JOHNS-MANVILLE RESEARCH AND ENGINEERING CENTER

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Title: DISPOSABLE DUST RESPIRATORS - Progress Report No. 2

SUMMARY

The project to develop a disposable dust respirator is reviewed chronologically, starting at the time just after the original J-M prototype was developed by T. J. Weeks. Subjects included in the Discussion are the field test of the original J-M mask, revision of Bureau of Mines (BM) specifications, modifications in the filter elements to meet the proposed BM specifications and a cooperative project with Willson Products, Division of Ray-O-Vac Company, to produce disposable dust masks.

A third layer of acrylic fiber and binder was added to the filter element, made by means of the CERA-FORM vacuum process, as a protective cover for the MICRO-FIBER filtration layer. However, it was realized later that the addition of the third layer caused the MICRO-FIBER layer to become compacted, and because of that we were not able to produce filter elements which would meet the proposed BM specifications for valveless, disposable dust respirators. The open structure needed in the MICRO-FIBER layer to meet the BM specifications was produced by applying a spray-coat of latex binder to the surface of a two layer element after it was removed from the mold, instead of adding the third layer of fiber and binder. The cured spray-coat of latex binder provides a satisfactory protective cover for the MICRO-FIBER filter layer.

Filter elements made from certain dry formed MICRO-FIBER mats, such as used to make J&J surgical masks, will meet the proposed BM specifications. Currently, Willson Products is investigating the possibility of making disposable dust masks by post-forming such MICRO-FIBER mats.

Contents: Summary, Introduction, Discussion, Conclusions and Recommendations, Appendices I (Tables 1 and 2), II (Formulas and Procedure for Making Filter Elements) and III (Photographs and Diagrams).

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## INTRODUCTION

A few years ago it became apparent that there was a need for efficient, comfortable dust respirators that were inexpensive enough that they could be disposed of after being used for relatively short periods, say one day. The need was especially prevalent among transient asbestos insulation workers (as well as other workers using dusty materials) who work on construction jobs where dust control measures and respirator maintenance programs, necessary to keep permanent type respirators in usable condition, are not practical or possible as they are under in-plant conditions. To help supply this need, J-M decided to develop such a respirator. The development of the first J-M prototype is described by T. J. Weeks in Progress Report No. 1, J-M Report No. 404-42 (March 21, 1969).

## DISCUSSION

### Field Test

In order to determine on-the-job wearer reaction to the first J-M prototype masks, a field test was conducted in April 1969, on the construction site of the Dresden Nuclear Power Plant at Joliet, Illinois. This was a cooperative effort by personnel from the Mount Sinai School of Medicine, Local 7 of the Asbestos Workers Union, Chicago and Johns-Manville.

For this test, approximately 100 J-M masks were made in three different styles. Some contained exhalation valves, some were without exhalation valves and some were placebos. The placebos contained no glass fibers, and, although they were not particularly effective in stopping fine dust particles, they had very low breathing resistances. They were included to determine whether some of the "cannot breathe" complaints were real or imaginary.

As a result of the field test it was learned that there were two major objections to the J-M masks:

1. The fit of the face piece was uncomfortable, especially across the nose. When the mask was adjusted tight enough to give a good seal around the face, the frame tended to pinch or dig into the nose, causing irritation.

2. Obstruction of downward vision. It was difficult or impossible for a man to see his feet when wearing the mask, and this is particularly dangerous when working on scaffolds or ladders. Those wearing eyeglasses had a special problem - when the frame was adjusted to fit well across the bridge of the nose, the glasses were pushed out of the normal position.

   It was also found that the filter elements were not durable enough. They tended to tear or puncture when creased and glass fibers on the outside surface were easily fuzzed off.

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The details of the field test are described in J-M Memorandum M404-69 (April 21, 1969) and in a report issued by W. J. Nicholson and D. A. Holaday of Mount Sinai (1969).

Redesign of Face Piece

The Van Dyck Corporation of Southport, Connecticut was contracted to redesign the face piece in accordance with our conclusions and recommendations drawn from the wearer reaction tests. The Van Dyck Corporation are designers of equipment and instruments for use with the human body. Their final proposed design is illustrated in Appendix III, Figure 1.

A principal feature of their proposed design is a flat nose piece which fits across the bridge of the nose; a strip of ductile aluminum is molded into the nose piece to permit it to be adjusted to fit various size noses and to hold the nose piece in shape. The remainder of the seal, which completes a circle around the mouth, is a roll-under type with a gradual transition to the flat nose piece. The vertical extension of the rubber frame below the ring as it crosses the chin was included to increase the area of the filter element. It would also serve to accommodate an exhalation valve, if needed.

While the nose piece was quite comfortable and fit well, it was found that the seal below the mouth tended to ride up when one was talking, etc., causing the seal to slide into the mouth in some cases. This condition might be alleviated by extending the ends of the face piece outward from the mouth to form hinged corners, more like the shape of our original J-M designed mask. An accordian-type folded filter element and the inclusion of ductile wire molded into the lower part of the face seal might also improve the Van Dyck design.

Improvement of Filter Element

While the Van Dyck project to redesign the face piece was in progress, an effort was being made at J-M to improve the durability and the efficiency and breathing resistance properties of the filter elements. A wide variety of tests and studies were made which included:

1. Variations in methods and techniques of preparing fiber slurries and forming filter elements, such as effects of pressure differentials across the formation molds, and effects of diluting latex before adding fiber.

2. Different latex binders, latex deposition agents and the addition of wetting agents to slurries for improved flexibility and durability of filter elements. (The binders tested are listed in Appendix I, Table 1.)

3. The effects of varying the ratios of MICRO-FIBER to rayon and the use of various grades of MICRO-FIBER in the filtration layer.

Although these studies did not result in any significant improvements in the filter element properties, they provided much background information and a better understanding of the process. For example, it was found that extreme dilution of the latex (i.e.: 1:1000) before the addition of fiber to slurries gave better distri-

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bution of latex on the fiber, as indicated by less clotting of the latex after the addition of the deposition agent (NaOH). Also, slurry temperatures must be maintained at least at 25C for satisfactory deposition of latex. On the other hand, a better binder system than that used in the formulations for the original J-M prototype was not found. The use of Code 110 MICRO-FIBER, when mixed with Code 106 in the filtration layer was found to have no significant effects on the properties of the filter element and so was eliminated from the formulations. The studies also showed that the pressure differentials across the formation molds had little or no effects on the filter element properties.

