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National Safety Council

Data Sheet I-531-Rev 80

# Dusts, Fumes, and Mists in Industry

INDUSTRIAL DUSTS, fumes, and mists, their hazards and their control, are discussed in this data sheet.* The general principles presented can be applied to recognize and evaluate most industrial situations involving these air contaminants and to determine the need for controls. This data sheet is intended to guide employers, plant and safety engineers, personnel managers, and supervisors.

2. A plant manager who believes that he has a toxic or irritating airborne particulate problem should consult a competent industrial hygienist. Such help may be obtained from his own company, insurance carrier, private consultants, and from state and federal agencies.

3. To protect the health of employees who work where a dust, fume, or mist created by a manufacturing process is released into the work environment, an evaluation and a control program may be required. In such a case, three steps must be taken:

a. The properties of the specific dust, fume, or mist and its possible physiological effects on employees must be ascertained.

b. The particular exposure must be evaluated by dust counts or by chemical analyses of air samples, and a step-by-step analysis of the operations must be made to find the areas where employees are exposed to hazardous amounts of the material. The operational analysis also should determine how the dust, fume, or mist is dispersed.

c. Appropriate methods of control must be provided where indicated. The type and extent of controls will depend upon the physical, chemical, and toxic properties of the dust, fume, or mist, the evaluation made of the exposure, and the nature of the operation that disperses the contaminant. The extensive controls needed for lead oxide dust, for example, would not be needed for limestone dust, since greater quantities of limestone dust can be tolerated.

4. Except for the skin diseases, most occupational diseases are contracted by inhalation of material. Lung tissue is by far the most efficient medium the body possesses for absorbing materials. In addition, the surface area of this lung tissue averages 55 square meters or about 590 square feet.

5. Certain dusts that reach the lungs can pass directly into the blood stream and be absorbed over a long period of time. Others may stay in the lungs and set up local irritant or damaging action.

6. Toxic and irritant dusts can also be ingested in amounts that may cause trouble. If toxic dust swallowed with food or saliva is not soluble in body fluids, it is eliminated directly through the intestinal tract. Toxic materials that are readily soluble in body fluids can be absorbed in the digestive system and picked up by the blood.

7. Contact of toxic and irritant dusts with the skin also may result in skin irritation.

8. As compared to inhalation, however, both ingestion and skin contact are of relatively minor importance in industrial poisoning insofar as dusts, fumes, and mists are concerned.

*This data sheet covers toxic and irritating air contaminants encountered in industry. It does *not* include a discussion of the explosive properties of such airborne particulate matter.

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## Origin and Properties of Particulate Matter

### Sources

9. The term *dust* as used in industry is generally applied to airborne solid particles that range in size from 0.1 micrometer ($\mu$m) to 25 micrometers (one micrometer = $10^{-6}$ meter = 1/10,000 centimeter = 1/25,400 inch). Process dusts below 0.5 $\mu$m in size are rare. Dusts above 5$\mu$m in size usually will not stay airborne long enough to present an inhalation problem.

10. Dust may enter the air from various sources. It may be dispersed when a dusty material is handled, such as when lead oxide is dumped into a mixer or a product is dusted with talc. Dust may be formed and dispersed when solid materials are reduced to small sizes in processes such as grinding, crushing, blasting, shaking, and drilling. In these processes, the mechanical action of the grinding or shaking device supplies a source of energy to disperse the dust formed (Figure 1).

11. When a solid such as a metal is heated to a temperature high enough to volatilize it, the volatilized matter later condenses in cooler air to form a *fume* (Figure 2). The solid particles that make up a fume are extremely fine, usually less than 0.5 $\mu$m in size. In some cases, the hot material reacts with the air to form an oxide. Examples are lead oxide fume from smelting and iron oxide fume from arc welding. Also, a fume can be formed when a material such as magnesium metal is burned or when welding or gas cutting is done on galvanized metal.

12. A *mist* is formed when a finely divided liquid is suspended in air. An example is the oil mist produced during cutting and grinding operations.

13. *Smoke* may be formed by the incomplete combustion of organic materials. Smoke generally contains droplets as well as dry particles. Tobacco, for instance, produces a wet smoke composed of minute tarry droplets. The size of the particles contained in tobacco smoke is about 0.25 $\mu$m.

14. Radioactive dust may be dispersed in the same ways as other industrial dusts. Radium, thorium, and other radioactive elements are present in extremely minute amounts in the atmosphere.

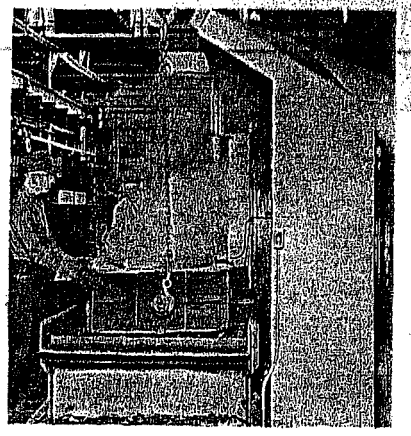

Figure 1. Dust from foundry sand is generated during the shake-out of castings. The mechanical action of the shake-out machine disperses the dust. Path taken by the dust particles as they are drawn into the hood shows the efficiency of the local exhaust system. (Courtesy American Foundrymen's Society)

### Magnitude of particulates

15. When a solid is broken into finely divided particles, its surface area is increased many times. For example, 1 cubic centimeter (0.061 cubic inch) of quartz in the form of a cube when crushed into 1 $\mu$m cubes will give $10^{12}$ (1,000,000,000,000 or one trillion) particles with a total surface area of 6 square meters (9,300 square inches), as compared with 6 square centimeters (0.930 square inch) for the original cube.

16. When a solid is broken into finely divided particles, the volume occupied by the mass is also increased because of the voids between the particles. A dust concentration of 50 million particles per cubic foot of air (mppcf), resulting from 1 cubic centimeter of material reduced to particles 1 cubic micrometer in size, will occupy an air space of 20,000 cubic feet.

17. Even smaller amounts of toxic dusts, fumes, and mists will make a workroom atmosphere hazardous. For example, the Threshold Limit Value for lead, as adopted by the American Conference of Governmental Industrial Hygienists, is 0.15 milligram per cubic meter of air (mg/m$^3$), which is 0.00000015 ounce per cubic foot. Therefore, the dispersion of only 0.0015 ounce of lead will be enough to give the Threshold Limit Value of 0.15 mg/m$^3$ of dust or fume in an air space of 10,000 cubic feet (280 m$^3$). The concentrations present in the workroom without harm to health differ for different substances.

18. A person with normal eyesight can detect dust particles as small as 50 $\mu$m in diameter. Smaller airborne particles can be detected individually by the naked eye only when strong light is reflected from them. Dust of respirable size (below 10 $\mu$m) cannot be seen without the aid of a microscope.

19. Most industrial dusts consist of particles that vary widely in size, with the small particles greatly outnumbering the large ones. With few exceptions, when dust is noticeable in the air around an operation, probably more invisible dust particles than visible ones are present.

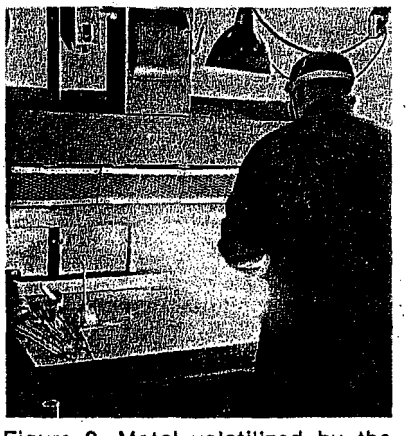

Figure 2. Metal volatilized by the heat of welding later condenses to form a fume. On this bench-welding installation, fumes are removed at their point of origin by a properly located local exhaust installation. (Courtesy American Foundrymen's Society)

### Separation in airborne dust

20. Dust in the air may or may not have the same composition as its parent material. The determining factors are particle size, density of each component in the original mixture, and hardness of materials (which will resist the pulverizing action of a mechanical device).

TABLE I. SETTLING RATES FOR SILICA DUSTS

| Size in Micrometers | Time to Fall 1 Foot (minutes) |
|---|---|
| 0.25 | 590.0 |
| 0.50 | 187.0 |
| 1.00 | 54.0 |
| 2.00 | 14.5 |
| 5.00 | 2.5 |

21. For example, foundry molding sand contains a large percentage of free silica (quartz) with a lower percentage of clays. Most of the clays consist of fine particles that can be airborne, but most of the free silica particles are too large to be airborne. The airborne dust, therefore, as compared with the original mixture, may contain a much higher percentage of clays and a much lower percentage of free silica.

