JOHNS-MANVILLE RESEARCH AND ENGINEERING CENTER

Report No. 404-42

Date March 21, 1969

Title: THROWAWAY MASK FOR FIBROUS DUSTS - Progress Report No. 1

SUMMARY

This project was initiated to develop an efficient, disposable, and comfortable mask for fibrous dusts. These requirements also involved the production of a fibrous test dust.

Recent tests at the U. S. Bureau of Mines indicate the objectives have been nearly achieved. Further work necessary includes finding a material for the frame which will be compatible with mass production methods. Also, although the filter is effective against fiber, the efficiency against silica dust needs improvement; this appears to be a minor problem and may be corrected at any time.

There should be no difficulty in producing an on-the-chin half mask which will be more comfortable and efficient than any presently on the market and which will retail for less than one dollar.

Contents: Summary, Introduction, Face Piece, Filter Element, Silica and Asbestos Dust Tests, Conclusions, Recommendations, and Appendix.

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Notebook 3768, pp. 50-116

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INTRODUCTION

At the present time a great many construction workers are exposed to fibrous dusts. The nature of their work takes them over a wide area and from contractor to contractor. This mobility prevents the establishment of a respirator maintenance program which would include the cleaning and filter and strap replacements necessary for a non-disposable mask. As a result, these men generally wear no respirator and have little or no protection. Therefore, after consultation with individuals from the American Industrial Hygiene Association (AIHA), International Association of Heat and Frost Insulators and Asbestos Workers, U. S. Bureau of Mines, and Mt. Sinai, J-M decided to develop a mask which would offer the workers protection. It should be safe, comfortable, effective against fibrous dusts, and disposable. Specifically, the mask is to meet the following criteria:

1. The mask shall be of the throwaway type with a maximum use period of 1 day. Preferably the entire mask will be discarded rather than just the filter element.

2. No more than 50,000 particles per cubic foot of air are to pass through the mask. The criterion for measurement will be the electron microscope.

3. None of the material of the mask can enter the air stream.

4. No materials can be used in the mask which are known to have biological activity or to be potential skin irritants.

5. For comfortable breathing, there should be a low pressure drop across the filter.

6. The filter element must not clog from airborne mists or exhaled breath.

7. The mask shall be "human engineered" so that it will be desirable for an employee to wear it, both from the comfort and appearance standpoint.

8. No leakage around the mask can be tolerated.

9. The worker should be able to talk and be understood at a distance of 4-6 feet.

10. The mask shall not interfere with goggles or safety glasses.

11. The entire mask should retail for no more than one dollar.

In addition, a fibrous dust must be prepared for testing the mask.

Since the mask is disposable and is aimed at a market which now has little respirator protection, it should be possible to sell at least one million a year.

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FACE PIECE

1. Seal

A meeting of the AIHA was attended to gain familiarity with respirators. After attending courses and lectures, it became apparent that the most difficult problem in respirator design is achieving an efficient face-to-mask seal. One idea that was discussed involved the use of a flexible wire circumference to allow the mask to be molded to shape. In addition, it was believed that a hinge would allow the mask to expand for a very large face.

Ideas for materials to be used between the face and mask included a liquid type seal, denture adhesive, inflatable tube of saran wrap, face putty, silicone gum, cream rolled in tissue, and a closed-cell foam coated with adhesive. After evaluating all of these ideas, with a number of possibilities for a liquid seal such as vaseline, natural gums, polybutanes, and PV alcohols, it became apparent that a silicone gum would be effective.

A conversation with Dr. Silas Brailey of Dow-Corning indicated that no allergenic response has ever been detected with a silicone gum. Silicone gum is used as a lubricant in artificial eyes and artificial limbs, and for baby rashes and running sores. However, if it is desired to use silicone gum, patch tests should still be run as agreed to by Dr. Selikoff.

The gum which appears most effective is SE 54 (General Electric), costing about $3.86/lb. It is necessary to stabilize the gum with 3-4 per cent Cab-O-Sil and 5 per cent SE 76. This results in a sticky, rigid gum. These compositions were prepared by E. J. Poltorak and his report should be consulted for exact compositions. However, this may be a moot point since tests at the Bureau of Mines indicate the gum does not improve the face-to-mask seal (discussed later). If it is desired to eliminate the silicone gum, it may be possible to use a closed-cell foam and foam it in place around the filter element.

2. Frame

In initial experiments a mold was made of modeling clay. This was in the form of a ring 7 in. in diameter with a groove to allow placement of silicone gum. A plastisol was poured into the mold over a wire ring to make the frame. Although plastisol was later abandoned after the frame was produced by extrusion, a description is included below because it may be useful when an injection molding technique is tried.

