FIBROUS DUST RESPIRATOR PROTECTION: DESIGNING FOR WORKMAN ACCEPTANCE AND EFFECTIVENESS

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INTRODUCTION

Health hazards associated with inhalation of fibrous dusts, especially asbestiform varieties, have become a matter of increasing concern. Simultaneously, the question has arisen whether designs and standards[1] originally derived from studies of non-fibrous particulate dusts were necessarily suitable for fibrous dusts as well, in view of the specific particle dynamics and airflow characteristics of the latter.[2]

The use of respirators has long been an accepted practice in the industrial hygiene precautions associated with the factory manufacture of asbestos products. Such practices are known to have been utilized even before the demonstration in the 1920's and subsequently of the risk of asbestosis associated with asbestos dust exposure.[3-5] At the present time, many asbestos factories have special respirator programs, with provision for regular maintenance and supervision. Respirators of different designs are used. In general, these are selected from the list of respirators approved for protection against pneumoconiosis-producing dusts by the Bureau of Mines. It is recognized, however, that there are no published data concerning the efficacy of these masks for fibrous dusts in particular, although such efficacy is widely assumed.

A serious risk of asbestos exposure has recently been demonstrated[6-8] for a group of workmen - insulation workers in the construction industry - for whom the advantages of an effective in-plant respirator program have not been generally available. These men are responsible for the installation of temperature insulation (heat loss, maintenance of low temperatures) in power plants, industrial installations, boiler rooms, ships' engine rooms, nuclear energy stations, chemical plants and refineries, as well as heating plants and distribution facilities in schools, public buildings, etc. Workmen in affiliated trades are responsible for sound insulation and fireproofing insulation. It is not known exactly how many men are employed as insulation workers in the United States. Reliable estimates suggest that some 50,000 are regularly so employed and perhaps another 50,000 do such work during a significant portion of their work time.[9]

Table 1 lists materials currently utilized in insulation work in the United States; in previous years, fibrous glass products were used less frequently, and cork, rockwool, wool felt and other organic fibers were more in evidence. Tables 2 and 3 detail the utilization of insulation materials in general by insulation workers at this time. Although a good deal of dust of granular nature is produced in this work (as, calcium silicate, calcium carbonate, diatomaceous earth, serpentine rock dust, cement, etc.), there is a significant amount of fibrous dust as well (fibrous glass, chrysotile, amosite, rockwool, and in recent years, relatively small quantities of crocidolite).

Dust is produced by such operations as mixing powdered materials (asbestos cements, finishing cements), handling, cutting and sawing friable materials (insulation block, pipe covering and fittings) either by hand or power saws, spraying insulating materials (often a mixture of asbestos, rockwool, binders and water), removal of old insulation, etc. While much of this work is done at open construction sites, it often takes place in crowded areas with poor ventilation, as in boiler and engine rooms or in the holds of ships.[10] Men usually work in small groups and move about a good deal. During new construction, ventilation is usually absent and this may also be the case during repair work. Insulation workers generally work at all parts of the trade; very few limit themselves to one material or one task. Conditions of work vary from job to job and from company to company. It is a highly skilled, well-paid trade of self-reliant craftsmen, most of whom remain at this employment throughout their working life.

USE OF RESPIRATORS BY INSULATION WORKERS IN THE UNITED STATES AND CANADA

It is recognized that respirator masks have significant limitations in the prevention of pneumoconiosis and are not a substitute for development and utilization of appropriate programs of dust suppression and prevention. Industrial hygiene procedures should be sought which make respirator masks unnecessary. Nevertheless, at the present time, unfortunately practices still exist by which dust is created. Pending their correction or elimination, it would appear necessary to provide suitable personal respirator protection for men at or near such work.

So much would appear obvious. Unfortunately, the obvious has also been the neglected. Although a potential hazard of asbestosis has been known to insulation workers for more than 35 years[11] the plain fact is that few insulation workers use personal respirator protection, even under obviously dusty conditions.

