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Development of Tailorable Advanced Blanket Insulation for Advanced Space Transportation Systems

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Development of Tailorable Advanced Blanket Insulation for Advanced Space Transportation Systems

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Ames Research Center
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Space Administration

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PREFACE

This report was prepared by the Woven Structures division of HITCO, Compton, California, under NASA Contract NAS2-12253. 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 Mr. Dominic P. Calamito, Project Engineer.

The report covers work performed during the period August 1985 to December 1986 and was submitted by the author in April 1987.

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1.0 INTRODUCTION AND BACKGROUND

1.1 As part of NASA's program to develop improved insulation materials for future space transportation systems, work has progressed on a concept using a woven fluted core fabric that has the flutes filled with fibrous insulation. This integrally woven material consists of parallel fabric faces connected to each other by fabric ribs that may be designed to a variety of flute cross sections. Variations of fluted core constructions used in some of the previous efforts included rectangular and triangular configurations, as well as configurations having two layers of flutes between the outer faces, see Figure 1-1. These fabrics have been woven from relatively fragile, high temperature yarns including Astroquartz®, Nextel®, Nicalon®, and combinations of these. Insulation in the flutes has, for the most part, been Q-Fiber Felt®. FRCI 20-12 Type 3 refractory material as supplied by NASA has also been used.

1.2 The prime attractiveness of this concept has been the integral bond between the two fabric faces assuring containment of the insulation material when the system is subjected to service temperatures and loads. The fluted core fabric also has sufficient flexibility to conform to geometric contours, and can be tailored to meet thermal and mechanical design requirements by varying flute size, fabric raw materials, and insulation fillers.

1.3 Use of this Tailorable Advanced Blanket Insulation (TABI) as thermal protection for Orbital Transfer Vehicles (OTV) appears promising. One concept is to incorporate TABI in a ballute system which consists of a fixed heat shield nose connected to an expandable or inflatable structure as illustrated in Figure 1-2. The structure, made from a number of TABI gores joined together, would be stowed in as compact a volume as possible, and on command, be deployed to its final shape. Each gore of the structure would have the TABI facing the environment's hot side with the integrally woven single ply fabric on the inflated ballute's cold side, as depicted in Figure 1-2.

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® Nextel is a registered trade mark of the 3M Co.
® Nicalon is a registered trade mark of Nippon Carbon, Ltd.
® Q-Fiber Felt is a registered trade mark of the Manville Co.

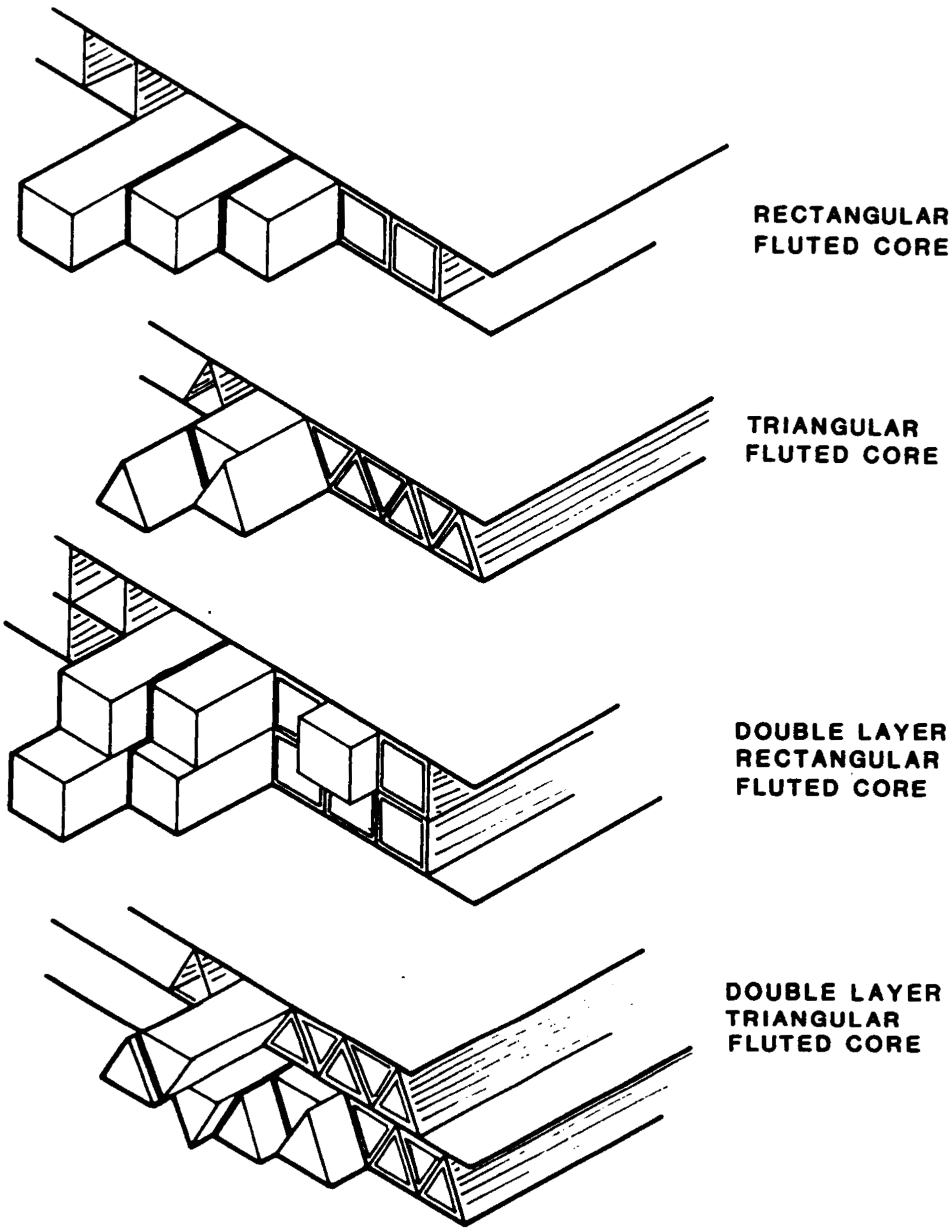


Figure 1-1

WOVEN FLUTED CORE CONFIGURATIONS USED IN PREVIOUS TABI DEVELOPMENT PROGRAMS. INSULATION MANDRELS ARE SHOWN PARTIALLY INSERTED INTO FLUTES.

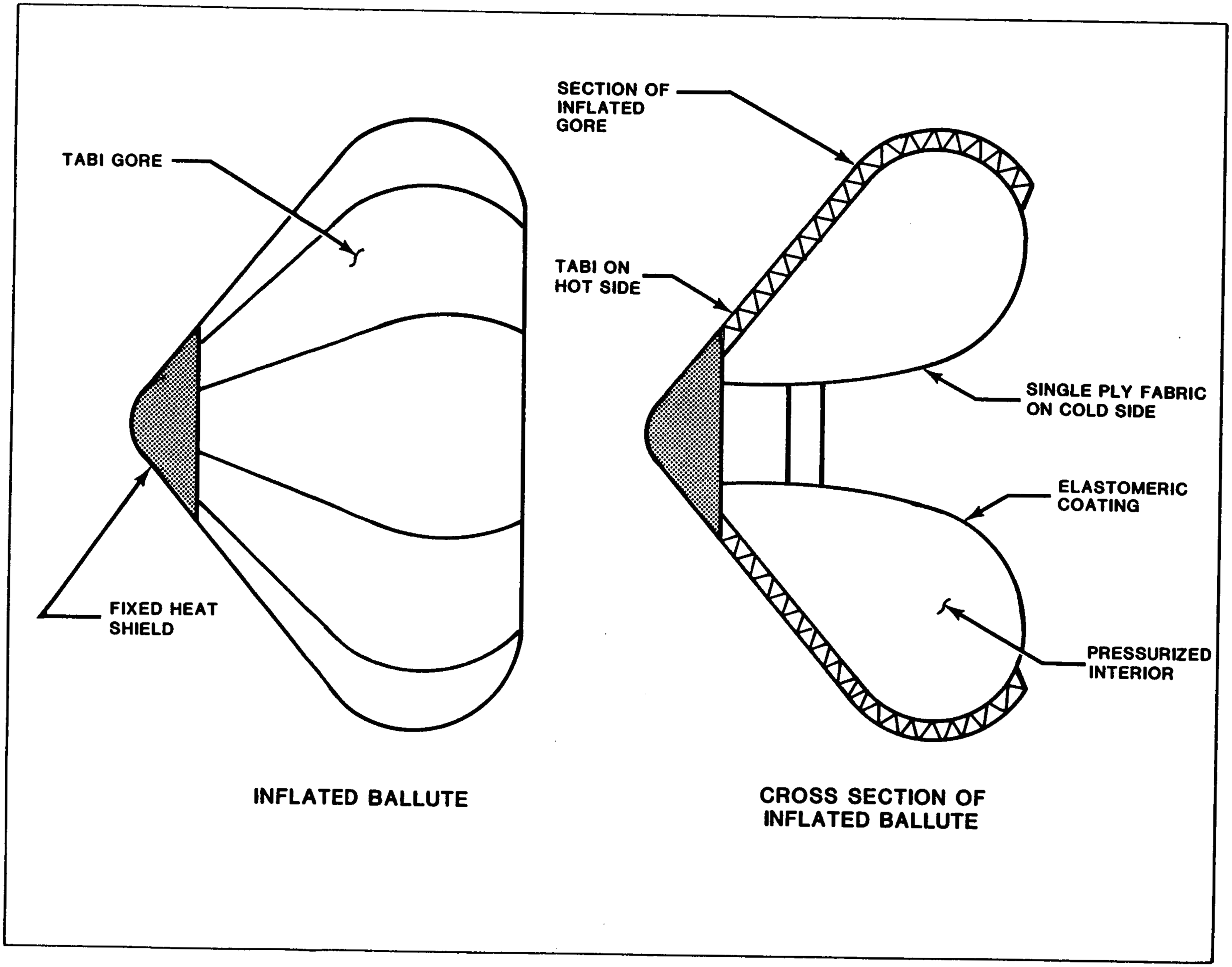


Figure 1-2
SCHEMATIC VIEW OF TABI CONCEPT FOR AN INFLATABLE BALLUTE

1.4 To further develop and explore TABI materials for these advanced applications, a contract was awarded in August 1985 to Woven Structures. This program consisted of two items. The first involved producing a quantity of flat TABI panels woven entirely from Nicalon silicon carbide yarns and insulating the fabric flutes with Q-Fiber Felt. The second item was to weave flat fluted core fabric from a combination of Nicalon and Astroquartz yarns, insulate the flutes with Q-Fiber Felt, and fabricate a two-gore assembly of the TABI panels. This task would demonstrate the feasibility of manufacturing contoured shapes which might be required for a ballute system. This report covers the work accomplished during the course of the contract.

2.0 TECHNICAL PROGRAM, ITEM 1

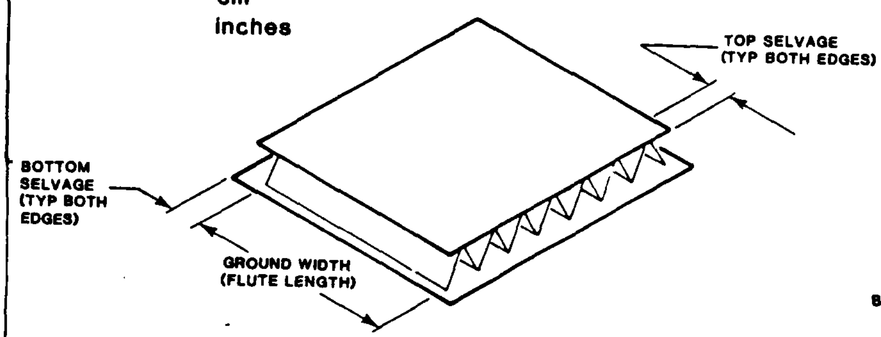
2.1 Objectives, Item 1. Thirty six and one half meters, (40 yards) of triangular cross section fluted core were to be woven from Nicalon silicon carbide yarn, and the 1.91 cm (0.75 inch) flutes filled with 3.57 kgs/cubic meter (6 lbs/cubic foot) Q-Fiber Felt. This material was to be furnished to NASA as 30 panels, each 122 cm (4 feet) long. The target characteristics and dimensions of the material established by NASA are shown in Table 2-1.

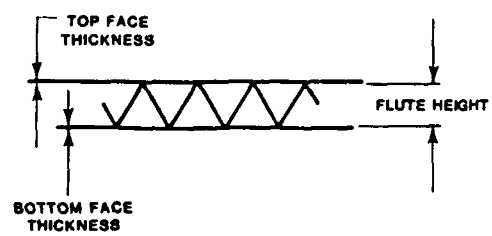
2.1.1 No major problems were anticipated in producing the fluted core fabric since a similar Nicalon fabric with a smaller cell height was successfully woven and converted to TABI panels on a NASA contract, NAS2-11718, completed just prior to this new requirement. However, since the flute height of the new panels was specified to be 1.91 cm (0.75 inch), instead of 1.27 cm (0.5 inch) as before, it was recognized that some development would be necessary to make suitable insulation mandrels for filling the fabric flutes. Single layer Q-Fiber Felt that could provide the correct density and thickness for the new effort was not available. Some effort was also expected for reducing the time consuming operation of inserting insulation mandrels into the fabric flutes which was experienced in the previous contract. Thought was also given to providing insulated fabric panels suitable for testing and evaluation by NASA and for possible fabrication efforts by others. Therefore, some changes were expected in procedures and in target characteristics of the new TABI panels.

Table 2-1

TARGET CHARACTERISTICS AND DIMENSIONS OF ITEM 1 FLUTED FABRIC

	TARGET VALUES
FABRIC YARN COUNT (WARP X FILL)	
TOP FACE	
ENDS/cm X PICKS/cm	6.3 X 7.1
ENDS/inch X PICKS/inch	16.0 X 18.1
RIBS	
ENDS/cm X PICKS/cm	6.3 X 7.1
ENDS/inch X PICKS/inch	16.0 X 18.1
BOTTOM FACE	
ENDS/cm X PICKS/cm	6.3 X 7.1
ENDS/inch X PICKS/inch	16.0 X 18.1
FABRIC AREAL WEIGHT	
kgs./sq. meter	1.11
oz./sq. yd.	32.5
PANEL AREAL WEIGHT (INCLUDING INSULATION)	
kgs./sq./meter	2.20
oz./sq.yd.	64.8
FABRIC FACE THICKNESS	
TOP FACE	
cm	0.038
inches	0.015
BOTTOM FACE	
cm	0.038
inches	0.015
FLUTE HEIGHT (OR CELL HEIGHT)	
cm	1.91
inches	0.75
GROUND WIDTH	
cm	66
inches	26
EACH SELVAGE, TOP FACE	
cm	2.54
inches	1
EACH SELVAGE, BOTTOM FACE	
cm	5.08
inches	2





2.2 Program Plan for Item 1. The flow chart in Figure 2-1 defines the tasks required to produce TABI panels. The discussion that follows includes the efforts involved in performing these tasks including the design considerations, processing difficulties, and the solutions to these problems.

2.2.1 Fabric Design and Programming. Producing woven fluted core requires the weaving of three fabrics simultaneously, one for the top face, rib and bottom face. Each fabric requires its own design and warp yarn system, and the overall design must be coordinated so that the warp yarns of the rib fabric lock properly at the nodes formed with the face fabrics. The design of the fluted fabric depends primarily upon the desired flute (or cell) height, individual face and rib fabric thicknesses, and types of yarns. Other considerations include selecting a style of weave for each fabric, which is in turn influenced by the end application requirements of the fluted core and by the properties of the yarns. The design task for this program involved laying out the placement of every warp and fill yarn for each fabric to produce the desired fabric construction and flute dimensions. The loom programming involved the design and setting up of the loom's control device to provide the proper sequencing of shed openings (raising and lowering of predetermined warp yarns) for each fill yarn (pick) insertion.

2.2.1.1 A plain weave fluted core fabric designed for a previous NASA effort to produce 1.27 cm (0.50 inch) flute height fabric was modified to make the 1.91 cm (0.75 inch) flute height required for Item 1. A schematic of this design is presented in Figure 2-2. The weave pattern at the nodes, is also illustrated in Figure 2-2. This was selected after evaluating three other designs and was used successfully for the fragile yarns in the prior program. It was recognized that the weave design selected, particularly the pick count, might require some modification if a tighter weave than that indicated in the target values of Table 2-1 could be achieved.

2.2.1.2 Also, as part of the design task, the yarn placement on the creels, the loom modifications and the loom set up requirements, including tensioning of the warp yarns, and the draw-in sequence were determined. Any fixtures necessary for processing were designed and fabricated, including triangular cross section wood mandrels to be used for inspecting the cell sizes of the woven fluted fabric. The dimensions for these check mandrels are presented in Figure 2-3.

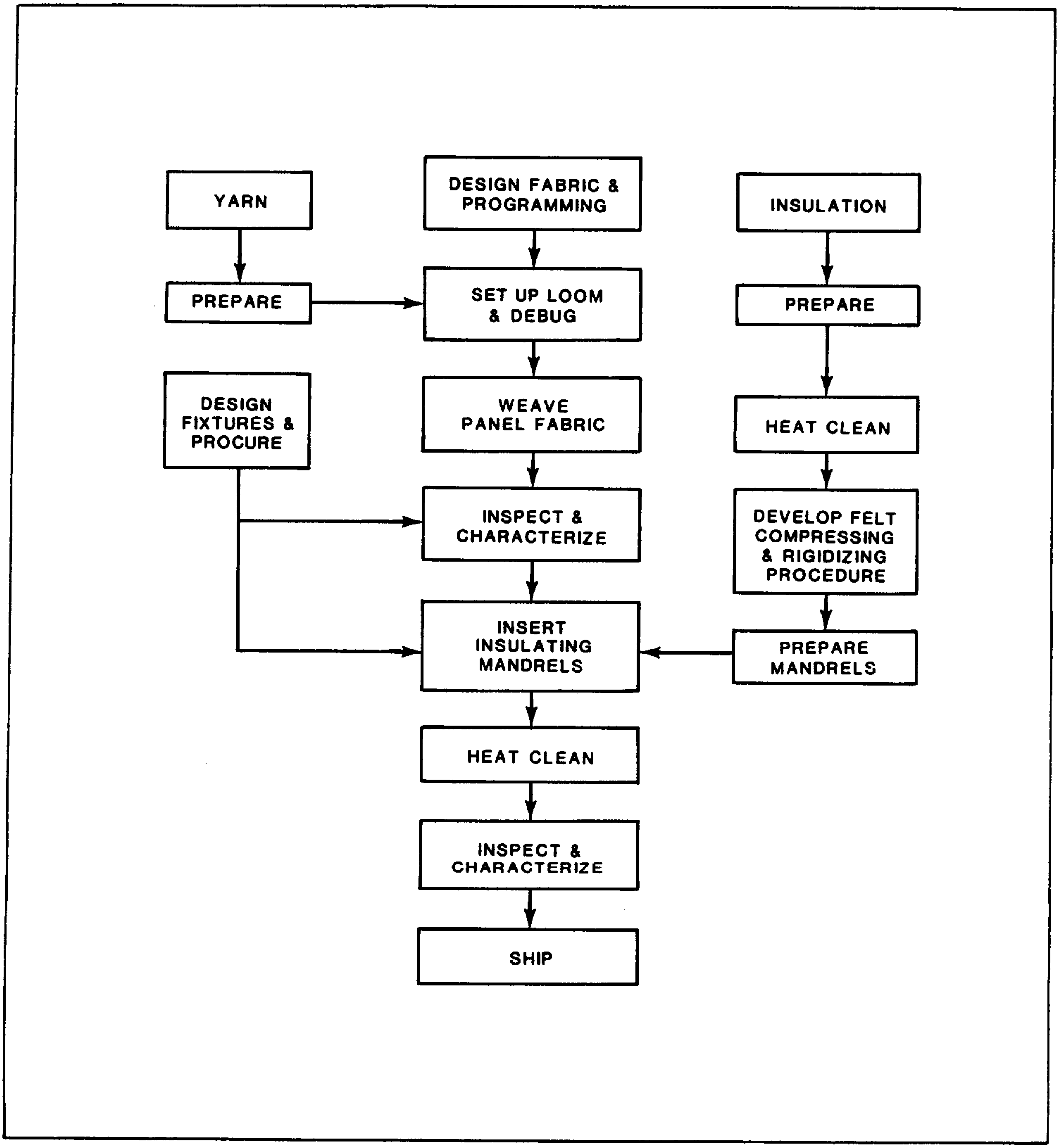


Figure 2-1
PROGRAM PLAN, ITEM 1

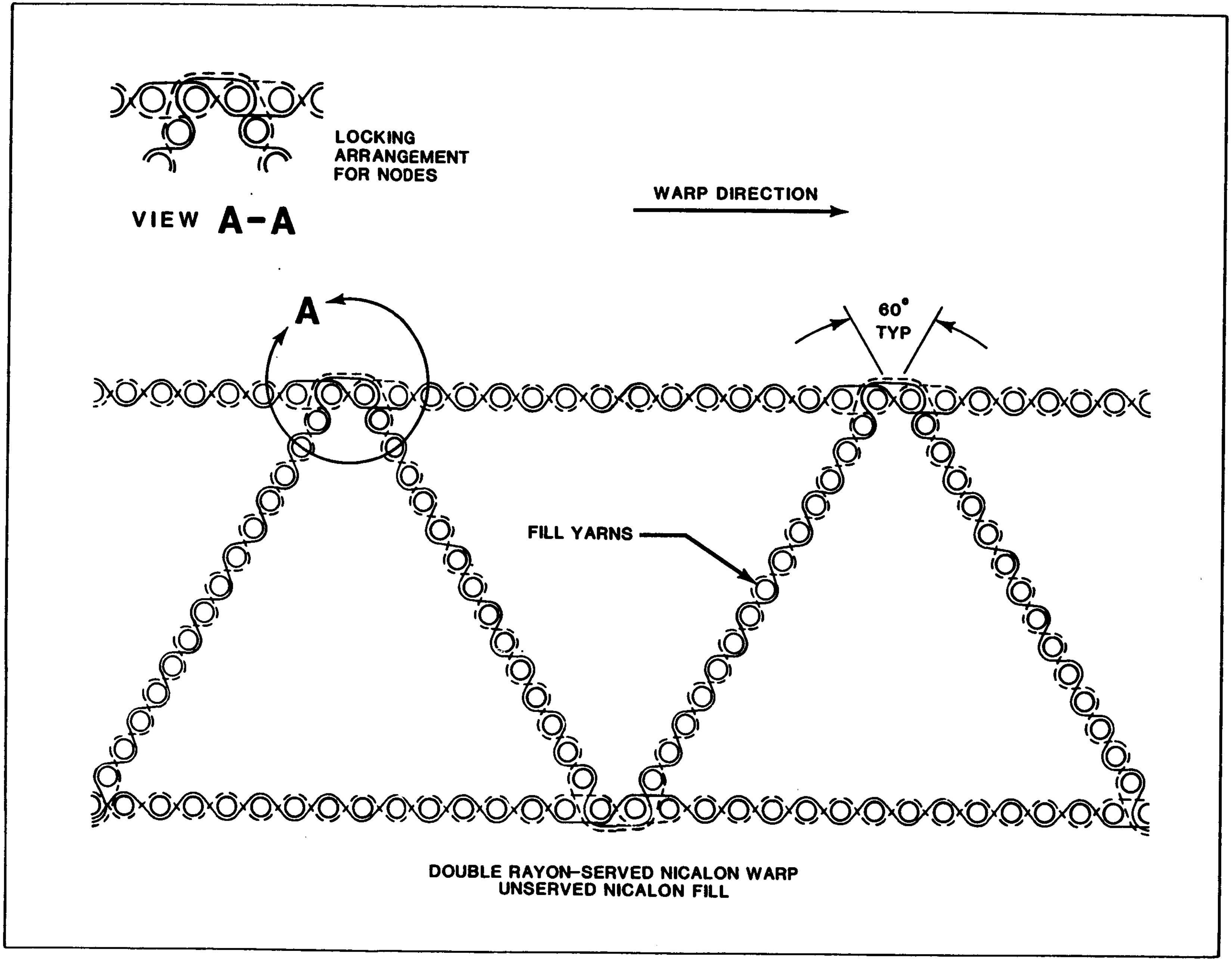


Figure 2-2

YARN ARRANGEMENT OF FLUTED CORE FABRIC, ITEM 1

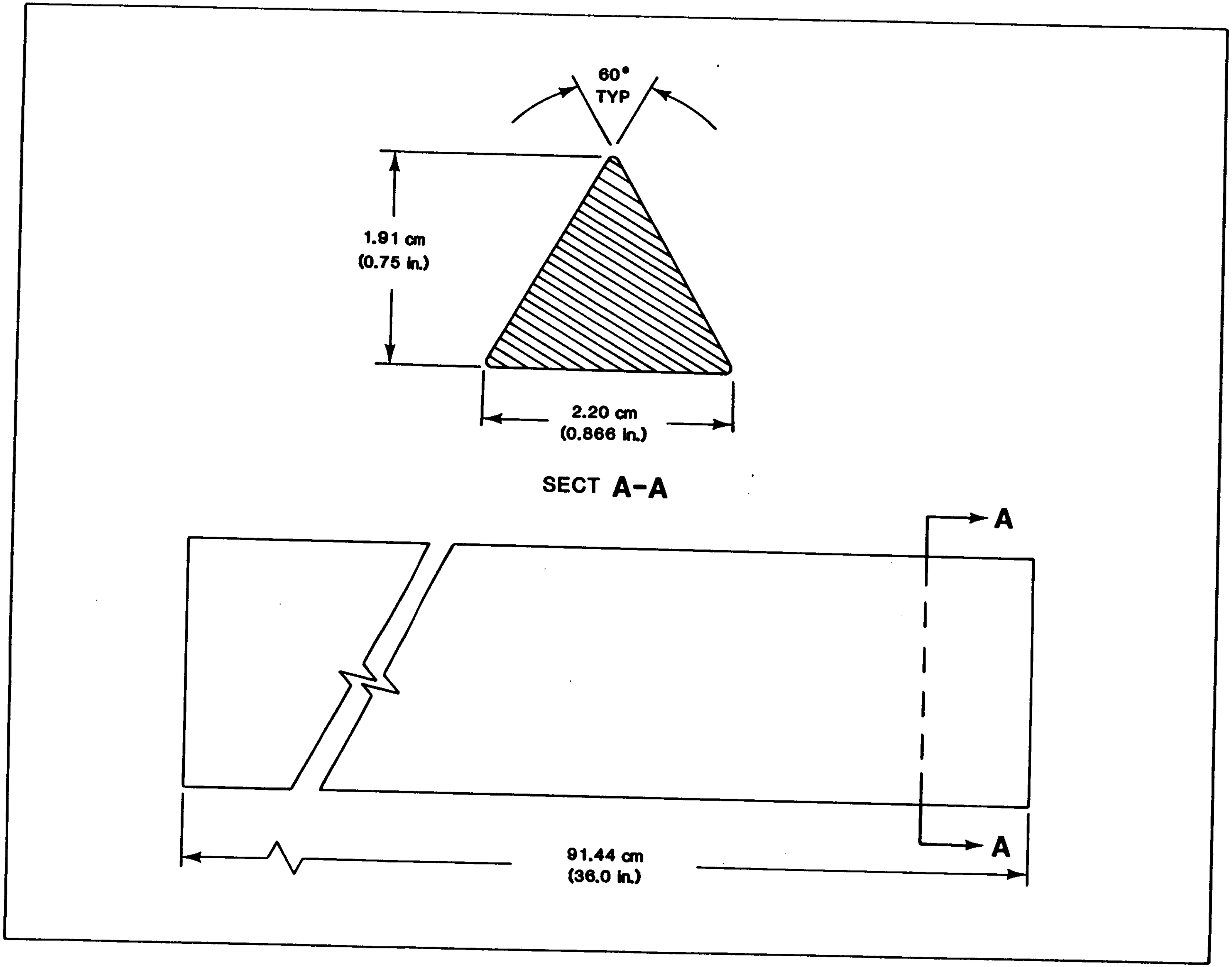


Figure 2-3
CHECK MANDREL DIMENSIONS FOR ITEM 1 FABRIC

2.2.1.3 During the design task, it was decided to provide a wider ground (width between selvages) portion of fabric than the noted target value. It was felt that the wider fabric might be advantageous should NASA choose to use the panels for fabricaton studies. The wider ground width selected was 71.1 cm (28 inch).

