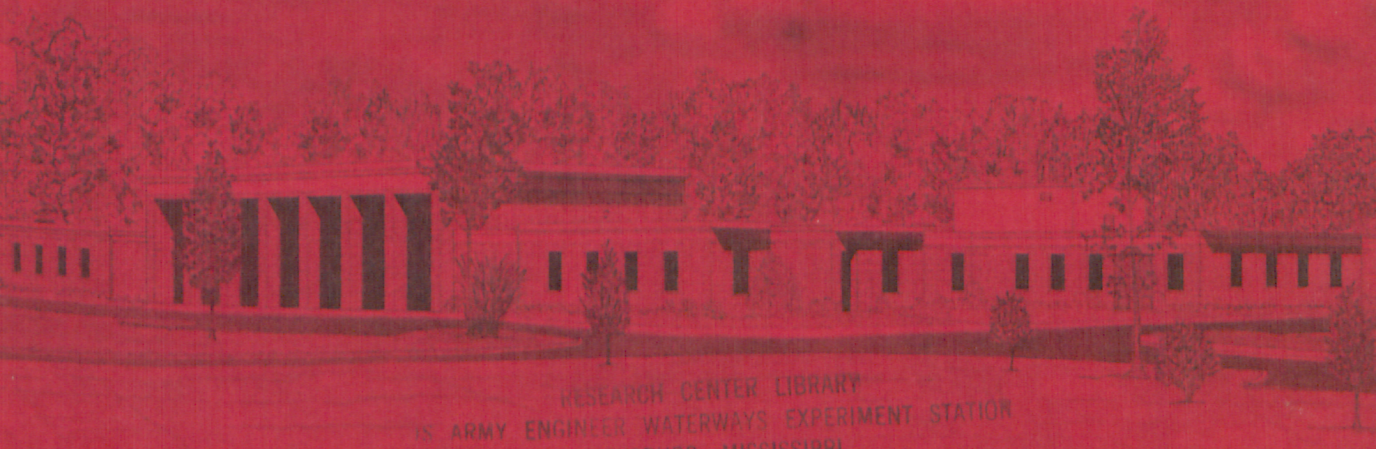
CONTRACT REPORT S-71-7

RESEARCH AND DEVELOPMENT OF PREFABRICATED AIRFIELD AND ROAD SURFACING MEMBRANE

by

G. C. Pedersen



September 1971

Sponsored by Research and Development Directorate
U. S. Army Materiel Command

Conducted for U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

Under Contract No. DACA39-68-C-0003

By Globe Albany Corporation, Buffalo, New York

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ARMY-MRC VICKSBURG, MISS.

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FOREWORD

The investigation described in this report was performed under Contract No. DACA39-68-C-0003 Neg, "Research and Development of Prefabricated Airfield and Road Surfacing Membrane," between the U.S. Army Engineer Waterways Experiment Station (WES) and the Industrial Fabrics Division of Albany Felt Company, Albany, N.Y. Since the inception of this contract, the name of Albany Felt Company has been changed to Albany International Corp., and the Industrial Fabrics Division has become part of its wholly-owned subsidiary, Globe Albany Corporation, Buffalo, N.Y.

The objectives of this investigation were to evaluate fibers, design yarns, design base fabric, design web and needling procedures, develop rubber, evaluate impregnation methods, evaluate calendering and press curing, develop non-skid surfaces, and test fabrications. The work was sponsored by the Research and Development Directorate, U.S. Army Materiel Command. This report was prepared by Mr. George C. Pedersen, Senior Development Engineer, Globe Albany Corporation.

The contract was monitored by Mr. S. G. Tucker, Chief, Membrane Section (WES), under the general supervision of Messrs. W. L. McInnis, Chief, Expedient Surfaces Branch (WES) and J. P. Sale, Chief, Soils Division (WES). Contracting Officer was COL Levi A. Brown, CE, (WES).

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SUMMARY

The U.S. Army desires an effective means for establishing an airfield or roadway without the expenditure of time necessary when conventional means are used. Where soil conditions permit the bare ground can be covered with a coated fabric called "Prefabricated Airfield and Road Surfacing Membrane". A research and development contract was negotiated between the U.S. Army Engineer Waterways Experiment Station (WES) and the Industrial Fabrics Division of Albany Felt Company, Albany, N.Y. for the purpose of developing a superior membrane for this purpose. Since the inception of this contract, the name of Albany Felt Co. has been changed to Albany International Corp., and the Industrial Fabrics division has become part of its wholly-owned subsidiary, Globe Albany Corporation, Buffalo, N.Y. Under this contract (No. DACA39-68-C-0003, as modified), a fundamental approach to the very wide range of options was taken. Because of this approach we were not limited to available fabric constructions or rubber compounds. We were thus able to consider the use of all the fibers and polymers that were available.

For the production of the fabrics, we considered fiber performance, yarn construction, weave construction for grab and tear strength, flexibility, winding equipment, dressing equipment, loom requirements, and selvage requirements. The final fabric product is clearly superior to any fabric heretofore available and is substantially different from any fabric available at the beginning of this work.

For the designation of the rubber compound, the commercially available polymers were screened and all promising materials were investigated in their available forms. The optimum material, a neoprene latex, was chosen. To properly optimize the performance of the membrane, the rubber must be prepared with additives. Some of the rubber considerations were: toughness, abrasion resistance, self-extinguishability, fiber wettability, penetration of the fabric, bonding to the base fabric, high strength adhesive joins, flexibility, U.V. resistance, jet-fuel resistance, and temperature resistance.

The final membrane sample used one basic rubber with three different levels of binding additive. The final rubber combination is satisfactory in all respects; however, further improvements are possible.

It was found that priming of the fabric to promote rubber bonding is mandatory for a suitable material to be developed.

For the combination of fabric, primer, and rubber to yield a satisfactory membrane material, many manufacturing variables were considered. Techniques were developed for this purpose.

In order to achieve the very high performance glued seams needed, many adhesives were tested, and the optimum material was chosen. Satisfactory techniques were developed to produce the required seams.

The anti-skid surface needed on the center of the runway is extremely important to achieve a satisfactory coefficient of friction against the airplane wheel. The optimum method is to apply a patterned coating to the membrane surface during the final assembly. Operator technique is important as is manufacturing technology. Further improvement is needed in this area.

Packaging of the final product was considered and is at the stage where the next logical steps are trials with full-sized pieces.

It is our opinion that the work done has led to definite and substantial improvements in the technological level of "Prefabricated Airfield and Road Surfacing Membrane" production. The minor improvement needed in the membrane can best be done while carrying out full-scale manufacturing efforts.

I. TECHNICAL WORK AND DISCUSSION OF RESULTS

For clarity, these discussions are broken down by subject and also by operations. Within each subheading, pertinent work is complete, or referred to another heading. For example, anti-skid surfaces are discussed in section I.G and sections I.I.3, I.K.3 and I.L.3. In section I.G the discussion is relative to the necessity of meeting the anti-skid requirements, while sections I.I.3, I.K.3, and I.L.3 deal with the production of membranes.

For reference purposes Table 1a and Table 1b have been included to give the material requirements for the membrane materials.

A. FIBERS

During the consideration of available fibers, the factors given consideration were:

(1) Availability - The material must either now be available or the production capacity must exist for usage of 300,000 lbs. month.

(2) Strength - In terms of lbs./in.^{2} (psi) for minimum volume;

(3) Tenacity - In terms of grams/denier (gpd) for minimum weight;

(4) Processability - The material must be handled on normal equipment;

(5) Suitability - There must be nothing in the membrane requirements that automatically eliminates the material.

An examination of published information on available fibers showed four possible candidates:

(1) Nylon - Published information on nylon gives a maximum breaking tenacity of 9.5 gpd, a maximum strength of 134,000 psi. Nylon has excellent aging and mildew resistances.

(2) Glass - Published information on commercially available yarn gives a maximum breaking tenacity of 9.6 gpd and a maximum strength of 313,000 psi. Glass is not affected by mildew and has excellent aging resistance.

(3) Polyester - Published information gives a maximum breaking tenacity of 9.5 gpd and a maximum strength of 168,000 psi. Polyester has excellent resistance to aging and mildew.

(4) Rayon - Published information gives a maximum breaking tenacity of 7.0 gpd and a maximum strength of 134,000 psi. Rayon has good resistance to aging but is attacked by mildew.

Rayon has no outstanding attributes and is subject to mildew attack, which could prove disastrous after prolonged unprotected storage; it was therefore eliminated from consideration.

Glass has outstanding strength and good tenacity. The problems of rubber adhesion and flex resistance are very severe. At the time of beginning this project, these problems were rather past the state-of-the-art and solutions far beyond the scope of this work. In addition, processing of glass on wide looms was not a commercial practice. Because of the above considerations, we concluded glass was not a suitable fiber.

On the basis of fiber properties, there is no decisive difference between nylon and polyester for the base fabric. Both fibers weregiven further consideration.

For the web, nylon has a clear advantage due to its superior stress recovery and is the fiber of choice.

B. YARNS

1. Weight of Yarns

In order to achieve a grab strength of 2,000 pounds/linear inch (pli), an original estimate of a theoretical fabric tensile strength of 1500 pli was made. The lower limit of the yarn size for a one-ply fabric, was estimated as follows:

Assume, (a) a balanced plain weave, and
(b) the yarn is cylindrical with diameter (D).

Then using: (a) pick count (ppi) times yarn strength squares 1,500 pli, and
(b) two times ppi times D equals 0.7.

Then, the lower limit for yarn weight is approximately 3,500 denier (d) if one uses 150,000 psi for strength and 9.0 gpd for tenacity.

In Section I.C is discussed the base fabric design. It follows from that discussion that the fabric should not have a maximum construction.

The choice of yarn weight is 4,000 d to 8,000 d.

2. Types of Yarn

The types of yarns of interest, high tenacity and high weight, are available in different degrees of twist. The yarns are given twist for a number of purposes depending on the end purpose. It is widely recognized that, with other variables constant, increasing twist of these types of yarn will:

(a) increase thickness of the fabric;

(b) increase stability of the fabric;

(c) improve processability;

(d) decrease strength of the yarn;

(e) decrease strength of the fabric;

(f) increase stiffness of the fabric.

As discussed in I.C, increasing stability of this material is undesirable. Items a, d, e, and f above are obviously undesirable.

It was decided, despite the much more difficult processing, to use yarns with minimum twist.

3. Suppliers and Tests

The major yarn suppliers are known to be quite reliable in reporting properties. For the fabric made in this work, the yarns were purchased from Du Pont. The yarns used were:

(a) 7,700 denier, 1344 filament, R02 bright type 73H Dacron(R) polyester yarn, Merge 12,000;

(b) 4,400 denier, 768 filament, R02 bright type 73H Dacron(R) polyester yarn.

(c) 7,560 denier, 1,260 filament, 0.5S, bright type 702 nylon yarn.

(d) 4,200 denier, 700 filament, 0.5S bright type 702 nylon yarn.

The stock used for the webs was Du Pont type 100, 6 denier, 3 inch nylon staple and Du Pont type 100, 15 denier, 3 inch nylon staple.

The base polyester yarn is 1,100 denier, which is reported by Du Pont to have a tenacity of 9.5 gpd and a breaking elongation of 11.5%. When the yarn is plied to form the 7,700 denier yarn, strength loss is reported to be about 10%, increase in elongation about 0.5%. These effects are somewhat less for the 4,400 denier yarn.

The base nylon yarn is 840 denier, which is reported by Du Pont to have a tenacity of 9.0 gpd and a breaking elongation of 15.5%. When the yarn is plied to form the 7,560 denier yarn, strength loss is reported to be about 10% and increase in elongation about 1.5%. These effects are somewhat less for the 4,200 denier yarn.

Our tests agree fairly well with published data. There is no known reason to prefer the Du Pont material, because other producers are capable of producing yarn with the required characteristics. For example, American ENKA Corp. submitted a sample of polyester identified as 1000/180-½Z Bright, which tested to have 9.0 gpd and 11.4% elongation at the break, e.g. identical to the Du Pont base yarn.

4. Suitability

It was shown in Tables 2, Table 3, Section I.E.5.a, and Section I.E.5.d, that the nylon fabrics were much more difficult to make self-extinguishing than polyester fabrics. This fact gave clear superiority to polyester, and it was chosen as the material for the base fabric.

The polyester yarn was subjected to prolonged (96 hours) exposure to JP-4 and found to have excellent resistance with no appreciable change in properties.

C. BASE FABRICS

The designs of the sample fabrics were based on several considerations:

(1) Design must be weavable in production looms;

(2) A sleazy fabric was desired to promote improved tear strength, but the fabric had to be processable;

(3) The yarn interlacing frequency would affect fabric thickness, weavability, and sleaziness;

(4) Unbalance of the weave would improve tear strength, e.g. 3 up, 3 down twill has the same interlacing frequency as a 6 harness satin, but it has lower tear strength.

Sample sets of fabrics were woven from polyester and nylon. Each sample set had two sub sets, one with heavy yarns and one with light yarns. Each sub set had four samples, each woven differently at three different theoretical strengths.

The details of the constructions are shown in Tables 4 and 5, and the results of preliminary testing are shown in Tables 2 and 3. The strengths reported in these were determined from samples which had been coated with a plastisol.

In all of the early work, we had difficulties in making meaningful grab strength tests. See Section I.G. for a discussion of the testing method.

D. WEB AND NEEDLING PROCEDURES

As originally conceived, the web on a needled fabric for an airfield membrane would serve to improve the bond between the base fabric and the rubber and to improve the wear characteristics of the membrane under drastic wear conditions. The presence of the web would, theoretically, spread a shear force from the rubber-web matrix. Similarly, in a grab test the presence of the web would serve to spread the load over a wider area, giving a higher strength. In circumstances when drastic wear of the membrane would occur, the web would become exposed and the nylon fibers would form part of the wear surface, the result being an improvement in wear resistance.

To be effective, the web must be sufficiently interlocked with the base fabric and bonded to the rubber to withstand the shear forces.

It is imperative that the base fabric not be significantly weakened during needling.

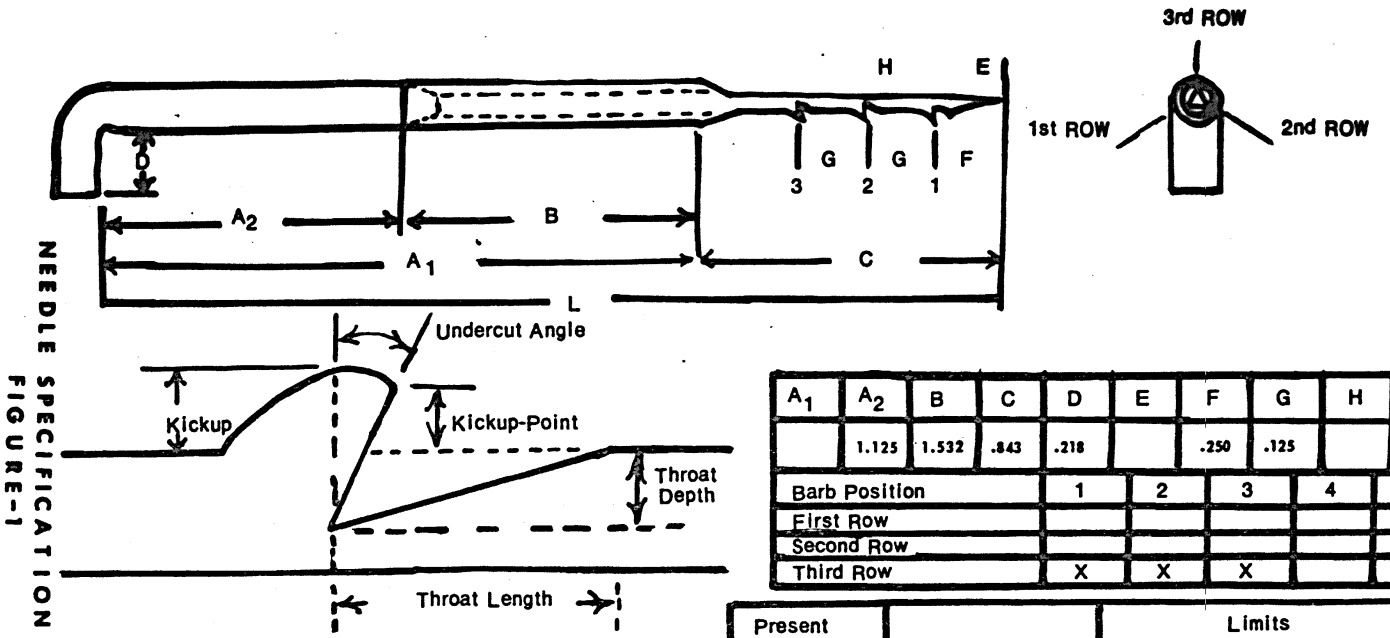
1. Web Selection and Preliminary Needling

The web is expected to be effective at low weights. Since the web is a weight and flammability penalty, it is imperative to utilize the expected benefits efficiently and to minimize the web weight. It was decided to make the initial trials at low web weight, 115 grains/square foot (grsf), and to increase the web weight only if necessary.

Two approaches were made to minimize the needling damage:

(a) Needle Design - Consideration was given, with several of our needling experts, to an appropriate needle design. Since only a light web is being needled, the needle must have low carrying power. The number and size of the needle barbs must be such that they are nearly filled with the web. If overly large barbs are used, they will collect the light web and still have enough exposed barb to catch and damage the base. If too many barbs are used, the web will become too concentrated in the area of original needle punch, and the web in nearby regions will be lighter. The web area that loses weight will not fill the barbs, and base damage will occur.

(b) Needle Orientation - The barbs of the needle interact most with the base fabric yarn when the barb is at a right angle to yarn fibers. If a barb does not intersect a set of yarns while it passes through the base fabric, it will not affect the strength. Conversely, if barbs do intersect a set of yarns, those yarns can be drastically affected. For example, using a triangular needle with barbs on one edge and needling a balanced weave base without any web, the following results are noted. When the needle is positioned at the normal or 180° from normal angle, only filling damage occurs. When the needle is positioned at 90° from the normal angle, only the warp is damaged. When the needle is turned 45°, 135°, 225°, or 315° from the normal, only slight damage is observed; and it is divided evenly between warp and filling. The normal angle is with the barbs facing the direction of feed of the base. It follows that if a triangular needle is used, it is possible to achieve a minimum damage, if there are barbs on one edge. Only triangular needles are readily available and the decision was made to use only one row of barbs on a triangular needle; shown in Figure 1.



NEEDLE SPECIFICATIONS
FIGURE-1

A_1	A_2	B	C	D	E	F	G	H	L
	1.125	1.532	.843	.218		.250	.125		3.500

Barb Position	1	2	3	4	5
First Row					
Second Row					
Third Row	X	X	X		

	Present Control Limits		Limits of Acceptance
Kickup UCL LCL	.0013 .0016 .0010		10%
Kickup Point UCL LCL	.0012 .0017 .0007		25%
Throat Depth UCL LCL	.0054 .0058 .0050		25%
Throat Length UCL LCL	.034 .039 .029		25%
Angle UCL LCL	18° 21 15		25%

TORRINGTON NO. 78 – 1216 – 221

(c) Other Possibilities - It is of interest to consider other needle possibilities since many shapes and designs can be obtained for trials. Imagining a square needle, it follows that if one of the edges was at 45° from the normal, the rest of the edges would also be at 45°, which would be an advantage. The advantage would be largely offset, however, by the packing of the yarns around the barbs. If the needle were diamond shaped or elliptical, and the barbs were on the obtuse angle or the minor axis, the yarns would not pack around the barbs. Due to the construction of the membrane base fabrics, the opening caused by the major axis of the needle would move the yarns away from the barbs if the axes are at 45° to the yarns.

One normal smooth barb on each side of the minor axis would be sufficient to carry all the available web.

In summary, a needle with the following characteristics should be useful for needling expedient airfield fabrics:

Blade Shape:	Elliptical or diamond with an axis ratio of 3:1
Barbs:	One on each side of the minor axis
Barb Type:	Smooth
Point:	Light ball
Blade Gauge:	0.017 x 0.051 inches
Shank Gauge:	0.072 inches
Orientation:	Axes at 45° to the shank
Needle Length:	3 inches

(d) Web and Needle Interactions - Preliminary testing was made with both 6- and 15-denier nylon staple. The 15-denier staple was immediately eliminated since with a light web, the coarse staple would not catch in the barb, needling efficiency was very poor, and damage to the base fabric was relatively high. The 6-denier staple was readily usable and the following parameters were selected:

Needle:	Torrington #78-1216-221
Needle Angle:	45°
Web:	115 grsf
Fabric:	01

The details of the needle are given in Figure 1.

2. The Effects of Needling Variables

In Section I are considered the effects of press-curing variables. With a set of standard press curing conditions, as determined in Section H, it becomes possible to consider the effect of needling variables, particularly take-up and penetration. The needling investigation was done with 2^2 factorial design on the fabric specified in Section G. The take-up was coded as a dummy variable with:

$$X_1 = \frac{\text{Penetration} - 3/8}{1/8} .$$

The take-up was coded as a dummy variable with:

$$X_2 = \frac{\text{Take-up} - 215}{80} .$$

The results of this experimented design are summarized in Table 6. Reduction of the data given in Table 6 gives:

$$\text{Warp Grab Strength} = 2{,}415 + 227\ X_1 + 68\ X_2$$

$$\text{Filling Grab Strength} = 2{,}090 - 244\ X_1 - 34\ X_2$$

$$\text{Warp Tear Strength} = 408 - 14\ X_1 - 10\ X_2$$

$$\text{Filling Tear Strength} = 430 - 35\ X_1 - 15\ X_2$$

$$\text{Thickness} = 89.5 + 5\ X_1 + 0.5\ X_2$$

Cursory examination shows that X_2, take-up, is not important in determining the final tested properties. Grab strength of 2,000 pli will be realized for X_1 less than 0, e.g. penetration less than 3/8". Filling strength decreases about 250 pli for each increase of 1/8" in penetration.

Two additional variables still remained to be considered: rubber and needle angle. It was anticipated with some confidence that 45° needle angle would give an optimum balance of properties. This was checked. The conditions used were:

Fabric:	24
Take-up:	300
Penetration:	4/8 inch
Web:	115 grsf
Needle:	Torrington #78-1216-221
Needle Angle:	60°

Amount of Rubber:	52%
Rubber:	CRL-3
Finished Thickness:	72 mils.

The samples were calendered on the production calender at 310° F and tested in the laboratory and gave the following results:

Warp Grab Strength:	1225 lbs/in
Filling Grab Strength:	1875 lbs/in
Warp Tear Strength:	125 lbs
Filling Tear Strength:	165 lbs
Flame-Out Time:	10 for sample #1
	0 for sample #2

The most obvious result of this test is the extreme effect of needle angle.

Changing the needle angle only 15° changes the warp/filling strength ratio from 1.15 to 0.654.

The effect of needle angle on tear strength is very similar to its effect on grab strength.

Since CRL-3 was selected as the preferred rubber, the fabric had to be changed to reflect the change in grab and tear strengths. Increasing the theoretical strength from 1,300 pli was sufficient, i.e. change from fabric #24 to fabric #4. Fabric #4 has the same weight as fabric #2, but is preferred because it is more stable.

E. RUBBERS - PRIOR TO 1969

1. General

a. Potential Polymers Commercially Available

A literature survey of commercially available rubbers and rubber-like polymers led to consideration of seven classes of materials which appeared to be potentially promising in this application. The seven classes and their designation are given in Table 7. Designations are those used by the American Society for Testing and Materials (ASTM) and will be referred to by these codes hereafter. A few other classes, given in Table 17, also appeared promising. Their higher cost, mainly, precluded our considering them as candidates. We believed that only two of the specifications were of primary importance, viz. flame resistance and solvent (JP-4) resistance. These would be the most difficult requirements to achieve and the others could be obtained in most cases as

by-products.

b. Physical Forms Available

There are four forms in which the basic raw materials may be used, but they are not common to each class of polymer considered (see Table 9). For example, some classes could be used only in latex form (NBR, CR, PVC), while these and others could be used in solvent solution or dry rubber form (CO, ECO, NBR, CR, ET, EOT, CSM). Only PVC is available in paste or plastisol form and it can also be used in solvent solution. Although dry rubbers are used to make solvent solutions, the CM class was available only in dry form in such a high average molecular weight that it was insoluble. The class was eliminated and, as a result, no work was done with it.

c. Abbreviations

When referring to drying, curing, or fusing operations, the time-temperature description is abbreviated as (time in minutes/temperature in ^{o}F). For example, 10 minutes at 325^{o} F is written as (10/325).

2. Plastisols

Of the four physical forms of rubber polymers available, plastisols are discussed first because their nature made them available to us earlier than the other forms. Plastisols are custom compounded, using special equipment which we do not have, and they are ready to use as received. Specifications were given to custom compounders, and they supplied us with lab evaluation samples.

a. Testing for Flame Resistance and Solvent Resistance

Tables 10, 11, 12, and 13 give the results for flame resistance tests and JP-4 resistance tests on plastisol films and on plastisol coated Dacron fabric (#24). Fabric was coated with a glass rod and each coat was fused separately (10/350). The plastisol films were cast on $\frac{1}{4}$-in.-thick plate glass with a Gardner Film Casting Knife, fused (10/350) cooled, and cut into $\frac{1}{2}$-in.-wide specimens, using a sharp razor blade and a steel ruler. Solvent resistance was determined after 24-hours immersion in JP-4 at room temperature.

Plastisol 76X-836 was not tested for JP-4 resistance because of its poor flame resistance (Table 10). LX-49 had poor flame resistance in film form (Table 10)and coated on fabric

(Table 12). The X-9017 appeared promising until it was immersed in JP-4. Using the results shown in Table 13, it was calculated that the film retained only 73% of its original ultimate elongation. As expected, the tensile strength increased - to 128% of the original value.

b. Plastisol Coated Flame-Proofed Fabrics

An attempt was made to improve the flame resistance of LX-49 since it apparently was not seriously affected by JP-4 (Table 10). A piece of Dacron fabric (#24) was dip-treated in an aqueous solution of Flamexx MM (see section I.E.5.d), then coated with LX-49 and flame tested. Pickup of Flamexx MM based on untreated fabric weight was 7.4%. Flaming times were3.0 sec., 24.5 sec., and a third specimen completely burned. There was no dripping.

c. Methods of Application

The X-9017 plastisol was applied by knife coating (knife-over-table) and by spraying. The former did not result in good penetration. Because the viscosity of the plastisol was somewhat high, it was necessary to add diisobutyl ketone (10 wt. - %). This allowed us to spray the material, but the penetration was still poor.

d. Final Remarks

Although the use of Flamexx MM with LX-49 did represent some improvement, flame resistance as well as JP-4 resistance were marginal; other difficulties inherent to plastisol systems are:

(1) Lack of sufficient penetration of the plastisol into the yarns;

(2) Necessity of solvent cleanup and general inconvenience of handling;

(3) Blocking at 180° F.

No further work was done using plastisols.

3. Solvent Solutions of Rubbers

a. Materials and Formulations

Dry rubber may be mixed or compounded on a two-roll rubber

mill or in a Banbury (internal) mixer. We used a 6" x 12" Stewart-Bolling rubber mill to compound all dry rubbers. The compounds were sheeted from the mill and tested. The classes of elastomers that we used as the basic raw materials were ET, CSM, NBR/PVC, CO, and CR. The formulations are given in Tables 14 through 21; numbers are in the usual units of PHR (parts per 100 parts of rubber) with the basic raw material being 100.

b. Nomenclature or Notations

The various compounds have been given short notations for convenience. The information included in a given compound notation is the name of the supplier of the basic raw material, the polymer class, and the number of the reformulation. In Tables 17, 19, and 20 the company names are Naugatuck (N), Goodyear (GY) and Goodrich (G), respectively.

c. Evaluation Procedures

After a compound was prepared on the mill, a suitable amount of it was placed between the hot plates (6" x 6") of a Carver Laboratory Press; the gap was set to about 150 mils, using a flat piece of steel between the plates, and the compound was cured. Cooling was achieved by immersion in tap water at room temperature. Specimens were cut, dried, and flame tested. Results are given in Table 22. Only CSM-1 and CR-1 were judged to have satisfactory flame resistance.

d. Preparation of Solvent Solutions

Solvent solutions are prepared by dissolving a previously compounded dry rubber in a suitable organic solvent. This is ordinarily done by cutting the rubber stock into small pieces and stirring the rubber/solvent slurry, using special mixers designed to cut or shear the rubber. In solvents, the rubber particles will tend to stick together and the mixer will tend to prevent, or at least reduce, this. "Lightnin" drive motors can be used. One suitable type of mixer is a three-bladed marine propeller with scalloped or serrated edges.

Although equipment was on hand to prepare solvent solutions, we did not do so. Our thinking was as follows: If the compounded dry rubber was cured and tested for flame resistance and found to burn, it would react the same way if we went through the intermediate steps of dissolving the rubber and preparing suitable samples that would be cured and flame

tested. Hence, we could find out the same information in much less time.

e. Solvent Solutions of PVC

Two formulations for solvent solutions of PVC are given in Tables 23 and 14. The stickiness of the ball mill grind caused a problem with the formulation given in Table 23. Since we had only one ball mill, we could not devote it exclusively to this formulation. It is impractical to mill both organic solvent dispersions and aqueous dispersions in the same mill jar using the same pebbles.

We did not prepare the other formulation (Table 14) because of the hazards presented in using the volatile, flammable solvents required. Although it might have been possible to reformulate using nonflammable solvents, our thinking at the time was to hold off on this unless we ran into trouble later on with other systems that we had not yet investigated.

f. Final Remarks

No further work was done with this type of system for several reasons. First, it is difficult to attain high solids contents in solvent solutions. Second, unlike latex, the viscosity of solvent solutions is directly related to the solids content. At high solid loadings, the viscosity is high enough so that the method of application is limited and handling is difficult. Third, a solvent-removal system would be necessary.

