NASA CONTRACTOR REPORT 177341

Thermal Blanket Insulation for Advanced Space Transportation Systems

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Thermal Blanket Insulation for Advanced Space Transportation Systems

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Prepared for
Ames Research Center
Under Contract NAS 2-11718

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

PREFACE

This report was prepared by the Woven Structures division of HITCO, Compton, California, under NASA Contract NAS2-11718. The program was administered by the NASA-Ames Research Center, Moffett Field, California, with Mr. P. M. Sawko serving as the NASA Technical Monitor.

Mr. R. H. Pusch served as Woven Structures' Program Manager, assisted by Messrs. David Falstrup and Dominic Calamito, Project Engineers.

This report covers work performed during the period October 1983 to December 1984 and was submitted by the author in February 1985.

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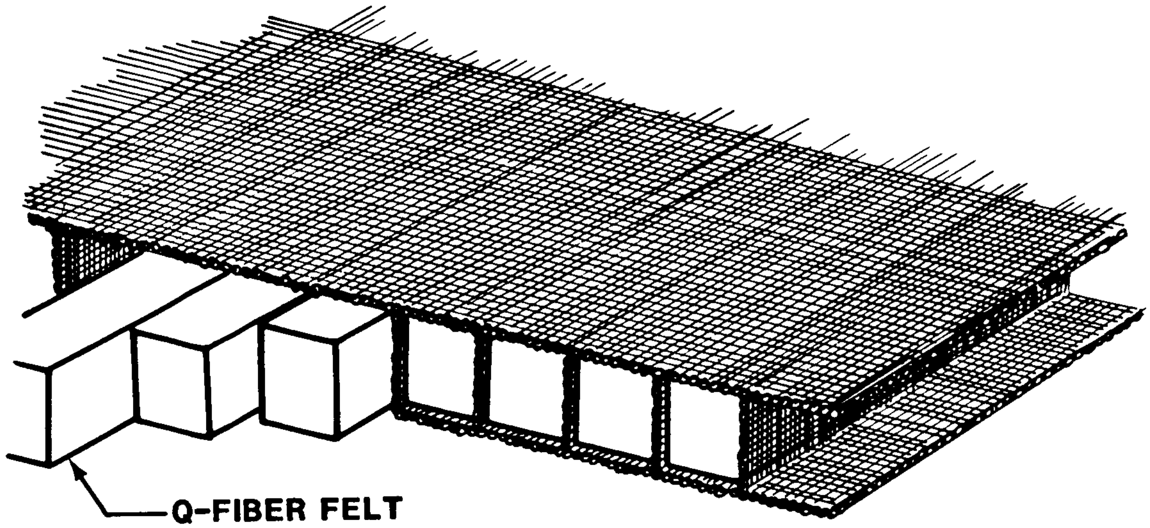
1.0 INTRODUCTION AND BACKGROUND

As a part of a NASA program to enhance the flexible reusable surface insulation materials for Advanced Space Transportation Systems, blanket type insulating materials were produced by Woven Structures on previous efforts. These thermal blankets were made from HITCORE, Woven Structures' trade name for fluted core fabric, an integrally woven material with parallel fabric faces connected to each other by fabric ribs. The HITCORE fabric can be designed with a variety of flute cross section configurations including triangular and rectangular, the latter of which was previously supplied to NASA. Also supplied was one configuration that had two layers of rectangular flutes between the outer fabric faces. ASTROQUARTZ® yarns were used to weave most of the fabrics and the flutes were filled with high temperature fibrous insulation. See Figure 1-1.

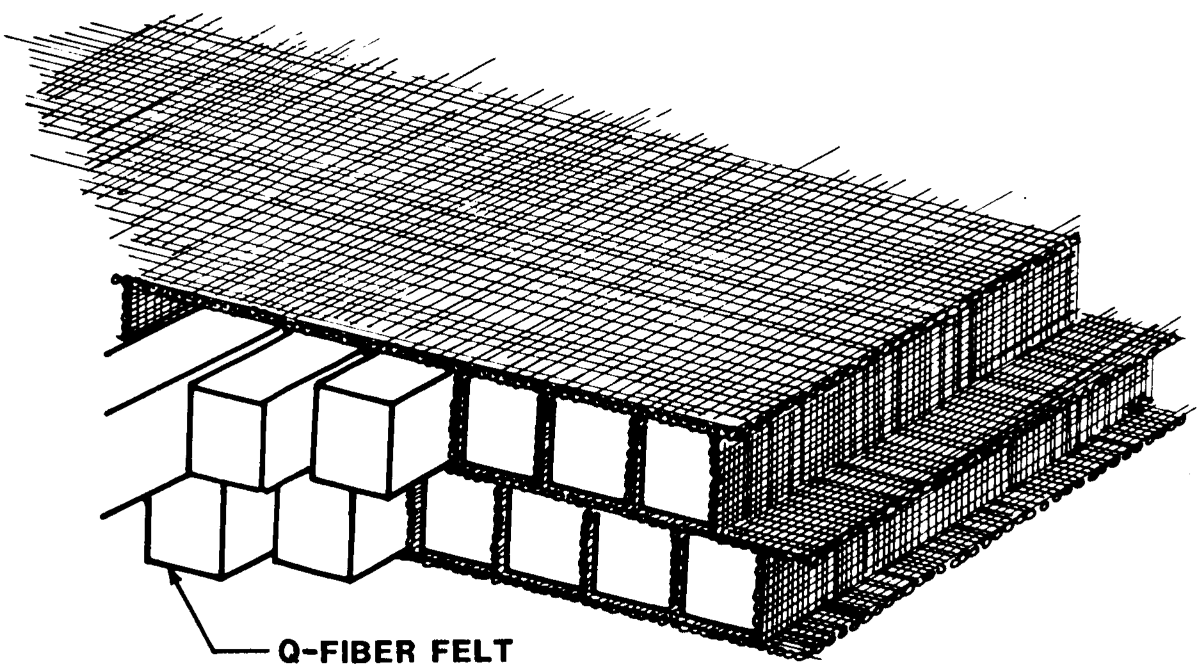
The concept of using this type of blanket insulation for Advanced Space Transportation Systems appeared attractive partly because of the integral bond between the two fabric faces that assured containment of the insulation material when subjected to service temperatures and loads. The material was also sufficiently flexible to conform to geometric contours, and could be tailored to meet thermal and mechanical design requirements by varying flute size, fabric raw materials, and insulation fillers.

The possibility of using some of the new high temperature yarns for weaving fluted core for the NASA program was of interest, and in October 1983 a contract was awarded to Woven Structures to produce four blanket configurations using these yarns.

®ASTROQUARTZ - Trade name of J. P. Stevens Co.



RECTANGULAR FLUTED CORE



DOUBLE LAYER RECTANGULAR
FLUTED CORE

FIGURE 1 - 1
WOVEN FLUTED CORE CONFIGURATIONS MADE FOR PREVIOUS NASA DEVELOPMENT PROGRAMS . INSULATION MANDRELS SHOWN BEING INSERTED INTO FLUTES.

2.0 TECHNICAL PROGRAM

2.1 Objectives

The program goal was to produce three yards each of four insulation blankets made from woven fluted core fabrics as follows:

Item 1. Single layer triangular HITCORE panel, having a 1.27 cm (1/2 inch) cell height and 66.04 cm (26 inch) minimum width. Fabric was to be woven from NEXTEL® ceramic yarn in a plain weave with a target yarn count of 10.2/cm x 10.2/cm (26/in. x 26/in.). The target face fabric areal weight was to be 0.421 Kg/sq meter (49.6 oz/sq yd). The fluted cells were to be filled with 3.57 Kg/cubic meter (6 lbs/cubic foot) Q-FIBER FELT®, and the target insulated panel weight was 2.91 Kg/sq meter (86 oz/sq yd).

Item 2. Double layer triangular HITCORE panel, each layer having a 1.27 cm (1/2 inch) cell height and 66.04 cm (26 inch) minimum width. The yarn and fabric construction and the target face fabric areal weight were to be the same as Item 1. The total fabric target weight was to be 2.91 Kg/sq meter (85.8 oz/sq yd). One layer of fluted cells was to be filled with Q-Fiber Felt as in Item 1 and the other layer with NASA-supplied FRCI-20-12 Type 3. The target insulated panel weight was 5.87 Kg/sq meter (173 oz/sq yd).

Item 3. Single layer triangular HITCORE panel, having a 1.27 cm (1/2 inch) cell height and 66.04 cm (26 inch) minimum width. The bottom face was to be woven from Nextel ceramic yarn and the top face from NICALON® silicon carbide yarn. The top face was to have a target count of 6.3/cm x 6.3/cm (16/inch x 16/inch), and the bottom face 9.45/cm x 9.45/cm (24/inch x 24/inch). The target top face areal weight was to be 0.258 Kg/sq meter (7.6 oz/sq yd) and the bottom face areal weight 0.387 Kg/sq meter (11.4 oz/sq yd). Total fabric weight was to be 1.42 Kg/sq meter (41.8 oz/sq yd). The fluted cells were to be filled with Q-Fiber Felt as in Item 1, and the target insulated panel weight was 2.64 Kg/sq meter (78 oz/sq yd).

Item 4. Single layer triangular HITCORE panel having a 1.27 cm (1/2 inch) cell height, woven entirely from Nicalon silicon carbide yarn. The target yarn count was to be 6.3/cm x 6.3/cm (16/inch x 16/inch). The target face fabric areal weight was to be 0.258 Kg/sq meter (7.6 oz/sq yd), and the total fabric weight was to be

®NEXTEL - Trade name of 3M Company
®Q-FIBER FELT - Trade name of Johns-Manville Corp.
®NICALON - Trade name of Nippon Carbon Co., Inc.

1.03 Kg/sq meter (30.4 oz/sq yd). The fluted cells were to be filled with Q-Fiber Felt as in Item 1, and the target insulated panel weight was to be 2.25 Kg/sq meter (66.4 oz/sq yd).

All panels were to be heat cleaned at 454.4°C (850°F) for four hours to remove most organic matter. Q-Fiber Felt was also to be heat cleaned for two hours at these temperatures prior to insertion in the flutes.

Figure 2-1 illustrates the four items schematically.

2.2 Program Plan

The tasks required for producing the four panels are as shown in Figure 2-2. The discussion that follows covers the effort involved in these tasks as well as some of the considerations and problems encountered during the course of the program.

2.2.1 Fabric Design & Programming. This task involved laying out the predetermined number of fill yarns (picks), to interweave properly with the required number of warp yarns to produce the desired fabric construction and flute dimensions. Consideration had to be given to the design of the yarn locking arrangement at the nodes of the triangles to minimize broken ends and weave separation that might occur during weaving. Schematics of the weave and node designs are shown in Figures 2-3 to 2-7. Of the four node locking designs shown in Figure 2-7, Type II was selected at the start of the program. During the weaving of the first ceramic fabric, severe breakage occurred because of the high yarn concentration at the nodes. The Type IV design was then introduced and the node breakage problem was eliminated. Most of the dimensional differences noted in these illustrations were required because of differences in yarn diameters. This was necessary to approach the target 1.27 cm (1/2 inch) cell height common to all four items. It was recognized that the original designs might have to be modified somewhat during the weaving task if necessary to achieve the target cell heights more closely. During the program it proved necessary to increase the face fabric pick counts of the three single layer core fabrics, Items 1, 3 and 4, in order to attain the proper cell dimensions. However, no major changes in the original designs were required.

Also as part of the design task, the yarn placement on the creels, the loom modifications and the set up requirements were planned, and the programming for the loom was designed. Triangular cross section wood mandrels to be used for checking cell sizes during weaving were also designed and fabricated during this task.

