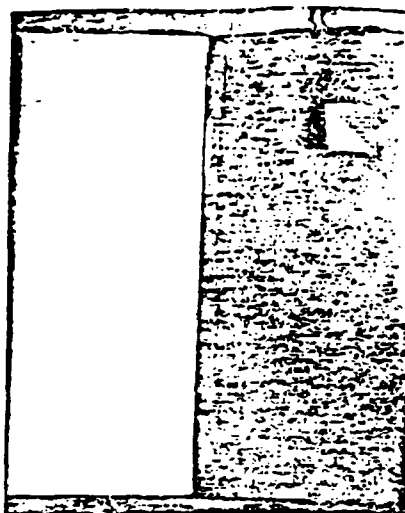


Fig. 11—Dust collector bags showing new bag and well worn bag with dust accumulation.

Where abrasive dusts may be encountered, the propellor blades must be checked and changed periodically to insure efficient fan performance. Figure 10 shows typical worn propellor blades which need changing in order to insure efficient ventilation. Note the maintenance man's quick method of obtaining an adequate door for fan blade replacement.

Cloth Type Collector Maintenance. Several types of dust collec-

Fig. 10—Worn propellor blades on fan handling air containing abrasive dust.

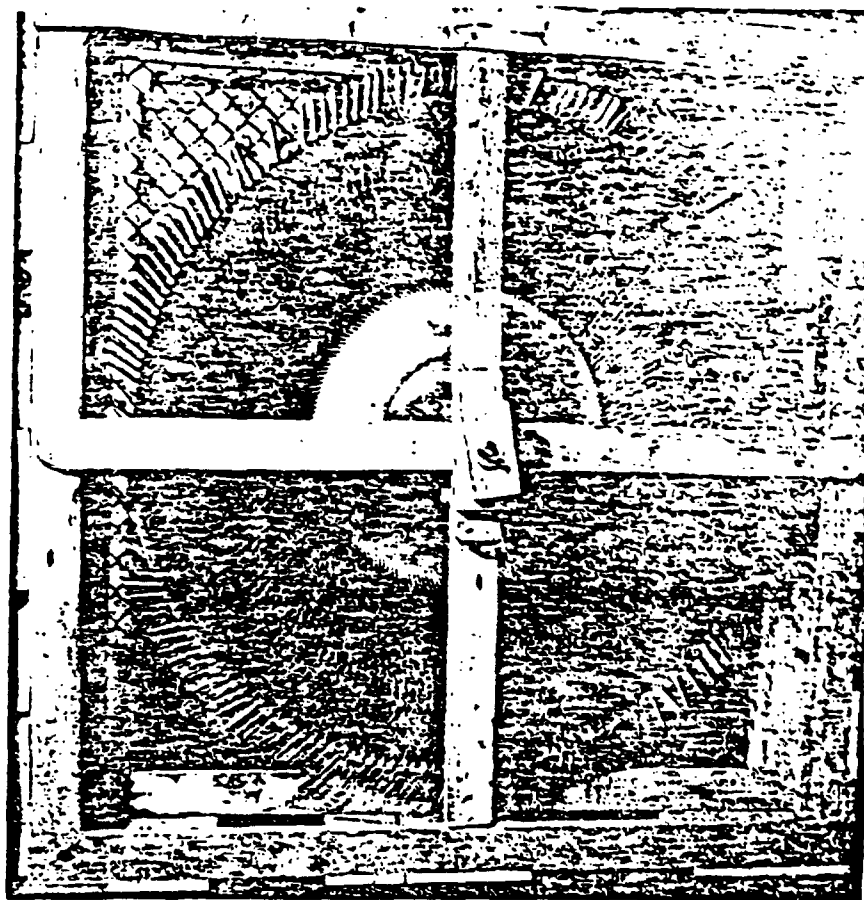
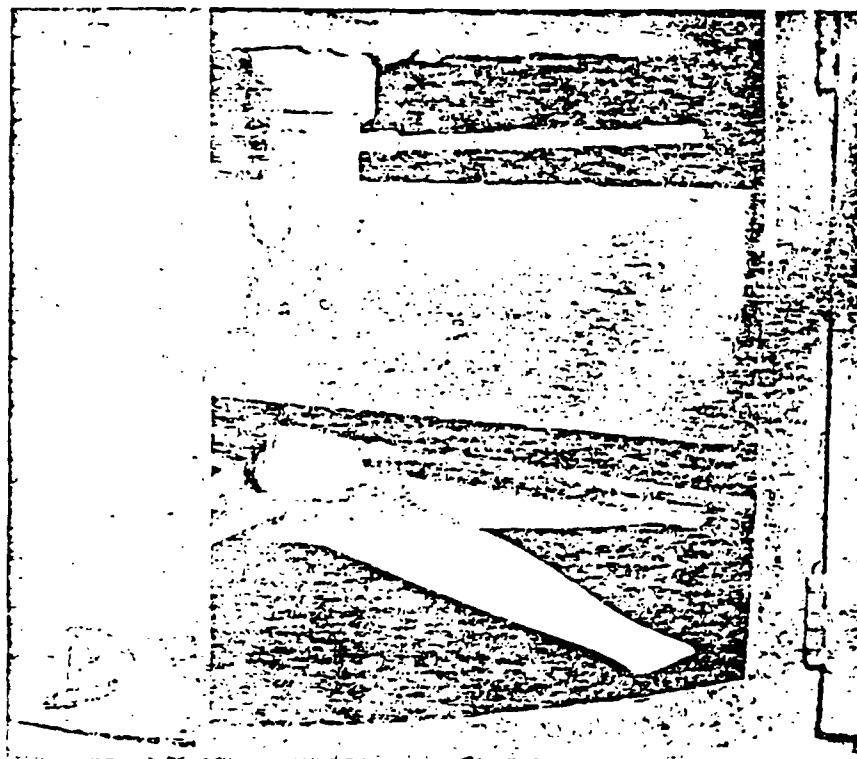


Fig. 12—Worn impellor for rotary centrifugal dust collector as crated for return to manufacturer for reblading.

tors are used in the foundry, each

having separate maintenance problems. Where there are no condensible fumes, high temperatures, or gummy materials present, the cloth type collector is commonly used.

Both the tube and the envelope type bag will eventually increase in resistance from the accumulation of lint in the cloth pores. This lint often comes from grinders' gloves and from paper used to clean safety glasses. When the cloth resistance increases sharply, the bags should be replaced. Otherwise, ventilation volume drops and rapping devices wear holes in bags which in turn lets the abrasive dust wear out the fan.

Even if lint does not get into the cloth pores, the mechanical cleaning will wear out the bags in approximately two years of twenty-four hours daily service. Figure 11 shows a worn bag in contrast to a new bag. Continued rapping has worn the old bag thin enough to permit dust to pass through in a few areas.

Rapping devices should be kept in good order to keep the collector bags

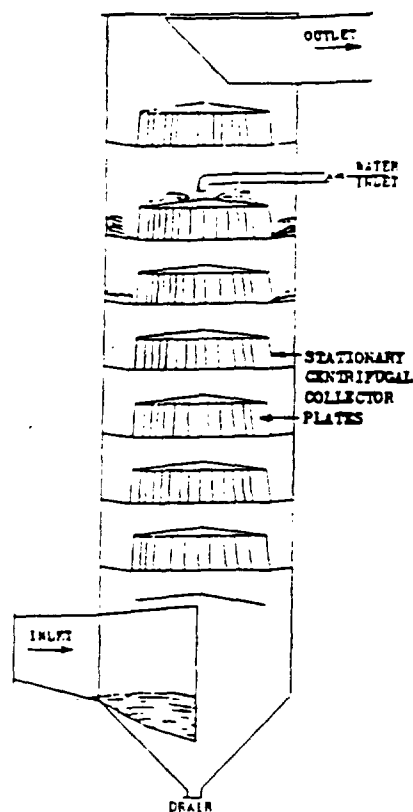


Fig. 13—Multistage wet centrifugal dust collector showing points where deposits may build up.

in full use. Cloth collectors should be shaken down at regular intervals such as lunch hours and at shift changes with fan turned off. The collected material hoppers should be emptied regularly to prevent unnecessary dust recirculation against the cloth sacks. The dirty air inlet must be kept baffled to prevent the air stream from impinging directly upon the collector sacks.

Rotary Centrifugal Collector Maintenance. The rotary centrifugal type of collector combines collector and fan functions. For light dust loads they will operate for long periods with only routine lubrication and general inspection. For heavy abrasive dust loads the rotary centrifugal fan collector should be provided with liners.

These liners should be checked periodically to prevent excessive damage to the main collector housing in case the liners wear through. By the time a set of liners has worn through, the fan impellor probably will need reblading. Prompt reblading service is provided by the manufacturer of this equipment.

Figure 12 shows a worn impellor crated for return to the manufacturer for reblading. For heavy dirt concentrations, a precleaner arrangement reduces the wear on the fan impellor and housing. The dust hopper for the rotary centrifugal collector should prevent any recirculation of the dust. Empty the hopper at frequent intervals.

Wet Collector Maintenance. There are several wet type dust collector arrangements available for foundry use. Their basic principle of operation is to mix the dirty air with a water fog or spray in order to wash the air. Some form of moisture elimination is then employed to separate the water and dirt mixture from the air stream. If rotary impellers are used, the impellers must be kept clean to prevent vibration. If baffles only are used, they should be checked periodically.

The eliminators must be kept in good order to prevent extra carry-over to the fan which may get out of balance from solids built up on the impellor. Where a mechanical sludge conveyor is used, the conveyor will need routine checking and occasional repair and replacement.

Do not put core oil fumes through a wet type rotary centrifugal collector. The fumes condense on the fan impellor, where they collect dirt, and throw the impellor out of balance.

Where a series of vertical centrifu-

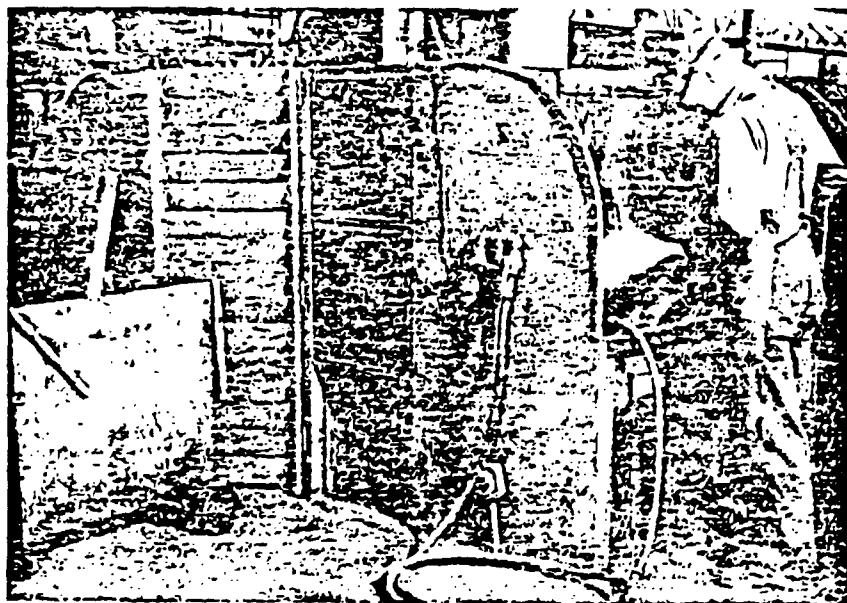
gal collector sections are used in a wet collector, adequate clean water must be passed through the collector to keep it flushed clean. If the water must be recirculated, adequate settling tanks or basins must be provided. Dirty water deposits sludge in the collector sections, as shown in Fig. 13. It also plugs the water lines and the drain, and wears out the circulating pump. Dirt also tends to collect at the collector inlet as shown in Fig. 13. This dirt must be removed at regular intervals from both the collector sections and inlet. Provide adequate clean water, and this cleaning problem will be reduced to the occasional cleaning of the collector inlet.

Air Filter Type Collector Maintenance. Figure 14 shows a grinding bench equipped with six sectional type air filters. These filters are removed every second day, cleaned in oleum, sprayed with SAE 10 lubricating oil, and reinstalled. This maintenance is done on the night shift when the grinding benches are not in use, but a spare set of filters with the portable dipping and draining equipment would make it possible to do this work at any time.

Summary

Proper dust control equipment maintenance consists of good routine care and inspection plus replacement of worn parts before equipment failure occurs.

Fig. 14—Down draft grinding bench showing filter cleaning equipment.



HEALTH PROTECTION IN
FOUNDRY PRACTICE



Papers presented at a Conference on Health Protection in Foundry Practice at the University of Michigan School of Public Health, April 11 and 12, 1952 in Ann Arbor, Mich. in collaboration with The Michigan Department of Health, Detroit City Department of Health, The Institute of Industrial Health, The Department of Production Engineering and the American Foundrymen's Society.

AMERICAN FOUNDRYMEN'S SOCIETY

CHICAGO

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MEASUREMENT OF DUST IN FOUNDRIES

by
Donald E. VanFarowe*

Health hazards associated with the use of silica dusts have been recognized since shortly after the birth of Christ. In the time of Selier II a disease known as "knife-grinders disease" was prevalent. Today we call it silicosis. During Nero's day men working in mines often covered their faces with transparent animal bladders to protect themselves from the "pernicious dusts". You may well ask the question then, if man has known about the effects resulting from the inhalation of silica dust for this many years, why hasn't more been done to prevent silicosis long ago? The answer may be given in part by the change in social organization since those days long ago in Egypt, Greece, and Rome. They, of course, had the "slave". If he became ill and died, they just bought another slave. Maybe the slaves felt that death or severe illness was a relief from the burdens too heavy to be borne. Medieval Europe was little better. The Lord of the Manor cared little about ills and woes of his subjects.

Since 1800 man's attitude to man has been changing. Today we have lost the cast system of society. Today, our fathers, our brothers, our uncles and our cousins are working in a more scientific industry. This change has become evident by laws regulating conditions of employment, including Workmen's Compensation and Health Laws. Dust is now classified as a hazard in industry for which the employer is liable. Physicians, chemists, and engineers have worked together in organizations such as health departments, universities and private research foundations to help the employer in dusty industries such as foundries to make a safe working place for his employees.

The definition of dust given by Webster is "a fine dry pulverized particle of earth or other matter."

The vast majority of dust in the air is below 10 microns in size. Most of it is even below 2 microns. It has a settling rate below 1 centimeter per second, and, therefore, is easily transported by the smallest air currents. In a sense it constitutes a part of the air itself and goes wherever it goes.

The measurement of the dust in the foundry requires two steps:

1. Sampling the dust, which must be removed from a representative volume of air and concentrated so that a quantitative study is possible and
2. Analysis, which requires the determination of the amount and kind of dust in the sample.

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The development of silicosis in most cases is a long range process varying from 5 to 20 years. Sampling may be a matter of 8 to 10 hours. It is obvious that the problem requires statistical interpretation. In order to get a reasonable measurement of the dust exposure, one must sample the locations and variations of dusty operations -- so-called dust floods and also average room concentrations. No definite pattern can be outlined since conditions and practical limitations will vary from one problem to another. The industrial hygienist must rely on his experience and horse-sense.

Instrumentation for Sampling

Dust collecting instruments may be divided into two groups according to the volume of air sampled:

1. Grab samples - instruments which sample a small amount of air in a few seconds.
2. Continuous flow rate - instruments which collect an integrated type of sample.

Each type of instrument has its merits. If one wishes to locate the source of dustiness, the grab sample method is ideal. In determining a health hazard, the grab sample method should never be used alone but may be used in conjunction with an integrating type dust collector.

Dust sampling instruments may again be divided into groups according to the method of collection: Impingement, filtration, electrostatic precipitation, and thermo precipitation. Sometimes it is necessary to use one or more of the above methods for measurement of atmospheric dust. The specific purpose for which the samples are to be used will determine the method of collection.

Impinger

The acceptable standard technique in the United States utilizes the Greenburg-Smith Impinger (Fig. 1). It is a device through which the air is drawn at a given rate. It has a small orifice which causes the air to travel at a high velocity making the dust particles in the air stream impinge upon the small glass plate below this orifice, due to their kinetic energy. The nozzle velocity is an important factor in the efficiency of the collection of the impinger. A suitable liquid is placed in the flask so that these particles are wetted and then suspended in the liquid (Fig. 2).

The air is drawn through this device by means of a suction pump. The amount of air is determined by a calibrated device on the pump so that the amount of air which has been drawn through the impinger may be determined (Fig. 3). Part of this liquid medium is then placed in a dust counting cell under a microscope and the number of particles counted in 1 cubic millimeter of the liquid (Fig. 4). When you look through the microscope ocular a dust count will look like this. The large square is 1/4 of a millimeter and each small square is 100 microns in size. These dust particles, as you can see, vary greatly in size from the largest to the smallest and also vary in transparency and shape, which can help to identify certain types of dust.

Figure 5 shows another dust field and also a large dust particle. After several of these samples have been counted to determine the average count, a multiplication factor can then be used to determine the number of particles in the liquid in the flask. Since we already know the amount of air we have drawn through the impinger we may calculate the number of particles in the air sampled.

Electrostatic Precipitator

The air passes into the tube between two high potential electrodes as shown in Fig. 6. The particles are collected on the inside wall of the tube. Two forces cause precipitation:

1. The ionic bombardment of the electric wind created by the corona discharge, and
2. The attraction of the charged particle to an oppositely charged plate.

The efficiency of this instrument is high for metal fumes and certain other selected materials. It is used principally for total weight and chemical analysis. However, it may be used for dust counting, provided certain conditions exist which will permit the use of this type of instrument.

Thermo Precipitator

I am sure that you have seen the principle of thermo precipitation in your homes or in offices, where a warm air stream laden with dust particles passes near a cold surface. The particles will precipitate out and cause dirty streaks on the walls. This same principle is applied in the thermo precipitator instrument. The air is heated by use of a hot wire and then passes over cooled surfaces, usually glass slides upon which the dust is collected.

The thermo precipitator has a high efficiency in the 0.2 to 20-micron size range.

This instrument is used principally for dust counts and particle size. The reliability of the instrument for dust counting purposes is poor. The sample that is collected is too small for chemical analysis; therefore, the instrument is seldom used for this purpose.

Konimeter

The konimeter (Fig. 7) employs the impingement principle and is classified as a grab sample instrument, since only 5 cc of air are sampled. The dust is impinged on a disk which has been covered with mineral oil or petroleum jelly. This instrument can be used for dust counts and particle sizes only. Samples for chemical analysis and gravimetric analysis cannot be collected by this method.

The efficiency of the konimeter is low and is selective with respect to particle size. However, it is probably the most convenient instrument for dust count-

ing available. Samples can be collected with speed. The konimeter should be used as relative indication of dustiness in conjunction with the impinger. This instrument has been used largely in Canadian and South African mines, where silicosis has been reduced and controlled successfully through its use.

Filtration

Filtration has been used widely as a means of collecting dust from gases (Fig. 8). In general there are two types of filtering materials used:

1. Insoluble, and
2. Soluble.

Insoluble includes filter paper, cotton batten, earthen wares, and cloth. Soluble filters include sugar, resorcinal, anthracene, etc.

When samples are collected in this manner, the results may be reported in either percentage by weight or weight per volume. A method of measuring the amount of air flow and a source of suction must be provided. The efficiency of the filtration method is largely depended upon the type of filtering material used and the particle size of the dust to be collected.

Summary of Instruments

In order to select the instrument suitable for the job, certain factors are taken into consideration:

1. Portability
2. Amount of sample required for analysis.
3. Reliability
4. Reproducibility of collection
5. Cost
6. Time
7. Physical and chemical properties of atmospheric dust.

There are limitations in instrumentation. Failure to recognize this fact would be unwise. One goal must be kept in mind -- that is to reduce silicosis.

Measurement of Dust Concentration

Samples for dust measurement may be taken under three conditions:

1. Moving particles in moving air, such as the duct system. Par-

particle size distribution may vary greatly over a cross-sectional area of duct-work due to air turbulence. It is obvious that sampling should take place in a location which is at least 7-10 diameter from the last elbow, restriction, etc., then using the traverse technique for taking a sample.

2. Still air -- general atmosphere. As mentioned earlier in the paper, the particle size of air-borne dust is 10 microns and below. This dust may be considered as part of the air itself. We know that the average man breathes about 10 cubic meters of air in an 8-hour day. Our job is to get a representative sample of the air that he breathes to evaluate the amount of dust in it, and its chemical analysis. The standard Greenburg-Smith Impinger, the electrostatic precipitator, and the thermo precipitator are examples of the type of sampling apparatus for this type of measurement.

3. Material sample -- settled dust or parent material. Percentage analysis on a sample of this type does not mean that the constituents appear in the same percentage in the air-borne dust caused by the parent material. An illustration in point may be as follows: Suppose you are breaking a rock wall with a sledge hammer. This can be a dusty operation. If you are to take a sample of the rock and of the mortar in proportion as it is in the wall and do an analysis on it, you would find about 10 per cent mortar. However, if you were to analyze the dust which was raised by this operation you would find that perhaps 95 per cent of the dust was from the mortar. The same situation prevails in dust analysis in foundries, so care must be taken with interpretation of analyses of this type.

Units in Measurement of Dust Concentrations

The concentration of dust may be measured in terms of counts per unit volume or weight per unit volume. Each has its purpose. The gravimetric method has the advantage over the counting technique in that it is most reproducible. Counting is subject to great variations depending on the skill, fatigue and inherent visual perceptibility. These variations can be minimized only by experience and training in industrial hygiene. The advantage of the counting technique is that the effect of the silicosis on the lung is a chemical reaction and, therefore, the number of particles, rather than the weight is the determining factor, since the amount of chemical activity is the function of the surface area exposed to body fluids.

Another advantage of the counting system is that low concentrations may be counted while it would be impossible to weigh such small amounts with any degree of accuracy on an ordinary analytical balance. Sometimes it is advantageous to establish a relationship between count and weight. This relationship should be established in each individual type of operation and dust. A practical figure which can be used for quartz is 1 milligram of dust equals about 300 million particles as determined by the light field impinger counting technique.

Particle Size Measurement

Whenever one sets about to measure something, there has to be a scale or unit. For dust measurement, we use the micron. It is about 1/25000 of an inch. In other words, if you take a ball about 1 in. in diameter and let that represent the dust particle which is 1 micron in size, an inch would be nearly a half mile. Example:

If a piece of quartz one centimeter cubed were divided into 1 cubic micron particles, you would have 1 million million particles. As mentioned previously in this paper, the chemical activity is a function of the surface area exposed to the body fluids; it would increase in this case from 6 square centimeters to 64.6 square feet or the size of an 8 x 8 rug. Also the million million cubic micron particles of quartz would constitute the maximum allowable concentration in a room 100 ft x 100 ft with a 20 ft ceiling.

When samples are collected in an impinger, particle sizes as high as 50 microns may be found. Man has been equipped by nature with a filter system in his upper respiratory tract which filters out particles larger than 10 microns. Particles usually not larger than 5 microns will get down into the lungs. We are, therefore, most interested in the dust below 5 microns. In the last several years particle size has become a target of concentrated study since many investigators feel that it is the particle size below 1 micron which is important in many of our respiratory diseases.

Methods of Measurement

The linear sizing of dust particles may be accomplished in three ways:

1. By comparison with a scale which is incorporated in the ocular of the microscope.
2. By projection in measurement of the particle on a suitable scale.
3. Size classification for dust may be accomplished by putting it into a liquid and allowing it to settle (Fig. 9). The larger particles will settle first and the smaller ones will remain suspended in the liquid for a period of time. This is a good method for a rough separation of coarse dust from the respirable size.

Composition of the dust in the Respirable Size

The analysis of dust for free silica in the respirable range is generally accomplished in one of several ways:

1. Chemical analysis
2. X-ray diffraction
3. X-ray spectrometry
4. Petrography

It would be of little value in describing these methods in detail. The method we use at the Michigan Department of Health is the x-ray spectrometer, which you see in Fig. 10. It is composed of several parts: the goniometer, the scaler, the recorder and the x-ray source.

Sample preparation for this instrument is an exacting process, depending upon the type of sample in which we are to determine the amount of free silica. The samples may come in chunks of rock or loose dust which has been collected on the gross air sampler which you saw previously. If the sample is in the form of rock, it has to be ground by the grinder, as you see in Fig. 11. After this process it is ground even more by a power pestle and mortar until it will pass through a very fine screen (Fig. 12). The sample is then a very fine powder with a maximum size of about 43 microns. It is then placed into a metal lozenge as you see in Fig. 13.

Here you see a closer view of the x-ray source and the goniometer. The x-rays pass through the slit optical system, strike the sample and are reflected up through the slit system to the Geiger Tube. The impulse from the Geiger Tube is sent to the scaler where it is counted. The number of counts are registered on the recorder. The Geiger Tube and the sample rotate so that the amount of x-ray that reflects off the sample at various angles may be recorded (Fig. 14). The results of the quartz sample are shown in Fig. 14. The ratio of the length of the quartz lines as compared to the length of the line of the internal standard is determined. With this figure, we use a chart as shown in Fig. 15 to get the percentage of quartz. This is the answer to our analysis.

Accuracy of Dust Determination

The purpose of dust sampling is not to measure the absolute dust concentrations but it is an index of the dust concentration. The requirements are physiological consideration. The dust concentration is adequate to measure silicosis-producing potentialities of dust concentration in the air provided the results are reproducible and proportional. An idea of the accuracy of dust measurement may be received when we think of how the standard of permissible quantities of dust have been established. Medical examination of hundreds of men have been taken and records of their physical condition and mortality recorded and collection of hundreds of dust samples have been taken to correlate with these medical findings.

Maximum Allowable Concentration

We have established maximum allowable concentrations of dust based on experience in dusty industries. These figures are not absolute -- that is to say, we cannot say that just above these figures you will get silicosis and just below them you are in the safe range. They are a guide, however, and to the best of our knowledge no one has gotten silicosis with a dust concentration below these figures. The maximum allowable concentration for silicon dust is as follows:

Silicon above 50%	--	5 M. P. P. C. F.
" 5-50%	--	20 "
" 0-5%	--	50 "

Conclusion on Analysis

In conclusion then the problem of measurement of dust in foundries requires the answers to these questions:

1. How much dust is there in the air?
2. What is the particle size distribution of the dust?
3. What is the chemical composition of the dust in the respirable size range (below 5 microns)?

More progress has been made to prevent silicosis in the last 30 to 40 years than has been accomplished since the world began. In those foundries where the dust counts have been reduced to the maximum allowable concentration limit, we do not know of a single case of silicosis which resulted from the exposure within this range. This does not mean that our maximum allowable concentration will always remain as it now stands, since future scientific studies may change these figures slightly or a different basis for a maximum allowable concentration may be established. They have proven to be a practical figure, since it is reasonably easy for a foundry to reduce the dust to these concentrations.

Dust counts are for two purposes:

1. Purely as an engineering measurement to determine the success of ventilation equipment or some other dust removal equipment.
2. For medical and engineering data to establish limits in order to provide proper occupational environment for all employees.

Industrial physicians, industrial hygienists, educational institutions, research organizations and government agencies have, therefore, taken new strides toward improving your working environment so that you may expect to live to enjoy old age.

Fig. 1--Greenburg-Smith
impinger for sampling
dust-laden atmosphere.

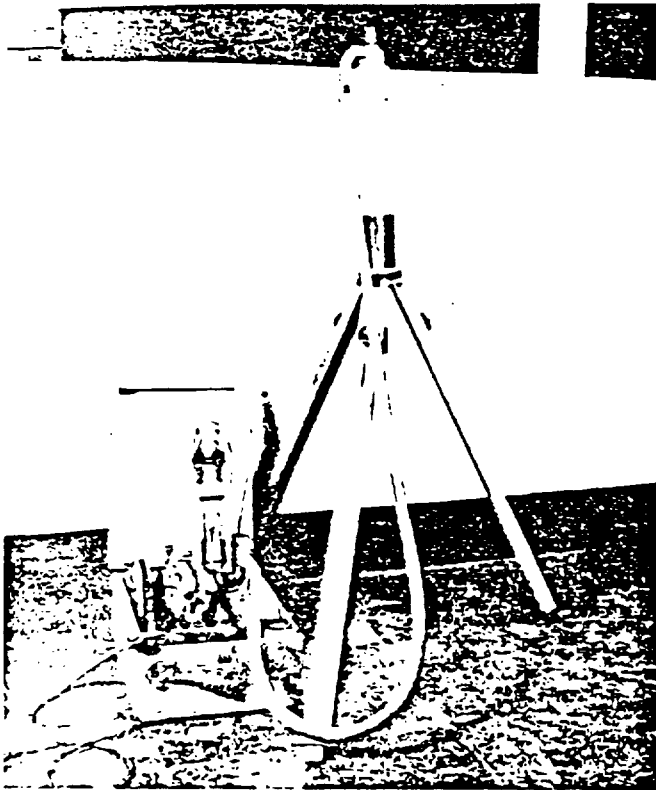


Fig. 2--Liquid in impinger
for wetting and suspending
air-borne dust in liquid.

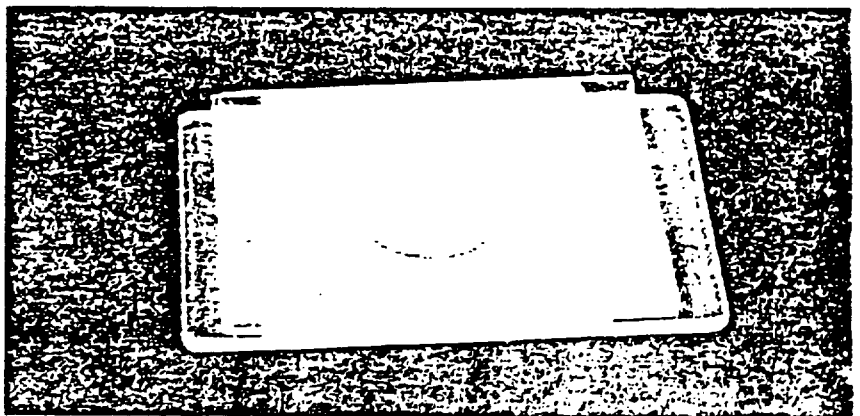


Fig. 3--Calibration
device for determining
air volume drawn
through impinger.

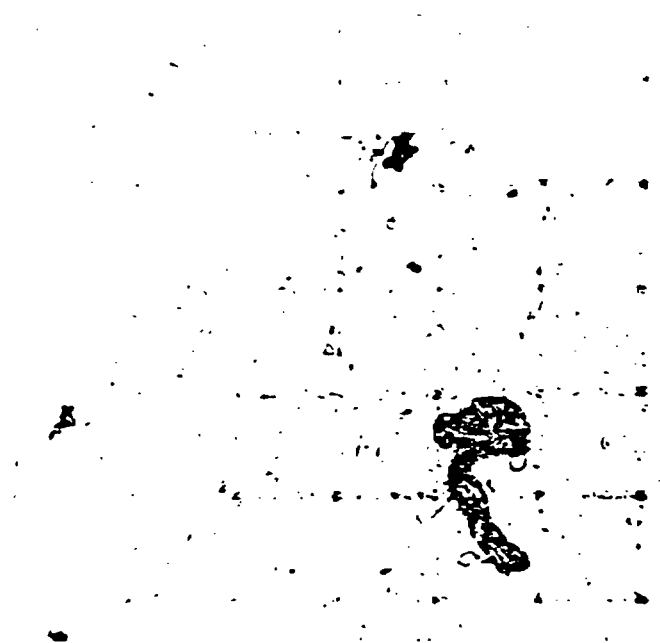


Fig. 4--Dust counting cell as viewed under microscope. Note large dust particle. Large square is $\frac{1}{4}$ mm; each small square is 100 microns.

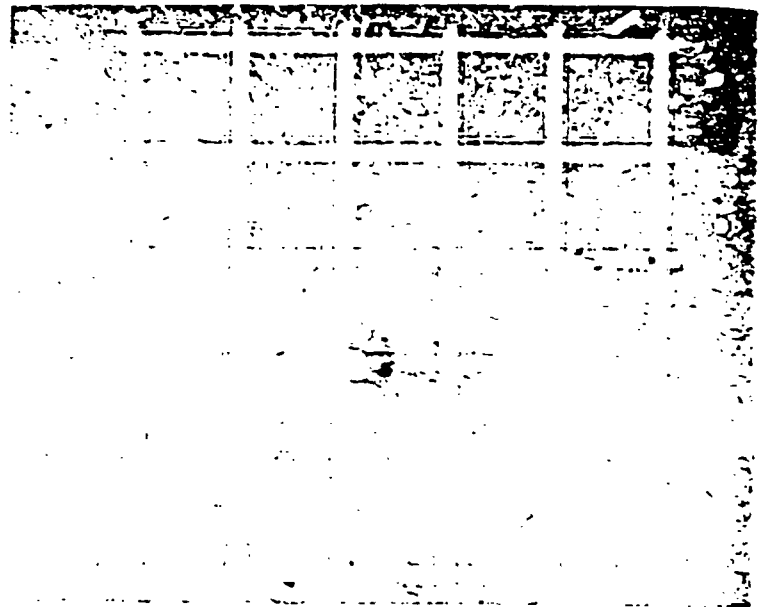


Fig. 5--Another dust field showing a large dust particle.

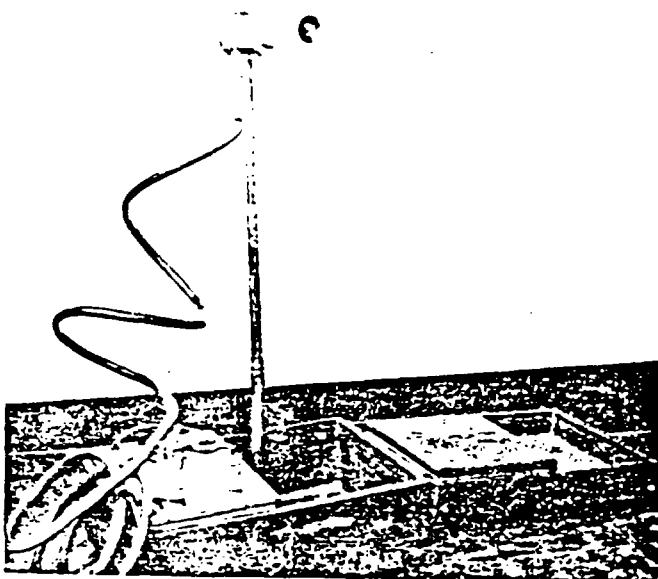


Fig. 6--Electrostatic precipitator type of dust-laden air sampling device.

Fig. 7--Konimeter employing impingement principle in sampling dust-laden air.

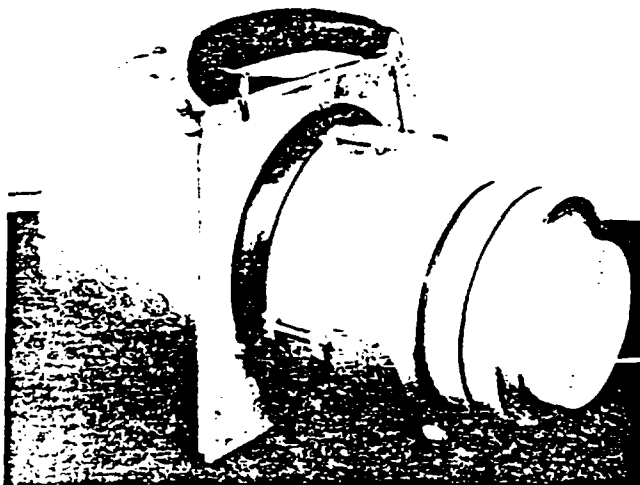
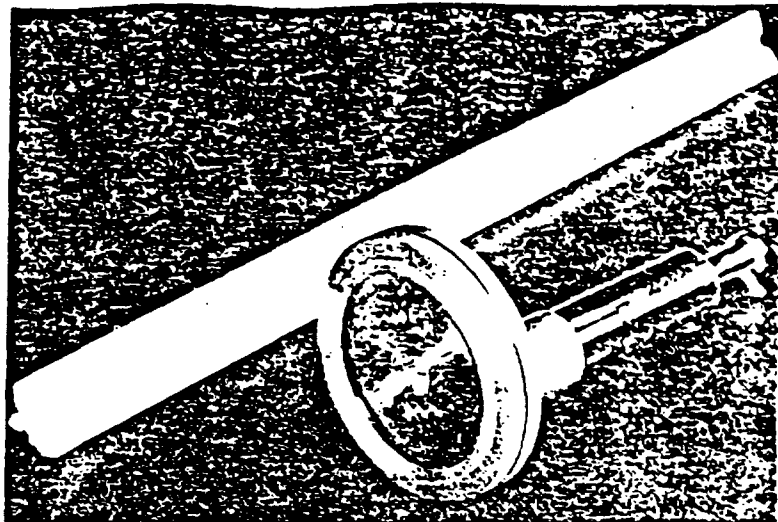
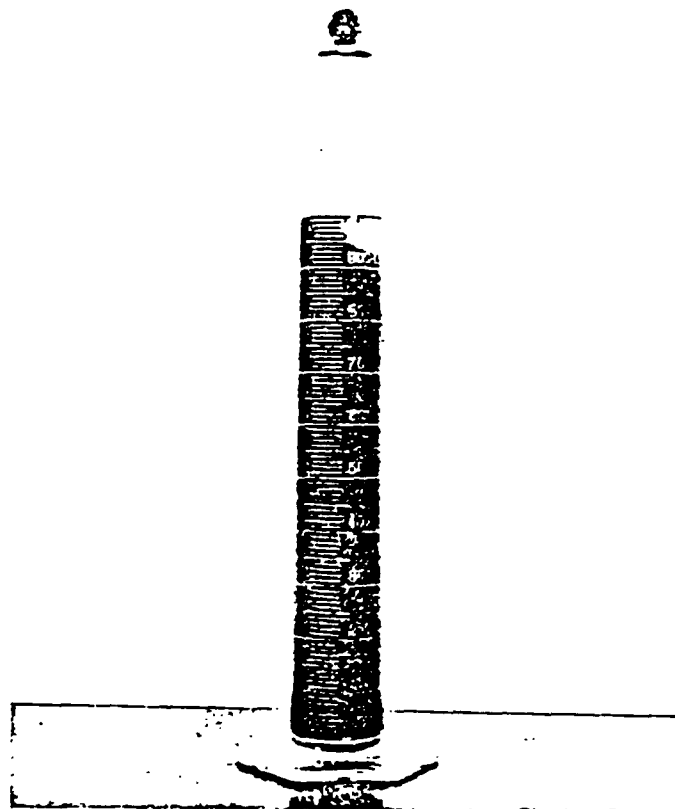


Fig. 8--Device for filtration as means of collecting dust from gases.

Fig. 9--Device for size classification of dust in a dust-laden air sample.



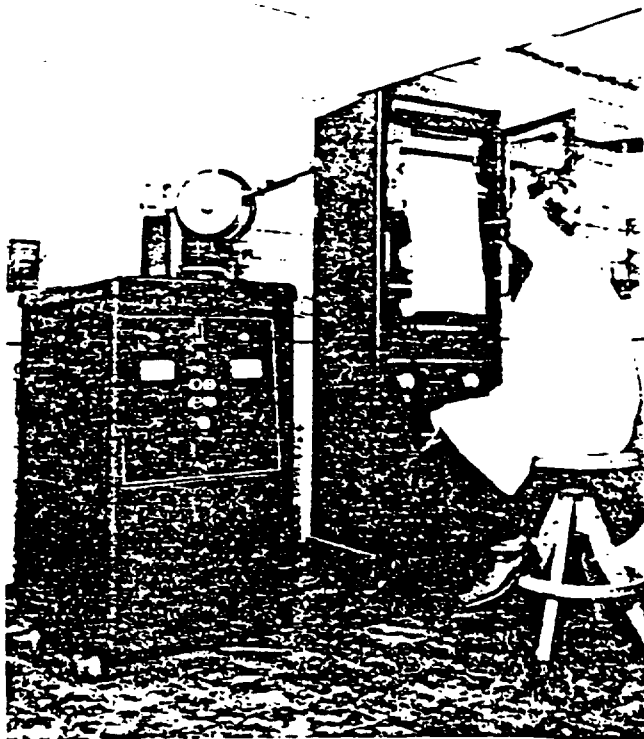


Fig. 10--X-ray spectrometer for analyzing dust for free silica in the respirable range.

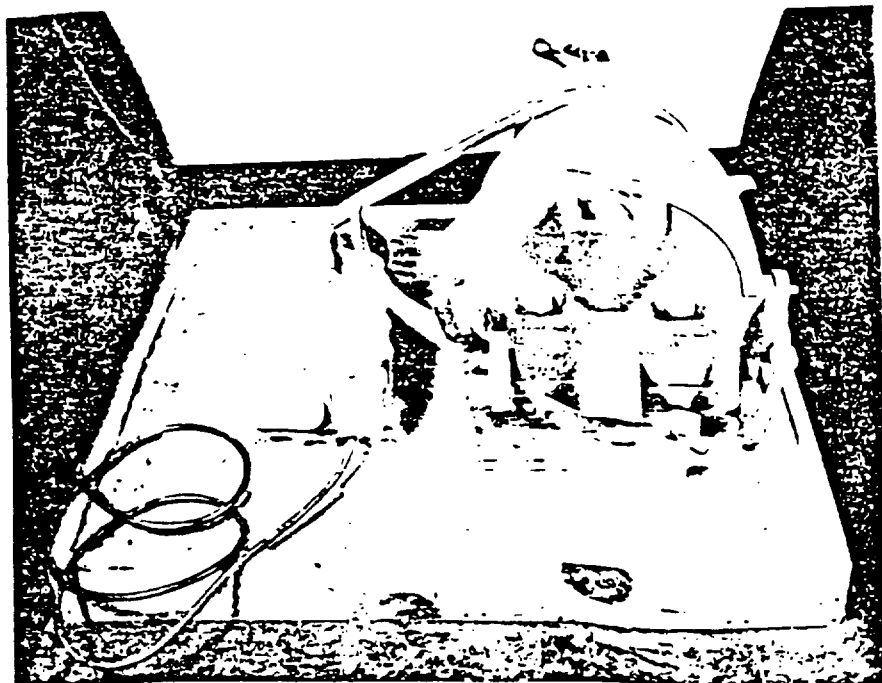


Fig. 11--Grinder for sample preparation.



Fig. 12--Power pestle and mortar for further preparation of sample.

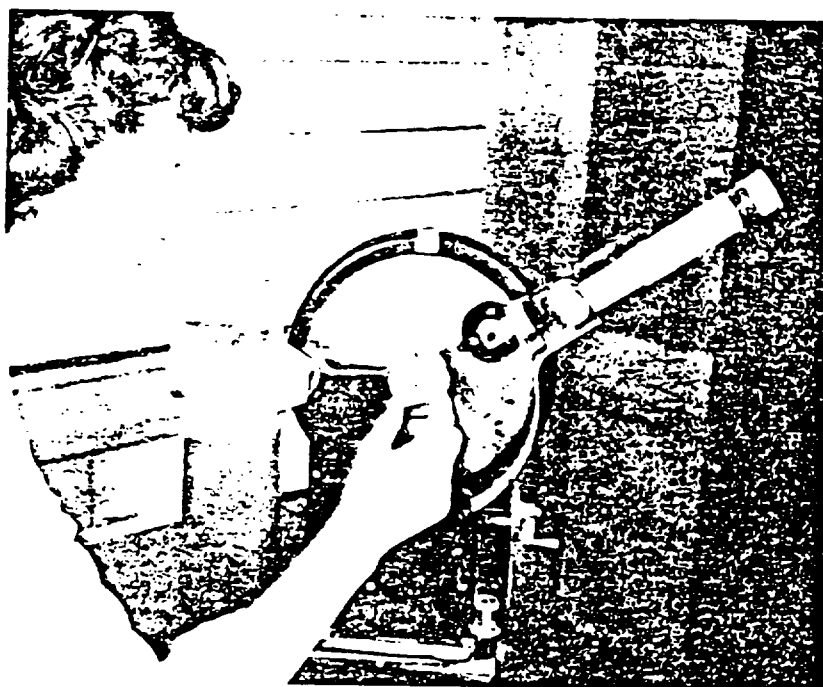


Fig. 13--Sample of fine powder in metal lozenge. Close up view of x-ray source and the goniometer.

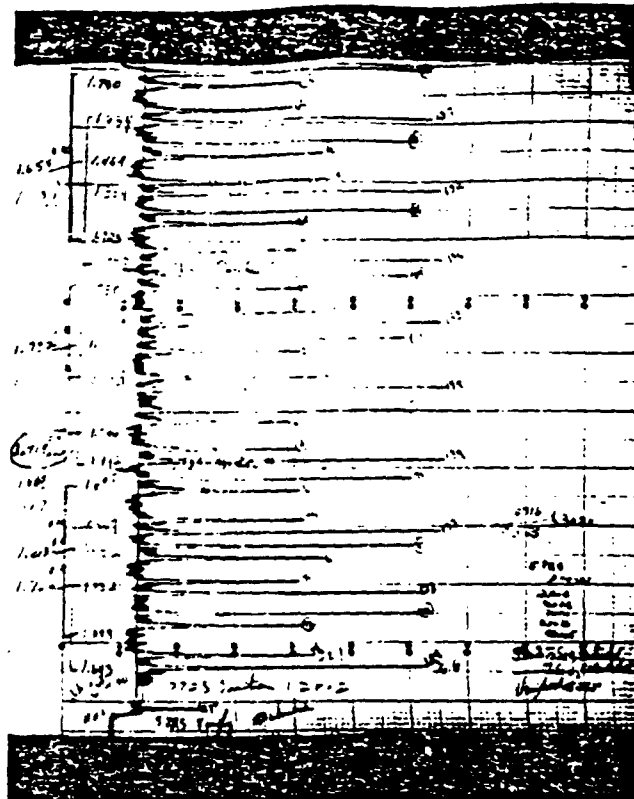


Fig. 14--Record chart from the x-ray spectrometer.

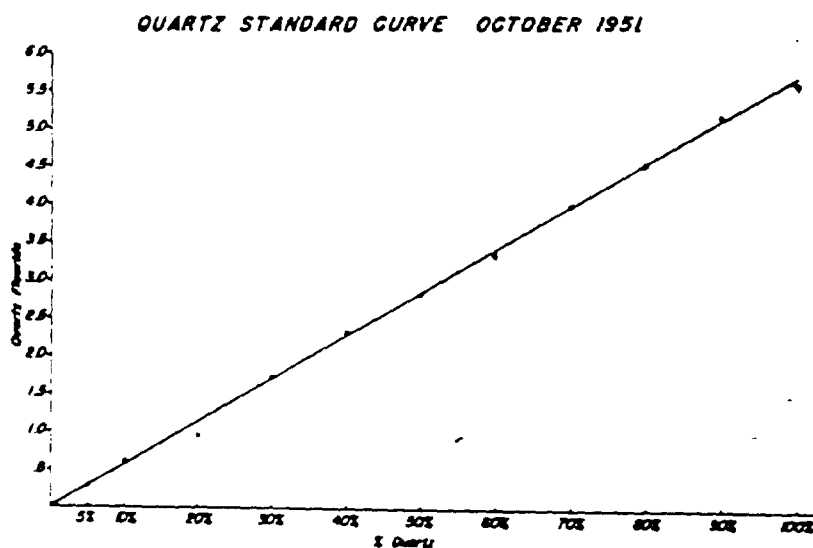


Fig. 15--Curve used in conjunction with Fig. 14 to determine percentage of quartz in a sample.

HOUSEKEEPING

by
Herbert J. Weber*

It is interesting to note that under the general topic of "Control of Dust" housekeeping has been placed first in the course material of this Conference. This is appropriate since good housekeeping is a basic and primary element in any regimen of dust-control. Even the most soundly engineered and expensive ventilating systems cannot be effective without good housekeeping--a fact that can be reduced to proof.

This is so because industrial housekeeping per se embraces in its definition not only the concept of well swept floors, clean windows, and orderliness but also the notions of decent wash and locker rooms, adequate illumination, and good maintenance of existing ventilating systems and other protective devices. It can probably be said that the greatest reduction in the incidence of occupational disease and of accidents in the foundry will be accomplished by good housekeeping.

The elements of this discipline -- and it is just that -- are not a magnanimous benefaction of management. They are a good investment; they are just good business! They constitute almost a complete answer to the question: "What can I do about industrial hygiene?" Even the smallest and least capitalized plant can afford good housekeeping and yet it is so often ignored.

If a plant manager were to walk into the treasurer's office and find twenty-dollar bills lying on the floor, in the waste basket, or on the window ledge, he would be scandalized. Yet in his own plant, equipment and material -- all of which represent dollars -- are sometimes strewn about in the same careless manner. What damage the dust and dirt is not doing to his men, is being done to his motors, machine tools, and other equipment. Aside from the moral obligation to the employees, poor housekeeping is bad business because of the unnecessary hidden costs.

There is a foundry in the middle west whose works manager decided to install a new concrete floor in the core room. When the contractor arrived to level off the sand and to drive stakes for the construction forms, he found a perfectly good concrete floor about a foot below the dirt! This story -- a true one -- needs no comment.

The unsavory reputation of the foundry industry of the past is not without justification. In this regard I should like to quote from an address given by Wm. B. Given, Chairman of the Board, American Brake Shoe Co. before the American Foundrymen's Regional Conference in Philadelphia in May 1949.

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"Some of you are too young to remember the foundries of the early days -- what terrible places they were for any man to work in. Unfortunately, there are still many foundries around the country which do not compare too favorable with those of the past.

During vacations while in college, 40 years ago, I worked two summers in a small machine shop which had, as one of its lean-tos, an iron foundry in which I also worked at times. It was probably worse than the average but typical of many of the old time foundries. The pay rates were about the lowest and the working conditions the poorest in that vicinity. It was hard work. It was extremely hazardous work. For illumination molders had a smoky kerosene torch. A hand shake-out method made it possible for them to breathe in the maximum of dust. The metal was all carried with hand ladles from the cupola to the molds over a floor as uneven as a pasture. There were no wash rooms. In the winter, a piece of hot metal was tossed into a bucket of water when it came time to wash up. Heating a foundry in winter time was unheard of. It was not unusual to build fires on heaps of sand in the morning, especially after a few days' shutdown before starting to mold. The toilet facilities were the great outdoors. Part of the young man's inherent resistance to a foundry job today comes out of past history -- that record of being an awful place to work. This generation still hears of the terrible burns suffered by molders of those days. The toughness necessary to be a foundry worker was real."

In the early days, the foundry industry depended largely on immigrant labor. Because of our compulsory educational system, the sons of those immigrants have had at least high school education. The U. S. Government, by appropriations from taxes, has made it possible for many ex-servicemen to receive a college education. These people are not going to be attracted to an industry with a reputation for sub-standard working environment because they have the mental acumen and training to find employment elsewhere.

The industry can and must atone for the sins of the past by eliminating exposure to occupational disease and by adopting now the basic elements of a modern industrial environment, the principal one of which is good housekeeping. Without it, the better people will not be attracted to the industry and the good men may leave in search of other employment.

If we had the money, we can replace every machine or piece of equipment in the foundry, but we can not so readily replace first class molders and we can not buy first class core makers -- we can only steal them from each other. It takes years to make a good foundryman and consequently the industry has a tremendous investment in people. To protect that investment and to make it possible and profitable to invest in newcomers, requires primarily a hygienic industrial environment which is attainable only by a regimen of good housekeeping. How many have had the experience of hiring 20 men today; of paying for their pre-employment physical examinations, and of having 18 of them quit the next day and the remaining two the next month?

Recently I read some interesting inspection reports of foundries made in 1932. I should like to quote briefly from them.

1. "The salient features of this foundry are its remarkably neat and orderly aspects -- and the total absence of any washing facilities."

2. "The toilet and changing facilities in this foundry are adequate -- but there are no provisions for washing."

3. "One woman works in the core room and has for many years. There is no woman's toilet."

These errors of omission, whether they are so intended or not, reflect the disregard of management for the welfare of its employees in the minds of the latter. This engenders a correlative attitude on their part towards management.

Because of poor housekeeping, there are insurance carriers who either hesitate to insure a plant even at increased premium or refuse to insure it at all. If a policy is carried by an insurance company that carrier is very interested in the hygienic and safe practices of the assured. Premium rates can often be substantially reduced by doing a better job of housekeeping because obviously the risk is less. Even if there have been no cases of occupational disease to date in a given plant, if the potential is there, the carrier cannot afford to take a chance because a series of cases may reach full bloom at once. Furthermore the carrier cannot easily defend a plant in litigation where housekeeping is poor.

Unions are beginning to insert health and safety clauses in their contracts. State factory inspectors are enforcing better working conditions. Failure to inaugurate a comprehensive program of plant hygiene is to stand in the way of progress and is a sure way to lose money. I know a company that operates many foundries and it is not by coincidence that the plant with the poorest housekeeping record also has the lowest production record and the highest cost per ton of castings.

In our own Company, we operated 58 plants most of them foundries, with an average population of 150 employees. We recently instituted a program whereby each plant is charged or credited in dollars for their safety and occupational disease expense. The system works as follows:

1. To start with, an audited premium is set up for each plant as required by the insurance company which is regulated by the State Insurance Law. The amount of audited premium is arrived at by multiplying the manual rate (industry wide rate) by each \$100.00 of payroll.

2. Regardless of accident or occupational disease experience each plant pays a basic minimum premium of 25 per cent of its audited premium.

3. The remaining 75 per cent of the total audited premium for all plants is then allocated amongst them as follows:

a. The losses incurred by each plant during the preceding year are related by ratio to the total company losses.

- b. Multiplying this ratio by the total of 75 per cent of the audited premium for all plants results in the "Indicated Premium Based on Loss Experience."

4. Adding this Experience Premium to the basic minimum premium yields the "Plant Total Premium."

5. Comparing this premium with that paid by the plant originally on audit gives the "Adjustment" due.

To give an example: Assume a company of ten plants. Let \$10,000.00 be the audited plant premium and \$100,000.00 be the audited company premium. Let \$5,000.00 be the losses on plant A and \$100,000.00 be the total company losses. Then $\$5,000.00/\$10,000.00$ equals $1/20$, the ratio of plant loss to the company loss.

Seventy-five per cent of the company audited premium is \$75,000.00 and $1/20$ of \$75,000.00 equals \$3,750.00, the indicated premium based on losses. \$3,750.00 plus the basic plant minimum premium (25% \$10,000.00 or \$2,500.00) equals \$6,250.00 or the adjusted premium. The plant audited premium (\$10,000.00) less the adjusted premium (\$6,250.00) equals \$3,750.00 in credit due the plant.

If the adjusted premium exceeded the audited premium the plant would be billed for the excess. We have plants that have earned as high as \$12,300.00 in a year which is credited to plant profit.

This system can really bring about remarkable changes in plant housekeeping because it deals in dollars just as production does. It can also be used where a company owns only one plant by charging or crediting the various departments with real dollars as a result of their occupational disease or accident record.

Money is as surely lost by bad housekeeping as by poor production -- volume and scrap products. A study of 43 foundries in New York State revealed the following startling relationships between housekeeping and the incidence of silicosis.

Note in Table 1 that no foundries were classified as having good housekeeping; only five were fair, eighteen poor, but most of them bad.

TABLE 1

House-keeping	Plants	Silicosis Incidence (Percent)		
		Med.	Max.	Min.
Fair	5	1.9	2.8	1.0
Poor	18	4.4	15.4	1.0
Bad	22	5.4	13.8	0.8

The median rate is lowest in plants having fair working conditions and lowest for those showing bad housekeeping, the unnecessary accumulation of waste materials, and other evidences of high dust exposure. The range in silicosis rates is also much less for the "fair" plants than for the others.

This classification of foundries is based only upon an evaluation resulting from a study of preliminary survey sheets and is not related to dust concentration rates. Nevertheless, the trend indicated is significant and lends additional support to our previous statements about housekeeping.

In one of our own brass foundries we had approximately 14 cases of lead poisoning a month. With little change in the ventilating system but by an excellent regimen of good housekeeping alone, we have not had a single case in over seven years.

We routinely analyze for lead urine samples submitted by all men working in our brass foundries. In January, 1952 our series of urinalyses for the plant showed every man to be in the normal range. If good housekeeping can accomplish that in a brass foundry, it certainly qualifies as one of the most important factors in the control of foundry dust. Figure 1 shows one section of that foundry. Parts of it are vacuum cleaned every Saturday, so that in a month the entire plant -- superstructures, windows, floors, cranes, duct work -- is thoroughly cleaned.

There is a foundry in the midwest which had not been cleaned for 30 years, according to its own figures. When the job was finally done, the amount of dust taken from three buildings amounted to over 100 tons. Another foundry in the same area removed over 60 tons of overhead dust.

Accumulations of overhead dust finally reach the angle of repose and dust from the superstructures and floors is constantly made air-borne by building vibration. Particles of physiologically significant size (below 5 microns - a micron is 1/25000th of an inch) will remain suspended in still air for very long periods thus contaminating the atmosphere long after the dust producing operation has ceased.

Tables may be found which give rates of settling in still air for spherical particles of different sizes. According to Stokes' law, a spherical particle having the same density as quartz and 100 microns in diameter will fall in still air at the rate of 160 fpm, a 50 micron particle at 40 fpm; a 10 micron particle at 1.8 fpm, and a particle 1 micron in diameter at 0.016 fpm or 1 ft per hr in still air. The dusts of a particle size which is dangerous are just the ones that linger in the breathing zone.

This law emphasizes the important fact that blowing down a foundry as it is called, dry sweeping, and poor housekeeping are conducive to occupational disease because fine dust once made air-borne does not settle rapidly. I have found high dust concentrations in foundries with very good ventilating systems because the floors and structural members were seldom if ever cleaned. For this reason, I have been strongly in favor of built-in vacuum cleaning systems capable of maintaining a suction of 11 in. of mercury which is approximately equivalent to a negative pressure of 5.1-2 psi.

Mobile units usually have a vacuum of only 5 in to 6 in. of mercury which in most cases is not enough for heavy duty foundry work.

The vacuum system can be made to pay for itself. It can be used to clean out molds in preference to using expensive compressed air and blowing the dust all over the plant. Bins, shake-out pits, annealing pits, core racks, pattern storage bins, etc., which are tough on the janitor or maintenance crew, can be cleaned with the system. Silica flour, bentonite, and binders can be conveyed into the sand system at the rate of 100 lb per min by vacuum. In non-ferrous work, metal chips and filings can be gathered from machine shop floors and conveyed to storage bins for remelt by means of the machine.

Most foundries use manual methods to a large extent and satisfactory dust control need not always involve elaborate local exhaust systems. Rather it is largely a matter of housekeeping. To keep a plant clean and orderly requires only the will to do so and the application of common sense. Many foundries allow discarded material to accumulate thereby taking up valuable floor space and making the cleaning job more difficult. In many cases disposal or proper storage of seldom used patterns or flasks will more than pay for itself in increased usable floor space and in greater ease of regular clean up.

Figure 2 shows a very good example of poor housekeeping. The picture was taken in a brass foundry where the dirt necessarily contains a high percentage of lead dust. It is quite evident that no one can work efficiently in such a cluttered area and any vibration or disturbance of the settled lead dust is certain to set it air-borne.

Figure 3 shows a very good example of a ladle heater exhaust hood, the benefits of which are seriously reduced by the type of housekeeping that prevails.

Figure 4 shows the rear view of sound proofed and exhausted chipping benches. The design and efficiency are excellent yet note the dirty condition behind the benches.

Figure 5 furnishes a very fine example of an exhaust hood over a cupola spout. It is evident how very little clean-up has been done in the area. The picture shows clearly the dust on the building columns, ladder and other equipment. Notice the milk bottle next to the fire clay plugs. Lead dust falls in that bottle and provides a simple way of becoming intoxicated on milk. It is not the pleasant form of intoxication but the kind known as lead intoxication or plumbism.

Figures 6, 7, 8 and 9 provide examples of fair housekeeping and Figures 10, 11, 12 and 13 are models of good foundry housekeeping.

The pictures impress me with one primary fact, namely; that it is foolish to spend a lot of money for expensive exhaust equipment and to ignore the clean-up phase of industrial hygiene. It is, as it were, putting the cart before the horse. A good exhaust hood may cost several thousand dollars to reduce half of the atmospheric contaminants. The other half can be removed by good housekeeping for a few dollars. Which pays the greater dividends? This is not to disparage exhaust ventilation; it is to put housekeeping in its proper order of importance.

We said before that proper illumination is also a part of any program of plant industrial hygiene. Figure 14 shows the middle bay of a manganese steel foundry where the average intensity was 1.6 foot-candles. Can one expect production, high morale, or employee health in such an environment?

Figure 15 shows the same bay after the intensity was increased to 11 foot-candles. Even this level is inadequate but it shows a vast improvement over the value of 1.6 foot candles.

Figure 16 shows the east bay of the same foundry. The illumination level was too low to register on a light meter.

Figure 17 shows the same bay after the intensity was increased to 10.3 foot-candles.

There is as high as a 20 per cent loss of efficiency of a luminaire if the reflectors are not kept clean. Here again the importance of good housekeeping is evident!

Good maintenance is also a part of good housekeeping. In Figure 18 is shown an example of poor maintenance. The cold air ducts protruding through the wall were originally designed to introduce fresh air about 1 ft from the floor. The vertical sections of the ducts were so badly damaged by the chill molds pictured, that part of the duct was removed. Note also the broken windows and open windows that cause air to short circuit to the overhead ventilators, thus defeating the designer's purpose. The money for the fresh air ducts in this case is wasted because of bad maintenance which is synonymous for bad housekeeping.

Figure 19 shows a broken furnace hood which is not as efficient as originally designed.

Bad maintenance means that we are not getting the return on our investment.

Here are a few things to check which I have personally encountered and the plant people were surprised that the dust and fume concentrations were so high.

1. Broken or disconnected exhaust hoods.
2. Broken, stuffed, or disconnected exhaust ducts. We once found a workman's overall jammed in the main header of an exhaust system.
3. Blast gates removed or jammed shut.
4. Burned out power ventilators.
5. Reversed fans. A motor burned out on a certain dust collector. The maintenance man installed another and had the motor running backwards.

6. Broken or open windows in the monitor which caused short circuiting of the air to the power ventilator.
7. Loose fan belts causing slippage and loss of suction.
8. Wrong wiring. One foundry bought an industrial vacuum cleaner which was wired for 440 volt current and was operating it on a 220 volt line. This gave them half the rpm and half the suction and they had become convinced that vacuum cleaners are no good.
9. Dirty dust collector bags so clogged that the suction on the exhaust system was reduced almost to none.
10. Torn dust collector bags, so that there was no dust collection at all and most of the contaminant was re-entering the foundry.
11. Man cooler fans directed in such a way as to neutralize the effects of an exhaust hood or so as to disperse a contaminant all over the foundry.
12. Broken or burned out lamps and dirty reflectors in the lighting system which reduced the intended intensity.
13. Broken doors on sand blast cabinets.
14. Fresh air intakes covered with debris so that no fresh air could enter the plant.
15. The indiscriminate use of compressed air for cleaning.
16. Weather caps on certain types of power ventilators jammed shut so that the fan could discharge no air.

Once a ventilating system is in perfect operating condition a maintenance man can very easily check its performance rapidly by a simple U tube water gage. By taking static pressure readings on each side of the dust collector, on the main duct, and on each branch, basic normal pressures can be determined. Any serious increase or decrease in these readings indicate trouble in the system.

I have purposely refrained from giving here a check list for plant house-keeping because I believe each plant has its own specific problems and some people are better housekeepers than others. But if a start is made, cleanliness engenders further cleanliness and progress will follow.

It is usually a good idea to make each man responsible for the condition of his work station and to grant awards to those who do the best job. If a shop is already littered with debris and covered with dirt and dust what difference does a little more make? We all hesitate however to soil a clean place.

The old adage is still true: "A place for everything, and everything in its place."

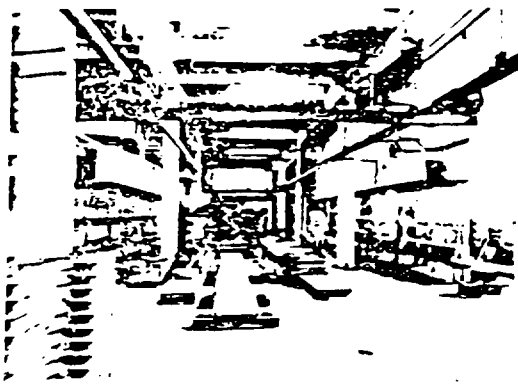


Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



Figure 6

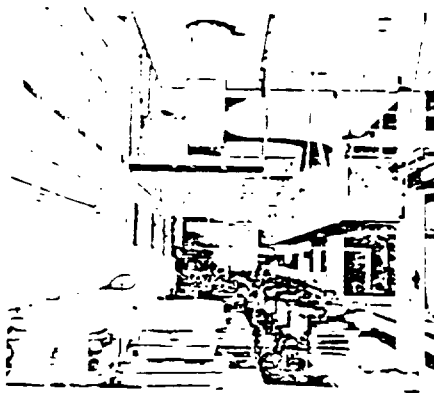


Figure 7



Figure 8

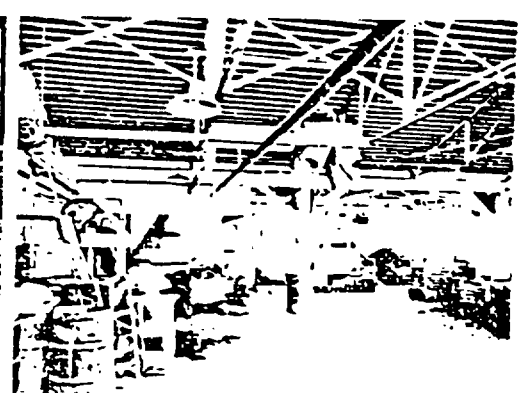


Figure 9

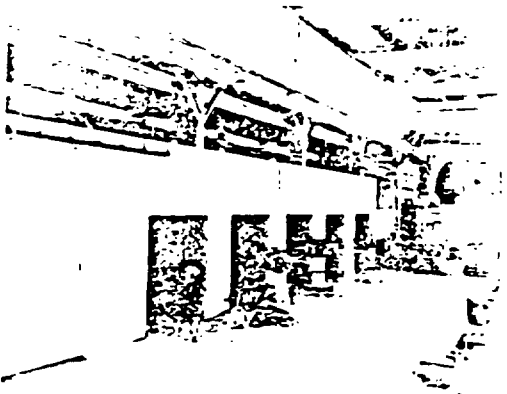


Figure 10



Figure 11



Figure 12



Figure 13



Figure 14



Figure 15

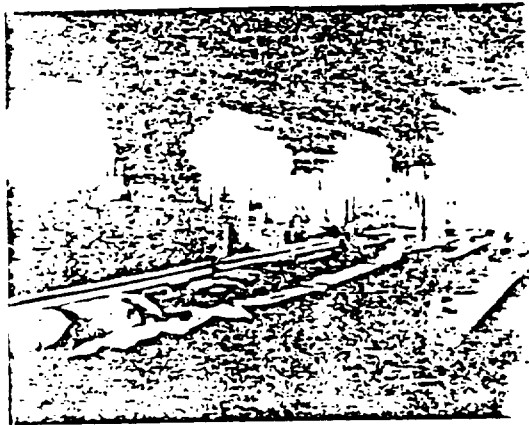


Figure 16



Figure 17



Figure 18

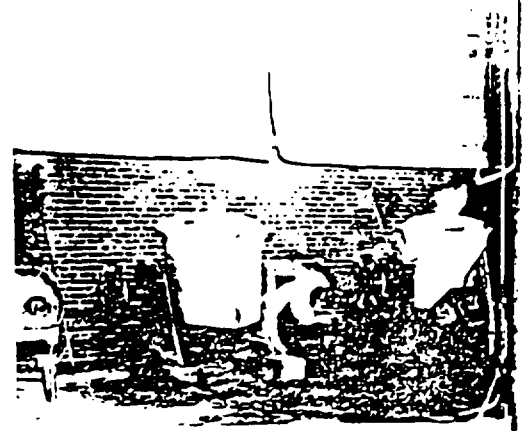


Figure 19

CONTROL OF DUST
ISOLATION, SUBSTITUTION, AND WETTING AGENTS

by
E. G. Meiter*

The dust problem in the foundry is recognized by the larger foundries, but may not be by the smaller ones. This lack of dust control in the smaller plants is not necessarily due to lack of interest but rather to the fact that they have not been reached by industrial hygiene and safety engineers to explain the importance and benefits to be derived from an adequate dust control program.

Naturally, to develop an effective dust control program it must be sold to top management, then to the supervisory force, and finally to the workers themselves. This selling job cannot be done by mail distribution of bulletins, advertising circulars or the like, but must be accomplished by personal calls by competent industrial hygiene or safety engineers.

To explain the benefits of a foundry dust control program, we must remember that management in general is fearful of "what's new" until it has proven itself. We can, therefore, expect at the beginning to receive some opposition to any changes in plant operations which may be suggested.

Laying the proper groundwork or educating management to appreciate the benefits of a dust control program is therefore important before we can expect to receive much cooperation.

It is not enough to tell an employer that the air in his foundry has so many million dust particles per cubic foot of air of a specified free silica content, because of which he should initiate a dust control program. What he wants to know is the practical significance of these figures. Are additional ventilating facilities necessary? Will the proposed changes slow down production or lead to an inferior casting? What are his legal responsibilities with reference to occupational disease? Practical answers to these questions will invariably sell the foundry dust control program to management.

Having sold management on the acceptance of the program, the importance of dust control may be brought to the attention of its employees in two ways. The medical aspects of the dust problem and the general precautionary measures to be taken may well be discussed with the employee by the examining physician during pre-employment and routine physical examinations. Additional information may be given by the industrial nurse during the employee's visit to the first aid room. The engineering aspects of the problem including the reasons for protective measures should be given through the same channels as the job instructions.

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The writer feels that too little attention is paid to job training with respect to the necessity of dust control measures. Herein lies the failure of many a well designed program. Job training in this phase of the work can very well be extended. Supervision and enforcement are important.

Factors such as plant layout, type and size of castings produced, and existing ventilation facilities will vary greatly from plant to plant, and it will be necessary to discuss dust control measures by isolation, substitution and wetting agents in general rather than in specific terms. Nevertheless certain principles that will be mentioned are applicable to all foundries.

1. Isolating Dusty Operations

Dust control by "isolation" is based on the theory to expose only those employees actually required to conduct the dust producing operations. In this way only a minimum number of employees are exposed which in most foundries is only a small percentage of the total employment.

Isolation may be in space or in time, and a brief discussion of each method is:

(a) Isolation in space.

Dust producing operations wherever possible should be segregated in separate buildings or departments, or completely enclosed within a department. The grouping of such dust producing operations also aids materially in the effective application of local exhaust or other dust control measures. In some instances, it may be more feasible to isolate the non-dusty rather than the dusty operations. For example, core making is not dusty in itself and the dust concentration in the core room is generally low provided good housekeeping is maintained. Usually the dust to which core makers are exposed comes from nearby operations not associated with their jobs. It is, therefore, highly desirable to isolate the core room from other dust producing operations.

(b) Isolation in time.

Dust producing operations may be delayed to the night shift or at other times when only a minimum number of workers are exposed. This type of isolation has gained wide favor in foundries by limiting the shake-out to the night shift when only a small crew, preferably protected by respirators, is in the foundry.

Sand conditioning is another operation which should be done on the night shift and the operators protected by respirators. Emptying dust collectors, and major cleanup operations may also be isolated in this manner.

Dust control by isolation as to space or time is especially applicable to small foundries because generally speaking it is the simplest method to apply and it is the least costly to install and operate.

2. Substitution of Less Toxic Materials.

As all dusts are not equally hazardous, the principle of substituting a non-toxic or less toxic material for a toxic one is a well recognized procedure for the engineering control of occupational disease. This method should always receive due consideration because it attacks the problem at the source and in addition it is both effective and usually inexpensive.

An important constituent of foundry dust, from the health standpoint, is the free silica which is present in molding sands, core sands, parting compounds, and sandblast sand. The elimination of free silica containing materials, or the use of materials containing less free silica is therefore desirable.

An example of a successful substitution is the steel grit or shot for sand in abrasive blasting. Studies made in the past by the U. S. Public Health Service and by other official and non-official agencies have shown this substitution for sand reduces both the dust concentration and the percentage of free silica in the dust to which the blast operator is exposed. It should be borne in mind that the use of nonsilicious abrasive alone does not entirely solve the dust problem as dust control measures are still necessary.

In abrasive blasting operations where sand must be used, commercial equipment is available which if properly installed and operated, provides adequate protection for the operator.

A further example of substitution is the use of parting compounds containing little or no free silica. Ground silica was formerly widely used, but in past years has given way to other compounds which are less or non-injurious to health. As an additional control measure, the so-called nonsilica parting compounds should also be applied without the unnecessary scattering of dust.

3. Wetting Agents.

The application of water is probably the oldest method of dust control. In the foundry it has been used principally for sprinkling floors, gangways and aisles to prevent the dispersion of dust. It is well known, however, that water does not wet small dust particles very readily; nor does it rapidly penetrate a porous mold. In other words, ordinary water is often "not wet enough" for many industrial applications. To overcome this undesirable characteristic of water, chemists within the past 20 years have developed materials which, when added to water even in minute quantities, will cause a considerable reduction in its surface tension. Such materials are known as wetting agents.

Wetting agents, designed for specific uses, are now commercially available which reduce the surface tension of water and increase the wettability of such materials as are used in foundry operations. Wet water spreads rapidly and penetrates much like a penetrating oil which creeps into all surfaces and crevices. Dusts difficult to wet can be wetted if the proper compound is used and correctly applied.

These wetting agents are shipped in concentrated form either as a liquid or as a solid (cartridge type) and usually require dilution before use. To accomplish this, automatic proportioning equipment is now available, and it is a necessary requirement for the successful use of wetting agents. The recommended dilution is 1 part of concentrate to 1000 parts of water by volume. The solid cartridge, which is generally equivalent to 1 gallon of liquid concentrate will treat approximately 1000 gallons of water.

Wet water is usually applied by spraying through one or more nozzles at pressures varying from 75 to 125 psi. For best results it is important to select a good type nozzle and spray pressure to create the correct size and pattern of spray droplets. Regardless of how efficient the wetting agent may be, if the nozzle and spray are not at a proper location, poor results will be obtained.

The discussion of wet water as it concerns the foundry industry will be limited to the application of dust control. Other suggested uses, such as, tempering molding sand and core sand, as well as a core wash are beyond the scope of this paper. The applications given are suggestive and are not intended to cover all phases of dust control.