Initial Studies - New York-New Jersey Insulation Workers. The largest single group of insulation workers in the United States and Canada is organized as the International Association of Heat and Frost Insulators and Asbestos Workers (IAHFIAW). This union is the lineal descendant of the first union of insulation workers in the United States, which was formed in New York City in 1884 under a charter issued by the Knights of Labor (predecessor of the American Federation of Labor) as the Salamander Association of Boiler and Pipe Felters.[12] In 1910, the present union was chartered, following the amalgamation of the Salamanders' Association of New York with other independent locals through the country.[13] The union is affiliated with the Building Trades Department of the AFL-CIO. There are 120 locals of this union in the United States and Canada. The largest local is in New York City (Local #12) and another large local (Local #32) is in Newark, New Jersey.

In 1963, a survey was undertaken of the members of these locals.[6,7] On January 1, 1963, there were 1,249 members of these two locals;

1154 were personally examined by one of us. Table 4 records the composition of the group surveyed and examined. During the examinations, each man was asked whether he used a respirator mask at his work and, if so, how frequently. Table 5 gives the result of this investigation. It demonstrates that only 3 per cent of the men regularly wore masks, 27 per cent used them less frequently, while 70 per cent had never concerned themselves with such devices.

Use of Masks - National Survey. Since the N.Y.-N.J. survey represented less than a 10 per cent sample of the national union membership, and since it was possible that work and trade practices might be different in N.Y.-N.J. compared with those elsewhere in the country, a larger survey was undertaken to obtain additional information on the question.

On January 1, 1967 there were 17,996 men on the rolls of the IAHFIAW, including men actively employed as insulation workers, those withdrawn from insulation work but working at other trades (often supervising insulation work), men who had retired because of age or illness, men serving in the armed forces, etc. Each of these men was sent a questionnaire in the first months of 1967. Among the questions asked was "Do you wear a mask working at a dusty job?" and additional information was requested concerning the recipient's evaluation of respirator masks with which he was familiar or had used. Other questions included the smoking habits of the individual, his work status, and information needed in a health study of the same group of men. 12,051 replied to the questionnaire, the replies being well distributed among the

several age groups (Table 6). The majority of those answering (83.1 per cent) were regularly employed as insulation workers at the time they completed the questionnaire.

The results of this survey demonstrated that the use of masks by insulation workers throughout the United States was not very much different from that found in N.Y.-N.J. Only 4 per cent always wore a mask at a dusty job and almost 30 per cent never used such protection (Table 7).

Characterization of Available Masks by Insulation Workers. 8,645 men completed that portion of the questionnaire which requested their evaluation of currently available masks. 4,937 stated that they were not satisfactory while 3,708 found them satisfactory. It was of interest, however, that those who answered "satisfactory" did not use masks any more often than those who were dissatisfied (Table 8)! Moreover, somewhat to our surprise, smoking cigarettes also made little difference (Table 9), perhaps because masks were not worn very much under any circumstances.

Analysis of the replies suggests that difficulties with masks known to these men could be listed in several categories (Table 10). The most common problem was discomfort - this was noted by 37 per cent of the men answering, while interference with breathing was noted by 21 per cent. The first problem was apparently a most common one. 2,517 men described the masks available to them as "restricting inhalation," "don't provide enough air," "require that I breathe faster and harder," etc. Only 16 noted that sticking valves underlay the difficulty in

breathing and 45 more commented that the restriction was noted only when the filter became wet. On the other hand, problems with filters were common enough in other ways. 1,185 men raised this question. 358 complained of clogging of the filters and 185 noted that the filters had to be cleaned very often. Condensation was felt unacceptable by 201, while 332 felt that the filters they used were ineffective in stopping fine particles. (It should be noted that all sorts of masks are used by these men, many not on the list of approved respirators.)

Problems of comfort and interference with vision were prominent among the replies. 573 men complained of poor fit in general and another 881 men felt the masks were uncomfortable over all. This was in addition to 765 men who wrote that their masks resulted in irritated skin and skin rashes. While tightness, stiffness, bulkiness, clumsiness, weight and size played a role, a major complaint (686 men) found the masks "hot" and sweating and perspiration were commented upon by another 779 men. 141 attributed the leaking to the inability of the mask to be made to conform to individual facial variations. Only a small minority (86) complained of difficulty in adjustment or tendency of the masks to "ride up".