4. Latex Compounds

a. Flame-Proofing Agents

At one point during our investigation, we believed that satisfactory flame resistance might be achieved only by using a flame-proofing agent to treat the fabric before coating with a latex that also contained one or more chemicals to inhibit and retard burning. The materials used and the suppliers are listed in Table 24. Flammability results are given in Tables 25 and 26 for Dacron and nylon fabrics, respectively.

The untreated fabrics burn up completely. In addition, the nylon fabric drips severely. After flame proofing, the nylon fabric still drips during testing but to a lesser degree. Dacron fabrics are easier to flame proof than the nylon fabrics. Lower levels of flame proofing agent add-on are satisfactory for Dacron compared to nylon.

b. Materials and Formulations

Latex systems proved to be the most convenient to prepare and to apply. Several formulations satisfy the flame resistance and JP-4 resistance specifications. Three classes of elastomers were used as the basic raw materials. Formulations are given in Tables 27 through 30. The results of the flame tests are given in Table 31. Note that the formulation notations contains the letter "L" (for latex) after the polymer class in order to avoid any possible mix-up with dry rubber formulations.

In order to preserve the stability of a latex system during compounding and storage, the materials that are added to the base latex must be mixable with water or dispersible in water. For example, in Table 27, the TCP must be emulsified, and both antimony oxide and carbon black must be ball milled before the materials can be added to the Polyco latex. Ludox HS-40 is colloidal silicon in an aqueous system. It is ready to use as received. It is also important for the pH of the additives to be near that of the base latex although many latexes are very stable over a wide pH range. An example of a material that is mixable with water and that is added to the latex in the form of a simple water solution is Tepidone, which is used in the CRL series (Table 30). The solids figures are not given in the formulations for the compounded latex since each additive may be prepared using any of several different recipes, each resulting in a different solids content. In this work, the higher the total solids content, the better. Refer to Appendix A for the additive recipes we used.

c. Evaluation Procedure

Small amounts of the latex formulations (5 to 10 grams) were placed in Petri dishes. The contained water was vaporized at 125° F or 150° F and the resulting films were cured or fused at the conditions noted in the tables. After cooling, strips were cut, and quick flame tests conducted using a lab Bunsen burner. Results are recorded as "burns", "borderline", or "self-extinguishing".

d. Flame-Proofing Agents and Latex Coatings

A number of samples were prepared by first pretreating the fabric with a flame-proofing agent and then following up with a latex coating. The samples were used to determine whether any incompatibility existed and to determine the effect on flame resistance. Data are given in Tables 32 and 33 for

Dacron and nylon fabrics, respectively. Only the more promising latexes were used. Flamexx MM and Del-Pol are both somewhat incompatible with latex. As a result, penetration of the latex into the pretreated fabric was less than desired. Although this seemed to be a setback, it was demonstrated that some subsequently coated Dacron fabrics achieved satisfactory flame resistance without pretreating the fabric.

e. Effect of Composition on Flame Test

To get a better feel for the dependency of flaming time on the amount of rubber in the composite, a series of samples of Dacron fabric (#20) were prepared by spray coating. These samples received successively greater amounts of the CRL-5 formulation. Each application was oven dried at 150° F and the final composites were cured (20/285). Data are given in Table 34 and are shown in Figure 2.

f. Latex Film Work

The resistance of CRL-3, CRL-4, CRL-5, CRL-6, and Vulcanol 7724 to JP-4 and water was evaluated in the following manner. Vulcanol 7724 is a fully compounded latex based on Du Pont's Neoprene latex 571 and supplied by Alco Chemical Corp. ready for use as received. Films, all thickened with 1 wt. - % Natrosal 250 HHR, were cast on $\frac{1}{4}$-in.-thick plate glass using a Gardner Film Casting Knife set at 20 mils. It was necessary to spray the plates with MS-122 Fluorocarbon Release Agent in order to be able to remove the CRL-5 and CRL-6 films. All films were dried at 125° F and cured (25/285). After cooling, 0.5-in.-wide specimens were cut for Instron tests that were run on: (a) control samples, (b) samples after room temperature immersion in JP-4 for 24 hours, and (c) samples after room-temperature immersion in water for 24 hours. Data are given in Table 35. Tensile strength of the immersed specimens was based on the thickness before exposure. Values are reported as averages, in most cases, of ten tests. During testing of the CRL series, Instron chart speed and rate of jaw separation were 10 in/min and 20 in/min, respectively. Initial jaw separation for Vulcanol 7724 was 1 in. but was 2 in. for the other cases.

The tensile strength values of the CRL series differ from that for Vulcanol 7724 by approximately a factor of two. Since the CRL values are all of the same general magnitude, one might conclude these are more accurate than the value for Vulcanol 7724. Such is not the case, however. In reality, the CRL values are somewhat inaccurate. The reason is that Vulcanol

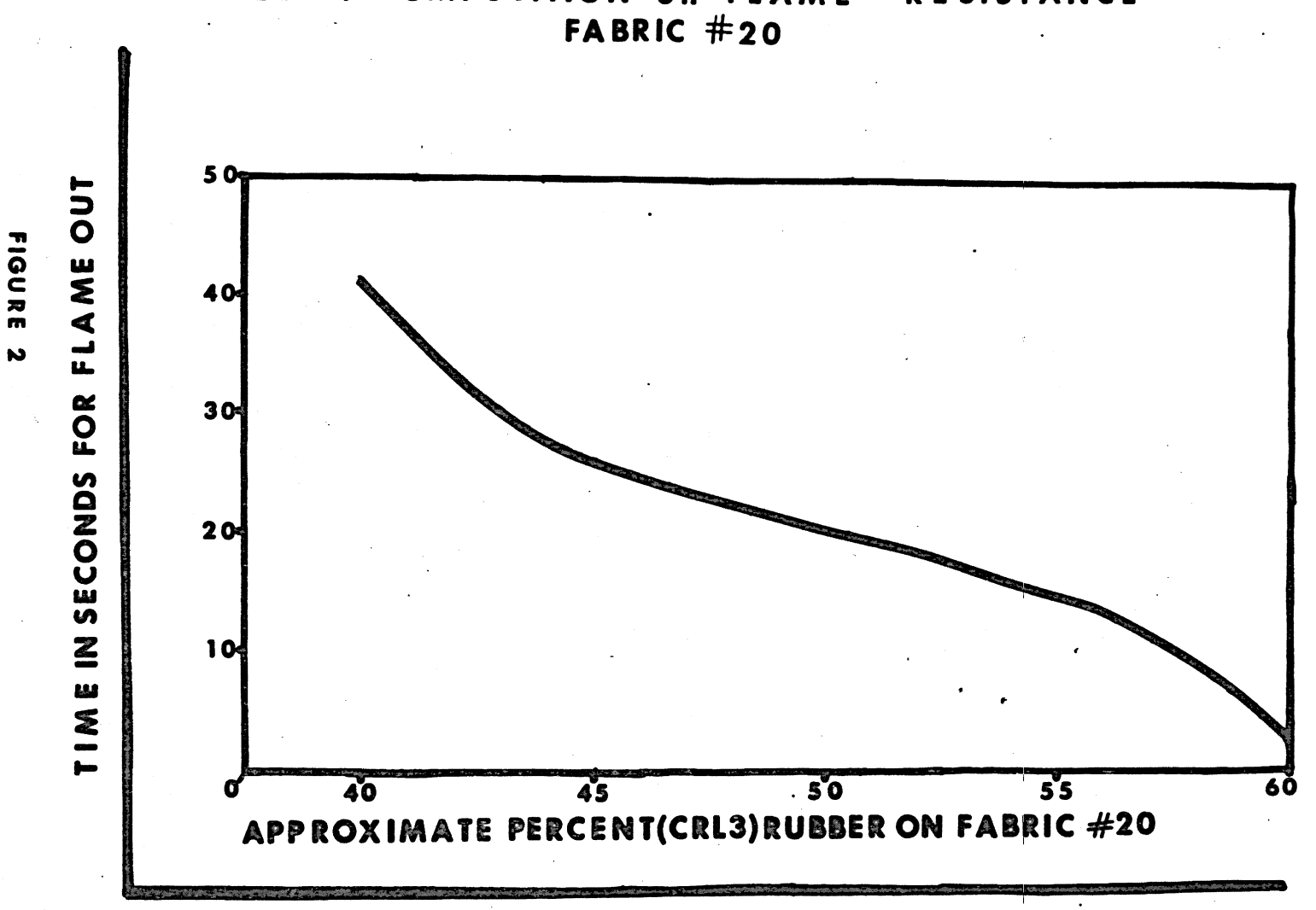

EFFECT of COMPOSITION on FLAME - RESISTANCE
FABRIC #20
TIME IN SECONDS FOR FLAME OUT
50
40
30
20
10
0
40
45
50
55
60
APPROXIMATE PERCENT(CRL3)RUBBER ON FABRIC #20

FIGURE 2

7724 was de-aerated by the supplier and the films made from it were of high quality and gave reasonably accurate results. It was impossible, however, to get quality films using the CRL latex series since these latexes were not de-aerated. The resulting films were full of pin holes and bubbles, and in film work, very minor imperfections have disproportionate affects on the physical properties.

Earlier attempts to evaluate the Taber abrasion resistance of rubber films made from the five latex formulations were unsuccessful. These films were so thin they wore out too early in the tests to give meaningful results. Another technique was used that involved alternately dipping metal plates into the latex and then oven drying (125° F to 150° F). The plates were of the same size and shape as the Taber S-16 Specimen Plates, but they were made of stainless steel. When the desired thickness was built up, the films were cured (25/285) removed from the steel plates, put on the S-36 Specimen Mounting Cards, and tested. Although this procedure worked with Vulcanol 7724, CRL-3, and CRL-4, problems were encountered with CRL-5 and CRL-6. See Table 36.

g. Other Fillers for Latex Compounds

Two additional fillers were investigated to develop a latex rubber having lower density. These were IGR-101 and Corcel 46; both are glass. Samples of each film were evaluated by adding (with stirring) 1, 5, 10, or 20 gram amounts to 100 grams of water and allowing them to set overnight before observation. Ten grams of Corcel 46 was the upper limit since most of the water was absorbed by this amount. Results were unsatisfactory in all cases. Attempts to thicken the slurry by addition of a thickening agent did not help.

h. Methods of Application

The comparatively low viscosity of latex formulations for impregnation and the presence of surface active agents tend to enhance penetration of the latex into the yarns, but preclude application by knife-coating. For coating, the latex formulations may be modified to allow for knife-coating. Spraying, dipping, and padding (or combinations of these) are the preferred methods.

i. Latex Stability

On September 23, 1968, we checked for stability all of our retained samples of the five compounded neoprene latex formu-

lations that we considered the best candidates. All but CRL-5, whose stability was questionable, appeared to be stable. Time lapse was over five months, which is judged to be very good. See Table 37.

5. Testing of Five Best Formulations

a. Preparation of Samples - Coating

Three Dacron fabrics (#4, #8, #20) were impregnated and coated on both sides until they were satisfactory in the flame resistance test. The five latex compounds used were CRL-3, CRL-4, CRL-5, CRL-6, and Vulcanol 7724. Sufficiently large pieces were used to obtain enough samples for testing. Coating was done by sewing the various pieces end to end in the form of an endless belt, installing them on our pilot plant coating line, and applying the latexes with a paint roller. Two passes were made using the latex without modification in order to facilitate complete impregnation into the yarns. Subsequent passes were made after the viscosity was increased by adding a thickening agent. This allowed a more rapid build-up of the surface coating. Natrosal 250 HHR was used as the thickening agent in the form of a 6 wt.-% based on solids only. The thickener was added to the latex within 15 minutes of preparation. Hydration is delayed for 20 minutes, which allows the operator sufficient time to achieve uniform concentration before thickening of the latex occurs.

Drying of the samples was effected by air and by infrared heaters. Generally, all samples were cut into two equal parts, the first of which was cured immediately under tension in a lab oven, the second part was cured the same way after calendering (Section I.E.5.b). To ensure complete removal of water, a four-step drying/curing procedure was followed: (35/200), (35/225), (20/250), and (20/285).

b. Preparation of Samples - Calendering

The second part, referred to in Section I.E.5.a, was calendered in our Maine mill on a two-roll calender. Sample widths were 24 inches. The applied load was 2,500 pli. The calendering conditions including roll speed, roll temperatures, and gap setting, are given in Table 38. The indicator temperature (250, 300, 350) were higher than the calender rolls surface temperature (230 - 240, not measured, and 315 - 325, respectively) as measured with a surface pyrometer. Gap settings were measured, at each end of the calender, with feeler gauges. Some difficulty was experienced with the rubber

sticking to the rolls. MS-122 Fluorocarbon Release Agent was applied to the rolls but it was not effective. Good release was obtained by wiping the rolls with a rag, wet with hydraulic oil, before each piece was run. Table 38 also gives the initial and final thickness for calendered samples.

c. Physical Testing

Both calendered and uncalendered samples were tested for thickness, basic weight, composition, tear strength, coefficient of friction, flame resistance, Taber abrasion resistance, grab strength, and Gurley stiffness. Taber abrasion tests were also run on samples that had been immersed for 24 hours in JP-4 at room temperature. Test results are given in Table 39.

b. Latex Compounding on a Commercial Scale

a. First Mixing - Surpass Chemical Co.

In order to impregnate and coat the several large pieces for testing at Vicksburg, larger amounts of compound latex were required than could be mixed here at AFC. The base neoprene latex, dispersions, and other materials were purchased and mixed in batches of about 8 55-gallon drums at a nearby specialty chemical house. Their mixer was a 500-gallon stainless steel tank with a removable head hinged across its diameter. Materials were all added at the top. Continuous agitation was provided by a side-entering (near bottom) slow speed, three-bladed marine propeller. Take-off was in the side close to the bottom. The compounded latex was gravity-fed directly into tared steel drums.

The formulation, concentrations, and wet weights are given in Table 40. Note that Agerite Powder, P-33 (a FT black), and Ethyl have been substituted for Neozone D Special, SRF black, and Thiuram E, respectively. Chemically they are the same.

b. Second Mixing - Surpass Chemical Co.

This mixing was done using the same equipment, the same methods, and the same materials as described in previous section. The only difference was in the amount made, which was about 34 55-gal. drums. See Table 41. Physical testing of this latex included measuring the Brookfield viscosity, total solids content, and specific gravity.

This mixing was done in four lots due to equipment size limitations. Two lab samples were withdrawn from each of these lots. One was taken just after the first drum, and the other was taken just before the last drum. Results of the testing are given in Tables 42 (viscosity) and 43 (solids). The specific gravity was 1.17.

c. Third Mixing - Alco Chemical Corp.

The mixing was done by a latex custom compounder who has cooperated with us for six years, Alco Chemical Corp. The order was for 17 55-gal. drums of CRL-3. The code name for this formulation was Vulcanol 8303, and the total solids content was 46.9%.

d. Costs of the Compounded Latex

The materials purchased for the second mixing at Surpass Chemicals are given in Table 44. The cost data are given in Table 45. Note that these figures do not include any labor charges. The cost to us for the third mixing was 60¢/dry lb.

F. ADHESIVES

22 adhesives from 12 companies (Table 46) were tested (see Table 47). Specimens were prepared by lap-joining together identical pieces (same fabric, same latex), one inch wide. Overlap area was 4 sq. in. in all cases. The specimens were allowed to cure for either 6 or 7 days at room temperature and tested on the Instron at 10 in./min, by measuring the shear force required for failure. Poor adhesives resulted in failure at the rubber-adhesive interface. Good adhesives resulted in failure within the rubber, or by rubber separating from the fabric. The best results are clearly those obtained with Bostik 1095/#9 Boscodur. Less desirable alternatives, which none-the-less gave good results, include the following:

(1) PPG-483/CH100
(2) PPG-G580
(3) 3M 1300L
(4) Uniroyal - 6130.

Samples of the nine best performing adhesives, listed in Table 48, were cast into films and tested for JP-4 resistance. The results of the tests are given in Table 49.

The procedure for film preparation was:

(a) Films were cast onto Teflon-coated glass fabric to a thickness of 15 mils;

(b) Films were air dried for at least 24 hours;

(c) Films were aged for at least seven days at room temperature;

(d) Films were cut into 1" wide strips;

(e) Several film strips were immersed in JP-4 for 24 hours at room temperature;

(f) The samples which could be tested were tested for tensile strength.

The effect of 24-hour immersion in JP-4 at room temperature on lapped joins was also evaluated. Results are shown in Table 50.

The results of the lab work on calendered samples show:

(a) Bostik 1095/#9 Boscodur is clearly the best adhesive;

(b) CRL-3 rubber has consistently higher join strength than CRL-4 (see Tables 47 and 49);

(c) Calendered samples have consistently higher join strengths than the same materials uncalendered.

On the basis of the lab work, an overlap of 8 inches was selected for the prototype membranes.

The seams in the first prototype of Membrane #1 were very weak, as follows:

1" wide x 12" sample	-	102 lbs. strength
2" wide x 12" sample	-	289 lbs. strength
3" wide x 12" sample	-	295 lbs. strength

The tests were run by having the overlap join between the sets of jaws while having only a single layer of membrane in the jaws. The low seam strength was clearly attributable to application technique and surface preparation as described in I.K.3., I.K.4., I.L.4. I.L.5.

After the assembly of the first prototype of Membrane #2, the results equivalent to those described for prototype #1, Membrane #1 were:

1" wide x 12" sample	-	713 lbs. strength
2" wide x 12" sample	-	1275 lbs. strength
3" wide x 12" sample	-	2200 lbs. strength

Failure was not due to adhesive failure. More information is available in Table 51.

Following the initial assembly of Membrane #1, prototype #1, contact was made with Graco Co., Inc. to see if the adhesive could be handled in a more efficient and effective manner. They reported that either their 5:1 Monark 225-654 mounted on cart or 9:1 President 225-840 mounted on cart was suitable. The details of the recommendations are given in Table 52.

G. TESTING

The tests made during this work were done according to the specified test methods (see Appendix B), except for grab strength and shear strength tests.

Grab strength proved impossible to measure according to test standards. The problem was that with only 1 sq. in. holding the fabric, and 2000 lbs. force being exerted, it proved difficult to hold the fabric without severely damaging the yarns.

The question to be answered was how to increase the coefficient of friction in the jaws to a point where the pressure required to hold the fabric is not so high as to damage the base yarns. After substantial use of time, a method was developed that proved satisfactory. During the grab strength tests a special rough material, described below, is placed between the jaws and the membrane on both sides.

The jaws are tightened to prescribed torque for manual jaws or to a prescribed pressure with pneumatic jaws.

The established torque is 100 ft-lbs. (or up to 150).

The established pressure is 2000 psi.

The rough material is made as follows:

> A 6" x 6" piece of very coarse emery (manufactured by Behr-Manning, Inc.) is glued to a 6" x 6" piece of fine emery paper. The pieces are glued back to back with a very small amount of Hysol epoxy patch #151. The mixed epoxy is diluted with acetone before applying. Care must be taken to avoid excessive epoxy. After evaporating the acetone, the pieces are

cured in a Carver press at 1000 psi and a temperature of 190° F for 10 minutes. In the press, nine layers of Teflon and a piece of Scott towel are put between the plate and the emery cloth.

For use the pieces are cut $1\frac{1}{2}$" x $1\frac{1}{2}$" and placed fine side against the jaw.

All of the grab strength tests were run at 10 in./min.

After the failure of Membrane #1 during the tests at WES on February 18-19, 1969, showed dramatically the limitation of existing lab tests for expedient airfield material. A test was developed which has some of the characteristics of the locked wheel test. Figure 3. diagrams the experimental arrangement used.

A description of the shear test follows:

a. The sample size is 3 inches x 12 inches.

b. The bottom of the sample is held securely in the Instron jaws.

c. One of the top jaws has a 3-inch x 3-inch smooth steel or rubber face.

d. The other top jaw has a 1" x 1" smooth steel face, on which the edges have been beveled on a 1/16" radius.

e. Hydraulically loaded jaws are used with a variable control on the pressure.

f. A 2-inch gage, measured between the 3" x 3" jaws, is used.

g. The speed is 10 inches per minute.

h. A light machine oil is applied to the surface of the 3" x 3" top jaw and to the surface of the membrane that contacts that jaw surface.

i. The 1" x 1" jaw and the surface of the membrane that contacts that jaw are cleaned with toluene. Care must be taken to avoid oil contamination on that side of the membrane.

j. The force to pull the membrane through the top jaws (called static force) typically peaks. and then decreases to a constant value (called dynamic force).

Interpretation of shear test results:

TEST ARRANGEMENT FOR SHEAR TEST

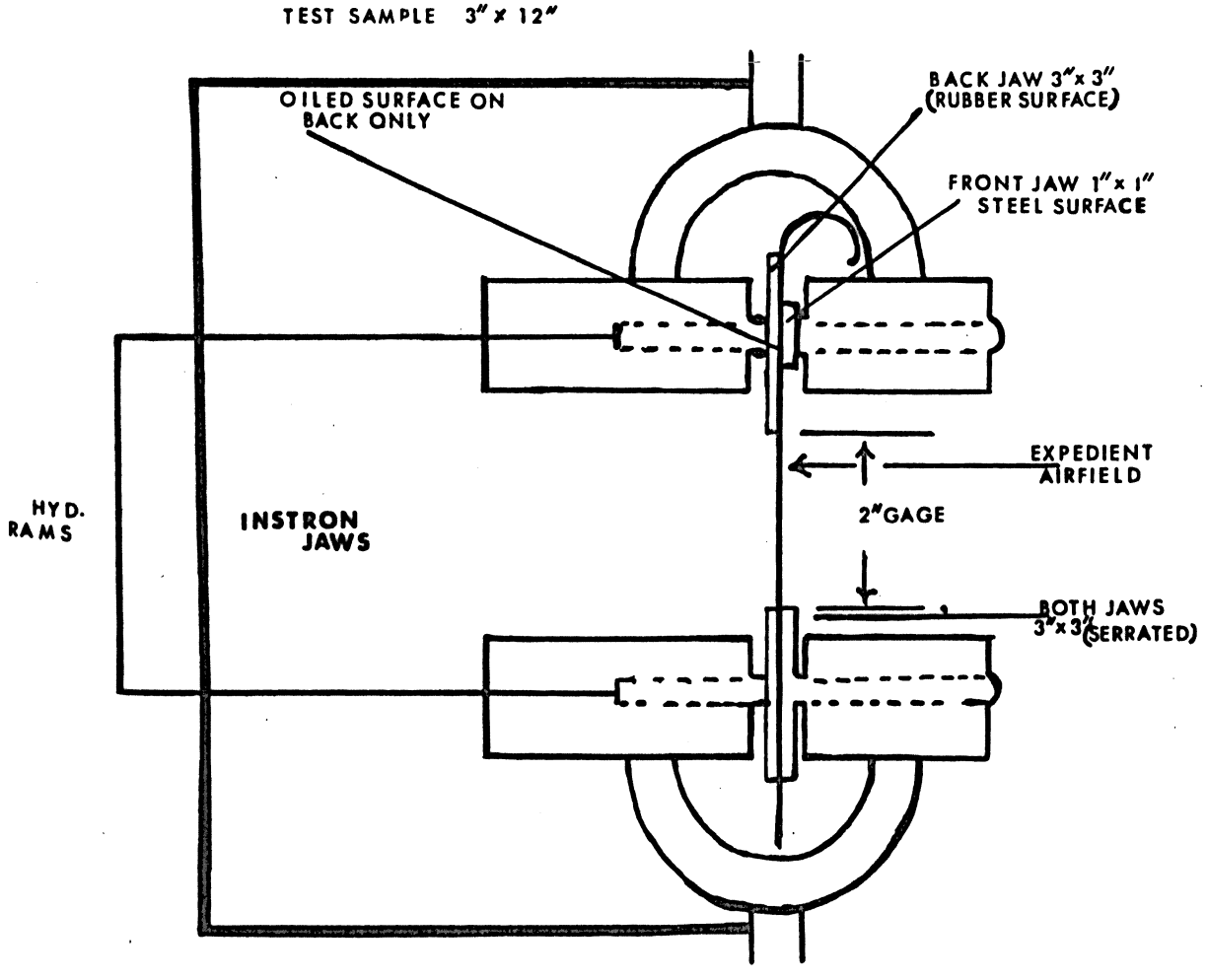


FIGURE 3.

The test is not, in its present state, 100% quantitive or foolproof. It does appear very useful. Visual examination of the tested samples quickly reveals major defects in the rubber as illustrated by the results given in Table 53.

It appears that for neoprene rubber, the dynamic force must achieve a value of 570 lbs. at 2000 lbs/sq. in. pressure to be satisfactory. If properly developed, the concept of the shear test shows substantial promise as a laboratory method of evaluating membrane-like materials. A complete evaluation would be a project in itself.

H. CALENDERING AND PRESS CURING

The analysis of press curing was made by:

(a) Roughly establishing some **nominal control values for the** needling variables;

(b) Producing a fabric at those established control values;

(c) Impregnating the control fabric **using** standard conditions;

(d) Carrying out a statistical design of press curing using the impregnated control fabric;

(e) Analysing the press curing results to select a 'standard' set of conditions;

(f) Carrying out a statistical design of needling. See Section I.D;

(g) Based on (f) above recheck.

The conditions selected for the nominal control value of the needling variables were:

Fabric	#1
Web	115 grains/ft.^{2} of Type 100, 6/3, nylon
Penetration	3/8"
Take-Up	300
Needle Density	34/inch
Needle Angle	45°
Needle Type	Torrington #78-1216-221

The control sample , **10" x 12",** shrank 4% in the filling and about $\frac{1}{2}$% in the warp during needling.

The control sample was impregnated with CRL-5 rubber to 50% dry rubber. The rubber was applied with a roller.

The pressing pressure and curing investigation was done with a 2 squared factorial design. The pressing pressure (psi) was coded as a dummy variable with:

$$X_1 = \frac{\log_{10}(\text{pressure}) - 2.0}{1.}$$

The pressing time (seconds) was coded on a dummy variable with:

$$x_2 = \frac{\text{time} - 60}{40}$$

The results of the experimental design, summarized in Table 55, indicate that grab strength and tear strength are not significantly affected by large changes in pressing pressure and pressing time. Thickness is affected by both variables. Increasing pressure or time decrease thickness; however, blistering may occur. For the standard conditions of pressing and curing, pressure was selected at 335 psi and time at 80 seconds. Increasing the time should have no adverse effect. For pressure changes within a factor of two, the effect on thickness will be minimal.

The results from these experiments was used as input for web and needling procedures, Section I.D.2. In Section I.D.2. are also considered the results of calendering a sample of fabric.

> The sample was extremely easy to calender and a thickness of only 72 mils was achieved with 7.6 oz./ sq.ft. total weight and 53% rubber. There was no indication of regain. On that basis it appeared that calendering would be straight forward.

The calendering of the #2 Membrane, Prototype #1, did not prove easy as discussed in Section I.M.3.

I. NON-SKID SURFACES

1. Materials and Methods of Application

Two approaches were taken:

(a) Modifying the rubber surface of the membrane, or

(b) Adding an anti-skid compound on top of the finished membrane material.

The first approach has the potential advantage of ease of application, economy, and a more flexible membrane.

Some Val Spar Anti Slip #1085 compound was applied as follows:

(a) A coat of CRL-3 was applied to #4 Membrane treated with CRL-3. The grit was sprinkled on while the latex was still wet; then the sample was dried at 125°F. Another coat of CRL-3 was applied and dried at 125°F. (b) Same as (a) but second coat of CRL-3 omitted. (c) Some of the grit was sprinkled on the dry surfaces and the CRL-3 was applied and dried at 125°F. (d) The grit was mixed in with the CRL-3 and applied to the membrane and dried.

The coated samples looked quite good and plans were initiated to apply the material to Membrane #2 after calendering.

After failure of Membrane #1, it became clear that if the base rubber had inadequate strength to withstand the locked wheel test, it certainly would not have enough strength to hold the anti-skid compound during the same test.

The second approach, adding an anti-skid compound to the surface, has the disadvantage of being rather tricky to do reproducibly and being expensive, but had the advantage of having been investigated at WES.

(a) The initial lab trials with the W.P. Fuller anti-skid compound, 201 Fuller Non-Skid, were disappointing. The 201 Fuller anti-skid compound was applied to WX-18 and to #8 fabric treated with the CRL-4 rubber. The application was by roller and was done over a 6" x 6" area. Adhesion to the rubber was poor in both cases. When the fabric was bent or flexed, the anti-skid compound tended to crack and flake off. A thin film of this

anti-skid compound was also stiff, brittle, and weak.

(b) A sample of material from American Abrasives Metals Co., Irvington, N.J., Neopoxo #42, was tested and compared to the 201 Fuller Non-Skid. The Neopoxo #42 was inferior due to poorer adhesion, poorer strength, and because it was more brittle.

Prior to production and testing of Prototype #1, Membrane #1, it appeared that the Valspar #1085 gave superior flexibility and adhesion. Plans were made and equipment ordered to apply the Valspar #1085 into wet rubber, dry, and over-coat with rubber for Prototype #1, Membrane #2, after calendering and before curing.

During the application of 201 Fuller Non-Skid to Prototype #1, Membrane #1, done with rollers (18" wide, 2" nap), it became clear that the rollers were not satisfactory for this purpose. The anti-skid was applied over templates as at WES.

The difficulties were:

(a) The coat was too heavy, and

(b) The coat was non-uniform because the grit tended to remain on the roller and in the trough.

During the locked-wheel skid tests of Prototype #1, Membrane #1, at WES, this matter was discussed in detail with Corps of Engineers personnel. The locked-wheel skid tests and discussions indicated the importance of having a very light coat of anti-skid and the importance of the method of application. An excessively heavy anti-skid coat is brittle and prone to break up and to flake off. Since the removed abrasive anti-skid compound is under the locked-wheel, it will abrade the rubber and the anti-skid compound. The abrasion may be substantial. The actual required amount of anti-skid is very low.