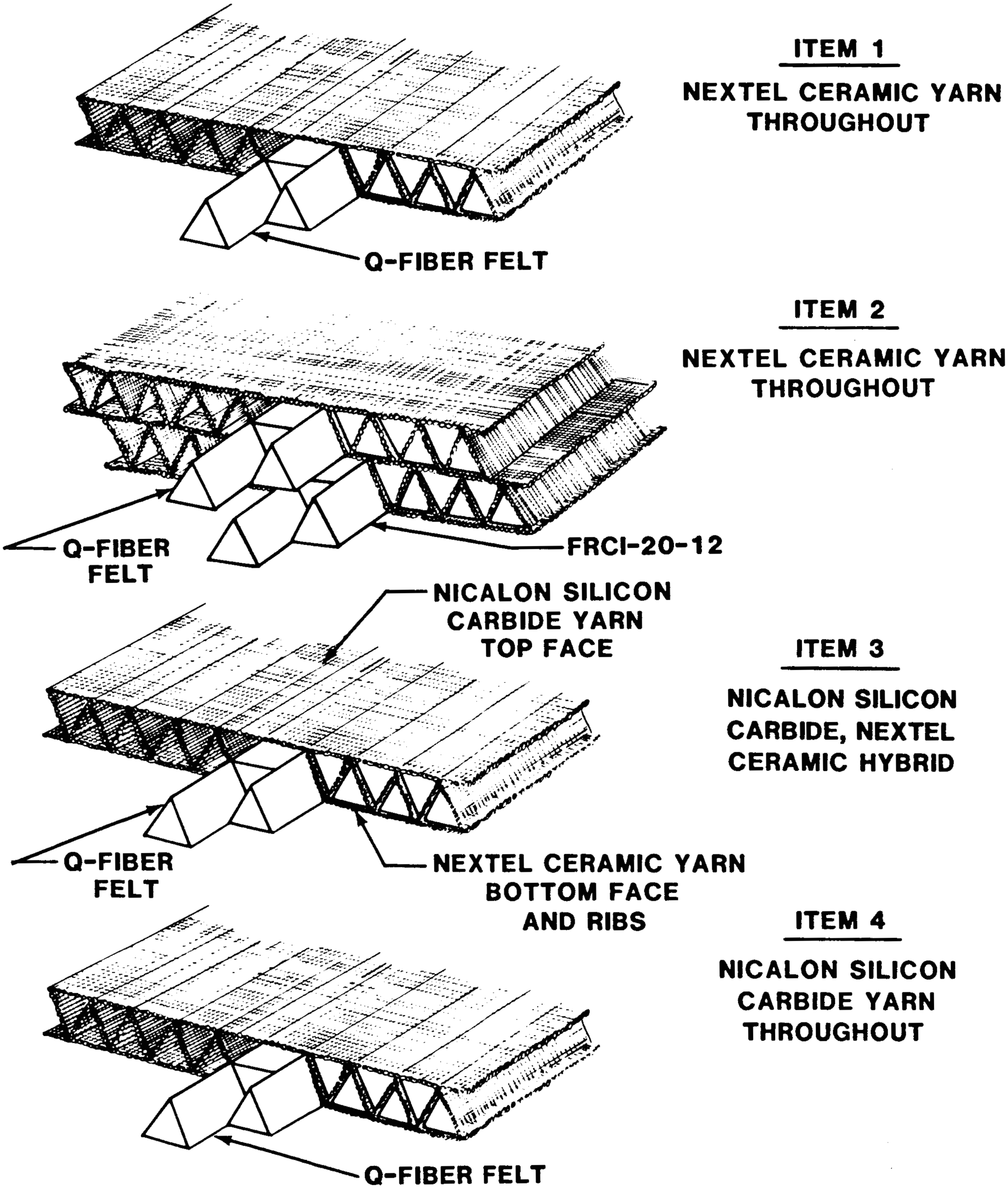


FIGURE 2-1

SCHEMATIC VIEWS OF FOUR BLANKET
PANELS TO BE PRODUCED IN PROGRAM

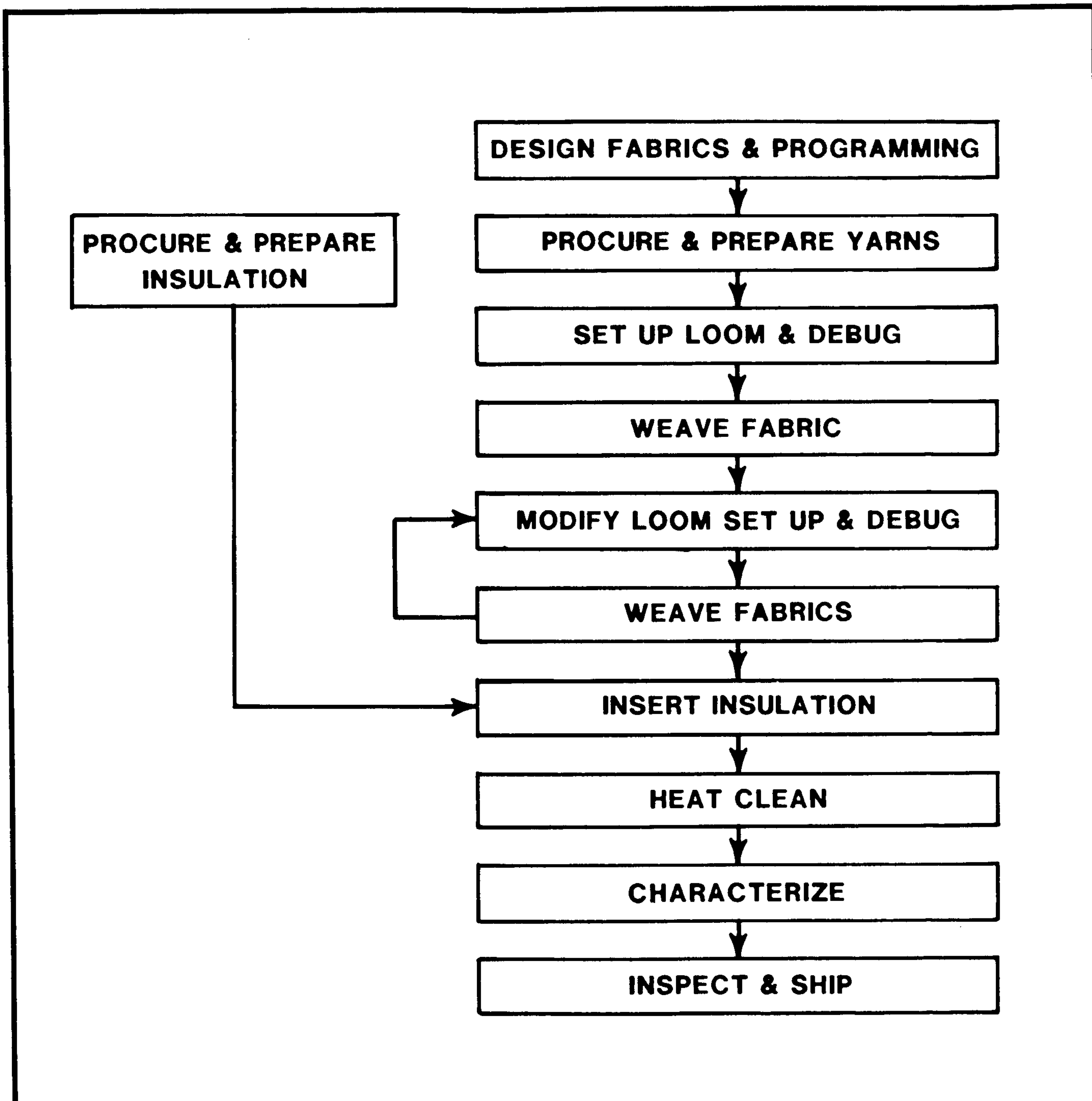


FIGURE 2-2

PROGRAM PLAN FOR PRODUCING INSULATION PANELS

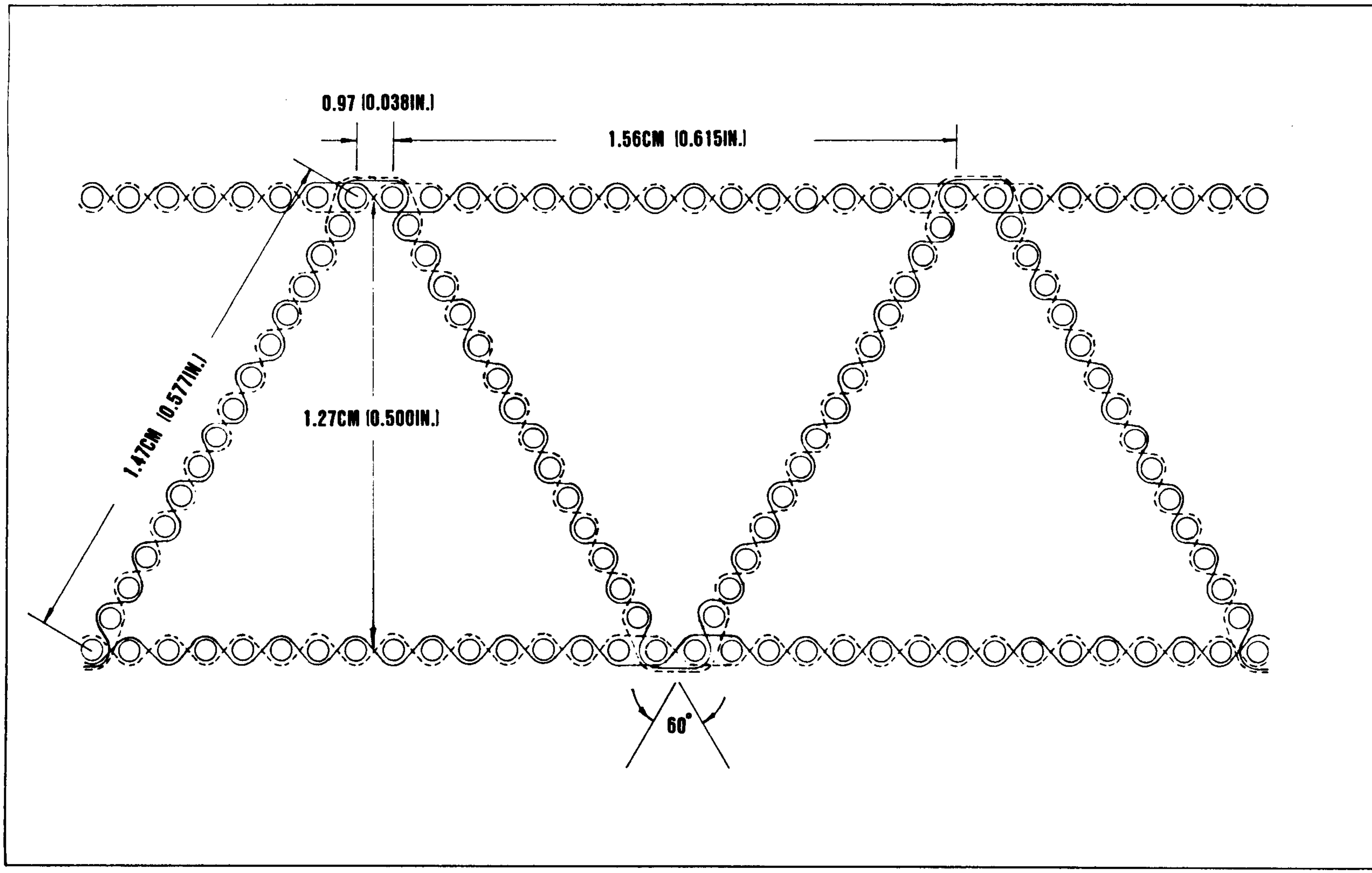


FIGURE 2-3

YARN ARRANGEMENT OF FLUTED CORE FABRIC, ITEM 1

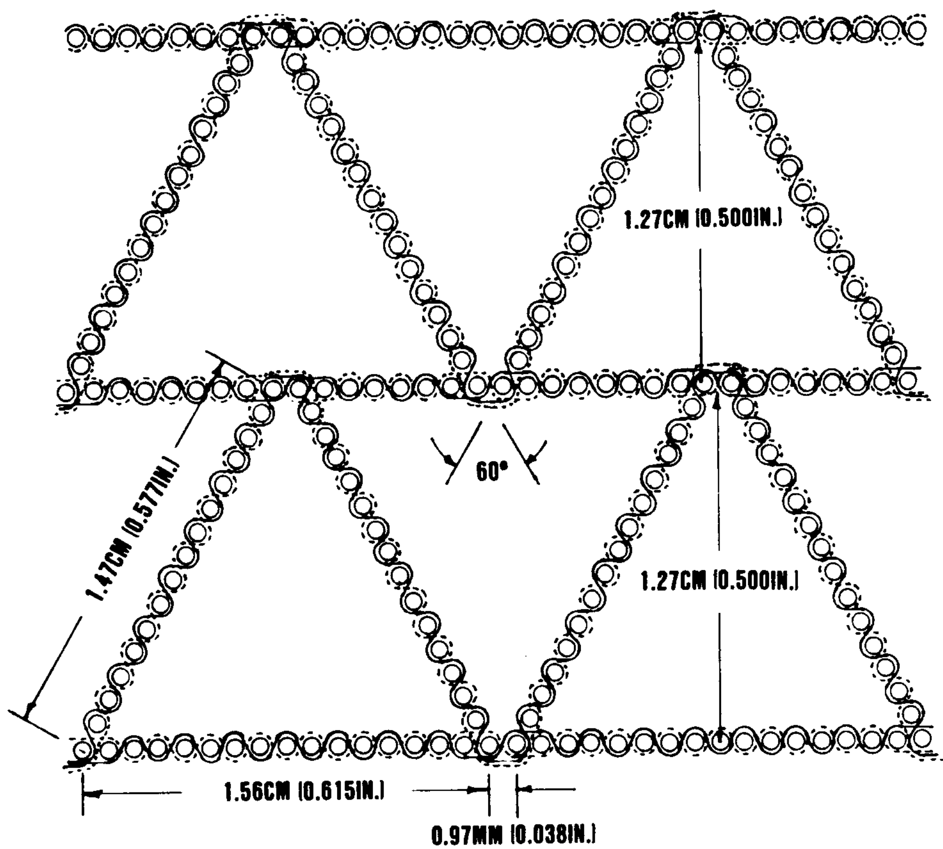


FIGURE 2-4
YARN ARRANGEMENT OF FLUTED CORE FABRIC, ITEM 2

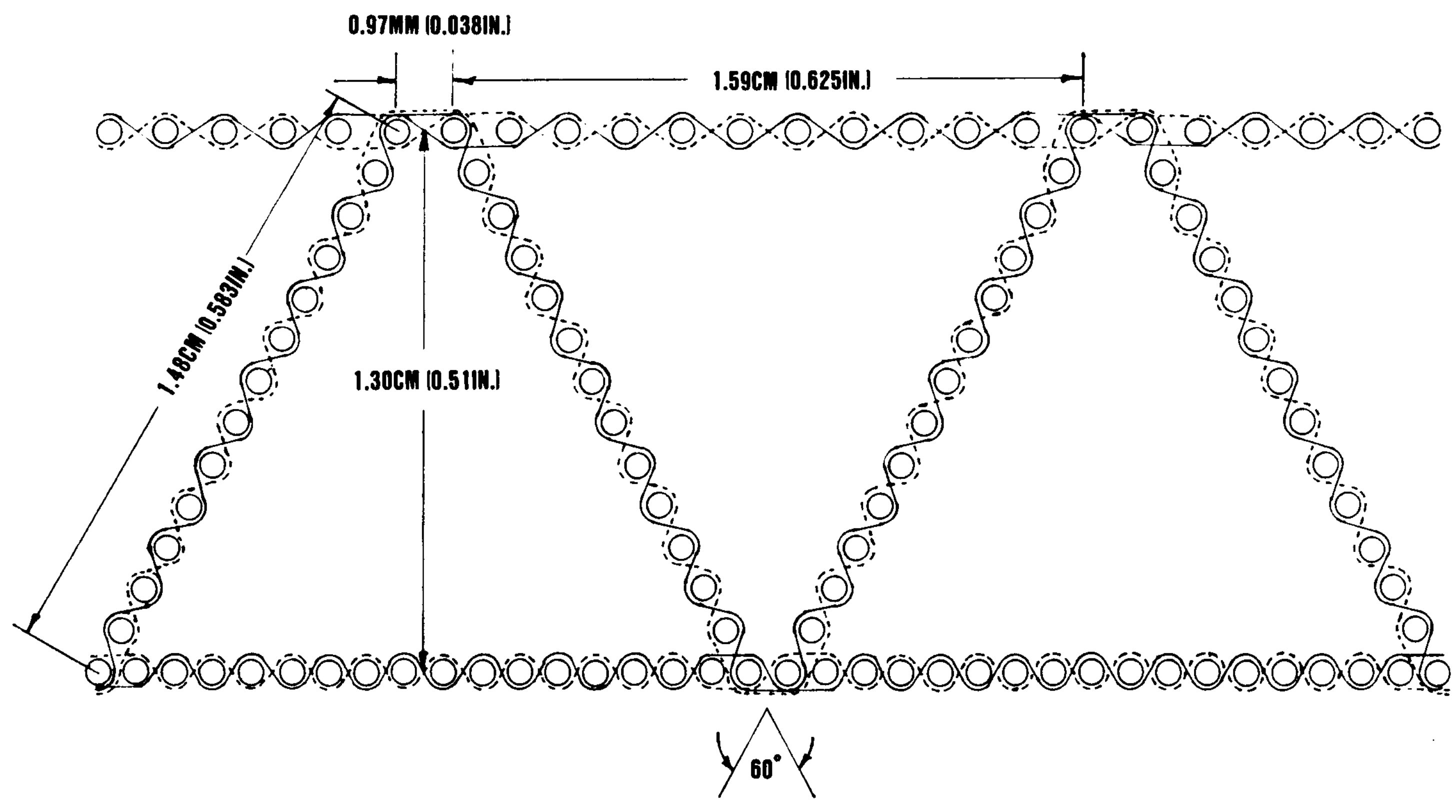


FIGURE 2-5

YARN ARRANGEMENT OF FLUTED CORE FABRIC, ITEM 3

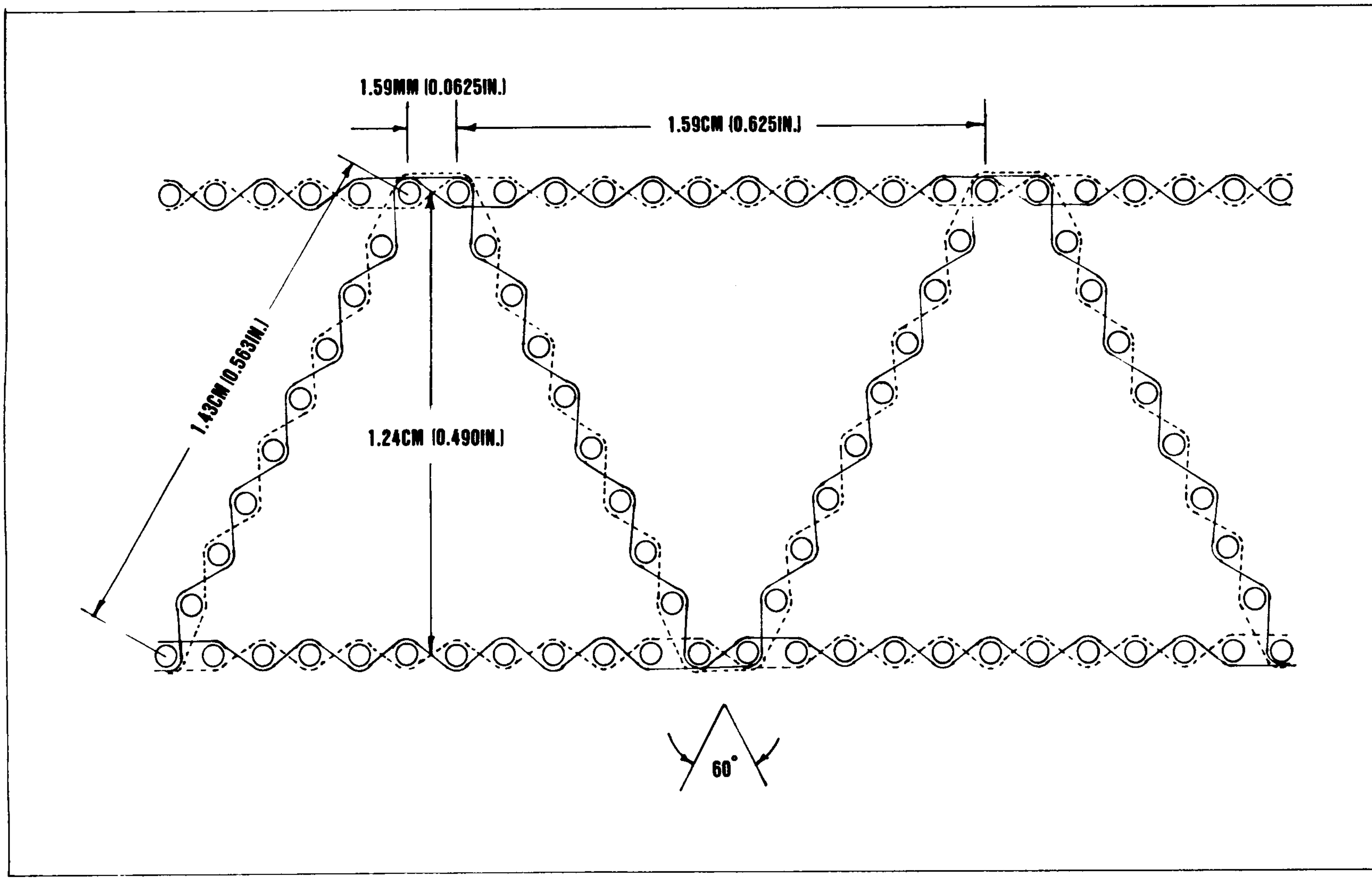


FIGURE 2-6

YARN ARRANGEMENT OF FLUTED CORE FABRIC , ITEM 4

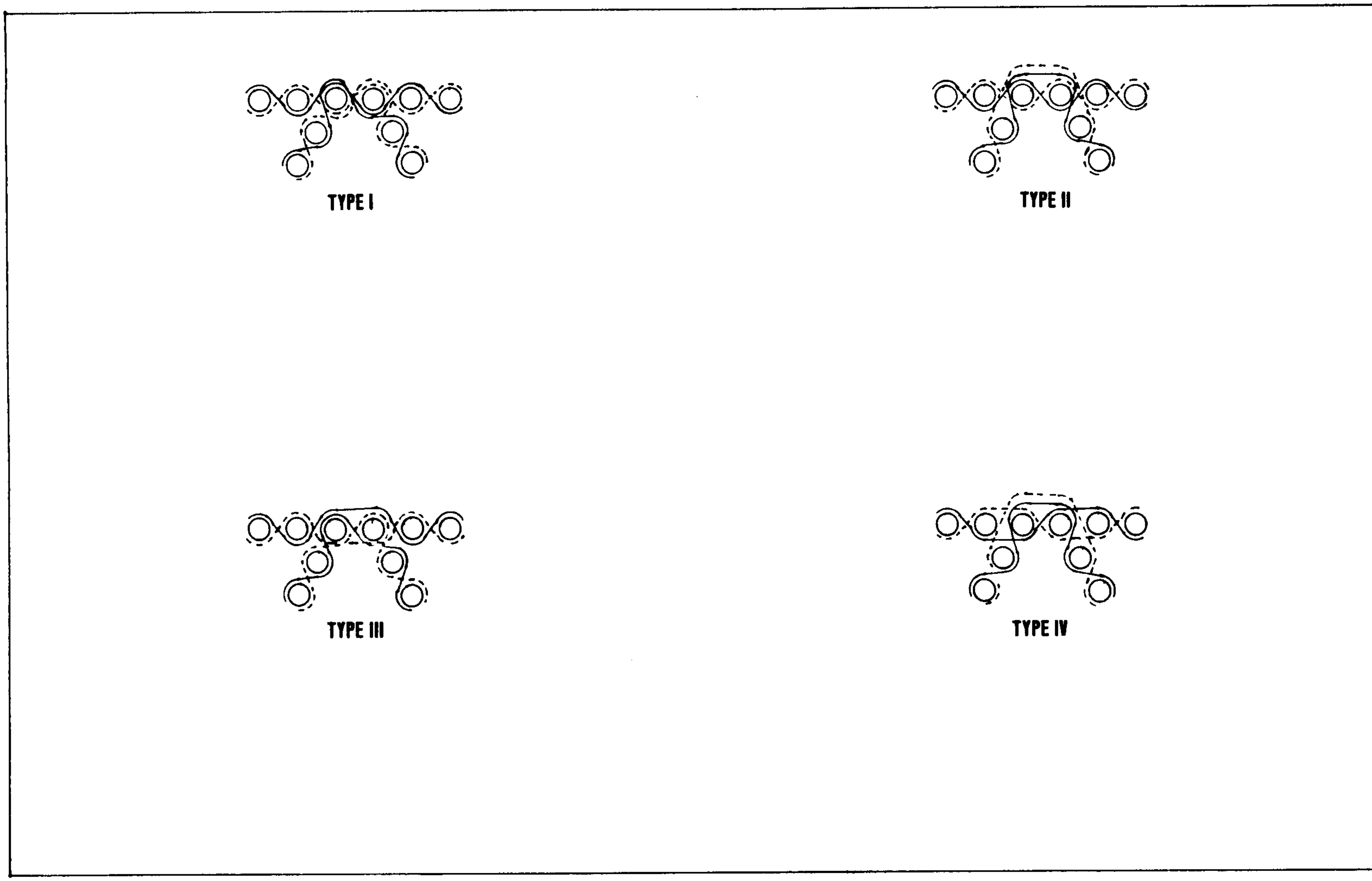


FIGURE 2-7

NODE ARRANGEMENTS CONSIDERED FOR FLUTED CORE FABRICS

It appeared that the most difficult item to produce would be Item 2, the double layer fabric, so it was decided to weave this first and then follow with Items 1, 3 and 4. Because of the high yarn costs, it was further decided to set up the first warp with glass yarn for debugging before using the more costly Nextel ceramic yarn required for Item 2.

2.2.2 Yarn Procurement and Preparation. The Nextel and Nicalon yarns were procured and then prepared for weaving. The Nextel ceramic fiber AB-312 consists of 390 continuous filaments, having a filament diameter of 10-12 micron. For this program a 900 denier 1/2 4Z ply yarn was selected. This yarn construction represents 2 strands of single continuous yarns Z twisted together at 4 twists per inch. "Materials Safety Data Sheet" supplied by 3M Company is shown in Appendix A.

The Nicalon yarn is a high strength, continuous, no twist silicon carbide fiber with 500 filaments per tow. The filament diameter is approximately 10-15 microns.

Past experience with these fragile yarns indicated that the Nicalon would have to be protected during weaving by double serving the yarn with a 150 denier rayon. This spirally-wrapped fine yarn was later removed during the heat cleaning operation. Predetermined lengths of the Nextel and served Nicalon yarns were wound on braider tubes using a modified winding machine suitable for fragile yarns. A sufficient number of these tubes were prepared to provide all the warp ends for each of the four fabrics designed.