An initial composition is 100 g Geon 121 plus 80 g DOP. This should be cured at 350C for 10-20 minutes. Increasing the amount of DOP increases the flexibility of the plastisol. In some cases, a two-fold process was used: a soft compound was prepared for the groove area; after this cured, a tougher composition was used to give the mask more body. In

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fact, in one case a low viscosity plastisol was used near the hinge area and the wire insert used only around the nose piece. This was fairly effective. It was very difficult to cement filter elements into the plastisol frame because the DOP plasticizer de-tacks adhesives.

An extrusion process was used for the production of frame prototypes. Compounding material, extruding frames, and design changes were carried out by E. J. Poltorak. These will be included in his final report, but a short summary is included here. The material used is a silicone rubber which is extruded with a 0.061-in. aluminum wire through a die. Illustrations by Poltorak are included (Figures 1A and 1B, Appendix) which shows the basic design of the die. This drawing is part of a plan for an injection mold, but the extrusion die has a similar cross section. A 14-in. piece of extruded material is cut and the ends butted together. This is cured giving a ring like a garter. At the mid-point, the wire is cut to allow a hinge action.

The harness utilizes a 3/8-in. rayon elastic band, although worker reaction indicates wider bands would be preferred. The top headbands are 12-in. long while the lower are 9 in. These lengths are before any stapling operations. The strap holders are of the same composition as the frame and are attached to the frame with Dow Corning Silicone Adhesive. The middle of the strap holders should be 1 in. above the hinges and 1 1/2 in. below the hinges.

The final material for the frame has not been decided upon since it will depend on its adaptability to an injection molding process. Several think sessions on the operations involved favor the injection molding approach. One substance rejected was ZERO-LITE since it was too brittle. A possibility already mentioned is plastisol. Another attractive candidate is a Shell product called Krayton 3226. A 5 lb sample under the name of Thermoplastic 226 was obtained and given to E. J. Poltorak along with processing information.

After a visit to MSA in Pittsburgh, it seemed that they had the makings of a disposable mask by pressing the filter element of their Dustfoe 77 into the rubber frame of the new Dustfoe 66 face piece. A metal band to give it rigidity and an exhalation valve could easily be included.

FILTER ELEMENT

After the frame design became stabilized, it was necessary to design a filter to complement it. Considerable trial and error went into this. The filter had to cover the nose yet allow good vision, could not touch the face, and had to expand with the hinge. Accordion-type pleats were discarded because they tended to come in contact with the face. Therefore, material was placed underneath the filter which still allowed the hinge action. Various shapes were made in modeling clay which was covered with coated gauze and sprayed with Krylon. This gave a stiff form which indicated a shape for the filter element.

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It was decided to have the entire mask a filter element; this would allow a low breathing resistance. Because of the filter's shape, it became obvious that it could be formed only by vacuum from a fiber slurry. Therefore, a mold had to be designed. Dr. E. F. Osborn suggested molding porous firebrick. Several bricks were surveyed and the most porous on hand was found to be Babcock & Wilcox K-28, although according to specifications K-26 should be acceptable. The brick is shaped with a file and saw, and is hollowed out with a vibrator to approximately 1/4-in. thickness (Figure 2, Appendix). A rubber diaphragm is cemented to the brick using Dutch Brand 8408 contact adhesive. A hole is cut in the diaphragm to allow application of vacuum (Figure 3, Appendix). Figures 2 and 3 are actual size. The mold edges are all rounded and the vertical indentation around the nose allows a crease when the mask is fully opened.

A considerable number of organic and glass fibers and binders were evaluated. The bottom of a plastic bottle was cut off and taped to a Buchner funnel of 115 cm diameter. A 60 mesh screen was placed in the bottom. Solutions were prepared in a volume of 1700 ml and poured into the funnel; vacuum was not used until the water had passed through. The filter disk was dried at 110C.

It became obvious that the main increases in resistance were due to the glass fiber and binder, with the organic fiber being mainly a diluent. Organics eliminated were PV alcohol, nylon, acrylic, dacron, and RD 101 bonding rayon. A 1/8 - 1/2-in. random-cut Fortisan block seemed to give the lowest resistance when mixed with glass fiber (J-M MICRO-FIBER). Fortisan is a rayon made by Celanese and is about 10 μ in diameter.

Binders which were tried and eliminated are all those in my lab. Generally, it was necessary to add 50 ml of saturated alum solution to break the binder emulsion. An exception was with the binder of choice, Hycar #2600 X 120. In this case, 1M NaOH is necessary.