22. Dust particles are, of course, attracted by gravity. Their settling rate through still air will vary with their size, density, and shape. The estimated settling rates for silica dusts in still air are given in Table I.

23. Because of air currents, the fine particles in dust clouds at an operation will remain suspended in the workroom air for relatively long periods of time. The smaller dust particles, moreover, will travel farther away from their point of origin than will the larger particles so that the farther dust is from its source, the greater percentage of small particles it contains.

## Inhalation of Dusts, Fumes, and Mists

24. With the exception of such fibrous materials as asbestos, particulates must usually be smaller than 5 $\mu$m in order to enter the alveoli or inner recesses of the lungs. Although a few particles up to 10 $\mu$m in size may enter the lungs occasionally, nearly all the larger particles are trapped in the nasal passages, throat, larynx, trachea, and bronchi, from which they are expectorated or swallowed into the digestive tract.

25. When larger particles of certain toxic dusts are trapped in the upper respiratory passages, they can be absorbed by the body fluids in the nasal passages and in the digestive tract before they are eliminated. Hence the final toxic effects of larger dust particles may be delayed. The larger particles of irritant dusts can cause immediate effects in the upper respiratory system.

26. Ragweed pollen, which varies from 18 to 25 $\mu$m in diameter, can cause hay fever from its action in the upper respiratory system. This type of dust and other allergenic types, as well as bacterial and irritant dusts, can cause difficulty even in the larger airborne sizes.

27. When dust-laden air is inhaled, some of the larger particles are trapped by the hairs in the nose. Other dust particles are removed from the air as it passes over the moist mucous membranes of the nose, throat, and other portions of the upper respiratory system.

28. The bronchi and other respiratory passages are covered with a large number of tiny, hairlike *cilia* or microscopic whiplashes, which aid in the removal of dust trapped on these moist surfaces. The cilia, all bending in one direction, make a fast stroke toward the mouth and a slower return stroke. This action tends to push mucus and deposited dust upward to the mouth so that the particles can be expectorated or swallowed.

### Retention of dust

29. Many studies have been made in an effort to determine the amount of dust that is retained in the lungs, but there is no simple answer to this question. It has been shown that the size of the dust particles, the rate of respiration, the density of the dust in the air, the efficiency of the dust-catching mechanism, and probably many other factors are involved.

### Sizes of dust particles inhaled

30. Although an occasional dust particle of larger size will enter the lungs, particles less than 3 $\mu$m in diameter are the most likely to do so and thus have the greatest opportunity to cause a physiological reaction. In silicotic lungs, for example, dust particles under 3 $\mu$m greatly outnumber larger ones, and many particles are less than 1 $\mu$m.

31. In the case of very fine fibrous asbestos dust, an exception occurs in the size of particles inhaled. Many fibers up to 100 $\mu$m long have been found in the lungs of asbestos workers at autopsy. A typical fibrosis caused by asbestos is produced by fibers ranging from 20 to 50 $\mu$m in length, but only a few micrometers wide.

### Physiological effects

32. The physiological reactions caused by the inhalation of airborne particulate matter will vary with different types of dusts, fumes, and mists. The reactions include:

a. The cardiopulmonary reaction, which consists of the pneumoconioses, such as *silicosis* and *asbestosis*. In certain cases, specific types of lung pathology result, and the heart may be affected (cor pulmonale) when the fibrosis is advanced. In other cases, there is mainly just an accumulation of a relatively inert dust in the lungs.

b. The systemic reactions that are caused by toxic dusts or fumes of such elements as lead, manganese, cadmium, and mercury, by their compounds, and by certain organic compounds.

c. Metal fume fever, which results from the inhalation of finely divided and freshly generated fume of zinc or possibly of magnesium or of their oxides. This is a transient condition.

d. Allergic and sensitization reactions, which may be caused by inhalation of, or skin contact with, such materials as organic dusts from flour, grains, and some woods and dusts of a few organic and inorganic chemicals.

e. Bacterial and fungus infections which occur from inhalation of dusts containing active organisms, such as wool or fur dust containing anthrax spores or wood bark or grain dust containing parasitic fungi.

f. Irritation of the nose and throat, which is caused by acid, alkali, or other irritating dusts or mists. Some dusts, such as soluble chromate dusts, may cause ulceration of the nasal passages or even lung cancer.

g. Damage to internal tissues, which may result from inhaled radioactive materials such as radium and its daughter products and from

## TABLE II. SELECTED INDUSTRIAL MINERAL DUSTS

| Substance | Description and Uses | Threshold Limit Values* |
|---|---|---|
| | **CRYSTALLINE FREE SILICA ($SiO_2$, including microcrystalline forms)** | |
| Chalcedony | A heat-resistant, chemically inert form of microcrystalline quartz. A decorative material. Rare in industry. | Calculate from formula: ** $\frac{300}{\%\ SiO_2 + 10}$ mppcf |
| Chert | A microcrystalline form of silica. An impure form of flint used in abrasives. | |
| Flint | A microcrystalline form of native quartz more opaque and granular than chalcedony. Used as an abrasive and in ceramics. | Total dust: $\frac{30}{\%\ \text{quartz} + 3}$ mg/m³ |
| Jasper | A microcrystalline impure form of silica similar to chert. Used for decorative purposes. Rare in industry. | |
| Quartz | Vitreous, hard chemically resistant free silica, the most common form in nature. The main constituent in sandstone, igneous rocks, and common sands. | Respirable dust: $\frac{10}{\%\ \text{quartz} + 2}$ mg/m³ |
| Tripoli (Rottenstone) | A porous, siliceous rock, resulting from the decomposition of chert or siliceous limestone. Used as a base in soap and scouring powders, in metal polishing, as a filtering agent, and in wood and paint fillers. A cryptocrystalline form of free silica. | Use respirable dust quartz formula. |
| Cristobalite | A crystalline form of free silica, extremely hard and inert chemically; very resistant to heat. *Quartz in refractory bricks and amorphous silica in diatomaceous earth are altered to* cristobalite when exposed to high temperatures (calcined). Cristobalite is extensively used in precision casting by the hot wax process, dental laboratory work, and certain specialty ceramics. | One-half the value calculated from the first formula for quartz. |
| Tridymite | Vitreous, colorless form of free silica. Formed when quartz is heated to 870 C (1598 F). | |
| | **AMORPHOUS FREE SILICA (Noncrystalline)** | |
| Diatomaceous earth | A soft, gritty amorphous silica composed of minute skeletons of small aquatic plants. Used *in filtration and decolorization of liquids, insulation, filler in dynamite, wax, textiles, plastics,* paint, and rubber. Calcined and flux-calcined diatomaceous earth contains appreciable amounts of cristobalite, and dust levels should be the same as for cristobalite. | Amorphous = 20 mppcf<br>Calcined: $\frac{300}{\%\ SiO_2 + 10}$ mppcf |
| Silica gel | A regenerative absorbent consisting of the amorphous silica manufactured by the action of HCl on sodium silicate. Hard, glossy, quartz-like in appearance. Used in dehydrating and in drying and as a catalyst carrier. | 20 mppcf |

other radioisotopes that emit highly ionizing radiation.

## Pneumoconioses

33. *Pneumoconiosis* comes from three Greek words that mean "lung," "dust," and "abnormal condition." The present generally accepted meaning of the word is merely "dusty lung." The kind of dust inhaled determines the type of condition or injury. A number of organic dusts are capable of producing lung diseases, but not all these diseases are classified as pneumoconioses because they are not all a "dusty condition" of the lung.

34. In very rare cases, enough dust had been inhaled to cause mechanical blockage of the air spaces. Flour dust has been known to cause this condition. Some dusts may be essentially inert and remain in the lungs indefinitely with no recognizable irritation, and a few like limestone dust may be gradually dissolved and eliminated without harm.

### Silicosis

35. The most important lung disease caused by the inhalation of mineral dust is *silicosis* — well-known in industries where crystalline free-silica dust is present, such as foundries, glass manufacturing, granite cutting, mining, and tunneling in quartz rock. It is found throughout the world, and in the past it has had many names, such as miner's asthma, grinder's consumption, miner's phthisis, potter's rot, and stonemason's disease. The same occupational disease, however, is meant by all these names, and it is caused by dust from crystalline free silica, usually quartz (see Table II).

36. Although considerable progress has been made in dust control in industry, workers still develop silicosis in plants and on jobs where dust control is not adequate. Engineering control is still the basic means of preventing this disease, and dust control equipment and procedures must be carefully selected and maintained.