The method of application is also a significant variable since the uniformity of the coat is affected, as is the quality of the bond to the substrate. The best known and tested method was that used at WES: A spray system. For Membrane #2 and Prototype #2, Membrane #1, a spray gun identical to that recommended by WES was used to apply the anti-skid compound.

The spray system has the advantage of improving the uniformity of application, improving the control of the amount of application, and increasing the rate of application. The spray system seems to improve adhesion of the resin to the substrate, presumably due to the high velocity of the spray on impact with the substrate.

The spray system for the application of the anti-skid compound is comprised of the following Binks equipment:

- One Model 7E2 Spray Gun with a #64191 rear closure

- One 5 gallon Heavy Viscosity Pressure Material Tank with bottom outlet, Model 17-5460

- One Model 85-103 Air Control Unit.

There are difficulties with this spray equipment. There is no provision for mixing the anti-skid in the holding tank. When spraying slowly, the grit-like material tends to settle out, but this is not a problem with a normal rate of usage. There is a marked tendency for the feed line to the spray gun to clog if spraying is stopped for more than about one minute.

2. Use of Template

With the 201 Fuller Non-Skid, it is not necessary or desirable to have complete coverage of the surface. WES reports that 23% coverage, 2-in.-diameter holes on 4-in. centers, is sufficient to achieve the required friction with 201 Fuller Non-Skid; the centers of all holes being spaced 4 in. from the center of all adjacent holes. This has been proven out with Membrane #1, Prototype #2. See Section I.N.5.

For Prototype #1, Membrane #1, the anti-skid compound was initially applied over a ½-in.-thick template. The template was too heavy to handle and was too thick. Part of that sample was prepared with a 1/8-in.-thick masonite template. The masonite template was only 4' x 3', which made the job very slow.

For Membrane #2, Prototype #1, a 96' x 48" masonite template was used. It proved necessary to provide shrouds around the template to prevent over-spray. The masonite templates were difficult to handle.

For the Prototype #2, Membrane #1, three masonite templates and one aluminum template were made. The aluminum template was made with handles and removable sides. It was intended that the aluminum template be cleaned and re-used. The masonite templates were made for backup if the aluminum template was unsatisfactory. On a technical level, the aluminum template proved quite satisfactory; however, it was somewhat difficult to move and clean.

The masonite and aluminum templates were considered approximately equal in overall usefulness. There is, however, an alternative that appears attractive: namely, to use a layer of prepunched disposable material to give the non-skid pattern.

The material might be either specially treated paper or plastic film. A material of that sort should be available in roll form, and it should also be possible to have a specified pattern punched in the material. In use the material would be laid down on the membrane and weighted or taped down. Adjoining strips could easily be overlapped to match the pattern. The anti-skid would be sprayed on and allowed to cure. The pattern material would be removed, leaving the patterned anti-skid. It should be possible to do a complete airfield section at one time using this method. The method should be a substantial improvement over the use of masonite templates, which are messy, difficult to position, and time-consuming.

J. PACKAGING

In considering the packaging requirements the important factors were:

(a) Volume - It is desired to minimize the total volume;

(b) Impact Resistance - To be air-droppable;

(c) Packaged Life - 10 years.

The total volume of an airfield section, at 0.080 inches thick, is only 45.3 cubic feet; whereas the maximum allowed package volume is 420 cubic feet. The difference between the membrane volume and the allowed package volume indicates a large probability that the actual required package size can be substantially less than the maximum allowed size.

The packaging problem is resolved into two separate factors. The first factor is how to prepackage the membrane into the minimum total volume of a suitable shape. The second factor is the selection of materials and techniques to combine the "prepackaged" membrane with the required accessories in a package suitable for air-dropping.

It was considered that the membrane would certainly not be fragile. The main packaging considerations would then be protecting the accessories, storage life, and suitability for air-dropping. The AFC packaging expert discussed the basic requirements with several vendors. The most promising prospect would utilize a combination of TRI-WALL PAK triple-wall, corrugated, 6" depth honeycomb. This exterior composite would be strapped to a wooden or plastic pallet. Figure 4 shows a conception schematic of the palletizing carton. The accessories would be packed into an interior composite carton that would fit, together with the prepackaged membrane, into the exterior palletizing carton. The membrane would be prepackaged, as discussed below, giving a particular shape. Figure 5 shows the projected result, based on rather optimistic packing.

To achieve the results depicted in Figure 5, the 66' x 103' membrane would be accordion-folded as shown in Figures 6, A & B, giving a folded strip with dimensions of 66' x 57" x 2". This strip would be accordion-folded as shown in Figures 6, C & D, giving the final shape of about 40" x 48" x 60". The folded membrane would be strapped to hold the required shape.

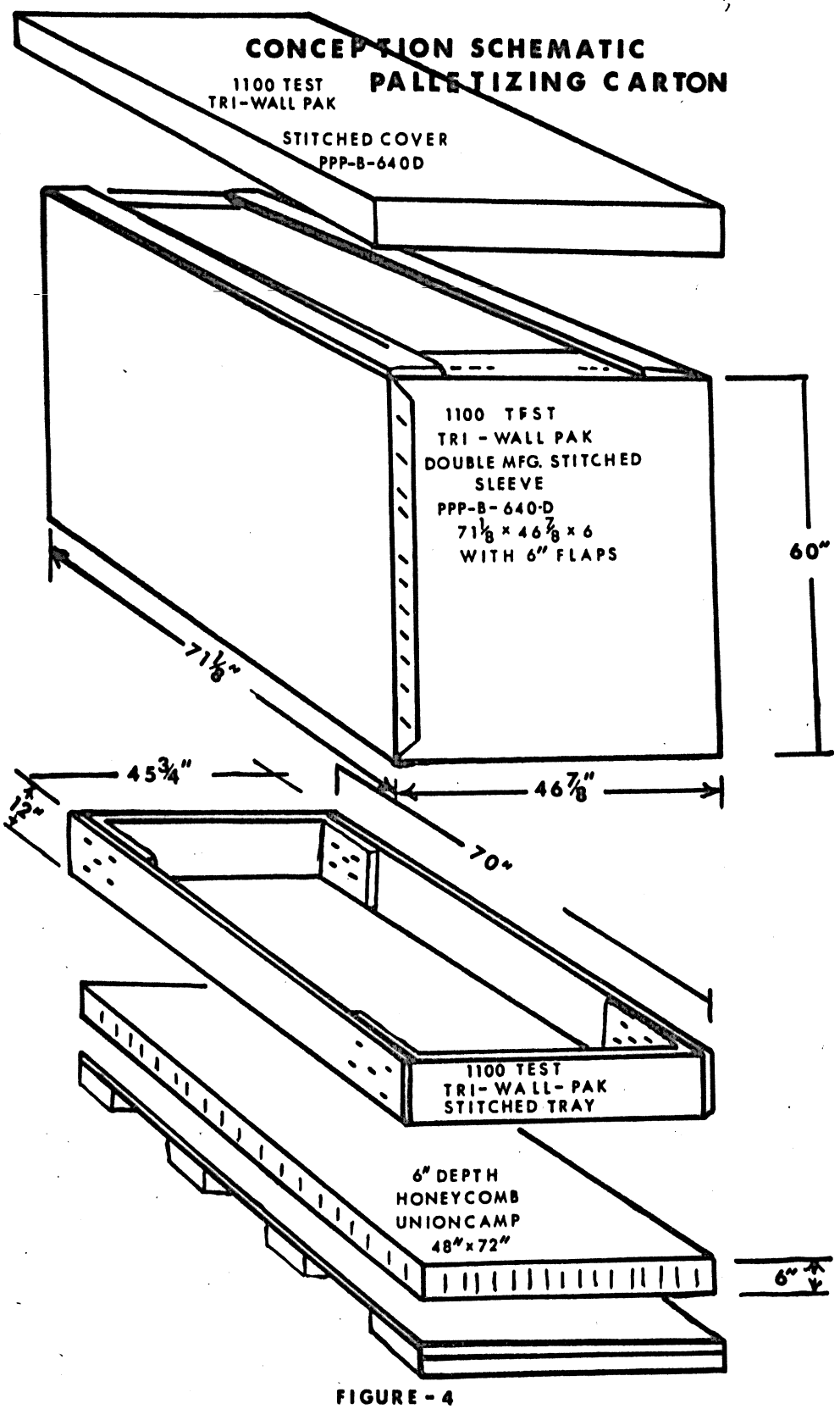

CONCEPTION SCHEMATIC
PALLETIZING CARTON
1100 TEST
TRI-WALL PAK
STITCHED COVER
PPP-B-640D
1100 TEST
TRI - WALL PAK
DOUBLE MFG. STITCHED
SLEEVE
PPP-B-640-D
71⅛ x 46⅞ x 6
WITH 6" FLAPS
60"
71⅛"
45¾"
46⅞"
70"
1100 TEST
TRI-WALL-PAK
STITCHED TRAY
6" DEPTH
HONEYCOMB
UNIONCAMP
48" x 72"
6"

FIGURE - 4

PRE-PACKAGED MEMBRANE

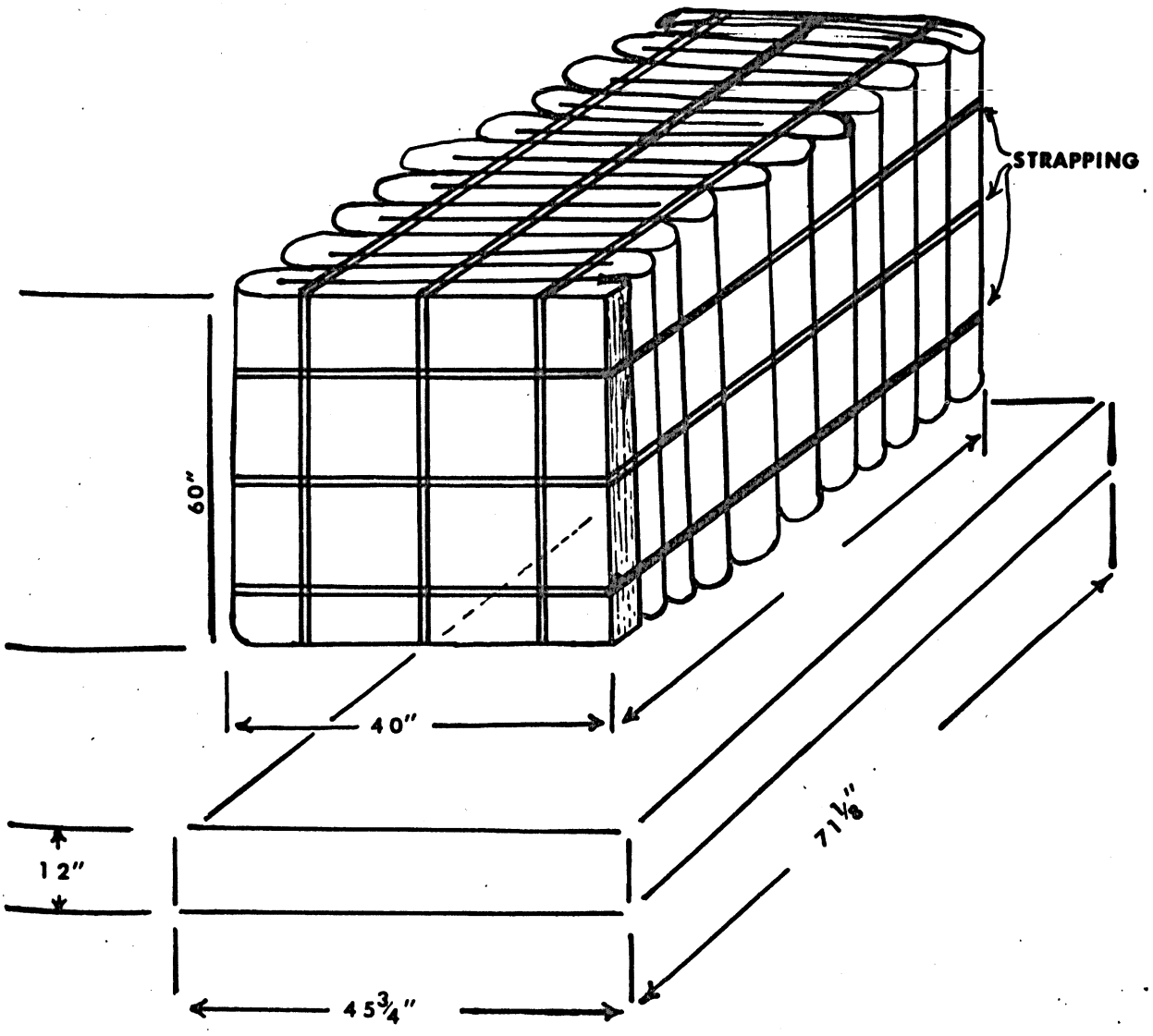
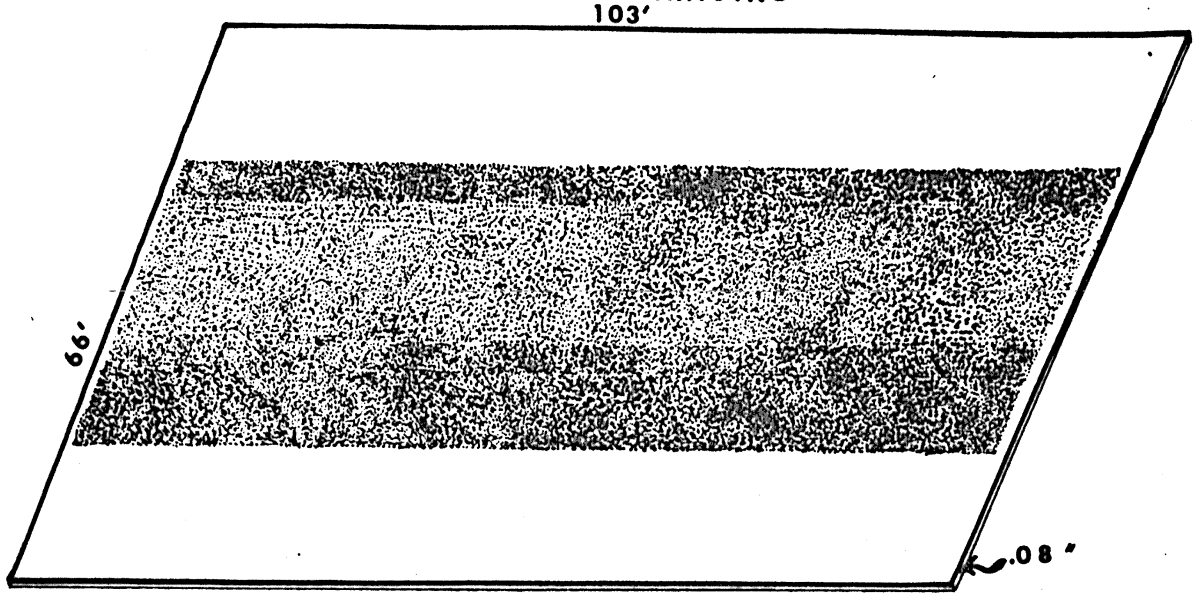
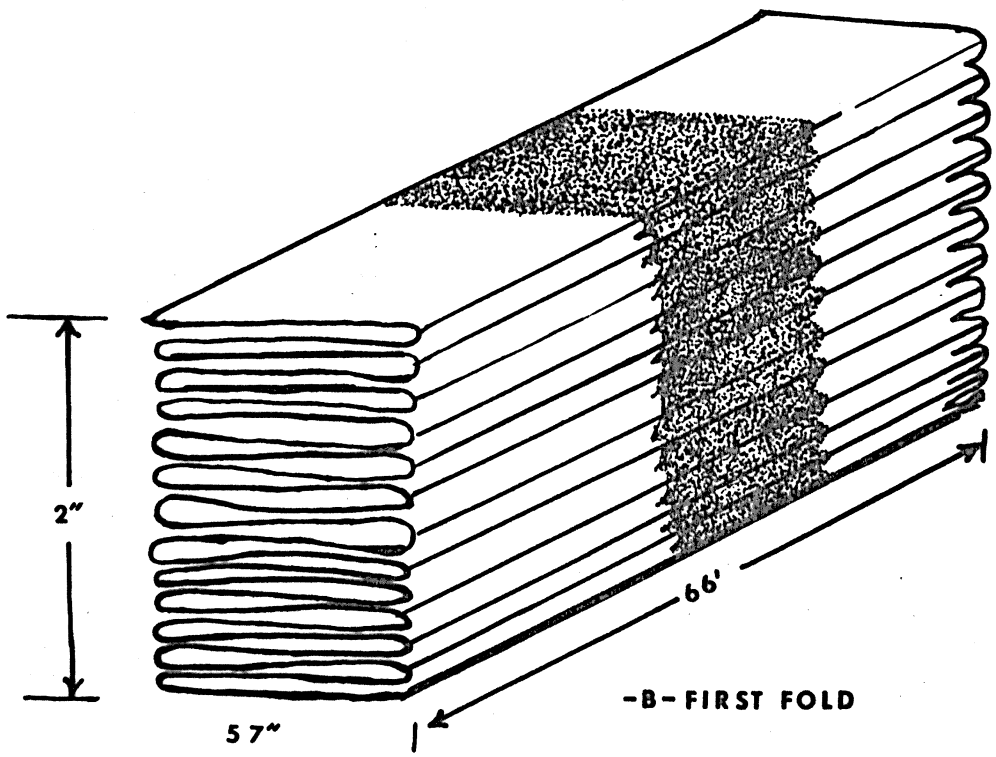


FIGURE-5

MEMBRANE PACKAGING



-A- FLAT SECTION



-B- FIRST FOLD

FIGURE-6

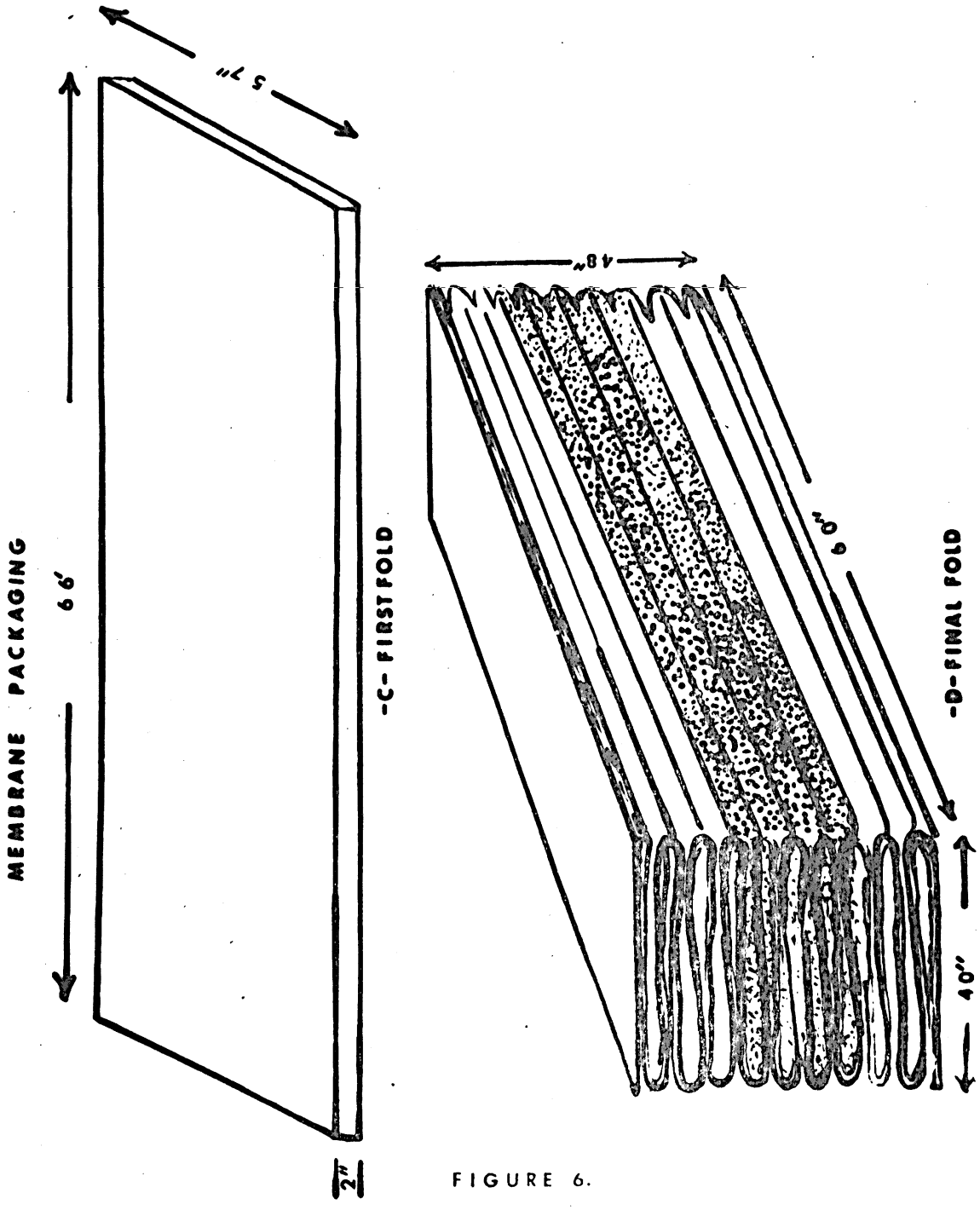


FIGURE 6.

It was intended to utilize Prototype #2, Membrane #1, for packaging trials. These trials would have given empirical packing factors to apply for the 103' x 66" full-sized pieces. Arrangements had been made to have several trial containers made up for the full airfield sections. Due to the financial situation, these plans were not pursued.

Prototype #1, Membrane #1, was packed without any particular effort into 42 cu. ft. This amounts to a packing factor of 0.0208 feet of membrane. (Packing factor is defined as the volume required to contain the prepacked membrane divided by the area of the membrane.)

If the package shown in Figure 5 can be realized in practice, the packing factor will be 0.0098, which represents an improvement of 2.1 times compared to Prototype #1, Membrane #1. While the realized packing factor of 0.0208 will allow one complete running section to be packed within the required volume, substantial improvement is certain. The required volume would be 142 cu. ft. with the realized packing factor.

Packing improvement is certain because:

(a) No attempt was made to minimize volume with Prototype #1, Membrane #1.

(b) The anti-skid application was much too heavy on Prototype #1, Membrane #1, which required extra space.

(c) The relative area covered with anti-skid decreased from 0.64 with the prototype to 0.47 with a full section. The anti-skid covered area is, of course, thicker than the bare membrane, and requires more volume.

We are quite confident that the packing factor can be reduced by 35% and are hopeful that a 45-55% reduction is attainable.

K. PRODUCTION OF PROTOTYPE #1, MEMBRANE #1

1. Fabric Production

a. Warp Dressing

The 4400 d Roto-Set Dacron warp yarns were dressed without R&D involvement by production personnel at the North Monmouth plant.

Reeling was done from producer-type packages directly onto a pinless dresser. There were not enough ends available from the original shipment; so the producers' packages split to provide more ends. From the pinless dresser, the yarns were warped onto the warp beam under a compressor roll. The warper would not handle a full beam; so a split beam was used. No difficulty was experienced.

b. Winding

4400 d Roto-Set Dacron yarns filling were wound on a standard Whitin - Schweiter automatic filling bobbin winder that is not equipped with layer lock . The $8\frac{1}{2}$-inch bobbins were turning 4000 rpm. There was no difficulty in winding.

c. Drawing-In

Standard procedure was used for drawing-in on 6 harnesses for the body, utilizing a straight draw, plus 2 harnesses for a selvage. The twistless yarn was reported to be somewhat difficult to draw in.

d. Weaving

The loom used was a 192" Crompton & Knowles D loom. The initial weaving and operating conditions were:

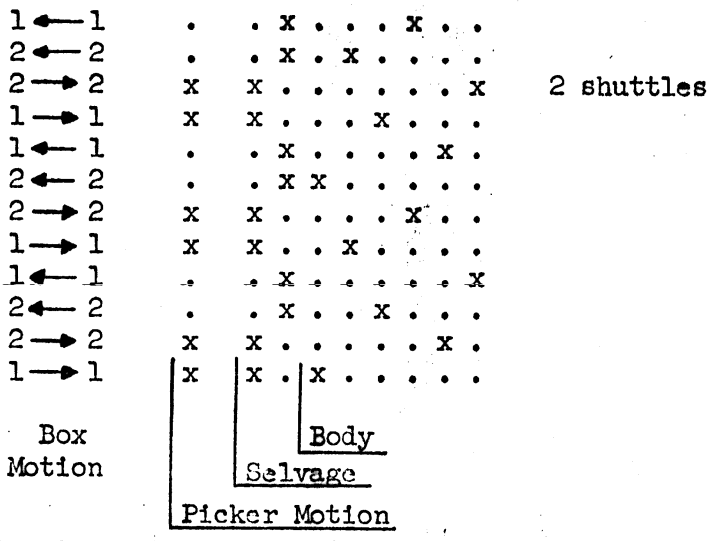
Reeding: $6\frac{1}{2}/4$

Total Ends in Warp: 4160

Reed Width: 160"

Number of Harnesses: 6 + 2

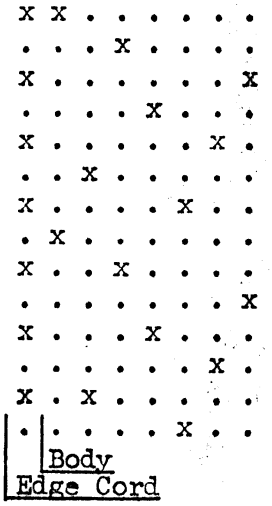
Weave Chain:



By changing loom adjustment, 21 ppi were achieved. In an attempt to increase the pick count, the head motion broke. After the head motion had been repaired, the end count was reduced from 26 ends per inch (epi) to 24 epi by rereeding 6/4. The maximum attainable pick count was increased to 22 ppi.

Attempting to weave the selvage from the warp was completely unsuccessful. The selvage yarns have higher take-up than the body and became too tight to weave.

In an attempt to increase the pick count, the warp was redrawn on 7 + 1 harnesses and reeded 6/4. The weave chain was altered to:



With the change of weave, the attainable pick count became 23 ppi. The decision was made to proceed with this construction, namely: 7 harness satin weave at 24 x 23 yarns per inch. The edge cords, which were each several ends of filling yarn, were run from spools.

In order to maintain the pick count at 23, the loom was extensively readjusted. Particular details follow:

3 nylon loops were used in the shuttle.

Beat of the pick was at front center.

Crossing of the harnesses was 1/8 to 1/4" ahead of beat up.

Head motion was set from 0 to 4 teeth ahead of the box motion.

The head motion timing gear was adjusted to have the first set screw between 12 and 12.30 o'clock, and the second set screw between 3 and 3.30 o'clock, referring to the adjustable gear as viewed from the open end.

The whip roll was raised one inch above the normal position.

The loom was operating at the very limit of its capabilities. As is usual when operating under these conditions, quality and productivity were both low. It proved totally impossible to pick out miss-picks.

e. Burling

The burling of this fabric was, as expected, extremely difficult and time-consuming. There were numerous miss-picks. It proved impossible to replace missing picks in burling. There were a number of double picks that caused a noticeable light pick count when one pick was removed. There were grease spots and slubs caused by men working on the loom during the many adjustments and minor repairs required. Approximately 10 times the normal burling work was required. The fabric was burled three times.

2. Impregnation, Coating and Curing

The spray line and oven are described in Appendix C.

During all of this work, variations in conditions were made almost continuously in our attempts to eliminate the numerous problems that arose.

The fabric was cut into two pieces; one piece was 100 yards long, the other piece was 50 yards long. The pieces were designated 1 and 2, respectively. Each piece of membrane had pieces of waste material sewn on both ends for each pass, for leaders and trailers for leading into and trailing out of the oven. The rubber used was CRL-3 rubber.

It was initially desired to produce portions of Prototype #1, Membrane #1, with two different weights; 7.5 and 7 oz./sq.ft.

A 6" wide by full width piece was taken from the end of each roll after each pass.

In discussion of the individual application passes are found data on the weight of the membrane. This weight is based on the 6" wide strip that was cut after each pass. The weight data from the strips were not used in the manufacture of the membrane.

To control the weight, the data from the weight and dimension of the full rolls were used.

During all of the impregnation and coating passes, the rubber application was alternated from one side to the other.

The details of each pass follow;

a. First Pass

The initial conditions for Roll 1 were:

Temperature:	230°F
Pin Setting:	160"
Application Rate:	6 lbs./minute (ppm); (2.4 oz/sq ft. wet rubber)
Holding Tank Pressure:	15 psi
Spray Booth:	#1
Speed:	2.6 fpm

Press Roll Pressure: 30 pli
Chromalox Setting: 70%

During this pass, the following changes in conditions and observations were made. The application rate was varied by changing the pressure on the holding tank from 13 to 20 psi. The chromalox units were cut off.

The edges of the fabric were curling at the spray booth and no rubber was being applied to some edge sections.

The pins were brought in to 154" to ease the strain on the pins.

The press roll was lifted.

There was no blistering.

The initial conditions for Roll 2 were:

Temperature:	230°F
Pin Setting:	154"
Application Rate:	Varied, not measured
Holding Tank Pressure:	10 psi
Speed:	3 fpm
Chromalox:	0
Press Roll Pressure:	None

During this pass the following changes in conditions and observations were made. The membrane blistered.

Variation in chromalox power from 0 to 70% did not improve the results.

Variation in air pressure on the holding tank from 10 to 13 psi did not help to eliminate the blistering.

b. Second Pass

The initial conditions for Roll 1 were the same as for Roll 1, pass 1, except the pin setting was 154". Severe blistering occurred. It could not be eliminated. Roll 1 was cut into two 50 yard pieces, 1A and 1B.

