meet existing codes, but as dust-tight as human ingenuity can design them. After the equipment is installed, it will be the purchaser's responsibility to see that it is regularly inspected and maintained to perform the service for which it was originally designed.

And we refer again to the employee's responsibility. When he elects to work in a foundry, he should be willing to co-operate and wear the safety devices which are provided by his employer, and it will be the purchaser's responsibility to see that the equipment is well cared for and properly maintained.

Our industry is a basic one and we hope that it will long continue to be essential. For this reason we want to assure those who are sitting on the side lines that it is our determination and hope that, with the help of those in the medical profession who have given so generously of their time in scientific study, we can soon determine the actual extent of the hazard.

In the meantime, while many diverse opinions are being brought into agreement, it is imperative that we give more than passive assent to suggested measures of precaution or improvement. The accomplishment of worth while results depends upon the diligent and active co-operation of everyone concerned and the utilization of all known means of prevention and control. Only through united effort can we hope to accomplish an effective program which will give maximum of advantage to employers and employees alike, and to such an end we are confident the foundry industry will continue to dedicate its earnest and conscientious efforts.

How to Determine the Dust Content of the Atmosphere in Dusty Industries

By DR. E. G. MEITER

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The importance of atmospheric dust as an agent in the causation of respiratory disease has long been known. However, it is only within the last few years that this subject has achieved medical and legal importance in dusty industries. Because of the extension of compensation laws to include occupational diseases, and through an ever-increasing number of legal suits against industrial concerns by employees claiming disability due to dust inhalation, there is need for a severe attack on the problem of eliminating or otherwise combating the dust hazard. In order to intelligently control the dustiness of the air, the amount of dust present must be determined. With a given dust, two factors are usually considered: (1) the number of dust particles in a given quantity of air, which is usually expressed in millions of particles per cubic foot of air; (2) particle-size, usually expressed in a size frequency distribution curve, that is the percentage less than stated size is plotted against the size of particles.

Instruments Used for Determining Atmospheric Dusts

Many instruments have been devised for determining the dust concentration in air and it may be well to give a brief historical review of this subject. The South African investigators began using the sugar tube method for the sampling of atmospheric dust in 1911; the same method was used by the U. S. Bureau of Mines as early as 1914. By this method a measured volume of the dust air is passed through

a tube containing granulated sugar, which filters out the suspended dust. At the laboratory, the sugar is dissolved in water and the number of dust particles are determined by counting those in a small volume of the sugar solution under a microscope. This method of dust sampling had certain disadvantages, the chief of which was the fact that the purest commercial sugar contained a certain quantity of dust, which introduced considerable errors, especially in those samples containing a low dust concentration. To overcome the limitations of the sugar tube method various other devices were developed, one of which was the Palmer apparatus. This apparatus consisted essentially of a pear-shaped glass bulb, the lower end of which terminated in a U-tube or trap. Suction was applied to the glass bulb by means of an electric exhaust fan and the volume of air measured by means of a Petot tube. Dust-free distilled water was put into the U-tube. The air drawn through the water in the trap broke it up into a spray within the larger portion of the sampling bulb, which washed out and retained the dust. The dust so obtained was analyzed by the usual methods. The Palmer apparatus also had certain disadvantages, the chief of which was that its efficiency as a dust catcher was low. In the search for a more portable type of instrument, which at the same time would yield rapid results, the South African investigators introduced in 1916 a new instrument known as the Kotzé konimeter. The konimeter samples dust by impinging a small volume of air against the surface of a vaseline-coated glass plate, the vaseline serving to catch the dust particles. The dust retained on the glass plate was then counted under the microscope at a suitable magnification. The chief disadvantages of the konimeter are that in atmospheres containing a high concentration of dust, the spots are too dense to allow counting the individual particles and the method can, therefore, not be used in such cases, also many samples had to be taken to secure a correct average determination in places where the dust concentration was variable.

As a result of the different methods of dust determination being used by the different governmental bureaus and others, it was soon found that the various dust-sampling methods did not yield absolute results, consequently some confusion arose in interpreting the various dust studies. In order to arrive at some basis of comparison the U. S. Bureau of Mines conducted a laboratory study of dust-sampling instruments. The results of this study were published in Public Health Bulletin No. 144 entitled "Comparative Tests of Instruments for Determining Atmospheric Dusts." (1925). During the course of this study two of the investigators, Dr. L. Greenburg and G. W. Smith, devised a new apparatus called the impinger. In the comparative study the dust collecting efficiency of the impinger was found to be high, and in addition the method offered several advantages over previous methods. After several modifications to meet special requirements, this instrument was adopted by the Federal Public Health Service and Bureau of Mines as the standard technique for the sampling of dust in air. The instrument has been used in the study of a number of dust trades, and is the commonly accepted method in use today.

Size of Dust Particles Taken into the Lungs

It has been observed from a study of silicotic lungs that most of the dust particles that have penetrated into the air sacs are less than 10 microns in longest dimension (1 micron is 1/1000th of a millimeter, or 1/2500th of an inch). It is generally agreed, therefore, that we need not bother with particles larger than 10 microns in measuring the concentration of a dangerous dust.

So that you may visualize the size of these small particles consider a 280 mesh

screen in which the screen openings are 50 microns. In the absence of a beam of light, an atmosphere containing these tiny particles will appear clear to the naked eye, and therefore is extremely deceptive. Only a powerful microscope can make such particles directly visible.