37. **Definition.** Silicosis has been defined as "a disease due to breathing air containing silica ($SiO_2$) characterized *anatomically* by generalized fibrotic changes and the devel-

**TABLE II. SELECTED INDUSTRIAL MINERAL DUSTS (Continued)**

| Substance | Description and Uses | Threshold Limit Values† |
|---|---|---|
| | SILICATES | |
| | (Compounds made up of silicon, oxygen and one or more metals with or without hydrogen. These dusts cause nonspecific dust reactions, but generally do not interfere with pulmonary function or result in disability.) | |
| Asbestos | A hydrated magnesium silicate in fibrous form. The fibers are believed to be the more hazardous component of asbestos dust. | 8 hr T.W.A. 5 fibers/ml › 5μm in length |
| Clays | A great variety of aluminum—silicate bearing rocks, plastic when wet, hard when dry. Used in pottery, stoneware, tile, bricks, cements, fillers, and abrasives. Kaolin is one type of clay. Some clay deposits may include appreciable quartz. Commercial grades of clays may contain up to 20 percent quartz. | 30 mppcf † or 10 mg/m³ of total dust, or 5 mg/m³ of respirable dust |
| Fuller's earth | A hydrated silica-alumina compound, associated with ferric oxide. Used as a filter medium and as a catalyst and catalyst carrier and in cosmetics and insecticides. | 30 mppcf |
| Kaolin | A type of clay composed of mixed silicates and used for refractories, ceramics, tile, and stoneware. | 30 mppcf |
| Mica | A large group of silicates of varying composition, but similar in physical properties. All excellent cleavage and can be split into very thin sheets. Used in electrical insulation. | 20 mppcf |
| Portland cement | Fine powder containing compounds of lime, alumina, silica, and iron oxide. Used as construction material. | 30 mppcf |
| Silicon carbide (Carborundum) | Bluish-black, very hard crystals. Used as abrasive and refractory material. | 30 mppcf |
| Talc (nonasbestiform) | A hydrous magnesium silicate used in ceramics, cosmetics, paint, and pharmaceuticals, and as a filler in soap, putty, and plaster. | 20 mppcf |
| Vermiculite | An expanded mica (hydrated magnesium-aluminum-iron silicate). Used in lightweight aggregates, insulation, fertilizer, and soil conditioners, as a filler in rubber and paints, and as a catalyst carrier. | 30 mppcf |

*These Threshold Limit Values (TLVs) were adopted by the American Conference of Governmental Industrial Hygienists in 1979.
**Threshold Limit Values obtained from formula apply to all the substances in "Crystalline Free Silica" group.

†Threshold limits given for substances in "Silicates" group for compounds containing *less* than 1 percent crystalline silica. For compounds containing more than 1 percent silica, calculate threshold limit from crystalline free silica formulas.

opment of miliary nodulation in both lungs, and *clinically* by shortness of breath, decreased chest expansion, lessened capacity for work, absence of fever, increased susceptibility to tuberculosis (some or all of which symptoms may be present), and by characteristic X-ray findings."*

38. **Factors of influence.** Silicosis has been known to manifest itself after widely differing periods of exposure to silica dust. Apparently, development of the disease depends upon:

a. The amount and kind of dust inhaled.

b. The percentage of free silica contained in the dust.

c. The form of the silica.

d. The size of the particles inhaled.

e. The duration of the exposure.

f. The powers of resistance of the individual concerned.

g. The presence or absence of a complicating process such as infection.

39. Many theories have been advanced over the years to explain why the crystalline form of free silica acts as it does in the lungs. Theories have been based on the hardness of the material and the effect of sharp edges, solubility phenomena, electrochemical action of the crystals, and immunological reactions.

40. It is believed now that silicotic fibrosis is caused not by the hardness or sharpness of the particles, but by a combination of slight solubility with a physiochemical effect and an immunological effect—but no one is certain of the exact mechanism of the disease. Experimental work on the reasons for the development of silicosis is still going on in various parts of the world. If the precise mechanism of silicosis could be determined, better medical preventive measures might be developed and possibly a cure could be found.

*"Report (Joint) of the Committee on Pneumoconiosis and the Committee on Standard Practices in Compensation of Occupational Diseases." *Year Book,* 1933. American Public Health Association. 1015 18th St. NW, Washington, DC 20036, p. 100.

41. The clinical signs of silicosis are not unique. Symptoms may be progressive with continued exposure to quantities of dust containing free silica, with advancing age, and with continued smoking habits.

42. **Three stages.** Silicosis is generally classified in three separate stages by medical authorities. More sophisticated classifications are sometimes used for the various X-ray stages and complications of the disease, but for a basic understanding the three stages give a good breakdown.

43. The *first stage* of the disease produces no disability. The affected person can carry on his work as well as ever. Frequently, the individual is not aware that anything is wrong, and the disease is revealed only by opaque nodular shadows on a chest X ray coupled with a known exposure to crystalline free silica.

44. In the *second stage,* respiration may be affected in some persons but not in all by any means. Labored breathing on heavy exertion usually is noted first, and a dry cough also may be present.

45. The *third stage* can develop after the second stage even though the individual has been removed from exposure to silica dust. However, the progress of the disease will be slower without continued dust exposure. Breathing may become severely labored. The worker is far below normal physically and is susceptible to respiratory diseases. Chest X rays may show an enlarged heart as a result of the body's attempts to overcome the resistance of restricted blood vessels in the lungs. Pulmonary tuberculosis is a frequent complication and occasionally results in death.

46. **Detection and development.** Silicosis may be detected by chest X rays in each of the three stages. However, X rays alone are not sufficient for a positive diagnosis, for the shadows may be due to a variety of other conditions, including infection or another type of pneumoconiosis. The individual must have had a definite exposure to free silica, because only it can cause silicosis. The complete occupational and medical history of the employee must therefore be evaluated before a conclusion can be reached. The correlation of chest X-ray findings and physical disability may be poor in many cases.

47. From most industrial experience, silicosis seldom develops in less than five years and in many cases may take 20 years or longer to become disabling.

48. The development of silicosis in its earliest stage is not perceived by the individual. The disease cannot be cured by any means yet known. Tuberculosis is more prevalent in persons with silicosis, but the incidence is decreasing, as it is in the general population.

49. People with early signs of silicosis are able to perform their duties and are not a menace to other employees, for it is not a contagious disease. A perceptible X ray change is not grounds for assuming disability because most people show chest changes with advance in age even without exposure to dust. Where there is a known exposure to silica dust, however, persons with early signs of silicosis should be seen periodically by a physician.

50. **Action of silica on the lungs.** At the points in the lung where silica dust is deposited and accumulated, a fibrous tissue develops and grows around the particles. This fibrous tissue is tough like scar tissue. It is not as elastic as normal lung tissue, does not permit the ready passage of oxygen and carbon dioxide, and as it proliferates, cuts down the amount of normal lung tissue. As a result, the available functional volume of the lung is reduced.

51. In some advanced cases, the fibrous tissue will slow down or even prevent the diffusion of oxygen from the lung to the blood in the capillaries, and the blood in the area will not be completely oxygenated. The fibrous tissue can also affect the blood vessels by obliterating them or cutting down the flow of blood. All these effects tend to limit the rate at which oxygen is supplied to the body tissues. *Emphysema* is the most obvious symptom.

52. As the inhalation of silica continues over the years, the amount of fibrous tissue will, of course, increase, with the ultimate result that the lungs will not readily oxygenate sufficient blood for the body's needs. Then when the oxygen demand of the body is increased by exertion, the individual will feel distress with shortness of breath.

53. **Amorphous free silica** differs from crystalline free silica in physical structure and in physiological effects. In the amorphous state, molecules of silica exist in random orientation, which may be caused by natural forces to form opal and diatomaceous earth (kieselguhr). Amorphous silica may be converted by artificial processes into such forms as silica gel, silica fume, and fused silica or quartz.

54. If amorphous silica is heated to a high temperature, as in calcining, forms of crystalline free silica called cristobalite and tridymite result. These intermediate forms of amorphous silica are known as cryptocrystalline (ultra-microcrystalline). Inhalation of these crystalline forms can readily cause diatomite pneumoconiosis.

55. When diatomaceous earth is calcined, particularly in the presence of a trace of alkaline flux, appreciable quantities are converted to cristobalite.

56. Various commercial products containing particles of silica under 1 micrometer in size are available. The physiological effects of these products have not been well defined. Until more experience with human beings is available, it is believed these products should be handled with care.