The conditions for Roll 2 were the same as for Roll 2, pass 1. Blistering was much more severe.

c. Third Pass

The initial conditions for Roll 1A, Roll 1B, and Roll 2 were:

Temperature:	230°F
Pin Setting:	154"
Application Rate:	3 ppm (1 oz/sq.ft. of wet rubber)
Holding Tank Pressure:	5 psi
Speed:	3 fpm
Chromalox:	50%
Spray Booth:	#2
Press Roll Pressure:	30 pli

During a check on the application rate, it was found to have changed from 3 ppm to 5½ ppm at the same holding tank pressure. There was no additional blistering. The press roll was used in an attempt to flatten the blisters. It was unsuccessful. After the third pass the weights were 5.1, 5.9, and 5.6 oz./sq.ft. for Rolls 1A, 1B, and 2, respectively.

d. Fourth Pass

The conditions for Roll 1A and Roll 1B were the same as in the third pass, except the press rolls were raised and the speed was found to have increased to 3.6 fpm without changing the controls.

There was no blistering. After fourth pass the weights were 5.7 and 6.4 oz./sq.ft. for Rolls 1A and 1B, respectively.

The conditions for Roll 2 were the same as for Rolls 1A and B, pass 4, except the speed was increased to 4 fpm and the application rate was increased to 5½ ppm.

Roll 2 finished pass 4 at 6.4 oz./sq.ft.

e. Fifth Pass

The conditions for Roll 1A were the same as for Roll 2,

pass 4, except the application rate was 3 ppm.

Roll 1A finished at 6.4 oz./sq.ft.

f. Sixth Pass

The conditions for Roll 1A were the same as in pass 5.

Roll 1A finished at 6.5 oz./sq.ft.

The weights, based on total weight and size, after coating were 7.5, 7.0, and 6.9 oz./sq.ft. for Rolls 1A, 1B, and 2, respectively.

g. Curing

All the rolls were given one pass with following conditions:

Temperature:	290°F
Pin Setting:	150 inches
Chromalox Setting:	80%
Speed:	1 fpm

Roll 1A finished at 7.0 oz./sq.ft.
Roll 1B finished at 6.7 oz./sq.ft.
Roll 2 finished at 6.6 oz./sq.ft.

There was no difficulty during the curing pass. An attempt was made to trim the edges with carpet trimmers, but they could not cut the membrane.

3. Assembly

During all of the assembly of this prototype piece, the air temperature in the building never exceeded 70°F and was usually about 60°F.

The original three rolls of membrane were inspected, trimmed, and cut to length. The best sections of all the rolls were selected for the prototype pieces. The inspection and selection of pieces was complicated by the many weaving faults that were evident. Six 50' pieces were selected and cut to length. The edge trimming of the six pieces was varied depending on the quality of the edges. The trimmed widths were from 9.5 to 11.8 ft. All of the marking was done with

straightedges and chalk. All cutting was done by Mamin cutters. The six pieces were positioned and prepared for seaming by washing the matching edges with water.

It was found impossible to achieve a clean surface. The water used to wash repeatedly became soapy . No other surface preparations for joining were made.

The adhesive, Bostik 1095/#9 Boscodur, was applied to the matching sides of the membrane with 9"-wide paint rollers. Each seam was completed before starting the next. The adhesive was extremely viscous and sticky. The application of the adhesive was unsatisfactory and time consuming.

When the adhesive had dried to the tacky stage, the pieces were joined as described below. Due to the difficulty of achieving a uniform coat of adhesive, the time required to apply the adhesive was excessive, and the adhesive dried nonuniformly. The procedure whereby the membrane pieces were joined together was: (a) each of the ends of the top piece of the overlap join was held up, and (b) a 300-lb. lawn roller was used to press the center of the section together. The roller was rolled back and forth across the joint, working toward one end, gradually forcing the membrane edges together. When one half of the seam was complete, the operation was completed for the other half. The pieces of membrane had been positioned prior to application of the adhesive, and there was no movement of the pieces during the joining.

The seams appeared weak after setting for several hours and were, in fact, found to be very weak when tested, as shown in Table 56.

The 201 Fuller Non-Skid was applied with paint rollers over templates. The paint rollers were 18" wide with 1" nylon nap rollers. Two templates were used, a 4' x 8' x $\frac{1}{2}$" plywood template, and a 4' x 3' x 1/8" Masonite template. Prior to the application of the anti-skid compound the membrane was washed. However, the results were the same as for the seaming; e.g. a soapy wash solution. The plywood template was completely unusable because of its thickness. The application of the anti-skid compound was done using the thinner Masonite template.

The application of the anti-skid compound with the large paint rollers was difficult due to:

(a) The fluid part of the mixture tending to transfer to the membrane with relatively little of the solid part.

(b) The application tending to be nonuniform.

(c) Application rate being very slow.

(d) The solid part of the mixture accumulating on the edge of the pattern holes and in the paint roller, from where it would fall in large drops.

After application of the anti-skid compound, the membrane was allowed to cure over the weekend, then coated, and shipped to WES. When packing the membrane, no effort was made to achieve a minimum size package. The final crate dimensions were 13'6" x 46" x 13". The material was surprisingly easy to handle and package.

4. Testing

WES reported Prototype #1, Membrane #1 failed the lock-wheel skid tests because of:

(a) Inadequate adhesion between the rubber and the base fabric;

(b) Excessive flaking off and removal of non-skid surface;

(c) Low shear and peel strengths developed by adhesive single lap joints.

The membrane was approximately $2\frac{1}{2}$ times poorer than the WX18 membrane in the lock-wheel skids to failure, but when failure occurred it was less severe than is the case with the WX18 membrane. The results of our regular lab tests are given in Table 56.

There was some question regarding the state-of-cure of the CRL-3 rubber, and a series of tests were performed to determine if this might have been a possible cause in the failure of Prototype #1, Membrane #1. Sample of the membranes were postcured under different conditions. The grab strength is not significantly affected as shown in Table 54. The shear test results given in Table 53, show two results:

(a) Prototype #1, Membrane #1, is clearly inferior to WX18.

(b) Increased cure does not significantly improve the shear resistance.

L. PRIMING AND RUBBER MODIFICATIONS SUBSEQUENT TO 1968

1. Work on Defining the Problem

a. Nature of the Problem

The performance of Prototype #1, Membrane #1, in the tests conducted at WES provided the impetus for our modifying the product. It was believed that the primary cause of failure was poor rubber-to-fabric bonding. The rubber itself also apparently had inadequate strength. Obviously, any improvements would have to come not in the area of the fabric but rather in the area of pretreating and rubberizing the fabric. Since Du Pont supplies both the Dacron yarn and the neoprene latex, we asked for the assistance of their people in the Textile Fibers and Elastomers departments.

b. Du Pont Test Work

We provided Du Pont with samples of Fabric #20, Prototype #1, Membrane #1, and CRL-3 rubber. A copy of Table 1a, which is a summary of the requirements for the expedient airfield, was also provided. Their evaluation involved preparation of samples that were cut into one-inch-wide specimens and tested for 180° peel adhesion. The control sample was made by bonding cotton duck, with an epoxy adhesive, to the Prototype #1, Membrane #1, that we supplied. All other samples were prepared completely by Du Pont, starting with Fabric #20 and three rubber formulations: CRL-3, CRL-6, and one of their own formulations (L-635). Impregnation was achieved by squeeze-roll application and build-up of the coating was achieved by brush. There were no instability problems. Immediately following the last coat of latex, a piece of cotton duck was pressed to the surface, using a hand-held roller. Each application was dried; all drying was done in a vacuum oven at 125°F. Final drying was overnight at 125°F, followed by a cure of (30/325).

They had no problems with bubbles or blisters during curing. One inch of the cotton duck at one end was not bonded to the coated fabric in order to facilitate testing. The end of the cotton duck was clamped in one jaw of an Instron machine and the corresponding end of the coated fabric was clamped in the other jaw. The force required to separate the composite was recorded. Data on sample preparation and test results (average of two) are given in Table 57.

The percent D417 pick-up was based on the weight of the untreated fabric. Saturant material is used for impregnation and was diluted with tap water to a total solids content of 40%, reducing the (LVF) Brookfield viscosity of the CRL-3 from 1150 and 358 centipoise to 55 and 33 centipoise, as measured at 6 rpm and 60 rpm, respectively. The #10 sample is the control sample, which was supplied by us. It was coated in our Maine mill with undiluted CRL-3. The L-635 formulation is given in Table 58. The samples were not pulled apart completely by Du Pont and they sent them to us. We tested them on our Instron at 10 in./min. jaw separation rate and obtained similar results. Our results are initialed (AFC) in Table 57.

2. Solving the Problem

a. Du Pont's Recommendations

Du Pont demonstrated that the rubber-to-fabric bond strength could be increased by a factor of at least three, using a combination of several changes.

(a) Pretreat the fabric with D417, a water-based primer system, described in Table 59 (see Section IV.N.1.g);

(b) Add a bonding agent (Hylene MP), see Appendix A, to the latex used for the impregnation of the fabric;

(c) Reduce the viscosity of the latex used for the impregnation with tap water.

In addition to the above recommendations for improving the rubber-to-fabric bond strength, Du Pont also offered some ideas on increasing the toughness of the rubber.

First, use Neoprene Latex 400, which has 47 wt.-% of chlorine in the polymer, instead of Neoprene Latex 571, which has 37 wt.-% of chlorine in the polymer. Second, for an accelerator, use thiocarbonilide instead of the Tepidone/Thiuram E combination. Third, go to a higher state-of-cure. This last item should also increase the abrasion resistance.

b. Follow-Up Work at Albany on Priming the Base Fabric

Work was conducted to determine procedures and techniques to be employed using the lab padder (three rolls vertically oriented with 10-in. faces). We wanted to learn the answers to several questions. Is heat stabilizing of the base fabric necessary or desirable, and if so, what time/temperature conditions are best? What total solids content of the D417 primer gives the recommended pick-up, which is 2.5% to 3.0% based on the untreated fabric weight? How many times does the fabric have to be dipped in D417 and run through the padder? Is drying between successive dips necessary to achieve the desired pick-up? What is the best nip pressure to achieve the desired pick-up? What conditions of time/temperature appear to be equivalent to the recommended cure for D417, viz. 4-$\frac{1}{2}$ min. at 400°F?

c. Results of Primer Work

In our investigation we obtained answers to the questions posed above. Heat stabilizing of the fabric is required, with (5/360) giving satisfactory stability. A TSC(*) of 6.1% in the D417 primer is suitable, this being the TSC of the primer as mixed. Two applications of the D417 primer are required for suitable pick-up and uniform distribution, with the fabric being passed through the squeeze rolls one time after each application. The fabric must be dried after each application. Squeeze-roll nip pressure of 60 pli was satisfactory and not critical. A partial primer cure of (2/360) was best, and the time/temperature relationship is critical. Overcuring reduces tear strength, reduces rubber to fabric adhesion, increases grab strength, and increases stiffness. (* Total Solids Concentration)

d. Follow-Up Work at Albany on Impregnating and Coating the Base Fabric

There were two objectives to be realized. First, to determine how to impregnate the fabric in a manner reproducible on production equipment. Second, to prepare and test samples.

Tests quickly revealed that the primed fabrics must be padded to insure complete penetration and impregnation of the rubber. Without padding, latex penetration is poor. Further padding test showed that five impregnations with padding gave good results. The results of a typical series of lab impregnations are shown in Figure 7.

e. Sample Preparation for Adhesion Tests

To evaluate the effect of Du Pont's recommendations on flame resistance, peel adhesion strength, grab strength, and tear strength, a series of samples were prepared as described in Table 60. Fabric #20 was used for these samples. The rubber formulations are given in Table 61.

f. Results of Adhesion Tests

Test results are shown in Table 62 and are summarized as follows. First, the adhesion of the CRL-3 to the fabric is low and is independent of the D417 primer (cf 2 and 3 peel adhesion). Second, Hylene MP in the impregnation latex (CRL-6) markedly improves the adhesion (cf 3 and 4 peel adhesion). Third, the dynamic slip resistance of the CRL-3 coated samples is low (1, 2, 3, 4) but is enhanced by a factor of two for CRL-7 coated samples (cf 3 and 5, cf 4 and 6). Fourth, the presence of Hylene MP in the impregnation latex lowers the tear strength (cf 3 and 4). Fifth, use of the D417 primer also lowers tear strength (cf 2 and 3). Sixth, the grab strength is increase somewhat by coating with CRL-7 instead of CRL-3 (cf 6 and 4).

g. D417 Primer Modification

Although Table 59 gives the most recent formulations and directions for preparation of the primer modified for particular needs, it is not the exact formulation we used in the lab work. The reason for this is that the supplier (DuPont) of the Hylene MP changed their manufacturing process to come up with a finer particle size. The

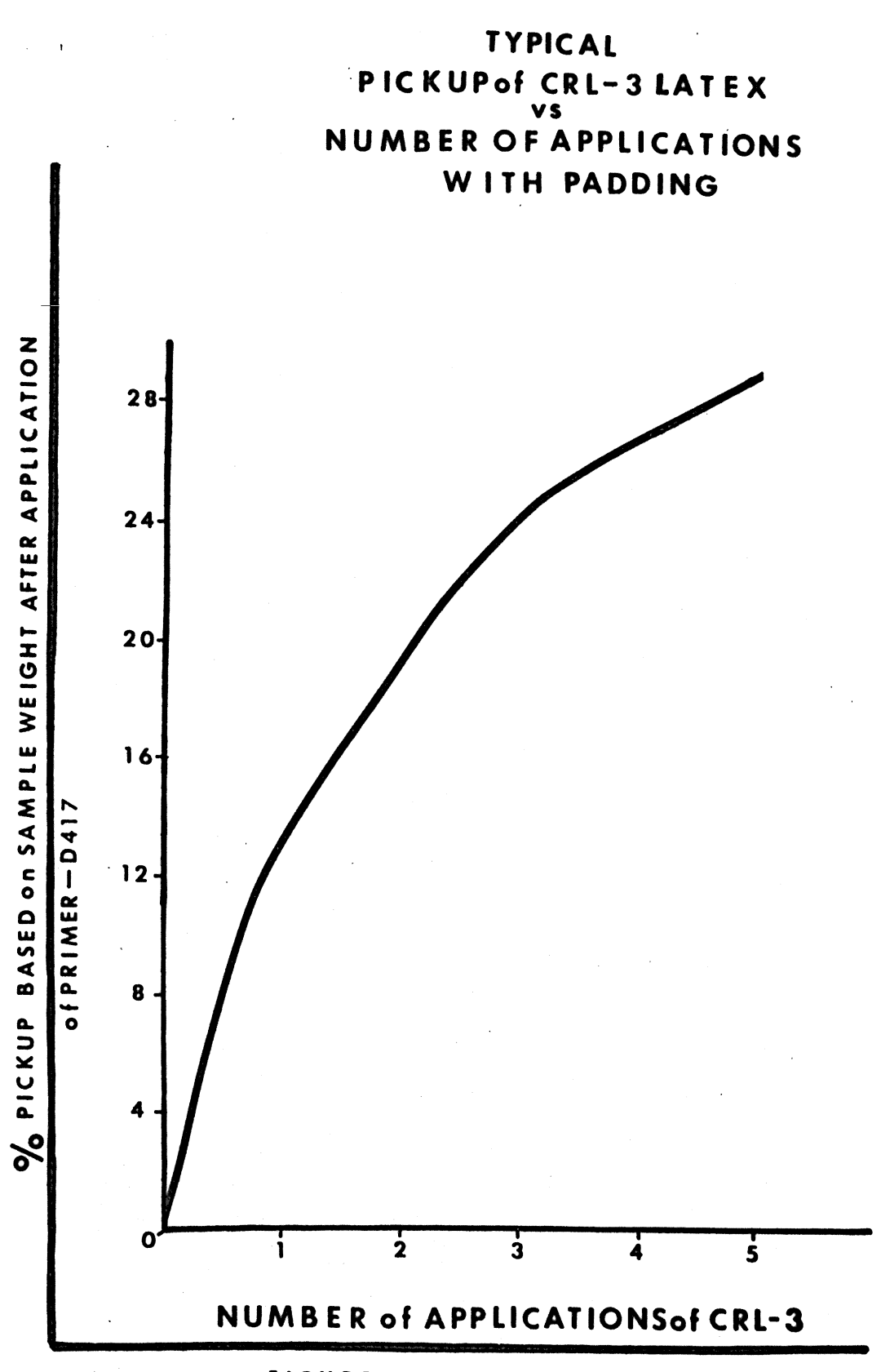

TYPICAL
PICKUP of CRL-3 LATEX
vs
NUMBER OF APPLICATIONS
WITH PADDING
% PICKUP BASED on SAMPLE WEIGHT AFTER APPLICATION
of PRIMER-D417
28
24
20
16
12
8
4
0
1
2
3
4
5
NUMBER of APPLICATIONS of CRL-3

FIGURE 7

original samples of Hylene MP were rather coarse and required ball-milling in the preparation of Part A for the D417 formulation. The more recent Hylene MP samples, with finer particle size, are readily dispersible in Part A. Hylene MP with lot numbers of 307 and higher have the fine particle size. The calculated TSC is 6.2%. Solids determinations averaged 6.7% before curing and 6.0% after curing. The small loss during curing is attributed to loss of phenol (Hylene MP is the bisphenol adduct of methylene bis 4-phenylisocyanate), which is regenerated when Hylene MP is heated above 300°F. The viscosity of D417, as originally formulated by Du Pont, was too high to achieve good penetration. We experimented with five different concentrations of gum tragacanth in water and measured the viscosity soon after mixing, and again after standing overnight. A gum concentration between 0.5% and 1.0% in Part B of the D417 formulation resulted in a suitable viscosity.

Du Pont's Textile Fibers people recommend using the D417 within two weeks, but only because they had no reason for allowing longer storage periods. They observed no change in the D417 during a two-week period. The Hylene MP should be stable indefinitely at room temperature in aqueous dispersion unless the Epon 812 reacts with it.

3. Discussion

This portion of the work conclusively demonstrated the following:

(a) A primer is required;

(b) Priming may be accomplished by padding;

(c) Padding is required during impregnation;

(d) Padding procedures were established;

(e) The first coat of rubber must include a bonding and strengthening agent;

(f) Excessive amounts of the bonding and strengthening agent markedly lowers the teat strength.

Other information is inferred from this portion of the work

as follows:

(a) The bonding and strengthening agent must be used with discretion;

(b) The CRL-3 rubber is too weak to withstand the shear experienced during the locked wheel test;

(c) Most of the rubber coating should be applied to the top side of the membrane for wear resistance.

Based on the available information, while realizing the substantial uncertainty of the effect of Hylene MP, a plan for the perfection of Prototype #2, Membrane #1, was prepared as described in Sections I.N.2 and I.N.3.

M. PRODUCTION OF PROTOTYPE #1, MEMBRANE #2

1. Fabric Production

a. Warp Dressing

The warp yarn, 7700 denier Dacron, was dressed directly from the producer packages. The warp was dressed by production personnel at the North Monmouth plant without R&D involvement. Reeling was done directly on to a pinless dresser. From the pinless dresser the yarns were warped on to the warp beam under a compressor roll. No difficulty was encountered.

b. Winding

The 7700 of Roto-Set Dacron filling yarns were wound on a standard Whitin-Schweiter Automatic Filling Bobbin winder that is not equipped with layer lock . The $8\frac{1}{2}$-inch bobbins were turning 4000 rpm. There was no difficulty in winding.

c. Drawing-In

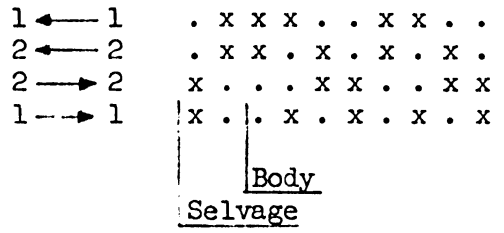
Standard procedure was used for drawing-in on 6 harnesses for the body, utilizing a straight draw, plus 2 harnesses for selvage. No difficulty was reported.

d. Weaving

The material was woven in a 130" Crompton & Knowles W3 loom. There was no difficulty in weaving.

The weaving set up and operating conditions were:

Reeding:	5.75/2
Total Ends in Drop:	1200
Reed Width:	104 inches
No. of Harnesses:	8 + 2
Weave Chain:	



Box Motion

Selvage:	28 ends each side draw in as, xx.. ..xx Harness: 9 10
Picks per Inch:	12
Set Up:	Standard Filament

e. Burling

Burling was straight forward and without difficulty.

f. Needling

The fabrics were needled on a 150-inch Hunter needle loom manufactured by James Hunter Div. of Crompton & Knowles. The conditions used were as follows:

Take Up:	215
Penetration:	7/16 inch
Needle:	Torrington #78-1216-221
Web:	115 grains/sq.ft. of Type 100 6/3 nylon
Needle Angle:	45°
Speed:	250 strokes/minute.

The material finished needling at 93 to 95 inches wide and 3.1 to 3.4 oz./sq.ft.

2. Impregnation and Coating

The spray line and oven used in this work are described in Appendix C.

The fabric was in five pieces, designated A to E, inclusive. The pieces were nominally 53 yards long by 94 inches wide. During these trials many changes were made in operating procedure.

Before each piece was treated, a leader was sewn on to bring it into the oven. After each pass, the leader was removed and the total roll weight was determined. The specific weights were determined from the dimensions and total weight of the pieces. The rubber used was CRL-3 rubber. Details of each pass follow:

a. Roll A

The initial conditions for the first pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. of Rubber/min.:	11
Lbs. Pressure on gage:	40
Spraying Unit used:	2nd
Speed:	6 fpm
Chromalox Setting:	50%
Press Roll Position:	Up

Comments on the first pass are:

(a) The fabric was coated web-side up;

(b) 40 lbs. pressure is maximum that can be obtained;

(c) The size at the start was 52 yds. x 94"; it finished 51.5 yds. x 92½";

(d) Cutting webbing off the edges should be done before coating;

(e) The uncoated fabric looked good before coating;

(f) Rubber soaked through but was spotty;

(g) The membrane finished at 4.8 oz./sq.ft.

The initial conditions for the second pass were:

Temperature:	230°F
Pin Setting:	92
Lbs. of Rubber/min.:	11
Lbs. Pressure on gage:	40
Spraying Unit Used:	1st
Speed:	6 fpm
Chromalox Setting:	50%
Press Roll Position:	Down with no hydraulic pressure.

Comments on the second pass are:

(a) The fabric was coated web-side up;

(b) The membrane finished at 51.5 yds. x 93";

(c) By squeezing with the rubber rolls, the fabric looked as though it was totally saturated;

(d) The membrane finished at 5.7 oz./sq.ft.

The initial conditions for the third pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	15
Lbs. Pressure on gage:	41
Spraying Unit Used:	2nd
Speed:	6 fpm
Chromalox Setting:	80%
Press Roll Pressure:	30 pli

Comments on the third pass are:

(a) The membrane was coated web-side up;

(b) We were not getting enough rubber onto the surface of the membrane. At approximately 20 yds, we stopped and hooked up a 4th spray nozzle. Too

much rubber was applied to the membrane, causing blistering. The application rate was reduced to 12 ppm and the Chromalox units were turned off.

The initial conditions for the fourth pass were as follows:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	varied* (large orifice)
Lbs. Pressure on gage:	varied*
Spraying Unit used:	2nd
Speed:	6 fpm
Chromalox Setting:	80%
Press Roll Pressure:	30 pli

Comments on the fourth pass are:

(a) The membrane was coated web-side down;

(b) The membrane finished at 47.75 yds. x 91.5";

(c) The membrane finished at 8.4 oz./sq.ft.

(d) * Due to the blistering and uneven distribution of rubber, it was decided that we would run at different application rates as indicated by gage pressure. 10 yds. of the membrane was run at 40 lbs. pressure and it blistered. 10 yds. of the membrane was run at 30 lbs. pressure and it blistered. 10 yds. of the membrane was run at 25 lbs. pressure and it blistered slightly. 10 yds. of the membrane was run at 21 lbs. of pressure and it did not blister. 10 yds. of the membrane was run at 12 lbs. pressure and it did not blister.

b. Roll B

The conditions for the first pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	Varied* (large orifice)
Lbs. Pressure on gage:	Varied*

Spraying Unit Used:	#2
Chromalox Setting:	80%
Press Roll Position:	Up

Comments on the first pass are:

(a) The fabric was coated web-side up;

(b) The fabric started at 60 yds. x 94" and finished at 60 yds. x 91.5";

(c) At approximately 30 ft., one nozzle plugged up. Had to shut down and clean out. Put in a 4th nozzle, ran again. Too heavy! Shut down again.

(d) After the second coat there were approximately
31 yards with heavy coat
16 yards with no coat
13 yards with light coat

(e) * The speed and application rate were also adjusted.

The initial conditions for the second pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	18 (3 nozzles - small orifice)
Lbs. Pressure on gage:	40
Spraying Unit Used:	2nd
Speed:	3 fpm
Chromalox Setting:	80%
Press Roll Position:	Up

Comments on the second pass are:

(a) The fabric was coated web-side up;

(b) Only the uncoated surface, 16 yards, was treated.

(c) Due to the uneven coats the weights taken are not of any use.

(d) There was no difficulty on this pass.

The initial conditions for the third pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	*varied
Lbs. Pressure on gage:	*varied
Spraying Unit Used:	#1 unit
Speed:	5 fpm
Chromalox Setting:	80%
Press Roll Position:	*varied

Comments on the third pass are:

(a) The fabric was coated web-side down;

(b) We made so many changes that they are too numerous to mention. We had to divide this roll into two pieces, 37.37 yds. x 91.5 " and 20 yds. x 92", respectively. We incurred blistering, plugging up of spray nozzles, uneven coating, etc.

(c) The membrane finished at 7.15 oz./sq.ft. for the long one, and 6.8 oz./sq.ft. for the short one.

c. Roll C

The initial conditions for the first pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	18
Lbs. Pressure on gage:	40
Spraying Unit Used:	1st
Speed:	3 fpm
Chromalox Setting:	80%
Press Roll Position:	Up

Comments for the third pass are:

(a) The fabric was coated web-side down;

(b) The fabric started at 58 yds. x 94" and finished at 56.5 yds. x 92";

(c) Due to the rubber dripping off the bottom of the

material, we increased the chromalox to 100% and increased the speed to 4 fpm. This corrected the problem. We ran out of latex with 12 yds. of fabric untreated. We filled the holding tank and finished the piece. We shut the exhaust fan off.

The initial conditions for the second pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	7
Lbs. Pressure on gage:	18
Spraying Unit Used:	2nd
Speed:	7 fpm
Chromalox Setting:	50%
Press Roll Position:	Up

Comments on the second pass are:

(a) The fabric was coated web-side down;

(b) There was no serious difficulty except for a few blisters on the web side.

The initial conditions for third pass were the same as for the second pass.

Comments on the third pass are:

(a) The membrane was coated web-side up;

(b) The membrane finished 56 yds. x 92.5";

(c) There were no serious difficulties during the third pass except for scattered small blisters;

(d) Membrane finished 7.0 oz./sq.ft.

The initial conditions for the fourth pass were the same as for the second pass; except the speed was increased to 11 fpm.

Comments on the fourth pass are:

(a) The membrane was coated web-side up;

(b) The membrane finished at 7.35 oz./sq.ft.

(c) Severe blistering occurred, and only 27 yds. was coated.

The initial conditions for the fifth pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	8
Spraying Unit Used:	2nd
Speed:	6 fpm
Chromalox Setting:	50% to 80%
Press Roll Position:	Up

Comments on the fifth pass are:

(a) The first 27 yds. was not coated;

(b) The membrane was coated web-side down;

(c) The membrane finished 8.0 oz./sq.ft.

(d) The chromalox was increased to 80% to improve drying.

d. Roll D

The initial conditions of the first pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	14 to 15
Spraying Unit Used:	1st
Speed:	3 fpm
Chromalox Setting:	80%
Press Roll Position:	Down with no pressure

Comments on the first pass are:

(a) The fabric was coated web-side down;

(b) The membrane finished at 5.35 oz./sq.ft.

(c) After coating 10 yds., the application rate was increased to 16 ppm.

The initial conditions for the second pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	7
Lbs. Pressure On gage:	18
Spraying Unit Used:	2nd
Speed:	7 fpm
Chromalox Setting:	50%
Press Roll Position:	Up

Comments on the second pass are:

(a) The membrane was coated web-side up;

(b) The membrane finished at 5.95 oz./sq.ft.

(c) The coating was relatively light and yet blistering occurred in spots.

The initial conditions for the third pass were the same as for the second pass.

Comments on the third pass are:

(a) The membrane was coated on web side;

(b) The membrane finished at 6.5 oz./sq.ft.

(c) We first ran a 3-ft. section before running the balance of the roll. The operation appeared satisfactory.

Noticing that the weight pickup looked very low, we checked the application rate and got only 3 ppm instead of the desired 7 ppm.

The initial conditions for the fourth pass were the same as for the second pass.

Comments on the fourth pass are:

(a) The membrane was coated web-side up;

(b) The membrane finished at 7.5 oz./sq.ft.

(c) There were a few blisters

e. Roll E

The initial conditions for the first pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	7
Lbs. Pressure on gage:	18
Spraying Unit Used:	1st
Speed:	7 fpm
Chromalox Setting:	80%
Press Roll Position:	Down with no pressure

Comments on the first pass are:

(a) The fabric was coated web-side down;

(b) The membrane finished at 5.2 oz./sq.ft.

(c) We noticed this drum of rubber was slightly thicker than rubber from previous drums.

(d) A few yds. of membrane was cut off for samples.

The initial conditions for the second pass were the same as for the first pass except the 2nd spray booth was used and the press roll was up.

Comments on the second pass are:

(a) The membrane was coated web-side up;

(b) The membrane finished at 5.65 oz./sq.ft.

(c) The speed was increased to 18 fpm due to blisters forming on the surface. Chromalox was decreased to 50%.

The initial conditions for the third pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	7
Lbs. Pressure on gage:	18
Spraying Unit Used:	2nd
Speed:	7 fpm

Chromalox Setting:	50%
Press Roll Position:	Up

Comments on the third pass are:

(a) The membrane was coated web-side up;

(b) The membrane finished at 6.6 oz./sq.ft.

