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OCCURRENCE AND MITIGATION OF INJURIOUS DUSTS IN STEEL WORKS

BY

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[Cooperation with the Bureau of the Public Health Service]

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OCCURRENCE AND MITIGATION OF INJURIOUS DUSTS IN STEEL WORKS.

By J. A. Watkins.

INTRODUCTION.

The Bureau of Mines, in its efforts to improve health conditions in mining and metallurgical industries, is investigating the effects of dusts in mines and metallurgical plants on those employed therein. This report treats of the effects of industrial dusts in steel works.

From the standpoint of the industrial hygienist, no health hazard to which those employed in modern industries are exposed is of greater importance than that of a dust-laden atmosphere. The statistician of a large insurance company has said that "the morbidity and the mortality of wage earners are high or low in almost exact proportion as the air conditions are those of relative purity or impurity, wholesomeness or pollution." This fact has become so generally recognized that many life insurance companies refuse to accept as risks those engaged in the so-called dusty trades.

PATHOGENICITY OF INDUSTRIAL DUSTS.

Dust may act injuriously in three different ways, depending on the character of the dust particles, as follows: (1) By irritant action, (2) by toxic action, and (3) by mechanical action.

It often happens that a dust acts in two or more of these ways simultaneously; for example, a dust may be both toxic and irritating. An example of dust which acts in an irritant manner is that from flint chert, or similarly siliceous rocks. The injurious action of such a dust is due to the particles being hard, sharp, and angular. When these sharp particles are inhaled they injure the delicate membranes lining the respiratory tract, set up an inflammation, and because they are with difficulty coughed or spit out, continue this action. The result is that the injured tissue becomes a fertile location for the growth of pathogenic organisms to which, because of natural resistance, it had previously been comparatively immune. Among these pathogenic organisms may be mentioned those of the common cold, influenza, pneumonia, and, of far greater importance, the causative organism of tuberculosis. In addition this type of dust is the cause of the inflammatory conditions of the nose and throat which are found in practically all those who work in an atmosphere in which it is suspended.

Of the dusts that act in a toxic manner, lead dust is an illustration. Lead poisoning has been so often and so fully discussed that it need not be dwelt on here.

There remain those dusts that act in a purely mechanical manner. Of these, flour dusts may be cited as an example. The particles of flour are neither hard, sharp, nor angular, neither are they toxic in nature, so that their injurious action lies only in the mechanical interference they may offer to certain physiological processes, as, for example, to that of respiration because of their clogging the minute air cells of the lungs.

Dusts may also be injurious to the eye and its appendages by acting in either an irritant, a toxic, or a mechanical way. The conjunctiva or exterior membrane is the part most frequently affected, because of its delicacy, sensitivity, and exposed situation. A conjunctival inflammation of greater or less severity is a common condition among those employed in certain dusty trades. Should the dust have a marked irritant action, ulceration or more serious conditions may result.

Because of the shape of the ear, dusts are prone to lodge therein and may either mechanically interfere with the proper functioning action of this organ, or, should the dusts have an irritant or toxic action, they may cause serious injury of the more delicate parts.

Much of the dust that is inhaled never reaches the lungs because it is caught in the nose, throat, and mouth. Some of this dust is swallowed; it may be poisonous, as lead dust, and be absorbed in the stomach and intestines. Other less poisonous dusts may none the less injure the throat and produce inflammation. Such dusts also interfere with the proper physiological action of the stomach and intestines, a common result being a stubborn constipation or diarrhea, according to the character of the dust swallowed.

As the skin is the most exposed part of the body, it frequently bears the brunt of the ill effects of industrial dusts, particularly of those dusts that act as local irritants. Such a caustic dust is that of calcined dolomite.

WHERE DUSTS ARE FOUND IN STEEL WORKS.

STORAGE BINS.

The storage bins of blast furnaces and steel plants contain large quantities of iron ore, coke, and limestone. When any one of these materials is required in the charging of a furnace, it is withdrawn through chutes into skips. The skips are hoisted to the top of the furnace and dumped. In this handling of the materials more or less dust is produced, which becomes suspended in the atmosphere to a varying extent, depending on a number of factors. Among the factors which influence the proportion of dust in suspension may be mentioned the weather conditions, particularly those of moisture precipitation, the situation of the bins with reference to facilities for natural ventilation, and the method employed in loading the skips.

BLAST FURNACE.

About blast furnaces the suspended matter in the air is mainly graphite. This is originally in solution in molten iron, but as the iron falls in temperature the graphite crystallizes out, and in tapping the furnace some graphite dust becomes suspended in the air and is carried by air currents to different parts of the casting shed.

Dust from the fire clay with which the tapping hole is plugged after casting often becomes suspended in the atmosphere near by. In cleaning out the tapping hole before casting, after the clay has been bored some distance with a drill, the débris is blown out with steam or compressed air. The men engaged are then enveloped in a cloud of this dust.

In rebuilding a blast furnace it is customary at some plants to grind the finished brick to certain sizes and shapes. Those engaged in such grinding are exposed to much dust, the particles of which are hard, sharp, and angular.

STOVES.

