DUST CONTROL IN UNDERGROUND MINING

by

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The topic of my presentation is "Dust Control in Underground Mining." There are, of course, several distinct aspects to this subject including those of ventilation planning, medical control programs and the techniques employed in evaluating the amount of dustiness in work environments. This presentation will deal with this last aspect, that of dust evaluation techniques, an evaluative function that provides much of the basic information source for the planning and conduct of appropriate medical and ventilation control programs. Further, in that standards of dustiness, as well as for other occupational exposures, are fast becoming part of the regulatory function of various federal and state agencies, it becomes increasingly important to pay attention to the proper structuring of these requirements as well as to the manner by which compliance with these requirements may be shown.

Throughout this presentation, when using the term "dust", this refers to the type of dust having the capacity for producing a lung condition known as silicosis. Quartz, chert, sandstone, crystobolite and other dusts wherein the free crystalline silica (SiO_2) is uncombined with other chemicals or minerals are those of concern in this respect.

It should be mentioned, however, that this is just one of a multitude of occupational exposures of concern to the mining industry. In addition to a variety of dusts, gases, vapors and mists, there are such physical agents as heat, noise and illumination which may effect human life, health and safety. Some of the considerations that will be reviewed with respect to dust evaluation have application to the evaluation of many of these other potential exposures.

Silicosis has been known for centuries and modern control measures have been used since the 1930's. It continues, however, to be an important occupational disease. The exact mechanism responsible for this lung condition is not understood completely but a number of facts regarding silicosis have been well established. The probability of getting silicosis varies with a number of factors, the most important being:

1. The concentration of dust in the air
2. The percentage of free silica in the dust

3. The duration of exposure
4. The size of the dust particles
5. The presence of other dusts, and
6. Individual susceptibility; a subjective expression which appears to be used in this instance, when objectivity fails to disclose a satisfactory cause-effect relationship. Someday, no doubt, medical research will be able to identify specific biological aspects that account for this individual susceptibility. When this time comes, it may be that, in addition to controlling the environment, this factor of worker selection will assume an expanded role in the prevention of silicosis.

A dust evaluation program, therefore, implies the use of dust sampling instruments and techniques to assess the character of the airborne dust. What factors must be considered in selecting the type or types of sampling equipment for this purpose?

First we must recognize that there is no sampling instrument that takes into account all of the possible variables relating to dust deposition in the human respiratory system. At best, therefore, a single sample will provide an estimate of potential exposure at that particular moment of time rather than an index of actual respiratory deposition. We must also concern our selection with the portability, reliability and durability of field sampling equipment and the capability of acquiring samples representative of human exposure without interfering with the normal work pattern or compromising the personal safety of the worker under study or of the technician performing the study. Another consideration is that under industrial conditions, the sample environment is not stable with respect to either space or time. Fluctuations are more likely to be the normal circumstance rather than the exception and knowledge of the fluctuations may be essential to ventilation control planning or as a measure of the hygienic significance of the exposure.

Further, we will need more than one type of sampling instrument since there is no single instrument that has the capability for practical, routine field evaluation of dust concentration, particle size and free silica. The only available instrument which attempts to hold forth the potential for evaluating these three parameters from a single sample is the Cascade Impactor, but it has important limitations. For special studies, the application of laborious microscopic techniques might provide some data on all three parameters from a single sample but these techniques are impractical for a routine program.

Probably the single most important requirement is that the sampling program has the capacity for giving results which can be compared with recognized guidelines such as the Threshold Limit Values promulgated by the American Conference of Governmental Industrial Hygienists.

This Threshold Limit Value for Siliceous dusts is a time weighted average exposure referable to each individual worker which infers knowledge of worker occupancy time as well as the dust status within areas.

This time weighted exposure value may be arrived at by summating the average dust concentration during each work activity with the time spent by the worker in performing the activity. In some instances, it may be possible to establish the average dust concentration subtended over a sequence of operations whereupon this concentration value would be equated with the worker time spent in accomplishing this sequence. Most recently, attention has been given to the use of personal or breathing zone samplers whereby the equipment is attached to the worker himself permitting the continuation of sampling throughout all or a portion of the work day. One obvious advantage of this method is that the need for time study data during the sampling period is greatly minimized. There are, however, other important factors concerning the suitability of this procedure which will be described later in this presentation.