(c) The add-on was substantially less than the theoretical amount.

The initial conditions for the fourth pass were the same as for the third pass.

Comments on the fourth pass are:

(a) The membrane was coated web-side up;

(b) The membrane finished at 7.6 oz./sq.ft.

(c) This pass went surprisingly well.

The initial conditions for the fifth pass were:

Temperature:	230°F
Pin Setting:	92"
Lbs. Rubber/min.:	8
Speed:	6 fpm
Chromalox Setting:	50%
Press Roll Position:	Up

Comments on the fifth pass are:

(a) The membrane was coated web-side up;

(b) The membrane finished 8.6 oz./sq.ft.

(c) There were a few blisters from the heavy coat;

(d) Again we noticed a difference in the viscosity of two drums of rubber. The crew stated that one drum was like milk in texture when stirred; the other was like milk shake.

f. Summary

After completion of the coating and impregnation, the membranes varied in weight from 6.8 to 8.6 oz./sq.ft. and in thickness from 120 to 140 mils. All the pieces were blistered.

3. Calendering and Press Curing

All of the calendering trials were done on piece #A, trimmed to 84 inches wide. The initial calendering trial was made at 200°F with a pressure of 1430 pli on the calender rolls. With a grab range of 0 to 40 mils and a speed range of 0.5 to 5 fpm; the thickness was only decreased from 135 to 120 mils.

The temperature was increased in steps up to 350°F with no improvement. S-wrapping during calendering of the membrane had no effect on thickness. There was a recurring problem associated with these trials: at loadings in excess of 700 pli, the fabric would wrinkle in the nip. Extremely high tensions were applied at take-up and let-off to straighten the fabric at the nip. The tensions applied were so high that two equipment failures occurred. The tension device jammed, and the wind-up drive shaft, a 1" x 1" solid steel shaft, broke. With these results it was concluded that we could not calender the material!

All of the remaining material was shipped, after trimming to 61 inches, to our subsidiary, Globe Woven Belting Company, Buffalo, N. Y., for press curing. The material was press cured at 285°F under maximum pressure, 200 psi, for 10 minutes. A thickness as low as 75 mils was recorded shortly after pressing. The material was trimmed and returned to our Auburn, Maine, plant for assembly.

4. Assembly

Because of the difficulty with temperature on Prototype #1, Membrane #1, the assembly of this sample was done in a more confined space and a space heater was used to preheat the building and to maintain the air temperature above 75°F.

It was not necessary to trim the rolls of membrane; however, due to the substantial losses incurred during trimming for press curing, little excess material was available. The

material was inspected and a selection made for the order of assembly. The material was cut and laid out as follows, from left to right: A,A,E,E,E,D,D,C,C,C,D,A. The letter refers to the roll designation and the top membrane at each seam is from the membrane on the right.

The pieces were positioned; the seam areas were washed with toluene, sanded, and washed again with toluene. The adhesive was applied to the matching sides of the seam with 9-inch-wide paint rollers. The adhesive was mixed about 1/2 to 1 hour before use and was thinned with toluene to a satisfactory viscosity prior to use. This operation was much improved compared to that for Prototype #1, Membrane #1. When the adhesive had dried to the tack-free stage, the seams were joined as with Prototype #1, Membrane #1.

The anti-skid compound, 201 Fuller Non-Skid, was applied over a masonite template with the spray rig described in Section 5. The anti-skid compound was applied to the center 32 feet of the membrane.

The 2-ft.-high sides were put on the template to minimize overspray. After completion of the non-skid surface, the membrane was trimmed and shipped to WES.

5. Testing

a. By Albany Felt Company

The results of the grab, tear, and flame tests are given in Table 63. The seam strengths were tested. Different widths of material were tested, the overlap joint being in between the jaws but not held in either jaw. The test results are as given in Table 51 for a speed of 10 inches/minute. The shear strength was tested as described in Section G. The test results are given in Table 64. The test results seemed very good, with the exception of the filling grab strength, and we were quite hopeful about the results of the tests at WES.

b. By WES

As given by WES in a letter report dated April 14, 1970, the results of the tests of Membrane #2 were:

The membrane conformed to all laboratory requirements.

The anti-skid compound was nonuniform in coverage and tended to crack and flake off when the membrane was folded.

The membrane did not develop the minimum coefficients of friction when dry or wet, because most of the anti-skid compound was removed during the skid-tests. Failure developed in the membrane during the fourth and fifth locked-wheel skid across the surfacing.

N. PRODUCTION OF PROTOTYPE #2, MEMBRANE #1

1. Fabric Production

a. Warp Dressing (EX-579)

The 4400 d Roto-Set Dacron warp yarns were transferred from producers package to 40 end warping spools. This was done on standard spooling equipment. Care was necessary to ensure the twistless yarn did not catch and pull during spooling. The warping operation was extremely difficult. While the yarn was being reeled onto a wooden system pin dresser, some of the yarns would become very tight and others would become very slack. The reason for this is the extremely low extendibility of the yarn. During the spooling operation, the yarns had been put on the spools at slightly different lengths and densities. The variations in length were as high as 2 to 4%. During the dressing, the rotation of the spool was controlled by the shortest yarns. The short yarns became tight and the longer yarns became slack. It was necessary to run the dresser manually and with great care to avoid tangling of the slack yarns. A total of 4200 ends were dressed at a length of 330 feet. The yarns were warped off the dresser on to the warp beam without difficulty. The difficulties in dressing had led to some damage of the warp yarns.

It was concluded that this system of dressing is totally unusable on a production basis. (Two other warp dressing systems were tested. See I.K and I.O.)

b. Winding

The 4400 d Roto-Set filling yarns were wound on a standard Whitin-Schweiter automatic filling bobbin winder that is equipped with layer lock . The 10.125" bobbins were turning 4000 rpm. There was no difficulty in winding.

c. Drawing-In

Standard procedure was used for drawing-in on 7 harnesses for the body in a straight draw plus 1 harness for the edge cord. The twistless yarn was somewhat difficult to draw in due to the tendency of the "hook" to catch only part of the yarn. After the ends were drawn-in, they invariably tangled, causing minor handling problems.

d. Weaving

The loom used was a 300" Crompton & Knowles F6 loom with extra strength beams. This is a standard felt loom. Two changes were made for this fabric:

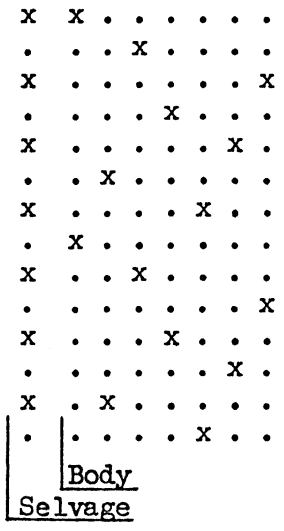
(a) The standard punched steel covered take-up rolls were re-covered with rubber lagging material.

(b) A powered wind-up roll was installed.

The weaving set up and operating conditions were:

Reeding:	6.00/4,4,4,4,4,5 (a 6-dent reed with 4 ends in each of 5 consecutive dents and 5 ends in the next dent)
Total Ends in the Warp:	4200 before dropping ends for width; 4175 after dropping ends
Reed Width:	165"
Number of Harnesses:	7 + 1

Weave Chain:



Shuttle:	Standard F2 shuttle with 4 nylon loops on both sides, and 2 nylon bristles.
Temples:	Single barrel on each side.
Pick Gears:	A:B:C:D; 50:22:48:44
Shuttle Tension:	Very low
Selvage:	None, one end from a separate spool was used for the edge cord. Edge cord must not be run from warp beam.
Picks/Inch:	25
Finished Width:	160"

This equipment was easily capable of weaving this 25 x 25 construction. During start-up the pick count was run up as high as 27 ppi. The poor dressing job led to noticeable variation in warp yarn tension and to warp yarn fraying. It was necessary to take pains removing all burrs and rough spots from material contacting the yarn (reed, shuttle box, race plate, needles, etc.). The tendency of the yarns to catch and pull is very marked and the results are quite noticeable in

the finished fabric.

e. Burling

The burling of this fabric was unusual. At approximately 1-ft. intervals across the width were noticeable streaks. The cause of the streaks could not be ascertained, but is probably either (1) 7700 denier yarn being spooled in place of the correct 4400 denier, or (2) two 4400 denier yarns were reeded and leased as one during dressing.

There were none of the normal weaving defects such as ends out, miss-picks, floats, broken ends. Almost every defect is attributed to the yarn catching somewhere. Defects found were: fraying, slubs, filling knots caused by slubs, and loose warp yarns.

2. Fabric Heat-Setting and Priming

a. Heat-Setting

Most of the fabric had a width of 154" before heat-setting (one portion was 158" wide, and another was 148" wide).

The spray line and oven are described in Appendix C. The heat was set at 360°F and the speed at 7 fpm. These conditions were used for all of the heat-setting trials described as follows:

(a) 5 ft. of 154"-wide material was heat-set at 144" between the pins (equivalent to 6% shrinkage) without difficulty.

(b) Trials of three large 154"-wide pieces at 145,144 and 142" between the pins led to the membrane jumping off the pins due to excessive shrinkage forces.

(c) One 154"-wide piece was heat-set with pin setting of $136\frac{1}{2}$" without difficulty. The piece was finished $137\frac{1}{2}$" wide.

(d) One 158"-wide piece was heat-set with a pin setting of $136\frac{1}{2}$". The piece finished 137" wide.

(e) One 148"-wide piece was heat-set with the pins set at 130". The piece, which ran without difficulty, finished 131" wide.

For the oven used, the construction of this fabric requires 11% allowance for shrinkage while heat-setting at 360°F. The total change was from 165 in the reed to 137 after heat-setting, giving a theoretical end count of 30 ends/inch. No change was detected in the length.

During heat-setting several pieces were run with the filling side up and several with the filling side down. For this fabric, which was woven without selvage, it is important to have the filling side down. Due to the unbalanced weave, the edges have a marked tendency to curl. If the filling side is up, the edges curl over the pins and subsequently form a bead along the edge of the fabric.

After completion of the initial heat-setting and priming of this fabric, a successful attempt was made to recover a portion of the fabric that had come off the pins.

The piece, approximately 60 ft. long and varying in width from 130 to 140 inches, was wet-up with water and run through the oven at 370°F and 7 fpm. The pins were set at 134½" and the fabric finished at 135" with no difficulty.

b. Priming

Two applications of D417 were made.

The first application was made in the second spray booth, at 7 fpm, 200°F, and 20 to 28 psi on the holding tanks. The application rate was approximately 11 ppm. The pressure of the press rolls was 30 pli. The fabric did not appear to dry completely. The fabric appeared completely saturated before the press roll.

The second application was identical to the first; except the oven temperature was increased to 220°F, and the primer was applied to the opposite side of the fabric. Application appeared completely satisfactory.

To check for dryness, the fabric was sent through the oven again and no weight was lost.

A trial precuring at 11 to 12 fpm and 360°F gave slightly excessive curing as judged by color and hand. The precuring of the rest of the fabric at 11 to 12 fpm and 350°F was completely satisfactory. The final precured fabric varied somewhat in color, a pale lemon yellow. The cause of the minor variation is not known. A total weight check of the fabric showed a primer pick-up between 1.9 and 2.6%.

3. Impregnation and Coating

Due to the differences in widths, the pieces were put through the oven with waste fabric separating them. All of the impregnation and coating passes were made at 7 fpm, and 200 to 210°F in the oven, except as noted below.

During all of the impregnation passes, the #1 Membrane tended to crease at the edges while going through the press rolls. The causes of the creases were:

(a) There was no fabric selvage and the edge tended to be thicker than the center; in winding, the thick edge tended to be stretched.

(b) The pins, which do the initial pulling of the fabric, tend to stretch the edges and distort the fabric. On long pieces this effect would be minimal since the wind-up roll would do most of the pulling.

(c) The press rolls are not correctly crowned. The rolls have not been recrowned in several years. The center sections are presumably worn.

The press roll exerted about 30 pli, and with a nip length of about 0.2, the pressure is only 150 psi, which is insufficient to damage the fabric. The major effect anticipated from the creases is a slight decrease in the amount of rubber applied during impregnation.

During the impregnation and coating passes of Prototype #2, Membrane #1, a piece of Membrane #3 was run ahead of Membrane #1. Membrane #3 was treated exactly as Membrane #1 except as noted below. The rubber used was CRL-3 with Hylene MP dispersion added as noted below. During all of

impregnation and coating operations there was no detectable change in width.

The details of each pass follow:

Impregnation Pass #1

All the fabrics were sprayed to saturation with CRL-3 rubber + 20 phr Hylene MP. After the fabrics were almost complete, it was noted that saturation was not complete on some of the edges of the fabrics. Material was treated warp-side up in spray booth #2.

Impregnation Pass #2

All the fabrics were sprayed to saturation with CRL-3 rubber + 10 phr Hylene MP. Material was treated filling-side up in spray booth #2.

Impregnation Pass #3

All the fabrics were sprayed to saturation with CRL-3 rubber + 10 phr Hylene MP. Material was treated warp-side up in spray booth #2.

Impregnation Pass #4

Identical to impregnation pass #2

Impregnation Pass #5

All the fabrics were sprayed to saturation with CRL-3 rubber + 10 phr Hylene MP. Material was treated warp-side up. The total amount of rubber spray-on during the fifth pass only amounted to 0.4 oz./sq.ft. of dry rubber, most of which was pressed out by the press rolls.

Coating Passes

The rubber for all coating operations was CRL-3 + 5 phr of Hylene MP. During all coating operations, no press roll was used.

Coating Pass #1

All membranes were sprayed with 0.2 oz./sq.ft. of wet rubber. The material was treated warp-side up in spray booth #2.

Coating Pass #2

Identical to coating pass #1, except filling-side was up.

Coating Pass #3

Identical to coating pass #1.

Coating Pass #4

The operation was switched to spray booth #1 for all subsequent passes. Otherwise this pass was identical to coating pass #2.

Coating Pass #5

Membrane #1 was sprayed with 0.45 oz./sq.ft. of wet rubber. Membrane #3 was sprayed with approximately 0.6 oz./sq.ft. of wet rubber. The material was treated filling-side up.

Coating Pass #6

Both membranes were sprayed with 0.5 oz./sq.ft. of wet rubber on the filling side. There were a few blisters on Membrane #3. The blisters were located on crease marks left from the impregnation. The membranes had become very stiff and tacky.

Coating Pass #7

The spray rate was increased to 0.6 oz./sq.ft. of wet rubber; otherwise conditions were identical to coating pass #2.

Coating Pass #8 and Coating Pass #9

Identical to coating pass #7

Coating Pass #10

Prior to coating pass #10, the Membrane #1 weight was 7.4 oz./sq.ft. The spray rate was increased to 0.9 oz./sq.ft. of wet rubber; otherwise conditions were identical to coating pass #4.

Coating Pass #11

The spray rate was increased to 0.95 oz./sq.ft. of wet rubber;

otherwise identical to coating pass #4.

Coating Pass #12

This pass was on the warp or bottom side; otherwise identical to pass #11.

Drying Pass

All the pieces were given a drying pass at 235°F and 2 fpm.

Curing Pass

All the pieces were given a curing pass at 335°F and 1 fpm. After curing, Membrane #1 weighed 8.5 oz./sq.ft. No weight determination was made on Membrane #3.

4. Assembly

The pieces of Membrane #1 were inspected, trimmed, and cut to length. For inspection the pieces were laid out on the floor, and areas with visible defects were noted. The lines for edge trim were snapped with a chalk line. The length cutting lines were snapped with a chalk line determined by a square from the trimmed edges. All cutting was done with Mamin cutters. (For production runs, edge trimming must be done with automatic cutters. The available edge trimmers would not cut the membranes.)

Three pieces were required to achieve the desired width. The first piece was made from one piece 21' x 124", and one piece 6' x 124". The pieces were to be joined by a 12" overlap transverse joint. The second piece was made 26' x 124". The third piece was made from one piece 18.33' x 124", and one piece 8.67' x 128". The pieces were to be joined by a 12" overlap transverse joint.

After longitudinal seaming the final dimensions were expected to be 26 ft. long by 29 2/3 ft. wide.

The pieces were positioned and prepared for seaming as follows:

(a) The overlapping sections were washed with toluene. (The overlap seam is 8").

(b) The overlap sections were sanded with a 3" x 8" belt

sander using fine sand paper. (The belt sander proved much superior to a circular sander). On both the top and bottom overlap sections, the amount of sanding was varied from relatively heavy near the edge to very light 9 inches from the edge. The top surfaces were sanded much more heavily than the bottom surfaces.

Due to the scant amount of rubber on the bottom, the sanding immediately exposed the base fabric. Where the transverse joints intersected the longitudinal joint, the fabric corners were sanded to a feather edge. The transverse edge of the upper membrane was sanded to a fine edge. The sanding of this edge was done from the bottom side of the membrane.

(c) After sanding and repositioning, the edges were again washed with toluene.

New adhesive was used for the joints. The new batch of adhesive was significantly lighter in color than the original lot, used for Prototype #1, Membrane #1, had been; and it seemed lower in viscosity. After thinning with about 20% of toluene, the adhesive was applied with 9" medium nap paint rollers. The transverse joints were completed before beginning the longitudinal joints.

After the adhesive had been applied to all of the overlapping edges of a seam, it was allowed to dry to the tacky stage suggested by the manufacturer. The ends of the top piece of the overlap joint were held up. A 300-lb. lawn roller was used to press the center portion of the seam together. The lawn roller was rolled back and forth across the joint, working toward one end of the seam (and then from there toward the other end), while gradually forcing the membrane edges to join. Each seam was completed in this manner before beginning another seam.

One flaw in the seams was noticed. As discussed in I.N.3, the edges of the membranes tend to be somewhat longer (1 or 2%) than the center. The membranes can still be joined without flaws; however, careful attention by the workers is required to ensure that the alignment is correct. Only a small advance is made on each pass of the lawn roller, as the top piece of membrane is pushed by the roller down onto the bottom piece of membrane.

After seaming,the entire top surface was washed with toluene in preparation for anti-skid compound.

The 201 Fuller Non-Skid was applied over the aluminum template with the Binks spray rig used for Membrane #2. All persons walking on the membrane surface wore specially cleaned overshoes. The aluminum template proved usable,although heavy and awkward. It proved very difficult to match the non-skid pattern. Only about 6 to 7 repeats could be made without cleaning the template. Cleaning the template took more time than the spraying; and during the cleaning operation, the spray rig invariably clogged up. The operating personnel were different than those when the first prototypes were made. Their inexperience led to some unnecessary drippage of anti-skid compound onto the membrane. An attempt was made to make more than 7 pattern repeats before cleaning the template. Dripping occurred from built-up anti-skid compound and an excessively heavy, messy pattern was applied.

After application of the anti-skid compound, the membrane was allowed to sit for three days to cure the adhesive and anti-skid. It was then shipped to WES together with lab samples of Prototype #2, Membrane #1, and Prototype #1, Membrane #3.

5. Testing

a. By Albany Felt Company.

No tests were made due to lack of funds.

b. By WES

As given by WES in a letter report dated April 14, 1970, the results of the tests on Prototype #2, Membrane #1, were:

The membrane met all laboratory requirements except flame resistance. Visual inspection indicated the need for improvements in non-skid application.

The membrane met the requirements for minimum coefficient of friction when wet and when dry. 48% of anti-skid compound was removed during the dry locked-wheel skid tests, however, only 4% was removed during the wet tests.

The membrane met the requirement for the test to failure with an 11-inch failure after 16 skids in one case and a small failure after 20 skids in another case.

c. Comments on Test Results

The field test results reported by WES are considered outstanding, particularly as compared to the earlier tests.

The requirements for flame resistance can be met. We were aware that the coating on the back side of the membrane was very light. This was done intentionally, as reported in Progress Reports #25 and #29. We decided to concentrate on solving the major problem of material failure by putting most of the rubber on the top surface, even though this action would certainly tend to increase flammability, since the combustible fabric is much more easily exposed on the back side. The flammability requirement can be met by any one of the following methods:

(a) At constant weight, put more rubber on the back side.

(b) At constant amount of rubber on the top, put more rubber on the back side.

(c) For the back side,develop a rubber with higher flame resistance.

Method (a) has the advantage of constant weight and simplicity. It has the disadvantage of slightly decreasing the amount of rubber on the top surface, which may decrease the number of skids to failure.

Method (b) has the advantage of simplicity and the disadvantage of increasing weight and stiffness.

Method (c) has the advantage of minimizing weight and the disadvantage of being more technically difficult.

The application of anti-skid compound can certainly be further improved. When applying the anti-skid compound with the hand-held spray rig, operator technique

is crucial in obtaining uniform and satisfactory coverage. Lack of funds prevented any preliminary spraying trials. This subject is considered in detail in Section I.N.4.

Substantial improvement in application technique is definitely obtainable.

O. PRODUCTION OF PROTOTYPE #1, MEMBRANE #3

1. Fabric Production

a. Warp Dressing (EX-585)

The 7700 d Roto-Set Dacron yarns were transferred from the producers package to 1¼-lb. tubes. This was done on a production tube winder. Great care was necessary to ensure the twistless yarn did not catch and pull during tube winding.

The warping operation caused some difficulty. The warping was done on our heavy-duty wire dresser. The dresser, custom-made for heavy and difficult monofilament and multifilament yarns, is capable of handling these yarns without difficulty. Difficulty was experienced, however, with the yarn slipping off the edge of yarn package. This caused the dressing to be time consuming. It is entirely possible to eliminate that problem by using an over-end creel, such as that used for Prototype #1, Membrane #1. The particular warping system suffers from the disadvantage that only 250 feet can be dressed on the warp. Two warps were dressed and woven, one 250 feet long and one 130 feet long.

It was concluded that this system of dressing was practical but uneconomical on a production basis (see Sections I.K and I.N).

b. Winding

The 7700 d Roto-Set Dacron filling yarns were initially wound on a standard Whitin-Schweiter automatic filling bobbin winder that is equipped with layer lock . The 10.125" bobbins were turning 4000 rpm. There was some

difficulty in winding. None of the bobbins produced would run in the loom. The yarn would sluff off the bobbin when the shuttle hit the box; on the next pick, a nice mess would be woven into the cloth.

An attempt was made to use cops,but the twistless yarn could not be held in the cop shuttle.

An attempt was made to wind the filling on a special research winder. This is a heavy-duty Whitin-Schweiter with speed control and heavy-duty tensioning devices. The attempt was not successful.

Another attempt was made to wind the filling yarn on a Lazenby winder. This trial was successful and high quality usable bobbins were produced. This winder is basically a slow device and 100% operator attention was required.

It is of interest to speculate on cause and effect of these winding difficulties. The 7700 d filling was wound on a Whitin-Schweiter winder without layer lock at the No. Monmouth plant. That filling yarn was used for sample production without any difficulty on a narrow (90")loom. The filling yarn wound on similar equipment at Albany could not be used on a wide (360") loom. The only significant difference between the winder at No. Monmouth and the winders at Albany is that the Albany winders are equipped with layer lock . The purpose of layer lock on the winder is to help hold the yarn in place on the bobbin. The winding results tend to indicate the use of layer lock is deleterious to a good filling bobbin of this yarn.

Weaving on a wide loom is much more demanding on the filling package compared to weaving on a narrow loom. In a wider loom the shuttle travels at a higher speed and has a higher peak acceleration when it hits the box. The high acceleration tends to loosen the yarn on the bobbin. If several layers of yarn become loose, they can tangle and will then either leave a slub or cause a smash.

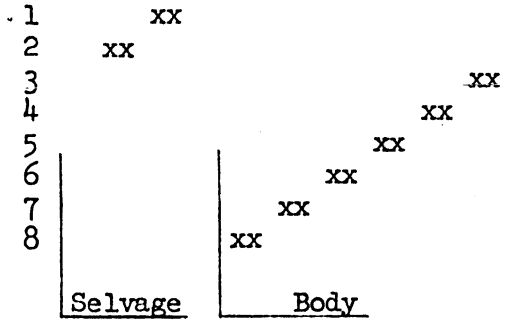
The question of how to wind the 7700 d filling yarn was not completely resolved. It can be wound satisfactorily; however, an acceptable commercial practice

was not achieved.

c. Drawing-In

The twistless yarn was somewhat difficult to draw in due to the tendency of the hook to catch only part of the yarn. After the ends were drawn-in, they invariably tangled causing minor handling problems.

The harness draw was:



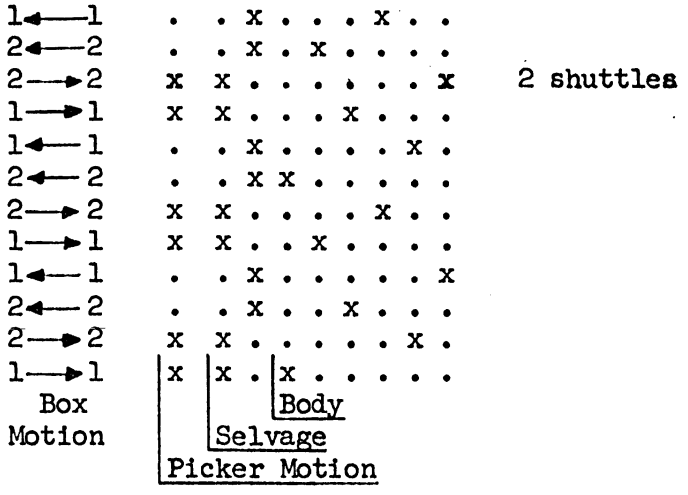
d. Weaving

The fabric was woven in a 360" Crompton & Knowles F6 loom with extra strength beams. The loom is modified to weave difficult and slippery monofilament and multifilament warps. The changes made specifically for Prototype #2, Membrane #1, are standard on this loom.

The weaving and operating conditions were:

Reeding:	5.5/4
Total Ends in Warp:	3640
Reed Width:	160"
Number of Harnesses:	6+2
Shuttle:	Standard F-2 bobbin shuttle with 4 nylon loops on both sides and 2 nylon bristles.
Temples:	Single barrel on each side.
Shuttle Tension:	Very low.
Selvage:	1" wide - run from selvage bracket and reeded 2 ends/dent.
Pick Count:	22.5

Finished Width: 156"
Weave Chain:



With the exception of the filling yarn, there were no major problems weaving this fabric. The problems with the filling yarn are discussed in I.O.1.b. As with the earlier fabrics, it was necessary to remove all rough spots and burrs that might catch the yarn.

e. Burling

The burling of this fabric was time consuming. Almost every defect was due to the filling yarn. Most of the defects were slubs, pulled yarn caused by winding, or knots caused by yarn tangling in the shuttle.

2. Fabric Heat-Setting and Priming

a. Heat-Setting

One piece, 250' long, was treated. The fabric was heat-set and primed in the North Monmouth spray line and oven described in Appendix C.

The conditions used for heat-setting were:

Temperature:	350 to 360°F
Speed:	2 fpm
Pin Width:	134"

The heat-setting was without difficulty and the fabric finished at 137". Since the fabric had a balanced selvage, there was no problem with the edges curling.

b. Priming

The conditions used for the first application of the D417 were:

Temperature:	200°F
Speed:	7 fpm
Spray Rate:	12.5 wet lbs./minute
Pin Width:	134"
Roll Pressure:	30 pli

The fabric did not dry completely

The conditions for the second application of the D417 were:

Temperature:	220°F
Speed:	7 fpm
Spray Rate:	10 wet lbs./minute
Pin Width:	134"
Roll Pressure:	30 pli

There were no problems with the priming steps.

The precuring was done at 350°F and 12 fpm, with no problems. During precuring the press roll was raised and the pins were set at 134 inches.

3. Impregnation and Coating

The 250-ft.-long piece of Fabric #25 (EX-585) that had been heat-set and primed, was partially impregnated, partially coated, and cured while doing Prototype #2, Membrane #1. The details of that work are given in Section I.N.3.

Due to financial limitations, it was not possible to finish the material. The piece of Prototype #2, Membrane #3, was used to check the operation and conditions for Prototype #2, Membrane #1, for which the supply of fabric was limited.

No final weights were determined.

4. Assembly

There was no membrane assembly. A 30-ft.-long sample was sent to WES.

5. Testing

a. By Albany Felt Company

There was no testing by AFC.

b. By WES

No test results were reported to us.

II. RESULTS

A. Available fibers were screened and the best fiber, polyester, was selected.

B. Available yarns were screened and optimum selections were made.

C. Numerous fabric constructions were considered and suitable selections made based on performance.

D. The use of a composite woven and non-woven - needled fabric was evaluated and shown to have promise.

E. Potential polymers were evaluated and tested in their available forms.

F. A satisfactory rubber was developed.

G. Numerous adhesives were evaluated and an optimum choice was made.

H. Different methods of achieving an anti-skid surface were investigated.

I. A method of bonding the rubber to the fabric was developed.

J. Test methods were developed to perform meaningful grab strength tests.

K. A shear test was developed to better characterize membrane performance.

L. Calendering of needled coated fabrics was evaluated with indefinite conclusion.

M. Press curing of needled coated fabrics was performed

N. Packaging was investigated with indefinite results.

O. Equipment requirements and specifications to produce the fabrics were defined.

P. Manufacturing techniques were developed to heat-set the fabrics.

Q. Manufacturing techniques were developed to prime the fabrics.

R. Manufacturing techniques were developed to impregnate, coat,

and cure the membranes.

S. Manufacturing techniques were developed to assemble the membranes.

T. The final membrane sample met all the key, or difficult, criteria initially sought.

III. CONCLUSIONS

A. Polyester is the preferred fiber for the base fabric.

B. Strength requirements can be met with one-ply fabrics and without multiple fabric layers.

C. Very low twist yarns are preferred.

D. High weight yarns are required. The minimum yarn weight to achieve 2000 pli strength is about 4400 denier.

E. For an unneedled membrane to achieve minimum thickness, maximum strength, and maximum tear strength, the weave must have relatively few interlacing points and be highly unbalanced.