Large quantities of gas pass with great velocity from the blast furnaces through the stoves. As a result, much finely divided furnace stock—the iron ore, coke, and limestone—is carried over. In some plants this dust is caught in so-called dust catchers, loaded in cars, and taken away. While the dust is being loaded, some of it becomes suspended and is blown about, and men working near the dust catchers are exposed to it.

Cleaning and repairing the stoves is particularly dusty work, and those laborers who do the cleaning and the masons, mechanics, and others concerned with repair are exposed to large quantities of this downcomer dust.

WASHERS AND BLOWERS.

Blast-furnace gas is washed to free it of much of its suspended matter and is then forced through conduits to gas-burning boilers and to gas engines which drive blowers and other equipment. While the washers and blowers are in working order and operating there is little dust in the air. Should an accident or breakdown take place, however, the atmosphere becomes at once heavily dust laden. Besides, it occasionally becomes necessary to clean the various parts of the equipment, and then the men engaged in the work are exposed to large amounts of flue dust.

DOLOMITE SHED.

Dolomite and other materials are collected, heated, ground, and otherwise prepared for use as refractory materials for lining furnaces, mixers, converters, and reheating furnaces. The men engaged in this work are exposed to enormous quantities of dust. At the dolomite sheds the dolomite is calcined and ground; at other places limestone, sand, fire clay, fire brick, and other refractory materials are handled.

OPEN-HEARTH FURNACES.

While an open-hearth furnace is in operation there is ample opportunity for a number of different dusts to become suspended, the most prominent being various carbon products, such as soot. Small quantities of graphite may become suspended during the tapping of a furnace. During bottom making the dolomite thrown into the furnaces gives rise to a dust cloud. Small amounts of other materials handled about open-hearth furnaces, such as iron ore and fluorspar, may at times become suspended.

ROLLING MILLS.

Most of the dust in a rolling mill consists of roll scale (partly oxidized iron and iron oxide) and soot. The former rises from the surface of the hot stock being rolled, particularly when the stock is sprayed with water or steam. Its source is mainly the upper side of the stock on the far side of the roll, and it leaves the stock at an angle of about 30° from the horizontal. The larger particles fall, while the smaller become suspended in the air and are carried to various parts of the building. The soot and other carbon products come from coal and gas fires in various parts of the plant and are carried to the rolling-mill buildings by air currents.

SOAKING PITS.

The soaking pits are reheating furnaces fired with gas. Often combustion is incomplete and as the tops of the furnaces are seldom tight, soot and like carbon products pollute the atmosphere. In addition, during the process of bottom making coke is thrown into the furnaces, and as a result much coke dust rises into the air.

SOFT-COAL FIRES.

A most prolific source of suspended matter in the atmosphere at steel plants is the soft-coal fires such as in some boilers and furnaces and in the "dinky engines." Although the dust and soot are probably of little sanitary significance, they are of great importance in a number of other ways, especially in their intimate relation to sufficient lighting. This is a serious problem. The soot settles on windows and illuminating units, and also interferes with the line of vision. Its effect on secondary and tertiary sources of light (the sky and the reflecting surfaces of buildings) is very noticeable. In the Pittsburgh district the brightness of the sky is markedly reduced at times because of the smoke cloud.

GAS PRODUCERS.

Dusty conditions are especially noticeable at gas producers. Here the amount of suspended matter is enormous.

BESSEMER CONVERTERS.

At the converters fine particles of graphite and the oxides of various metals are suspended in the air after a blow. Where converters are being repaired, refractory materials are used and at times the dust from these pollutes the atmosphere. Where ganister is ground its dust often becomes suspended in enormous quantities.

FOUNDRY.

Usually the foundry building is overcrowded and has no flooring of any kind except loose earth. In addition, much hot metal is poured, brass and other alloys as well as iron and steel; molds are made and destroyed, and castings are cleaned and "blasted". As a result of each these processes much finely divided matter becomes suspended in the air.

GRINDING EQUIPMENT.

At times various grinding devices are used in a steel plant, as in the mechanical departments where emery wheels are used and in that part of the foundry where castings are finished. Fire brick are sometimes ground to various sizes and shapes to meet certain requirements, and, more rarely, grinding has to be done in the pattern shop. These operations give rise to dusts to which the men employed about the places are exposed.

SAMPLING DUSTY AIR.

APPARATUS.

In order to determine the extent to which the various dusts were suspended in the atmosphere at various working places in a steel plant a number of air samples were taken and sent to the laboratory for quantitative reports. The sampler used was that devised by Passed Assist. Surg. A. J. Lanza, United States Public Health Service, and Edwin Higgins, mining engineer, of the Bureau of Mines. The device is illustrated in Plates I and II. As described by them in Technical Paper 105,[a] it is as follows:

[a] Lanza, A. J., and Higgins, Edwin, Pulmonary disease among miners in the Joplin district, Missouri, and its relation to rock dust in the mines; a preliminary report: Tech. Paper 105, Bureau of Mines, 1915, pp. 24-25.

The device consists essentially of the following parts:

1. A glass bulb or container for the filtering medium. This bulb is partly filled with granulated sugar, which has been found in tests made in South Africa and in tests by the Bureau of Mines to be superior to any other medium as a dust filter. This sugar is prevented from passing into the sampling device by means of a perforated glass plate inserted in the bottom of the glass bulb.

