

MEDICAL SURVEILLANCE OF
ASBESTOS WORKERS

Presented by

Henry J. Trochimowicz, Sc.D.
Chief, Physiology Section
Haskell Laboratory for Toxicology and Industrial Medicine

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A Standards Advisory Committee for Asbestos (OSHA) has recommended an exposure limit of two fibers greater than five microns in length per cubic centimeter. This proposal, based on a (National Institute of Occupational Safety and Health) NIOSH criteria document, would not be effective for two years, in order to allow the installation of the necessary engineering controls. This advisory committee, representing government, labor, and industry, also suggested that the future standard include a program of comprehensive medical surveillance which will be the topic of my discussion today.

According to the proposed recommendations, medical surveillance is required, except where a variance from the medical requirements of this proposed standard have been granted, for all workers who are exposed to asbestos as part of their work environment.

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For the purposes of this requirement, the term "exposed to asbestos" will be interpreted as referring to "time-weighted average exposures above 1 fiber/cc or peak exposures above 5 fibers/cc."

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The major objective of such surveillance will be to insure the proper medical management of individuals who show evidence of reaction to previous dust exposures, either due to excessive exposures or unusual susceptibility. Such medical management might include job placement, improved work practices, cessation of smoking, or specific therapy for asbestos-related disease or its complications.

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However, medical surveillance cannot be a guide to adequacy of current controls when environmental data and medical examinations only cover recent work experience because of the prolonged latent period required for the development of asbestosis and neoplasms.

According to NIOSH criteria, medical surveillance should include pre-employment medical examinations of applicants, periodic medical evaluations of exposed workers, and other recommendations such as a comprehensive medical examination on termination of employment and the maintenance of medical records by the employer. First, let's talk about the components of the preplacement medical examination as recommended by NIOSH. In taking a medical history on a new employee,

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it is of special interest to know whether or not there was a past exposure to asbestos or other "fibrosis-producing" dust. Previous exposure, in conjunction with a history of cardiopulmonary or gastrointestinal disease, might contraindicate the placement of a new employee in an area of asbestos exposure. Smoking habits are also an integral part of a medical history and may influence job placement since the peril of lung cancer from asbestos exposure is increased by smoking. In fact, tests conducted by Selikoff and Hammond have shown that asbestos insulation workers who smoke have 90 times the incidence of lung cancer compared to smokers with no asbestos exposure.

The second part of the preplacement examination would include a complete physical with special attention to pulmonary rates, clubbing

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of the fingers, and other cardiopulmonary signs often associated with fibrosis in the lung. Laboratory tests should incorporate routine clinical chemistry, a chest roentgenogram (PA 14" x 17"), and measurements of pulmonary function. In the NIOSH criteria, the measurements of pulmonary function which are required include:

- 1) forced vital capacity (FVC), i.e., the greatest amount of air that can be expired after a maximal inspiratory effort, and
- 2) forced expired volume in one second (FEV₁), i.e., the fraction of the vital capacity expired in one second. The vital capacity (FVC) may be normal but the timed vital capacity (FEV₁) greatly reduced in diseases such as asbestosis, due to lower airway constriction and subsequent increased resistance to flow. Thus, if the results from a pre-employment examination revealed a pre-existing lung disease, placement of that individual in an area of asbestos exposure should be discouraged.

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In addition to a comprehensive pre-employment examination, periodic medical surveillance of asbestos-exposed workers is also a recommendation in the proposed NIOSH criteria. History and physical examination will be similar to that of the pre-employment examination. However, NIOSH criteria specify the frequency of chest x-rays and pulmonary function tests. These tests, to be performed at the employer's

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expense, will be done every two years on all employees exposed to asbestos and annually on those individuals:

- 1) who have a history of 10 or more years of employment involving exposure to asbestos or,
- 2) who show roentgenographic findings (such as small opacities, pleural plaques, pleural thickening, or pleural calcification) which suggest or indicate pneumoconiosis or other reactions to asbestos, or
- 3) who have changes in pulmonary function which indicate restrictive or obstructive lung disease.

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Other proposed recommendations in the NIOSH criteria entail a comprehensive medical examination on termination of employment. This examination is to be performed on all workers exposed to asbestos and should include the previously mentioned components of the periodic medical examinations. Maintenance of all medical records of exposed employees is the responsibility of the employer; such records will be kept for a period to be determined by the Secretary of Labor in consultation with the Secretary of Health, Education, and Welfare. However, the present emergency standard for asbestos specifies that all records be maintained for at least 20 years. As far as access to medical records is concerned, the proposed criteria state that these be made available only to Health, Education, and Welfare and Department of Labor physicians and medical consultants, and physicians

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designated and authorized by the employee. Whether or not the medical representative of the employer would have access to these records is not clear at this time.