2.2.2 Yarn Procurement and Preparation. Nicalon silicon carbide yarn was procured and prepared for weaving. This yarn, designated as NLP-201, flexible grade was ordered with a "P" type, or epoxy compatible sizing. The product, according to literature information, is a tow material composed of 500 round cross section continuous filaments having a range of diameters from 10 to 20 microns (39.37×10^{-5} inch). Its yield count is listed as 200 tex, (200 gm/1000 meters), which corresponds to 1800 denier, (1800 gm/9000 meters) or 2480 yards per pound. Past experience indicated that this yield value was overstated approximately 10% partly due to the sizing and possibly a greater number of filaments falling in the higher end of the filament diameter range. Additional yarn was included in the procurement to allow for this lower yield. Further information on Nicalon yarn is contained in Appendix A. Prior work with this yarn required that both warp and fill yarns be protected during weaving by double serving the yarn with 75 denier rayon. Each direction of serving had 4 TPI (turns per inch). This spirally-wrapped fine yarn, the sizing on all the yarns, and other organic matter were to be removed later during the heat cleaning operation. It was subsequently determined that the amount of sizing and serving yarn removed from the panels amounted to 6.6% by weight. Predetermined lengths of the served Nicalon were wound on plastic spools using a modified winding machine suitable for fragile yarns, and a sufficient number of these spools prepared to provide all the warp ends for the Item 1 fabric.

2.2.3 Loom Set Up and Debugging. A modified Crompton and Knowles Cotton King loom set up for the previous NASA program (NAS2-11718) was essentially still intact, and a small amount of Nicalon yarn remained on the creels. It was decided to utilize this set up and material to determine whether Nicalon fill yarn could be woven without the serving protection. After sufficient weaving trials, it was found that the unserved Nicalon remained undamaged and could indeed be used as filling. This then suggested that a higher pick count than the target value could be attained. After further experimentation, the pick counts of both Nicalon face fabrics were raised over 25%, thus providing a more desirable TABI material of less porosity. It was then decided to incorporate the unserved fill yarn and the higher pick count for Item 1. Part of the Nicalon remaining on the creels was woven into a small quantity of 1.27 cm (0.5 inch) flute height core for some preliminary experiments related to Item 2. The balance of the Nicalon was utilized to partially debug the Item 1 design. During this activity, another weaver was trained to weave the fluted core fabric.

2.2.3.1 After depleting the residual Nicalon yarn, the creels were stripped of spools and thoroughly cleaned. Any ceramic guides exhibiting wear as a result of abrasive action of the Nicalon were replaced. Each creel spindle and lease rod surface indicating roughness was polished with steel wool to prevent uncontrollable tension on warp yarns. The loom was inspected and found to be in satisfactory condition except for the pin take-up roll which was damaged beyond repair. This take-up roll is important in pulling the fabric through the loom at the precise rate established in the programming. A new pin take-up roll was installed and covered with staple card clothing and a low density of pins, Figure 2-4. The heddles in the loom's harnesses appeared to be in good condition and were not replaced. The creels were then loaded with the proper amount and predetermined arrangement of warp spools, the yarns drawn into the loom, and start-up weaving initiated. A schematic view of the loom set up is depicted in Figure 2-5. Figure 2-6 is a view of the creeled warp spools in a relaxed state prior to the addition of tensioning weights. Figure 2-7 pictures the path of the warp yarns from the creels to the rear of the loom. Warp yarns passing through the heddles and reed are seen from the front side of the loom in Figure 2-8. A shuttle passing through the shed opening is also shown. Figure 2-9 pictures the operator weaving the fluted core fabric. The new pin take-up roll pulling the fabric through the loom is also seen in this illustration. Debugging was completed in less than a week and production weaving of the fluted fabric began.

2.2.4 Weaving. In the early stages of weaving, the production rate was relatively low, only 152 cm (5 feet) per day, but eventually doubled with experience. After every 122 cm (4 feet) of fabric was woven, this length was cut from the loom and inspected for cell size and weaving defects. Flutes were verified for proper

FIGURE 2-4
NEW PIN TAKE-UP ROLL INSTALLED ON LOOM

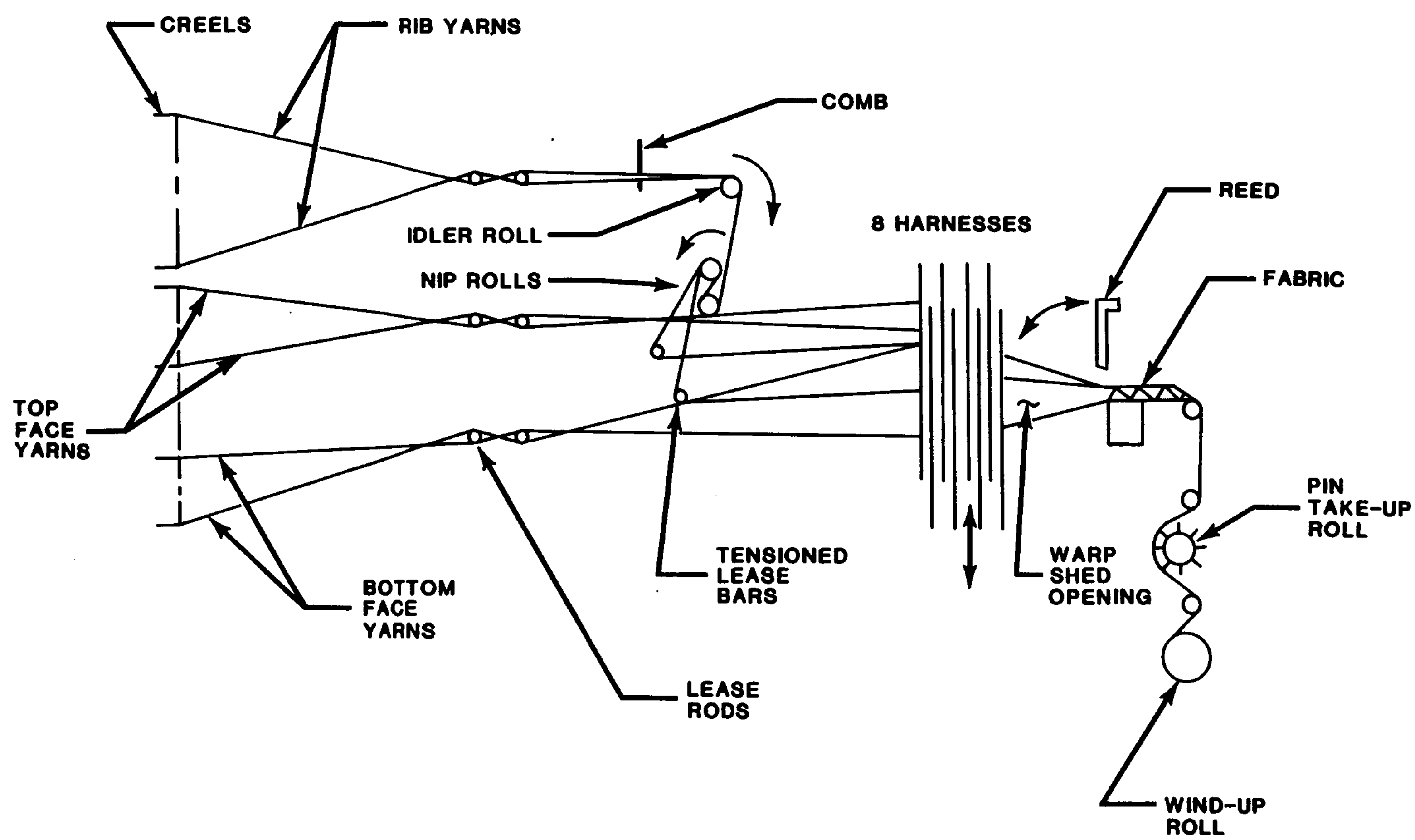


Figure 2-5
SCHEMATIC VIEW OF LOOM SETUP FOR ITEM 1
SHOWING PATH OF WARP YARNS FROM CREELS TO FABRIC

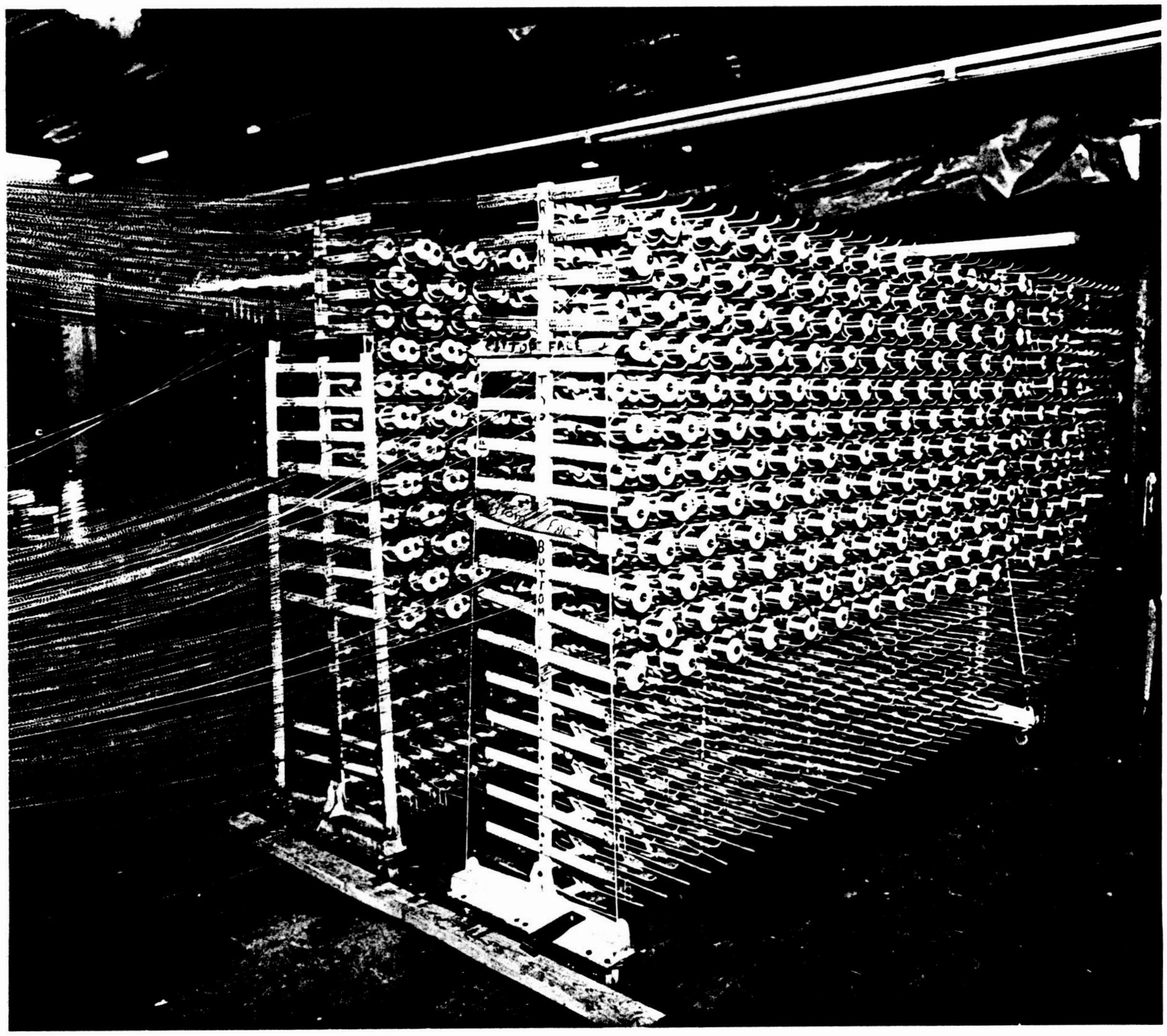


FIGURE 2-6

CREELS LOADED WITH WARP YARNS

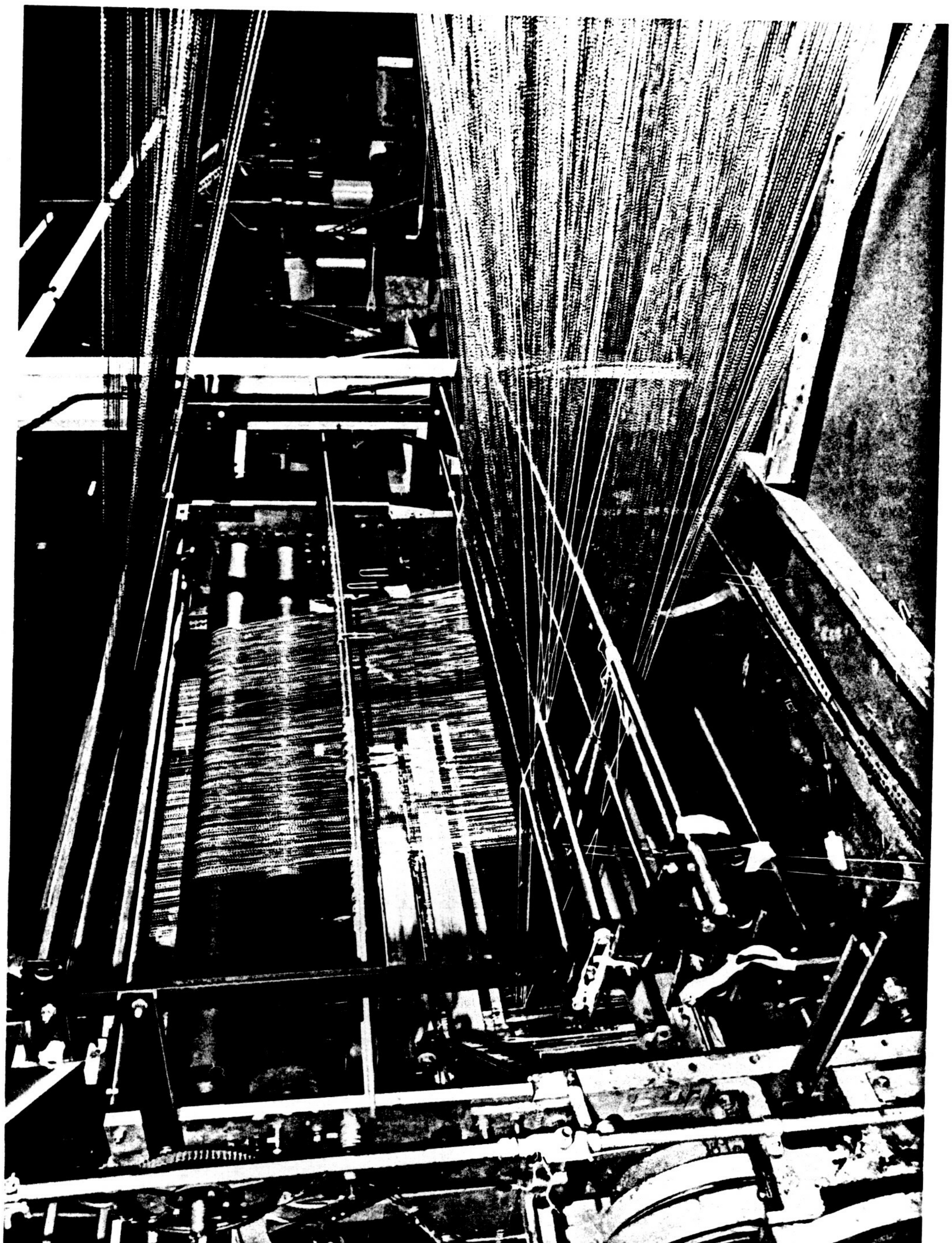


FIGURE 2-7
PATH OF WARP YARNS FROM THE CREELS TO THE REAR OF THE LOOM
NOTE LEASE RODS AND NIP ROLLS FOR RIB FABRIC YARNS

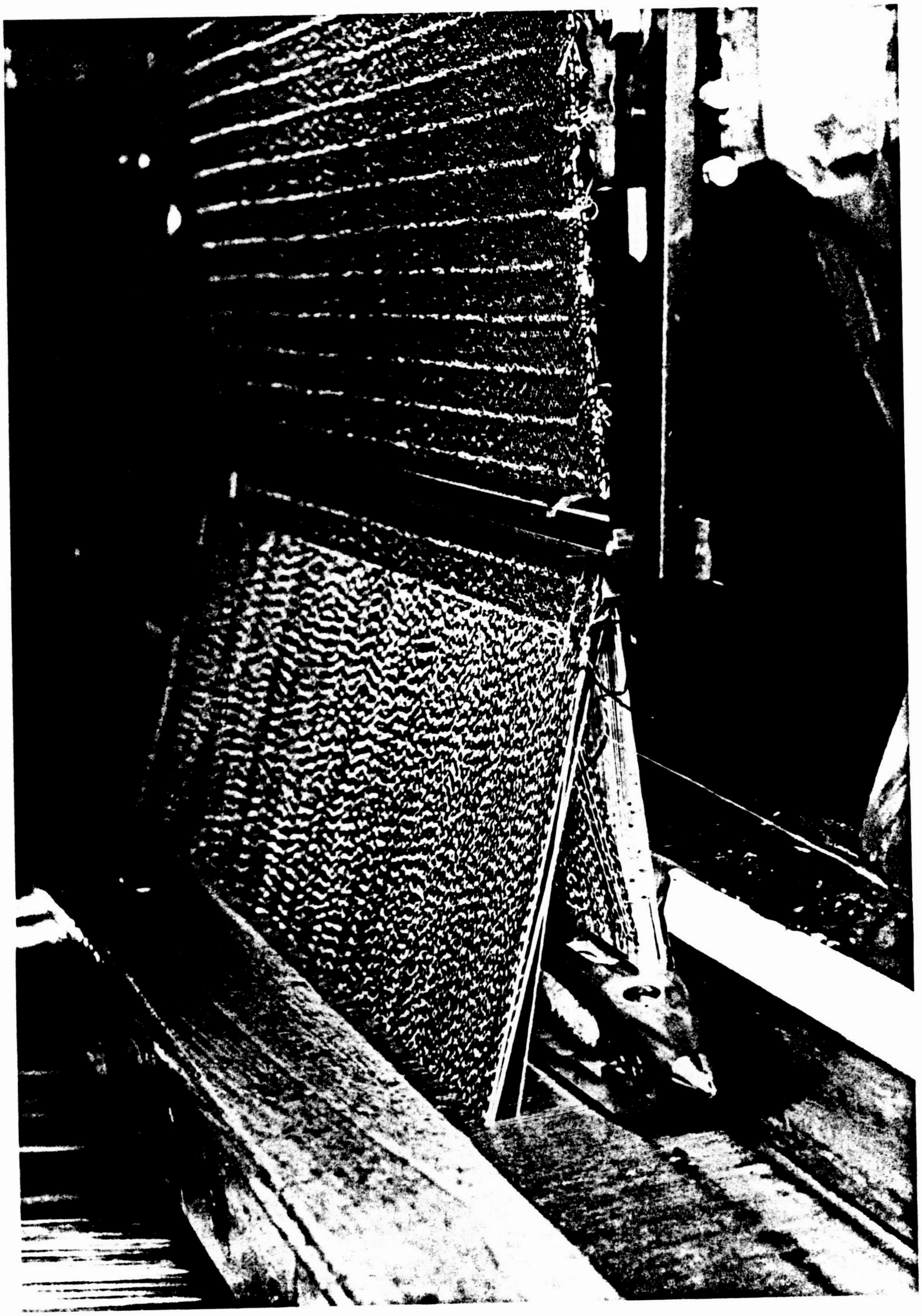


FIGURE 2-8
WARP YARNS PASSING THROUGH REED.
SHUTTLE SHOWN IN SHED OPENING

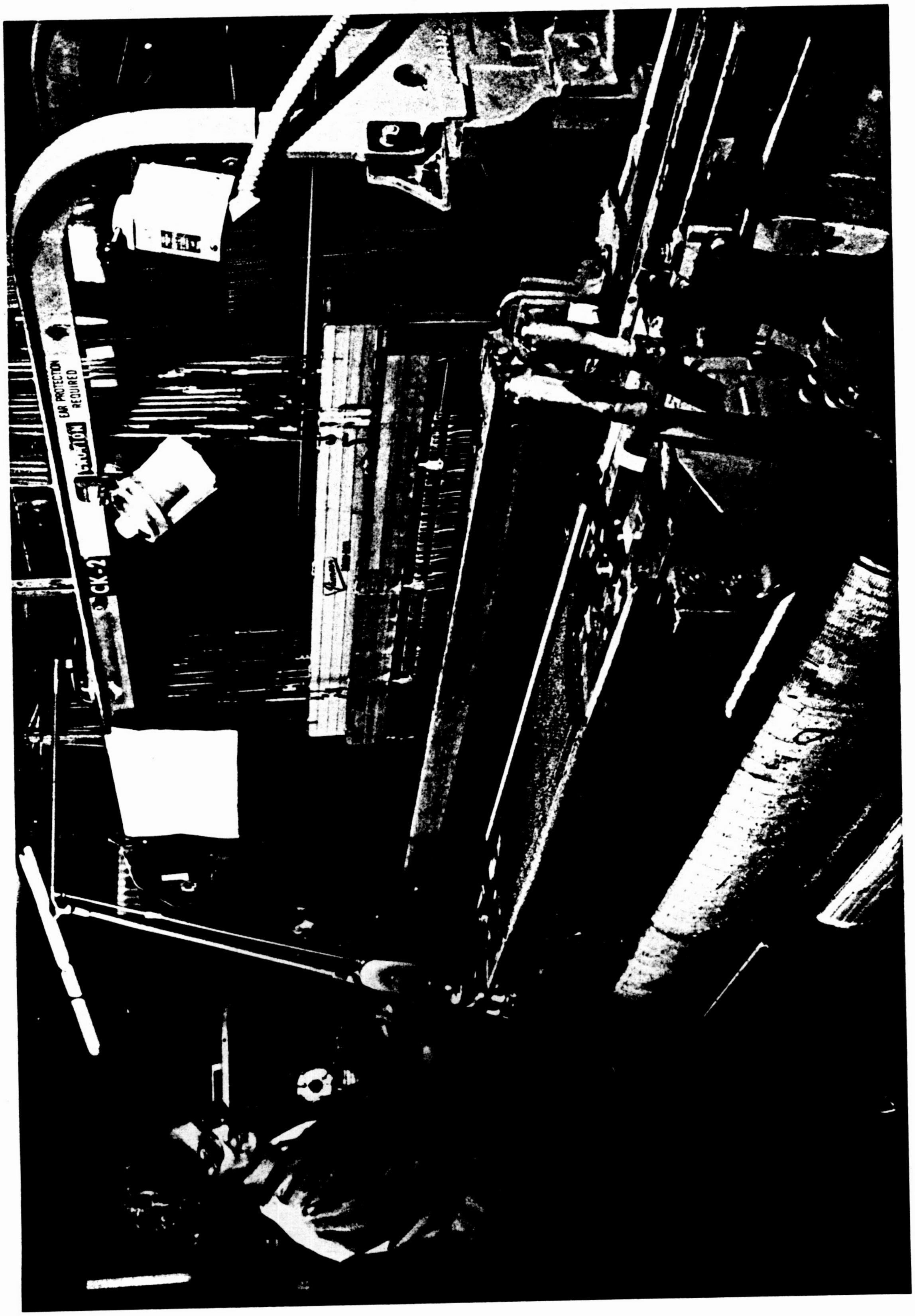


FIGURE 2-9
OPERATOR WEAVING FLUTED CORE FABRIC. NOTE TAKE-UP ROLL IN OPERATION

dimensions by inserting 13 check mandrels in adjacent cells of relaxed fabric, Figure 2-10. Occasionally a tight or loose cell occurred due to the sensivity of adjusting the take-up mechanism of the loom when correcting a missed filling insertion. The mechanism required precise adjustment, otherwise a tight or loose cell would result. However, very few weaving defects were observed. The fluted fabric was now ready for insertion of Q-Fiber Felt insulation.

