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May 6, 1969

File 259

Dr. Irving J. Selikoff
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Dear Irving:

Enclosed is my portion of our paper on "Fibrous Dust Respirator Protection". As soon as you have an opportunity to read it, please call me. The figures in the paper (Figure 1, Electron Micrograph of "Standard" Fibrous Dust, and Figure 2, General View of the Face Mask) will be ready in a day or two. I will send them as soon as they are available.

Sincerely yours,

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Enc.

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Design criteria

The following specific criteria were established for the design of a face mask which would gain a high degree of acceptance on the part of workers:

1. The mask had to be effective against both particulate and fibrous dusts, and it had to meet the Bureau of Mines requirements for approval under Schedule 21B(16).

2. The mask was to be designed to be used for one day and then it was to be discarded. There are a number of masks on the market today which utilize a disposable filter element which fits into a more or less permanent face-piece that is used over and over. Although some of these masks are relatively effective, unfortunately the most effective ones have gained only modest acceptance on construction site jobs. There are several reasons for this low rate of usage. Unless a job-site facility is provided to repair, replace, and maintain the face-pieces, they quickly become dirty and very unappealing from the wearer's point of view. In general job-site repair and maintenance facilities for face masks are not available. Thus, it appeared that one way to avoid this problem was to design an effective mask which would [illegible] economical that it could be discarded in its enti[illegible] [illegible]

3. The mask had to have a low pressure drop across the filter element to minimize breathing resistance during day-long use.

4. The worker had to be able to talk through the mask and be understood at a distance of at least 5 feet.

5. The mask had to be comfortable to wear, and it had to fit more than 90 per cent of the various facial types that would be encountered.

Development of "standard" fibrous dust

In developing a filter medium that would be effective against fibrous dusts, it was necessary first to develop a "standard" fibrous dust. In general, the available standard tests for the efficiency of face mask filters against dusts utilize a standard particulate silica dust or an aerosol dispersion of spherical liquid droplets. For the most part it has been assumed that filter media which are effective against particulate dusts are also effective against fibrous dusts. However, the airflow characteristics and particle dynamics of fibrous particles are known to differ from the characteristics of more or less spherically shaped particles. Therefore, it was important in this study to measure directly the effectiveness of various filter media against a fibrous dust such as asbestos.

It was found that a satisfactory "standard" fibrous dust could be prepared by micropulverizing and air-jet-milling a specially cleaned source of chrysotile asbestos fiber (17).

The fibrous dust prepared in this way was predominantly of respirable size with most of the fibers less than 10 microns long and less than 1 micron in diameter (Figure 1). This dust could be dispersed in a satisfactory manner with the silica dust apparatus and feed mechanism described in Bureau of Mines Standard Method No. R-6(18).

Essentially this apparatus and method consist of aspirating the dust into an airstream, and then passing the dust through a cyclone to drop out the larger particles before the dust-laden air is passed into a large chamber (8 ft by 8 ft by 6 ft) in which the face mask and filter are cemented over a port. Air is drawn through the mask at the rate of 32 liters/minute. In the case of fibrous dusts, the air which has passed through the mask is siltered through an MSA #1106B glass fiber filter backed up with a Millipore filter. These filters were weighed before and after the test to determine the amount of breakthrough in the mask under test. In several cases the filters were examined with an electron microscope to detect any asbestos present in quantities too small to be detected with the weighing procedure.

Tests of mask filter media against asbestos dust

A number of commercially available masks were tested against the "standard" fibrous dust along with the JMS prototype mask developed as part of this project. The result of these tests is shown in Table 11. All the masks, except one, were relatively efficient in removing chrysotile asbestos from the air.

Even though a number of the masks tested were less than 99 per cent efficient against standard silica dust, with the one exception noted, they were all more than 99 per cent effective against chrysotile asbestos dust. The filter media used in the masks tested ranged from rosin wool through mixtures of fine glass fibers with cellulose or synthetic fibers to open-cell urethane foam. The latter was least effective against the asbestos dust. Based on these results, it appears that finely dispersed chrysotile asbestos may be more easily filtered out of an airstream than very finely divided particulate dusts such as silica. It must be pointed out, however, that these results apply only to chrysotile asbestos. Amosite and crocidolite asbestos have not been tested in this way, and since these fibers tend to break down into relatively rigid, spicule-like fibers, they may show a different filtration behavior than does the relatively flexible chrysotile fiber.