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On the request of the Director of NIOSH, Dr. Marcus Key, the American Industrial Hygiene Association (AIHA) has submitted its comments on the proposed NIOSH recommendations which are to be incorporated into the proposed standard for asbestos. The AIHA had several reservations about the details of the medical surveillance program and has recommended the following changes:

- 1) Sputum cytology is of limited value and should not be included. Because of their sporadic appearance and, in the case of fibers, their relation to recent dust exposure, the AIHA was of the opinion that the quantitative assessment of asbestos bodies and fibers in sputum was not, in the light of present knowledge, a very useful procedure.
- 2) X-rays should include both a lateral and posterior-anterior view. The AIHA feels that periodic x-rays can be extremely beneficial in detecting early lung structure changes if a lateral, as well as a posterior-anterior view, is taken.
- 3) Medical records should be made available to those physicians to whom the employee releases the information, and to the employer's medical representative. Since the employer is responsible for the health of the employee, it was felt that his medical representative should have access to the medical records.

In reference to the proposed NIOSH recommendations on medical surveillance, the Industrial Union Department of the AFL-CIO has submitted its comments to the Occupational Safety and Health Administration. The NIOSH criteria on medical surveillance are acceptable to the union with the following qualifications:

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1) Medical examinations should be paid for by the employer and performed by the physician of the employee's choice. The union feels strongly that the employee should have his choice of physicians and that examinations by a company physician might, in some way, jeopardize the job security or job placement of the employee.

2) All medical records and results of such examinations should be the property of the employee and released only to such persons as he chooses and to HEW who may not release them to the employer and who shall hold them under conditions of strict confidentiality. Again, the union stresses that an employer should not have access to such records in the event that he (the employer) might use them against the employee. Should this right of workers to confidential handling of medical information be incorporated into law, medical surveillance of exposed workers would be a difficult, if not impossible, problem.

In summary, I have discussed the proposed recommendations on medical surveillance which may eventually be incorporated into the new standard for asbestos. Whether or not all of these items will be incorporated is not known. However, most of the recommendations -- such as periodic medical examinations which include chest x-rays and pulmonary function tests -- are sound and should be used in monitoring workers exposed to asbestos.

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SLIDE #1

DEFINITION

THE TERM "EXPOSED TO ASBESTOS" WILL BE INTERPRETED
AS "REFERRING TO TIME-WEIGHTED AVERAGE EXPOSURES
ABOVE 1 FIBER/CC OR PEAKS ABOVE 5 FIBERS/CC."

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SLIDE #2

OBJECTIVE OF MEDICAL SURVEILLANCE PROGRAM

1. PROPER MEDICAL MANAGEMENT OF INDIVIDUALS WHO
SHOW EVIDENCE OF REACTION TO PAST DUST
EXPOSURES DUE TO
 - EXCESSIVE EXPOSURES
 - UNUSUAL SUSCEPTIBILITY
2. ~~SHOULD~~ CANNOT BE A GUIDE TO ADEQUACY OF CURRENT CONTROLS

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SLIDE #3

PREPLACEMENT EXAMINATION

1. HISTORY

- A. PAST EXPOSURE TO ASBESTOS OR OTHER DUSTS
- B. HISTORY OF CARDIOPULMONARY OR GASTROINTESTINAL DISEASE
- C. SMOKING HABITS

2. PHYSICAL EXAMINATION

- SPECIAL ATTENTION TO PULMONARY RALES, CLUBBING OF THE FINGERS, AND OTHER CARDIOPULMONARY SIGNS

3. LABORATORY TESTS

- A. ROUTINE TESTS
- B. CHEST X-RAY (PA 14" x 17")
- C. PULMONARY FUNCTION TESTS (FVC AND FEV₁)

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SLIDE #4

PERIODIC MEDICAL SURVEILLANCE
OF EXPOSED WORKERS

1. CHEST X-RAY AND PULMONARY FUNCTION TESTS

- A. PA - 14" x 17"
- B. FVC AND FEV₁
- C. EVERY TWO YEARS ON ALL EXPOSED WORKERS
- D. ANNUALLY ON THE FOLLOWING WORKERS:
 - THOSE WITH ≥ 10 YEARS EXPOSURE
 - THOSE WITH X-RAY CHANGES
 - THOSE WITH PULMONARY FUNCTION CHANGES