2.2.5 Insulation preparation. Q-Fiber Felt is a felted batting material formed from silica fibers of 1.4 micron (5.51×10^{-5} inch) average diameter. It is available in two nominal thicknesses and one bulk density; 1/2 inch and 3/16 inch thickness, each at 6 pounds per cubic foot density when measured at nominal thickness. Additional information on Q-Fiber Felt is presented in Appendix B. The 1/2 inch Q-Fiber Felt furnished by the supplier, is a soft, fluffy batting material in a form not suitable for insertion into fabric flutes. While its nominal thickness is 1.27 cm (0.5 inch), actual thicknesses range from 1.59 to 1.9 cm (0.625 to 0.75 inch). The 3/16 inch nominal thickness Q-Fiber Felt has an actual thickness range of 0.636 to 1.27 cm (0.25 to 0.5 inch). In the previous TABI effort, NAS2-11718, a procedure was developed to compress and rigidize the 1/2 inch nominal Q-Fiber Felt into panels 1.27 cm (0.5 inch) thick. The panels were cut into triangular cross section mandrels and then inserted into the fabric flutes.

2.2.5.1 Unfortunately, Q-Fiber Felt is not available at a nominal thickness of 3/4 inch, so it was proposed to combine individual layers of 3/16 inch and 1/2 inch felts to obtain an approximate 3/4 inch batting with a 6 lbs/ft^3 density. The flow chart in Figure 2-11 presents the procedure adopted to prepare the Q-Fiber Felt insulation.

The following paragraphs discuss additional information pertinent to the insulation preparation procedure:

(1) Q-Fiber Felt Sheets. The Q-Fiber Felt batting was supplied in sheets of 152.4 cm x 91.4 cm (60 inches x 36 inches). For subsequent processing, seven individual sheets, 30.5 cm x 71.1 cm (12 inches x 28 inches) were cut from each as-received sheet using a knife. This allowed a minimum of waste. A panel of each thickness available is pictured in Figure 2-12.

FIGURE 2-10
CHECK MANDRELS BEING INSERTED INTO FLUTES OF FABRIC

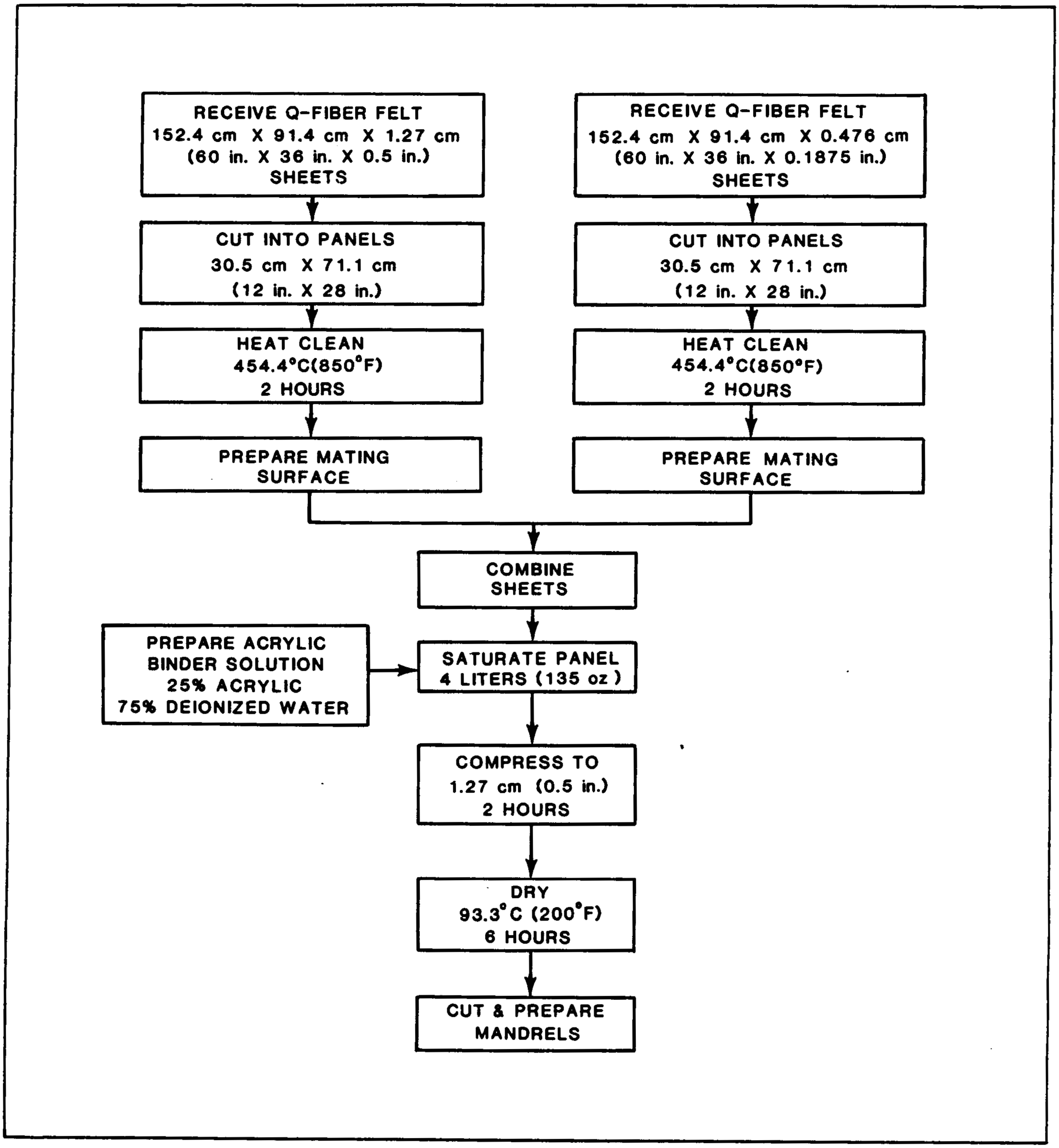


Figure 2-11

PROCEDURE FOR PREPARING INSULATION MANDRELS

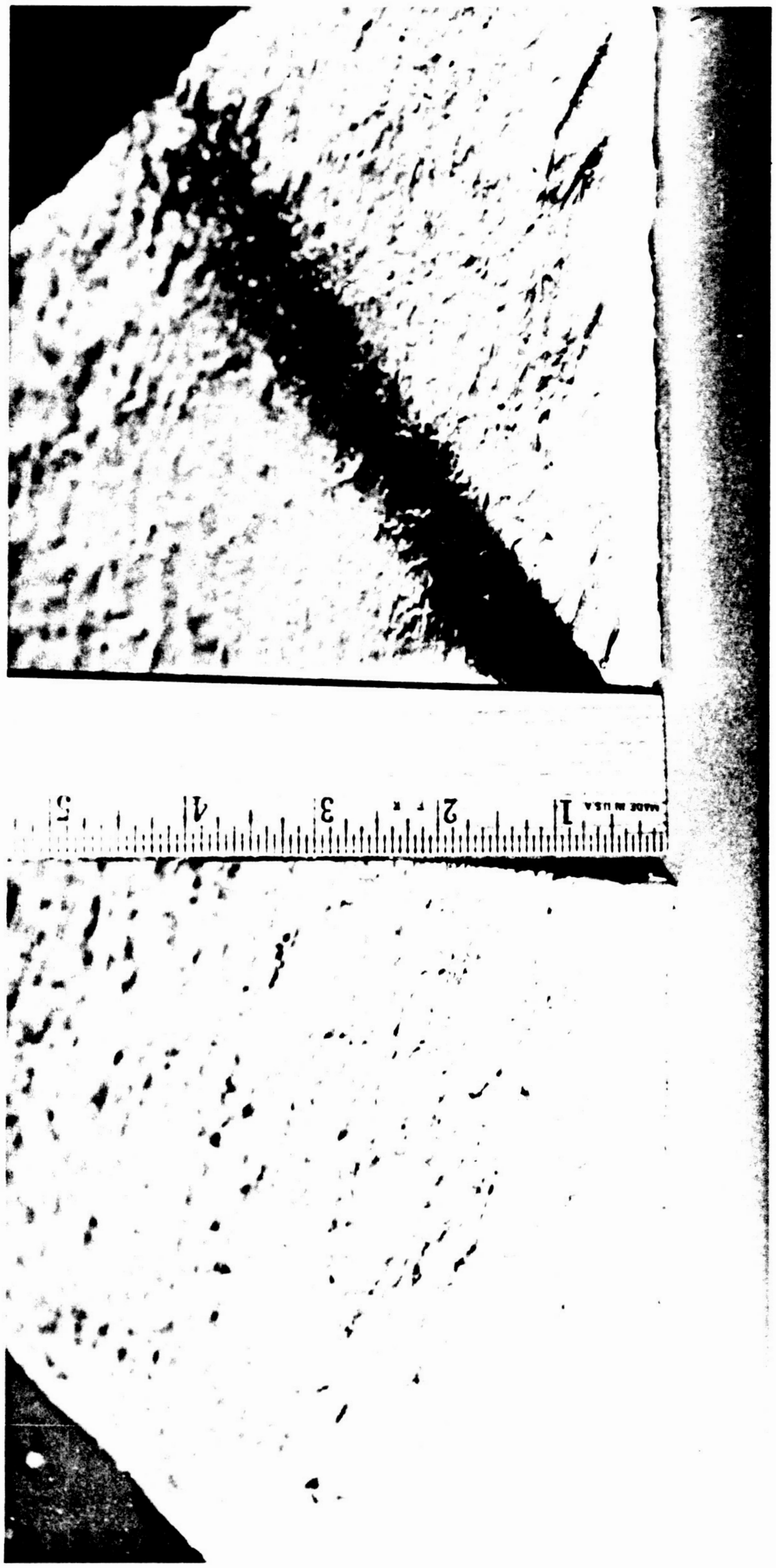


FIGURE 2-12
Q-FIBER FELTS, 1/2 INCH & 3/16 INCH NOMINAL THICKNESSES

(2) Heat Cleaning. Work completed in earlier programs determined the necessity for heat cleaning all incoming Q-Fiber Felt to remove contaminating materials that could become objectionable later in the process. Felt panels were placed on racks made of flat expanded metal supported by four legs. The metal tray surfaces were covered with clean Astroquartz fabric to prevent contamination of the felt. Heat cleaning was carried out in a large air-circulating oven. Because of the relatively large quantity of material to be processed, it was essential to build several additional racks to meet schedule requirements. These were also employed for drying saturated felt panels and final heat cleaning of TABI panels.

(3) Combining Layers of Q-Fiber Felt Panels. A large percentage of the fibers in Q-Fiber Felt occur in laminar plies stacked up to form the thickness of the batting. The relatively small quantity of fibers protruding between plies results in low interlaminar strength and provides a poor outer surface for bonding with other layers of batting. Recognizing this deficiency, it was felt that the best approach for bonding the two felt materials should be based on altering the laminar orientation of the mating surfaces as well as some of the plies of fibers below these surfaces. A somewhat crude, but effective, technique was developed in which a "comb" modified each mating surface. The 7.6 cm x 15.2 cm (3 inch x 6 inch) comb consisted of a 0.318 cm x 0.318 cm (0.125 inch x 0.125 inch) mesh stainless steel wire cloth woven from 20 gauge wire. Two adjacent wires along all edges were removed thus exposing the large number of parallel wire ends which provided the teeth of the comb. Each mating surface of batting was mechanically altered by applying the comb in a series of short, curved strokes that penetrated the surface and caused some of the surface and below-surface fibers to stand up in a direction normal to the plane of the felt. See Figures 2-13 and 2-14. The two mating surfaces were then placed together as pictured in Figure 2-15, and pressed together dry in preparation for the next operation. Figure 2-16 shows the felts after being combined and dry-pressed.

FIGURE 2-13
PREPARING MATING SURFACES OF Q-FIBER FELT WITH COMB

FIGURE 2-14
Q-FIBER FELT SURFACES AFTER COMBING

FIGURE 2-15
COMBINING Q-FIBER FELTS AFTER COMBING

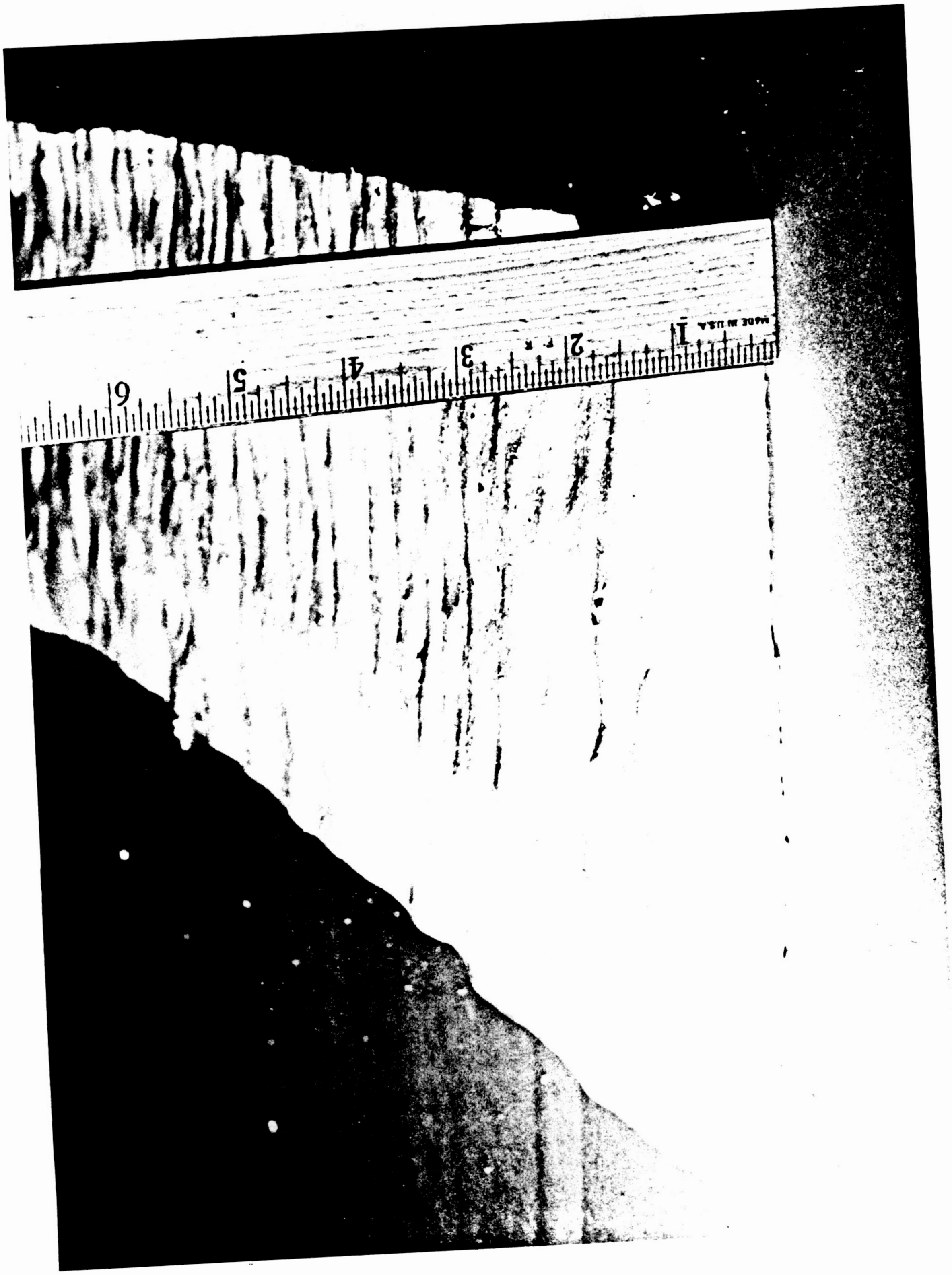


FIGURE 2-16
COMBINED FELTS AFTER DRY COMPRESSING

(4) Binder Treatment. The binder employed for saturating the felt was Carboset®, an acrylic resin product of B. F. Goodrich Co. which is a clear water soluble system containing 40% resin solids, see Appendix E. The combined panels were saturated with a 25% by volume solution of the resin in deionized water. 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 in. x 30 in. x 0.25 in.) aluminum plate. Four liters (135 ounces) of the diluted solution was poured onto the felt. In Figure 2-17 the operator is adding resin to the felt.

(5) Compressing and Drying. The saturated panel was covered with a layer of polyester film and placed on top of an aluminum plate identical to the bottom plate. A stack of up to 7 of these saturated panels, films and plates, with 1.27 cm (0.5 inch) spacers between the plates was loaded in a pneumatic press, and the stack pressurized until the individual panels reached the spacer thickness. Figure 2-18 pictures the press partially set up with the stack of saturated panels ready to be compressed. After 2 hours of compression, pressure was released and the stack removed from the press. Each panel from the stack with its bottom supporting film was set on a rack, see Figure 2-19, and dried in the oven for 6 hours at 93.3°C (200°F). After drying, the panel thickness had recovered close to 1.9 cm (0.75 inch). The panels were considered satisfactory for cutting into mandrels since they were relatively free of binder migration to the outer surfaces. In the early stages of the previous program this heavy skin of surface binder resulted in the mandrels damaging the flutes of the fabric during the insertion operation. This problem was substantially reduced by lowering the percentage of resin in the saturating solution and by drying at a lower temperature. This experience was applied successfully to the current effort. The pick-up in weight of the Q-Fiber Felt by the acrylic resin solids was 36.0%, based on the dried felt weight.

(6) Cutting and Preparing Mandrels. Very few problems were encountered while cutting mandrels from the rigidized panels. A diamond-tipped circular saw

FIGURE 2-17
ACRYLIC RESIN SOLUTION BEING POURED ONTO FELT

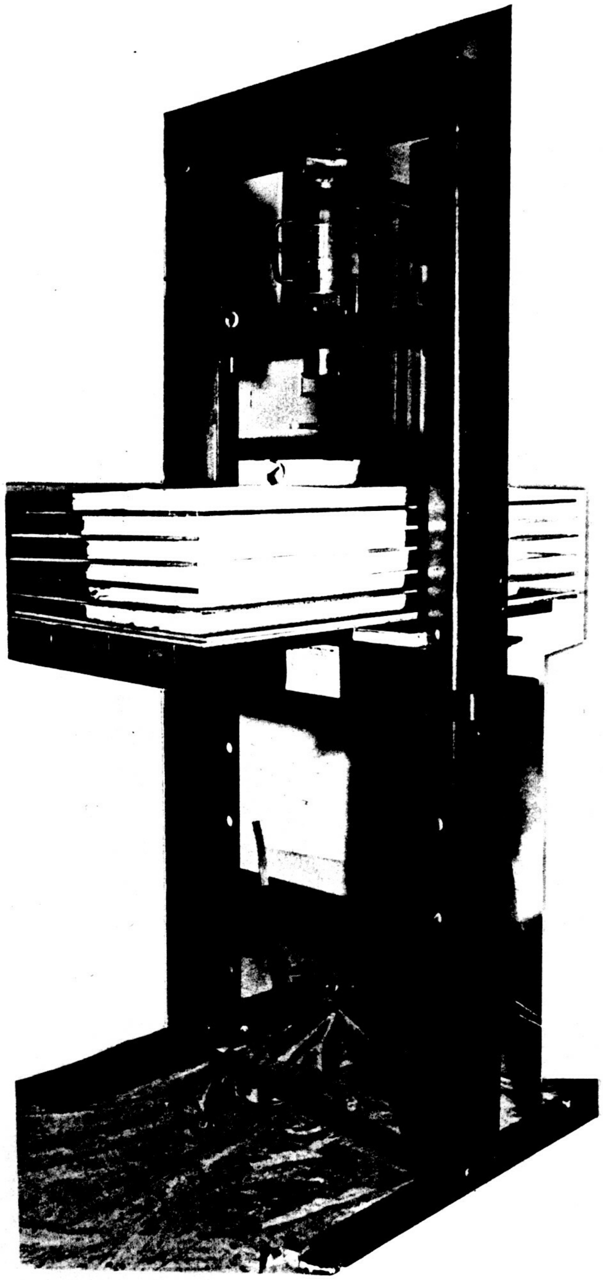


FIGURE 2-18

STACK OF IMPREGNATED PANELS IN PRESS READY TO BE COMPRESSED

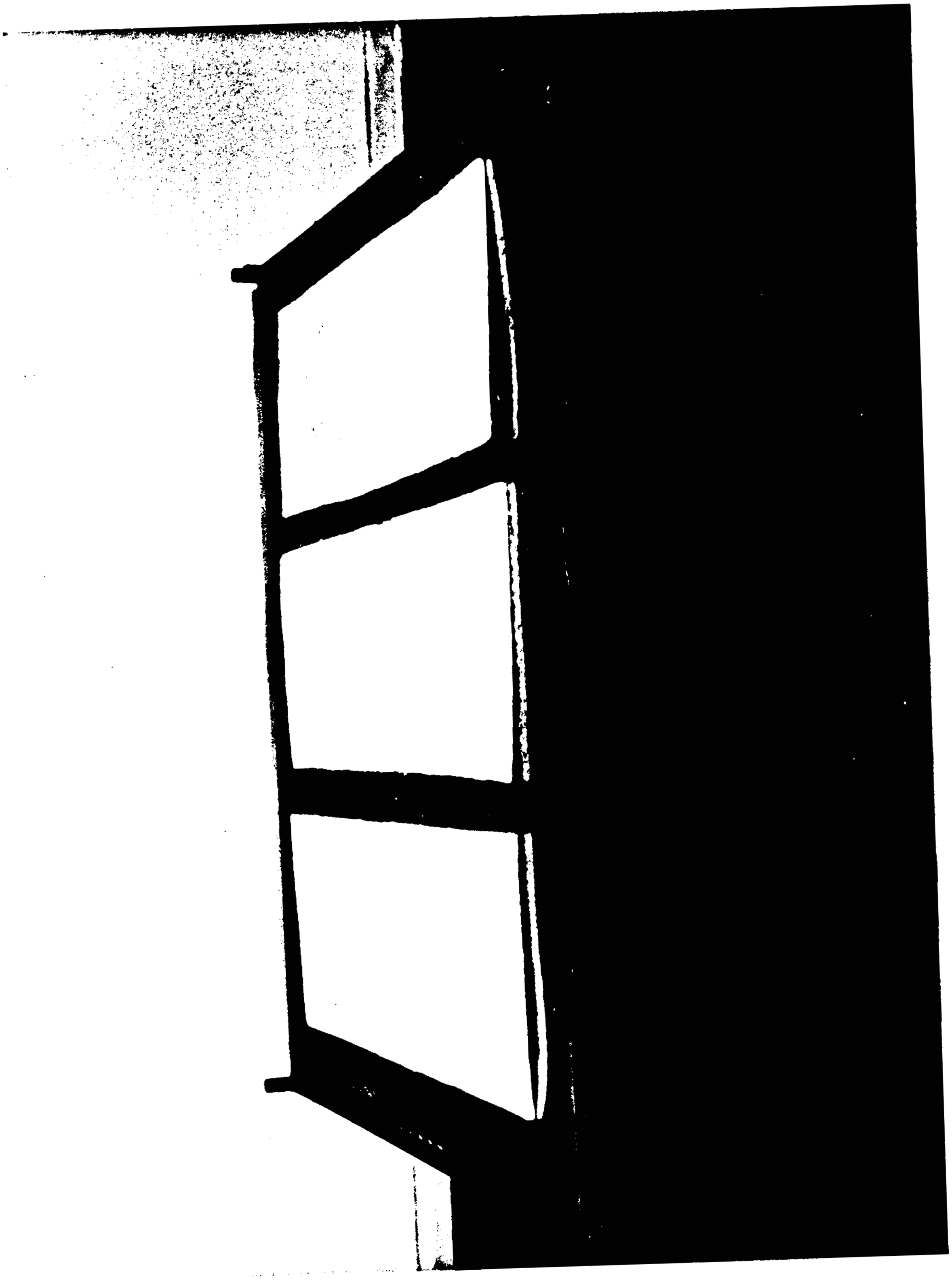


FIGURE 2-19
COMPRESSED FELT PANEL ON DRYING RACK

blade provided accurate cutting with very little resin build-up on the blade. The saw angle was set to 60° to cut the 71.1 cm (28 inch) long mandrels with an equilateral triangular cross section, see Figure 2-20. The insulation mandrel dimensions are given in Figure 2-21. Two finished cut insulation mandrels ready for insertion are pictured in Figure 2-22. After each cut which formed one side of a mandrel, the panel was flipped over to cut the second side of the mandrel as well as the first side of the next mandrel. As a result, about half of all the mandrels had the bond line of the two Q-Fiber Felt components near the apex and the other half had the bond line close to the base. Those mandrels with the bond lines near the apex were very fragile and many broke during handling and subsequent insertion attempts. It was necessary to procure and process additional Q-Fiber Felt to replace this loss.