2. That part of the Draeger oxygen-breathing apparatus known as the mouthpiece, with inhalation and exhalation tubes attached. The mouthpiece may be held in position when the device is in use by means of a cap to which straps are attached. It is not necessary, however, to use a cap when one becomes familiar with the device.

3. A nose clip to prevent air from passing through the nostrils.

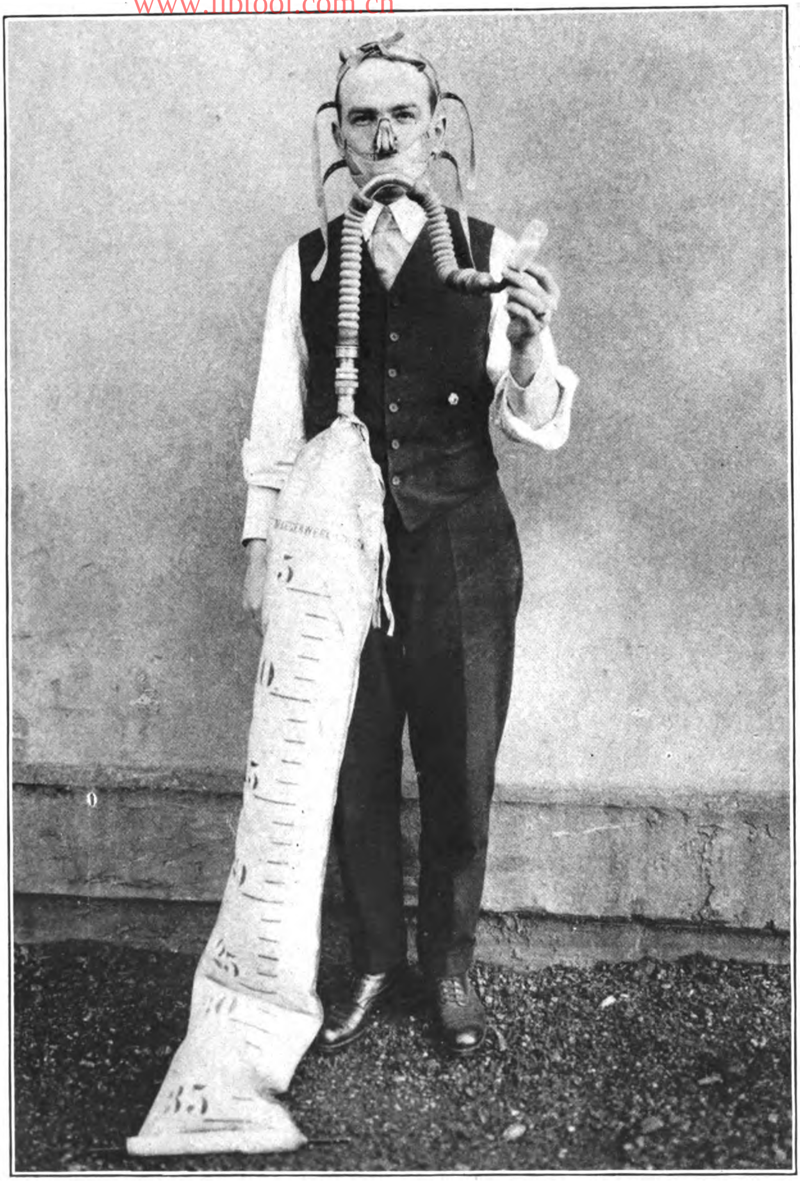
4. What is known as a Draeger liter bag, having a capacity of 35 liters.

METHOD.