Face mask design

The most difficult part of face respirator design is the face frame itself. If the face frame does not provide a tight, non-leaking seal against the face, it really does not matter much whether it is attached to a 99.9 per cent efficient filter medium or a 95.0 per cent efficient medium. In most cases the fit of the face frame is the limiting factor in the efficiency of the overall face respirator assembly.

The JMS prototype mask utilizes a rubber compound face-piece with an aluminum wire insert. The purpose of the wire insert is to permit shaping of the face-piece to the contours of the individual wearer's face. The overall appearance of the mask is illustrated in Figure 2. The wire insert is discontinuous so that the face-piece has, in effect, a hinge on each side of the wearer's mouth. The hinge facilitates the fitting of the mask to the individual, and it also accommodates movement of the mouth when the wearer speaks.

In some of the early prototype masks, a bead of special silicone gum was an integral part of the face-piece. The purpose of this gum was to form a semi-liquid seal between the face-piece and the wearer's face. However, tests of the efficiency of the prototype mask assemblies did not show any particular advantage from the use of the silicone gum, and it was not used in the field trials of the mask.

Field tests of the JMS mask

A series of 2-day field trials of the mask was conducted with the cooperation of the International Heat and Frost Insulators and Asbestos Workers Union and Brand Insulations, [illegible], an insulation contractor. Three types of masks were evaluated:

Type A - JMS prototype mask with an [illegible]

Type B - JMS prototype [illegible]

[illegible]

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men

Six groups of six men were selected to test the masks. The workers in each group wore each mask, but in a different sequence. This was done to remove any time or sequence dependence from the test. Each worker wore a given mask for half a day (approximately five hours) and then he completed the type of questionnaire shown in Table 12. It is interesting to note that prior to the tests many of the men on this construction site had been using a nuisance-type dust mask which, although it was not particularly effective against respirable particles and fibers, was comfortable.

In rating the masks, the workers showed a definite preference for Type A as the best mask. This preference appeared to be associated with the use of an exhalation valve in the mask. Type B and Type C masks were preferred the least by approximately equal numbers of workers. This lack of preference for or against B relative to C indicates that breathing resistance was not a serious factor in these masks.

Two major objections were raised to all the masks regardless of type. First, the comfort of fit, particularly around the bridge of the nose, was a problem. Second, the bulkiness of the mask interfered with downward vision, and it interfered with glasses when these were worn by the worker. These objections are serious enough, we believe, to require some redesign of the face-piece and the shape of the filter element before the mask will meet the design criteria established for it. However, we are convinced that it is possible to develop an acceptable face respirator mask which is highly affective against fibrous dusts. Such a mask probably can incorporate "throw-away" or "disposable" features which will permit the use by the workers of an essentially new mask each day. A mask with these features, we belive, will gain wide acceptance on construction job sites, where hazardous dusts exist.

Acknowledgement

We wish to acknowledge the useful discussions with Mr. Earle Shoub and Mr. R. H. Schutz of the U.S. Bureau of Mines, Division of Accident Prevention and Health, concerning the testing and evaluation of face mask respirators.

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TABLE 11

FILTER EFFICIENCY AGAINST CHRYSOTILE ASBESTOS DUST

	Respirator Masks							
	JMS	2*	3*	4	5	6*	7	8
Avg. fiber concentration (mg/m^3)	30.1	30.1	15.4	24.9	24.9	27.0	15.4	27.0
Total fiber challenge (mg)	86.7	86.7	44.4	71.7	71.7	77.8	44.4	77.8
Initial inhalation resistance ($mm \cdot H_2O$)	6	22	16	18	44	13	1	4
Final inhalation resistance ($mm \cdot H_2O$)	8	29	50	38	84	36	--	23
Filter efficiency	>99.9	>99.9	>99.9	>99.9	>99.9	99.6	99.1	97.4

*Masks approved by the Bureau of Mines for use against pneumoconiosis-producing dusts.

REFERENCES

1-15: Dr. Selikoff's portion of this paper.

16. U.S. Bureau of Mines Schedule 21D (Part 14, Subchapter B, Chapter 1, Title 30). January 19, 1965.

17. Weeks, T.J., and Burns, A.F., "Performance of Dust Respirators Against A Fibrous Dust", to be published.

18. Brenenborg, F.J., "Testing Respirators Against Silica Dust", U.S. Bureau of Mines Standard Method No. R-6 (April 15, 1968).