275 men were concerned that their masks would fog up their glasses or that the mask's glass would itself be fogged. In addition, 136 men noted that their masks interfered with their vision on the job, a worrisome complaint to men who often

must work on high scaffolds, under somewhat precarious conditions. The mask design in 91 other instances was stated to interfere entirely with the wearing of glasses.

The quality of the masks available was not found deficient too often. 81 men found their masks cheaply made and 47 more found them flimsy. Only 31 found the elastic straps uncomfortable. The fact that 104 men found sanitary problems ("there is no clean place to put the masks down," "there are usually no facilities for washing masks") is perhaps not a criticism of the masks themselves but a reflection of the problem in general in this trade. A similar explanation may be offered for the fact that 546 men found the masks either never or only infrequently available while 44 more noted that the filters for such masks were usually unavailable for replacement. Too, the fact that available masks were inconvenient to work with and in the way, especially in tight quarters, was noted by a surprisingly high percentage of the men (589) and such interference with work was noted by 179 men who commented that they could not easily speak to other men on the job through available masks. Surprisingly, one recommended self-contained air supply respirators. 13 had never seen a mask worn on any job. 494 men (4.1 per cent) found no problems with masks at this time.

In general, the men did not question the efficacy of the masks - only 415 raising this question - including 219 who considered that the effectiveness was limited to rather short periods of time. Moreover, none admitted that they rejected masks because they

interfered with smoking (although 20 felt that chewing tobacco might give equal protection and one acknowledged that he preferred to breathe through a cigar rather than through a mask's filter).

The summarized data may be considered against the background of knowledge that from 1963 to 1967 information had been widely disseminated among the members of the IAHFIAW concerning not only the risk of asbestosis but also of lung cancer and other neoplasms, with dust exposure.[14,15]

Since the results of the investigation suggested that difficulties with available masks might in part be responsible for the failure of these men to utilize personal respirator protection and since it was anticipated that such protection could be useful in some circumstances, it was felt desirable to attempt to design a respirator mask that would be suitable for insulation work. In such design, two essential features were considered important.

1. The mask should be acceptable to insulation workers - that is, it should aim at avoiding the difficulties insulation workmen have recorded as having been found with those masks they had used. If this were not achieved, effectiveness in terms of protection would be irrelevant. No mask is effective if it remains in the tool box or clothes locker. Thus, the mask had to be comfortable, should not interfere with breathing even at the end of a day's work, filters should present no problem, there should be no interference with vision, etc.
2. Effectiveness was to be measured in terms of fibrous dusts, including asbestos.

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 be so economical that it could be discarded in its entirety at the end of a day's work.

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.[17] 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.[18]

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). A considerable number of fibers in the sample are ultimate fibrils of asbestos with diameters of 250-300 Å. A few fibers in the sample have lengths of 50 μ to 300 μ with diameters less than 5 μ. 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[19]. This is the first time, we believe, that a practical "standard" fibrous dust has been prepared in quantity, and samples of the dust are available for research and development purposes.*

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. When this type of test is used with finely divided silica dust, the air which has passed through the mask is filtered through an MSA #1106B glass fiber filter. This filter is weighed before and after the test to determine the amount of breakthrough in the mask under test. We used this same procedure with the fibrous dust tests, but to check the ability of the MSA glass filter to trap all the asbestos fibers which penetrate the test mask, we backed up the MSA filter with an 0.8 μ Millipore filter. We could detect no weight gain on the Millipore filter. In addition, when the Millipore filter was examined with an electron microscope, only a few individual asbestos fibers could be detected

*Inquiries concerning samples should be sent to Dr. F. L. Pundsack, Johns-Manville Research and Engineering Center, P.O. Box 159, Manville, NJ 08835.

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on it. Therefore, the use of the MSA #1106B filter with this test procedure for fibrous dust yields valid breakthrough data.

Tests of Mask Filter Media Against Asbestos Dust. A number of commercially available masks were tested against the "standard" fibrous dust along with the first 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 first 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 First JMS Prototype 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, Inc., an insulation contractor. Three types of masks were evaluated:

Type A - JMS prototype mask with an exhalation valve;

Type B - JMS prototype mask without an exhalation valve;

Type C - Placebos. A mask with the JMS face-piece, but with a filter medium with essentially no breathing resistance.