During this phase of the project, it was also necessary to find a substitute for the Fortisan which was used in the original formulations, since Celanese was no longer producing that type of fiber. After screening a large number of other fibers, most of which were immediately rejected because of high shrinkage on drying, Type 61 Creslan (1.5 denier), an acrylic fiber made by American Cyanamide, was found to be quite suitable. (A list of fibers tested is shown in Appendix I, Table 2.)

Two important changes were subsequently made which contributed significantly to the durability of the filter elements. The first was the addition of a third layer over the filtration layer. This layer, which consisted of rayon (or acrylic) fiber and latex binder (same formulation as for the first layer), serves as a protective cover for the MICRO-FIBER-containing filtration layer. The cover layer prevented fuzzing off of the glass fibers and also contributed to the overall strength of the element. In addition, the three layer construction made it possible to reduce, or eliminate, the latex binder in the filtration layer, a change which seemed to improve the effects of the MICRO-FIBER on the efficiency of the filter element.

The second change was the method of adding the latex binder to the third layer in the filter element. It was suggested by B. F. Goodrich personnel that much of the deposited latex was probably being removed from the fiber during the vacuum formation of the filter elements, since the anionic latex is not very tightly bound to the anionic acrylic fiber. At their suggestion, the problem was overcome by adding a coating of coagulated latex to the surface of the filter element after it was formed. After forming the first and second layers in the usual manner, a third layer consisting of acrylic fiber only was added. Then the mold was dipped into a slurry which contained only well diluted, coagulated latex. (Fifty ml of Hycar 2600 x 137 diluted to 50 gal with water, and coagulated by adding 200 ml of 5 N NaOH.) When the coagulated latex particles were drawn into the filter-element fibers, they tended to remain on or near the surface of the element, because of their relatively large size. This produced a protective skin at the surface of the filter element which improved its strength and durability.

Formulas and procedures for making filter elements, with semi-automatic equipment mentioned later in this report, are given in Appendix II.

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Improvements in Filter Element Production Methods

Two important changes were made in the method of producing filter elements. The first was the substitution of wire-screen molds for the hand-carved fire-brick molds on which filter elements were formed during the early phases of the project. The fire-brick molds certainly served their purpose, in that they were a convenient and relatively easy means of making molds of various shapes, during the periods when the exact shape of the filter element needed was an experimental matter. However, when it was necessary to make a large number of filter elements, the fire-brick molds became clogged, or they might break as a result of continued handling. Therefore, when the shape of the filter element was established, a screen mold, of the type used in the CERA-FORM process, was made. With the screen molds, there was very little clogging, and so the filter elements were much more uniform. Furthermore, when the screen molds did become clogged, they were easier to clean than the fire-brick molds. A picture of two different screen molds is shown in Appendix III, Figure 2.

The other production change made was the method of curing the latex binder in the filter elements. A heating chamber, in which the temperature was maintained at about 150 - 200C, was installed adjacent to the filter-element vacuum forming apparatus. Then, instead of removing the elements from the mold and curing them in an oven for about 1 hr at 110C, the elements were cured on the mold by placing them in the hot air chamber and drawing the hot air through the element. It was found that when the temperature in the chamber was up to about 200C, the elements could be cured by drawing the hot air through for about 20 sec. Those elements were as strong and durable as elements cured for 1 hr at 110C. Some difficulty was experienced in removing elements from the screen mold after curing, but it is believed that it is an engineering problem which could be solved.

Proposed License Arrangements With Safety Equipment Manufacturers

During the summer of 1969, it was decided that J-M should not go into the business of manufacturing and selling dust masks. Instead, several companies who are already in that business were invited to use our method of making filter elements under a license arrangement in which J-M would receive a royalty for each mask that they sell. The royalty was set at $0.03 per mask. In response, several companies signed non-exclusive agreements and sent representatives to discuss the process and observe a demonstration of our method of forming filter elements. The companies which signed agreements and the dates of their visits were:

| | |
|---|---|
| Willson Products, Division of Ray-O-Vac Company | July 10, 1969 |
| Welch Manufacturing Company | September 18, 1969 |
| Mine Safety Appliances Company | November 19, 1969 |
| American Optical Company | December 4, 1969 |

The Minnesota Mining and Manufacturing Company also sent representatives on August 5, 1969, but since they did not sign an agreement, only non-confidential matters were discussed at that meeting.

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Of the companies which responded, Willson Products was the only one that became actively interested.

J-M - Willson Project

In July 1969, a cooperative project was started with Willson Products toward the production of disposable dust masks for the market. The aim was to develop a system to produce 10,000 masks per day. Mr. G. R. Russum (J-M - REC) worked closely with the Willson engineers in the preliminary designing and planning of the manufacturing equipment needed.

The plan of the production equipment centered around a series of filter element screen molds mounted in pairs on an automatic turntable. (A schematic diagram of that apparatus is shown in Appendix III, Figure 3.) The turntable would stop for a set period of time (about 10 sec) in a position such that each of the screen mold pairs would be at a station. A different operation in the formation of the filter element would take place at each station. For example, at Station No. 1 the molds would be dipped into a slurry tank long enough to draw up enough acrylic fiber and latex binder to form the first layers; at the same time the molds at Station No. 2 would dip into a slurry tank long enough to draw up enough MICRO-FIBER to form the second layers; etc., etc. Then the turntable would advance to position each pair of molds at the next station in line while the operations were repeated. In addition to dip tanks, some of the stations would include hot-air drying chambers for curing the latex, and a blow-off point where the completed filter element would be transferred from the formation molds to a heat-sealing apparatus for attachment to a face piece. By the time a given mold completed the circle, a filter element would be formed and released from the mold. Using such equipment, it was planned to produce dust masks at a rate of 12 per minute. In addition to the operating part of the equipment, plans were also drawn up for the necessary mixing and backup tanks, connecting pipes, etc.

In order to test certain engineering principles that would be used in the production equipment, an experimental production unit (EPU) was constructed in the Research Center pilot plant area. The paper machine vacuum system was used for that unit. A time controlled pneumatic dip device, a means of varying the amount of vacuum applied to the screen mold, and an oven into which the mold could be "dipped" to cure the binder in the filter element were some of the features of the EPU. The screen mold was mounted on a trolley so that it could be moved from one station to another and operated manually.