It is necessary, therefore, to make a microscopical examination of the atmosphere to learn how badly polluted it may be. Larger particles such as are visible to the naked eye are essentially harmless in the causation of silicosis, as these are caught by the membranes provided by nature in the nasal and other respiratory passages and are eventually coughed up or eliminated before any damage is done.

When small dust particles are dispersed in air, they are carried about like smoke and settle out very slowly. How long such particles will remain suspended in quiet air can be roughly determined from Stoke's law. Assuming a round particle to be one micron in diameter, it can be calculated by means of this law that such a particle will fall only 20.3 feet in 24 hours. It can be seen, therefore, that any fine dust dispersed into the air is not only a momentary hazard but remains in the air for an indefinite period. This fact is often overlooked by workmen, as it is usually assumed that as soon as the dust cloud is no longer visible all dust has settled out.

The term "dusty working place" is only a relative one. Most air, both inside and outside of factories, contains some dust. It is, therefore, necessary to adopt a standard content for the dividing line between slightly dusty and dusty working places. The Wisconsin dust code prescribes a "tentative figure of 15 million countable dust particles under 10 microns in longest dimension with free silica content of 35 per cent in a cubic foot of air as determined by Public Health Service technique. Variations in free silica content will make proportional inverse changes in this standard." In accordance with this standard the permissible count for practically pure silica would be 5,250,000 particles.

How Dust Samples are Collected

As mentioned previously, the instrument used in collecting the dust samples is that known as the "Impinger." With this instrument the air to be sampled is drawn through a glass tube and impinged at a high velocity on a glass plate which is immersed beneath a suitable liquid contained in the collecting flask.

The impinger, therefore, combines the principle of collecting dust by impingement with a water-washing or bubbling method and so possesses the advantages of both principles. The dust is thus trapped and remains in the collecting liquid. Suction is applied to the impinger by means of a steam ejector operated by compressed air. Where compressed air is not available, a small electrically-operated vacuum pump may be used. The rate of air flow is measured either by means of a small vacuum gage or an orifice-type flow meter.

The entire apparatus is calibrated before use against a standard gas meter, so that a known volume of air may be sampled. The rate of sampling is approximately one cubic foot of air per minute. The dust-collecting device is placed in close proximity to the breathing level of the workmen involved while performing their respective duties, so that air samples representing actual working conditions may be obtained. After a sufficient volume of dust-laden air has been sampled, the collecting liquid is placed in a suitable container and removed to the laboratory for the necessary analysis.

When the dust sample reaches the laboratory, the entire sample is filtered into a clean graduated flask through a 280-mesh screen so that only particles smaller than 50 microns are permitted to pass; particles larger than 50 microns are not considered

injurious and are, therefore, removed from the sample. After proper dilution, the contents of the graduated flask are thoroughly shaken so that a uniform suspension is obtained, and two portions of about one cubic centimeter are removed with a pipette to just fill two Sedgwick-Rafter counting cells. The cells are allowed to stand at least 20 minutes and the dust particles are then counted by means of a microscope.

The microscope with an Abbe condenser is provided with an eyepiece micrometer, a 16-millimeter objective and a 7.X eyepiece. The eyepiece micrometer has a large square engraved on it, and this square is divided into 100 squares, one of which is further divided into 25 smaller squares. The proper tube length of the microscope is determined by calibration with a stage micrometer, so that a side of the large square of the eyepiece covers 1 millimeter (1,000 microns).

The large square of the eyepiece micrometer, therefore, encloses the dust in an area of one square millimeter, and since the counting cell is one millimeter deep, all the dust suspended in one cubic millimeter of the sample is under the ruled field. All particles visually less than 10 microns in longest diameter in one quarter of the field are counted at five points on the cell, namely, near the four corners and the center.

Two cells of each dust sample are counted and the average of 10 counts is obtained. Control counts are subtracted from the average sample counts, giving finally, average net counts of the number of particles which are then calculated in terms of particles per cubic foot of air sampled.

Having determined the concentration of dust particles less than 10 microns in diameter in a given atmosphere, it is also necessary to obtain information regarding the mineral composition of the dust before any evaluation of the health hazard can be made.

In general it may be said that the harmfulness of a quartz containing dust is usually in direct proportion to its free-silica (SiO_2) content. It is, therefore, necessary to distinguish between "free silica", that is the silica that occurs as quartz, and "combined silica", or the silica that is combined with other elements in the various silicate minerals. It should be borne in mind, therefore, that the total silica reported in the customary chemical analysis is no measure of the amount of free silica.

The quartz content of fine dusts is usually determined by a combination of petrographic and chemical methods. Each dust presents individual problems and no individual technique applies to all dusts regardless of their composition. Those interested in this problem should consult Reprint No. 1560 of the Public Health Reports, February 24, 1933, entitled "The Quantitative Determination of Quartz (free silica) in Dusts" by Adolph Knopf, Professor of Physical Geology, Yale University, and Consultant, United States Public Health Service.

Discussion of Dust Problems

By DR. LEONARD GREENBURG

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The speaker said in part: On the technical side of this problem you have been presented with two excellent papers by Mr. Jones and Dr. Meiter. There is little that I should add from this point of view. Perhaps the most valuable contribution that I can make is to present to you my own personal view of the broader administrative aspects of this problem gained as a result of many years of close contact. In order to do this, let us analyze the problem in its simplest terms.