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 "disposable type" face respirator mask which is highly effective against fibrous dusts. An active development program is underway to produce a second prototype JMS mask which will satisfy all the major criteria for acceptability of such a mask.

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TABLE 1

INSULATION MATERIALS (U.S.) - 1969[8]

1. MATERIALS CONTAINING ASBESTOS

PRODUCT	ASBESTOS CONTENT
BLANKETS	100% - AMOSITE
MOULDED	95% - AMOSITE (5% FILLER)
INSULATION BLOCK	(A) 85% MAGNESIA: 10-15% AMOSITE + CHRYSOTILE
	(B) 85% CAL. SILICATE: 10-15% AMOSITE
	(C) 85% CAL. SILICATE: 10-15% AMOSITE + CHRYSOTILE
	(D) 85% CALCINED DIATOMACEOUS SILICA: 10-15% AMOSITE + CHRYSOTILE
	(E) 85% CAL. SILICATE: 10-15% CHRYSOTILE
FINISHING "CEMENTS"	(A) 100% CHRYSOTILE
	(B) 50% CHRYSOTILE: 50% CEMENT
SPRAYED ASBESTOS	10-15% ASBESTOS - VARIABLE

2. FIBROUS GLASS AND/OR MINERAL WOOL

BLOCK, ROLLS, PREFABRICATES, HIGH TEMPERATURE INSULATION, FINISHING CEMENTS, MINERAL WOOL AND CEMENT.

3. PLASTICS

POLYSTYRENES AND POLYURETHANES: PREFABRICATED, POWDERED AND FOAMED IN PLACE

4. OTHER

CORK, GLASS FLAKES, ADHESIVES (EPOXY AND SOLVENTS; ASPHALT BASE AND SOLVENT, WHEAT PASTE, SILICONES, MAGNESIA, PORTLAND CEMENT)

TABLE 2

USE OF ASBESTOS INSULATION (PER CENT)

VARIATION BY CONSTRUCTION TYPE, 1969

Construction	Fibrous Glass	Asbestos	Other
Commercial (schools, factories)	75	10	15
Power process (power plants, boiler rooms)	20	60	20
Marine	20	70	10

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Table 3
USE OF ASBESTOS BY INSULATION WORKMEN IN THE U.S.,1969

Material	Volume % of Total	Application % of Time
Asbestos	35	43
Fibrous Glass	45	40
Other	20	17

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TABLE 4

INSULATION WORKERS, NY-NJ

632 MEMBERS JAN. 1, 1943

890 JOINED 1-1-43 TO 12-31-62

STATUS JAN.1, 1963

TOTAL COHORT.....1,522

DECEASED (262 + 11)..... 273

ALIVE.....1,249

YEARS FROM ONSET OF EMPLOYMENT		STATUS				TOTAL	
		RE-TIRED	ILL	WITH-DRAWN	WORK-ING	EXAM-INED	NOT EXAMINED
50+	36	22	8	1	5	29	7
45 - 49	39	17	8	2	12	37	2
40 - 44	59	15	9	4	31	53	6
35 - 39	88	4	2	9	73	81	7
30 - 34	121	0	3	10	108	111	10
25 - 29	18	0	0	1	17	17	1
20 - 24	61	0	1	3	57	58	3
15 - 19	187	0	0	11	176	177	10
10 - 14	228	0	2	19	207	211	17
5 - 9	186	0	0	8	178	165	21
0 - 4	226	0	0	2	224	215	11
TOTAL	1,249	58	33	70	1,088	1,154	95
PER CENT EXAMINED		(81%)	(82%)	(81%)	(94%)	(92%)	

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TABLE 5

UTILIZATION OF RESPIRATORY PROTECTION BY INSULATION WORKERS, NY-NJ, 1905 - 1962

YEARS FROM ONSET OF EMPLOYMENT	NUMBER	UTILIZATION OF "MASKS" NEVER	SOMETIMES	USUALLY	ALWAYS
50+	29	25	4	0	0
45 - 49	27	27	7	3	0
40 - 44	53	45	6	0	2
35 - 39	81	67	10	3	1
30 - 34	111	85	26	0	0
25 - 29	17	13	3	0	1
20 - 24	58	42	12	4	0
15 - 19	177	126	41	5	5
10 - 14	211	129	67	7	8
5 - 9	165	110	39	10	6
0 - 4	215	139	62	7	7
	1,154	808	277	39	30
					6%