2.2.6 Insertion of Insulation Mandrels. In prior developments on TABI materials, a major problem was the lengthy time required to insert the rigidized insulation materials. One cause for this situation was the need to insert reasonably straight, fragile abrasive mandrels into fabric flutes which inherently are not perfectly straight. To overcome this problem, experiments were attempted to straighten and rigidize the flutes with plastic mandrels before inserting the insulation mandrels. The results of these tests proved promising and a large number of extruded nylon mandrels were procured. The dimensions of these mandrels are given in Figure 2-23. The nylon mandrels were inserted into all of the flutes of a panel, Figure 2-24, and a 6.7% by volume aqueous solution of Carboset was applied by brushing both sides of the fabric, as seen in Figure 2-25. The panel was racked until all flutes appeared straight, and allowed to air dry overnight, Figure 2-26. Figure 2-27 illustrates the rigidized panel after the mandrels are removed. The edge cross section of the rigidized flutes can be seen in Figure 2-28. The amount of resin solids added to the fabric was approximately 2.0%. The sharp angles of the insulation mandrels were filed down, and the mandrels inserted into the fabric flutes as seen in Figure 2-29. This flute-straightening procedure proved to be very effective in reducing the insertion time. However, this gain was partially offset by the fragility of

FIGURE 2-20
DRIED COMPRESSED INSULATION PANEL BEING CUT
INTO MANDRELS USING CIRCULAR SAW

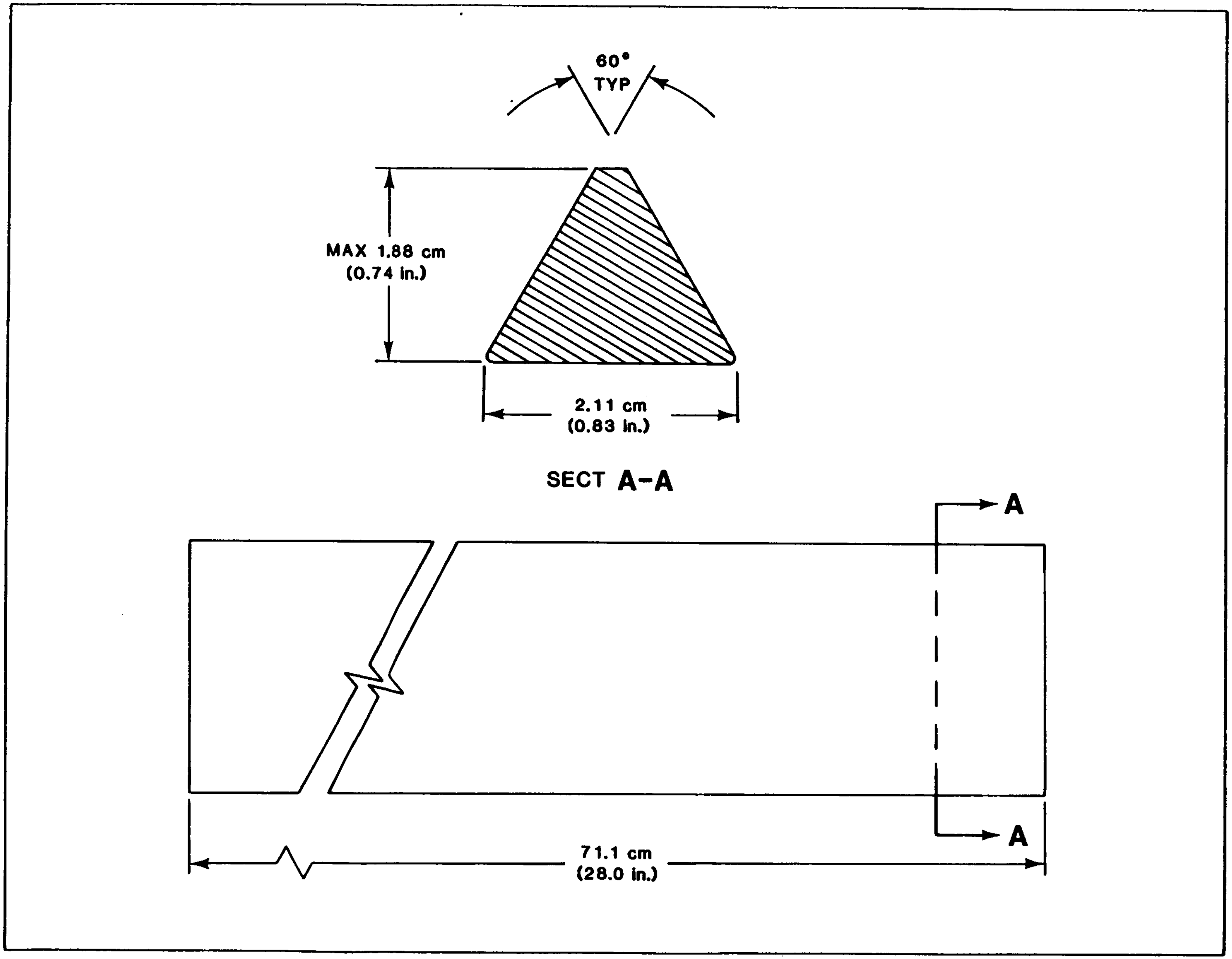


Figure 2-21

DIMENSIONS OF INSULATION MANDRELS FOR ITEM 1

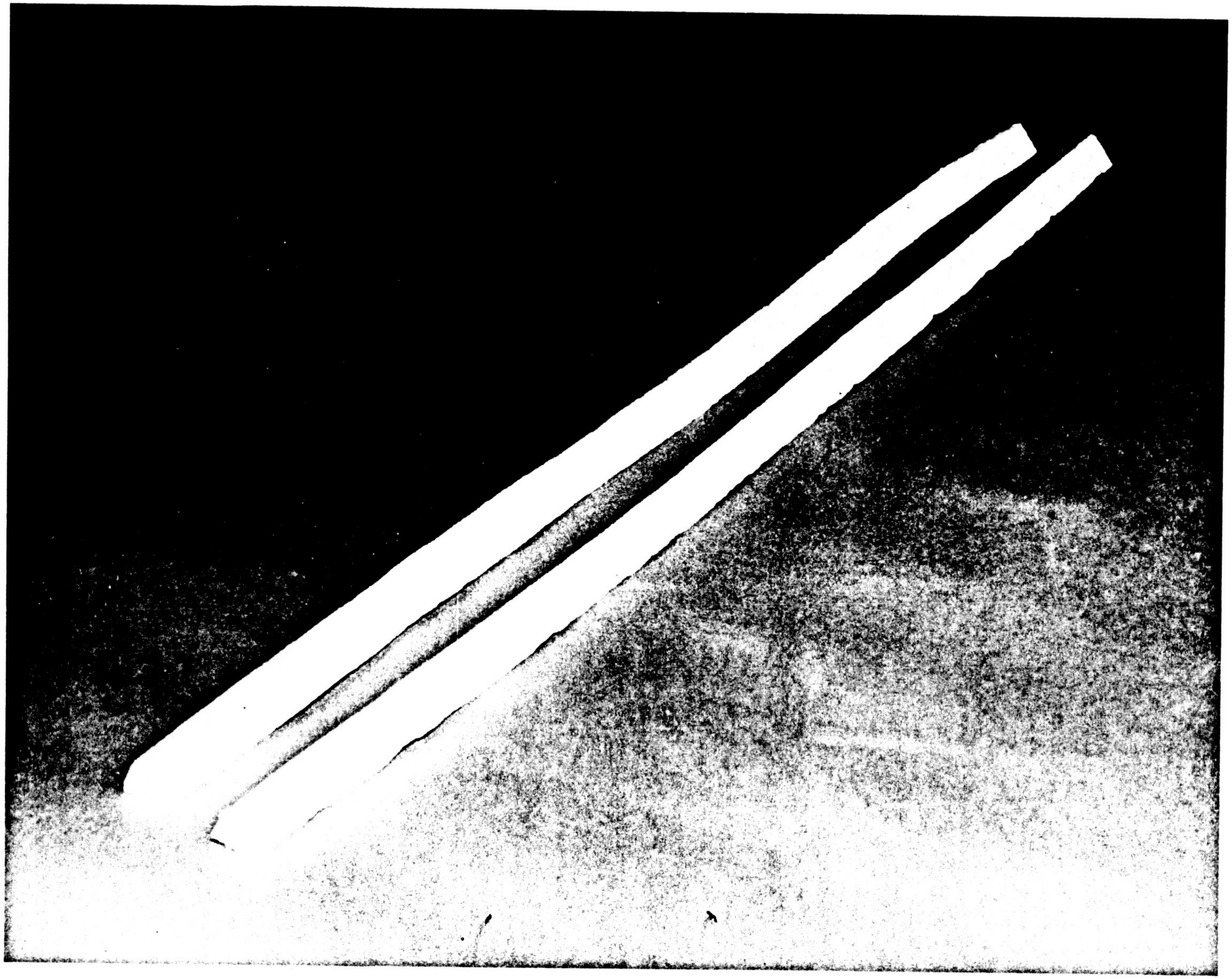


FIGURE 2-22

CUT INSULATION MANDRELS READY FOR INSERTION INTO FLUTED CORE FABRIC

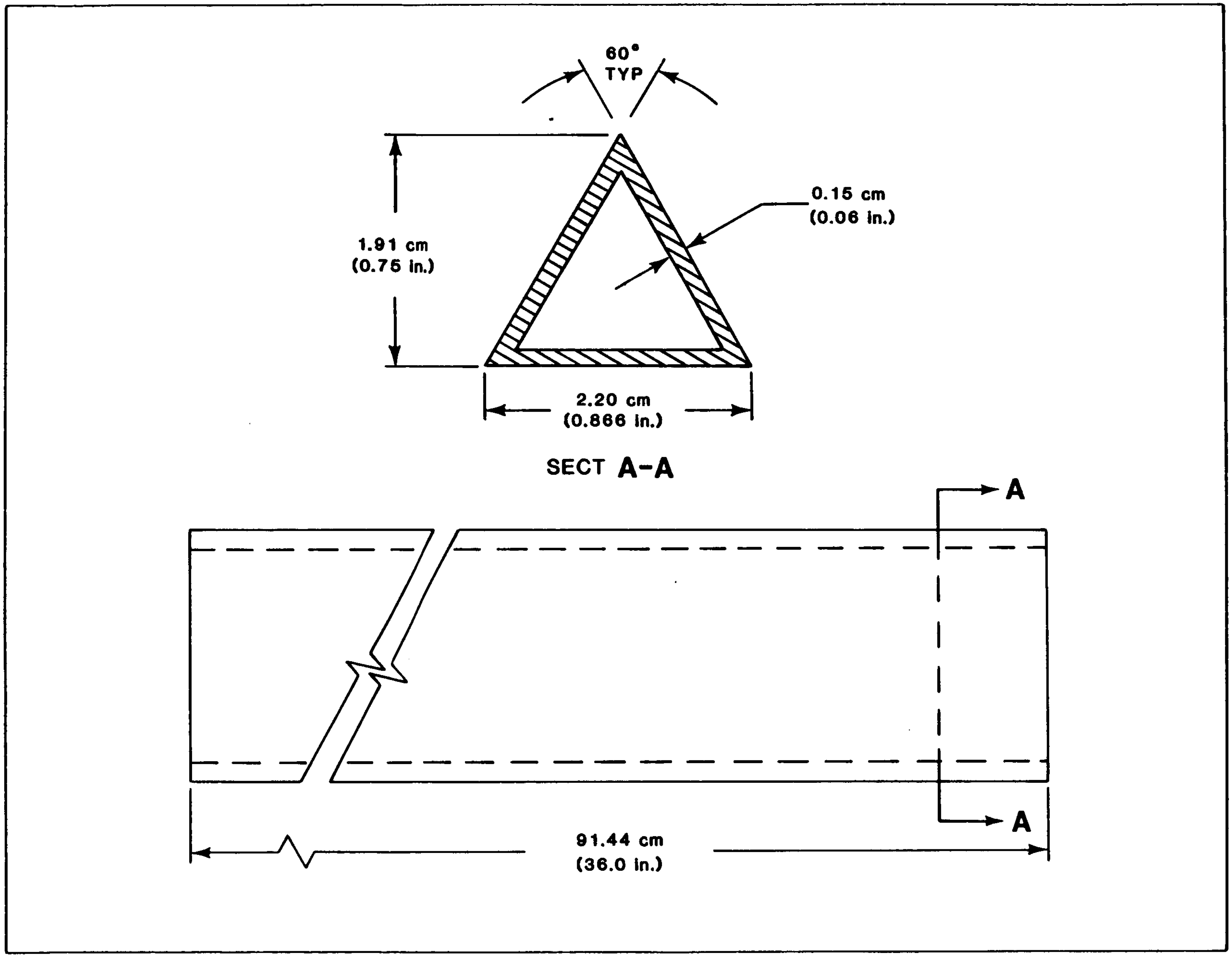


Figure 2-23
DIMENSIONS OF NYLON MANDRELS
FOR RIGIDIZING ITEM 1 FLUTED CORE FABRIC

FIGURE 2-24
INSERTING NYLON MANDRELS INTO FLUTED CORE FABRIC

FIGURE 2–25
APPLYING RESIN TO FABRIC

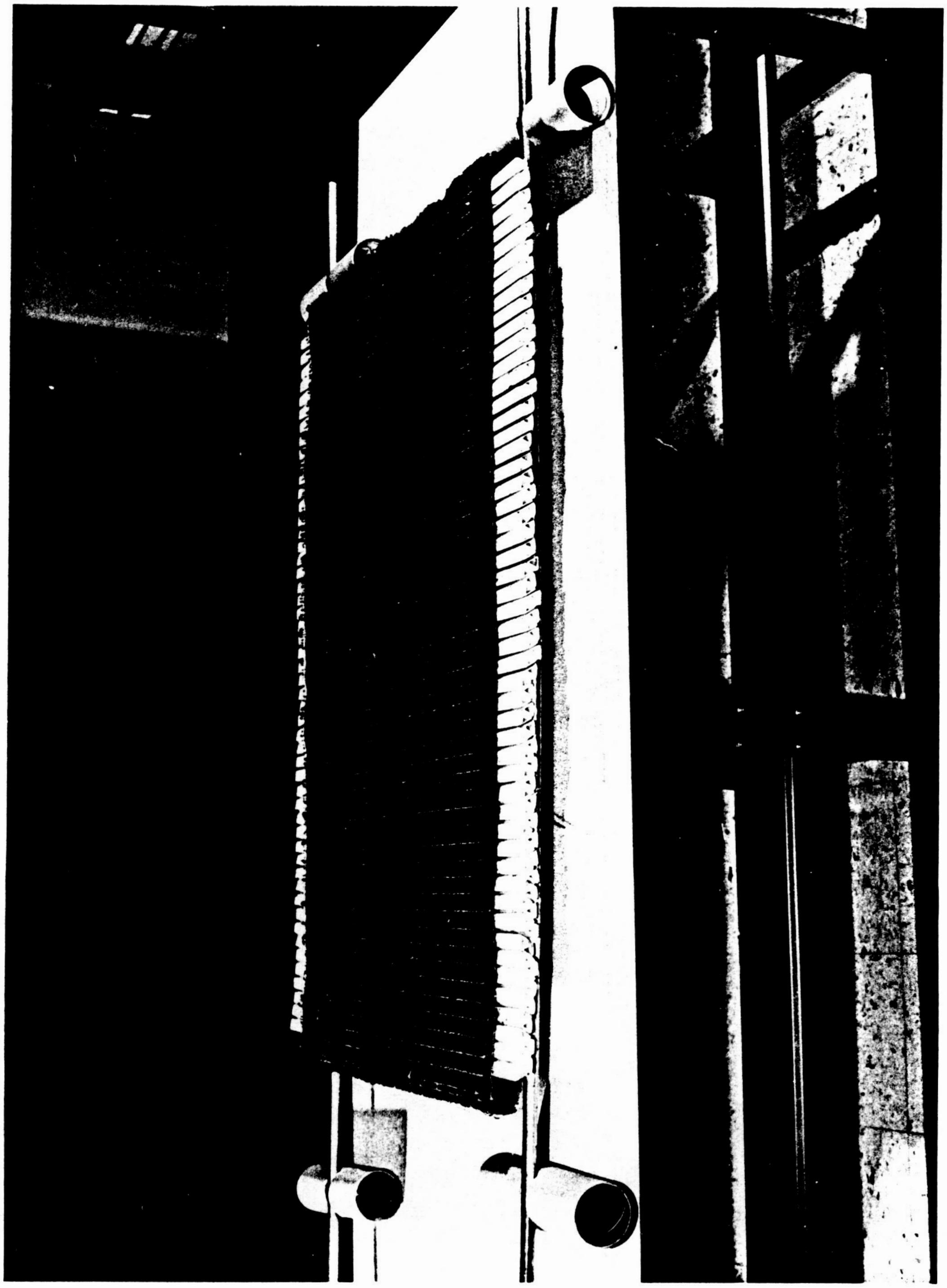


FIGURE 2-26
RESIN IMPREGNATED PANEL READY FOR DRYING

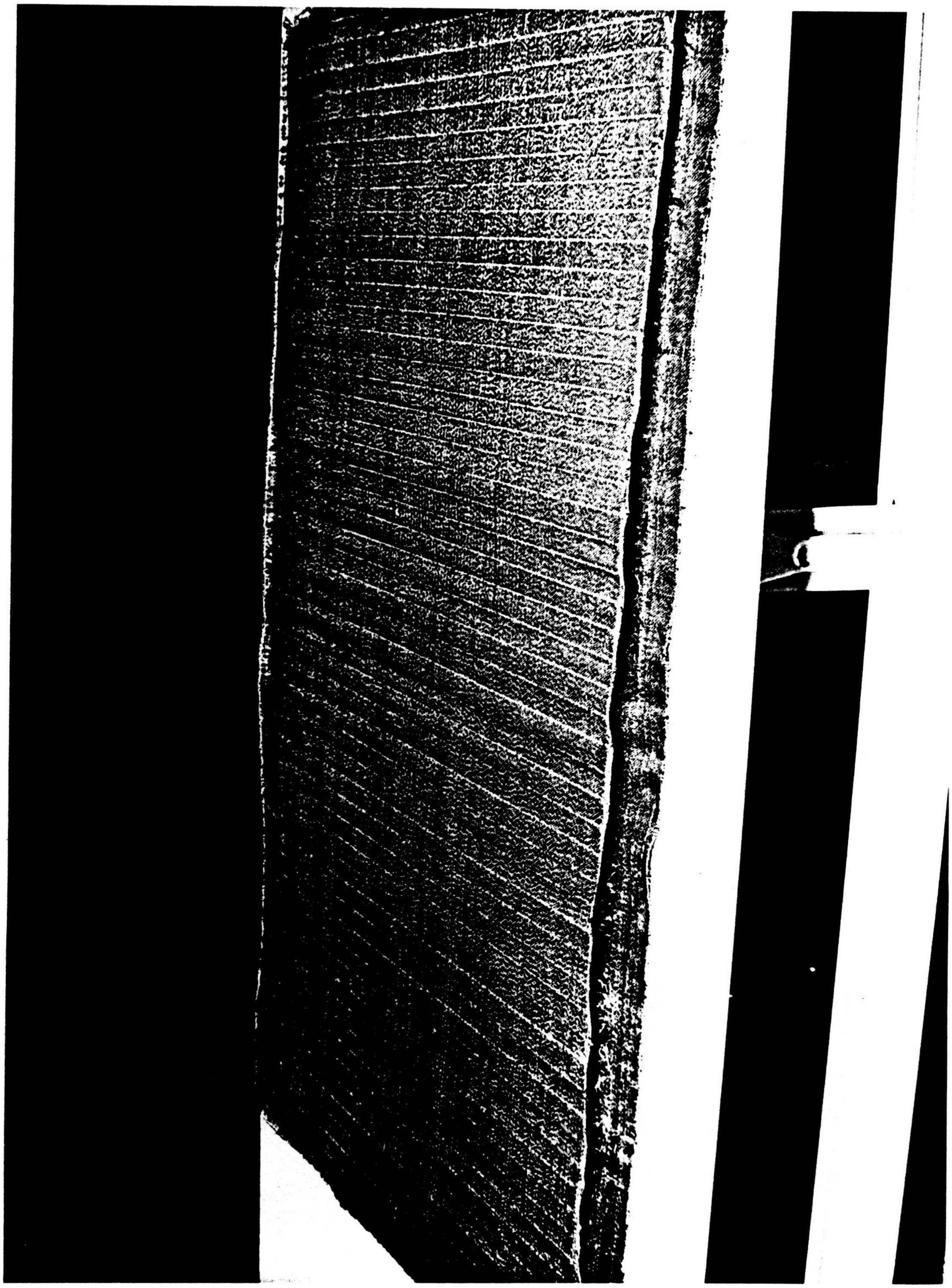


FIGURE 2-27

RIGIDIZED FABRIC AFTER DRYING & REMOVING NYLON MANDRELS

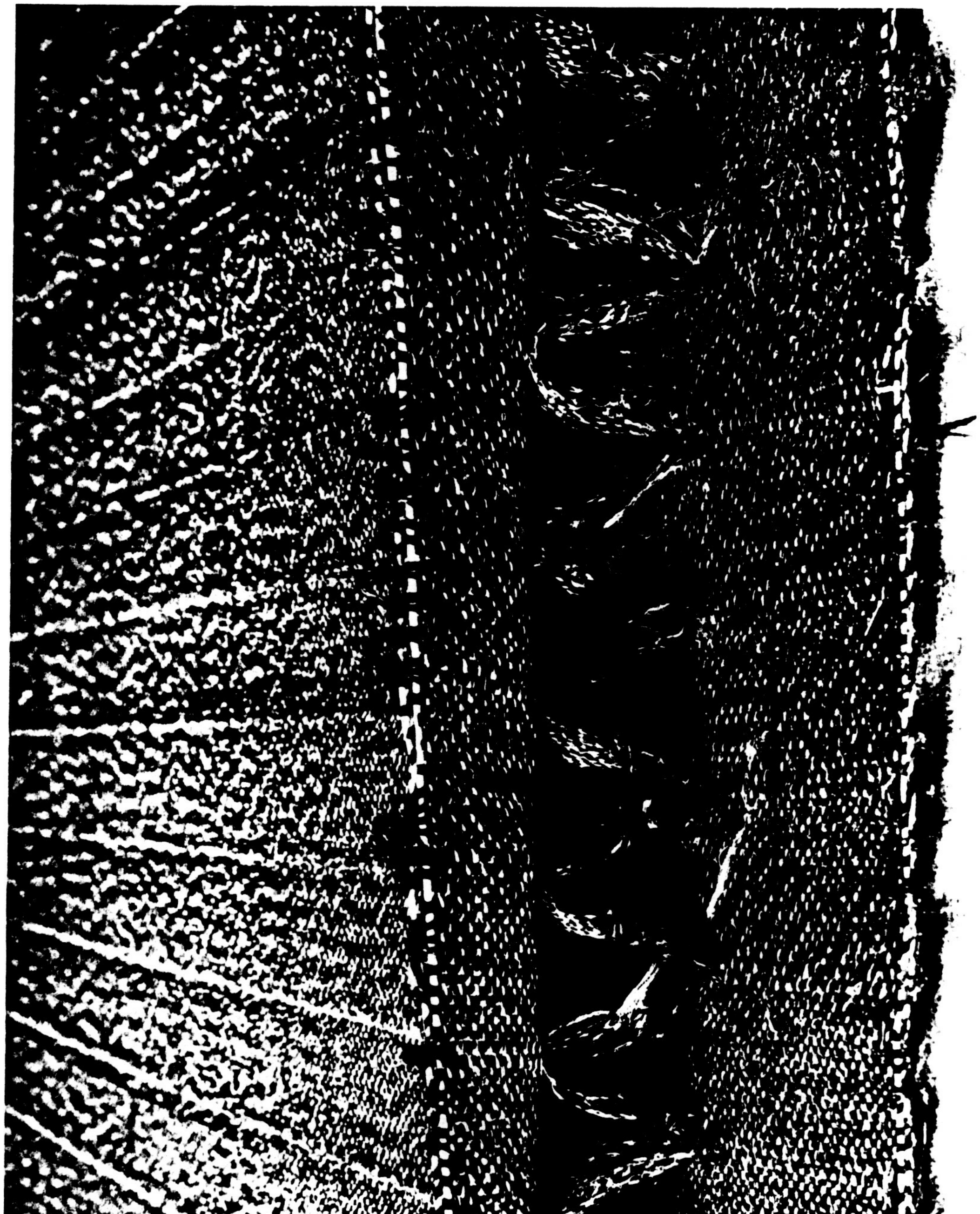


FIGURE 2-28

CLOSE UP OF FLUTE OPENINGS OF RIGIDIZED PANELS

FIGURE 2-29
INSERTING INSULATION MANDRELS INTO FLUTES OF RIGIDIZDED FABRIC

the mandrels noted in paragraph 2.2.5.1 (6) and as shown in Figure 2-30. Occasionally time was also lost when attempting to insert insulating mandrels into slightly undersized cells. When mandrels broke while being inserted, they were painstakingly and carefully removed from the cells so as not to damage the fabric. Tight or loose cells required custom fitted insulation mandrels. Nevertheless, the number of panels that were insulated per day doubled before very long.

2.2.7 Heat Cleaning. The insulated panels were positioned on clean, glass-covered drying racks and heated in the large oven at 454.4°C (850°F) for 4 hours, after which the organic acrylic binder, yarn lubricants, and rayon serving appeared to be essentially removed. During the early heat cleanings, observations revealed an enormous amount of smoke generated in the temperature range of 204°C to 260°C (400°F to 500°F). To reduce the sudden generation of smoke, the heat cleaning cycle was modified to include three constant temperature steps. Once reaching 177°C (350°F), 232°C (450°F), and 316°C (600°F), the temperature remained constant for two hours, after which a one hour heat up time was programmed to arrive at the next temperature step. After completing these intermediate temperature steps, the temperature increased to 454°C (850°F) and continued at that setting for four hours. Panels heat cleaned in this fashion generated very little smoke and appeared to be equal to those cleaned by the original cycle.

2.2.7.1 Midway through the program an accident occurred during a heat cleaning cycle involving four panels. Due to a malfunction, the oven temperature rose to 537.8°C (1000°F), activating a sprinkler head, consequently soaking the panels. The panels were dried in another oven, visually inspected and found to be free of any physical damage. Later, these panels were heat cleaned again, identified and shipped to NASA.