57. **Free silica and silicates.** Free silica is uncombined silicon dioxide ($SiO_2$). Silicates contain silicon and oxygen combined with other elements in a more complex molecule. Analyses of minerals, particularly in geological reports, are sometimes reported as percentages of oxides, which may include $SiO_2$, $Al_2O_3$, $K_2O$, $Fe_2O_3$. The $SiO_2$ reported in such chemical analyses is the total of the silicon dioxide present, both the free silica (if present), and the silica combined in the mineral. Such analyses are not reliable indications of the silicosis potential of the material.

58. It is uncombined or free silica that is most important in industrial dust exposure. So that an exposure can be properly evaluated, the percentage of uncombined silica must be determined by petrographic analysis using a polarizing microscope or, preferably, by X-ray diffraction

analyses and special analytical chemical procedures.

59. There has been some experimental evidence that some dusts may tend to inhibit the action of silica on the body, but this inhibiting action is so slight and uncertain that it must be discounted in practice. In fact, there also is evidence that the nonsiliceous components of a dust mixture containing free silica may provoke a disabling condition more severe than that caused by the silica acting alone.

60. With the exception of asbestos and some talcs, the silicate dusts do not ordinarily cause a serious disabling lung condition such as is produced by free silica. Much higher levels of silicate dusts than of free silica dust can be tolerated.

61. In many industries, people have worked with silicate dusts that contained no free silica without development of disability or of nodulation in the lungs. The X ray may show shadows indicating dust deposits in the lungs, but the pneumoconiosis is essentially harmless. However, partially disabling pneumoconioses have been reported where people have worked for long periods of time in very high concentrations of certain silicate dusts.

62. Disabling pneumoconioses from exposure to abnormally high concentrations of mica, tremolite talc, and kaolin dusts have been described in the literature. The clinical signs are not the same for these silicate dusts as for free silica, but the symptoms can be marked.

63. The body does not have adequate defense against indiscriminate amounts of dust of any kind. Therefore, although specific symptoms have not been described for many mineral dusts, the general experience would indicate that dust levels should be kept within Threshold Limit Values or below (Table II, pages 4 and 5).

### Asbestosis

64. Asbestos is a general term applied to several minerals having a fibrous character. These asbestos minerals are hydrated silicates of magnesium with variable amounts of iron, calcium, sodium, potassium, and aluminum present as impurities.

65. Asbestos when inhaled produces fibrous tissue in the lungs of both humans and animals. It has been shown that fibers of asbestos must be present for the production of *asbestos*. Other silicate minerals of the same chemical composition but nonfibrous in form produce no reaction, or a relatively mild reaction, but not the severe reaction of fibrous asbestos dust.

66. These facts lead to the conclusion that asbestosis is mainly the result of physical irritation of the lung tissue and not of a chemical action, which is thought to be one of the causes of silicosis. It is suspected that lung cancer may be induced by asbestos. However, there is no impressive amount of evidence to support this assumption.

67. The fine airborne fibers of asbestos can pass through the upper respiratory tract to the lower parts of the lungs to cause irritation and to form "*asbestos bodies*" where the fibers are encapsulated. This diffuse fibrosis probably begins as a "collar" about the terminal bronchioles. There is evidence that other minerals having a fibrous character can produce a reaction similar to that of asbestos. Glass fiber, however, does not produce such a reaction.

### Talcosis

68. As used in industry, "talc" is a very general term. To the geologist, talc is a hydrous magnesium silicate, which may be a relatively pure mineral or may be mixed with tremolite or with dolomite depending upon where it is mined. The term "talc" is applied commercially to carbonate mixtures that have the same general feel and physical properties; it also is applied to pyrophyllite, a hydrous aluminum silicate, which frequently is mixed with a high percentage of quartz. The free silica generally found with pyrophyllite can cause silicosis. It is therefore essential to know which talc is being used in order to evaluate a specific dust exposure.

69. Talcosis is usually associated with tremolite talc. This disease produces changes in the lungs and symptoms similar to those of asbestosis.

### Anthracosilicosis

70. Anthracosilicosis, a complex form of pneumoconiosis, is a chronic disease caused by breathing air containing dust that has free silica as one of its components and that is generated in the various processes involved in mining and preparing anthracite (hard coal) and, to a lesser degree, bituminous coal.

71. The disease is characterized anatomically by generalized fibrotic changes throughout both lungs and by the presence of excessive amounts of carbonaceous and siliceous material. Such lungs on autopsy are coal black.

72. Symptoms found in early stages of the disease are shortness of breath, cough with a coal-black sputum, pain in the chest, and in some cases physical weakness. In the advanced stages, there are loss of weight and decreased capacity for work, partly caused by pulmonary infection (frequently bronchitis), and in some cases there may be heart failure.

73. Experiments with animals showed that mixtures of coal and quartz produced more fibrosis than did quartz alone. The harmful effects of coal dust do not come only from the silica in the dust. Coal dust alone in very heavy concentrations over a period of many years can cause breathlessness and ventilatory impairment.

### Miscellaneous pneumoconioses

74. Even though a dust is classified as "harmless," excessive amounts of it can lead to trouble by causing a pneumoconiosis or simply by mechanically irritating the walls of the respiratory system. Moreover, even though there is no chemical or physical irritation, mechanical plugging of the lungs and interference with their ordinary process can result. Mica dust and kaolin dust are two good examples of dusts that ordinarily are considered benign but in excessive amounts can cause a troublesome pneumoconiosis.

75. **Mica pneumoconiosis** has been observed in grinding operations where mica dust, but no free silica, was present. There were marked changes in the X-ray pictures of the lungs and some disability. The cases occurred where the dust exposures were massive over many years.

76. **Kaolinosis** has been described as a condition induced by inhalation

of dust released in the grinding and handling of kaolin (china clay). Where the cases occurred, dust levels of several hundred million particles per cubic foot of air were common.

77. **Aluminum dust** is not considered to be harmful except where exposures are massive. Without adverse effects, aluminum dust inhalation has been used as part of an endeavor to prevent silicosis. Also without adverse effects, extensive exposures to aluminum dust have occurred in the grinding of aluminum parts and castings. It can therefore be concluded that reasonably good control will prevent harm from aluminum dust.

78. **Bauxite pneumoconiosis** (Shaver's disease) has been found only in workers exposed to fumes containing aluminum oxide and minute or ultramicroscopic silica particles arising from smelting bauxite in the manufacture of corundum, an impure form of aluminum oxide. It is essentially a diffuse interstitial fibrosis and marked associated emphysema, with a complete absence of any nodular fibrosis. It definitely does not occur from the use of corundum grinding wheels or from other forms of aluminum oxide.

79. Some pneumoconioses may show marked shadows on an X-ray film; these shadows, without the necessary information on the exposure of the individual, may be alarming in a general X-ray screening program. On clinical examination of individuals showing the X-ray markings, however, often no disability or symptom can be found.

80. These shadows are frequently encountered when the dusts contain atoms of relatively high molecular weight because the heavier atoms are fairly opaque to X rays. Insoluble barium dusts and tin oxide dusts, for example, can show very marked shadows on X-ray films without producing signs of significant pathology (barium dust that is soluble in the body fluids can give a toxic reaction).

81. Iron oxide, particularly excessive fume from welding operations, may produce *siderosis* with a pigmentation of the lungs (black in welders and red in iron ore miners) without disability. The X-ray shadows produced by the iron oxide in the lungs are somewhat similar to the shadows from silicosis. Because of this similarity, differential diagnosis is often difficult, and heavy exposures to iron oxide dust and fume may lead to medicolegal problems.

82. Limestone, marble, lime, gypsum, and portland cement dusts apparently have no serious effect even after long exposures. Also, many silicates and other minerals have not caused impairment in individuals inhaling the dusts, and the resulting pneumoconioses are generally classed as benign. However, because some limestones contain significant amounts of quartz, a quartz determination is advisable.