Prior work with Nicalon silicon carbide yarn indicated the need to handle this material with serious thought for the safety and health of personnel, particularly with respect to potential dermatitis problems. Throughout the program, from yarn preparation to getting panels ready for shipment, all personnel involved were instructed on the care required for safe handling of the material. No serious problems were encountered. A "Materials Safety Data Sheet", as furnished by Dow Corning, is included in Appendix B of this report.

2.2.3 Loom Set Up and Debugging. Setting up the weaving equipment involved the placement of creels behind the loom, loading them with the tubes of prepared warp yarns, and drawing the yarn ends through the loom. Figure 2-8 is a schematic view of the set up showing the path of the warp yarns coming from the creels. Pairs of warp yarns are shown, each pair providing for one layer of cloth. The four pairs shown were required for Item 2, the double layer

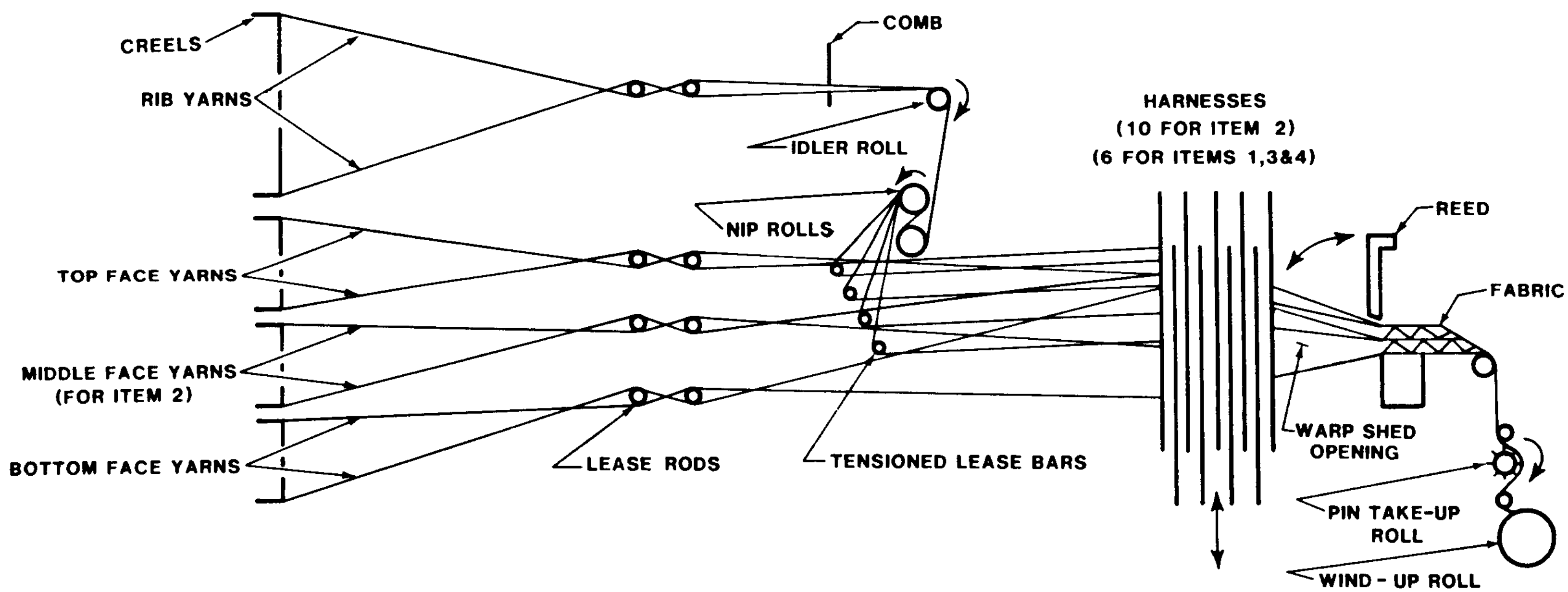


FIGURE 2-8
SCHEMATIC VIEW OF LOOM SETUP SHOWING
PATH OF WARP YARNS FROM CREELS TO FABRIC

core material since it had two outer face fabrics, a middle fabric, and ribs. The single layer core fabrics required only three pairs of warp yarns since they had no middle fabric.

It was decided to weave core fabric with a ground width of 71.1 cm (28 inches) with 2.54 cm (1 inch) selvages. For Item 2, 3,744 spools of ECG 75 1/3 fiberglass yarn were loaded on the creels to provide the warp system for debugging and weaving trials, and each warp end was tensioned with hairpin weights. The face fabric yarns were drawn over lease rods, through the harnesses and then through the reed. The rib yarns were drawn through in a similar manner except that they were directed around a pair of driven nip rolls, and that the lease bars were spring tensioned. Each of the 10 harnesses had sufficient heddles to accept its share of the 3,744 yarns. Yarns from the heddles were pulled through the 5.12 dents per cm (13 dents per inch) of the reed. Ten yarns were drawn through each dent of the reed.