Wet water may be employed in three different ways to control dust in the foundry:

1. As a means of preventing the dispersion of dust which may have accumulated on floors.
2. To suppress dust at the point of origin.
3. To remove dust from the air after it has escaped from its source.

A brief discussion of each method is:

1. As a means of preventing the dispersion of dust which may have accumulated on floors, many foundries now sprinkle floors, gangways, and aisles with water to lay the dust, and there is a definite need for an improved control method. Ordinary water wets only the surface of the floor sand, thereby causing mud, or if too much is applied causes puddles which introduces the hazard caused by the spattering of metal. As little penetration takes place, air currents absorb the moisture rapidly, allowing the floor to become dusty again soon after sprinkling. Wet water, however, will penetrate and disperse through the sand, clay or other materials without forming mud or pools of water. Walking over the newly sprayed floors will not disturb the top surface and expose the dry dust underneath, but will merely pack the surface. Again it must be emphasized that correct application of the wet water is necessary to secure optimum results.

2. In suppressing dust at its point of origin, wet water has been found useful to control dust arising from sand conditioning machines at the locations where sand is dumped into hoppers by bucket or conveyor. Flat spray nozzles mounted above the hoppers provide a mist blanket which settles the dust.

A further application is to prevent the dry binders added to sand mullers from being exhausted to the dust collector. The method recommended is to install flat spray nozzles on the periphery of the muller casing and spray toward the center, forming a liquid blanket over the muller.

3. To remove dust from the air after it has escaped from its source, wet water has been used to control dust at shake-out operations which are either ventilated or unventilated. Where ventilation is applied, it is used to supplement the ventilation already provided. Methods of spraying vary. Where no ventilation is applied, one method employs a cluster of solid cone atomizing nozzles mounted on vertical and horizontal piping extending over the top of the shake-out. If this construction interferes with crane operation, a swivel pipe fitting can be installed which allows the nozzle piping to swing back against the wall or post. Some foundries use cranes to remove large heavy castings from the flask. The flask is swung by the crane and bounced against another casting usually located in the center of the shake-out floor. Such operations are very dusty, and the dust is hard to control, due to the various sizes of castings and the large areas covered. Wet water can be used to control the dust at such operations by installing the spray nozzles on the crane bridge and mounting the water tank on the crane itself.

Unfortunately there is a lack of published data relative to the application and efficiency of wetting agents for foundry dust control. Such data no doubt will become available from time to time. While the method may have only a limited application in some foundries, and should not be regarded as a cure-all, nevertheless, it should be tried and experimented with as an additional tool for foundry dust control.

Conclusion

The dust hazard in the foundry industry can be controlled by proper education and supervision of all concerned.

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TRAINING COURSE OUTLINE
ON
FUNDAMENTALS OF FOUNDRY SAFETY

Basics of Foundry Safety (Organizing a Safety Program)

Foremen's Safety Conferences - Committees

The Foreman - The Key Man

Building Safety into the Plant

Plant Inspections

Building Safety into the Working Force (Employee Training)

Creating and Maintaining Interest in Safety

Safeguarding Mechanical Equipment

Electrical Hazards

Handling Materials

Personal Protective Equipment

Accident Records and Analysis

Fire Prevention and Protection

Industrial Health

PERSONAL PROTECTIVE EQUIPMENT

A. Respiratory Equipment

1. Air supplied suits
 - a. Used under conditions which are both immediately hazardous to life and corrosive to the skin and mucous membranes
 - b. Air connections to both hood and body of suit
 - (1) Substantial harness for dragging hose lines
 - c. No authoritative specifications available
2. Self-contained breathing apparatus
 - a. Used under conditions dangerous to life and inaccessible by means of hose lines
 - b. To be used only by crews trained in operation
 - c. Types available are
 - (1) Oxygen tank
 - (2) Chemical types which produce their own oxygen
 - (3) Air tank types
 - d. Oxygen tank types are approved by U. S. Bureau of Mines under American Standards Assn. Code Z2-1938
3. Hose masks
 - a. Used under conditions immediately hazardous to life but accessible by means of a hose line
 - b. Tight-fitting face mask and hose line through which it is possible to breathe if the air supply fails
 - (1) Substantial harness must be worn for dragging the hose line and life line
 - c. Air supplied by low pressure blower; may be power-operated, but must be equipped to operate by hand
 - d. Approval by U. S. Bureau of Mines as above
4. Air-line respirators
 - a. Used where man can escape without respiratory protection
 - b. Air supply preferably from high-pressure blower not internally lubricated, but may be from compressor
 - c. Abrasive blasting protectors are one special type
 - d. Approval by U. S. Bureau of Mines

A. Respiratory Equipment (Continued)

5. Gas masks

For conditions which may be toxic and irritating; not useful in protecting against oxygen deficiency

- a. Tight face-piece with separate canister of chemicals carried on harness
- b. Canister types are:
 - (1) Organic vapors - black
 - (2) Acid gases - white
 - (3) Organic vapor and acid gas mixtures - yellow
 - (4) Ammonia - green
 - (5) Organic vapors, acid gases, and ammonia - brown
 - (6) All industrial gases including carbon monoxide, smoke and fumes - red
 - (7) Hydrocyanic acid - white with green stripes
 - (8) Chlorine - white with yellow stripes
- c. Definite routine of inspection and care required for successful use
- d. Employees should be carefully trained in use under emergency conditions
- e. Approval by U. S. Bureau of Mines as above

6. Cartridge respirators

- a. Used where injury will occur only by long exposure
- b. Have face-piece and canister combined
- c. Only types approved at present are for
 - (1) Organic vapors
 - (2) Dust, fumes and mists in combination with Organic vapors

7. Filter respirators

- a. Used only for protection against dust, mist, fog, and other particulate matter
- b. Requirements for satisfactory filter include:
 - (1) Sufficiently fine to filter out all of the particulate matter from the air
 - (2) Resistance low enough not to interfere with the man's work
 - (3) Specifications are compromise between the two
- c. Approvals are issued on basis of schedule of several test procedures for protection against
 - (1) Pneumoconiosis producing dust
 - (2) Toxic dusts
 - (3) Fumes and mists

8. Care of respiratory protective equipment

- a. Cleaning after each use
- b. Periodic sterilization
- c. Storage in clean, dry place
- d. Marking for the use of particular individual

B. Head Protection

1. Hard hats
 - (a) Impact resistance in both hat and cradle
2. High dielectric strength often required
3. U. S. Treasury Department Specification #367-A is usually quoted. There is no approving agency
4. Hair protection
5. Acid hoods

C. Eye protection

1. Chemical Goggles
 - a. Splash-proof
 - b. Vapor-proof
2. Impact Goggles
 - a. Eye-cup
 - b. Spectacle type with or without side shields
3. Miscellaneous types (half and half, glass blowers, etc.)
4. Face shields for protection from mild impact
5. Babbitting masks for protection from molten metal
6. Welding masks and goggles for protection from ultra-violet, infra-red, and visible radiation

D. Foot Protection

1. Safety toe shoes and boots
 - a. American Standards Assn. Z-41 series codes
 - b. External foot guards
2. Conductive shoes
3. Non-sparking shoes for explosive surroundings
4. Wooden-soled shoes for protection from heat and wet

E. Hand protection: gloves, pads, metal mesh

F. Body protection

1. From heat and hot metal
 - a. Leather, asbestos, wool and other flame-proofed fabrics
 - b. American Standards Assn. L-18 series codes on leather and asbestos garments

2. From cuts and impacts - leather, padded canvas, metal clothing

- ### G. Safety belts

- References: Safe Practices Pamphlets - No. 16 - "Protective Clothing"

- 29 -

**References: "Symposium on Foundry Dust Control" -
American Foundrymen's Society**

**"Fundamentals of Design, Control, Operation and
Maintenance of Exhaust Systems" -
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**"Industrial Health Engineering" by Allen D. Brandt -
John Wiley & Sons, New York, 1947 - \$6.00**

**"Industrial Hygiene and Toxicology" edited by
Frank A. Patty, Interscience Publishers,
New York, 1949 - \$25.00**

SYMPOSIUM ON FOUNDRY SAFETY

HEALTH AND AIR POLLUTION



Papers presented at a Conference on Safety, Health and Air Pollution at the University of Illinois, Division of University Extension, February 17, 18 and 19, 1953, at Urbana, Ill. Conducted by the American Foundrymen's Society and the Department of Mechanical Engineering, University of Illinois.

AMERICAN FOUNDRYMEN'S SOCIETY

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This address presented by Mr. Wagner, President of
American Foundrymen's Society at Conference Dinner,
Wed. evening, Feb. 18, 1953.

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**ENGINEERING MANUAL FOR CONTROL
OF IN-PLANT ENVIRONMENT
IN FOUNDRIES**

AMERICAN FOUNDRYMEN'S SOCIETY
Des Plaines, Illinois

EXHIBIT

B

per cubic meter of air. This limit may easily be exceeded during the phosphorizing phase of melting phosphor-copper. Local exhaust ventilation usually is indicated.

Resins

With the advent of shell molding, more resins now are being used in foundry operations. Such resins are of the thermo-setting type; once the resin is cured, it cannot be softened or remolded. Types now being marketed include the phenol-formaldehyde and urea-formaldehyde resins, some of which contain hexamethylenetetramine (known as "Hex" in the trade).

The phenol-formaldehyde resins give off odors of phenol and formaldehyde on heating. Urea decomposes to ammonia and carbon dioxide so that in shell molding a distinct odor of ammonia may be noted. Hexamethylenetetramine is a skin irritant, and decomposes and releases formaldehyde upon exposure to heat.

All of these resins are toxic, but protection lies in the fact that in severe concentrations man cannot tolerate them. Thus, in practice, fumes from the resins will at most be a nuisance and the degree of nuisance will indicate whether exhaust ventilation is justifiable.

Some resins in use are skin irritants and are capable of producing dermatitis in susceptible persons. Resin dust suspended in air, like cereal flour or coal dust, can be highly explosive.

Sea Coal

Sea coal is principally carbon and is a common ingredient of molding sand used for facing in the foundry. Carbon dust gives rise to a condition of the lungs called anthracosis, which is responsible for characteristic shadows in a chest x-ray. Anthracosis has been considered thus far to be a relatively harmless condition.

Silica

Silica is one of the principal atmospheric contaminants in the foundry. The chemically combined silicas, other than asbestos, are regarded as being physiologically inert. Thus silicates such as bentonites, slag wool, etc., are not known to produce disabling disease.

Free silica (SiO_2) causes the occupational disease known as silicosis, which is characterized in x-rays principally by nodular shadows due to true fibrosis or scarring of the lung tissue, and clinically by decrease of pulmonary function. It is disabling in advanced stages or when accompanied by tuberculous infection.

Usually three factors must be present *simultaneously* in order to produce silicosis:

- 1) Duration of exposure. Two years or longer are required, depending on degree of exposure.
- 2) Respirable particle size. Particles of free silica in excess of 5 microns in diameter are not regarded as being physiologically significant because they are too large to reach the innermost part of the lungs where reaction occurs.
- 3) Concentration of dust. The tolerable concentration depends on the percentage of free silica in dust (Table 1 of appendix to this section).

A major source of exposure is the uncontrolled use of silica flour either in molding sand or in core

washes and sprays. This material falls in the dangerous particle size range, and is usually 100 per cent free silica. Zircon, which is nontoxic and has a specific gravity of approximately twice that of silica, has been an effective substitute for silica flour in some applications. Because of its density and tendency to flocculate, zircon dust settles very rapidly.

Sand-handling and conditioning systems, shakeout, and sometimes sand-slinging operations constitute sources of exposures to silica dust.

Dust sources usually are more severe in mechanized plants, but this is offset by the fact that such plants are subject to better control by means of local exhaust systems.

Good housekeeping is one of the most important means of controlling the hazard from silica dust. Good evidence exists that the incidence of silicosis is inversely proportional to good housekeeping. The higher the level of housekeeping, the lower the number of cases of occupational disease.

Silicones

In foundries, silicones are used as mold-release agents during shell molding. Experience to date indicates that they are not a serious hazard to health.

Nonhydrolyzable silicones used as mold-release agents are of a very low order of toxicity. From a practical standpoint, the hazards from handling them are minor. However, silicones are new chemicals and toxicological studies made are insufficient to determine that the nonhydrolyzing types can be ignored.

Although the nonhydrolyzing types of silicones appear neither toxic nor irritating, the hydrolyzing types are highly corrosive. They present practical hazards from vapor inhalation and contact with the skin and eyes. In dangerous concentrations they have adequate warning properties in that an employee could not tolerate an atmosphere that would be harmful to him.

Care should be used in handling the hydrolyzing types, since a small droplet splashed in the eye could cause serious damage and even loss of the eye. Direct skin contact, while likely to cause a severe burn, is not apt to cause death unless a large portion of the body is exposed.

Since many types of silicones are available, safe practices indicate that only those of a low order of toxicity should be used as mold-release agents. These are the methyl, mixed methyl, and phenyl-polysiloxane types.

Solvents (General)

Because of the large number of solvents used in the foundry, it is impractical to treat them specifically here. However, no absolutely safe solvent exists—except, perhaps, water. Some solvents are more toxic than others, but all of them can be used safely if the toxic properties are known and safe handling procedures are followed.

All containers of solvents should have warning labels attached, giving the chemical name and stating the handling precautions to be followed. For example:

CARBON TETRACHLORIDE

DANGER!

HAZARDOUS VAPOR AND LIQUID MAY BE FATAL IF INHALED OR SWALLOWED

USE only with adequate ventilation

DO NOT use in confined unventilated places without protective respiratory equipment

DO NOT breathe vapor

AVOID prolonged or repeated contact with skin

DO NOT take internally

Some states already have labeling codes that have the force and effect of law.

Since most solvents are flammable, they present the danger of fire or explosion in addition to their toxic properties.

Given the chemical (not trade) name of the ingredients, the characteristics and dangers of the solvent can be ascertained. Threshold limits are of wide range because of varied toxicity factors, and maximum allowable concentrations range from 1 part per million for nitrobenzene, to 500 parts per million for petroleum naphtha.

Sulphur Dioxide

Sulphur used as a deoxidant in the manufacture of magnesium castings burns down to sulphur dioxide. Breathing zone concentrations of the dioxide gas vary during the production of magnesium castings.

A concentration of 10 parts per million is common, and 50 parts per million is rare. Maximum allowable concentration is 10 parts per million.

Continued exposures in excess of the maximum allowable concentration produce inflammation of the respiratory system, increased fatigue, excess acid in the urine, and alteration of the senses of smell and taste.

Exposure to concentrations of the order of 500 parts per million are dangerous to life. In foundries this value will not be reached. Concentrations in excess of the maximum allowable are so intolerable to man that he will not remain in an atmosphere dangerous to his life.

The gas may be regarded as an irritant nuisance and, depending on degree present, exhaust ventilation may be required.

Tellurium

Tellurium is used in foundry practice to increase the chill-depth hardness and to improve the machinability of alloys. It is generally used in very small amounts (5 grams to 800 lb of metal).

Fumes of the element are toxic, characterized principally by a garlic odor of the breath and urine, suppression of sweat, dryness of the mouth, metallic taste, loss of appetite, salivation, and vomiting. Serious industrial poisonings are rare.

Maximum allowable concentration is 0.1 milligrams per cubic meter of air. If foul breath is to be avoided, this value should not be exceeded. Systemic poisoning does not occur unless the exposure is to a concentration of 0.8 milligrams or more per cubic meter of air.

For practical purposes, the presence or absence of "tellurium breath" can be relied upon to measure the degree of exposure. If this is heeded as an indication of the need for control measures, injurious exposure is not likely to occur.

Tin

The metal tin is commonly used in alloys and is considered nontoxic. Inhalation of tin oxide over long periods may result in a nondisabling pneumoconiosis, as demonstrated by x-rays. No cases have been reported in the foundry industry.

In practice, use of tin does not present a health problem. No maximum allowable concentration has been established.

Welding

(See Welding and Wood Working Section 9.)

Zinc

Inhalation of the fumes of zinc oxide gives rise to a malaria-like illness called brass-founders ague, zinc chills, smelter shakes, or metal fume fever. The illness rarely lasts more than a day, causes no permanent disability, and is never fatal.

When brass contains zinc, fumes of the oxide are readily given off in voluminous amount during melting and pouring because of the low boiling point of the metal.

Maximum allowable concentration is 15 milligrams per cubic meter of air.

APPENDIX

MAXIMUM PERMISSIBLE LIMITS OF AIR CONTAMINATION

The following maximum allowable concentration (M.A.C.) values for continuous 8-hr exposure are recommended by the American Conference of Governmental Industrial Hygienists, and are revised when toxicological data warrants.

GASES AND VAPORS			
Substance	M.A.C. (ppm*)		
Acetaldehyde	200	Amyl acetate	200
Acetic acids	10	iso-Amyl alcohol	100
Acetic anhydride	5	Aniline	5
acetone	500	Arsine	0.05
croton	0.5	Benzene (benzol)	35
Acrylonitrile	20	Bromine	1
Ammonia	100	1, 3-Butadiene	1,000
		n-Butanol	50
		2-Butanone	250
		n-Butyl acetate	200
		Butyl "cellosolve"	200
		Carbon dioxide	5,000
		Carbon disulfide	20
		Carbon monoxide	100
		Carbon tetrachloride	50
		"Cellosolve"	200
		"Cellosolve" acetate	100
		Chlorine	1
		2-Chlorobutadiene	25
		Chloroform	100
		1-Chloro-1-nitropropane	20
		Cyclohexane	400
		Cyclohexanol	100
		Cyclohexanone	100

*ppm - part per million.

SECTION 4

Molding and Coremaking Problems

The operations of coremaking and shell molding involve sand preparation, and are basically the same in all branches of the foundry industry whether the operations be mechanized or not. However health hazards, if any, arising out of such processes vary not only from shop to shop but from workman to workman.

Some casting processes require more critical sand preparation than others: parting and facing compounds vary in degree of toxicity: some shops use core blower machines, others do not: the manual application of silica flour to a mold face may be done in a safe manner by one molder, whereas the same job may be hazardous when performed by a careless one.

It is beyond the scope of this section to consider all the differences in shop practices and conditions that might be encountered in sand preparation, coremaking and molding, hence recommended safe procedures herein described refer to general foundry practice. It should be borne in mind that regulatory codes by any authority of jurisdiction must be complied with regardless of the recommendations in this Manual.

SAND PREPARATION

For convenience, several operations may be classified under the general heading of sand preparation as follows:

1. Unloading (receiving)
2. Conveying
3. Storing
4. Drying and cooling
5. Mixing

It should also be kept in mind that sand used in foundry practice usually is a mixture of sand grains, silica flour, bentonite, carbon, various binders and metallic impurities. Thus the tendency to regard silica as the sole potential health hazard in sand preparation should be avoided. Sand constantly reused eventually becomes contaminated with metallic particles, and in the case, for example, of the manufacture of high-lead bronze or beryllium-copper castings, the contamination from lead or beryllium may be a far greater health hazard than that due to pure silica dust.

Thus the existence of a health hazard resulting from any of the five operations previously mentioned depends on a number of factors as follows:

1. Physical state of the sand
2. Chemical composition of the sand
3. Method of operation or handling
4. Frequency and duration of dusty exposure

In lieu of a quantitative hygienic study, application of these four factors to a specific situation should en-

able the foundryman to approximately evaluate an exposure. If a health hazard is then found to exist control measures may be applied according to the ventilating principles and methods set forth in Sections 2 and 3 of this Manual.

Bearing in mind these four basic factors, it may be of benefit to consider their application to a specific operation and wherein health may be affected by them. For example, applying these factors to the operation of sand unloading, the following analysis may be made:

Factors	Effect on Health	Reason for Effect
Physical State of Sand		
1) New sand already screened and dust free	No health hazard	Particles too large for retention in the lungs
2) New sand wet condition	No health hazard	No dust
3) New sand fine and dry	Potential hazard	Dusts
4) Used sand	Potential hazard	Contains fines and therefore dusts
Chemical Composition of Sand		
1) Olivine (mixture of silicates and oxides) and zirconite sands	No health hazard	Physiologically inert materials
2) Clays (mixture of silicates) and inert binders (dextrose)	No health hazard	Physiologically inert materials
3) Sand contaminated with toxic metallic particles	Potential hazard	Poisonous metallic dust
4) Pure quartz (Silica SiO_2)	Potential hazard	Siliceous dust
Method of Operation		
1) Unloaded by vacuum system	Potential hazard	Dusts unless controlled at specific locations
2) Compressed air in closed pipe system	Potential hazard	Dusts unless controlled at specific locations
3) Belt conveyor	Potential hazard	Dusts unless controlled at specific locations
4) Clam shell	Potential hazard	Dusts
5) Mechanical shovels	Potential hazard	Dusts
6) Work done outdoors	Potential hazard	Natural ventilation minimizes dust concentration
7) Manual indoor work (sweeping, sand cutting)	Potential hazard	Dusts
Frequency and Duration of Operation		
1) Eight hr/day every day	Potential hazard	Sufficient exposure
2) Eight hr/day — one day/week	Potential hazard	Weighted exposure
3) One hr/day — 5 days/week	Potential hazard	Weighted exposure

BERTRAM H. JOHNSON
1875 - 1935

The American Foundrymen's Association suffered the loss of one of its most loyal and beloved members and active workers, in the death of Vice President Bertram H. Johnson, who while attending the 1935 Toronto Convention, became ill and passed away in that city on August 29. For many years Mr. Johnson had been active in the work of the A.F.A., serving on committees and representing the Association in its connections with other technical organizations. Elected a director in 1926, he served in this capacity for three years. Then in 1934 he was named Vice President, serving with such distinction that he was elected for a second term at the Toronto Convention.

Mr. Johnson was born at Lynn, Mass., where he received his early education. His technical training was obtained at Massachusetts Institute of Technology. After graduation he became associated with Taylor and Gooding, engineers and machinists of Lynn, and when that firm was merged with the John T. Robinson Co., Hyde Park, Boston, Mr. Johnson accepted the position as superintendent. In 1910, he became connected with the Cresmon-Morris Co., of Philadelphia as works manager and remained associated with that company for a period of over 15 years. He then became connected with R. D. Wood Company, first at its Florence Pipe Foundry & Machine Co., Florence, N. J., plant and later in the Philadelphia office as assistant to the President, the position he held at the time of his death.

Mr. Johnson was identified with a group of foundrymen, who in 1926, conceived the idea of establishing a trade association for the gray iron jobbing foundry industry, which resulted in the formation of the Gray Iron Institute. Mr. Johnson was elected first vice president of the Institute and later served for one year as president.

Mr. Johnson was an active member of the Philadelphia Foundrymen's Association during his entire residence in that city. He took an active part in all technical and committee work and was a leader in the reorganization of the Philadelphia Foundrymen's Association as the Metropolitan Philadelphia Chapter of A.F.A.

TRANSACTIONS

of the

American Foundrymen's Association



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1936

capable as he may be, is generally unfamiliar enough with this particular field to qualify, originally at least, for that work.

MEMOR: Are there any authentic published negative reproductions that would guide, not the amateur in any but a physician who has pursued it beyond the experimental stage, in differentiating between silicosis and tuberculosis?

MR. CUMMINGS: Yes, I think there are. The question of differential diagnosis of silicosis is one that is difficult and though one might get reproductions of cases which were typical for any given industry, it would be quite possible to bring forth films which simulated the appearance of the films that were used for demonstration which might consist of quite another pathological process, and hence I would still suggest that this particular field be left in the realm of experts, much as Ontario has delegated its authority to people who have made a special study of it.

Dust Collection in the Foundry

By S. D. MOXLEY,* BIRMINGHAM, ALA.

Abstract

Due to the need for preventing health hazards in foundries and to the increasing inclusion of references to dust elimination in state labor and occupational disease acts, greater attention must be paid to dust collection in foundries. A most economical way to meet this problem is to do a good job of house cleaning and by the installation of proper equipment for eliminating dust. The dust collection problems consist of three phases, apprehension, collection and disposal. Each of these three phases are discussed. Types of equipment are shown and compared. Dust characteristics are described. Under collection seven types of equipment are listed and discussed. In conclusion, it is stated that it is for the engineer and foundryman to properly analyze the problem at hand and to ascertain the degree of fineness of dust it is expected to collect before choosing the collector.

1. In recent years there has been an increasing interest shown in the prevention of dust in the foundry. Many of the northern and eastern states have references to dust elimination in their labor laws and quite a number have included occupational diseases caused by excessive dust inhalation in their workmen's compensation laws. This legislative action is rapidly spreading to other states and will in time no doubt include all of the states in the Union. Industry is vitally interested in this problem from the standpoint of health, dust nuisance in plant and surrounding community, and depreciation in equipment.
2. Undoubtedly the most economical way to meet this problem is to do a good job of house cleaning first and then install the proper equipment for eliminating the dust. There are so many kinds of equipment and methods used in the various phases of dust collection and air conditioning that the engineer and foundryman faced with dust problems sometimes become confused while at

* Chief Engineer, American Cast Iron Pipe Co.
Note: This paper was presented at a session on Dust Control and Safety Codes at the 1935 Convention of A. P. A. in Toronto, Canada.

tempting their solution. There is a methodical approach to the problem in every case, and there are a few basic principles involved which, while familiar to most engineers, are not always practiced in the foundry. It is the aim of this paper to clarify some of the points that most commonly cause confusion and result in inefficient and inadequate systems.

3. Quite often a system is designed for sand conditioning as well as elimination of dust nuisance. The same equipment can perform both of these operations satisfactorily, as usually they are inter-related. It is not often in the foundry that the recovered material has any economic value, therefore the separation of sizes of particles collected is not important. The problem then naturally breaks down into the following three distinct phases: Apprehension, collection and disposal.

APPREHENSION

4. In most cases the apprehension of the dust is the simplest but least understood of the problems. Almost without exception the best place to catch the dust is at the point of creation, as once it is liberated into the atmosphere it is very difficult, if not impossible, to recover.

Use of Hoods.

5. It is common practice to provide hoods over dusty areas which are fitted with suction pipes leading to the collector. This is illustrated in a general way by A of Fig. 1. In this type of installation the hood should be as small as possible and the openings in the hood reduced to a minimum. It has been found by the writer that with most foundry dust it is necessary to maintain a velocity in all hood openings of from 250 to 300 ft. per min. to prevent dust escaping from the hood. Fig. 1 B illustrates roughly the use of a small hood attached to a flexible exhaust pipe, which has been used quite successfully in connection with snagging wheels for grinding castings. There are many other variations of this principle used in connection with grinding operations.

6. Fig. 1 C illustrates a close fitting hood applied where dry sand is fed on a belt. The hood openings are kept as small as possible.

7. When conditioning sand by removal of fines, it is most effective to pass all of the shake-out sand through a current of air. A successful method of removing the desired size of particles is

shown in Fig. 1 D. A constant velocity and volume is maintained in the duct at all times. The end of the duct is provided with a hinged hood having an opening near the sand stream, approximately 50 per cent larger than the duct itself. This hood can be adjusted to varying distances from the sand stream, which regulates the effective velocity through the sand stream and hence the particle size removed from the sand. As the air velocity in the

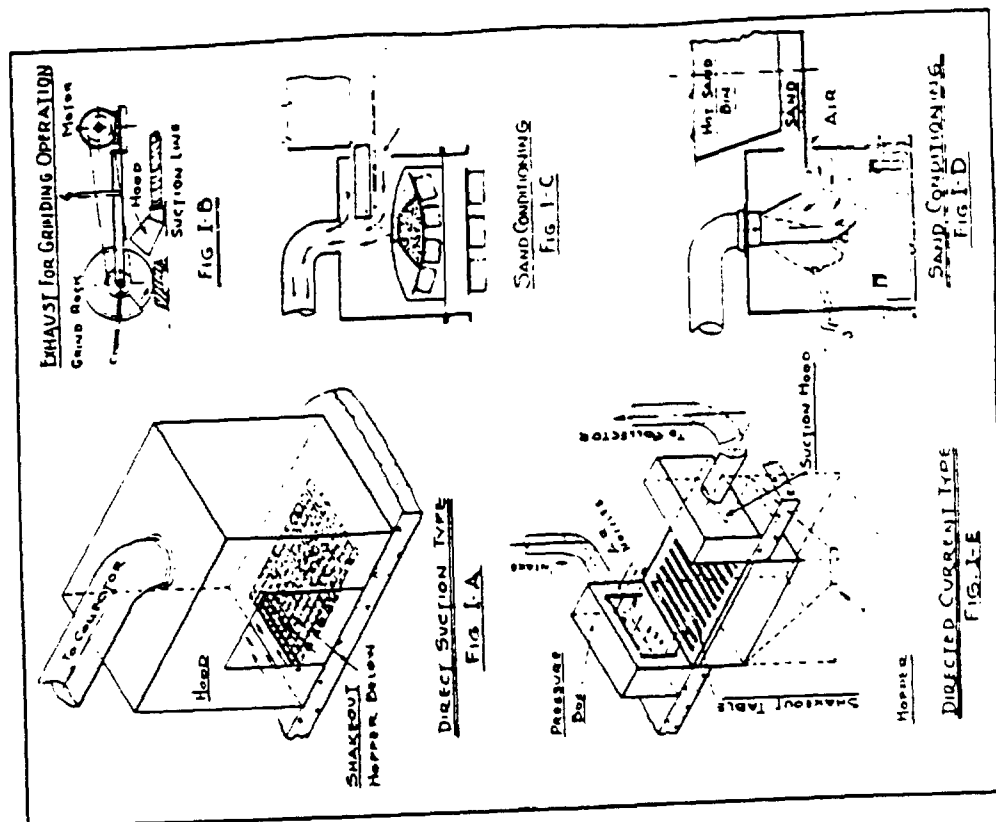


FIG. 1. TYPICAL HOODS FOR TRAPPING DUST

dust is always greater than at the opening of the hood, any particle which is picked up at the hood opening will surely be carried in suspension to the dust collector with no clogging of the air duct.

8. A method of controlling dust known as the air curtain dust control system has recently been developed and patented which has proved quite successful. Fig. 1 E illustrates its application to a shake-out station. A pressure box is provided with thin slots on the top and sides which keeps a thin layer of air moving at a high velocity over and around the shake-out operation. This prevents the dust generated in the shake-out operation from passing through the air curtain and into the atmosphere. At the other end of the station is a suction hood which receives the projected air curtain and exhausts it along with the dust laden air arising from the shake-out. The air is passed through equipment which removes the dust before it is recirculated.

9. In sand conditioning machinery, where the sand is handled in many types of machines and conveyors, there are of necessity large amounts of dust created. It is usually possible, although sometimes inconvenient, to provide practically all such equipment with hoods which are exhausted to a dust collector. The removal of fines for sand conditioning purposes should be done at the shakeout while the sand is hot, as this is usually the first point of origin of dust in the plant. If separation is made at this point there would naturally be less dust to escape in the remaining operations. Oftentimes it is almost impossible to provide suitable hoods for shake-out and cleaning stations. In such cases these departments can be enclosed or moved to a distance from the other operations to prevent atmospheric contamination in the rest of the plant. The men in these departments may be provided with suitable respirators.

Correct Design of Hood Pipes.

10. Correct design of the pipes connecting the hoods to the dust collectors is essential to an efficient system. Branch lines should enter the main at the smallest possible angle and the main should be increased in size proportionately at each connection to prevent variation in the velocity of the air. These branch lines should enter the sides of the main. Dust pipes which incline downward in the direction of flow usually give trouble by clogging.

11. A system should contain as few elbows as possible and they should be of the longest radius permissible and never less than

$1\frac{1}{2}$ times the diameter as measured on the center line of the elbow. Ordinary foundry dust can be handled with little clogging of the pipes by an air velocity of between 2500 and 3000 ft. per min.

COLLECTION

Types of Collectors.

12. In dust collecting equipment for sand conditioning and dust nuisance prevention in the foundry, the following types of equipment usually are considered:

- (a) Centrifugal.
- (b) Centrifugal, (Pan Type).
- (c) Cloth Screen.
- (d) Cloth Bag.
- (e) Electrical Precipitation.
- (f) Washer.
- (g) Froth-Flotation.

13. Each of these types has distinct advantages in certain fields and the writer believes there is no particular type that can be economically and satisfactorily applied to all problems. It should be remembered that every dust prevention job is more or less peculiar in itself, and the equipment selection should be the one best adapted to all phases of the problem.

Dust Characteristics.

14. Fig. 2A shows certain characteristics of dust, and the general range of the various types of dust collecting apparatus with reference to recovery. This chart reproduced from the original supplied by the American Air Filter Co., Inc. has been modified slightly by the writer with reference to range of recovery of grain sizes by some of the equipment suggested for recovery. This has been done to make it more applicable to foundry dusts.

15. The dust to be recovered should be analyzed for the following:

- (a) The nature of the dust from the standpoint of grain size and percentages of the various sizes of particles.
- (b) Specific gravity.
- (c) Amount of clay or other sticky substances contained.
- (d) Moisture.

(c) Temperature

(f) The degree of fineness it is necessary to collect (this factor is usually determined by the shop conditions and the proximity to the surrounding communities).

Head Openings.

16. Next, the hoods at the various points of collection should be designed and the areas of head openings determined. With known velocities the volumes of air can be determined and correct design of air ducts made. These calculations will also show the volume of air to be handled by the dust collector and the pressure under which the system is to operate.

17. If possible, the probable dust concentration per cubic foot of air which will be delivered to the dust collector should next be determined. Usually, all of this information can be determined by the local engineer in cooperation with testing laboratories or engineers representing manufacturers of dust collecting equip-

Type	Style	Vol. Air Per Sq. Ft. Min. Grain Size Microns	Temperature Lumina	Moisture Lumina	Dust Con. Cent. Gr. Int. Gr. Cn. Ft.	Concentration 5 Gr. Int. Gr. Cn. Ft.	Efficiency 5 Gr. Cn. Ft. Unit	Relative Cost 15,000 Cn. Ft. Unit	Max. Gr. Seen With Naked Eye	May Be Seen With Microscope	Dusts	Fumes	Heavy Industrial	Electrical Precipitation	Air Cleaners	Washers	Oil Flotation
A	70-75	900° F	Dewpoint	Any	75	95%	85%	\$ 750									
B	70-75	800° F	Dewpoint	Any	75	90%	55%	1,000									
C	50-60	850° F	Dewpoint	Any	50	95%	90%	2,000									
D	35-40	500° F	Dewpoint	Any	10	98%	95%	2,500									
E	35-40	1800° F	Dewpoint	Any	10	98%	95%	3,000									
F	25-30	750° F	Dewpoint	150	50	90%	90%	2,000									
G	5-10	200° F	Dewpoint	10	025	99%	99%	4,000									
H	5-10	Cotton 200° Wool 250° Fabr.	Dewpoint	20° Above	025	99%	99%	6,000									
I	Any	Suspended Particle	None	None	Any			10,000									
J	5-10	Boiling Point of Liquid	None	None	017	99%	99%	4,000									
K	5-10	Boiling Point of Liquid	None	None	25	99%	99%	4,500									

Table 1
Dust Collector Characteristics

*For detail sketches or illustrations or apparatus of these styles, see Figs. 1, 2, 4, 5, 6, 7 and 8.

FIG. 2A.—SIZE AND CHARACTERISTICS OF AIR BORNE SOLIDS (REPRODUCED BY PER-
MISSION OF THE AMERICAN AIR FILTER CO. SLIGHTLY MODIFIED BY S. D. MORTLEY
WITH REFERENCE TO RANGE OF RECOVERY OF GRAIN SIZE AND THE EQUIPMENT
SUGGESTED FOR RECOVERY.)

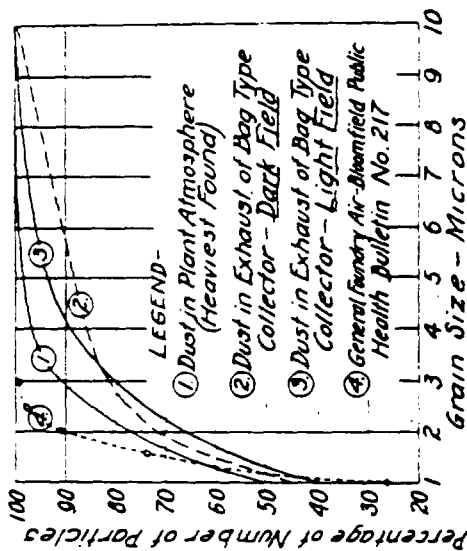


FIG. 20. PARTICLE SIZE DISTRIBUTION OF AVERAGE DUST BY NUMBER OF PARTICLES INSTEAD OF WEIGHT AS SHOWN IN FIG. 20. SAMPLE TAKEN BY IMPINGER METHOD AND COUNT MADE USING MAGNIFICATION OF 500.

plation is in sand conditioning, exhausting tumbling barrels, etc., rather than preventing pollution of the atmosphere. These general types are familiar to foundrymen. (Fig. 3, A and B.)

21. Style C, Table 1, indicates reported characteristics of a centrifugal cone collector which consists of a number of small centrifugal cones connected as a unit. (Fig. 3 C.)

22. Styles D and E, Table 1 (Fig. 3, D and E), show the more efficient styles of centrifugal collectors. The double scroll type, shown as style E, is one of the most efficient of the centrifugal collectors from the standpoint of collection of the finer particles. The skimmer type collector is shown as style D (Fig. 3 D), which has a relatively high efficiency in collecting fine particles.

23. The characteristics of the fan type centrifugal collector are given as style F, Table 1. It is a combination fan and centrifugal collector driven by an electric motor. (Fig. 3 F.)

24. If the dust concentration is high, and the percentage of fine particles is high, with a relatively low specific gravity dust, these types of collectors can not be depended upon to solve a dust nuisance. When 50 per cent or more of a dust passes through a 325 mesh screen these types of collectors are apt to release into the atmosphere objectionable amounts of dust. This is particularly true when a large proportion of these fine particles is clay or other binding materials of impalpable character. However, on dusts

having high specific gravity such as pure silica sand, this type of machine can be efficient in the collection of extremely fine particles.

25. The cloth screen filter which has found wide application in the collection of foundry dust has characteristics shown under Style G, Table 1 (Fig. 4). Where it is necessary to collect the extreme fines, and where the dust concentration per cu. ft. of air is not high, this type of equipment has proved most efficient. The limitations of this apparatus are usually found in the amount of moisture in the air, the temperature, the nature of the dust, and the dust concentration of the air stream.

26. Where high concentrations are combined with relatively high percentage of very fine particles, and where the particles

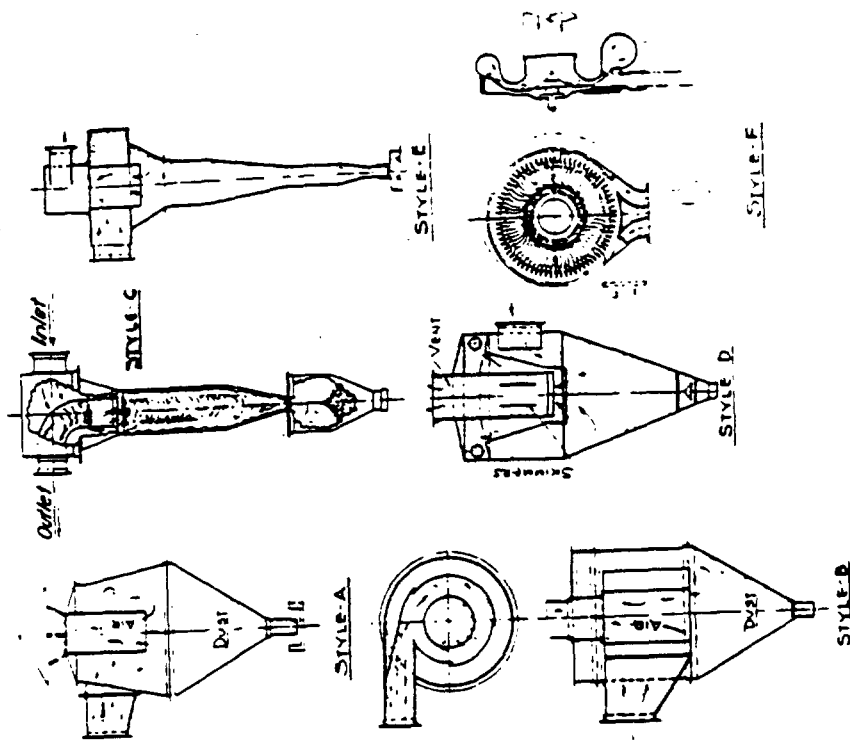


FIG. 3. SIX STYLES OF CENTRIFUGAL DUST COLLECTORS. STYLE F IS A FAN TYPE CENTRIFUGAL COLLECTOR.

themselves are composed of clay or other sticky substance with moisture included, the shaking mechanism is usually found inadequate to clean the cloth screen. This shaking is usually done by mechanically operated rappers, and the air must be cut off during the rapping operation. Practically any size material can be collected efficiently by this type of apparatus if it is provided with an expansion chamber or balloon type manifold which will first settle out of the air stream the larger particles.

Cloth Bag Collectors

27. For the higher concentrations of dust and the greater percentages of impalpable fines the bag type cloth filter of Style II, Table 1 and Fig. 5, has been found more satisfactory. It is also more effective on relatively high moisture conditions. The reason for this is that the bag type collector has a much more effective shaking mechanism. The collecting unit is divided into compartments, each containing from 15 to 18 bags suspended on a rack which is shaken by pneumatic equipment. During the shaking period the compartment is disconnected from the fan and the direction of the air is reversed. The compartment is then automatically cut into service while another compartment is disconnected for shaking. By this arrangement only a small part of the capacity of the collector is removed from service during the shaking operation. Large amounts of moisture can be handled by the bag type collector with little difficulty if the temperature of the air is kept some 20 degrees Fahr. above the dew point.

ELECTRICAL PRECIPITATION

28. Another type of dust collecting equipment which may require consideration in the collection of foundry dust is the electrical precipitator. Characteristics of this equipment are given in Table 1. The principle of operation is to pass the dust laden air through a strong electrostatic field where the dust particles are ionized. In this condition they will be attracted by the electrodes of opposite polarity.

29. A simple form of the apparatus is shown as Fig. 6, where a fine wire is suspended in and insulated from a vertically mounted pipe. By electric connection the pipe acts as the positive electrode and the wire as the negative electrode. Dust laden air passing through the pipes becomes a part of the electric circuit, and is ionized, caused the suspended particles to be precipitated on the

interior of the pipe. Another form of this apparatus is also indicated (Fig. 6) where vertically supported concrete slabs form the positive electrodes, while vertically suspended wires between these slabs form the negative electrodes. In this case the ionized dust particles are attracted to the sides of the concrete slabs. They are

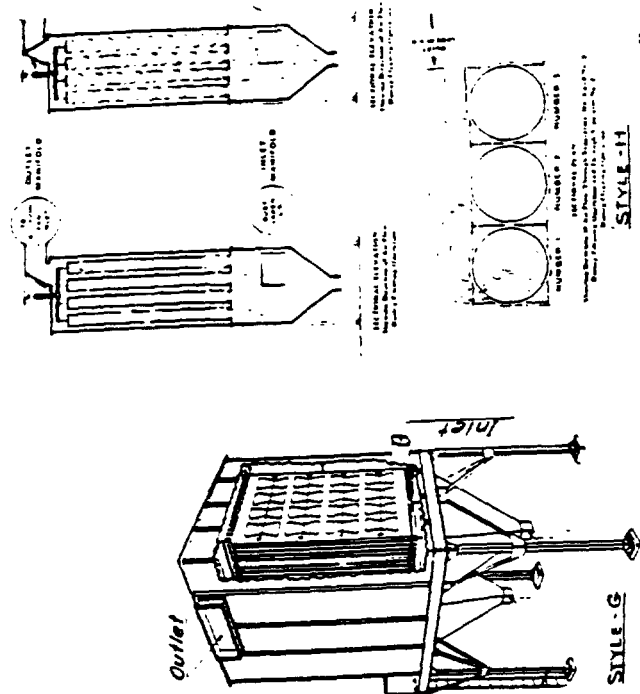


FIG. 4 CLOTH SCREEN FILTER.

FIG. 5 - BAG TYPE CLOTH FILTER.

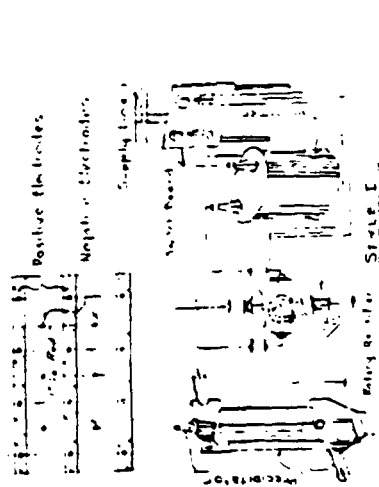
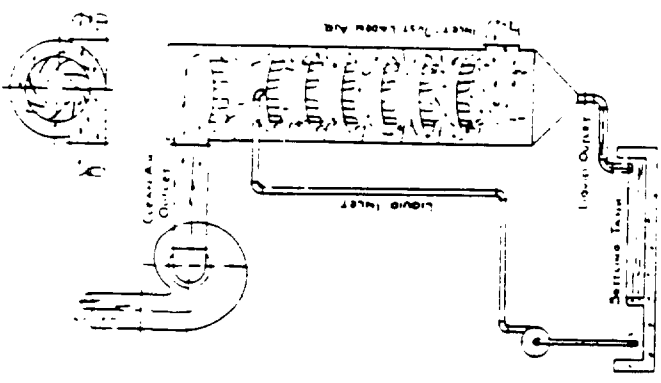
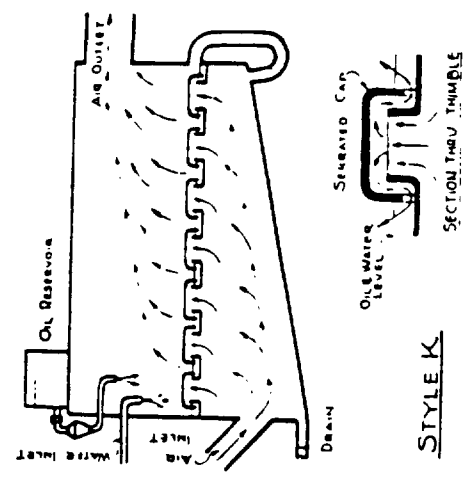


FIG. 6 TWO ELECTRICAL PRECIPITATION TYPE COLLECTORS.



STYLE J
FIG. 7 - WET DUST SETTLING COLLECTOR



STYLE K
FIG. 8 - FROTH FLOTATION DUST COLLECTOR

discharged by gravity into hoppers below. Sometimes mechanical scraping or cleaning devices are used to remove the precipitated dust.

30. The efficiency of this type apparatus on fine particles can be very high if the equipment is designed properly. The writer does not know of an installation of this kind being used for the collection of foundry dust. The reason it has not been used in this field, probably, is the high initial cost of the equipment. With the rapid improvements now being made, this disadvantage may shortly be overcome.

31. Style J (Fig. 7) shows an adaptation of the wet dust collector principle which has recently been applied to the collection of foundry dust. The dust laden air is introduced at the bottom of the tower tangentially. Water or other absorbing liquid enters the top of the tower and falls in a spray through succeeding plates, making contact with the upward moving dust laden air. Vanes are mounted on the bottom of the center plates which cause the air to travel upward in a spiral course. There are two washes per plate and usually six plates or twelve washes are used.

32. The collected material is absorbed in the liquid and flows by gravity from the bottom of the tower into settling tanks. The water from these tanks is recirculated in the tower and the sediment is disposed of by the most convenient means.

33. In Table 1 there are given reported characteristics of a collector of this type (Style J). The claims made for this equipment are beyond the performance of the usual type of scrubbers or air washers which have been tried in the dust collection field. The author has indicated such characteristics as were available without having them verified.

34. An equipment using oil flotation which utilizes the bubble tower principle is shown as Style K (Fig. 8). This newly developed apparatus was announced and displayed about a year ago. Dust-laden air is drawn through ducts to a distributing chamber. The air passes upward through thimbles and is deflected downward by means of hooded bells passing first through water and then through a froth filter carpet. The filter carpet is obtained by frothing oil on the surface of the water. The dust trapped in the wetting agent is floated over an adjustable weir to a settling chamber. The cleaned air passes to the exhaust manifold and into the atmosphere.

35. The characteristics shown for Style K in Table 1 are

based on tests made in the laboratory of a well known technical school. These tests were made using dusts similar to that encountered in the foundry. Additional time and practice will be required to determine the full scope of application of this equipment in the foundry dust collecting field.

OTHER TYPES

36. Attempts have been made to adapt many other types of collecting equipment to foundry dust, such as the dry air filter using a paper composition filter medium, the viscous film filter, and the usual types of air washers. Little success has been met with these types of equipment in the foundry dust collecting field as they are either not suited to the type of dust, or the dust concentration is far beyond the range of the equipment. For these reasons, they have been purposely omitted from this paper. The dry air filter is effective in cleaning air for ventilating and positive pressure respiratory systems, as the viscous type filter is suitable for cleaning air to compressors. Such services are not within the scope of this paper.

DISPOSAL

37. The disposal of the collected dust often presents a real problem, as once the dust is collected it must not be liberated into the air. There are many types of equipment such as screw conveyor loaders, etc., which can be adapted to most installations. Often the dust is so fine that it cannot be transported in open wagons or cars and if air tight wagons or cars are used, the vibration in transit settles the dust so that the whole mass becomes hard and cannot easily be discharged. A method of overcoming this difficulty, which has been used quite successfully, is to discharge the dust into an agitated water tank some 2 ft. below the surface of the water, thus mixing a sludge composed of water and dust. This sludge can be readily pumped to the disposal point by suitable sludge pumps. After each pumping the sludge line should be thoroughly purged with clean water to prevent settlement in the line.

POWER AND MAINTENANCE

38. The power requirements of the various dust collecting equipments will depend altogether on the particular installation. In centrifugal collectors of the low efficiency type it may be as low as 1 H.P. per 1000 cu. ft. of air per min. and as high as 3 H.P. in

the high efficiency unit, where it is necessary to greatly increase the air velocity in the collector in order to collect a greater proportion of the extreme fine particles. In general, it can be said that the maintenance on these types of machines is relatively low, as the only upkeep involved is caused by abrasion on the collector and fan. The fan is usually protected by being placed at the outlet end of the collector, thus handling the finer and less abrasive particles. To overcome this wear, the centrifugal fan type collector has a rubber lined rotator and casing when installed for abrasive dust.

39. The power required in cloth collectors will vary from 1 to 2 H.P. per 1000 cu. ft. of air per min. depending upon the relative size of the equipment and the concentration and nature of the dust. Maintenance is relatively high because of screen and bag replacement. Also, the equipment is more elaborate as there are more moving parts to keep in repair and adjustment.

40. In the washer type collector the air velocity is relatively low with a corresponding low power requirement of 1.5 H.P. per 1000 cu. ft. or less. The water recirculated will contain relatively large amounts of dust unless large and hence expensive settling tanks are provided. Due to the small amount of water recirculated, the total cost of pump maintenance would not be high.

41. The power requirement for the oil flotation collector is approximately 1.5 H.P. per 1000 cu. ft. The water and settling tank requirements approximate those of the washer type. Only a small amount of low cost oil is required.

CONCLUSIONS

42. In solving a foundry dust problem there are many factors to be considered. In northern climates the shop buildings are necessarily completely enclosed and the operations compact. Many of them are in densely settled communities. Such conditions demand highly efficient dust collecting equipment which in some cases might approach air-conditioning practice. In the south we find open type buildings with maximum natural ventilation in thinly populated areas. Under such conditions a much higher dust concentration can be discharged from the operations without undue pollution of the surrounding atmosphere.

43. Weight efficiencies of dust collectors are of little value unless considered along with a complete analysis of the dust to be

caught and the operating conditions. The percentage of silica has a direct bearing on the problem.

44. Some workers in the field have recommended the maximum number of particles per cu. ft. based on certain free silica content for safe atmospheric working conditions.

45. Rather than efficiency, a more satisfactory way of expressing effectiveness would be the concentration and dust count of the air exhausted from the collector. Such information can be readily obtained by various apparatus such as the impinger dust sampling apparatus as used by the United States Public Health Service. These values could then be compared with those thought to represent safe atmospheric working conditions. These data would indicate the advisability of discharging a collector into an enclosed building.

46. It is for the engineer and the foundryman to properly analyze the problem at hand, and to ascertain the degree of fineness of dust it is expected to collect before attempting to choose the collector. Since any type of collector will collect a certain amount of real fine particles, in general, it is better to have an inefficient collector than no collector at all. If the dust is collected immediately at the point of its creation, the chances are good that the dust found in the general atmosphere of the shop will be within reasonable safe limits.

(Discussion of this paper begins on page 222)

Methods of Dust Control

By J. D. LEITCH,* TORONTO, CANADA

Abstract

Dust must arise from a source and, according to the author of this paper, the point to begin elimination of the dust hazard is at that source. In his paper, the author discusses methods used for controlling the dust hazards which originate at different types of sources. He discusses the general methods used in dust suppression problems and the estimation of the hazard, contending that the efficiency of a dust collection system is best determined by dust counts. He explains methods used for testing ventilating equipment and discusses the selection of fans. The latter section of the paper deals with the dust collection equipment itself. Dust collectors of various types and respirators such as helmets, filter type respirators and positive pressure masks are discussed. The paper closes with the admonition that maintenance of equipment is necessary to the successful operation of such equipment and to the efficiency of any installation.

1. The engineering aspects of the dust problem must deal entirely with prevention and must be concerned with manufacturing processes, production requirements, and other economic considerations. It is necessary to obtain the greatest reduction in dust concentration with the minimum capital expenditure and maintenance costs. It can readily be shown by considering a number of particular cases, that money spent to improve health conditions often has resulted in unexpected economies in the processes which more than paid for the original outlay in a very short time.

DIFFICULTY OF LAYING DOWN GENERAL REGULATIONS GOVERNING THE CONTROL OF DUST IN INDUSTRY

2. From a public health point of view, it is desirable to lay down minimum rules covering the suppression of dust for all op-

* Ontario Department of Health.

NOTE: This paper was presented at a session on Dust Control and Safety Codes at the 1933 Convention of A.F.A. in Toronto, Canada.

discharged by gravity into hoppers below. Sometimes mechanical scraping or cleaning devices are used to remove the precipitated dust.

30. The efficiency of this type apparatus on fine particles can be very high if the equipment is designed properly. The writer does not know of an installation of this kind being used for the collection of foundry dust. The reason it has not been used in this field, probably, is the high initial cost of the equipment. With the rapid improvements now being made, this disadvantage may shortly be overcome.

31. Style J (Fig. 7) shows an adaptation of the wet dust collector principle which has recently been applied to the collection of foundry dust. The dust laden air is introduced at the bottom of the tower tangentially. Water or other absorbing liquid enters the top of the tower and falls in a spray through succeeding plates, making contact with the upward moving dust laden air. Vanes are mounted on the bottom of the center plates which cause the air to travel upward in a spiral course. There are two washes per plate and usually six plates or twelve washes are used.

32. The collected material is absorbed in the liquid and flows by gravity from the bottom of the tower into settling tanks. The water from these tanks is recirculated in the tower and the sediment is disposed of by the most convenient means.

33. In Table I there are given reported characteristics of a collector of this type (Style J). The claims made for this equipment are beyond the performance of the usual type of scrubbers or air washers which have been tried in the dust collection field. The author has indicated such characteristics as were available without having them verified.

34. An equipment using oil flotation which utilizes the bubble tower principle is shown as Style K (Fig. 8). This newly developed apparatus was announced and displayed about a year ago. Dust laden air is drawn through ducts to a distributing chamber. The air passes upward through thimbles and is deflected downward by means of hooded bells passing first through water and then through a froth filter carpet. The filter carpet is obtained by frothing oil on the surface of the water. The dust trapped in the wetting agent is floated over an adjustable weir to a settling chamber. The cleaned air passes to the exhaust manifold and into the atmosphere.

35. The characteristics shown for Style K in Table I are

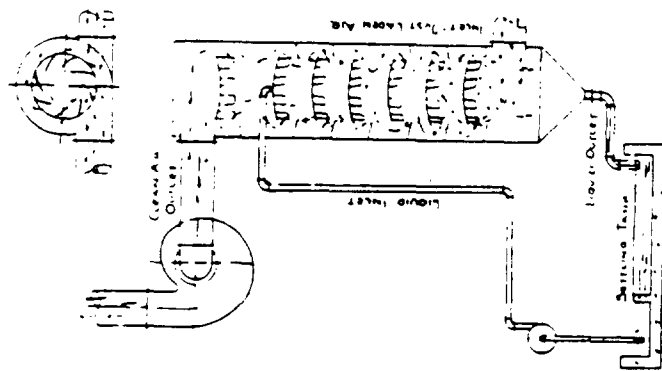


FIG. 7. WET DUST STYLE COLLECTOR

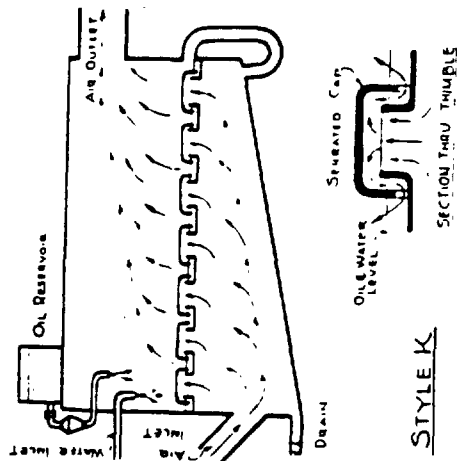


FIG. 8. FROTH FLOTATION STYLE COLLECTOR

based on tests made in the laboratory of a well known technical school. These tests were made using dusts similar to that encountered in the foundry. Additional time and practice will be required to determine the full scope of application of this equipment in the foundry dust collecting field.

OTHER TYPES

36. Attempts have been made to adapt many other types of collecting equipment to foundry dust, such as the dry air filter using a paper composition filter medium, the viscous film filter, and the usual types of air washers. Little success has been met with these types of equipment in the foundry dust collecting field as they are either not suited to the type of dust, or the dust concentration is far beyond the range of the equipment. For these reasons, they have been purposely omitted from this paper. The dry air filter is effective in cleaning air for ventilating and positive pressure respiratory systems, as the viscous type filter is suitable for cleaning air to compressors. Such services are not within the scope of this paper.

DISPOSAL

37. The disposal of the collected dust often presents a real problem, as once the dust is collected it must not be liberated into the air. There are many types of equipment such as screw conveyor loaders, etc., which can be adapted to most installations. Often the dust is so fine that it cannot be transported in open wagons or cars and if air tight wagons or cars are used, the vibration in transit settles the dust so that the whole mass becomes hard and cannot easily be discharged. A method of overcoming this difficulty, which has been used quite successfully, is to discharge the dust into an agitated water tank some 2 ft. below the surface of the water, thus mixing a sludge composed of water and dust. This sludge can be readily pumped to the disposal point by suitable sludge pumps. After each pumping the sludge line should be thoroughly purged with clean water to prevent settlement in the line.

POWER AND MAINTENANCE

38. The power requirements of the various dust collecting equipments will depend altogether on the particular installation. In centrifugal collectors of the low efficiency type it may be as low as 1 H.P. per 1000 cu. ft. of air per min. and as high as 3 H.P. in

the high efficiency unit, where it is necessary to greatly increase the air velocity in the collector in order to collect a greater proportion of the extreme fine particles. In general, it can be said that the maintenance on these types of machines is relatively low, as the only upkeep involved is caused by abrasion on the collector and fan. The fan is usually protected by being placed at the outlet end of the collector, thus handling the finer and less abrasive particles. To overcome this wear, the centrifugal fan type collector has a rubber lined rotator and casing when installed for abrasive dust.

39. The power required in cloth collectors will vary from 1 to 2 H.P. per 1000 cu. ft. of air per min. depending upon the relative size of the equipment and the concentration and nature of the dust. Maintenance is relatively high because of screen and bag replacement. Also, the equipment is more elaborate as there are more moving parts to keep in repair and adjustment.

40. In the washer type collector the air velocity is relatively low with a corresponding low power requirement of 1.5 H.P. per 1000 cu. ft. or less. The water recirculated will contain relatively large amounts of dust unless large and hence expensive settling tanks are provided. Due to the small amount of water recirculated, the total cost of pump maintenance would not be high.

41. The power requirement for the oil flotation collector is approximately 1.5 H.P. per 1000 cu. ft. The water and settling tank requirements approximate those of the washer type. Only a small amount of low cost oil is required.

CONCLUSIONS

42. In solving a foundry dust problem there are many factors to be considered. In northern climates the shop buildings are necessarily completely enclosed and the operations compact. Many of them are in densely settled communities. Such conditions demand highly efficient dust collecting equipment which in some cases might approach air-conditioning practice. In the south we find open type buildings with maximum natural ventilation in thinly populated areas. Under such conditions a much higher dust concentration can be discharged from the operations without undue pollution of the surrounding atmosphere.

43. Weight efficiencies of dust collectors are of little value unless considered along with a complete analysis of the dust to be

caught and the operating conditions. The percentage of silica has a direct bearing on the problem.

44. Some workers in the field have recommended the maximum number of particles per cu. ft. based on certain free silica content for safe atmospheric working conditions.

45. Rather than efficiency, a more satisfactory way of expressing effectiveness would be the concentration and dust count of the air exhausted from the collector. Such information can be readily obtained by various apparatus such as the impinger dust sampling apparatus as used by the United States Public Health Service. These values could then be compared with those thought to represent safe atmospheric working conditions. These data would indicate the advisability of discharging a collector into an enclosed building.

46. It is for the engineer and the foundryman to properly analyze the problem at hand, and to ascertain the degree of fineness of dust it is expected to collect before attempting to choose the collector. Since any type of collector will collect a certain amount of real fine particles, in general, it is better to have an inefficient collector than no collector at all. If the dust is collected immediately at the point of its creation, the chances are good that the dust found in the general atmosphere of the shop will be within reasonable safe limits.

(Discussion of this paper begins on page 222)

Methods of Dust Control

By J. D. LEITCH,* TORONTO, CANADA

Abstract

Dust must arise from a source and, according to the author of this paper, the point to begin elimination of the dust hazard is at that source. In his paper, the author discusses methods used for controlling the dust hazards which originate at different types of sources. He discusses the general methods used in dust suppression problems and the elimination of the hazard, contending that the efficiency of a dust collection system is best determined by dust counts. He explains methods used for testing ventilating equipment and discusses the selection of fans. The latter section of the paper deals with the dust collection equipment itself. Dust collectors of various types and respirators such as helmets, filter type respirators and positive pressure masks are discussed. The paper closes with the admonition that maintenance of equipment is necessary to the successful operation of such equipment and to the efficiency of any installation.

1. The engineering aspects of the dust problem must deal entirely with prevention and must be concerned with manufacturing processes, production requirements, and other economic considerations. It is necessary to obtain the greatest reduction in dust concentration with the minimum capital expenditure and maintenance costs. It can readily be shown by considering a number of particular cases, that money spent to improve health conditions often has resulted in unexpected economies in the processes which more than paid for the original outlay in a very short time.

DIFFICULTY OF LAYING DOWN GENERAL REGULATIONS GOVERNING THE CONTROL OF DUST IN INDUSTRY

2. From a public health point of view, it is desirable to lay down minimum rules covering the suppression of dust for all op-

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Note: This paper was presented at a session on Dust Control and Safety Codes at the 1933 Convention of A.F.A. in Toronto, Canada.

erations in industry. Because of the wide variation in the dust producing processes in industry, it immediately becomes apparent that some attempt must be made to subdivide these processes. The first natural division would appear to be a division of the industries themselves into groups: foundries, granite cutting, mining, etc. This is hardly a satisfactory division from the point of view of the engineer whose job it is to consider all the industries.

3. When the foundry division alone is considered, a wide variety of processes is encountered, such as tumbling, grinding, sandblasting, coreblowing, shaking out, molding and brushing, but on examination of, say the granite industry, some overlapping occurs, for in that industry we find operations involving sawing, surfacing, polishing, sandblasting and chiseling. If a foundry were visited and then a granite shop, it would be seen that although some of the operations are similar, the most efficient methods of removing the dust are quite different in detail. Observations in a number of foundries show variations in type of equipment installed. An example of this may be noted in the different methods of sandblasting castings, i. e., barrels, sandblast rooms, cabinets and special equipment, among which may be listed numerous homemade devices. However, in spite of these variations, a number of general cases may be considered, into which most of the common processes will fit.

CONSIDER DUST SOURCE

4. First, let us consider the source of dust as a variable condition. In other words, we should always go to the source of the dust hazard and try to suppress it there before contamination of the shop air occurs.

Point Source.

5. When the source of dust is at a fixed point, it is natural to think of using a fairly high velocity through a relatively small pipe attached as closely as possible to the point. This method is desirable from the point of view of handling the minimum amount of air but care must be taken that the hood be attached very close to the point source, because it is well known how rapidly the velocity falls off as we move away from the hood face. Should the point source move in a random way, the problem of maintaining the hood close to the point becomes difficult in some cases, e. g., it is very difficult in the case of the hand pneumatic tool in the granite

industry and not so difficult in the surface machine in the same industry.

Wide Source.

6. If the origin of the dust is over a wide area one naturally thinks of two methods.

- a. Enclosing the source as much as possible and then removing sufficient air to maintain the enclosure at a pressure somewhat lower than atmospheric, or,
- b. Providing ventilation over a wide area. This necessarily involves a high volume of air and a relatively low velocity.

7. The former method would appear to be more feasible in cases where such enclosure does not interfere with the process.

Moving Dust Clouds.

8. If the process produces a cloud of dust having a definite direction of motion, advantage should always be taken of that fact by arranging to draw off the dust in the same direction. A simple example of this is the grinding wheel and the standard method of ventilating it. There are a number of cases, however, where this is not so easy on account of interference with the process, and ingenuity is required of the engineer who tackles such a problem.

Intermittent Source.

9. It often happens in industrial processes that a dust cloud is produced in the form of puffs at regular intervals. These clouds of dust may be so high in concentration as to render it impossible to collect all of them by means of a low volume of air at a high velocity. In such a case, it would be better to use a hood having a large area giving a lower velocity of air, so that the dust would be caught before it left the range of influence of the exhaust system.

10. From the point of view of economy, first, in the conservation of heat, it is desirable to remove a minimum quantity of air from the shop; second, from the point of view of power consumption, it is desirable to use the minimum velocity at the source of dust yet obtain conditions within the safe dust concentrations as laid down by the health authorities. Therefore, it is apparent that for every dust suppression problem, there is a best choice of air

volume and velocity according to the design of hood required by the process. What these conditions are for any particular operation, can be determined only by experiment and experience. Every foundry operator and every engineer who is concerned with the dust problem, will be required to do some experimental work which will lead to solutions of these problems for each dust-producing operation in industry. It is obvious that those men who are daily in contact with these operations, who understand the production requirements, who fully appreciate the nature of their problems, will be the most likely persons to solve them.

GENERAL METHODS

11. In looking at a dust suppression problem, it is often advisable to consider a variety of methods, that is, not necessarily assume that all dust suppression problems will be most effectively solved by means of ventilation. Consideration must be given to methods involving water or other liquids as a means of settling dust. The advisability of entirely enclosing the operation or isolating it from the general shop atmosphere also must be weighed. Making certain parts of the operation automatic might be considered, thereby eliminating the necessity for workmen to stand in a dusty atmosphere; or the whole process might be changed and carried out in such a way that no dust hazards exist. A good example of this is the use of water blast in cleaning large castings. Then again consideration might be given to the materials that are used. A suitable product might be obtained by the use of a substance that produces dust which has a relatively low health hazard. This has been done in a number of cases, i. e., non-silica parting, artificial grind wheels, and steel grit in blast cleaning operations.

12. These general methods are mentioned, not because they will necessarily lead to a solution of any particular problem, but to widen the approach. In other words, it should never be assumed that the only and best method has been found.

13. One of the first things that should be done in an attempt to introduce a dust control program in a particular industry, is a thorough shop cleaning, including rafters, window sills, windows, floors, walk-ways, etc. This will be a very large job, and more than likely expensive the first time, but once done, it will be found that periodic cleanings will be much less costly. As a matter of fact, a program of regular periodic shop-cleaning would serve as

an excellent indicator as to the effectiveness of any steps taken to control dust at its various sources throughout the shop. Of course, the shop-cleaning process is a very dusty one and the use of water sprays and suction devices is preferable to blowing with compressed air.

ESTIMATION OF THE HAZARD

14. It is extremely difficult to estimate the maximum permissible concentration of a particular dust in industry in keeping with the good health of the worker. It has been suggested as a tentative goal that the maximum concentration of dust containing 35 per cent silica should be not greater than 10,000,000 particles per cu. ft. below 10 microns in size. Of course, if the dust is quartz, which is 100 per cent silica, the maximum permissible concentration will be proportionately less.

15. In estimating the dustiness of an atmosphere, the present method is that of the United States Public Health Service which uses a bright field in the microscope and a magnification of 100, the sample being collected by the Greenburg Smith impinger method. Apart from any differences in dust counting methods, and there are differences, any one of the recommended methods is quite useful in arriving at a measure of the effectiveness of a ventilating system should dust counts be made before and after its installation. A number of reports claim very high efficiency for various types of dust collectors, but the method of arriving at this efficiency is based, in almost every case, on weighing the dust entering the system and that caught by the collector. It is apparent that this method is not at all in keeping with efficiencies based on dust counts because a particle 100 microns in diameter will weigh a million times as much as a particle 1 micron in diameter; so that the efficiency of a dust collector would appear very much higher if there were any large particles in the dust fed into the collector. It is felt that the particles between 1 and 5 microns ($1/25000$ to $1/50000$ th of an inch) in diameter are biologically significant and for that reason, it becomes necessary to make dust counts rather than measure efficiencies by weights. Of course, such measurements of the efficiency of a dust collector or arrester are only of significance in a case where the cleaned air is returned to the shop atmosphere, a procedure which should not be carried out unless some type of collector

is developed which meets the requirements laid down by the methods of dust counting.

16. At the present stage of the dust problem, it would seem that the most *practical* means of diagnosing the dust hazard is the naked eye, with all due respect to dust counts. If a shop is very dark so that no dust is visible, it would be advisable to use a powerful flashlight or clean some of the windows so that the sun's rays might show up the dust. It may be that in the near future a more rapid method of estimating a dust hazard will come into general use. Let us hope that this is so, for it is quite out of the question for any but the larger firms to consider purchasing of present equipment and employing of trained personnel for regular routine tests.

17. The first problem in the removal of dust is to get rid of all visible dust for in so doing a very great amount of the invisible particles will also be removed.

TESTING VENTILATING EQUIPMENT

18. If a survey is made of the various State laws relating to dust control in the United States, a very wide variation in the requirements is found. Some statements are made demanding that the static pressure measured behind the hood should give 2 in. of water difference in level in a manometer. In another State, for the identical operation, 5 in. of water is required as a minimum (this refers to grinding wheels). There is a great difference between 2 and 5 in. of water static pressure. Assuming the hood designs to be identical in both cases this would mean a difference in the air velocities of approximately 6 to 1. There cannot be very much scientific basis for regulations which vary by a factor of 6 to 1. However, this is not the worst indictment of these regulations. The worst is that static pressure readings taken behind the hood measures the sum of two factors and does not give a measure of the velocity of air being handled by the system. The two factors are—(1) loss of head due to resistance at opening, and (2) loss of head necessary to set the air in motion.

19. If static pressure is to be a measure of the effectiveness of a dust collecting system, it is necessary immediately to specify exactly the shape and size of the hood in every particular application; a procedure which is of course out of the question. It would be far better to say that the velocity in the duct must be

not less than say 1000 ft. per min., the duct must not be smaller than say 4 in. in diameter and that the air velocity at the source must be no less than 400 ft. per min. In other words, it is necessary to define the minimum volume and velocity of air for any particular application. It is because of the ease with which static pressure readings can be taken that it has been used so much in the past, but their only value lies in observing the constancy of an exhaust system from time to time, thereby assisting in the detection of excessive fan wheel wear, belt slipping or dust arrester leaks. Care must be taken that the complete system, as far as duct inlets are concerned, is operated in identical manner at every test.

20. This immediately brings up the problem of testing and inspecting dust-removing equipment. In order to determine the most important factors, i. e., volume and velocity of air handled, the use of the pitot tube in conjunction with a manometer is most suitable for the duct system; and for the measurement of air velocities below 500 ft. per min., the Kata thermometer has proven its value in many cases.

21. The American Society of Heating and Ventilating Engineers has formulated standard methods of testing fans, and these methods involve the use of a pitot tube in a definite manner. Such a procedure as recommended is too elaborate for factory inspection purposes or for the average individual in industry, but, if we neglect the refinements in measurement, the pitot tube will prove a most useful instrument in the hands of anyone who is willing to investigate his ventilating system.

SELECTION OF A FAN

22. The selection of a fan for a particular dust problem is of primary importance and, to the end that the fan manufacturer may give the advantage of his experience, a precise statement of the problem on hand is essential so that he may intelligently recommend the proper fan, of sufficient size driven at an adequate speed. The author has seen a number of foolish applications of fans and does not blame the fan manufacturer for these, as very often he is not consulted, the fan merely being purchased through a purchasing agent according to a requisition with inadequate specifications supplied by some mechanic. The ordinary propeller

fan should never be used in forcing air through a duct system which offers any appreciable resistance.

23. The choice of fan depends not only on the operation but on the type and shape of the material to be handled. Therefore, it is necessary, in asking the fan manufacturer for a quotation, that all the details be submitted with the request. The author recalls recently seeing a letter written by a manufacturer to a fan company in which he outlined the piping on a very rough sketch and he received a quotation on a particular fan by return mail. It was apparent, on looking at the sketch, that the system of ventilation would require two separate installations, as the purposes for which the fan was to be installed were of two radically different natures.

PIPING

24. If a uniform distribution of suction is to be maintained, it is very necessary that the piping be properly proportioned. The author once went into a foundry in which a 15 in. diameter pipe ran directly over a number of tumbling barrels. From this 15 in. pipe, a 3 or 4 in. pipe ran down to each barrel. A number of manholes had been cut in the pipe and, on inquiry, it was found that every two or three weeks, the big pipe had to be opened and emptied. The cost of this work probably would have paid in a short time for the proper proportioning of the piping, apart from any gain in efficiency of the ventilating system.

25. The use of dampers at the various inlets of a ventilating system may seem very feasible from the point of view of controlling the air movement and is undoubtedly of value in adjusting improperly designed piping installations; but if an installation is properly designed, the use of dampers will be entirely superfluous and will serve only to upset the system.