2. HISTORY AND PHYSICAL EXAMINATION

- A. CARDIOPULMONARY SIGNS OR SYMPTOMS
- B. SMOKING HISTORY
- C. EXPOSURE HISTORY

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SLIDE #5

OTHER PROPOSED RECOMMENDATIONS

1. COMPREHENSIVE TERMINAL MEDICAL EXAM
 - A. ON ALL WORKERS EXPOSED TO ASBESTOS
 - B. SHOULD INCLUDE COMPONENTS OF PERIODIC EXAMS
2. MAINTENANCE OF MEDICAL RECORDS
 - A. FOR A PERIOD TO BE DETERMINED
 - B. EMERGENCY STANDARD STATES 20 YEARS
3. ACCESS TO MEDICAL RECORDS ONLY BY:
 - A. HEW AND DEPARTMENT OF LABOR PHYSICIANS
AND MEDICAL CONSULTANTS
 - B. PHYSICIANS DESIGNATED AND AUTHORIZED BY THE
EMPLOYEE

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SLIDE #6

COMMENTS ON NIOSH MEDICAL
SURVEILLANCE PROGRAM

1. AIHA

- A. SPUTUM CYTOLOGY OF LIMITED VALUE AND SHOULD NOT BE INCLUDED.
- B. X-RAYS SHOULD INCLUDE BOTH A LATERAL AND POSTERIOR-ANTERIOR VIEW.
- C. MEDICAL RECORDS SHOULD BE MADE AVAILABLE TO THOSE PHYSICIANS TO WHOM THE EMPLOYEE RELEASES THE INFORMATION, AND TO THE EMPLOYER'S MEDICAL REPRESENTATIVE.

2. AFI-CIO (INDUSTRIAL UNION DEPARTMENT)

- A. MEDICAL EXAMINATION SHOULD BE PAID FOR BY EMPLOYER AND PERFORMED BY PHYSICIAN OF EMPLOYEE'S CHOICE.

ALL MEDICAL RECORDS AND RESULTS SHOULD BE THE PROPERTY OF THE EMPLOYEE AND RELEASED ONLY TO:

- DESIGNATES OF EMPLOYEE
- HEW (UNDER STRICT CONFIDENTIALITY WITHOUT RELEASE TO EMPLOYER)

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DISCUSSION OF PRESENTATION

Henry J. Trochimowicz

- Q. This standard is started primarily for asbestos workers but what about other workers that have exposure to asbestos? I can see by the criteria what they are attempting to do, but how many people are we going to keep under medical surveillance?
- A. Evidently it is going to be, at least the proposed recommendation says, an employee doesn't have to be a "so-called asbestos worker". If the employee had an exposure to asbestos greater than the definition (1 fiber/cc) or peak values above 5, then he is an asbestos worker under the law and the medical surveillance part of this law will apply to him.
- Q. If this occurs just one day over a ten-year period, does that keep him under surveillance?
- A. Dr. Zapp It's like, if you exceed the speed limit on one occasion only, if you don't get caught at that moment by radar, you're probably all right. But this is not defined as a man whose occupation statistically exposes him to asbestos, like an insulation applicator, but rather any employee who is exposed to more than 1 fiber/cc time-weighted average. That, by definition, brings him under this program.
- Q. What are some of the other dusts in addition to asbestos that you made reference to in your speech that should be considered?
- A. Silica, coal dust, beryllium.

Dr. Zapp I think the important thing to note here is the direct head-on collision between the labor point of view and the management point of view (the AHA point of view) in respect to the confidentiality of medical records.

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Labor wants to keep them entirely secret from the employer. They have a reason for it. We don't understand that particularly in Du Pont because we've never operated in this way. Some of the trades represented by the International Unions have been burned in the past. When the employer finds out that a man begins to show some signs of pneumoconiosis, he's fired--that's the end of it. These people are fighting for their jobs; they're protecting their positions. They're saying, don't let the employer know that I have spots on my lungs because if you do, he's going to fire me. There is a lot of bitterness there and there's been a lot of trickery, in a way, too. Under the Coal Mine Safety Act this issue came up and it was agreed that the employer would not take the chest x-rays. He would get them done by some independent person or a group of doctors who were consultants. They found out that some of these independent consultants had agreed with the employer that when they would do a chest x-ray, they would have two films in the cassette. The employee would get one and the employer the other one. As a result, the United Mine Workers simply boycotted the whole program and demanded that all x-rays be taken by the Department of Health, Education and Welfare. This fortunately didn't carry. HEW wouldn't pick that up. Now I think that there are some severe penalties for doctors who do take double films. The Regulations specifically say that you are not allowed to do it; it will be a violation of the law if you carried out this kind of trickery. Labor's demand has been backed that the information be confidential to them and to HEW. It is too bad that this kind of employee-employer relationship exists in these industries. Fortunately, we haven't had to contend with that kind of thing in Du Pont.