At this point, therefore, it should be clear that:

1. In light of the variable response of the human respiratory system to dust exposure, the instability of the environmental level of dustiness, the errors involved in time study data and other uncertainties and variables, there is no need for great accuracy in dust determinations. Effort to obtain accuracy greater than that which is necessary to give the needed and useful information is impractical.

(and)

2. The Threshold Limit Value for siliceous dust is an expression of time weighted average exposure to an individual worker. This suggests that we expect single sample values both greater and lesser than this average value. This in turn suggests a statistical approach in the development of a dust evaluation program particularly when it becomes necessary to have such information for comparison with regulatory requirements. I will return to this statistical aspect after discussing the present and proposed alternate TLV for siliceous dusts.

The present TLV was developed from data obtained using the familiar impinger type collecting system and optical evaluation technique by low power, light field microscope. For this impinger system, air is impinged at a high velocity against a glass plate which is immersed in an absorption medium. The dust particles are momentarily arrested by the impinging process, are wetted by the water or the absorption liquid, and thus are trapped. Subsequently, a portion of the absorption liquid is transferred to a counting cell and the number of dust particles within a known volume is counted with the aid of a microscope. There are a variety of counting cells that can be used. At our operations, we use a Spencer Haemocytometer cell which, as the name suggests, is also used for counting blood cells.

Knowing the sample flow rate and the time interval over which the sample was taken, this count is translated into an expression of airborne dust concentration in terms of millions of particles per cubic foot of air. Each separate sample usually encompasses a 5-10 minute sampling period. Dust particles larger than 5 microns are not included in the microscopic count and due to possible solubility of the dust in the collecting solution, the sample counts should be performed within 24 hours subsequent to sampling. Correspondingly, the range of particle sizes is between the resolution limit of the microscopic system (about 0.7 microns) and 5 microns. Although the collection efficiency of the impinger itself rapidly diminishes for particles less than 1 micron, this is of little concern since the microscopic system would not see these particles even if collected. If it may seem rather appalling that such instrument and optical inefficiencies are tolerated, one must remember that these are the techniques used in studies, dating back more than 25 years, in which the health status of workers has been correlated with their occupational exposure to dust, these studies being, as previously stated, the basis for the present TLV. There are investigators who substitute a molecular filter type device for the impinger and this method of sampling is particularly useful when size distribution as well as the number of particles is to be determined. Further, by having the sample on a filter rather than in a liquid medium, the dust count can be progressed at any convenient time. For the comparison with the TLV, these methods give similar results since the same optical system is the limiting factor.

The remaining fragment of information necessary to arrive at an exposure index for comparison with the TLV is the amount of free silica in the dust. Since relatively greater sample amounts are needed for the chemical or X-ray diffraction quantitation of free silica, the sampling instrument is usually a high volume device. So-called "rafter" or settled dust samples are rarely typical of the airborne dust fraction and use of same should be avoided.

This, therefore, is a brief sketch of the techniques used to determine a worker's exposure status with respect to the present Threshold Limit Value. Slide 1 shows the present and proposed Threshold Limit Values by the ACGIH.

In its 1968 Notice of Intent, the ACGIH has proposed an alternative TLV for siliceous dust based on size selective gravimetric techniques where the sample is collected on a filter.

As previously indicated, there are some important features concerning the suitability of this technique. For example, using the impinger technique for a full shift occupational exposure study on a worker, one full day could be occupied in taking the necessary samples and at least one additional day spent in counting the samples and integrating these counts with the time distribution data. The gravimetric filter technique would allow this same study to be expedited by attaching the sampling instrument on the worker under study thereby obtaining a continuous sample throughout his work performance with interruptions of sampling only as necessary to accommodate the flow rate performance of the portable suction pump. Subsequent to sampling, the filters would require only a standardized weighing procedure and a simple summation to express this full shift exposure. As an area

ACGIH THRESHOLD LIMIT VALUE FOR CRYSTALLINE FREE SILICA DUSTS

PRESENT

rtz, calculated from formula:

$$MPPCF = \frac{250}{\%SiO_2+5}$$

e:

(1) MPPCF = Millions of particles per cubic foqt of air, based on impinger samples by light-field techniques.