Generally, for screening purposes concentrations were 1 1/2 g Fortisan, 0.063 g Code 106 MICRO-FIBER, 0.66 g Code 110 MICRO-FIBER, about 2 ml pure binder diluted in water, with alum added last. The fibers were all prepared in water so volumes were used. The glass fiber was brought to pH 3 with HCl to disperse it after being mixed 30 seconds in a Waring Blendor. The mixing time on the glass fiber is critical and has some effect on filter efficiency. Fortisan was mixed in a Waring Blendor for 1 minute.

The method of evaluation for the flat disks was three-fold. First, the "Harry-pull-test" involved Harry Scezney pulling the disk apart with his hands to test for strength and flexibility. Next, the resistance was determined at 85 liters/minute and compared to an MSA filter element. Finally, the filter was tested against silica dust at 32 liters/minute. The apparatus is discussed in detail later.

After initial tests indicated a possible filter composition, filters were drawn on the firebrick mold. It was necessary to use the equipment in the CERA-FORM pilot area in PD #2 and to have a minimum of 20 lb pressure. Mixtures were prepared in 5 gal buckets to give four mask elements. Material was sucked on, blown off, and dried at 110C.

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The technique finally developed involves a double-dip procedure and results in a two-layer filter element. The back-up element is rayon and binder only, and provides strength; it also can catch any glass which might break off the front element. The front element acts as the filter and contains glass, rayon, and little binder. This method also allows less glass fiber to be used since it is more compacted in the thinner first layer. The mold is dipped into the first bucket and then immediately into the second. Each dip should use 1/4 of the material in each bucket. The compositions used were:

Bucket 1	Bucket 2
7 g Fortisan*	6 g Fortisan*
100 ml dilute Hycar #2600.X 120 (diluted 10:1)	3.5 g Code 110 MICRO-FIBER*
200 ml 1 M NaOH	0.64 g Code 106 MICRO-FIBER*
Sufficient water to give 5 gal slurry	20 ml dilute Hycar #2600 X 120 (diluted 10:1)
	100 ml 1 M NaOH
	Sufficient water to give 5 gal slurry

*Stock slurries of these fibers are prepared as previously described for test filter disks. Their concentrations are generally as follows: Fortisan, 1.5 g/650 ml; Code 110, 0.40 g/100 ml; and Code 106, 0.25 g/100 ml.

A slight increase in Code 106 causes a large increase in efficiency and resistance; therefore, Codes 106 and 110 are mixed. Generally, air-flow resistances range from 6 to 12 mm of water, and tests for efficiency against silica dust showed less than 0.5 per cent penetration. Correlating weight, resistance, and efficiency indicate that a filter weighing more than 5.5 g is suitable. However, Bureau of Mines tests, using a more finely divided silica, show that a 5.5 g mask has a penetration of 1.5 per cent. On the basis of these results, it is suggested to make a trial change in the composition increasing the amount of Code 106 in bucket #2 by about 50 per cent. In the glass fiber slurries made to date, it has been noted that after each slurry is prepared, a new screening is necessary because the amount of agitation used in dispersing the fiber has an effect on the efficiency. The amounts of binder and NaOH have not been finalized. To increase mask flexibility, it is suggested that the amount of Fortisan in bucket #1 be decreased about 15 per cent. It may be advisable to find a more flexible binder.

It is necessary to wash the mold thoroughly after the masks are drawn. When the mold ultimately does become clogged, as indicated by thin spots in the filter, glass cleaning solution works well.

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The filter has a very wrinkled appearance and an area of 32 in.^{2}. The wrinkled appearance could be eliminated by using shorter fibers or less vacuum. However, this wrinkled configuration may be the source of the excellent loading characteristics of the mask, as shown in Memorandum M404-66. The filter element is cemented to the frame with Dow Corning Silicone Adhesive. A double falp exhalation valve, supplied by American Optical Company, was added by cutting a hole in the bottom of the filter element and cementing with the silicone adhesive.

The MSA Dustfoe 77 filter element has a composition similar to our element. The Analytical Laboratory's analysis of the MSA element is included in Notebook No. 3743, pp. 121-123. The probable composition is 14.4 per cent glass fiber, about 3 μ and less; 49 per cent rayon, 15-25 μ ; and 36.5 per cent PVC-PVAC copolymer binder, of which 13.2 per cent is PVAC.

SILICA AND ASBESTOS DUST TESTS

A glove box was modified for testing the mask at J-M. Figure 4 in the Appendix shows this set-up.