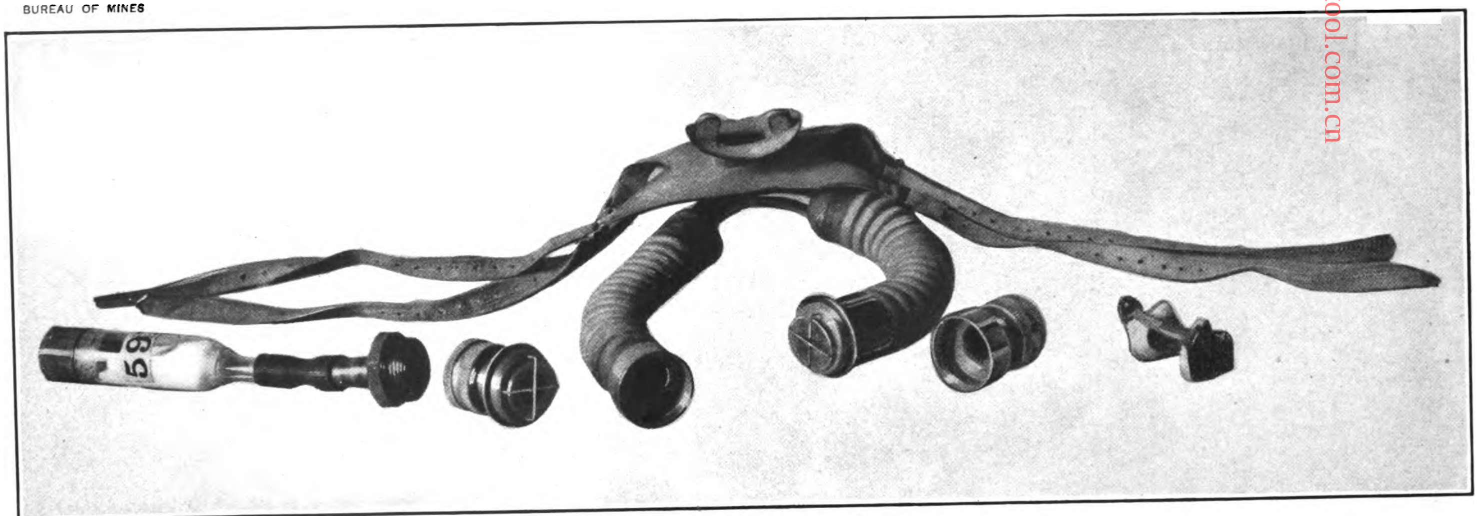
In order to collect a sample, the apparatus, with a dust bulb and the liter bag attached, is adjusted to the mouth. The nose clip is then placed on the nose and the person taking the sample breathes naturally. When air is inhaled, the valve in the inhalation tube opens, allowing the air to pass to the lungs (through the dust bulb), at the same time the valve in the exhalation tube closes, making it impossible to draw air from the liter bag. When air is exhaled from the lungs the valve in the inhalation tube closes and that in the exhalation tube opens. In taking a sample, then, the air passes through the bulb (where the dust is intercepted by the sugar) into the lungs, and thence through the exhalation tube to the liter bag, where it is measured. Ordinarily, sufficient accuracy may be secured by inhaling and breathing out a total of 35 liters of air. However, if the place in which a sample is taken is only slightly dusty, the bag may be filled a second time, thus making a total of 70 liters of air for the sample.

ACCURACY OF SAMPLING DEVICE.

The air exhaled from the lungs occupies about one-fiftieth less volume than the air that is inhaled. This difference does not cause an appreciable error and correction may be made easily. The taking of a large volume of air—35 liters, or 70 liters if desired, is taken at one sampling—makes for accuracy. Although the liter bag is not elastic, a small source of error may arise in determining just when it should be considered full of air. Error from this source, however, may be reduced to a minimum by practice in using the device. As to the velocity of the air entering the sugar bulb and the frequency of the inhalations, the device enables the sampler to imitate closely the breathing of a miner at work.



APPARATUS FOR DETERMINING DUST IN AIR.



DETAILS OF DUST-SAMPLING DEVICE.

In sampling the air in steel plants a greater volume of air was sampled than in the work done by Lanza and Higgins; the bag was filled five to twenty-seven times instead of once or twice. These larger volumes were taken because the amount of suspended matter in any working place in a steel plant varies decidedly from time to time, the factors concerned being not only the natural ventilation and the weather conditions but also the particular operations being carried on. It was thought that sampling the air over a considerable period of time would make the results representative of the average conditions as to suspended matter. A number of samples were taken in each place under different conditions of weather and plant operation.

Photomicrographs of the dust particles, reproduced herewith, were taken at the Pittsburgh experiment station of the Bureau of Mines, under the direction of Reinhard Thiessen, assistant chemist.

The laboratory determinations were also made at the Pittsburgh station of the Bureau of Mines under the direction of A. C. Fieldner, chemist.

The technique is in brief as follows: The glass bulb that contains the filtering medium (sugar), and whatever dust has been caught, is washed out thoroughly with hot distilled water. The sugar goes into solution, and the dust remains suspended therein. This is then passed through a Gooch crucible of known weight, using short-fiber asbestos as a filter. The Gooch crucible is then dried at 110° C. for one hour, cooled in a calcium chloride dessicator to room temperature, and then weighed. The increase in weight represents the weight of the dust.

The laboratory data are tabulated as follows:

Dust in air at various places in steel plants.

ORE BINS.

Laboratory No.	Sample No.	Sample taken—	Character of dust.	Amount of dust per 100 liters (milligrams).
23932	1	On larry	Coke	3.04
23933	2	.....do	.....do	4.7
23934	3	.....do	.....do	5.2
23938	4	.....do	.....do	22.8
23941	5	.....do	Iron ore	19.0
23942	6	.....do	.....do	23.5
23943	7	Under chutes	Coke	40.0
23950	8	.....do	.....do	44.0
23946	9	.....do	Iron ore	38.6
23571	10	.....do	Limestone	44.2

BLAST FURNACES.

Laboratory No.	Sample No.	Sample taken—	Character of dust.	Amount of dust per 100 liters (milligrams).
23621	1	Furnace shed during cast	Graphite	0.15
23612	2	.....do	.....do	.12
23935	3	Around dust catcher	Flue dust [a]	7.11

[a] Coke, limestone, iron ore.

Dust in air at various places in steel plants—Continued.

DOLOMITE SHED.

Laboratory No.	Sample No.	Sample taken—	Character of dust.	Amount of dust per 100 liters (milligrams).
23944	1	In shed	Dolomite	5.5
23945	2	....do	....do	[a] 12.5
23947	3	....do	....do	[b] 19.6
23948	4	....do	....do	[b] 22.4
23949	5	....do	....do	[b] 28.6
23520	6	....do	....do	[b] 33.4
23610	7	....do	....do	[b] 6.5

OPEN HEARTH.