(2) The percentage of crystalline free silica in the formula is the amount determined from air-borne samples, except in those instances in which other methods have been shown to be applicable.

PROPOSED (ALTERNATIVE)

Quartz, calculated from formula:

(1) TLV for respirable dust

$$mg/m^3 = \frac{10}{\%\ \text{Respirable Quartz} + 2}$$

Both concentration and per cent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

Aerodynamic Diameter (μ) (unit density sphere)	% Passing Selector
≤ 2	90
2.5	75
3.5	50
5.0	25
10	0

(2) "Total dust" respirable and non-respirable

$$mg/m^3 = \frac{30}{\%\ \text{Quartz} + 2}$$

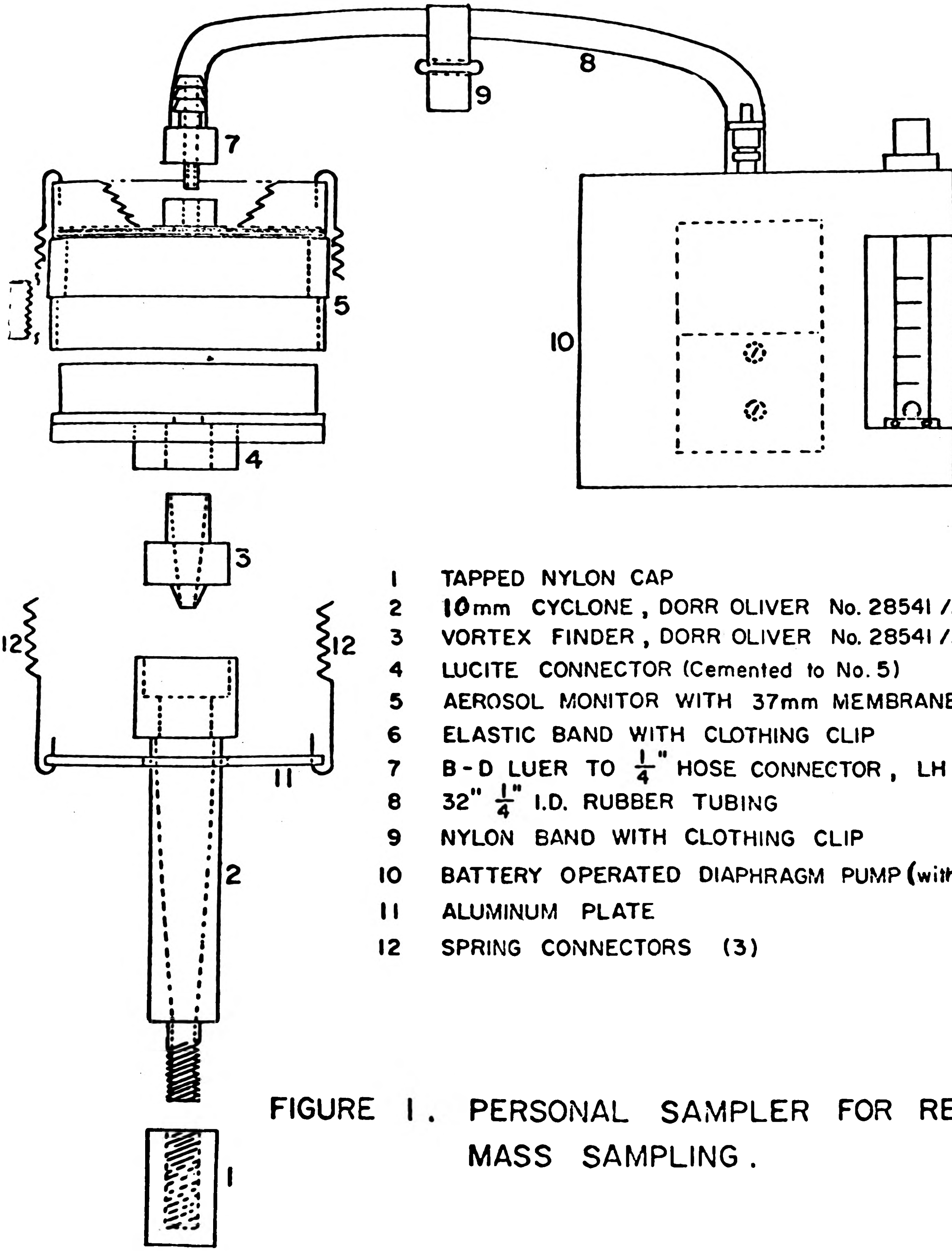
sampler, furthermore, a number of these devices mounted at fixed locations would have the potential for giving a great amount of general dustiness data with relatively little effort.