DUST COLLECTORS

26. Four or five main types of dust collectors are in common use today. First, and perhaps the most common, is the ordinary cyclone. This type of dust collector is far from efficient in the removal of fine particles and under no condition should the exhaust from it be returned to the workshop nor should its exhaust be located near an open door or window. The second most common type in use is perhaps the cloth screen or cloth bag type. For a number of years, this type has held the foremost position as a

collector of fine dust, but the author knows of no tests that have been made regarding its efficiency on a dust counting basis and it is advisable that such tests be carried out. Often the claims made by the manufacturer would indicate that such a dust arrester would permit of the air being returned to the room. It may be quite true that when an arrester of this type is now its efficiency is high but there is certainly no assurance that it will continue to function in that manner.

27. Another type of arrester that apparently is gaining ground is the centrifugal type in which the fan is so designed and driven at such a high speed that the dust is thrown out at the periphery and collected by centrifugal force. Any test information which the author has seen on this type of collector, has always been taken on a weight basis, which is anything but adequate from a health point of view.

28. Considerable work has been done in the past few years on the problem of smoke abatement and in this work some new designs of gas washers have been developed. There is a similarity between these gas washers and some new designs on dust collectors of the water type. In one machine, the dust laden air impinges on a series of wet baffle plates as it passes upwards through the collector. The author often has considered the principle of the Greenburg-Smith impinger type of dust sampling apparatus to possess a principle worth investigating with a view to its adoption in dust collector design. One of the great difficulties in gas washers developed for the smoke abatement problem has been the high consumption of water. It has also proved expensive to recirculate the acidified water. This should be a much easier task in collecting silica dust.

29. Many applications in industry do not provide any dust collection whatever as the amount of dust does not warrant such expense nor does the location require that the exhaust air be absolutely clean. In the author's opinion, it would be far better to use no dust arrester and exhaust the air containing the dust high into the atmosphere than to install a dust arrester of low efficiency and recirculate the air back into the shop.

30. The choice of a dust arrester, although important, is not the most important problem. The main problem is catching the dust at its source and carrying it through a dust system to a point where its disposal can be safely effected.

31. It is well known that the use of dust arresters often pays for itself over and over again if the product being collected is at all valuable. In a recent case the amount of material collected in three months more than paid for the complete installation since the material collected was worth about 10 cents per lb.

32. In choosing a cloth type of dust arrester, the most important factor (assuming a good grade of cloth) is the ratio of cu. ft. of air handled to the sq. ft. of cloth through which the air must pass. It is recommended that this ratio be not more than 3 or 4 to 1 in the collection of silica dust in foundry practice. This ratio may be increased slightly as dust concentrations drop but it is important that it be kept as low as economically possible. The author once was called out to investigate the reason why no air was being delivered by a unit heater. The unit heater had a capacity of 3000 cu. ft. per min. and was equipped with a propeller fan. On investigation, it was found that the 24 in. square duct had a sheet of cheesecloth, mounted on a wooden frame, inside it so that the ratio was 750 to 1. The owners were amazed when told that they could not get air through cloth like that.

RESPIRATORS

33. The subject of respirators is one of considerable importance in dust control. It is not meant that the use of a respirator is a desirable solution, for it is well known that most workmen would rather "take a chance" than suffer the inconvenience of wearing a respirator. Many dust producing processes in industry do not lend themselves readily to effective ventilation by means that are at all economical, and it becomes necessary to rely upon some type of protective device worn by the workman. Perhaps the outstanding process of this type is sand-blasting, but here the problem is further complicated by the danger of injury from the bounding abrasive, which makes it necessary not only to provide safe-guarding of health, but protection from cuts.

34. Respirators, in a broad sense, may be divided into three classes:

- a. Helmets.
- b. Filter Type Respirators.
- c. Positive Pressure Masks.

Some of the fundamental considerations in the choice of a suitable respirator may be summed up as follows:

Helmets

35. Where dust is at all hazardous to health, it is essential that all helmets be supplied with air at a positive pressure, preferably from a source of fresh air, rather than from the compressed air lines. The amount of air required by a helmet depends on the design of the helmet itself, and how it is to be worn by the operator. A loosely fitting helmet will require considerably more air per minute than one which fits rather tightly over the face or neck of the workmen. In general, the amount of air should be sufficient to maintain the positive pressure within the helmet throughout the entire breathing cycle of the workman, so that at no time will air be drawn in through any crevices. A sufficient pressure inside the helmet should be 2 or 3 ounces above atmospheric and an adequate volume of air should be about 6 cu. ft. per min. Of course, it is not meant that this air volume will develop sufficient pressure inside a helmet in every case, especially if the helmet is a loosely fitting one.

36. A helmet should preferably be designed in such a way that its weight rests on the shoulders thereby permitting a free movement of the man's head. The air line attached to the helmet should be firmly fastened to the man's body, so that he will experience no inconvenience in moving it about inside, say, a sand-blast room.

Filter Type Respirators

37. The main requirement of any filter type respirator is that the rate of flow of air through the filter medium be as low as possible, for if the workman must exert himself in breathing, considerable dust will be pulled through the filter. This would mean that the filtering medium should present as large an area as possible, and the main problem becomes one of convenience in wearing an apparatus which must present so large an area.

38. A filter mask, which is efficient, will naturally plug up sooner than one which is inefficient, and it is essential, both from the point of view of economy, and efficient health protection, that the filtering medium may be readily replaced or cleaned.

Positive Pressure Masks

39. It is undoubtedly true that a positive pressure mask is far superior to any filter type, but it requires a supply of air. Many

companies who use such masks attach them to their compressed air lines through an adjustable reducing valve, and the objection is raised by the workman that the air smells of burnt oil and contains considerable amount of water vapour. Both of these objections can be overcome by the use of a small blower which will provide an adequate supply of air at a sufficiently high pressure from a source that is free from contamination. There is considerable room for development of a cheap and effective blower designed for use with fresh air masks. The use of air filters and after-coolers in the compressed air lines presents another approach to this problem.

THE IMPORTANCE OF MAINTENANCE

40. Machines, like everything else in this world, wear out; and the essential parts must be replaced by new ones from time to time. This is particularly true of fans, especially when there is abrasive dust in the air which they handle. The author has found fan wheels in such installations completely worn out, the ventilation system practically useless and the driving of the fan merely a waste of money. Regarding dust arresters, especially of the cloth type, great care must be taken to maintain them or they will plug up and develop such a high resistance that the air cannot get through them, with the result that eventually the cloth tears away from its support and large quantities of dust come out of the clean air side. Dust arresters should be cleaned at regular intervals, better often for short intervals than for long intervals at less frequent times. One naturally should consider how to reduce the maintenance costs and it is proposed that every man who has installed a fan and dust arrester should look and see whether the dust arrester or the fan comes first in the ventilating system. If the fan, he should change it and save the wear on his fan wheel. This may seem like a very obvious remark, but in many instances this point has been neglected with the result that the fan wheel was completely worn out in a relatively short time.

GENERAL CONCLUSIONS

41. It might be well to sum up with a few general conclusions:

1. No source of dust is too insignificant for attention.

2. Any efforts made to control dust will probably result in other economies being effected.
3. A dust problem requires not only cooperation of employers, but of employees as well, in a conscientious effort to control the dust hazard.
4. There is always a best way of handling a given dust problem, and this can usually be determined only by experiment in the application of fundamental principles.
5. Apart from all dust counts as a means of indicating the relative hazards in industry, the ultimate test of the effectiveness of the dust control can be determined only by medical examination. Therefore, it is a necessary part of any dust control program that periodical examination be made of all workmen engaged in dusty atmospheres.

(Discussion of this paper begins on page 222)

DUST CONTROL — DISCUSSION

P. J. PORTER: In Mr. Moxley's paper, paragraph 11, it is stated that the proper air velocity to handle ordinary foundry dust would be between 2500 and 3000 ft. per min. I would like to ask Mr. Moxley if they had long horizontal pipe runs, because it has been our experience and, I believe, common practice, to keep the pipe velocity about 3500 ft. per min.

MR. MOXLEY: We have found, with the amount of dust in our plant (and we are talking about the dust as indicated by the curves on the slides I have just shown) that between 2500 and 3000 ft. per min. will prevent clogging of the dust line. It is most important to reduce the dust at each intake and correctly design the duct as it goes along through the shop. We have one duct 48 in. in diameter and gradually reduce it to 12 in. in diameter. Its horizontal length is about 200 ft., and we do not have clogging. Our velocity is kept maybe closer to 3000 than 2500 ft. per min. but it plays between those figures.

MEYER: Would moisture in the air affect the 2500 to 3000 ft. per min. velocity of which Mr. Moxley speaks?

MR. MOXLEY: We have made a complete analysis of our dust and it shows approximately one per cent moisture. Of course, as the moisture increases, it may go beyond the range of a cloth collector. As moisture increases, it is more and more difficult to handle the dust without clogging the pipes and the velocity should be increased.

MEYER: It has been indicated in one of the papers that manufacturers of dust collectors have recommended a return of the air into the shop after it has passed through the exhaust system. I would like to correct that impression. I believe I am correct in saying that manufacturers of dust collectors with whom I am acquainted have not for some years past recommended the return of any of that air to the shop.

DR. J. T. MCKENZIE: I would like to ask Mr. Allan whether he has any data on the washer type collector to indicate the retention of the fine particles. After listening to the discussion at the health hazards session this week and that today, it is quite apparent that the harmful size of the dust particles lies somewhere between half a micron and ten microns. You could have collection which is 99.9 per cent efficient by weight of the dust collected without taking out very much of the fine material. If the dust which is being put into the collector is 99.5 per cent above ten microns, you could have that efficiency without doing a bit of good, if you do not take out the fine particles.

J. R. ALLAN: In answer to Dr. McKenzie, we have not made any test on the efficiency of such collectors that we have installed. Where we have them on the foundry shakeouts and the tumbling mills, the set-up is so we are unable to get a reasonable sample and we have made no attempt to make the tests referred to by the first speaker. We have some cloth collectors on carburizing materials and these showed consider-

¹ Foughorn Corp., Hagerstown, Md.

² American Cast Iron Pipe Co., Birmingham, Ala.

³ International Harvester Co., Chicago, Ill.

able evidence of dust in the discharge stack. The wet collectors on the same type of work indicated no visible trace in the discharge stack.

MR. LARREN: I wish to correct an impression that I may have given I said that as a *practical* measure in the immediate future in our attack on the silicosis problem, the use of the naked eye in determining atmospheric dustiness would seem the most practical thing to do. From the point of view of measuring the efficiency of dust collectors, I would be much more in favor of dust count by standard methods in terms of micron size.

DR. MCKENZIE: As I understand it, the dust you see does not hurt you. Is that right?

MR. LARREN: That may be true and is true, of course, of the larger particles. I am sure that if you have a large cloud of fine particles you can see them, though not individually, especially if contrast in light exists in the shop.

DR. MCKENZIE: The point I am making is that the dust collector will render air, which though perfectly invisible, may be very dangerous, especially if you return the air to the shop. The type of collector that takes out only the visible dust, returns all the harmful dust to the shop.

MR. LARREN: At no time did I recommend having the air returned to the shop.

MR. MOXLEY: I would like to say a word regarding the checking of a dust hazard by the naked eye. It is quite generally recognized that you can barely see a particle of over ten microns in diameter. A micron is 1/1000th of a millimeter.

Most of the workers in the medical field claim that the upper limit really is about eight microns. I have heard of one case where the worst dust hazard in the plant was in the core room where there was no visible dust at all.

That is the reason I put a great deal of dependence upon weight efficiencies and dust counts in analyzing the effectiveness of a dust collector. I still believe the weight efficiency method is a fairly good measure but only when considered along with all of the other characteristics that are available.

H. L. MCKINNON: On the question of the dust count in our plant, we have made upward of two hundred tests in the past four months, involving the actual dust count from a wet collector. We have, at the present time, three large machines in operation, two of which have been tested for dust count. The question of what the final dust count will be, we find, bears very close relation to the fineness of the dust when at the source because you will get a percentage of the fines on any of these collectors.

We found, for instance, in getting dust which was swept off the beam of a foundry and tested, that we got a very high rate of efficiency and a comparatively low dust count with that material.

Then we tried some silica flour which had been ground under 325

U. S. O. Bartlett & Snow Co. Cleveland, O.

mesh, 92 per cent of which was less than five microns, and we found that the dust count went up materially with the same loading.

We found an analysis of some of the dust swept off the rafters indicated that the dangerous dust was not more than 20 per cent of the total dust, about 80 per cent being above the ten micron size.

We have not gone far enough along yet to give anyone any final conclusion on this. We do know that we can get within the range of reasonable cleanliness with the wet collector and we do know that the dust count will vary definitely with the nature of the dust that is fed into the system.

I want to make one remark in regard to Mr. Moxley's paper, namely, in the tabulation of the wet collector, he made the statement that the maximum loading be 25 grains per cu. ft. That we feel is not strictly so; we have used much higher loadings than that in certain instances. I am satisfied we can take any loading. It depends entirely upon the fineness of the product and I would not want to take 25 grains per cu. ft. of 325 mesh material into a machine. I would not want to guarantee the condition on the output of that machine. The fact is, it is going to be possible and is possible now to get a reasonable dust count with the wet process.

W. G. FRANK: Working in both the dust collecting and the air filter field, I must say I have enjoyed the various papers very much. There have been many interesting details given which should furnish an incentive for further thought and development in dust collecting practices for the best interests of everyone concerned, especially the workman who is handicapped in some instances by difficult conditions.

It is quite definitely true, if a manufacturer takes steps to introduce dust collecting equipment in his plant he will not only have the satisfaction of improving sanitary conditions but he will also reap a definite benefit in improving his production and in reducing his costs.

F. A. ENGLAND: It has been inferred that dust collectors might be sold just for the sake of making sales without taking actual conditions in the foundry or any other manufacturing plant into consideration.

I do not believe that is so with established manufacturers of dust collecting apparatus. None of them, including ourselves, would make any kind of a recommendation unless we were pretty sure as to what was to be accomplished.

In other words, when we are making a recommendation for equipment, whether by invitation or otherwise, we would not make any recommendation for size of collector, or size, speed or power of fan, unless we knew in considerable detail what the dust collector should do.

We must know what a collector should do. Neither we, nor any other manufacturer, can back up an installation recommended unless we are sure that the pipe system, the hood system, etc., are designed properly. Many times we have no control over the installation of hoods and pipes, yet we feel it our duty to ascertain beforehand that hood and pipe conditions and construction are correct. I believe that people who have dust

*American Air Filter Co., Louisville, Ky.
*W. W. Sly Mfg. Co., Cleveland, O.

problems may go to any established manufacturer with confidence that the recommendations made by the manufacturers will be in accordance with the problems presented.

CHARMAN F. W. BEAVER: I do not think that there is any question as to the soundness of the ethics of the manufacturers involved, when led to Mr. Elting's rebuttal. I think, rather, the statement mentioned was meant to convey that very often a plant manager or his mechanical superintendent simply requests the purchasing department to order some fan, without the purchasing agent or anyone else knowing for what purpose the fan is to be used.

I believe there is no doubt, if the master mechanic had told the purchasing agent that he wanted a fan for a special use as applied to a certain problem of removing dust, and his requirements passed on to the manufacturer, he would have been given full information and probably many questions would have been asked before apparatus was shipped.

E. H. BARNUM: I think a little more consideration might be given to some of the facts brought out by Mr. Leitch.

This is absolutely a competitive proposition. We as foundrymen, have a distinct responsibility. I recall that in the early days of dust collecting we, ourselves, had been sold equipment that through lack of knowledge was guaranteed to do certain things without specific measurements. I think the time has come when any equipment manufacturer selling equipment to perform a certain job should not undertake a sale until he knows all the facts. Unless he does, the equipment so installed is absolutely useless to accomplish the purpose for which it was installed.

Salesmen differ. Some want sales and some want to put equipment in to perform a certain function they agree that it will do. So, I say again, I believe that the equipment men have to work closer to the foundrymen to know what the problem is. In my opinion when a piece of equipment is installed, it should be subjected to the same type of test as we are going to be subjected to by the health authorities in coming into the foundry and analyzing our dust and our conditions. Equipment so purchased should meet specifications agreed upon, based on and subjected to tests and methods used by state and insurance inspectors in determining dust counts.

Incidentally, I believe the manufacturers are going to have to perform a service which they so far have given to us only when requested, and then, probably, in only a superficial way. I think they will have to have a service and come in and check us up to see that the equipment is just where it belongs, the same checking we receive from our state inspectors. In other words, we have to be a little ahead. That is going to cost money, but it will be of untold value to foundries where they do not have a mechanical organization with sufficient knowledge to keep the equipment up. We need help, some of the larger plants as well as the smaller, but particularly the smaller ones. Any improper operation of

*Engineering Executive, Campbell, Wyant & Cannon Foundry Co., Muskegon Mich.
*General Electric Co., West Lynn, Mass.

the smaller foundries is a reduction on the larger ones and on the operations of the industry as a whole.

So, I say again, I think we as foundrymen are going to appeal to the manufacturer to work with us and I think they, in turn, should demand to know of us what our true conditions are. Then between the two, I am sure we are going to make tremendous strides in overcoming a hazard that without doubt exists.

Mr. LEBLANC: The problem of loss of heat is a very important one and one that costs a considerable amount of money. In the ventilating of the foundling barrels, for instance, I believe the air enters at one end and goes out through a pipe at the other end. Why not pipe in the air ventilating the foundling barrels the same as you pipe the dusty air out? I know installations where 10,000 cu. ft. of air per min. are being taken from the shop which would mean a considerable saving in heat if the air were not taken from the shop but brought in from the outside.

Regarding sand blast rooms which in many cases require ten or even twenty thousand cu. ft. of air per min. in their ventilation, I do not see why such equipment should or could not be ventilated in a similar manner, i. e., by bringing the air in from outside. The only objection I can see is that the man might feel rather cold in the winter time, but I am sure he would enjoy it in the summer time. In the winter time it is not necessary for a man so well clothed as the man in the sand blast room, to have as high a temperature of air as the man in the shop. After all, the man in the sand blast room is a very busy man and therefore does not require such a high temperature on the very cold days when it is 20 or 30 degrees below zero. I think it would be quite feasible to install heating coils to take the chill off the air when necessary.

I place these points before you for your consideration. I have not yet seen an installation to which these considerations were given.

There is another point and I have often wondered why advantage of it has not been taken; that is, the sand blasting of castings in a more automatic way, with the man standing external to the apparatus. I refer to the granite industry where they sand blast and the man always stands outside. When you understand that dust conditions such as prevail inside sand blast rooms are of the order of 2,000 or more, million particles per cu. ft., it becomes of some importance that the operator preferably stay outside. I think we may all look for the development of sand blasting machinery in which the man does not enter the room.

DR. J. G. CUNNINGHAM: I am very interested in this problem of the extent of the dust in the air. It does seem to me to be unfortunate that the impression was left that any of us would depend on eyesight entirely for estimating the dust hazard.

I am sure Mr. Leitch, in his discussion of the subject, was referring to gross exposure to dust. In a great many instances where dust is visible there is fine dust also. I do not think that anyone familiar with the subject would undertake to say that there was no health hazard because they could not see any dust, particularly if they knew that the

Department of Health, Province of Ontario, Toronto, Can.

processes might end the dust into the air. It is quite possible to have a health hazard from silica and not be able to see the dust.

It is true that in indirect light one can see the evidence of dust where it would not be seen in ordinary light. I do think it is important, in discussing estimation of dust concentration to understand that we are referring only to gross exposures.

C. J. HEXON* (Submitted in Written Form): In testing the efficiency of various types of centrifugal dust collectors, it is essential that each dust collector be tested under identical conditions, preferably on the same problem. To state in one case that 50 per cent of the dust collected passes through a 325 mesh screen in one locality may mean something entirely different to say that 50 per cent passes a 325 mesh screen in another locality. In one case, the 50 per cent passing may mean on down through a 2500 mesh screen on which no type of centrifugal separator would be very effective, and in the other case, the 50 per cent passing 325 mesh may show that that passing would all be retained on a 400 mesh screen on which a high efficiency centrifugal collector would show very favorably.

* Research Corporation, New York, N. Y.

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American Foundrymen's Association

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**Tentative Recommended Good Practice Code
and Handbook on the Fundamentals of
Design, Construction, Operation, and
Maintenance of Exhaust Systems**



Developed by
A. F. A. Industrial Hygiene Codes Committee
and

Approved by the Board of Directors

as a

**Tentative Code of Recommended Practices
for the Foundry Industry**

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Price per Copy \$4.00

FOREWORD

In 1935, when the Safety and Hygiene Section of the A.F.A. was instituted, the Board of Directors, realizing that there was urgent need of having the industry develop foundry process codes as promptly as possible in order to have recommended uniform practical information available for the industry, authorized the formation of an Industrial Hygiene Codes Committee. The Board of Directors in listing the various fields of activities for this committee, presented the following objectives:

- (a) "To assist in the standardization of dust eliminating equipment and improvement of shop operation conditions in the foundry industry."
- (b) "To promote standards for dust elimination and control equipment in cooperation with agencies of manufacturers of such equipment."

The Industrial Hygiene Codes Committee was then formed, and made a survey of the needs of the industry. The Committee decided upon the following fields for first consideration in preparation of recommended practices. Additional fields will be undertaken as codes for this group are completed.

1. Grinding, Polishing and Buffing Equipment Sanitation.
(Tentative Code published as A.F.A. Preprint 36-28 - 2nd Edition)
2. Testing and Measuring Air Flow in Exhaust Systems.
(Tentative Code published as A.F.A. Preprint 36-27 - 2nd Edition)
3. Fundamentals of Design, Operation, Construction and Maintenance of Exhaust Systems.
(Tentative Code published by A.F.A.)
4. Metal Cleaning.
5. Non-Ferrous Melting.
6. Foundry Industry Code.
7. Foundry Partings.
8. Wood Working Machinery Exhausts.

The Committee, in presenting its recommended practices, is interested in serving the needs of the foundry industry, particularly the smaller foundries where they do not regularly employ an engineering staff. Furthermore, the Committee has as one of its objectives the obtaining of uniformity in the safe guarding of processes and operations.

It is believed the engineering data included in these tentative codes of minimum requirements will enable the foundry industry to solve their ventilating problems at minimum cost, consistent with good engineering practice.

INTRODUCTION

This tentative code of recommended good practice covering the fundamentals of design, construction, operation and maintenance of exhaust systems has been developed by a committee of the American Foundrymen's Association to cover the necessary engineering data required for designing and installing exhaust systems in the gray iron, malleable, steel, and non-ferrous branches of the foundry industry, and has been approved for publication by the Board of Directors.

Many foundries have, in addition to casting cleaning departments, pattern, machine, and maintenance departments which are considered integral parts of the foundry operation. Also in many instances, there are additional departments wherein further operations are carried on in the processing of materials where this code may be applied.

The purpose of this code is to provide the industry with sufficient engineering and construction information so that exhaust systems may be properly designed and installed, and is therefore recommended as a guide in furthering good practice.

The Technical Committee, which prepared this code, known as the American Foundrymen's Association Industrial Hygiene Codes Committee, is as follows:

Chairman, J. R. Allan, International Harvester Co., Chicago, Ill.
R. J. Aldrich, Sloan Valve Co., Chicago, Ill.
F. H. Amos, International Harvester Co., Chicago, Ill.
C. P. Guion, W. W. Sly Manufacturing Co., Chicago, Ill.
E. E. Birkland, Crane Co., Chicago, Ill.
Carl F. Larsson, American Air Filter Co., Inc., Chicago, Ill.
S. McMullan, Western Electric Co., Cicero, Ill.
J. G. Liskow, Claude B. Schneible Co., Chicago, Ill.
Nathan Lesser, Deere & Co., Moline, Ill.
R. W. McCandlish, Research Corporation, Chicago, Ill.
John F. Tobin, American Blower Corporation, Chicago, Ill.
Secretary, E. O. Jones, American Foundrymen's Association, Chicago, Ill.

Conferees: G. A. Kluge, Central Blow Pipe Co., Chicago, Ill.
J. M. DallaValle, United States Public Health Service, Washington, D. C.
L. C. Stokes, Department of Labor, State of Illinois, Chicago, Ill.
C. S. Anderson, Belle City Malleable Iron Co., Racine, Wis.
L. S. Peregoy, Sivy Steel Casting Co., Milwaukee, Wis.
J. O. Houze, National Malleable & Steel Castings Co., Cicero, Ill.

Section V: Application of Exhaust Systems

(A) Functions of an Exhaust System. Exhaust systems shall be installed for the removal of all matter such as dust, dirt, refuse, fumes, vapors, gases, and mists, that constitute a health, safety, fire, or explosion hazard or nuisance, and such exhaust systems shall catch such dust, dirt, refuse, fumes, vapors, gases, and mists, at the point of origin and before they become diffused into the general atmosphere of the work place or room. The exhaust systems shall convey such matter collected to some safe place for disposal and further provide for the discharge of the exhausted air in the manner provided for in any of the recommended good practice codes of the American Foundrymen's Association or by law.

NOTE: An exhaust system shall not be confused with a ventilating system, which type of system has to do with the general atmospheric control and ventilation of a work place or room.

The primary consideration in designing an efficient exhaust system shall be that of providing hoods or enclosures or other devices that effectively catch the matter in question and prevent its diffusion into the work place or room.

When detailed engineering information is given in any of the American Foundrymen's Association recommended practice codes, or in requirements specified by law, as to the exact design features for hoods, enclosures, and devices, such designs shall be followed, but in the absence of definite design instructions, the following factors shall be considered and used in developing hoods, enclosures, and devices for catching matter.

(B) Characteristics of Matter to be Exhausted.

(1) General: The characteristics of matter to be exhausted vary with types of operation, process, or equipment used. Such matter, whether in the form of solids, liquids, or gases which, due to their shape, density, or through kinetic energy imparted to them by some force may remain in suspension in the atmosphere for a relatively long period of time before settling to a resting place by the force of gravity.

(2) Size of Particle Matter: The length of time that particles of matter remain in suspension in the atmosphere depends upon the particle size, shape and its specific gravity. The smaller and the more microscopic the particle, the slower the rate of settling in air by gravity due to the relatively large surface area compared to weight.

The chart of "Size and Characteristics of Air Borne Solids" on Figure 2 shows the rate of settling in FPM for various sizes of spherical particles with a density of 1, the laws of settling, comparison of particle size, surface area of particles, and the like.

As a general rule, the particle size of hygienic interest are those under 10 microns in size (1 micron - 0.00003937"). Particles over 10 microns in size may not be of hygienic interest but shall be exhausted because they may cause some other form of hazard and at the least, they are a nuisance.

(3) Action of Gases. Gases including vapors when liberated into atmosphere are acted upon by gravity. Such matter having a density greater than air will descend, whereas with a density less than air, it will ascend. Gases and vapors escaping into atmosphere at high temperatures, may have a density greater than air at atmospheric temperatures, but because of expansion of volume due to heat, are lighter than air until cooled to the surrounding air temperature, by which time the gases and vapors will have permeated to a considerable extent into the atmosphere.

Heavier than air gases and vapors, particularly if released near atmospheric temperature, will fall by gravity and concentrate in more or less concentrated pockets in relatively still air.

When dealing with gases and vapors it shall be necessary to determine their density in order to estimate their probable direction of travel when released to atmosphere.

(4) Diffusion of Matter in Atmosphere. When matter in the form of solid or liquid particles, or in a gaseous state, is released by some force or cause, the tendency is for such matter to diffuse and permeate into the atmosphere. The condition of air not being in motion is rarely encountered. Air is usually in motion and is motivated by drafts from the outside wind pressures, heat radiating surfaces, ventilating equipment, moving parts of equipment, occupants moving about, transporting of materials, and many other influencing factors. The degree and speed of diffusion of matter into atmosphere increases with the magnitude of air movement.

Matter that is released to atmosphere under pressure, or by dynamic forces, will diffuse to a greater distance at an initially higher speed, depending on size, shape, and density of the particle matter, but the microscopic sizes will lose their initial velocity in a very few inches of travel. Gases and vapors also diffuse at a slow rate.

Theoretical specifications for the diffusion and permeation of matter in atmosphere in work places or rooms, are of little practical value beyond a knowledge of the tendencies. When solid, liquid, or gaseous matter is visible to the eye, a study of the diffusion tendencies shall be observed to determine their direction and speed. When the matter has little or no visibility, smoke bomb tests should be resorted to which will give some idea of the directional tendency. It should be borne in mind that the smoke particles may be of different size and density than the matter being studied.

(5) Prevention of Diffusion of Matter. Whenever practicable, the area of generation or cause of matter escaping to the atmosphere, should be surrounded by an exhaust hood, enclosure, or device that will prevent the diffusion of the matter into the atmosphere of the work place or room. When such exhaust applications are not possible, exhaust hoods shall be located as close as possible to the point of origin of the matter escaping so that the air flowing towards the hood opening will have its maximum effect in directing the matter into the hood. If the nature of the operation or forces involved give the matter decided directional tendencies, the hood opening shall be located as near in the path of travel as possible to take full advantage of these tendencies.

The influence of air movement from surrounding forces when such air movement prevents the proper functioning of the exhaust hood, enclosure, or device catching the matter to be exhausted, shall be properly shielded or baffled from the operation to permit the proper functioning of the exhaust equipment.

(C) Enclosed Processes. Enclosed processes such as tumbling barrels for milling castings, abrasive cleaning rooms, cabinets and barrels, sand mullers and mixers, and the like, are relatively easy to exhaust and the dust is prevented from escaping and diffusing into the general atmosphere by keeping such enclosures under negative pressure. Due consideration shall be given to providing for the necessary inlet of air into the equipment, and such air inlet shall not be less in cross section than the area of the exhaust pipe serving the equipment.

(D) Codified Hoods. Hoods which are code prescribed as to the shape and size, and minimum branch pipe air velocities such as grinding, polishing, and buffing hoods, catch the particles of matter of hygienic interest but may not always carry heavy particle sizes with the flow of air into the hoods because of the high inertial effect imparted to them by rotating wheels and belts. Such hoods have been developed to their present standard from years of experience and adaptability to the job. Such hoods shall be made to not less than the minimum requirements as prescribed by the recommended good practice codes of the American Foundrymen's Association or by law.

(E) Partial Enclosures. Such operations as are conducted inside a partial enclosure, where the work is between the point of exhaust and the operator, and the operator is positioned at the face or just outside of the one opening into the enclosure, are readily exhausted. It is only necessary to maintain a flow of air into the enclosure opening as may be prescribed for the particular kind of matter to be exhausted; but in no event shall the average face velocity be less than 100 F.P.M. and shall be greater, depending on specific requirements or if there is a code requirement specifying the velocity for the particular operation.

For large and complicated enclosures such as are used in connection with continuous conveyor systems and the like, where the product being worked on passes through one side and out on the other side of the enclosure, more study is required to determine the amount or quantity of air flowing into the various openings of the enclosure to prevent the escape of matter into the general atmosphere. If the enclosure is exceptionally long and more tunnel-like in shape, and the operator works along one side of the enclosure, it is usually advisable to admit air from openings through the side and if possible about the breathing level so that the operator always has fresh air flowing past his head towards the work and the exhaust. In these more complicated enclosures, the average velocity of air shall be increased to compensate for the unequal exhaust distribution, and shall not be less than 150 ft. per minute for the aggregate of all openings depending upon the specific requirements.

(F) Operations Outside the Exhaust Hood. Every attempt shall be made to perform the operations within an exhausted hood or enclosure to prevent the diffusion of matter into the general atmosphere; but if, because of the size, type or nature of the work or operation, it is physically or economically impracticable to provide such safeguards, it shall be necessary to provide exhaust hoods as close as practical to the operation.

Some of the more important elements that shall be considered in designing such hoods are:

1. Effective Range of Air Velocity Entering an Exhaust System. Air tends to flow towards an exhaust hood from all directions and the immediate effect on the general atmosphere is that a local zone of air somewhat resembling a spheroid in shape, moves constantly into the exhaust hood opening. The inflowing velocity of the air into the hood rapidly decreases away from the face of the hood, hence, it is essential that the exhaust hoods shall be placed as close as possible to the point to be exhausted.

The shape of the face of the hood shall conform to the general shape of the area to be exhausted and shall be large enough in area to catch any matter liberated by the operation that would contaminate the atmosphere.

Smaller size objects to be exhausted in front of a hood do not divert to any extent or influence the air flow into the hood but large objects, such as tanks, and the like, distort the air flow and allowances shall be made for such distortion so that the required air velocity is provided at the proper place.

The contour lines of velocity in front of any round exhaust pipe, with no large obstruction in front of it, shall be determined graphically from the charts on Figure 3, for either pipe with or without flange.

NOTE: The graphs illustrate the improvement in higher velocities in front of a round exhaust pipe by using a flange.

The contour lines of velocity in front of exhaust hoods with no large obstructions in front of them, shall be based on the velocities at the hood center line or axis by the formula:

$$V = \frac{Q}{10X^2 + A}$$

Where V = Velocity FPM at X

Q = CFM flowing into hood

X = Any point X distance in terms of feet on the centerline or axis of hood

A = Area of hood face in square feet

The velocities to the side of the hood centerline or axis may be approximately determined graphically by plotting contour lines of equal velocities, using constants in terms of hood axial dimensions patterned after the contour lines shown on Figure 3.

The volume of air entering the hood shall be determined by the formula:

$$Q = 10VX^2 + AV$$

If one or more sides of a hood are extended as for a hood set on a bench or floor, or located against a wall, the volume Q may be reduced 20%, as compared with a hood that is open

all around the periphery; and the velocity at any point X under these conditions will be approximately the same as for the velocity calculated for the hood open on all its sides.

The contour lines of velocity in front of exhaust hoods, with large obstructions in the path of the inflowing air, shall be studied graphically by making sketches to scale of the hood and obstructions and approximating the velocity contours beyond the hood according to the following figures most nearly approximating the condition:

Figure 4, showing a hood located on a table, bench, floor or against a wall or the like.

Figure 5, showing a hood and obstruction with approximate end to side ratio of 1:2.

Figure 6, showing a hood and obstruction in which the length is great compared with the side.

2. Velocity Required for Catching Matter. Matter liberated beyond an exhaust hood is difficult to catch. If the matter particles are produced so that they are thrown dynamically in one general direction, as from a wheel or belt, the hood shall be located in the direction of the path of the particles, otherwise excessive velocities are required to overcome the kinetic force of the particles of matter, or they are not diverted from their path of travel at all. The necessary velocity required at the point of liberation to catch the particles of matter shall be carefully determined. For economical and practical results in the final installation, small testing hoods should be tried out to determine the actual velocities required to accomplish the desired results.

(G) Ventilation of Heated Masses and Equipment.

(1) General - Heated surfaces whether of masses of hot material or furnaces under temperature cause definite movement of air vertically and if vents in such heated surfaces emit products of combustion, as from furnaces, in addition to the heat caused by radiation from the surfaces, the air movement is accelerated.

Such heated surfaces need not be equipped with exhaust systems provided there are no toxic or irritating dust, fumes, vapors, gases, or harmful concentration of carbon monoxide present. Exhaust systems shall be installed to exhaust all heated surfaces causing a toxic or irritating concentration of matter in the room atmosphere.

The removal of excessive heat or non-toxic fumes and gases may be accomplished by general ventilation or natural draft hoods, or stacks, whichever method suits the general condition.

(2) General Ventilation Applied to Heated Surfaces. The vertical movement of air induced by heated surfaces affords a natural means of ventilating a work place or room provided provisions are made in the architectural design of the building for the escape of the heated air, or non-toxic or irritating fumes and gases through roof ventilators, monitors, skylights and sash, or by mechanical ventilators and shall be not less than 2 cu. ft. of air per minute for each square foot of floor area. The floor area involved shall be considered the gross area of the floor embracing all of the heated surfaces. In the case of isolated heated surfaces, the floor area to be assumed shall not be less than ten times the projected floor area of the heated surfaces.

(3) Natural Ventilation Applied to Heated Surfaces. Natural draft hoods and stacks when applied to heated surfaces shall have the hood fit as closely to sides of the heated surfaces as possible; but if the hoods are used as canopies over the heated surfaces, the edges of the hood shall project out beyond the heated surfaces 1" for each 2" distance from the face of the hood to the top of the heated surfaces.

The stacks shall have an area of not less than 10% of the projected floor area of the hood and the total bends in the stack from its connection to the hood to the outlet shall not exceed 180°; and no single bend shall be more than 90°. When total bends approach 180° in the stack, stack height should be increased to obtain greater chimney effect to offset resistance caused by the bends.

(4) Exhaust Systems Applied to Heated Surfaces. Where exhaust systems are necessary in connection with heated surfaces or hot objects, to carry away excessive heat, toxic or irritating matter, the hoods or enclosures shall fit as closely around the heated surfaces or objects as practical. Wherever required or possible, the sides of the hood or enclosure should extend downwards to cover the sides of the heated surfaces, allowing a space between the heated sides and the sides of the hood to provide a space for the flow of air. Air shall be admitted to the hoods or enclosures by means of openings. The velocity of the air flow into these openings must be sufficient to prevent the escape of hazardous matter.

For calculating the volume of air to be exhausted from the heated surfaces, it is first necessary to determine the rate of maximum heat input into the object to be exhausted - if it is a furnace, heated tank or vat, in terms of BTU per hour. This can be ascertained from the amount of fuel used, whether it is solid, liquid or gaseous fuel, electricity or steam. Next, the final temperatures of the discharged air shall be considered, taking into account the effect of the heat on the fan and fan bearings. If the hooded parts and pipe ducts are in close proximity to people working, the effect of radiant heat from the hoods and piping shall be considered and reduced final temperatures of air discharged should be selected so that radiant heat will not cause unbearable conditions.

Air movement will not remove radiant heat and the objectionable radiant heat can only be reduced by cooler surfaces involving the handling of the larger volumes of air.

When the heat input in BTU per hour is known and the final temperature of the air discharge selected, the volume of air to be handled per minute by the exhaust system shall be determined from the curve on Fig. 7. From the side of the chart or ordinate, find the BTU input per hour and read crosswise to the intersection of the curve of desired final temperature and then down to the abscissa to find the volume of air to be exhausted.

The volume of air to be exhausted is in terms of standard air and shall be corrected for final temperature in determining the fan and pipe sizes.

If it is necessary to exhaust a heated mass that has been removed from its source of heat supply, each individual job shall be calculated independently, taking into account the kind of material, final temperature of material, specific heat of material, surface area, character of surface, volume of air moving around material, desired cooling rate and final exhausted air temperature. If the products of combustion of any furnace are exhausted by an independent stack, the heat contained in the products of combustion should be deducted from the heat input into the furnace when ventilation of furnace proper is being computed.

(H) Removal of Hot Gases and Fumes. When any type of furnace or oven equipment emits toxic or irritating fumes and gases, hoods shall be provided where such gases or fumes are discharged for the removal of such matter from the general room atmosphere. In the case of irritating, but not necessarily toxic gases and fumes, natural draft hoods and stacks may be employed. Where toxic material is present, exhaust systems shall be installed.

(1) Natural Draft Hoods. When draft hoods are installed for the removal of gases and fumes, the hoods shall enclose or cover all of the area at the point where such gases and fumes are liberated from the equipment producing them. The area of the natural draft stack shall not be less than 10% of the projected floor area of the hood; and the total bends in the stack, from hood to the outlet, shall not exceed 180° and no single bend shall be more than 90°. When total bends approach 180° in the stack, stack height should be increased to obtain greater chimney effect to offset resistance caused by the bends.

If gases and fumes are liberated from the equipment under considerable pressure so that natural draft will not overcome their directional tendencies, then exhaust systems shall be installed to positively remove such matter.

(2) Exhaust Systems for the Removal of Gases and Fumes. Whenever any piece of equipment emits toxic or harmful irritating gases and fumes, such matter shall be removed by exhaust systems. The directional tendencies of the gases and fumes escaping from the equipment shall

be carefully studied and the volume of such matter flowing out of the equipment shall be determined. The hoods shall be designed to receive all of such matter and the minimum volume of air to be exhausted shall not be less than twelve times the volume of gases and fumes emitted from the equipment.

(I) Removal of Gases, Fumes and Vapors Heavier than Air. Many gases are heavier than air with a result, due to their greater specific gravity, will fall rather than rise and when diffusing into the general atmosphere, will concentrate in the air near the floor or breathing zone. The character, specific gravity and the tendency of these gases to fall or to accumulate in pockets, shall be determined.

In exhausting fumes and gases heavier than air, the exhaust hood shall be located at or near the floor in order to remove the gases with the least amount of travel. The volume of fumes or gases produced shall be determined and the amount of exhaust provided for their removal shall not be less than four times the volume of such heavier-than-air fumes or gases.

(J) Air Curtains. Certain operations may produce dust, gases, fumes, or vapors which cannot be exhausted by any type of hood or enclosure and in some such instances, the air curtain principle of catching hazardous matter may be adaptable. A relatively thin continuous sheet of high pressure air forming a curtain which is blown out of a pressure box, shall surround the operation on the open sides to be exhausted and directed toward a receiving hood having sufficient exhaust to remove the air discharged from the pressure box plus such air as is induced into the pressure stream. The distance from any point of origin of dust, gases, fumes or vapors to the inner sides of air curtain should not be less than eight inches and if the object producing the dust, gases, fumes or vapors is very hot or if there is considerable steam or other fumes tending to cause considerable agitation of air within the air curtain, the distance from any point of origin to the inner sides of the air curtain shall not be less than twelve inches.

The air required for the air curtain may be recirculated by obtaining the required volume of air from the air exhausted from the receiving hood.

Figure 8 shows a diagrammatic outline as to how the air curtain functions and designing information is given for the proper functioning of air curtains.

(K) Exhausting Dissimilar Matter. No dissimilar matter shall be handled through one exhaust when the intermingling or contact of one type of matter with another type of matter will cause a fire or explosion hazard either in the piping system, collection unit, or air flow producing equipment. Operations generating sparks such as from hot materials or from grinding wheels, shall not be consolidated in the same exhaust system that also handles inflammable or explosive matter.

(L) Dissimilar Velocity Requirements. No exhaust system should be designed with the intent to handle a number of branches which may have a wide variation in velocity requirements because the system will require sufficient power to handle the highest velocity branch pipes which is far greater than required for the lower velocity branches.

Code of Recommended Good Practices

for

Metal Cleaning Sanitation



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INTRODUCTION

This code of recommended good practice for metal cleaning sanitation has been developed by a committee of the American Foundrymen's Association to cover the necessary engineering data in the design and operation of metal cleaning units and processes as well as specifications for personal protection of workers engaged in metal cleaning wherever such operations may be carried on in the gray iron, malleable, steel and non-ferrous branches of the foundry industry, and has been approved for publication by the Board of Directors of that Association.

Many foundries have, in addition to casting cleaning departments, pattern, machine and maintenance departments which are considered integral parts of the foundry operation. Also, in many instances there are additional departments wherein further operations are carried on in the processing of materials where this code may be applied.

The purpose of this code is to provide the industry with sufficient engineering, construction and operating information so that safe practices may be followed and exhaust systems may be properly designed and installed and the proper personal protection equipment provided, and is therefore recommended as a guide in furthering good practice.

The technical committee which prepared this code, known as the American Foundrymen's Association Industrial Hygiene Codes Committee, is as follows:

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Section IV: Cleaning Processes

(A)-GENERAL:

There are numerous methods or processes for the cleaning of metal parts in use today. This code prescribes engineering recommendations for the operation of such equipment, control of health hazards involved, and makes definite recommendations in connection with some of the more pertinent accident hazards.

The hazards involving health and safety with any type or process of cleaning must be recognized and thoroughly understood in order to provide the proper kind of installation and for safe operation.

(B)-METHODS OF CLEANING:

The cleaning of metal parts is accomplished by one of the following five methods:

1. Mechanical cleaning which includes such equipment and methods as tumbling mills, abrasive blasting units, hydraulic pressure methods, grinding, brushing, scraping and chipping.
2. Burning, which consists of the removal of surface matter by the application of heat or flames;
3. Solvent cleaning, which consists of the removal of matter from the surfaces of product by putting such matter in suspension, solution or dissolving the substance which holds such matter to the surfaces;
4. Chemical cleaning, which consists of the removal of matter from the surfaces of the product by saponification, emulsification or chemical reaction between the chemical cleaner and the matter to be removed; and
5. Electrolytic cleaning, either by the anodic or cathodic methods which consists of accelerating the action of alkaline or acid cleaners by the use of electric current.

(C)-SELECTION OF PROPER CLEANING METHODS:

Every type of product to be cleaned should be studied to determine the best method to clean the matter from the surfaces, depending on the kind of matter to be removed and the degree or standard of cleaning desired.

Matter to be cleaned from the surfaces of a product is divided into the following four classifications:

1. Inorganic insolubles, which includes oxides, sands, sulfides, dirt, dust, chips and abrasives.
2. Oils, which include oils that have not been changed chemically such as untreated animal, vegetable and mineral oils.
3. Treated oils, waxes, greases and soaps which include sulphonated and chlorinated oils and waxes, treated animal, vegetable and mineral waxes and fats, metal salts of fatty acids and greases.
4. Miscellaneous chemical compounds which includes fatty acids, inorganic acids and other chemicals and matter encountered in metal treatment.

Most metal cleaning operations present health or accident hazards, varying in degree and intensity with the type of cleaning methods employed. These hazards depend upon the toxicity of the cleaning medium or matter removed, the effect of the cleaning medium on the skin and eyes or through inhalation, the ability to protect the operators and others from direct contact with the process, the isolation or enclosing of the process and the like.

In addition to possible hazards from the cleaning operations, other hazards may prevail, particularly in solvent cleaning because of the evaporation of the solvents themselves from the surfaces of the product during cleaning or in the handling of the product after cleaning.

(D)-KNOWLEDGE OF HAZARDS:

1. GENERAL:

A complete study of the health and accident hazards shall be made to determine all the direct or indirect hazardous exposures or effects for whatever cleaning practice may be employed. The toxic properties of the cleaning medium or the matter to be removed from the product shall be definitely determined.

2. DUST HAZARDS:

The mechanical cleaning processes usually produce dust, much of which may be comprised of minute particles which, unless controlled by exhaust systems, may contaminate the general atmosphere and if of a toxic nature, may cause an occupational health hazard through inhalation, or may constitute a fire or explosion hazard. Such hazards exist if there are silica, certain oxides and the like, present. Dust hazards may not only exist in the actual cleaning operations but may also be present in the disposal of the refuse.

3. CHEMICAL HAZARDS:

The cleaning of product in solutions, solvents or acids, presents in many instances a very definite occupational, health, accident, fire or explosion hazard. Not only do some solutions and acids employed constitute a definite hazard in the raw state but some may through decomposition through the action of metals, water, heat and the like, cause secondary substances that are hazardous and even deadly in their effect. Due to the many possible compositions, solutions, solvents and acids available for good results in metal cleaning, a close analysis shall be made of the solutions or acids to be used and the effects of their decomposition.

The health hazard due to the use of some cleaning solutions, solvents and acids varies tremendously. Some only produce skin irritations resulting because of the removal of the natural oils from the skin while others cause irritation due to direct contact.

Other solutions and acids cause burns on the skin or may poison those coming in contact with them due to their toxic properties, by absorption into the skin.

Some solutions, solvents and acids cause occupational diseases through inhalation. In certain types of cleaners the fumes, mist or resulting gases are very toxic.

Certain persons are hypersensitive to some cleaning solutions, solvents and acids, and therefore operators should be carefully selected for such cleaning operations by a proper medical examination and observation.

4. SELECTION OF CLEANING EQUIPMENT:

A thorough study of every cleaning operation shall be made and only such equipment or practices shall be installed or inaugurated consistent with the quality of cleaning desired that can be operated and maintained in a safe manner from all hazards.

5. INSTRUCTIONS FOR OPERATING CLEANING OPERATIONS:

All cleaning equipment shall be operated and maintained to minimize hazardous exposure. Whenever any hazard of any kind exists, operators and others having to do with the process shall be instructed in their duties and in the care of the operation. Instructions shall include the dangers involved and in the use of whatever personal protective equipment and first aid practices that are to be followed.

In the absence of better information and instructions, the recommendations of the equipment or cleaning medium vendors shall be followed.

6. REPAIRS AND MAINTENANCE:

Close supervision and maintenance of cleaning equipment shall be in effect. Such supervision not only is an economic problem but will minimize exposure to health and accident hazards.

Some person or department shall be made responsible for the strict supervision over the carrying out of instructions for the safe operation and for the repair and maintenance of all such equipment.

7. ACCIDENT, FIRE AND EXPLOSION HAZARDS:

Only a few accident, fire and explosion hazard recommendations are enumerated in this code. Information is available on this subject from a number of recognized sources and use should be made of all such information.

8. PERSONAL PROTECTION:

Whenever any cleaning process requires the operators and others to wear personal protection equipment or clothing, such equipment and clothing shall be provided and worn during exposure to hazards. Instructions shall be given to those required to wear such equipment and clothing and supervision shall be maintained to see that such equipment and clothing are properly used and kept in a clean, hygienic and safe manner.

Section V: Alkaline Cleaning Processes

(A)-GENERAL DESCRIPTION OF PROCESSES:

Alkaline cleaners are used for the removal of oil and grease by either emulsification of the oils or saponification of the fatty acids in the oils or greases and for stripping off of paint by attacking the oil in the paint or japan, which will release the pigments on the surfaces and as neutralizers after some pickling operations.

There are many alkaline solutions, either straight or compounded, used to accomplish specific results and these vary with the kinds of metal to be cleaned and the nature and standard of cleaning required.

The cleaning solutions are heated and in some cases combine either the anodic or cathodic electrolytic processes for certain characteristic results.

(B)-HAZARDS INVOLVED:

The accident hazard is quite involved in the use of alkaline cleaning solutions because of the danger from burns to the eyes and the skin of operators. These solutions remove the natural oils from the skin and dermatitis may result. The health hazard is not particularly involved otherwise, except at the time when compounds are added to the hot solutions and if added too rapidly, excessive effervescence takes place. This gas should not come in contact with the skin or eyes and should not be inhaled.

Minimum Velocity of Air in (FPM)
Required in Pipe

3,600 ft.

4,000 ft.

5,000 ft.

6,000 ft.

Minimum Center Pipe (VP)
In Inches W.G.

0.97 in.

1.21 in.

1.88 in.

2.70 in.

All tests for air velocity shall be made with all branch pipes of the exhaust system fully opened at the same time.

NOTE: See American Foundrymen's Association Code of Recommended Good Practices for Testing and Measuring Air Flow in Exhaust Systems.

Section X: Abrasive Blasting Processes

(A)-GENERAL DESCRIPTION OF PROCESSES:

The abrasive blasting of metal parts embraces varied types of equipment, purposes, and methods of projecting the abrasives, as well as kinds of abrasive material employed. The personal element is extremely involved, particularly in those types of operations where the operator must be within, or adjacent to the compartment when in operation.

The abrasive blasting process is used for the removal of rust, scale, paint, sand and other surface cleaning operations, also core knockouts, and to produce certain characteristic finishes.

(B)-DUST EXPOSURES INVOLVED:

The abrasive blasting process cleans the product rapidly and therefore may produce large quantities of dust. The amount of dust is dependent upon the condition of the surfaces of the product, the amount of abrasives used per unit of time, the method of abrasive propulsion, and the kind of abrasive material used. Additional dust may be generated in the pneumatic and mechanical handling of the abrasives and in cleaning the abrasives for re-use and disposal of refuse.

Due to the dust created in such operations, all types of equipment and auxiliary appurtenances shall be substantially built and so constructed that there is no outward leakage of dust to the general atmosphere when in operation and the exhaust equipment is operating. When leakage outwardly occurs, the operators are not only affected but all other occupants in the immediate vicinity of the equipment are exposed. When the type of equipment is such that the operator must be within the blasting chamber in the direct presence of the dust created, the operator shall be protected by wearing suitable fresh, uncontaminated air-supplied respiratory equipment.

(C)-GENERAL CONSTRUCTION SPECIFICATIONS:

1. GENERAL:

There are several different types of abrasive blasting equipment and many adaptations of the various types to meet specific abrasive blasting problems. Many of the fundamentals of exhaust requirements are more or less common for the various types as well as the uniformity of requirements for auxiliary appurtenances.

2. AIR INTAKE OPENINGS:

Openings shall be provided in all units of the abrasive blasting equipment

and its appurtenances for the admission of ventilating air, so that there will be a definite flow of air of sufficient volume through the parts of the equipment to the exhaust system to continuously remove the dust created. Such openings provided shall be so located as to afford a uniform distribution of air flow through the parts to be exhausted and the openings within range of the abrasives used shall be so baffled or protected that abrasives will not ricochet through the openings to the outside of the equipment to cause a accident hazard or dust emitted to cause a health hazard.

3. ENTRANCE, PRODUCT AND INSPECTION OPENINGS:

All entrance, product and inspection openings, manholes and doorways into the blasting chamber of the abrasive blasting equipment or to the pits, hoppers, conveyor housings and other enclosures in the auxiliary appurtenances shall be completely closed and sealed when the equipment is in operation and the door or opening joints shall be so designed or provided with gaskets so that dust and abrasives will not escape into the general atmosphere. Suitable fasteners or locking devices shall be provided to keep the doors or covers in a closed and tight position when the equipment is in operation.

All door openings or turntable openings into abrasive cleaning rooms shall be close fitting and door joints properly baffled or sealed to prevent dust leakage or the escape of abrasives into the general atmosphere, particularly when there is chance of the abrasive stream being directed at such openings. One method of sealing the joints tight to prevent dust leakage outward and the escape of abrasives is shown on Fig. 4, which consists of a rubber tube held in place in the joint which is inflated when the doors or turntables are in closed position. Mechanical or electrical interlocks are provided so that the blasting operation cannot be started until the doors and turntables are in closed position and the tubes inflated.

4. FOUNDATION JOINTS:

Any sections of the abrasive cleaning equipment or its auxiliary appurtenances that are fastened directly to the floor or foundation and in which section there is dust produced, shall be sealed to the floor or foundation to prevent outward leakage of dust or abrasives into the general atmosphere.

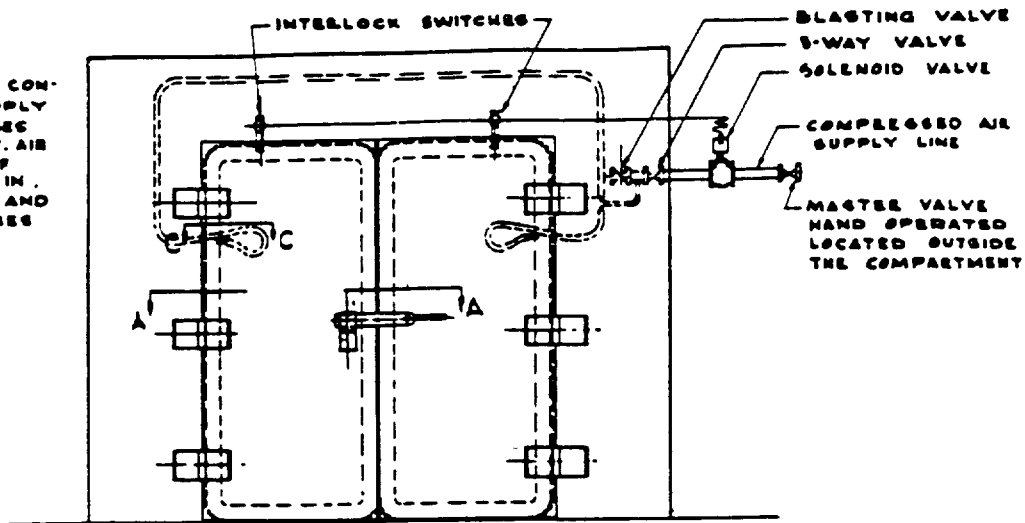
5. PITS AND HOPPERS:

When pits and hoppers are required below the abrasive cleaning equipment, and such pits or hoppers are not an integral part of and sealed to the abrasive blasting equipment, they shall be tightly covered around the outside edges of the equipment, except for such air intake openings provided for the admission of air for ventilating purposes to prevent the escape of dust into the general atmosphere, and such pits or hoppers shall be exhausted into the exhaust equipment provided for the abrasive blasting equipment.

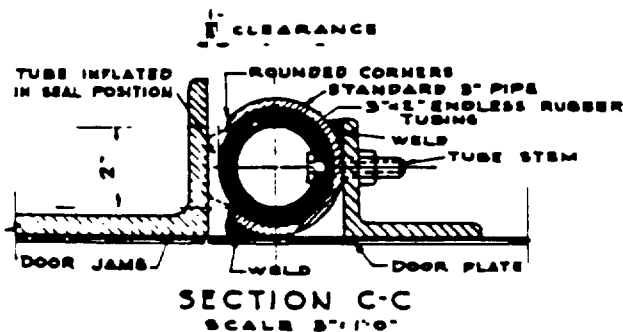
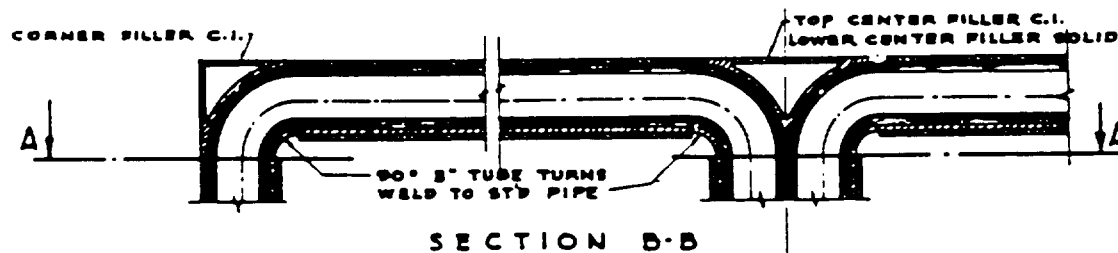
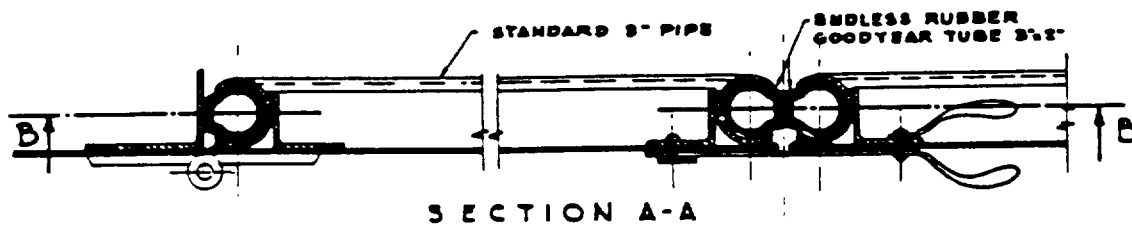
6. GENERAL CONSTRUCTION:

All abrasive blasting equipment and auxiliary appurtenances shall be substantially constructed. All joints and connections shall be made dust-tight. All exposed parts subjected to excessive abrasion shall be protected by lining with replaceable abrasive resisting rubber covered duck or other suitable material to further resist the erosion and prevent deterioration of the equipment that would otherwise permit dust leakage to the general atmosphere.

SOLENOID VALVE CONTROLLING AIR SUPPLY AND BLASTING TUBES SO ARRANGED THAT AIR SUPPLY IS SHUT OFF UNTIL DOORS ARE IN CLOSED POSITION AND INTERLOCK SWITCHES CLOSED.



FRONT ELEVATION OF ABRASIVE BLASTING LOOM OR COMPARTMENT SHOWING APPLICATION OF TUBE SEALS TO DOOR OPENINGS



NOTE: INTERLOCKING SYSTEM MAY BE EITHER ELECTRICAL OR PNEUMATIC.

PATENTED

PNEUMATIC SEALS FOR SEALING DOOR AND TURNABLE OPENINGS
FIGURE 4.

(D)-EXHAUSTING ABRASIVE BLASTING EQUIPMENT:

All abrasive blasting equipment and auxiliary appurtenances creating or conveying dust and dirt shall be connected to exhaust systems that shall be operated during any time the equipment is in operation to remove the dust and prevent its escape into the general atmosphere from the equipment.

(E)-EQUIPMENT EXHAUST REQUIREMENTS:

1. GENERAL:

All parts and sections of abrasive blasting equipment and the auxiliary appurtenances producing dust or handling abrasives shall be exhausted and the volume of air exhausted and the flow of air into air intake openings shall not be less than the following minimum requirements.

2. AIR INTAKE OPENINGS:

Air intake openings provided for the purpose of admitting air into the equipment or appurtenances to remove the dust therein to the exhaust system shall be of sufficient area to admit the required volume of air and the average entrance velocity of the air into such openings shall be sufficient to prevent outward leakage of dust and shall not be less than 300 F.P.M. unless otherwise specified.

3. ABRASIVE AIR WASHING UNITS

Whenever an abrasive blasting equipment is provided with an abrasive air washing unit to wash and remove the dust and refuse from the abrasives by air before re-using, it shall return the abrasives that are suitable for blasting.

4. PNEUMATIC CONVEYORS FOR ABRASIVES

Whenever pneumatic conveyors are used for conveying the used abrasives, dust and refuse to the abrasive washing unit, the air transport velocity shall not be less than 6500 F.P.M. and the air volume shall not be less than 100 cu.ft. per pound of abrasives and refuse handled.

5. MECHANICAL CONVEYORS FOR ABRASIVES

The casings enclosing mechanical conveyors for handling abrasives, dust and refuse shall be operated under negative pressure and shall have an air flow sufficient to prevent the leakage of dust to the general atmosphere.

6. DISCHARGE OPENINGS

Whenever there are chute or conveyor discharge openings discharging into the general atmosphere, the average velocity of air entering into the equipment at such opening shall not be less than 300 F.P.M.

7. SPECIFIC REQUIREMENTS FOR VARIOUS TYPES OF EQUIPMENT

(a) ABRASIVE BLASTING ROOMS

Abrasive blasting rooms in which the operator is working within the room shall be provided with down-draft ventilation of not less than an average of 80 F.P.M. velocity over the entire projected floor area of the room and the air shall be exhausted from the room downward through the floor or on at least two sides of the room at the floor line, except that in special instances cross ventilation may be used providing the average velocity shall not be less than 80 F.P.M. over the vertical cross section of the room.

(b) ABRASIVE BLASTING TUNNELS

Abrasive blasting tunnels are equipment in which the product to be cleaned passes into the cleaning room or chamber through an entrance opening by some means of conveyance and passes out of the room through an exit opening. Such equipment may be equipped for automatic blasting or operators may

be within the tunnel to perform the blasting operation. Entrance and exit openings shall be provided with vestibules of sufficient length or number of turns so that the baffling over the cross-sectional area of the vestibule openings provided for the prevention of the ricocheting of abrasives will be effective. The baffling in each vestibule may consist of at least two sets of doors or three sets of flexible curtains made of abrasive resisting material. The spacing of the doors or curtains shall be such that at least one set of either remains in closed position when the product is passing through the vestibule, unless the product is so large that the blasting operation may be stopped during the time the product is being transferred into or out of the tunnel and in which event tightly sealed doors may be used at the entrance and exit openings.

An average air velocity of at least 300 F.P.M. shall be drawn into the vestibules through the net open area of the doors or curtains.

The abrasive blasting portion of the tunnel, excluding the vestibules only, wherein operators are stationed for performing the abrasive blasting operations, shall be provided with downdraft ventilation of not less than an average of 80 F.P.M. velocity over the entire projected floor area of the blasting portion and the air shall be exhausted from the chamber downward through the floor or on at least two sides of the chamber at the floor line, except that in special instances cross-ventilation may be used providing the average air velocity shall not be less than 80 F.P.M. over the vertical cross-section of the chamber, except in cases where large bulky product is regularly passed through the tunnel, such as rolling stock, the amount of ventilating air may be reduced by providing for not less than 100 F.P.M. average air velocity over the net effective horizontal or cross-sectional area.

When abrasive blasting tunnels are operated automatically, or the blasting is directed by operators stationed outside of the tunnel, the same air velocity shall be used, but the air may be exhausted from the blasting portion of the tunnel at any place suitable for the installation.

(c) **ROTARY ABRASIVE BLASTING TABLES:**

Rotary abrasive blasting tables are equipment in which product is loaded on to a horizontal rotating table and passes into an enclosed chamber for abrasive cleaning. The exposed portion of the loading and unloading zone of the table shall be as small as possible so as to obtain as great a distance as possible between the entrance and exit openings in the chamber and the abrasive projecting units.

The entrance and exit openings shall be made as small as possible and shall be completely curtained with at least three sets of abrasion resisting rubber covered duck or other suitable material, spaced not less than 4" apart. Additional curtains shall be located within the chamber adjacent to the blasting units to minimize the escape of abrasives toward the entrance and exit openings.

The volume of air exhausted from the chamber shall not be less than the equivalent of 200 C.F.M. per sq. ft. of gross area of the inlet and outlet openings without the protective curtains in place.

(d) ABRASIVE BLASTING MILLS:

Abrasive blasting mills, whether of the barrel or conveyor type, shall be ventilated at least equivalent to twenty air changes per minute, based on the empty cubical contents of the work chamber.

(e) ABRASIVE BLASTING HAND CABINETS:

Abrasive blasting hand cabinets are small enclosures in which the parts are cleaned either by the manipulation of the product or abrasive stream by the operator from the outside who views the operation through a glass window.

Wherever possible, product openings or openings through which the hands are extended, should be closed dust-tight during operations, but in no event shall the average velocity of air entering all openings in the cabinet be less than 500 F.P.M. The amount of air exhausted from the cabinet shall be equivalent to at least twenty times the volume of the cubical contents of the cabinet per minute.

(f) HYDRAULIC BLASTING OR CLEANING UNITS

Hydraulic blasting or cleaning units employing water as a means for cleaning with or without abrasives shall be confined within enclosures that will effectively prevent water and/or abrasives from splashing or ricocheting outside the enclosure. Such enclosures need not be totally tight unless there is evidence of dust escaping from the cleaning operation that would contaminate the general atmosphere of the work place or room. When there is contamination of the general atmosphere because of such blasting operations, exhaust ventilation shall be applied to the enclosure that will exhaust the cubical contents of the enclosure not less than ten times per minute.

The tendency to generate dust in hydraulic blasting or cleaning operations is increased on types of units employing large volumes of water at low water pressures in the neighborhood of 100 lb. Installations requiring more than one operator within an enclosure shall employ baffling in the form of curtains or partitions that shall prevent the operators from being struck from the other blasting jets.

8. LOSS OF ABRASIVES

In order that usable abrasives may not be carried into the main exhaust system to the dust collection equipment and thereby be lost, the outlets from the blasting compartment shall be of sufficient area to prevent usable abrasives from being entrained in the exhausted air and such outlet openings should not have a velocity greater than 500 F.P.M. unless suitable abrasive traps are provided to return the abrasives and the necessary allowances for resistance to air flow caused by the trap shall be included in the resistance losses in the exhaust system.

9. ALLOWANCES FOR COMPRESSED AIR

When compressed air is used for the propulsion of the abrasives, the amount of compressed air discharged within the mill, room or cabinet shall be determined and added to the required amount of air for exhausting the abrasive cleaning equipment and auxiliary appurtenances.

The amount of compressed air discharged increases as the blasting nozzles wear and 50 per cent shall be added to the discharged capacities of the total normal areas of all blasting nozzle areas when new. The amount of compressed air

discharged for a given area and total nozzle area may be determined from the following table.

AIR DISCHARGE WITH ABRASIVES FOR
VARIOUS BLASTING-NOZZLE SIZES AND PRESSURES

Nozzle Dia. Inches	Area of Nozzle Sq. In.	CFM FREE AIR DISCHARGED					
		50 lb.	60 lb.	70 lb.	80 lb.	90 lb.	100 lb.
3/16	.02761	27.9	31.9	36.5	40.4	44.7	49.2
1/4	.04909	49.5	57	64.6	72.3	80	88
5/16	.07670	77.1	89.3	101	113	124	137
3/8	.1104	111	129	145	162	179	197
7/16	.1503	151	175	198	221	243	268
1/2	.1963	197	228	258	289	320	350
9/16	.2485	250	289	327	366	402	443
5/8	.3068	309	357	405	452	499	547
11/16	.3712	373	432	489	547	600	661
3/4	.4418	444	514	582	650	717	786

(F)-DESIGN OF EXHAUST SYSTEMS:

All abrasive blasting equipment and their auxiliary appurtenances shall be connected to exhaust systems and the minimum air velocity in any branch pipe or header pipe shall not be less than 3600 F.P.M.

Such exhaust systems shall be designed in accordance with the rules and engineering data prescribed in the American Foundrymen's Association Recommended Good Practice Code and Handbook on the Fundamentals of Design, Construction, Operation and Maintenance of Exhaust Systems.

The resistance of abrasive cleaning equipment to the flow of air varies greatly with the various types of equipment and the vendors of equipment shall be consulted as to the resistance loss to be expected and such information shall be given in terms of velocity pressure corresponding to the velocity in the connecting branch pipe exhausting the equipment.

(G)-TESTING EXHAUST SYSTEMS:

A pitot tube shall be used to measure the velocity pressure of the air flow in the branch pipes and headers of the exhaust system and such measurements shall be taken in the center of a straight portion of a pipe that is not less than ten pipe diameters downstream from an elbow or bend or as near this location as the pipe installation will permit and the velocity pressure as indicated by a manometer gauge shall not be less than 0.97 in. W.G. for 3600 feet minimum velocity.

NOTE: See American Foundrymen's Code of Recommended Good Practices
for Testing and Measuring Air Flow in Exhaust Systems.

(H)-COLLECTION OF DUST AND DIRT:

All exhaust systems shall be provided with dust collection equipment to remove the dust or dirt from the exhausted air from the abrasive blasting equipment and their auxiliary appurtenances and all such air shall be discharged out of doors except that exhaust systems connected to hydraulic blasting and cleaning units will not require dust collection equipment and such air exhausted shall be discharged out of doors.

(I)-RESPIRATORY PROTECTION:

All operators who must work in the direct presence and in contact with the dust and dirt created by the abrasive or hydraulic blasting and cleaning operations shall be provided with, and shall wear, fresh air supplied airline helmets or masks. The airline supplying fresh air to the helmets or masks shall not be less than 1/2 in. inside diameter.

The helmets or masks shall be provided with a supply of fresh, filtered air and

if such air is cold due to climatic conditions, the air shall be heated to at least 65° F. before entering the helmet or mask. Compressed air shall not be used as a fresh air supply for any helmet or mask unless an adequate air filter is provided to remove all dust and carbon monoxide.

The amount of air to be supplied to any helmet or mask shall not be less than 14 cu. ft. of air per minute so that there will always be a sufficient volume of air present to thoroughly purge the helmet or mask equipment and prevent dust and dirt from entering the helmet or mask openings.

No valves for controlling the air supply to the helmets or masks shall be permitted in order to prevent operators from reducing the required volume of air.

In all other respects, helmets and masks shall meet the minimum requirements for airline helmets and masks as specified by the U. S. Bureau of Mines.

(J)-BODY PROTECTION:

All operators who must work in the direct presence of the abrasive blasting or cleaning operations or water shall wear suitable protective clothing.

In abrasive blasting operations all portions of the body shall be protected from abrasives.

In hydraulic blasting or cleaning operations water-proof and ventilated clothing shall be worn to protect the operator from becoming wet.

(K)-DUSTING AND REMOVING ABRASIVES FROM PRODUCT:

Wherever it is necessary to remove loose dust or abrasives from cavities in a product that has been blasted and such removal is accomplished with an air blast, such dusting operation shall be performed within the abrasive blasting equipment with the exhaust system operating and shall not be done outside in the general atmosphere so that the dust will contaminate the general atmosphere. If it is necessary to perform the dusting operation outside of the abrasive blasting equipment, such dusting operations shall be performed in a special cabinet or booth that is properly ventilated to prevent contaminating the general atmosphere.

(L)-SUPERVISION AND MAINTENANCE:

1. SUPERVISION

Due to the hazards from dust exposure with the use of abrasive blasting equipment and its auxiliary appurtenances, the operators of such equipment shall be thoroughly instructed in their duties so that the equipment shall be used in the manner intended and shall be operated in accordance with the instruction given by the manufacturer.

2. MAINTENANCE:

The very nature of abrasive blasting operations is destructive to equipment and auxiliary appurtenances and a careful inspection shall be made periodically to make sure that the equipment is functioning properly and that it is in good state of repair. Defects shall be corrected in order to protect the operator or those in the immediate vicinity and to prevent dust and dirt from getting into the general atmosphere.

Close inspection and supervision shall be maintained over the use and care of all respiratory equipment to make sure that it is in perfect working and sanitary condition at all times.

Respiratory equipment shall not be interchanged between operators.

Means shall be provided for sterilizing respiratory equipment.

ADEQUATE DUST CONTROL KEEPS FOUNDRY CLEAN

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DURING THE PAST DECADE or two much thought, time and money have been expended on "cleaning up the foundry." This has been done not only by plant operating and engineering personnel but also by dust control equipment manufacturers, consulting engineers and institutions, and industrial hygiene personnel in insurance companies and official agencies, such as City, State and Federal Health and Labor Departments.

As a result of these combined efforts the foundry industry as a whole has come a long way, and the foundry no longer can be considered as a dark, dirty, dusty, dangerous place of employment. There are exceptions, of course, and the job of cleaning up is far from complete, but the industry and the American Foundrymen's Society deserve credit for the tremendous strides made in improving working conditions.

Before discussing the subject of this paper, let us recall some of the more important reasons which prompted dust elimination, since if we have clearly in mind the reasons why a job should be done we know better how to proceed than if we are groping in the dark. Probably the most compelling reason was the incidence of silicosis among foundry workers. There is little agreement among the rates reported by different investigators (references 1, 2, 3, 4, 5, 6, 7, 8), making the selection of a good average value out of the question.

The lack of agreement may be attributed to the different types of foundries studied, number and type of foundry workers included in the group, and procedure followed by the investigators. Very high incidences are reported by some investigators, but their studies covered selected employees rather than all employees in one or more foundries. The findings from all studies which covered all foundry workers and different foundries indicate silicosis to be present in less than 10 per cent of the workers. For 80 foundries in New York State, for example, the incidence was 2.7 per cent; an additional 4.5 per cent showing fibrosis⁸. These data show that while the silicosis rate in the foundry industry as a whole was not high enough to be alarming, it was high enough to justify immediate and concerted action.

The second compelling reason was the high rate of labor turnover and the difficulty, especially in times

of prosperity, of keeping men on the job. This relationship existed to a certain extent between the foundry industry as a whole and other industry generally; more so from one foundry to another; and most of all from certain types of jobs to others in a foundry.