23926	1	On charging floor	([c])	0.61
23927	2	....do	([c])	.52
23572	3	....do	([c])	.54
23620	4	....do	([c])	.47
23931	5	....do	([c])	.92

SOAKING PITS.

23936	1	In building	Coke and soot	0.61
23937	2	....do	....do	.58
23622	3	....do	....do	.47
23930	4	....do	....do	.51

ROLLING MILLS.

23929	1	In building	Roll scale	0.87
23939	2	....do	....do	.98
23940	3	....do	....do	1.02
23928	4	....do	....do	.90
23611	5	....do	....do	2.01

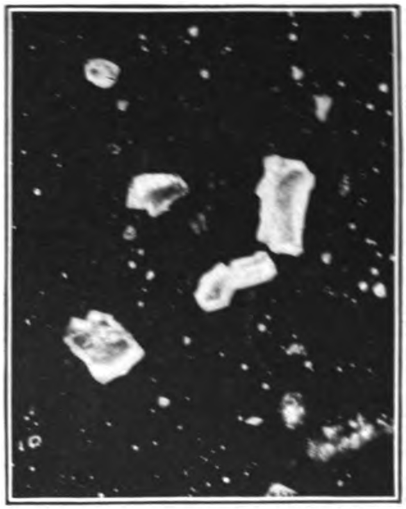
[a] After grinding. [b] During grinding. [c] Graphite, ore, fluorspar, dolomite, soot, etc.

COMMENT ON DUSTS COLLECTED.

IRON-ORE DUST.

The table shows that at times iron-ore dust is suspended in the atmosphere around the ore bins in exceptionally large quantities—as much as 23.5 mmg. per 100 liters. While this dust (see Pl. III, *A*) contains many particles varying from 4 to 10 microns in size, a characteristic feature noted in the study of this dust was the enormous number of ultramicroscopic particles. The larger particles readily break up into these ultramicroscopic particles in a fluid medium. A somewhat similar occurrence probably takes place in the respiratory tract; and if so would make the removal of these particles by coughing or expectorating very difficult, if not impossible. The larger particles are irregular, roughly spherical, and have few sharp edges but some points. Iron-ore dust has no toxic action and the particles examined were not very hard. Its physiological effect

A. IRON ORE DUST. PARTICLES MAGNIFIED 550 DIAMETERS.



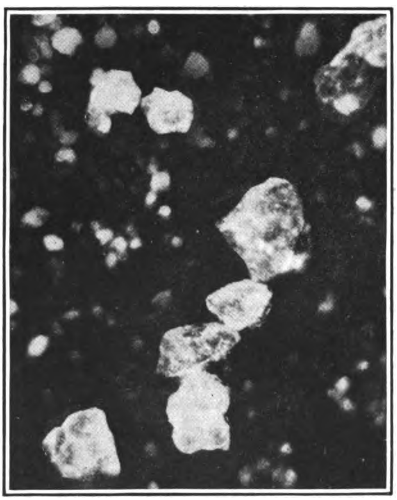
B. LIMESTONE DUST. PARTICLES MAGNIFIED 550 DIAMETERS.

C. COKE DUST. PARTICLES MAGNIFIED 550 DIAMETERS.

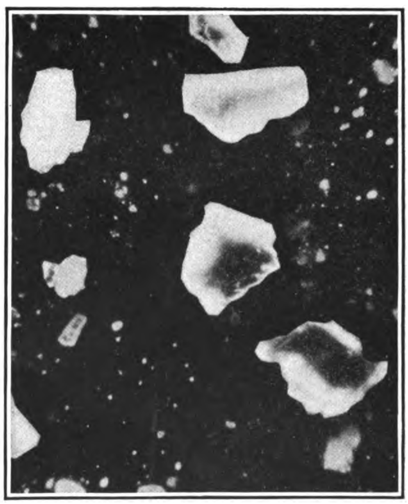
D. LIMESTONE DUST, LARGE PARTICLES. MAGNIFIED 550 DIAMETERS.

A. FLUE DUST FROM AIR ABOUT DOWN-COMER. PARTICLES MAGNIFIED 550 DIAMETERS. *a*, COKE; *b*, LIMESTONE; *c*, IRON ORE.

B. ROLL-SCALE DUST. PARTICLES MAGNIFIED 550 DIAMETERS.



C. DOLOMITE DUST. PARTICLES MAGNIFIED 550 DIAMETERS.



D. SILICA DUST. PARTICLES MAGNIFIED 550 DIAMETERS.

on man can be surmised only, but is probably limited to that caused by the mechanical action of the particles, which act as irritating bodies where they lodge in the respiratory tract.

COKE DUST.

Coke dust occurs in the same places as iron-ore dust, and is also suspended in enormous quantities there. As the particles are lighter, they remain suspended for a much longer period. Coke particles (see Pl. III, *C*) are markedly irregular, angular, have many sharp points and edges, and are brittle and hard. They retain the latter characteristics practically unchanged after immersion in water for two or three days. Coke dust is not toxic, and acts in a mechanical manner only, but because of its hard, sharp points it no doubt injures delicate tissues with which it comes in contact.