The EPU was also used to make many of the experimental runs in the program to improve the filter element. (For typical procedures using the EPU refer to Appendix II.)

As part of the J-M - Willson project, the dust mask was redesigned in accordance with the Willson plan for manufacturing. An important consideration in redesigning the mask was to include a convenient method of attaching the filter element to the face piece. The first method tried was to provide a means by which the filter element could be attached to a face piece directly as the filter element was formed. The injection-molded vinyl face piece included a perforated strip, with holes about 3/8 in. in diameter, on the filter element side of the face

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piece (illustrated in Appendix III, Figure 4). After forming the first layer of the filter element on the screen mold, the face piece was slipped over the first layer on the mold and as the fibers for the second layer were added, they were drawn through the holes in the attachment strip and into contact with the first layer, thus locking the face piece between the first and second layers. This method was not carried to a successful conclusion, since a good air-tight seal between the filter element and face piece could not be obtained. However, it could probably be a suitable method if the seal were completed by heat sealing or by the addition of a bead of cement.

A method which seemed more suitable at the time was to attach the filter element to the face piece by heat sealing after each part was formed separately. (This method is illustrated in Appendix III, Figure 5.) The filter element contained a 1/4-in. flange around the base which was mated with a flange around the face piece. The plan was to join the flanges together using a specially constructed heat-sealing device.

Bureau of Mines Specifications (As Related to J-M Filter Element)

During a visit to the U.S. Bureau of Mines (BM), in January 1969, T. J. Weeks and A. F. Burns found that the original J-M prototype masks easily met the BM specifications (Schedule 21B) for breathing resistance and silica dust leakage which were in force at that time (Memorandum M404-66, February 4, 1969). The test data are shown in the following table.

| | BM Specs | J-M Masks | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Initial inhalation resistance (mm $H_2O$) | 30.0 max | 9.0 | 7.0 | 7.0 |
| Final inhalation resistance (mm $H_2O$) | 50.0 max | 14.0 | 11.0 | 11.0 |
| Silica Leakage (mg) | 1.5 max | 1.5 | 3.0 | 2.6 |

Note: Although the silica leakage values were close to or greater than the BM Specs, there was sufficient latitude to increase the inhalation resistance values so that the leakage values could be decreased to meet the BM Specs.

It was known at that time that the BM specifications would be revised, and that the breathing resistance specifications were to be reduced. However, when they were made known, the proposed specifications, and particularly the proposed test procedure, were more stringent than we expected. These specifications are shown in the following table.

Proposed Bureau of Mines Specifications for
Valveless Disposable Dust Respirators

| | |
|---|---|
| Initial Breathing Resistance | 12 mm $H_2O$ |
| Final Breathing Resistance | 15 mm $H_2O$ |
| Silica Leakage | *1.5 mg |

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*1. Actually 4.5 mg/3 masks = 1.5 mg/masks with not more than 2 mg for any one mask.

*2. A very recent development is the publication of the Notice of Proposed Rule Making in the Federal Register (March 10, 1971) in which the maximum allowable silica penetration is proposed as 2 mg/mask.

Air Conditions (as supplied by means of a breathing machine)

| | Temperature | Relative Humidity |
|---|---|---|
| Inhalation Cycle | Room | Room |
| Exhalation Cycle | 95 ± 3F | 94 ± 3% |

Exhalation cycle conditions to simulate actual exhalation breath conditions.

While we had made some improvements in breathing resistance and silica leakage properties over the original J-M filter elements, when tested under the proposed BM conditions our filter elements fell far short of meeting the final breathing resistance specifications. This was evidently due to moisture buildup from the high humidity in the exhalation air. For example, the data in the following table are for a series of J-M - type filter elements tested under both the standard (Schedule 21B) and the proposed conditions.

| | Using Standard Schedule 21B Conditions | | | | | | Using Conditions Proposed [illegible] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Filter Elements Tested At Willson Products Co. | | | | | | Tested at the Bureau of Mines | | Tested at Willson |
| Initial BR (mm $H_2O$) | 7.4 | 12.0 | 11.0 | 5.7 | 5.7 | 5.7 | 11.0 | 12.0 | 5.6 |
| Final BR (mm $H_2O$) | 10.0 | 19.0 | 15.0 | 10.0 | 7.6 | 8.1 | 83.0 | 58.0 | 63.0 |
| Silica Leakage (mg) | 0.8 | 1.7 | 1.2 | 1.8 | 1.5 | 0.8 | 1.3 | 1.2 | 2.4 |

Note: During the J-M - Willson phase of the project, all testing was done by R. Witman of Willson, since Willson has testing facilities similar to those used at the Bureau of Mines. The above tests at the Bureau of Mines were run under the direction of R. Witman.

Many attempts were made to improve the filter elements to meet the proposed specifications. Some of the innovations tried are listed as follows:

1. Post treatment of filter elements with wetting agents. (Aerosol OT and Triton X-100)

2. Post treatment of filter elements with water repellent (Paramul Repellent 115 by American Cyanamid Co.).

3. Variations in fiber composition, mainly in the filtration layer, as on the following page:

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- Various ratios of acrylic fiber and MICRO-FIBER including 100 per cent MICRO-FIBER,

- Various sizes of acrylic fiber (1.5, 3.0 and 5.0 denier).

- Reviewed the effects of various sizes of MICRO-FIBERS (Codes 100 through 110).

Post treatments with either wetting agents or water repellents produced only slight improvements at best. Also, the use of coarser acrylic fibers than the 1.5 denier normally used had no significant effects on the properties.

It was found, however, that if Code 108 MICRO-FIBER was used instead of Code 106 and the MICRO-FIBER to acrylic fiber ratio in the filtration layer was increased somewhat, some improvement was noted, but still not enough to meet the proposed BM specifications. The method of applying the latex binder as a final dip coat (as described earlier in this report) also probably contributed to the improved properties.

The following data are examples of the properties of typical elements as produced during that phase of the project.

| | | | |
|---|---|---|---|
| Initial BR (mm $H_2O$) | 8.9 | 9.1 | 14.0 |
| Final BR (mm $H_2O$) | 10.2 | 12.7 | 19.0 |
| Silica Leakage (mg) | 2.2 | 2.5 | 1.1 |

The data show that either the breathing resistance specifications or the silica leakage specifications could be met, but we could not seem to find the optimum conditions to meet all specifications in a given filter element.