Instances are known, for example, where the foundries found it necessary to clean up in order to operate at all; they could not hire men fast enough nor keep them long enough to maintain an effective working force. To these reasons must be added the desire of most management to improve the working conditions in the plants under their jurisdiction. Without the cooperation and backing of foundry management, much of the effort of those actively engaged in this work would be wasted.

The subject of dust control is much too big to be covered in one paper. There are large and small foundries; iron, steel, brass, magnesium and other similar types of foundries; there are jobbing foundries and production or assembly line foundries; there are mechanized foundries and others that are operated almost entirely by hand; and many other classifications which indicate unique differences requiring special control equipment, if not, indeed, wholly different approaches to the dust control problem. This discussion, therefore, will be confined to those operations common to a number of foundries regardless of type. The methods, equipment, or principles outlined are applicable to the control of the dust at the multitude of operations or dust sources not common to many foundries.

Foundry processes may be divided into the following five groups which afford a convenient pattern to follow in discussing the dust problems and their control:

1. Preparation of molds and cores.
2. Melting and pouring of the metal.
3. Breaking out castings from the molds and removing core sand.
4. Cleaning the castings.
5. Reconditioning the molding sand.

Preparing Molds and Cores

Little dust is dispersed in making molds by hand from damp sand. Even if sandslingers are used for throwing the molding sand into the flasks, not much dust is dispersed if the sand is moist. Most of the dust found in hand-molding areas is chargeable to poor housekeeping which allows the accumulation of dry

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Fig. 2—Partially-enclosing hoods have been fitted to the tilting furnaces shown at the left of photograph.

will suffice for furnaces which would otherwise require two to ten times as much air flow to accomplish a satisfactory job of control. Proper exhaust rates cannot be recommended for melting furnaces because they are governed so completely by the fit of the hood, the size and type of the furnace, and the nature of the materials melted.

Two miscellaneous operations associated with melting and pouring produce dust exposures that merit mention. These are abrasive cutting wheels for shaping or sizing refractory brick to be used in foundry furnaces, ovens and ladles, and ladle cleaning, repairing and relining. Dust at the abrasive saw should be controlled as described for similar saws used for cutting cores.

Dust produced in connection with ladle maintenance can be controlled by exhausting air from the ladles through a flexible hose, which terminates inside and near the bottom, whenever the workman is inside the ladle. The amount of air that should be exhausted depends upon the size of the ladle, but should be about 200 cfm per square foot of opening at the top of the ladle. If work of this nature is infrequent and of short duration, the man doing it can be protected by wearing a mechanical filter respirator of a type approved by the Bureau of Mines.

Shakeout and Core Knockout

Shaking out castings and removing core sand are important sources of dust dispersion. The amount of dust dispersed will vary tremendously, depending upon a number of factors. Among these are: (1) temperature of the casting; (2) dryness of the molding sand; (3) ratio of metal to sand; (4) shakeout and core sand removal methods employed, and (5) care taken in handling castings, dusty flasks and bottom boards.

From Table 1 it may be seen that of the 33 dust concentration measurements made at shakeout operations in the New York State survey, 13, or 39 per cent, were found to be less than 15 mppcf; four, or 12 per cent, were found to be between 15 and 30 mppcf; and the remaining 16, or 49 per cent, exceeded 30 mppcf. From the data shown in the report it may be

determined that the median concentration of the median values for all 12 foundries is 18.9 mppcf. This figure does not compare too unfavorably with the 16.3 mppcf given earlier for the molding areas.

Core knockouts may produce even greater variations in dustness than shakeouts. Breaking out soft core sand by hand with a bar and hydraulic blasting, of course, disperse very little dust, while pneumatic chipping on large, irregularly shaped castings disperses enormous amounts. Only six measurements of dust concentrations at core knockout operations were



Fig. 3—Positive dust control is effected at a shakeout by means of an exhaust-ventilated enclosing hood.

made in the New York State study. From Table 1 it may be seen that two of these concentrations, or 33 per cent, were below 15 mppcf; three, or 50 per cent, were between 15 and 30 mppcf; and the remaining one, which constituted 17 per cent of the total, exceeded 30 mppcf.

Shakeout and core knockout operations in particular should be segregated from less dusty operations such as molding, coremaking, pouring and melting in order that the dust created by them be prevented from making those other operations hazardous to health. Even if the shakeout is operated on an off-shift, much unsuspected dust may be added inadvertently to the adjacent molding area during the working shift by jarring loose some of the dust that had accumulated on the rafters and other surfaces of the molding area during the shakeout period.

Dust control measures for shakeout operations differ with the shakeout procedure, depending upon whether the work is done by hand or mechanical means, and whether or not it is done at central or localized locations. In the jobbing, and possibly even the semi-production foundry, the molds are stored over a large floor area until they are poured in a group.

Shakeout under these circumstances does not permit the application of local exhaust ventilation. Dust control can be accomplished by (1) allowing the castings to cool as much as possible before shakeout; (2) wetting down the floor and molds before shakeout and the mold sand immediately afterward; and (3) handling castings, bottom boards and flasks carefully. In addition, if this work is done during an off-shift, fewer men will be exposed to the dust dispersed.

Good general ventilation is necessary in the shakeout area, not only to keep the dust at a minimum but also to dilute the irritating gases and smoke to an unobjectionable level. Large roof fans which are operated only during the shakeout period are of great help in this respect. Even if the foregoing measures are taken, it is sometimes necessary for the men engaged in shakeout operations to wear appropriate respirators.

In contrast to general or scattered shakeout operations, dust control in the mechanized or production foundry can be accomplished very effectively as a rule by local exhaust ventilation. A thorough discussion of ventilating shakeout operations would require more time and space than is permissible here. Therefore, the subject will be covered only briefly; reference should be made to other articles for details¹⁰. The central shakeout table is in common use in mechanized foundries. Whether the molds reach the shakeout table by conveyor, crane, or other means is not important except as it affects hood design.

To keep the required exhaust rate at a minimum and still accomplish good control, the shakeout table should be enclosed as completely as possible. Typical installations are shown in Figs. 3, 4 and 5. The common types of hoods in use are termed overhead hoods and side hoods. Downdraft and complete enclosures have been attempted without much success. Downdraft fails largely because the air flow is least when it is needed most because the sand and the casting cover some of the grille just as the mold breaks, and complete enclosures are frequently impracticable because of changes in mold and casting sizes and shapes.

Although the dust from large shakeout tables can be captured effectively by the use of simple side hoods, side shields attached to the hoods reduce substantially

the required ventilation rate for adequate dust control. The time and effort spent by the hood designer and the foundry operating heads on developing an operating procedure that will permit the use of side shields will be repaid many times over in lower operating cost and improved dust control. The usual exhaust rates for hoods at shakeout tables range from 200 to 400 cfm per square foot of shakeout grille, depending on how nearly the hood encloses the table.

As with shakeout operations, removing core sand presents dust control problems which vary tremendously from foundry to foundry. The problems as well as the control measures are not unlike those associated with the shakeout. If the removal of core sand is not difficult and is accomplished by hand, such as the use of an iron bar or knocking the castings together, dust control can be effected by doing this work in a central exhaust ventilated booth similar to a spray-paint booth. An exhaust rate of about 150 cfm per square foot of booth opening will be adequate.

For cores which are difficult to remove, pneumatic chipping, blowing with compressed air, or blasting with water or a mixture of water and sand is required. These operations (with the exception of hydraulic blasting) should be done in an exhaust ventilated chamber or room similar to sandblasting rooms. Air at the rate of about 80 cfm per square foot of horizontal cross-sectional area should be moved through the room, which should be kept under a small negative pressure at all times to prevent the escape of dust. These conditions merely prevent the escape of dust from the chamber or room; they do not protect the worker in the room. Such workers require supplied-air respirators or helmets for adequate protection.

Cleaning castings by chipping, blasting, grinding, tumbling, brushing, and burning produces much dust.

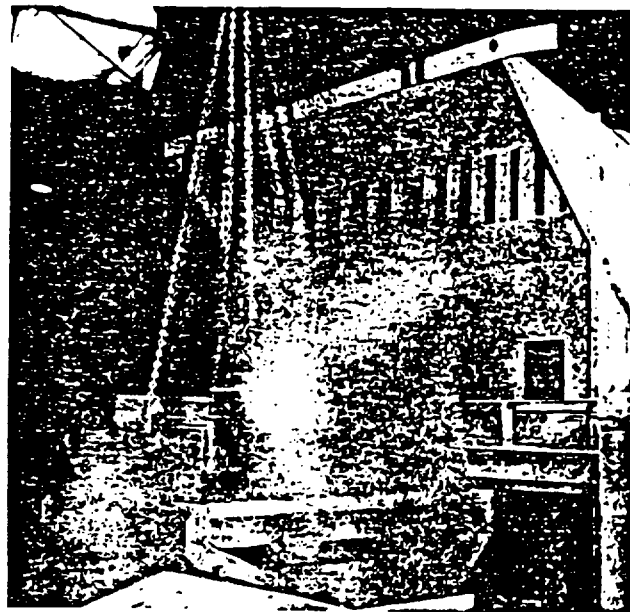


Fig. 4 (left)—A sidedraft hood installation provides positive control of dust at a central shakeout station.

Fig. 5 (above)—Effective dust control at a large shakeout operation is obtained by means of a sidedraft hood.

Most of these operations, however, lend themselves very well to dust control by local exhaust ventilation. In fact, dust control in the cleaning room of most foundries is much more common and effective than in other departments of the foundry. Consequently, dust concentrations at casting cleaning operations in the run-of-mine foundry are usually low, notwithstanding the fact that these operations are potent sources of dust production and dispersion.

This is evidenced, for example, by the results reported in Table 1. Of the 26 dust concentrations determined in ten different foundries, 17, or 65 per cent, were less than 15 mppcf; eight, or 31 per cent, were between 15 and 30 mppcf; and only one, or 4 per cent, was above 30 mppcf. Further analysis of the data given in the report of the New York State study shows the median dust concentration of the median values for all plants to be 13.3 mppcf. This is lower than the similar values given earlier for the shakeout and molding operations.

Details on hood or enclosure design and on required exhaust rates for stationary grinding wheels, tumbling barrels, and blast cleaning equipment such as rotating tables, cabinets and rooms have been presented several times elsewhere^{11,12}, and will not be repeated here. Dust from portable grinders and brushes should be controlled by downdraft or side-draft, preferably in booths or partial enclosures, as shown in Figs. 6 and 7. The required ventilation rates vary with the nature of the hood but, in general, are such as to produce a capture velocity of not less than 250 fpm in the grinding area.

Good general ventilation is adequate if only a few portable grinders are used and if the castings are free

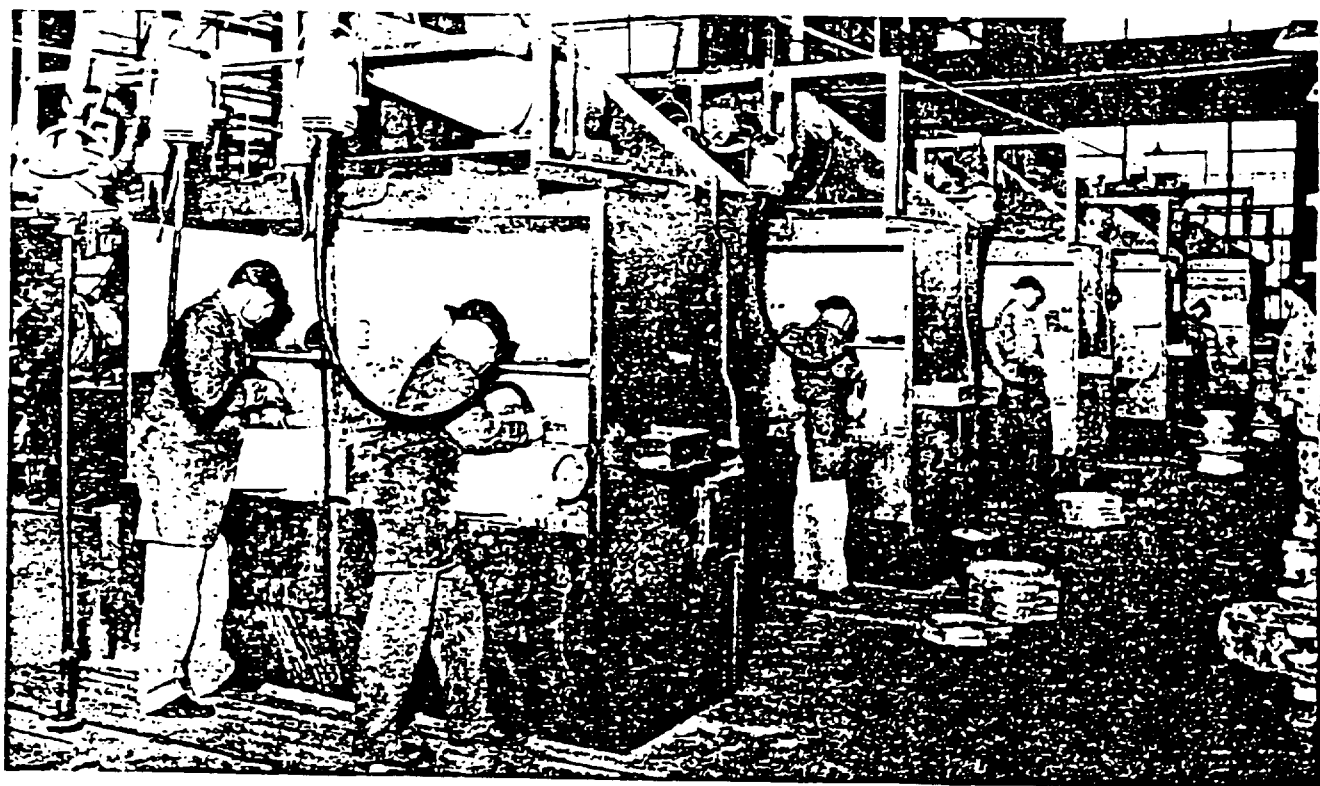
from sand. Swing-frame grinders should be provided with booth-type hoods which partially enclose the frames of the grinding equipment. The required rate of air flow depends on several circumstances, but for an arrangement such as shown in Fig. 8 an inward air flow of 150 to 200 fpm into the hood opening directly behind the grinding wheel produces good ventilation results.

Probably the most difficult problem of dust control in certain foundries is that associated with pneumatic chipping of sand which adheres to the castings, especially large and irregularly shaped steel castings. Local exhaust by means of movable hoods has not proven practicable. Hydraulic blasting with sand and water is being used with some success for such cleaning jobs (Fig. 9). Even shot blasting can replace some of the pneumatic chipping being done. While these procedures do not eliminate the dust problem *per se*, they must of necessity be done in chambers or rooms which prevent escape of the dust. The workers who operate the blasting equipment must be protected by suitable respiratory protective devices if stationed inside the cleaning room.

Burning off excess metal from castings seldom is done to such an extent as to introduce a dust, smoke or gas control problem except for the burner. Good general ventilation will solve this problem as a rule, but if it is a continuous operation it should be done in an exhaust hood similar to a spray booth which is ventilated at a rate of about 100 cfm per square foot of opening into the booth.

Careless handling of castings while charging the tumblers or while grinding will produce considerable unnecessary dust. A word is in order regarding general ventilation in the casting cleaning room. Since most of the operations are usually provided with local exhaust ventilation and the exhausted air is not re-

Fig. 6—Downdraft-type grinding booths provide dust control. The hood is an integral part of the collector.



circulated, the required make-up air is adequate to accomplish good ventilation in cleaning operations.

Distribution of the make-up air may not be satisfactory, however, and if the make-up air is drawn from adjoining foundry departments, the air entering the cleaning room may be contaminated excessively before it enters. This condition can be avoided by enclosing the cleaning room and drawing the air from some room or shop where there is little atmospheric contamination, or by supplying outside air, which must be tempered in cold weather.

Sand Conditioning

Dust produced by sand conditioning in foundries varies from almost none in the small foundry, where the used sand is moistened and cut over by hand, to large amounts in those foundries where sand conditioning is almost wholly mechanized and the used sand must be handled considerably before its moisture content can be increased. Even with mechanized handling little dust is produced if the sand is damp. Sand conditioning equipment that must be considered in the dust control program includes screens, conveyors, mullers, riddles, elevators, magnetic separators.

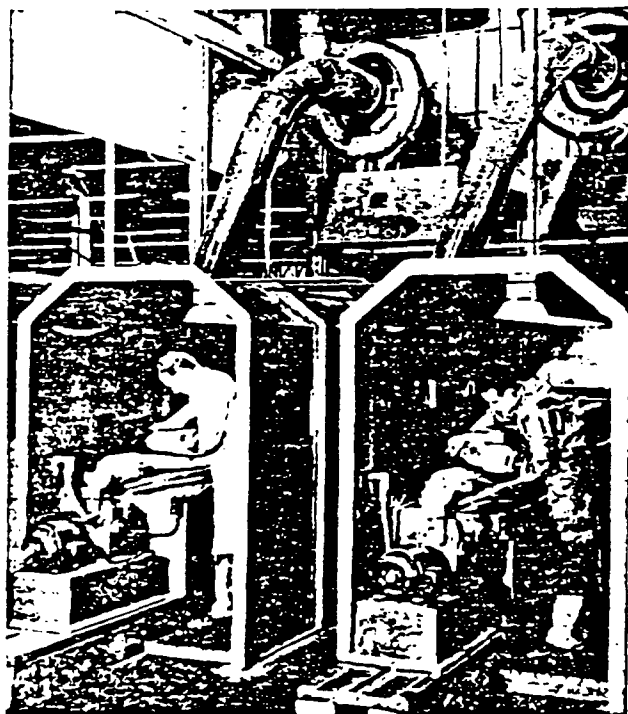


Fig. 7—Booth-type exhaust enclosures for controlling the dust created by belt-sanding of propeller blades.

The amount of dust produced by sand conditioning equipment is influenced largely by whether the sand is handled dry or moist, and whether or not control measures are in use. From Table 1 it will be seen that the concentrations found in the New York study were quite high. Of the 12 measurements made, three concentrations, or 25 per cent, were found to be less than 15 mppcf; five, or 42 per cent, were between 15 and 30 mppcf; and the other four concentrations, or 33 per cent, exceeded 30 mppcf. The data in the report show that the median concentration of the me-



Fig. 8—A battery of exhaust-ventilated booths controls the dust produced in swing-frame grinding operations.

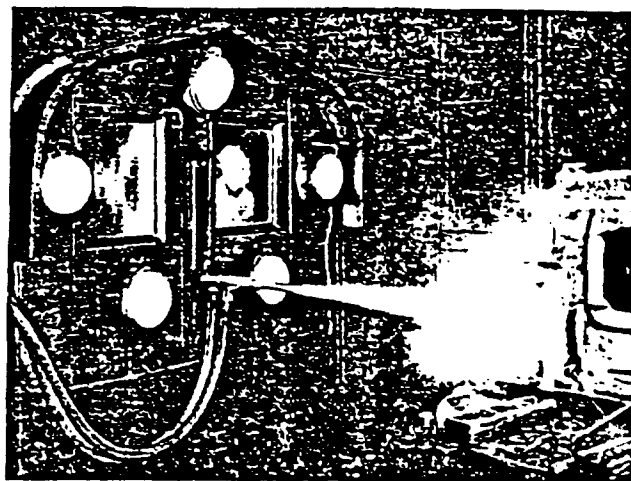


Fig. 9—Hydraulic blasting method of cleaning large castings of adhering sand prevents escape of much dust.

dian values for the seven plants in which sand conditioning operations were investigated was 27.2 mppcf. The comparable concentrations for the molding area, shakeout and cleaning room were only 16.3, 18.9 and 13.3, respectively.

Dust control at sand conditioning is a relatively simple and straightforward procedure. Electric riddles, except when used only infrequently, should be housed in booths similar to spray-paint booths which are ventilated at about 100 cfm per square foot of opening into the booth. If other unit or portable conditioning equipment is used, the sand should be moistened properly before it is processed, and in some instances respirators are needed by the men who operate this equipment.

Mullers, screens, transfer points at belt conveyors, elevators and magnetic separators should be hooded or enclosed and ventilated at rates summarized in Table 2. Figure 10 shows a diagram of a complete sand conditioning system with hoods as required.

The foregoing related almost entirely to specific conditions and control measures. There are a few

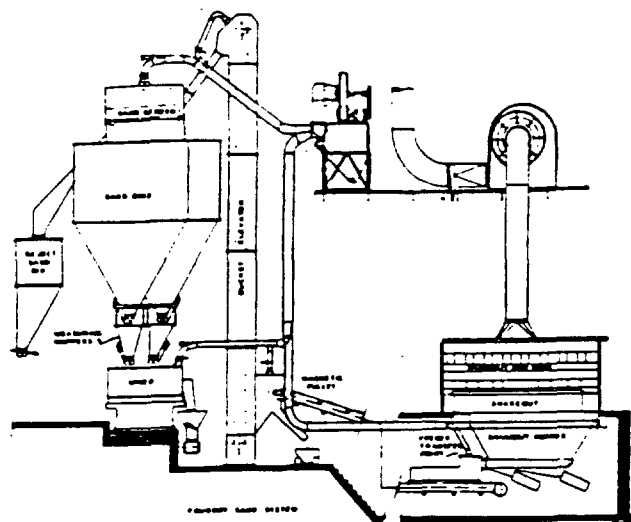


Fig. 10—Diagrammatic sketch showing a complete sand-conditioning system with dust control hoods as needed.

important fundamental considerations which apply almost equally to all foundries. These are (1) building construction and plant layout, (2) general ventilation, and (3) housekeeping.

Building construction, especially the layout or arrangement of departments and equipment, is of primary concern in dust control. Generally, little can be accomplished in this direction in existing foundries. New foundries, on the other hand, should be so laid out that there is a smooth or natural flow of materials.

Mechanization is important not only because it increases efficiency in production, but because it also makes possible more specific and positive dust removal. In one case an existing small brass foundry was rearranged and mechanized at what management felt was terrific cost. New cases of lead poisoning did not occur, whereas they had not been uncommon before the changeover. In addition, and to the pleasant surprise of management, production per man more than doubled and the percentage of rejects dropped almost one half.

Walls should be smooth and painted in light colors. Projections, exposed beams, etc., should be kept to a minimum so that there are fewer places for dust to collect and from which it must be removed routinely lest it be puffed loose. Good illumination aids

TABLE 2—MINIMUM VENTILATION RATES FOR HOODS AT SAND CONDITIONING EQUIPMENT

Equipment	Exhaust Requirement
Transfer Points	350 cfm per foot of belt width but not less than 150 fpm indraft.
Bucket Elevators	Exhaust from elevator head 100 cfm per sq ft of casing cross section
Sand Screens	Flat deck—50 cfm per sq ft of screen area but not less than 200 fpm indraft Cylindrical—100 cfm per sq ft of screen cross section. Volume may be doubled to provide required fines removal
Sand Mullers	150 fpm through openings in dust hood.
Sand Bins	150 fpm indraft but not less than 0.5 cfm per cu ft of bin capacity.

in speeding production and in housekeeping. The size of the foundry in relation to its production rate has a profound influence on the dustiness because the atmospheric dust concentrations decrease as the crowding decreases.

Good general ventilation is important because all foundries have many minor and scattered dust sources. Even if the main dust sources are controlled effectively by means of local exhaust and other specific measures, good general ventilation is needed to prevent the general dust level from rising to undesirable levels.

A rule of thumb method for deciding upon minimum general ventilation required is 20 air changes per hour for mechanized foundries, and 12 air changes per hour for plants that are not mechanized. When applying this rule, it must be remembered that the general ventilation required varies considerably from plant to plant. In some instances these suggested rates will be inadequate, especially if the other and more specific control measures are lacking.

Before the dust measurements had been made, all foundries studied were classified into three groups as regards the housekeeping in evidence. For the purpose of this classification housekeeping only was considered. The approximate average dust concentrations for the molding areas, the shakeout operations, and the cleaning departments (the three departments for which dust concentrations are reported in each housekeeping class) were 7 mppcf for the good housekeeping group; 25 mppcf for the average group; and 32 mppcf for the group classified as poor.

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THE FOUNDRYMAN LOOKS AT AIR POLLUTION

By

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ABSTRACT

The air-borne contaminants from a foundry are classified as dust, fumes, and noxious gases. They originate at many points in the foundry. Particle size is the most important property of solid contaminants. Each foundry finds itself in a different situation because the nature of the operation differs from foundry to foundry and because location of the foundry is of great importance. The foundryman and the local air-pollution control authorities should cooperate in working out an individual program for collecting dusts and fumes, employing the knowledge and research methods at hand.

The technical methods for controlling air pollution are fairly well developed. These include dry inertial collectors, and wet scrubbers which have a wide range of efficiencies and also a wide range of costs. Filtering methods and electrostatic precipitators are among the most efficient dust collectors. Several newer methods are going through the production development stages.

In spite of a number of factors which partially offset the cost of air-pollution control, cleaning air rarely yields a net profit. The actual cost will depend largely on the amount of cleaning required by the local conditions. The public will eventually pay this cost.

The Problem

The foundryman has a definite interest and a responsibility in preventing excessive discharge of waste into the atmosphere. But how much waste can be discharged into the air before we say the discharge is excessive or that the air is "polluted"? A few decades ago, dense clouds of smoke coming from the stacks of our industrial plants were regarded as a sign of prosperity, and nothing short of a dense cloud of noxious fumes would have been described as air pollution. On the other hand, refreshing country air contains wind-borne dust, pollen, and gasses from decaying vegetation.

The present trend is to define some concentration of contaminants between these two extremes as excessive. Air is regarded as polluted when the concentration of contaminants exceeds that which is injurious to property, to health, or to human comfort. For the most part, therefore, air pollution is of greatest concern in large centers of industrial activity. Overloading of the air with dirt may result from

numerous small sources of contaminants over a large area, or a single concentrated source, or any combination of these two conditions. Smoke and fly ash from industrial stacks, railroad locomotives, or the chimneys of homes and schools are the most obvious sources of contaminants. Burning trash and leaves in metropolitan areas, gob piles in coal-mining areas, and the exhaust from Diesel locomotives and trucks or even passenger automobiles also contribute their share of contaminants. It can be seen that the foundry, in most cases, is just one of the many sources of air pollution in a community.

Aside from the contribution of the foundry to the over-all burden of contaminants in an industrial area, the foundry, as an individual industrial plant, has a problem of community relations. When the neighbors see nothing but smoke pouring from the foundry, they get the impression that the foundry is a smoky, dirty place. They are inclined to blame their dirty washing on the smoke that they can see, even though the actual source of the dirt may be some distance away or perhaps just the general condition of that particular area.

One of the problems facing the foundry is that of attracting young men to work in that industry. Certainly a reputation for smoke and dirt does not help the foundry solve this problem.

Each Foundry is an Individual Control Problem

To those who have studied air-pollution problems, it is evident that each plant presents an individual problem. The methods for reducing contaminants must be tailored to fit this individual situation. The municipal and county programs, in each case, form the backbone of air-pollution control. Each company within a local air-pollution control district should work out its own program in cooperation with the local air-pollution control engineer. Any program of air-pollution control should make the widest use of the knowledge that is available.

The first information required in setting up an individual program for the control of air pollution is a knowledge of the physical and chemical nature of the contaminants emitted into the air, especially

*Battelle Memorial Institute, Columbus, Ohio.

their particle-size distribution. The concentration of the contaminants and the points at which they leave the plant also need to be known. Other important factors are the natural surroundings of the plant and locations of population centers and farms. Of equal importance are the atmospheric conditions under which the contaminants are found objectionable.

In the dispersion of air-borne contaminants, the nature of the country and the atmospheric conditions play major roles. Flat country, especially near the Great Lakes where strong winds are frequent, favors the rapid dispersal of dust, fumes, and noxious gases. Narrow, deep valleys furnish pockets in which contaminants may collect to form relatively high concentrations. Temperature inversions which form over pockets in the land stabilize the air and prevent the normal vertical dispersion of contaminants. A temperature inversion is a condition in which the air at ground level is colder than the air above it.

Los Angeles county is an outstanding example of the influence of the nature of the land surface and atmospheric conditions on the buildup of contaminants over an industrial area. In Los Angeles county, a large concentration of industry is situated in a basin surrounded on three sides by mountains. Temperature inversions, in effect, put a lid on this basin. Because they cannot get out of the basin, smoke and fumes and noxious gases frequently build up for several days. Fogs, rolling in from the ocean, combine with the concentration of man-made contaminants to create a powerful eye-irritating smog. It is because of this set of conditions, which are abnormal for most of the rest of the country, that the air-pollution standards for Los Angeles must be so rigid.

Devices for Analyzing Air-Borne Contaminants

There are well-established technical methods for determining what are the air-pollution problems of any individual industrial plant. These methods utilize devices for collecting and analysing the air-borne contaminants. Analysis of an individual foundry's contribution to air pollution can be made right at the source. For example, the amount and nature of emissions from a cupola can be determined. Measurements of dirt falling on the surrounding community also can be made. A new device, developed at Battelle, not only determines the amount of dirt fall but also establishes the direction from which dirt is coming.¹ A knowledge of the direction from which the dirt is coming is of special interest in determining whether the contaminants are of local origin or have been blown in from another area or community.

Devices for measuring the influence of the surface of the land and the atmospheric conditions on the dispersion of contaminants are also in use. For studies just above ground level, instruments have been attached to fixed structures. A new technique uses a kite balloon to carry weather instruments and air-sampling devices up to altitudes of 500 ft or higher.^{1,2,3} In highly industrialized areas, these methods provide the tools for securing a three-dimensional picture of contamination of the air.

The Nature of Air-Borne Contaminants

An effective program for controlling air pollution from the foundry must be based on a knowledge of the origin and nature of the contaminants that are emitted into the air. It is customary to divide the contaminants into four principal classes: (1) smoke, (2) dusts, (3) fumes, and (4) noxious gases. Smoke is defined as the solid or liquid particles resulting from incomplete combustion of organic materials. Soot is an example. Dusts are solid particles of any nature which have been produced by mechanical processes and released into the air. Particles of iron and abrasive from the grinding of castings are typical dusts found in the foundry. Fumes are solid or liquid particles in the air, commonly generated by sublimation, vaporization, or chemical reactions. The white fumes liberated during the baking of cores, and the brownish fumes which arise from hot iron or steel are typical examples of fumes in the foundry. Sulphur dioxide and carbon monoxide are typical noxious gases with which the foundryman is familiar.

Probably the most important property of contaminants is their particle size.⁴ Particle size coupled with density and shape determines the distance contaminants will travel in air before they settle to the ground. Visibility of contaminants is determined by the number and size of the particles in the air and by the degree to which moisture condenses on the particles to form fog. Finally, the particle size of the contaminants determines what methods of sampling and analysis can be used for studying the air and what type of equipment can be used for separating the contaminants from air, and for their subsequent disposal.

In view of the importance of particle size in air-pollution control, the foundryman should have an idea of the size of particles involved. The size of smoke, dust, and fume particles is commonly expressed in terms of the average diameter of the particles measured in microns. A micron is 1/1000 of a millimeter, or 1/25,400 of an inch. The size of particles in the air may range from over 1000 microns for raindrops to considerably less than 0.01 micron for sulphur dioxide and other gases. Several other examples which are useful in visualizing the size of the particles are: (1) a 50-mesh sand has an average diameter of 295 microns, (2) a 325-mesh silt has a diameter of 44 microns, (3) the smallest particle visible to the naked eye is 10 microns in diameter, and (4) the particles in tobacco smoke have an average of about 0.3 micron.

Particles below 1 micron in diameter tend to stay suspended in quiet out-door air almost indefinitely, whereas those larger than 1 micron tend to settle at a more or less rapid rate. In agitated air, such as found in foundries and other industrial plants, particles 10 microns or larger in diameter may stay suspended in the air for a considerable length of time.

The range of particle size for a number of industrial dusts and fumes is shown by means of bars in Fig. 1. Foundry dusts include such coarse particles as the cinders and other debris blown out the stack of a cupola and the finer dusts from the foundry

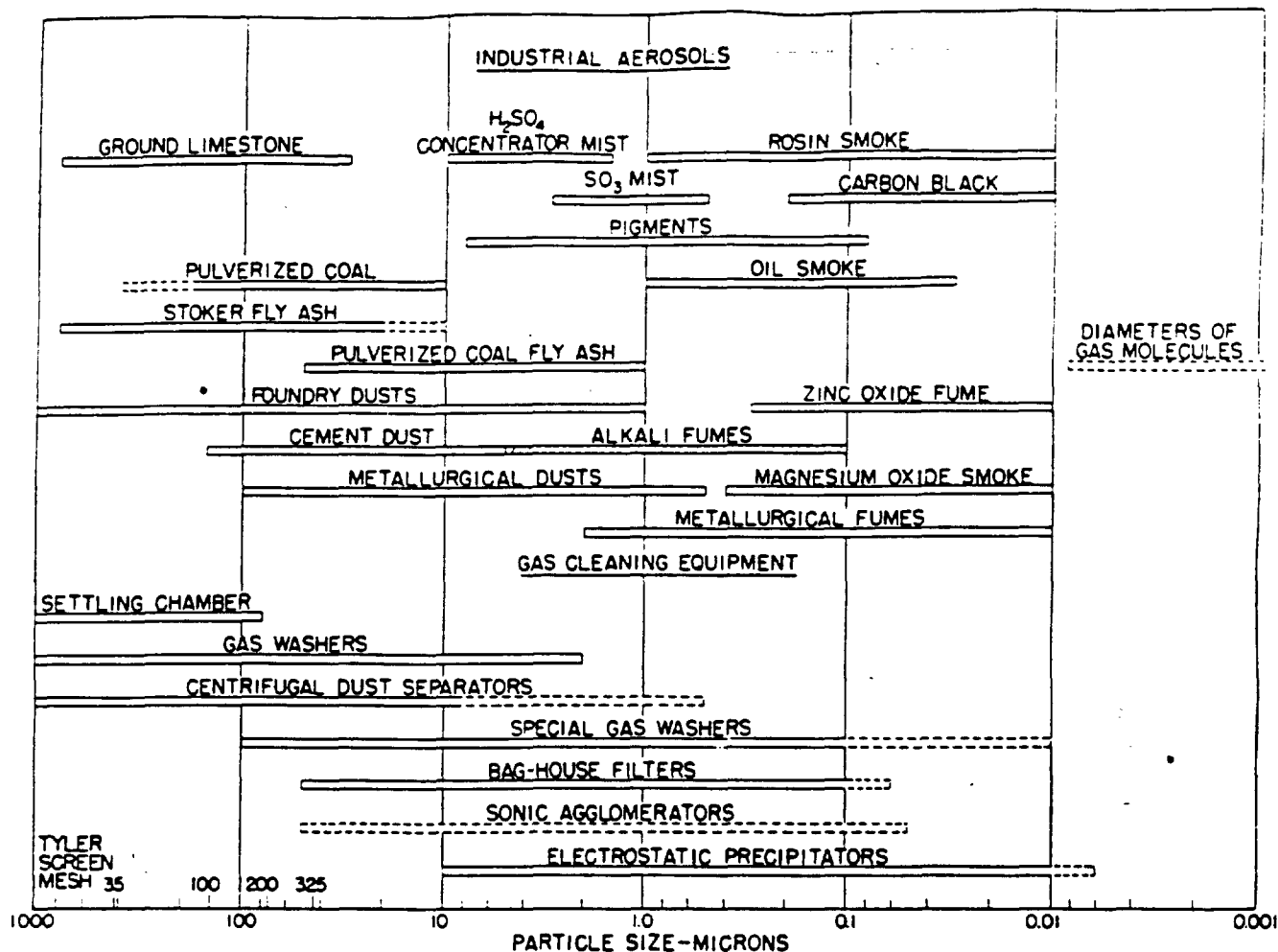


Fig. 1 —Particle Size of Industrial Aerosols and Equipment for Cleaning Gases

shake-outs and cleaning room. Metallurgical fumes comprise such contaminants as the brownish fumes coming off the electric or open hearth, and that part of the cupola and the non-ferrous-melting furnace emissions resulting from volatilization and oxidation of the metallic constituents of the charge.

It is apparent that the foundryman must contend with the entire range of particle sizes considered to be air contaminants. For the sake of economy in controlling the air contaminants, the foundryman should use the type of collection equipment that will do each job at the lowest cost.

The particle-size ranges for which broad classes of collecting equipment are effective are shown in the lower half of Fig. 1. Additional details on collecting equipment are given in a later section.

Source of Contaminants

Air-borne contaminants come from many points in the foundry. In many cases, the melting department is a major source. In fact, the melting department has been the first to attract the attention of air-pollution control authorities in many cities. The electric furnace and open hearth for steel and iron melting emit clouds of reddish-brown fumes, especially during melt-down when the charge is not protected by the

metal is at its maximum temperature. The advent of the oxygen boil in steelmaking has aggravated the fume problem.

The open-top cupola belches forth a stream of hot gases clouded with solid particles. The coarsest particles are the size of coarse sand. The finest particles must be viewed with an electron microscope to distinguish them. Coarse particles settle on the foundry roofs, yards, and on the foundry's immediate neighbors. The finer particles drift away to settle at some distance from the foundry. Sulphur dioxide, formed from sulphur in the coke, and unburned fumes from oily scrap add their characteristic unpleasant odors.

A typical sample of the cupola stack-gas emissions will contain on the order of 35 per cent of its particles in the zero to 5-micron range and about 50 per cent of the particles will be over 44 microns (325 mesh). The remaining 15 per cent will be spread out over the range of 5 to 44 microns. The concentration of particles above 44 microns (325 mesh) is chiefly dust and debris consisting of broken coke, fine metal chips, rust, sand, and dirt, which are picked up by the rising gas stream and carried out the stack. The particles in the 0 to 5-micron range are chiefly fumes from the volatilization and oxidation of iron, silicon, manganese, and certain tramp elements by the in-

largely responsible for the opacity or color of the stack gases, primarily because there are so many particles in a given weight of fume as compared to a given weight of the coarse particles. It takes 1000 particles, 1 micron in diameter, to weigh as much as one particle 10 microns in diameter.

The core room also is a major contributor of fumes in the atmosphere in and around a foundry. Fumes given off from core oil and cereal binders during the baking of cores are pungent and irritating. A host of obnoxious compounds have been identified in the fumes given off by linseed oil during drying. These include acrolein, formic acid, acetic acid, acrylic acid, butyric acid, carbon monoxide, and a number of other volatile products.⁵ Presumably, many of these same compounds are generated during the baking of cores and also during casting and shake-out of molds containing cores.

No entirely satisfactory substitute for core oil has been developed which does not give off fumes and odors. In some cases, the odors of the substitutes were more obnoxious to many foundrymen than the odors from core oil.

The shake-out and cleaning room are also sources of large quantities of fumes, dusts, and noxious gases. In the shake-out, large quantities of hot sand are suddenly exposed to air. Particularly where many cores are used, large quantities of fumes and noxious gases are generated by the incomplete combustion of organic materials in the mold. Added to this burden are fine sand and binder materials thrown in the air by mechanical agitation used to shake the molding material off the casting. In the cleaning room, the problem is mostly one of dust generated by such operations as chipping, blasting, and grinding, although metal and other fumes do arise from welding operations.

Miscellaneous sources of air contamination in the foundry are open fires, handling of dry sand before it is tempered, parting agents, metal fumes from the ladle during transfer and pouring, and mold gases. The foundry pattern shop also has its dust-control problem. In this case, however, the materials involved are woodworking shavings, chips, sawdust, and, if metal patterns are used, there is the possibility of metal and abrasive dust.

Methods for Control

The industrial hygienists have developed excellent methods for reducing the concentration of contaminants in the air within the foundry. They have approached the problem from several angles, among which are (1) to prevent or to reduce the production of dust, fumes, or noxious gases, (2) to reduce the use of materials which give rise to dust, fumes, and noxious gases, (3) to provide personal safety equipment to prevent inhalation of dust, fumes, or noxious gases, and (4) to extract the dust and fumes from the various points in the plant where the contaminants are generated.

The extracted dust- and fume-laden air may be exhausted directly into the atmosphere outside the

foundry. If the burden of dust and fumes of this air is great, the air must be passed through an air cleaner to avoid air-pollution problems. The foundryman is then faced with making a decision as to what type of dust collector to use.

Control of air pollution starts with the dust hood and ducts to convey the dirt-laden air to the collectors. Much good engineering has gone into dust hoods and ducts. Since the principles are well known, the subject will not be discussed here except to mention one of the problems encountered in the foundries that have applied dust control to existing plants. In most instances, space is at a premium, and dust-control equipment must be built into extremely limited space. This leads to a temptation to use hoods, piping, and collectors of inadequate size.

Available Types of Dust Collectors

The technical methods for cleaning dirty air and gases discharged into the atmosphere are fairly well developed. The proper selection and application of cleaning equipment depends on a knowledge of the types of collectors available and their performance. Dry inertial collection methods are the most economical but have definite limitations. These methods depend on gravity or the momentum of a particle to carry it out of the gas stream. In its simplest form, the dry collector is merely a settling chamber or an enlargement in the duct carrying the dust-laden gas. Practical limitations on the size of such chambers do not permit designs with low enough gas velocities to extract fine particles. The minimum particle size normally collectible in a settling chamber is on the order of 40 to 80 microns, depending on the design.

The cyclone collector is a widely used collector of the inertial type. By introducing the dust-laden gas tangentially into a circular chamber, a centrifugal motion is created which throws the dust particles to the side where they deposit, or drop to the cleanout in the bottom.

Decreasing the diameter of the cyclone makes the gas travel in a tighter circle and increases the centrifugal force for throwing the dust out of suspension. The small-diameter cyclones, therefore, are more efficient where particles in the smaller size range are encountered. On the other hand, because of rebound of coarse particles, the collector may not be as efficient for removing particles of large size. Multiple units of small-diameter cyclones are required to handle a large volume of gas.

A large variety of makes and configurations of cyclone collectors is commercially available. In general, however, the collecting efficiency drops off rapidly for particles below about 20 microns in diameter for the large-diameter cyclone and below 10 microns in diameter for the small-diameter multiple cyclones. In addition, the collecting efficiency is practically nil for particles below 5 microns for simple cyclones and 2 microns for multiple cyclones. This, of course, limits the type of dust that may be collected. Efficiencies in the neighborhood of 97 per cent have been reported on coarse material, such as saw dust from planing mills.⁶ In contrast, they may

collect only between 10 and 25 per cent of the solid material in stack gases from a boiler.⁷

In many cases, where it is necessary to install additional exhaust fans, or where space is limited, a mechanical centrifugal collector will be found practical. This type of collector uses a high-speed impeller to provide the centrifugal force for throwing the dust out of suspension. The impeller also acts as a fan for drawing the dust-laden gas through the cleaner. At the point of greatest concentration of dust, part of the air is skimmed off and carried to a settling chamber. After depositing the entrained dust, the air is recirculated in the system.

Louver and dry skimmer collectors also depend on inertia for throwing the dust out of suspension. Inertia concentrates the particles of dust in the small end of a slotted metal cone. About 90 per cent of the air passes through these slots to the blower and stack, while the concentrated suspension passes into a small cyclone. The exhaust from the cyclone is recycled in the concentrator.

Centrifugal Separators and Louver Collectors

Both mechanical centrifugal separators and louver collectors have application for collecting particles in the size range collected by cyclone separators. Dry inertial collectors, as a class, are not suitable for collecting fine dust (particularly particles below 10 microns in diameter). They are satisfactory, however, as rough cleaning devices for reducing the load on high-efficiency final collectors with which they are frequently used. On the other hand, as final cleaners for coarse, non-toxic materials, such as wood or metal chips, they do an excellent job and are simple and inexpensive. These collectors can be built to handle relatively hot gases which makes them eminently suited for such applications in cupolas where merely the removal of the coarse particles from the stack gas is sufficient to satisfy local conditions.

When dry inertial collectors are inadequate, it is advisable frequently to go to one of the wet collecting methods. Wet collecting methods depend on a simple process of washing or scrubbing the dirt out of the gas and wetting the particles to increase their effective diameter so they may be removed by simple collectors, such as a cyclone. In addition to removing dust, wet collectors also can remove sulphur gases which may sometimes be important.

Static Spray Washers

The simplest form of wet cleaner is the static spray washer which may be seen mounted on the top of many cupolas. This equipment can remove 50 to 75 per cent of the solid matter and a portion of the SO_2 in the cupola effluents. However, a large portion of very fine solid particles escape.

Wet scrubbers are more efficient in removing the smaller size particles than are the simple spray washers. Wet scrubbers depend on mechanical means of admixing a spray of water with the dust-laden gas. They employ the cyclone, rotary centrifugal collector,

Roughly speaking, the efficiency of these scrubbers is related to the work applied to admixing the water and gas. Scrubbers can be very efficient and give very clean gas. Because of the high power requirements for the highly efficient scrubbers, it is customary where very clean gas is required, to use a scrubber of moderate efficiency, followed by other types of final cleaners which require less power. The wet cleaner reduces the load and, at the same time, cools the gas.

Cloth filters or bag houses are becoming a more familiar sight around the foundry. They operate on the same principle as the vacuum cleaner in the home. They have been applied to cleaning the exhaust from the shake-out and cleaning rooms. In similar applications, they have been found to operate with dust-collecting efficiencies of over 99 per cent.⁸ It has been only recently, with the development of the glass-cloth bag which will withstand temperatures up to about 500 F, that bag houses have been utilized for the difficult job of cleaning the hot gases from the cupola. They have been found to satisfy the difficult requirements of the Los Angeles County Air Pollution Control District.⁸ All material passing through the cloth filter is below 5 microns. Efficiencies are good on particles down to a fraction of a micron. Bag houses are limited, however, to applications where there are no condensable fumes or gummy materials present.

Electrostatic Precipitators

Electrostatic precipitators are probably the most efficient of all collectors. Collecting efficiencies are very high on particles down to a fraction of a micron. Although electrostatic methods do not remove gases, there seems to be no lower limit to the size of solid particles that they will remove.

Electrostatic precipitators employ up to 75,000 volts to induce a negative electrostatic charge on the surface of the dust particles. The dust particles are then repelled to the positive electrode, which is constructed to serve as a dust catcher.

Among the newer methods for collecting dust and smoke are the sonic agglomerators.^{9,10} Sound waves cause the small particles of dust to vibrate, thereby increasing the number of collisions between particles. Upon collision, surface forces on the particles of certain types of materials cause them to adhere to one another. Through a series of collisions and adhesions, small particles agglomerate to such size that they can be removed from the gas with a cyclone separator. The method is limited to very small particles, as are found in smoke, and it does not work on all materials. Further developmental work is required before its possibilities in the foundry are known.

One of the latest improvements in wet collecting equipment is the Venturi scrubber.¹¹ In this scrubber, water is broken up into a very fine mist. The mist and gas pass through the venturi portion of the collector where the very small droplets wet and absorb the very small particles of dust. A cyclone separator then collects the wetted particles and drops

Control of Combustible Fumes

Combustible fumes can be destroyed by oxidation or combustion. Where the ratio of combustible material to air is high enough, as in the cupola stack gases, combustion will be self-sustaining once it has been started. An ignitor is sometimes used for igniting the gases during periods when they do not ignite freely. Lean mixtures, which will not maintain combustion, must be heated to temperatures on the order of 1200 to 1400 F. to complete the oxidation. In some instances, fumes from the baking of cores have been reduced by recirculating the air in the oven through the burners.

One of the newer methods for oxidizing combustible fumes is the catalytic combustion process. Very dilute mixtures of combustible vapor or gas will oxidize at temperatures as low as 350 F. or less, in the presence of a catalyst. This principle has been applied commercially to the oxidation of a number of fumes and gases, including the fumes from the baking of cores. Of special interest is the fact that the heat obtained from the oxidation of these fumes is returned to the oven to reduce the amount of outside fuel required to keep the oven hot.

The Cost

The purchase cost of dust-collecting equipment ranges from something less than \$100 per 1000 cu ft per min treated for simple cyclone separators, to \$1000 or even more for certain of the very high efficiency collectors, such as bag houses, electrostatic, or disintegrator-type washers.^{12,13} Power consumption may be as low as 0.1 kw per 1,000 cu ft per min for simple gravity settling chambers, to as high as 10 kws per 1,000 cu ft per min for high-efficiency scrubbers. These figures are for total power, including electrical energy, water-pumping power, power for necessary auxiliary equipment, and pressure drop through the apparatus.

One thing that must not be overlooked in estimating the cost of dust-control equipment is the actual volume of gas handled. The more gas handled, of course, the larger the size of collecting equipment required. In the design of dust hoods, for example, sufficient excess air must be drawn through the equipment to flush all the dust-laden air from the source. The equipment must clean all this air plus any excess that is taken in. Cupola stack gases are another example where the volume of gases emitted is greater than may seem at first. The volume of gases generated by a cupola may be 2 to 4 times the volume of air blown into the tuyeres. Burning of the gases in the stack and aspiration of air in the charging door may increase this volume to 5 to 7 times that of the tuyere air. Cooling of these gases before they are passed through the dust collectors, of course, reduces considerably the volume of gas that must be handled. Nevertheless, the volume that must be handled is more than the volume of air blown into the tuyeres.

Who pays the cost of clean air? The answer to this is simple and one which everybody should know.

The cost of clean air is eventually paid by the public. The degree that air pollution is controlled in the future will depend largely upon the amount the public is willing to pay for controls in terms of increase of cost of products.

The materials recovered in the air-cleaning operation seldom have much value. There have been figures published on the large savings in nonferrous smelting operation by collection of the dust from the flue gases. For example, it has been estimated that \$27,000,000 worth of metals have been recovered in the copper industry alone.¹⁴ Unfortunately, in the foundry industry, in general, the products recovered in the dust collectors are not nearly so valuable. For the most part, they may be classified merely as dirt which has to be hauled off to the dump.

Fly ash collected from the cupolas may have some value as a filler for concrete. However, it probably must sell for considerably less than concrete itself. It must be used close to the source and must be available in quantities large enough to be worth handling. Recently it has been found that fly ash makes a capable pipe eliminator of the non-exothermic or insulating type to apply to the surface of feeders on castings.¹⁵ This would permit the foundry to consume its own fly ash to some advantage.

For the most part, the small quantities of salvageable material involved make the cost of handling more than the products might be worth. It seems hardly worthwhile to develop a useful market for them.

Other opportunities to realize some return on the investment in dust collectors are difficult to evaluate in dollars and cents until the equipment is installed. The factors which may partially offset the cost of clean air are: (1) reduced maintenance, for example, less frequent cleaning of the roof, (2) better working conditions and workers' morale, and (3) better relations with the neighbors. The last two factors should help attract better workers into the foundry and reduce labor turnover.

The by-products and other benefits derived from gas cleaning rarely yield a net profit on the entire cost of the gas cleaning operation, but they may help materially to reduce the expense.

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DISCUSSION

Chairman: F. W. SHIPLEY, Caterpillar Tractor Co., Peoria, Ill.

Co-Chairman: J. R. ALLAN, International Harvester Co., Chicago.

Recorder: H. F. SCOSSE, American Foundryman's Society, Chicago.

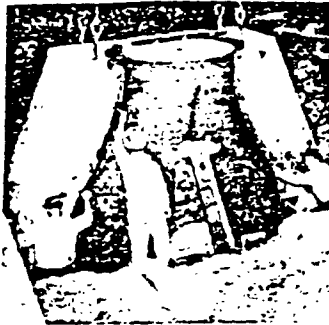
ORVILLE LAABS¹: Which type of dust and fume collector is preferable, the dry or the wet type?

MR. KEYSER: Foundrymen should use whichever type dust and fume collector is necessary to meet local air pollution ordinances. Use the dry type if possible because of its lower maintenance costs.

K. M. MORSE²: What data can you give us on the size spectrum of cupola emissions, Mr. Keyser?

MR. KEYSER: About 50 per cent of the particulate matter emitted is dust larger than 44 microns. Approximately 35 per cent is metal oxides 5 microns and smaller. Very little matter between 5 and 44 microns is emitted.

¹Director of Personnel, Universal Foundry Co., Oshkosh, Wis.
²Industrial Hygienist, U. S. Steel Co., Pittsburgh.



Setting an external core for a 50,000-lb 4-stage centrifugal blower casing at Chambersburg Engineering Co., Chambersburg, Pa. The finished mold—entirely cement-bonded sand—consists of a bed, a semi-cylindrical core with a separate nozzle core at each end, and four external cores. Already in place is one of the nozzle cores (dark colored). At the start, a bed of cement sand is levelled in a frame containing core prints. The semi-cylindrical core is rammed in place in a box assembled on the bed. Cores are aligned using gage lines on the bed and a level. All compound surfaces are carefully gaged during assembly to insure specified wall thicknesses.

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The truth about disease caused by foundry dusts

This paper—by the man credited with having done most to separate fact from fiction in the field of dust-caused diseases in the foundry—was given at the Foundry Health Conference held at Ann Arbor, Mich., on April 11-12, 1952. It and all others presented at that time have been compiled into a 200-page publication, *Health Protection in Foundry Practice*, published by A.F.S.

■ Although others may soon replace it at the top of the list, silicosis has for almost a century been the principal occupational disease caused by foundry operations. There are still far too many foundries producing this entirely preventable disease. On the other hand, more and more foundries have developed dust control to such a degree that it has not caused any silicosis in their employees for many years. This is the goal toward which all of us are working.

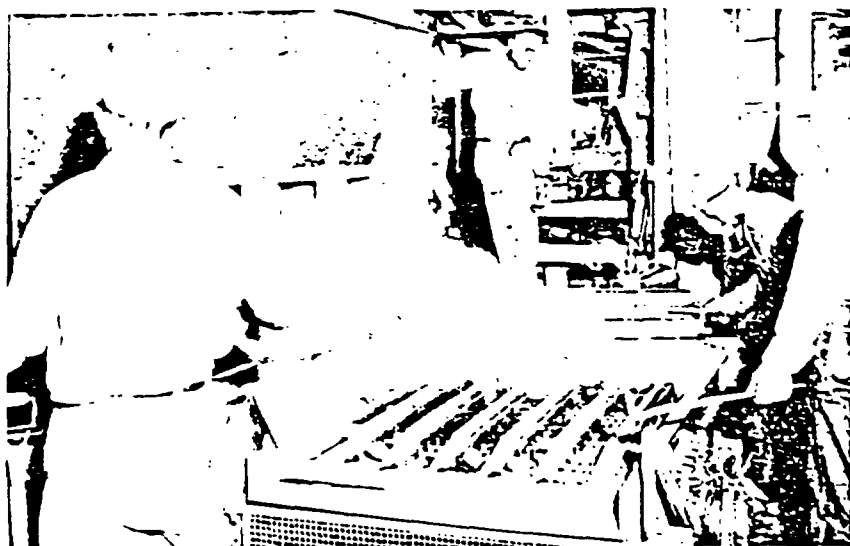
Terminology

Silicosis is readily defined as a "fibrosis of the lungs resulting from the inhalation of dust containing free silica"; it offers little grounds for misunderstanding. Pneumoconiosis, on the other hand, has caused more definition trouble than all the others put together, yet generically it is the simplest to define. It simply means, "dust in the lungs". There is no implication of what the dust is or whether or not it causes reaction.

It is a shortening of Zenker's original term, "pneumonoconiosis" which he proposed in 1836. Therefore there should be no implication of fibrosis in the term, because we now know (as Zenker did not) that there are numerous dusts which are entirely inert when deposited in the lungs, which do not cause irritation or fibrosis, and which do not predispose to tuberculosis. These have been called the "benign pneumoconioses" to differentiate them from the fibrotic pneumoconioses.

Because pneumoconiosis is a general term and covers all dusts whether harmful or not, it should have no place in occupational disease laws. There the terminology should

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Dust exposure at shake-out and other dust-producing operations can be readily minimized by appropriate hoods, forced exhausts, and other devices, whether the operation is manual or powered. Establishing healthy conditions is only the first step in combatting the industrial silicosis problem as it exists today.

be specific and only those pneumoconioses which may result in impairment of lung function should be included—silicosis and asbestosis.

Pathological aspects

Foundryman's silicosis is a modified silicosis. The fibrous nodules seldom are the classical whorled spheres resulting from pure quartz exposure. The old sandblasters had those before they used positive pressure helmets. Today's foundrymen are exposed to far less quartz (or free silica) dust than they are to iron and carbon dust. Dust in typical foundry atmospheres seldom contains more than 20 per cent free silica, with iron dust running from 60 to 70 per cent and carbon dust from 10 to 20 per cent.

With such atmospheres and with the total dust counts sufficiently high, a modified silicosis may result in which the fibrous nodules develop

more slowly, if at all; they always are more irregular than with free silica alone, and secondary emphysema does not occur around them. There also appears to be less susceptibility to tuberculosis than with the classical quartz fibrosis.

It is because of these modifying dusts already present in foundry atmospheres that the author does not recommend the use of aluminum dusting. Workers are already getting the maximal benefit from modifying dusts without adding another modifier. The goal is to continually reduce the silica percentage along with total dust dissemination, not to add other dusts to the air.

Functionally, silicosis becomes a disease only when it is advanced or when it is complicated with tuberculosis. With early discrete nodular fibrosis, there is no interference with the exchange of gases across the alveolar membrane, and no loss of elasticity of the lungs. Only when

fibrotic nodules become confluent and massive fibrosis and secondary emphysema result is there a measurable impairment of lung ventilation.

Witnesses for this are the thousands of foundry workers with minimal silicosis who daily do their heavy physical work without difficulty and who show entirely normal ventilatory values with function tests. Exceptions are the occasional individuals with very little silicosis and high-grade obstructive emphysema. These usually are the older workers who have a naturally decreasing elasticity of the lungs combined with long-standing chronic bronchitis, bronchiolitis, or asthma, the bronchial irritation often having been caused by excessive smoking plus chronic sinus infection.

These cases cause the most medico-legal difficulties because they have real ventilatory disability which most doctors truly believe is entirely due to silicosis. Statistical studies on the incidence of emphysema in the general population at various age levels will help solve some of these difficulties. Such studies are currently being made. However, still more necessary is the constant realization that minimal silicosis never is disabling except when associated with tuberculosis, with a continuing program to educate the medical profession to these facts.

Iron dust in the lungs

Another factor in foundrymen's silicosis which bears constant repetition is the iron dust which all foundry workers have deposited in their lungs. That these iron collections contribute to the x-ray pattern of the silicosis is seldom considered in evaluating the degree of development of a case.

The amount of iron in the lungs may vary all the way from the minimal and probably negligible traces in molders and coremakers to the gross collections in welders, burners, and grinders. Some of the latter may have nodular x-ray patterns due to the iron alone which are radiologically indistinguishable from silicosis. For this iron pigmentation, Zenker's term "siderosis" is perfectly proper, provided there is no implication of fibrosis in the term.

Siderosis is as benign a form of pneumoconiosis as could be desired. It causes neither fibrosis, irritation, nor progressive tuberculosis. Yet it is being misdiagnosed as silicosis every day, and workers so affected, with or without minimal silicosis, all

too often are being advised by their doctors to leave their trades. The fear caused by such well-meant but ill-considered advice has caused more disability than has silicosis itself, in the opinion of the author.

Think of iron first

The author also believes that the time has come to think first of iron when evaluating the nodular x-ray patterns of foundry workers, even when there is no doubt about there being some silicosis present as well. The first question should be, "How much of this nodulation is due to iron collections?" While the answer is not always easy or possible, it makes for far less pessimism in the prognosis when one can say that a considerable part of the nodulation is probably due to iron.

The industrial hygienist has the very important job of making foundry atmosphere increasingly safe for the continued employment of the workers. Industrial physicians, on the other hand, have the equally important job of making these workers feel secure in their chosen trade.

Workers must be assured that their lung changes will not progress to a dangerous stage with the improved dust control. New employees with minimal and uncomplicated silicosis or siderosilicosis must be accepted without hesitation and so placed that their minimal changes will not increase materially. Where this has been done it has been a major factor in helping solve the silicosis problem.

Industrial commissions, no matter who the personnel, cannot be expected to consider minimal silicosis as non-disabling as long as foundries consider such workers unemployable. The unhesitating hiring of affected workers would be a major step in the right direction. There is no reason why minimal silicotic workers cannot stay on their jobs and new workers with minimal changes cannot be hired in foundries where dust control has improved to such a degree that new cases of silicosis can no longer develop.

Reassurance, optimism

The time has come for reassurance and optimism in dealing with this problem, and the medical profession must be the first to recognize this. Such optimism is only impossible in foundries which are still producing silicosis cases; their first step must be to correct the offending dust pro-

ducers. Foundries that are safe for any worker must change their employment practices and allow almost anyone to work in them.

There must be less concern about potential future liability cases, and less rejection of workers with minimal lung changes. The danger of tuberculosis developing in a silicotic lung later in life has diminished almost to the vanishing point as the opportunities for contact with active cases of tuberculosis decrease.

Moreover, workers with minimal changes acquired over a period of years will not progress to a more advanced stage of silicosis if properly placed and protected. It seems much sounder to take a chance with workers having a minimal amount of silicosis than to make them unemployable and semi-invalids.

Few offending foundries

Even though relatively few foundries today are still producing new cases of silicosis, a considerable number have old employees with varying degrees of silicosis who had their significant dust exposures many years ago. It is from this group of older workers that most of our disabled advanced cases arise.

Unfortunately, however, from time to time real cases develop in younger workers, and these special hazards need special attention. Large steel foundries, for example, make large and complicated castings with difficult cleaning problems. Cores frequently cannot be blasted or washed out, but must be dug out with pneumatic hammers. These operations have been the main silicosis producers, but have been largely solved by the development of larger and more forceful hydraulic blasters.

While the first step is to so control dusty operations that silicosis cases no longer will develop in anyone, that is not enough to solve the problem. Those who already have some silicosis must be allowed to continue their chosen work, not only for their former employers but for new employers as well.

They must be reassured by industrial physicians that they are not assuming undue risks by continuing their trades, which makes medical control of equal importance with engineering control. In fact, it must be a joint program with mutual cooperation between the engineer and the doctor. With such a team, any silicosis hazard can be adequately controlled provided the will to do the job is there.

Practical Aspects of Dust Suppression

PART I

By W. B. LAWRIE

M.Sc., F.R.M.S., A.I.M.

INCIDENTAL generation of large quantities of dust is a feature of many industrial processes. In some, the dust is dangerous to health; in others, although perhaps innocuous, it appears in objectionable quantities. Higher output often increases the density of the dust cloud generated, so the modern factory may aggravate the dust problem.

The term "dust suppression" includes all methods by which atmospheric dust concentrations are reduced. These methods fall into two main groups. One approach aims at prevention of dust generation. The other is directed to the control of dust clouds which have been allowed to form.

The former, which may be described as *dust elimination*, is always the better and often the more difficult method.

The latter, referred to as *dust control*, is never so good, although it may be the only practical expedient. It is, however, of great practical importance to keep in mind these fundamental differences in technique.

Dust suppression can be applied in three ways. First and best is elimination of the dusty process. The second is alteration of the process giving rise to the dust, so

that less dust is produced. This is not so good as complete elimination, but it reduces the amount of dust to be controlled, and so facilitates application of control methods. Finally, the dust cloud may be controlled after it has been allowed to form in the atmosphere.

Where no alternative is available, control methods will have to be applied. In the over-all design of a dust suppression system, however, they should always be considered last. Success often depends on the thoroughness with which the first two methods have been used, and the degree to which the actual formation of the dust cloud has been restricted before the control methods were applied.

Although local exhaust ventilation is often necessary, it is only one way of controlling dust, and in certain cases may not even rep-

resent the major feature of a good dust-suppression system.

Local exhaust ventilation is not always successful. It commonly fails to achieve its end because it has been regarded as the only method, instead of being used in conjunction with other methods of dust suppression.

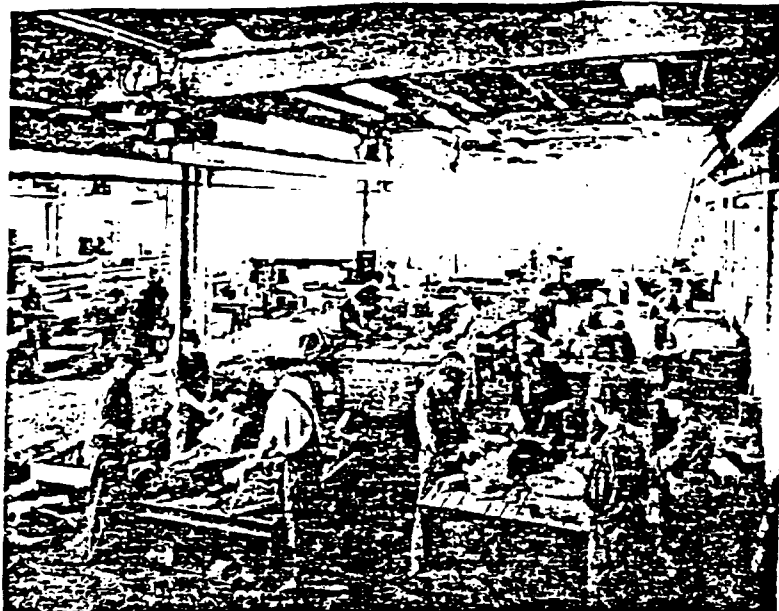
One other general observation must be made. Local exhaust ventilation is employed to remove dust—not air. This requires some knowledge of the properties of the dust to be removed, and also of the manner in which it might be expected to behave. It also means that the normal method of estimating the requirements of the ventilating system, with reference to the volume of air extracted, may give an inadequate impression of the amount of dust it will remove.



Dust and smoke collector hoods behind shakeouts have a capacity of 18,000 cubic feet of air per minute. (Allis-Chalmers Manufacturing Co.)

This article, which appeared originally in the British Journal of Industrial Safety, is presented in condensed form through courtesy of the Royal Society for the Prevention of Accidents, London.

Illustrations are from industrial plants in the U. S. A. Part II of this article, which deals more specifically with local exhaust ventilation, will appear in an early issue.



Down-draft ventilation through grille-topped tables is effective in removing dust generated in the process of sanding and grinding castings.

This should not be overlooked when testing an installation. The fact that a unit extracts a sufficient volume of air per minute may not necessarily indicate that it is extracting dust satisfactorily.

Recent work implies that there is still ample scope for either fundamental or empirical developments, based on observed phenomena, and that careful aerodynamic studies may yield fruitful results.

This method of approach demands a much fuller cooperation than is often evident between the ventilating engineers, the mechanical engineers who design the plant, and the men in charge of production. If the factory is a new one, this cooperation should include the architect so that a suitable building can be erected. In these circumstances the various methods of dust suppression can be applied, either singly or in conjunction with each other.

It is important to realize, however, that such a result will be achieved only when the various dust control methods are seen in proper perspective and used in suitable coordination. If ventilating equipment is used, as it often will be, the ventilating engineer

and the production engineers of the industry concerned should appreciate each other's methods, and the difficulties and limitations inherent in these methods.

Elimination of Dust

The best way of dealing with unwanted dust is to stop making

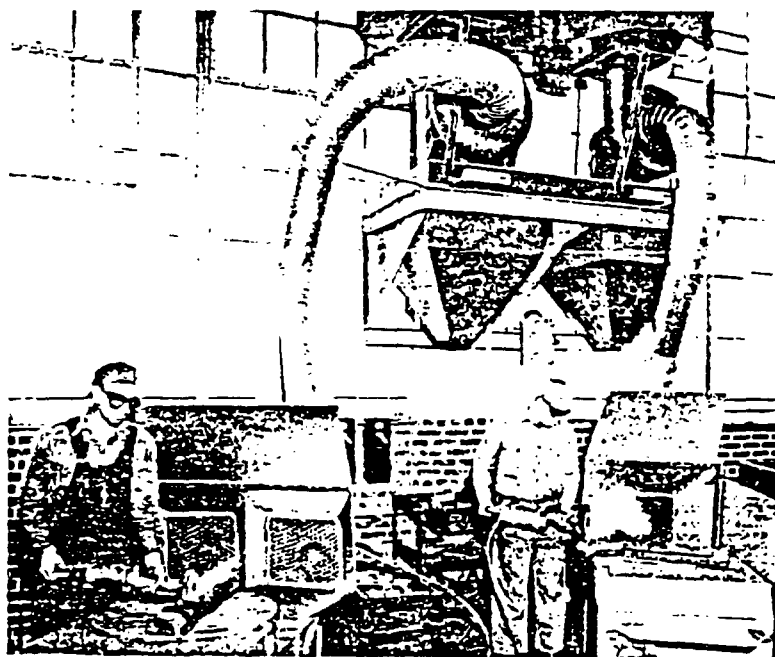
it. In general, this is by no means the simplest method of dust suppression, but it is always the best because it provides a complete and final answer to the problem. Furthermore, it avoids the necessity for costly control appliances which may occupy an embarrassingly large amount of space and make heavy and continuous demands on the engineering staff if a reasonable state of efficiency is to be maintained.

Probably the earliest way of dealing with dust was to wet it. This may offer one method of dust elimination if it proves possible to wet the raw material before process work commences. No dust will be raised as long as the material remains wet.

While water will not wet finely divided materials, they can often be wetted if the surface tension of the water is lowered by the addition of wetting agents, giving what is called "wet water." A further advantage of wet water is that it penetrates large masses of material much more quickly.

There are, however, other ways of eliminating dust, although the

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Well designed hoods remove dust from grinding without drawing it past the worker's breathing zone. Exhausted air is filtered before it is recirculated through the workroom (American Air Filter Co.)

Dust Suppression

(From page 27)

possibility of so doing can be determined only by experts in the process concerned. It demands a wide knowledge of the technical or scientific principles involved in the industry, coupled with great flexibility of mind and the faculty of devising new, and perhaps unconventional working methods.

A good deal of dust may result from dressing or cleaning steel castings after they have been removed from the mould. This dressing is necessary because some of the moulding material adheres to the casting, and must be removed by pneumatic chisels.

If it were possible to make castings in such a fashion that none of the moulding material adhered to the steel, this dusty cleaning process could be avoided. This opens up a wide field of investigation which the British Steel Founders' Association is vigorously exploring.

This particular work is regarded as long-term policy, and in consequence other methods of eliminating the dust are being tried in the treatment of castings. One successful development has resulted from changing the method of cleaning. A flux injected oxy-acetylene burner is now being used to clean the casting in place of the pneumatic chisel. This has not eliminated the cleaning process, but it has offered a method of cleaning which, in certain cases, may eliminate the dust cloud.

These examples indicate a way of dealing with the dust problem which is far too often ignored, and emphasize the need for a close examination of all dusty processes with a view to eliminating the dust. Even where there appears to be little chance of immediate success, the ideal should never be forgotten, and the installation of a dust-control system should not be allowed to stifle efforts to attain a dust-free process.

The second object in dust elim-

ination is, perhaps, less ambitious than the first. This is a change in the process to reduce the amount of dust generated. It is always important to reduce, as far as possible, the dust which is generated, because the smaller the residual dust cloud can be made, the easier it becomes to control it.

One example of this approach occurs in the efforts that founders are making to reduce the amount of core binder used in moulds. The atmospheric impurity produced by the core binder is in the form of fumes, not dust, but the principle remains the same. Once again no general suggestions can be made, because each industrial process must be treated by a specialist who understands all the factors involved.

This discussion has been concerned only with the reduction of the total amount of dust which must be dealt with by control methods. But there may be another very important factor. Some dusts are dangerous to health, and the total dust cloud may contain a dangerous fraction. In this case, the outstanding reason for eliminating part of the dust lies in the fact that the health risk can be removed if the dangerous fraction of the cloud can be eliminated.

A well-known dangerous dust is free silica (SiO_2). It is known that in many industrial processes where free silica dust is likely to be produced, it will be accompanied by other dusts which may not be dangerous. Efforts are being made, therefore, to eliminate the free silica fraction of the airborne dust cloud. One example of this is discontinuing the use of silica flour as a parting powder. Other powders are used which may produce just as much dust, but the dust is innocuous.

Control of Dust

When the limit of practicable dust suppression has been reached

by the more positive methods of eliminating dust at source, there will still remain ample scope for the application of control methods in cases where it is impossible to prevent the formation of the dust cloud. The common method of dust control is by ventilation, and this may be employed as local exhaust ventilation or as general ventilation, or more probably as a duplex system using both.

It is of some practical importance to appreciate that local exhaust ventilation and general ventilation form two complementary parts of one ventilating system. They should therefore be designed together in new buildings, and when local exhaust ventilation must be fitted into an existing room the whole system should be integrated wherever possible.

Local Exhaust Ventilation

When the evolution of dust has been prevented as far as possible, the next logical step is to design local exhaust ventilation. This should prevent the dust cloud from spreading into the general atmosphere of the room.

Two advantages accrue when this is done. In the first place, the dust can be removed more effectively and more cheaply if it can be contained in a small space and exhausted as a concentrated cloud. In the second place, general ventilation can be designed on the assumption that very small amounts of dust will be present in the general atmosphere. This implies that a relatively small volume of air will have to be handled. Capital costs will fall, and equally important, heating costs will be reduced also.

Dust-producing processes should always be housed in buildings designed to facilitate ventilation. More emphasis should be laid on the simple fact that ventilation is cheaper and better in a properly designed building. Ventilation of a dusty process often means that large volumes of air will be extracted from the building. This in turn means that heat loss in the

King Wrong and Whitey

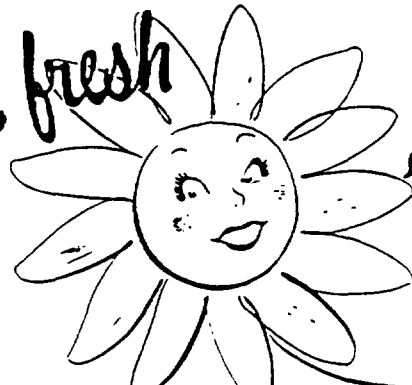


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tested as they are turned in or before being issued for use. If a tool proves defective it is immediately tagged and turned in to the electrical department for repair. Since a tool can be completely tested in seven seconds this additional work places no burden on the tool crib. Weighing less than six pounds, it may also be used as a portable instrument to test tools at the point of operation.

Most electrical departments have accepted this new testing device because it aids them in spotting the hazard. It means that after a tool crib attendant has found that the equipment ground is broken or that there is a power ground, the tool is then tagged and sent to the electrical department and gives the electrician a clue as to what to look for rather than to spend time tearing down the entire equipment.

Dust Suppression

—From page 68

signed ventilating system merely serves to pollute the whole room, rendering conditions worse by dissipating impurities which would otherwise have polluted only the air above their point of origin.