A modified C & K Cotton King fly shuttle loom adjusted to operate at 105 picks per minute was used for the program. This loom was modified with improved nip rolls for metering the rib warp yarns. A new take-up control mechanism was installed to provide reliable control of the take-up motion, and allow reverse movement of the woven cloth during weaving.

Figure 2-9 is a view of the warp yarns coming off the creels. Figure 2-10 shows the yarns entering the rear area of the loom. The face fabric yarns can be seen passing over the lease rods, and the rib fabric yarns over the nip rolls. In Figure 2-11, the warp yarns can be seen passing through the heddles of the harnesses to the reed, and the yarns exiting the reed where the fabric is formed is shown in Figure 2-12. Figure 2-13 shows the woven fabric being pulled around the take-up roll and being wound on the wind-up roll.

All yarns were pulled around the take-up roll and weaving was started, using glass yarn in the fill. After the fabric was formed, the draw of the yarns was further verified against the original design, and the loom programming checked against the design. During the debugging several mechanical problems were encountered. Among these were the following:

(1) Excessive broken fabric rib warp ends during weaving. This problem was aggravated by the large number of warp yarns in the set up which resulted in poor shedding and improper tracking of the shuttles. Considerable time was spent in making adjustments to the harness levels and to adjusting the picking mechanism. The problem was eventually alleviated by switching over to smaller, lighter weight shuttles.

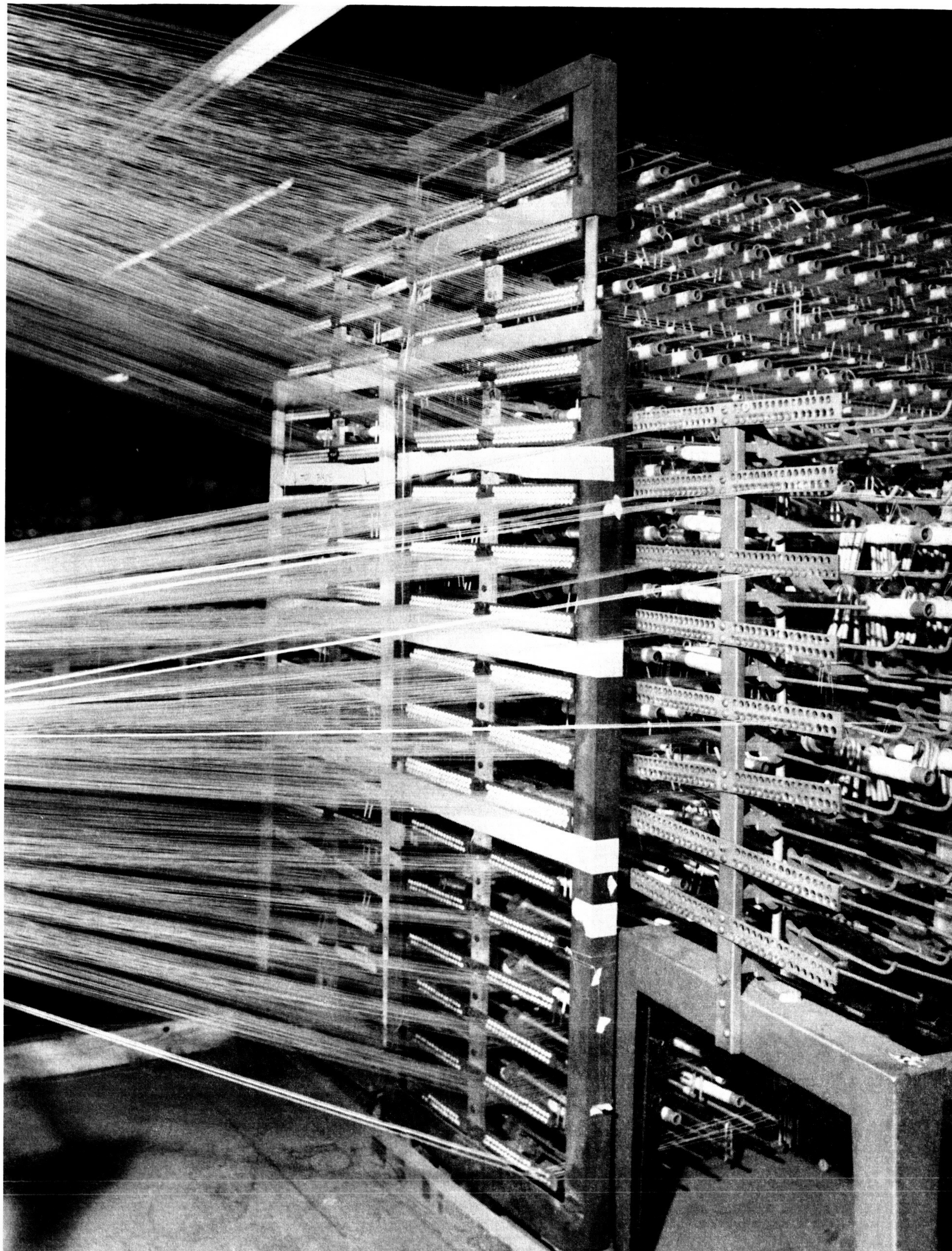


FIGURE 2-9
VIEW OF WARP YARNS COMING FROM CREELS

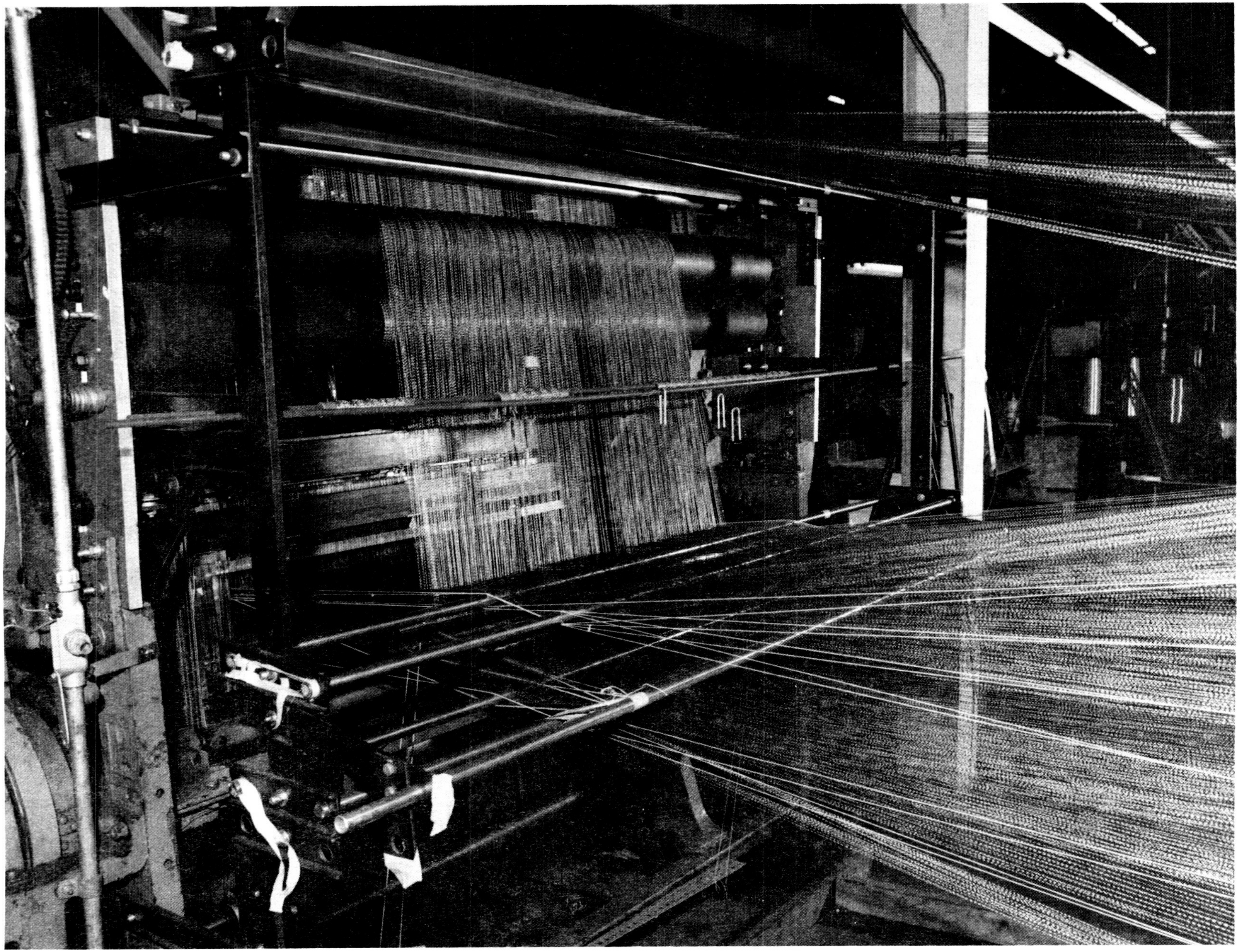


FIGURE 2-10

WARP YARNS LEADING TO BACK SIDE OF LOOM,
NOTE LEASE RODS AND NIP ROLLS FOR RIB FABRIC YARNS

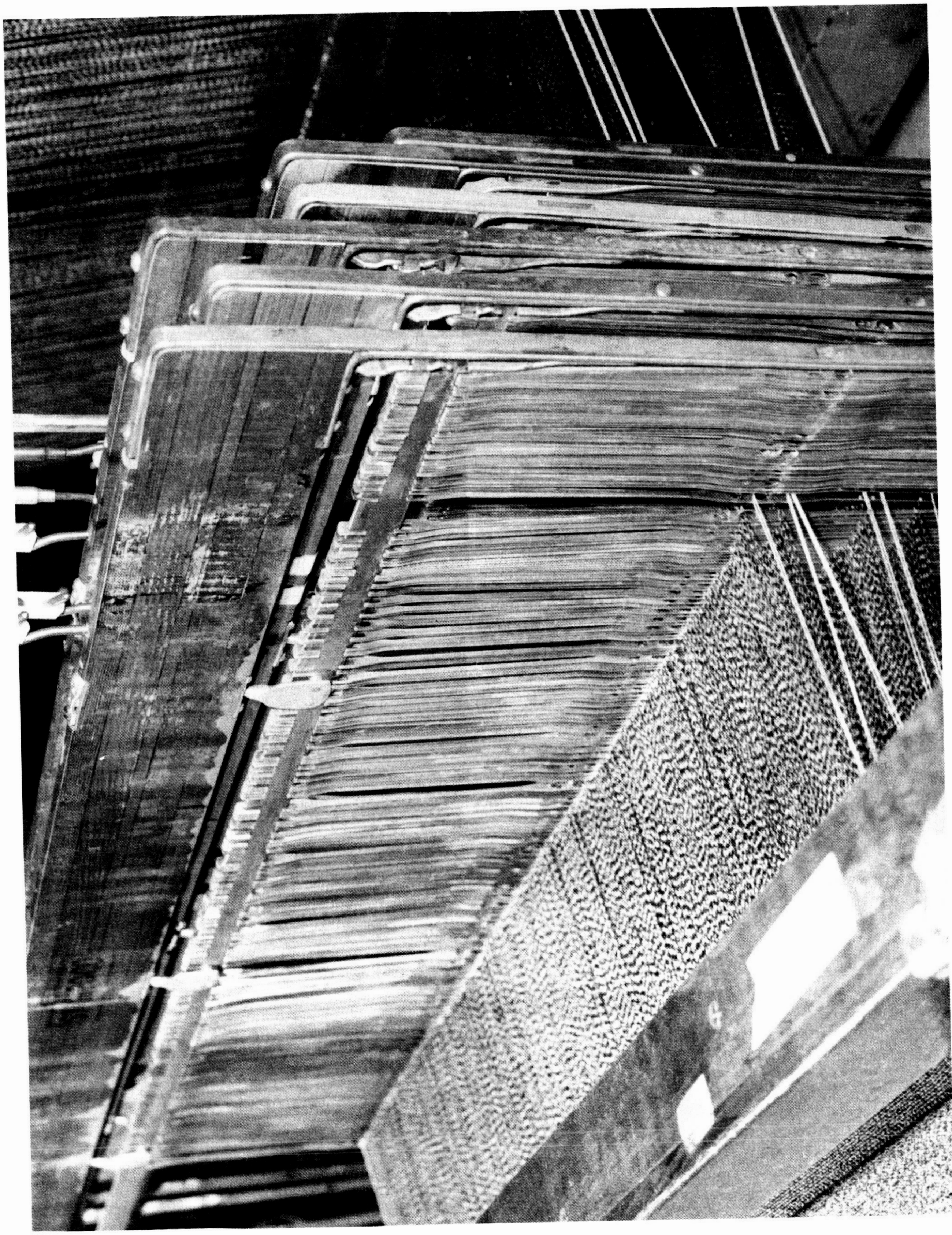


FIGURE 2-11
WARP YARNS PASSING THROUGH HEDDLES IN HARNESSES. VIEW FROM FRONT OF LOOM

FIGURE 2-12

WARP YARNS EXITING FROM REED , NOTE SHUTTLE PASSING THROUGH SHED OPENING OF PARTED SHEETS OF W9 WARP YARNS. VIEW FROM FRONT OF LOOM

(2) Excessive broken ends and floats on bottom fabric face. This problem was also related to the crowding of warp yarns passing through the harnesses which resulted in broken ends and in entangled heddles that did not provide proper shed openings. This problem was eased by adding an extra creel and redistributing the warp yarns on the creels. Also, a modification was made to the heddle restraints on the harness frames to allow the heddles to move more freely on their supports.

(3) Slippage of card clothing on take-up roll. The take-up roll of the loom was covered with card clothing, a tape with staple-like protrusions, spirally wrapped around the surface of the roll. The extremely high load required to draw the fabric through the loom caused the card clothing to pull away from its wood support on the roll. The card clothing was eventually removed and a high density installation of pins was made on the surface of the wood supporting roll. This eliminated the slippage problem. The pinned take-up roll is shown in Figure 2-13.