**TABLE III. SELECTED TOXIC DUSTS AND FUMES**

| Substance | Description and Effects | Threshold Limit in Milligrams per Cubic Meter of Air* |
|---|---|---|
| *Antimony* | *Gray metal often associated with lead and arsenic. Hazardous from inhalation and ingestion. Soluble salts may cause dermatitis.* | 0.5 |
| Arsenic | Silvery brittle crystalline metal. Hazardous from inhalation and ingestion. Usually encountered as arsenic trioxide. | 0.5 |
| Barium (soluble compounds) | Soluble barium chloride and sulfide are toxic when taken by mouth. | 0.5 |
| Beryllium | Light weight, gray metal. The metal, low-fired oxides, soluble salts, and some alloys are toxic by inhalation. | 0.002 |
| Chromic acid and Chromates | Red, brown, or black crystals. Caustic action on mucous membranes or skin. | 0.05 |
| Cyanide (as CN) | Nonvolatile cyanides are ingestion hazards. Cyanides inhibit tissue oxidation upon inhalation and cause death. | 5.0 (skin**) |
| Dinitrobenzene | Yellowish crystal. Hazardous from skin absorption, inhalation, and ingestion. | 1.0 (skin**) |
| Fluorides | Inorganic fluorides are highly irritant and toxic. | 2.5 |
| Hydroquinone | Colorless hexagonal crystals. Contact with the skin may cause sensitization and irritation. Excessive exposure to dust may cause corneal injury. | 2.0 |
| Iron oxide fume | *Major sources are cutting and welding.* | 5.0 |
| Lead | Lead fumes and lead compounds cause poisoning after prolonged exposure. Most important means of entry into body is inhalation. Skin absorption is of significance only from such organic compounds as lead *tetraethyl.* | 0.15 |
| Lead arsenate | White crystals—highly toxic. | 0.15 |
| Magnesium oxide fume | White powder. Inhalation of freshly generated fume may cause metal fume fever. | 10.0 |

*These *Threshold Limit Values* were adopted by the American Conference of Governmental Industrial Hygienists in 1979.
**The substance can penetrate the skin to contribute to the exposure.

## Toxic Dusts and Fumes

83. Systemic reactions are caused by toxic dusts and fumes of various

**TABLE III. SELECTED TOXIC DUSTS AND FUMES (Continued)**

| Substance | Description and Effects | Threshold Limit in Milligrams per Cubic Meter of Air* |
|---|---|---|
| Manganese | Silvery gray metal. Hazardous from inhalation of fumes or dust. | C-5.0*** |
| Pentachlorophenol | Dark-colored flakes. Harmful dust. Emits toxic fumes when heated. | 0.5 (skin**) |
| Phosphorus (yellow) | Poisonous mainly by inhalation. Severe burn hazard from skin contact. | 0.1 |
| Picric acid | Yellow crystals or liquid. Explosive—particularly metallic salts. Emits toxic fumes on decomposition. | 0.1 (skin**) |
| Selenium compounds | Toxicity varies somewhat according to the solubility of the specific compound. Often causes contact dermatitis. | 0.2 |
| Sodium hydroxide | White, deliquescent pieces or lumps. Has severe action upon all body tissue. | 2.0 |
| Tellurium | Similar to selenium chemically and in physiological effects. | 0.1 |
| Titanium dioxide | White to black powder. Considered in the nuisance category. | 10.0 (total dust < 1% quartz or 5.0 mg/m³ respirable dust) |
| Trinitrotoluene | Colorless to yellow monoclinic crystals. Emits toxic fumes of oxides of nitrogen when heated to decomposition. Highly poisonous explosive. | C-0.5*** |
| Uranium | Highly toxic and a radiation hazard that requires special consideration. | 0.2 |
| Vanadium pentoxide | Yellow to red crystals. Acts chiefly as an irritant to the conjunctiva and respiratory tract. | 0.5 (dust) C-0.05 (fume)*** |
| Zinc oxide | Amorphous white or yellow powder. The powder is essentially nontoxic, but freshly generated fume may cause metal fume fever. | 5.0 |
| Zirconium compounds | Most compounds are insoluble and have low toxicity. | 5.0 |

*These Threshold Limit Values were adopted by the American Conference of Governmental Industrial Hygienists in 1979.
**The word "skin" in this table indicates that the substance can penetrate the skin to contribute to the exposure.
***C—Indicates that this limit should not be exceeded at any time.

elements and their compounds and by certain organic compounds. All metallic fumes are irritating, especially when freshly generated. Industrially important metals and their compounds that can have a toxic effect when the dust or fume is inhaled include arsenic, antimony, cadmium, chromium, lead, manganese, mercury, selenium, tellurium, thallium, uranium, and a few others.*

84. The effect of some metals, such as magnesium and zinc, appears to be transient. Only limited data are available on the exotic and rare earth metals.

85. Although the dusts and fumes from metals with low toxicity do not need as much attention as the dusts and fumes from highly toxic metals, they should not be neglected or disregarded. The metals with low toxicity are controlled more readily because greater amounts can be tolerated, but their dusts and fumes should be kept at reasonable levels since excessive amounts of any of them can be harmful (Table III).

## Lead poisoning

86. Although extremely severe cases of lead poisoning are rare in industry today, lead exposures must be controlled to prevent even the moderate symptoms, which can be troublesome. Inhalation of the dust of lead compounds is the most common mode of entry of lead into the system. Ingestion of lead compounds can add to the problem if personal hygiene is poor. Workers should therefore be encouraged to wash thoroughly before eating, and lunchrooms should be segregated from work areas.

87. It should be recognized that lead is a normal constituent of plants and animals. People ingest and excrete lead daily even though they are not exposed to lead in their daily work. The body can handle and eliminate small amounts without harm. When intake rates exceed the normal excretion level, buildup occurs in the body. There is a safe level of absorption, and if the concentration of lead dust in the air of work areas is kept below the threshold limit, there should be no difficulty.

88. The importance of maintaining the concentration of airborne lead at a very low value stems from lead's high toxicity and its tendency, in small amounts, to accumulate in the human system. When lead absorption in the body reaches a sufficient degree, symptoms of poisoning or intoxication appear.

## Beryllium intoxication

89. A worker can be exposed to two types of beryllium:

a. Elemental beryllium and compounds and alloys of beryllium that may be released into the work environment as particulate matter.

*See the National Safety Council Data Sheets listed in the Bibliography.

b. Bulk forms of beryllium that pose a skin hazard to employees. These forms include soluble beryllium compounds or solid forms (for example, crystals, chips, or shavings) of soluble or insoluble beryllium that could penetrate the skin.

90. Beryllium intoxication is a severe systemic disease that can result from the inhalation of dust or fume of metallic beryllium, beryllium oxide, and soluble beryllium compounds.

91. There are two forms of the disease. One is an acute form of chemical pneumonitis with cough, pain, difficulty in breathing, cyanosis, and loss of weight. In the chronic type, known as berylliosis, there may be loss of appetite and weight, weakness, cough, extreme difficulty in breathing, cyanosis, and cardiac failure. Formerly, mortality was high in chronic beryllium intoxication, and many who survived suffer from pulmonary distress.

92. Individual susceptibility apparently is an important factor in the development of the disease. In many instances, one employee has developed the severe symptoms while other employees doing the same work have shown no signs of disability.

93. Beryllium intoxication has never been demonstrated in individuals mining or handling ore only. There is no evidence of intoxication from the ingestion of beryllium oxide, beryllium metal, or any of the beryllium alloys. Only the inhalation of beryllium-bearing dusts or fumes produces systemic disease. Accordingly, control of such dusts and fumes at or below concentrations specified by ACGIH Threshold Limit Values* is to be recognized as a basic protective measure.

94. When the soluble salts of beryllium, especially beryllium fluoride, come in contact with cuts or abrasions on the skin, deep ulcers may be formed that heal very slowly. Complete surgical excision of the ulcer is sometimes required in order to effect healing.

## Arsenic poisoning

95. Elemental arsenic is utilized in the production of various alloys. It increases the resistance of copper to corrosion, improves its machinability, and raises its annealing temperature.

96. Arsenic and its compounds require intelligent handling. Employees must be completely familiar with the potentially hazardous nature of such materials. Employee training must include thorough indoctrination in the use of personal protective equipment.

97. Where arsenic fumes may be present, such as in the sintering and roasting of arsenic-bearing ores, complete enclosure and exhaust ventilation of the operation is needed. If respirators are required for protection against arsenic and its compounds, a respirator approved by the National Institute for Occupational Safety and Health (NIOSH), for protection against fumes not significantly more toxic than lead, or a similarly approved air-line respirator, should be used.

98. The effects of **chronic poisoning** by arsenic or arsenic compounds first show themselves on the skin, on the mucous membranes of the eyes, and upper air passages, in the gastrointestinal tract, and in the nervous system. Often symptoms such as weakness, loss of appetite, and occasional nausea develop slowly, with the eyes, skin, and respiratory system being affected later.

99. **Dusts on the skin,** especially where there are folds, as around the mouth, or where the surfaces are moist, as in the armpits, set up an eruption or eczematous condition which, if not treated, will lead to extensive ulceration. Inhalation of excessive amounts of dust will lead to perforation of the nasal septum.