2.2.8 Characterization. A close-up of a completed, insulated TABI panel is shown in Figure 2-31. Representative measurements were compiled on completed panels and the results shown in Table 2-2. As expected, the actual areal weight of the uninsulated fabric exceeded the target weight in Table 2-1 by nearly 12%. This resulted from the increased pick count of the top and bottom fabric faces of the woven core. The actual insulated panel areal weight surpassed the target

FIGURE 2-30
INSULATION MANDREL BROKEN AT BOND LINE OF Q-FIBER FELTS NEAR APEX

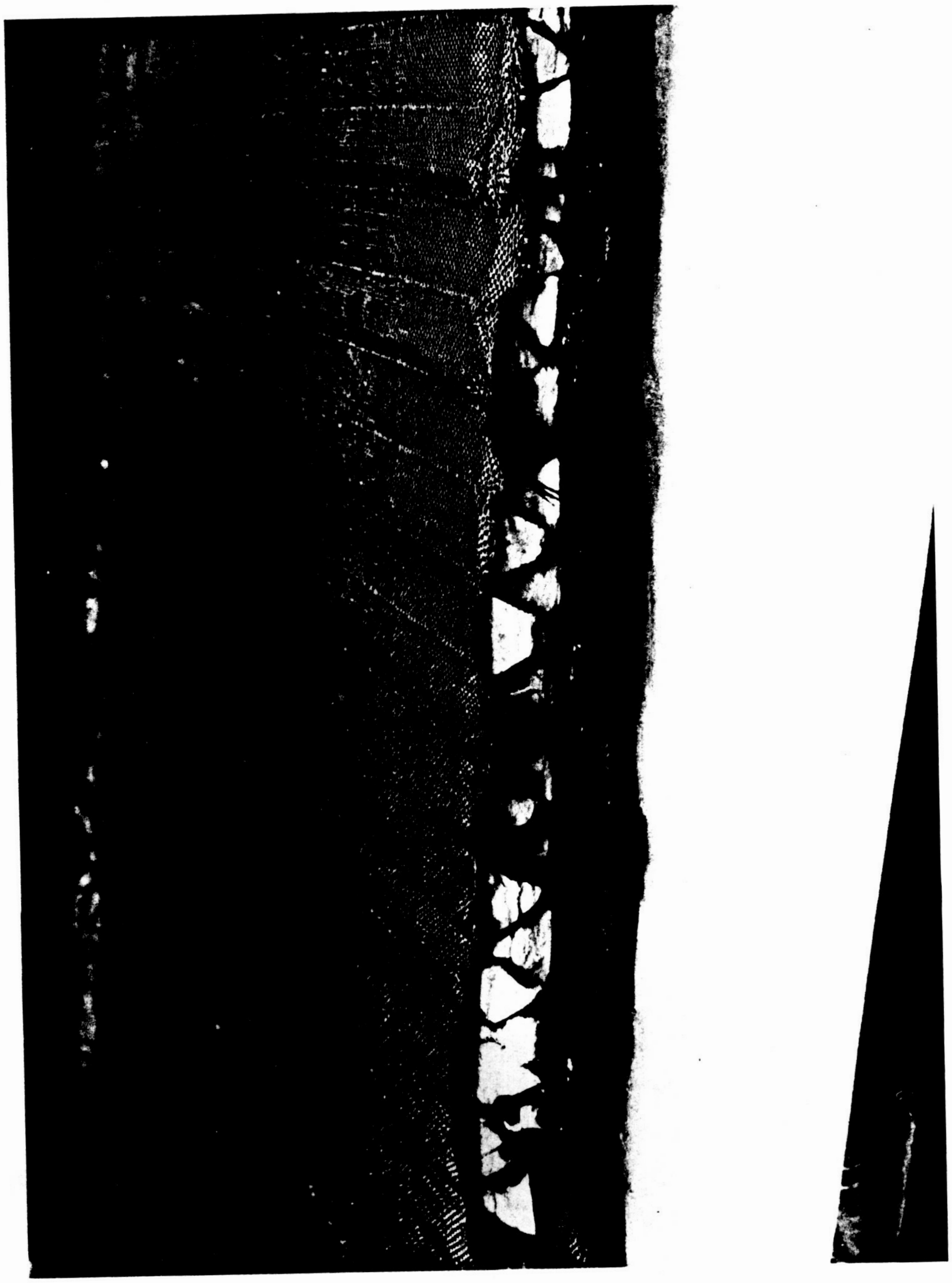
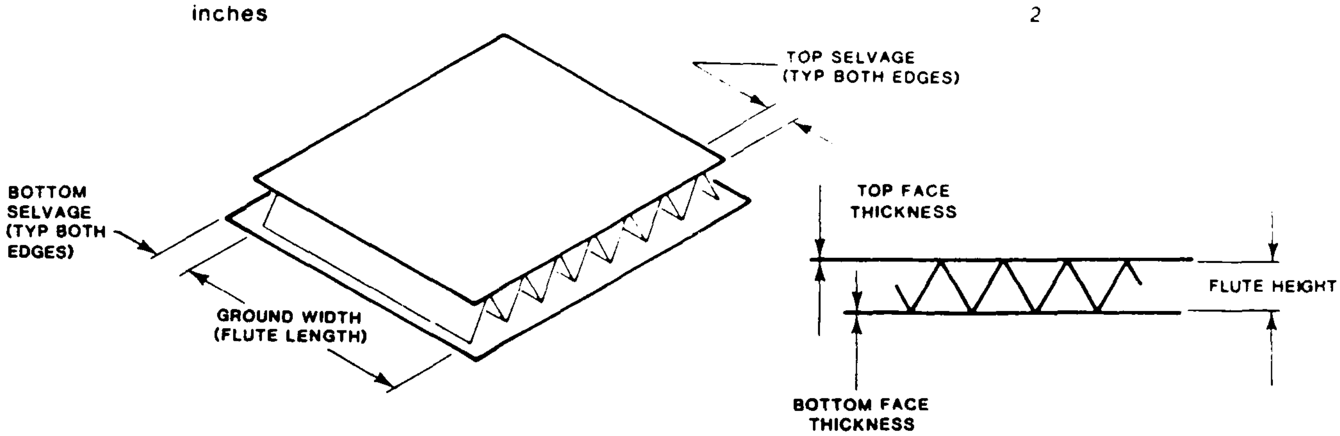


FIGURE 2-31
CLOSE-UP OF COMPLETED INSULATED TABI PANEL

Table 2-2

ACTUAL CHARACTERISTICS AND DIMENSIONS OF ITEM 1 FLUTED FABRIC

FABRIC YARN COUNT (WARP X FILL)	MEASURED VALUES
TOP FACE	
ENDS/cm. X PICKS/cm.	6.3 X 9.1
ENDS/inch X PICKS/inch	16.0 X 23.2
RIBS	
ENDS/cm. X PICKS/cm.	6.3 X 7.0
ENDS/inch X PICKS/inch	16.0 X 17.7
BOTTOM FACE	
ENDS/cm. X PICKS/cm.	6.3 X 9.1
ENDS/inch X PICKS/inch	16.0 X 23.2
FABRIC AREAL WEIGHT	
kgs./sq. meter	1.23
oz./sq. yd.	36.38
PANEL AREAL WEIGHT (INCLUDING INSULATION)	
kgs./sq./meter	2.72
oz./sq.yd.	80.09
FABRIC FACE THICKNESS	
TOP FACE	
cm.	0.043
inches	0.017
BOTTOM FACE	
cm.	0.041
inches	0.016
FLUTE HEIGHT (OR CELL HEIGHT)	
cm.	1.91
inches	0.75
GROUND WIDTH	
cm.	71.1
inches	28
EACH SELVAGE, TOP FACE	
cm.	2.54
inches	1
EACH SELVAGE, BOTTOM FACE	
cm.	5.08
inches	2



value by 24%. The calculated weight of the insulation equalled 1.69 kg/sq meter (49.4 oz/sq yd). When added to the target fabric areal weight, the target insulated panel areal weight value approaches the actual value. It thus appears that the estimated panel areal weight value was too low.

3.0 TECHNICAL PROGRAM, ITEM 2

3.1 Objectives, Item 2. The prime objective of this item was to determine the feasibility of fabricating a spherically-shaped, two-gore structure from a hybrid TABI panel material. Each gore of the assembly would be constructed from a continuous fabric length consisting of three segments, (1), woven fluted core with a Nicalon fabric top face and rib, and with an Astroquartz fabric bottom face, (2), a transition zone from fluted core to single ply fabric, and (3), an extension of single ply Nicalon fabric. This "Integrally woven fluted Core And Single ply fabric" length will be referred to as ICAS hereafter in this report. During the definition stage, the dimensional requirements were finalized for each fabric segment depicted in the ICAS sketch of Figure 3-1. It was also determined that the spherical radius of the two-gore assembly of fluted fabric segments be approximately 1.52 meters (5 feet) as shown in Figure 3-2, and that the flutes of the joined gores be filled with 3.57 kg/cubic meter (6 pounds/cubic foot) Q-Fiber Felt. The heat cleaning cycle for the joined gores was to be essentially the same as for the Item 1 panels, and the outer surface of the Astroquartz fabric coated with General Electric RTV 560 Silicone Rubber Compound.

3.2 Program Plan for Item 2. The tasks required for Item 2 are presented in the Program Plan, Figure 3-3. The following paragraphs discuss the effort involved in the performance of these tasks. No substantial development effort was foreseen for most of the tasks, including the design and weaving of the fluted core and single ply fabric segments, and the preparing and inserting of the insulation mandrels. The method for preparing and joining gores, and the technique for coating with silicone rubber were expected to provide the main areas of investigation.

3.2.1 Fabric Design and Programming. The fluted core portion of the ICAS was similar to the plain weave construction of Item 1 except for the substitution of Astroquartz

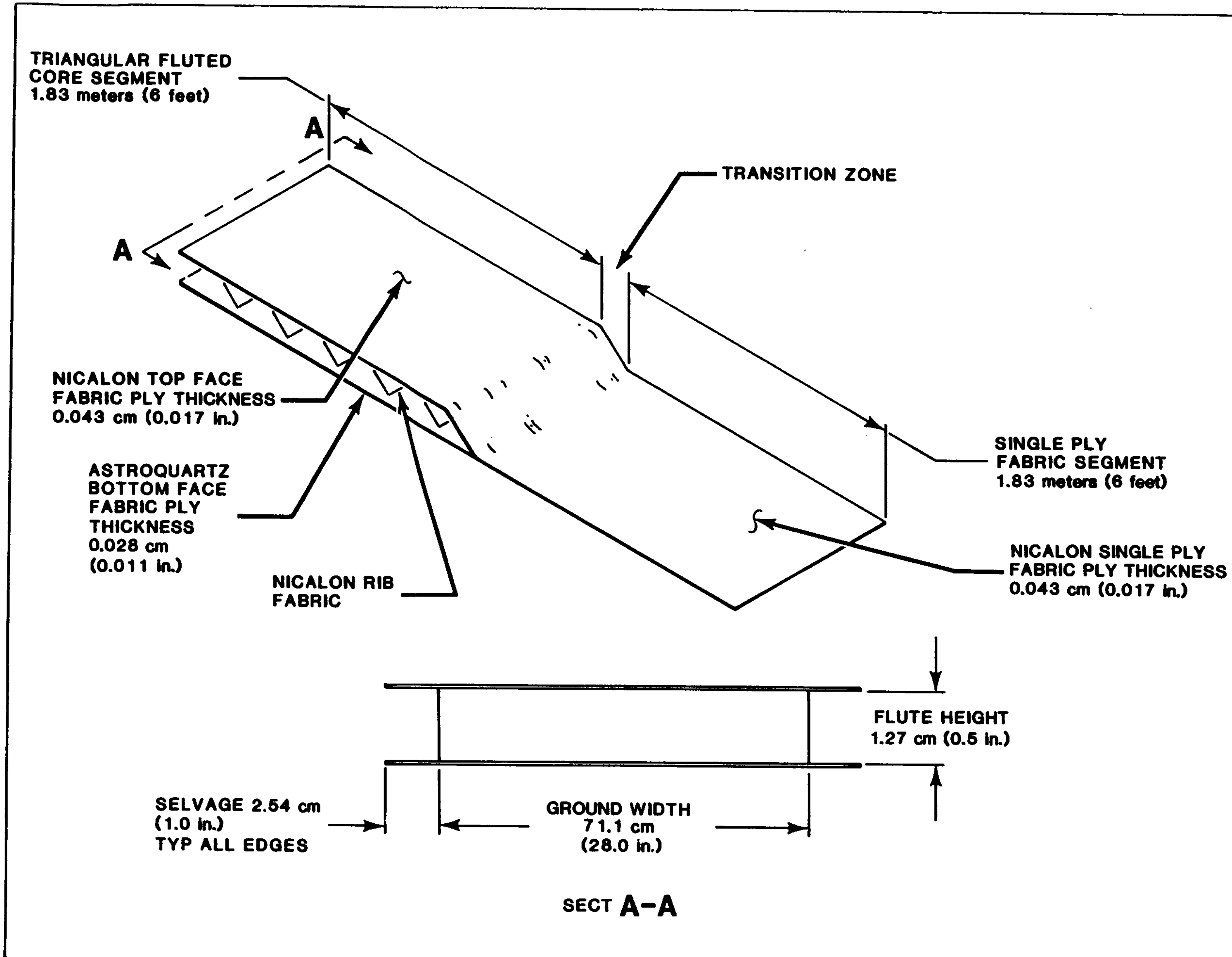


Figure 3-1

DIMENSIONAL REQUIREMENTS OF INTEGRALLY WOVEN FLUTED CORE AND SINGLE PLY FABRIC, I C A S

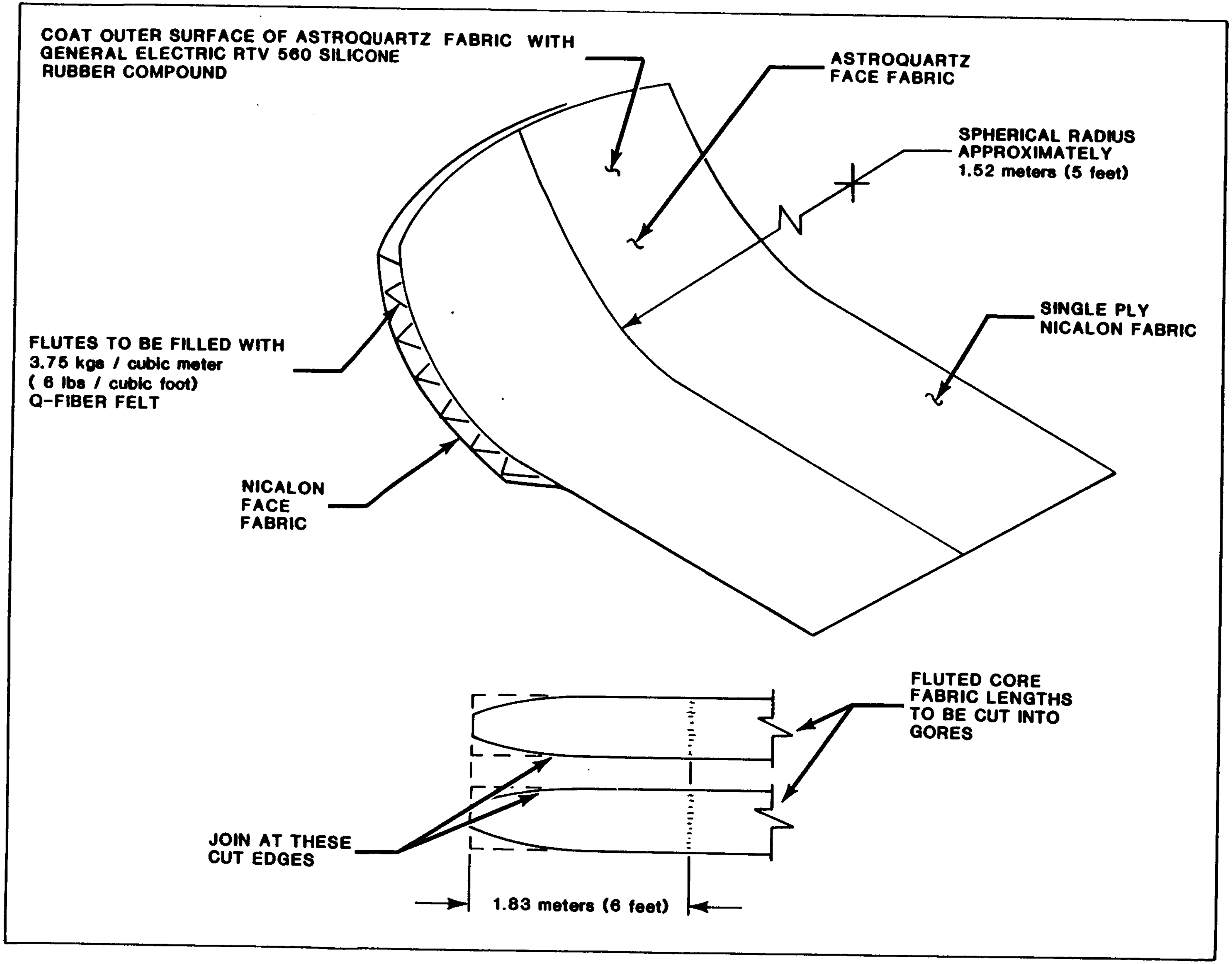


Figure 3-2

TARGET REQUIREMENT FOR 2-GORE ASSEMBLY OF FLUTED CORE FABRIC

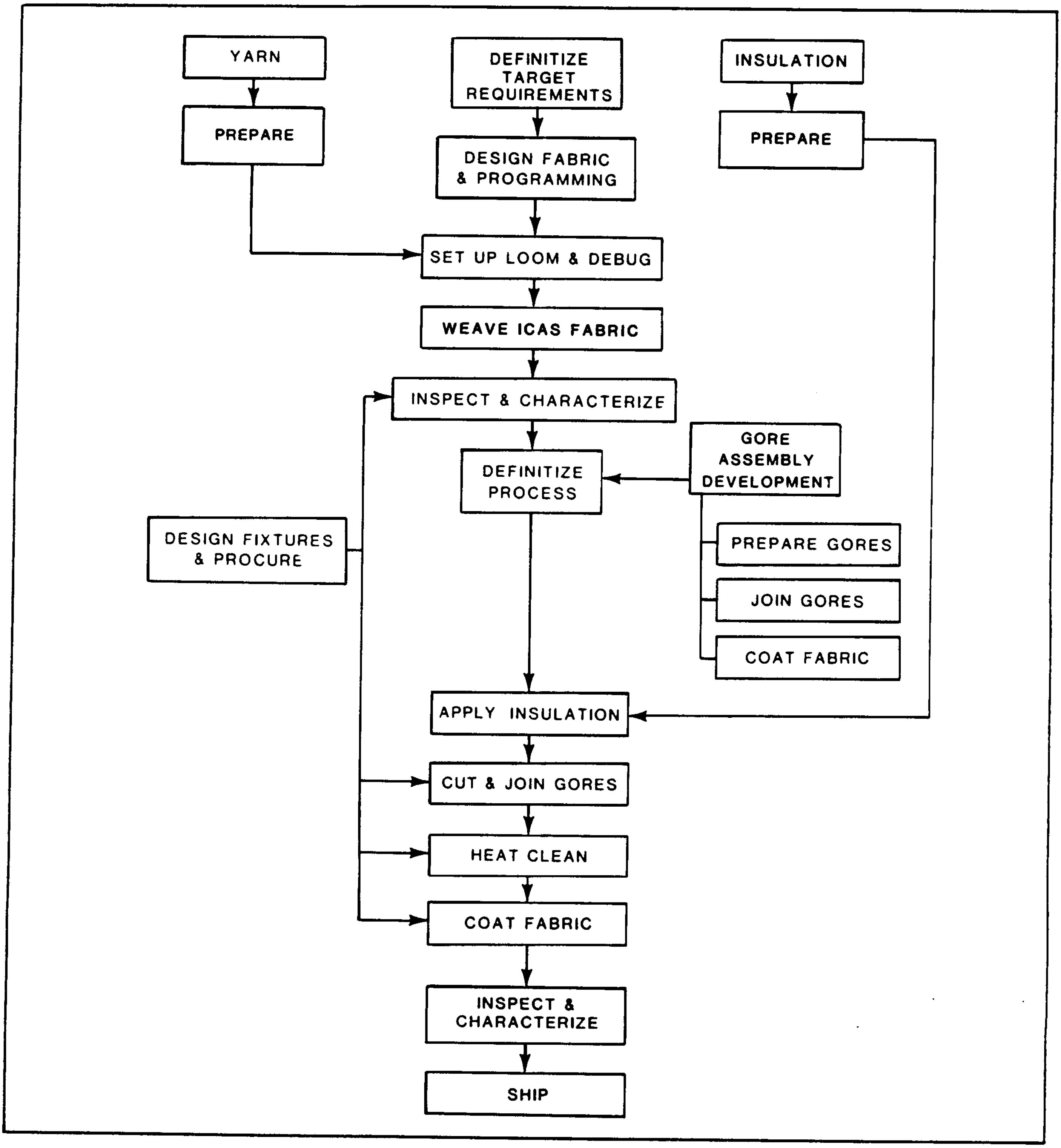


Figure 3-3
PROGRAM PLAN, ITEM 2

yarn for Nicalon in the bottom face fabric. Based on the experience gained in weaving Item 1, it was decided to weave the Item 2 Nicalon top face and rib fabrics with the same target constructions as before. The Astroquartz bottom fabric would be woven as tightly as possible. The target yarn counts of the three faces are shown in Table 3-1. The schematic for this design is presented in Figure 3-4.

3.2.1.1 The basic tasks of the design phase were similar to those for Item 1. An important design consideration of the Item 2 fabric involved selecting a means to weave a continuous transition from the hybrid fluted core to the single ply Nicalon fabric. Some thought also had to be given to closing out the last cell to prevent unravelling of the fluted core fabric during any handling or subsequent testing. The simplest method would allow the Nicalon top face and rib to weave down and interlock with the Astroquartz bottom face. The Astroquartz warp yarns would then be programmed to drop out, while the Nicalon yarns continued to weave a single ply fabric. Three variations of this concept were examined as illustrated in Figure 3-5. In the first design, the top face and rib weave separately to the bottom face, and then weave together forming a multi-layer Angle Interlock fabric of Nicalon. The Astroquartz bottom face drops out once the locking occurs. The Angle Interlock construction would offer much strength to the single ply segment of the ICAS fabric, but would also result in additional weight and cost. The second design resembles the first, except that after locking, the Nicalon top face and Astroquartz bottom face both terminate permitting the Nicalon rib to continue weaving the single ply extension. Two problems existed with this design, (1) a gap is created between the top face and rib as they weave separately, and (2), the top face warp yarns might possibly pull out from the lock. The third design involves weaving the top face and rib fabrics together and locking these to the bottom face. After the lock, the Astroquartz bottom face and Nicalon rib terminate, and the Nicalon top face continues to weave the single ply segment of fabric. This third design eliminated the gap and yarn pullout problems of the second design and was therefore selected for the transition portion of the ICAS fabric. The transition zone showing dropped-off yarns emanating from the fluted core segment is seen in Figure 3-6. These protruding yarns will be trimmed to approximately 0.64 cm (0.25 inch) before coating with RTV.

Table 3-1

TARGET YARN COUNTS OF FLUTED CORE SEGMENT OF I C A S , ITEM 2

FABRIC YARN COUNT (WARP X FILL)	TARGET VALUES
NICALON FACE	
ENDS/cm X PICKS/cm	6.3 X 9.4
ENDS/ inches X PICKS/ inches	16 X 24
NICALON RIBS	
ENDS/cm X PICKS/cm	6.3 X 7.1
ENDS/inches X PICKS/ inches	16 X 18
ASTROQUARTZ FACE	
ENDS/cm X PICKS/cm	9.4 X 9.4
ENDS/ inches X PICKS/ inches	24 X 24

