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## PRACTICAL DISCUSSION OF THE MIDGET IMPINGER FOR DUST SAMPLING

Department of Labor and Industry

Wm. H. Chesnut - Secretary

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COMMONWEALTH OF PENNSYLVANIA

*Uncontrolled
occupational diseases,
like uncontrolled
accident hazards
are a costly
and needless
by-product
of industry.*

DEPARTMENT OF LABOR AND INDUSTRY

# PRACTICAL DISCUSSION OF THE MIDGET IMPINGER

# FOR DUST SAMPLING

Edited by

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Safety engineers who are confronted with the task of determining the degree of hazard of a particular dust within their plant, are often unfamiliar with the scientific field concerning the best equipment to suit their particular purpose.

In order to obtain a technical review of the various available equipment for dust work, and the principles involved, our department has requested J. B. Littlefield to present a paper on a practical discussion of this subject.

Mr. Littlefield's research experience with the U. S. Bureau of Mines, and the part he has played in designing dust-collecting equipment, make his presentation of timely interest.

In tunnel-construction work now progressing in Pennsylvania, we find the newly-designed, hand-operated midget impinger outfit extremely valuable in dust determinations of drilling operations, chiefly because of its lightness and portability.

However, a description of this equipment is being presented , by Mr. Littlefield, for the benefit of safety engineers who have found other equipment either too cumbersome, or impractical due to plant operations that will not permit the use of lengthy electrical wiring, or air-sampling hose connections.

Mr. Littlefield aslo presents a review of dust sampling practice both in this country and abroad.

"PRACTICAL DISCUSSION OF THE MIDGET IMPINGER

FOR DUST SAMPLING

John B. Littlefield

THE MINE SAFETY APPLIANCES CO.

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"Boiled down to fundamentals, the question at hand is: 'What measure of air dustiness will show whether a particular atmosphere has a safe or dangerous concentration of dust?' The particles which are dispersed into the atmosphere by industrial processes are very small and those that remain in suspension for any time are extremely small indeed. The latter usually range in size from ten microns down with by far the greatest proportion one micron or less in size.

In selecting a mode of attack on this problem it is necessary to consider the properties and characteristics of the material with which we are dealing. A thousand particles, one-micron in size, of a given substance have the same mass as one-ten micron particle. A one millimeter sphere of quartz, weighing approximately one and a third milligrams, if crushed into one-micron particles would result in one thousand million particles and this operation would increase the surface area of the material by one thousand times. One more point to remember is that the larger and heavier a particle is the more rapidly it falls and is, so to speak, removed from circulation. A ten micron particle of silica, in still air, falls about 70 feet an hour and a one-micron particle will fall only about ten inches in the same length of time.

The selection of the sampling method is greatly influenced by the method used for the determination or estimation of the concentration or relative concentration. Four possible means of measuring the relative amount of dust are obvious; first by mass or weight, second by chemical analysis, third by measurement of surface area and fourth, by number concentration. Determination by weight is not desirable for several reasons. First, because it is too greatly influenced by a small number of large particles and affected very little by a large number of small particles. This method is applicable to the determination of poisonous dusts which are quite soluble or to dispersions of particles of uniform size such as fumes. At the present, however, we are mainly concerned with fibrosis-producing dusts such as silica or quartz and it is well known that a given weight of very small particles is much more harmful than the same weight of larger particles. It must also be remembered that particles 10 microns or larger in size rarely enter the lungs, but are caught in the nose and are either discharged or swallowed. Another objection to determinations by weight is that ordinarily very large volumes must be sampled in order to obtain sufficient material to weigh.

Chemical analysis introduces the same difficulties as determination by weight in that large particles influence the results unduly. Available methods for quartz are slow and none too satisfactory. This means, however, is eminently satisfactory for determining the toxic metal dusts and fumes.

Determination of surface area would probably yield the most desirable results but unfortunately no practical and convenient methods are available. The surface area of the quartz dust inhaled is probably the greatest factor in its fibrosis producing effect.