Flat roofs offer the worst conditions for upward ventilation. The rising air does not converge to the point at which the fan is placed, but spreads horizontally on meeting the ceiling. The best way of dealing with such a state of affairs is to insert a false ceiling.

The false ceiling is perforated all over its surface and the extraction fans are installed in the ceiling above it. There is, therefore, an even extraction rate over the whole area of the ceiling and the rising air will be extracted at the point it meets the ceiling. The method is more efficient if hanging partitions are placed over areas where large volumes of fumes are generated.

Downward Ventilation

Rooms which do not contain hot processes may be ventilated downward, from roof to floor. This method is not so common in British industry, but there seems

minimum. Adequate facilities for all types of maintenance and repair work are available to a group of some of the most highly skilled mechanics ever assembled in one job.

Last, but not least, in its contribution to a good safety record, has been the program instituted by the contractor to have the workmen utilize their leisure hours constructively. Available for the use of all concerned are free movies, a very complete library, a hobby shop, a recreation room, a music room, the local radio station which broadcasts 24 hours a day, and the local daily paper.

Only through the active combined efforts of the top management of The Corps of Engineers, the contractor, and the insurance company has it been possible, under such rigorous conditions, to attain a safety record which is five times as good as the average construction of this type, in the Continental United States.

Check It

— From page 35

and engineered, being made of heavy gauge sheet metal, fully grounded, protected by a fused circuit, operated at a safe voltage of 6 volts, and contains heavy duty contacts, relays and good wiring inside.

Further, the use of the instrument is not confined to power hand tools. It may be used to test extension cords, extension lights, electric fans, vending machines, pedestal grinders, office machines, desk lamps, floor scrubbing and polishing machines, and, in fact, any single-phase electrical device which receives its power from a receptacle. Incidentally, the instrument contains receptacles that will accommodate any type of electrical cap. All that is necessary is to operate the three push buttons in proper sequence, testing all circuits and watching for the safe (green light) and unsafe (red light) conditions.

Location for Use

The most logical location for use of this equipment is in the tool crib and the test can be performed by a tool crib attendant. Tools are



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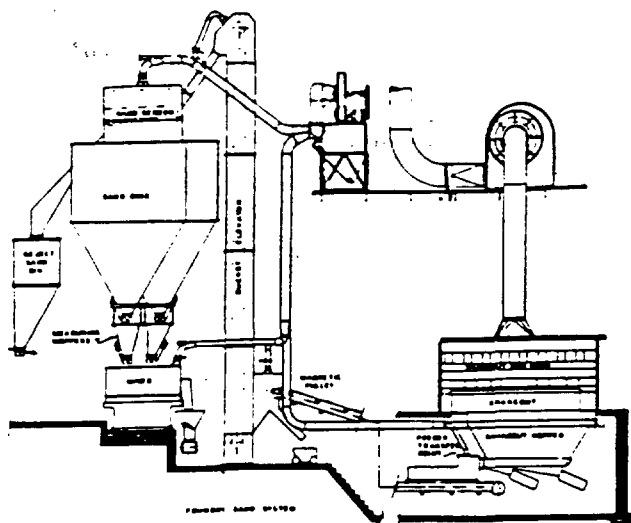


Fig. 10—Diagrammatic sketch showing a complete sand-conditioning system with dust control hoods as needed.

important fundamental considerations which apply almost equally to all foundries. These are (1) building construction and plant layout, (2) general ventilation, and (3) housekeeping.

Building construction, especially the layout or arrangement of departments and equipment, is of primary concern in dust control. Generally, little can be accomplished in this direction in existing foundries. New foundries, on the other hand, should be so laid out that there is a smooth or natural flow of materials.

Mechanization is important not only because it increases efficiency in production, but because it also makes possible more specific and positive dust removal. In one case an existing small brass foundry was rearranged and mechanized at what management felt was terrific cost. New cases of lead poisoning did not occur, whereas they had not been uncommon before the changeover. In addition, and to the pleasant surprise of management, production per man more than doubled and the percentage of rejects dropped almost one half.

Walls should be smooth and painted in light colors. Projections, exposed beams, etc., should be kept to a minimum so that there are fewer places for dust to collect and from which it must be removed thoroughly lest it be jarred loose. Good illumination aids

TABLE 2—MINIMUM VENTILATION RATES FOR HOODS AT SAND CONDITIONING EQUIPMENT

Equipment	Exhaust Requirement
Transfer Points	350 cfm per foot of belt width but not less than 150 fpm indraft.
Bucket Elevators	Exhaust from elevator head 100 cfm per sq ft of casing cross section.
Sand Screens	Flat deck—50 cfm per sq ft of screen area but not less than 200 fpm indraft. Cylindrical—100 cfm per sq ft of screen cross section. Volume may be doubled to provide required fines removal.
Sand Mullers	150 fpm through openings in dust hood
Sand Bins	150 fpm indraft but not less than 0.5 cfm per cu ft of bin capacity.

in speeding production and in housekeeping. The size of the foundry in relation to its production rate has a profound influence on the dustiness because the atmospheric dust concentrations decrease as the crowding decreases.

Good general ventilation is important because all foundries have many minor and scattered dust sources. Even if the main dust sources are controlled effectively by means of local exhaust and other specific measures, good general ventilation is needed to prevent the general dust level from rising to undesirable levels.

A rule of thumb method for deciding upon minimum general ventilation required is 20 air changes per hour for mechanized foundries, and 12 air changes per hour for plants that are not mechanized. When applying this rule, it must be remembered that the general ventilation required varies considerably from plant to plant. In some instances these suggested rates will be inadequate, especially if the other and more specific control measures are lacking.

Before the dust measurements had been made, all foundries studied were classified into three groups as regards the housekeeping in evidence. For the purpose of this classification housekeeping only was considered. The approximate average dust concentrations for the molding areas, the shakeout operations, and the cleaning departments (the three departments for which dust concentrations are reported in each housekeeping class) were 7 mppcf for the good housekeeping group; 25 mppcf for the average group; and 32 mppcf for the group classified as poor.

Acknowledgments

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THE FOUNDRYMAN LOOKS AT AIR POLLUTION

By

N. H. Keyser* and H. P. Munger*

ABSTRACT

The air-borne contaminants from a foundry are classified as dust, fumes, and noxious gases. They originate at many points in the foundry. Particle size is the most important property of solid contaminants. Each foundry finds itself in a different situation because the nature of the operation differs from foundry to foundry and because location of the foundry is of great importance. The foundryman and the local air-pollution control authorities should cooperate in working out an individual program for collecting dusts and fumes, employing the knowledge and research methods at hand.

The technical methods for controlling air pollution are fairly well developed. These include dry inertial collectors, and wet scrubbers which have a wide range of efficiencies and also a wide range of costs. Filtering methods and electrostatic precipitators are among the most efficient dust collectors. Several newer methods are going through the production development stages.

In spite of a number of factors which partially offset the cost of air-pollution control, cleaning air rarely yields a net profit. The actual cost will depend largely on the amount of cleaning required by the local conditions. The public will eventually pay this cost.

The Problem

The foundryman has a definite interest and a responsibility in preventing excessive discharge of waste into the atmosphere. But how much waste can be discharged into the air before we say the discharge is excessive or that the air is "polluted"? A few decades ago, dense clouds of smoke coming from the stacks of our industrial plants were regarded as a sign of prosperity, and nothing short of a dense cloud of noxious fumes would have been described as air pollution. On the other hand, refreshing country air contains wind-borne dust, pollen, and gasses from decaying vegetation.

The present trend is to define some concentration of contaminants between these two extremes as excessive. Air is regarded as polluted when the concentration of contaminants exceeds that which is injurious to property, to health, or to human comfort. For the most part, therefore, air pollution is of greatest concern in large centers of industrial activity. Overloading of the air with dirt may result from

numerous small sources of contaminants over a large area, or a single concentrated source, or any combination of these two conditions. Smoke and fly ash from industrial stacks, railroad locomotives, or the chimneys of homes and schools are the most obvious sources of contaminants. Burning trash and leaves in metropolitan areas, gob piles in coal-mining areas, and the exhaust from Diesel locomotives and trucks or even passenger automobiles also contribute their share of contaminants. It can be seen that the foundry, in most cases, is just one of the many sources of air pollution in a community.

Aside from the contribution of the foundry to the over-all burden of contaminants in an industrial area, the foundry, as an individual industrial plant, has a problem of community relations. When the neighbors see nothing but smoke pouring from the foundry, they get the impression that the foundry is a smoky, dirty place. They are inclined to blame their dirty washing on the smoke that they can see, even though the actual source of the dirt may be some distance away or perhaps just the general condition of that particular area.

One of the problems facing the foundry is that of attracting young men to work in that industry. Certainly a reputation for smoke and dirt does not help the foundry solve this problem.

Each Foundry is an Individual Control Problem

To those who have studied air-pollution problems, it is evident that each plant presents an individual problem. The methods for reducing contaminants must be tailored to fit this individual situation. The municipal and county programs, in each case, form the backbone of air-pollution control. Each company within a local air-pollution control district should work out its own program in cooperation with the local air-pollution control engineer. Any program of air-pollution control should make the widest use of the knowledge that is available.

The first information required in setting up an individual program for the control of air pollution is a knowledge of the physical and chemical nature of the contaminants emitted into the air, especially

*Battelle Memorial Institute, Columbus, Ohio.

their particle-size distribution. The concentration of the contaminants and the points at which they leave the plant also need to be known. Other important factors are the natural surroundings of the plant and locations of population centers and farms. Of equal importance are the atmospheric conditions under which the contaminants are found objectionable.

In the dispersion of air-borne contaminants, the nature of the country and the atmospheric conditions play major roles. Flat country, especially near the Great Lakes where strong winds are frequent, favors the rapid dispersal of dust, fumes, and noxious gases. Narrow, deep valleys furnish pockets in which contaminants may collect to form relatively high concentrations. Temperature inversions which form over pockets in the land stabilize the air and prevent the normal vertical dispersion of contaminants. A temperature inversion is a condition in which the air at ground level is colder than the air above it.

Los Angeles county is an outstanding example of the influence of the nature of the land surface and atmospheric conditions on the buildup of contaminants over an industrial area. In Los Angeles county, a large concentration of industry is situated in a basin surrounded on three sides by mountains. Temperature inversions, in effect, put a lid on this basin. Because they cannot get out of the basin, smoke and fumes and noxious gases frequently build up for several days. Fogs, rolling in from the ocean, combine with the concentration of man-made contaminants to create a powerful eye-irritating smog. It is because of this set of conditions, which are abnormal for most of the rest of the country, that the air-pollution standards for Los Angeles must be so rigid.

Devices for Analyzing Air-Borne Contaminants

There are well-established technical methods for determining what are the air-pollution problems of any individual industrial plant. These methods utilize devices for collecting and analysing the air-borne contaminants. Analysis of an individual foundry's contribution to air pollution can be made right at the source. For example, the amount and nature of emissions from a cupola can be determined. Measurements of dirt falling on the surrounding community also can be made. A new device, developed at Battelle, not only determines the amount of dirt fall but also establishes the direction from which dirt is coming.¹ A knowledge of the direction from which the dirt is coming is of special interest in determining whether the contaminants are of local origin or have been blown in from another area or community.

Devices for measuring the influence of the surface of the land and the atmospheric conditions on the dispersion of contaminants are also in use. For studies just above ground level, instruments have been attached to fixed structures. A new technique uses a kite balloon to carry weather instruments and air-sampling devices up to altitudes of 500 ft or higher.^{1,2,3} In highly industrialized areas, these methods provide the tools for securing a three-dimensional picture of contamination of the air.

The Nature of Air-Borne Contaminants

An effective program for controlling air pollution from the foundry must be based on a knowledge of the origin and nature of the contaminants that are emitted into the air. It is customary to divide the contaminants into four principal classes: (1) smoke, (2) dusts, (3) fumes, and (4) noxious gases. Smoke is defined as the solid or liquid particles resulting from incomplete combustion of organic materials. Soot is an example. Dusts are solid particles of any nature which have been produced by mechanical processes and released into the air. Particles of iron and abrasive from the grinding of castings are typical dusts found in the foundry. Fumes are solid or liquid particles in the air, commonly generated by sublimation, vaporization, or chemical reactions. The white fumes liberated during the baking of cores, and the brownish fumes which arise from hot iron or steel are typical examples of fumes in the foundry. Sulphur dioxide and carbon monoxide are typical noxious gases with which the foundryman is familiar.

Probably the most important property of contaminants is their particle size.⁴ Particle size coupled with density and shape determines the distance contaminants will travel in air before they settle to the ground. Visibility of contaminants is determined by the number and size of the particles in the air and by the degree to which moisture condenses on the particles to form fog. Finally, the particle size of the contaminants determines what methods of sampling and analysis can be used for studying the air and what type of equipment can be used for separating the contaminants from air, and for their subsequent disposal.

In view of the importance of particle size in air-pollution control, the foundryman should have an idea of the size of particles involved. The size of smoke, dust, and fume particles is commonly expressed in terms of the average diameter of the particles measured in microns. A micron is 1/1000 of a millimeter, or 1/25,400 of an inch. The size of particles in the air may range from over 1000 microns for raindrops to considerably less than 0.01 micron for sulphur dioxide and other gases. Several other examples which are useful in visualizing the size of the particles are: (1) a 50-mesh sand has an average diameter of 295 microns, (2) a 325-mesh silt has a diameter of 44 microns, (3) the smallest particle visible to the naked eye is 10 microns in diameter, and (4) the particles in tobacco smoke have an average of about 0.3 micron.

Particles below 1 micron in diameter tend to stay suspended in quiet out-door air almost indefinitely, whereas those larger than 1 micron tend to settle at a more or less rapid rate. In agitated air, such as found in foundries and other industrial plants, particles 10 microns or larger in diameter may stay suspended in the air for a considerable length of time.

The range of particle size for a number of industrial dusts and fumes is shown by means of bars in Fig. 1. Foundry dusts include such coarse particles as the cinders and other debris blown out the stack of a cupola and the finer dusts from the foundry

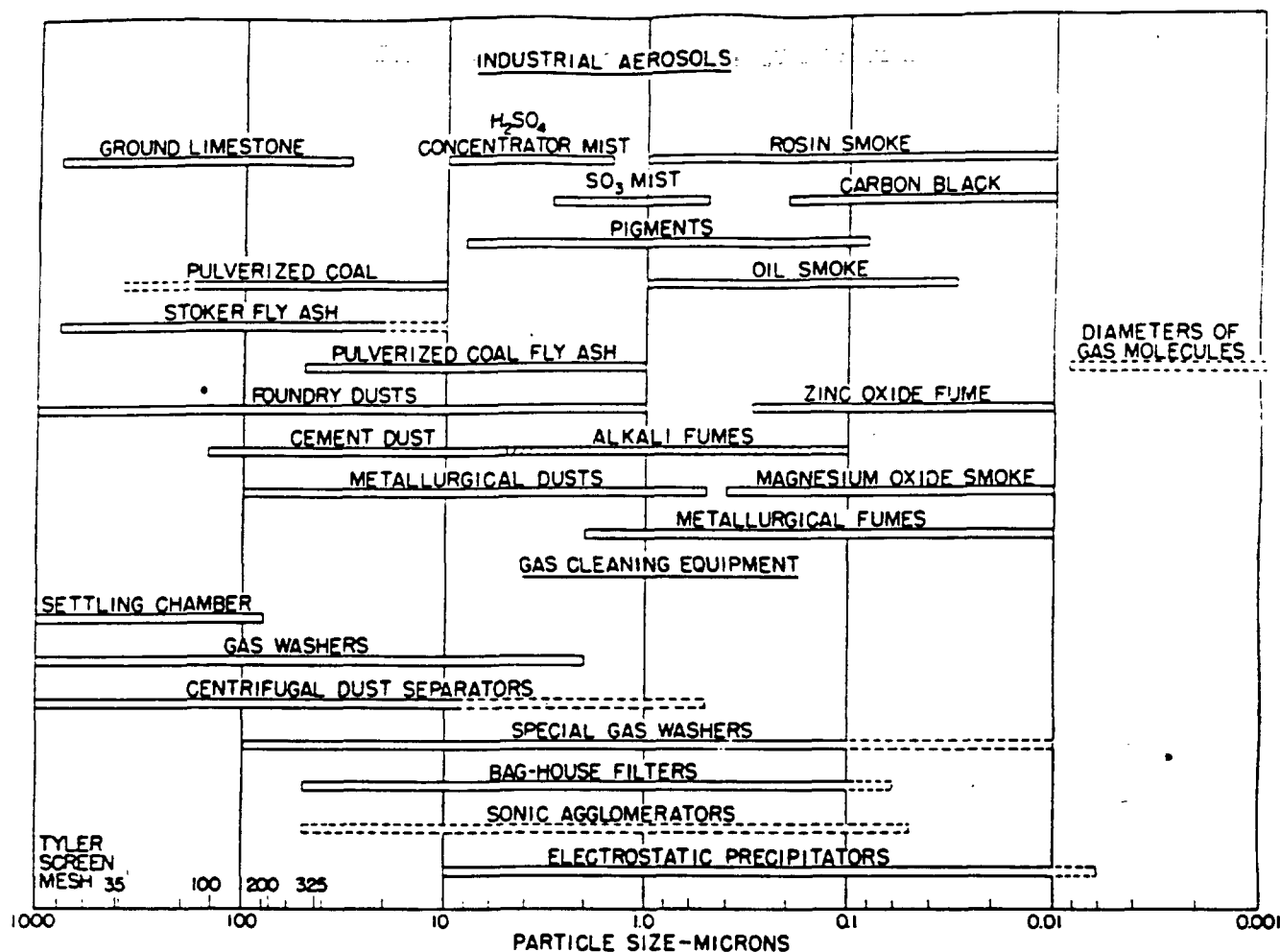


Fig. 1 —Particle Size of Industrial Aerosols and Equipment for Cleaning Gases

shake-outs and cleaning room. Metallurgical fumes comprise such contaminants as the brownish fumes coming off the electric or open hearth, and that part of the cupola and the non-ferrous-melting furnace emissions resulting from volatilization and oxidation of the metallic constituents of the charge.

It is apparent that the foundryman must contend with the entire range of particle sizes considered to be air contaminants. For the sake of economy in controlling the air contaminants, the foundryman should use the type of collection equipment that will do each job at the lowest cost.

The particle-size ranges for which broad classes of collecting equipment are effective are shown in the lower half of Fig. 1. Additional details on collecting equipment are given in a later section.

Source of Contaminants

Air-borne contaminants come from many points in the foundry. In many cases, the melting department is a major source. In fact, the melting department has been the first to attract the attention of air-pollution control authorities in many cities. The electric furnace and open hearth for steel and iron melting emit clouds of reddish-brown fumes, especially during melt-down when the charge is not protected by the

metal is at its maximum temperature. The advent of the oxygen boil in steelmaking has aggravated the fume problem.

The open-top cupola belches forth a stream of hot gases clouded with solid particles. The coarsest particles are the size of coarse sand. The finest particles must be viewed with an electron microscope to distinguish them. Coarse particles settle on the foundry roofs, yards, and on the foundry's immediate neighbors. The finer particles drift away to settle at some distance from the foundry. Sulphur dioxide, formed from sulphur in the coke, and unburned fumes from oily scrap add their characteristic unpleasant odors.

A typical sample of the cupola stack-gas emissions will contain on the order of 35 per cent of its particles in the zero to 5-micron range and about 50 per cent of the particles will be over 44 microns (325 mesh). The remaining 15 per cent will be spread out over the range of 5 to 44 microns. The concentration of particles above 44 microns (325 mesh) is chiefly dust and debris consisting of broken coke, fine metal chips, rust, sand, and dirt, which are picked up by the rising gas stream and carried out the stack. The particles in the 0 to 5-micron range are chiefly fumes from the volatilization and oxidation of iron, silicon, manganese, and certain tramp elements by the in-

largely responsible for the opacity or color of the stack gases, primarily because there are so many particles in a given weight of fume as compared to a given weight of the coarse particles. It takes 1000 particles, 1 micron in diameter, to weigh as much as one particle 10 microns in diameter.

The core room also is a major contributor of fumes in the atmosphere in and around a foundry. Fumes given off from core oil and cereal binders during the baking of cores are pungent and irritating. A host of obnoxious compounds have been identified in the fumes given off by linseed oil during drying. These include acrolein, formic acid, acetic acid, acrylic acid, butyric acid, carbon monoxide, and a number of other volatile products.⁵ Presumably, many of these same compounds are generated during the baking of cores and also during casting and shake-out of molds containing cores.

No entirely satisfactory substitute for core oil has been developed which does not give off fumes and odors. In some cases, the odors of the substitutes were more obnoxious to many foundrymen than the odors from core oil.

The shake-out and cleaning room are also sources of large quantities of fumes, dusts, and noxious gases. In the shake-out, large quantities of hot sand are suddenly exposed to air. Particularly where many cores are used, large quantities of fumes and noxious gases are generated by the incomplete combustion of organic materials in the mold. Added to this burden are fine sand and binder materials thrown in the air by mechanical agitation used to shake the molding material off the casting. In the cleaning room, the problem is mostly one of dust generated by such operations as chipping, blasting, and grinding, although metal and other fumes do arise from welding operations.

Miscellaneous sources of air contamination in the foundry are open fires, handling of dry sand before it is tempered, parting agents, metal fumes from the ladle during transfer and pouring, and mold gases. The foundry pattern shop also has its dust-control problem. In this case, however, the materials involved are woodworking shavings, chips, sawdust, and, if metal patterns are used, there is the possibility of metal and abrasive dust.

Methods for Control

The industrial hygienists have developed excellent methods for reducing the concentration of contaminants in the air within the foundry. They have approached the problem from several angles, among which are (1) to prevent or to reduce the production of dust, fumes, or noxious gases, (2) to reduce the use of materials which give rise to dust, fumes, and noxious gases, (3) to provide personal safety equipment to prevent inhalation of dust, fumes, or noxious gases, and (4) to extract the dust and fumes from the various points in the plant where the contaminants are generated.

The extracted dust- and fume-laden air may be exhausted directly into the atmosphere outside the

foundry. If the burden of dust and fumes of this air is great, the air must be passed through an air cleaner to avoid air-pollution problems. The foundryman is then faced with making a decision as to what type of dust collector to use.

Control of air pollution starts with the dust hood and ducts to convey the dirt-laden air to the collectors. Much good engineering has gone into dust hoods and ducts. Since the principles are well known, the subject will not be discussed here except to mention one of the problems encountered in the foundries that have applied dust control to existing plants. In most instances, space is at a premium, and dust-control equipment must be built into extremely limited space. This leads to a temptation to use hoods, piping, and collectors of inadequate size.

Available Types of Dust Collectors

The technical methods for cleaning dirty air and gases discharged into the atmosphere are fairly well developed. The proper selection and application of cleaning equipment depends on a knowledge of the types of collectors available and their performance. Dry inertial collection methods are the most economical but have definite limitations. These methods depend on gravity or the momentum of a particle to carry it out of the gas stream. In its simplest form, the dry collector is merely a settling chamber or an enlargement in the duct carrying the dust-laden gas. Practical limitations on the size of such chambers do not permit designs with low enough gas velocities to extract fine particles. The minimum particle size normally collectible in a settling chamber is on the order of 40 to 80 microns, depending on the design.

The cyclone collector is a widely used collector of the inertial type. By introducing the dust-laden gas tangentially into a circular chamber, a centrifugal motion is created which throws the dust particles to the side where they deposit, or drop to the cleanout in the bottom.

Decreasing the diameter of the cyclone makes the gas travel in a tighter circle and increases the centrifugal force for throwing the dust out of suspension. The small-diameter cyclones, therefore, are more efficient where particles in the smaller size range are encountered. On the other hand, because of rebound of coarse particles, the collector may not be as efficient for removing particles of large size. Multiple units of small-diameter cyclones are required to handle a large volume of gas.

A large variety of makes and configurations of cyclone collectors is commercially available. In general, however, the collecting efficiency drops off rapidly for particles below about 20 microns in diameter for the large-diameter cyclone and below 10 microns in diameter for the small-diameter multiple cyclones. In addition, the collecting efficiency is practically nil for particles below 5 microns for simple cyclones and 2 microns for multiple cyclones. This, of course, limits the type of dust that may be collected. Efficiencies in the neighborhood of 97 per cent have been reported on coarse material, such as saw dust from planing mills.⁶ In contrast, they may

collect only between 10 and 25 per cent of the solid material in stack gases from a boiler.⁷

In many cases, where it is necessary to install additional exhaust fans, or where space is limited, a mechanical centrifugal collector will be found practical. This type of collector uses a high-speed impeller to provide the centrifugal force for throwing the dust out of suspension. The impeller also acts as a fan for drawing the dust-laden gas through the cleaner. At the point of greatest concentration of dust, part of the air is skimmed off and carried to a settling chamber. After depositing the entrained dust, the air is recirculated in the system.

Louver and dry skimmer collectors also depend on inertia for throwing the dust out of suspension. Inertia concentrates the particles of dust in the small end of a slotted metal cone. About 90 per cent of the air passes through these slots to the blower and stack, while the concentrated suspension passes into a small cyclone. The exhaust from the cyclone is recycled in the concentrator.

Centrifugal Separators and Louver Collectors

Both mechanical centrifugal separators and louver collectors have application for collecting particles in the size range collected by cyclone separators. Dry inertial collectors, as a class, are not suitable for collecting fine dust (particularly particles below 10 microns in diameter). They are satisfactory, however, as rough cleaning devices for reducing the load on high-efficiency final collectors with which they are frequently used. On the other hand, as final cleaners for coarse, non-toxic materials, such as wood or metal chips, they do an excellent job and are simple and inexpensive. These collectors can be built to handle relatively hot gases which makes them eminently suited for such applications in cupolas where merely the removal of the coarse particles from the stack gas is sufficient to satisfy local conditions.

When dry inertial collectors are inadequate, it is advisable frequently to go to one of the wet collecting methods. Wet collecting methods depend on a simple process of washing or scrubbing the dirt out of the gas and wetting the particles to increase their effective diameter so they may be removed by simple collectors, such as a cyclone. In addition to removing dust, wet collectors also can remove sulphur gases which may sometimes be important.

Static Spray Washers

The simplest form of wet cleaner is the static spray washer which may be seen mounted on the top of many cupolas. This equipment can remove 50 to 75 per cent of the solid matter and a portion of the SO_2 in the cupola effluents. However, a large portion of very fine solid particles escape.

Wet scrubbers are more efficient in removing the smaller size particles than are the simple spray washers. Wet scrubbers depend on mechanical means of admixing a spray of water with the dust-laden gas. They employ the cyclone, rotary centrifugal collector,

Roughly speaking, the efficiency of these scrubbers is related to the work applied to admixing the water and gas. Scrubbers can be very efficient and give very clean gas. Because of the high power requirements for the highly efficient scrubbers, it is customary where very clean gas is required, to use a scrubber of moderate efficiency, followed by other types of final cleaners which require less power. The wet cleaner reduces the load and, at the same time, cools the gas.

Cloth filters or bag houses are becoming a more familiar sight around the foundry. They operate on the same principle as the vacuum cleaner in the home. They have been applied to cleaning the exhaust from the shake-out and cleaning rooms. In similar applications, they have been found to operate with dust-collecting efficiencies of over 99 per cent.⁸ It has been only recently, with the development of the glass-cloth bag which will withstand temperatures up to about 500 F, that bag houses have been utilized for the difficult job of cleaning the hot gases from the cupola. They have been found to satisfy the difficult requirements of the Los Angeles County Air Pollution Control District.⁹ All material passing through the cloth filter is below 5 microns. Efficiencies are good on particles down to a fraction of a micron. Bag houses are limited, however, to applications where there are no condensable fumes or gummy materials present.

Electrostatic Precipitators

Electrostatic precipitators are probably the most efficient of all collectors. Collecting efficiencies are very high on particles down to a fraction of a micron. Although electrostatic methods do not remove gases, there seems to be no lower limit to the size of solid particles that they will remove.

Electrostatic precipitators employ up to 75,000 volts to induce a negative electrostatic charge on the surface of the dust particles. The dust particles are then repelled to the positive electrode, which is constructed to serve as a dust catcher.

Among the newer methods for collecting dust and smoke are the sonic agglomerators.^{9,10} Sound waves cause the small particles of dust to vibrate, thereby increasing the number of collisions between particles. Upon collision, surface forces on the particles of certain types of materials cause them to adhere to one another. Through a series of collisions and adhesions, small particles agglomerate to such size that they can be removed from the gas with a cyclone separator. The method is limited to very small particles, as are found in smoke, and it does not work on all materials. Further developmental work is required before its possibilities in the foundry are known.

One of the latest improvements in wet collecting equipment is the Venturi scrubber.¹¹ In this scrubber, water is broken up into a very fine mist. The mist and gas pass through the venturi portion of the collector where the very small droplets wet and absorb the very small particles of dust. A cyclone separator then collects the wetted particles and drops

Control of Combustible Fumes

Combustible fumes can be destroyed by oxidation or combustion. Where the ratio of combustible material to air is high enough, as in the cupola stack gases, combustion will be self-sustaining once it has been started. An ignitor is sometimes used for igniting the gases during periods when they do not ignite freely. Lean mixtures, which will not maintain combustion, must be heated to temperatures on the order of 1200 to 1400 F, to complete the oxidation. In some instances, fumes from the baking of cores have been reduced by recirculating the air in the oven through the burners.

One of the newer methods for oxidizing combustible fumes is the catalytic combustion process. Very dilute mixtures of combustible vapor or gas will oxidize at temperatures as low as 350 F, or less, in the presence of a catalyst. This principle has been applied commercially to the oxidation of a number of fumes and gases, including the fumes from the baking of cores. Of special interest is the fact that the heat obtained from the oxidation of these fumes is returned to the oven to reduce the amount of outside fuel required to keep the oven hot.

The Cost

The purchase cost of dust-collecting equipment ranges from something less than \$100 per 1000 cu ft per min treated for simple cyclone separators, to \$1000 or even more for certain of the very high efficiency collectors, such as bag houses, electrostatic, or disintegrator-type washers.^{12,13} Power consumption may be as low as 0.1 kw per 1,000 cu ft per min for simple gravity settling chambers, to as high as 10 kws per 1,000 cu ft per min for high-efficiency scrubbers. These figures are for total power, including electrical energy, water-pumping power, power for necessary auxiliary equipment, and pressure drop through the apparatus.

One thing that must not be overlooked in estimating the cost of dust-control equipment is the actual volume of gas handled. The more gas handled, of course, the larger the size of collecting equipment required. In the design of dust hoods, for example, sufficient excess air must be drawn through the equipment to flush all the dust-laden air from the source. The equipment must clean all this air plus any excess that is taken in. Cupola stack gases are another example where the volume of gases emitted is greater than may seem at first. The volume of gases generated by a cupola may be 2 to 4 times the volume of air blown into the tuyeres. Burning of the gases in the stack and aspiration of air in the charging door may increase this volume to 5 to 7 times that of the tuyere air. Cooling of these gases before they are passed through the dust collectors, of course, reduces considerably the volume of gas that must be handled. Nevertheless, the volume that must be handled is more than the volume of air blown into the tuyeres.

Who pays the cost of clean air? The answer to this is simple and one which everybody should know.

The cost of clean air is eventually paid by the public. The degree that air pollution is controlled in the future will depend largely upon the amount the public is willing to pay for controls in terms of increase of cost of products.

The materials recovered in the air-cleaning operation seldom have much value. There have been figures published on the large savings in nonferrous smelting operation by collection of the dust from the flue gases. For example, it has been estimated that \$27,000,000 worth of metals have been recovered in the copper industry alone.¹⁴ Unfortunately, in the foundry industry, in general, the products recovered in the dust collectors are not nearly so valuable. For the most part, they may be classified merely as dirt which has to be hauled off to the dump.

Fly ash collected from the cupolas may have some value as a filler for concrete. However, it probably must sell for considerably less than concrete itself. It must be used close to the source and must be available in quantities large enough to be worth handling. Recently it has been found that fly ash makes a capable pipe eliminator of the non-exothermic or insulating type to apply to the surface of feeders on castings.¹⁵ This would permit the foundry to consume its own fly ash to some advantage.

For the most part, the small quantities of salvagable material involved make the cost of handling more than the products might be worth. It seems hardly worthwhile to develop a useful market for them.

Other opportunities to realize some return on the investment in dust collectors are difficult to evaluate in dollars and cents until the equipment is installed. The factors which may partially offset the cost of clean air are: (1) reduced maintenance, for example, less frequent cleaning of the roof, (2) better working conditions and workers' morale, and (3) better relations with the neighbors. The last two factors should help attract better workers into the foundry and reduce labor turnover.

The by-products and other benefits derived from gas cleaning rarely yield a net profit on the entire cost of the gas cleaning operation, but they may help materially to reduce the expense.

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DISCUSSION

Chairman: F. W. SHIPLEY, Caterpillar Tractor Co., Peoria, Ill.

Co-Chairman: J. R. ALLAN, International Harvester Co., Chicago.

Recorder: H. F. SCOBIE, American Foundryman's Society, Chicago.

ORVILLE LAABS: Which type of dust and fume collector is preferable, the dry or the wet type?

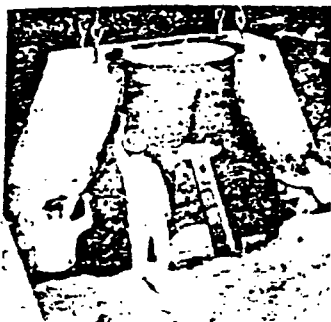
MR. KEYSER: Foundrymen should use whichever type dust and fume collector is necessary to meet local air pollution ordinances. Use the dry type if possible because of its lower maintenance costs.

K. M. MORSE: What data can you give us on the size spectrum of cupola emissions, Mr. Keyser?

MR. KEYSER: About 50 per cent of the particulate matter emitted is dust larger than 44 microns. Approximately 35 per cent is metal oxides 5 microns and smaller. Very little matter between 5 and 44 microns is emitted.

¹Director of Personnel, Universal Foundry Co., Oshkosh, Wis.

²Industrial Hygienist, U. S. Steel Co., Pittsburgh.



Setting an external core for a 30,000-lb 4-stage centrifugal blower casting at Chambersburg Engineering Co., Chambersburg, Pa. The finished mold—entirely cement-bonded sand—consists of a bed, a semi-cylindrical core with a separate nozzle core at each end, and four external cores. Already in place is one of the nozzle cores (dark colored). At the start, a bed of cement sand is levelled in a frame containing core prints. The semi-cylindrical core is rammed in place in a box assembled on the bed. Cores are aligned using gage lines on the bed and a level. All compound surfaces are carefully gaged during assembly to insure specified wall thicknesses.

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The truth about disease caused by foundry dusts

This paper—by the man credited with having done most to separate fact from fiction in the field of dust-caused diseases in the foundry—was given at the Foundry Health Conference held at Ann Arbor, Mich., on April 11-12, 1952. It and all others presented at that time have been compiled into a 200-page publication, *Health Protection in Foundry Practice*, published by A.F.S.

■ Although others may soon replace it at the top of the list, silicosis has for almost a century been the principal occupational disease caused by foundry operations. There are still far too many foundries producing this entirely preventable disease. On the other hand, more and more foundries have developed dust control to such a degree that it has not caused any silicosis in their employees for many years. This is the goal toward which all of us are working.

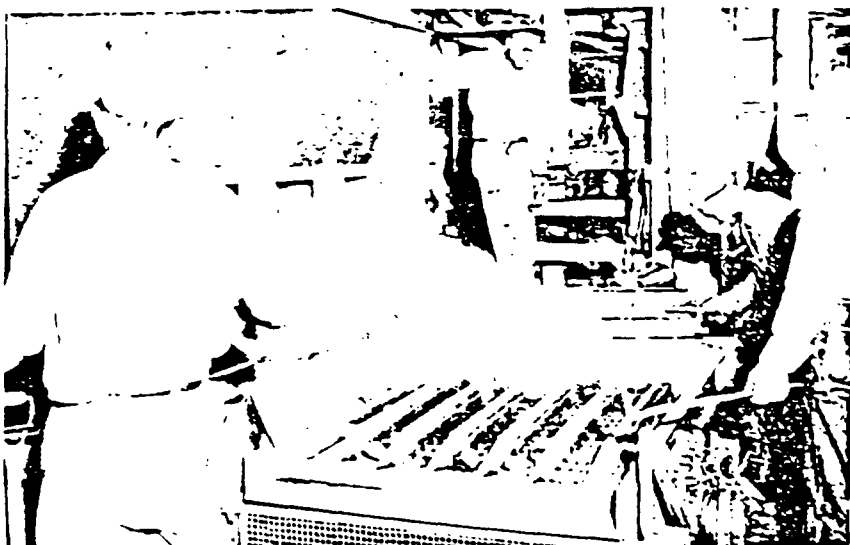
Terminology

Silicosis is readily defined as a "fibrosis of the lungs resulting from the inhalation of dust containing free silica"; it offers little grounds for misunderstanding. Pneumoconiosis, on the other hand, has caused more definition trouble than all the others put together, yet generically it is the simplest to define. It simply means, "dust in the lungs". There is no implication of what the dust is or whether or not it causes reaction.

It is a shortening of Zenker's original term, "pneumonoconiosis" which he proposed in 1836. Therefore there should be no implication of fibrosis in the term because we now know (as Zenker did not) that there are numerous dusts which are entirely inert when deposited in the lungs, which do not cause irritation or fibrosis and which do not predispose to tuberculosis. These have been called the "benign pneumoconioses" to differentiate them from the fibrotic pneumoconioses.

Because pneumoconiosis is a general term and covers all dusts whether harmful or not, it should have no place in occupational disease laws. There the terminology should

O. A. SANDEE / Industrial Medical Consultant, Milwaukee, Wis



Dust exposure at shake-out and other dust-producing operations can be readily minimized by appropriate hoods, forced exhausts, and other devices, whether the operation is manual or powered. Establishing healthy conditions is only the first step in combatting the industrial silicosis problem as it exists today.

be specific and only those pneumoconioses which may result in impairment of lung function should be included—silicosis and asbestosis.

Pathological aspects

Foundryman's silicosis is a modified silicosis. The fibrous nodules seldom are the classical whorled spheres resulting from pure quartz exposure. The old sandblasters had those before they used positive pressure helmets. Today's foundrymen are exposed to far less quartz (or free silica) dust than they are to iron and carbon dust. Dust in typical foundry atmospheres seldom contains more than 20 per cent free silica, with iron dust running from 60 to 70 per cent and carbon dust from 10 to 20 per cent.

With such atmospheres and with the total dust counts sufficiently high, a modified silicosis may result in which the fibrous nodules develop

more slowly, if at all; they always are more irregular than with free silica alone, and secondary emphysema does not occur around them. There also appears to be less susceptibility to tuberculosis than with the classical quartz fibrosis.

It is because of these modifying dusts already present in foundry atmospheres that the author does not recommend the use of aluminum dusting. Workers are already getting the maximal benefit from modifying dusts without adding another modifier. The goal is to continually reduce the silica percentage along with total dust dissemination, not to add other dusts to the air.

Functionally, silicosis becomes a disease only when it is advanced or when it is complicated with tuberculosis. With early discrete nodular fibrosis, there is no interference with the exchange of gases across the alveolar membrane, and no loss of elasticity of the lungs. Only when

fibrotic nodules become confluent and massive fibrosis and secondary emphysema result is there a measurable impairment of lung ventilation.

Witnesses for this are the thousands of foundry workers with minimal silicosis who daily do their heavy physical work without difficulty and who show entirely normal ventilatory values with function tests. Exceptions are the occasional individuals with very little silicosis and high-grade obstructive emphysema. These usually are the older workers who have a naturally decreasing elasticity of the lungs combined with long-standing chronic bronchitis, bronchiolitis, or asthma, the bronchial irritation often having been caused by excessive smoking plus chronic sinus infection.

These cases cause the most medico-legal difficulties because they have real ventilatory disability which most doctors truly believe is entirely due to silicosis. Statistical studies on the incidence of emphysema in the general population at various age levels will help solve some of these difficulties. Such studies are currently being made. However, still more necessary is the constant realization that minimal silicosis never is disabling except when associated with tuberculosis, with a continuing program to educate the medical profession to these facts.

Iron dust in the lungs

Another factor in foundrymen's silicosis which bears constant repetition is the iron dust which all foundry workers have deposited in their lungs. That these iron collections contribute to the x-ray pattern of the silicosis is seldom considered in evaluating the degree of development of a case.

The amount of iron in the lungs may vary all the way from the minimal and probably negligible traces in molders and coremakers to the gross collections in welders, burners, and grinders. Some of the latter may have nodular x-ray patterns due to the iron alone which are radiologically indistinguishable from silicosis. For this iron pigmentation, Zenker's term "siderosis" is perfectly proper, provided there is no implication of fibrosis in the term.

Siderosis is as benign a form of pneumoconiosis as could be desired. It causes neither fibrosis, irritation, nor progressive tuberculosis. Yet it is being misdiagnosed as silicosis every day, and workers so affected, with or without minimal silicosis, all

too often are being advised by their doctors to leave their trades. The fear caused by such well-meant but ill-considered advice has caused more disability than has silicosis itself, in the opinion of the author.

Think of iron first

The author also believes that the time has come to think first of iron when evaluating the nodular x-ray patterns of foundry workers, even when there is no doubt about there being some silicosis present as well. The first question should be, "How much of this nodulation is due to iron collections?" While the answer is not always easy or possible, it makes for far less pessimism in the prognosis when one can say that a considerable part of the nodulation is probably due to iron.

The industrial hygienist has the very important job of making foundry atmosphere increasingly safe for the continued employment of the workers. Industrial physicians, on the other hand, have the equally important job of making these workers feel secure in their chosen trade.

Workers must be assured that their lung changes will not progress to a dangerous stage with the improved dust control. New employees with minimal and uncomplicated silicosis or siderosilicosis must be accepted without hesitation and so placed that their minimal changes will not increase materially. Where this has been done it has been a major factor in helping solve the silicosis problem.

Industrial commissions, no matter who the personnel, cannot be expected to consider minimal silicosis as non-disabling as long as foundries consider such workers unemployable. The unhesitating hiring of affected workers would be a major step in the right direction. There is no reason why minimal silicotic workers cannot stay on their jobs and new workers with minimal changes cannot be hired in foundries where dust control has improved to such a degree that new cases of silicosis can no longer develop.

Reassurance, optimism

The time has come for reassurance and optimism in dealing with this problem, and the medical profession must be the first to recognize this. Such optimism is only impossible in foundries which are still producing silicosis cases; their first step must be to correct the offending dust pro-

ducers. Foundries that are safe for any worker must change their employment practices and allow almost anyone to work in them.

There must be less concern about potential future liability cases, and less rejection of workers with minimal lung changes. The danger of tuberculosis developing in a silicotic lung later in life has diminished almost to the vanishing point as the opportunities for contact with active cases of tuberculosis decrease.

Moreover, workers with minimal changes acquired over a period of years will not progress to a more advanced stage of silicosis if properly placed and protected. It seems much sounder to take a chance with workers having a minimal amount of silicosis than to make them unemployable and semi-invalids.

Few offending foundries

Even though relatively few foundries today are still producing new cases of silicosis, a considerable number have old employees with varying degrees of silicosis who had their significant dust exposures many years ago. It is from this group of older workers that most of our disabled advanced cases arise.

Unfortunately, however, from time to time real cases develop in younger workers, and these special hazards need special attention. Large steel foundries, for example, make large and complicated castings with difficult cleaning problems. Cores frequently cannot be blasted or washed out, but must be dug out with pneumatic hammers. These operations have been the main silicosis producers, but have been largely solved by the development of larger and more forceful hydraulic blasters.

While the first step is to so control dusty operations that silicosis cases no longer will develop in anyone, that is not enough to solve the problem. Those who already have some silicosis must be allowed to continue their chosen work, not only for their former employers but for new employers as well.

They must be reassured by industrial physicians that they are not assuming undue risks by continuing their trades, which makes medical control of equal importance with engineering control. In fact, it must be a joint program with mutual cooperation between the engineer and the doctor. With such a team, any silicosis hazard can be adequately controlled provided the will to do the job is there.

Practical Aspects of Dust Suppression

PART I

By W. B. LAWRIE
M.Sc., F.R.M.S., A.I.M.

INCIDENTAL generation of large quantities of dust is a feature of many industrial processes. In some, the dust is dangerous to health; in others, although perhaps innocuous, it appears in objectionable quantities. Higher output often increases the density of the dust cloud generated, so the modern factory may aggravate the dust problem.

The term "dust suppression" includes all methods by which atmospheric dust concentrations are reduced. These methods fall into two main groups. One approach aims at prevention of dust generation. The other is directed to the control of dust clouds which have been allowed to form.

The former, which may be described as *dust elimination*, is always the better and often the more difficult method.

The latter, referred to as *dust control*, is never so good, although it may be the only practical expedient. It is, however, of great practical importance to keep in mind these fundamental differences in technique.

Dust suppression can be applied in three ways. First and best is elimination of the dusty process. The second is alteration of the process giving rise to the dust, so

that less dust is produced. This is not so good as complete elimination, but it reduces the amount of dust to be controlled, and so facilitates application of control methods. Finally, the dust cloud may be controlled after it has been allowed to form in the atmosphere.

Where no alternative is available, control methods will have to be applied. In the over-all design of a dust suppression system, however, they should always be considered last. Success often depends on the thoroughness with which the first two methods have been used, and the degree to which the actual formation of the dust cloud has been restricted before the control methods were applied.

Although local exhaust ventilation is often necessary, it is only one way of controlling dust, and in certain cases may not even rep-

resent the major feature of a good dust-suppression system.

Local exhaust ventilation is not always successful. It commonly fails to achieve its end because it has been regarded as the only method, instead of being used in conjunction with other methods of dust suppression.

One other general observation must be made. Local exhaust ventilation is employed to remove dust—not air. This requires some knowledge of the properties of the dust to be removed, and also of the manner in which it might be expected to behave. It also means that the normal method of estimating the requirements of the ventilating system, with reference to the volume of air extracted, may give an inadequate impression of the amount of dust it will remove.



Dust and smoke collector hoods behind shakeouts have a capacity of 18,000 cubic feet of air per minute. (Allis-Chalmers Manufacturing Co.)

This article, which appeared originally in the British Journal of Industrial Safety, is presented in condensed form through courtesy of the Royal Society for the Prevention of Accidents, London.

Illustrations are from industrial plants in the U. S. A. Part II of this article, which deals more specifically with local exhaust ventilation, will appear in an early issue.



Down-draft ventilation through grille-topped tables is effective in removing dust generated in the process of sanding and grinding castings.

This should not be overlooked when testing an installation. The fact that a unit extracts a sufficient volume of air per minute may not necessarily indicate that it is extracting dust satisfactorily.

Recent work implies that there is still ample scope for either fundamental or empirical developments, based on observed phenomena, and that careful aerodynamic studies may yield fruitful results.

This method of approach demands a much fuller cooperation than is often evident between the ventilating engineers, the mechanical engineers who design the plant, and the men in charge of production. If the factory is a new one, this cooperation should include the architect so that a suitable building can be erected. In these circumstances the various methods of dust suppression can be applied, either singly or in conjunction with each other.

It is important to realize, however, that such a result will be achieved only when the various dust control methods are seen in proper perspective and used in suitable coordination. If ventilating equipment is used, as it often will be, the ventilating engineer

and the production engineers of the industry concerned should appreciate each other's methods, and the difficulties and limitations inherent in these methods.

Elimination of Dust

The best way of dealing with unwanted dust is to stop making

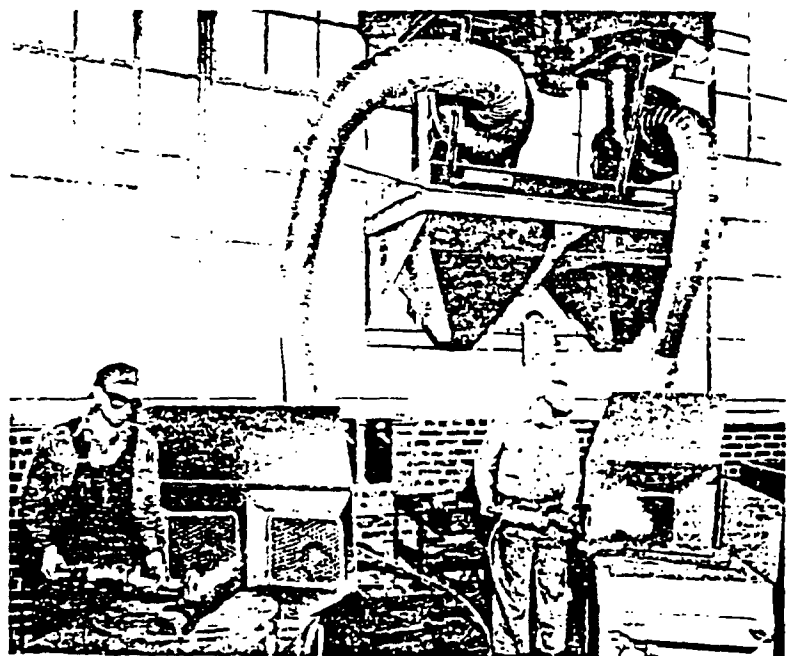
it. In general, this is by no means the simplest method of dust suppression, but it is always the best because it provides a complete and final answer to the problem. Furthermore, it avoids the necessity for costly control appliances which may occupy an embarrassingly large amount of space and make heavy and continuous demands on the engineering staff if a reasonable state of efficiency is to be maintained.

Probably the earliest way of dealing with dust was to wet it. This may offer one method of dust elimination if it proves possible to wet the raw material before process work commences. No dust will be raised as long as the material remains wet.

While water will not wet finely divided materials, they can often be wetted if the surface tension of the water is lowered by the addition of wetting agents, giving what is called "wet water." A further advantage of wet water is that it penetrates large masses of material much more quickly.

There are, however, other ways of eliminating dust, although the

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Well designed hoods remove dust from grinding without drawing it past the worker's breathing zone. Exhausted air is filtered before it is recirculated through the workroom [American Air Filter Co.]

Dust Suppression

(From page 27)

possibility of so doing can be determined only by experts in the process concerned. It demands a wide knowledge of the technical or scientific principles involved in the industry, coupled with great flexibility of mind and the faculty of devising new, and perhaps unconventional working methods.

A good deal of dust may result from dressing or cleaning steel castings after they have been removed from the mould. This dressing is necessary because some of the moulding material adheres to the casting, and must be removed by pneumatic chisels.

If it were possible to make castings in such a fashion that none of the moulding material adhered to the steel, this dusty cleaning process could be avoided. This opens up a wide field of investigation which the British Steel Founders' Association is vigorously exploring.

This particular work is regarded as long-term policy, and in consequence other methods of eliminating the dust are being tried in the treatment of castings. One successful development has resulted from changing the method of cleaning. A flux injected oxy-acetylene burner is now being used to clean the casting in place of the pneumatic chisel. This has not eliminated the cleaning process, but it has offered a method of cleaning which, in certain cases, may eliminate the dust cloud.

These examples indicate a way of dealing with the dust problem which is far too often ignored, and emphasize the need for a close examination of all dusty processes with a view to eliminating the dust. Even where there appears to be little chance of immediate success, the ideal should never be forgotten, and the installation of a dust-control system should not be allowed to stifle efforts to attain a dust-free process.

The second object in dust elim-

ination is, perhaps, less ambitious than the first. This is a change in the process to reduce the amount of dust generated. It is always important to reduce, as far as possible, the dust which is generated, because the smaller the residual dust cloud can be made, the easier it becomes to control it.

One example of this approach occurs in the efforts that foundries are making to reduce the amount of core binder used in moulds. The atmospheric impurity produced by the core binder is in the form of fumes, not dust, but the principle remains the same. Once again no general suggestions can be made, because each industrial process must be treated by a specialist who understands all the factors involved.

This discussion has been concerned only with the reduction of the total amount of dust which must be dealt with by control methods. But there may be another very important factor. Some dusts are dangerous to health, and the total dust cloud may contain a dangerous fraction. In this case, the outstanding reason for eliminating part of the dust lies in the fact that the health risk can be removed if the dangerous fraction of the cloud can be eliminated.

A well-known dangerous dust is free silica (SiO_2). It is known that in many industrial processes where free silica dust is likely to be produced, it will be accompanied by other dusts which may not be dangerous. Efforts are being made, therefore, to eliminate the free silica fraction of the airborne dust cloud. One example of this is discontinuing the use of silica flour as a parting powder. Other powders are used which may produce just as much dust, but the dust is innocuous.

Control of Dust

When the limit of practicable dust suppression has been reached

by the more positive methods of eliminating dust at source, there will still remain ample scope for the application of control methods in cases where it is impossible to prevent the formation of the dust cloud. The common method of dust control is by ventilation, and this may be employed as local exhaust ventilation or as general ventilation, or more probably as a duplex system using both.

It is of some practical importance to appreciate that local exhaust ventilation and general ventilation form two complementary parts of one ventilating system. They should therefore be designed together in new buildings, and when local exhaust ventilation must be fitted into an existing room the whole system should be integrated wherever possible.

Local Exhaust Ventilation

When the evolution of dust has been prevented as far as possible, the next logical step is to design local exhaust ventilation. This should prevent the dust cloud from spreading into the general atmosphere of the room.

Two advantages accrue when this is done. In the first place, the dust can be removed more effectively and more cheaply if it can be contained in a small space and exhausted as a concentrated cloud. In the second place, general ventilation can be designed on the assumption that very small amounts of dust will be present in the general atmosphere. This implies that a relatively small volume of air will have to be handled. Capital costs will fall, and equally important, heating costs will be reduced also.

Dust-producing processes should always be housed in buildings designed to facilitate ventilation. More emphasis should be laid on the simple fact that ventilation is cheaper and better in a properly designed building. Ventilation of a dusty process often means that large volumes of air will be extracted from the building. This in turn means that heat loss in the

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tested as they are turned in or before being issued for use. If a tool proves defective it is immediately tagged and turned in to the electrical department for repair. Since a tool can be completely tested in seven seconds this additional work places no burden on the tool crib. Weighing less than six pounds, it may also be used as a portable instrument to test tools at the point of operation.

Most electrical departments have accepted this new testing device because it aids them in spotting the hazard. It means that after a tool crib attendant has found that the equipment ground is broken or that there is a power ground, the tool is then tagged and sent to the electrical department and gives the electrician a clue as to what to look for rather than to spend time tearing down the entire equipment.

Dust Suppression

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signed ventilating system merely serves to pollute the whole room, rendering conditions worse by dissipating impurities which would otherwise have polluted only the air above their point of origin.

Flat roofs offer the worst conditions for upward ventilation. The rising air does not converge to the point at which the fan is placed, but spreads horizontally on meeting the ceiling. The best way of dealing with such a state of affairs is to insert a false ceiling.

The false ceiling is perforated all over its surface and the extraction fans are installed in the ceiling above it. There is, therefore, an even extraction rate over the whole area of the ceiling and the rising air will be extracted at the point it meets the ceiling. The method is more efficient if hanging partitions are placed over areas where large volumes of fumes are generated.

Downward Ventilation

Rooms which do not contain hot processes may be ventilated downward, from roof to floor. This method is not so common in British industry, but there seems

minimum. Adequate facilities for all types of maintenance and repair work are available to a group of some of the most highly skilled mechanics ever assembled in one job.

Last, but not least, in its contribution to a good safety record, has been the program instituted by the contractor to have the workmen utilize their leisure hours constructively. Available for the use of all concerned are free movies, a very complete library, a hobby shop, a recreation room, a music room, the local radio station which broadcasts 24 hours a day, and the local daily paper.

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Check It

—From page 35

and engineered, being made of heavy gauge sheet metal, fully grounded, protected by a fused circuit, operated at a safe voltage of 6 volts, and contains heavy duty contacts, relays and good wiring inside.

Further, the use of the instrument is not confined to power hand tools. It may be used to test extension cords, extension lights, electric fans, vending machines, pedestal grinders, office machines, desk lamps, floor scrubbing and polishing machines, and, in fact, any single-phase electrical device which receives its power from a receptacle. Incidentally, the instrument contains receptacles that will accommodate any type of electrical cap. All that is necessary is to operate the three push buttons in proper sequence, testing all circuits and watching for the safe (green light) and unsafe (red light) conditions.

Location for Use

The most logical location for use of this equipment is in the tool crib and the test can be performed by a tool crib attendant. Tools are



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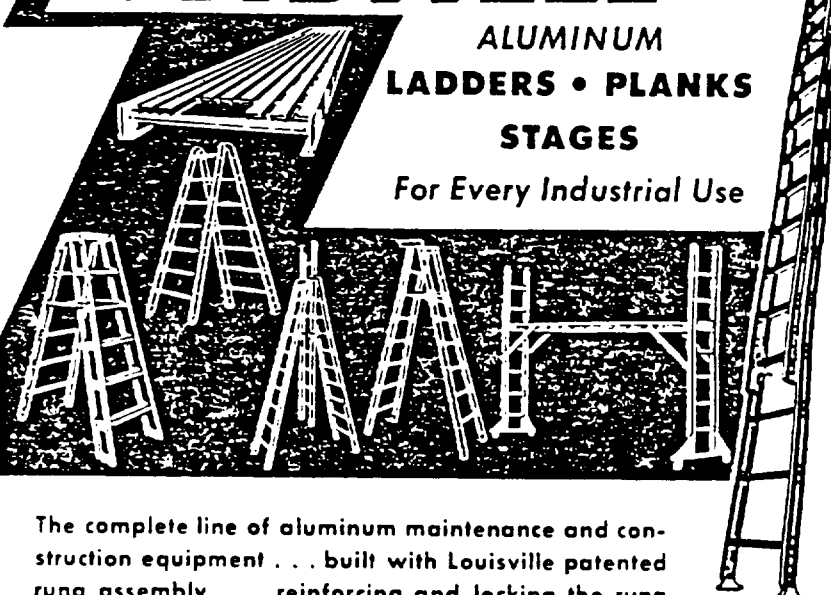
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to be a growing tendency to use it in Sweden. Its advantages are obvious and it extracts dust and fumes without lifting them past breathing level in the process. The general method is to blow in suitably heated air at roof level. The incoming air may be blown through distributors or through a perforated false roof.

In the latter method a second, perforated, ceiling is placed below the ceiling and air is introduced under pressure between the ceiling and the false ceiling, so that it enters the room through the perforations in the false ceiling. The air is extracted below breathing level, and if the processes in the room are provided with local exhaust ventilation this may serve to extract all or part of the air. The whole system needs careful balancing.

Supply of Outside Air

All the air extracted from a building must be replaced by fresh air from outside, and this incoming air should be under control. This is because the uncontrolled ingress of air may short circuit the general ventilation system and give rise to drafts. In hot processes they may be strong enough to vitiate the whole ventilating system.

The incoming air should be clean, and great care should be taken to avoid contaminating this air before it enters the building. Air intakes should be arranged so that they cannot draw dusty air from outlet ducts which are discharging from other parts of the building or from particular processes.

One method of preventing this is to place outlet ducts high up over the buildings. These outlet ducts should be designed to discharge at high velocity, so that the used air will be carried away from the factory.

Outlet ducts should never be fitted with covers. These covers restrict the discharge velocity and baffle the air stream, so that the spent air is turned down over the factory roof, instead of being delivered high up into the outside atmosphere.

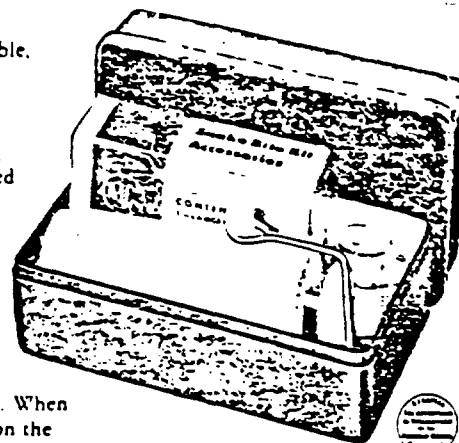
Ideally, incoming air should be delivered to the place at which it



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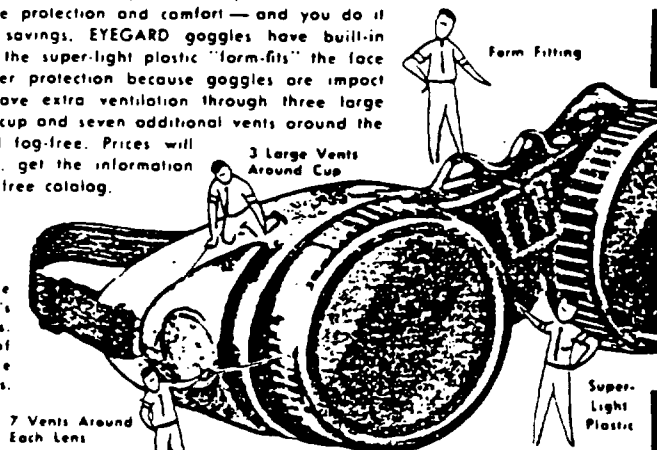
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is needed, because if it is introduced at some distance from this point it will mix with fumes from other sources as it passes through the building. It will, in any case, lose its velocity if it has to travel long distances. If velocity can be maintained, a smaller volume will be needed. On the other hand, drafts must be avoided so that incoming air should not be delivered in the form of a jet, which might impinge on the occupants of the room. When the air has lost its velocity in transit it may still be controlled by reason of temperature.

In plenum systems, it has been found in Sweden that the incoming air can be introduced at a lower temperature than that of the air in the room. As the air is blown in at a height of about 7 feet, this cool air falls to the floor. The angle at which it falls can be controlled by regulating the inlet temperature and the whole system gives a sweeping effect as the cool fresh air falls to the floor before warming up and rising to the roof extractors. This kind of control offers real possibilities, although further information is still needed to obtain the correct air movement by judicious use of velocity and temperature.

One final point might be noticed in general ventilation technique. Certain industries produce large volumes of dust and fumes at particular stages in the process. In these cases it may represent a considerable saving in heating costs if the general ventilation system is designed so that the extraction volume can be increased to meet the short periods at which the maximum dust or fume production occurs.

Tact is giving a person a shot in the arm without letting him feel the needle.

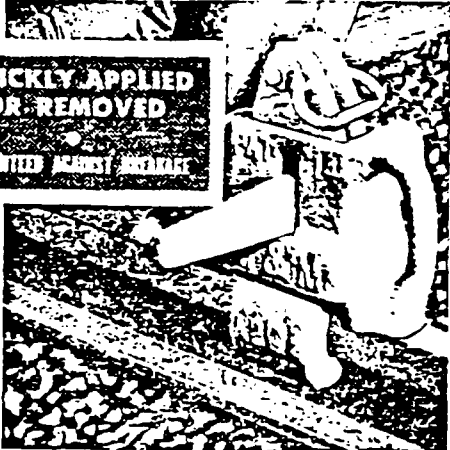
"Smithers," said the boss to a meek employee. "I understand you've been going over my head."

"Not that I know of, sir," replied the employee.

"Well, isn't it true that you've been praying for a raise?"

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PART II

Practical Aspects of Dust Suppression

By W. B. LAWRIE
M. Sc., F.R.M.S., A.I.M.

LOCAL exhaust ventilation systems normally consist of a hood, duct and a dust collector. Theoretical considerations are usually concerned with hood designs, duct designs, and fan characteristics. But the major problem is to get the dust into the duct.

Once the dusty air is safely through the hood and into the duct it can easily be conveyed to a dust collector. It is quite another

matter to capture the dust cloud. Far too little is known about the mode of dust formation, and propagation from its point of origin. The aerodynamics at this end of the local exhaust system have unfortunately received nothing like the attention given to the somewhat easier problems of dust conveying and theoretical fan design.

The first necessity in any local exhaust ventilation system is to capture and contain the dust. It is probably true that this has been achieved only where it has proved possible to enclose completely the point of origin of the dust. It is certainly true to say that total enclosure represents the most efficient and the cheapest method.

Here again there is an urgent need for better cooperation between process men, machine designers and ventilating engineers. Every dust-producing process should be carefully studied with a view to devising working methods which allow total enclosure. This should be done before open hoods are considered. In many cases total enclosure has not yet been achieved, but the point at which the dust is generated should still be enclosed so far as this is practicable, and the partial enclosure should be designed so that the volume of air inside it is as small as possible. This implies a close fitting hood with a small opening.

Where it can be arranged such a design has advantages over the big

This article, Part II of one which appeared originally in the *British Journal of Industrial Safety*, is presented in condensed form through courtesy of the Royal Society for the Prevention of Accidents, London. Part I, which appeared in the February issue, dealt with the more general aspects of dust suppression.

Illustrations are from industrial plants in the U. S. A.

open fume cupboard type of enclosure which has a large area across which air has to be extracted. These large open faces need large volumes of extraction air and give a correspondingly large heat loss. Even the high air volumes used provide only low velocities over the face of the opening, and may not give efficient control of the dust.

More thought should be devoted to the use of high velocity air curtains which operate on small air volumes. These would result in much smaller heat losses, and there is reason to believe that they provide more efficient dust control. High velocity air curtains may be obtained from suction fans, or they may be provided by jets. The jet may, of course, dissipate dust, if a dusty object is lowered into it, but it can be employed in conjunction with an exhaust hood, when the positive, high-velocity, low-volume air curtain it gives is used to direct the dust into the exhaust hood.

A careful study of the process generating the dust may suggest adaptations which will facilitate application of local exhaust ventilation. A good example appears in the modern mechanized foundry where moulds are placed on a conveyor belt. Molten metal is poured into each mould from a ladle which is supported on a block and tackle running on an overhead rail.

The system can be operated in two ways. Either the moulds can move past the ladle which remains stationary, or the ladle can be moved along the conveyor belt from mould to mould. Fumes are evolved as the metal is poured into the mould and local exhaust ventilation is applied to control them. If the ladle remains stationary, and the moulds are brought to it, the area of the pouring operation is limited to this one position, so

local exhaust ventilation need only be applied to a small area.

If the ladle is moved along the conveyor, fumes are generated along its full length so that the local exhaust ventilation must be applied over a much bigger area.

When large numbers of machines or processes operating in a single room have to be fitted with local exhaust ventilation, it is almost certain that there will be a high rate of air extraction from the room. This involves a correspondingly high heat loss.

Efforts are being made to supply cold air to the local exhaust ventilation system. If this could be done, unheated air from outside would feed the local exhaust units and be extracted and returned to outside atmosphere without being heated, and without affecting the heat balance in the room. Much more thought needs to be given to this idea, which would offer great savings in fuel costs.

Local exhaust ventilation is sometimes applied to enclosures of the fume cupboard type in small rooms. The reason for the small room is that the dusty process is thereby separated from other work. In these cases great care must be taken with the supply of air from outside.

If the fan on the fume cupboard is large, the rate of air extraction through the hood may be so high that a negative pressure is set up in a small room. In consequence, the opening of a door may allow such a rush of air into the room that the direction of air flow across the hood face is reversed, and the dust blown all over the room by the erratic eddy currents which result. This effect is not so apparent in large rooms.

Recent Developments

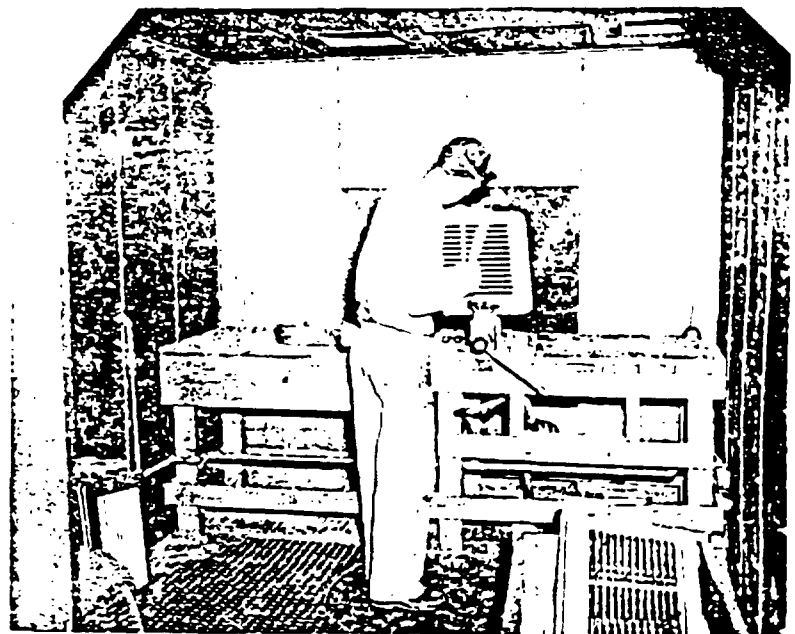
Much exploratory and development work has been undertaken recently in one industry and the results have been published.

In 1948 a rapid dust estimation technique was devised to permit rough comparisons between conditions in different foundries and to facilitate collection of dust samples. This method shows the residual dust concentration in the air and permits an estimate of the efficiency of various dust-suppression measures.

In half a dozen buildings selected at random, it was noticed that the dust concentration in the roof exceeded that at the breathing level, which suggests that general ventilation might be defective.

It was also noticed that swing-

—To page 142



This man is filing magnesium castings in a booth equipped with exhaust ventilation.



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Steel cables stretched between steel towers or poles are frequently used to protect high voltage electrical equipment. In fact, almost all very high voltage transmission lines have one or more grounded conductors located above the phase wires (which are generally carried on suspension insulators) to protect the system against a stroke. The same system is sometimes used for oil tanks or other structures.

Wire fences, particularly when mounted on wood posts, may carry a lightning stroke a long distance and frequently kill cattle grazing along such a fence line. Wire fencing should be grounded at intervals of about 150 feet to prevent the transmission of this hazard to persons or animals at a distance from the point originally struck.

With present engineering knowledge, almost any structure can be made reasonably safe from lightning damage. Steel-frame buildings are inherently protected if the foundations are reasonably deep, but occasionally damage is done to brick, stone, or terra cotta copings when lightning makes its way through such material to the steel frame beneath it. This can be taken care of by a flat strip or small angle of metal placed along the outer edge of the masonry and connected at intervals to the building steel.

The basic principles of lightning protection should be understood by every safety engineer since it is both an occupational and an off-the-job hazard.

Dust Suppression

—From page 29

frame grinders without local exhaust ventilation gave dust concentrations similar to those at swing frames fitted with remote hoods and extraction fans. This suggested that remote hoods were inadequate.

An average of samples taken at pedestal grinders was then assessed because these machines are normally fitted with local exhaust ventilation through the wheel guard. The average dust concentration obtained was compared with that

which are located within six feet of a down conductor are generally tied into the lightning system to avoid side flashes to such grounded metallic masses. The multiple ground system also furnishes a more direct path to ground for a flash striking at the side of a building.

The grounding is generally accomplished by clamping each down conductor to a pipe or rod which has been driven deep enough to reach a layer of permanently moist ground. In most locations, this will be at a depth of six to eight feet. Where the soil is very dry, or where there is rock within two or three feet of the surface, a ground loop of heavy stranded copper or galvanized wire is placed in a trench 15 to 18 inches deep and all down conductors attached to it.

Such loops are frequently used as part of the protective system for old and valuable trees. All of the old trees at Mt. Vernon (some of them planted by George Washington) are so protected. In such cases, the down conductors are led radially outward in shallow trenches to the loop which is of great enough diameter to be outside of the root area. If rods were driven close to the trunk the current from a stroke might seriously damage the roots.

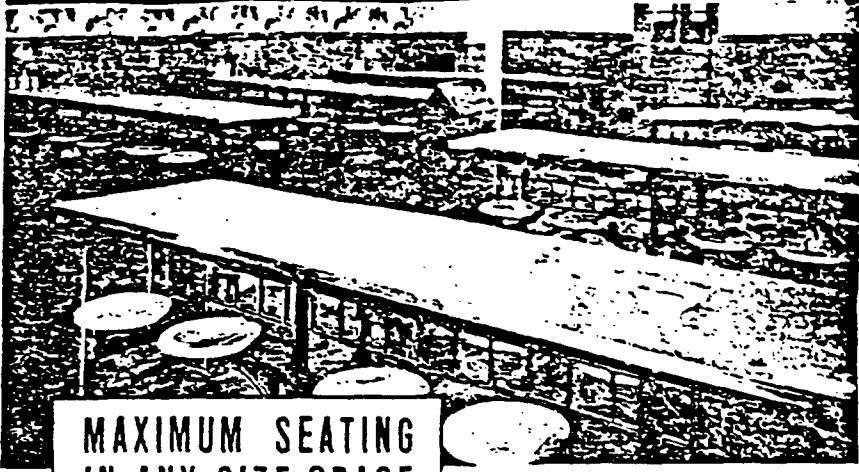
A tall, grounded metallic object will give almost perfect protection to any object located within a 15 degree angle of its top, and any object within a cone making a 30 degree angle with the ground receives considerable protection. By using a series of grounded vertical steel poles, very good protection may be secured for structures within a cone making a 15 degree angle with the ground. If the tops of such poles are connected with heavy-stranded cable the volume protected becomes "tent shaped."

Such systems are widely used in industry, particularly for explosives loading units and similar plants where it is desired to keep the discharge well away from the structure but are seldom used for residences because of their more or less ungainly appearance. However, ornamental bronze flag poles could be designed and located so as to afford protection to moderate



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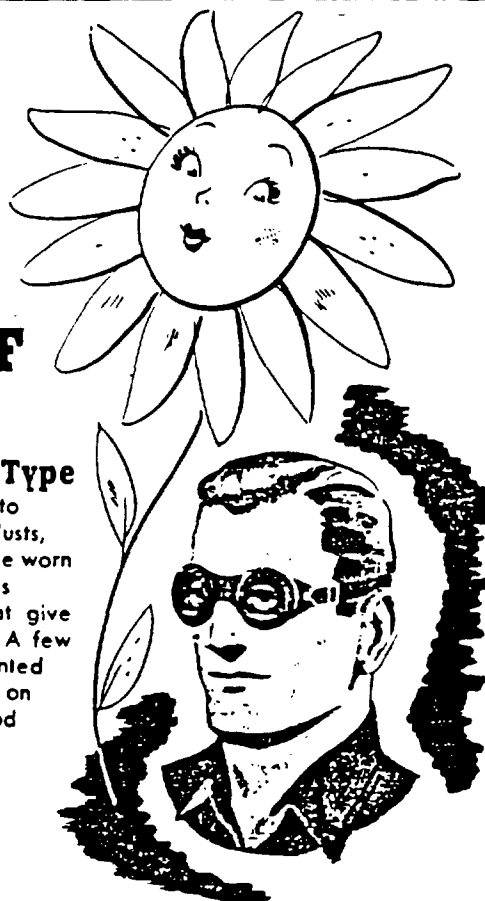
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given by portable grinders, pneumatic chisels and swing frame grinders, all of which were operating without exhaust. It was anticipated that there would be a considerable difference between these two averages, but this did not prove to be the case. This result may be due to the fact that the exhaust systems are drawing average dusty air from all over the workroom, or it may indicate that the local exhaust ventilation was not so good as expected.