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We wouldn't take advantage of labor on this point. I hope we can work out a satisfactory compromise because certainly in our own Company, it is essential in the workings of our medical program to let the doctor know the condition of his employee. I don't see how you can possibly justify having a plant doctor on the payroll if all of the labor people are going out and having their examinations done by someone else at the employer's expense. Without any access by the plant doctor to those records, the whole system will hang or fall on how they resolve this issue. The final decision will be made by the Department of Labor.

- Q. Is there any possibility of a dual standard along these lines of physical examinations, one for the transitory type employee versus the permanent employee with Du Pont? Has there been any discussion on it at all?
- A. I would interpret the proposed regulation to say that if you put a man into a position where he is exposed to more than 1 fiber/cc, that he has to come under the medical surveillance program. He has to be examined every two years on periodic examination until he has accumulated 10 years exposure, then he goes on an annual basis. I think that is the only difference.
- Q. I'm interested in how you keep track of the asbestos worker who works with forty different contractors over a period of years. Are there any guidelines to follow?
- A. Dr. Zapp You will notice that on the pre-employment examination, you will have to take a history of past exposure. I think it would figure into that. If he tells you that he's never had an exposure in his life before and you take him at his word, I think you're justified.

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- Q. How does this time-weighted average of 1 fiber/cc relate to the 2 fibers/cc previously discussed in the recommended standard?
- A. Dr. Zapp Just like with noise, you have a noise limit that is safe for human exposure and you don't have to wear protection but at a somewhat lower level they will probably specify that you go into a conservation of hearing program which is medical surveillance, and that's what they're doing here.

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SURVEILLANCE OF THE ATMOSPHERE

This section will indicate the method that is currently recommended by the Department of Labor to be used for evaluating environmental conditions of asbestos operations. But, before this is undertaken a review is to be made of the first method--impinger collection and the subsequent change to the present procedure of filter collection.

The first standard for controlling exposure to asbestos was recommended in 1938. This was based on a study by Dreesen, et al.* of four asbestos textile plants. The study was a joint effort by the U.S. Public Health Service and the North Carolina State Board of Health. A tentative limit of 5 million particles per cubic foot (mppcf), using the impinger collection technique and light field microscopy, was suggested. These investigators found numerous cases of pneumoconiosis where concentrations exceeded this value and only three possible cases when the concentrations were below this value. To recall a point, the latent period for development of disease is on the order of 10 to 20 years. In this study, only five persons had been exposed for more than ten years to concentrations from 0 to 4.9 mppcf. None of 39 persons exposed to concentrations below 2.5 mppcf showed evidence of asbestosis. In addition, only six of these 39 had been employed more than five years. Another factor of this study was the length of employment of these workers. Of the total 541 employed, 333 of them had worked less than five years in the textile industry, 66 were employed for as long as ten years and only two for more than twenty years. The average age of these textile workers was about 32 years.

*Dreesen, W. C., J. M. Dallavalle, J. I. Edwards, J. W. Miller, and R. R. Sayers, A Study of Asbestosis in the Asbestos Textile Industry, Public Health Bulletin #241, 1958.

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The investigators recognized these limitations and stated, "5 mppcf may be regarded tentatively as the threshold value for asbestos-dust exposure until better data are available."

What about the impinger collection technique that was used in this study to determine the degree of dustiness? The standard impinger method was used because it was the accepted means for assessing the dusty trades. Although it still retains that function today, the trend is toward the respirable fraction and gravimetric means of assessment.

In the impinger, air is drawn through a glass jet set at a fixed distance from the bottom of a flask. The jet is immersed in water, alcohol, or a mixture of both. As the particles strike the bottom of the flask they become suspended in the liquid. Collection efficiencies vary but are generally on the order of 98% for particles greater than 1 to 2 μ m.

The sample must be counted within 24 hours of collection. This is to reduce the chance of the particles to flocculate or for some small particles to go into solution. A sample is withdrawn from the collecting flask and placed into a counting cell. The counting cell should be no more than 1 mm and no less than 0.25 mm in depth. Settling times of the particles in the cell vary depending on their size, density, and the collecting media. The period to allow for particle settling varies from 20 to 30 minutes. All of the particles will not settle in this time span. Once started, the count must be completed within ten minutes. All of these factors have to be recorded in order to reduce the known variabilities when comparing studies involving dust counting.