## Metal fume fever

100. Metal fume fever is an acute condition of short duration caused by a brief high exposure to the freshly generated fumes of metals such as zinc or magnesium or their oxides. Symptoms appear from four to twelve hours after exposure and consist of fever and shaking chills. There is complete recovery usually within one day, and ordinarily the employee can return to the same job without recurrence. However, after a period in which there has been no contact with the fume, for example, after a layoff, resumption of exposure is likely to bring on an attack.

101. To cause metal fume fever, heavy concentrations of fumes are required. Zinc oxide fume is the most common source, but cases caused by the inhalation of fumes from magnesium oxide, copper oxide, and other metallic oxides have also been reported. The condition does not occur from the handling of these oxides in powder form. Apparently, it results only from the inhalation of extremely fine particles freshly formed as fume (nascent fume).

102. Nickel, mercury, and other metals may also produce a fever followed by the toxic effects of the element.

## Welding fumes

103. Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc welded in a protective, inert atmosphere such as argon. Although these arcs create relatively little fume, they do produce an intense radiation which can produce ozone.

104. Similar processes are used to arc weld steels, also creating a relatively low level of fumes. Ferrous alloys also are arc welded in oxidizing environments which generate considerable fume, and can produce carbon monoxide. Such fumes generally are composed of discrete particles of amorphous slags containing iron, manganese, silicon, and other metallic constituents depending on the alloy system involved.

105. Chromium and nickel compounds are found in fumes when stainless steels are arc welded. Some coated and flux-cored electrodes are

*Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment," published by American Conference of Governmental Hygienists, 2205 South Road, Cincinnati, Ohio 45238.

formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides.

106. Because of these factors, arc welding fumes frequently must be tested for individual constituents that are likely to be present to determine whether specific TLVs have been exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases. Most welding does not produce exposures inside the welding helmet above 5 $mg/m^3$.

## Allergic Reactions

107. When in the form of dust, a large number of materials may cause various allergic reactions in susceptible individuals. Examples of such agents are certain animal products, foods, drugs, and chemicals. The bodily systems usually involved in allergic reactions, which may be quite severe, are the skin, respiratory system, and gastrointestinal system. Occasionally, two or more systems are involved. Some of the allergic reactions are dermatitis, hay fever, asthma, and hives.

108. Usually, the victim is subjected to a series of exposures without any reactions during which sensitization is built up. These exposures may occur continuously for years. Then, at the end of the "incubation period," which varies according to the individual, a reaction is produced.

109. For a true allergic reaction two factors are required:

a. A history of prior exposure to the material involved (sometimes not known by affected employees).

b. A "challenge dose" of the material, which provokes the allergic reaction.

110. Continuous exposures may act as "desensitizing doses," and under these conditions an allergic individual may work without incident for long periods of time only to find that reexposure after removal from the sensitizing material (such as after a vacation) causes an allergic response to recur.

111. Medical and engineering recommendations to prevent allergic reactions are based on prevention of exposure by means of personal protective equipment, ventilation methods, or removal of sensitized individuals from the exposure.

## Infections

### Infection and pneumoconiosis

112. The presence of pulmonary disease that significantly interferes with the natural defenses against foreign particles may increase susceptibility to pneumoconiosis. Conversely, a pneumoconiotic lung is more prone to infection. For example, tuberculosis occurs more frequently among silicotics than among normal persons. Severe disability or death of a silicotic, when caused by pulmonary conditions, usually results from complicating tuberculosis either alone or combined with other infections.

### Bacteria and fungi

113. The possibility of lung infections from the inhalation of bacteria and fungi exists in several industries. Pulmonary anthrax from the inhalation of dust containing anthrax spores has occurred among employees engaged in the handling of wool and the crushing of bones from infected animals.

114. Fungi (molds) growing on grain have been found in sputum of workers shoveling the grain and are believed to be the cause of outbreaks of respiratory disorders. Fungi found in sugar cane residues (bagasse) are believed to be part of the cause of *bagassosis*. Fungal spores formed under the bark of some trees have been blamed for respiratory difficulties among employees who debark dry logs.

115. Although the incidence of occupationally related bacterial and fungal infections is found to be relatively low, the respiratory effects can be troublesome and, in the case of pulmonary anthrax, even fatal. The basic methods of control are the same as those for the pneumoconiosis-producing dusts, but sterilization and disinfection must be added.

## Radioactive Dusts*

116. A radioactive contaminant may offer a chemical toxicity hazard in addition to an ionizing radiation exposure, and it may be present as a gas, dust, fume, or mist.

117. Radioactive contaminants taken into the body may be deposited in various organs where they constitute sources of internal radiation. The chemical characteristics of the radioactive contaminant or isotope determine the organ in which it will be deposited. The excretion rate is also dependent upon the chemical nature of the isotope, because the radioactive isotopes of an element follow the same metabolic process as do the stable isotopes of that element.

118. If a radioisotope has been deposited in the body, the internal exposure is regarded as continuous until the isotope is lost by radiological or biological decay. In some cases, exposures may last a lifetime.

119. Because radioisotopes are selectively taken up in individual organs, they may cause only localized irradiation. The radiosensitivity of the organ dictates the extent of the hazard of a particular radioactive substance. Solubility and particle size determine how much of the active material will gain access to and remain in the blood stream and various organs.

120. If radioactive airborne contamination is known to be present, control measures are mandatory. If the presence of contamination is unknown but suspected, sampling must be done to determine whether or not airborne concentrations of the radioisotope are below the Threshold Limit Value.

121. Good personal hygiene and good operating techniques are much more important in the handling of radioactive materials than in the handling of most other materials used in industry.

122. Engineering controls for radioactive dusts are similar to those for other dusts and depend primarily

*For a detailed discussion of radioactivity and an extensive bibliography, see the chapter entitled "Ionizing Radiation" in the *Fundamentals of Industrial Hygiene* manual, published by the National Safety Council.

upon capture at the point of generation. The difference lies in the fact that controls for radioactive dusts must be extremely efficient. Threshold Limit Values for radioactive particulate matter are very low, and in some cases 100 percent efficiency in capture and retention is required.

## Permissible Dustiness

123. Threshold Limit Values of mineral dusts and toxic dusts—that is, time-weighted average concentrations considered permissible for exposures of eight hours per day, five days per week—have been published by the American Conference of Governmental Industrial Hygienists. These values have been obtained from the experience of many groups in industry and from laboratory studies on animals. They are reviewed annually and changed as necessary on the basis of experience. Permissible exposure limits are set by OSHA regulations.

124. These values are set only as guides for the best practice and are not to be considered absolute values. There is reasonable assurance that occupational disease will not occur if exposures are kept below these levels. On the other hand, occupational disease is likely to develop in some people if the recommended levels are exceeded consistently.

125. The currently recommended threshold limits of particulate dusts, fumes, or mists can be found in the most recently published ACGIH list (see Bibliography), or the ACGIH can be consulted directly. Information on threshold limits also can be obtained from the National Safety Council, state occupational health agencies, the American Industrial Hygiene Association, and compensation insurance carriers.

126. No one knows the exact concentration at which workers will start to develop silicosis, asbestos, or lead poisoning. With some toxic dusts, however, experience has been wide enough to establish the present threshold limits as fairly reliable. For example, if the level of lead in a workroom is kept below 0.15 mg/m$^3$, experience has shown that cases of lead intoxication will not occur.

### Mineral dusts

127. In the United States, the threshold limits for mineral dusts are expressed in millions of particles per cubic foot of air (mppcf) or mg/m$^3$. The concentration of a mineral dust is determined by counting dust particles that are less than 10 microns in size in an aliquot sample after sampling a known volume of air in a known volume of liquid, or by weighing a collection filter before and after a sample is taken. In England and some other areas, the number of particles per cubic centimeter is the current basis of measurement.

128. In comparing United States and foreign dust counts, it is helpful to keep in mind that 100 particles per cubic centimeter is equivalent to approximately 3 million particles per cubic foot.

129. It is difficult to compare dust counts with results obtained on the basis of weight. However, with either type of measurement, a threshold limit can be set as an objective. Experience has shown that maintaining dust levels below the recommended threshold limits has resulted in a great decrease in the incidence of occupational diseases.

130. Threshold limits are based on the percentage of free silica where this substance is the important constituent of the dust. If silicosis is to be prevented, these limits must not be exceeded.

131. As more experience accumulates, original threshold limits sometimes can be modified. In some cases, it has been necessary to lower the limits, for the objective is to protect the more susceptible individuals. In a few cases, experience has shown that the limits were too stringent, and it has been possible to raise the limits to allow for more reasonable controls.