F. The preferred weaves for unneedled membranes are 6 and 7 harness satins.

G. Needled fabrics show no significant advantage over unneedled fabrics.

H. Fabric widths of up to 156 inches can be handled on production equipment.

I. The preferred form of rubber is latex.

J. The preferred rubber is basically neoprene with flame proofing agents, bonding agents, surface conditioning agents, wetting agent, coloring agent, anti-oxidant agent, accelerating, and curing agents added.

K. The base fabric should be heat-set prior to treatment.

L. The base fabric must be primed prior to impregnation.

M. Care must be taken to ensure complete impregnation of the primed fabric prior to coating.

N. The primers and latexes can readily be applied with commercial spray equipment, provided a squeegee roll is available to insure penetration of the base during impregnation.

O. Suitable winding equipment was identified.

P. Suitable dressing equipment was identified.

Q. A suitable loom was identified.

R. A superior adhesive was identified.

S. A method of making satisfactory overlap joins was developed.

T. The best method of making an anti-skid surface was identified.

U. A membrane with clearly superior physical properties was developed.

V. Because of the significant progress made in airfield membrane manufacturing, full-scale field trials should be initiated.

IV. RECOMMENDATIONS

There are no recommendations.

TABLE 1a - ORIGINAL MATERIAL REQUIREMENTS FOR PREFABRICATED AIRFIELD AND ROAD SURFACING MEMBRANES

PROPERTY	REQUIREMENT
Grab Strength	2000 lbs./in., warp and fill
Tear Strength	200 lbs., across warp and fill
Heat Resistance	90% Retention of Strength after 5 min. at 350°F
JP-4 Resistance	90% Strength after 24 hours Immersion
Flexibility	Sufficient to allow air shipment
Flammability	Self-extinguishing
Ease of Joining Sections	As easy as is practical to maintain airtight waterproof joints for C-130 aircraft operations
Coefficient of Friction - Aircraft Tires against Membrane Surface	0.5 Minimum Dry 0.3 Minimum Wet
Service Life	36 to 48 months with 10% replacement permitted
Weight	4 to 6 lbs./sq.yd.
Storage (unprotected)	10 Years - 80% of original properties
Packaging	Air droppable with all accessories included. Maximum size 6' x 6' x 12'.
Non-Skid Surface	Applied in factory as integral part of surfacing
Manufacturing Production	Plants in the U. S. in time of war capable of minimum production rate of 150,000 - 200,000 square yards

TABLE 1b - REVISED MATERIAL REQUIREMENTS FOR PREFABRICATED AIRFIELD AND ROAD SURFACING MEMBRANES

PROPERTY	REQUIREMENT
Grab Strength	*1800 - 2000 lbs./in., **2800 - 3000 lbs./in., warp and fill
Tear Strength	*300 lbs., **700 lbs. across warp and fill
Heat Resistance	90% retention of strength after 5 min. at 350°F
Abrasion Resistance	Minimum of 350 cycles of H-18 abraser wheels, with 1000 grams/wheel
JP-4 Resistance	90% strength after 24 hours immersion
Flexibility	Sufficient to allow air shipment, 4 hours at 125°F, 4 hours at -40°F
Flammability	Self-extinguishing, after flame time 5 seconds, length of char 2 in.
Ease of Joining Sections	As easy as is practical to maintain airtight waterproof joints for C-130 and C-5 aircraft operations. Strength of joints shall be equal to or greater than materials joined.
Coefficient of Friction for Nonskid Surface - Aircraft Tires against Membrane Surface	0.5 minimum dry 0.3 minimum wet

* C-130 Aircraft
** C-5A Aircraft

TABLE 2 - SOME PRELIMINARY TEST DATA FOR NYLON FABRICS

FABRIC NO.	FABRIC THICKNESS mils	WARP* GRAB STRENGTH lbs./in.	FILLING* GRAB STRENGTH lbs./in.	DEL-VAL** FLAME TEST sec.	FLAMEXX-MN** FLAME TEST sec.	ANTIMONY OXIDE** FLAME TEST sec.
50	70	2000	2000			
51	75	1725	2140			
52	74	2025	1950			
53	70	1900	2075			
54	88	2025	2050+			
55	-	-	-			
56	77	1990	1650			
57	74	1950	1750			
58	-	1325	-			
59	-	1840	1470			
60	-	-	1700			
61	-	-	1750			
62	-	1660	1660	7	60+ (drips)	Burns & drips (with 7% add-on)
63	-	-	-			
64	-	-	-			
65	-	-	-			

TABLE 2 (continued)

FABRIC NO.	FABRIC THICKNESS mils	WARP* GRAB STRENGTH lbs./in.	FILLING* GRAB STRENGTH lbs./in.	DEL-VAL** FLAME TEST sec.	FLAMEXX-MN** FLAME TEST sec.	ANTIMONY OXIDE** FLAME TEST sec.
66	74	2140	2000			
67	75	2050	1925			
68	75	1950+	1750			
69	-	2010	2025			
70	-	1900	1200***			
71	-	-	-			
72	-	1160	-			
73	-	1750	1660			

* Results are the average of two samples except if slippage occured. If one sample slipped, the value for the other sample is given. If both samples slipped, the average of the peak force is given and the result is followed by a + sign.

** Except as noted these are direct comparative tests for the flame out time of Nylon and Dacron samples.

*** Very little coating.

TABLE 3 - SOME PRELIMINARY TEST DATA FOR DACRON FABRICS

FABRIC NO.	FABRIC THICKNESS mils.	DEL-VAL* FLAME TEST sec.	FLAMEXX-MN* FLAME TEST sec.	ANTIMONY OXIDE* FLAME TEST sec.
01	61			
02	67			
03	74			
04	64			
05	71			
06	74			
07	82			
08	75			
09	65			
10	47			
11	44			
12	58			
13	56			
14	58			
15	49			
16	60	0	24	1
17	67			
18	74			
19	66			
20	68			
21	55			
22	51			
23	41			
24	53			

*) Except as noted these are direct comparison tests for the flame out time of Nylon and Dacron fabrics.

TABLE 4 - EXPEDIENT AIRFIELD FABRICS CONSTRUCTION DATA

NYLON

FABRIC NO.	YARN DENIER	COUNT ENDS $in.^{-1}$ x PICKS $in.^{-1}$	WEAVE	THEORETICAL WEIGHT oz./sq.ft.	THEORETICAL STRENGTH lbs./inch
50	7560	12 x 12	2 x 2 Basket	3.0	1500
51	"	"	1-1/2 Weave	"	"
52	"	"	3/1 Twill	"	"
53	"	"	2/2 Crowfoot	"	"
54	"	15 x 15	3 x 2 Basket	3.7	1850
55	"	"	3/1 1/1 Twill	"	"
56	"	"	3/3 63° Twill	"	"
57	"	"	6 Harness Satin	"	"
58	"	10 x 10	1-1/2 Weave	2.4	1300
59	"	"	2/2 Crowfoot	"	"
60	"	"	2/2 Twill	"	"
61	"	"	3/1 Crowfoot	"	"
62	4200	20 x 20	2 x 2 Basket	2.7	1560
63	"	"	3/1 Twill	"	"
64	"	"	1-1/2 Weave	"	"
65	"	"	2/2 Crowfoot	"	"
66	"	26 x 26	3 x 3 Basket	3.1	2030
67	"	"	3/3 63° Twill	"	"
68	"	"	3/1 1/1 Twill	"	"
69	"	"	6 Harness Satin	"	"
70	"	17 x 17	1-1/2 Weave	2.4	1330
71	"	"	3/1 Crowfoot	"	"
72	"	"	2/2 Twill	"	"
73	"	"	2/2 Crowfoot	"	"

TABLE 5 - EXPEDIENT AIRFIELD FABRICS CONSTRUCTION DATA

DACRON

FABRIC NO.	YARN DENIER	COUNT ENDS $in.^{-1}$ x PICKS $in.^{-1}$	WEAVE	THEORETICAL WEIGHT oz./sq.ft.	THEORETICAL STRENGTH lbs./inch
01	7700	12 x 12	2 x 2 Basket	2.8	1500
02	"	"	1-1/2 Weave	"	"
03	"	"	3/1 Twill	"	"
04	"	"	2/2 Crowfoot	"	"
05	"	15 x 15	3 x 3 Basket	3.5	1850
06	"	"	3/1 1/1 Twill	"	"
07	"	"	3/3 63° Twill	"	"
08	"	"	6 harness satin	"	"
09	"	10 x 10	1-1/2 Weave	2.3	1300
10	"	"	Plain Weave	"	"
11	"	"	2/2 Twill	"	"
12	"	"	3/1 Crowfoot	"	"
13	4400	20 x 20	2 x 2 Basket	2.7	1560
14	"	"	3/1 Twill	"	"
15	"	"	1-1/2 Weave	"	"
16	"	"	2/2 Crowfoot	"	"
17	"	26 x 26	3 x 3 Basket	3.5	2028
18	"	"	3/3 63° Twill	"	"
19	"	"	3/1 1/1 Twill	"	"
20	"	"	6 Harness Satin	"	"
21	"	17 x 17	1-1/2 Weave	2.3	1326
22	"	"	3/1 Crowfoot	"	"
23	"	"	2/2 Twill	"	"
24	"	"	2/2 Crowfoot	"	"

TABLE 6 - EFFECTS OF NEEDLING ON MEMBRANE PROPERTIES

DUMMY VARIABLE		PENETRATION	TAKE-UP	GRAB STRENGTH		TEAR STRENGTH		THICKNESS
X	X_2	in.		WARP pli	FILLING pli	WARP lbs.	FILLING lbs.	mils
0	0	3/8	215	2412	2187	426	434	88
0	0	3/8	215	2557	2337	393	523	88
-1	-1	2/8	130	2120	2275	413	441	83
+1	-1	4/8	130	2505	1812	425	402	96
-1	+1	2/8	300	2187	1987	377	442	87
+1	+1	4/8	300	2712	1962	422	339	94

TABLE 7 - CLASSES* OF BASIC RAW MATERIALS CONSIDERED FOR FABRIC IMPREGNATING AND COATING

1.	Chloroprene rubber (= neoprene)	CR
2.	Chlorosulfonyl-polyethylene	CSM
3.	Chloropolyethylene	CM
4.	Polyvinyl chloride	PVC
5.	Nitrile-butadiene rubber	NBR
6.	Ethylene polysufide rubber	ET
	Ethylene ether polysulfide rubber	EOT
7.	Polychloroxirane (= epichlorohydrin elastomer)	CO
	Ethylene oxide and chloromethyl oxirane (= epichlorohydrin copolymer)	ECO

* ASTM D1418-66a: Nomenclature for Synthetic Elastomers and Latices.

TABLE 8 - POLYMER CLASSES NOT CONSIDERED

CLASS	TRADE NAME	MANUFACTURER
Fluoroelastomers	Viton	Du Pont
Fluorosilicone Elastomers	Silastic	Dow Corning
Polyvinyl Fluoride Resin	Dalvor	Diamond Alkali
Copolymers of Hexafluoro-propylene & Vinylidene Fluoride	Fluorel Elastomer	Minnesota Mining & Manufacturing
Copolymers of Chlorotri-fluoroethylene & Vinylidene Fluoride	Kel-F-Elastomer	Minnesota Mining & Manufacturing

TABLE 9 - PHYSICAL FORMS IN WHICH THE BASIC RAW MATERIALS MAY BE USED FOR FABRIC IMPREGNATING AND COATING

	Plastisol	Dry	Solvent Solution	Latex
Application	Dip, roll, or spray	Friction, and/or calender	Dip, roll, or spray	Dip, roll, or spray
Dry	No	No	Yes - to vaporize solvent	Yes - to vaporize water
Fuse	Yes - in Oven	No	Only PVC solvent solutions - in oven	No
Cure	No	Yes - by press, Roto-Cure, or in oven	Yes - by press, Roto-Cure, or in oven	Yes - by press, Roto-Cure, or in oven

TABLE 10 - FLAME RESISTANCE & SOLVENT RESISTANCE OF PLASTISOL FILMS

Item	Flame Resistance	Solvent Resistance
X-9017 (Chemical Products)	6 sec. and 12 sec. on duplicate samples. (20 mils). Some after-glow.	Samples shrunk in both directions, became stiff, lost recovery, and discolored slightly.
76X-836 (Stanley Chemical)	Samples (20 mils) burn readily.	Not tested.
LX-49 (Taurus Chemical)	Duplicate samples (19 mils) completely burn up. (31.0 sec. and 36.5 sec.).	Slight stiffening, no discoloration.

TABLE 11 - FLAME TEST RESULTS ON DACRON FABRIC #24 COATED ON BOTH SIDES WITH X-9017 PLASTISOL

Sample Number	Weight-% PVC*	Flaming Time, Sec.		
1	41.7	Over 60. Burns completely		
2	50.5	22.6, 6.2, 14.5, 11.0,	$\overline{13.6}$**,	no dripping
3	57.5	2.5, 2.2, 2.5, 1.3,	$\overline{2.1}$,	no dripping
4	70.1	0.5, 2.0, 0.4, 0.1,	$\overline{0.8}$	

* 100% - weight-% PVC = Weight-% fabric

** Figure with line over it is arithmetic average

TABLE 12 - FLAME TEST RESULTS ON DACRON FABRIC #24 COATED ON BOTH SIDES WITH LX-49 PLASTISOL

Sample Number	Weight-% PVC	Remarks
1	45.4	Burns completely
2	50.0	Burns completely
3	65.8	Burns completely
4	68.4	Burns completely

TABLE 13 - EFFECT OF JP-4 ON X-9017 PLASTISOL FILM

	Control	After 24-Hour Immersion in JP-4 at Room Temperature
Thickness, in.	0.020	0.020
Breaking Force, lb.	16.23	20.90
Tensile Strength, psi	1623	2090
Stretch at Break, in.	12.84	9.38
Ultimate Elongation, %	642	469

Conditions: Film fused 10 min./350°F
Test Specimens 0.50 in. wide
Chart Speed 10 in./min.
Rate of Jaw Separation 20 in./min.
Initial Jaw Separation 2 in.

TABLE 14 - LOW-TEMPERATURE FLEXIBLE PVC SOLVENT SOLUTION COATING

Ingredients	Amount	Part
Geon 103 EP	72	1
Tetrahydrofuran (THF)	408	
Acryloid A-101	24	2
Methyl ethyl ketone	36	
Estane 5740X1	4	3
THF	22	

Procedure: Add part 1 to part 3 and mix.
Then add part 2 to this mix.
Bake 3 minutes at 212°F.

TABLE 15 - ET DRY RUBBER FORMULATIONS

	ET-1	ET-2	ET-3
Thiokol FA	100	100	100
Zinc Oxide	10	10	10
SRF black	60	40	5
MBTS	0.4	0.4	0.4
Diphenylguanidine (DPG)	0.1	0.1	0.1
Stearic acid	0.5	0.5	0.5
Antimony oxide	-	20	55
Blackbird sulfur	0.5	-	-
Cure	*	20/316	20/316

*Stock appeared scorchy before milling was complete, therefore the compound was discarded without curing and flame testing.

TABLE 16 - CSM-1 DRY RUBBER FORMULATION

Hypalon 30	100
Staybilite Resin	3
Tri-Mal	40
MBTS	1.5
Thiuram M	0.5
Ti-Pure R-902	70
Cure	15/350

TABLE 17 - N-NBR/PVC-1 DRY RUBBER FORMULATION

Paracril Ozo.	100
Zinc Oxide	5
Naugawhite or Octamine	1
Stearic Acid	0.5
Calcene TM	50
Plasticizer SC	10
Monaplex DOA	15
SRF black	3
Blackbird Sulfur	1.5
Monex	0.6
Oncor 23A	15 - 20
Chlorowax 70	30 - 40

TABLE 18 - CO DRY RUBBER FORMULATIONS

	CO-1	CO-2	CO-3	CO-4	CO-5
Hydrin 200	100	100	100	100	100
Zinc Stearate	1	2	2	2	2
Red Lead Oxide	5	5	5	5	5
Antimony Oxide	10	10	5	10	10
Agerite Resin D	1	1	1	1	1
FEF Black	50	50	50	50	50
Dechlorane 355	20	20	30	20	20
Chlorowax 40	-	5	20	-	-
Chlorowax 70	-	-	-	-	3
Piperozine Hexahydrate	-	1.5	1.5	1.5	1.5
Halowax 0077	-	-	-	4	-
Cure	15/300	15/350	20/350	20/350	20/350

TABLE 19 - GY-NBR/PVC DRY RUBBER FORMULATIONS

	GY-NBR/ PVC-1	GY-NBR/ PVC-2	GY-NBR/ PVC-3	GY-NBR/ PVC-4	GY-NBR/ PVC-5
Cheminic 400	100	100	100	100	-
Cheminic 450	-	-	-	-	100
Antimony Oxide	10	10	-	10	-
Dechlorane 355	-	20	20	30	30
Chlorowax 40	-	5	-	-	-
Chlorowax 70	-	-	10	5	5
Oncor 23A	-	-	20	-	20
SRF Black	5	5	5	5	5
McNamee Clay	40	40	20	20	20
Tri-cresyl Phosphate (TCP)	15	15	15	15	15
Blackbird Sulfur	1	1	1	1	1
Amox No. 1	1	1	1	1	1
Unods	0.3	0.3	0.3	0.3	0.3

Cure all 10/310

TABLE 20 - G-NBR/PVC DRY RUBBER FORMULATIONS

	G-NBR/ PVC-1	G-NBR/ PVC-2	G-NBR/ PVC-3	G-NBR/ PVC-4
Hycar 1203 X11	100	100	100	100
Zinc Oxide	5	5	5	5
Stearic Acid	1	1	1	1
Blackbird Sulfur	1	1	1	1
FEF Black	30	20	20	20
MT Black	30	20	20	20
Antox	1	1	1	1
Paraplex G-25	15	15	-	-
Monaplex DOA	15	15	-	-
TCP	-	-	30	25
Dechlorone 355	20	30	30	30
Antimony Oxide	-	10	10	10
Chlorowax 70	-	-	-	5

Cure all 15/350

TABLE 21 - CR-1 DRY RUBBER FORMULATION

Neoprene W	75
Neoprene FB	25
Acroflex CD	2
Stan-Mog 100	4
Hydral 710	30
Dixie Clay	20
SRF Black	5
Antimony Oxide	15
ZB-112	10
NA-22	0.5

Cure 15/350

TABLE 22 - FLAME RESISTANCE TEST RESULTS USING CURED RUBBER SHEET MADE FROM DRY RUBBER COMPOUNDS

Formulation	Remarks
ET-1	Not tested. Poor formulation; scorchy stock.
ET-2	Burns
ET-3	Burns
CSM-1	Self-extinguishing
N-NBR/PVC-1	Not tested. Intractable during milling.
CO-1	Burns
CO-2	Borderline. Some dripping. Some after-glow.
CO-3	Burns
CO-4	Better than CO-3 but still burns
CO-5	Better than CO-4 but still burns
GY-NBR/PVC-1	Burns but requires long ignition time
GY-NBR/PVC-2	Burns but requires long ignition time
GY-NBR/PVC-3	Burns but requires long ignition time
GY-NBR/PVC-4	Burns
GY-NBR/PVC-5	Ignites with difficulty. Borderline.
G-NBR/PVC-1	Burns
G-NBR/PVC-2	Burns
G-NBR/PVC-3	Burns
G-NBR/PVC-4	Burns
CR-1	Self-extinguishing

TABLE 23 - NONFLAMMABLE PVC SOLVENT SOLUTION COATING

Ball Mill Grind*	162	parts by weight
Geon 222) in solution	90	
Toluene)	50	
Trichloroethylene	226	
Perchloroethylene	45	
Solvesso 100	45	

*Ball Mill Grind:

Antimony Oxide	45
#10 Whiting	55
Celluflex CEF	2
Geon 222) in solution	9
Toluene)	39
Toluene	12
	162

TABLE 24 - FLAME-PROOFING AGENTS FOR PRETREATING THE FABRIC

Material	Supplier
Antimony Oxide	Various, e.g. National Lead Co.
Del-Val	(New)Action Products Co.
Flamexx MM	Guardian Laboratories, Inc.
Flamexx MM-N	Guardian Laboratories, Inc.
Vitard V25-3647 Fire Retardant Dispersion	National Starch & Chemical Corp.

TABLE 25 - FLAME TEST RESULTS ON DACRON FABRICS TREATED WITH FLAME-PROOFING AGENTS

Fabric Number	Agent	Solids Content %	Pick-Up %	Flame Test
16	(Control)	-	-	Burns
16	Antimony Oxide	50	30.8	14.8, 33.0, $\overline{23.9}$
16	Antimony Oxide	25	15.5	Burns
16	Antimony Oxide	12.5	8.2	Burns
16	Antimony Oxide	6.3	4.4	Burns
16	Del-Val		11.8	$\overline{0}$
16	Vitard		8.3	Burns
16	Flamexx MM	21.3	11.8	1.0, 0.8, 0.8, 1.5
16	Flamexx MM	11.1	4.7	$\overline{0}$
24	Flamexx MM	20	7.4	$\overline{0}$
24	Flamexx MM	11.1	3.3	$\overline{0}$
24	Flamexx MM	5.3	1.5	1.0, 0.9, 0, $\overline{0.6}$
24	Flamexx MM	2.7	0.5	0.1, 0, $\overline{0}$

TABLE 26 - FLAME TEST RESULTS ON NYLON FABRIC #62 TREATED WITH FLAME-PROOFING AGENTS

Agent	Solids Content %	Pick-Up %	Flame Test
(Control)	-	-	Burns, drips
Antimony Oxide	50	31.6	Burns, drips
Del-Val		10.6	13.6, 5.5, 4.8, 3.3, $\overline{6.8}$
Vitard		15.8	Burns, drips
		8.6	Burns, drips
		3.9	Burns, drips
Flamexx MM	11.1	7.0	Burns, drips
Flamexx MM-N	25	11.5	2.5, 3.5, 3.7, 5.0, $\overline{3.6}$
	20	8.5	1.3, 4.8, 0, 1.0, $\overline{1.8}$
	15	8.4	1.0, 8.4, 1.3, 1.5, $\overline{3.0}$
	10	3.8	3.3, 4.8, 3.5, 9.1, $\overline{5.2}$
	5	0.8	7.5, 60.0, 23.5, $\overline{30.2}$

TABLE 27 - B-PVCL LATEX FORMULATIONS

	B-PVCL-1	B-PVCL-2	B-PVCL-3	B-PVCL-4	B-PVCL-5	B-PVCL-6
Polyco 446-L	100	100	100	100	100	-
Polyco 630-18	-	-	-	-	-	100
TCP	30	30	30	30	30	30
Antimony Oxide	4	12	24	44	44	44
SRF Black	2	2	2	2	2	10
Ludox HS-40	-	-	-	-	10	10
Fused all	10/300					

B-PVC/PVDCL-1 Polyco 2637 used as received. Dried at 140°F. Film was self-extinguishing.

B-PVC/PVDCL-2 Polyco 2605 used as received. Dried at 140°F. Film was brittle and self-extinguishing.

PVDCL = Polyvinylidene chloride latex

TABLE 28 - G-NBR/PVCL AND G-PVCL LATEX FORMULATIONS

	G-NBR/ PVCL-1	G-NBR/ PVCL-2	G-NBR/ PVCL-3	G-NBR/ PVCL-4	G-PVCL-1*
Geon Latex 552	100	100	100	100	-
Geon Latex 352	-	-	-	-	100
Santicizer 141	-	-	-	-	25
Antimony Oxide	10	20	40	60	45
Chlorowax 40	-	-	-	-	7
DOA	10	10	10	10	-
Calcium Carbonate	-	-	-	-	250
SRF Black	2	2	2	2	15
Dyphos	-	-	-	-	5

Fused all 15/300

*Poor formulation. Did not test.

TABLE 29 - GY-NBRL LATEX FORMULATIONS

	GY-NBRL-1	GY-NBRL-2	GY-NBRL-3	GY-NBRL-4
Pliovic Latex 300	-	-	40	40
Chemigum Latex 248	70	-	30	30
Chemigum Latex 550	-	70	-	-
Chlorowax 40	20	20	20	30
Antimony Oxide	5	15	5	7.5
SRF Black	5	5	5	5
Acrysol GS	0.33	0.33	0.33	0.33
Zinc Oxide	5	5	-	-
Blackbird Sulfur	2	-	-	-
Zinc Captax	1	1	-	-
Ethyl Zimate	1	1	-	-
Cure	15/300	15/300	5/350	5/350

TABLE 30 - NEOPRENE LATEX FORMULATIONS

CRL-	1	2	3	4	5	6
Neoprene Latex 571	100	100	100	100	100	100
Zinc Oxide	5	5	5	5	5	5
Neozone D Special	2	2	2	2	2	2
Tepidone	1	1	1	1	1	1
Thuiram E	1	1	1	1	1	1
Aquarex SMO	3	3	3	3	3	3
Aquarex WAQ	1	1	1	1	1	1
Chlorowax 40	30	30	-	-	-	-
Rez-O-Sperse 3	-	-	30	30	30	30
Antimony Oxide	6	6	6	6	6	6
Hydral 710	50	-	50	-	-	50
Dixie Clay	-	50	-	50	50	-
SRF Black	10	10	10	10	10	10
Hylene MP	-	-	-	-	20	20

Cure all 15/300

TABLE 31 - FLAME TEST RESULTS ON FILMS MADE FROM LATEX

Formulation	Flame Test Results
B-PVCL-1	Burns
B-PVCL-2	Burns
B-PVCL-3	Borderline
B-PVCL-4	Self-extinguishing
B-PVCL-5	$\overline{0}$
B-PVCL-6	*
G-PVCL-1	Poor formulation. Did not test.
B-PVC/PVDCL-1	Self-extinguishing
B-PVC/PVDCL-2	Self-extinguishing
G-NBR/PVCL-1	Burns
G-NBR/PVCL-2	Burns
G-NBR/PVCL-3	Borderline
G-NBR/PVCL-4	Self-extinguishing
GY-NBRL-1	Burns
GY-NBRL-2	Burns
GY-NBRL-3	Burns
GY-NBRL-4	Burns
CRL-1	Self-extinguishing
CRL-2	Self-extinguishing
CRL-3	Self-extinguishing
CRL-4	Self-extinguishing
CRL-5	*
CRL-6	*

*Apparently not tested. No data in notebook.

TABLE 32 - FLAME TEST RESULTS USING DACRON FABRIC PRETREATED WITH A FLAME-PROOFING AGENT AND COATED WITH LATEX

Fabric Number	16	16	24
Agent	Flamexx MM	Flamexx MM	Flamexx MM
Solids Content, %	21.3		
Add-on, %	11.3	66.5	3.3
Latex	V-7724	CRL-4	CRL-2 & V-7724
Flaming Time	1.5, 3.5, 4.5, 4.9	3.7, 2.2,	16.2, 28.2, 21.2, 25.8
Avg. Flaming Time	3.6	3.0	22.8

TABLE 33 - FLAME TEST RESULTS USING NYLON FABRIC #62 PRETREATED WITH A FLAME-PROOFING AGENT & COATED WITH LATEX

Agent	Flamexx MM	Flamexx MM	Flamexx MM
Solids Content, %	11.1	11.1	11.1
Pick-Up, %	8.2	7.3	7.3
Latex	B-PVCL-4	G-NBR/PVCL-4	CRL-2
Fiber, %	61.1	43.8	54.2
Rubber, %	38.9	56.2	45.8
Flaming Time, sec.	35.8, 42.0, 95.0	18.3, 2.5, 1.0, 0.9	156.0, 120.0
Flaming Time, Avg.	57.6	5.7	138.0

TABLE 34 - EFFECT OF COMPOSITION ON FLAME TEST USING DACRON FABRIC #20 COATED WITH CRL-5

Sample Number	Composition % Rubber	% Fiber	Flaming Time, Sec.	Avg.
1	40.2	59.8	59.3, 25.4, 40.7, 42.6 38.4	41.3
2	44.9	55.1	24.5, 52.8, 27.3 25.3 21.0	26.2
3	50.0	50.0	10.0, 27.1, 23.2, 16.8, 25.2	20.5
4	54.5	45.5	30.7, 19.5, 2.5, 4.7, 17.0	14.9
5	59.7	40.3	6.4, 1.5, 1.0, 1.0, 3.1	2.6

TABLE 35 - TEST RESULTS FOR NEOPRENE LATEX FILMS

LATEX	FILM THICKNESS $X10^3$ IN.	AVERAGE TENSILE STRENGTH, psi			AVERAGE ULTIMATE ELONGATION, %			% OF ORIGINAL RETAINED TENSILE		ELONGATION	
		CONTROL	H_2O	JP-4	CONTROL	H_2O	JP-4	H_2O	JP-4	H_2O	JP-4
CRL-3	5.0	1076	1080	644	709	790	464	100	59.8	+112	65.4
CRL-4	5.0	1084	936	600	595	689	391	86.3	55.3	+116	65.7
CRL-5	7.0	1065	908	663	347	589	323	85.3	62.3	+170	93.2
CRL-6	5.0	1264	1024	792	356	467	272	81.1	62.6	+131	76.5
V-7724	5.0	2212	1908	1304	1448	1222	1104	86.7	59.2	84.4	76.3

TABLE 36 - TABER TEST RESULTS OF NEOPRENE LATEX FILMS

TYPE OF RUBBER	FILM THICKNESS in.	NO. CYCLES TO WEAR-THROUGH	WEIGHT LOSS gm.	WEAR FACTOR*	AVG. WEAR FACTOR
CRL-3	.005	17	.006	352	
CRL-3	.005	16	.004	250	298
CRL-3	.005	17	.005	294	
CRL-4	.005	22	.004	182	
CRL-4	.005	20	.003	150	166
CRL-5	.007	504	.291	578	
CRL-5	.007	341	.199	584	578
CRL-5	.007	252	.143	568	
CRL-6	.005	27	.005	185	
CRL-6	.005	13	.003	231	222
CRL-6	.005	16	.004	250	
V-7724	.005	128	.026	203	
V-7724	.005	118	.026	220	228
V-7724	.005	82	.021	256	

*Wear Factor = Weight Loss in mg./Total number cycles x 1000

TABLE 37 - NEOPRENE LATEX STABILITY

DESIGNATION	DATE COMPOUNDED	STABILITY
CRL-3	April 10, 1968	OK
CRL-4	April 3, 1968	OK
CRL-5	March 27, 1968	Questionable
CRL-6	April 10, 1968	OK
Vulcanol 7724	(In March)	OK

TABLE 38 - CALENDERING CONDITIONS

FABRIC NUMBER	LATEX NUMBER	TEMP. READ, °F.	SPEED SETTING*	GAP SETTING, MILS	THICKNESS, IN. INITIAL	FINAL
4	CRL-3	300	3	35	.085	.079
	CRL-4	300	3	30	.095	.079
	CRL-5	350	5	30	.101	.090
	CRL-6	250	1	49	.097	.088
	7724	250	1	20	.093	.088
8	CRL-3	300	7	30	.105	.087
	CRL-4	350	5	40	.112	.092
	CRL-5	250	3	65	.119	.106
	CRL-6	350	5	40	.102	.090
	7724	300	3	35	.102	.099
20	CRL-4	350	5	35	.087	.080
	CRL-5	300	3	20	.086	.077
	7724	250	5	30	.081	.080

* Only available data was that a setting of 5 is equal to 15 ft./min.