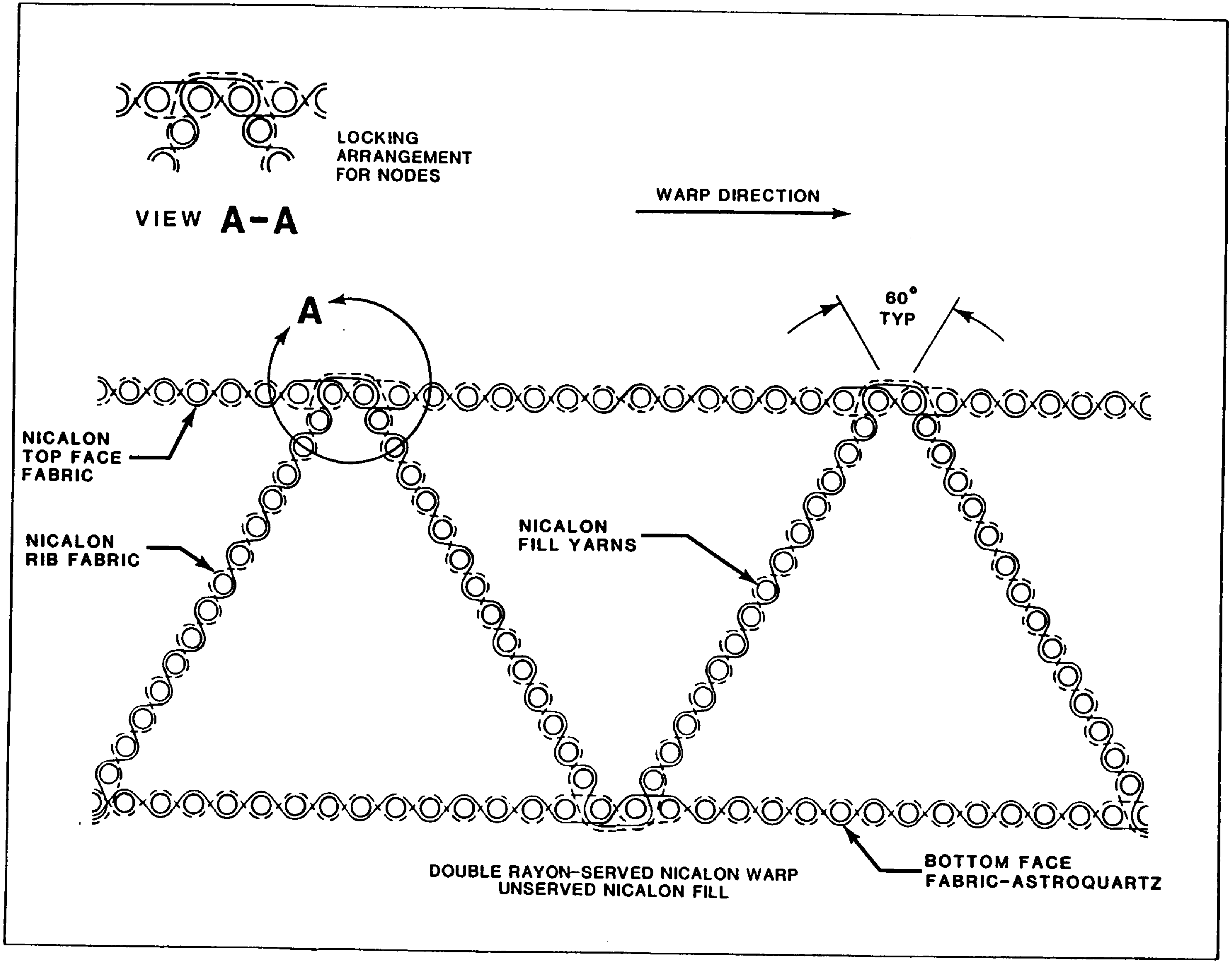


Figure 3-4
YARN ARRANGEMENT OF FLUTED CORE FABRIC, ITEM 2

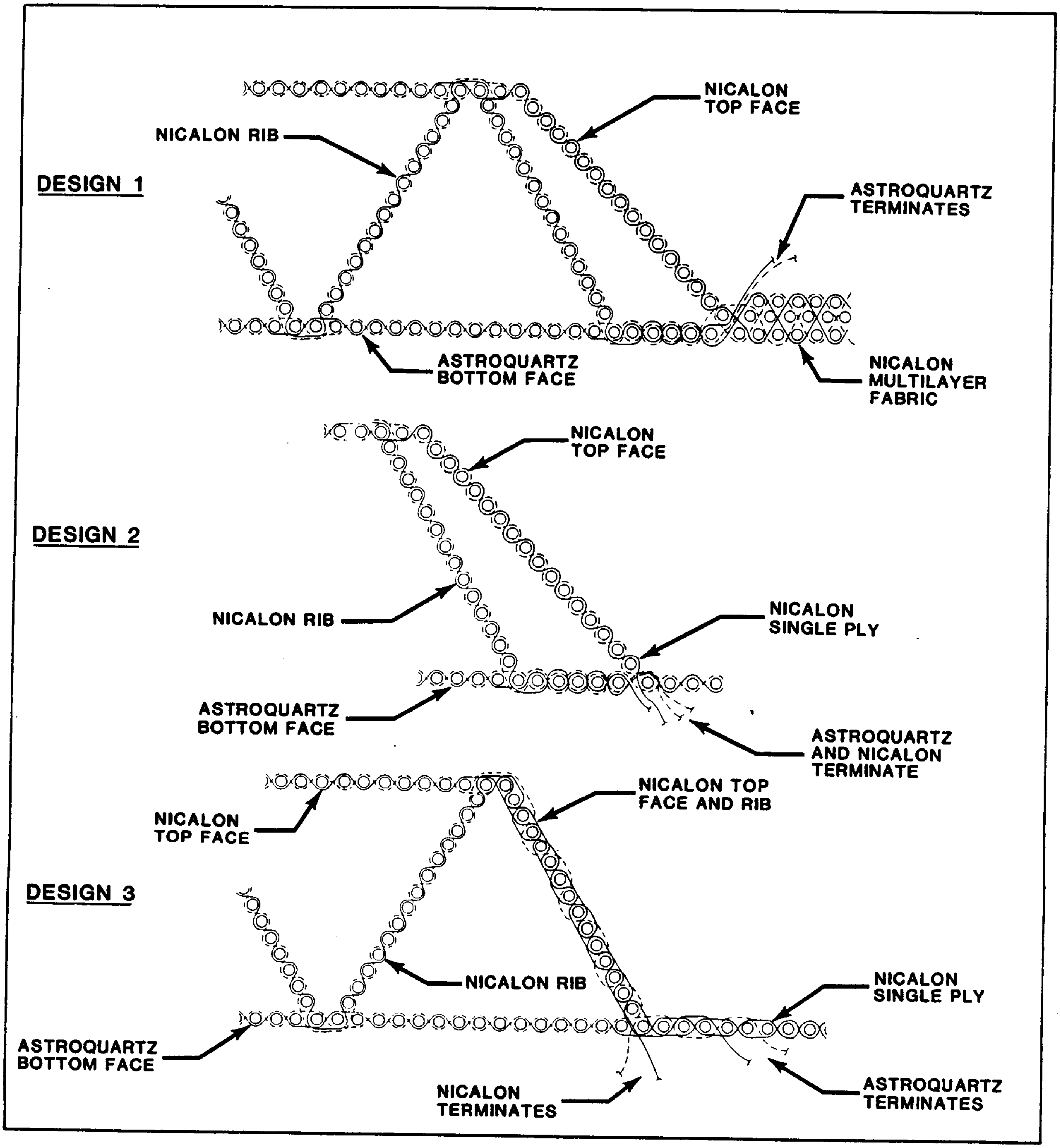


Figure 3-5

TRANSITION ZONE DESIGNS

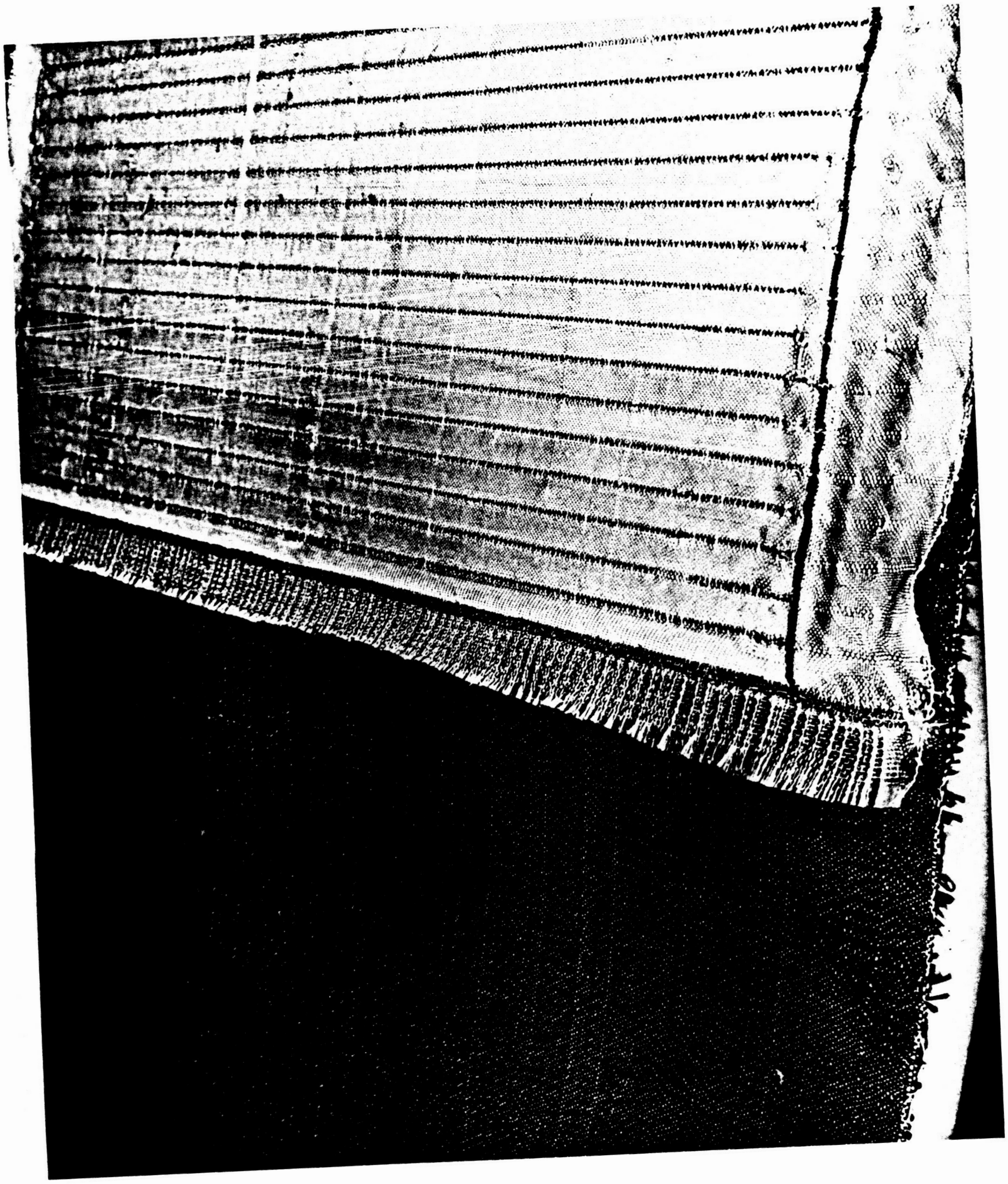


FIGURE 3-6
ICAS TRANSITION ZONE

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~~BLACK AND WHITE PHOTOGRAPH~~

3.2.2 Yarn Procurement Preparation. All Nicalon silicon carbide yarn necessary for Item 2 was procured and prepared jointly with the Item 1 requirements. This included winding and double serving. Astroquartz II 300 2/4 yarn with a starch-oil sizing, was purchased and prepared. Appropriate amounts of yarn were wound on a sufficient number of spools. This high purity fused silica ply-twisted yarn is constructed from basic strands, each consisting of 120 continuous filaments. In building this 300 2/4 yarn, two strands are ply-twisted together, and then four of these combined by ply-twisting in a direction opposite to the first operation. Each finished yarn thus consists of eight strands, and has an approximate yield of 3750 yards/pound. Filament diameter is 9 microns, (35.43×10^{-5} inches). Additional information on Astroquartz II is presented in Appendix C.

3.2.3 Loom Set Up and Debugging. Upon completion of Item 1, the warp spools were stripped from the creels and all equipment cleaned. After inspecting and polishing all potentially abrasive surfaces, the creels were loaded with the predetermined number of Nicalon and Astroquartz yarns. The yarns were drawn in to the loom through the heddles and reed, and weaving trials were started. It was necessary to debug each of the three segments mentioned earlier. The Nicalon single ply fabric, was debugged first. This was done by floating the rib and bottom faces while weaving 45.7 cm (1.5 feet) of the plain weave top face to the target warp and fill counts. This fabric was satisfactory and it was felt that the dropping out of the rib and bottom faces would not be detrimental to the weaving of the single ply fabric.

3.2.3.1 The hybrid fluted core fabric was then debugged and loom adjustments made until the cell height was 1.27 cm (0.5 inch). Samples of the start-up fluted core fabric were filled with insulation mandrels, and after examining the Astroquartz fabric, it was felt that the weave was too porous and might later lead to excessive wicking when coating with silicone rubber. The pick count of the Astroquartz bottom face was then increased from 9.4 picks per cm (24 picks per inch) to 10.6 picks per cm (27 picks per inch). The porosity of a sample with the higher pick count appeared to be sufficiently reduced and a decision was made to incorporate the tighter weave in the ICAS fabric.

3.2.3.2 During the debugging of the fluted core section, considerable breakage of warp yarns across the entire width of the bottom Astroquartz face fabric was experienced. Considerable effort was expended in trying to determine the cause of this breakage. A close examination of loom parts in contact with the yarns revealed that the dents of the reed, particularly on the left and right ends of the reed, were badly grooved and probably were contributing to the yarn breakage. These reed dent grooves are shown in Figure 3-7. However, replacement of the reed only partially alleviated the condition. The problem was corrected by a combination of remedies which included polishing the surface of the shuttle for the Astroquartz yarn, adding more tensioning weights to the Astroquartz yarns on the creel to minimize warp yarn slackening, adjusting the powering mechanism of the loom's shuttles, and leveling the shuttle boxes. After this effort, the shuttles were able to pass through the shed openings with an acceptable, minimal amount of yarn breakage. Debugging of the fluted core section was then resumed until the target cell size was achieved.

3.2.4 Weaving. It was decided to weave an additional 30.4 cm (1 foot) of both the fluted core and flat fabric segment ends of the ICAS to insure sufficient material for trimming. After weaving, the first ICAS fabric was removed from the loom and inspected for defects and proper cell size. Unfortunately, while weaving the fluted core segment, an accident occurred just a short distance from the transition zone. The program chain controlling the weave pattern lodged allowing more Nicalon fill yarns to be packed into the top face. The high yarn density in that area resulted in breakage of several Nicalon warp yarns and thus created a hole on the top face. Later, efforts to repair the fabric by hand sewing with Nicalon yarn proved unsatisfactory, and the ICAS length was rejected for any further processing. The program chain mechanism was adjusted to eliminate any recurrence of this mishap. The cells of core fabric segments of the first and subsequent ICAS lengths were inspected similarly to Item 1, though using mandrels dimensioned in Figure 3-8. Altogether, four ICAS lengths were produced. An area of the number three ICAS was slightly damaged during subsequent fabrication operations, so replacements were made for the first and third lengths. The second and fourth ICAS lengths were inspected and found to be almost defect-free.

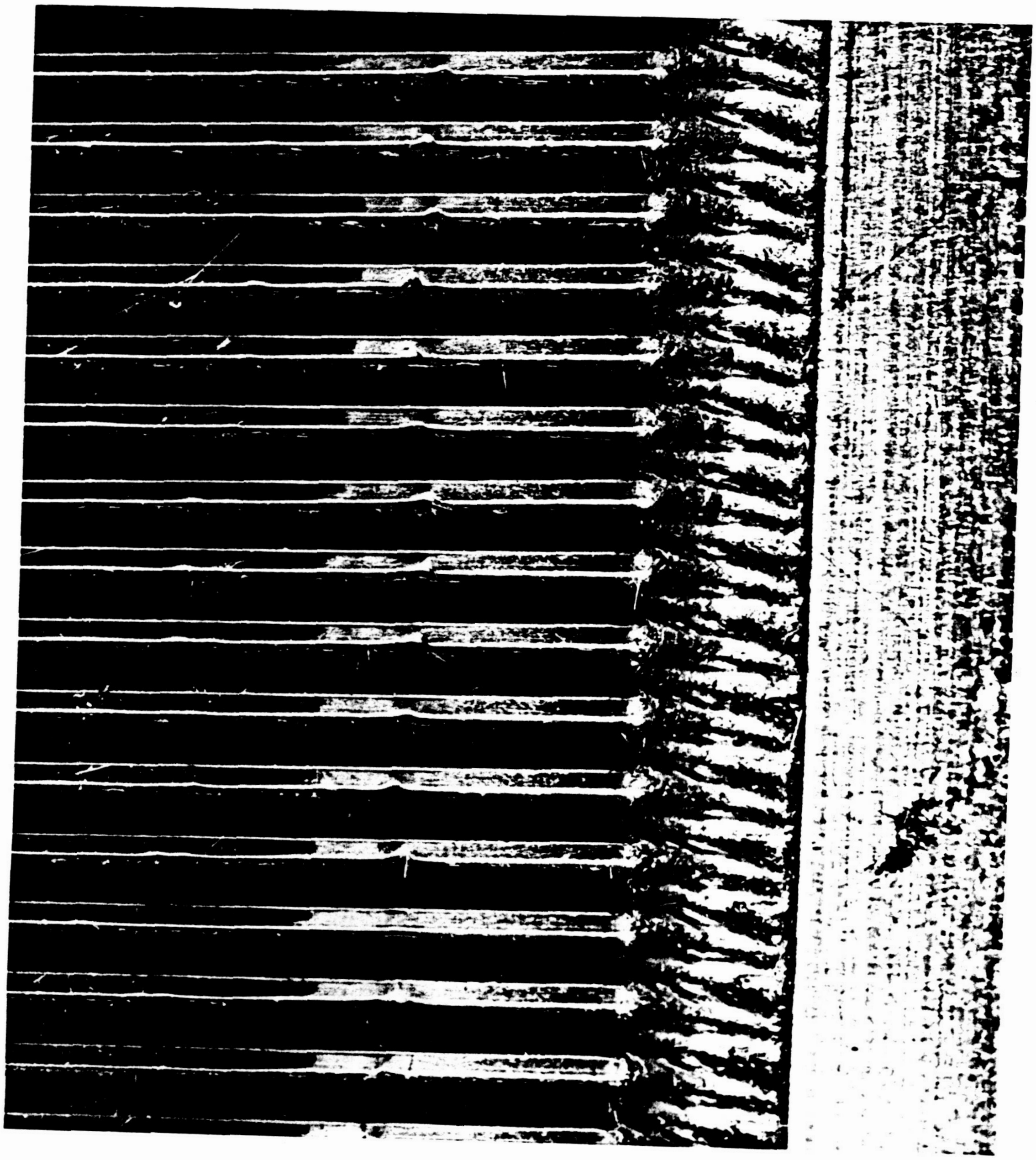

FIGURE 3-7
RESULTS OF NICALON ABRASION ON DENTS OF REED

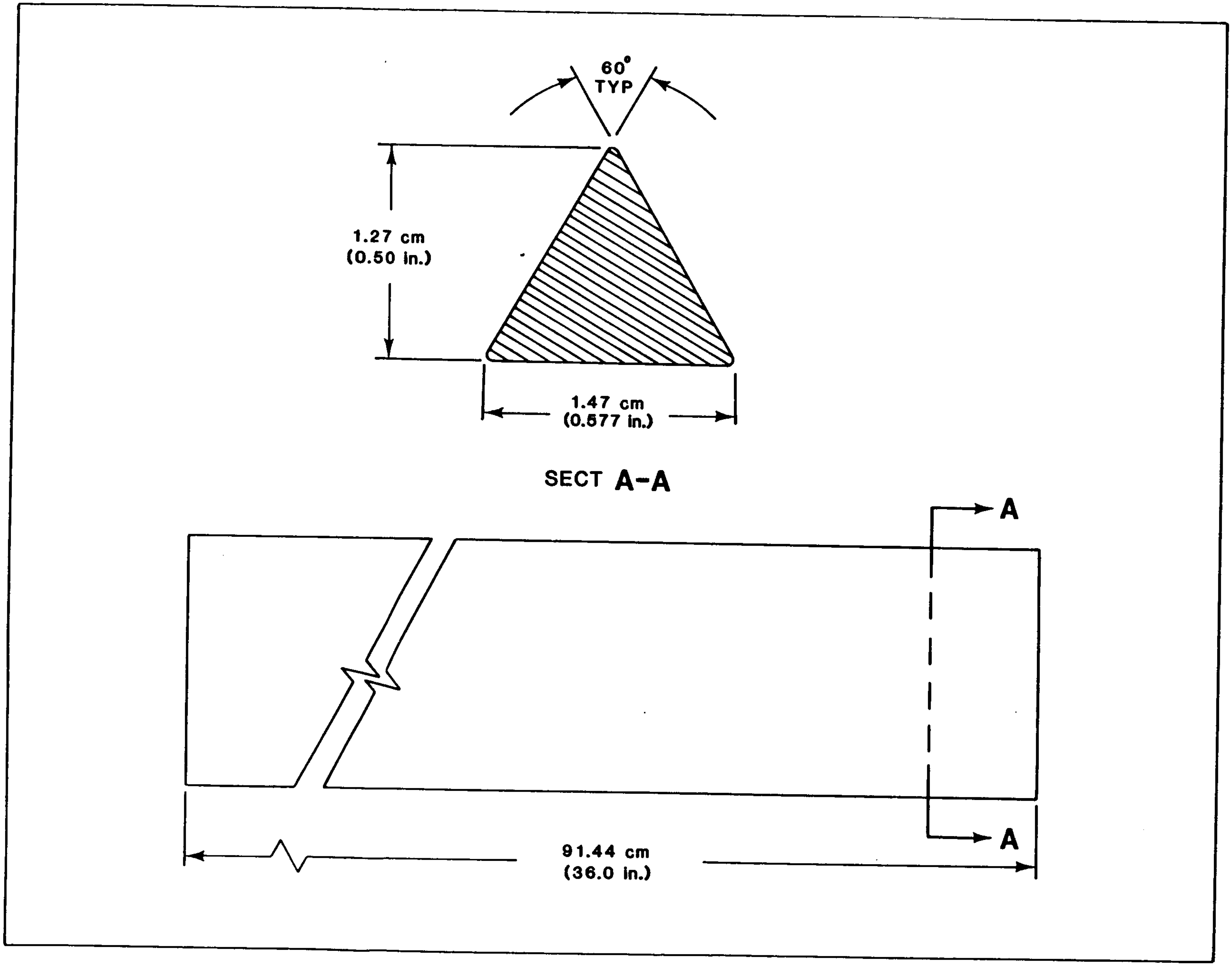

Figure 3-8
CHECK MANDREL DIMENSIONS FOR CORE FABRIC SEGMENT OF ITEM 2

3.2.5 Insulation Preparation. Standard one half inch nominal thickness Q-Fiber Felt was converted to insulation mandrels for insertion into flutes of the core fabric segments using a modification of the procedure for Item 1. The new procedure is presented in Figure 3-9. The concentration of acrylic binder in the saturating solution was increased to provide stronger mandrels with better handleability. Also, saturated insulation panels were allowed to air dry for two hours prior to oven drying. When dried rapidly, the acrylic solution migrated to the surfaces excessively, leaving too little resin in the center of the panel. This excess migration resulted in soft panel centers, expansion of panel thickness, and weak mandrels. Dimensions of the cut mandrels are presented in Figure 3-10.

3.2.6 Gore Assembly Development. Several concepts to fabricate a two-gore structure from the fluted core fabric segments were considered. Among these was an idea to overlap the edges of adjacent gores and sew through the overlapped layers. Another was to provide wide borders of fabric on each edge of adjacent gores, sew mating borders together, and fill the void between top and bottom faces with insulation. These and other concepts were ruled out because of the concern that the joint could not be reliably insulated. Also, it was believed that these types of joints would add to the stiffness of gore assemblies, and would present serious manufacturing difficulties when scaled up to large parts.

3.2.6.1 The concept adopted for this effort was the use of tadpole insulated joints between adjacent gores. This was believed to be the most viable from three standpoints: 1) providing good flexibility to the joint, 2) offering more reliable thermal protection, and 3) presenting fewer manufacturing problems on scale-up. A schematic depiction of this concept is seen in Figure 3-11.

3.2.6.2 The initial joint development utilized fluted core specimens woven during start-up and debugging. To provide the tadpole, it was decided to investigate high temperature tubular braids filled with materials that were resilient as well as insulating. Two diameters of Nicalon braids were prepared, 0.64 cm (0.25 inch), and 0.95 cm (0.38 inch), and these were filled with bundles of 62 parallel Nicalon yarns and 120 yarns respectively, Figure 3-12. After preliminary evaluation of these materials, it was determined that the larger diameter braid would best fill the gap at