Generally, in the silica dust test 1 g doses of silica are added in three batches 10 minutes apart with a final wait of 20 minutes; the total test lasts 40 minutes. This concentration is necessary to achieve a 0.2 g build-up on the filter element. A 0.8 μ Millipore is used as a backup filter. During this entire period, the dust-laden air is being pulled through the mask at 32 liters/minute. The weight increase of the Millipore, divided by the weight increase of the filter element, gives per cent silica breakthrough.

It became apparent early in this program that it would be necessary to test the mask against a fibrous dust. Up to the present time there has been no suitable test dust, so manufacturers have never challenged their filter elements with asbestos. Therefore, it was decided to develop an asbestos test dust.

Initial mixtures tried included air-jet milled and micropulverized THERMOBESTOS insulation, Jeffrey 7TF2, and mixtures of MICRO-CEL E and 7TF2. None of these remained suspended. Finally, Plastibest 20, when micropulverized and air-jet milled twice, seemed to give a finely dispersed dust (Figures 5 and 6, Appendix). Addition of MICRO-CEL E or silica did not improve the characteristics of the mixture. For the asbestos dust test, 300 mg slugs of Plastibest 20 are added as in the silica dust test. This results in approximately 0.15 g build-up on the filter.

The Plastibest 20, when dispersed in the Bureau of Mines test chamber, acted very well. A complete description is included in Memorandum M404-66. Briefly summarized, the dust dispersed well, the concentration remained quite constant, and photomicrographs of dust taken from the chamber showed it to be very well dispersed. Most fibers are below 10 μ in length and many fibrils are visible.

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CONCLUSIONS

By referring to the objectives in the Introduction, one can determine the extent to which they have been achieved:

1. A completely disposable one-day mask has been prepared. The mask is very durable, can literally be squeezed into a ball and jammed into one's pocket, and yet be reformed and is usable when taken out.

2. It was decided at a meeting a Mt. Sinai that a fiber count is meaningless and impossible. Therefore, all discussions on amounts of fiber will be on a mass basis. There was no detectable increase in the weight of a Millipore filter behind a J-M mask exposed to asbestos (see Memorandum M404-66).

3. Microscopic analysis of Millipore backup filters indicated no filter material was released into the air stream during a 40 minute test at 32 liters/minute.

4. The final composition of the frame has not been decided upon. Only innocuous materials will be considered.

5 & 6. Pressure drop before and after the silica dust and asbestos dust tests is lower than any mask currently approved by the Bureau of Mines. The resistance buildup with an increasing dust load is less than any mask tested, approved or unapproved (see Memorandum M404-66). In fact, the mask is so durable and the loading characteristics so good that the mask could possibly be reworn several times.

7. Several masks have been worn by J-M pilot plant personnel. The reaction was favorable because of low breathing resistance, good visibility, and comfortable fit.

8. Bureau of Mines coal dust tests indicate a leakage of 5 per cent. This is low for an on-the-chin half mask and well below the 10 per cent leakage allowed by the Bureau's specifications. It is doubtful if the leakage rate can be considerably improved.

9 & 10. It is easy to be understood through the mask, and the mask does not interfere with glasses.

11. The mask should retail for less than one dollar. If the silicone gum and exhalation valve can be eliminated, as Bureau of Mines tests suggest, a retail price of 80 cents or less is conceivable.

In addition, an excellent fibrous dust of Jeffrey chrysotile (Plastibest 20) has been prepared (see Memorandum M404-66).

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RECOMMENDATIONS

Based on experience, both at J-M and at the Bureau of Mines, the following comments are made:

1. Eliminate the silicone gum.

2. Eliminate the exhalation valve. In addition to previous reasons, the low resistance may prevent the valve from seating properly.

3. Improve the filter by increasing Code 106 MICRO-FIBER so that silica breakthrough is reduced to near 0.2 per cent using our laboratory test; this should equal about 0.8 per cent using the Bureau of Mines test.

4. Use wider headbands and bigger strap hooks, rather than the small bra and girdle hooks now employed. Worker reaction has been very favorable due to low breathing resistance, improved visibility, and comfort. Negative aspects were the narrow headbands and the silicone gum.

5. Bureau of Mines tests showed that the mask has excellent loading characteristics with respect to no increase in resistance (see Memorandum M404-66).

6. It is suggested that not a great amount of time be wasted in redesigning the groove, since our mask on-the-chin has a low leakage compared to most half masks. We may be fighting an inherent design problem for on-the-chin half masks.