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The microscope used for the standard dust counting method can be a laboratory grade optical unit with a 10 power objective lens. Counting is done under light field techniques at about 100 magnification. The area to be counted shall be defined preferably by an ocular grid or by rulings on the counting cell.

This method requires very clean sampling and counting apparatus, a dust-free area for both preparation of equipment and for counting, experience with the techniques of dust counting, and patience. This is a very tedious procedure and experience with it is not gained overnight.

What are some of the inadequacies of this procedure when comparisons are made with the new method? In those studies very few fibers were seen in the counting cell. There are two reasons for this; they are:

- 1) the impinger is not efficient for the collection of fine particles (fibers) and 2) the resolving power of the microscope is not adequate to detect small particles.

The impinger has a collection efficiency related to the aerodynamic size of the particulate and is not efficient for particles with falling speeds less than 1 μ m unit density sphere. Electron micrographs reveal that many of the airborne asbestos fibers are on the order of hundredths to tenths of a micron in diameter. In comparisons with other methods, it was noted that the impinger collected only about one out of every hundred airborne fibers. Of the total dust count, fibers made up usually less than ten percent of the total count.

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In addition to not being able to resolve very small particles, the small fibers would not settle in the allotted time to that plane in the cell where particles are to be counted. This would also reduce the number seen during the counting period.

Impinger samples are not handy for long personal samples. This is primarily due to both evaporation of the absorbing media (alcohol) and the movement of the worker.

The confidence limits of a dust count improve, as the number of particles counted increase. Because only a few fibers were seen in impinger samples, it was decided to count all particles in the counting cell at the established plane. This result gave an overall appraisal of dustiness rather than associating a fiber count to a degree of hazard. The original investigators realized this point. It was felt by them and others that if this level of dustiness (TLV) was not exceeded, that the asbestos hazard would be reduced.

The TLV of 5 mppcf, based on the early studies of Dreessen and others, was in effect from 1946 to 1970. However, in 1968 and 1969, tentative standards were proposed that were based on a new method of collection and counting.

It was evident from the preceding discussion on the impinger method that another procedure was needed to obtain a statistically useful index of airborne fiber concentrations. Interest in the fiber content arises from the need to measure that item in the environment that is the most relevant to the disease causing mechanism. A correlation between fiber count and disease or exposure and health was needed.

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As this aspect of asbestos fiber concentration to disease was reviewed, it was made known that the British were using a method whereby asbestos fibers were counted in the workroom atmosphere. They had started out in 1951 with a thermal precipitator. But because this unit did not count fibers longer than 10 μ m, a better method was sought. In 1960, they started using a long-running thermal precipitator and were able to collect and count the long fibers. They made a second change in 1965 when they started collecting samples with cellulose membrane filters.

As an informational note, in the standard thermal precipitator, dust-laden air is drawn vertically into the sampling head and down a narrow vertical channel between two glass coverslips. Halfway between these two coverslips is stretched a horizontal wire, heated electrically. Dust is deposited by a thermal effect, opposite the wire, in two strips on the coverslips. The coverslips are then mounted, dust side down, on microscope slides and the dust is then counted.

In the "long-running" thermal precipitator, the dust-laden air is drawn from a vertical passage and along a horizontal channel, the floor of which is formed by a glass coverslip. At first particles settle out from the air by gravity and the remainder are precipitated thermally beneath a heated wire.

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With the British already using a method to count asbestos fibers in the workroom atmosphere, we felt it was necessary to arrive at a similar procedure.

In 1968 and 1969, the American Conference of Governmental Industrial Hygienists published notices of intended changes to lower the TLV from 5 mpcf to 2 mpcf based on light field counting techniques. In addition to this, a value of 12 fibers per milliliter of air was suggested as an alternative for the 2 mpcf. The fiber count was to be determined by the membrane filter method at 430 X magnification, phase contrast illumination. Only fibers greater than 5 μ m in length were to be counted.