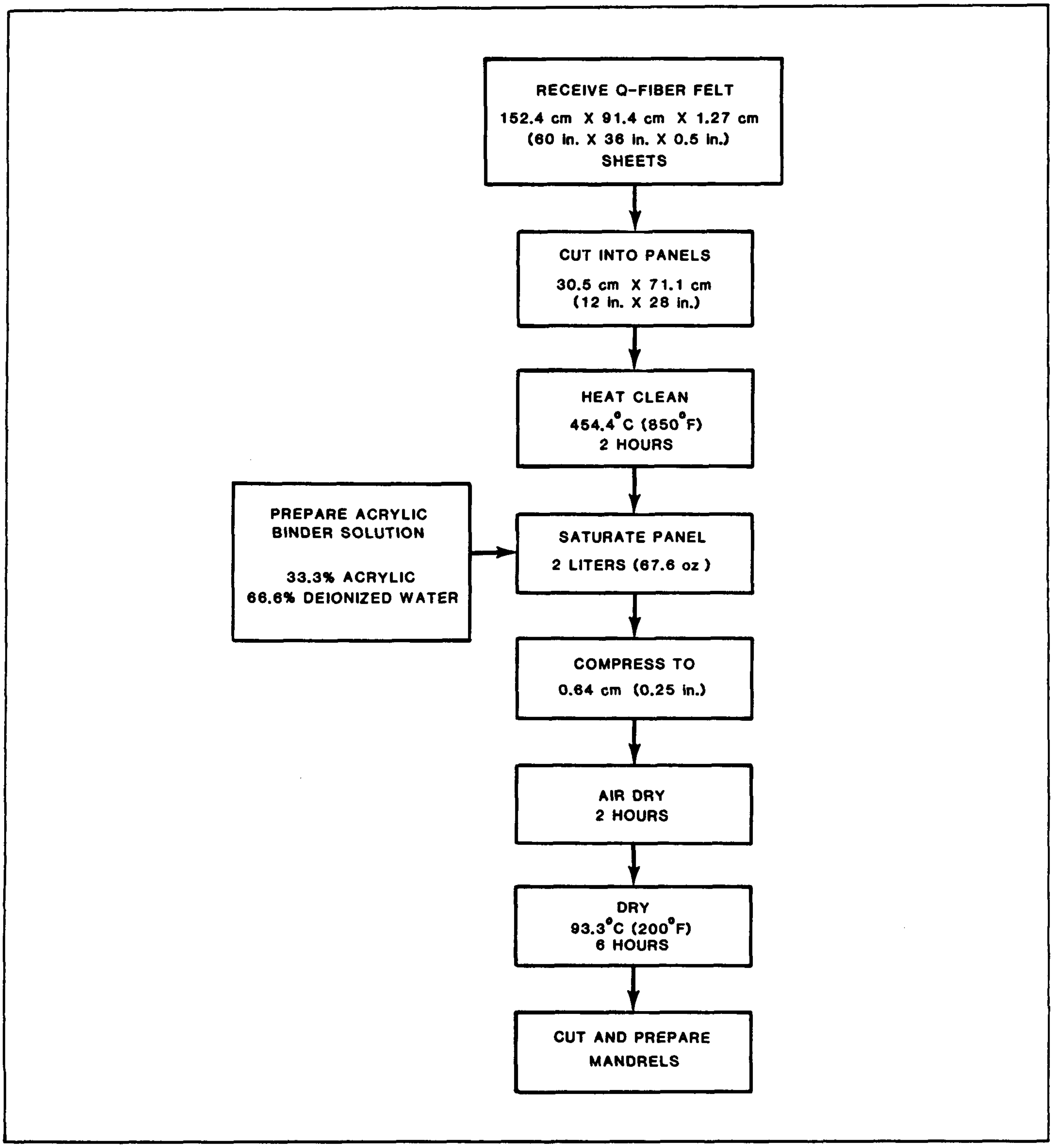

Figure 3-9

PROCEDURES FOR PREPARING INSULATION MANDRELS, ITEM 2

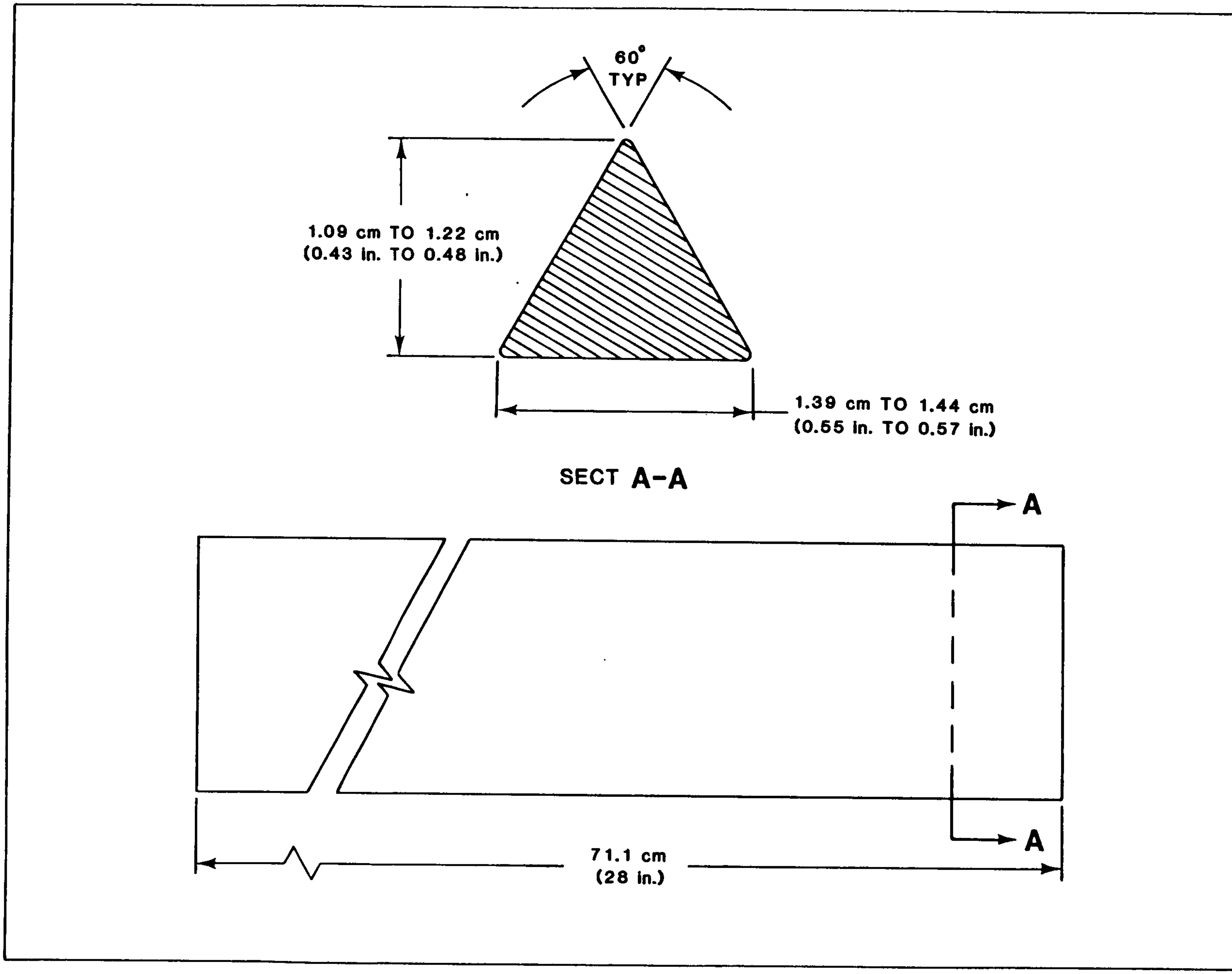

Figure 3-10
DIMENSIONS OF CUT INSULATION MANDRELS, ITEM 2

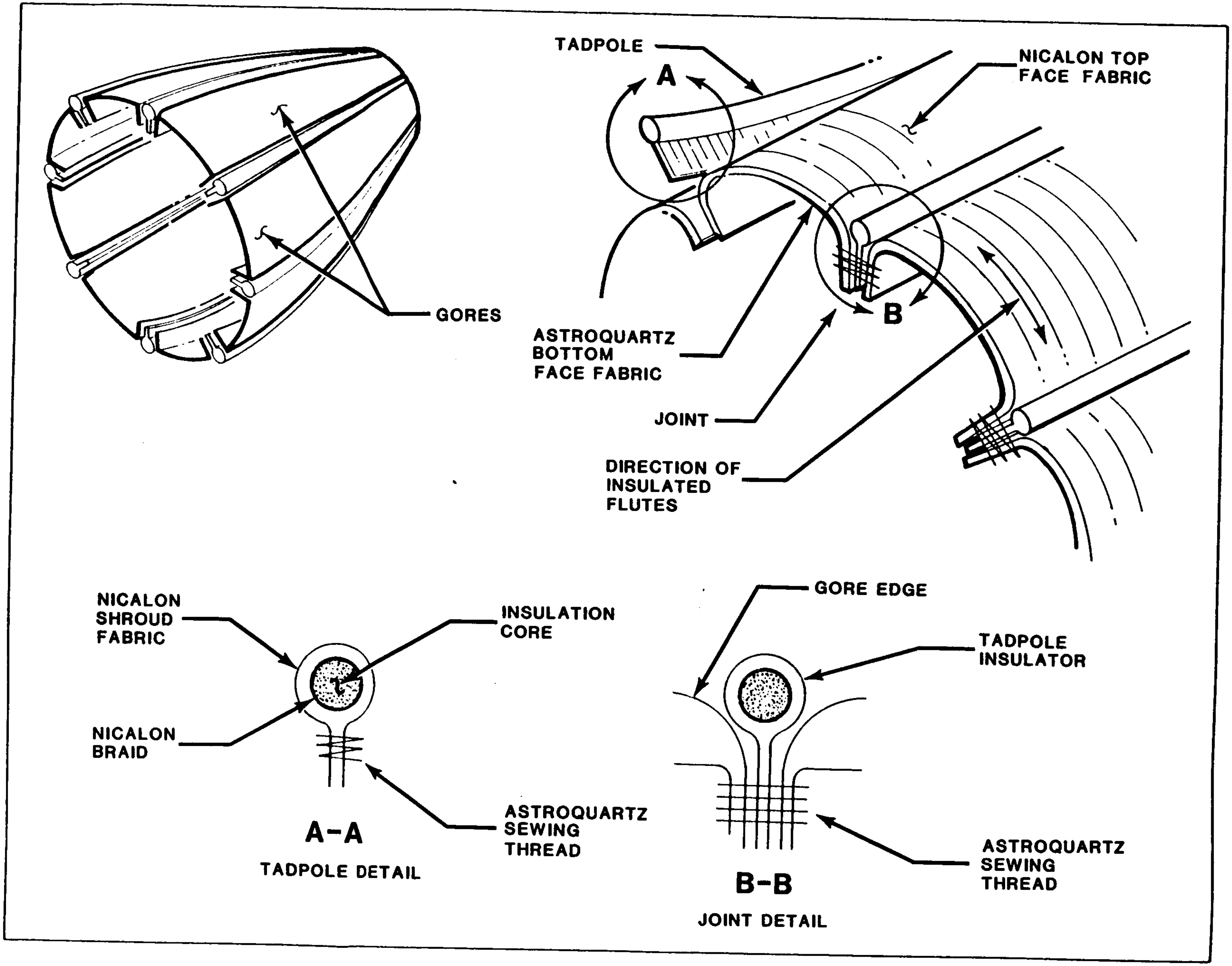

Figure 3-11

CONCEPT FOR JOINING GORES OF FLUTED CORE FABRIC USING TADPOLE INSULATION

FIGURE 3-12
NICALON BRAIDS FILLED WITH NICALON YARNS

the gore joint. A plain weave shroud of Nicalon fabric was used to form all but the first tadpole configuration.

3.2.6.3 Models of three variations of the basic gore joint were produced to resolve sewing techniques and to determine which design would offer the optimum strength and thermal protection. Astroquartz II sewing thread Type Q-12 with 9855 Teflon coating was used throughout the program, both for machine and hand stitching. This high-twist thread made from continuous silica filaments has a minimum breaking strength of 6.8 kg (15 pounds). Additional information on this sewing thread is presented in Appendix D. A Singer type 17 cylinder-bed sewing machine fitted with a Singer No. 110/18 needle was used, see Figure 3-13.

3.2.6.4 The three models prepared are shown schematically in Figures 3-14 to 3-16. A portion of insulation and ribs were removed from one side of each of the two panels to be joined so that approximately 7.6 to 10.2 cm (3 to 4 inches) of single ply Nicalon and Astroquartz fabric remained at the edges. In Model A, stitching was performed at points A, B, C, and D. The first stitch A was done to encapsulate the Q-Fiber Felt. To achieve a higher joint strength, the shroud fabric, in this case a balanced harness weave, was attached to the Nicalon top face at point B. Once these points were stitched, the Nicalon braid was placed in the shroud and the tadpole closed by stitching through the shroud at point C. The tadpole and uninsulated edges were then stitched together at point D. This model exhibited very good flexibility at the joint. However, due to the looseness of the shroud fabric and the positions of the stitching points, the joint had a tendency to separate from point A to B. This was not acceptable since there would be no thermal protection beneath these points.

3.2.6.5 In Model B, the thermal protection and strength qualities were enhanced by the addition of Q-Fiber Felt insulation, the positions of the stitching points, and the change to a plain weave Nicalon shroud. The Nicalon top face and plain weave shroud were sewn together at point A and again slightly lower at point B. The double stitching in this area decreased the possibility of the gore edges separating from the tadpole and of the joint failing. After the tadpole insulator was closed at stitch C, a 10.2 cm (4 inch) wide strip of 1/2 inch nominal thickness Q-Fiber Felt

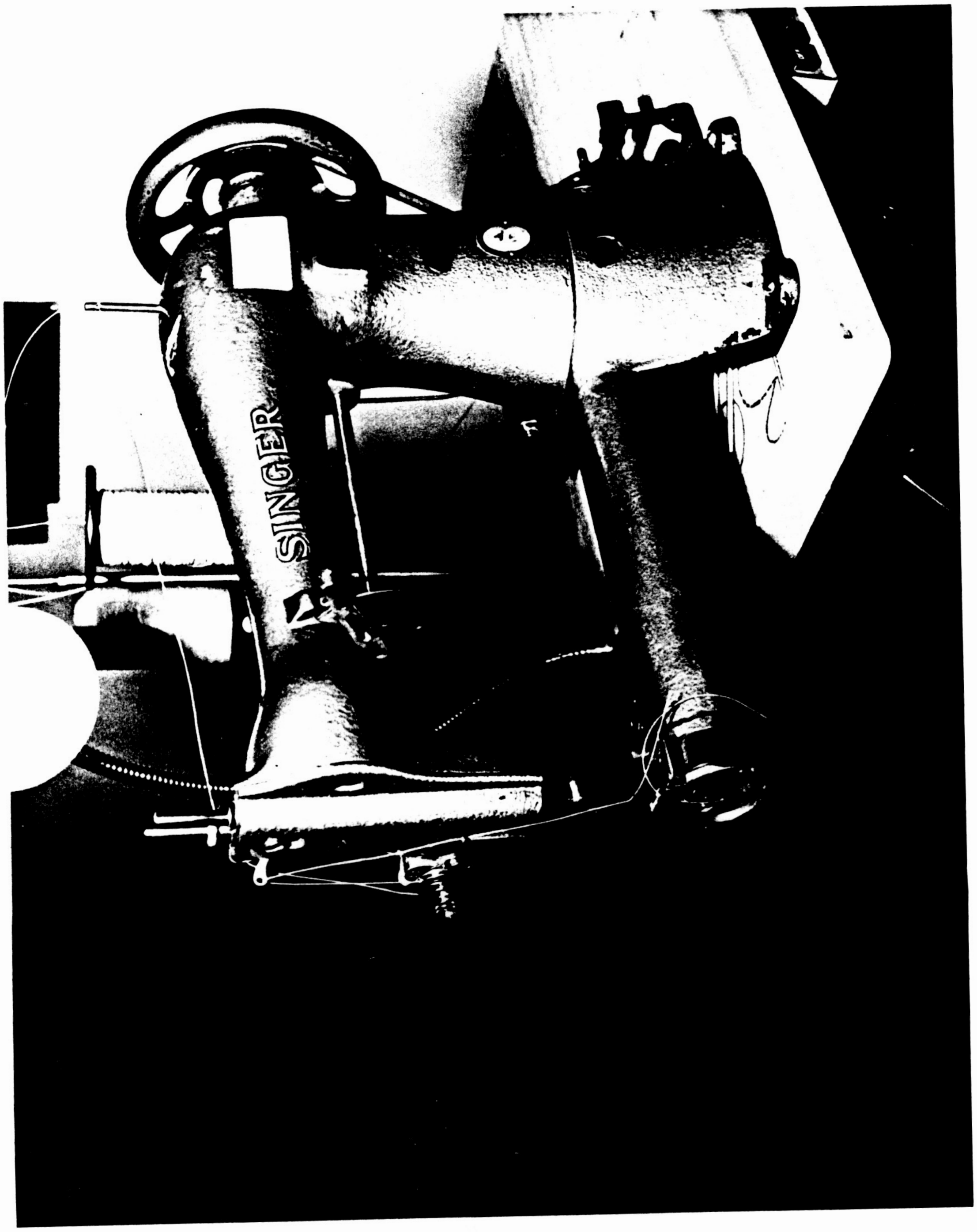

FIGURE 3-13
SEWING MACHINE USED FOR JOINING GORES

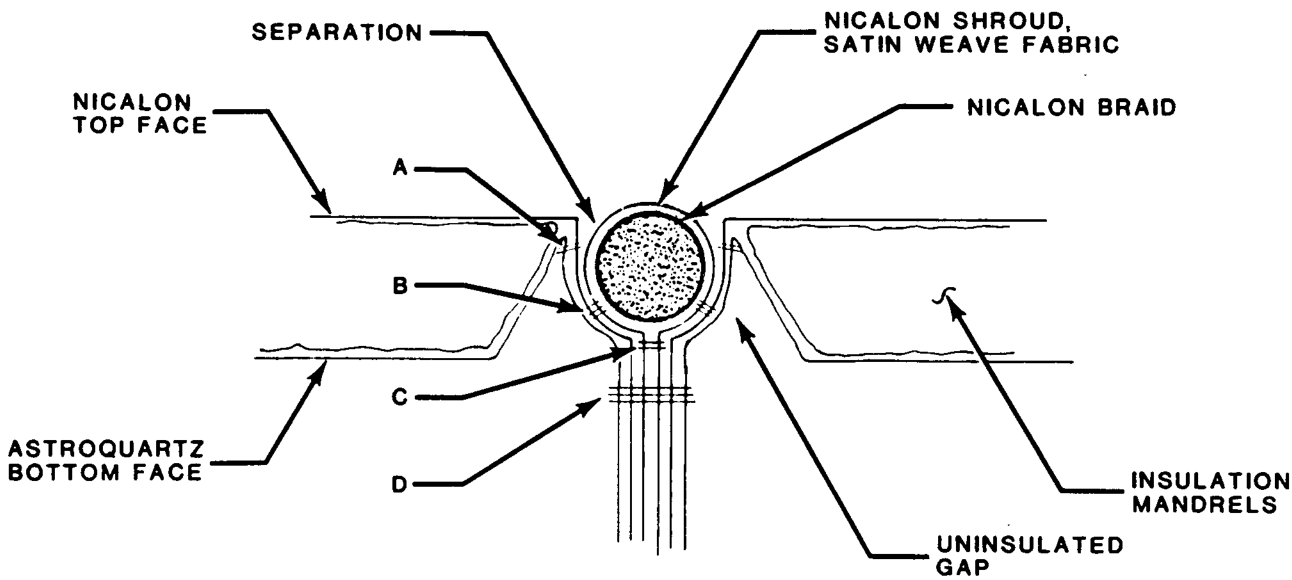

Figure 3-14
MODEL A
TADPOLE INSULATOR JOINT

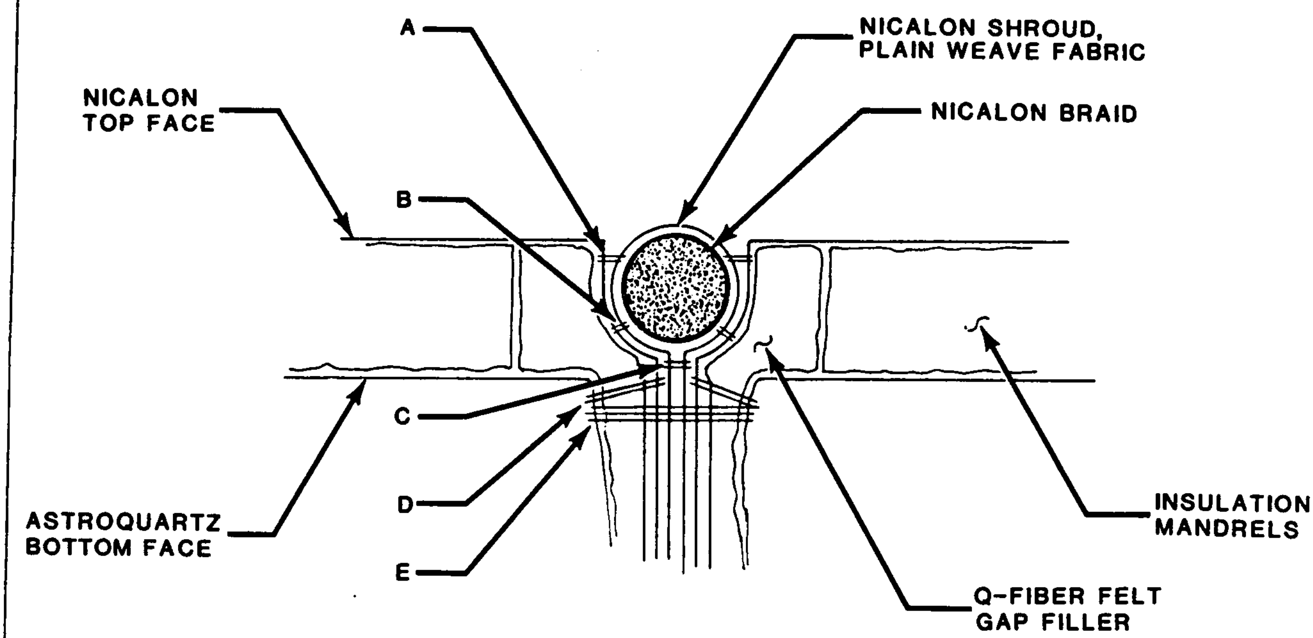

Figure 3-15
MODEL B
TADPOLE INSULATOR JOINT

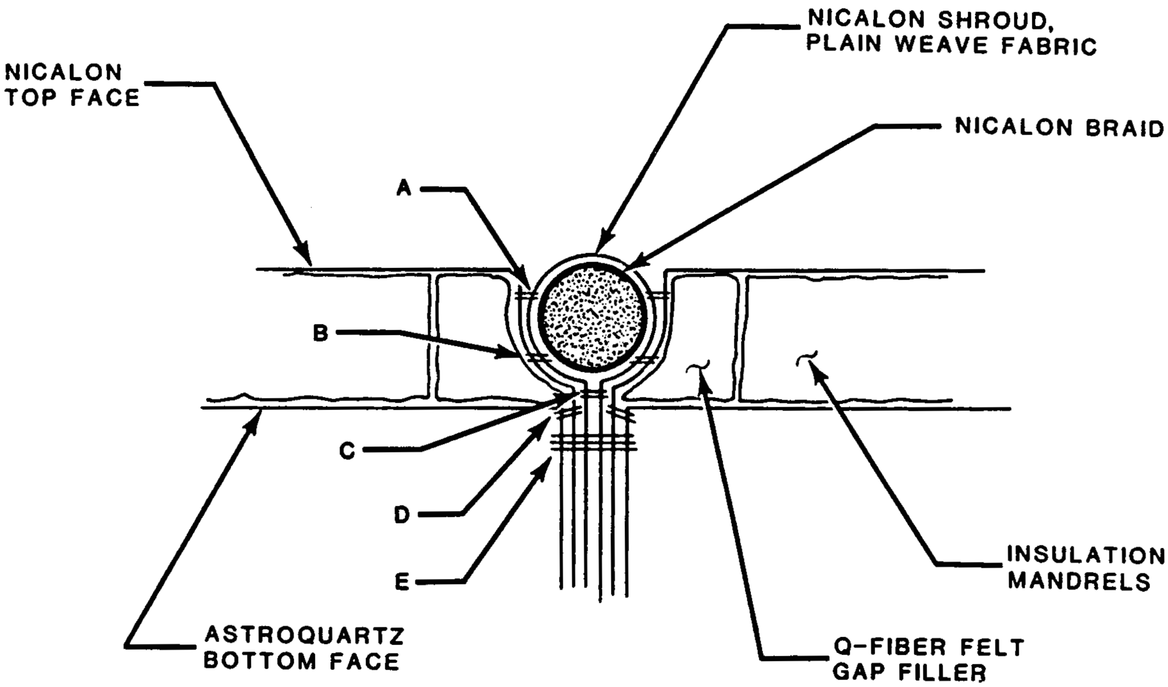

Figure 3-16
MODEL C
TADPOLE INSULATOR JOINT

was firmly placed along the edge of the insulation mandrels and sandwiched between the Nicalon top face and Astroquartz bottom face. This gap filler was then sewn together at point D and the joint tail fabrics stitched together at point E. The addition of the gap filler appeared to offer increased thermal protection at the joint area, and after much flexing of the specimen, the joint appeared undamaged. There was a significant improvement in joint strength of Model B over Model A. However, the gap filler insulation that extended along the tadpole tail restricted the flexibility of the joint. Also, the overall thickness of the joint tail did not permit machine stitching, so hand sewing was necessary.

3.2.6.6 Model C resembled B except that the Q-Fiber Felt gap filler did not extend along the tadpole tail. Once points A, B, and C were stitched, a 1.72 cm (0.68 inch) wide strip of the 1/2 inch nominal thickness Q-Fiber Felt material was butted against the edges of the insulation mandrels. The gap filler was contained by closing the gore edges at stitch D. The joint was completed by sewing the uninsulated edges and tadpole together at point E. Model C exhibited much more flexibility than Model B. Using the sewing machine at point E resulted in a more uniform and tighter stitch than the hand sewn Model B. At this point, the Model C joint appeared to be the best choice.

3.2.6.7 The model specimens were heat cleaned to determine the effect on stitching. It was discovered that the thread had lost most of it's strength, and upon close examination found that the Astroquartz had become badly abraded by the Nicalon silicon carbide fabric. Loss of the thread's binder also contributed to the reduced strength. It was then decided to encase the Astroquartz thread with a high TPI count of double-served, 75 denier nylon yarn. Served sewing thread was used on all subsequent stitching, and the abrasion problem was greatly reduced.

3.2.6.8 To improve the insulation capability of the tadpole, it was decided to fill the Nicalon braid with Q-Fiber Felt rather than Nicalon yarns. Strips of standard 1/2 inch nominal thickness insulation 1.27 cm x 3.6 meters (0.5 inch x 12 feet) were prepared by attaching two 1.8 meter (6 foot) lengths end-to-end with adhesive-bonded rabbit joints. Each strip was fed into a 32 carrier braiding machine set up with 2 ends per carrier, while the Nicalon yarns braided around the insulation. The finished braid diameter was 0.95 cm (0.375 inch). The braid with the Q-Fiber Felt filler is shown in Figure 3-17.

3.2.6.9 Further evaluation of heat cleaned specimens revealed that the A and B stitch points of the Model C joint restricted the hinging movement of the gores. This reduced the flexibility of the joint and put an excessive load on the Astroquartz stitching during handling. As a result, a Model D was fabricated, Figure 3-18, in which only one stitch point, A, was used between the shroud and Nicalon top face and located just above the bottom Astroquartz face. The tadpole was formed at the B point, the gap filler closed out at the C point, and the tail joined at D. Since this model offered greater flexibility and reduced stress on the stitching, this joint design was selected for fabricating the two-gore assembly. Figure 3-19 is a partial assembly of this model's cross section before the addition of the braid. Figure 3-20 is a cross section of a completed Model D joint. The braid insulation, gap filler and the plies making up the joint tail can be seen in this photo.

3.2.7 TABI Coating Development. The objective of this task was to develop a procedure for coating the Astroquartz face of the fluted core fabric segments with RTV silicone rubber. The goal was to provide a reliable, uniform thickness, pressure membrane with a good mechanical bond to the fabric. Several factors were considered prior to preparing specimens. These included determining the stage at which the TABI gores should be coated, the effect of the high working viscosity of the RTV, and the potential problem of coating the large area of the fabric with a material with limited pot life. It was decided that coating the gores following the joining process and heat cleaning would permit RTV to fill any voids produced during the sewing operations. It was also decided that the viscosity of the RTV would be reduced by dilution with solvents, if necessary, and that smaller areas of the fabric would be coated to accommodate the working time of the RTV. The edges of smaller areas would be overlapped to insure coating continuity.