After a considerable debugging effort, two feet of glass fabric with ceramic fill yarns was successfully woven and the flutes verified for proper dimensions by inserting thirteen consecutive wood check mandrels after relieving the tension on the fabric while still on the loom. A technician inserting these mandrels is shown in Figure 2-14, and a close-up of a portion of these inserted mandrels shown in Figure 2-15. Based on this sample, it was decided to switch the warp over to ceramic yarn and the glass yarn on the creels was replaced with Nextel. The new warp was then drawn through in the same manner as the previously used glass yarn.

2.2.4 Weaving. As anticipated, weaving of the double layer fabric proved to be the most difficult task of the program because of the high density of fragile warp yarns, (total number of warp yarns per unit of fabric width), in this case, 51.2/cm (130/inch). While the actions taken during the debugging phase and noted in paragraph 2.2.3 were helpful, considerable time was required to weave this fabric without excessive yarn breakage. Yarn crowding was so severe that it became necessary to insert fill yarns manually in the bottom face fabric's locking sequence. In spite of these problems, Item 2 was satisfactorily completed.

After completion of the double layer fabric, the set up was modified by removing the creeled Nextel warp yarns from the middle fabric layer and from one rib fabric, both of which were no longer needed. The remaining yarns were then redrawn in a manner similar to the procedure used in the original set up. New programming was installed, and the single layer

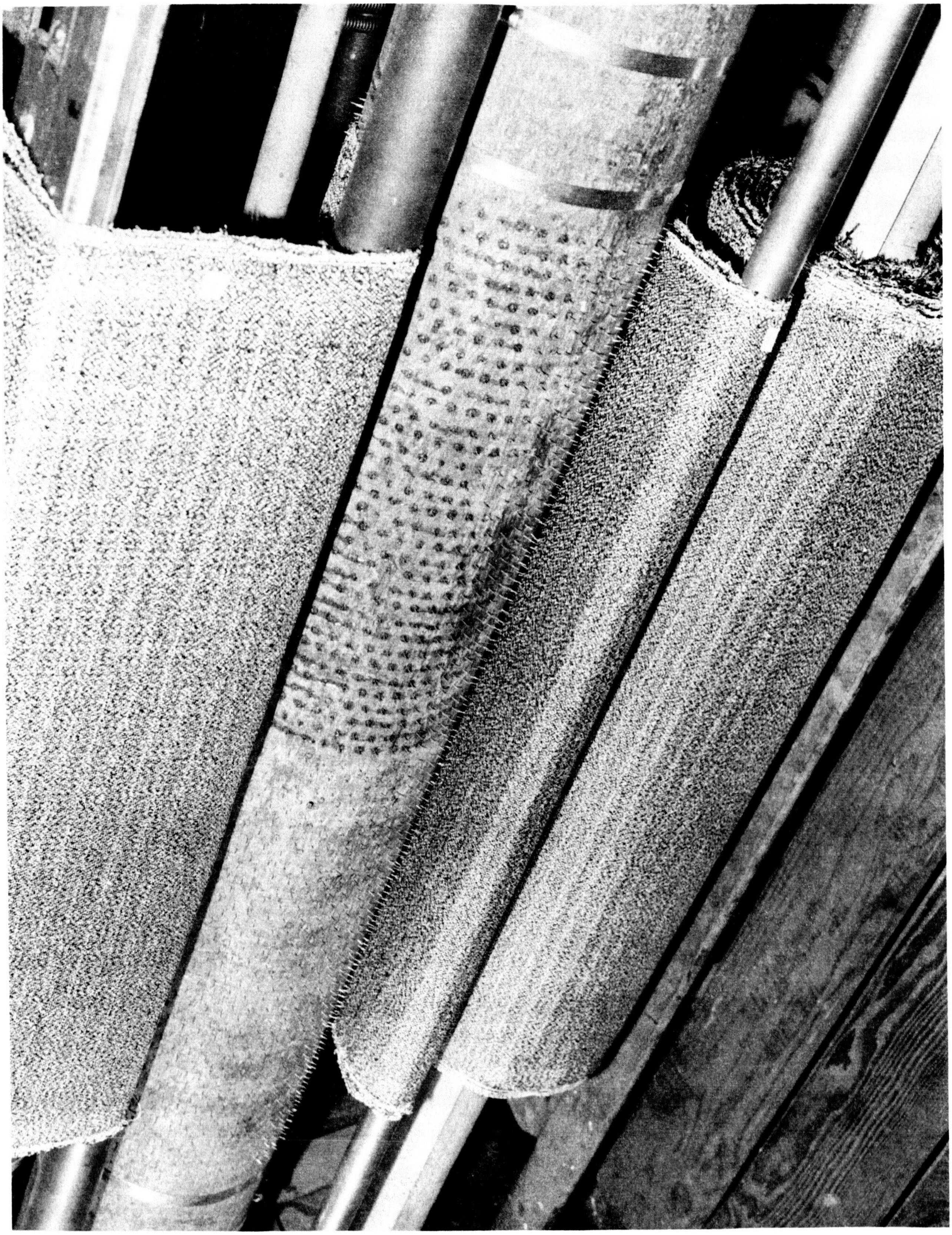


FIGURE 2-13

TAKE-UP ROLL WITH PINS PULLING FABRIC THROUGH THE SYSTEM.
NOTE FABRIC WIND-UP ROLL UNDER TAKE-UP ROLL

FIGURE 2-14
TECHNICIAN INSERTING WOOD MANDRELS TO CHECK FOR CORRECT FLUTE DIMENSIONS.

FIGURE 2-15
WOOD CHECK MANDRELS IN FLUTES OF FABRIC ON LOOM.

fluted fabric, Item 1, was woven. No unusual problems were encountered in weaving, primarily because the warp yarn density was reasonably low, 30.7/cm (78/inch). At the completion of Item 1 weaving, the set up was modified again, this time to remove the Nextel top face warp yarns and replace them with Nicalon silicon carbide yarns in preparation for weaving Item 3. After drawing in the yarns and installing the programming, weaving proceeded without any unusual problems, again because the warp density was low, 25.2/cm (64/inch). The set up was modified again after completing the weaving of Item 3 by replacing the creeled Nextel yarns of the lower face and ribs with Nicalon, redrawing, and installing the new program for Item 4, the all-Nicalon fluted fabric. Weaving proceeded without problems, because of the protective serving on the yarn and because of the low warp yarn density, 18.9/cm (48/inch). All four fluted fabrics were now ready to be filled with insulation.

2.2.5 Insulation Preparation. The NASA-supplied FRCI-20-12 Type 3 insulation for filling one layer of the double fluted core fabric was in a rigid form, and, as received, could be cut into mandrels suitable for insertion. The only problem encountered with this material was its abrasive nature. In cutting this material on a circular saw the conventional blades used became too dull to use after cutting only about a dozen mandrels. For cutting large quantities it is believed that other types of blades or cutting discs could be used.

Preparing the Q-Fiber Felt for use as insulation mandrels required developing a procedure, since the as-received felt had neither the rigidity nor thickness that was required. The material has a nominal thickness of 1.27 cm (1/2 inch) and a bulk density of 3.57 Kg/cubic meter (6 lbs/cubic foot), which corresponds to an areal density of 1.22 Kg/sq meter (36 oz/sq yd). The task was to compress and rigidize the material into a felt having an actual thickness equal to its nominal value, and to maintain the nominal bulk density. In a previous program, Q-Fiber Felt as received had a thickness of 1.59 cm (5/8 inch). It was found necessary to heat treat the material prior to any compressing operations to prevent contamination from appearing on the felt or subsequently on the fluted core fabric. An aqueous solution of an acrylic resin was used to saturate the felt, which was then compressed between two plates and dried. Basically, this was the procedure planned to be used for the current program. The initial Q-Fiber Felt used for the new effort had the same thickness as that used in the previous program and the procedure used was essentially per the plan. However, material received subsequently had a thickness of 2.86 cm (1 1/8 inch) and could not be compressed properly by the original procedure. A deviation in the procedure was therefore developed for the thicker felt received. The original and deviated procedures are shown in Figure 2-16.

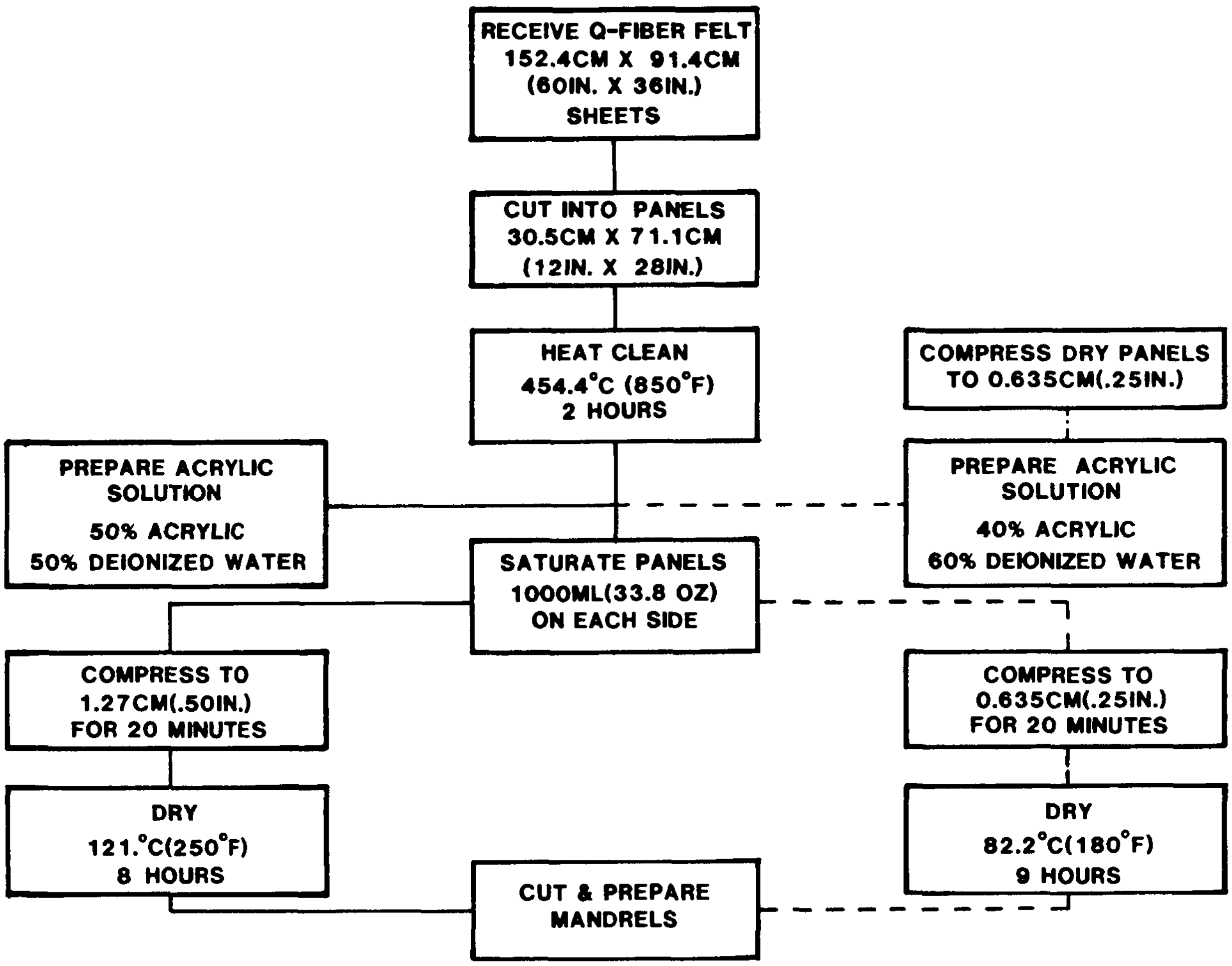


FIGURE 2-16

PROCEDURES FOR PREPARING INSULATION. DASHED LINES SHOW DEVIATIONS REQUIRED FOR THICKER Q-FIBER FELT RECEIVED.

The following discussion covers additional information pertinent to the insulation preparation procedure:

(1) Q-Fiber Felt Sheets. All material as-received came in sheets 152.4 cm x 91.4 cm (60 inches x 36 inches). These were cut with a knife into 30.5 cm x 71.1 cm (12 inches x 28 inches) panels for subsequent processing. Seven panels were cut from each sheet with a minimum of waste.

(2) Heat Cleaning. Panels were placed on racks made of flat expanded metal tray surfaces supported by four legs. The metal tray surfaces were covered with clean Astroquartz fabric to prevent contamination to the felt. Heat cleaning was carried out in a large air-circulating oven.

(3) Dry Compressing. When working with the thinner Q-Fiber Felt, the saturated, compressed and dried panels maintained their 1.27 cm (1/2 inch) thickness. Attempts to compress the thicker Q-Fiber Felt in the same manner resulted in panels that recovered almost to their as-received condition. It was found that pre-compressing the felt to 0.635 cm (1/4 inch) in a dry state was helpful in achieving the desired thickness after subsequently compressing when saturated.

(4) Binder Treatment. The binder used for saturating the felt prior to compression was Carboset, an acrylic resin product of B. F. Goodrich Co. which is a clear, water soluble system containing 40% resin solids. A 50% solution of this material in deionized water was used for saturating the initial thin Q-Fiber Felt panels, but attempts to use this concentration on the thicker felt were unsatisfactory.

    It was found that the resin migrated to the panel surfaces during drying to such a degree that mandrels cut from these panels had an extremely hard surface that damaged the fabric flutes during insertion. Reducing the resin content in the saturating solution by 20% was helpful in alleviating this problem.

    For the saturating operation, each panel was placed on a sheet of polyester film which in turn had been placed on a 35.6 cm x 76.2 cm x 0.635 cm (14 inches x 40 inches x 1/4 inch) clear acrylic plate. 1000 ml (33.8 oz) of the diluted solution was poured on one side of the felt. The panel was turned over and an equal amount of solution poured on the second side. Figure 2-17 shows saturating resin being added to the felt.

FIGURE 2-17
ACRYLIC RESIN SOLUTION BEING POURED ONTO FELT.

(5) Compressing and Drying. Figure 2-18 is a schematic view of the apparatus used for compressing the saturated panels. A layer of polyester film was placed on top of the saturated panel, and an acrylic plate identical to the bottom plate placed over the film. Lengths of steel channel were positioned above the top and below the bottom acrylic plates, and spacers placed around the edges, between the two plates. Spacers for panels that originated from the thin Q-Fiber Felt were 1.27 cm (1/2 inch) thick. Spacers for panels originating from the thicker felt were 0.635 cm (1/4 inch) thick. C-clamps were used to compress the panels to the spacer thicknesses. The compressed assembly is shown in Figure 2-19. After 20 minutes, pressure was released and the top plate and film removed from the stack.