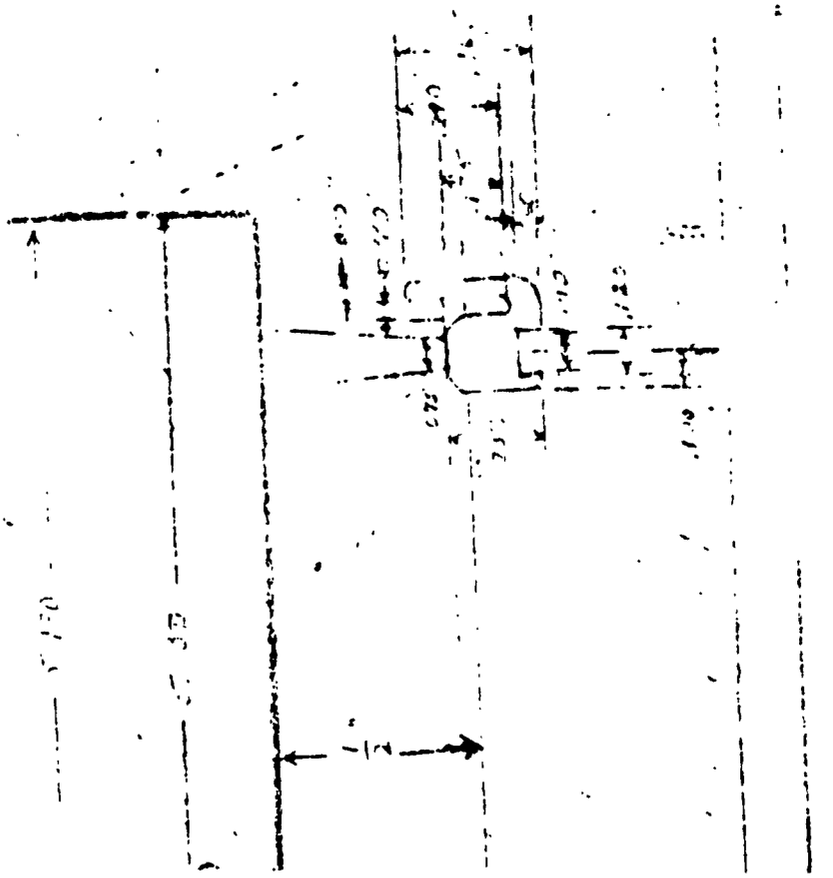
7. The hinge action has not been spectacularly successful, pending a flexible enough binder. The double harness should be retained for fit.