Thus, the choice of a suitable measurement of air dustiness has narrowed down to terms of number concentration, at least for fibrosis-producing and mixed dusts. For such a measurement, means must be found for counting the particles in a given volume of air. The smallest particle readily visible to the naked eye is about 100 microns in diameter, so a microscope must be used to render the particles visible, Microscopic counting, however, is not the complete answer to the question. The main difficulty is that with higher and higher magnification more and more particles are made visible; this number is greatly increased with darkfield illumination in which the sample is illuminated from the side and the tiny spots of light reflected from the particles are observed instead of the particles themselves. Darkfield illumination is best illustrated by a simple example: we do not see the dust in this room, but if we darken the room and look at a beam of sunlight entering through a small opening we say we see the dust in that beam of light. What we really see, is the light reflected from the particles of dust, most of which are much smaller than the 100 micron particle which is visible to the naked eye.

Working with very high magnification is troublesome and counting the small particles found is extremely tedious. Slight changes in technique introduce wide variations in results and no matter how refined the technique one can probably never reach the point where every particle may be counted. For very high magnification, the sample must be deposited dry and unless very large areas are to be counted, the deposit must be uniform. Consideration of these difficulties leads to the practical solution of the problem. Is it necessary to collect all the particles in a given sample or to count all of them? Is it even necessary to count all that may be found in a given small portion of a sample? Instead of attempting the impossible or impractical, an empirical method is used. Instead of counting all of the particles, one counts the portion that may be seen under prescribed conditions. The empirical results thus obtained under the selected conditions must be reproducible; they must be correlated with studies on the hygienic effect of the dust in question. Once the method has been established as a measure of various conditions, and when sufficient data to show the effect of these conditions on the health of workers has been accumulated, we are prepared to study air dustiness and to say whether a given condition is relatively safe or harmful.

Now that an empirical method of determination of relative number concentration has been selected as most practical, a method for collecting the sample must be devised. The fact that dusts are dispersions of solid particles, varying greatly in size and composition, renders the collection of a sample extremely difficult. Gases are readily collected by bubbling through a suitable sampling liquid, but with a solid, the liquid must be absorbed upon the solid surface before wetting can occur. Only a few per cent of a fine dust can be removed from suspension in air by bubbling through a liquid. Many ideas have been put forward for collecting dust samples from air or for determining the amount of dust in suspensions without collection, but most of them have been dropped for one reason or another. To better understand the problem, it will help to discuss a few of these methods very briefly, and point out some of their disadvantages.

Perhaps the simplest method of studying dust conditions is by observation of the amount deposited as on rafters or beams over a given period, or by simple observation of the dust in air as illuminated by a beam of light. This gives a rough idea of whether the location is dusty or not but practically no quantitative information.

The next step, the sedimentation sampler, is based upon the same idea. A container with removable ends is opened at the sampling location and flushed out by moving through the air. It is then closed and allowed to stand in a place free of drafts or temperature changes until all the particles, or at least all that can be seen with a microscope are settled. Then a slide which had been placed upon the bottom of the cell is removed and the number of particles per unit area are counted with a suitable microscope. This method has the disadvantage of requiring a long settling time between samples which may be collected with each apparatus. The necessity of placing the apparatus quickly in the position for settling in a location free of drafts and temperature changes renders it impractical for field use and the fact that it is a "grab" sampler makes single determinations of little value unless the dust suspension is known to be uniform.

The next principle of interest is that of filtration. The air to be sampled is drawn through either an insoluble or a soluble porous medium such as a paper thimble of a layer of granular material such as sugar, anthracene or salacylic acid. Samples collected on insoluble filters could only be determined gravimetrically with the attendant errors due to particle size variation inherent in such a determination. The samples collected on soluble filters could be counted after solution of the filter material. Some crystals used for filters contained much and variable amounts of insoluble impurities. These filters are difficult to prepare and inconvenient to handle and the increase in resistance as the pores become clogged renders accurate measurement of sample volume difficult.

Although washing is a very inefficient method of removing dust from air, many devices working on this principle have been tried. One of the best known is "The Palmer Apparatus"; that uses a spray for intimately mixing air and liquid. Such devices, in addition to being inefficient are very cumbersome, fragile, and difficult to clean.