The compressed saturated felt made from the thinner Q-Fiber Felt, along with the bottom layer of polyester film, was placed on a stainless steel sheet supported on the drying rack, as shown in Figure 2-20, and dried in the circulating oven at 121.1°C (250°F) for 8 hours. These panels retained their compressed thickness after drying and were ready for being cut into mandrels. Because of the problem of excessive recovery and resin migration, the panels made from the thicker felt were dried more slowly. After placing these saturated compressed panels on the rack, they were air dried at room temperature overnight and then oven dried at 82.2°C (180°F) for 9 hours. These panels still exhibited some resin migration on the surfaces but were considered suitable for cutting into mandrels.

(6) Cutting and Preparing Mandrels. A standard rip saw blade on a table saw was used to cut the dried panels into mandrels, as shown in Figure 2-21. The saw angle was set to 60° to cut the equilateral triangular cross section. Figure 2-22 shows the target cross section dimensions of the insulation mandrels. Mandrel lengths were 71.1 cm (28 inches).

2.2.6 Insertion of Insulation Mandrels. Prior to inserting the mandrels, all sharp edges were removed by filing. To facilitate the insertion task, it was necessary to expand the fabric flutes as much as possible prior to inserting each mandrel. This was done by inserting several wood check-mandrels in the flutes adjacent to the one to be filled with insulation as shown in Figure 2-23.

Because of some of the weaving problems encountered, a number of flutes in some of the fabrics, especially the double-layered Item 2, had "tight", or slightly smaller dimensions than others. For these flutes, mandrels were tailored to fit. There were no major problems encountered in the insertion task.

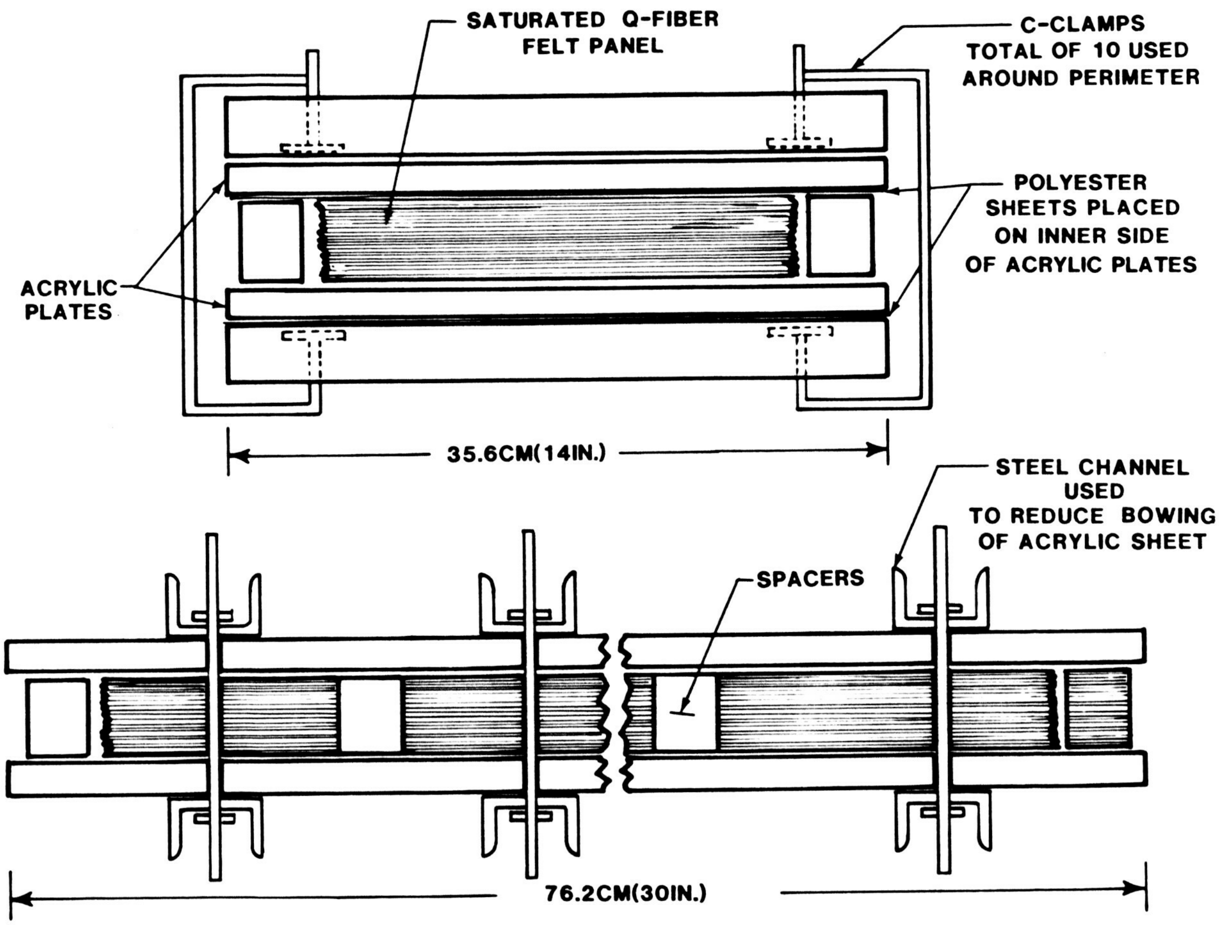


FIGURE 2-18
SCHEMATIC ASSEMBLY OF COMPRESSION APPARATUS

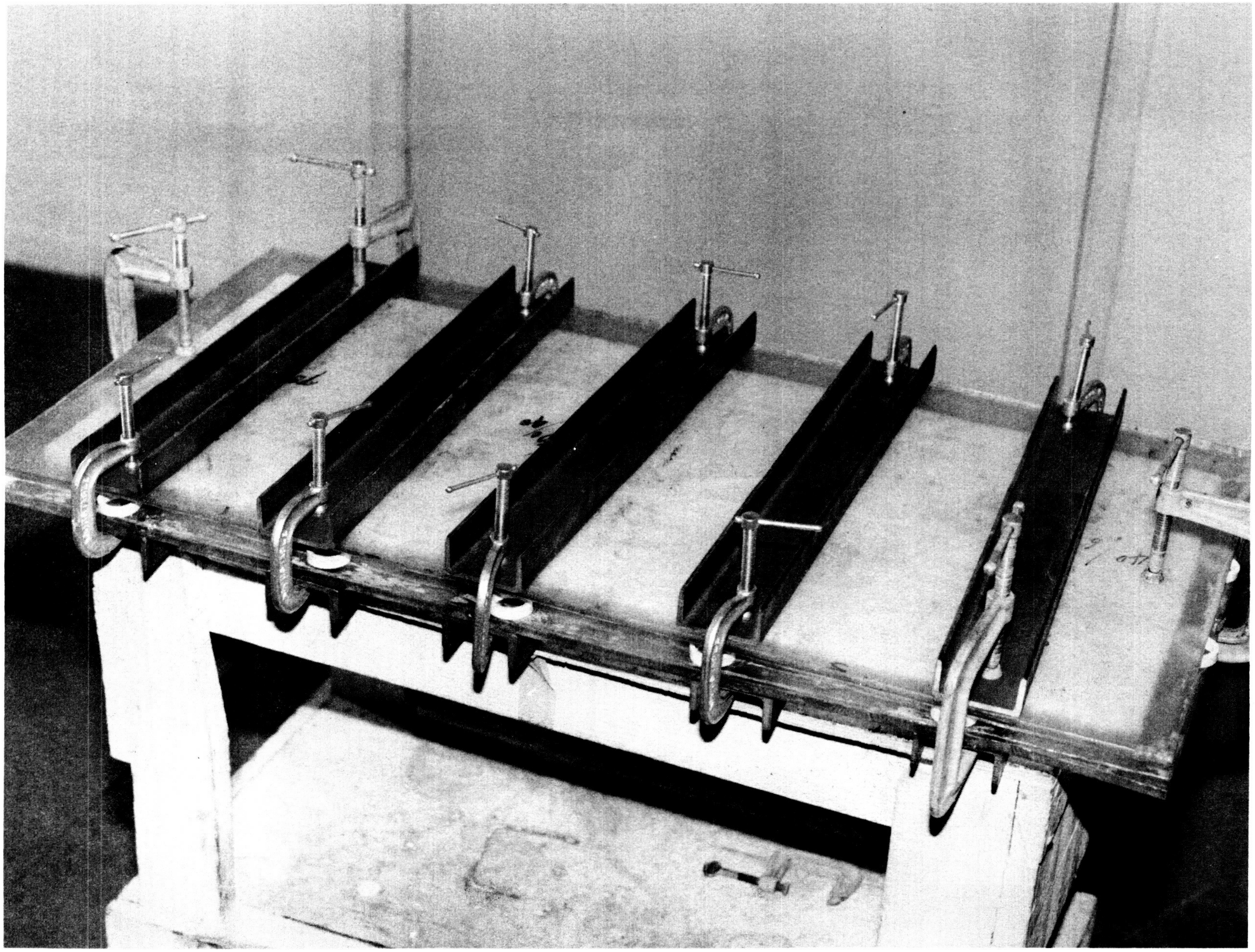


FIGURE 2-19
SATURATED FELT COMPRESSED IN ASSEMBLY

FIGURE 2-20
COMPRESSED SATURATED PANEL ON DRYING RACK.

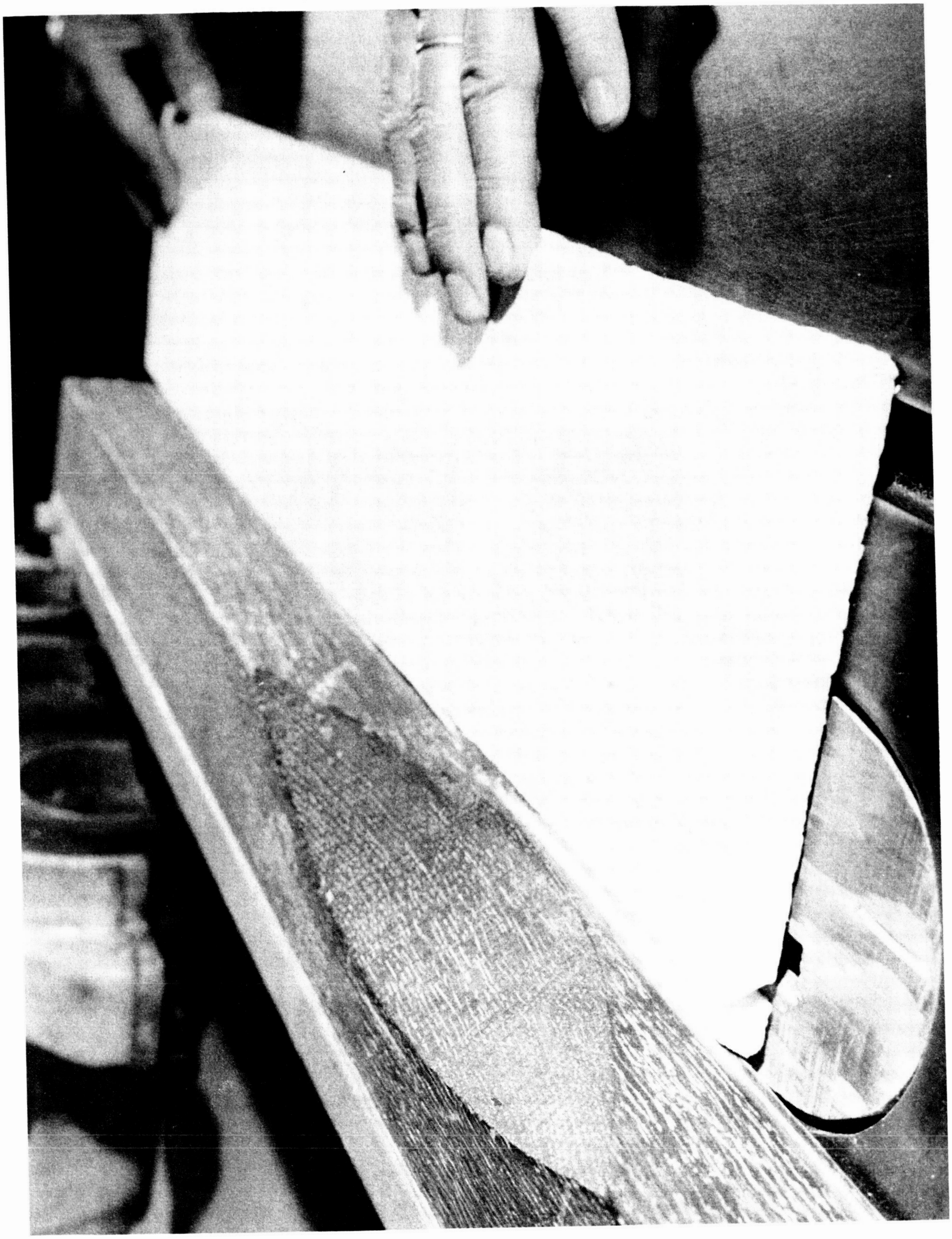


FIGURE 2-21
DRIED COMPRESSED PANEL BEING CUT INTO MANDRELS USING CIRCULAR SAW

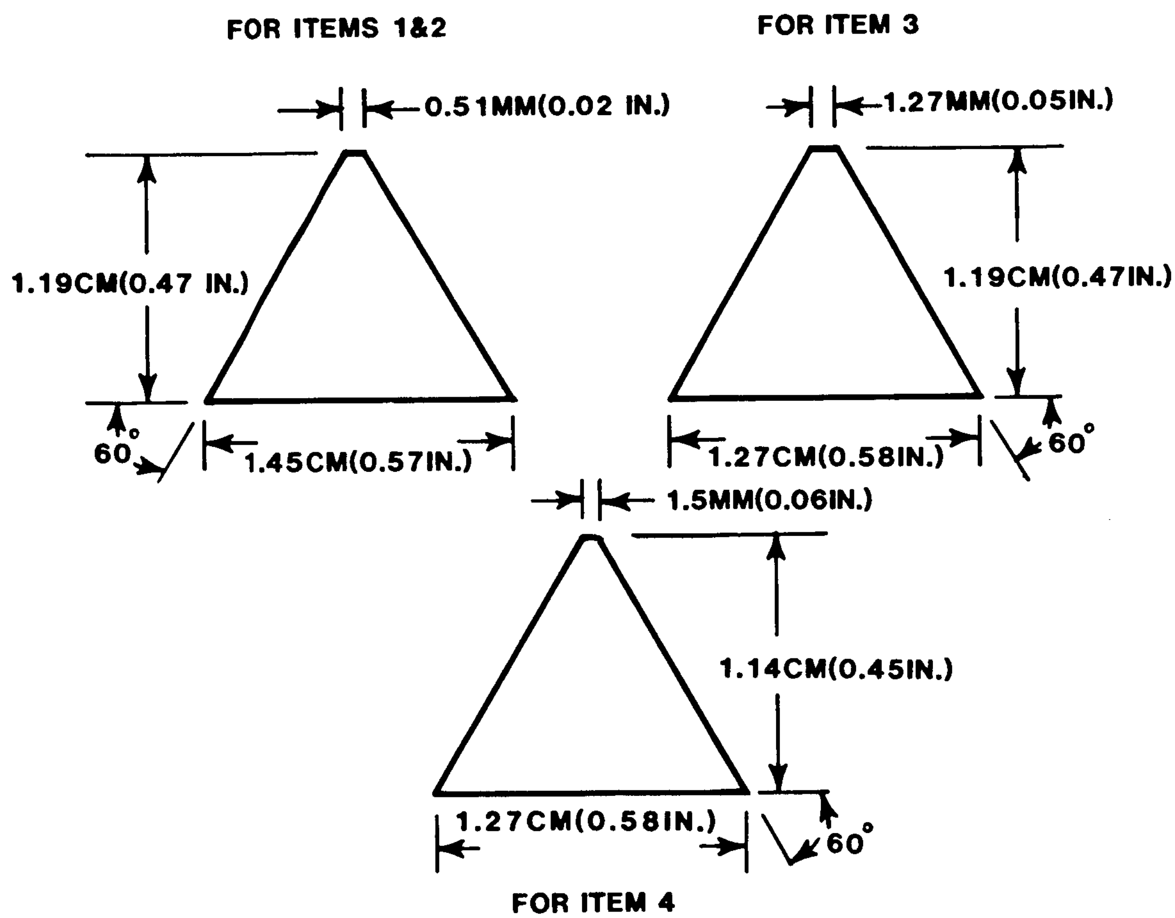


FIGURE 2-22
TARGET CROSS SECTION DIMENSIONS FOR INSULATION MANDRELS.