While this exploratory work was proceeding, the engineers engaged in new designs for dust control apparatus asked for a method by which the dust movements in the air could be seen. They did not particularly want the method to be quantitative, because dust concentrations could already be determined when necessary. They did, however, want to see the locus of the moving dust clouds, particularly when local exhaust ventilation was applied.

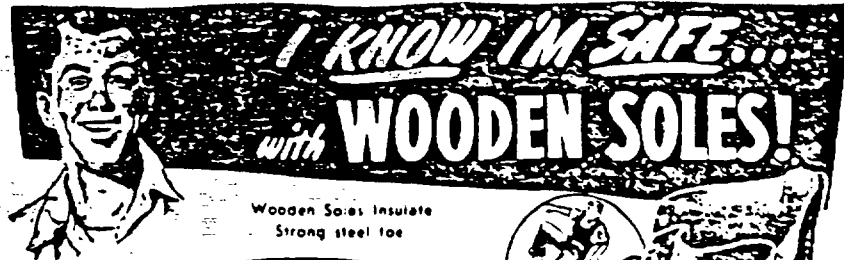
This demand was met by the development of means by which the dust could be seen and photographed with a cine camera. The new technique has been used for empirical development work, and in an attempt to determine the natural flow of dust from its point of origin, in certain instances. The object was to use the dust to observe the aerodynamics of the system.

First results have shown that an abrasive wheel running without local exhaust ventilation and in laboratory conditions, may give a dust cloud which appears to circulate in a vortex above and behind the wheel itself. It was seen that the fine dust from a pneumatic chisel might flow up the arm of the operator, and was not projected along the path of the metal chips.

Observations were also made on floor-stand grinders fitted with local exhaust ventilation, when it was noticed that the fan effect of the wheel itself might be so great that the dust was projected from the front of the guard, and not extracted by the fan.

In one instance, two dust streams were seen on a pedestal grinder fitted with extraction ventilation. One stream was obviously caused by the fan effect of the

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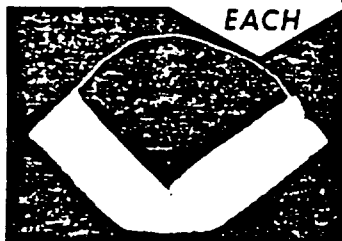
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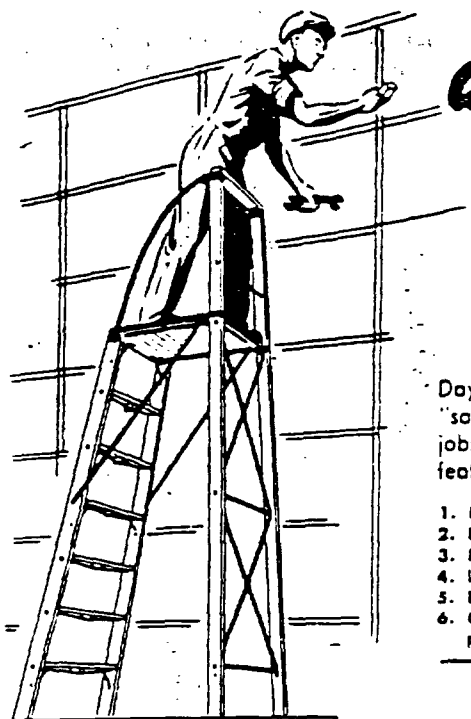
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wheel, because just above the wheel this dust stream was running out of the guard toward the operator. The other dust stream was moving into the guard immediately above the first one. The second stream was due to the dust extraction system fitted to the wheel, but it did not appear to contain as much dust as the outgoing stream. The implication is that a local exhaust system might extract air but fail to control dust.

Swedish engineers have been successful in avoiding use of hoods over small high-frequency furnaces. Because of the strong upward convection currents over a furnace it has been normal in the past to fit a hood and fan over the top to collect the rising fumes. These hoods are often a nuisance, especially if cranes are necessary. The high-frequency furnace is of small diameter, and so it was found possible to avoid the hood by applying a very high velocity air curtain immediately over the furnace.

In this instance the curtain is not a jet, as used on the dressing-bench, but is provided by suction fans. The exhaust appliances are below floor level and offer no restriction to the process work. Amount of air handled has been reduced so that the heat loss in the building is smaller and the fumes have been controlled.

Conveyor belts dealing with fuming moulds are often passed through an exhausted tunnel, which may be of considerable length. Large volumes of air may be needed to exhaust these tunnels, so efforts have been made in Sweden to supply some of this air direct from outside in order to reduce heat loss in the room. These efforts have been so successful that in certain instances more than half the ventilating air is never heated.

Conclusion

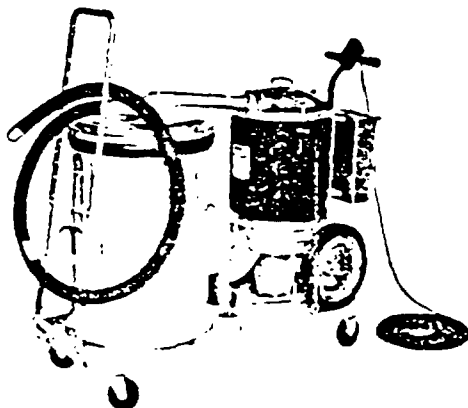
It is impossible, in a general survey, to discuss in detail any single feature of the diverse and complicated devices used to suppress dust. If dust suppression is rightly approached, it is not easy to discuss more than one industry, although it is obvious that if dust were completely controlled in one

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industry, a proper understanding of the scheme would offer many suggestions to other industries.

For these reasons some features of dust suppression have been observed with a view to suggesting practical aspects essential to ultimate success.

Examination of many plants leads to the conclusion that the first necessity is a more liberal approach to the whole matter. It is essential that all available methods should be examined, and that the final scheme should represent an integration of every available resource.

In particular, a practical outlook demands that local exhaust ventilation should not be regarded as the only way of dust suppression. It will doubtless have to be applied in many cases, and it will continue to serve over a wide field. Nevertheless, greater efficiency will be obtained, as it is progressively embodied in plans which incorporate other ideas.

So far as local exhaust ventilation is concerned, there is still a great need for careful study of the aerodynamic conditions at the entrance to hoods, and the manner in which the mechanics of dust generation influences these conditions. Instances of recent practical work have been given to illustrate the value of empirical development, because it appears, that calculations of air flow may not necessarily indicate the efficiency of dust control.

Industrial Health

—From page 60

do not fade in the winter, and areas of dilated capillaries in the skin surface. The thing which is of most clinical importance, of course, is the tar wart since this is very closely related to the tar cancer. Of these 211 men, 66 had had one or more tar warts. The earliest wart developed after 11 months of exposure and the longest exposure before the development of a tar wart was 41 years. Twenty-six of the men had had only one wart and the others had had varying numbers up to 63 warts on one individual with 26 years' exposure.

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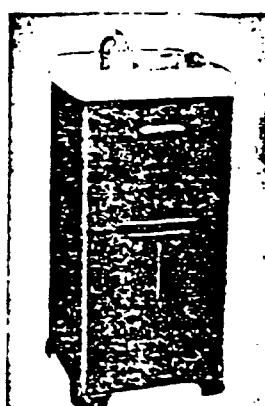
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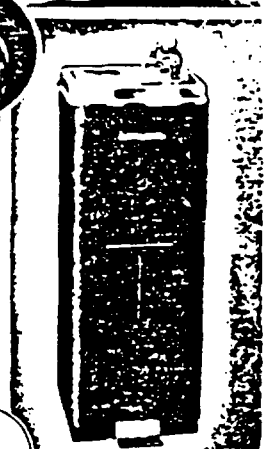
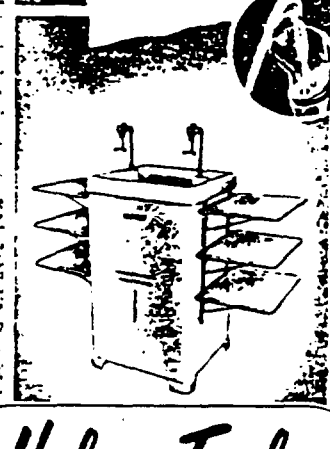
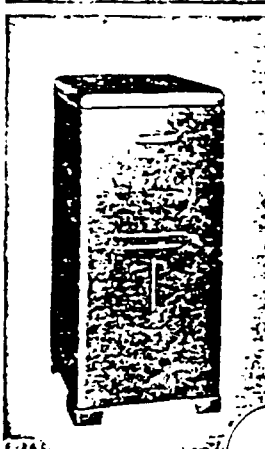
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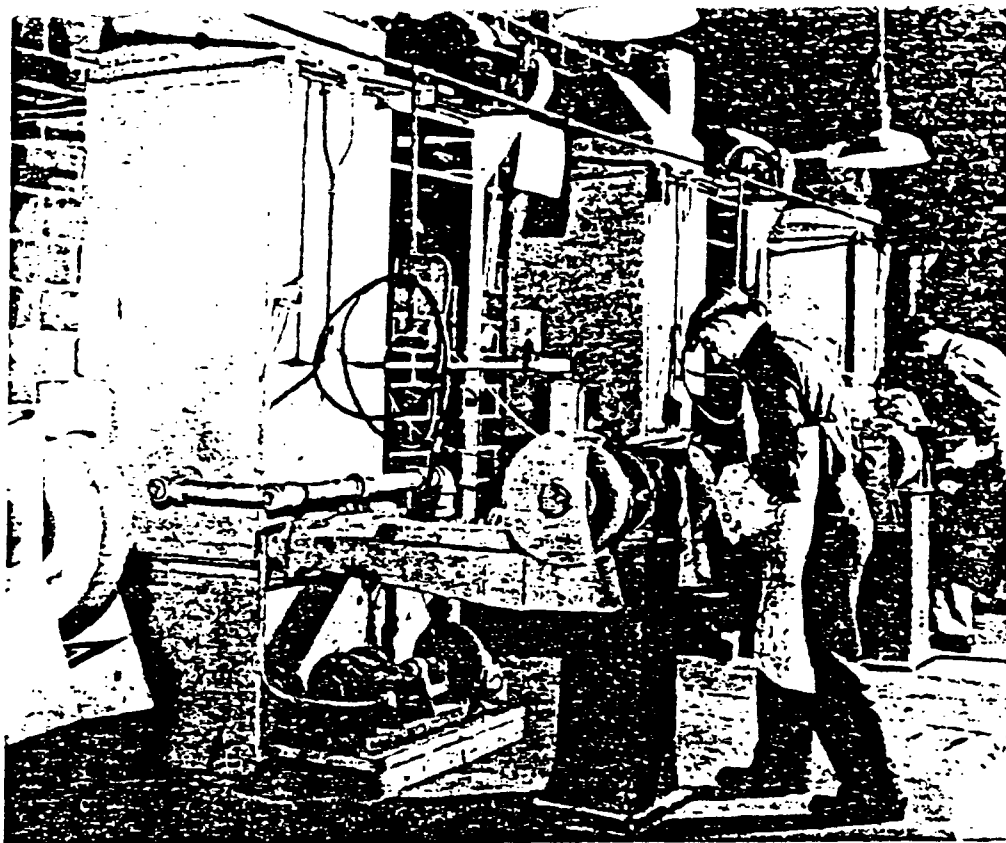
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A heavy spray of water precipitates dust at the grinding wheel. Good safety practice interconnects power for wheel and water supply so wheel cannot be operated without water.

Foundry Safety Practices

This article is condensed from the introduction to the new dust and ventilation control manual, which is being prepared for early publication by the Dust & Ventilation Control Committee of AFS.

■ The American Foundrymen's Society, recognizing the present day exigencies of the industry it represents, constituted the committee on Safety, Hygiene, and Air Pollution in September 1950. The committee was charged with the job of formulating a code of good practices in these three related fields. The objective is to make the foundry a better place to work; to enable the industry to be better neighbors in the community.

The Society recognized that the industry has a moral obligation to prevent accidents and to eliminate occupational disease; that it must do its part in controlling air pollution by taking such steps as are practical according to financial means.

Today, management knows that it must provide safe and healthful working conditions if it is to succeed; and that it is better for an industry to establish its own standards of safe practices than to wait and

have them imposed by others who are not as familiar with its specific problems.

Adherence to a program designed to eliminate accidents and occupational disease is not merely a desirable trait but is just good business. Whether one is self-insured or not, accidents and occupational disease are expensive in medical, compensation, and production costs. These, at times, are hidden, but careful analysis will show them to be surprisingly high.

Furthermore, it is in the interest of the Foundry Industry to improve working conditions in order to obtain a competitive advantage. The better workmen will not be attracted to the foundry, or if they are, they will not stay unless there is some assurance of freedom from injury and sickness. High employment turn-over is costly.

There is a great investment in supervisors and skilled workmen and it is good business to keep them on the job. If the money were available every machine and piece of equipment in the foundry could be replaced but not so, good production people.

Law suits for injury and damage caused by air pol-

bottom might be more expensive than control. Pollutants, such as beryllium, lead, phosphorus, iron oxide, phenol, etc., from foundry operations can quite easily cause neighborhood damage and even personal illness.

By reason of the foregoing, the work of the committee has been directed towards formulating this code of prevention and control. The members thereof are people who are either working in the foundry industry or are closely associated with it as equipment suppliers. Consequently they are familiar with the specific problems of producing castings.

The recommended good practices developed here are based on present day knowledge of the principles of safety, hygiene, and air pollution. It is subject to revision when and if new data or conditions indicate. The recommendations of this code must be practical if they are to be adopted and effective if they are to be of benefit. There are many potential hazards to health in foundry practice but only the more common and principal ones are treated here.

Most foundries are not equipped to make environmental measurements, but threshold limits enable the foundry man to ascertain the relative toxicity of the principal contaminants in his plant. For instance, it will be seen later that 66 times as much iron oxide can be tolerated in the atmosphere as lead.

Medical Protection

In regard to the medical phase of worker protection, good practice suggests as minimum:

(1) Pre-placement physical examination and chest x-ray. This enables management to place an employment applicant on a job suitable for him without endangering fellow employees. For example, a man without depth perception hardly qualifies as a crane operator.

(2) Annual physical examination and chest x-ray. This practice keeps the Company's physician informed of the state of a man's health so that incipient disease can be arrested early; reclassification of employment can be made, or other action can be taken as indicated by the examination. This redounds to the benefit of both the employer and employee.

(3) Adequate first aid facilities in case of injury or illness. The benefits of first aid should be obvious.

The following sections indicate when remedial measures are required and how they can be accomplished.

Casting Industry Health Hazards

Acrolein (acrylic aldehyde)

This gas forms in foundry operations from the thermal decomposition of core oil. It is very poisonous but has adequate warning properties. It is so irritating to the eyes that man cannot tolerate a concentration that would permanently injure him or cause death. It may be classified as a nuisance gas rather than a toxic material because in practice exposure of five minutes to one part per million parts of air is intolerable. The maximum allowable concentration is 0.5 part per million parts of air.

Hygienic control consists preferably of local exhaust ventilation or air dilution by general ventilation.

Aluminum

Shaver and Riddell (J. Ind Hyg Tox 29:115 (1947)) have reported a number of cases of lung disease occurring in the manufacture of alumina abrasives. As far as the casting and grinding of aluminum alloys is concerned, the metal may be considered non-poisonous.

The principal danger is from fires and dust explosions in dust collecting systems.

Antimony

Cases of industrial poisoning from antimony are rare. It is difficult to obtain a clear picture of symptomatology and in foundry operations it probably is an unimportant contaminant. Men exposed to antimony fumes and dust have developed dermatitis and ulceration of the nasal septum.

The maximal allowable concentration is 0.5 milligram of antimony per cubic meter of air, a value not likely to be encountered with the percentages of antimony used in foundry today.

Beryllium

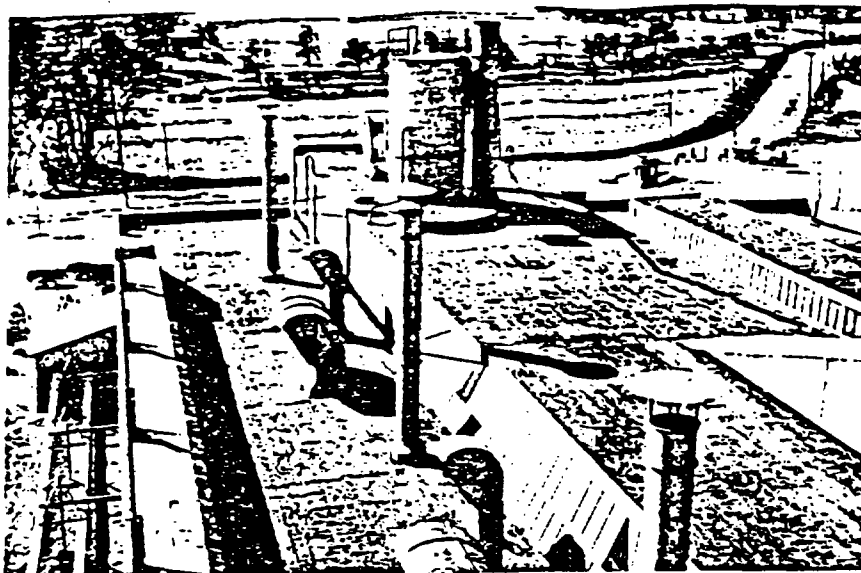
It is only in recent years that this metal was recognized as an industrial hazard. In 1945, 170 cases of illness occurred in certain Ohio beryllium plants. Five of these people died. Many cases have been reported from other areas which have been sufficiently authenticated. One can conclude that beryllium is very toxic even though the National Institute of Health bulletin No. 181 published in 1943 indicated that there is no specific toxic action attributable to the beryllium ion.

There are two manifestations of beryllium poisoning: the acute pulmonary disease similar to pneumonia and a delayed chemical pneumonitis now usually called pulmonary granulomatosis.

Most of the cases reported in the literature occurred in the fluorescent lamp manufacturing industry where the exposure was to beryllium phosphors; but six cases of typical pulmonary disease due to the metal were reported from one plant engaged in casting a 5% beryllium copper. Four of these six cases died. Beryllium copper castings manufactured today contain about 0.30% beryllium and to date no hazard to health with this alloy has been demonstrated.

From the data presently available, it appears that only a few persons are susceptible to chronic berylliosis and that mere traces of the metal in the atmosphere can produce symptoms in them. A susceptible person may show symptoms when exposed to the extremely low value of one microgram per cubic meter of air. Authenticated "neighborhood cases"—people who live near the beryllium plant—seem to substantiate this, since they were exposed to extremely low concentrations of dust.

There are no sufficient data available upon which to base a maximal allowable concentration but some investigators believe that in-plant atmospheric concentrations should not exceed 2 micrograms per cubic meter of air as an average for an eight hour day, and no one should be exposed to a concentration in excess of 25 micrograms per cubic meter of air for any period however short. These are extremely minute values and to maintain an environment so free of con-



Building ventilation balance is of vital importance in air pollution control. This modern foundry has multi-way dust collector with discharge stack, mold conveyor ventilating hood, discharge stacks, compensating air supply units for efficient operation.

tamination requires exceptionally good dust control, housekeeping, and personal hygiene.

When compounds of beryllium come in contact with cuts or abraded surfaces of the skin, deep ulcers are formed which are very slow in healing and treatment sometimes requires complete surgical excision to effect a cure.

An interesting feature of beryllium poisoning is the delayed effect which sometimes occurs. The onset may be delayed for many months or years after the final exposure of the patient. Mortality is high.

Because of the mysterious nature of the effects of this metal on man, foundries engaged in the production of beryllium-copper castings—if they do not have an industrial hygiene staff—would do well to use an industrial hygiene consulting service or their State unit of the U. S. Public Health Service, which is free, in establishing a regimen of atmospheric control.

As far as medical procedures are concerned the following are suggested.

- (1.) Preplacement examinations.
- (2.) Periodic examinations
 - a. Weekly for employees where acute intoxication is possible, monthly for those where chronic poisoning might occur.
 - b. X Ray of chest every six months.
 - c. Special examinations upon presentation of complaints or on persons who have undergone surgical operations.
- (3.) Termination examinations.

The periodic examination should include weight, vital capacity, breath holding test, examination of skin, examination of nose and throat.

It has been recommended that applicants with the following abnormalities be rejected for employment where a beryllium exposure is possible: chronic cough; chronic respiratory infection; chronic malaria; disease of liver, kidneys, or heart; abnormal blood pressure.

Great stress seems to be placed upon the immediate investigation of any worker in whom there develops cough, pain or tightness of the chest, anorexia, loss of weight, or shortness of breath.

Chromium

Air contaminated with chromic acid mist or with chromates or dichromates is the principal exposure to chromium in industry. In this form it causes chrome ulcers and dermatitis.

In foundrying, particularly in the manufacture of stainless steel castings, chromium is present in the an as the element or as a chromic salt (chromic oxide Cr_2O_3). Exposures occur from melting, gate and head burning, and grinding. Elemental chromium or chromic oxide have not been conclusively demonstrated to be toxic. There is some evidence that this oxide can be irritating to the nose and throat and both the element and the oxide can produce dermatitis.

Systemic diseases definitely traced to chromium compounds are rare. Some investigators have noted a high incidence of pulmonary carcinoma amongst workers who were exposed to chromates rather than to elemental chromium or chromic oxide.

Little difficulty from chromium has been experienced in the manufacture of ferro-chrome castings except mild irritation of the nose and throat in susceptible persons working as burners.

The maximal allowable concentration for chromic oxide is 0.1 milligram per cubic meter of air. This value is easily exceeded in the case of unexhausted burning and grinding operations involving ferro-chrome castings.

Cobalt

No proven cases of industrial intoxication have been reported and no threshold limit has been established for this metal.

Radioactive cobalt, however, is now used in the foundry industry in place of radium to radiograph castings. Radiation hazards are the same as those of radium and the Atomic Energy Commission will not release radio-active cobalt to industry unless the A.E.C. safeguards are complied with.

The serious effects of exposure to excessive radiation are well known and the established tolerance dose is 200 milliroentgens per week based on a forty hour week.

In practice, foundrymen using radio-active isotopes

will be guided by the protective regulations of the Atomic Energy Commission and other agencies.

fluorides

Fluorides, sometimes in the form of cryolite (sodium aluminum fluoride) are used in the manufacture of ductile iron and magnesium castings. They are classified as protoplasmic poisons.

Various degrees of respiratory irritation may result from the inhalation of fluorides in the form of dust. This is accompanied after a few minutes by a discharge from the nose or nose bleed. No such effects are noted when the concentration does not exceed 2.5 milligrams per cubic meter of air which is the threshold adopted in the United States.

Dental fluorosis—mottling and discoloration of the teeth—occurs also when the maximal allowable concentration is exceeded for a long period of time.

Cryolite is much less soluble in body fluids than is sodium fluoride and consequently, the danger of physiological effects is less with cryolite than with the more soluble fluorides.

In the manufacture of ductile iron or magnesium castings, the threshold limit is easily far exceeded which is hazardous. Exhaust ventilation is usually indicated at the station where inoculation occurs.

Iron Oxide

Fumes and dust of iron oxide occur during melting, burning, pouring, grinding, welding, and machining operations connected with the manufacture of all ferrous castings. Exposure is particularly high when manganese steel castings are involved.

Iron oxide is physiologically inert but it produces a pulmonary condition called siderosis which is non-disabling. Particles of iron oxide are radio-opaque and produce nodular shadows in a chest roentgenogram that resemble the discrete fibrotic nodulation of silicosis. As a result cases of siderosis are frequently confused in radiographic diagnosis with silicosis, a disabling disease, and compensation awards have been made on the basis of x-ray evidence alone when actually no disability was sustained.

The nodular shadows of siderosis may be compared to a tattoo mark on the arm. They are permanent but there is no loss of function. In severe exposures—80 milligrams of iron oxide per cubic meter of air—siderosis can be produced in as short a time as one year.

In foundry, the job exposures are in the following order of severity:

(1.) Burning. (2.) Grinding. (3.) Welding (4.) Machine grinding. (5.) Pouring. (6.) Melting.

The recommended maximal allowable concentration of iron oxide expressed as Fe_2O_3 is 10 milligrams per cubic meter of air per 8 hour day. In all of the job exposures listed, the threshold limit will usually be greatly exceeded unless adequate exhaust ventilation is provided. In the case of machine grinding operations, exposures can sometimes be controlled by adding a wetting agent to the coolant.

Lead

In non-ferrous foundry, this metal presents the greatest hazard to health. All compounds of lead are

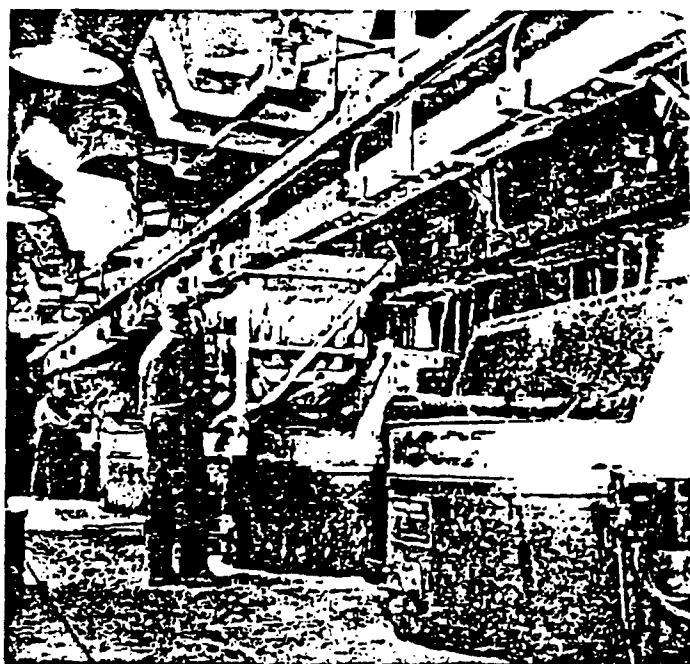
poisonous but in varying degrees according to their solubility in tissue fluids. The low incidence of lead intoxication among miners of galena (lead sulphide) is probably due to the very low solubility of lead sulphide in the tissue fluid of the lungs.

In foundry processes, it is evolved as lead oxide in melting, pouring, and welding operations. This is a very soluble form. In cleaning and machining operations, it occurs in the dust formed as elemental lead which is not as soluble as the oxide. If atmospheric concentrations were of the same order of magnitude, the incidence of lead poisoning will be greater where the oxide is the contaminant.

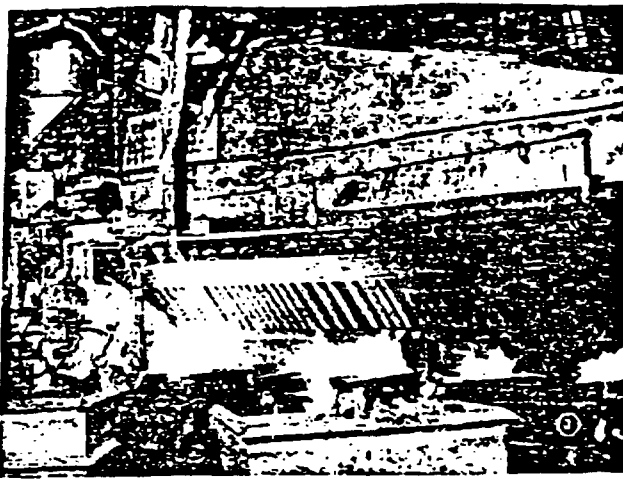
Lead Concentration

The maximal allowable concentration for lead adopted in the United States is 0.15 milligrams per cubic meter of air. This standard does not take into consideration the degree of solubility of the various lead compounds. In foundry work, if the average atmospheric concentration of the oxide is kept to 0.15 milligrams per cubic meter of air, men can work in that exposure for a life time without experiencing symptoms of lead intoxication. At 3.0 milligrams per cubic meter, poisoning may occur in susceptible persons. At 5.0 milligrams per cubic meter, most workers will experience symptoms more or less serious. In practice these values are sometimes difficult to meet without adequate exhaust ventilation. Even in the manufacture of "pure" copper castings there is often sufficient lead present as impurity to produce atmospheric concentrations of lead of the order named.

The literature is replete with data on the etiology, diagnosis, control, and treatment of lead intoxication. It is sufficient to state here that in the production of alloy castings containing lead, there is always a serious potential hazard to health especially in the melting, pouring, cleaning, and machining opera-



These hooded core sand mixers require only sufficient air volume to convey the dust and maintain adequate velocity to prevent escape of dust into the room.



Compensating uniform flow pouring hood (above) affects path of flaming hot gases. Open-side smoke-off exhaust hood (below) is made possible by compensating air. High velocity air prevents fumes from spreading.



tions. In any non-ferrous casting work, where lead is present as a "trace" metallurgically, there may be a hazard to health.

Lead can enter the body by ingestion or by inhalation so that even in the case of good dust control, cases of lead intoxication can occur, if food is permitted to be eaten in the foundry or liquids drunk from open containers, such as milk bottles. Foods and liquids may absorb lead dust and fume in sufficient amount to produce poisoning. Industrial experience has shown that such practice is unwarranted.

Magnesium

Apart from its inflammable nature, magnesium has not been shown to be poisonous as such. The maximal allowable concentration is 15 milligrams per cubic meter of air.

Fire and explosion is an outstanding hazard.

Manganese

Acute intoxication is almost unknown and chronic poisoning, a very disabling and serious condition, is rather infrequent industry-wide. Well established cases fail to respond to treatment.

In foundry, manganese is usually associated with the production of manganese steel castings and manganese bronze. The maximal allowable concentration

is 6.0 milligrams per cubic meter of air. This value is seldom exceeded in the foundry industry even in the case where no exhaust ventilation is provided.

Phosphorus

This element is used in the manufacture of phospho-copper. Acute poisoning from phosphorus has not been demonstrated. Chronic poisoning occurs slowly following inhalation of fumes. It is believed that necrosis of the jaw occurs when phosphorus enters the system by way of carious teeth. Pathology of the bone is characteristic of poisoning by phosphorus.

Chronic cases in industry are not uncommon and because carious teeth afford a suitable background for the beginning of the disease, persons with poor dental hygiene should not be exposed to the fumes for prolonged periods.

Phosphorus ignites spontaneously in air to form phosphorus pentoxide (P_2O_5) and must be stored under water. Because of the ignition characteristics burns frequently occur in industry which are often complicated by chronic poisoning because the substance is absorbed from the burned area.

The maximal allowable concentration is 0.1 milligram per cubic meter of air. This limit may easily be exceeded during the phosphorizing phase of melting phospho-copper. Local exhaust ventilation is usually indicated.

Resins

With the advent of shell molding, more resins are used. They are of the thermosetting type. That is, once the resin is cured, it cannot be softened or remolded. There are various types on the market such as the phenol-formaldehyde and urea formaldehyde resins. Some contain hexamethylenetetramine.

The phenol-formaldehyde resins on heating give off odors of phenol and formaldehyde. Urea decomposes to ammonia and carbon dioxide so that in shell molding one often notices a distinct odor of ammonia. Hexamethylenetetramine releases formaldehyde. All of these are poisonous, but in severe concentrations, man cannot tolerate them. In practice then, fumes from the resins will be at most a nuisance rather than a hazard and the degree of nuisance will indicate whether exhaust ventilation is justifiable.

All resins are primary skin irritants and are capable of producing dermatitis in susceptible persons.

Sea Coal

This is a common facing used in the foundry and usually contains less than 2% free silica. It is principally carbon. Carbon dust gives rise to a pulmonary condition called anthracosis which is responsible for characteristic shadows in a chest radiograph. It has been considered as a relatively harmless condition. Recent research, however, has indicated that it may be a true disease.

When carbon dust is associated with silica dust as an atmospheric contaminant—and it usually is in foundry practice—an exposure results that is capable of producing a true disease entity known as silico-anthraco-sis.

Permissible dustiness for sea coal and for mixtures of sea coal and silica depends on the percentage of

The pouring zone in any foundry is a potential danger area. Adequate safety precautions and fume controls will minimize accidents.



free silica present. Safety factors are variable.

A formula commonly used for determining the maximal allowable concentration for a mixed dust is as follows:

$$\frac{(\text{dust count found}) (\% \text{ free silica})}{8 \text{ hour day}} = 50 \text{ million particles cu. ft. of air 8 hour day}$$

However, even though by this formula, a supposed safe atmosphere could result with a dust count of 100 million particles per cubic foot of air, for good industrial hygiene and an acceptable environment, a dust count should never exceed 50 million particles per cubic foot of air per 8 hour day. If it does, dust control is inadequate.

Silica

Silica is one of the principal atmospheric contaminants in the foundry. The chemically combined silicas, other than asbestos, are regarded as being physiologically inert. Thus silicates such as bentonites, slag wool, etc., are not known to produce disabling disease.

Free silica (SiO_2) does cause the occupational disease known as silicosis which is characterized radiographically principally by nodular shadows due to true fibrosis of the lung tissue and clinically by decrease of pulmonary function. It can be disabling. It is especially serious when accompanied by tuberculous infection.

Usually three factors must be present simultaneously to produce the disease:

(1) Duration of exposure. Two to twenty years are required depending on degree of exposure.

(2) Respirable particle size. Particles of free silica in excess of 5 microns in diameter are not regarded as being physiologically significant because they are too large to reach the alveoli of the lungs where chemical reaction occurs.

(3) Concentration of dust. The tolerable concentration depends on the percentage of free silica in the

dust. The formula used under "Sea Coal" may be applied here.

In non-ferrous founding, the hazard from silica dust is usually not severe except in the case where silica washes are sprayed on molds and cores or sand conditioning practice is uncontrolled with respect to ventilation. The low incidence of silicosis in non-ferrous work is due to the facts that: the sand is usually in a tempered state during shakeout; there is seldom any burn-in; castings are often shot or sand blasted before grinding and chipping.

In ferrous founding, one of the greatest sources of exposure is the uncontrolled use of silica flour. This material falls in the dangerous particle size range and is usually 100% free silica. Zirconite, which is non-toxic and has a specific gravity of approximately twice that of silica, has been an effective substitute for silica flour in some applications. Because of its density and tendency to flacculate, zirconite dust settles very rapidly.

Sand handling and conditioning systems, shakeout, and sometimes sand slinging operations constitute the principal exposures to silica dust.

Dust sources are usually more severe in mechanized plants but this is offset by the fact that they are more adapted to local exhaust systems.

Good housekeeping is one of the most important ways of controlling the hazard from silica dust. There is good evidence in the literature that the incidence of silicosis is inversely proportional to good housekeeping.

The higher the level of housekeeping, the lower the number of cases of occupational disease.

Silicones

In founding, silicones are used as mold release agents during shell molding. Experience to date indicates that they are not a serious hazard to health.

Non-hydrolyzable silicones used as mold release agents are of a very low order of toxicity. From a practical view point, the hazards from handling them are exceedingly minor. However, silicones are new

chemicals and sufficient toxicological studies have not been made to enable us to state that the non-hydrolyzing types can be ignored.

Although the non hydrolyzing types of silicones appear neither toxic nor irritating, the hydrolyzing types are highly corrosive. From a practical view point, they present hazards from vapor inhalation and contact with the skin and eyes. In dangerous concentrations they have adequate warning properties so that a man could not tolerate an atmosphere that would be harmful to him.

Care should be used in handling the hydrolyzing types since a small droplet splashed in the eye could cause serious damage and even the loss of the eye. Direct skin contact while likely to cause a severe burn is not apt to cause death unless a large portion of the body is exposed.

Because there are many kinds of silicones available, safe practices indicate that those of a low order of toxicity be used as mold release agents. These are the methyl, mixed methyl, and phenylpolysiloxanes.

Solvents (General)

Since there are so many solvents used in the foundry, it is impractical to treat them specifically here. There is no such thing as a safe solvent, except perhaps, water. Some are more toxic than others but all of them can be used safely if the poisonous properties are known and safe handling procedures are followed.

All containers of solvents should have labels attached, giving the chemical name and stating the handling precautions. For example:

CARBON TETRACHLORIDE

DANGER!

**HAZARDOUS VAPOR AND LIQUID
MAY BE FATAL IF INHALED OR SWALLOWED**

Use only with adequate ventilation.

Do not use in confined unventilated places without protective respiratory equipment.

Do not breathe vapor.

Avoid prolonged or repeated contact with skin.

Do not take internally.

Fire and Explosion

Most solvents are flammable so that in addition to their toxic properties, they present the danger of fire or explosion.

Given the chemical (not trade) name of the ingredients, the characteristics and dangers of the solvent can be ascertained. There is a wide range of threshold limits because of varied toxicity factors and maximal allowable concentrations range from 5 parts per million for nitrobenzene to 500 parts per million for petroleum naphtha.

Sulphur Dioxide

Sulphur which is used as a deoxidant in the manufacture of magnesium castings burns to sulphur dioxide. Breathing zone concentrations of the dioxide during the production of magnesium castings vary.

A concentration of 10 parts per million is common and of 50 parts per million rare. The M.A.C. is 10 parts per million.

Continued exposure in excess of the M.A.C. produce inflammation of the respiratory system, increased fatigue, excess acid in the urine, and irritation of the senses of smell and taste.

Exposures to concentrations of the order of 500 parts per million are dangerous to life. In rounding, this value will not be reached and concentrations in excess of the M.A.C. are intolerable to man so that he will not remain in an atmosphere dangerous to life.

The gas may be regarded as an irritant nuisance, and depending on degree, exhaust ventilation may be indicated.

Tellurium

Tellurium is used in foundry practice to increase the chill-depth hardness of chilled cast wheels, and to improve the machineability of alloys. It is usually used in very small amounts (5 grams to 800 lbs. of metal).

The fumes of the element cause poisoning characterized principally by the garlic odor of the breath and urine, suppression of sweat, dryness of the mouth, metallic taste, loss of appetite, salivation, and vomiting. Serious industrial poisonings are rare.

Systemic Poisoning

The maximal allowable concentration is 0.01 milligram per cubic meter of air. If foul breath is to be avoided, this value should not be exceeded. Systemic poisoning does not occur unless the exposure is to a concentration of 0.8 milligrams or more per cubic meter of air.

For practical purposes then, the presence or absence of tellurium breath can be relied upon to measure degree of exposure. If this is heeded as an indication of the need of control measures, injurious exposures are not likely to occur, according to Patty. This is confirmed by the experience of others.

Tin

This metal is commonly used in alloys. It is considered non-toxic. The inhalation of tin oxide over long periods may result in a benign non-disabling pneumoconiosis known as stannosis. No cases have been reported in the foundry industry.

In practice, it does not present a health problem. No maximal allowable concentration has been established.

Zinc

The inhalation of the fumes of zinc oxide gives rise to a malaria-like illness called brass-founders' ague, zinc chills, smelter shakes, or metal fume fever. Recent research has now shown that finely divided oxides of other metals, such as magnesium, can also produce metal fume fever. The illness rarely lasts more than a day, causes no permanent disability, and is never fatal. Immunity is often acquired after repeated exposures.

When brass contains zinc, fumes of the oxide are readily given off during melting and pouring in voluminous amounts because of the low boiling point of the metal.

The maximal allowable concentration is 15 milligrams per cubic meter of air.

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Silica Content of Foundry Dust

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ABSTRACT

This paper gives a general introduction to the importance of knowing the silica content of foundry dust, the methods used to determine it, and some of the problems associated with the determination.

Characteristics and Health Hazards of Silica

Silica is SiO_2 , a mineral which, when inhaled over a period of many years in the form of microscopic dust particles, can cause a disease known as silicosis. Most foundrymen are somewhat familiar with this fact. The silica which causes this disease is known by many other names: quartz, crystalline silica, or many commonly used foundry terms, such as bank sand, beach sand, core sand, dune sand, quartzite, sandstone, sharp sand, silica flour, silica sand. There is also a form of silica called amorphous silica, which does not have a crystal structure and does not have the property of producing silicosis.

There are two slightly different crystalline forms of silica called tridymite and cristobalite, which are formed from quartz upon heating. Quartz turns into tridymite at approximately 1600 F (867 C), and tridymite into cristobalite at about 2700 F (1470 C). Tridymite and cristobalite are both considered to have a much greater tendency towards production of silicosis than does quartz.

Related to silica are the silicates. These are generally considered non-toxic dusts. However, asbestos is a silicate sometimes used in foundries which is capable of causing serious disease.

Also present in foundry dusts are many other minerals and other types of dusts, which are called nuisance dusts, and have little or no physiological effect on the body. Examples are ilundum (Al_2O_3), Portland cement, graphite, gypsum, etc.

The health hazard presented by dusts suspended in air in a foundry can be evaluated by knowing the amount of quartz in the dust. For this purpose, the amount of inert or nuisance dust present can almost be ignored, and health evaluations can be

based on the quantity of crystalline silica or quartz in the breathed dust.

OSHA has established the following limits for mineral dust in foundries:

Quartz (respirable) Limit =

$$\frac{10}{C_{\text{respirable quartz}} + 2} \text{ mg } M^{-1}$$

Quartz (total) Limit =

$$\frac{30}{C_{\text{total quartz}} + 2} \text{ mg } M^{-1}$$

Tridymite and Cristobalite Limit = one-half quartz limit

Nuisance Dust (respirable) Limit = 5 $\text{mg } M^{-1}$

Inert (total) Limit = 15 $\text{mg } M^{-1}$

These limits represent the amount of dust in air to which a worker may be exposed without running the risk of adverse health effects.

Of the five limits given above, the one most commonly used is the one for respirable quartz. A sample of the air a worker breathes is taken using sampling equipment which separates out the particles too large to reach the lungs, giving the concentration of dust to which he is exposed (Figs 1 and 2).

The silica content of that dust is then determined, plugged into the formula to give the limit for that dust, and the limit and the air sample are compared. The limit for total (respirable + non-respirable particle sizes) dust is used less frequently, because it does not reflect as accurately the health hazard of the dust being evaluated. The limits for tridymite and cristobalite are not used frequently because of the difficulty of analysis for these two forms of silica. More about this later.

The inert or nuisance dust limit is not used frequently in foundries because almost all foundry sand contains more than 1% crystalline silica, which necessitates the use of the silica limits. The nuisance dust fraction of the total dust may then be ignored, since it contributes practically nothing to the overall health exposure.

Distribution of Silica in Foundries

Unfortunately, there is almost no rule of thumb which can be applied to give an idea of how much silica is present in the dust associated with a given foundry operation. From the results of 55 settled dust samples obtained from 13 foundries over the past

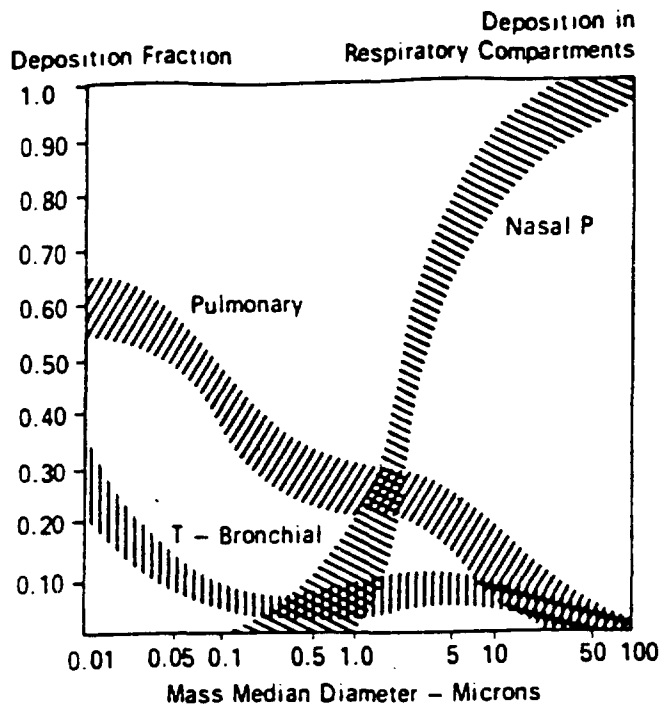


Fig. 1. Area of the lungs where different particle sizes are deposited. (Copyright 1973 United States Steel Corporation).

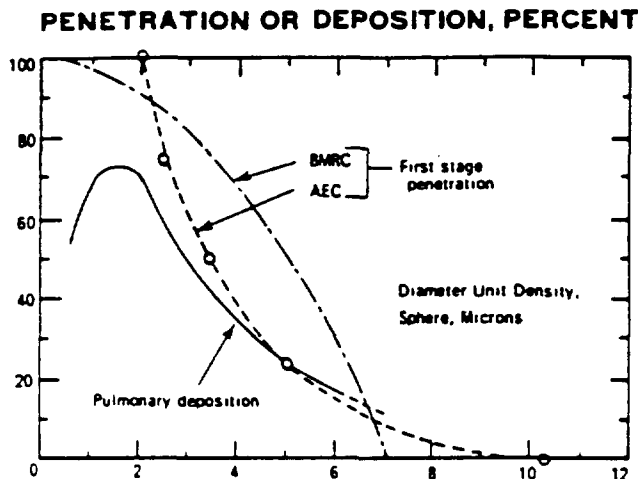


Fig. 2. Comparison of size-selective air sampling criteria and pulmonary deposition. The BMRC and AEC curves are the percent of particles of a given size which pass through a sampling device, such as a cyclone, to be collected on a filter. (Copyright 1973 United States Steel Corporation).

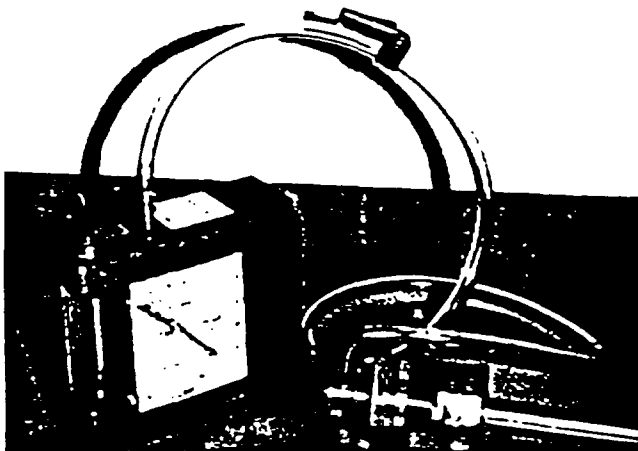


Fig. 3. MSA Model G pump with 10 mm nylon cyclone and filter assembly for breathing zone sampling of respirable dust.

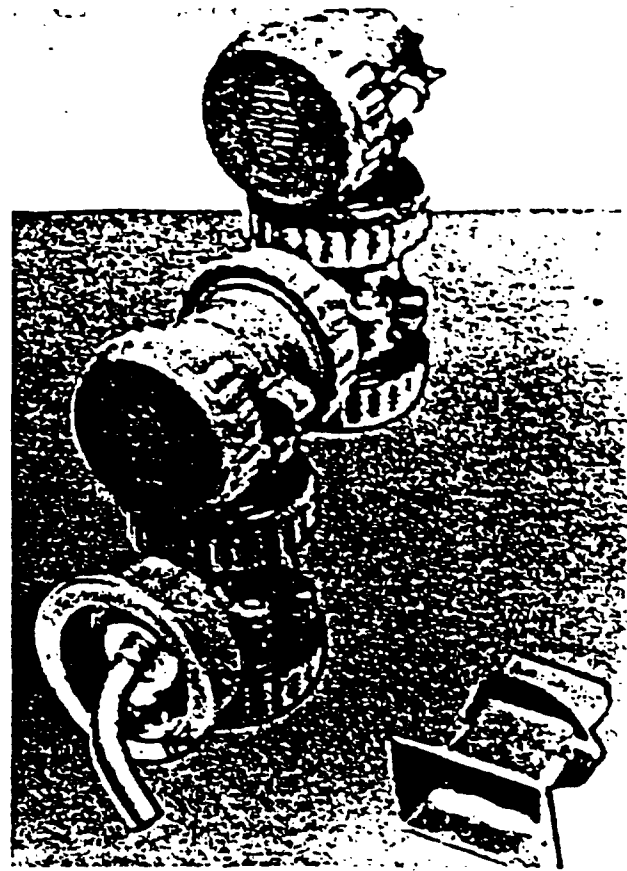


Fig. 4. Cassella cascade impactor for size separation of dust.

5 years which were analyzed for crystalline silica, we have found that the silica content of foundry dust is highly variable and must be evaluated on an individual basis for separate foundry and operations. The range for all 13 foundries and 55 samples from 0.4% to 75% crystalline silica. However, over a period of time, the analysis of a number of samples will give a reasonably good idea of the silica content of dust in a given foundry.

There are many reasons for this wide range and high variation in silica content of foundry dust. The major reason is that there are different formulations of foundry sand for specific types of jobs. Some foundries find it possible to conduct their business without using any silica sand at all; olivine, a magnesium iron silicate, is an example of a substitute for silica in non-ferrous operations. Chromite is beginning to be used in steel foundries and aluminum silicate, zircon and carbon sand have been tried but are not widely used.

Another reason for the variation is that the dust from different foundry operations mixes in air. Very few foundries have their molding, shake-out, cleaning, and sand mixing operations completely isolated, so that airborne dust from one operation will drift into other areas of the foundry.

A third reason is that dust particles have different sizes, and the large-sized particles settle out of air much more rapidly than the very small ones. If the large particles have a higher silica content than the small ones, after the big particles settle out, the airborne dust will have less silica than the total dust in the foundry. The variation of silica content with particle size depends on the characteristics of the silica, how it has been used, whether it has been fractured into small pieces or does not fracture as easily as the other minerals used in the foundry sand, and a host of other characteristics.

Another large variable in the process is the exact method of collecting and analyzing the dust. The next section gives information on these methods.

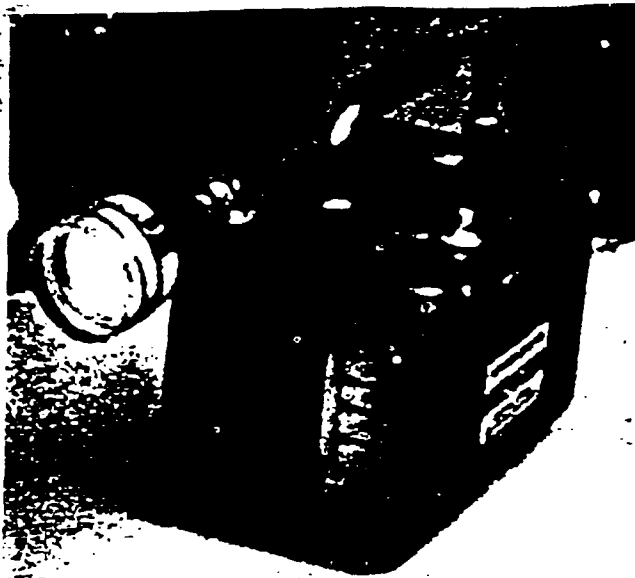


Fig. 5. Unico Model 30 high volume pump for total dust sampling.

Tridymite and cristobalite are known to be present in some foundry sands, but there is little data available. An AFS committee is developing a paper on the subject of silica conversion. They are not thought to be a significant problem in other than ferrous foundries, because it takes a good deal of heat for a long period of time to convert quartz into tridymite and cristobalite. This time and temperature criterion is commonly assumed to be filled only in ferrous foundries because of the higher temperature of the metal, and then only in castings weighing on the order of 1 ton or more.

The quartz present at the interface between molten steel and the mold may be converted over a period of many hours to tridymite and cristobalite and stick to the mold. It then produces a very significant hazard of silicosis to workers involved in the cleaning operation, because of the difficulty of ventilating a cleaning operation on a casting weighing several tons. It will also contaminate the recycled sand, exposing other foundry workers.

Evaluation of Silica Content of Dusts

Obviously, the best way to determine the amount of silica dust to which a worker is exposed would be to analyze the dust which he breathes. This could theoretically be achieved by taking a long-term air sample at the breathing zone of the worker throughout several hours or perhaps several days of exposure, weighing the dust collected to determine the extent of his exposure and then analyzing the dust for silica to determine the appropriate limit. The sampling equipment necessary for collecting the dust is

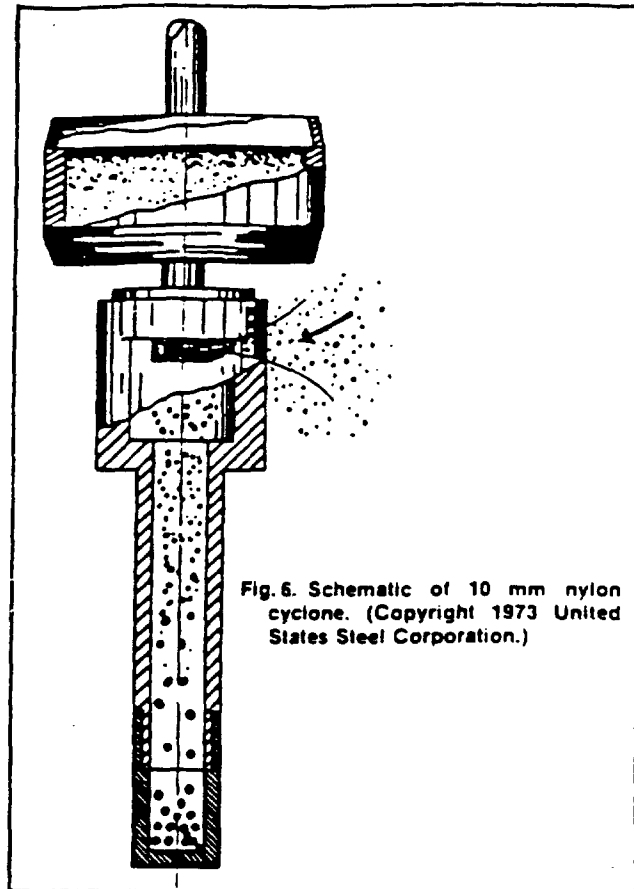


Fig. 6. Schematic of 10 mm nylon cyclone. (Copyright 1973 United States Steel Corporation.)

available and is very commonly used for evaluating dust exposures. (Figs. 3 and 4).

It is difficult to collect enough dust on a filter to make an analysis of the amount of silica contained in the dust. This is because in order to be portable enough to sample the worker's breathing zone, it must be of a small size, which limits the capability of the equipment to sample large volumes of air.

The problem has been skirted by two methods: one is to use a stationary sampler powered by line current which is capable of taking a very high volume sample of air, and collecting a large quantity of dust; the other is to find a location in the foundry where dust has settled out of the air and has remained undisturbed. A few grams of this settled dust may be collected and analyzed.

Under ideal circumstances, the dust collected for silica analysis should represent the particle sizes which are capable of

SIZE SELECTIVE CHARACTERISTICS OF NYLON (10 MM) CYCLONE

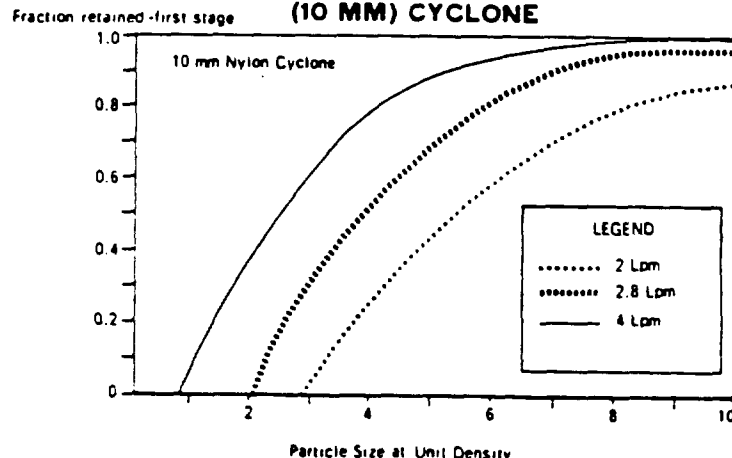


Fig. 7. Size selective characteristics of 10 mm nylon cyclone. (Copyright 1973 United States Steel Corporation.)

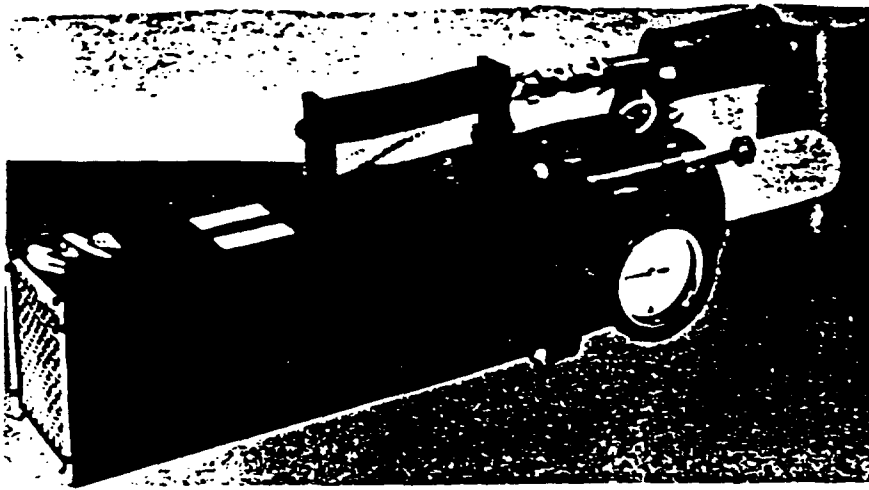


Fig. 8. Hexplet elutriator for respirable dust high-volume sampling.

entering and being retained in the lung. Obviously, collecting settled dust would only be an approximation of this. Collecting all airborne dust by a stationary sampler would also be only an approximation, since some of the dust would be in the process of settling out, and some of the dust would be airborne but still have particle sizes too large to enter the lung (Fig. 5). Devices have been developed which automatically screen out particles that are too big, and pass only those which would enter the lung. Several devices have been developed which are called size selective samplers, including the half-inch steel cyclone for high volume size selective sampling, the ten millimeter nylon cyclone for personnel monitoring, (Figs. 6 and 7) and a number of other devices such as elutriators, cascade impactors, etc. (Figs 8 and 9).

Analytical methods for silica content of dusts range from the Talvitt methods, which are basically chemical methods depending on the different solubilities of crystalline and other forms of silica and other minerals; x-ray diffraction, which uses an x-ray beam to measure the amount of a certain crystalline structure in the sample; differential thermal analysis, which depends on the amount of heat absorbed by different minerals at different temperatures; petrographic, which is a microscopic technique which counts particles of different mineral species; and infrared, which depends on the absorption of different wavelengths of light by different minerals.

Of these, the Talvitt methods have been the most commonly used. Their primary disadvantage is that with mixtures of different minerals, the crystalline silica content determined may vary considerably from just a slight change in the amount of time taken in some of the steps, or the exact temperature utilized during some of the steps. The Talvitt methods also take a large amount of time per sample.

X-ray diffraction seems to be the wave of the future in silica analysis. It has been used quite successfully for analyzing bulk samples, such as settled dust samples, and is very accurate in determining crystalline silica. It can determine not only quartz, but also cristobalite and tridymite, and can be used for distinguishing many other types of species in this manner. The question of accuracy of x-ray diffraction for very small quantities, such as those collected on a breathing zone sample from a foundry worker, has been raised, but many workers in the field believe that this has been solved, and that x-ray diffraction is the method of choice for this purpose. X-ray diffraction equipment is very expensive, but it is much more rapid than chemical methods and thus less expensive for large sample numbers over a period of time.

The other methods mentioned above all suffer from some large disadvantages, primarily problems arising from in-

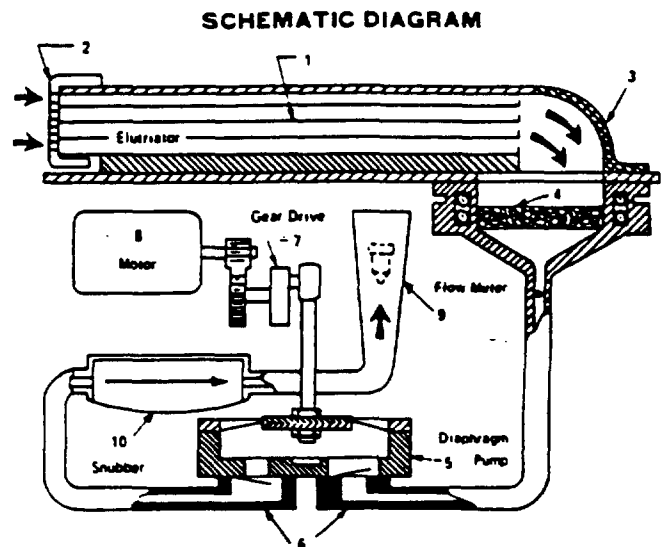


Fig. 9. Schematic of horizontal elutriator. Large particles settle out in the horizontal portion of the device. (Copyright 1973 United States Steel Corporation.)

terferences from other types of minerals present in the sample.

Conclusion

The silica content of dust is an essential piece of information in the evaluation of health hazards in foundries. It cannot be guessed at, but must be determined by competent people who have the facilities for performing an analysis and the ability to recognize the limitations of various methods of sampling and analysis and take these into account in their evaluations.

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Determining Crystalline Silica Compliance Using Respirable Mass

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ABSTRACT

This study examined approximately 1275 samples of respirable mass and crystalline silica collected under Wisconsin OSHA compliance sampling. Information was developed to estimate compliance with OSHA crystalline silica standards using respirable mass without crystalline silica determination. This is a much less expensive method of determining the probability of compliance with the need for a minimum amount of actual crystalline silica determinations. Average free silica concentrations are presented for the various foundry areas and job descriptions as well as percentages of samples that were not in compliance indicating common problem areas.

Introduction

Free silica determinations using x-ray diffraction,^{1,2} colorimetric^{3,4} or infrared methods⁵ need trained operators and expensive equipment not available in many small Wisconsin foundries.

Commercial availability of membrane filters, battery operated pumps, cyclones, and relatively inexpensive accurate microbalances have changed the evaluation of dusty atmospheres from total impinger dust counting^{6,7} to weighing membrane filter respirable mass which can be performed rapidly and with much greater reproducibility between operators in different laboratories than impinger dust counting.

NIOSH⁸ has proposed changing the current free silica standard (standard = 10/% free silica + 2) to 50 micrograms for alpha quartz. This would necessitate the free silica determination of every sample collected and call for routine air sampling and medical examinations for all employees exposed to more than 25 micrograms of quartz or 12.5 micrograms of cristobalite and tridymite.

The idea of respirable mass as a single indicator would be much less expensive than free silica determinations and may be performed in even the smallest foundry with little operator training or time. With this in mind the authors decided to review compliance samples collected in the State of Wisconsin.

Respirable silica samples were collected over approximately a 1-1/2 year period by field industrial hygiene compliance officers under a Wisconsin-OSHA⁹ 7(c) (1) compliance program. A 7(c) (1) compliance program is essentially an agreement between the participating state and the U.S. Department of Labor whereby inspections are conducted under the federal program with the state personnel being "on loan" to the Department of Labor. Funding in this case was 50-50 by the parties involved. Inspectors were supplied by the Section of Occupational Health of the Wisconsin Division of Health; the Wisconsin Department of Industry, Labor and Human Relations; and the Wisconsin Area Office of the Occupational Safety and Health Administration.

Sampling Methods

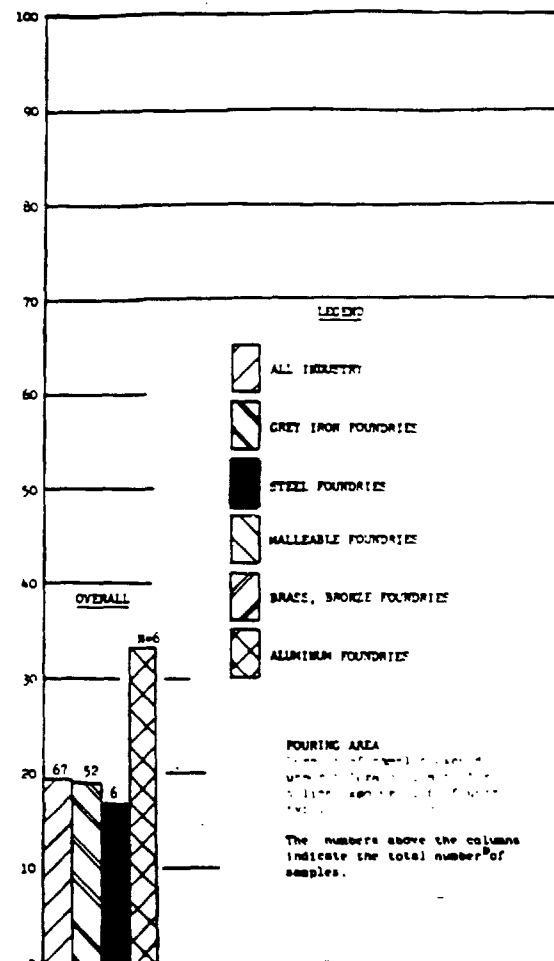
The OSHA target health hazard program¹⁰ includes silica as one of the substances having proven widespread potential for disabling lung disease, so during the course of the program there was considerable emphasis placed on silica sampling. Companies inspected consisted of 65 Wisconsin foundries employing the majority of the State's foundry workers, and 20 other manufacturing facilities that used silica in various processes or operations.

Table 1. Breakdown of Data into Job and Area

Job Title/Job	Total No. Samples	% Samples Exceeding 5 TD	Average % Free Silica
MOLTING AREA	55	56	7.36
furnace loading	6	17	7.96
crucible operator	1	100	8.40
electric arc furnace operator	1	0	1.81
induction furnace operator	1	0	2.06
gas fired furnace operator	1	100	2.62
large ladle lining	15	60	10.73
small ladle lining	27	56	6.84
crane operator	2	100	2.47
POURING AREA	67	19	4.94
hand pouring	18	6	2.76
shifter	19	21	5.50
dumper	20	25	3.78
crane operator	1	0	4.00
centrifugal casting	3	33	3.61
SAND SYSTEM	307	47	6.49
bulldozer operator	107	50	5.93
pit man	47	72	9.89
spadeout operator	116	66	6.10
payloader (bucket)	23	9	4.74
pile setting	7	29	4.85
sand carrier (mullbarrow)	8	75	9.99
shovel	3	100	8.94
CORNDRAKING AREA	93	37	9.04
bulldozer operator	39	56	11.51
oil sand core maker	15	20	8.61
shell core maker	15	20	6.59
no base	5	40	13.20
core blower operator	10	0	3.96
helper	1	0	7.64
core finishing and assembly	13	38	8.73
MOLDING AREA	204	30	6.48
floor molding	9	22	5.22
large core setting	4	50	4.21
riding sand slinger	12	75	8.37
crane operator	12	75	6.70
small automatic molding oper.	15	0	2.36
core setting (small)	7	29	5.97
CPO molding	3	33	8.44
copr/arg molder	11	16	3.66
large automatic molding oper.	3	66	10.90
squeezer molder	52	15	5.09
shell molding	2	0	5.45
no base molding	2	0	0.80
hand operator slinger oper.	12	58	12.88
helper (molding)	15	33	5.76
general molding	25	28	5.94
CLEANING ROOM	436	46	5.74
vacuumator	80	44	6.52
stand grinder	57	33	4.36
hand chipper-grinder	78	68	7.21
shesout operator	0	25	13.33
hoodout	22	59	7.26
band grinder	65	47	5.32
band chipper	8	63	7.10
material handler, flag	20	25	5.70
inspector-courier	16	56	7.07
swing frame grinder	16	14	4.06
cut off saw	11	19	2.72
crane operator	11	45	2.49
armature blasting	9	56	15.28
belt grinder	3	33	10.72
tumbling barrel operator	4	50	5.81
flame cut-off	7	67	1.00
welding	1	100	4.62
scarfing	3	100	22.18
MISCELLANEOUS	25	40	10.41
hand sweeping	16	50	6.15
power sweeper	7	0	2.60
helper (general)	1	0	3.70
laborer	20	36	4.46
INDUSTRY OTHER THAN FOUNDRY	83	34	6.47
blaster	12	58	10.42
crusher or grinding mach.oper.	7	29	7.71
grinding silica containing	12	33	4.74
base material	1	-	-
sizing & cutting base material	12	-	7.11
handling powders	11	31	5.72

About 1275 samples, excluding blanks, were taken for a determination of respirable mass and percent alpha-quartz. Locations selected were not representative of particular operations, but were sampled because they appeared to have the greatest dust exposure and consequent potential of being the greatest health hazard. Statistical methods were not applied because the samples were not random.

The sampling was conducted with nylon cyclones and holders using two-part 37-mm cassettes with 37-mm thick absorbent filter pads and 37-mm 5 micron pore size polyvinyl chloride



filters. The air sampling pumps had been modified to include a pulsation dampener and a larger battery pack. Pumps were periodically calibrated.

The sampling devices were placed on individual employees, with the cyclone attached in the approximate breathing zone—usually clamped on the worker's collar. The individual workers were instructed to work in a normal manner, and to keep the sampler in place during operation, rest periods and lunch break. The inspector removed the device, usually at the end of the workshift. Close observation was made of the sampling device to ensure the continued proper flow rate of 1.8 liters per minute, and reduce the possibility of tampering. Most of the inspections were made using a team approach, where 2, 3 or up to 5 inspectors would be sampling in adjacent areas, so overlapping observations were possible. The number of inspectors on the team was dependent on the size of the company and number of sampling sites. The team approach was complimented by several of the larger foundries inspected because management and labor felt this method of inspection was less disruptive than having one inspector in the plant for weeks on end.

Sample volumes ranged from 50 to 950 liters, the majority falling between 550 and 900 liters (as shown in Table 2) or 5 to 8-12 hr. Inspection-type sampling is done for extended periods—the whole workshift, if possible—to obtain representative samples because the larger sample size increases the accuracy of the analytical procedures.

The filters were weighed on three different balances one of which had weights to the nearest one-hundredth of a milligram

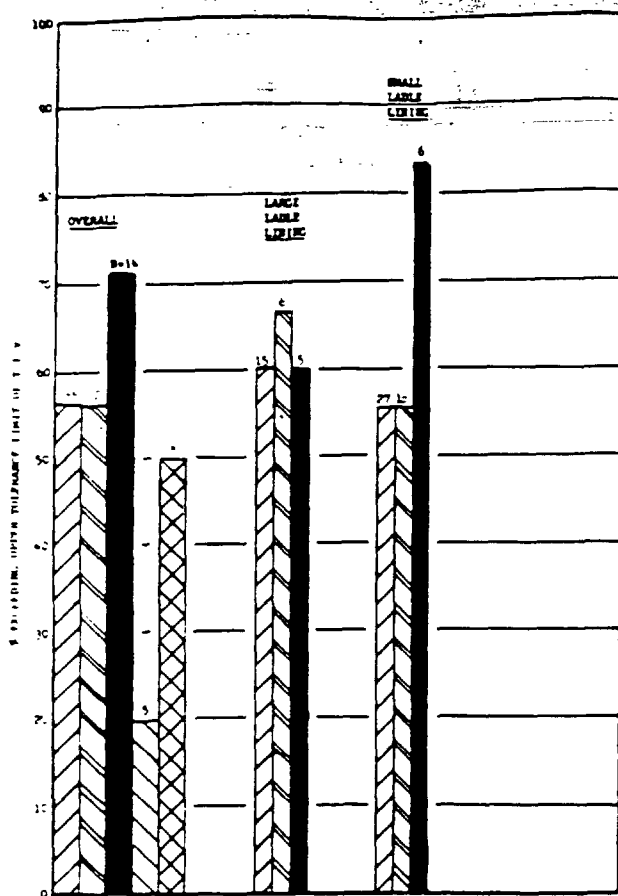


Fig. 2. Melting departments.

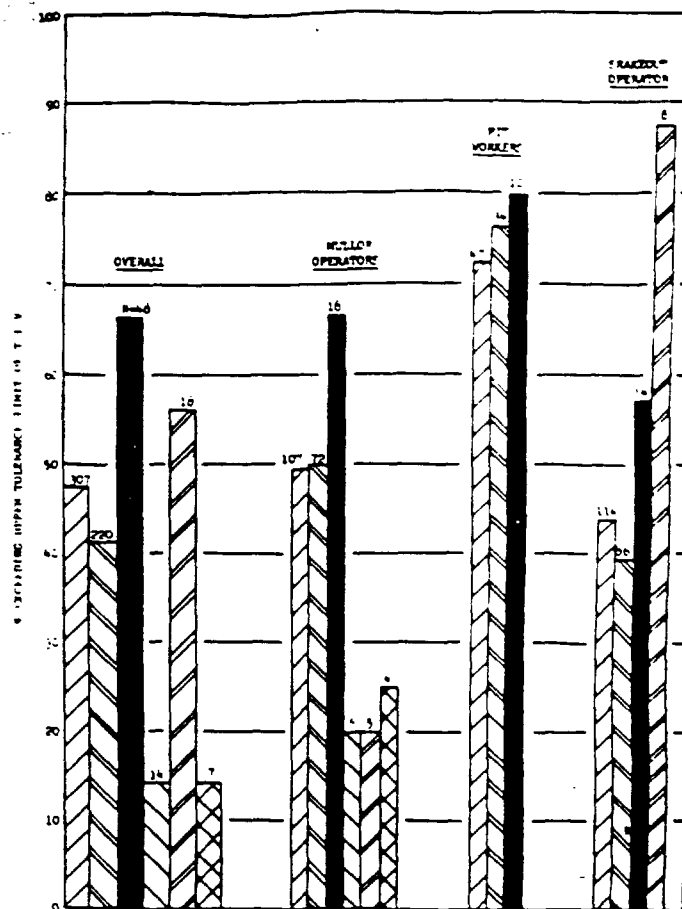


Fig. 3. Sand system.

and the others weights to the nearest microgram. Initial and final weights were made on the same balance. Comparisons between two of the balances showed no difference. In all weightings static bars were used to remove static electricity.

The samples analyzed in the Wisconsin State Hygiene Laboratory were by the Talvite⁴ method or by x-ray diffraction, with x-ray diffraction being the method of choice. Some of the samples taken during the program were submitted to the OSHA Laboratories at Salt Lake City. Both laboratories have participated in the Proficiency Analytical Testing Program by the National Institute of Occupational Safety and Health with comparable satisfactory results. Both laboratories use both procedures and there was no attempt to separate samples by laboratory or by method or any combination of these variables.