LIMESTONE.

The particles of limestone dust (see Pl. III, *B* and *D*) examined are hard. They are decidedly irregular and, when magnified 500 diameters, their points and edges are seen to be decidedly sharp. The dust sampled contains much ultramicroscopic matter, but these invisible particles are probably just as hard and sharp as those that are visible. The particles are heavier than coke-dust particles and therefore do not remain suspended as long, but they are harder and smaller. Such particles undoubtedly would be decidedly irritating to delicate tissues, especially those of the respiratory tract.

FLUE DUST.

Flue dust is the term applied to the mixture of finely divided coke, limestone, and iron ore from the blast-furnace top. Large particles are carried over by this blast, but an enormous amount is finely divided matter, much of it ultramicroscopic. (See Pl. IV, *A*.) Its physiological effects would be similar to coke, limestone, and iron-ore dust, as discussed above.

GRAPHITE.

Molten iron holds graphite in solution. When the iron cools somewhat, the graphite crystallizes. Relatively very little of the graphite dust is of microscopic proportions; much of it is in thin, irregularly rounded soft flakes measuring $\frac{1}{4}$ to $\frac{1}{3}$ mm. in width. As graphite dust is not toxic, it is believed to be of no hygienic significance in a steel plant.

DOLOMITE.

As regards industrial hygiene, dolomite, $CaMaCO_3$, is the most important dust in a steel plant, not only because of its character and action but also because of the enormous quantities of it suspended in the atmosphere of certain working locations. The dolomite particles examined are very irregular, with few sharp points, but generally with some sharp edges, and are hard. The particles examined were 5 to 15 microns in size. (See Pl. IV, *C*.) Calcined dolomite contains a large percentage of free lime which on becoming moist slakes and is then very irritating to the tissues of the body, particularly those of the nose, throat, and eyes. Its effect on the delicate membranous lining of the respiratory tract can be readily surmised.

OTHER REFRACTORY MATERIAL.

A highly siliceous sandstone, termed ganister, is used to some extent in patching and repairing the interior of an open-hearth furnace; fire clay also is occasionally used. The dust rarely becomes suspended in sufficient quantities to be of much hygienic significance. The silica particles examined (see Pl. IV, *D*) were 5 to 20 microns in size, irregular, angular, sharp, and exceedingly hard.

ROLL SCALE.

When hot iron or steel is rolled, it is subjected to much pressure and while in transit is sprayed with water or steam. On the far side of the roll a great deal of so-called roll scale (partly oxidized iron and iron oxide) is given off, the lighter particles of which become suspended in the air. These suspended particles are irregular and measure 10 to 20 microns in diameter. Many are elongated, with sharp edges and points. (See Pl. IV, *B*.) The particles are hard and brittle. A sample of roll-scale dust contains little ultramicroscopic matter. The dust is not toxic.

GENERAL METHODS OF MITIGATING THE DUST HAZARD.

There are three general methods of abating dust in the industries, as follows: (1) Preventing dust suspension, (2) removing suspended dust from air, and (3) providing against the inhalation of dust.

A fourth method which may be mentioned is to house incompletely the department in which there is much suspended matter and prohibit employees from working or remaining therein. Some of the above methods, or a combination of two or more of them, will be applicable in most instances and will prove successful.

PREVENTING SUSPENSION.

Usually in each case a thorough study of the existing conditions must be made with a view to determining the origin of the dust and the cause of its suspension. Then suspension may be prevented in a number of ways, according to the conditions, which will vary in each instance. It may be necessary, as frequently happens, to alter the usual procedure of the manufacturing process or to change machinery or equipment in order to obtain satisfactory results. Where the manufacturing process or the materials handled will not be adversely affected, sprinkling with water may prove effective. Occasionally it becomes necessary to substitute for the dust-producing materials in use other materials which do not become finely divided or suspended.

REMOVING SUSPENDED DUST FROM AIR.

Foremost among the methods employed for dust removal is that of an efficient system of exhausting and supplying air. A system of electric precipitation can be used, but its usefulness is limited largely to dust in flues.

PREVENTING INHALATION OF DUST.

Where other methods are impracticable or exposure to dust is occasional, employees should be required to wear respirators, or their duties and places of work should be altered.

ABATEMENT OF DUSTS IN THE STEEL INDUSTRY.

ORE BINS.

Dust originates when the furnace stock is drawn from the bins into the skips. All employees about ore bins, the so-called "back-gang," are exposed, but those particularly liable to be affected are the men operating the skips or the larry cars. Although judiciously sprinkling the stock with water may lessen the dust, sprinkling can not be done in a manner continually or entirely satisfactory. The relation between such wetting down and the amount of dust suspended in the air is clearly shown after rain or snow. Men employed at the bins should be furnished respirators and be required to wear them. In addition, provisions should be made for ample natural ventilation. At some bins an exhaust system would do much to remove dust.

BLAST FURNACES.

Graphite dust arises mainly during a cast. As the total time of casting is small in comparison with the time the men are on duty, and as the casting house, being large, high, and open on two or more sides, usually has ample natural ventilation, it is improbable that dust is a health hazard of much importance about the furnace. Moreover, nothing can be done to prevent the formation of graphite or its suspension in the air.