TABLE 39 - PHYSICAL TEST RESULTS ON DACRON FABRICS COATED WITH FIVE BEST LATEX FORMULATIONS

FABRIC NUMBER	LATEX NUMBER	THICK-NESS in.	WEIGHT oz./sq.ft.	COMPOSITION %Rub.	%Fib.	TEAR STRENGTH lb./in.	COEFFICIENT OF FRICTION Dry	Wet	FLAME OUT TIME sec.	TABER ABRASION WEIGHT LOSS, g. Control	JP-4	GRAB STRENGTH WARP lbs./in.	FILL lbs./in.	GURLEY STIFFNESS grams
4	CRL-3	.085	6.98	60.0	40.0	431 Avg.	1.17	1.27	12.2	.662	2.478	1,837 Avg.	1,850 Avg.	34.9
	CRL-4	.095	6.56	57.3	42.7	364 "	1.08	1.11	21.2	.635	2.017	1,765 "	1,725 "	40.5
	CRL-5	.101	7.36	61.9	38.1	-	0.82	0.90	13.1	.633	2.276	-	-	64.0
	CRL-6	.097	7.25	61.3	38.7	-	0.79	0.86	30.6	.487	1.827	-	-	75.4
	7724	.093	6.74	58.4	41.6	-	1.09	1.27	35.3	.718	1.478	-	-	43.4
8	CRL-3	.105	9.13	61.6	38.4	540 Avg.	1.10	1.16	2.3	.859	-	2,187 Avg.	2,037 Avg.	42.0
	CRL-4	.112	8.73	59.9	40.1	414 "	0.94	1.09	2.2	.749	2.754	2,065 "	1,900 "	85.3
	CRL-5	.119	9.35	62.6	37.4	-	0.81	0.78	1.2	.748	2.719	-	-	119.5
	CRL-6	.102	7.82	55.3	44.7	-	0.72	0.84	21.2	.585	2.005	-	-	119.5
	7724	.102	8.93	60.8	39.2	-	1.30	1.34	30.1	1.002	1.778	-	-	51.9
20	CRL-3	.084	7.61	54.0	46.0	304 Avg.	1.18	1.14	9.2	.644	2.540	2,162 Avg.	2,112 Avg.	45.5
	CRL-4	.087	7.20	51.4	48.6	250 "	1.07	1.24	15.1	.662	2.480	1,900 "	1,775 "	42.7
	CRL-5	.086	6.87	49.0	51.0	-	0.80	0.93	22.3	.503	2.143	-	-	56.2
	CRL-6	.085	7.16	51.2	48.8	-	0.82	0.91	14.7	.350	2.104	-	-	56.2
	7724	.081	7.61	54.0	46.0	-	1.29	1.38	27.9	.927	1.604	-	-	34.1
WX-18	1st sample	.067	7.20	68.4	31.6	300	0.65	1.18	1.1	.683	4.360	1,500	1,400	37.0
	2nd sample	.072	7.40	-	-	-	1.28	1.19	out immed.	.787	4.043	-	-	29.9
4C*	CRL-3	.079	-	-	-	-	1.16	1.07	2.1	.579	2.052	-	-	37.0
	CRL-4	.079	-	-	-	-	1.14	1.11	14.1	.603	2.193	-	-	38.4
	CRL-5	.090	-	-	-	-	1.00	1.04	10.4	.494	2.259	-	-	44.1
	CRL-6	.088	-	-	-	-	0.76	0.83	25.2	.461	1.781	-	-	56.9
	7724	.088	-	-	-	-	1.33	1.33	40.8	.686	1.271	-	-	24.9
8C	CRL-3	.087	-	-	-	-	0.97	0.92	2.8	.699	2.787	-	-	69.7
	CRL-4	.092	-	-	-	-	1.13	1.04	3.3	.656	2.410	-	-	76.8
	CRL-5	.106	-	-	-	-	0.77	0.81	1.8	.737	2.483	-	-	95.3
	CRL-6	.090	-	-	-	-	0.88	1.05	13.2	.492	1.873	-	-	113.8
	7724	.099	-	-	-	-	1.27	1.47	19.5	.914	1.858	-	-	56.9
20C	CRL-3	-	-	-	-	-	-	-	-	-	-	-	-	-
	CRL-4	.080	-	-	-	-	1.16	1.28	5.1	.510	2.334	-	-	38.4
	CRL-5	.077	-	-	-	-	0.91	0.90	25.5	.308	2.003	-	-	46.2
	CRL-6	-	-	-	-	-	-	-	-	-	-	-	-	-
	7724	.080	-	-	-	-	1.28	1.23	28.6	.779	1.536	-	-	27.7

* C = calendered

TABLE 40 - CRL-3 FORMULATION (I)

	PHR	Scaled Up Dry lbs.	Total Solids Content, %	Scaled Up Wet lbs.
Neoprene Latex 571	100	2010	50	4020
Aquarex WAQ	1	20.1	25	80.5
Zinc oxide	5	100.5	60	168
Agerite Powder	2	40.2	55	73.1
Ti-Rite HA	50	1005	50	2010
Rez-O-Sperse 3	30	603	67	920
P-33 black	10	201	65	309
Ti-Rite AO	6	120.6	60	201
Tepidone	1	20.1	50	40.2
Ethyl Tuads	1	20.1	50	40.2
Aquarix SMO	3	60.3	33	183
TOTAL	209	4200.9		8045.0

Calculated total solids content 52.3%

Calculated amount of neoprene 47.8 wt.-% (based on solids)

TABLE 41 - CRL-3 FORMULATION (II)

	PHR	Scaled Up Dry lbs.	Total Solids Content, %	Scaled Up Wet lbs.
Neoprene Latex 571	100	4367.6	50	8735.2
Aquarex WAQ	1	43.7	25	174.8
Zinc oxide	5	218.4	60	364.0
Agerite Powder	2	87.4	55	158.9
Ti-Rite HA	50	2183.8	50	4367.6
Rez-O-Sperse 3	30	1310.3	67	1955.7
P-33 black	10	436.8	65	672.0
Ti-Rite AO	6	262.0	60	436.7
Tepidone	1	43.7	50	87.4
Ethyl Tuads	1	43.7	50	87.4
Aquarex SMO	3	131.0	33	397.0
	209	9128.4		17436.7

Calculated total solids content 52.3%

Calculated amount of neoprene 47.8%

TABLE 42 - BROOKFIELD (LVF) VISCOSITY OF CRL-3 (II)
(SECOND MIXING - SURPASS CHEMICAL CO.)

Spindle Number	Shear Rate, rpm	Viscosity, cps *
2	6	1040
	12	790
	30	500
	60	360
3	6	1300
	12	920
	30	590
	60	430

* Averaged over initial (I) and final (II) samples from each of four lots

TABLE 43 - TOTAL SOLIDS DETERMINATION OF CRL-3 (II)
(SECOND MIXING - SURPASS CHEMICAL CO.)

Lot	TSC, % (average of 2)
2369 - I	52.7
2369 - II	52.4
Average for 2369	52.6
2469 - I	52.5
2469 - II	51.9
Average for 2469	52.2
2569 - I	51.9
2569 - II	52.8
Average for 2569	52.4
2669 - I	53.1
2669 - II	51.9
Average for 2669	52.5
Average for the mixing	52.4

TABLE 44 - MATERIALS CHARGES FOR SECOND MIXING
-SURPASS CHEMICAL CO.-

Material	Net Weight Purchased	Dry Pounds	Unit Price ¢/lb.	Adjusted Unit Price ¢/lb. Dry	Cost Based On CRL-3 Formulation
Neoprene Latex 571	9288	4644	.445/Dry	.445	44.50
Aquarex WAQ	50	50	.26	.26	.26
Zinc oxide	400	240	.56/wet	.934	4.67
Agerite Powder	200	110	.915/wet	1.663	3.33
Ti-Rite HA	4411	2205	.15/wet	.30	15.00
Rez-O-Sperse 3	2000	1330	.20/wet	.299	8.95
P-33 black	700	455	.53/wet	.816	8.16
Ti-Rite AO	445	267	.58/wet	.967	5.80
Tepidone	50	50	.52	.52	.52
Ethyl Tuads	107	53	1.50/wet	3.00	3.00
Aquarex SMO	135	135	.57	.57	1.71
				Total =	$ 95.90

$$\frac{\$\ 95.90}{209 \text{ dry lb.}} = \frac{\$\ 0.46}{\text{dry lb.}}$$

TABLE 45 - CHARGES FOR SECOND MIXING
-SURPASS CHEMICAL CO.-

	Total Charges, $	Charge per Dry lbs.**, $
Materials	4,200	0.46
Mixing	851	0.093
Shipping	246*	0.027
Total	5,297	0.58

* 18,400 lb. gross went as 20,000 lb. @ $ 1.23/cwt.

** Total dry weight from Table 41 is 9128 lbs. (calculated)

Total wet weight from Table 44 is 17437 lbs. (calculated)

TABLE 46- ADHESIVES

MANUFACTURER	DESIGNATION
Minnesota Mining & Mfg. Company	EC-776 1022 1300 L 2141 2210
Pittsburg Plate Glass Industries	G483/CH100 Bondmaster G580
Uniroyal, Inc.	M6130
Hughson	Chemlok 305 TS-701-58
United Shoe Machinery Corp.	Bostik 1095/Boscodur #9 Bostik 1125A/Boscodur #19 Bostik 7133C
Compo Industries, Inc.	Compo 5134 Compothane 1878
Xylos Rubber Company	Loxite 7021
W. P. Fuller Paint Company	Fuller #22
Devcon Corporation	Flexane 85
Polymer Industries, Inc.	Polybond BW23 R-4
Armstrong	D-284
Victor Balata	Victor Cement
Hooker Chemical Company	Neoprene P-1

TABLE 47 - ADHESIVE TEST RESULTS

ADHESIVE	FABRIC NO.	LATEX NO.	BREAKING FORCE, LBS. 1ST	2ND	AVERAGE	HOW FAILURE OCCURRED
EC-776	20	CRL-3	560	615	588	Adhesive - Adhesive
	4	CRL-4	445	545	495	Adhesive - Adhesive
	8	CRL-4	400	405	402	Adhesive - Adhesive
	4	7724	290	365	328	Adhesive - Adhesive
	8	7724	310	320	315	Adhesive - Adhesive
	20	7724	350	360	355	Adhesive - Adhesive
	4C	CRL-4	420	-	420	Adhesive - Adhesive
	8C	7724	350	420	385	Adhesive - Adhesive
3M-2210	20	CRL-3	915	920	918	Rubber - Rubber
	4	CRL-4	700	730	715	Mostly Adhesive - Both
	8	CRL-4	720	810	765	Mostly Rubber - Mostly Rubber
	4	7724	410	550	480	Mostly Adhesive - Mostly Adhesive
	8	7724	530	690	610	Both - Mostly Rubber
	20	7724	500	565	532	Adhesive - Adhesive
	4C	CRL-4	1005	-	1005	Mostly Rubber
	8C	7724	660	800	730	Both - Mostly Rubber
Uniroyal 6130	20	CRL-3	860	970	915	Rubber - Rubber
	4	CRL-4	900	910	905	Mostly Rubber - Mostly Rubber
	8	CRL-4	700	780	740	Both - Both
	4	7724	570	680	625	Adhesive - Adhesive
	8	7724	570	630	610	Adhesive - Adhesive
	20	7724	660	685	672	Adhesive - Adhesive
	4C	CRL-4	1150	-	1150	Rubber
	8C	7724	565	735	650	Adhesive - Adhesive

TABLE 47(continued)

ADHESIVE	FABRIC NO.	LATEX NO.	BREAKING FORCE, LBS. 1ST	2ND	AVERAGE	HOW FAILURE OCCURRED
Compthane 1878	20	CRL-3	305	335	320	Adhesive - Adhesive
	4	CRL-4	210	285	248	Adhesive - Adhesive
	8	CRL-4	410	520	465	Adhesive - Adhesive
G-580	20	CRL-3	985	1100	1043	Rubber - Rubber
	4	CRL-4	1040	1080	1060	Rubber - Rubber
	8	CRL-4	910	1000	955	Mostly Rubber - Mostly Rubber
	4	7724	315	450	382	Adhesive - Adhesive
	8	7724	480	550	515	Adhesive - Adhesive
	20	7724	510	560	535	Adhesive - Adhesive
	4C	CRL-4	1200	-	1200	Rubber
	8C	7724	615	630	623	Adhesive - Adhesive
Loxite 7021	20	CRL-3	645	810	728	Adhesive - Both
	4	CRL-4	800	810	805	Mostly Adhesive - Mostly Adhesive
	8	CRL-4	605	690	648	Adhesive - Adhesive
	4	7724	290	440	365	Adhesive - Adhesive
	8	7724	400	430	415	Adhesive - Adhesive
	20	7724	355	390	372	Adhesive - Adhesive
	4C	CRL-4	930	-	930	Both
	8C	7724	375	395	385	Adhesive - Adhesive
Bostik 1095 + #9 Boscodur	20	CRL-3	1090	1205	1148	Rubber - Rubber
	4	CRL-4	1000	1220	1110	Rubber - Rubber
	8	CRL-4	1060	1075	1068	Rubber - Rubber

TABLE 47 (continued)

ADHESIVE	FABRIC NO.	LATEX NO.	BREAKING FORCE, LBS. 1ST	2ND	AVERAGE	HOW FAILURE OCCURRED
Bostik 1095	4	7724	920	920	920	Rubber - Rubber
+	8	7724	765	820	792	Rubber - Rubber
#9 Boscodur	20	7724	830	920	880	Rubber - Rubber
	4C	CRL-4	1300	-	1300	Rubber - Rubber
	8C	7724	895	915	905	Rubber - Rubber
Compthane						
1878	4	7724	480	540	510	Adhesive - Adhesive
	8	7724	410	410	410	Adhesive - Adhesive
	20	7724	435	560	498	Adhesive - Adhesive
Fuller						
#22	20	CRL-3	595	600	598	Adhesive - Adhesive
	4	CRL-4	560	665	612	Adhesive - Adhesive
	8	CRL-4	550	640	595	Adhesive - Adhesive
	4	7724	680	785	732	Mostly Adhesive - Mostly Adhesive
	8	7724	630	700	665	Mostly Adhesive - Mostly Adhesive
	20	7724	715	740	728	Mostly Adhesive - Mostly Adhesive
	4C	CRL-4	750	-	750	Adhesive
	8C	7724	765	810	788	Both - Both
PPG						
483/CH100	20	CRL-3	1060	1105	1082	Rubber - Rubber
	4	CRL-4	970	1060	1015	Rubber - Rubber
	4	7724	635	660	648	Adhesive - Adhesive
	8	7724	665	780	722	Adhesive - Adhesive
	20	7724	610	630	620	Adhesive - Adhesive

TABLE 47 (continued)

ADHESIVE	FABRIC NO.	LATEX NO.	BREAKING FORCE, LBS. 1ST	2ND	AVERAGE	HOW FAILURE OCCURRED
PPG	4C	CRL-4	1240	-	1240	Rubber
483/CH100	8C	7724	760	835	798	Rubber - Rubber
Chemlok	8	7724	950	980	965	Mostly Rubber - Mostly Rubber
305	8C	7724	720	965	842	Rubber - Rubber
Bostik	8	7724	710	715	712	Mostly Adhesive - Mostly Adhesive
7133C	8C	7724	740	830	785	Rubber - Rubber
3M-1022	8	7724	510	530	520	Adhesive - Adhesive
	8C	7724	605	665	635	Adhesive - Adhesive
3M-1300L	8	7724	955	975	965	Rubber - Rubber
	8C	7724	920	1020	970	Rubber - Rubber
3M-2141	8	7724	500	530	515	Adhesive - Adhesive
	8C	7724	515	560	538	Adhesive - Adhesive
Compthane	4C	CRL-4	160	-	160	Adhesive - Adhesive
1878	8C	7724	330	350	340	Adhesive - Adhesive
3M-2210	4	CRL-5	840	890	865	Mostly Adhesive - Mostly Adhesive
	8	CRL-5	715	740	728	Adhesive - Adhesive
	20	CRL-6	960	980	970	Mostly Adhesive - Mostly Adhesive
	WX-18	-	635	660	648	Adhesive - Adhesive

TABLE 47 (continued)

ADHESIVE	FABRIC NO.	LATEX NO.	BREAKING FORCE, LBS. 1ST	2ND	AVERAGE	HOW FAILURE OCCURRED
PPG	4	CRL-5	965	1045	1005	Rubber - Rubber
483/CH100	8	CRL-5	930	960	945	Both - Both
	20	CRL-6	1190	1200	1195	Rubber - Rubber
	WX-18	-	680	720	700	Adhesive - Adhesive
Bostik 1095	20	CRL-6	1240	1300	1270	Rubber - Rubber
+	WX-18	-	680	745	712	Adhesive - Adhesive
#9 Boscodur						
3M-1300L	4	CRL-5	1010	1125	1068	Rubber - Rubber
	8	CRL-5	1020	1085	1052	Mostly Rubber - Mostly Rubber
	20	CRL-6	1240	1370	1305	Rubber - Rubber
	WX-18	-	865	910	888	Adhesive - Adhesive
G-580	4	CRL-5	1040	1150	1095	Rubber - Rubber
	8	CRL-5	930	1015	972	Mostly Rubber - Mostly Rubber
	20	CRL-6	1180	1200	1190	Rubber - Rubber
	WX-18	-	640	700	670	Adhesive - Adhesive
Uniroyal 6130	4	CRL-5	890	950	920	Mostly Rubber - Mostly Rubber
	8	CRL-5	775	790	782	Mostly Adhesive - Mostly Adhesive
	20	CRL-6	1140	1145	1142	Rubber - Rubber
	WX-18	-	670	710	690	Adhesive - Adhesive

TABLE 48 - NINE BETTER PERFORMING ADHESIVES

NAME	SUPPLIER
Chemlok 305	Hudson Chemical Company
EC-776	Minnesota Mining & Mfg. Co.
1300L	Minnesota Mining & Mfg. Co.
2210	Minnesota Mining & Mfg. Co.
483/CH100	Pittsburgh Plate Glass
G580	Pittsburgh Plate Glass
6130	Uniroyal
Bostik 1095/#9 Boscodur	United Shoe Machinery Co.
Loxite 7021	Xylos Rubber Co.

TABLE 49 - EFFECT OF JP-4 ON NINE ADHESIVE FILMS

ADHESIVE	FILM THICKNESS IN X 10^{3}	AVERAGE BREAKING FORCE, LBS. CONTROL	AVERAGE BREAKING FORCE, LBS. TEST*	AVERAGE TENSILE STRENGTH, PSI CONTROL	AVERAGE TENSILE STRENGTH, PSI TEST	AVERAGE EXTENSION, IN CONTROL	AVERAGE EXTENSION, IN TEST	ULTIMATE ELONGATION, % CONTROL	ULTIMATE ELONGATION, % TEST
305	12.1	3.23	2.08	266	172	0.09	0.10	18	20
EC-776	2.5	2.58	1.57	1032	628	2.32	4.89	464	978
1300L	2.2	1.70	XX	773	-	0.09	-	18	-
2210	1.5	2.20	XX	1466	-	7.99	-	1598	-
483	1.2	4.19	XX	3491	-	7.50	-	1500	-
G580	2.1	3.54	XX	1685	-	4.88	-	976	-
6130	2.0	3.21	XX	1605	-	8.72	-	1744	-
1095	2.0	5.04	5.42	2520	2710	3.23	5.39	646	1078
7021	3.0	5.16	2.62	1720	873	5.12	7.01	1032	1402

*After 24 hour immersion in JP-4

XX Could not be tested

TABLE 50 - EFFECT OF JP-4 ON ADHESIVES IN LAPPED JOINS

ADHESIVE	FABRIC #	LATEX	AVERAGE BREAKING FORCE	TYPE OF FAILURE
Uniroyal 6130	4	7724	Bond destroyed	-
"	20	CRL-3	161 lbs.	Adhesive
"	20	CRL-6	193 lbs.	Adhesive
"	20	7724	Bond destroyed	-
"	8	CRL-5	469 lbs.	Adhesive
"	4	CRL-4	21 lbs.	Adhesive
"	4	CRL-5	311 lbs.	Adhesive
"	8	CRL-4	40 lbs.	Adhesive
"	8	7724	Bond destroyed	-
Loxite 7021	20	CRL-3	803 lbs.	Adhesive
"	4	CRL-4	364 lbs.	Adhesive
"	4	7724	186 lbs.	Adhesive
"	20	7724	206 lbs.	Adhesive
"	8	7724	192 lbs.	Adhesive
"	8	CRL-4	495 lbs.	Adhesive
3M 2210	8	CRL-4	113 lbs.	Adhesive
"	8	7724	79 lbs.	Adhesive
"	20	7724	115 lbs.	Adhesive
"	4	CRL-5	189 lbs.	Adhesive
"	20	CRL-6	168 lbs.	Adhesive
"	8	CRL-5	334 lbs.	Adhesive
"	20	CRL-3	199 lbs.	Adhesive
"	4	CRL-4	20 lbs.	Adhesive
"	4	7724	Bond destroyed	-
Bostik 1095/	4	7724	410 lbs.	Adhesive
#9 Boscodur	20	CRL-6	1040 lbs.	Rubber - Adhesive
"	8	CRL-4	669 lbs.	Rubber - Adhesive
"	20	CRL-3	940 lbs.	Rubber - Adhesive
"	20	7724	480 lbs.	Adhesive
"	8	CRL-5	1240 lbs.	Rubber
"	8	7724	300 lbs.	Adhesive
"	4	CRL-5	1100 lbs.	Rubber
"	4	CRL-4	802 lbs.	Adhesive
3M 1300 L	8	CRL-5	825 lbs.	Adhesive
"	4	CRL-5	240 lbs.	Adhesive
"	8	7724	171 lbs.	Adhesive
"	20	CRL-6	322 lbs.	Adhesive

TABLE 50 (continued)

ADHESIVE	FABRIC #	LATEX	AVERAGE BREAKING FORCE	TYPE OF FAILURE
PPG 483	4	7724	38 lbs.	Adhesive
"	8	7724	193 lbs.	Adhesive
"	20	7724	190 lbs.	Adhesive
"	20	CRL-3	555 lbs.	Adhesive
"	4	CRL-5	500 lbs.	Adhesive
"	8	CRL-5	863 lbs.	Adhesive
"	20	CRL-6	690 lbs.	Adhesive
"	4	CRL-4	81 lbs.	Adhesive
G580	20	7724	Bond destroyed	-
"	20	CRL-3	425 lbs.	Adhesive
"	20	CRL-6	685 lbs.	Adhesive
"	4	7724	Bond destroyed	-
"	8	CRL-4	272 lbs.	Adhesive
"	4	CRL-5	370 lbs.	Adhesive
"	4	CRL-4	144 lbs.	Adhesive
"	8	7724	Bond destroyed	-
"	8	CRL-5	484 lbs.	Adhesive

TABLE 51 - LAP JOIN STRENGTHS FOR MEMBRANE #2

JOIN	SAMPLE WIDTH in.	GAUGE in.	STRENGTH lbs/in.	COMMENT
E_2 to E_3	1	8	713	Material broke
E_2 to E_3	2	8	700	Material broke
E_2 to E_3	3	8	730+	Samples slipped at 2200 lbs.
E_1 to E_2	3	9	1470	Material broke
E_3 to D_1	3	9	1600	Adhesive failed
D_2 to C_1	3	9	1630	Adhesive failed
D_2 to C_1	3	9	1800	Material broke
C_1 to C_2	3	9	1040	Adhesive failed
C_2 to C_3	3	9	1520	Adhesive failed

TABLE 52 - ADHESIVE APPLICATION EQUIPMENT
RECOMMENDED BY GRACO

Item 1 - Graco #225-654 Monark 5-1 mounted con cart, complete with Hose and hand operated Dispensing Valve
Cat. C-3 P.2 Price $ 517.75

or

Graco #225-654 Monark 5-1 mounted on cart, less Hose, hand operated Dispensing Valve, and Plate
Price $ 392.05

Graco #205-435 Automatic Dispensing Valve with 164-750 Tip and 164-743 Needle
Cat. C-3 P.9 Price $ 110.00 ea.

Graco #206-763 Nylon Hose 3/4" MBE 6' long
Price $ 23.60 ea.

Item 2 - Graco #225-840 President 9-1 mounted on cart, complete with Hose and hand operated Dispensing Valve
Cat. C-3 P.2 Price $ 617.75

or

Graco #225-840 President 9-1 mounted on cart, less Hose, hand operated Dispensing Valve, and Plate
Price $ 494.05

Graco #205-435 Automatic Dispensing Valve with 164-750 Tip and 164-743 Needle
Cat. C-3 P.9 Price $ 110.00 ea.

Graco #206-763 Nylon Hose 3/4" MBE 6' long
Price $ 23.60 ea.

Item 3 - Graco #205-788 Monark 5-1 Pump
Cat. C-3 P.5 Price $ 444.00

Graco #204-490 Inductor, complete with Material Plate and Controls
Cat. C-3 P.4 Price $ 257.00

TABLE 52 (continued)

Item 4 - Graco #205-789 President 9-1 Pump
Cat. C-3 P.5 Price $ 615.00

Same Inductor as Item 3.

Dispensing Valves Automatic and Hose as in Items 1 and 2.

TABLE 53 - SHEAR TEST OF MEMBRANE #1, PROTOTYPE #1

SAMPLE OR PIECE IDENTIFICATION	PRESSURE lbs./sq.in.	PEAK FORCE lbs./in.	DYNAMIC FORCE lbs./in.	COMMENTS
WX-18	2000	765	570	Considerable rubber removal
CRL-5	2000	930	620	Considerable rubber removal
A*	2000	780	440	Severe rubber removal
B*	2000	810	435	Severe rubber removal
C*	2000	795	435	Severe rubber removal
D*	2000	825	480	Severe rubber removal
E*	2000	750	470	Severe rubber removal
WX-18	500	107	107	Very slight effect
CRL-5	500	185	130	Slight rubber removal
A*	500	157	105	Considerable rubber removal
B*	500	166	105	Considerable rubber removal
C*	500	159	105	Considerable rubber removal
D*	500	175	115	Considerable rubber removal
E*	500	170	110	Considerable rubber removal

*These samples are Membrane #1, Prototype #1, postcured as given in Table 54.

TABLE 54 - EFFECT OF POSTCURING ON STRENGTH OF MEMBRANE #1, PROTOTYPE #1*

SAMPLE	POST CURE TIME minutes	POST CURE TEMPERATURE °F	WARP GRAB STRENGTH lbs./in.
A	6	300	2172
B	20	300	2150
C	13	310	2148
D	6	320	2025
E	20	320	2148

*The material was cut from roll A1.

TABLE 55 - EFFECT OF PRESSING AND CURING ON MEMBRANE* PROPERTIES

DUMMY VARIABLE X_1	VARIABLE X_2	PRESSURE psi	TIME sec.	TEMP. °F	PRESSED THICKNESS mils	WARP STRENGTH pli	FILLING TEAR STRENGTH lbs.	COMMENTS
0	0	100	1	310	94	2250	547	5% blistered
0	0	100	1	310	93	2162	526	No blisters
-1	-1	10	20	310	112	2112	560	No blisters
-1	+1	10	100	310	99	2194	544	No blisters
+1	-1	1000	20	310	93	2037	516	50% blistered
+1	+1	1000	100	310	82	2194	481	25% blistered

*Membrane is as described in section I.I.

TABLE 56 - LAB TEST RESULTS ON MEMBRANE #1, PROTOTYPE #1

Warp Grab Strength:	1850-2050 lbs./inch
Filling Grab Strength:	1950-2150 lbs./inch
Tear Strength:	350-500 lbs.
Weight:	6.5 - 7.5 oz./sq.ft.
Thickness:	0.075 inches
Flammability:	10 - 30 sec. flame out time
Lap Join Strength:	100 - 150 lbs./inch

TABLE 57 - PEEL ADHESION RESULTS ON COATED SAMPLES PREPARED BY DUPONT

Sample Number	% D-417 Pickup	Saturant Material (40%TSC)	Coating Material	Average Peel Adhesion, lb.	Test Remarks
1	0	CRL-3	CRL-3	14.5 13.8 (AFC)	Some rubber failure but mostly rubber-to-fabric failure.
2	0	CRL-6	CRL-6	11.0 15.8 (AFC)	Some rubber failure but mostly rubber-to-fabric failure.
3	0	L-635	L-635	18.5 18.3 (AFC)	Some rubber failure but mostly rubber-to-fabric failure.
4	3.0	CRL-3	CRL-3	18.0 23.5 (AFC)	Some rubber failure. Some rubber-to-duck failure.
5	3.0	CRL-6	CRL-6	21.0 25.8 (AFC)	Some rubber failure but mostly rubber-to-duck failure.
6	3.0	L-635	L-635	20.5 22.0 (AFC)	Some rubber failure. Some rubber-to-duck failure.
7	2.5	CRL-3	CRL-3	18.0 21.0 (AFC)	Some rubber failure. Some rubber-to-duck failure.
8	2.5	CRL-6	CRL-6	22.0 27.0 (AFC)	Some rubber failure but mostly rubber-to-duck failure.
9	2.5	L-635	L-635	14.5 14.5 (AFC)	Some rubber failure. Some rubber-to-fabric failure.
10	0	CRL-3*	CRL-3	7.0 9.3 (AFC)	Used epoxy to bond duck to rubber. Rubber-to-fabric failure.