### Toxic dusts

132. In all countries, threshold limits for toxic dusts are expressed in milligrams per cubic meter of air. With toxic dusts, the average levels must be kept below the suggested threshold limits. In fact, it is advisable to keep the levels of toxic dusts as low as practical in the specific circumstances. Little in the way of experience or data will be developed if the levels are kept unusually low, but few if any cases of occupational disease will occur from these dusts.

### Nuisance dusts

133. Even though a dust may be considered generally innocuous and not be recognized as the direct cause of a serious pathological condition, its level should be kept as low as is practical. Dust levels well below the suggested threshold limits are desirable.

134. A concentration of 30 mppcf (10 mg/m$^3$) is suggested as the threshold limit for a number of nuisance dusts. With good engineering practice, there is no need for this level to be exceeded. Any reduction below this level will increase the comfort of employees and improve plant housekeeping.

### Toxic mists

135. Spray painting operations should be examined for the possibility of hazards from inhalation and skin contact with toxic and irritating mists of solvents and pigments. The solvent vapor evaporating from the sprayed surface is also a health hazard.

136. Electroplating processes involve risk of skin contact with strong chemicals and, in addition, may present a respiratory hazard if mist or gases from the plating solutions are dispersed into the workroom air.

137. Oil mist is a problem in shops where oil is used as a coolant. Condensation on walls and ceilings increases the fire hazard.

## Methods of Control

138. Various methods of controlling dusts, mists, and fumes are available. Basic engineering dictates where possible an operation should be made dustless through control at the source. This method is always the most effective, for it either completely prevents the contaminant from entering the workroom atmosphere or limits to safe levels the amounts that do escape. In addition, this method is generally the least expensive.

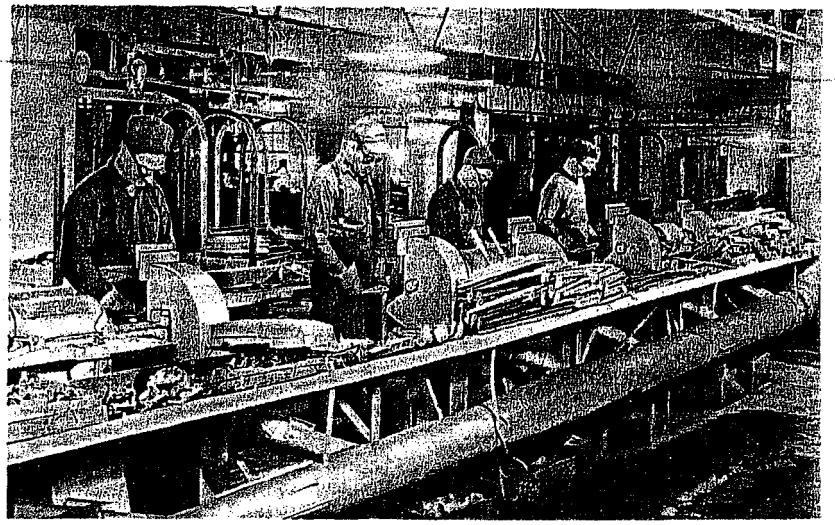

Figure 3. Each of these grinding wheels is partially enclosed by an exhaust hood. Efficient local exhaust is achieved by drawing the dust into the hoods, through branch ducts, and into a central duct which leads to the collection point. (Courtesy American Foundrymen's Society)

139. When control at the source is not possible, other methods may have to be considered. Any one or a combination of the following types of dust control may be needed to limit the exposure.

a. The dusty operation may be enclosed, with or without a local exhaust system. An enclosed operation generating large quantities of dust usually needs to be exhausted, or the dust will leak into the surrounding atmosphere. Examples are sandblast cabinets or sandblast rooms and the dry boxes used to handle radioactive materials.

b. The dusty work may be performed in a separate building or may be isolated by partitions to reduce the number of employees exposed to the dust. The employees who are still being exposed should be protected by respiratory protective equipment.

c. A less hazardous material may be substituted. For instance, steel shot may be used instead of silica sand in abrasive cleaning.

d. Keeping the materials moist may be a practical means of control. Examples are the careful and proper wetting down of aisles in a foundry and the use of water in drilling.

e. Electrostatic precipitation is also a means of removing harmful or nuisance dusts from the atmosphere.

f. Local exhaust systems may be installed with virtually full or partial enclosure. Examples are an exhaust hood on a grinding wheel (Figure 3) and an exhaust hood at a bagging or filling operation.

g. General room ventilation can be used to dilute the dust by adding large quantities of air and thus preventing buildup of dust concentrations. Examples of this method are roof fans and roof monitor windows. But it generally is inefficient and expensive to attempt to control contaminants by dilution.

h. The dusty work may be performed at night or on weekends to reduce the number of employees exposed. Cleaning dust accumulations from overhead beams, for instance, is preferably done during a weekend. The employees who are exposed should wear appropriate type of respiratory protective equipment.

i. The number of working hours at the particular exposure can be reduced. However, other methods of control are preferable.

j. Use of respiratory protective equipment certified by NIOSH can give excellent protection against all types of dust, but in most cases should be considered as a temporary control measure. In a sandblast room, however, air-supplied helmets usually are required continuously during operations. Respiratory protective equipment, nevertheless, should not be considered as a universal substitute for adequate local exhaust removal, elimination of the contaminant, or containment.

140. Many states and municipalities have dust control codes or ordinances with which employers must comply. In a few states, for instance, written approval of plans must be obtained before a local exhaust system is installed. Each employer should therefore know his state and municipal dust control requirements.

141. Each type of exposure must be considered separately. For example, a local exhaust system suitable for welding or cutting of steel might not be satisfactory for welding or cutting steel that is coated with red lead.

## Local exhaust systems

142. A local exhaust system for the control of an industrial dust or fume traps the air contaminant near its source so that an operator standing at the process is not exposed to harmful concentrations. The system should be designed to enclose the process as completely as possible. This method usually is preferred to general ventilation, but should be used only when the contaminant cannot be controlled by isolation, process revision, or substitution of less harmful materials. Even though a process has been isolated, it may still require a local exhaust system.

143. A local exhaust system consists of four principal parts:

a. Hoods or other inlets, into which the airborne contaminant is drawn.

b. Ducts, to carry the contaminated air to a central point.

c. Dust and fume collectors, to clean the air before it is discharged.

d. A fan and motor to keep the air moving through the system.

144. Although each of these parts should be designed and installed to perform its required function with respect to the system as a whole, design of the exhaust hood demands the greatest care. The degree of control of dust at the point of generation or dispersion is determined by the shape of the hood or degree of

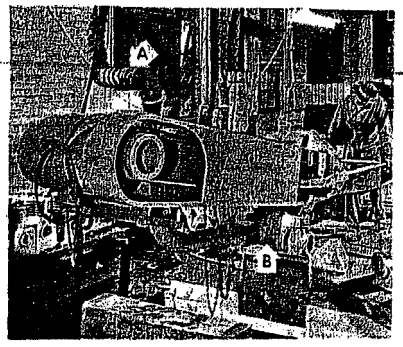


Figure 4. Since this swing-frame grinder is used in a variety of positions, the local exhaust system must be adjustable. The flexible duct (A) permits movement of the exhaust hood (B) as needed. (Courtesy American Foundrymen's Society)

enclosure, the location of the hood and its distance from the dust source, and the rate of flow of air into the hood. A poorly designed hood can make an exhaust system ineffective.

145. There is no "standard hood." In every case, the hood must be designed to fit the specific operation and to make the exhaust effective without interfering with the operation (Figure 4). Among the factors to be considered are the natural air currents in the room and other exhausts or windows in the area.

146. The hood should be shaped to conform to the shape of the area of dust production so as to secure reasonably uniform air velocity over this area. A hood that does not enclose the process should be placed with its opening as close as possible to the point of generation of the dust or fume (Figure 5) because the velocity of the air in the zone of the hood influence is inversely proportional to the square of the distance from the face of the hood.

147. The hood opening, or part of it, should be located so as to receive directly dust that is thrown off along a well-designated path (Figure 6). The directional energy of the material can thus be used for its own capture. Air movement must always be past the employee, then over the dust source, and directly into the face of the hood.

148. The fan should be of sufficient capacity to maintain the required air capture velocity at the point of generation of the dust. Internal baffles should be installed to guide the air flow where it is most needed. Flanges should be provided wherever possible to reduce the air flow from areas where no dust is produced; that is, air-flow contours should be controlled.