In 1970 and 1971, the light field technique TLV was eliminated and only the fiber count technique was recommended. Also in these years, the TLV was lowered from 12 fibers per ml to 5 fibers per ml. This change in the sampling and counting technique was brought about by work carried out by the Division of Occupational Health of the U.S. Public Health Service. Their study carried out in asbestos textile plants, was concerned primarily with obtaining some relationship of dust counts by impinger sampling to fiber counts from membrane filters using a higher resolution microscope objective for the latter. The information they obtained was not meant at that time to replace the standard impinger method. With the ratios they obtained they attempted to:

- 1) indicate an approximation of the relationship of impinger counts to fiber counts from Britain,

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- 2) give some indication of fiber counts from personal samples,
- 3) determine some index which may be used in the absence of better information to estimate the proportion of asbestos in a mixed dust exposure.

From this study the following relationships were determined:

<u>Light Field Technique</u>	<u>Membrane Filter Method</u>	<u>Fiber Length</u>
1 mpcf	10 fibers/ml	all fibers
1 mpcf	6 fibers/ml	> 5 μ m
1 mpcf	3 fibers/ml	> 10 μ m

This study shows the effect on the TLV intended changes of 1968 and 1969 of 2 mpcf or 12 fibers/ml for fibers greater than 5 μ m in length.

Based on the established TLV of 5 mpcf still being used at the time of the study the following equivalent relationships can be stated:

Total fibers - 50 fibers/ml

Fibers longer than 5 μ m - 30 fibers/ml

Fibers longer than 10 μ m - 15 fibers/ml

If the suggested level of exposure was to be limited to 5 fibers/ml for fibers greater than 5 μ m in length, it can be seen that the impinger technique would require a TLV of less than 1 mpcf. This would be near the lower practical limit of sensitivity of the impinger technique. Accurate measurements would be very difficult by the impinger method.

Another fact was that this relationship was obtained for asbestos textile mills and would not necessarily be valid for other industries. In fact, the results could not be related from one plant to another for the same operation.

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One definite result of this study was that the estimate of risk of disease should be based on fiber counts since this method yielded a more direct estimate of airborne asbestos concentrations.

This leads us to the procedure recommended by the National Institute of Occupational Safety and Health to be used for airborne determinations of asbestos concentrations.

Collection of Sample

The sample should be collected on a 37-millimeter "Millipore" Type AA filter mounted in an open face filter holder. The filters are contained in plastic filter holders and are supported on pads which also aid in controlling the distribution of air through the filter. To yield a more uniform sample deposit, the filter-holder face-cups should be removed. The filters just described are often referred to as Field Monitors. They come preassembled from the Millipore Corporation. The stated pore size of these filters is 0.8 μ m. Collection efficiency is very high for particles below the stated pore size. Particles are collected on the surface of the filter. They do not penetrate into the filter structure.

It must be emphasized that this procedure is only good for Millipore Corporation filters. If any other membrane filters are used a relationship has to be developed between both types of filters.

There are three choices of filters that can be ordered for the Field Monitors. The one recommended is the white with no grid markings. This filter is selected over the one with grid markings for two reasons.

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They are as follows:

- 1) the mounting media does not clear the grid markings on the filter, and
- 2) sometimes the grid markings may interfere with fibers that are to be counted.

The other choice, the black filter, is not able to be cleared.

It is advisable to seal that portion of the filter holder that is not removed during the sampling procedure. After sampling, the top section that is replaced to cover the face of the filter, should also be sealed.

Sampling flow rates may vary from 1 lpm to 2.5 lpm which is just about the maximum flow rate obtainable by personal sampling pumps. In one Federal Government publication the recommendation was to use 2 lpm as the flow rate and a minimum sampling time of 15 minutes when an evaluation was needed to determine if there was the possibility that the excursion limit of 10 fibers/ml might be exceeded. There are some definite problems with such a recommendation. They are:

- 1) When it is evident that the TLV is being exceeded, a 15-minute sample may be too long in duration. If too much material is collected on a filter, there may be sloughing-off of some of the heavy deposits of material, there will be overlapping of fibers with some actually being hidden during the counting phase, and with heavy deposits, there may be some shifting of the fibers when the clearing material is used.

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- 2) The pump that may be used at this time may not have the capacity of 2 lpm. Does this mean the sample cannot be taken? No. What is required though is the known flow rate and the length of sample time.