TABLE 6

INSULATION WORKERS RESPONDING TO QUESTIONNAIRE CONCERNING UTILIZATION OF MASKS

	Age Distribution of Members		Age Distribution of Respondents	
	Number	Per cent	Number	Per cent
< 20	133	0.7	79	0.7
20 - 29	3,974	22.1	2,383	19.8
30 - 39	5,607	31.1	3,629	30.1
40 - 49	4,098	22.8	2,969	24.6
50 - 59	2,378	13.2	1,756	14.6
60 - 69	1,171	6.5	833	6.9
70 - 79	319	1.8	214	1.8
80+	66	0.4	41	0.3
Unknown	250	1.4	147	1.2
	17,996	100.0	12,051	100.0

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TABLE 7

"DO YOU WEAR A MASK WORKING AT A DUSTY JOB?"

	NUMBER	PER CENT
NEVER	3,592	29.7
SOMETIMES	6,071	50.4
USUALLY	1,483	12.3
ALWAYS	477	4.0
NOT STATED	428	3.6
	12,051	100.0

TABLE 8

UTILIZATION OF MASKS: CORRELATION WITH WORKMEN'S ACCEPTANCE (1000 MEN)

EVALUATION OF MASKS	USED MASKS "NEVER" OR "SOMETIMES"	USED MASKS "USUALLY" OR "ALWAYS"
MASKS SATISFACTORY	46.7%	30.6%
MASKS UNSATISFACTORY	30.9%	58.5%
NO COMMENT	22.5%	10.9%

TABLE 9

UTILIZATION OF MASKS

BY SMOKERS (1000 MEN)

	USE OF MASKS (PER CENT)				
	No Answer	Never	Sometimes	Usually	Always
Cigarette smokers	3.3	18.7	52.3	17.9	7.6
Ex-smokers	5.9	16.7	46.0	19.8	11.5
Cigar/pipe smokers	1.5	25.0	46.9	25.0	1.5
Non-smokers	3.4	18.6	43.4	22.1	12.4

TABLE 10

"WHAT DIFFICULTIES HAVE YOU HAD WITH MASKS?" (12,051 MEN)

	DIFFICULTY	NUMBER	PER CENT
1.	COMFORT OF FIT	4,481	37.2
2.	DIFFICULTY IN BREATHING	2,580	21.4
3.	DIFFICULTIES WITH FILTERS	1,185	9.8
4.	INTERFERENCE WITH VISION	569	4.7
5.	CAUSING PHYSICAL SYMPTOMS ("HEADACHES", SINUS)	164	1.4
6.	COMPLAINTS ABOUT QUALITY	138	1.1
7.	UNSANITARY	104	0.9
8.	INTERFERE WITH COMMUNICATION	179	1.5
9.	AWKWARD	414	3.5
10.	ALL OTHER	1,950	16.1

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.

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TABLE 12. QUESTIONNAIRE USED IN FIELD TRIALS OF FACE MASK

INTERNATIONAL ASSOCIATION OF
HEAT AND FROST INSULATORS AND
ASBESTOS WORKERS

SECOND DAY OF TEST

ON THIS DAY, WEAR A MASK LABELED_____.

AT THE END OF THE DAY PLEASE ANSWER THESE QUESTIONS.

TYPE OF JOB:_____

HOW MANY HOURS DID YOU WEAR THE MASK? _____

EVALUATION OF MASK WORN 2ND DAY	POOR	FAIR	GOOD	EXCELLENT
EASE OF BREATHING	____	____	____	____
COMFORT OF FIT	____	____	____	____
INTERFERENCE WITH VISION	____	____	____	____
AIR LEAKAGE AROUND MASK	____	____	____	____
IRRITATION ABOUT FACE	____	____	____	____
SWEATING	____	____	____	____
CONDENSATION OF MOISTURE	____	____	____	____
QUALITY OF MATERIALS	____	____	____	____
APPEARANCE OVERALL	____	____	____	____
WEIGHT OF MASK	____	____	____	____
SPEAKING AND COMMUNICATIONS WITH OTHERS	____	____	____	____
INTERFERENCE WITH WORK	____	____	____	____
COMPARISON WITH OTHER MASKS USED IN PAST	____	____	____	____