8. Test the mask against amosite and crocidolite.

9. Refer to Memorandum M404-66 for complete results of tests at the Bureau of Mines.

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APPENDIX

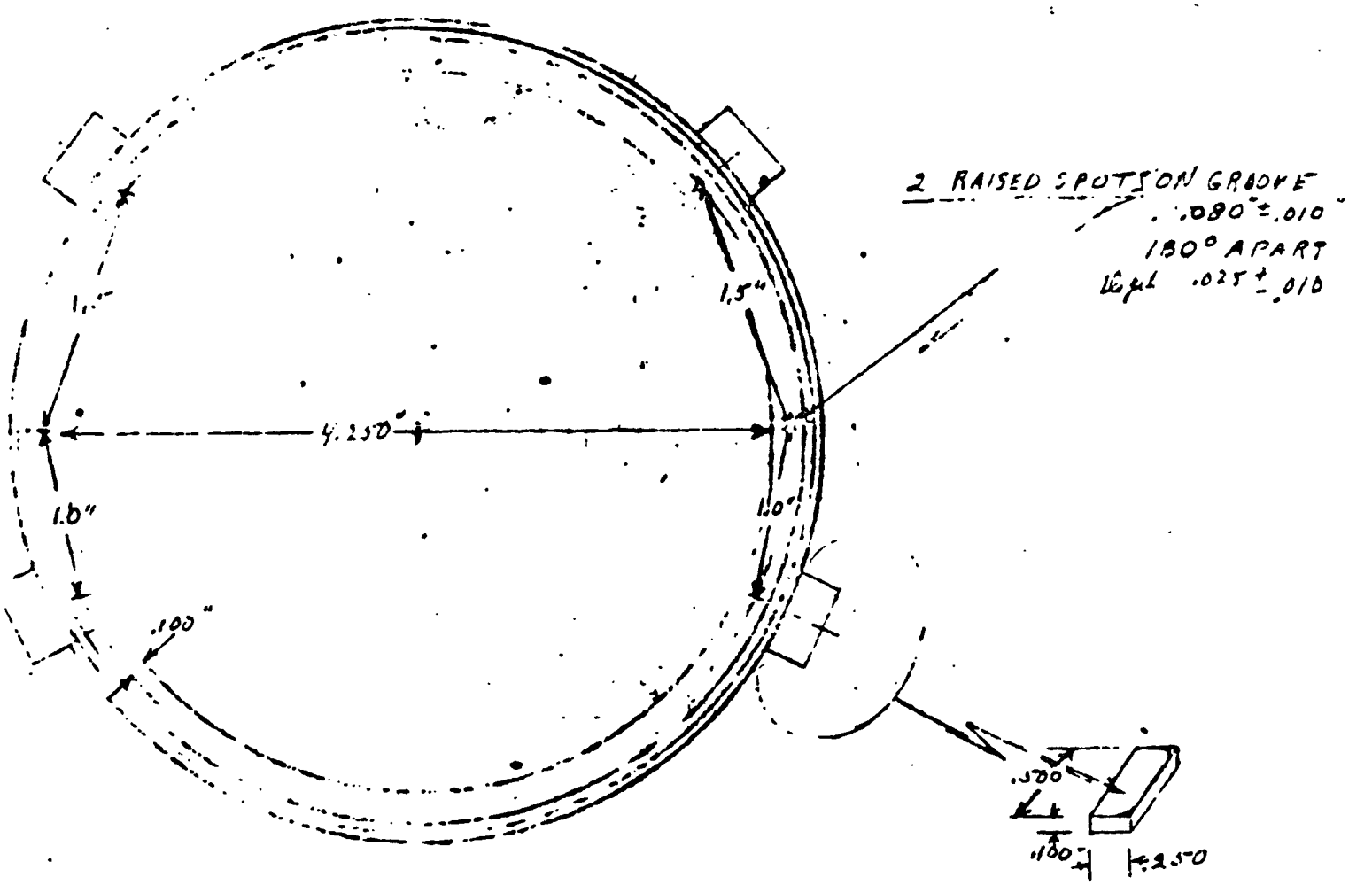
FIGURE 14

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APPENDIX

FIGURE 1B

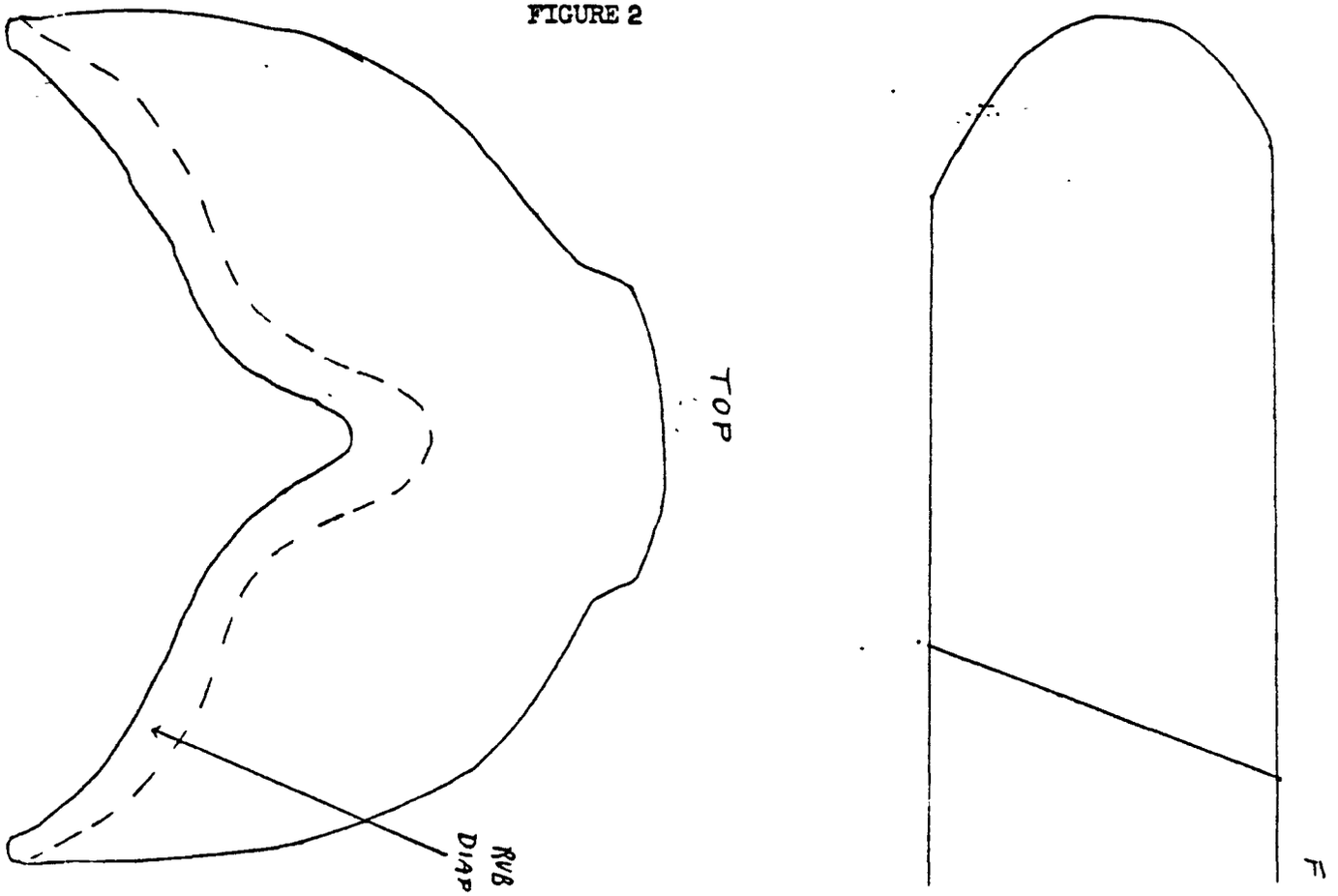