This recommendation that is referred to above, probably is attempting to relate to the counting requirements that are needed in order to obtain a statistically acceptable sample. In order to have an accurate estimate of the number of fibers, the statistical error resulting from the random distribution of the fibers must be kept reasonably low. To quote from the Criteria Document on Asbestos:

"Since fiber counts follow a Poisson distribution, a count of 100 fibers in a sample would have a standard deviation of $\sqrt{100}$ or 10 fibers or $\pm 10\%$. Thus the 95% confidence limits would be approximately 2 standard deviations or $\pm 20\%$. Since the 37 mm filter has an effective collecting area of 855 mm^2 and the projected field area of the Porton reticle is 0.005 mm^2 , each field represents $1/171000$ of the sample. Based on this ratio, the following number of fields must be counted to measure the various limits in various sampling times:"

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Sampling Time (minutes)	Flow Rate (lpm)	Number of fields for 100 Fibers	
		<u>2 fibers/ml</u>	<u>10 fibers/ml</u>
10	2	435	91
15	2	286	<u>58</u>
30	2	143	<u>29</u>
90	1	100	20
90	2	<u>50</u>	10
240	1	<u>26</u>	7
240	2	<u>18</u>	4
480	1	<u>18</u>	4

They do not recommend counting a field with more than 20 fibers because particulates may be present that would interfere with the accuracy of the count. This restricts the sampling parameters that are recommended to those underlined in the above table.

It is suggested that at least 100 fibers be counted in a sample and that the minimum number of fields should be 20 and the maximum 100. Presently the sources we use for counting filter samples only count 20 fields.

Some judgement is needed in terms of what we are looking for and how to apply this idea of statistical accuracy. We know that when we are in a high dust atmosphere that we are not going to sample for such a long period that we will overload the filter and make counting difficult. In this case 20 fields would probably be sufficient. When we are in a light dust atmosphere we will automatically sample for a longer period with the idea that enough fibers have to be collected to obtain a good count. Even if very few fibers are collected on a long-running sample

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and for which only 20 fields are counted, it would still be possible to say that the airborne concentration is less than some value which would automatically be very low.

Location of Filter

The filter should be located as near as possible to the breathing zone of the worker. The most logical place is on the worker's lapel. Normally either side would probably be acceptable. However, observations should be made of air currents in the area as the dust may be directed to one side or the other of the worker.

Sampling Pump

There are a number of battery-powered personal sampler pumps on the market. Their sampling rates as indicated earlier vary from 1 to about 2.5 lpm. These pumps usually are able to operate continuously for eight hours. The three manufacturers' pumps available are Mine Safety Appliances' Monitair, Bendix's C-110 Personal Sampler and Casella's Personal Sampler. Only the Casella pump does not have a visible rotameter. This is a definite disadvantage because as the charge decreases on the battery, the flow rate could be reduced without it being noticed. With the other units it is possible to continuously check on the flow rate during sampling and make required adjustments to keep a uniform flow rate. However, keeping a uniform flow rate is not as critical as knowing the volume of air sampled.

Knowing accurately the volume of air sampled is essential. The accurate calibration of a sampling device is necessary to the correct interpretation of an instrument's reading. Personal sampling pumps

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should be calibrated prior to their being used. In the laboratory a wet test meter is suggested and in the field a rotameter is convenient. The calibration chain is as follows: the flow rate standard instrument, the filter and the pump.

Sample Preparation - (In addition, see article by Public Health Service included with these proceedings.)

The mounting medium used in this method is prepared by dissolving 0.05 gms of membrane filter per milliliter of a 1:1 solution of dimethyl phthalate and diethyl oxalate. The index of refraction of the medium thus prepared is ND 1.47. It is desired to have some separation of the indices of refraction between the mounting media, the membrane filter, and the asbestos fibers. This is not as critical in phase contrast as in light field techniques. The index of refraction for chrysotile asbestos is 1.55 and for membrane filters is about 1.5.

The filter as received from the field should have the face cups sealed in place. This is to assure unnecessary contamination and the prevention of damaging the filter.

To prepare a sample for microscopic examination, a drop of the mounting medium is placed on a freshly cleaned, standard (25 mm x 75 mm) microscopic slide. A wedge-shaped piece with an arc length of about 1 cm is excised from the filter with a scalpel and forceps and placed dust-side up on the drop of mounting solution. If the mounting solution was placed on top of the filter, air bubbles could be formed and it may be possible for displacement of the fibers on the filter surface. A No. 1-1/2 coverslip, carefully cleaned with lens tissue, is placed over the filter wedge. Slight pressure on the coverslip achieves

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contact between it and the mounting medium. The sample may be examined as soon as the mount is transparent. This usually requires about 15 minutes. The sample should be counted within 2 days after mounting.