Results

Sample results were tabulated and fed into a computer at the Wisconsin State Laboratory of Hygiene. Information included was: company, date of sample, sample identification number, volume sampled, respirable mass on filter, respirable mass per cubic meter, percent free silica, shift during which sample was taken, Standard Industrial Classification (SIC) number of the company, general work area of worker sampled, primary workstation, and secondary workstation. The allowable respirable dust was calculated for each sample according to the Occupational Safety and Health Standards,¹¹ section 1910.93, using the formula $10\text{-mg}/\text{M}^3$ divided by percent free silica plus 2. A comparison of the actual respirable dust to the allowable

was then made and computed as a percentage of the standard. For example, 70% would indicate that the sample was within allowable limits or 0.7 of the threshold limit value (TLV), and 150% would indicate an overexposure to silica dust or 1.5 times the TLV.

Various sort routines were programmed to arrive at some trend indicators. The results were separated into SIC code, area, and workstation. The more common workstations and general work areas, according to type of foundry, are depicted in Figs. 1-6 according to the ratio of samples taken that exceeded 120% of the allowable respirable dust concentration for the particular samples. 120% was chosen as the upper tolerance limit to take sampling and analytical tolerances into account—that is, a result exceeding 120% of the allowable is a violation of the OSHA standard even with maximum random errors. Figures 1-6 can be looked upon as the odds of receiving an OSHA citation in a particular area or at a particular job. Many of the seventy-some job classifications are not given individual treatment due to an inadequate number of samples taken. They are included in the overall percentages for each area. Table 1 in the appendix shows the breakdown of jobs into areas. Figures 1-6 show that several jobs are generally hazardous and should be looked at in all foundries. These include ladle lining, muller operations, working in pits below shakeouts and shakeout operators. The cleaning room is generally dusty, but a lower percent quartz permits more respirable dust. It is interesting to notice that hand-chipper-grinders have a 68% OSHA Standard violation rate, but the hand grinders that do not chip have a 47% violation

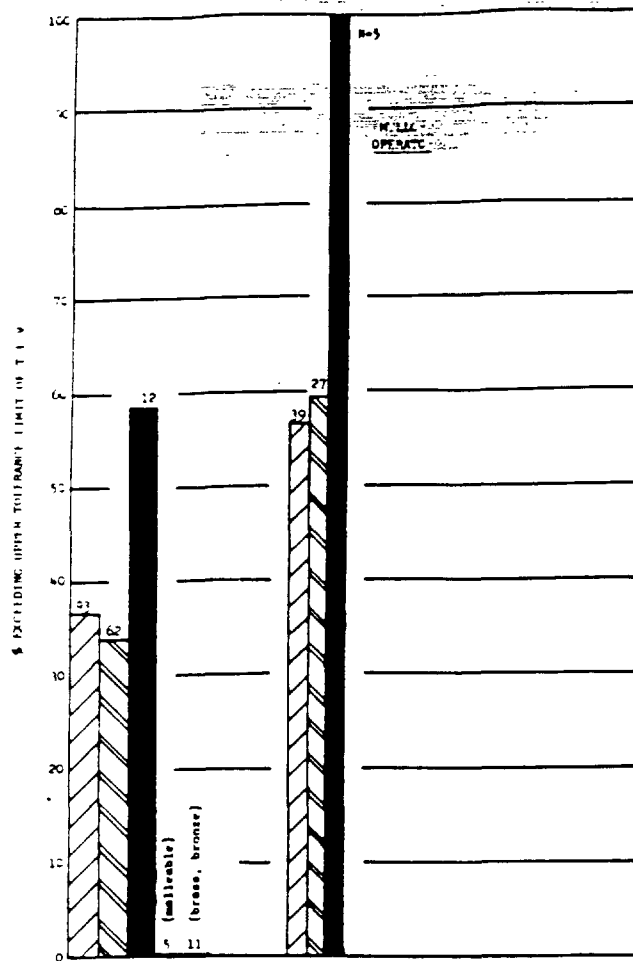


Fig. 4. Coremaking.

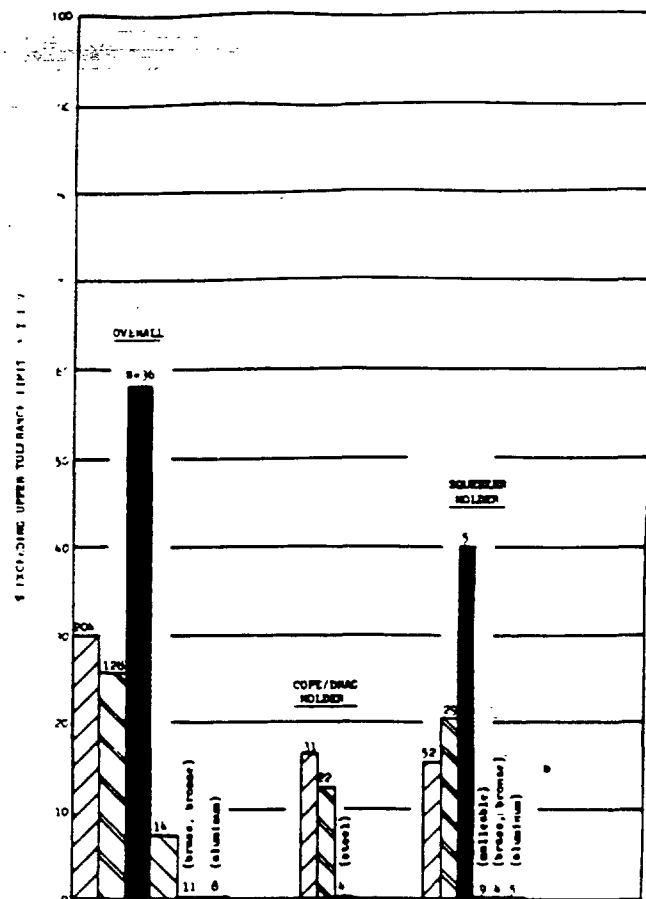


Fig. 5. Molding.

rate. This may be because chipper-grinders have to work on dirtier castings, and the exhaust from air powered chisels may help to blow the dust out of casting cavities and into the breathing zone, whereas grinders usually have peripheral exhausts that have less of a tendency to kick up additional dust.

Apparently steel foundries as a class have the highest overall risk. Steel is generally poured the hottest of the primary metals. This converts some quartz to cristobolite which has a TLV half that of quartz. In addition the higher temperatures cause a larger percentage of the respirable fraction to be alpha-quartz possibly due to temperature fracturing of the quartz crystals, contributing to higher free silica content of the respirable mass. Steel foundries generally make larger castings, reuse sand indefinitely and have to employ more and heavier risers and gating systems. Steel castings are also hard to clean, and the job shop nature of the industry keeps automation or standardization of products out of the picture.

Collection Efficiency

The data was examined to see if the length of sample time had any effect on the collection efficiency, which presumably would show up as increased respirable mass per cubic meter with increased sample time. The data was sorted into 50-liter steps by number per step and average respirable mass. Table 2 indicates no trend that is significantly valid. The three groups from 250 to 400 liters appeared to be abnormally high, but there were not enough samples in the particular groups to draw a conclusion.

Hazard Classification Guesstimation (HCG)

Somewhere between "I can't breathe for the dust," and "This is like a garden," lies "I wonder if that dust is bad news." As with most airborne contaminants, nasal analysis leaves much to be desired by way of accuracy.

Table 2. Average Respirable Mass Concentrations by Collection Volume

Liters Collected at 1.0 Liters/Min.	Number of Samples	Average Respirable Mass, mg/M ³
50 - 100	1	1.93
100 - 150	2	1.55
150 - 200	1	1.04
200 - 250	3	1.49
250 - 300	4	5.18
300 - 350	5	4.64
350 - 400	11	10.20
400 - 450	4	2.92
450 - 500	12	1.53
500 - 550	12	2.25
550 - 600	20	1.74
600 - 650	86	2.04
650 - 700	152	1.85
700 - 750	267	2.42
750 - 800	369	2.20
800 - 850	198	2.21
850 - 900	116	2.11
900 - 950	15	1.64

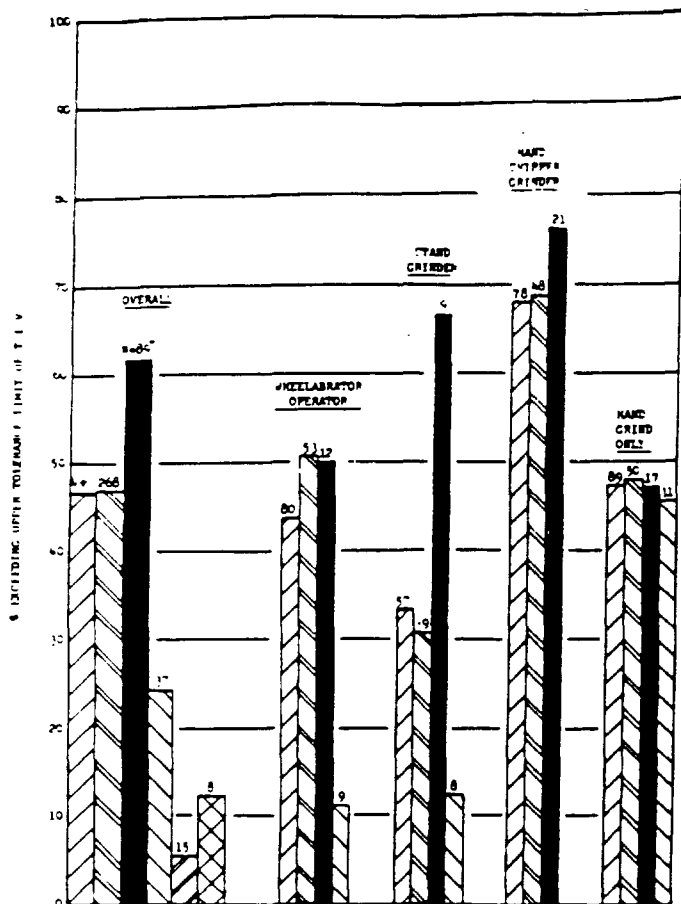


Fig. 6. Cleaning.

Accuracy in hazard determination can be expensive—for instance, a determination of free silica content by a commercial laboratory is about \$50. The authors felt that it could be economically beneficial for a company to use respirable mass to

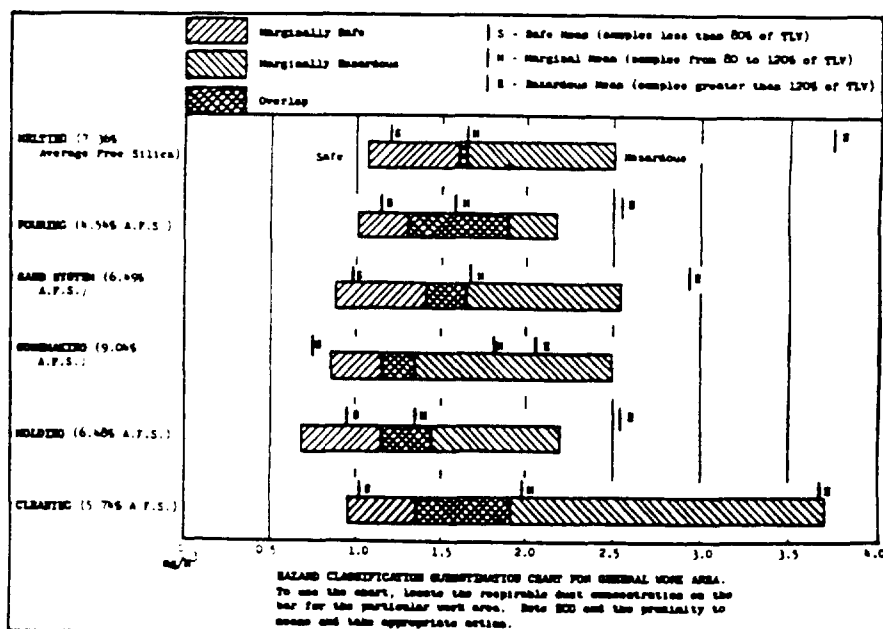
determine the likelihood of having a health hazard without having to analyze each sample for free silica content.

The major areas and workstations were split into three categories, using respirable mass means and ranges. If the actual respirable dust concentration was less than 80% of the allowable for the particular sample, the sample was put in the safe category, those greater than 120% in the hazardous category, with the remainder put into the marginal category. Samples with more than 10-mg/M³ were rejected, as they are a hazard. For each area and job, a mean and range (with 10% of the "outliers" eliminated) were determined for the three categories, using only the amount of respirable dust, and not the percent quartz. The three categories were consolidated into the bar graphs (Figs. 7, 8) for use in plotting a known respirable mass with an unknown percent quartz and coming to a reasonably accurate conclusion with respect to the health hazard. The cross-hatched portions indicate that within that range, dust concentrations could be in one of two, or perhaps even three, categories, actual hazard classification depending on the percentage of free silica. If, as an example, a cleaning room sample was 1.5-mg/M³, the job could be marginally safe, as the safe range runs from 0.00- to 1.90-mg/M³, and the marginal range runs from 0.95- to 3.70-mg/M³. The sample could also be marginally hazardous, as that range is 1.35-mg/M³ and above, so a strict classification would not be possible. However, if the respirable dust level in the cleaning room is less than 0.95-mg/M³, we would not anticipate a problem, and would anticipate a problem at greater than 3.70-mg/M³.

Further explanation of this method of determining hazard class may be by another example. Suppose a respirable mass sample was collected on a small pouring ladle reliner operator in the melting department for 7 hr or 756 liters and the filter gained 1.588 mg. From Fig. 2 one would expect about a 55% chance of having a problem in the melting department of all foundries. Looking further, a steel foundry would expect an 83% chance of a problem in this operation.

The respirable mass (1.588 mg x 1000-L/M³:756L = 2.10 mg/M³) of 2.10 mg/M³ can be used with Figs. 7 and 8 to confirm the existence of a problem. Using Fig. 7 for the melting department shows 2.10 mg in the marginally hazardous area well above the safe and marginal means. Using Fig. 8 for small ladle lining shows the sample in the marginal area well above the marginal means. Without a free silica determination this sample would be considered hazardous.

Fig. 7. Hazard classification guessimation chart for general work area.



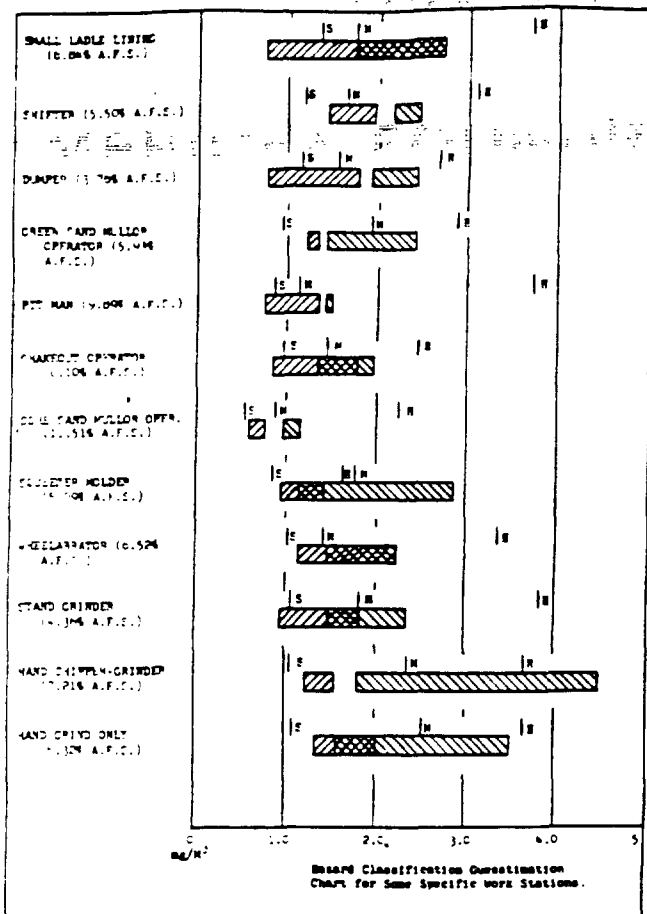


Fig. 8. Hazard classification guesstimation chart for some specific workstations.

If the filter had weighed 0.529 mg the respirable mass of 0.70 mg M^1 would from Figs. 7 and 8 be considered safe.

To test our theory of guesstimating the hazard class, it was tried on 69 'virgin' samples - those not included in the original data. About 85% was established accuracy in getting the samples into the correct category, so the method works with a good degree of accuracy.

The samples the authors missed on, in general, had an unusual percentage of quartz. This shows that a free silica determination is required for absolute certainty in hazard classification. As a rule of thumb, the authors feel that respirable silica dust concentrations below 1 mg M^1 would not constitute a health hazard, and concentrations above 2 mg M^1 are likely to be hazardous.

The cost of setting up a lab to do x-ray diffraction analysis is substantial (\$40,000 for the x-ray alone). It should be more

economical, without too much sacrifice in accuracy, for a company or group of smaller companies to purchase two sampling pumps and chargers, a few cyclones, tubing, filters, etc. (\$1,000); an accurate balance (\$2,000); and proceed to sample and use the Hazard Classification Guesstimation (HCG) presented in this paper. The HCG would have to be supplemented by an initial determination of quartz percentages to see if they fall within the ranges found in our data, and then an occasional silica analysis to see if any change is noted due to change of type of sand, new molding or casting procedures or other process changes. It should be borne in mind that sand composition will vary in different localities, and the type of foundry and particular process will also have a bearing on the respirable portion and free silica content of the sample.

The sampling equipment, balance and related equipment cost translates into about 60 samples run for quartz. The HCG is a closely approximate way of checking levels to detect changes, at an expense that is not overwhelming.

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A New Method for Monitoring Silicosis

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ABSTRACT

Current methods for monitoring the development of silicosis after high levels of exposure to silica-containing dusts are unsatisfactory for the following reasons:

- 1) They do not detect silicosis until late in the course of the disease.
- 2) They are not always reliable, as for example, when there is a discrepancy between x-ray and pulmonary function tests.
- 3) Subjective judgements often are involved in the interpretation of x-rays with differences of opinion between radiologists.
- 4) Current methods are expensive, time-consuming and, in the case of x-ray, potentially dangerous.

The studies presented in this report describe a simple and accurate technique for determining the amount of silicon a worker has been exposed to presently or in the past. The technique is based on the use of one of the newest tools of medical science — scanning electron microscopy and energy-dispersive x-ray analysis.

Introduction

Energy-dispersive x-ray analysis (EDXA) (Fig. 1 and 2) is an analytical technique which permits simultaneous multi-elemental analysis of all elements above atomic number 8 while the object is being examined in the scanning electron microscope (SEM). The authors have used this technique to study lung tissue from a case of interstitial fibrosis in which numerous electron-dense materials, observed by conventional transmission electron microscopy, were identified by EDXA and SEM as containing iron (Fe), nickel (Ni), chromium (Cr) and cobalt (Co).¹ The authors have also studied silicosis with this technique and established the levels of silicon (Si) in lung tissue, both in normal and silocotics.² The usefulness of this method was also demonstrated on lung tissue where conventional diagnostic criteria failed to establish a diagnosis of silicosis.³

Conventional methods of detecting Si usually employ ashing techniques which not only require a relatively large amount of tissue but also can only be used to evaluate one element at a time.

The technique which we are developing for the evaluation of silica exposure involves SEM and EDXA examination of 2-3 drops of blood. The technique is based on the fact that Si has been found in organs other than lung in silicotics. It was the authors' speculation that this was only possible if it arrived at these sites via the vascular system.

Equipment and Procedures

The authors' plan was to examine a group of control rats and a group which was given intratracheal injections of crystalline

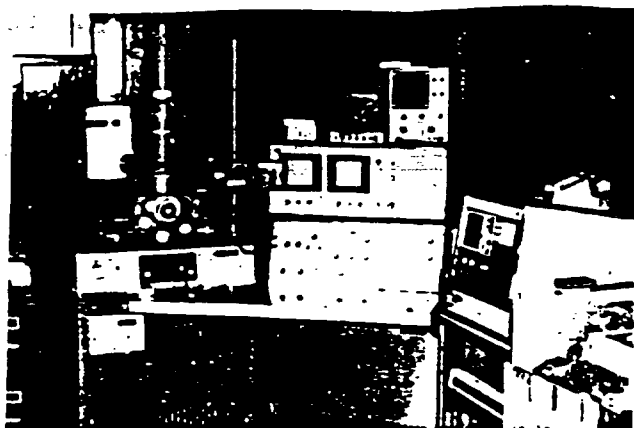


Fig. 1. A scanning electron microscope with a computer-based energy-dispersive x-ray analyzer.

silica powder (Fig. 3). Samples of the rat blood were examined by placing a few drops on the surface of a carbon planchet (Fig. 4). After air drying the dried blood was placed in an SEM and examined for areas of thickest clotting. Three areas were then analyzed at 500X magnification for 200 sec each.

The analyses were done using an Ortec 165eV resolution Si (Li) detector and a Tracor Northern NS-880 computer-based data handling system. All spectra were stored on magnetic tape for future reference.

Spectral data were computer matched to reference spectra and elemental concentration ratios calculated. These concentration ratios were corrected for absorption, fluorescence

and atomic number effects, assuming carbon as the background. Due to the inherent difficulties in determining the exact amount of material examined, the data was presented as a silicon to sulfur (Si/S) ratio.

The concept of EDXA is based on the fact that x-rays are generated by the collision of the primary electron beam with the specimen. The wavelength, energy and the number of x-rays will be dependent on the elements present in the specimen and their abundance. Using a solid-state Si semiconductor detector, x-rays emitted from the sample are collected and used to generate a small electrical signal whose charge is proportional to the energy of the incoming x-ray photon. This signal is electronically processed and displayed on a cathode ray screen (CRS). The x-axis of this spectrum represents x-ray energy and the y-axis represents the abundance of every element above atomic number 8 in the area of the specimen being examined. These spectra can be stored on magnetic tapes. Fig. 5 shows a spectrum of a typical 200-sec analysis. Each peak seen on the CRS represents an element found in the tissue. The vertical dotted line (KL marker) is placed over the peak to be identified and the element symbol read at the lower left of the screen. The peak identified in Fig. 5 is Si of atomic number 14. Such an analysis can then reveal more than 80 elements simultaneously and in a matter of minutes.

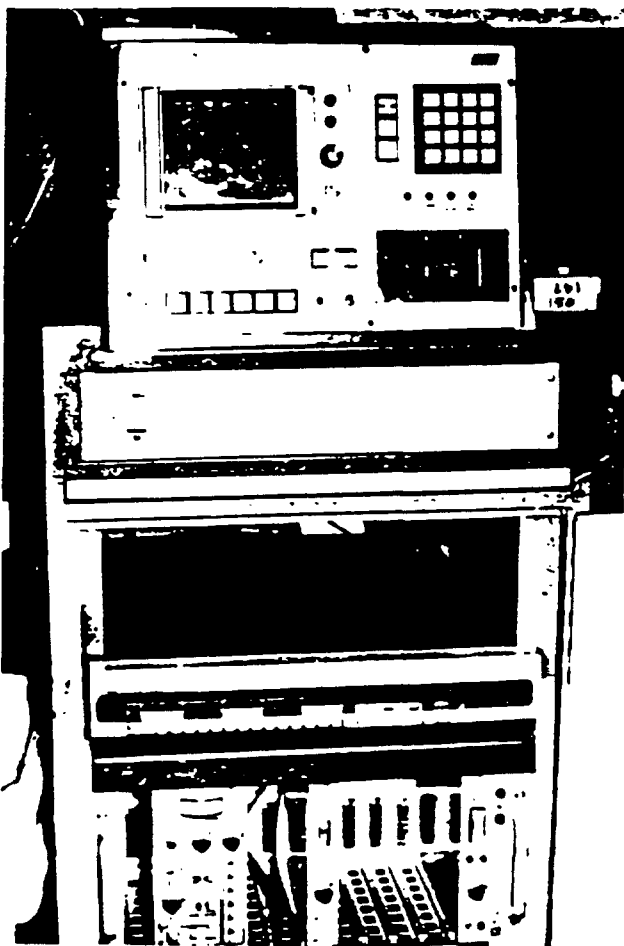


Fig. 2. Close-up view of computer-based analyzer with magnetic tape for spectra storage.

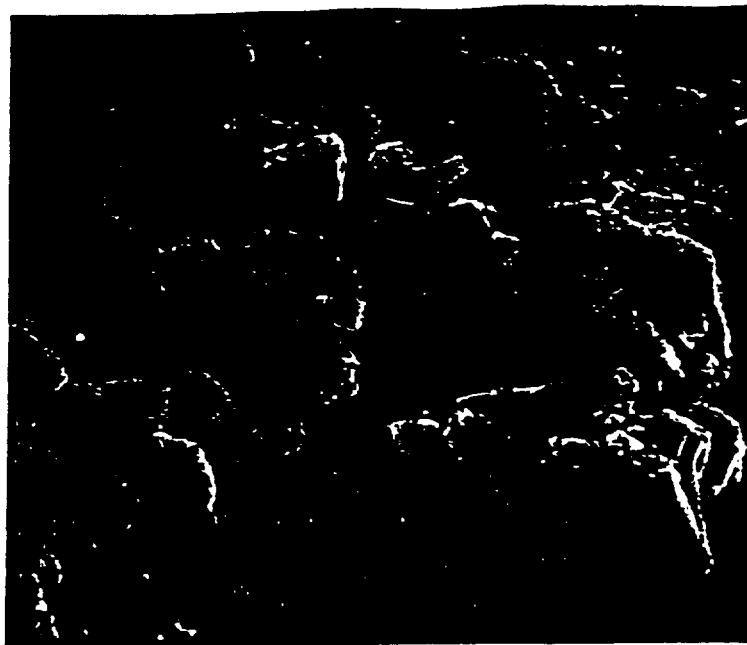


Fig.3. Scanning electron micrograph of the silica dust used in the animal experiments. (X1000)



Fig.4. A one-inch stub of spectroscopically pure carbon containing a thin section of lung tissue. The stub containing either a section of lung tissue or a few drops of dried blood can then be analyzed by energy-dispersive x-ray analysis.

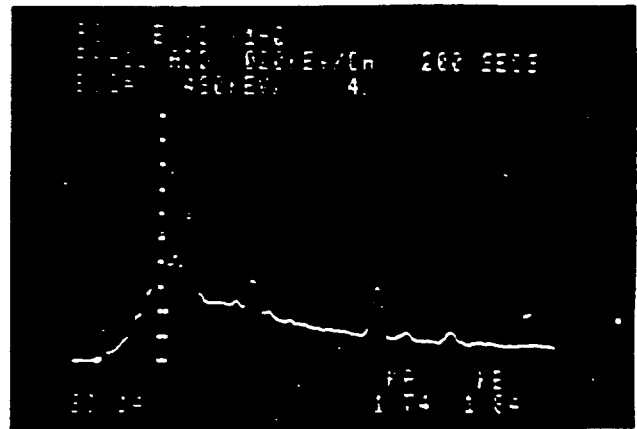


Fig.5. View of screen of cathode ray tube showing peaks of individual elements in lung tissue subjected to EDXA. The peak on the left shows the silicon level.

Results

The results of our animal studies reveal that after one injection the blood Si levels gradually increased and reached a peak after one week (Fig. 6). The blood Si level in these animals was three times that of the control ($p < 0.05$). The Si level remained elevated for at least three weeks after the injection.

When multiple injections of the same dose were given, at one-week intervals, there was a progressive rise in the Si level (Fig. 7), reaching a maximum point after four injections. The total Si count after four injections was 10 times that of the control ($P < 0.01$). The observations suggest that silica introduced transtracheally into the lung reaches the bloodstream within a week and remains in the vascular system more than three weeks.

Studies are now in progress to determine the length of time that Si levels remain elevated after initial exposure. An attempt will also be made to establish the level of Si in blood which

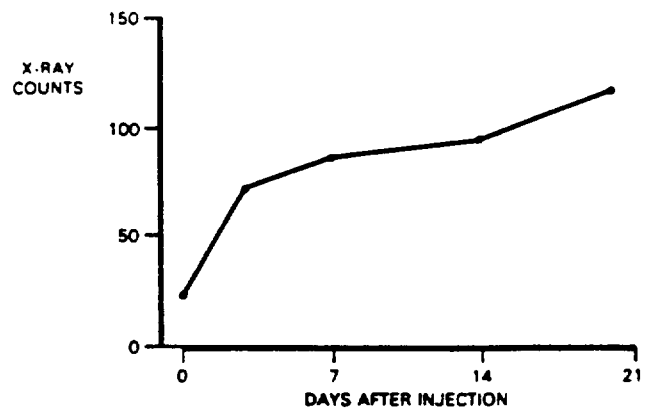


Fig.6. Blood silicon levels in rats after one injection of silica dusts.

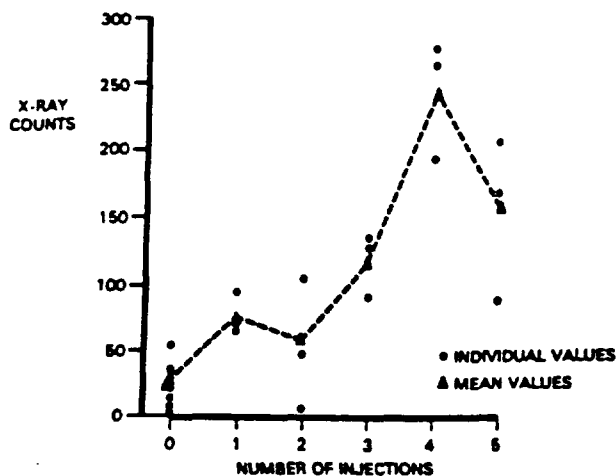


Fig. 7. Blood silicon levels in rats after multiple injections of silica dusts.

would be considered to be toxic. In other words what level of Si would be considered as follows:

- 1) Normal
- 2) Elevated

- 3) Dangerous but not likely to cause disability
- 4) Toxic and coexistent with silicosis.

To evaluate the results, the final phase of the study will be to determine Si levels in anonymous workers who have been exposed to silica dust.

The importance of a simple blood test to industry would be its value in monitoring silica exposure. An employee or a future employee could be monitored for Si levels, the values reflecting not simple silica exposure, but actual silica levels in the lung. Any worker with dangerous levels of Si in the blood could be removed from subsequent exposure before the levels become toxic. Such a test, unlike conventional methods now in use, would be simple, reliable and safe.

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Description of a New Study of Occupational Health Hazard Control Technology for the Foundry Industry

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Introduction

For years foundrymen have been reducing or, in some cases, eliminating workplace hazards using their own ingenuity as well as approaches described in the industrial ventilation manual of the American Conference of Governmental Industrial Hygienists, and the *Foundry Environmental Control* series of the American Foundrymen's Society.^{1,2} Very little documentation exists, however, concerning the effectiveness with which these methods protect foundrymen from exposure. A lack of documentation limits the use of available methods and tends to hide problems for which adequate solutions have not been found and which should be the subject of research and development programs. It was to fill these information gaps as well as to provide a ready source of information concerning foundry environmental control technology that the National Institute for Occupational Safety and Health (NIOSH) undertook, in 1976, a comprehensive study of the foundry industry using the Environmental Research Center of Rexnord Inc. (then the Environmental Sciences Division of Envirex Inc.) as their representative. The study was performed primarily through studies of the effectiveness of existing control measures and was conducted in twenty-four iron, steel, copper-base and aluminum foundries around the country. The report of this study is now available from NIOSH.³

Priorities for Study

It was apparent at the outset that a study conducted in twenty-four foundries would not be able to evaluate solutions to all foundry hazards, thus criteria were established to assure that available solutions for the most pressing problems facing the foundry industry were investigated. The principal factors used to set priorities were the severity of the hazard, the potential for overexposure, the number of workers affected, and the use of control methods in existing foundry operations. Highest priority was placed on methods to control air contaminants, since these posed a severe potential health hazard. Many air contaminant control measures were known to exist although overexposure of workers still continues. Less attention was paid to noise control, because noise is less of a hazard than air contaminants and control technology for noise has only been applied to a limited extent in foundries. Heat stress control in foundries is achieved for the most part through acclimatization programs for workers and through ventilation of hot processes and so this area became an adjunct of the air contaminant control study.

Methods

This study was performed on a completely voluntary basis and recommendations for candidate foundries were elicited from a foundry trade association, foundry professionals, and the literature. The foundries selected included captive and job shops

involving large and small production of very small to very large castings, and a wide variety of molding and coremaking processes.

Contrary to what one might suspect, effective control technology was not found to be limited to high production, captive foundries or to foundries with the greatest available resources. The principal resource which distinguished foundries with good health hazard control programs from those without, was an awareness and desire on the part of management and labor to provide a safe and healthy work environment. Foundries who eliminated hazards were those who had the determination to explore various alternatives, to work patiently toward reducing worker objections to new practices, to minimize process disruptions, and to maintain levels of system performance through careful operation and maintenance.

It was desired to use as much of the foundry's own data as possible to verify the effective performance of a particular control method. Unfortunately, very little data has been taken after control systems were installed. The majority of foundry sampling data involved measurements taken to identify problem areas. Consequently, the great majority of the sampling data presented in the NIOSH report was taken by the study team.

Foundry Hazards

The following are hazards that current literature indicates to be of high hazard potential, as well as some of their major sources in foundries.

Free Crystalline Silica

This hazard, primarily associated with fine respirable quartz particles, is ubiquitous in sand cast foundries and is found particularly in operations which transport or process dry sand after shakeout. In ferrous foundries the burn-on of sand into the casting caused by molten metal penetration into mold and core materials creates another substantial problem during manual abrasive cleaning operations. At high temperatures, quartz transforms to cristobalite which is more hazardous still. Cristobalite is present as a significant hazard during furnace and ladle relining.

Metal Dust and Fume

Common alloy metals of hygienic significance found in casting operations include lead, copper, nickel, chrome, zinc, magnesium, manganese, iron and aluminum. Lead stands out as a severe acute hazard and nickel has recently become suspect as a carcinogen. The fume hazard of each metal during melting and pouring operations as well as welding and arc-air gouging depends upon its relative toxicity, percentage used in the alloy, and alloy melting and boiling temperatures. Metal dust is usually associated with abrasive grinding operations.

Coal Tar Pitch Volatiles

Organic mold and core materials undergo destructive distillation after molds are poured producing various compounds, including benzo(a)-pyrene, a known carcinogen. The question has arisen as to whether these compounds are the cause for the elevated lung cancer incidence in foundry workers. Research is needed to establish the potential hazard during the casting process.

Gases and Vapors

Many of the gaseous hazards are the result of thermal transformations and breakdown of binders and additives during the process of producing molds and cores using hot methods, and during thermal decomposition during casting. Examples are:

- 1) Carbon monoxide from thermal decomposition of any

organic material, including combustion of coke used as a fuel in cupolas

- 2) Acrolein from thermal decomposition of glycerin in many core oils during core baking and casting.
- 3) Methylene biphenyl di-isocyanates (MDI) during thermal decomposition during casting of urethane polymers used in nobake cores and molds.
- 4) Ammonia from thermal breakdown when intense heat is used to accelerate the curing of resinous binders containing nitrogen compounds and during mold decomposition of furan and phenolic hot box (shell) molds and cores.
- 5) Formaldehyde, found in all furan resin mixtures; phenol, from phenolic resins; and furfuryl alcohol, used in the production of furan resins and in some modified phenolic resins, are emitted from hot box coremaking as well as during casting.

Other gaseous hazards include amines (catalysts for organic binder systems), hydrogen sulfide (water quenching of sulfurous slag materials at cupola slag spouts) and sulfur dioxide (burning of high sulfur coke in cupolas).

Noise

Noise is hazardous because it can cause hearing damage and pose a threat to life and limb by the worker not being able to hear a warning signal. Noise within foundries has been increasing steadily over the years as a result of mechanization and high production. Principal noise sources include loud furnaces (gas fired crucible, electric arc), shakeout, casting transport, handling and manual cleaning with abrasive tools.

Conclusions of the Study

The following are a few of the major conclusions of the study.

Green Sand Systems

Control of green sand systems requires a combined program of effective ventilation and effective housekeeping. Many sand system ventilation methods, in use in foundries for many years, were found to be effective in controlling dust exposure. An alternative to conventional dry sand transporting and processing, the Schumacher process, effectively limited dust emissions from return sand by mixing prepared sand with it, thus reducing the amount of ventilation required. Substitute molding sands did not eliminate silica from dust when silica sand was used for cores, or clay was used as a binder. The problem with shakeout hoods, particularly the sidedraft variety in use on shakeouts loaded by overhead crane, was that they were gradually demolished by the operation, permitting the flask handlers to be overexposed to respirable silica. When a large flask was unloaded onto the shakeout table by overhead crane, not all of the contents of the flask always fell out; some mold materials were hung up in the flask. The crane operator removed these materials by ramming the flask against the shakeout hood. One foundry, realizing that work practices such as this will likely continue, but also fed up with annual replacement of hoods, constructed a structure mounted on the shakeout table itself which solved the problem. The modified shakeout with a shakeout hood behind it are shown in Fig. 1 from the NIOSH report. The structure did not upset the vibration of the shakeout, but special retaining plates were needed to prevent the shakeout table from being displaced off of its springs when the structures were rammed. After one year the shakeout hood had still encountered no abuse.

Melting and Casting

Charge bucket filling was found to be a dusty operation. Much of the dust produced was induced in strong drafts of air toward the melting area because of a high volume of exhaust and lack of



Fig. 1. Structure mounted on shakeout to protect sidedraft hood from damage (reprinted from NIOSH Technology Assessment).



Fig. 2. Complete fume capture during tapping of an induction furnace through the use of furnace and ladle mounted capture hoods (reprinted from NIOSH Technology Assessment).

makeup air in most foundries.

Ventilation methods and isolation of workers in booths controlled exposure to metal fume, heat stress and, in some cases, noise, during melting, hot metal transfer, and pouring operations, as well as during ductile metal treatment.

Lead fume is receiving a considerable amount of attention at present because OSHA has lowered the permissible exposure level (PEL) for lead from $200 \mu\text{g}/\text{m}^3$ down to fifty. The results obtained during studies in two copper-base foundries alloying with lead have shown that with careful design of localized ventilation in conjunction with administrative control of work practices, it was possible to reduce the exposure level of workers below the $200 \mu\text{g}/\text{m}^3$ level. Efforts to further reduce exposure levels will require resolving certain problems which limit the effectiveness of ventilation methods.

The furnaces evaluated during the two case histories of nonferrous operations were tilting induction furnaces, used extensively for copper-base alloy melting. These furnaces were amenable to control using commercially available ventilation hoods. Such hoods have been found to provide adequate control during the charging and meltdown cycles, but were not effective by themselves in capturing fume during tapping into ladles because of interferences from ladle support mechanisms. In the presence of interferences, fume control was still achievable if a ladle ventilation hood were used in conjunction with the furnace hood. Such an arrangement is shown in Fig. 2 from the NIOSH



Fig. 3. Fume control during metal pouring using a mobile ladle mounted capture hood (reprinted from NIOSH Technology Assessment).

report. This particular ladle hood was a commercially available mobile hood which can provide exhaust above the ladle during the entire ladle filling, slagging, hot metal transfer, and pouring operation (Fig. 3).

Unfortunately, the transfer paths from furnaces to pouring lines in many nonferrous foundries are not direct and the use of this commercially available close-capture method, although still possible, is not at all straightforward. Use of the method in those cases could slow down the operation to the point of causing chilling of the metal, resulting in excessive scrap. The strong dependency of ventilation methods on foundry layout is so critical that no nonferrous foundry should consider renovations or new foundry layout without providing proper provisions for ventilation control during hot metal transfer and mold pouring. Another critical variable in the use of mobile ladle hoods is the need for quiescent air patterns in the foundry. Many foundries, because of high negative pressure, are beset by strong air drafts through doorways. The above mobile ladle hood does not function properly in the presence of strong drafts.

Ventilation of mechanized pouring lines in ferrous foundries was accomplished with commercially available, as well as custom designed, sidedraft hoods. Control of mold decomposition products during mold cooling was simplified in such systems. On the other hand, effective smoke and fume control during open floor pouring operations, such as pallet lines, was much more difficult. One foundry developed its own powered conveyor system for rapidly moving molds from the pouring area to an isolated cooling area immediately after mold pouring.

Ferrous Cleaning and Finishing

Control of respirable dust and fume in the breathing zones of all workers manually cleaning ferrous castings was not found during the study. Two sources of dust posed special hazards for cleaning and finishing operations: dust created by grinding casting surfaces having imbedded sand, and loose dust in internal casting cavities remaining after precleaning.

Besides manual cleaning and finishing operations, another silica dust hazard occurred during removal of sprues, gates, and risers using hammers. Control of silica dust is hampered because this is one of the hottest operations in the foundry, due to the fact that castings are often processed immediately after shakeout. Mancooler fans and high velocity fresh air ducts were used to prevent excessive heat stress on workers, and these methods disrupted the ability of ventilation hoods to capture dust before it entered the breathing zone.

Because no methods were available to provide adequate ventilation for this process, engineering personnel from one

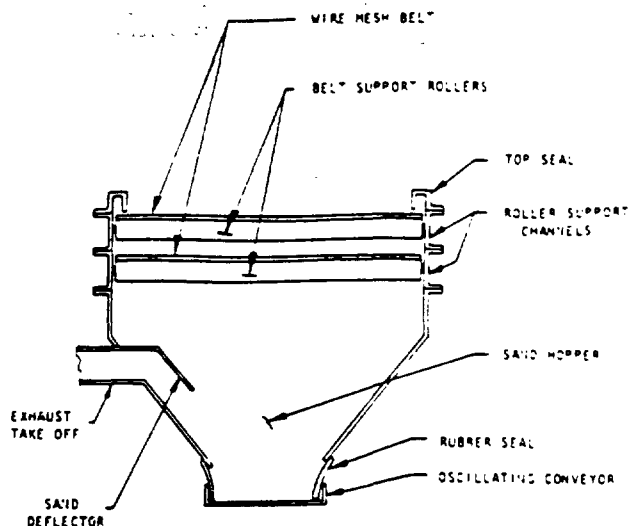


Fig. 4. Cross section of wire mesh belt conveyor (reprinted from NIOSH Technology Assessment).

foundry took it upon themselves to develop their own ventilation technique, a downdraft mesh belt conveyor. An end view, cross-sectional sketch of the method is shown in Fig. 4. Sand and dust were drawn together through the conveyor; the dust was exhausted to a fabric collector and the sand fell onto a conveyor which transported it back into the sand system. This method prevented overexposure of foundry workers to free silica. The conveyor system, all custom designed, has the obvious look of ruggedness which one would expect from a system designed by individuals cognizant to the severe service imposed by the foundry environment.

Molding and Coremaking Using Chemically Bonded Sand

New chemical binding systems are becoming rapidly popular and the need exists to scrutinize these methods to ascertain proper ventilation requirements. One such coremaking process which was evaluated during the study was phenolic urethane coremaking. The gassing of the cores with triethylamine (TEA) or dimethylethylamine (DMEA) occurs in a sealed corebox and after the setting process the gases are purged from the core and exhausted through a sealed duct system. Two potential problems were found with this method which required the use of auxiliary ventilation to provide effective control. The first resulted because the gas purging cycle was established on the basis of removing sufficient gas to terminate the chemical setting process, not on the basis of removing all of the residual gas. Removing all of the gas would probably have required an excessively long purge cycle, detracting from the high production capabilities of the core machine. Thus core machine operators and core finishers were subject to exposure from residual gases during core handling and processing.

The second problem is related to the operation and maintenance of the core machine itself. Effective containment of gases requires proper sealing from parting line gaskets, blow seals, and stripper pin O-rings. Gas blow-by was also caused by excessive backpressure on these seals from excessive sand fines and moisture in the sand or from the air compressor. To prevent exposure to the catalytic gases from seal failures and also to reduce exposure to residual gases from completed cores, one foundry has employed a capture hood adjacent to the corebox, and another one above the core retrieval rack (Fig. 5). Distributed fresh air is utilized throughout the coremaking area to dilute escaping, residual gases.

Summary

This description of the NIOSH foundry health hazard technology assessment study was presented to create an awareness of some of the ways that foundrymen are using to resolve worker hazards. The NIOSH report contains many case histories of methods which could have a broad base of application in foundries. In addition, there are a number of problems which were investigated for which effective solutions were not found. Manual chipping and grinding of ferrous castings was found to be incompletely controlled with existing methods. The conditions under which ventilation systems on floorstand grinders are capable of controlling dust are not well defined. Ladle relining creates hazards from quartz and cristobalite which have defined control using available ventilation methods. Metal fume control during the arc-air process is very worker-dependent, but exactly which operational procedures are critical has not been established. Noise solutions have been limited to the use of enclosures in certain restricted cases and substitution of quiet components for noisy ones. Much research and development into health hazard control technology for foundries remains to be done. However, each time a foundry takes it upon itself to attempt a solution and then makes the results of that attempt, either positive or negative, available in the literature, the environmental control effort to provide a healthful work environment for all foundrymen comes closer and closer to fruition.

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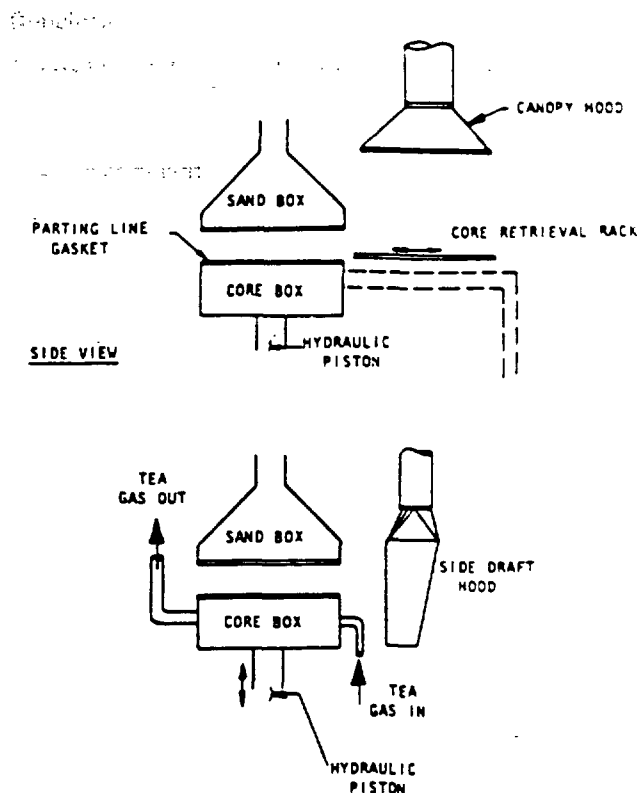


Fig. 5. Exhaust of cold box coremaking (reprinted from NIOSH Technology Assessment).

AFS RESEARCH

An Examination of the Potential Free Silica Formation During the Grinding of Gray Iron

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ABSTRACT

Historically, quartz exposures in ferrous foundry cleaning rooms were not thought to be a problem. Recently, though, high levels of dust containing quartz have been found in these cleaning rooms despite many process changes aimed at lowering them. As a result, questions have been raised concerning the source of the quartz in the dust.

There are potentially a number of sources for the quartz. The purpose of this investigation was to examine one potential source: the formation of quartz from oxidation of silicon (Si) in the casting or from the grinding wheel at the point of grinding. The contribution of the grinding wheels themselves to quartz levels was also determined.

Two types of bar stock, a gray iron (2.54% Si) and an ingot iron (total impurities including Si 0.14%), were each ground using a silicon carbide wheel and an aluminum oxide wheel individually. Grinding was done in an unventilated enclosure designed to contain the dust generated. Respirable dust samples were taken in the enclosure while grinding.

Analysis of the samples by x-ray diffraction showed that the amount of quartz in the respirable dust samples did not exceed the background levels found on blank filters that were analyzed by the same method.

An additional test was performed using two gray iron gear blanks. One gear blank was cleaned in an airless abrasive blast, the other was in the as-cast condition taken directly from the shakeout. Analysis of the respirable dust samples taken indicated no presence of crystalline quartz above background levels in the collected dust.

It is therefore concluded that the Si in the metal did not react with the oxygen in the atmosphere to a measurable extent. The absence of quartz above background levels on the filters also indicated that the grinding wheels did not contribute to quartz in the analyzed dust.

Introduction

In July, 1976 an ad hoc committee was formed by the American Foundrymen's Society to investigate the sources of quartz exposures in ferrous foundry cleaning rooms.

Excessive exposures to free silica (its three principal mineral forms being alpha quartz, cristobalite and tridymite) can, if left unabated or untreated, cause an employee to develop the pneumoconiosis called silicosis. The development of this disease is a function of the duration of exposure, level of exposure to the dust, concentration of crystalline free silica in the dust, particle size of the dust and existing physiological conditions.

Recent reports¹ as well as personal observations had indicated that quartz exposures in cleaning rooms were excessive despite many process changes meant to lower exposure. Such process changes as the application of nonsilica washes, nonsilica facing sands, airless abrasive blasting of castings prior to hand chipping and grinding, and the increased use of local exhaust ventilation had limited effect on exposures.

Gilliland² in 1973 showed that sand grains were adhering to the surface of castings despite airless abrasive blasting. Later, private research comparing the quartz contents of dust generated from the grinding of castings which had been treated with an electrically charged 204C (400F) caustic soda bath to that of nontreated castings indicated that the quartz may be bound chemically, as well as mechanically, to the surface of the casting.

When metal penetration was studied in 1977³ it appeared that sand grain adherence to the casting surface was due to some type of physiochemical reaction. The effect of the reaction produces a series of casting surface defects which are progressively harder to remove. These defects, in ascending order of difficulty of removal, are "rough surface," "sand burn-on," "sand burn-in" and "metal penetration." Each degree of severity involves some type and quantity of sand grain adherence to the casting surface. The presence of these sand grains indicated a potential source for the quartz found in ferrous foundry cleaning room dust samples.

Airless abrasive blasting of castings both before and after rough grinding has been increasingly used in the industry for both cosmetic and functional purposes. The possibility was explored whether castings could be airless abrasive blasted in such a way that adherent and embedded sand grains could be completely removed before rough grinding. If this could be accomplished, it was felt that a major source of silica in cleaning room airborne dusts would be eliminated.

To test this theory, two batches of identical castings were blasted for 3 min and 15 min, respectively, to simulate short and very long duration cycles. Each batch of castings was then hand ground in a "clean" room and airborne dust samples taken. Before each test, the "clean" room was vacuumed out and purged with clean air to remove any residual dust from previous

Table 1. Weight Percent of Quartz as a Function of Blasting Time

Type of Sample	Location	15 Minute Blasting			3 Minute Blasting		
		Concentration mg/m ³	Wt % Quartz	TLV ⁽¹⁾ mg/m ³	Concentration mg/m ³	Wt % Quartz	TLV ⁽¹⁾ mg/m ³
Respirable Dust (RD)	Breathing Zone (BZ)	24.0	4.3	1.59	9.5	3.2	1.92
Total Dust (TD)	BC	24.0	1.1	7.3	44.0	1.1	7.3
RD	Area Sample (AS)(I)	5.1	2.0	2.5	8.6	2.2	1.92
TD	AS (I)	21.0	<1.0	10.0	35.0	1.0	7.5
TD	AS (II)	20.0	<1.0	10.0	31.0	2.1	5.88

(1) TLV (Respirable Dust) = $(10 \text{ mg/m}^3) \div (\text{Wt \% Quartz} \div 2)$

TLV (Total Dust) = $(30 \text{ mg/m}^3) \div (\text{Wt \% Quartz} \div 3)$

tests. The airflow in the room was also controlled to approximate conditions in a foundry (50 fpm). The dust samples were analyzed by x-ray diffraction for quartz and weight gain.

The weight percent quartz in the dust was low to begin with in all cases, yet did not seem to be a function of the blasting time. The concentration of dust in the air, however, was less for castings blasted 15 min than for those with the 3 min cycle.

This is probably due to the more complete removal of quartz-containing material adhering to the casting surface which otherwise would have had to be removed by grinding. Unfortunately, no data was recorded to determine this parameter. In all cases the calculated theoretical Threshold Limit Value (TLV) was violated (see Table 1).

These results indicated that possibly some baseline level of quartz was being generated which could not be controlled through conventional production techniques. To explore this possibility and its source, the tests reported here were initiated.

Silicon is a very reactive metal⁴ and a constituent, to some extent, in most ferrous castings. The presence of Si raises the possibility that at the point of grinding the Si was reacting with the oxygen in the atmosphere to form free silica.⁴

Test Condition and Materials

The experimental procedure was designed to specifically determine if the origin of respirable free silica was from the grinding wheel and/or the ferrous metals being ground. To investigate these two possible sources, four sets of closely controlled grinding conditions were evaluated using:

- 1) a low Si content grinding wheel and low Si content metal;
- 2) a high Si content grinding wheel and a low Si content metal;
- 3) a low Si content grinding wheel and a high Si content metal; and
- 4) a high Si content wheel and a high Si content metal.

In an attempt to isolate the source of quartz, multiple respirable dust samples were taken during each grinding condition. Since respirable dust (that dust which has a particle diameter less than 10 micrometers but greater than 0.1 micrometers) is of primary concern from a physiological standpoint (it can reach the lung), sampling equipment capable of removing the coarser fraction of particles present (those greater than 10 micrometers in diameter) and collecting the respirable fraction was used.

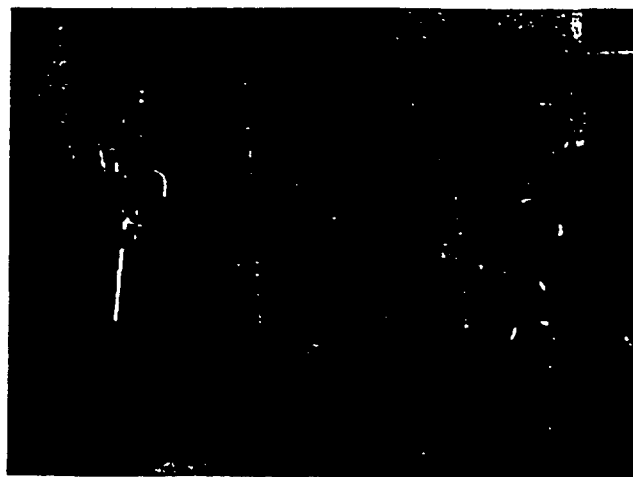


Fig. 1. Air sampling train.

A dust sample which does not size fractionate the particulate collected is called a total dust sample.

The air sampling train (Fig. 1) consisted of a 10 mm Dorr Oliver cyclone as a prefilter to remove the nonrespirable particulate, followed by a 5 micron pore size PVC filter 37 mm in diameter. A battery operated diaphragm pump with pulsation dampener was used to draw the air through the sampling train at a rate of 1.8 lit/min. This is the designed flow rate for this particular size selective prefilter to maintain optimum separation of the respirable from the nonrespirable particulate.

An aluminum oxide wheel was used as the low Si content grinding wheel. A silicon carbide wheel was used to represent a high Si content wheel. Complete analyses of these two wheels is provided in Table 2. Both wheels used were 14 x 2-1/2 x 1-1/4 in. with a grit size of 16.

The grinding machine was a 3 horsepower double wheel stand grinder with a spindle speed of 1,800 revolutions per minute (RPM). A grinding wheel speed of 6,795 surface feet per minute (SFPM) was obtained using these wheels. A higher wheel speed would have increased the metal removal rate and the amount of dust generated but would not have affected the chemical composition of the dust.

To satisfy the low Si metal condition of the test, ingot iron was chosen. The ingot iron was in the form of rough sheared stock

Table 2. Chemical Analysis of Grinding Wheels, as Provided by Manufacturers

Silicon Carbide Grinding Wheel	
Material	Content
Silicon Carbide (SiC)	98.06
Free Silicon (Si)	0.63
Free Silica (SiO ₂)	0.57
Free Carbon (C)	0.25
Iron (Fe)	0.16
Aluminum (Al)	0.23
Calcium (Ca)	0.05
Magnesia (Mg)	0.05
	100.0%

Aluminum Oxide Grinding Wheel	
Aluminum Oxide (Al ₂ O ₃)	95.27
Titania (TiO ₂)	2.67
Silica	1.05 *
Zirconia (ZrO ₂)	0.35
Iron Oxide (Fe ₂ O ₃)	0.15
Manganese Oxide (MnO ₂)	0.11
Calcium Oxide (CaO)	0.05
Magnesia (MgO)	0.31
Alkalis (Soda + Potash)	0.04
	100.0%

*This value is for silica present in a chemically combined form, not free silica. It is in the form of a glassy slag within the grains of the fused alumina.

approximately 2-1 2 x 2-1 2 x 3/8 in. in size. A continuous cast gray iron bar of 2-1 2 in. diameter was used as the high Si metal (Fig. 2). This gray iron casting was chosen because of the absence of silica-containing materials used in the continuous casting process. Chemical analysis of these two metals is provided in Table 3.

All grinding and air sampling for these tests was conducted in an enclosure with a volume of 28.5 cubic feet (Fig. 3). This enclosure contained the grinder, a pneumatically operated device for forcing the metal coupons against the wheel at a uniform pressure, and the air sampling train. Access doors were provided for cleaning, wheel changes, servicing of air samples, etc. Air samples were collected during all previously enumerated test conditions.

The flowrate was set using a Brooks precision rotometer which had been calibrated with a soap film flowmeter before and after the tests. The flowrate was checked after the first 7 min of each test then at 15 min intervals. The cyclones were disassembled after every test and cleaned in an ultrasonic bath containing a cleaning detergent. They were then rinsed with

Table 3. Chemical Analysis of Bar Stock

Iron Stock

Iron	99.86%
All Other Elements	0.14%

Continuous Cast Gray Iron

Iron	93.4%
Carbon (C)	3.24
Silicon (Si)	2.54
Manganese (Mn)	0.759
Sulfur (S)	0.048

Gear Blank

Iron (Fe)	94.07%
Carbon (C)	3.20
Silicon (Si)	1.86
Manganese (Mn)	0.70
Sulfur (S)	0.12
Phosphorus (P)	0.05

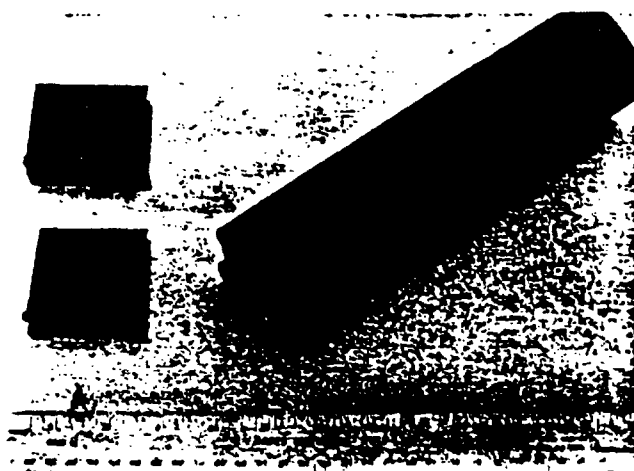


Fig. 2. Rough sheared ingot stock (low Si) and continuous cast bar stock (high Si) for test specimens.

isopropyl alcohol and allowed to air dry. All of the air samples were analyzed by x-ray diffraction for quartz and cristobalite content.

Two sampling trains were placed near the rear of the enclosure approximately 12 in. from the exhaust port of the grinder.

A grinding time of 45 min was determined to be adequate to collect an air sample with a sufficient quantity of dust to be analyzed accurately by x-ray diffraction.

During each grinding condition test, metal was fed into the grinding wheel by pressure applied with a pneumatic pressure feed device (Fig. 4). Air pressure to the 2 in. pneumatic cylinder on the pressure feed device was supplied by a 1 horsepower portable compressor. The low Si metal was fed into the wheel at a pressure of 20 psi, the high Si metal at a pressure of 45 psi. The

Table 4. Test Parameters

Test Number	1	2	3	4	Gear Blank (as cast)	Gear Blank (shot blasted)
Type Wheel	Al	SiC	Al	SiC	SiC	SiC
Type Metal Ground	II	II	CI	CI	GI	GI
Air Pressure to feed cylinder (PSI)	20	20	45	45	40	40
Grinding Time (minutes)	45	45	45	45	15,30	15,30
Loss of metal weight during test (oz)	2	2	7	57	26	21
Loss of wheel weight during test (oz)	5	2	3	33	-	2
Ambient Temperature (outside enclosure) (°F)	66	64	70	69	73	73
Temperature rise in enclosure (°F)	35	32	70	72	39	44
Cross section of metal area against area (in ²)	2.18	2.18	4.91	4.91	-	-

Al - Aluminum Oxide
SiC - Silicon Carbide
II - Ingot Iron
CI - Continuous Cast Iron
GI - Gray Iron



Fig. 3. Enclosed cabinet for grinding and air sampling tests.

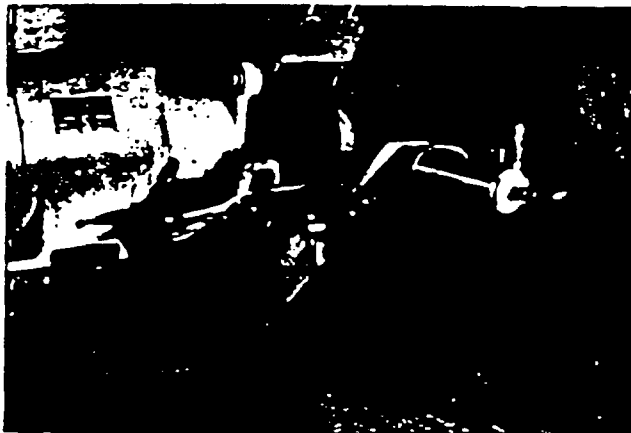


Fig. 4. Pneumatic device for feeding metal samples into grinding wheel.

difference in pressure was to compensate for the difference in cross sectional area of the low and high Si metals against the grinding wheel. These pressures were also chosen because they were the minimum amounts needed to create a continuous stream of glowing swarf. This is a condition commonly created when castings are ground in a ferrous foundry cleaning room. For a detailed listing of the testing parameters, consult Table 4.

Before the test began, all the bar stock used was cleaned with a degreasing solvent to remove any surface coatings which might be present and thus affect air sampling results. The bar stock was also airless abrasive blasted to remove any oxides.

The enclosure was brushed and vacuumed to remove any residual materials between tests. Both the grinding wheel and the metal to be ground were weighed before and after each test to determine material loss. Grinding wheels were dressed before the start of each test and at 15 min intervals thereafter. During the dressing operation, the doors of the enclosure were opened and the sampling pumps turned off. The temperature inside the enclosure was monitored during the test in order to determine if it might prove a factor in any reactions that might occur.

The parameters of the tests taken using the gear blanks (Fig. 5) is also listed in Tables 3-5.

Three air samples were taken to determine background levels of dust for comparison purposes. During these tests the grinder was off and all equipment surrounding the test enclosure was turned off. Background samples were taken both outside and inside the grinding enclosure at the same location as the air samples taken during the grinding test.

Results

Table 5 presents the analytical results from these tests. The amount of dust collected on the filters was anywhere from 38 to 350 times the amount needed for accurate analysis by x-ray diffraction. The amount of quartz collected on the filters was within the range of quartz present on the blank filters. As a result, it was determined that no measurable amount of quartz is being generated by a chemical reaction between the Si in the metal and atmosphere during grinding. In addition, the wheels

Table 5. Quantities of Dust Collected (mm)

Type of Metal Feed Stock	Continuous		Gear Blank	
	Ingot Iron	Cast Gray Iron	Gray Iron Shot Blast	Gray Iron Not Shot Blast
WHEEL TYPE				
Aluminum Oxide				
Sample 1	3.80	34.56	-	-
Sample 2	3.75	35.18	-	-
Silicon Carbide				
Sample 1	4.90	34.08	10.36 *	10.55 *
Sample 2	4.94	32.02	25.13 **	20.74 **
Sample 3	-	30.68	-	-
Background Levels	Within enclosure <0.010 mg		Outside enclosure 0.010 mg	

Each of the samples were analyzed for quartz content. In all cases the quartz content did not exceed the amount found on the blank filters submitted for analysis. 16 filters were submitted for analysis (including three background samples) along with 6 blank filters.

* 15 minute air sample.

** 30 minute air sample.

themselves did not generate any measurable amount of free silica.

Discussion

The results of these tests indicate that further investigation should be conducted to determine the source of high silica dust levels commonly found in ferrous foundry cleaning room air samples. If indeed the casting surface is the source of the free silica, then tests similar to these in concept should be performed. A logical next step would be to conduct other tests using a cast plate instead of bar stock and a surface grinder instead of a stand grinder. Shallow cuts with a surface grinder in an enclosure on plates cast under varying conditions would demonstrate whether the generation of silica dust is a surface phenomenon. The tests herein reported were not designed to investigate this theory. Different molding media and mold coatings should also be used.

Another theory is that there are chemical and physical reactions occurring at the mold-metal interface at which various forms of iron silica-silicate materials are formed. Some of these materials may create or generate free silica when mechanical energy is applied.

Visual examination and subjective judgments are normally applied to determine when a casting surface is clean. Examination of casting surfaces both by low power magnification and copper plating techniques reveals the gradual diminishing of embedded silica with increased blast cleaning time. Unfortunately, these methods have not evolved to the point of quantifying the amount of embedded silica on the surface to determine if, upon being ground or chipped, the resulting exposure would be within permissible limits. These techniques, at this time, do not lend themselves to production use efficiently.

A measurement technique which lends itself to production use, giving both accurate results and a correlation with expected

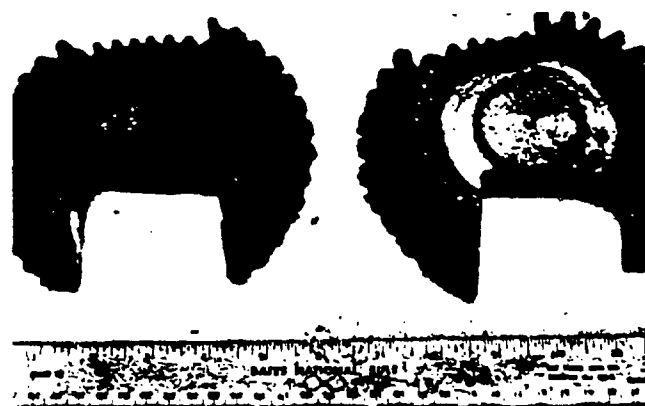


Fig. 5. Gear blank test specimens.

exposure, should be developed. A problem to be overcome with the use of this type of measurement would be the nonuniform distribution of embedded silica in the casting surface.

Since there appears to be little published information on the surface of castings specifically concerning the physical and chemical state of any silica present, a microscopic examination of surface defects pertaining to metal penetration should be done. Such a study could also determine the thickness of metal penetration. With such information, judgments regarding the ability of airless abrasive shot blasting to remove them could be made.

Examination of the surface of "new" versus "used" shot to see if silica is adhering to the shot surface may be of some value. This silica may redeposit on the casting surface by electrostatic attraction during airless abrasive shot blasting only to be removed during subsequent mechanical surface treatment, i.e.,

grinding, chipping, etc.

A related theory would be that during abrasive blasting some sand grains are being blasted on and mechanically bonded to the surface of the casting due to the impaction of the shot. As the surface is ground, these particles of sand are liberated, causing exposure.

An analysis of grinding dust itself by scanning electron microscopy or some other appropriate analytical method or device would give an insight into the source of the silica.

Since it was the tests conducted some years ago on castings which were treated to a hot, electrically charged caustic soda bath which seemed to indicate some chemical (versus mechanical) adherence, perhaps these tests should be repeated under more closely controlled conditions, particularly since these tests were of unknown reliability with no hard data available.

There are a number of theories regarding the formation of silica on the surface of the casting with ensuing free silica exposures when those surfaces are ground. The theory that was tested during these experiments was that the Si in the metal or in the abrasive media was reacting with the atmosphere to form free silica.

Conclusion

The results of these tests indicate that the reaction of the Si in the metal and oxygen in the atmosphere at the point of grinding does not occur to any measurable extent.

Acknowledgments

We would like to thank the Norton Company, Worcester, MA for the grinding wheels used in this study; Wells Manufacturing, Skokie, IL for the bar stock; and Wagner Castings, Decatur, IL for the chemical analysis of the bar stock.

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Foundry Health & Safety Guide Series



Foundry Health & Safety Guide

revised 6/76

1. Procedures of Occupational Safety and Health Review Commission
2. Silica
3. Carbon Monoxide
4. Noise
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14. Inert Nuisance Particulates
15. Tellurium
16. Aluminum and Aluminum Oxide
17. Magnesium and Magnesium Oxide
18. Nickel
19. Sulfur Dioxide
20. Acrolein
21. Zinc Oxide
22. Urethane Resins
23. Lead
24. Copper
25. Chromium and Its Compounds
26. Calcium Carbide (carbide)



Foundry Health & Safety Guide

SILICA

Free silica or quartz (SiO_2) is a major constituent of foundry sand and can be presented in high concentrations in silica flour and in some silica mold or core washes. Tridymite and cristobalite are also crystalline forms of silica; these can be generated at the mold metal interface as a result of the high temperature transformation of quartz.

Many foundry operations result in employee exposure to fine dust generated as a result of mechanical or thermal fracture of sand particles. The main sources of foundry exposure involve (1) the handling or mulling of new sand or dry sand from shakeout, (2) use of silica-containing parting compounds or mold washes, (3) shakeout and (4) casting cleaning. Other sources of silica dust exposure include general maintenance and cleaning and furnace and ladle repair operations.

OSHA EXPOSURE LIMITS are calculated from the following formulas

Substance	mppcf	mg/m ³
crystalline quartz (respirable)	(in mppcf) = $\frac{250 *}{\% \text{ SiO}_2 + 5}$	(in mg/m ³) = $\frac{10 \text{ mg/m}^3 **}{\% \text{ SiO}_2 + 2}$
crystalline quartz (total dust)		(in mg/m ³) = $\frac{30 \text{ mg/m}^3}{\% \text{ SiO}_2 + 2}$

cristobalite, tridymite and silica flour (intended) —

use 1/2 the value calculated from the count or mass formulas for quartz.

mppcf = millions of particles per cubic foot of air, based on impinger samples counted by light-field techniques

mg/m³ = milligrams per cubic meter of air

* percentage of crystalline silica in the formula is the amount determined from airborne samples except in those instances in which other methods have been shown to be applicable.

** both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size selector having, in brief, the ability to retain all particles greater than 10 microns and passing 90 percent of the particles 2 microns or less in diameter.

HAZARD

The degree of hazard depends on silica content, concentration and size of the airborne dust, as well as the length of exposure. Silicosis (occasionally complicated by tuberculosis) is the occupational disease associated with excessive exposure. Heavy exposures have produced symptoms in less than one year after initial exposure; many years, however, are generally required to produce symptoms.

CONTROL PROCEDURES

Process — Substitution of other materials, such as nonsilica mold parting compounds, molding aggregates and abrasive grits, should be considered first. All sources of dust exposure should be enclosed as much as possible and exhaust ventilated to a suitable collector. Some dust sources, such as abrasive blasting operations, mullers, screens and some shakeouts, can be completely enclosed. Only partial enclosures, however, are possible at other operations, such as chipping and grinding operations and most shakeouts. The poorer the enclosure, the greater the exhaust capacity required to provide positive control. Local exhaust ventilation systems should be designed by an experienced ventilation engineer in accordance with design criteria presented in, *Industrial Ventilation - a Manual of Recommended Practice*, available from the Committee on Industrial Ventilation, P. O. Box 453, Lansing, MI 48902; American National Standard Z9.2-1971, *Fundamentals Governing the Design and Operation of Local Exhaust Systems* available from the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018 and the *AFS Foundry Environmental Control Manual, Volume 1*.

Housekeeping — Settled silica-containing dust is an important source of exposures in most foundries. Settled dust is easily reentrained by slight vibration or air currents. Settled dust should be periodically removed, using vacuum methods, from all overhead structures, equipment and floors. Vacuum cleaning will be required at infrequent intervals if all major sources of dust are properly controlled, using local exhaust ventilation.

Personal Protection — Respiratory protection should be selected from those approved by the National Institute for Occupational Safety and Health for protection against pneumoconiosis-producing dusts.

Medical Program — Employees who have been or who are exposed to silica dust should be under medical supervision. This is discussed in more detail in Foundry Health & Safety Guide No. 5 entitled "Foundry Medical Program".



Foundry Health & Safety Guide

VENTILATION CONTROL IN THE FOUNDRY

INTRODUCTION

The American Foundrymen's Society's Foundry Health and Safety Guide Series refer to specific substances to which foundry workers may be exposed. The presence and concentration of certain airborne contaminants depends primarily upon the type of foundry (ferrous or nonferrous), the molding and coremaking process (green sand, nobake, hot-box, etc.) method of melting, pouring, shakeout and casting cleaning as well as other variations in the production of the casting. When employee exposure exceeds the OSHA 8-hour Exposure Limit, or ceiling limit, control procedures are required. The AFS Foundry Health & Safety Guides usually refer to local exhaust ventilation at the source as the most effective approach when it is necessary to develop feasible engineering control procedures, where other basic principles of control including change of material or operation, isolation, improved housekeeping are impractical or would have little effect.

The intent of this guide is to present a few concepts of ventilation from the standpoint of effectiveness, economics and energy conservation in an effort to result in a control system that satisfies the employer when investing in a control measure intended to provide a healthy place of employment. Some excellent sources of reference on ventilation control are listed in the back of this guide and include basic concepts of ventilation as well as design of hoods and systems for specific foundry operations and processes.

LOCATIONS OF LIKELY NEED FOR CONTROL MEASURES

There are certain basic locations in a foundry where excessive exposure to airborne contaminants are most frequently encountered, particularly when ventilation controls are ineffective or non-existent. The principal locations or processes where ventilation control is almost a must in every case because of inherent problems are, in order of decreasing probability:

- 1) cleaning operations — free silica dust and metal dust
- 2) sand preparation — free silica dust, miscellaneous binder dusts
- 3) shakeout — free silica dust, carbon monoxide, smoke
- 4) conveyor systems — free silica dust
- 5) melting and pouring operations — metal fumes, carbon monoxide, smoke, vapors
- 6) coremaking — vapors and gases dependent on process used
- 7) molding — free silica dust, parting compounds

TYPES OF VENTILATION

There are two basic types of mechanical exhaust ventilation.

Local Exhaust — Local exhaust ventilation does as its name implies: removes the contaminant at the source. It is far more desirable than general or dilution ventilation, mainly because it is more effective for contaminant control as well as being more economical. Less exhaust air volume is required to control the emission of contaminants with a corresponding saving in loss of tempered air exhausted to the outside. An outside supply of fresh-tempered makeup air, necessary to replace the air being exhausted, is therefore also held to a minimum.