The major deterrant to extensive use of size-selective gravimetric sampling appears, therefore, to be the absence of a hygienic limit expressed in gravimetric terms that has an appropriate relationship to the TLV derived from count techniques. This relationship has been under study for several years and in 1967 it was reported, from studies performed in the Vermont granite industry, that 10 MPPCF of granite dust will give 0.1 milligrams per cubic meter of free crystalline silica in the respirable fraction. Correspondingly, based on this observation, formula 1) of the proposed alternative TLV was derived (refer to slide). Formula 2) arises from several studies indicating a percentage of quartz in a gross sample of airborne dust to be about 3 times that in the respirable fraction. Hence the factor of 3 and it should be noted here that these are studies on foundry dust. Other investigators have stated count-weight relationships different than this 0.1 mg per cubic meter being equivalent to 10 MPPCF. In 1943, for coal dust, when the weight was confined to the fraction of dust smaller than 5 microns and the count to particles greater than 1 micron, this relationship was expressed as 0.1 mg. per cubic meter as equivalent to 6.5 MPPCF. In 1967, also for coal dust, an impinger vs size-selective sampler study gave the ralationship as 0.1 mg. per cubic meter being equivalent to 5.6 MPPCF. Yet another report, on "typical mineral dusts" with a mass average size of about 3 microns and a median count size of about 1 micron, expresses this relationship at 0.1 mg. per cubic meter equivalent to 0.85 to 1.4 MPPCF.

Correspondingly, even though there is a great appeal to this relatively uncomplicated procedure, it would be unwise to blindly adopt it unless its suitability is well established for the type of dust operations involved. This caution is particularly pertinent in that, in this age of regulatory urgency, the dust evaluation results may be the focus of a possible enforcement action.

Slide 2 shows one type of size-selective mass sampler. Samples for the % respirable free silica would require a separate instrument such as a horizontal elutriator developed by the British Medical Research Council or its equivalent. One other disadvantage that I might mention to this method when used as a personal sampler is that unless the worker wearing the sampler is closely supervised, the results therefrom could be significantly altered, either intentionally or unintentionally by the worker. For example, if a certain level of cumulative calculated exposure ever became an index of whether or not a worker would be allowed to continue in employment, an unattended worker could elect to manipulate the sampler results in line with his particular motivation.

Turning now to the role of statistics in a dust evaluation program, it seems to me that statistical concepts are the only way that we



1	TAPPED NYLON CAP
2	10mm CYCLONE, DORR OLIVER No. 28541/4A
3	VORTEX FINDER, DORR OLIVER No. 28541/4B
4	LUCITE CONNECTOR (Cemented to No. 5)
5	AEROSOL MONITOR WITH 37mm MEMBRANE FILTER
6	ELASTIC BAND WITH CLOTHING CLIP
7	B-D LUER TO $\frac{1}{4}$" HOSE CONNECTOR, LH/L
8	32" $\frac{1}{4}$" I.D. RUBBER TUBING
9	NYLON BAND WITH CLOTHING CLIP
10	BATTERY OPERATED DIAPHRAGM PUMP (with belt clip)
11	ALUMINUM PLATE
12	SPRING CONNECTORS (3)

FIGURE 1. PERSONAL SAMPLER FOR RESPIRABL MASS SAMPLING.

can attempt to scientifically deal with such questions as: How shall a program of obtaining data be planned so that reliable conclusions can be made from the data? How shall the data be analyzed? What conclusions are we entitled to draw from the data? And finally, how reliable are the conclusions? At least some semblance of statistical concern removes some of the arbitrariness from data collection.