A more recent development is the Thermal Precipitator, which operates on a unique principle. The sample is caused to pass between two parallel cover-glasses; between and parallel with these glasses is a heated platinum wire which is perpendicular to the direction of flow of the sample. This device takes advantage of the phenomena that a body warmer than the gas about it is surrounded by a dust free zone. This zone is intercepted by the surfaces of the cover-glasses which are kept cool by masses of metal in close contact. Also since particulate matter in warm gases tends to deposit upon cool surfaces we have two forces which act to deposit the dust from the sample upon the two discs of glass. The sample appears as a narrow strip on each glass parallel with the wire. These samples may be used for count or particle size determination after they are suitably mounted upon a slide. The Thermal Precipitator is used in England and South Africa for checking other methods and to some extent for routine sampling. It is high in collection efficiency except possibly for the larger particles. Its main disadvantages are the difficulty in preparing and mounting the cover glasses and the small sampling rate possible for this instrument, about 6 ml per minute.

The most recent development, the Electrostatic Precipitator, which will be described in detail later by Mr. Barnes, is without question the most satisfactory device for complete separation of solid dispersions from gases. It collects a large sample in a short time and if properly constructed and operated has an efficiency of 100 per cent.

We come now to the most widely used class of dust collecting instruments, the devices which operate upon the impingement principle. Three types of impingers are fairly well known; The "Konimeter", the "Owens-jet dust sampler, and the "Greenburg-Smith Impinger."

The Konimeter was developed in South Africa about 1916 and is widely used both there and in Canada today. It consists of a small pump with a spring operated piston which when released draws a 2½ or 5 cc sample of air through a small circular orifice that faces and is close to a glass plate which is prepared with an adhesive film. The dust in the air sample is impinged upon the adhesive film and sticks there.

The Owens-jet Sampler is very similar in principle except, that it uses a clean glass sample plate and the dust laden air is humidified in a chamber, then upon being drawn through a slit orifice the reduction in pressure causes condensation of moisture on the particles, thus causing them to adhere to the glass surface. The piston in the pump is actuated by hand instead of by a spring. Both of these instruments, especially the Konimeter have many desirable characteristics. They also have several important shortcomings: both are spot or grab samplers, and unless a great many samples are collected at one location, a fair average of the concentration of dust will not be obtained. The samples are obscured by deposits of moisture or oil droplets and the presence of smoke in the sample either makes the sample spot hazy or results in unduly high counts if darkfield illumination is used. There is also a possibility that with the Owens-jet dust sampler some of the sample deposited at the beginning of the piston stroke is subsequently blown off.

At the Bureau of Mines in 1922, during a joint investigation of these and other sampling devices by the U. S. Public Health Service and other interested parties, the Greenburg-Smith Impinger was developed. Recent models of this impinger consist of a graduated tubular glass flask, 50mm or 2 inches in diameter and 210 mm or 8½ inches high, a number 10 rubber stopper with one hole accommodating a combined suction connection and inlet tube. The inlet tube extends to within 5 mm of the flat bottom of the flask where it is drawn down to a 2.3 millimeter nozzle.

In operation, the graduated flask is filled with about 75 cc of water or alcohol and the side arm of the impinger is connected with a source of suction providing a flow of 1 cu. ft. per minute at a head of about 39 inches of water. Suction is provided either by a portable electric pump or by an air ejector. Both are cumbersome and heavy and of course limited to use only where electric power or compressed air is available. The necessary equipment with hoses, wrenches, pipe fitting or motor, pumps and wire usually exceeds fifty pounds. Making connections interferes with work being done in the vicinity where it is desired to collect the sample. Despite these difficulties the use of the Greenburg-Smith Impinger has grown and for some years has been considered in this country the standard method for collecting samples for measurement of air dustiness. It has achieved this success because in conjunction with the standard light-field technique for counting, a strictly empirical method, uniform and reproducable results could be obtained under similar conditions with different impingers operated by different persons and with the samples counted by independent technicians.

It is true that this empirical method has been subjected to some variations such as the introduction of different types of cells and the use of micro-projection methods of counting, but these changes were adopted only after long study showed that the results obtained with a variety of samples checked results obtained by the previously accepted technique.

Although the advantages of the impinger method greatly outweighed its disadvantages certain changes appeared imperative if the method were to continue the standard. Changes in our ideas of safety and suitable working conditions and in our compensation laws awakened widespread interest in dust hazards with the result that many new workers entered the field.