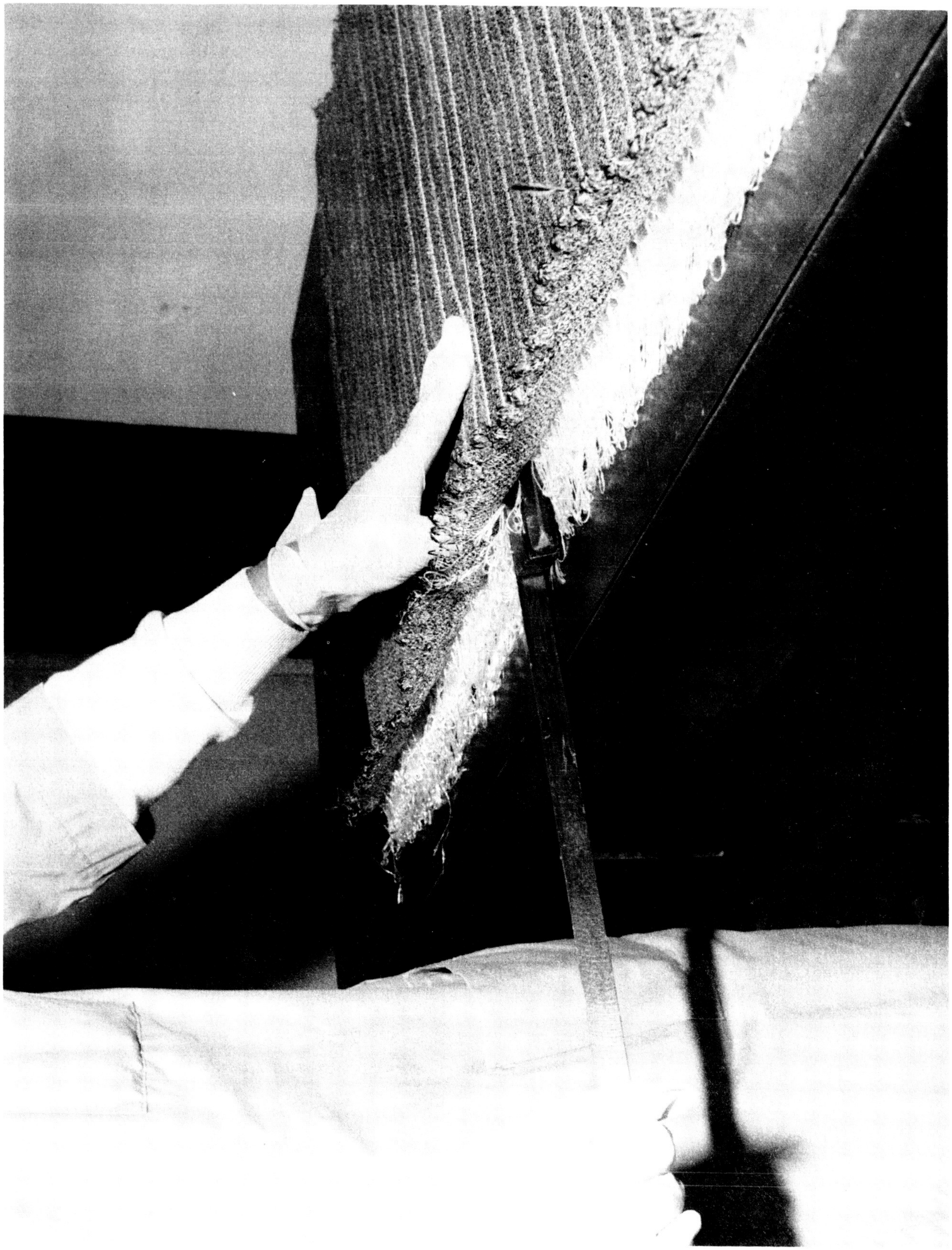


FIGURE 2-23
EXPANDING FLUTES WITH WOOD MANDRELS PRIOR TO INSERTING INSULATION MANDRELS

2.2.7 Heat Cleaning. The insulated panels were positioned on the drying racks and heated in the circulating oven at 454.4°C (850°F) for four hours after which time the organic acrylic insulation binder, yarn lubricants, and rayon serving appeared to be essentially removed. A completed insulated panel of Item 3, having a Nicalon top face and having Nextel ribs and bottom face, is shown in Figure 2-24.

2.2.8 Characterization. Each of the four fabrics produced were characterized in their as-woven, (greige goods) form.

Measurements were made of the warp and fill yarn counts in the fabric faces and ribs, areal weights, and of the thicknesses of the face fabrics. After heat cleaning, areal weights and thicknesses of the insulated panels were measured. These measurements are presented in Tables 2-1 to 2-4 along with the target values that were estimated at the start of the program. A review of this data shows that there was less than 7.00% difference between the actual and target greige goods fabric weights. The differences between the actual and target insulated panel weights were also small, and with the exception of Item 2, the double layer fabric panel, all panel weights were below target estimates. Considering all the variations that go into the weaving of a complex textile fabric such as fluted core, and the variables added by inserting an insulation material in the flutes, it is felt that this correlation is exceptionally good.

After characterization, the panels were inspected and were found to be free of any major defects. They were then carefully packaged and shipped to NASA.

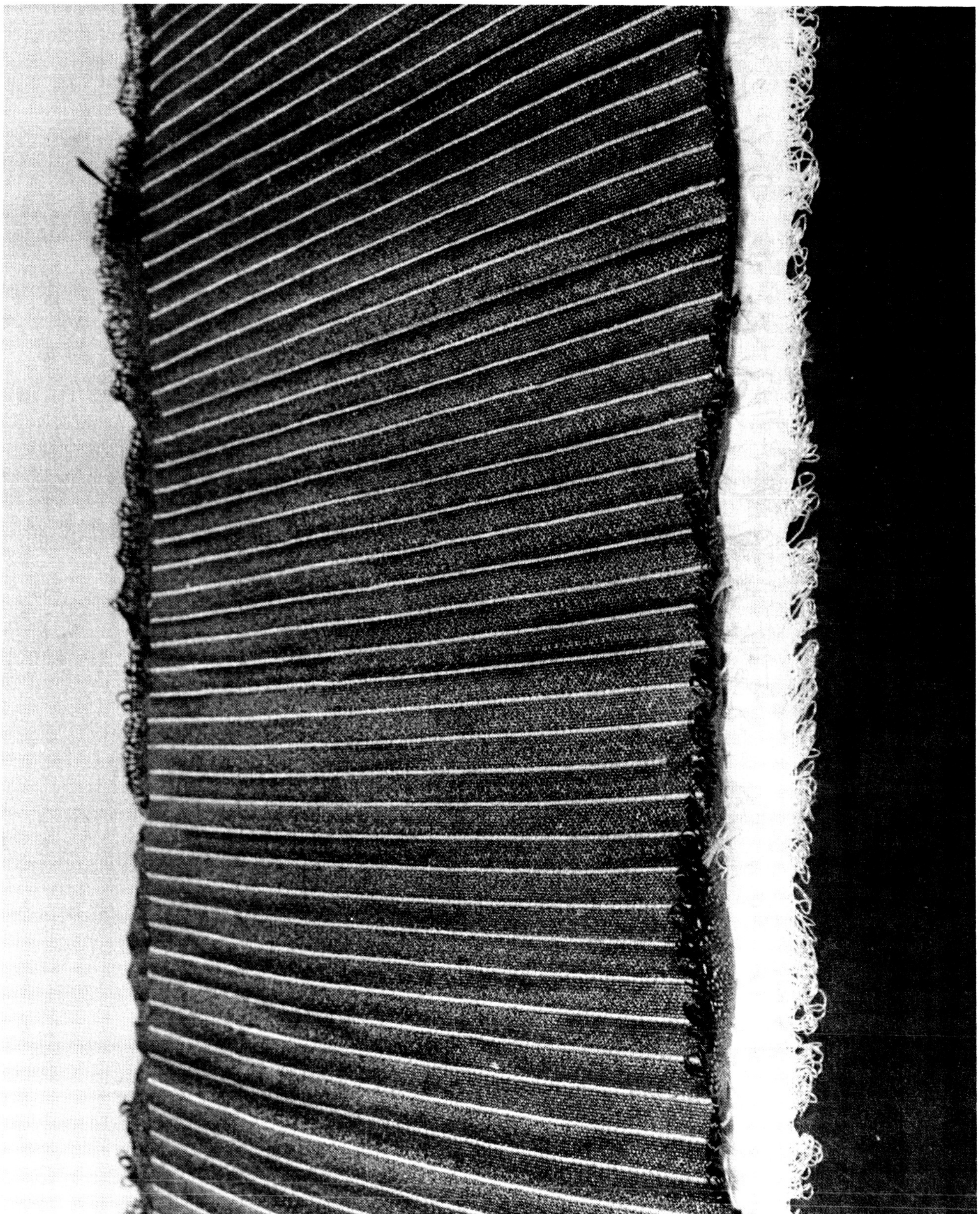


FIGURE 2-24
COMPLETED INSULATED FLUTED CORE PANEL , ITEM 3.

Table 2-1

Characterization of Fabrics and Insulated Panels

	Item 1	
	Actual	Target
Fabric Yarn Count (Warp x Fill)		
Top Face		
Ends/cm x Picks/cm	10.3 x 8.9	10.2 x 10.2
Ends/in.x Picks/in.	26.2 x 22.7	26.0 x 26.0
Ribs		
Ends/cm x Picks/cm	10.3 x 8.9	10.2 x 10.2
Ends/in.x Picks/in.	26.2 x 22.7	26.0 x 26.0
Bottom Face		
Ends/cm x Picks/cm	10.3 x 8.9	10.2 x 10.2
Ends/in.x Picks/in.	26.2 x 22.7	26.0 x 26.0
Fabric Areal Weight		
Kg/sq. meter	1.67	1.68
oz./sq. yd.	49.0	49.6
Panel Areal Weight		
Kg/sq. meter	2.78	2.91
oz./sq. yd.	81.7	86.0
Fabric Face Thickness		
Top Face		
mm	0.43	-
in.	0.017	-
Bottom Face		
mm	0.43	-
in.	0.017	-
Panel Thickness		
cm	1.52	1.30
in.	0.60	0.51

Table 2-2

Characterization of Fabrics and Insulated Panels

	Item 2 Actual	Item 2 Target
Fabric Yarn Count (Warp x Fill)		
Top Face		
Ends/cm x Picks/cm	10.4 x 9.6	10.2 x 10.2
Ends/in.x Picks/in.	26.3 x 24.4	26.0 x 26.0
Ribs		
Ends/cm x Picks/cm	10.4 x 9.6	10.2 x 10.2
Ends/in.x Picks/in.	26.3 x 24.4	26.0 x 26.0
Bottom Face		
Ends/cm x Picks/cm	10.4 x 9.6	10.2 x 10.2
Ends/in.x Picks/in.	26.3 x 24.4	26.0 x 26.0
Fabric Areal Weight		
Kg/sq. meter	2.98	2.91
oz./sq. yd.	87.6	85.8
Panel Areal Weight		
Kg/sq. meter	6.24	5.87
oz./sq. yd.	183.6	173.0
Fabric Face Thickness		
Top Face		
mm	0.46	-
in.	0.018	-
Bottom Face		
mm	0.46	-
in.	0.018	-
Panel Thickness		
cm	3.15	2.57
in.	1.24	1.01

Table 2-3

Characterization of Fabrics and Insulated Panels

	Item 3	
	Actual	Target
Fabric Yarn Count (Warp x Fill)		
Top Face		
Ends/cm x Picks/cm	6.3 x 7.1	6.3 x 6.3
Ends/in.x Picks/in.	16.0 x 18.0	16.0 x 16.0
Ribs		
Ends/cm x Picks/cm	9.4 x 10.7	9.4 x 9.4
Ends/in.x Picks/in.	24.0 x 27.1	24.0 x 24.0
Bottom Face		
Ends/cm x Picks/cm	9.4 x 10.7	9.4 x 9.4
Ends/in.x Picks/in.	24.0 x 27.1	24.0 x 24.0
Fabric Areal Weight		
Kg/sq. meter	1.51	1.42
oz./sq. yd.	44.4	41.8
Panel Areal Weight		
Kg/sq. meter	2.45	2.64
oz./sq. yd.	72.1	78.0
Fabric Face Thickness		
Top Face		
mm	0.38	-
in.	0.015	-
Bottom Face		
mm	0.48	-
in.	0.019	-
Panel Thickness		
cm	1.40	1.32
in.	0.55	0.52

Table 2-4

Characterization of Fabrics and Insulated Panels

	Item 4	
	Actual	Target
Fabric Yarn Count		
(Warp x Fill)		
Top Face		
Ends/cm x Picks/cm	6.3 x 7.1	6.3 x 6.3
Ends/in.x Picks/in.	16.0 x 18.1	16.0 x 16.0
Ribs		
Ends/cm x Picks/cm	6.3 x 7.1	6.3 x 6.3
Ends/in.x Picks/in.	16.0 x 18.1	16.0 x 16.0
Bottom Face		
Ends/cm x Picks/cm	6.3 x 7.1	6.3 x 6.3
Ends/in.x Picks/in.	16.0 x 18.1	16.0 x 16.0
Fabric Areal Weight		
Kg/sq. meter	1.11	1.03
oz./sq. yd.	32.5	30.4
Panel Areal Weight		
Kg/sq. meter	2.20	2.25
oz./sq. yd.	64.8	66.4
Fabric Face Thickness		
Top Face		
mm	0.38	-
in.	0.015	-
Bottom Face		
mm	0.38	-
in.	0.015	-
Panel Thickness		
cm	1.42	1.27
in.	0.56	0.50

3.0 CONCLUSIONS AND RECOMMENDATIONS

The feasibility of weaving Nextel ceramic and Nicalon silicon carbide yarns into fluted core, multi-faced fabrics was demonstrated. Single layer, triangular cross section, fluted core fabrics made from these yarns with warp yarn densities up to 30.7/cm (78/inch) can be woven fairly readily. Double layer fabrics of the same type are considerably more difficult to weave unless the warp yarn density can be reduced appreciably below the 51.2/cm (130/inch). A procedure to prepare and insert mandrels of Q-Fiber Felt into the flutes to make insulated panels from these fabrics was also demonstrated.