STOVES.

Ordinarily, the men employed at the stoves are not exposed to much dust, but all precautionary measures against it should be taken while the stoves are being cleaned or repaired and when the dust catcher is being emptied. Respirators should be required, and as an additional safeguard the dust should be well sprinkled with water.

WASHERS AND BLOWERS.

Men employed about washers and blowers may occasionally be exposed to large amounts of dust, and to meet this condition they should be required to wear respirators. Also, the dust should be wet down.

DOLOMITE SHED.

As the dolomite shed is sometimes filled with a cloud of dust effective measures of mitigation are most urgent. Much of the dust originates at the grinding machine. To avoid pollution of air in which men are working, the machine should be placed elsewhere, or should be entirely inclosed and an air-exhaust system installed for removing the dust of grinding. Dust also rises into the air while the calcining furnaces are being charged. It is believed that the exercise of more care by the crane operator when dumping the dolomite into a furnace would do much to abate dust. In addition, all employees in this department should wear respirators. As a health hazard, the dust in this department has other injurious effects than those to the respiratory tract. The calcined dolomite contains much free lime which when moist irritates the skin and the mucous membranes exposed to it. This dust frequently accumulates in the clothing and on the skin. When warm weather or hard work makes men perspire freely the skin is irritated, becomes painful, and a serious condition may result. It is important to have this department equipped with ample washing and bathing facilities and to require the men to bathe thoroughly after each turn of duty. In addition, they should gargle water, douche the nose, and wash the teeth in order to clear away any dust. Another important facility that should be provided these men is a clothes locker, which should be dust proof if it is to be in the dolomite shed. Men employed in the shed should put on clean underclothing and socks each day, and to encourage them in doing this facilities such as wash sinks, hot water, soap, and drying racks should be supplied.

OPEN-HEARTH DEPARTMENT.

In the open-hearth department suspended dust is neither an urgent nor a difficult condition to meet. Though the various materials used, as discussed above, do at times become finely divided and suspended, the quantity of this dust is not large. In addition, the open-hearth buildings are exceptionally large and if two or more sides are left open the ample natural ventilation will effectively carry the dust away.

ROLLING MILLS.

The reduction to a minimum of dust in the rolling mills should receive attention. As the points of origin of this dust—at the rolls—are comparatively small, preventive efforts can be concentrated. It is believed that a fine water spray falling with force just beyond the place where the dust begins to rise would prove effective. Water sprays are now used to cool the rolls, and little difficulty or extra labor and expense should be needed for placing the additional spray. If wet down in this manner the dust would fall with the roll scale into the scale pit, whence it could be subsequently removed.

SOAKING PITS.

In addition to the soot, which is described elsewhere, coke dust becomes suspended in the air as a result of the operation called bottom making, during which finely divided coke is thrown into the pits. The only way to mitigate the dust hazard is to require the men to wear respirators.

SOFT-COAL FIRES.

The abatement of soot and dust from soft-coal fires has received much attention lately and has been discussed at length in publications of the Bureau of Mines.[a] In a steel plant, dust from this source can be greatly reduced and practically eliminated. With substitution of gas and coke for soft coal in furnaces and dinky engines, and with more care to insure complete combustion, and other improvements in methods of firing, this objectionable feature will disappear.

BESSEMER DEPARTMENT.

In the Bessemer department attention should be given to preventing dust suspension at the grinding machines in the converter repair shop. The comment on measures demanded at the dolomite shed is applicable to this department as well.

FOUNDRY.

Many and diverse conditions give rise to dust in the foundry. To abate the dust a great deal of effort and every means of prevention and mitigation must be employed. Castings should be cleaned and "blasted" in a separate room where only those men needed for the work are allowed to remain. These employees should be required to

[a] Randall, D. T., The smoke problem at boiler plants: Bull. 39, Bureau of Mines, 1912, 31 pp.; Randall, D. T., and Weeks, H. W., The smokeless combustion of fuel in boiler furnaces: Bull. 40, Bureau of Mines, 1912, 188 pp.; Flagg, S. B., Smoke ordinances and smoke abatement: Bull. 49, Bureau of Mines, 1912, 55 pp.

wear respirators. Casting, especially the casting of brass and similar alloys, should be done in a separate building where precautions are taken to insure ample ventilation by natural and artificial means. The main foundry room should be given more floor space and, except where molds are made, should have suitable flooring of steel plate or brick. This flooring should be sprinkled with water frequently. In addition provision should be made for an abundant supply of fresh air. Grinding wheels should be supplied with an effective exhaust system, and as an additional safeguard the men engaged should be required to wear respirators.

PUBLICATIONS ON METALLURGY.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the superintendent of documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 16. The uses of peat for fuel and other purposes, by C. A. Davis. 1911. 214 pp., 1 pl., 1 fig.

BULLETIN 64. The titaniferous iron ores in the United States; their composition and economic value, by J. T. Singewald, jr. 1913. 145 pp., 16 pls., 3 figs.

BULLETIN 67. Electric furnaces for making iron and steel, by D. A. Lyon and R. M. Keeney. 1914. 142 pp., 36 figs.

BULLETIN 70. A preliminary report on uranium, radium, and vanadium, by R. B. Moore and K. L. Kithil. 1913. 100 pp., 2 pls., 2 figs.