HOW DO YOU LIKE THE MASK YOU WORE TODAY AS COMPARED WITH THE FIRST MASK YOU TESTED? (CHECK ONE)

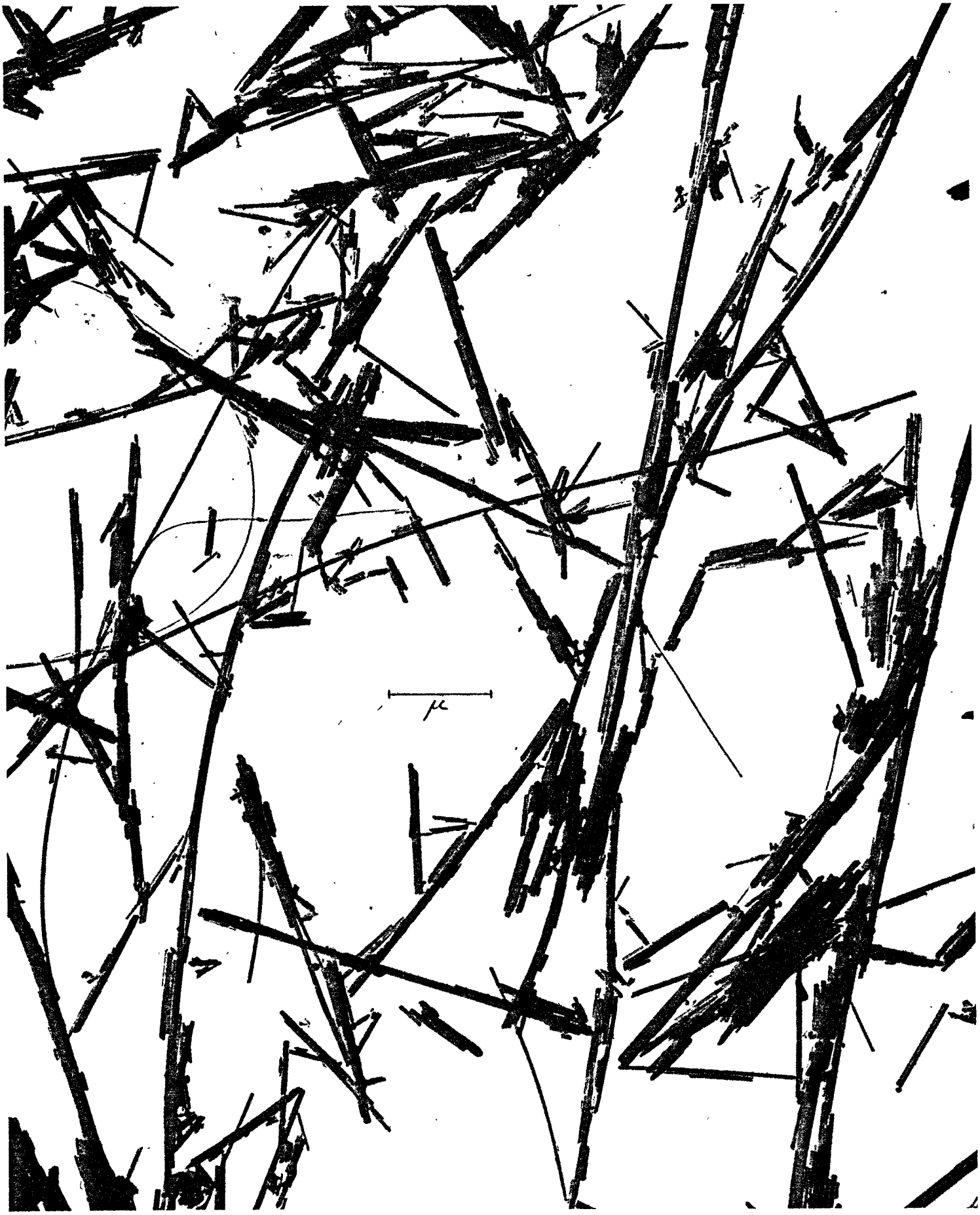
ONE MASK ABOUT AS GOOD AS THE OTHER ☐

I PREFER THE MASK I WORE TODAY ☐

I LIKE THE FIRST MASK BETTER ☐