It should be re-emphasized that the TLV for siliceous dust is a time weighted average exposure value for an individual worker and therefore, if our data is to have some comparative value with respect to the Threshold Limit, our program must have some rational basis upon which to predicate its design or to express the results therefrom. This is particularly true where the problem is that of long-term exposure to relatively low levels such as modern day exposures to siliceous dusts.

Statistics has been defined as the art and science of dealing with variation. A statistical analysis of a set of sample numbers permits us to learn something about the main features of these set of numbers.... their average, how much they vary from one another, etc. .... for the purpose of making inferences about the universe from which the samples were taken. Once we think we have a "reasonably" accurate description of the situation, we can then begin to plan what ought to be done (perhaps nothing) to change it in some direction or other to serve the purpose at hand. We are not interested in accumulating any more data than necessary to develop this inference and statistics may tell us how much data appears necessary.

The most difficult decision is the determination of what is an acceptable, reasonably accurate description of the situation. How great an error are we prepared to accept and over what minimum period of time is this error to be applicable? In what percentage of instances can we anticipate that our average will be beyond these limits of error? These are important questions that need answering. If we select a time baseline of one year, is an error of ± 50% of the true average exposure acceptable? What is an acceptable probability that our answer will be within these limits .... in 95 out of 100 times, 90 out of 100 times? After all, it should be clear that even the most comprehensive sampling program is incapable of producing an irreproachable, absolutely accurate exposure value referrable to any individual worker and this limitation should receive recognition when accessing the success or failure of complying with the Threshold Limit Value. In fact, the Threshold Limits Committee of the American Conference of Governmental Industrial Hygienists, under whose auspices the Threshold Limit Values are issued have voiced serious concern about the possible misuse of these values and have repeatedly recommended against their adoption in legislative codes and regulations.

Secondly, we must decide on a plan for obtaining the data necessary for providing information within the context of the acceptable error endpoints of our first decision. We recognize the impossibility of directly studying each worker's exposure on an individual basis with any reasonable degree of frequency and therefore must try, wherever possible, to make our sample values reflective of potential exposures to workers other than the one being immediately sampled. This may mean that our sample will reflect certain job operations, work patterns, or work locations or other categorizations which have some common application to a number of workers. The frequency of sampling, within whatever categorization is decided upon, can therefore be statistically determined so that the accumulation of the time-concentration dependent elements referrable to each individual worker will permit an estimate of his time weighted average exposure within the limits of acceptable error.

It is beyond the scope of this presentation to become further involved in the fundamentals of statistics. In this highly complicated and regulated society of today, however, the science of statistics has an important, and possibly, a necessary role, even in such problems as the design of dust sampling programs.

There are two federal agencies involved in the regulatory phase of occupational health - the Department of Labor and the Department of Interior.

The Department of Labor has promulgated their regulations under the authority of the Walsh-Healy Act. Correspondingly, the regulations apply to contractors with the federal government whose supply contracts exceed $10,000 per year. These regulations were to be effective as of February 17 of this year but this effective date has been deferred to May 17 by the new Secretary of Labor. I understand that the Department of Labor is considering modification of the sections on occupational noise exposure and Threshold Limit Values but I have no information as to the content of these possible changes.