BULLETIN 73. Brass-furnace practice in the United States, by H. W. Gillett. 1914. 298 pp., 2 pls., 23 figs.

BULLETIN 77. The electric furnace in metallurgical work, by D. A. Lyon, R. M. Keeney, and J. F. Cullen. 1914. 216 pp., 56 figs.

BULLETIN 81. The smelting of copper ores in the electric furnace, by D. A. Lyon and R. M. Keeney. 1915. 80 pp., 6 figs.

BULLETIN 84. Metallurgical smoke, by C. H. Fulton. 1915. 94 pp., 6 pls., 15 figs.

BULLETIN 85. Analyses of mine and car samples of coal collected in the fiscal years 1911 to 1913, by A. C. Fieldner, H. I. Smith, A. H. Fay, and Samuel Sanford. 1914. 444 pp., 2 figs.

BULLETIN 91. Instruments for recording carbon dioxide in flue gases, by J. F. Barkley and S. B. Flagg. 1915. 60 pp., 1 pl., 25 figs.

BULLETIN 100. Manufacture and uses of alloy steels, by H. D. Hibbard. 1915. 78 pp.

BULLETIN 108. Melting aluminum chips, by H. W. Gillett and G. M. James. 1916. 88 pp.

BULLETIN 116. Methods of sampling delivered coal, and specifications for the purchase of coal by the Government, by G. S. Pope. 1916. 64 pp., 5 pls., 2 figs.

BULLETIN 122. The principles and practice of sampling metallic metallurgical materials, with special reference to the sampling of copper bullion, by Edward Keller. 1916. 102 pp., 13 pls., 31 figs.

Technical Paper 8. Methods of analyzing coal and coke, [illegible] M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 [illegible]

Technical Paper 50. Metallurgical coke, by A. W. [illegible] 48 pp., 1 pl., 23 figs.

Technical Paper 76. Notes on the sampling and analysis of coal, by A. C. Fieldner. 1914. 59 pp., 6 figs.

Technical Paper 80. Hand firing soft coal under power-plant boilers, by Henry Kreisinger. 1915. 83 pp., 32 figs.

Technical Paper 86. Ore-sampling conditions in the West, by T. R. Woodbridge. 1916. 96 pp., 5 pls., 17 figs.

Technical Paper 95. Mining and milling of lead and zinc ores in the Wisconsin district, Wisconsin, by C. A. Wright. 1915. 39 pp., 2 pls., 5 figs.

Technical Paper 102. Health conservation at steel mills, by J. A. Watkins. 1916. 36 pp.

Technical Paper 106. Asphyxiation from blast-furnace gas, by F. H. Willcox. 1916. 79 pp., 8 pls., 11 figs.

Technical Paper 136. Safe practice at blast furnaces; a manual for foremen and men, by F. H. Willcox. 1916. 73 pp., 1 pl., 43 figs.

Technical Paper 157. A method for measuring the viscosity of blast-furnace slag at high temperatures, by A. L. Feild. 1916. 29 pp., 1 pl., 7 figs.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

Bulletin 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp. 5 cents.

Bulletin 7. Essential factors in the formation of producer gas, by J. K. Clement, L. H. Adams, and C. N. Haskins. 1911. 58 pp., 1 pl., 16 figs. 10 cents.

Bulletin 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp., 6 figs. 5 cents.

Bulletin 47. Notes on mineral wastes, by C. L. Parsons. 1912. 44 pp. 5 cents.

Bulletin 54. Foundry cupola gases and temperatures, by A. W. Belden. 1913. 20 pp., 3 pls., 16 figs. 10 cents.

Bulletin 97. Sampling and analysis of flue gases, by Henry Kreisinger and F. K. Ovitz. 1915. 68 pp., 1 pl., 37 figs. 15 cents.

Bulletin 98. Report of the Selby Smelter Commission, by J. A. Holmes, E. C. Franklin, and R. A. Gould, with reports by associates on the commissioners' staff. 1915. 525 pp., 41 pls., 14 figs. $1.25.

Technical Paper 31. Apparatus for the exact analysis of flue gas, by G. A. Burrell and F. M. Seibert. 1913. 12 pp., 1 fig. 5 cents.

Technical Paper 41. The mining and treatment of lead and zinc ores in the Joplin district, Missouri, a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs. 5 cents.

Technical Paper 54. Errors in gas analysis due to the assumption that the molecular volumes of all gases are alike, by G. A. Burrell and F. M. Seibert. 1913. 16 pp., 1 fig. 5 cents.

Technical Paper 60. The approximate melting points of some commercial copper alloys, by H. W. Gillett and A. B. Norton. 1913. 10 pp., 1 fig. 5 cents.

Technical Paper 90. Metallurgical treatment of the low-grade and complex ores of Utah, a preliminary report, by D. A. Lyon, R. H. Bradford, S. S. Arentz, O. C. Ralston, and C. L. Larson. 1915. 40 pp. 5 cents.

Technical Paper 109. Composition of the natural gas used in 25 cities, with a discussion of the properties of natural gas, by G. A. Burrell and G. G. Oberfell. 1915. 22 pp. 5 cents.