* Undiluted

TABLE 58 - DUPONT'S L-635 LATEX FORMULATION

	PHR
Neoprene Latex 635	100
Zinc oxide	10
Neozone D	3
Hylene MP	20
Merpol HCS	1

TSC as made = 55.5%

TABLE 59 - D417 PRIMER FORMULATION

Part A.

Hylene MP	3.62 parts by weight
Aersol OT	0.12
Water	6.0

Part B.

Gum tragacanth	0.75
Epon 812	1.57
Water	87.94
Total	100.00

A. Dissolve the Aerosol OT in hot water; add the Hylene MP to this solution with rapid stirring.

B. Dissolve the gum in the water; add the Epon 812 to this solution.

Mix by adding the gum/Epon solution (Part B) to the Hylene MP dispersion (Part A).

The amounts of water used in either Part A or Part B are not critical, but the sum of the amounts of water from these two parts is critical (from processing point of view only) and should be equal to 93.94 lbs. or parts. The Aerosol OT dissolves slowly in water; so we heated the water in order to speed things up. You may not want to heat the whole 6.0 parts of water; in which case something less can be used with no problem as long as the correct total amount is added eventually. The Hylene MP is now made in a form that merely requires rapid stirring (e.g. Lightnin Mixer).

Ball-milling is no longer necessary for Hylene MP when the lot number comes after #306. The gum tragacanth dissolves very slowly in water; so we added the water to the gum and then only as fast as it would take up the water. After all of the gum is wet and the lumps broken, a smooth paste is obtained to which all the rest of the water can be added.

TABLE 60 - DESCRIPTION OF SAMPLE PREPARATION

NUMBER	PRIMER	LATEX FOR 1st COAT	LATEX FOR SUBSEQUENT COATS
1	None	CRL-3 at 52% TSC	CRL-3
2	None	CRL-3 at 40% TSC	CRL-3
3	D417	CRL-3 at 40% TSC	CRL-3
4	D417	CRL-6 at 40% TSC	CRL-3
5	D417	CRL-7 at 40% TSC	CRL-7
6	D417	CRL-8 at 40% TSC	CRL-7

All the samples were heat-set at 360° F for 5 minutes. The D417 Primer is described in Table 59 and the method of priming is described in section I. N. 2.c. All of the samples received five impregnation passes with padding, prior to coating.

TABLE 61 - NEOPRENE LATEX FORMULATIONS

	CRL-3	CRL-6	CRL-8	CRL-7
NEOPRENE LATEX 571	100	100	-	-
NEOPRENE LATEX 400	-	-	100	100
AQUAREX WAQ	1	1	1	1
ZINC OXIDE	5	5	5	5
NEOZENE D SPECIAL	-	2	-	-
AGERITE POWDER	2	-	2	2
DIXIE CLAY	-	-	-	-
HYDRAL 710	50	50	50	50
REZ-O-SPERSE 3	30	30	16	16
SRF BLACK	-	10	-	-
FT BLACK	10	-	10	10
ANTIMONY OXIDE	6	6	6	6
TEPIDONE	1	1	-	-
THIURAM E	-	1	-	-
ETHYL TUADS	1	-	-	-
A-1 THIOCARBONILIDE	-	-	2	2
AQUAREX SMO	3	3	3	3
HYLENE MP	-	20	20	-
	209	209	215	195

TABLE 62 - TEST RESULTS FOR RUBBER CHANGES AND FABRIC PRIMER*

SAMPLE NO.**	PEEL STRENGTH lbs./inch	FLAME-OUT time, sec.	TEAR STRENGTH lbs.	"SLIP" STRENGTH lbs./inch dynamic	"SLIP" STRENGTH lbs./inch static	GRAB STRENGTH lbs.
1	8	1.0	250	590	860	1550
2	6	1.1	300	635	970	-
3	8	1.5	235	530	960	-
4	27+	1.3	167	545	760	1950
5	23+	60***	116	1150	1640	-
6	26+	4.5	130	1075	1400	2060

* Test results are based on few tests

** As in Table 60

*** Insufficient rubber on the back side gave prolonged burning in two tests, e.g., 1-10 minutes

TABLE 63 - TEST RESULTS FOR MEMBRANE #2, PROTOTYPE #1

ROLL NO.	AVERAGE GRAB STRENGTH WARP lbs./in.	AVERAGE GRAB STRENGTH FILLING lbs./in.	AVERAGE TEAR STRENGTH WARP lbs.	AVERAGE TEAR STRENGTH FILLING lbs.	AVERAGE FLAME-OUT TIME WARP sec.	AVERAGE FLAME-OUT TIME FILLING sec.
A	2005	1543	426	399	.61	.85
C	2090	1512	411	300	.80	2.60
D	1975	1550	419	293	.70	.80
E	2024	1590	399	297	.48	1.00

TABLE 64 - SHEAR TEST OF MEMBRANE #2

SAMPLE OR PIECE IDENTIFICATION	PRESSURE lbs./sq.in.	PEAK FORCE lbs./in.	DYNAMIC FORCE lbs./in.	COMMENTS
WX-18	2000	765	570	Considerable rubber removal
CRL-5	2000	930	620	Considerable rubber removal
A	2000	810	645	Slight pilling
D	2000	725	530	Slight pilling
E	2000	800	525	Slight pilling
WX-18	500	107	107	Very slight effect
CRL-5	500	185	135	Slight rubber removal
A	500	165	137	Very slight pilling
D	500	170	125	Slight pilling
E	500	165	132	Slight pilling

APPENDIX A

LIST OF DISPERSIONS, EMULSIONS, & SOLUTIONS

A. DISPERSIONS & EMULSIONS

Antimony Trioxide (50%)

Antimony Trioxide	100
Daxad 11 Solution (10%)	30
Ammonium Caseinate Solution (10%)	30
Water	40

Ball mill 24 hours

Carbon Black (33%)

SRF Carbon Black	100
Marasperse N22 Solution (10%)	50
Sodium Hydroxide Solution (5%)	10
Water	140

Ball mill 72 hours

Clay (50%)

Dixie Clay	100
Daxad 11 Solution (10%)	10
Calgon Solution (10%)	5
Water	85

Ball mill 24 hours

Hylene MP (40%)

Hylene MP	100
Daxad 11 Solution (10%)	30
Ammonium Caseinate Solution (10%)	30
Aerosol OT Solution (5%)	10
Water	80

Ball mill 24 hours

Hydrated Alumina (33%)

Hydrated Alumina (Hydral 710)	100
Daxad 11 Solution (10%)	50
Ammonium Caseinate Solution (10%)	30
Emulphor ON-870 Solution (10%)	5
Water	115

Ball mill 24 hours

Neozone D Special (50%)

Neozone D Special	100
Daxad 11 Solution (10%)	30
Ammonium Caseinate Solution (10%)	30
Water	40

Ball mill 24 hours

Thuiram E (33%)

Thuiram E	100
Daxad 11 Solution (10%)	30
Ammonium Caseinate Solution (10%)	30
Water	140

Ball mill 24 hours

Santicizer 141 (65%)

Santicizer 141	100.00
Oleic Acid	1.92
Ammonia (28%)	0.54
Water	51.40

Emulsify in homogenizer

Tricresyl Phosphate (50%)
or Dioctyl Adipate (50%)

A	Tricresyl phosphate (or DOA)	100
	Oleic Acid	5
B	Triethanalamine	5
	Ammonium Caseinate Solution (10%)	30
	Water	60

Emulsify in homogenizer

Chlorowax 40 (60%)

Chlorowax 40	100.0
Sorapon SF-78	4.2
Toluene	5.3
Water	56.0

Ball mill 24 hours

Dyphos (46%)

Dyphos	100
Darvan No. 1	8
Water	100

Ball mill 24 hours

A-1 (33%)

A-1	100
Daxad 11 Solution (10%)	30
Ammonium Caseinate Solution (10%)	30
Water	140

Ball mill 24 hours

B. SIMPLE WATER SOLUTIONS

Ingredient	Suggested Concentration, %
Aerosol OT	5
Aquarex SMO	33
Aquarex WAQ	25
Calgon	10
Daxad 11	10
Emulphor ON-870	25
Marasperse N22	10
Sodium Hydroxide	5
Tepidone	50

C. COMPLEX WATER SOLUTION

Ammonium Caseinate (10%)

Ammonium Caseinate (e.g. Sheftene)	100
Dowicide G	3
Water	897

Procedure:
1) Heat water to 190°F
2) Add Dowicide G
3) Add ammonium caseinate slowly while stirring
4) Stir until smooth

APPENDIX B

SUMMARY OF TEST METHODS AND PROCEDURES

CCC-T-191b Method or ASTM Method	Test	Remarks
5041	Weight	Results reported in oz./sq.ft.
5050.1	Yarns per inch in woven fabric	
5100 D 1682-64	Breaking strength and elongation	Rate of jaw separation was 10 in./min. Jaws faced with emery cloth to prevent slippage.
5134	Tearing strength	Rate of jaw separation was 10 in./min. Jaws faced with emery cloth to prevent slippage.
5516	Water resistance and water permeability	For coated fabrics only. Hydrostatic head shall be 20 in. for 10 min.
5872	High temperature effect on blocking	For coated fabric only. Specimens exposed for 2 hours at 180°F.
5874	Low temperature effect on coated fabric	Expose specimen for 4 hours at -40°F
5902, 5903-T D 626-55T	Vertical flame resistance	Char length not a consideration

APPENDIX B (continued)

CCC-T-191b Method or ASTM Method	Test	Remarks
	Heat resistance	Use method 5100 after 5 min. in forced draft oven preheated to 3 50°F
	Solvent (JP-4) resistance	Use method 5100 after 24-hour immersion at room temperature
	Flexibility	Used Gurley Stiffness Tester. Specimen size 4" x 1"
	Thickness	Used Aminco Thickness Gauge at 30 oz./ sq.ft. pressure on a one-inch diameter presser foot
	Abrasion resistance	Measured on Taber Dual Abraser (Model 505) using H-18 Calibrade wheels, 500 gram load on each wheel, 1000 wear cycles. Used compressed air to clean off wheels after every 200 cycles. Specimens weighed before and after to determine weight loss
D 1894-63	Coefficient of friction	Procedure B: Moving sled, stationary plane (anodized aluminum). Run on Instron friction fixture. Load was 1.53 lb.; speed 50 in./min.
	Shear test	As discussed in section H.

APPENDIX C

COATING LINE USED

The equipment used for heat-setting, priming, impregnating, coating, and curing is illustrated in Figure C1. A description of the equipment follows.

Quantity	Description
1	Inspection table, 168" wide, w/inspector's platform, w/160" surface unwind unit with 14" dia. rolls, w/15'0" surface wind-up unit, 8-1/2" dia. rolls with 1 h.p., 220/440 V., 3 phase motor. (Not shown)
1	Birch Bros. BB 1081 Heavy Duty Butt Seam Portable Railway Sewing Machine, Serial #154-236, 16" seam for carpet material, 3/4 h.p., 115 V., 1 phase drive, w/Union Special 81200 AZ modified single thread overedging head, Eastman rotary trimmer, power drive and return.
1	Toledo Scale, above floor platform, can also be put in floor, 500 lbs. dial, 800 lbs. tare with 48" x 72" added platform. (Not shown)
2	Spray Engineering Model 2652-4 Four Gun Traversing Spray Units with limit switches, air regulating control set, hoses and guns for 156" web, driven by 1/2 h.p., 440 V., 3 phase motor. Down draft exhaust box with 34" exhaust fan and 3 h.p., 440 V. motor. Each unit has two 100 gallon pressure feed tanks with control heads.
1	American Air Compressor Co. 40 h.p., 440 V. Horizontal Air Compressor, 10" x 10" with after cooler, separator, and receiver.
1	Birch Bros. 15 Ton Padder, two 16" dia. rubber covered rolls, 15'0" face, w/5 h.p. adjustospede drive and gear box. Top roll lifted by air cylinders.
1	Butterworth Pin Tenter Drying Range wired for 440 V., horizontal pin chain, 180" wide x 60' long, w/automatic guiders, pre-heat section of six 11 KW 220 V. calrod heaters, dryer section has eight 15 h.p. motors and fans, duct type air distribution systems, air driven 24" exhaust blower, 4 zone automatic heat control with total of 310 KW heaters in ducts, pin chain drive by 15 h.p. variable speed SCR

APPENDIX C (continued)

Quantity	Description
	(Butterworth Pin Tenter Drying Range - continued)
	drive, 22'0" face surface winder at discharge end of dryer, 10" dia. rolls, driven through Reeves adjustable gear box, w/two 1/2 h.p., 115/220 V. motors and slitters.
1	Inspection table 156" wide, w/160" adjustable center unwind, w/inspector's platform, w/160" adjustable tension bar stand, w/156" surface wind-up with 11" rolls and 1-1/2 h.p. 220/440 V. motor with variable speed PIV drive. Table equipped with adjustable slots for use of Maimin cutters for slitting. (Not shown)
	Various doffing trucks, chain falls and trolleys, mono-rail system w/scale and Sonoco storage tubes.

FLOOR PLAN OF NORTH MONMOUTH COATING LINE

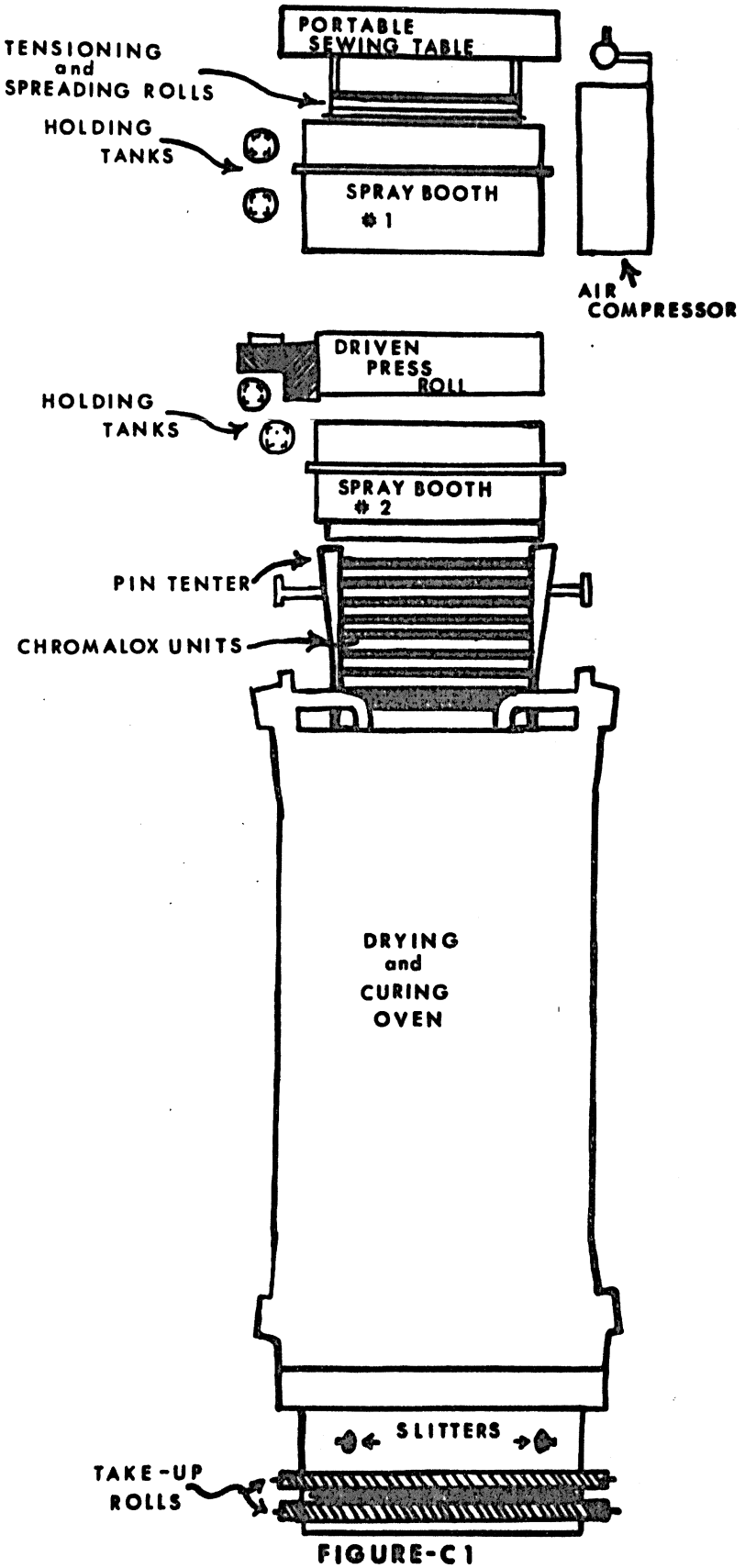
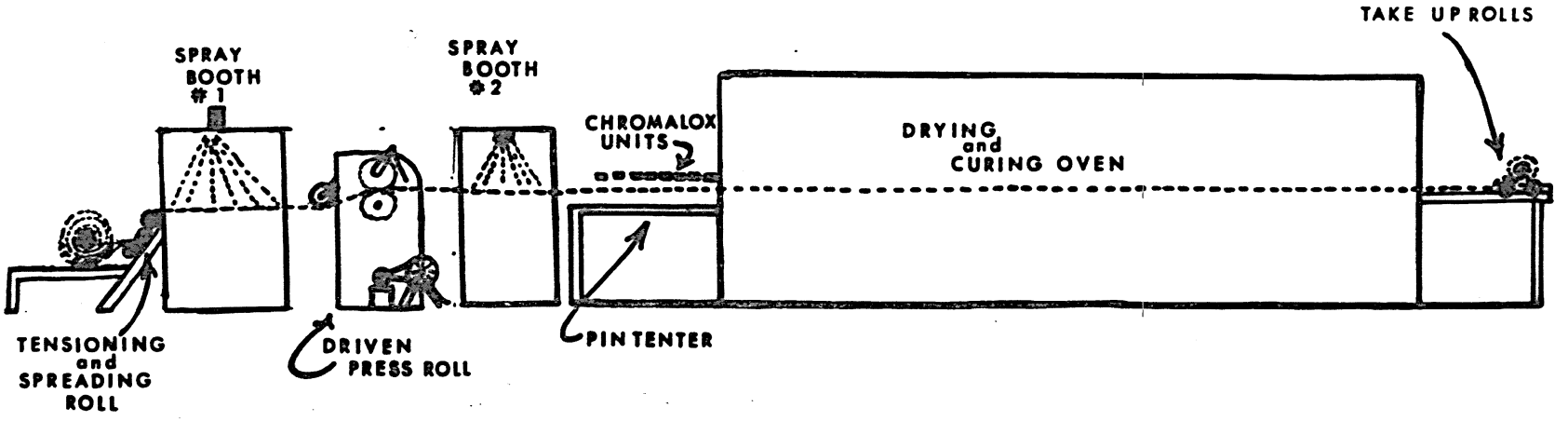


FIGURE-C1

FIGURE C2

SCHEMATIC OF NORTH MONMOUTH COATING LINE



APPENDIX D

LIST OF CHEMICALS & SUPPLIERS

X-9017 (Plastisol)	Chemical Products
76X-836 (Plastisol)	Stanley Chemical
LX-49 (Plastisol)	Taurus Chemical
JP-4 (Solvent)	Mobil Oil
Flamexx MM (Flame Retarder)	Guardian Laboratories
Flamexx MM-N (Flame Retarder)	Guardian Laboratories
Geon 222 Resin	B. F. Goodrich
Antimony Oxide (Flame Retarder)	Whittaker, Clark & Daniels
Darvan No. 1 (Dispersing Agent)	R. T. Vanderbilt
No. 10 White (Filler, Reinforcing, Extender)	Georgia Marble
Solvesso 100 (Solvent)	Esso Standard Oil
Geon 103 EP Resin	B. F. Goodrich Chem.
Acryloid A-101 (Plasticizer)	Rohm & Haas
Estane 5740X1	B. F. Goodrich Chem.
Thiokol FA	Thiokol Chemical
Zinc Oxide (Curing Agent)	Eagle-Picher
SRF black-Sterling S	Cabot
MBTS (Accelerator)	(Various)
DPG Diphenylquanidine (Accelerator)	American Cyanamid
Stearei Acid (Activator, Curing Agent)	(Various)
Calgon (Dispersing Agent)	Hagon Chemicals & Controls
Hypalon 30	Du Pont
Staybelite Resin (Plasticizer, Tackifier)	Hercules
Tri-Mal (Stabilizer)	National Lead
Thiuram M (Accelerator)	Du Pont
Ti-Pure R 902 (Pigment)	Du Pont
Paracril Ozo	Uniroyal Chem.
Naugawhite (Antioxidant)	Uniroyal Chem.

Octamine (Antioxidant)	Uniroyal Chem.
Calcine TM (Reinforcing)	PPG Industries
Plasticizer SC (Plasticizer)	Harwick Standard Chem.
Monex (Accelerator)	Uniroyal
Oncor 23A (Flame Retarder)	National Lead
Chlorowax 70 (Plasticizer, Flame Retarder)	Diamond Alkali
Hydrin 200	B. F. Goodrich Chem.
Zinc Stearate (Multifunctional)	(Various)
Red Lead Oxide (Curing Agent)	Eagle-Picher
Agerite Resin D (Anti Oxidant)	R. T. Vanderbilt
FEF Black-Sterling SO (Filler, Reinforcing)	Cabot
Dechlorane 355 (Flame Retardant)	Hooker Chemical
Chlorowax 40 (Plasticizer, Flame Retarder)	Diamond Alkali
Piperazine Hepohydrate (Accelerator)	Jefferson Chem.
Halowax 0077 (Fire Retarder)	Koppers
Chemivic 400	Goodyear
Chemivic 450	Goodyear
McNamee Clay (Reinforcer, Filler)	R. T. Vanderbilt
Tricrisylphosphate (Plasticizer, Flame Retarder)	(Various)
Amax No. 1 (Accelerator)	R. T. Vanderbilt
Unads (Accelerator)	R. T. Vanderbilt
Hycar 1203 X 11	B. F. Goodrich
Blackbird Sulfur (Curing Agent)	C. P. Hall
MT Black (Color, Filler, Reinforcing)	Cabot
Antox (Antioxidant)	Du Pont
Paraplex G-25 (Plasticizer)	Rohm & Haas
Monaplex DOA (Plasticizer)	Rohm & Haas
Neoprene W	Du Pont
Neoprene FB	Du Pont

Acroflex CD (Antioxidant)	Du Pont
Stan-Mog 100 (Retarder)	Harwick Standard Chem.
Hydral 710 (Flame Retarder, Filler)	Aluminum Co. of America
ZB-112 (Flame Retarder)	Humphrey Chem.
NA-22 (Accelerator)	Du Pont
Del-Val	Action Products
Vitard Fire Retardant Dispersion	National Starch & Chem.
Polyco Latex 446-L	Borden Chem.
Polyco Latex 630-18	Borden Chem.
Ludox HS-40 (Reinforcing, Binding)	Du Pont
Geon Latex 352	B. F. Goodrich
Geon Latex 552	B. F. Goodrich
Santicizer 141 (Plasticizer)	Monsanto
Calcium Carbonate (Color, Filler, Reinforcing)	(Various)
Dyphos (Stabilizer)	National Lead
Pliovic Latex 300	Goodyear
Chemigum Latex 248	Goodyear
Chemigum Latex 550	Goodyear
Acrysal GS (Thickener)	Rohm & Haas
Zinc Captax (Accelerator)	R. T. Vanderbilt
Ethyl Zimate (Accelerator)	R. T. Vanderbilt
Neoprene Latex 571	Du Pont
Neozone D Special (Antioxidant)	Du Pont
Tepidone (Accelerator)	Du Pont
Thiuram E (Accelerator)	Du Pont
Aquarex SMO (Wetting Agent)	Du Pont
Aquarex WAQ (Multifunctional)	Du Pont
Rez-O-Sperse 3 (Flame Retarder)	Dover Chemical
Dixie Clay (Filler, Reinforcing)	R. T. Vanderbilt

Hylene MP (Bonding Agent)	Du Pont
Vulcanol 7724 (Custom Compounded Latex)	Alco Chemical
MS-122 Fluorocarbon Release Agent	Miller-Stephenson
Polyco Latex 2637	Borden
Polyco Latex 2605	Borden
Neopoxo 42 (Anti-Skid)	American Abrasive Metals Co.
P-33 Black (Fine Thermal Furnace Black)	R. T. Vanderbilt
Agerite Powder (Antioxidant)	R. T. Vanderbilt
Ti-Rite HA (Flame Retarder, Filler)	Technical Inds.
Ti-Rite (Flame Retarder)	Technical Inds.
Ethyl Tuads (Accelerator)	R. T. Vanderbilt
Vulcanol 8303 (CRL-3)	Alco Chemical
Neoprene Latex 635	Du Pont
Neozone D	Du Pont
Merpol HCS (Surface Active Agent)	Du Pont
Neoprene Latex 400	Du Pont
A-1 Thiocarbonilide (Accelerator)	Monsanto
Aerosol OT (Dispersing Agent)	American Cyanamid
Gum Tragacanth (Thickener)	Howe & French
Epon Resin 812	Miller-Stephenson
Daxad 11 (Dispersing Agent)	W. R. Grace
Sheftene Ammonium Caseinate	Sheffield Chemical
Morasperse N22 (Dispersing Agent)	American Can
Emulphor ON-870 (Stabilizer)	General Aniline & Film
Dowicide G	Dow Chemical
Santicizer 141 (Plasticizer, Flame Retarder)	Monsanto
Oleic Acid (Curing Agent)	(Various)
Triethanolamine (Curing Agent)	(Various)
Sorapon SF-78 (Dispersing Agent)	General Aniline & Film

APPENDIX E

ABBREVIATIONS

D	-	diameter in inches
d	-	denier
epi	-	ends per inch
fpm	-	feet per minute
gpd	-	grams per denier
grsf	-	grains per square foot
phr	-	parts per hundred parts rubber
pli	-	pounds per linear inch
ppi	-	picks per inch
ppm	-	pounds per minute
psi	-	pounds per square inch
TSC	-	total solids concentration
YS	-	yarn strength in pounds

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13. ABSTRACT The U. S. Army desires an effective means for establishing an airfield or roadway without the expenditure of time necessary when conventional means are used. Where soil conditions permit the bare ground can be covered with a coated fabric called "Prefabricated Airfield and Road Surfacing Membrane." A research and development contract was negotiated between the U. S. Army Engineer Waterways Experiment Station (WES) and the Industrial Fabrics Division of Albany Felt Co., Albany, N. Y., for the purpose of developing a superior membrane for this purpose. Since the inception of this contract, the name of Albany Felt Co. has been changed to Albany International Corp., and the Industrial Fabrics division has become part of its wholly-owned subsidiary, Globe Albany Corporation, Buffalo, N. Y. Under this contract (No. DACA39-68-C-0003, as modified), a fundamental approach to the very wide range of options was taken. Because of this approach we were not limited to available fabric constructions or rubber compounds. We were thus able to consider the use of all the fibers and polymers that were available. For the production of the fabrics, we considered fiber performance, yarn construction, weave construction for grab and tear strength, flexibility, winding equipment, dressing equipment, loom requirements, and selvage requirements. The final fabric product is clearly superior to any fabric heretofore available and is substantially different from any fabric available at the beginning of this work. For the designation of the rubber compound, the commercially available polymers were screened and all promising materials were investigated in their available forms. The optimum material, a neoprene latex, was chosen. To properly optimize the performance of the membrane, the rubber must be prepared with additives. Some of the rubber considerations were: toughness, abrasion resistance, self-extinguishability, fiber wettability, penetration of the fabric, bonding to the base fabric, high strength adhesive joins, flexibility, U. V. resistance, jet-fuel resistance, and temperature resistance. The final membrane sample used one basic rubber with three different levels of binding additive. The final rubber combination is satisfactory in all respects; however, further improvements are possible. It was found that priming of the fabric to promote rubber bonding is mandatory for a suitable material to be developed. For the combination of fabric, primer, and rubber to yield a satisfactory membrane material, many manufacturing variables were considered. Techniques were developed for this purpose. In order to achieve the very high performance glued seams needed, many adhesives were tested, and the optimum material was chosen. Satisfactory techniques were developed to produce the required seams. The anti-skid surface needed on the center of the runway is extremely important to achieve a satisfactory coefficient of friction against the airplane wheel. The optimum method is to apply a patterned coating to the membrane surface (continued)

DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Adhesives						
Expedient surfacings						
Fabrics						
Membranes						
Neoprene latex						
Prefabricated membrane surfacing						
Rubber						

13. ABSTRACT (concluded) during the final assembly. Operator technique is important as is manufacturing technology. Further improvement is needed in this area. Packaging of the final product was considered and is at the stage where the next logical steps are trials with full-sized pieces. It is our opinion that the work done has led to definite and substantial improvements in the technological level of "Prefabricated Airfield and Road Surfacing Membrane" production. The minor improvement needed in the membrane can best be done while carrying out full-scale manufacturing efforts.