FIGURE 1. ELECTRON MICROGRAPH OF "STANDARD" FIBROUS CHRYSOTILE DUST

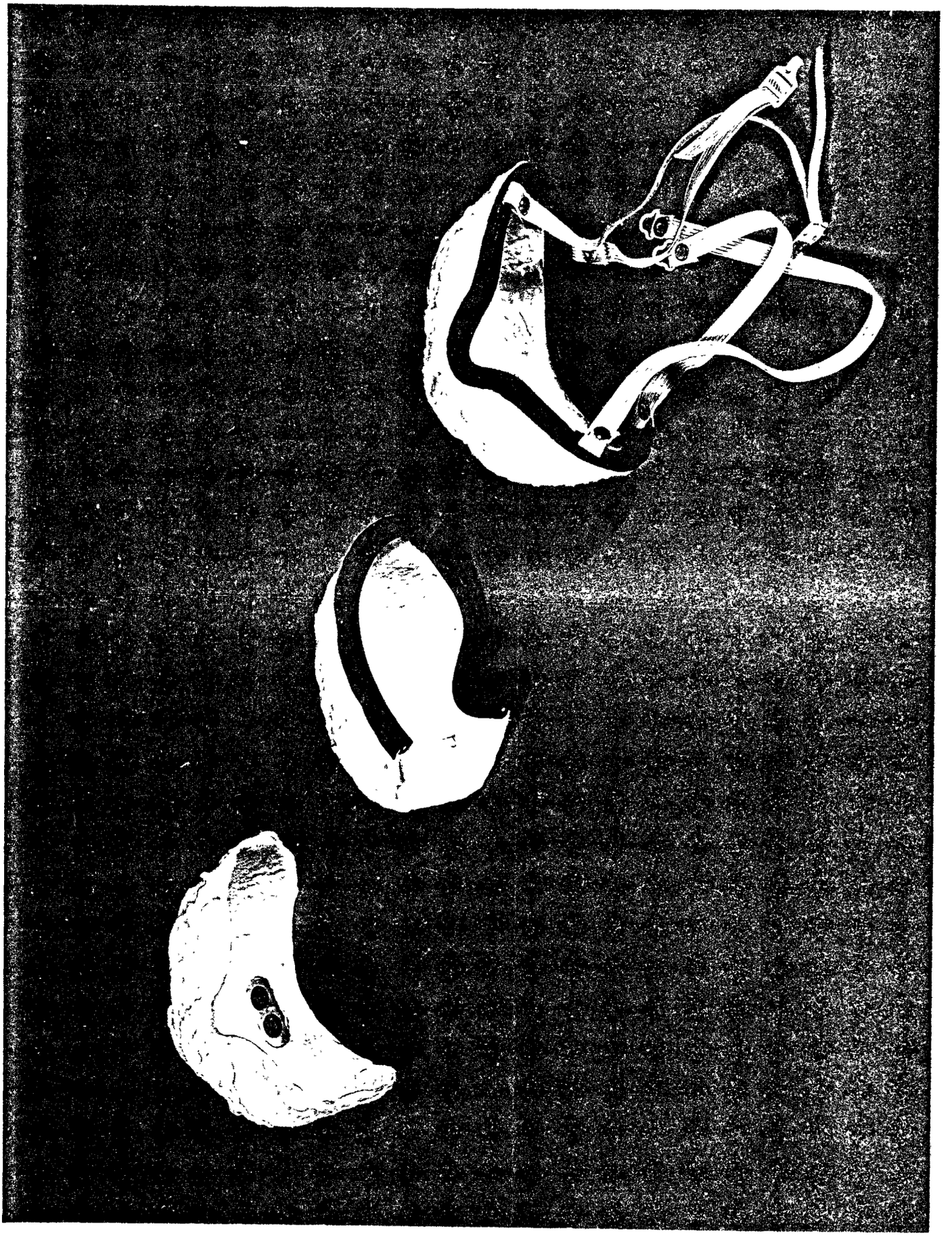
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FIGURE 2. FEATURES OF THE FIRST JMS PROTOTYPE FACE MASK

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