Dry-Formed MICRO-FIBER Mats - I

During the fall of 1970, a surgical mask made by Johnson & Johnson Company was brought to our attention. These masks are simply pleated sheets with binding and tie-strings. The sheet material from which they are formed is a MICRO-FIBER product which is made at the J-M Waterville plant. It consists of a mat of Code 108 MICRO-FIBER which is deposited directly as it is made onto a backing sheet of non-woven rayon. The mat is then covered with a second sheet of rayon. The density of the Code 108 mat is 2 g/ft$^2$.

Several of the J&J masks were sent to Willson for evaluation as a possible filter element medium, and the results of the tests, as shown in the following table, were very favorable. The data are for unfolded sheets in single and double thicknesses.

| | 36 sq in sheets | | 25 sq in. |
|---|---|---|---|
| | Single | Double | Double |
| Initial BR (mm $H_2O$) | 3.5 | 6.3 | 7.4 |
| Final BR (mm $H_2O$) | 11.0 | 11.4 | 11.0 |
| Silica Leakage (mg) | 5.3 | 0.7 | 0.8 |

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The properties for the double thickness sheets are well within the proposed BM specifications.

As a result of those tests, Willson became interested in the possibility of using such dry-formed MICRO-FIBER mats as a filter medium for their disposable dust masks. That phase of the project will be described in more detail in a later section of this report.

Further Improvement of Filter Element

A comparison of the characteristics of the J&J surgical mask material with the filtration layers in our slurry formed filter elements showed that the MICRO-FIBER in the J&J mask was much more fluffy than that in the slurry formed elements. It was believed that this was the key to making filter elements which would meet the proposed BM specifications. In an attempt to make the filtration layer more fluffy, a series of elements were made in which only Code 110 fiber was used and in larger amounts than had been used up to that time. It was believed that the coarser MICRO-FIBER might form a more open structure. However, the breathing resistances of those elements were too high. Evidently, the formation of the outer layer over the filtration layer caused the filtration layer to become compacted.

In order to avoid compacting the filter layer, it was decided to eliminate the outer layer and replace it with a spray-coat of latex binder. The first and second layers were formed on the mold in the usual manner; the second (filtration layer) consisted of Code 110 MICRO-FIBER only. The latex binder in the first layer was cured by drawing hot air (approximately 175C) through the filter element on the mold for about 20 or 30 sec. The two-layer element was then removed from the mold, and the outside surface of the filter element was sprayed with a dilute suspension of latex binder. The spray-coat of binder was then cured by placing the filter element in an oven at 100C for 1 hr. Since, for these experimental elements, a small hand spray gun was used, the exact amount of latex applied was not determined. However, the cured spray-coat of latex binder provided a satisfactory protective cover for the MICRO-FIBER filter layer.

A series of filter elements were made by this method using various amounts of Code 110 MICRO-FIBER in the filtration layers. The formulations and preparation details are given in Appendix II. It should be noted that the filtration layers of the filter elements made according to this method contained considerably more (about two or three times as much) MICRO-FIBER than those in standard three-layer elements.

These elements were tested at Willson using the proposed BM procedure. The test results, listed on the following page, show that filter elements which meet the proposed BM specifications can be made by means of the modified method.

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| Relative Amount of Code 110 in Element | B* 2 | D* 1.5 | A* 1 | C* 1 |
|---|---|---|---|---|
| Initial BR (mm $H_2O$) | 13.5 | 6.7 | 6.7 | 7.4 |
| Final BR (mm $H_2O$) | 15.0 | 11.5 | 9.2 | 8.4 |
| Silica Leakage (mg) | 0.4 | 0.6 | 0.9 | 1.2 |

Dry-Formed MICRO-FIBER Mats - II

The satisfactory results of tests made on J&J surgical mask sheet material (discussed earlier in this report) has prompted Willson to pursue the possibility of using such material for making disposable dust masks. They are currently working directly with J. W. Helmick of the Waterville Technical Center to determine the best grade (or Code) of MICRO-FIBER and the optimum density of the MICRO-FIBER layer to use. They are also looking for a suitable material (or materials) to use as backing sheets to cover the MICRO-FIBER layer.

One Willson plan for making dust masks from the MICRO-FIBER mats is to post-form them in a concave mold which will be approximately half-pear shape. In order to keep the filter elements rigid, they will contain folds or pleats running outward from the face seal. They will be held in shape by means of a ring of silicone rubber (or other flexible material) which will be added around the edge of the element by injection molding while it is held in place in the concave mold.

Another plan is to form the MICRO-FIBER mat over a rigid plastic frame. A picture of an early prototype of such a mask is shown in Appendix III, Figure 6.

In addition to using MICRO-FIBER mats for making disposable dust masks, Willson is also considering the possibility of using some type of a MICRO-FIBER product for making BM approved replaceable filter elements for permanent type masks.

Current Status of Project

At the present time, Willson is planning to make their disposable dust masks by post-forming J-M dry-formed MICRO-FIBER mats. One reason for this decision is that it appears to be the quickest means to produce a J-M - Willson mask for the market. Another reason is that the Willson capital expenditure needed for equipment for that process would be much less than would be needed for the slurry process.

On the other hand, we now have the key to producing slurry-formed filter elements that will meet the proposed BM specifications, and therefore, if it becomes useful, either for the J-M - Willson mask or for any other reason, the method is available.

*Element identification (see Appendix II).

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## CONCLUSIONS AND RECOMMENDATIONS

1. The key to making filter elements which will meet the proposed BM specifications for valveless disposable dust respirators, is a fluffy or open structure in the MICRO-FIBER filtration layer.

2. The addition of a third layer of acrylic fiber and binder over the MICRO-FIBER filtration layer makes a stronger filter element and prevents fuzzing off of MICRO-FIBER, as occurs when that layer is exposed.

3. However, the addition of the third layer causes the MICRO-FIBER layer to become compacted. This makes it difficult or impossible to produce an open enough structure in the MICRO-FIBER layer to meet the proposed BM specifications.

4. The open structure needed in the MICRO-FIBER layer can be produced if, instead of adding the third layer of acrylic fiber and binder as usual, a spray-coat of latex binder is applied to the surface of a two-layer filter element after it is removed from the mold. The cured spray-coat of latex provides a satisfactory protective cover for the MICRO-FIBER filter layer.

5. Dry-formed MICRO-FIBER mats, such as used to make J&J surgical masks, have an open enough structure to meet the BM specifications. Willson has demonstrated that such mats can be post-formed into filter elements for disposable dust masks.

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APPENDIX I

Table 1. Binders Tested for Improved Durability of Filter Elements

| Manufacturer | Type | Designation |
|---|---|---|
| B. F. Goodridge Co. | Acrylic | Hycar 2660 x 120<br>Hycar 2600 x 137<br>Hycar 2600 x 140 |
| Goodyear Co. | SBR | Pliolite LPF 3187<br>620 |
| National Starch Co. | Vinyl Chloride Acetate with Natron 86 | 78-5182 |
| BASF Corporation | Acrylic esters (hard)<br>Acrylic monomer (soft) | Acronal 230D<br>Acronal 330D |

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APPENDIX I

Table 2. Synthetic Fibers Tested as Substitutes for Fortisan

| Manufacturer | Type | Designation |
|---|---|---|
| American Cyanamide Co. | Acrylic | Type 61 Creslan<br>Type 98 Creslan |
| Hystron Fibers, Inc. | Polyethylene - Tetrephthalate | Trevia 120 |
| FMC Corporation | Rayon | S-12R RD-101<br>S-13 |
| American Enka Corporation | Viscose Rayon | Zantrel 700 |
| Du Pont | Polyester<br>Polyvinyl alcohol<br>Nylon | Dacron |

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APPENDIX II

Formulas for Making Filter Elements

Stock Slurries of Fiber

| | | |
|---|---|---|
| MICRO-FIBER | 47.5 g | (concentration 2.5 g/L) |
| Water (30 - 40C) | 19 L | |

Beat small batches in a Waring Blendor for about 30 sec - or entire batch with a high speed Lightning mixer.

Add HCl to reduce pH to 3 for dispersion of fiber.

| | | |
|---|---|---|
| Acrylic Fiber | 264 g | (concentration 2.31 g/L) |
| Water (30 - 40C) | 30 gal | |

Beat with high speed Lightning mixer in 55-gal drum for about 15 minutes.

Working Slurries

Slurry No. 1 - Base Layer

| | |
|---|---|
| Stock slurry of acrylic fiber | 13 L |
| Water (30 - 40C) | about 30 gal |
| Hycar 2600 x 137 | 37.5 ml diluted to 2 gal |

Add to slurry and stir.

| | |
|---|---|
| 5 N NaOH | 200 ml diluted to 2 gal |

Add to slurry while stirring.

Slurry No. 2 - Filtration Layer

| | |
|---|---|
| Stock slurry of MICRO-FIBER | x L |
| Stock slurry of acrylic fiber | y L |
| Water to make | 50 gal |

x - depends on amount needed
y - may be 0 in some cases
(or 13 L generally used)

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Slurry No. 3 = Outside Layer of Fiber

| | |
|---|---|
| Stock Slurry of acrylic fiber | 13 L |
| Water to make | 50 gal |

Slurry No. 4 = Coagulated Latex

| | |
|---|---|
| Water (30 - 40C) | about 40 gal |
| Hycar 2600 x 137 | 50 ml diluted to 2 gal |
| 5 N NaOH | 200 ml diluted to 2 gal |

Add slowly to slurry while stirring

| | |
|---|---|
| Water to make | 50 gal |

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APPENDIX II

Procedure for Making Three-Layer Filter Elements
Using Semi-Automatic Equipment (EPU)

| | |
|---|---|
| Working Slurry No. 1 | 2 sec dip |
| Working Slurry No. 2 | * |
| Working Slurry No. 3 | 2 sec dip |
| Working Slurry No. 4 | 1 sec dip |
| Curing oven at about 175C | 30 sec |
| Remove filter element from mold | Blow-off |

*Time of this dip depends on total amount of fiber wanted in the filtration layer.

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APPENDIX II

Procedure for Making Spray-Coated Filter Elements
(Elements Made for Testing at Willson Using Proposed BM Procedures)

| | | Element Identification |
|---|---|---|
| Working Slurry No. 1 | 2 sec dip | |
| Working Slurry No. 2 (x = 32 L, y = 0) Code 110 MICRO-FIBER | 4 sec dip | A |
| Curing oven at about 175C | 30 sec | |
| Remove two-layer filter element from mold | Blow-off | |
| Spray-coat surface of element evenly with Hycar 2600 x 137 diluted 1 part with 5 parts water | | |
| Cure at 110C for 1 hr | | |

---

Repeat above except:

| | | |
|---|---|---|
| Working Slurry No. 2 | 8 sec dip | B |

---

After using 25 gal of Working Slurry No. 2, add 25 gal water, thereby, diluting slurry to 16 L MICRO-FIBER Stock Slurry to 50 gal water.

---

Then repeat above procedure except:

| | | |
|---|---|---|
| Working Slurry No. 2 (first time) | 8 sec dip | C |
| Working Slurry No. 2 (second time) | 12 sec dip | D |

---

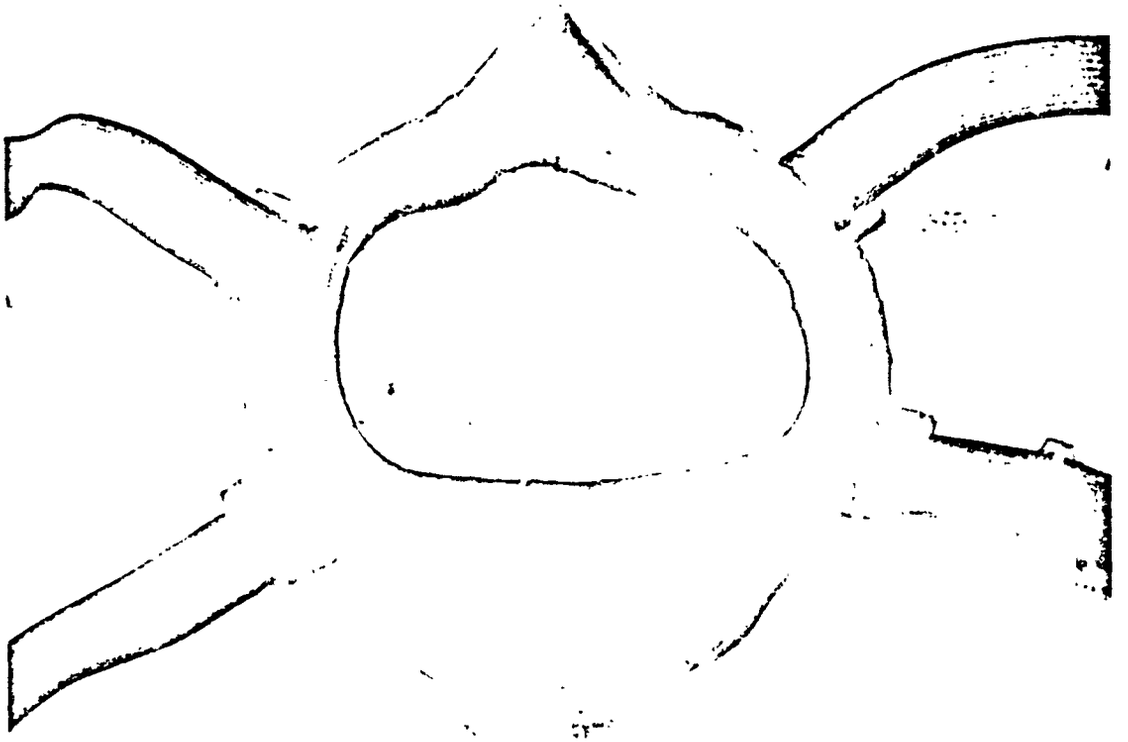
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Note: Working Slurries No. 3 and 4 are not used in making spray-coated filter elements.

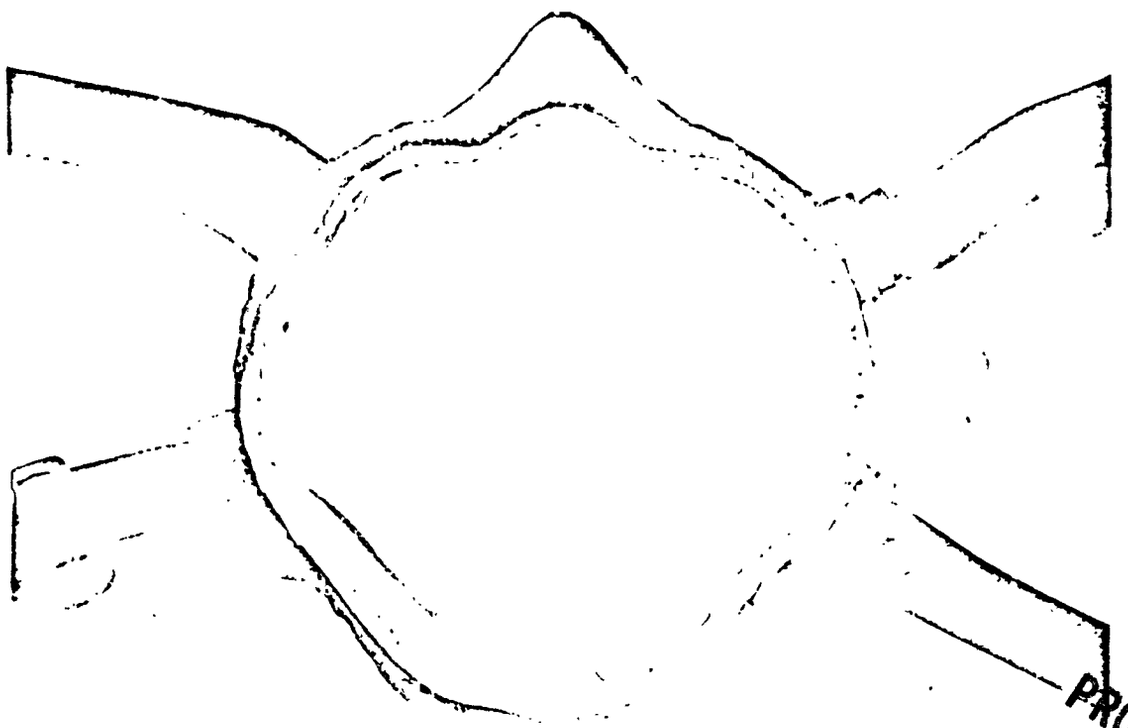
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APPENDIX III



Inside View



Outside View

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Figure 1. Prototype Showing Face Piece
Designed by Van Dyck Corporation

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APPENDIX III

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Figure 2. Wire Screen Molds Used to Form Filter Elements

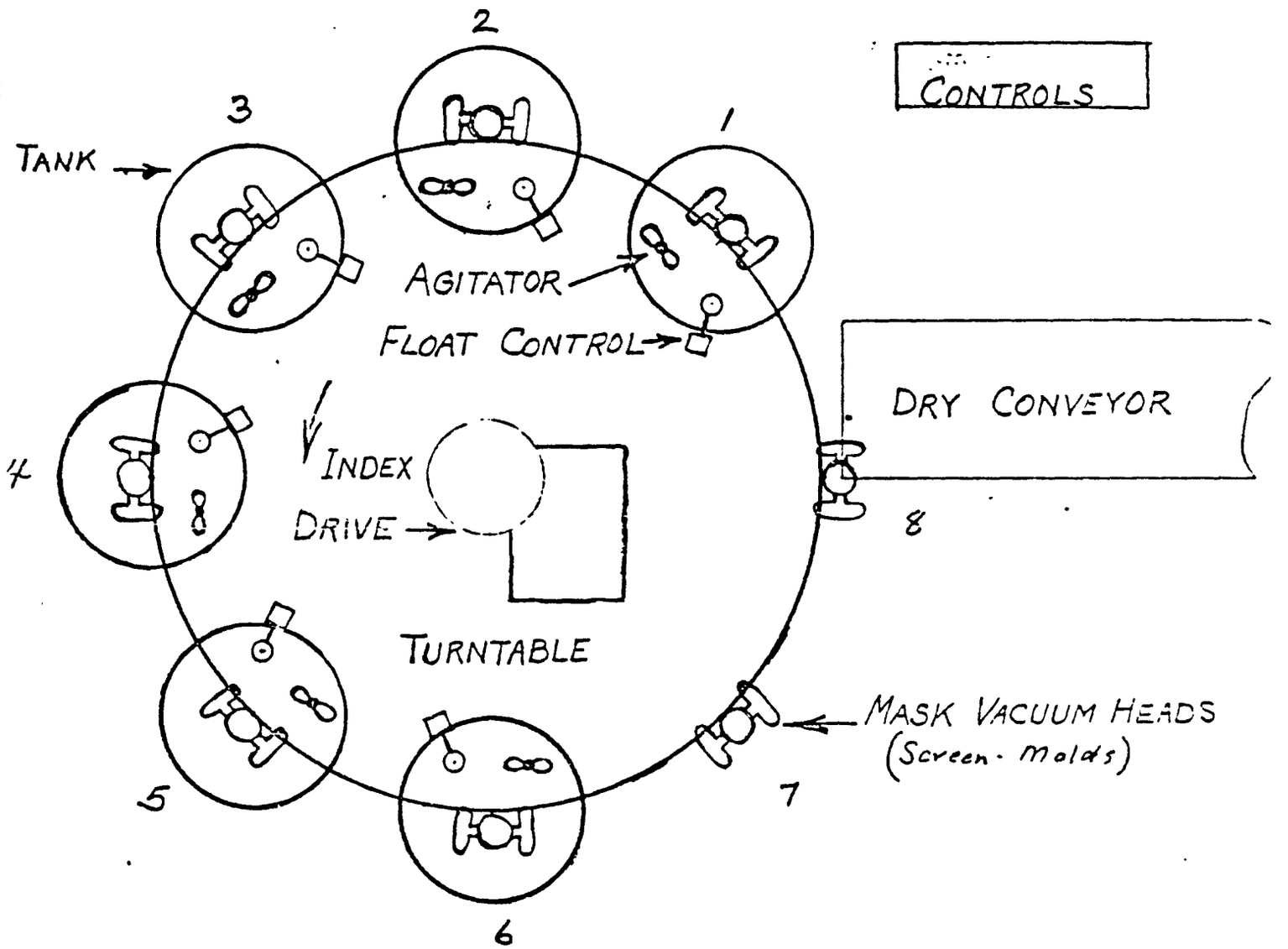
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APPENDIX III

Figure 3. Schematic Diagram of Willson Apparatus For Manufacturing Disposable Dust Masks

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Figure 4. J-M - Willson Mask Filter Element
Formed Directly onto the Face Piece

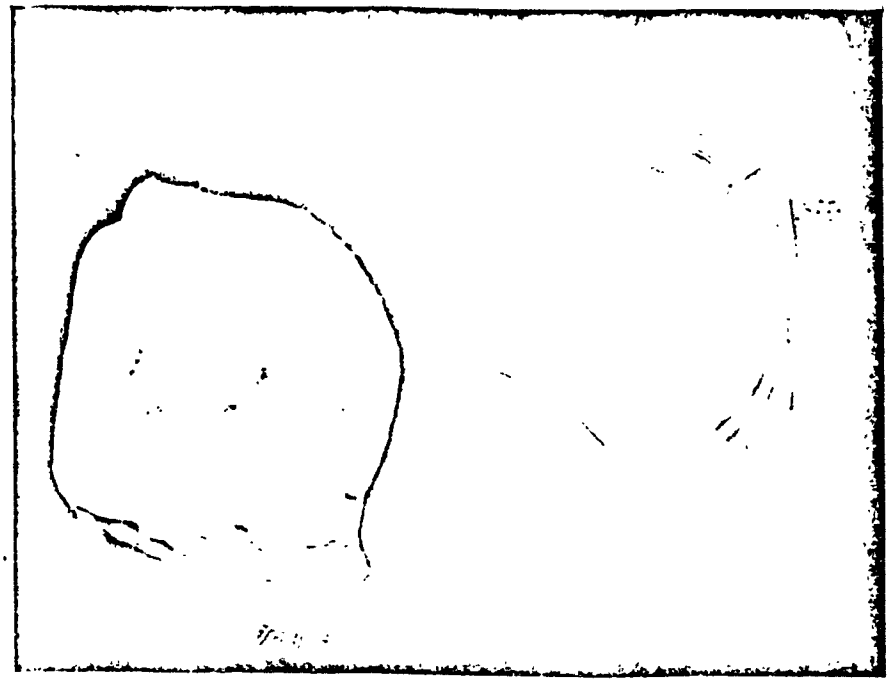
Note: Picture shows a completed dust mask and a face piece slipped over the screen mold. Ordinarily the face piece would be slipped over the first layer of the element after it is formed on the mold.

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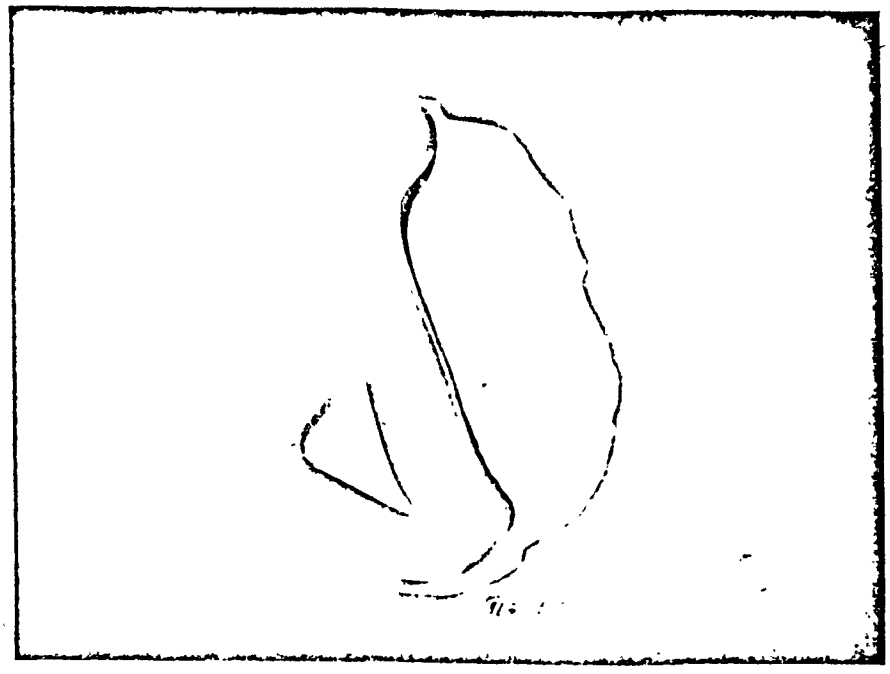
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APPENDIX III



Before Joining



After Joining

Figure 5A. J-M - Willson Mask Filter Element and Face Piece Joined By Heat Sealing

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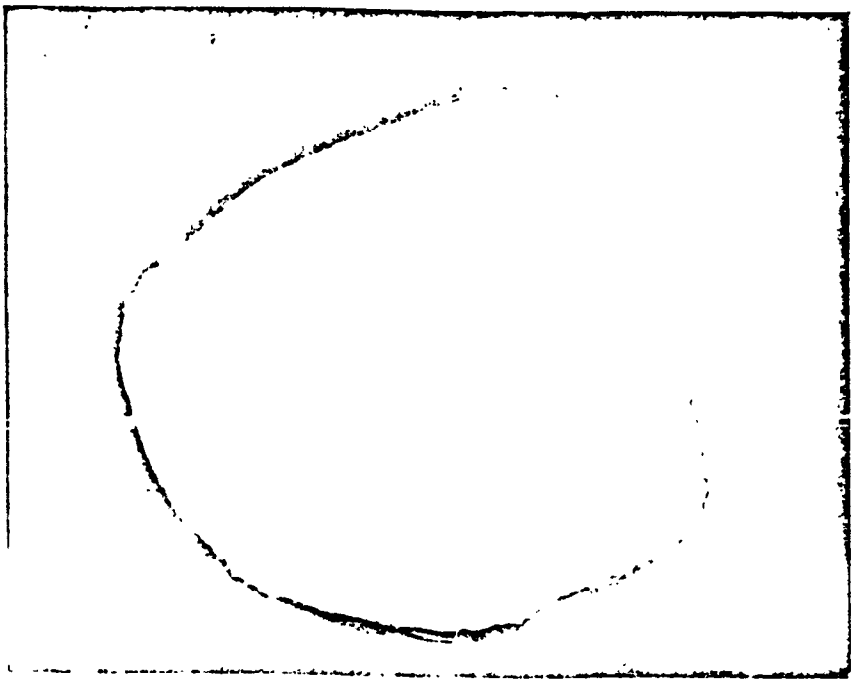
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Outside View

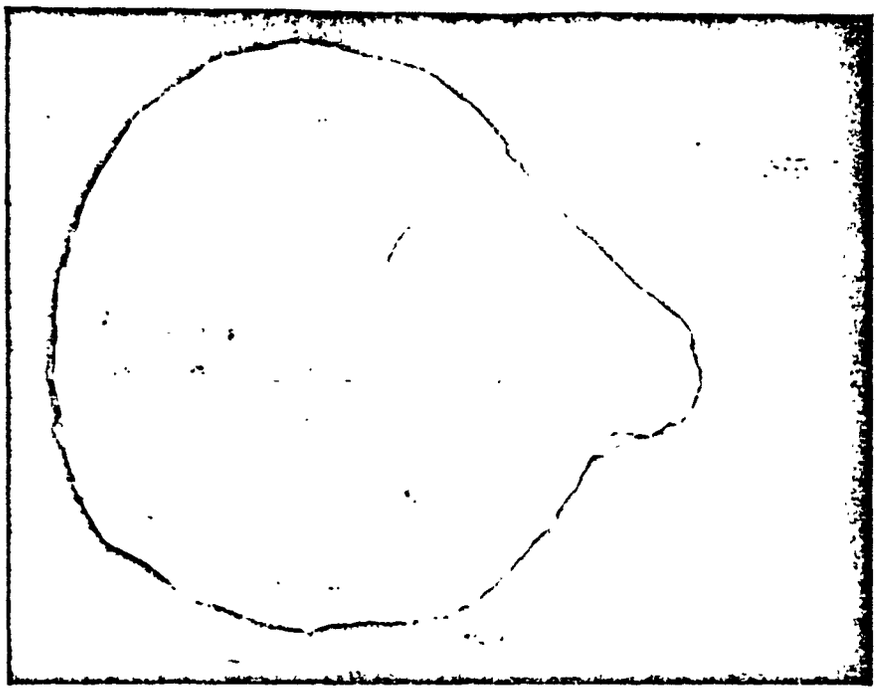
Figure 5B. J-M - Willson Mask Filter Element
and Face Piece Joined by Heat Sealing

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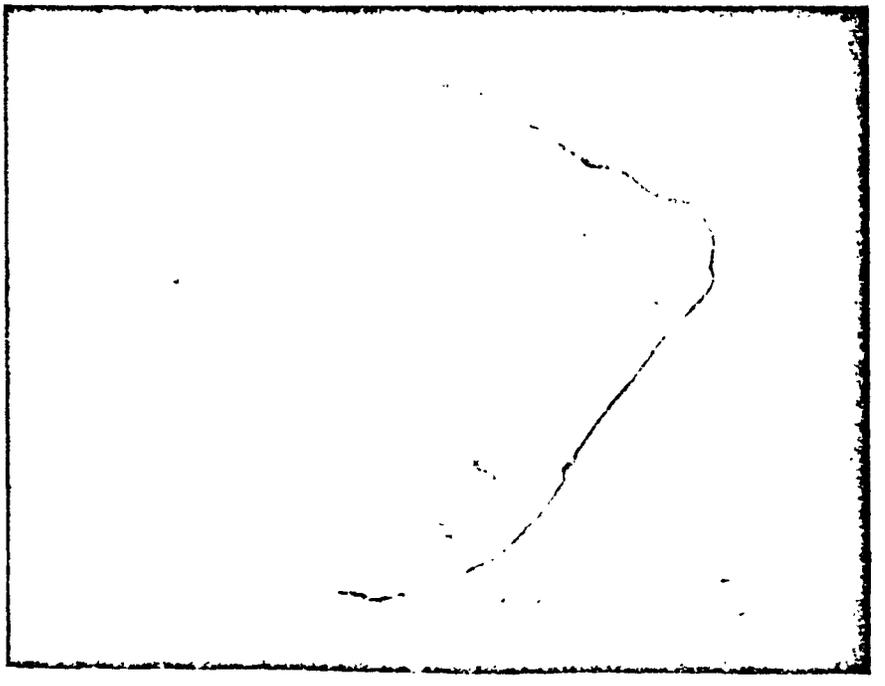

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Inside View



Outside View

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Figure 6. Prototype No. 1

Willson Mask Made With Dry-Formed MICRO-FIBER Mat


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