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APPENDIX

FIGURE 2

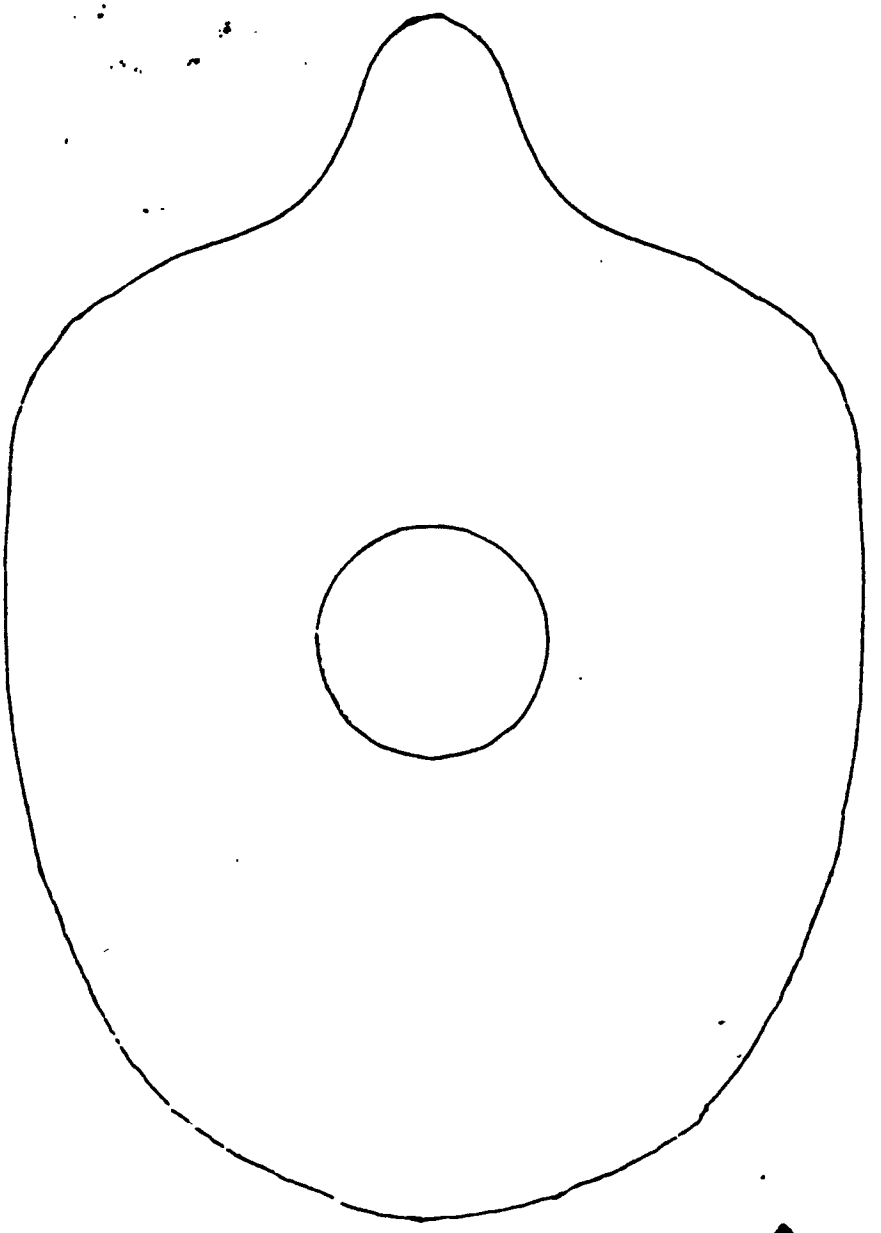


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APPENDIX

FIGURE 3



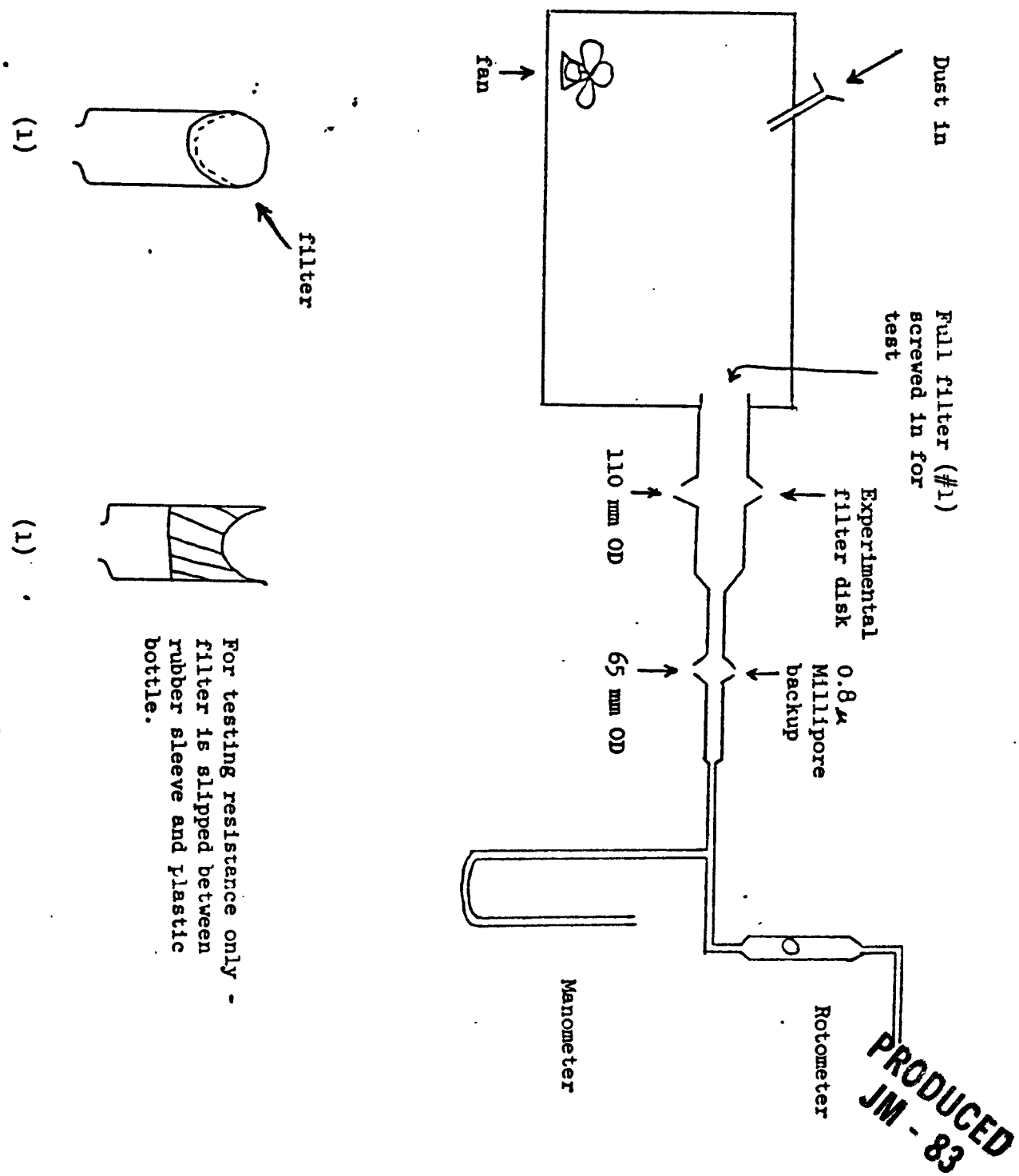
Rubber Diaphragm
Actual Size

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FIGURE 4



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APPENDIX



Figure 5. Electron micrograph of micropulverized and air-jet milled Plastibest 20.

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APPENDIX



Figure 6. Micrograph of micropulverized and air-jet milled Plastibest 20 taken with phase contrast illumination.

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