The Department of Interior's regulations are still in the proposed stage and May 1, 1969 is the deadline for any interested person to submit comments or for persons who may be adversely effected to request a public hearing on designated parts of the regulation. It is a sure bet that the Department of Interior will receive a great amount of mail in this respect. The Department of Interior's regulations are promulgated under the authority of the Federal Metal and Non-Metallic Mine Safety Act and according to the Act they will become effective one year after the date of publication of notice in the Federal Register. This notice was published on January 16, 1969. The regulations are applicable to essentially all mining operations, except coal mining, and the next sequential stage of milling processes, such as the processing of concentrates. Smelting or other processing to metal or near metal forms does not appear to be included within the jurisdiction of the regulations.

Insofar as the Threshold Limit Value for siliceous dust in concerned, both documents incorporate, either by reference or within the document itself, the present TLV and proposed alternate TLV of the ACGIH which were shown on the first slide. In neither document, however, is there wording to the effect that the TLV should be used in accordance with the intent of the concepts described in the preface section of the ACGIH publication. In that the ACGIH has included this admonishment in their TLV publication, it seems appropriate that the federal regulations should refer to the entire publication so that there is no misunderstanding as to the true stature of the Threshold Limit Value.

Mr. Chairman, this concludes the prepared portion of my talk. I will be glad to attempt to answer any questions at this time or later if this is your preference.

COMMENTS

QUESTION: I'd like to ask Mr. Gilliland if his company requires the miners to take an x-ray examination periodically?

ANSWER: On essentially a yearly basis after they reach a certain age.

QUESTION: Has there been any attempt to correlate the results of the x-ray examination with the dust count?

ANSWER: Yes, of course, it is pretty difficult to try to come up with definite answers.

QUESTION: Have you reached any rate or average?

ANSWER: At present we have a very eager young doctor who is putting this all on IBM right now.

QUESTION from another conferee: I'd like to ask if you have any answers or opinions or ideas as to why the differing trends in the fatal frequency rate and the non-fatal frequency rate.

ANSWER: No, I have nothing really substantial. We hope there has been an improvement in the non-fatal frequency rate. We also wonder if there could be something in the reporting of the non-fatal in the manner in which they're handled at the local company level. But I have nothing specifically.

QUESTION: Mr. Gilliland, I'd like to know what kind of dust loadings you've come across in the mining industry and what type of efficiency of collection or reduction that you are planning for these things?

ANSWER: Of course, you can run across high levels now and then. I'm talking about occupational exposures. I'm not talking about air pollution as such. This is on-sight type of work and if a workman collars a hole dry you can get into dust counts that are billions, 500 million very easily. If he uses normal precautionary techniques you can pretty well hold your average dust count well within say 5 million particles per cubic foot. This is our design criteria.

QUESTION: At the present time what are the particle size criteria that are used for determining what you consider harmful?

ANSWER: We have not gone over to the gram-metric type of device. You probably sensed that I was a little critical of it. It's a one count technique. You automatically reject any particles in the count that are greater than 5 microns. There are not many of them anyhow and the limits of the optical system used doesn't see any particles below say 7/10 of a micron so we're dealing with particle sizes between 7/10 of a micron and 5 microns.

QUESTION: What does the doctor say is harmful?

ANSWER: Well, I don't know exactly how to answer your questions, what the doctors say. Their knowledge is gaining from these basic epithemialogical studies. I image they would tend to agree with this cutoff of 5 microns as the particles larger than this would not generally be respirable. Of course, no matter what the doctor says if we can't see the dust with the microscopic system we're using it doesn't really matter much what he says in that particular case.

QUESTION: Mr. Gilliland, it's asserted that the 3 milligram per cubic meter standard that's being talked about in connection with coal dust is based upon statistics that come from the British experience. We now hear about Czechoslovakia, Poland and Yugoslavia, would you comment a little on taking the foreign experiences as a basis in coming up with standards in the conditions in this country?

ANSWER: I am not too familiar with the coal dust standard. We're not in the coal business so I am not too concerned with this but I think I did make a definite point on my talk that our present threshold limit value is based on human experience on epithemialogical studies made in the United States with the type of equipment that we accomodate within the United States. You have to be very cautious in adopting any other instrumentation or any other standards where they don't have this wealth of background experience. I hope this avoided answering your question properly.