The Federal Bureau of Mines has long led the way in the promotion of health and safety in the mining industry and about 1930 this organization started an enlarged program of dust investigation. Comprehensive studies of dust conditions in mining operations showed the

the need of a compact, lightweight sampling device which could be used at any place independent of any power supply.

A hand operated impinger was the obvious answer but the amount of energy required to create a flow of 1 cubic foot per minute against a head of 39 inches of water was considerable more than a man could be asked to expend except over very short periods. This was tried but the change did not reduce either the weight or the size of the apparatus.

You, no doubt, are wondering what is sacred about a 1 cubic foot per minute sampling rate, especially since the sample is ordinarily diluted to several hundred cubic centimeters, then only three or four cubic centimeters are used to fill several counting cells and finally the dust in only 2½ cubic milimeters of the liquid or about one ten-thousandth of the original sample is counted. That thought proved to be the answer to the question; a continuous sample over a suitable length of time is most desirable but the rate can be reduced greatly provided it is known and is constant. Then if the size of the impinger, the volume of collecting fluid and the final dilutions are all reduced proportionately one can then count a larger proportion of the sample. A sampling rate of one tenth of a cubic foot per minute was selected and several experimental "midget impingers" were constructed in 1936 and 1937. Experimental work showed that an impinger with a 1 mm nozzle operated at a head of 12 inches of water would give a sampling rate of 0.1 cubic feet per minute and would check the 1 cubic foot per minute impinger as well as two of the latter check each other.

Two difficulties were encountered in construction of the midget impinger; first small capacity pumps are hard to find and are very low in efficiency and second, it is hard to maintain a constant head and consequently a constant flow by regulating the crank speed. The first difficulty was met by constructing a four cylinder radial pump so that suction was always provided by one cylinder while the crank was rotated. The second problem solved later when the Mine Safety Appliances Company undertook to make the midget impinger available to industry. A vacuum regulator was devised as an integral part of the pump and thus a constant head is provided at any crank speed above fifty to sixty revolutions per minute. This arrangement works so satisfactorily that the crank may be jerked or even reversed during operation without changing the flow even momentarily. The entire apparatus as finally developed, complete and ready for sampling weighs less than nine pounds and occupies less than one-third cubic foot of space.

Finally, I want to point out some of the precautions that should be observed in using the Midget Impinger. Because of the small sample volume more care must be exercised to prevent contamination. The flask and nozzle should be washed, rinsed and assembled, then rinsed several times through the intake tube and side arm finally rinsing with the dust free collecting fluid; then the cap and side arm stopper which have been washed and rinsed are put in place. The impinger should be dried and the joint between the stopper and the top of the flask protected with a turn of friction tape or scotch tape. This is important because when the sample is returned to the laboratory for counting, the outside can be washed and dried, then when the tape is removed the joint is clean and dirt will not drop into the sample when the stopper is removed for dilution. The end of the hose that connects to the side arm of the flask should be rinsed after each days use, and the cap and side arm stopper should be put in a clean metal case which is carried in the pocket when they are removed to collect a sample. A water-tight hunter's match case is ideal.

Contamination is avoided by diluting the sample in the original collection flask and by removing portions for counting with a clean pipette. Of course, if the concentration of dust is very high, a portion must be removed and diluted in a volumetric flask.

Alcohol, either 95 per cent ethyl or a practical grade of normal propyl is recommended for use as the collecting medium in either the large or midget impinger. The advantages of alcohol are: (1) greater ease of cleaning the apparatus such as impingers and counting cells. (2) Wetting of some dusts such as coal, and better dispersion of aggregates; (3) Reduced solubility of most mineral dusts; (4) Freedom from danger of freezing samples in winter, and (5) Solubility of the oil mist collected by impingers near rock drilling operations where oilers are used in the compressed air lines for rock drills. When using alcohol a settling time of 25 minutes for the sample in a Sedgwick-Rafter counting cell gives results which agree with those obtained with a 20 minute settling time for water. It is important to avoid using mixtures of alcohol and water or denatured alcohol in impingers as some of the sample may be carried out of the flask by the foam which these mixtures generate.