Recommendations to be considered for future efforts are as follows:

(1) For further efforts to weave double layer core fabrics using these fragile, high temperature yarns, consideration should be given to a less dense weave construction to reduce the yarn densities in the loom. Changes in the creel arrangement could be made to minimize the number of friction points on the warp yarns. This would help to minimize tensioning problems. Additional harnesses should also be considered to reduce the large number of ends per harness, and thereby reduce the problem of warp yarns becoming entangled with each other. A special type of reed might also be considered, one with thinner dent wires. This would provide more free space for the yarns as they pass between the dent wires.

(2) Additional work should be considered on improved methods to fill the flutes with insulation. Use of binders other than acrylics should be explored, and drying techniques to minimize binder migration investigated. Also, a program to develop mandrels compressed to an undersized condition, and have them capable of expanding to fill the flutes after heat treatment, would provide a rapid method for inserting insulation into the flutes. Insulation mandrels could be inserted with a minimum amount of friction resistance from the interior surfaces of the flutes, and the mandrels would not be obstructed by tight warp ends in the flutes.

(3) Alternate methods for filling the flutes with insulation should also be explored. Suspensions of silica, or other high temperature fibers, in water might be introduced into the flutes to provide wet felts. When dewatered, the flutes should be completely filled with insulation.

This study should investigate the insulation density attainable and the effect of fiber length and orientation on insulation efficiency and strength.

4.0 LIST OF APPENDICES

A. Manufacturer's Material Safety Data Sheet for Nextel Ceramic Yarn

B. Manufacturer's Material Safety Data Sheet for Nicalon Silicon Carbide Yarn

APPENDIX A

MANUFACTURER'S MATERIAL SAFETY DATA SHEET FOR NEXTEL CERAMIC YARN

Nextel®

Ceramic Fiber Products

3M

Health Safety Bulletin

Technical Bulletin

Inhalation

Health hazards associated with the inhalation of Nextel® 312 Ceramic Fibers are judged to be minimal based upon current theory and knowledge. A typical Nextel 312 Ceramic Fiber may be characterized as having a large diameter (7 to 13 microns) in addition to great length. As a result, these fibers would not be considered to be in the respirable range.

Data compiled at the Fulmer Research Institute indicates that fibers between about five microns and 100 microns long and about two microns or less in diameter are more suspect in causing health problems due to inhalation. Small diameter fibers from materials such as asbestos can be inhaled into the lungs and may cause fibrosis or cancer.

While no health standards exist for employee exposure to Nextel 312 Ceramic Fibers, a comparison can be made with current Occupational Safety and Health (NIOSH) standards for fiberglass exposure. The OSHA asbestos fiber standard does not allow more than two fibers per cubic centimeter of air based on a count of fibers greater than five microns in length. The NIOSH proposed standard for fibrous glass states that no more than three fibers per cubic centimeter of air having a diameter less than 3.5 microns and a length greater than ten microns shall be present in the workplace air as a time-weighted average concentration for up to a ten hour workshift in a 40 hour workweek. The 7 to 13 micron diameter Nextel 312 Ceramic Fibers are outside of the diameter range of fibers to be regulated by the proposed standard. In addition, the concentration of airborne Nextel 312 Ceramic Fibers monitored in typical processing areas have been found to be very low and well within the proposed NIOSH standard.

Localized exhaust and/or use of approved dust respirators is recommended in areas where Nextel 312 Ceramic Fibers become readily airborne. Adequate general ventilation and good housekeeping practices reduce the amount of airborne fibers in the workplace.

Skin Irritation

Temporary local skin irritation may occur when processing or using Nextel 312 Ceramic Fiber materials. This irritation is similar to that produced by glass fibers, and is typified by itching and slight reddening and swelling of the skin. Processes which yield excessive filament breakage, such as chopping, increase the potential for skin irritation. Adequate local exhaust ventilation, good housekeeping practices, and careful work habits help to reduce exposure. Safety glasses and protective clothing, such as lab coats, gloves, and tight fitting cuffs, provide additional protection to skin and eyes. If irritation occurs, wash skin with soap and water and change clothing.

Heat Cleaning/Heat Treating

Nextel Ceramic Fibers are coated during manufacture with sizings or finishes which serve as aids in textile processing. Sizing 170 (an organic polymer) is generally used as sizing for Nextel 312 Ceramic Fibers. After processing, the sizing is removed by heat cleaning and may decompose to hazardous byproducts or process contaminants. Detailed air sampling analysis during heat cleaning has shown carbon monoxide to be the predominant byproduct with trace quantities of other compounds generated. Measures taken to control carbon monoxide levels will sufficiently remove any additional byproducts. Control of carbon monoxide levels may be most effectively achieved through the use of exhaust ventilation, for example an exhaust enclosure or hood. The ventilation system should provide a minimum capture velocity of 150 feet per minute and not be subject to disturbances produced by cross drafts. See Heat Cleaning/Heat Treating Procedure Bulletin for detailed instructions.

APPENDIX B

MANUFACTURER'S MATERIAL SAFETY DATA SHEET FOR NICALON SILICON CARBIDE YARN

ORIGINAL PAGE IS
OF POOR QUALITY

DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

EMERGENCY PHONE NO: (517) 496-5900

SECTION I

PRODUCT NAME OR NUMBER: NICALON(R) SILICON CARBIDE FIBER

RECEIVED JAN 17 1985

MANUFACTURERS NAME: DOW CORNING CORPORATION
ADDRESS: SOUTH SAGINAW ROAD, MIDLAND MI 48640

PROPER SHIPPING NAME(49 CFR 172.101): NONE
D.O.T. HAZARD NAME(49 CFR 172.101):NONE
D.O.T. ID NO (49 CFR 172.101): N.A.
D.O.T. HAZARD CLASS (49 CFR 172.101): NONE
RCRA HAZARD CLASS*(40 CFR 261): NONE
E.P.A. PRIORITY POLLUTANTS (40 CFR 122.53): NONE
HEALTH (NFPA): 1 FLAMMABILITY (NFPA): 0 REACTIVITY (NFPA): 0
CAS. NO.: ARTICLE DCWC: NONE
GENERIC DESCRIPTION: SILICON CARBIDE
* IF DISCARDED

SECTION II HAZARDOUS INGREDIENTS

NONE PRESENT %: TLV (UNITS):
%: TLV (UNITS):

SECTION III HEALTH HAZARD DATA HEALTH (NFPA) 1

EFFECTS OF OVEREXPOSURE: EYE: DIRECT CONTACT WILL CAUSE MECHANICAL IRRITATION.
SKIN: MAY CAUSE TRANSITORY MECHANICAL DERMATITIS.
THRESHOLD LIMIT VALUE OF PRODUCT: 10 MG/M3 (FOR "NUISANCE DUSTS").

EMERGENCY AND FIRST AID PROCEDURES: EYE: FLUSH WITH WATER. SKIN: FREQUENT RINSING OF SKIN SURFACES WITH WATER TO REMOVE ACCUMULATED FIBERS WILL MINIMIZE IRRITATION.

SECTION IV FIRE AND EXPLOSION HAZARD DATA FLAMMABILITY (NFPA) 0

FLASH POINT (METHOD USED): OPEN/CLOSED - NONE

FLAMMABLE LIMITS IN AIR, % BY VOLUME LOWER: NOT APPLICABLE
UPPER: NOT APPLICABLE

EXTINGUISHING MEDIA: NOT APPLICABLE
SPECIAL FIRE FIGHTING PROCEDURES: NOT APPLICABLE
UNUSUAL FIRE AND EXPLOSION HAZARDS: NONE KNOWN TO DOW CORNING.

(R) INDICATES REGISTERED OR TRADEMARK NAME OF DOW CORNING CORPORATION

PAGE 1

DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

NAME OR NUMBER: NICALON(R) SILICON CARBIDE FIBER

SECTION V PHYSICAL DATA

BOILING POINT: NOT APPLICABLE
SPECIFIC GRAVITY: NOT APPLICABLE
MELTING POINT: NOT APPLICABLE
VAPOR PRESSURE: NOT APPLICABLE
VAPOR DENSITY (AIR=1): NOT APPLICABLE
PERCENT VOLATILE BY VOLUME (%): NOT APPLICABLE
EVAPORATION RATE (ETHER = 1): NOT APPLICABLE
SOLUBILITY IN WATER (%): LESS THAN 0.1%
FLASH POINT (METHOD USED): OPEN/CLOSED - NONE
ODOR,APPEARANCE, COLOR: NO ODOR, THREAD, DARK COLOR.

RECEIVED
JAN 17 1985

SECTION VI REACTIVITY DATA REACTIVITY (NFPA) 0

STABILITY: STABLE
CONDITIONS TO AVOID: NOT APPLICABLE
INCOMPATIBILITY (MATERIALS TO AVOID): NONE
HAZARDOUS DECOMPOSITION PRODUCTS: NONE
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.
CONDITIONS TO AVOID: NOT APPLICABLE

SECTION VII SPILL, LEAK AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: NO PROBLEM.
WASTE DISPOSAL METHOD: DOW CORNING SUGGESTS THAT ALL LOCAL,STATE AND FEDERAL REGULATIONS CONCERNING HEALTH AND POLLUTION BE REVIEWED TO DETERMINE APPROVED DISPOSAL PROCEDURES. CONTACT DOW CORNING IF THERE ARE ANY DISPOSAL QUESTIONS.

D.O.T.(49 CFR 171.8)/E.P.A.(40 CFR 117)SPILL REPORTING INFORMATION

HAZARDOUS SUBSTANCE: NONE RQ: NOT APPLICABLE
CONCENTRATION OF HAZARDOUS SUBSTANCE: NOT APPLICABLE
REPORTABLE QUANTITY OF PRODUCT: NOT APPLICABLE

(R) INDICATES REGISTERED OR TRADEMARK NAME OF DOW CORNING CORPORATION

PAGE 2

DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

NAME OR NUMBER: NICALON(R) SILICON CARBIDE FIBER

SECTION VIII SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (SPECIFY TYPE): NOT NORMALLY REQUIRED. IF AIRBORNE DUST CONCENTRATIONS EXCEED THE TLV, OR IF UPPER RESPIRATORY TRACT IRRITATION OCCURS, USE A RESPIRATOR DESIGNED FOR NUISANCE TYPE DUSTS.

VENTILATION

LOCAL EXHAUST: NONE SHOULD BE NEEDED.
SPECIAL: NONE KNOWN TO DOW CORNING.
MECHANICAL (GENERAL): RECOMMENDED.
OTHER: NONE KNOWN TO DOW CORNING.

PROTECTIVE GLOVES: LEATHER OR OTHER IMPERVIOUS GLOVES IF FIBERS IRRITATE SKIN.

EYE PROTECTION: PROPER EYE PROTECTION SHOULD BE WORN IN ANY TYPE OF INDUSTRIAL OPERATION.

OTHER PROTECTIVE EQUIPMENT: AS REQUIRED BY YOUR COMPANY.

SECTION IX SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: USE REASONABLE CARE AND CAUTION.

OTHER PRECAUTIONS: NONE KNOWN TO DOW CORNING.

NOTE: NONE

THIS DATA IS OFFERED IN GOOD FAITH AS TYPICAL VALUES AND NOT AS A PRODUCT SPECIFICATION. NO WARRANTY, EITHER EXPRESS OR IMPLIED, IS HEREBY MADE. THE RECOMMENDED INDUSTRIAL HYEJENE AND SAFE HANDLING PROCEDURES ARE BELIEVED TO BE GENERALLY APPLICABLE. HOWEVER, EACH USER SHOULD REVIEW THESE RECOMMENDATIONS IN THE SPECIFIC CONTEXT OF THE INTENDED USE AND DETERMINE WHETHER THEY ARE APPROPRIATE.

PREPARED BY: L C VANVOLKINBURG
LAST REVISED: MARCH 15, [illegible]
DATE: JANUARY 11, 1985
PREVIOUS REVISION DATE: MARCH 22, [illegible]

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Technical Monitor, Paul M. Sawko, MS 234-1
NASA Ames Research Center, Moffett Field, CA 94035
(415) 694-6079 FTS 464-6079

16. Abstract

The feasibility of weaving Nextel ceramic and Nicalon silicon carbide yarns into integrally woven, three dimensional fluted core fabrics was demonstrated. Parallel face fabrics joined with woven fabric ribs to form triangular cross section flutes between the faces were woven into three single and one double layer configurations. High warp yarn density in the double layer configuration caused considerable yarn breakage during weaving. The flutes of all four fabrics were filled with mandrels made from Q-Fiber Felt and FRCI-20-12 to form candidate insulation panels for Advanced Space Transporation Systems. Procedures for preparing and inserting the mandrels were developed. Recommendations are made on investigating alternate methods for filling the flutes with insulation, and for improving the weaving of these type of fabrics.

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