Evaluation of the Filter Sample

The filter samples mounted in the manner previously described are evaluated in terms of the concentration of asbestos fibers greater than 5 μ m in length. A microscope equipped with phase-contrast optics and a 4 mm "high-dry" achromatic objective is suitable for this determination. 10 X eyepieces, one of which contains a calibrated reticle at the level of the field-limiting diaphragm, should be used. Two suggested reticles are the Porton or Patterson Globe and Circle. The Porton reticle is probably used more than the Patterson reticle. In the Porton reticle the left half of the field serves to define the counting area of the field. In referring to the counting accuracy, a minimum of 20 fields or 100 fibers should be counted. A fiber is any particle that has an aspect ratio of three or greater to one. All fibers longer than 5 μ m are counted.

Sample Calculation

The following formulae are used to determine the number of fibers per ml:

$$1) \frac{\text{Filter area (mm}^2\text{)}}{\text{Field area (mm}^2\text{)}} = K$$

the effective area of the 37 mm filter is 855 mm^2

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$$2) \frac{\text{Average net count} \times K}{\text{Air volume sampled (ml)}} = \text{fibers/ml}$$

The field area used has to be calibrated prior to counting with a microscope stage micrometer. For this example, the assumption is made that it is 0.005 mm^2 .

$$\text{Therefore: } 1) K = \frac{855 (\text{mm}^2)}{0.005 (\text{mm}^2)} = 171,000$$

Assuming the average net count per field of 20 fields was 5 fibers and the sample was collected at 2 liters per minute (2000 ml/min) for 90 Minutes: Then:

$$2) \frac{5 (\text{fibers}) \times 171,000}{2000 (\text{ml/min}) \times 90 (\text{min})} = \frac{855}{180} = 4.7 \text{ fibers/ml}$$

Principles of Sampling - (This section is quoted from the Criteria Document on Asbestos; reviews the topic very concisely.)

"A dust sampling procedure must be designed so that samples of actual dust concentrations are collected accurately and consistently. The results of the analysis of these samples will reflect, realistically, the concentrations of dust at the place and time of sampling.

In order to collect a sample representative of airborne dust, which is likely to enter the subject's respiratory system, it is necessary to position a collection apparatus near the nose and mouth of the subject or in his 'breathing zone'.

The concentration of dust in the air to which a worker is exposed will vary, depending upon the nature of the operation and upon the type of work performed by the operator and the position of the operator relative to the source of the dust. The amount of dust inhaled by a worker

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can vary daily, seasonally, and with the weather. In order to obtain representative samples of workers' exposures, it is necessary to collect samples under varying conditions of weather, on different days, and at different times during a shift.

The percentage of working time spent on different tasks will affect the concentration of dust the worker inhales, since the different tasks usually result in exposure to different concentrations. The percentage can be determined from work schedules and by observation of work routines.

The daily average weighted exposure can be determined by using the following formula:

$$\frac{(\text{Hours X conc. task A}) + (\text{Hours X conc. task B}) + \text{etc.}}{8 \text{ Hours (or actual hours worked)}}$$

The concentration of any air contaminant resulting from an industrial operation also varies with time. Therefore, a longer sampling time will better approximate the actual average."

Some information has been done on insulators and the various tasks that they perform in their work. The jobs performed by the insulating worker have been divided into six areas and are outlined as follows with the approximate time spent at each task:

1) Prefabrication (10%)

materials are pre-cut and shaped using hand or power saws

2) Application (40%)

materials are fitted, hammered, or carved and attached to the surface to be covered

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3) Finishing (30%)

materials are coated with asbestos containing cements,
resins, asbestos or cotton cloth, or sealers

4) Tearing Out (10%)

removal of old or unusable materials in the process of
insulating or reinsulating

5) Mixing (5%)

cements are mixed separately or in combination in buckets
or troughs

6) General (5%)

cleaning up of old insulation, transporting of materials, etc.

In one set of studies the following asbestos fiber concentrations
were found at the various tasks:

Operation	Concentration (fibers/ml)		upper
	Mean	Range	Mean
Prefabrication	9.0	0.1 - 25	7.0
Application	5.8	0.1 - 65	3.7
Finishing	2.9	0.1 - 25	2.9
Tearing Out	9.2	0.2 - 27	5.8
Mixing	2.6	0.2 - 18	8.5
General	5.0	0.1 - 23	1.6

From the values in the range column, it will be noticed that there
is a wide variability of airborne concentrations. It seems that there
are two definite operations of significant exposure--prefabrication and
tearing out.

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This table is not meant to indicate what the specific problem areas are and the airborne concentrations that may be expected. Every situation is different--time spent on each operation, the environmental influences on the area (wind currents primarily), the work load, individual work habits, etc. Every location must be evaluated individually.

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