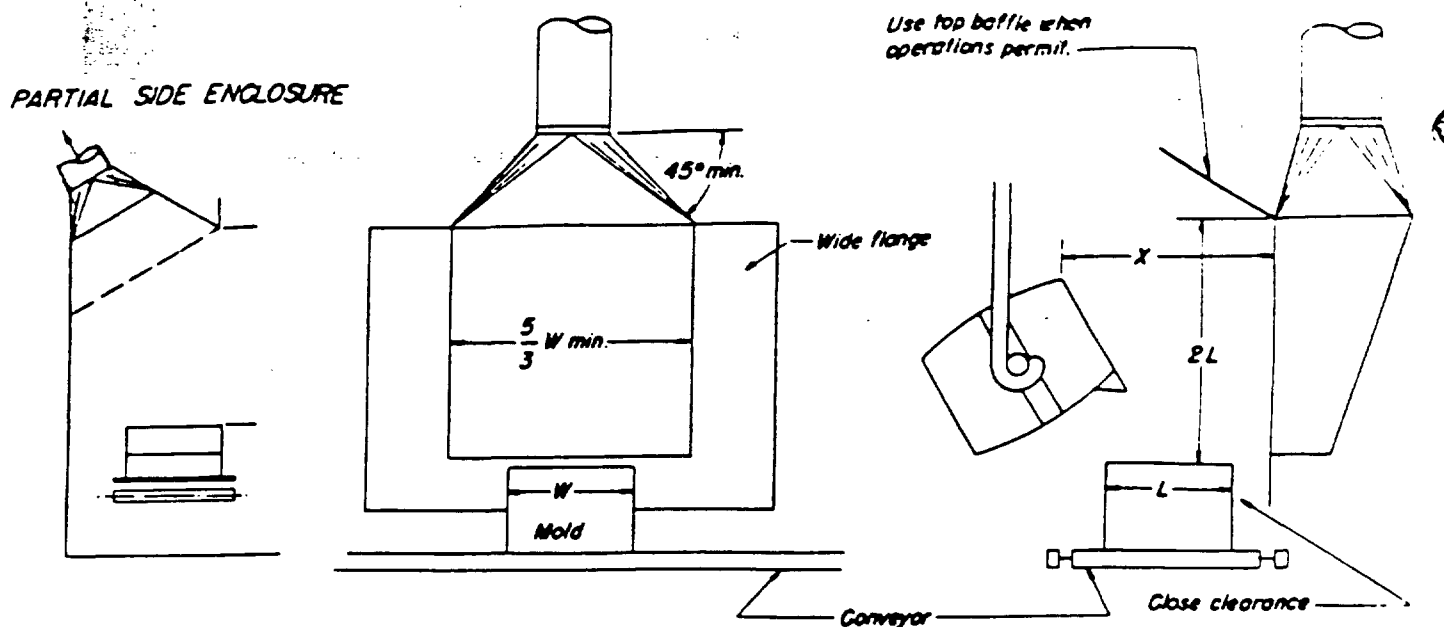


Fig. 1. Pouring station. (Courtesy of the American Conference of Governmental Industrial Hygienists)

Another desirable feature is that the air contaminant is not allowed to drift from the source of generation and contaminate other work sites. Figure 1 is an example of local exhaust ventilation control of metal fumes during pouring.

General Ventilation — This method of ventilation is an attempt at moving large enough quantities of air in the hope that air contaminants will be diluted to a concentration which is not injurious to the worker. This method of contaminant control is usually ineffective. General ventilation is usually considered quite wasteful in power to move the air, as well as fuel required to temper (heat) the large quantities of makeup air required to replace the volume being exhausted.

DESIGN OF SYSTEMS

A local exhaust ventilation system consists of 1) a hood to enclose as much as possible the source of contamination, 2) a duct system to convey the contaminant, 3) a collector if required, 4) a fan to create a negative pressure within the hood causing room air to flow into it and 5) an exhaust stack to convey the air to the outside.

A good workable ventilation system follows certain basic design principles. Air resists the movement of any object moving through it. Conversely, air can experience considerable resistance in its performance in a local exhaust ventilation system, beginning at the hood inlet and ending at the stack discharge. Hood entrance losses, friction losses, turbulence and other factors contribute to excess energy being expended in many cases without a corresponding return for this investment in terms of performance or desired control. Some basic concepts to consider for each principal segment of the system are as follows:

Hood — The success of any system depends on the ability of the hood to capture the contaminant. Known as control or capture velocity, this criteria is given in terms of the air velocity that is considered adequate to convey the contaminant from its source to the hood inlet. When the contaminant is being released within an enclosure, then the control velocity of concern is the velocity at which the air enters the available openings. For example, a minimum air velocity of 150 lineal feet per minute entering the front opening or face of a swing grinder booth containing the grinder is generally sufficient to contain contaminants within the booth. If this opening is 3 feet wide and 4 feet high (12 ft^2) then the exhaust volume required would be $150 \text{ fpm} \times 12 \text{ ft}^2$ or 1800 cubic feet per minute (cfm).

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OCCUPATIONAL HEALTH REGULATIONS

NO. 3

MAXIMUM PERMISSIBLE CONCENTRATIONS
OF ATMOSPHERIC CONTAMINANTS IN PLACES OF EMPLOYMENT

Effective July 1, 1958

CONSULT LOCAL HEALTH DEPARTMENTS AND PHYSICIANS
FOR
INFORMATION AND ADVICE
ON METHODS OF CONTROL OVER
HEALTH HAZARDS TO ALL WORKERS
AND
INDUSTRIAL DISEASES AND INJURIES



TEXAS STATE DEPARTMENT OF HEALTH
DIVISION OF OCCUPATIONAL HEALTH
Austin, Texas

OH-13-2
July 1958
Supersedes OH-13-1
(September 1957)

00103

These standards were amended and adopted by
The Texas State Board of Health on June 9, 1958
in accordance with the authority granted in
Article 44184 of the Revised Civil Statutes, State of Texas,
and are promulgated also in accordance with
Article 4477, Section 19.

CONTENTS

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00104

MAXIMUM PERMISSIBLE CONCENTRATIONS
OF ATMOSPHERIC CONTAMINANTS IN PLACES OF EMPLOYMENT

Scope; Purpose; Availability of Pertinent References

Scope: This regulation applies to all places of employment in Texas. It does not cover maximum permissible dose of radiation or the minimum environmental sanitation requirements, nor include measures required for control of community external air pollution or air pollution nuisances.

Purpose: The purpose of this regulation is to prescribe to employers the maximum average atmospheric concentration of contaminants to which they are permitted to expose employees during an eight-hour working day in their places of employment, including industrial establishments.

Pertinent References: Copies of related laws, regulations, opinions of the Attorney General of Texas, and Advisory Standards currently applicable will be provided to any citizen of Texas upon request.

II. Applicability of Figures Listed Herein

Individual people react differently after excessive exposures to atmospheric concentrations of contaminants in places of employment. Listed herein are weighted average concentrations generally safe in places of employment during an eight-hour working exposure. These are not maximum values which cannot be exceeded momentarily depending upon, but not limited to, such factors as nature of contaminant; frequency of occurrence of high concentration; variable durations of exposure; probability of acute poisoning from high concentration for even short periods; cumulative effects. Employers shall consider these factors prior to exceeding values listed herein.

III. Revision

Values listed herein are based upon information obtained from recent experience, experimental study reports, or a combination of the two. Regular review will result in revision as justified. The State Board of Health solicits and will consider pertinent data based upon facts and experiences received from individuals, industries, governmental agencies, or others.

IV. Definitions

1. Industrial Establishment is defined to mean an institution, a place, building or location related to manufactures or to the product of industry or labor.
2. Places of Employment is defined to mean any place where two or more persons are directly or indirectly employed by another for direct or indirect gain or profit.

00105

V. MAXIMUM PERMISSIBLE CONCENTRATIONS DURING ONE WORKING DAY

A. <u>Gases and Vapors</u>	<u>P.P.M.*</u>	<u>Approx. per Cu. v.</u>
Acetaldehyde	200	360
Acetic acid	10	25
Acetic anhydride	5	20
Acetone	1,000	2,400
(t)Acetylene tetrabromide	1	14
Acrolein	0.5	1.2
Acrylonitrile	20	45
Allyl alcohol	5	12
Allyl chloride	5	15
(t)Allyl glycidyl ether (AGE)	10	45
Allyl propyl disulfide	2	12
Ammonia	100	70
Amyl acetate	200	1,050
Amyl alcohol (isoamyl alcohol)	100	360
Aniline	5	19
Arsine	0.05	0
Benzene (benzol)	25	80
Benzyl chloride	1	5
(t)Boron trifluoride	1	3
Bromine	1	7
Butadiene (1,3-butadiene)	1,000	2,200
Butanone (methyl ethyl ketone)	250	740
Butyl acetate (n-butyl acetate)	200	950
Butyl alcohol (n-butanol)	100	300
(t)Butyl glycidyl ether (BGE)(n-butyl glycidyl ether).	50	270
Butylamines	5	15
Butyl cellosolve (2-butoxyethanol)	50	240
(t)Butyl mercaptan	10	35
Carbon dioxide	5,000	9,000
Carbon disulfide	20	60
Carbon monoxide	100	110
Carbon tetrachloride	25	160
Cellosolve (2-ethoxyethanol)	200	740
Cellosolve acetate (2-ethoxyethyl acetate)	100	540
Chlorine	1	3
(a)(t)Chlorine dioxide	0.1	0
Chlorine trifluoride	0.1	0.
(t)Chloroacetaldehyde	1	3
Chlorobenzene (monochlorobenzene)	75	350
(t)Chlorobromomethane (ClBrCH ₂)	400	2,100
Chloroform (trichloromethane)	100	490
1-Chloro-1-nitropropane	20	100
Chloropicrin	1	7

*Parts of vapor or gas per million parts of air by volume.

/Approximate milligrams per cubic meter of air.

(t)Toxicological information or injury reports on these items is of recent origin and most probably will require revision at an early date.

(a)New - Added 1958.

00106

Liquids and Vapors (Cont.)

	<u>P.P.M.*</u>	<u>Approx. Mg. per Cu. M.†</u>
Chloroprene (2-chloro-1,3-butadiene)	25	90
Cresol (all isomers)	5	22
Cyclohexane	400	1,400
Cyclohexanol	100	410
Cyclohexanone	100	400
Cyclohexene	400	1,350
Cyclopropane	400	690
Decaborane	0.05	0.3
Diacetone alcohol (4-hydroxy-4-methyl- 2-pentanone)	50	240
Diborane	0.1	0.1
o-Dichlorobenzene	50	300
5-Dichlorodifluoromethane	1,000	4,950
1,1-Dichloroethane	100	400
1,2-Dichloroethane (ethylene dichloride)	100	400
1,2-Dichloroethylene	200	790
Dichloroethyl ether	15	90
Dichloromonofluoromethane	1,000	4,200
1,1-Dichloro-1-nitroethane	10	60
Dichlorotetrafluoroethane	1,000	7,000
Diethylamine	25	75
Difluorodibromomethane	100	860
(c) Diglycidyl ether (DGE)	10	55
Diisobutyl ketone	50	290
Dimethylaniline (n-dimethylaniline)	5	25
(c) Dimethyl formamide	20	60
(c) 1-1 Dimethylhydrazine	0.5	1
Dimethylsulfate	1	5
Dioxane (diethylene dioxide)	100	360
Dipropyleneglycolmethylether	100	600
Epichlorohydrin	25	90
Ethyl acetate	400	1,400
Ethyl acrylate	25	100
Ethyl alcohol (ethanol)	1,000	1,900
Ethyl mercaptan	250	640
Ethyl amine	25	45
Ethylbenzene	200	870
Ethyl bromide	200	890
Ethyl chloride	1,000	2,600
Ethyl ether	400	1,200
Ethyl formate	100	300
Ethyl silicate	100	850
Ethylene chlorohydrin	5	16

*Parts of vapor or gas per million parts of air by volume.

†Approximate milligrams per cubic meter of air.

(c) Toxicological information or injury reports on these items is of recent origin and most probably will require revision at an early date.

(a) New - Added 1958.

00107

267

A. <u>Gases and Vapors (Cont.)</u>	P.P.M.*	Approx. per Cu. Ft.
Ethylenediamine	10	30
Ethylene dibromide (1,2-dibromoethane)	25	190
Ethylene imine	5	9
Ethylene oxide	50	90
Fluorine	0.1	0
Fluorotrichloromethane	1,000	5,600
Formaldehyde	5	6
Furfural	5	20
(t) Furfuryl alcohol	50	200
Gasoline	500	2,000
(t) Glycidol	50	150
Heptane (n-heptane)	500	2,000
Hexane (n-hexane)	500	1,800
Hexanone (methyl butyl ketone)	100	410
Hexone (methyl isobutyl ketone)	100	410
(a)(t) sec-Hexyl acetate	100	590
Hydrazine	1	1
Hydrogen bromide	5	17
Hydrogen chloride	5	7
Hydrogen cyanide	10	11
Hydrogen fluoride	3	2
Hydrogen peroxide, 90%	1	1
Hydrogen selenide	0.05	0
Hydrogen sulfide	20	30
Iodine	0.1	1
Isophorone	25	140
(t) Isopropyl glycidyl ether (IGE)	50	240
Isopropylamine	5	12
(n) Mesityl oxide	25	200
Methyl acetate	200	610
Methyl acetylene	1,000	1,650
Methyl acrylate	10	35
Methyl alcohol (methanol)	200	260
Methyl bromide	20	80
Methyl cellosolve (2-methoxyethanol)	25	80
Methyl cellosolve acetate (ethylene glycol monomethyl ether acetate)	25	120
Methyl chloride	100	210
Methylal (dimethoxymethane)	1,000	3,100
Methyl chloroform (1,1,1-trichloroethane)	500	2,700
Methylcyclohexane	500	2,000
Methylcyclohexanol	100	470
Methylcyclohexanone	100	460

*Parts of vapor or gas per million parts of air by volume.

†Approximate milligrams per cubic meter of air.

(t) Toxicological information or injury reports on these items is of recent origin and most probably will require revision at an early date.

(n) New value, 1958.

(a) New - Added 1958.

00103

268

A. Cases and Vapors (Cont.)

	P.P.M.*	Approx. Mg. per Cu. M.†
Methyl formate	100	250
Methyl isobutyl carbinol (methyl amyl alcohol)	25	100
Methyl mercaptan	50	100
(t) Methyl styrene	100	480
(t) Methylene chloride (dichloromethane)	500	1,750
Monomethyl aniline	2	9
(t) Naphtha (coal tar)	200	800
Naphtha (petroleum)	500	2,000
Nickel carbonyl	0.001	0.007
Nitric acid	5	25
p-Nitroaniline	1	6
Nitrobenzene	1	5
Nitroethane	100	310
Nitrogen dioxide	5	9
Nitroglycerin	0.5	5
Nitromethane	100	250
2-Nitropropane	50	180
Nitrotoluene	5	30
Octane	500	2,350
Ozone	0.1	0.2
Pentane	1,000	2,950
Pentanone (methyl propyl ketone)	200	700
Perchloroethylene (tetrachloroethylene)	200	1,350
(t) Perchloromethyl mercaptan	0.1	0.8
Phenol	5	19
(t) Phenyl glycidyl ether (PGE)	50	310
Phenylhydrazine	5	22
Phosgene (carbonyl chloride)	1	4
Phosphine	0.05	0.07
Phosphorus trichloride	0.5	3
Propyl acetate	200	840
Propyl alcohol (isopropyl alcohol)	400	980
Propyl ether (isopropyl ether)	500	2,100
(t) n-Propyl nitrate	25	110
Propylene dichloride (1,2-dichloropropane)	75	350
Propylene imine	25	60
(t) Propylene oxide	100	240
Pyridine	10	30
Quinone	0.1	0.4
Stibine	0.1	0.5
Stoddard solvent	500	2,900
Styrene monomer (phenylethylene)	100	420
Sulfur dioxide	5	13

*Parts of vapor or gas per million parts of air by volume

†Approximate milligrams per cubic meter of air.

(t) Toxicological information or injury reports on these items is of recent origin and most probably will require revision at an early date.

(a) New - Added 1958.

00103

263

A. <u>Gases and Vapors (Cont.)</u>		P.P.M.*	Approx. per Cu. ft.
	Sulfur hexafluoride	1,000	6,000
	Sulfur monochloride	1	6
	Sulfur pentafluoride	0.025	0
	p-Tertiary butyl toluene	10	60
(t)	Tertiary butyl alcohol	100	300
	1,1,2,2-Tetrachloroethane	5	35
	Tetrahydrofuran	200	590
	Tetranitromethane	1	8
	Toluene (toluol)	200	750
	o-Toluidine	5	22
(t)	Tolylene-2,4-diisocyanate	0.1	0
	Trichloroethylene	200	1,050
(a)(t)	Trichloropropane	50	300
(t)	Triethyl amine	25	100
	Trifluoromonobromomethane	1,000	6,100
	Turpentine	100	560
	Vinyl chloride (chloroethylene)	500	1,300
(t)	Vinyl toluene	100	480
	Xylene (xylol)	200	870
(t)	Xylidine	5	25
(#)(t)	Teflon decomposition products	0	0
(#)(t)	Pentaborane (B ₅ H ₉)	0	0

B. Toxic Dusts, Fumes, and Mists

	Mg. per Cu. ft.
Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene)	0.
Amate (ammonium sulfamate)	10
Antimony	0.
ANTU (alpha naphthyl thiourea)	0.
Arsenic	0.
Barium (soluble compounds)	0.
(t) Beryllium	0.1
Cadmium oxide fume	0.
Calcium arsenate	0.
Chlordane (1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane)	0.
Chlorinated camphene, 60%	0.
Chlorinated diphenyl oxide	0.

*Parts of vapor or gas per million parts of air-by volume.

^Approximate milligrams per cubic meter of air.

(t) Toxicological information or injury reports on these items is of recent origin and most probably will require revision at an early date.

(a) New - Added 1958.

(#) Until more data are forthcoming, it is important that atmospheric concentrations of these materials to which workers are exposed must be kept as near 0 as possible.

^Milligrams of dust, fume, or mist per cubic meter of air.

00110

Toxic Dusts, Fumes and Mists (Cont.)		Mg. per Cu. M. ^{ft}
Chlorodiphenyl (42% chlorine)	1	
Chlorodiphenyl (54% chlorine)	0.5	
Chromic acid and chromates (as CrO ₃)	0.1	
Crag herbicide (sodium 2-(2,4-dichlorophenoxy) ethanol hydrogen sulfate)	15	
Cyanide (as CN)	5	
2,4-D(2,4-dichlorophenoxyacetic acid)	10	
DDT (2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane)	1	
Dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8, 8a-octahydro-1,4,5,8-dimethanonaphthalene)	0.25	
Dinitrobenzene	1	
Dinitrotoluene	1.5	
Dinitro-o-cresol	0.2	
EPN (O-ethyl O-p-nitrophenyl thionobenzenephosphonate)	0.5	
Ferbam (ferric dimethyl dithiocarbamate)	15	
Ferrovandium dust	1	
Fluoride	2.5	
Hydroquinone	2	
Iron oxide fume	15	
Lead	0.2	
Lead arsenate	0.15	
Lindane (hexachlorocyclohexane, gamma isomer)	0.5	
(t) Lithium hydride	0.025	
Magnesium oxide fume	15	
Malathion (O,O-dimethyl dithiophosphate of diethyl mercaptosuccinate)	15	
Manganese	6	
Mercury	0.1	
Mercury (organic compounds)	0.01	
Methoxychlor (2,2-di-p-methoxyphenyl-1,1,1-trichloroethane)	15	
Molybdenum (soluble compounds)	5	
(insoluble compounds)	15	
Nicotine	0.5	
(t) Paradichlorobenzene	450	
Parathion (O,O-diethyl O-p-nitrophenylthiophosphate)	0.1	
Pentachloronaphthalene	0.5	
Pentachlorophenol	0.5	
(a)(t) Phosphoric Acid	1	
Phosphorus (yellow)	0.1	
Phosphorus pentachloride	1	
Phosphorus pentasulfide	1	
Picric acid	0.1	

Milligrams of dust, fume, or mist per cubic meter of air.

(a) Toxicological information or injury reports on these items is of recent origin and most probably will require revision at an early date.

(a) New - Added 1958.

00111

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B. Toxic Dusts, Fumes and Mists (Cont.)

	Mg. per Cu. M.
Pyrethrum	2
Rotenone	5
Selenium compounds (as Se)	0.1
Sodium hydroxide	2
Sodium fluoroacetate (1080)	0.1
Strychnine	0.15
Sulfuric acid	1
TEDP (Tetraethyl dithionopyrophosphate)	0.2
TEPP (Tetraethyl pyrophosphate)	0.05
Tellurium	0.1
Tetryl (2,4,6-trinitrophenylmethylnitramine)	1.5
Thiram (tetramethyl thiuram disulfide)	5
Thallium (soluble compounds)	0.1
Titanium dioxide	15
Trichloronaphthalene	5
Trinitrotoluene	1.5
(a) Triorthocresyl phosphate	0.1
Uranium (soluble compounds)	0.05
(insoluble compounds)	0.25
Vanadium	
(V ₂ O ₅ dust)	0.5
(V ₂ O ₅ fume)	0.1
Warfarin (3-[α -acetonylbenzyl]-4-hydroxycoumarin)	0.5
(c) Yttrium and inorganic compounds	5
Zinc oxide fumes	15
Zirconium compounds (as Zr)	5

C. Mineral Dusts

	M.P.P.C.F.*
Aluminum oxide	50
Asbestos	5
Dust (nuisance, no free silica)	50
Mica (below 5% free silica)	20
Portland cement	50
Talc	20
Silica	
High (above 50% free SiO ₂)	5
Medium (5 to 50% free SiO ₂)	20
Low (below 5% free SiO ₂)	50
Silicon carbide	50
Soapstone (below 5% free SiO ₂)	20

*Milligrams of dust, fume, or mist per cubic meter of air.

(c) Toxicological information or injury reports on these items is of recent origin and most probably will require revision at an early date.

**Millions of particles per cubic foot of air.

00112

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OPERATIONAL USE OF
INFORMATION TECHNOLOGY

1998-1999

1998-1999
1998-1999

K

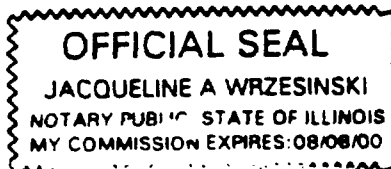
FURTHER AFFIANT SAITH NAUGHT.

Darin V. Osmond
Darin V. Osmond

SUBSCRIBED AND SWORN TO
BEFORE ME on this
8th day of April, 1998,
which witness my hand and seal of office.

My Commission Expires:

Jacqueline A. Wrzesinski



NO. 93-042852

AUGUST GORDON, ET AL.	§	IN THE DISTRICT COURT OF
	§	
VS.	§	HARRIS COUNTY, TEXAS
	§	
BOB SCHMIDT, INC., ET AL.	§	80TH JUDICIAL DISTRICT

AFFIDAVIT OF BARBARA J. BARRON

Before me, the undersigned authority, on this day personally appeared Barbara J. Barron, who being duly sworn, on his oath, did state as follows:

1. I am over the age of 21 and am fully competent to testify as to matters set forth in this affidavit.
2. The following documents, which are attached as exhibits to Borden, Inc.'s Motion for Summary Judgment, are true and correct copies:

"Exhibit C": Central Foundry Plaintiffs' Answers to Interrogatory No. 6;

"Exhibit D": Excerpts from Deposition of Wightman M. Cannon, Jr.;

"Exhibit E": Excerpts from Deposition of Robert Yaw;

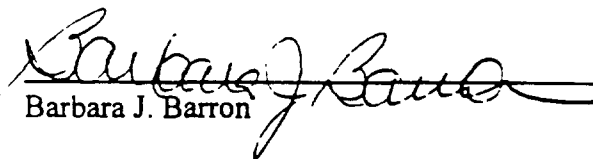
"Exhibit F": Excerpts from Deposition of Billy Don Kizziah;

"Exhibit G": Excerpts from Deposition of John Paul Singleton;

"Exhibit J": Texas Occupational health Regulations, OH-13-2 (1958);

"Exhibit K": OSHA citations and records related to Central Foundry (identified in Deposition of Billy Don Kizziah at 192-200 [Exhibit F]).

FURTHER AFFIANT SAITH NAUGHT.


Barbara J. Barron

October 25, 1978

OSHA - BHAM

2-Year Initial Noise Abatement Period
Central Foundry - Tuscaloosa, AL

Acting ARA for Federal/State Operations

A full scale foundry inspection was recently completed at Central Foundry in Tuscaloosa by the NEP team. Thirty-two (32) serious violations and fifteen (15) other violations both with multiple instances have been proposed for citations by the team. Further, a probable serious violation with multiple instances for overexposure to free silica is likely.

One of the grouped serious violations is for multiple violations of 1910.95(b)(1), failure to determine and implement feasible engineering and/or administrative controls for noise. This item cites twelve (12) different areas. The areas are: #6 Foundry, #6 Mill, #3 Foundry Core Room, #3 Foundry, Link Belt Dept., #4 Mill, #4 Foundry (including hot metal crane operators), Semi-continuous Dept., Industrial Castings Dept., Five (5) foot Millroom, Ten (10) foot Millroom and the Ten (10) foot Mill Abrasive Saw Operator. The company asked for a minimum abatement period of 24 months for this item. The industrial hygienist who participated in the inspection, Charles Cashio, has expressed the opinion that the time requested is reasonable in consideration of the task at hand.

Due to the large number of items cited and the substantial amount of engineering controls which must be simultaneously determined and implemented, in addition to noise reduction, including: extensive electrical corrections, extensive machine guarding, and repairs to cranes, I think the 24 months abatement period requested for the noise item is not excessive. With the company having their economic and technical resources occupied in several areas concomitantly, the effort to correct the cited noise problem will likely take the full abatement time requested. I would therefore like to recommend the approval of a 23-month abatement date which would take into consideration the time required for processing of the citations and still

Acting AEA for Federal/State Oper.

- 2 -

October 25, 1978

afford the company the full 24 months desired.

Your consideration in this matter is appreciated.

HON D. EIMER

Acting Supervisor, IH

HDE/lp

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Employer Name: Type Of Legal Entity <u>Corporation</u>		5. Type Of Business Or Plant <u>Gray Iron Foundry</u>	
NAMES AND ADDRESSES OF ALL ORGANIZED EMPLOYEE GROUPS.		7. AUTHORIZED REPRESENTATIVES OF EMPLOYEES	
Name: <u>Int'l Welders & Allied Workers</u> Local No.: <u>311</u> Address: <u>P.O. Box 180</u> City: <u>Holt AL</u> State: <u>AL</u> Zip Code: <u>35401</u>		Name: <u>[REDACTED]</u> Title: <u>[REDACTED]</u> Organization: <u>[REDACTED]</u> Home Address: <u>[REDACTED]</u> Zip Code: <u>[REDACTED]</u>	
Name: <u>Machinist & AeroSpace Workers</u> Local No.: <u>455</u> Address: <u>3424 Pike Street</u> City: <u>Holt AL</u> State: <u>AL</u> Zip Code: <u>35401</u>		Name: <u>[REDACTED]</u> Title: <u>[REDACTED]</u> Organization: <u>[REDACTED]</u> Home Address: <u>[REDACTED]</u> Zip Code: <u>[REDACTED]</u>	
EMPLOYER REPRESENTATIVES CONTACTED:		9. OTHER PERSONS CONTACTED.	
Name: <u>YNUARD DUNCAN</u> Title: <u>Dir. of Personnel</u> Function: <u>LOC</u>		Name, Occupation & Affiliation: <u>[REDACTED]</u> Home Address: <u>[REDACTED]</u> Zip Code: <u>[REDACTED]</u>	
Name: <u>Jim Luna</u> Title: <u>V/P Mgr</u> Function: <u>LOC</u>		Name, Occupation & Affiliation: <u>[REDACTED]</u> Home Address: <u>[REDACTED]</u> Zip Code: <u>[REDACTED]</u>	
Name: <u>Joe Sledge</u> Title: <u>PLT Eng</u> Function: <u>LOC</u>		Name, Occupation & Affiliation: <u>[REDACTED]</u> Home Address: <u>[REDACTED]</u> Zip Code: <u>[REDACTED]</u>	
Name: <u>Hoyt Latner</u> Title: <u>PLANT MGR</u> Function: <u>C</u>		Name, Occupation & Affiliation: <u>[REDACTED]</u> Home Address: <u>[REDACTED]</u> Zip Code: <u>[REDACTED]</u>	
10. COVERAGE INFORMATION <u>Company has another</u> <u>gray iron foundry in Quake-town Pa.</u>		11. Date & Time of Entry: <u>12/23/78 9 AM</u> 12. Date & Time Walkaround Began: <u>12/23/78 1 PM</u> 13. Date & Time Closing Conference Began: <u>12/20/78 10 AM</u> 14. Date & Time of Exit: <u>12/19/78 1 PM</u>	
5. EVALUATION OF SAFETY AND HEALTH PROGRAM: (Codes:)		Health Monitoring Program Hazard? <u>Noise only Audible by K of ALA</u> Medical Programs Frequency? <u>per employment</u> Agent? <u>Dr. Guin Dr. Wood Hosp.</u> Extent? <u>general phys.</u> Content? <u>[REDACTED]</u> Hazard Control - Engineering & Administration - Personal Protective Equipment - Regulated Areas - Emergency Procedures Records: <u>(100) - (101) - (102) - Supplementary Health</u> If SH, specify <u>[REDACTED]</u> Notice to Employees (Poster) <u>(Y) N</u> Add'l Comments: <u>[REDACTED]</u>	
Comprehensiveness of Safety & Health Program Written? <u>Y</u> <u>(N)</u> Copy Enclosed? <u>Y</u> <u>(N)</u> Communication of Program to Employees How? <u>Bulletin Board & Safety Posters</u> Safety Meetings Frequency? <u>No set times dates etc</u> By Whom? <u>Foreman & Supervisors</u> Enforcement: <u>Foreman talks to person then</u> How? <u>Letter in pers. file</u> Safety Training Program <u>0 1 2 3</u> Health Training Program <u>0 1 2 3</u> Safety Staff <u>Sledge (Y) N</u> Health Staff <u>(Y) N Dr. J.C. Guin</u> Accident/Injury Investigations Performed <u>[REDACTED]</u> Preventative Action Taken <u>(Y) N</u>		16. FOLLOW UP INSPECTION RECOMMENDED <u>Y</u> 17. CSO Date & Date of Follow Up <u>[REDACTED]</u> 18. Accompanied By <u>GARY Sherrill + Mike Cashio</u>	

20. ADDITIONAL COMMENTS

This inspection was started by CSM Hirano on 8/12 as a result of an employee complaint. The place of employment was the list to receive a general scheduled complete inspection under Foundry inspection program, for this reason Mr. Hirano and Mr. Wyatt scheduled the complete wall to wall safety and health inspection. opening conference was held with management by Mr. Hirano on 8/12 following the opening conference an orientation walk through started. Mr. Hirano, Sheerill, & Cashio completed this walk through on 8/25/78. During the course of this initial phase Mr. Hirano was notified that a two week class assignment in Chicago had approved and he was scheduled to attend. This with no assignment of acting team supervisor for two weeks have delayed the inspection for 4 weeks. Mr. Wyatt decided it would be in the best interest of the Company and the department to assign another CSM to complete the inspection. Mr. Powers because of his NEP training and Foundry experience was assigned by Mr. Wyatt to complete this inspection. Mr. Hirano on 8/25/78 after learning of the change in scheduled, call Mr. Luna and explained the change to him.

On 8/28/78 at 8 AM T (Powers) reported to Mr. Duncan's office arranged by Mr. Hirano & Luna. I was told that Mr. Duncan, another meeting and that I should report to Mr. Joe Slodge start the safety inspection. Mr. Slodge offered full cooperation did alter his schedule in many cases, so that all areas and open could be inspected.

During the course of the inspection Mr. Slodge and Gibson openly admitted that the companies safety programs had diminished and in many cases did not exist. Examples were:

1. Lack of cooperation and coordination between employees and management to detect and resolve safety deficiencies.
2. Very little effort to maintain equipment in safe condition:

- (a) Broken wooden ladders generally through out facility.
- (b) Exposed live electrical equipment generally through out.
- (c) Machine guarding poor in many areas.
- (d) No set program on use of PPE.
- (e) Many many others as noted on the attached 18a.

3. The company has no one appointed that has time to keep and maintain a safety program. Mr. Slodge has the title, however I feel he has less than 5% of time for safety. His job as chief Eng takes most of his time.

4. In my opinion the company needs a safety manager.

Cont.

20. ADDITIONAL COMMENTS

Summons to District Conference

On 11/23/78, AMI & 9/23/78 OSHA's Union and Team entered and subsequently held a company conference. I learned that the Union had been given the right to have a Vice-President for management training (See attached document) and a Chairman for the company (Checklist for routine union representation). The Union advised management on the complaint and we would make a general health/safety presentation to the employees. The objectives and mechanics of the EIP program were given. The OSHA-NAF is here to give him some help on the scope of the inspection.

Union was very interested by the complaint and asked to know what it was. I could not furnish that information. The complaint had requested his name not be released. Union was concerned that anyone from "International Union" representative in a plant committee could file a complaint and that we had no procedure to determine the validity of the complaint. He insisted all items alleged on the complaint were true and told us he expected us to address each one at the next inspection. (We later learned that the complaint was not true but his phone number in the building of the complaint instead of the firm's phone number and we knew his identity.) Union stated they had considered their legal options but would cooperate with us.

Union advised us that they would determine when we could take a union rep with us. Their reps did regular duties and at times could not be released due to absences, etc. We gave them 1-2 days lead time on the areas to inspect and let them bring a rebel for the rep in that specific area. They then made a initial walk-around.

The following day (3/24/73) Ray began looking for and injuries. He also obtained copies of 11/71's and 1/73's dating back to 11/75 and forwarded them to Union. Ray compiled a detailed list of first aid injuries we have in latter support activities for PPE.

Cont. from page 1

Closing Conference with Union representatives 10/16/78 10.
Attached list of persons in attendance.
CSHO's Powers & Cashie present.

A joint closing conference with employer and employee representatives was not practical because the individual conferences were set up prior to program directive #200- and it was not convenient to change the times etc. CSH explained the reason for separate closing conferences and advised the employees of their right to participate in any subsequent conferences. Employees were also advised that they would receive copies of all citations and Notification of penalty. Publications were given to union repa (see attached notes). Citation processing explained, follow-up procedure explained, methods of computing abatement dates and the employer's rights pertaining to same. All alleged violations were reviewed. PPE requirements were discussed in detail. Some remarks by Mr. Sewell indicated some resistance. It was also explained that the requirements by law are not limited to those disclosed during the inspection and that the general standard safety requirements were minimum acceptable compliance. Employees may elect to add to these requirements to increase overall safety in the work place.

Management Closing Conference 10/17 - 10/19/78

Closing conference booklet 3030 was given to each representative and all items reviewed by CSHO Powers. General requirements of program directive #200-82 explained. Safety programming was discussed. All alleged violations were reviewed and discussed. Management indicated no resistance to any of the alleged violations at this time. Mr. Duncan asked about how much the penalty would be. I explained the method used to calculate the penalty and told them the number of serious violations. I explained the amount of penalty would be recommended by CSHO to \$0. and would be placed on the citation when issued. A long discussion started on the abatement dates. At 5:15 PM I suggested I return on 9/19/78 to confirm the abatement dates and answer any other questions. Management agreed and we adjourned.

On 10/19/78 the management ^{union} ~~opening~~ conference was again ~~reviewed~~. Each item on the various 1 Ba were reviewed again. Abatement dates were discussed. Management seem to agree with the conditions ~~on~~ willing to abate, however they felt it would be a major undertaking in almost all areas, and I agree. The abatement dates listed on the 1 & are generally what management asked for ~~in~~ computing their dates. The overall abatement process had to be consistent. The plant has recently reduced their work force by 1/2 and according to management the company has not made money in the past 5 years. The abatement cost is one of major concern. Mr. Duncan indicated this factor may be the one that broke the company back, so to speak meaning this cost along with the other financial problems may cause the plant to be closed.

CITATION and NOTIFICATION OF PENALTY

Birmingham Area Office
2047 Canyon Road
Birmingham, Alabama 35216

1	1
Serious	1

to The Central Foundry Company
P. O. Box 188
Holt, Alabama 35401

11	173	P-634	475
REGION	AREA	PAGE	
4	0350		23

INSPECTION DATE
8/23/78 - 10/18/78
INSPECTION SITE
Holt Road

THE LAW REQUIRES that a copy of this Citation be posted immediately in a prominent place at or near the location of the violation(s) cited below. The Citation must remain posted until the violation(s) cited below have been corrected or for 3 working days (excluding weekends and Federal holidays) whichever is longer.

PENALTIES ARE DUE WITHIN 15 DAYS OF RECEIPT OF THIS NOTIFICATION UNLESS CONTESTED (See enclosed Booklet)

This Section Be Detached Before Posting

This citation describes violations of the Occupational Safety and Health Act of 1970. The penalty(ies) listed below are based on these violations. You must correct the violations referred to in this citation by the dates listed below and pay the penalties proposed, unless within 15 working days (excluding weekends and Federal holidays) from your receipt of this citation and penalty you mail a notice of contest to the U.S. Department of Labor Area Office at the address shown above. (See the enclosed booklet which outlines your responsibilities and courses of action and should be in conjunction with this form.)

NUMBER	DATE, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
1a	CFR 1910.94(a)(5)(ii)(b): Abrasive blasting respirator(s) were not worn by all abrasive blasting operator(s) using silica sand in manual blasting operations where the nozzle and blast were not physically separated from the operator in an exhaust ventilated enclosure: Abrasive blasting operation located in area adjoining the industrial castings department (respirator program in compliance with 1910.134 must be instituted in connection with use of an abrasive blasting respirator), on or about 8/29/78.	12/18/78 ✓ 11/18	\$630
1b	CFR 1910.95(a): Protection against the effects of noise was not provided for employee(s) exposed to sound levels which exceeded those listed in Table G-16 of subpart G of 29 CFR part 1910: Hearing protection was not worn by all exposed employees in the: ✓ a) #6 Foundry. ✓ b) #6 Mill. ✓ c) #3 Foundry Core Room. ✓ d) #3 Foundry. ✓ e) Link Belt Department. ✓ f) #4 Mill. ✓ g) #4 Foundry, including hot crane operators. ✓ h) Semi continuous department. ✓ i) Industrial Castings. ✓ j) 5' Millroom. ✓ k) 10' Millroom. ✓ l) Mill abrasive saw operator. On or about 10/18/78.	1-18 12/18/78 ✓ 10/18/80 ✓ 74. 8/21/79 OK BP	\$1,000
16b	29 CFR 1910.95(b)(1): Employee(s) were subjected to sound levels exceeding those listed in Table G-16 of subpart G of 29 CFR part 1910 and feasible administrative or engineering controls were not utilized to reduce sound levels:	12/18/78 ✓	

AREA DIRECTOR

G. L. Kett

NOTICE TO EMPLOYEES - The law gives an employee or his representative the opportunity to object to any abatement date set for a violation if he believes the date to be unreasonable. The contest must be mailed to the U.S. Department of Labor Area Office at the address shown above within 15 working days (excluding weekends and Federal holidays) of the receipt by the employer of this citation and penalty.

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EMPLOYER RESPONSIBILITIES AND COURSES OF ACTION - The enclosed booklet outlines employer responsibilities and

Page 1
TOTAL PENALTY FOR CITATION
\$1,630
DOL
Area Office

SHO No. P4685	2. Report No. 475	3. Date/Time 8/29/78	4a. Type OS	4b. Number 1	Page 1
5. In No. 15	6. Instance -	7. Standard Allegedly Violated 1910.94(a)(5)(ii)(b)	8. Abatement Period Almo (30d)	9. No. of Inj.	10. REC.
SAVE ID Code 1-43-1	Tape Ref. No.		b. A/D/V/Variable Information.		

abrasive blasting operation located in area adjoining the Industrial Castings Dept
(which requires program in compliance with 1910.134 must be made in connection
with use of an abrasive blasting respirator)

1. DISTANCE DESCRIPTION (a. Hazardous Oper.; Condu. Acc.; b. Equip.; c. Location; and d. Injury/Ill.)

- A) SANDBLASTING, NO DANGER CONTROL (No Abrasive Blasting Resp. Worn)
- B) SAND BLASTING, NO DANGER CONTROL
- C) SAND BLASTING, NO DANGER CONTROL, Industrial Castings
- D) CUTS - other injuries resulting from high pressure sand blast such as loss of skin in exposed areas of body (FACE)
- SILICOSIS Possible

Respirator - NURDY 7100-38, GGG/12

BLASTING IN THIS LOCATION FOR 3 MONTHS

Measurements.

13. PHOTO

NO DUST SAMPLES TAKEN, ~~THE~~ SNAPPY HAZARD IS EVIDENT
Silica Dust exposure is HIGHLY LIKELY, ~~the~~ Respirator was used but
NO Respirator Program

14. PHOTO

a. Occupation (E & Employer)	b. No.	c. Total Duration	d. Frequency	e. Exposed Employee - Name, Address & Phone
SAND BLASTING	2	5 YR 24 HR 24	8 hr/da (BLASTING 24 HRS/DA)	[REDACTED]
SAND BLASTING	2	18 YR 24 HR	8 hr/da	[REDACTED]

Cont'd

EMPLOYER KNOWLEDGE.

Abrasive blasting Respirator was supplied BUT NOT USED

COMMENTS (Employer, Employee, Closing Conf.)

STILL TOOKS WORK NOT WITH DERN CHANGES, PLUS - SMALL
MISSED BUT DUE TO WORK, CAN'T HAVE WELL, THAT IS WHY HE WON'T WEAR IT
Traffic.

tech speed to Joe Study by phone wants 2nd, due to number of letters

Cont'd

OTHER EMPLOYER INFORMATION

N/A

CLASSIF

a. Prob. of Injury/Ill or b. No. Cal. Days Uncon.	c. Gravity-Based Penalty	d. Times Repeated/ Degree Of Willful	e. Proposed Adjusted Penalty
A	7000	-	11 Size 21 Good Faith 31 History 41 Total

Area Office

35216

CITATION NO.

3

3

INSPECTION DATE

8/23 - 10/18/78

INSPECTION SITE

Holt Road
Holt, Alabama

THE LAW REQUIRES that a copy of this Citation be posted immediately in a prominent place at or near the location of the violation(s) cited below. The Citation must remain posted until the violations cited below have been corrected, or for 3 working days (excluding weekends and Federal holidays) whichever is longer.

PENALTIES ARE DUE WITHIN 15 DAYS OF RECEIPT OF THIS NOTIFICATION UNLESS CONTESTED (See enclosed Booklet)

This Section Must Be Detached Before Posting

Citation issued on 2/23/79 is Amended:

The Central Foundry Company
Post Office Box 1888
Holt, Alabama 35401

This citation describes violations of the Occupational Safety and Health Act of 1970. The penalty(ies) listed below are based on these violations. You must correct the violations referred to in this citation by the dates listed below and pay the penalties proposed, unless within 15 working days (excluding weekends and Federal holidays) from your receipt of this citation and penalty you mail a notice of contest to the U.S. Department of Labor, Area Office at the address shown above. (See the enclosed booklet which outlines your responsibilities and courses of action and should be read in conjunction with this form.)

NUMBER	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
STANDARD, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION		
(Revised as shown below) CFR 1910.1000(c): Employee(s) were exposed to material(s) in excess of the 8-hour time weighted average limit(s) listed for that material(s) in table Z-3 of subpart Z of 29 CFR part 1910: Free silica containing dust at the following areas - AS OF 9/4/78 ✓ (a) Linkbelt holeman. DOWN 2 (b) No. 6 foundry permanent mold - core and iron pouring areas. ✓ (c) 5-foot mill - millers, <u>grinders</u> , chippers. <i>ALL GRINDERS STOPPED</i> ✓ (d) 10-foot mill - millers and <u>grinders</u> . <i>Now using secondary</i> ✓ (e) 5-foot centrifugal casting department - operators, <u>valvemen</u> , <u>cranemen</u> , and core pinners. <i>2-3 out of 4</i> ✓ (f) Linkbelt miller. DOWN ✓ (g) No. 6 foundry permanent mold shakeout. DOWN ✓ (h) 10-foot centrifugal casting department - pipe roller. <i>3 out of 3 shut 1 part time</i>	2/25/80	\$900
(Revised as shown below) CFR 1910.1000(e): Feasible administrative or engineering controls are not determined and implemented to reduce employee exposure(s): (a) No. 6 foundry permanent mold - core and iron pouring areas, shakeout. (b) 5-foot mill - millers, <u>grinders</u> , chippers. (c) 10-foot mill - millers and <u>grinders</u> . (d) 5-foot centrifugal casting department - operators, <u>valvemen</u> , <u>cranemen</u> , pipe rollers, and core pinners, Linkbelt miller.		

AREA DIRECTOR

C. L. Wyatt

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EMPLOYER RESPONSIBILITIES AND COURSES OF ACTION - The enclosed booklet outlines employer responsibilities and courses of action and should be read in conjunction with this notification.

CITATION AND NOTIFICATION OF PENALTY

OSHA 2 REV. 5/76

TOTAL PENALTY FOR THIS CITATION: \$900
Make check or money order payable to "DOL OSH" - Indicate OSH on Remittance

Birmingham Area Office
2047 Canyon Road
Birmingham, Alabama 35216

TYPE OF VIOLATION(S)	CITATION NO.
PERMANENT	3

Citation issued on 2/23/79 is Amended:

The Central Foundry Company
Post Office Box 186
Holt, Alabama 35401

INSPECTION DATE
8/23 - 10/18/78
INSPECTION SITE
Holt Road
Holt, Alabama

THE LAW REQUIRES that a copy of this Citation be posted immediately in a prominent place at or near the location of the violation(s) cited below. The Citation must remain posted until the violations cited below have been corrected, or for 3 working days (excluding weekends and Federal holidays) whichever is longer.

PENALTIES ARE DUE WITHIN 15 DAYS OF RECEIPT OF THIS NOTIFICATION UNLESS CONTESTED (See enclosed Booklet)

This Section May Be Detached Before Posting

This citation describes violations of the Occupational Safety and Health Act of 1970. The penalty(ies) listed below are based on these violations. To correct the violations referred to in this citation by the dates listed below and pay the penalties proposed, unless within 15 working days (excluding weekends and Federal holidays) from your receipt of this citation and penalty you mail a notice of contest to the U.S. Department of Labor Office at the address shown above. (See the enclosed booklet which outlines your responsibilities and courses of action and should be read in conjunction with this form.)

NUMBER OARD, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
(a) 10-foot centrifugal casting department - pipe roller.		
Step 1 - Effective respiratory protection shall be provided and used by employee(s) as an interim protective measure.	3/18/79	
Step 2 - A written detailed plan of abatement leading to the complete abatement of this item shall be submitted to the Area Director. Such a plan shall: a) employ the use of qualified engineering personnel; b) include detailed engineering studies and their results; c) outline the ordering of equipment and materials and completion of the design phase; and d) outline dates for the anticipated implementation of the plan.	Extended 8/25/79 5/28/79	
Step 3 - Feasible engineering controls and/or administrative controls shall be determined.	8/23/79	
Step 4 - Abatement shall be completed by implementation of feasible engineering and/or administrative controls and its effectiveness at achieving compliance verified. 90-day progress letters are requested during the abatement period.	Amended 2/25/80 8/25/80	
(Revised as shown below) CFR 1910.134(a)(2): The employer did not establish and maintain a respiratory protection program which included the requirements outlined in paragraph (b) of this section:	4/30/79	
In the following work areas -		
(a) Linkbelt holman.		
(b) No. 6 foundry permanent mold - iron pouring and core areas, shakeout.		
(c) 5-foot mill - millers, chippers and grinders.		

EA DIRECTOR

L. Wyatt

ICE TO EMPLOYEES - The law gives an employee or his representative the opportunity to object to any abatement date or a violation if he believes the date to be unreasonable. contest must be mailed to the U.S. Department of Labor Office at the address shown above within 15 working days (excluding weekends and Federal holidays) of the receipt by the employer of this citation and penalty.

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TOTAL PENALTY FOR THIS CITATION
Make check or Money Order Payable To "DOL-OSHA"
Indicate OSHA No on Remittance

EMPLOYER RESPONSIBILITIES AND COURSES OF ACTION - The enclosed booklet outlines employer responsibilities and courses of action and should be read in conjunction with this notification.

CITA

NOTIFICATION OF PENALTY

OSHA 2 REV. 5/76

CITATION and NOTIFICATION OF PENALTY

Birmingham Area Office
2047 Canyon Road
Birmingham, Alabama 35216

5/24/79		P4684-475	
REGION	AREA	PAGE	
4	0150	3	3

TYPE OF VIOLATION(S)	CITATION NO.
SERIOUS	3

INSPECTION DATE
8/23 - 10/18/78
INSPECTION SITE
Holt Road
Holt, Alabama

THE LAW REQUIRES that a copy of this Citation be posted immediately in a prominent place at or near the location of the violation(s) cited below. The Citation must remain posted until the violations cited below have been corrected, or for 3 working days (excluding weekends and Federal holidays) whichever is longer.

PENALTIES
ARE DUE
WITHIN 15
DAYS OF
RECEIPT
OF THIS
NOTIFICATION
UNLESS
CONTESTED
(See enclosed
Booklet)

TO:

The Central Foundry Company
Post Office Box 186
Holt, Alabama 35401

This Section Must
Be Detached
Before Posting

Citation describes violations of the Occupational Safety and Health Act of 1970. The penalty(ies) listed below are based on these violations. You must correct the violations referred to in this citation by the dates listed below and pay the penalties proposed, unless within 15 working days (excluding weekends and Federal holidays) from your receipt of this citation and penalty you mail a notice of contest to the U.S. Department of Labor Area Office at the address shown above. (See the enclosed booklet which outlines your responsibilities and courses of action and should be read in conjunction with this form.)

VIOLATION NUMBER	BOARD, REGULATION OR SECTION OF THE ACT VIOLATED:	DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
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- (d) 10-foot mill - grinders and millers.
- (e) 5-foot centrifugal casting department - operators, valvemmen, cranimen, pipe roller, and core primers.
- (f) Linkbelt miller.
- (g) 10-foot centrifugal casting department - pipe roller.

DIRECTOR

Wyatt

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TOTAL PENAL
FOR THIS
CITATION
Make check or Money
Order Payable to
"DOL-OSHA"
Indicate OSHA
on Remittance

Birmingham Area Office
2047 Canyon Road
Birmingham, Alabama 35216

REGION 4 AREA 0350

TYPE OF VIOLATION(S)	CITATION NO.
Serious	3

INSPECTION DATE
8/23/78 - 10/18/78
INSPECTION SITE

Bolt Road

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This Section Must Be Detached Before Posting

The Central Foundry Company
PO Box 186
Bolt, AL 35401

This citation describes violations of the Occupational Safety and Health Act of 1970. The penalty(ies) listed below are based on these violations. To correct the violations referred to in this citation by the dates listed below and pay the penalties proposed, unless within 15 working days (excluding weekends and Federal holidays) from your receipt of this citation and penalty you mail a notice of contest to the U.S. Department of Labor Office at the address shown above. (See the enclosed booklet which outlines your responsibilities and courses of action and should be read in conjunction with this form.)

NUMBER AND REGULATION OR SECTION OF THE ACT VIOLATED:	DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
violations described in this citation are alleged to have occurred on or about the day the inspection was made unless otherwise indicated in the description given below.			
29 CFR 1910.1000(c):	Employee(s) were exposed to material(s) in excess of the 8-hour time weighted average limit(s) listed for that material(s) in table Z-3 of subpart Z of 29 CFR part 1910: Free silica containing dust at the following areas: a) Linkbelt Holesman b) #6 foundry permanent mold - core and iron pouring areas c) Five foot mill - millers, grinders, chippers d) Ten foot mill - millers and grinders	2/25/80	\$900
29 CFR 1910.1000(e):	Feasible administrative or engineering controls not determined and implemented to reduce employee exposure(s): A) #6 foundry permanent mold - core and iron pouring areas; five foot mill - millers, grinders, chippers; C) ten foot mill - millers and grinders. Step 1 - Effective respiratory protection shall be provided and used by employee(s) as an interim protective measure. Step 2 - A written detailed plan of abatement leading to the complete abatement of this item shall be submitted to the Area Director. Such a plan shall: a) Employ the use of qualified engineering personnel; b) Include detailed engineering studies and their results; c) Outline the ordering of equipment and materials and completion of the design phase; and d) Outline dates for the anticipated implementation of the plan. Step 3 - Feasible engineering controls and/or administrative controls shall be determined. Step 4 - Abatement shall be completed by implementation of feasible engineering and/or administrative controls and its effectiveness at achieving compliance verified. 90-day progress letters are requested during the abatement period.	3/18/79 5/28/79 8/23/79 2/25/80	

DIRECTOR

G. L. WATTS

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On Last

1845 PENALTY FOR THIS CITATION

Make Remittance Order Payable To "DOL OSHA" Indicate OSHA No on Remittance

Birmingham Area Office
2047 Canyon Road
Birmingham, Alabama 35216

REGION 4 AREA 0350 PAGE 2 of 3

TYPE OF VIOLATION(S)	CITATION NO.
Serious	3

INSPECTION DATE
8/23/78 - 10 /18/78
INSPECTION SITE

Holt Road

TO The Central Foundry Company
PO Box 186
Holt, AL 35401

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ITEM NUMBER	STANDARD, REGULATION OR SECTION OF THE ACT VIOLATED: DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED
1c	29 CFR 1910.134(a)(2): The employer did not establish and maintain a respiratory protection program which included the requirements outlined in paragraph (b) of this section: * In the following work areas: A Linkbelt - - - - - Holesman B #6 foundry permanent mold, iron pouring and core areas, <i>silica</i> C Five foot mill - millers, chippers and grinders D Ten foot mill, grinders and millers.	4/30/79
1d	29 CFR 1910.134(b)(1): Written standard operating procedures governing the selection and use of respirators were not established: (See Item 1c(a) above).	
1e	29 CFR 1910.134(b)(2): Respirator(s) were not selected on the basis of hazards to which the worker was exposed: (See Item 1c(a) above).	
1f	29 CFR 1910.134(b)(3): The users of respirators were not instructed and trained in the proper use of respirators and their limitations: (See Item 1c(a) above).	
1g	29 CFR 1910.134(b)(4): Where practicable, the respirators were not assigned to individual workers for their exclusive use: (See Item 1c(a) above).	
1h	29 CFR 1910.134(b)(5): Respirators were not regularly cleaned and disinfected: (See Item 1c(a) above).	
1i	29 CFR 1910.134(b)(6): Respirators were not stored in a convenient, clean and sanitary location: (See Item 1c(a) above).	
1j	29 CFR 1910.134(b)(7): Respirators used routinely were not inspected during cleaning and worn or deteriorated parts replaced: (See Item 1c(a) above).	

AREA DIRECTOR

G. L. WYATT

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CITATION AND NOTIFICATION OF PENALTY
CASE FILE COPY

OSHA 2 REV. 7

On L
Page
TOTAL PE
FOR T
CITAT
Make check
Order Pay
DOLO
Indicate OS
on Remit

Birmingham Area Office
2047 Canyon Road
Birmingham, Alabama 35216

2/23/79 P4006- 475

REGION	AREA	PAGE
4	0350	3 of 3

PENALTIES
ARE DUE
WITHIN 15
DAYS OF
RECEIPT
OF THIS
NOTIFICATION
UNLESS
CONTESTED
(See enclosed
Booklet)

TYPE OF VIOLATION(S) CITATION NO.

Serious

3

INSPECTION DATE 10/18/ 78
8/23/78

INSPECTION SITE
Holt Road

TO The Central Foundry Company
PO Box 186
Holt, AL 35401

THE LAW REQUIRES that a copy of this
Citation be posted immediately in a promi-
nent place at or near the location of the vio-
lation(s) cited below. The Citation must
remain posted until the violations cited be-
low have been corrected or for 3 working
days (excluding weekends and Federal holi-
days) whichever is longer.

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ITEM NUMBER AND/OR REGULATION OR SECTION OF THE ACT VIOLATED:	DESCRIPTION	DATE BY WHICH VIOLATION MUST BE CORRECTED	PENALTY
--	-------------	---	---------

k
9 CFR 1910.134(b)(8): Appropriate surveillance of work area con-
ditions and degree of employee exposure or stress was not maintained;
See Item lc(a)

L
9 CFR 1920.134(b)(9): There were no regular inspections and eval-
uations to determine the continued effectiveness of the respirator
program. (See Item lc(a)

J
9 CFR 1910.134(b)(10): Persons were assigned to tasks requiring
use of respirators and it had not been determined that they were
physically able to perform the work and use the equipment, and the
respirator user's medical status was not reviewed periodically (for
at least annually); (See Item lc(a)

n
9 CFR 1910.134(b)(11): Approved or accepted respirators were not
used when they were available:

A DIRECTOR

C. L. WYATT

\$900

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representative the opportunity to object to any abatement date
if he believes the date to be unreasonable. The objection
must be mailed to the U.S. Department of Labor
Office at the address shown above within 15 working days
(including weekends and Federal holidays) of the receipt by
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filing a complaint or for exercising any rights under this Act.
An employee who believes that he has been discriminated
against may file a complaint no later than 30 days after the
discrimination with the U.S. Department of Labor Area Office
at the address shown above.

TOTAL PENALTY
FOR THIS
CITATION
Make check or Money
Order Payable To
"DOL OSHA"
Indicate OSHA No.
on Remittance

WORKSHEET

CSHO No. 24684	2. Report No. 475	3. Date/Time 2/15/79 6:00 PM	4a. Type S	4b. Number 3	Page 1
Item No. 1a	5. Instance E-H	7. Standard Allegedly Violated 10.1000(c)	8. Abatement Period Previously listed		9. No. of inst. 8
1. SAVE ID Code NONE		6. Trade Ref. No. NONE	b. AVD/Variable Information.		

ADD to EXISTING LOCATIONS ON CITATION #3

E) S' Centrifugal casting department - operators, maintenance, and core producers

F) Linkbelt Mules

G) #6 Foundry permanent mold shakeout

INSTANCE DESCRIPTION (a. Material; b. Date; c. Acc.; d. Equip.; e. Location; and f. Injury/Illness):

A) Employees are exposed to free silica at several steps in the manufacturing process of cast iron pipe and fittings.

B) N/A

C) See attached sampling data sheets for job positions sampled

D) Silicosis

Measurements: RESAMPLE = These positions were resampled in accordance with IHFOM procedures when initial sampling was inconclusive (gray area). A short discussion on several of descriptions is attached and a general summary is attached.

13. PHOTO

a. Occupation (s) Employer	b. No.	c. Total Duration	d. Frequency	e. Exposed Employee - Name, Address & Phone
See Attached Sampling Data Sheets				

EMPLOYER KNOWLEDGE: Previous citation (1973) on silica, Silica involved in process

COMMENTS (Employer, Employee, Closing Conf.):

OTHER EMPLOYER INFORMATION

CLASSIF.: N X Y 5 IN IN	14. Penalties			
a. Prob. of Injury/Ill. or b. No. Cal. Days Uncorr.	b. Gravity-Based Penalty	c. Times Repeated/Degree Of Willful	d. Adjustment Factors	
		1) Size 2) Good Faith 3) History 4) Total		e. Proposed Adjusted Penalty

12.5. Soil / initial sample results is contained in the
 1H. section of the original lettering.

NOTES

1) Production in the 5' centrifugal casting department was normal on the day last sampled (2/16/75). Production was down somewhat the next day - the virus sampled. Permanent reduction - #6 from avg. 40 tons/day but made only 35 tons on 2/16/75. Link Belt department is #1 foundry averaging 16 tons/day. On 2/16/75, they made 16 tons (Baker furnished by Frank Gustafson, Eng. Dept.)

2) Permissible and actual exposures are calculated on the individual sample sheets returned from SCL. Error factors are calculated below. First applying error factor to the permissible level and then to the actual level.

Sample	Permissible level	Actual level	Result
23-14	$625 \times 1.25 = 781$	728	Violation not down
23-15	$476 \times 1.25 = 595$	657	in violation
23-16	$342 \times 1.25 = 427$	316	Violation not down
23-17	$811 \times 1.25 = 1014$	1344	in violation
23-20	$764 \times 1.25 = 961$	1263	in violation
23-23	$586 \times 1.25 = 735$	811	in violation
23-24	$555 \times 1.25 = 694$	1015	in violation
23-25	$526 \times 1.25 = 658$	876	in violation

Sample	Permissible level	Actual level	Result
23-14	625	$728 \times .75 = 546$	no violation
23-15	476	$657 \times .75 = 493$	in violation
23-16	342	$316 \times .75 = 237$	no violation
23-17	811	$1344 \times .75 = 1014$	in violation
23-20	764	$1263 \times .75 = 947$	in violation
23-23	588	$811 \times .75 = 608$	in violation
23-24	555	$1015 \times .75 = 761$	in violation
23-25	526	$876 \times .75 = 657$	in violation

3) Calibration data attached

4) Error factor accompanied on the surveys.

CSHO No. 24084	2. Report No. 475	3. Date/Time 2/15/79 6:00 AM	4a. Type S	4b. Number 3	Page 2	0. 3
Item No. 16	6. Instance -	7. Standard Allegedly Violated 10.1000(e)	8. Abatement Period Previously listed	9. No. of Inst. 2	10. REC ✓	
a. SAVE ID Code 29711		Type Ref. No. none		b. AVD/variable information.		

4) Employees are exposed to free silica for which feasible engineering and/or administrative controls have not been implemented

B) N/A

c) See attached sampling data sheets for jet-bring tions and locations sampled

D) Silicosis

MEASUREMENTS: NE-HH-P-E - Sample with Bendix Model 44 personal sampling pump. Resampling at position where no sample was inconclusive. See attached Sampling of Point Source. 13. PHOTO
- after 20th / B pump / of 3

a. Occupation (& Employer) | b. No. | c. Total Duration | d. Frequency | e. Exposed Employee - Name, Address & Phone

See Attached Sampling Data Sheets

Cont'd

EMPLOYER KNOWLEDGE: High administrative knowledge of school problems

5 COMMENTS (Employer, Employee, Closing Conf.)

7 OTHER EMPLOYER INFORMATION

B CLASSIF..		1. Penalties are categorized as follows: a. 1-1000 dollars b. 1001-5000 dollars c. 5001-15000 dollars d. 15001-25000 dollars e. 25001-50000 dollars f. 50001-100000 dollars g. 100001-250000 dollars h. 250001-500000 dollars i. 500001-1000000 dollars j. 1000001-2500000 dollars k. 2500001-5000000 dollars l. 5000001-10000000 dollars m. 10000001-25000000 dollars n. 25000001-50000000 dollars o. 50000001-100000000 dollars p. 100000001-250000000 dollars q. 250000001-500000000 dollars r. 500000001-1000000000 dollars s. 1000000001-2500000000 dollars t. 2500000001-5000000000 dollars u. 5000000001-10000000000 dollars v. 10000000001-25000000000 dollars w. 25000000001-50000000000 dollars x. 50000000001-100000000000 dollars y. 100000000001-250000000000 dollars z. 250000000001-500000000000 dollars aa. 500000000001-1000000000000 dollars ab. 1000000000001-2500000000000 dollars ac. 2500000000001-5000000000000 dollars ad. 5000000000001-10000000000000 dollars ae. 10000000000001-25000000000000 dollars af. 25000000000001-50000000000000 dollars ag. 50000000000001-100000000000000 dollars ah. 100000000000001-250000000000000 dollars ai. 250000000000001-500000000000000 dollars aj. 500000000000001-1000000000000000 dollars ak. 1000000000000001-2500000000000000 dollars al. 2500000000000001-5000000000000000 dollars am. 5000000000000001-10000000000000000 dollars an. 10000000000000001-25000000000000000 dollars ao. 25000000000000001-50000000000000000 dollars ap. 50000000000000001-100000000000000000 dollars aq. 100000000000000001-250000000000000000 dollars ar. 250000000000000001-500000000000000000 dollars as. 500000000000000001-1000000000000000000 dollars at. 1000000000000000001-2500000000000000000 dollars au. 2500000000000000001-5000000000000000000 dollars av. 5000000000000000001-10000000000000000000 dollars aw. 10000000000000000001-25000000000000000000 dollars ax. 25000000000000000001-50000000000000000000 dollars ay. 50000000000000000001-100000000000000000000 dollars az. 100000000000000000001-250000000000000000000 dollars ba. 250000000000000000001-500000000000000000000 dollars bb. 500000000000000000001-1000000000000000000000 dollars bc. 1000000000000000000001-2500000000000000000000 dollars bd. 2500000000000000000001-5000000000000000000000 dollars be. 5000000000000000000001-10000000000000000000000 dollars bf. 10000000000000000000001-25000000000000000000000 dollars bg. 25000000000000000000001-50000000000000000000000 dollars bh. 50000000000000000000001-100000000000000000000000 dollars bi. 100000000000000000000001-250000000000000000000000 dollars bj. 250000000000000000000001-500000000000000000000000 dollars bk. 500000000000000000000001-1000000000000000000000000 dollars bl. 1000000000000000000000001-2500000000000000000000000 dollars bm. 2500000000000000000000001-5000000000000000000000000 dollars bn. 5000000000000000000000001-10000000000000000000000000 dollars bo. 10000000000000000000000001-25000000000000000000000000 dollars bp. 25000000000000000000000001-50000000000000000000000000 dollars bq. 50000000000000000000000001-100000000000000000000000000 dollars br. 100000000000000000000000001-250000000000000000000000000 dollars bs. 250000000000000000000000001-500000000000000000000000000 dollars bt. 500000000000000000000000001-1000000000000000000000000000 dollars bu. 1000000000000000000000000001-2500000000000000000000000000 dollars bv. 2500000000000000000000000001-5000000000000000000000000000 dollars bw. 5000000000000000000000000001-10000000000000000000000000000 dollars bx. 10000000000000000000000000001-250000000000000000000000000000 dollars by. 25000000000000000000000000001-500000000000000000000000000000 dollars bz. 50000000000000000000000000001-1000000000000000000000000000000 dollars ca. 100000000000000000000000000001-2500000000000000000000000000000 dollars cb. 250000000000000000000000000001-5000000000000000000000000000000 dollars cc. 500000000000000000000000000001-10000000000000000000000000000000 dollars cd. 1000000000000000000000000000001-25000000000000000000000000000000 dollars ce. 2500000000000000000000000000001-50000000000000000000000000000000 dollars cf. 5000000000000000000000000000001-100000000000000000000000000000000 dollars cg. 10000000000000000000000000000001-250000000000000000000000000000000 dollars ch. 25000000000000000000000000000001-500000000000000000000000000000000 dollars ci. 50000000000000000000000000000001-1000000000000000000000000000000000 dollars cj. 100000000000000000000000000000001-2500000000000000000000000000000000 dollars ck. 250000000000000000000000000000001-5000000000000000000000000000000000 dollars cl. 500000000000000000000000000000001-100	
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WORKSHEET

CSHO No. 24684	2 Report No. 475	3 Date/Time 2/15/79 6:00 AM	4a. Type S	4b. Number 3	Page 3	0'
Item No. 1 C	6 Instance -	7 Standard Allegedly Violated 10.134 (a)(2)	8 Abatement Period Permanent		9 No of inst. 10 RE	
SAVE ID Code none		Tape Ref. No. none	d. AVD/Variable Information.			

Add to Existing Locations on Citation #31

E) S' Centrifugal casting department - operators valve men
examiners, pipe rollers, and core pinners

F) Linkbelt Muller

~~to be removed from citation~~ metal structure

G) 10' Centrifugal casting department - pipe rollers

INSTANCE DESCRIPTION (a. Hazards-Oper./Cond.-Acc.; b. Equip.; c. Location; and d. Injury/Ill.)

A) Respiratory protection program was not established and maintained to protect employees from effects of free silica.
A. pressure

B) A/A

C) See attached sampling data sheets for jobs c-d
locations sampled

D) Silicosis

Cont'd

MEASUREMENTS: REAMPLE: Positions resampled using Bendix model 44

umps in accordance with HFI 5017 procedures. These initial

impl results are inconclusive. See attached sampling data

sheet and HFI 1B page 1 of 3

13. PHOTO

R-1
F-1-11

a. Occupation (a. Employer)	b. No.	c. Total Duration	d. Frequency	e. Exposed Employee - Name, Address & Phone
See attached Sampling Data Sheets				

Cont'd

EMPLOYER KNOWLEDGE

What admitted knowledge of silica problem.

COMMENTS (Employer, Employee, Closing Cont.)

OTHER EMPLOYER INFORMATION

Cont'd

CLASSIF.

1. Factors in Consideration of Willful or Reckless Violation

PENALTY	a. Prob. of Injury/Ill. or b. No. Cal. Days Uncorr.	b. Gravity-Based Penalty	c. Times Repeated/ Degree Of Willful	d. Adjustment Factors			e. Proposed Adjusted Penalty
				1) Size	2) Good Faith	3) History	4) Total

754
May 23, 1979

~~XXXXXXXXXXXX~~
~~XXXXXXXXXXXX~~
The Central Foundry Company
P. O. Box 188
Holt, AL 35401

~~XXXXXXXXXXXX~~
~~XXXXXXXXXXXX~~
Per your request, I am listing the silica sample results we obtained during our inspection at Central Foundry:

<u>DATE</u>	<u>JOB</u>	<u>SILICA PERCENTAGE</u>	<u>MAX. PERMISSIBLE LEVEL PER mg/m³</u>	<u>ACTUAL LEVEL MEAS. PER mg/m³</u>
10/11/78	Sprayman	14	.625	.536
	Machine Operator	56	.172	.221
	Sprayman	22	.417	.286
	Craneman	24	.385	.550
	Pipelader	24	.385	.506
	Valveman	21	.435	.400
	Shakeout	16	.556	.158
	Muller	29	.323	.255
10/10/78	Muller	18	.500	.674
	~~Holeman~~	25	.323	.700
	Holeman	9	.909	.567
	Shakeout	20	.455	.124
10/6/78	Core Machine Opr.	4	1.667	.825
	Core Machine Opr.	5	1.429	.811
	Weight Changer	5	1.429	.494
	Weight Changer	2	2.5	1.494
	Molder	12	.714	.204
	muller Miller	5	1.429	1.239
	Machine Operator	2	2.5	.737
	Bench Molder	7	1.111	1.013
	Core Machine Oper.	6	1.25	.395
10/5/78	Shakeout	13	.666	.463
	Holeman	8	1.0	.973
	Shakeout	29	.323	.511
10/4/78	Molder	1	3.33	.123
	Core Mach. Opr.	2	2.5	1.491

Mr. Joe Sledge

- 2 -

May 23, 1979

<u>DATE</u>	<u>JOB</u>	<u>SILICA PERCENTAGE</u>	<u>MAX. PERMISSIBLE LEVEL PER mg/m³</u>	<u>ACTUAL LEVEL MEAS. PER mg/m³</u>
10/3/78	Grinder	13	.666	.332
	Sprayman	17	.526	.286
	Pipe Loader	33	.286	.627
9/27/78	Set-up	19	.48	.297
	Surface grinder	15	.59	.194
9/20/78	Core Machine Oper.	14	.63	1.115
	Machine Operator	33	.29	.777
	Iron Pourer	15	.59	1.36
9/7/79	Miller	33	.29	.407
	Miller	38	.25	.489
	Miller	37	.26	.397
	Wheelabrator Oper.	24	.38	.260
	Grinder	18	.50	.277
	Chipper	42	.23	.499
	Chipper	25	.37	.532
	Grinder	21	.43	.296
9/31/78	Grinder	22	.42	.604
	Grinder	35	.27	.316
	Grinder	32	.29	.462
	Miller	36	.26	.412
	Inspector	21	.43	.238
	Grinder	30	.31	.245
2/15/79	Operator	9.2	.892	.316
	Shakeout	11	.769	1.263
	Valveman	16	.555	1.015
	Core Pinner	19	.476	.807
	Sprayman	14	.625	.728
	Operator	17	.526	.876
2/16/79	Perm. Mold Shakeout	15	.586	.871
	Linkbelt Muller	9.4	.877	1.399

If we can help interpret these results or be of any other service to you, please let us know.

Sincerely,

C. L. WYATT
Area Director

GS/lp

IN THE DISTRICT COURT OF
HARRIS COUNTY, TEXAS

AUGUST GORDON, <u>et al.</u> ,	)	
	)	
Plaintiffs,	)	
	)	
vs.	)	No. 93-42852
	)	
BOB SCHMIDT, INC., <u>et al.</u> ,	)	
	)	
	)	
Defendants.	)	

AFFIDAVIT OF DARIN V. OSMOND

Before me, the undersigned authority, on this day personally appeared Darin V. Osmond, who being duly sworn, on his oath, did state as follows:

1. I am over the age of 21 and am fully competent to testify as to matters set forth in this affidavit.

2. The following documents, which are attached as exhibits to Borden, Inc.'s Motion for Summary Judgment, are true and correct copies:

"Exhibit C": Central Foundry Plaintiffs' Answers to Interrogatory No. 6;

"Exhibit D": Excerpts from Deposition of Wightman M. Cannon, Jr.;

"Exhibit E": Excerpts from Deposition of Robert Yaw;

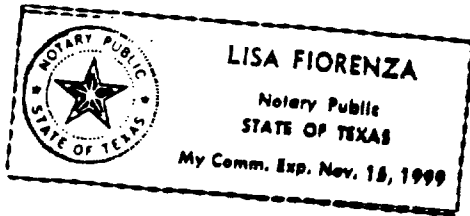
"Exhibit F": Excerpts from Deposition of Billy Don Kizziah;

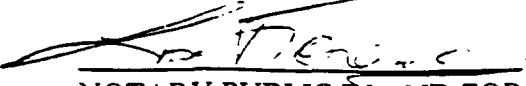
"Exhibit G": Excerpts from Deposition of John Paul Singleton;

"Exhibit J": Texas Occupational Health Regulations, OH-13-2 (1958);

"Exhibit K": OSHA citations and records related to Central Foundry (identified in Deposition of Billy Don Kizziah at 192-200 (Exhibit F)).

SUBSCRIBED AND SWORN TO BEFORE ME, the undersigned authority, on this the 9 day of April, 1998, to certify which witness my hand and seal of office.




NOTARY PUBLIC IN AND FOR
THE STATE OF TEXAS

11-15-99
My Commission Expires: