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ARGONNE NATIONAL LABORATORY
P. O. Box 299
Lemont, Illinois

GLOVES FOR PROTECTIVE ENCLOSURES

by
D. A. Davis, J. E. Ayer and R. M. Mayfield

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ABSTRACT

A study of the glove problem has been made by the ANL Glove Committee as a necessary prerequisite to any attempt at coordination or standardization. This report consists of a compilation of the findings of the Committee and the resulting compromises which are felt necessary to the resolution of the problem.

Materials, methods of manufacturing and general properties of gloves are described. Glove design has been analyzed and suggestions are made in regard to an acceptable standard. Permeability characteristics of various glove compounds are reviewed and the effect of moisture contamination upon hypothetical systems is tabulated. An electrical test is proposed for the determination of glove soundness.

INTRODUCTION

In the past few years, protective gloves for use in enclosed systems where pyrophoric, radioactive, toxic, or poisonous materials are handled have been the object of considerable attention.⁽¹⁾ New emphasis has been placed upon glove quality, length of life, permeability characteristics, and glove design. Because the philosophies of glove users have not been consistent, producers have been subjected to design requirements which are unusual or even unique. These diversified requirements have resulted in manufacturing methods not amenable to the mass production which will be required by increasing demand.

MATERIALS

At the present time, gloves are formed by a dipping process employing three basic compounds: neoprene, either latex or milled, butyl and natural rubber. Natural rubber is unrealistic for most applications due to its high rate of deterioration when exposed to the conditions present in most protective enclosures, although it has been used where a high degree of dexterity and sensitivity are desired. Attempts have been made to utilize butyl, principally due to its low permeability characteristics. However, the high percent set at break and manufacturing difficulties tend to discount its use, at least for the present. Thus, neoprene, by a process of elimination, becomes the most suitable material which may be considered for general applications.

MANUFACTURING METHODS

In order to produce in quantity an inexpensive glove adequate to the needs of the glove user, the limitations impressed upon the manufacturer must be appreciated.

At the present time, a batch-type dipping process employing (1) latex or (2) milled neoprene is used predominantly in glove manufacture. The latex process employs an alkaline dispersion of polymerized chloroprene in water to which has been added suitable compounds to develop desirable properties in the finished product. These addition agents may consist of fillers, coloring agents, accelerators, antioxidants, vulcanizing agents, etc. The actual process may vary, but in one instance the forms are first dipped, fingers down in a jelling agent or coagulant and then into the latex solution at room temperature. The coagulant causes the neoprene lattices to be attracted to and deposited upon the forms. Control of thickness is primarily a function of dip time and in some cases more than one immersion may be required. Between dips, the film is allowed to dry with the form in an inverted position. After the desired thickness has been obtained, the film is leached to remove water-soluble materials, dried, and the cuff ends are trimmed and rolled. Following these operations, the gloves are vulcanized and cured at elevated temperature, stripped from the forms, inspected and packed for shipment.

The milled neoprene, or cement, process is somewhat more involved than the latex process. In this manufacturing method, dry, raw neoprene is compounded by milling it under pressure between large steel rolls. During the milling, suitable additives are introduced into the base material. The resulting mixture, along with a hydrocarbon solvent, is charged into a mixing drum, where it is agitated until a uniform dipping solution is obtained. The thickness of the finished glove is dependent upon the dip time and the number of dips. Dip time is quite short, since prolonged immersion softens and removes some of the material previously deposited. Sufficient time must be allowed for the solvent to evaporate between dips, in order to harden the deposited film. Unless care is exercised, foreign particles, such as insects, dust, etc., may become deposited on the sticky surface after each dip and then be covered by the following dip. Entrapment of air during dipping is also a problem. The flow characteristics of the compound must be carefully controlled to produce uniform thickness. While some of these problems are common to both methods of production, they are multiplied in the milled process by the number of dips involved. After the proper thickness has been obtained and the film has dried, the subsequent processes are similar to those employed in the latex process except that leaching is not required.

Butyl gloves have been formed by pressure molding as well as by dipping. Little process information has been made available on either

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process. It appears, however, that pressure molding is an expensive method which can be justified only when the properties peculiar to this material are required.

By and large, the present methods of glove manufacture require forms over which the glove is molded. These forms are of as great importance to the manufacturer as the compound from which the gloves are produced. The relatively high cost and fragile nature of some forms is an important consideration in glove manufacture. Forms may be fabricated in aluminum or porcelain and, if not carefully designed with complete knowledge of the dipping process, may, when dipped, produce gloves with surface imperfections. Because it is felt by some glove manufacturers that such imperfections are more prevalent with cast aluminum forms, the porcelain type is generally favored. Porcelain forms, however, are not without disadvantages; in general, they are fragile and require careful handling.

In the past, many glove users have designed their own forms to the shape desired only to later discover that the manufacturer had reason to excuse his production of faulty gloves. This experience has resulted in a trend to allow the manufacturer, from a basic design provided by the user, to provide his own forms.

PHYSICAL PROPERTIES

Properties of neoprene gloves may vary over a wide range depending upon the compound and the manufacturing method. The two manufacturing methods have been discussed, but compounding is far too involved to be treated here. It suffices that rubber compounds are extremely complex chemical mixtures, the physical properties of which are not well defined and cannot, in most cases, be correlated with service performance of the end product. Because of this fact, property tests are best suited for selecting a compound that may warrant further testing; once this compound has proved its serviceability, physical tests prove useful in controlling the product.

Unfortunately, the serviceability of protective gloves has not been evaluated to the point where specific compounds or rigid standards can be established. The properties to be desired will depend on the ultimate use and various types of tests will be required.

The latex process is noted for the production of quite uniform films over a wide range of thickness. The film produced is intrinsically more permeable to moisture than the milled neoprene film, but the permeability characteristics may be improved by compounding. Similarly, the latex film may show less resistance to certain solvents and chemicals. Discounting this basic difference, most other physical properties can be matched in

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either milled or latex glove materials. However, it is generally conceded that maximum values of strength may be more easily obtained with milled neoprene. Unfortunately, because of the anomalous behavior of rubber compounds, improvement of one property may drastically reduce another. For example, a milled compound may have extremely valuable physical properties and still it might be utterly impossible to produce an acceptable end product because of surface imperfections.

Some property values of actual glove materials are summarized in Table I. The values shown are typical of several materials presently available. They are in general agreement with results obtained on similar material by other laboratories or manufacturers and are intended to indicate order of magnitude only.

The tensile strength, elongation, percent set, and tear values are of uncertain significance at present. The serviceability of gloves may have little direct bearing on these properties since the gloves will seldom be loaded in tension and never to a degree approaching their ultimate strength or elongation. One may argue, however, that while these properties may not in themselves be significant, they are nevertheless an index to all-around quality. The truth in this general belief may exist in the extremes of the tensile strength range. Compounds with extremely low tensile strength are usually poor in most mechanical properties, while those with high tensile strength are usually good in most mechanical properties. There is evidence to support the value of percent set at break as an indication of material quality as it affects gloves. It has been found that, in general, glove materials with a high (>20) percent set at break tend to have a low "elasticity."

Tear resistance values are misleading since they do not lend themselves to easy comparison between test laboratories, even though identical specimen shapes and testing procedures are used. Such values are primarily intended for compound control and at best are not suited for purchase specifications.

Some glove users feel that permeability of glove materials is of extreme importance. Since permeability, as a figure, is difficult to analyze without taking into consideration the application to which the glove material will be put, this property will be discussed in a separate part of this paper.

DESIGN CONSIDERATIONS

Recognizing the limitations of the manufacturing process, it is now possible to suggest certain conditions which will result in a reasonably designed glove for general-purpose application. The varied conditions imposed upon glove manufacturers for the dimensions and shapes of gloves and recommendations suggested as a result of a study by the ANL Glove Committee follow:

Cuff Design

Basically, there are three methods which have been used for terminating the cuff. These include (1) rolling the uncured end of the glove to form a uniform bead, (2) cutting and trimming the non-uniform end of the glove created in the dipping process with no further treatment, and (3) the use of an O-ring over which the uncured end of the glove is rolled to form a bead. The use of an O-ring is discouraged due to fabrication difficulty. The O-ring bead is sometimes relied upon as a means of attaching and sealing the glove to the box. This practice is not recommended. Trimming the cuff is obviously a simple finishing operation, but since the user may prefer the ease of handling inherent in a glove having a beaded end, method (1) is to be preferred.

Although the opening diameters of gloves in use vary from as large as 14" to under 5", the majority are grouped at approximately 8" and 5" inside diameter. Decisions made in establishing these dimensions are based upon consideration of the amount of space available for an opening into the enclosure and a size necessary to permit freedom of shoulder and arm movement when the hand is inserted into the glove. Future installations should consider only the use of a glove having one or the other of these dimensions, depending entirely upon the application, in order to take full advantage of commercial availability.

In this discussion, port design has purposely been omitted, but it must be recognized that stressing a cuff to fit an oversize port results in decreased glove life.

Length

Like the diameter of the cuff, the over-all length of the glove (tip of middle finger to end of gauntlet) in the past has been a matter of individual preference, resulting in a variation in length of those gloves in use from 24" to 40". Most users now agree that 30" is the optimum length for the 8" diameter glove and 27" for the 5" diameter. Several factors were considered in arriving at these figures.

The glove should be of a length which, after being attached and fully extended, will allow the average worker's fingers to conveniently reach the end of the glove. A length greater than this would tend to allow the glove to slide from the hand. A glove length shorter than the average reach when used in the larger enclosures would, of course, not allow complete utilization of available space. A 30" length generally will best provide these conditions. After allowance for mounting of the glove over the ring or flange, a useable length of approximately 29" will result. This will vary somewhat with the mounting arrangement. Gloves of varying length can be dipped from a single well-designed glove form. This is accomplished

by designing the form with a cylindrical section at the cuff end in which the diameter is held constant over a 4" or greater length, beginning 28" from the finger tip. Gloves having the same gauntlet diameter but of lengths from 28" to 32" can thus be obtained for any special requirements from a single form design.

Finger Length

Differences of opinion exist regarding the finger lengths desired in gloves. This is evidenced in the forms designed by various users on which the middle finger length varied from $2\frac{1}{2}$ " to $3\frac{1}{4}$ ". Recently, this has been generally compromised at 3" with other fingers of the glove being proportionately shorter. The influencing factor in determining this length is the opinion that the hand of the glove user should seat in the glove at the finger tips in preference to seating at the webs between the fingers. This allows small objects to be picked up and handled with much more ease and dexterity than would otherwise be possible. A 3" middle finger length will provide this condition for most users without sacrificing comfort in the glove.

Hand Shape

The curvature of the fingers is another factor worthy of consideration in the design of gloves. Straight-fingered gloves are generally undesirable in that they represent an unnatural position of the user's fingers. This will cause the user to stress the glove fingers to conform to his normally curved fingers. Since greater stress on the glove is necessary when gripping objects or in closing the hand, the result is greater fatigue. The fingers should be designed with a slight curvature such as is normally found in rubber industrial-type gloves. The area between the fingers of the glove should be designed without sharp changes in direction. The use of larger radii is much less prone to create manufacturing difficulties. For this reason, as well as to enable small objects to be picked up easily, the tips of the fingers of the glove should be well rounded.

Since gloves may be employed in a series of enclosures used by a number of workers, the glove should be designed with only one hand size. A standard hand size is also essential if the form investment cost is to be held to a minimum. Most users agree that a size $9\frac{1}{2}$ or 10 can be utilized in all but the extreme cases. An attempt has, therefore, been made to standardize on size $9\frac{3}{4}$. It is better that the glove fit freely enough to permit the use of a thin inner glove where conditions warrant.

Differences of opinion also exist on whether the glove should fit snugly or somewhat loosely at the wrist. Those in favor of the snug fit validly maintain that this will aid in preventing the glove from slipping from the hand under certain circumstances, such as when working in an

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enclosure with a slightly negative pressure. The disadvantage here, however, is the difficulty in getting the hand in and out of the glove. The majority prefer a larger wrist which will enable the hand to be inserted and removed easily. The tendency for the glove to slip from the hand due to a loosely fitting wrist may be remedied through proper design of the glove hand by hollowing the palm to closely follow the contour of the user's hand.

Thickness

Glove thickness is, of course, a prime consideration. The thickness chosen is dependent upon the application of the glove. Principally, it is a matter of dexterity versus safety; the thicker the glove, the less dexterity and the more safety from hazard offered. Fortunately, it is not imperative that users agree on any one thickness since a manufacturer can produce a variety of thicknesses from the same form. For most production-type applications, a glove having a nominal thickness of 0.030" is recommended. Operating conditions, however, will dictate the required thickness and density commensurate with safety. Where it is felt that danger of puncture of a 0.030" thick glove exists, a protective leather outer glove is commercially available.

Figures 1 and 2 pictorially represent a glove shape which would adequately fill the need for a standard glove design.

IMPRESSIONS

Incidental to this report, but exemplifying the unusual types of gloves which may be impressed upon the manufacturer are the following:

- (1) Gloves with serrated palms and fingers. These gloves have been made in an attempt to overcome a slippery surface and are made on forms which are serrated, the glove being turned inside out after removal from the form. Although the desired result is accomplished, it is generally agreed that the serrations are a frequent source of defects; hence, they are not advocated. A much more satisfactory means of accomplishing the intended purpose is a method of etching the palm and finger surface after the glove has been produced. This method is recommended where a roughened surface is desired.
- (2) Gloves with bellows or accordion sleeves. The intention in this type of glove is to allow the gloved hand to be extended and retracted in the protective enclosure with little interference, particularly when the hands are retracted to a position near the front of the working space. The bellows is a source of manufacturing problems and defects in the gloves due to sharp changes in direction of the surface. Generally, this type does

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not accomplish its purpose without disadvantage. The glove has a tendency to bunch at the elbow when working close to the front of the space.

- (3) Gloves having a standard commercial-type hand cemented to a sleeve of appropriate shape. This type of manufacture offers two distinct advantages: (a) a variety of hand sizes and thicknesses can be made available without investment in a like number of dry box glove forms, and (b) the hand can be of a thickness differing from the sleeve. The latter is of advantage in applications where dexterity requires a very thin glove and good fitting hand. Obtaining a good bond where the hand is cemented to the sleeve is mandatory because of possible leakage of hazardous materials.
- (4) Gloves having a flat hand and a neutral thumb. One advantage of this type of glove is that it may be used in a location where it is helpful to be able to insert either the right or the left hand, for example, between a right and left-hand glove mounted in a standard manner. The use of such a glove in normal installations and applications is discouraged, because stressing the rubber is necessary with normal hand movements, resulting in fatiguing and awkward operations.

PERMEABILITY

Permeability characteristics of glove materials are considered by some users to be important properties from the standpoint of gas-tight integrity of protective systems. It is obvious from the results of Table I that, with regard to water diffusion, latex neoprene has the highest permeability and pressure molded butyl the lowest permeability of the materials tested. The test information⁽²⁾ was obtained by the following means:

A 3" diameter disc of the test material was clamped securely over the top of a small test cup containing 25 ml of distilled water. The cup was then inverted and placed on a 1/4" mesh wire screen in a draft-free location (75° ± 1°F and 50% relative humidity). After five days in an inverted position, the cup was weighed. The cup was inverted once more and allowed to remain for 240 hours, after which the final weight was obtained. The difference in weight is the weight loss in milligrams shown in the formula below:

$$\text{Water permeability for 1-mil thickness, expressed in milligrams/sq. in./day} = \frac{\text{Wt. Loss in Mg} \times \text{Thickness in Mils}}{\text{Days Exposure (10)} \times \text{Area in sq. in. (4.91)}} *$$

*This procedure appears to be a modification of ASTM Specification E-96-53T Procedure B. The modification is the inversion of the sample cup during the testing period.

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If the test room air was theoretically dry, then the reported values would probably increase by a factor of approximately two.

The second consideration involved in further evaluation of the permeability of glove materials is the actual atmosphere conditions under which the gloves are to be used. Some of the more common types are listed below:

1. Air Atmosphere

- (a) once through room air - with or without drying
- (b) closed cycle (recirculating) air - with or without drying
- (c) essentially static - with or without drying

2. Protective Atmosphere

- (a) same as 1(b) with purification added
- (b) same as 1(c) (gas flushed)

(These are by no means all of the types in use, but sufficient systems are covered for the purposes of this analysis.)

It is beyond the scope of this article to calculate the moisture effects upon all of the above systems under all of the possible conditions that might be encountered. However, certain comparisons are indicated in Table II, where a limited amount of permeability data is given. The systems considered are a twelve-cubic foot static atmosphere containing two gloves and the same atmosphere with recirculation and purification. It should be pointed out that for all considerations, the gloves are assumed to be a membrane, upon one side of which is an atmosphere of water. This is, of course, an improbable condition which, it is felt, will lead to conservative estimates with regard to the extent of permeation of water vapor through the gloves. For static conditions, it appears that the dew point after a 24-hr exposure with no attempt at drying the inside atmosphere will be affected by the water permeation. The dew point is, in effect, directly proportional to the water permeability of the glove material.

In the case of a dynamic system with recirculation of the atmosphere each six minutes, with purification and drying to a dew point of -70°C , the moisture accumulation results in an elevation of dew point by only 16°C under the most severe conditions of permeability observed.

It should be immediately apparent that moisture contamination from the gloves would be of little concern in most air systems, especially those employing dryers. This would also be true of the protective atmosphere systems except where purity is of more than casual consideration. The inlet air rate equivalent to the glove material permeability is presented in Table II. For these calculations, only the accumulation of moisture is considered, and leakage of air at 50% relative humidity at 24°C is assumed.

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The air rate leakage equivalent to glove permeability may be equated in terms of the dimensions of a hole necessary to pass this quantity under set differential pressure conditions. The gloves of highest permeability material would leak moisture at a rate equivalent to a hole of 0.0168" dia. and that of lowest permeability to a hole of 0.0078" dia. For this reason, it is felt that justification for limiting the moisture permeability of a glove material can only be found for systems which have a very high gas-tight integrity.

At this point, it might also be well to point out that the admission of some materials into protective enclosures may profoundly affect the moisture contamination of the system. Hygroscopic matter containing water of crystallization which varies with the humidity conditions impressed upon it (for example, textile material, paper and other wood products) will give up equilibrium moisture when exposed to an atmosphere of decreased humidity. The moisture contribution of these materials will result in elevating the operating dew point until their vapor pressures are in equilibrium with the surrounding atmosphere.

In conclusion, before specifying the ultimate in glove materials from the moisture contamination standpoint, the system should be carefully analyzed. The actual moisture diffusing through the gloves and moisture contributed by other sources should be determined. The effect of each contributing source upon the required purity or operating dew point should then be ascertained. The results of such an analysis will quickly indicate the area of most concern with respect to the loss of integrity due to moisture contamination.

Incidental to this analysis, preliminary calculations of air permeability through latex neoprene for the conditions assumed in Table II indicate diffusion of the order of 10^{-6} ft³/min.

No values are reported on the resistance of various glove materials to solvents, chemicals or sterilization. This is a local problem of little concern to some users. Where the end use dictates such requirements, a material or compound should be selected that will provide the desired properties, based generally on retention of tensile properties after exposure to the deteriorating influence. It must be recognized that the selection of special compounds will result in high glove costs unless volume purchasing is realized or the compounds find general acceptance.

INSPECTION AND TESTING

No systematic inspection and testing program is in existence today by most glove users. This is so for many reasons, foremost of which is the fact that specifications of even the vaguest nature have, until recently, been essentially nonexistent. Under these conditions one can only

inspect, in a visual manner, for the most obvious defects. Another complicating factor, mentioned earlier, has been the form problem. If the purchaser's forms are used, the producer is prone to attribute many defects and rejections to the forms which, according to him, are of improper design. The producer's opinions, of course, stem from his awareness of the limitations of dipping forms in his particular process.

In addition to a visual or minimum inspection, some users have subjected gloves to an air-water immersion test for the detection of pin holes. At best, this is a slow, cumbersome, and inconclusive test, since small pin holes in certain regions, such as the finger area, will not show up under this method of testing. Water tests have been used under somewhat similar circumstances - the glove being filled with water, suspended by its cuff, and water leakage observed. This test also fails to detect small pin holes. A need exists for a soundness check that is fast, eliminates arbitrary defect classification and is easily and simply performed.

The electrical industry has for years used an electrical test to determine glove soundness.⁽³⁾ It is only natural that, since such gloves are used to handle live circuits of high voltage, they should be tested under conditions simulating service, allowing an adequate safety factor. The point to be made here, however, is that, while gloves for protective systems are not generally intended for electrical work, the electrical test does appear to be a positive way of accurately checking glove soundness and it can be adapted very easily to inspecting this type of glove. As a matter of fact, many glove manufacturers have the necessary equipment on hand that can be used with little or no alteration. Further, one manufacturer has agreed to give 100% electrical inspection once standards are set.

Briefly, the electrical test consists of filling the glove with fresh tap water and immersing it in water to approximately 1" of the rolled cuff. The water inside and outside is at the same level and forms the testing electrodes. These are connected to the transformer by means of a chain or a sliding rod dipping into the water in the glove and by direct connection to the metal-containing vessel. Current measurements are made by inserting an appropriate meter in series with the glove under test. Current readings, when required, are generally taken near the end of the proof voltage test period.

The actual equipment involved for a test of this type of hood gloves will depend on whether AC or DC voltage is used, the proof voltage specified, and the number of gloves to be tested at any one time. From the test results summarized in Figures 3 and 4, equipment capacities can be estimated. Here again, the results are based on individual tests in each case and are only intended to indicate, in a cursory manner, the relationship between voltage and current.

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For AC testing, a 5-kva transformer is more than adequate for testing 4 to 6 milled neoprene gloves simultaneously. A 5-kv proof test voltage is suggested for this heavy weight glove. Pinholes and other serious defects are generally detected at 3 kv or less. DC testing can be accomplished with lower capacity equipment because of the nonexistence of the reactive current. In contrast, the suggested proof voltage will be about 10 kv or about two times the AC value. Roughly speaking, a 10 to 20-kva unit should be adequate for testing 4 to 6 gloves simultaneously.

As far as preference of method is concerned, no hard and fast rule can be suggested. DC testing lends itself to ease of setup, smaller equipment and very likely a smaller dollar investment and operating cost. Heating of the glove material is more pronounced in the AC test and the alternate mechanical stressing produced by the alternating current has shown no valid advantages to justify its preference. It is ultimately intended that the producer assume the responsibility for electrical testing, where required, thus relieving the purchaser of other than a spot check that could conceivably be conducted by a testing laboratory.

Values may require some adjustment for thinner materials and some latex neoprene materials are not generally amenable to electrical tests of the type described due primarily to adsorbed water. There is reason to believe, however, that by possible compound adjustment and suitable variation of the electrical test that they, too, could be checked for soundness by this procedure.

The advantage of the electrical test is its speed of operation for multiple testing. It provides a go no-go type inspection that is reproducible at any installation and eliminates the necessity for any arbitrary classification of defects.

Tests and procedures for determining other glove properties have been fairly well established; ASTM and Federal Specifications⁽⁴⁾ are available.

CONCLUSIONS

At the present time, gloves are manufactured by a dipping process employing rather expensive forms and various compounding formulae. It is felt that, in the interests of economy and consistency, some standard be provided glove manufacturers for gloves to be used in protective systems. In this consideration, an analysis suggests milled neoprene (with latex a close second) as the most suitable material to be employed at present.

The physical strengths of glove materials may be regarded as only loosely indicative of glove quality, although there is an indication that percent set may be related to inelasticity and "deadness." Tests to determine

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the formation of gloves, existence of pinholes, internal blemishes, etc., at present, are considered inadequate and an electrical test is recommended. This test is suggested for the determination of glove soundness on the basis of testing ease, positiveness, and simplicity.

Permeability of glove materials indicated by the four materials tested shows little effect upon the purity of dynamic systems with purification. The effect of permeability is considered to be small compared with that contributed by leaks, the introduction of hygroscopic materials, etc., in the system. It is maintained that the use of low permeability characteristics as a criterion for material choice should be resorted to only after it is concluded from thorough analysis of the system that glove permeability is the limiting factor.

Two standard gloves are suggested as per Figures 1 and 2. Two standard forms may be employed for the manufacture of these gloves, the thickness and length of which may be varied within limits without requiring additional forms.

The solutions offered to the "glove problem" are not intended to be a panacea. They are, however, presented as a point of departure for the supply of a relatively economical glove adequate for general purpose use.

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The manufacturing side of the story was obtained through the assistance of the following concerns:

B. F. Goodrich Company	Riverside, N.J.
Charleston Rubber Company	Charleston, S.C.
Miller Products Company	New York 7, N.Y.
Minor Rubber Company	Bloomfield, N.J.
Pioneer Rubber Company	Willard, Ohio
Seamless Rubber Company	New Haven 3, Conn.
Surety Rubber Company	Carrollton, Ohio
White Rubber Company	Ravenna, Ohio
Wilson Rubber Company	Canton, Ohio

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TABLE I.

Selected Properties of Glove Materials

Type Material	Tensile Strength, psi	Percent Ultimate Elongation	Percent Set At Break	Tear Resistance, lb/in.		Water Permeability, mg/in ² /day/mil thickness (240 hr)	Air Diffusion,* lb/in ² /day/ft ³ /ft ² /mil thickness (x 10 ⁻⁴)
				(Die C)	(Die B)		
Milled Neoprene							
A	3,250	860	15	227	753	17	10.8
B	1,825	640	37	210		19	
C	2,710	640	16		643		
Latex Neoprene							
A	2,675	700	11	180		43	9.7
B	2,350	740	8	140		42	
C	2,798	873	7		580		
Butyl (Pressure Molded)							
A	1,950	760	30	147		2	
(Dipped)							
A	1,325	600	25	130		6	
B	1,175	520	19	140		7	

*Test conducted by B. F. Goodrich Company, Akron, Ohio.

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TABLE II

Glove Permeability Calculations for Various Atmosphere Conditions

	Units	Latex	Milled	Dip Butyl	Mold Butyl
Water Permeability (Approx. Values for Convenience of Com- putation)	Mg/H ₂ O/in. ² /day/mil Mg/day/glove ^(a)	40 400	20 200	10 100	2 20
Water Entering Static System	Grains/24-hr day ^(b) Grains/ft ³ /day	12.3 1.03	6.16 0.51	3.08 0.26	0.62 0.05
Dew Point at End of 24-hr Period	°C ^(c)	-9	-17	-24	-40
Water Entering Dynamic System	Grains/min ^(d)	8.55 x 10 ⁻³	4.28 x 10 ⁻³	2.12 x 10 ⁻³	4.30 x 10 ⁻⁴
Equilibrium Dew Point	°C	-54	-59	-63	-68
Inlet Air Rate Equivalent to Glove Permeability	Ft ³ /min ^(e)	1.78 x 10 ⁻³	8.9 x 10 ⁻⁴	4.41 x 10 ⁻⁴	8.95 x 10 ⁻⁵
Hole Dia. to Allow Above Leak	in.	0.0168	0.0143	0.0116	0.0078

(a) Glove - 300 in.² area/30-mil thickness.

(b) Assuming above conditions in a box of 12-ft³ volume with two gloves in box.

(c) Assuming no moisture in box at start of 24-hr period.

(d) Assuming box conditions (a) and atmosphere circulating at 1 cfm and purification to an inlet air dew point of -70°C.

(e) For moisture considerations assuming air leakage at 50% relative humidity and 24°C with a differential pressure of 0.75" of water toward box interior.

FIGURE 1
SUGGESTED DESIGN FOR 8-INCH DIAMETER GLOVE

FIGURE 2
SUGGESTED DESIGN FOR 5-INCH DIAMETER GLOVE

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