149. Enough air must be supplied to the room from the outside to replace the air that is removed by the exhaust system. Otherwise, there will be interference with other exhaust systems in the area or with maintaining gas or oil flames or adequate combustion in nearby furnaces. Great difficulty has occurred

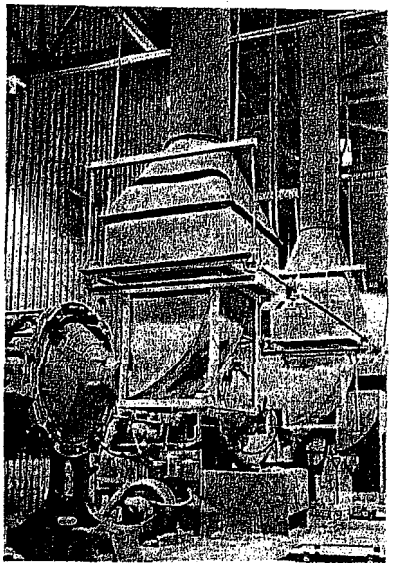

Figure 5. To achieve the proper exhaust air velocity, the hoods for these barrel furnaces can be positioned as close to the furnace spouts as practical. Such positioning is made possible by mounting the hoods on a trolley suspended from an overhead track. (Courtesy American Brake Shoe Co.)

where an exhaust system caused a slightly negative pressure in a room containing a gas furnace. As a result air came down the furnace flue, and the area became contaminated with carbon monoxide from the furnace.

150. With small exhaust systems, air that is removed usually can be replaced by infiltration flow, but larger exhausts may need a positive air supply (Figure 7). An adequate supply of makeup air, tempered when necessary, is one of the most frequently overlooked fundamentals of ventilation. Air always should be supplied in quantities equal to or slightly in excess of the amounts exhausted.

151. The size of the ducts, the type and size of the dust collectors, and the type and size of the fan and motor (explosion-proof where necessary) are among the other factors that must be considered in the design of an exhaust system. Preventing ignition of a combustible contaminant is a prime safety consideration. Discussion of the subject of exhaust system design is beyond the scope of this data sheet; consultation with an experienced ventilation engineer may be necessary.

152. Also, information can be secured from several excellent publications, one of which is the current edition of *Industrial Ventilation—A Manual of Recommended Practice,* published by the American Conference of Governmental Industrial Hygienists. Another is Part IV of *Fundamentals of Industrial Hygiene,* 2nd ed., published by the National Safety Council.

### General ventilation

153. General ventilation should be used to supplement local exhaust systems, not to replace them. It should be noted, however, that where local exhaust systems can be used, they will always do a better job than general ventilation.

154. General ventilation requires the introduction of enough clean air

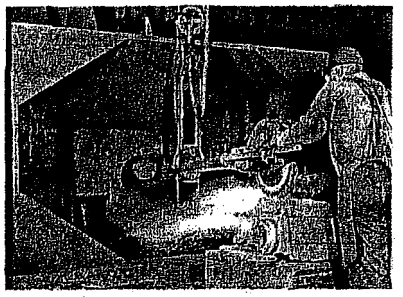

Figure 6. The centrifugal force created by this grinding wheel causes the generated dust to travel in a well-defined path. To prevent dispersion of the dust, the exhaust hood is placed directly in the dust stream, close to its source. (Courtesy American Foundrymen's Society)

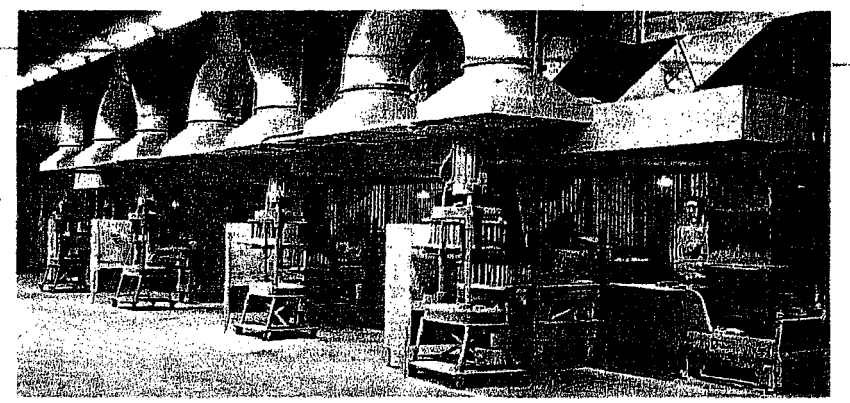

Figure 7. In this foundry, local exhaust hoods are installed over each station having a shell-moulding machine and glue press. Adequate make-up air is supplied from ventilating duct situated between molding machines and presses. (Courtesy American Foundrymen's Society)

from the outside to dilute the contaminated atmosphere to a safe level. This method requires larger volumes of air than local exhaust systems would to accomplish the same control, and will not be effective uniformly over a large room. It should be considered only when local exhaust systems require such assistance. This is usually where the sources of dust are widely dispersed and each source is small.

155. General room exhaust and supply fans must be carefully installed. Eddy currents, which will interfere with local exhaust systems, must be avoided. Employees must not be exposed to excessive concentrations of dust as the dust-laden air moves away from the point of generation, and sufficient makeup air from the outside must be supplied to the room to replace the air that is exhausted. The location and design of the source of supply are important. It is becoming common practice to supply clean, tempered air to the work zone for controlled dilution.

### Wet methods

156. Wet dust is not dispersed as readily as dry dust—advantage of this fact should be taken whenever possible. Carloads of dry minerals in some cases may be wetted down before they are unloaded. Aisles in foundries should be wetted down to prevent dispersal of the dust by traffic. Water sprays can be used at some operations. Wet drilling methods can be used for rock drilling to wet the dust as it is formed.

### Personal protective equipment

157. Respirators of various designs are available which will give protection against toxic and pneumoconiosis-producing dusts by filtering out the contaminant from the air. NIOSH has set up performance standards for dust respirators and gives approval to respirators that meet these standards. It is important that a respirator be used *only* for the particular dust exposure for which it has been approved. Respirators for use in mines are certified by the Mining Safety and Health Administration.

158. Although approved respirators will give excellent protection when properly fitted, they should be used only as supplements to other methods of control or for short or occasional exposures and not as primary controls.

159. Proper fitting of a mechanical filter respirator to the face of the individual is most important because even a small space between the facepiece and the face will permit dustladen air to bypass the filter.

160. Respirators must be inspected and cleaned daily. Filters should be replaced before they become so plugged with dust as to seriously increase resistance to breathing. Proper filters for replacement should be available.

### Medical program

161. An effective medical control program will help prevent cases of occupational disease. Such a program can also serve as a check on the engineering controls because symptoms of exposure in a group of workers will indicate a failure that must be corrected. The extent of the medical program will depend upon the seriousness of the exposures.

162. An industrial hygiene program should parallel the medical program. Both are essential to protect the health of employees.

163. The physical examination for new employees should include a thorough preemployment history with the occupational background given in detail. Chest X rays should be made of all new employees who will be working in dust exposures that could produce disabling pneumoconiosis. The examining physician should decide on placement of those who have pneumoconiosis, active or significant past tuberculosis, abnormally low timed vital capacity, or serious pulmonary diseases.

164. Periodic physical examinations, including chest X rays, should be made of employees exposed to toxic dusts, fumes, and mists. Such checks can help find incipient cases of poisoning in which symptoms are slight, and the X rays can pick up early symptoms of lung conditions. Suitable preventive measures can then be taken.

165. Routine periodic clinical examinations, stipple cell counts, porphyrin determinations, and properly evaluated blood and urine lead-level measurements are practical methods for checking employees exposed to lead. If unsafe exposures are found, further environmental control is mandatory. Affected employees should, of course, be given proper medical treatment.

166. Medical controls for employees who work with radioactive dusts must be more stringent than the medical controls for most dusts. An extensive bioassay sampling program is nearly always required.

### Other control measures

167. Although the most effective method of control is to prevent contamination of workroom air and thus prevent inhalation of harmful dusts, the importance of personal hygiene should not be overlooked. The periodic medical examinations provide a good opportunity for in-

struction of employees in various personal hygiene measures.

168. Good washing facilities, clean lunchrooms, and clean work clothes can help prevent additional, even though minor, exposure to toxic materials. Also, contaminated work clothes should not be taken home where a toxic dust could contaminate the home or expose other members of the family. These recommendations become mandatory where such materials as beryllium and radioisotopes are handled.

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An Alphabetical Index of all Industrial Safety Data Sheets (Stock No. 123.09) is available from the Council on request.