3.2.7.1 General Electric RTV 560 is a two-component room temperature vulcanizing silicone rubber compound. It is red in color and has a viscosity of approximately 30,000 centipoise (20.2 pounds/foot-second). After catalyzing with 0.5% DBT (dibutyl tin dilaurate),

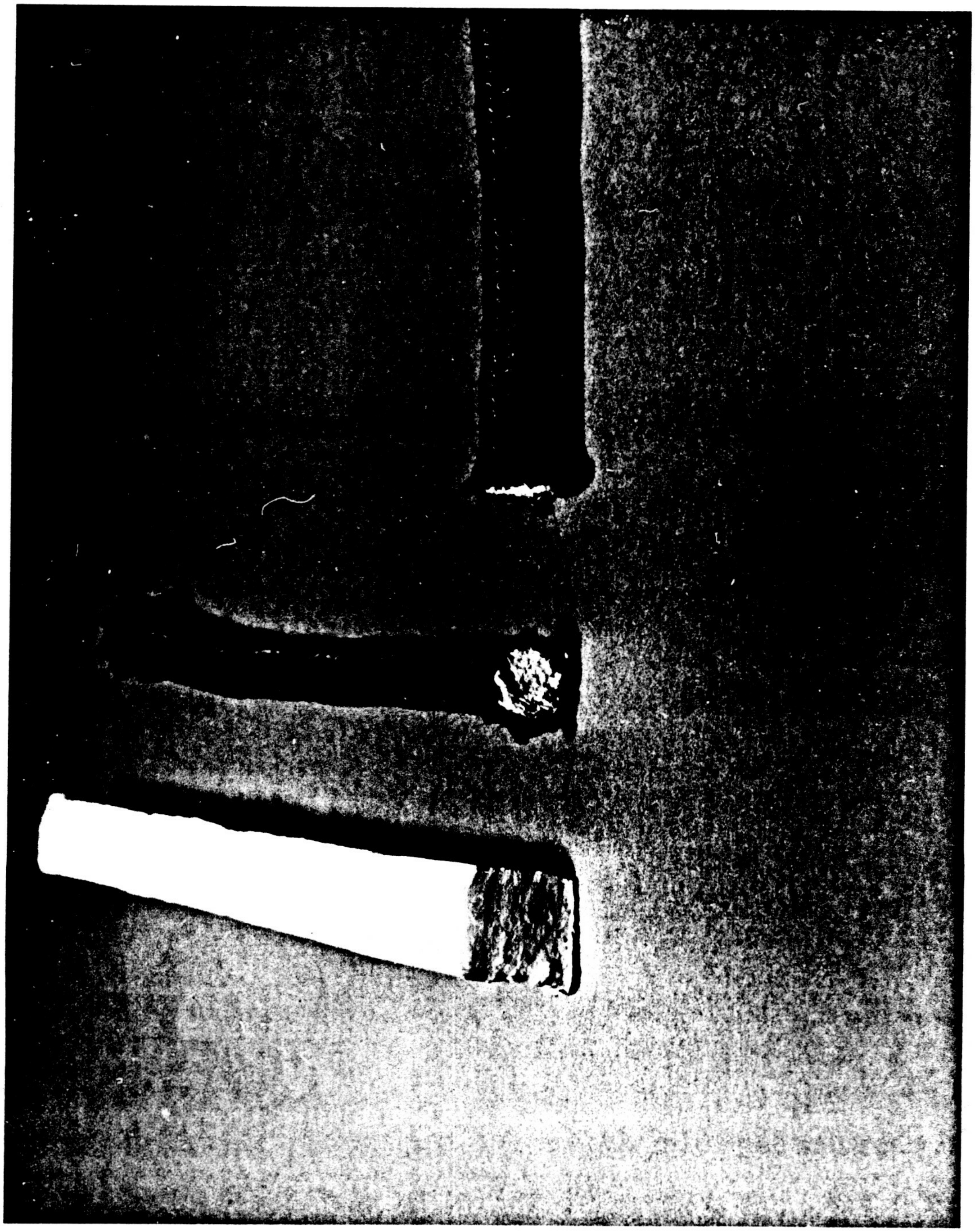

FIGURE 3-17
NICALON BRAID WITH Q-FIBER FELT FILLER
NOTE CROSS SECTION OF INSULATION STRIP USED FOR FILLER ON LEFT

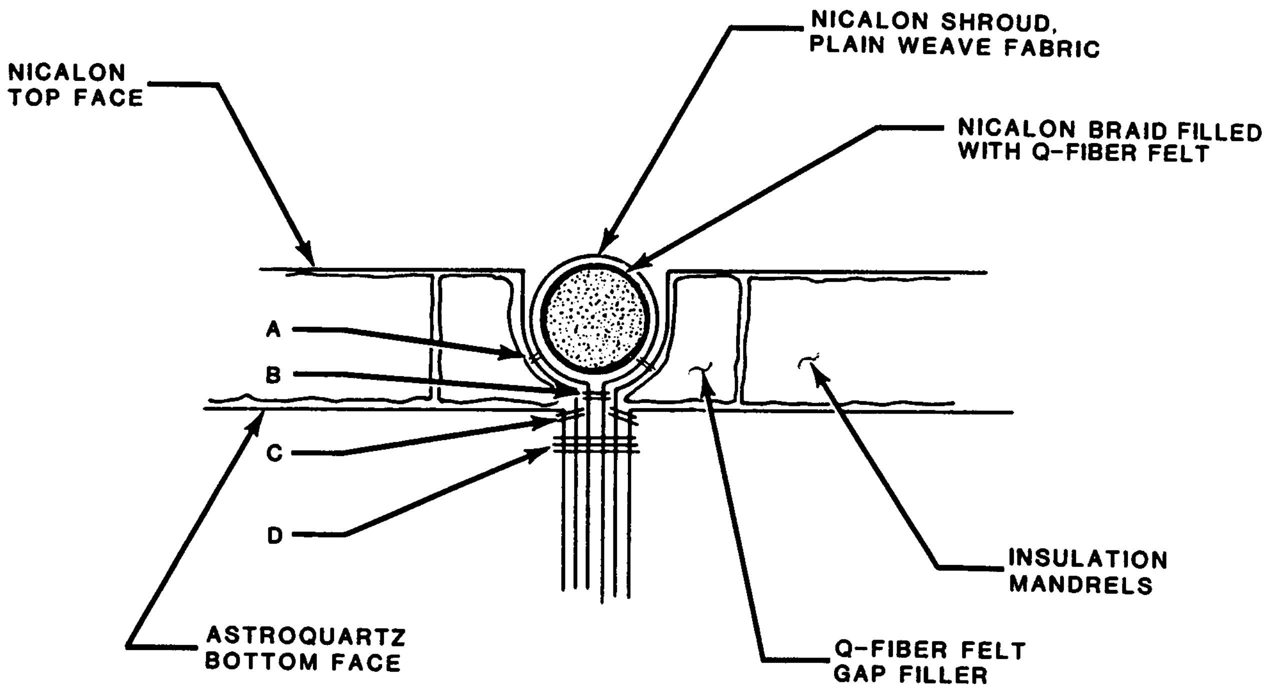

Figure 3-18
MODEL D
TADPOLE INSULATOR JOINT

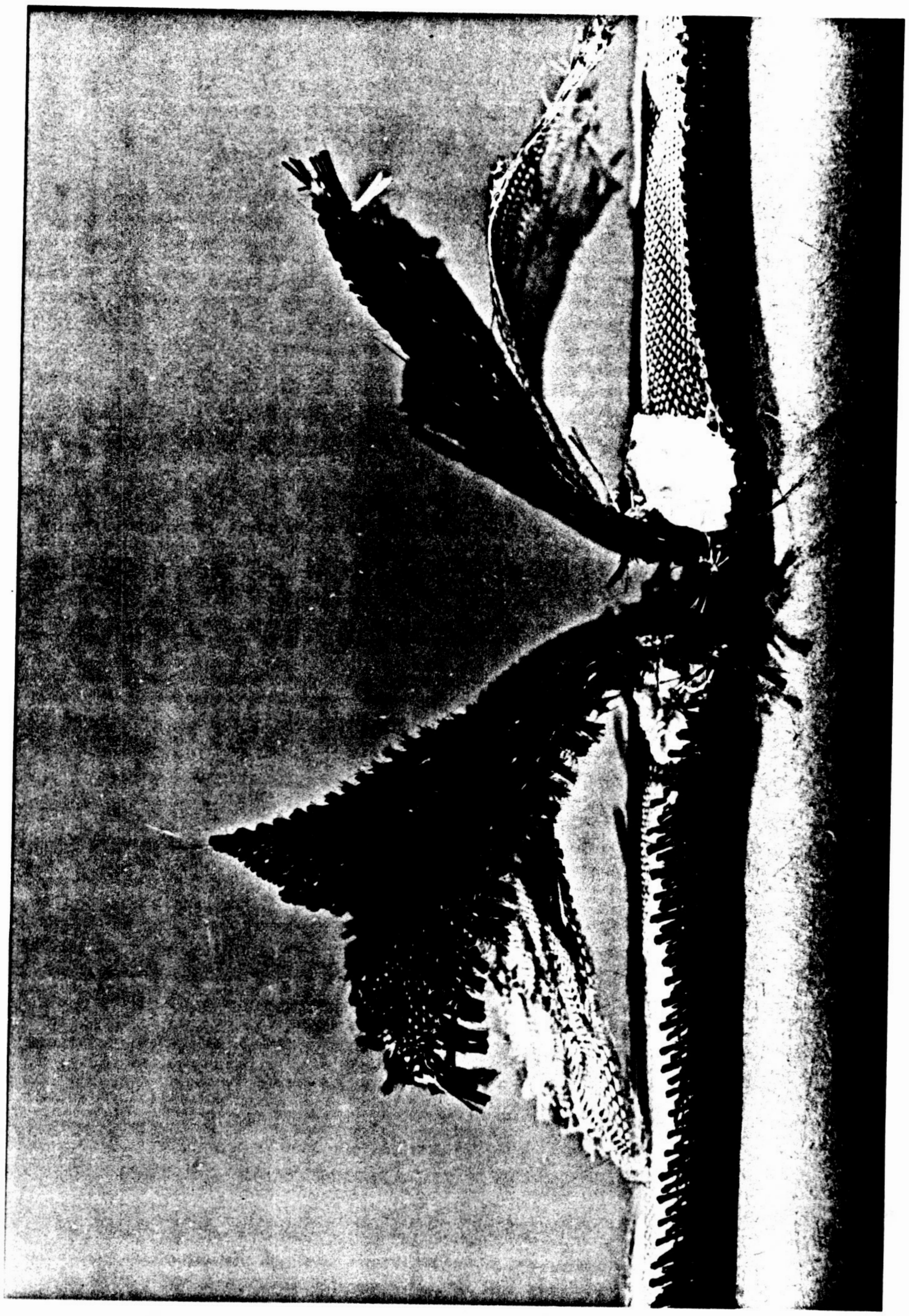

FIGURE 3-19
MODEL D INSULATOR JOINT BEFORE ADDITION OF TADPOLE BRAID

FIGURE 3-20
CROSS SECTION OF MODEL D JOINT

working time is approximately one hour. Additional information on this material is presented in Appendix F. The initial work involved becoming familiar with the RTV, attempting various techniques to coat samples, determining attainable coating thicknesses, and observing the degree of RTV wicking into the Q-Fiber Felt. Fluted core start-up material was used for the tests. Six coating techniques were investigated.

(1) Spread Coating. An amount of RTV 560 calculated to cover 497 cm^2 (77 in^2) with 3.2 mm (0.125 inch) of coating thickness was prepared by thoroughly mixing the silicone rubber with 0.5% catalyst. The mix was poured onto the Astroquartz fabric and spread over the entire surface with a straight edge. The material spread quite easily at first, but after about 20 minutes the rubber began to set and further spreading was difficult. The specimen was then left to cure overnight at room temperature. While curing, air bubbles appeared at the surface, indicating that the catalyzed mix might require deaerating before spreading. After curing, a cross section of the sample revealed that the RTV bonded well to the Astroquartz and did not wick into the Q-Fiber Felt insulation. The thickness of the coating, however, was not uniform. Based on these observations, scaling-up to spread-coat large areas might cause problems in producing a uniform coating thickness. Also, it appeared that the large areas might have to be treated by coating many small increments in order to accommodate the short working time of the catalyzed RTV and the potential need for practical sized deaeration equipment.

A second sample was prepared aimed at attaining a thinner and more uniform coating. A fabric specimen 103.2 cm^2 (16 in^2) was placed on a flat surface with the Astroquartz fabric side exposed to allow spread coating with a knife gage set at 0.159 cm (0.0625 inch) above the fabric. The calculated amount of RTV for this area and thickness was catalyzed with only 0.3% DBT to increase the working time, and the mix deaerated in a vacuum. When cured, the surface of the coating appeared very smooth and free of air bubbles. Although a thinner coating was obtained, the spread-coating method was abandoned because producing a uniform thickness by this technique did not appear feasible.

(2) Casting. A 30.5 cm x 30.5 cm (12 inch x 12 inch) area of polyester film was enclosed by a dam consisting of four acrylic strips 0.127 cm (0.050 inch) high to provide a mold for casting RTV. The intent was to cast a cured, uniform sheet which could then be bonded to the Astroquartz fabric. The RTV was catalyzed ith 0.3% DBT, and 2.0% by weight of toluene added to reduce viscosity. After deaerating, the mix was poured into the mold and a squeegee used to spread the RTV and fill the cavity to the height of the dam. The cured cast RTV exhibited good thickness uniformity and was free of air bubbles. Catalyzed RTV was then brushed onto the Astroquartz surface of a 103.2 sq cm (16 in^2) fluted core specimen, a portion of the cured film placed firmly over the brush coat, and the freshly applied RTV bonding layer left to cure overnight. The adhesive layer added about 20% to the overall RTV thickness. Examination of the cured specimen, Figure 3-21, revealed a very uniform, thick RTV sheet, well bonded to the Astroquartz, and probably suitable for coating large areas. However, a film thickness of 0.127 cm (0.050 inch) would produce a pressure membrane having excessive areal weight of approximately 1.75 kg/sq meter (51.6 oz/sq yd). Film thicknesses below 0.05 cm (0.020 inch) would be more suitable, but no existing sources could be found for producing large quantities of uniform, thin, RTV film.

(3) Transfer Coating. The first transfer coating trial attempted to achieve a film thickness of 0.018 cm (0.007 inch) over a 497 sq cm (77 in^2) fabric area. Approximately 0.3% by weight of DBT catalyst was added to the RTV, thoroughly mixed and then spread evenly over a polyester film. The RTV was then transferred by firmly rubbing the polyester and RTV against the Astroquartz fabric. After curing overnight, the polyester peeled away leaving an apparent smooth and uniform coating of RTV. Further examination of the coated sample revealed that the RTV did not adhere well at the nodes of the flutes and could be easily scraped away. The coating at the nodes appeared to have blistered or lifted from the fibers in that area. Between nodes though, the RTV produced an excellent smooth coating of the desired thickness, see Figure 3-22.

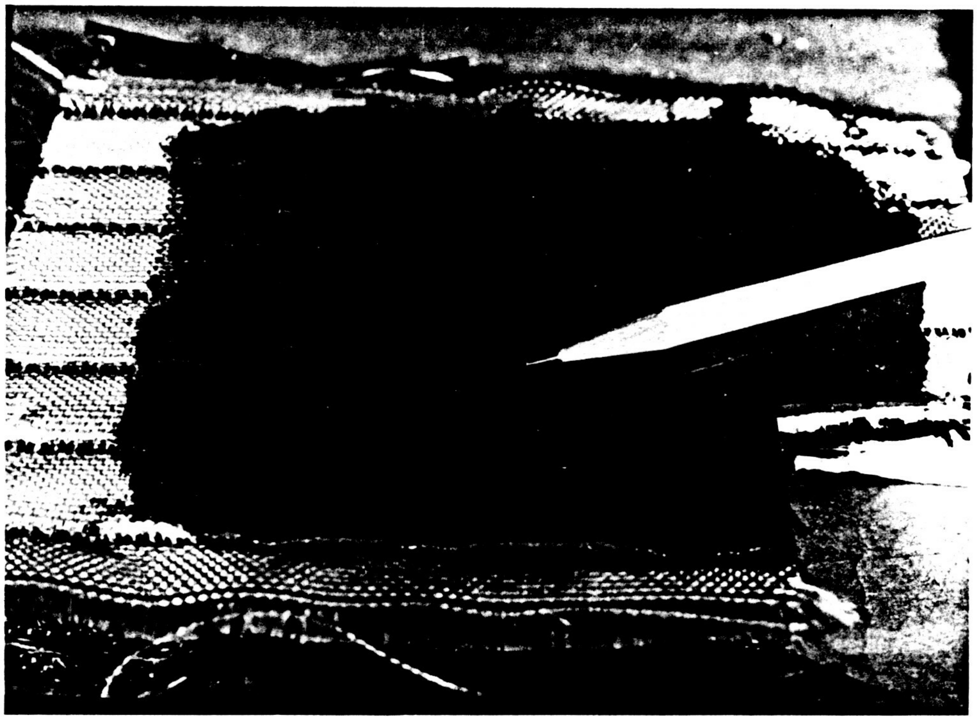

FIGURE 3-21
CAST RTV FILM BONDED TO FABRIC USING RTV AS ADHESIVE. GOOD SURFACE RESULTED BUT COATING TOO HEAVY

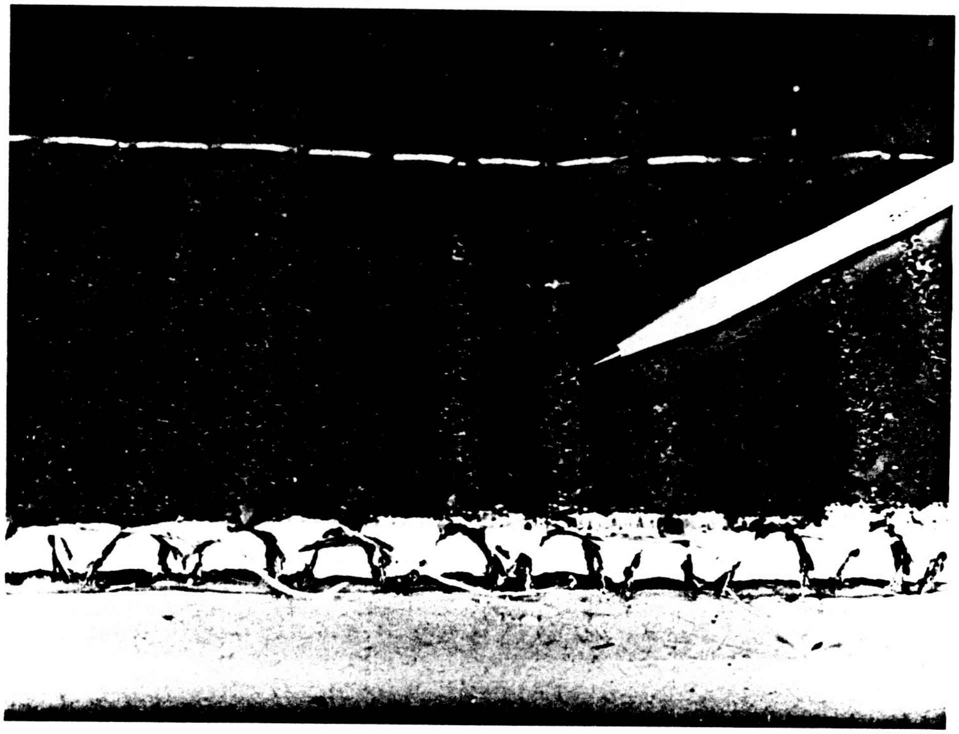

FIGURE 3-22
TRANSFER COATING SPECIMEN
NOTE BLISTERING AT NODES

The blistering effect at the nodes was first thought to be the result of gasses entrapped in the RTV as well as the lower yarn density in the recessed node area. Since the yarn count at the node is relatively low, there is less bonding surface for the RTV. Another specimen was prepared by the same technique except that the catalyzed RTV mix was deaerated. Once again the RTV seemed to have blistered at the nodes, yet appeared excellent between nodes. This result indicated that deaerating the RTV mixture may not be necessary.

(4) Squeegee Coating. Catalyzed RTV was poured onto a fabric sample and the coating spread with a squeegee tool. Care was taken to force the RTV into the nodes to assure adhesion in these areas. When cured, the coated sample was examined, only to find that the RTV had blistered again at the nodes. This method produced a film thickness of approximately 0.038 cm (0.015 inch).

(5) Combination Brush and Transfer Coating. Catalyzed RTV was brushed onto the Astroquartz fabric and then a transfer coat applied atop the brush coat. The result was a uniformly smooth coating, with a thickness approximately 0.05 cm (0.020 inch). It was observed that pockets were formed between the transfer and brush coats, directly over the nodes.

(6) Brush Coating. The final attempt to coat a TABI sample involved a brush coat of RTV. Using a paint brush with short, stiff bristles, catalyzed RTV was "worked" into the fabric and node areas. This technique produced excellent adhesion to the fabric without blistering at the nodes, Figure 3-23. The surface texture of the coating was not as smooth as those produced by the other methods, and had an appearance resembling the weave of the fabric, Figure 3-24. The texture was improved somewhat by applying an additional light coat of RTV. Coating thickness at the flute faces approached 0.0025 cm (0.010 inch) while the thickness at the nodes was nearly 0.05 cm (0.020 inch). This technique proved to be the most successful, even though it was the most tedious. A decision was made to brush coat the heat cleaned two-gore assembly. After some experimental work to coat single-ply Nicalon fabric using some of the coating techniques tried for Astroquartz, it was also decided to use brush coating on any silicon carbide fabric that may require coating.

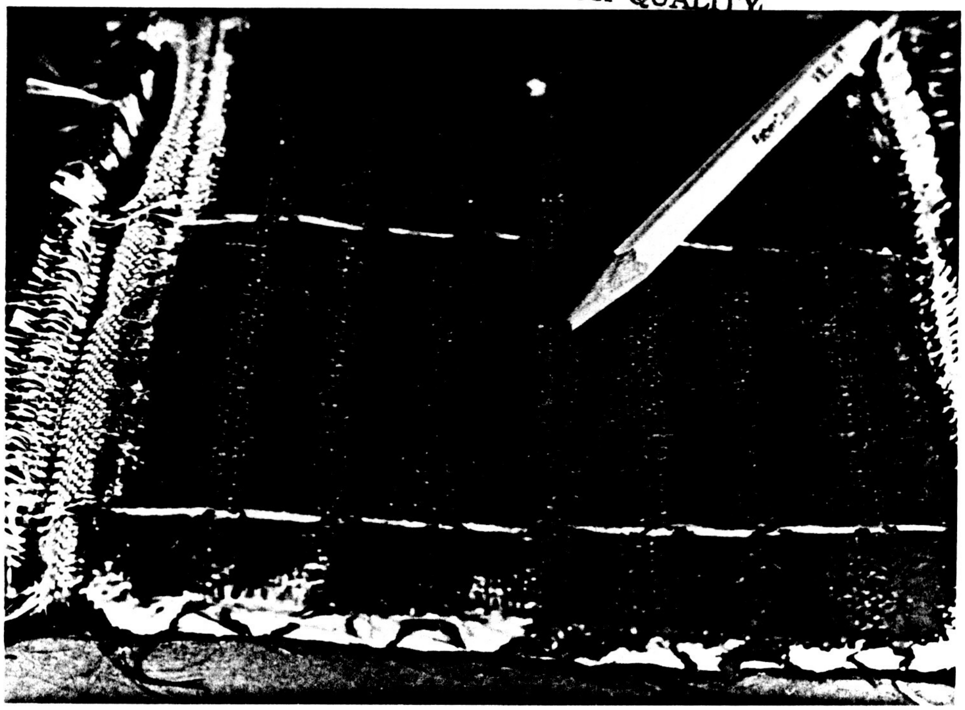

FIGURE 3-23
BRUSH-COATED SPECIMEN
NOTE GOOD COVERAGE OVER NODES

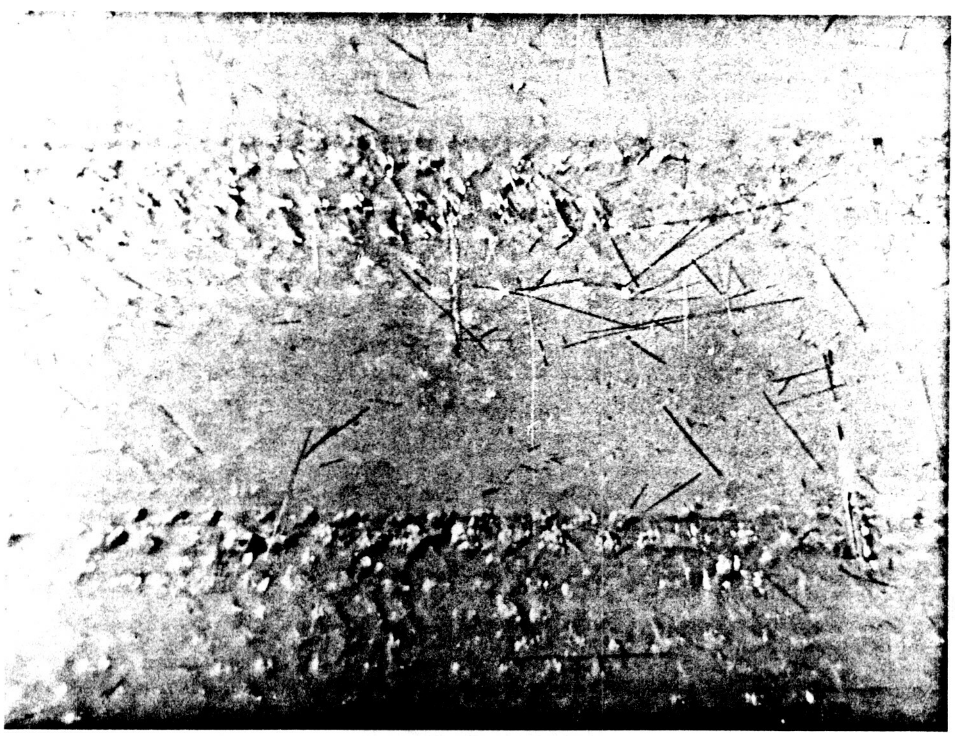

FIGURE 3-24
CLOSE-UP OF BRUSH-COATED NODE AREA.
COATING APPEARANCE HAS TEXTURE OF FABRIC WEAVE

3.2.8 Assembly of Two-Gore TABI Panels. Having developed the techniques for preparing, joining, and coating ICAS, a procedure was definitized for producing the Item 2 assembly, as presented in Figure 3-25. The pertinent tasks of this procedure are described in the following steps:

(1) Scribing Contour of Flute Length. A decision was made to process only one edge of each ICAS since there was nothing to gain by proccessing both edges for a two gore assembly. Before committing ICAS fabric to processing, two lengths of fiberglass Hitcore® fluted fabric were cut and joined to verify the desired spherical radius of approximately 1.52 meters (5 feet). The Hitcore was placed on a flat surface and an arc scribed on the mating edge of each length of fabric using a flat template with a radius of 9.1 meters (30 feet). Each fabric's edge was cut approximately 7.62 cm (3 inches) beyond the scribed line, and the two lengths sewn together along the marked lines. The assembly was inspected on a spherically shaped fixture and conformed to the desired contour.

The second and fourth ICAS fabric lengths were then scribed using the flat template. The side of one Astroquartz face fabric was scribed as depicted in Figure 3-26. The other mating fabric was scribed on the opposite side with the template reversed. The arc began at a point in the transition zone, 7.6 cm (3.0 inches) from the fabric edge. This arc defined the ends of the insulation mandrels which were to be inserted later.

(2) Removing Ribs. All Nicalon rib fabric between the scribed mating line and the edge of each fabric was removed to provide sufficient fabric for constructing the tadpole joint. To facilitate insertion of insulation into the flutes, one of the mating ICAS fluted core segments had previously been rigidized using the nylon mandrels and acrylic resin processing steps of Item 1. The stiffness of the yarns made the removal of the ribs extremely difficult, and it was decided that the other ICAS would not be rigidized. The rigid yarns were softened with warm deionized water to facilitate handling and, with care, removed. Figure 3-27 is a close-up view showing resin-stiffened ribs partially removed. Fabric cleared of ribs from the fabric edge to the scribe line is seen in Figures 3-28 and 29.

® Hitcore is a registered trade mark of HITCO.

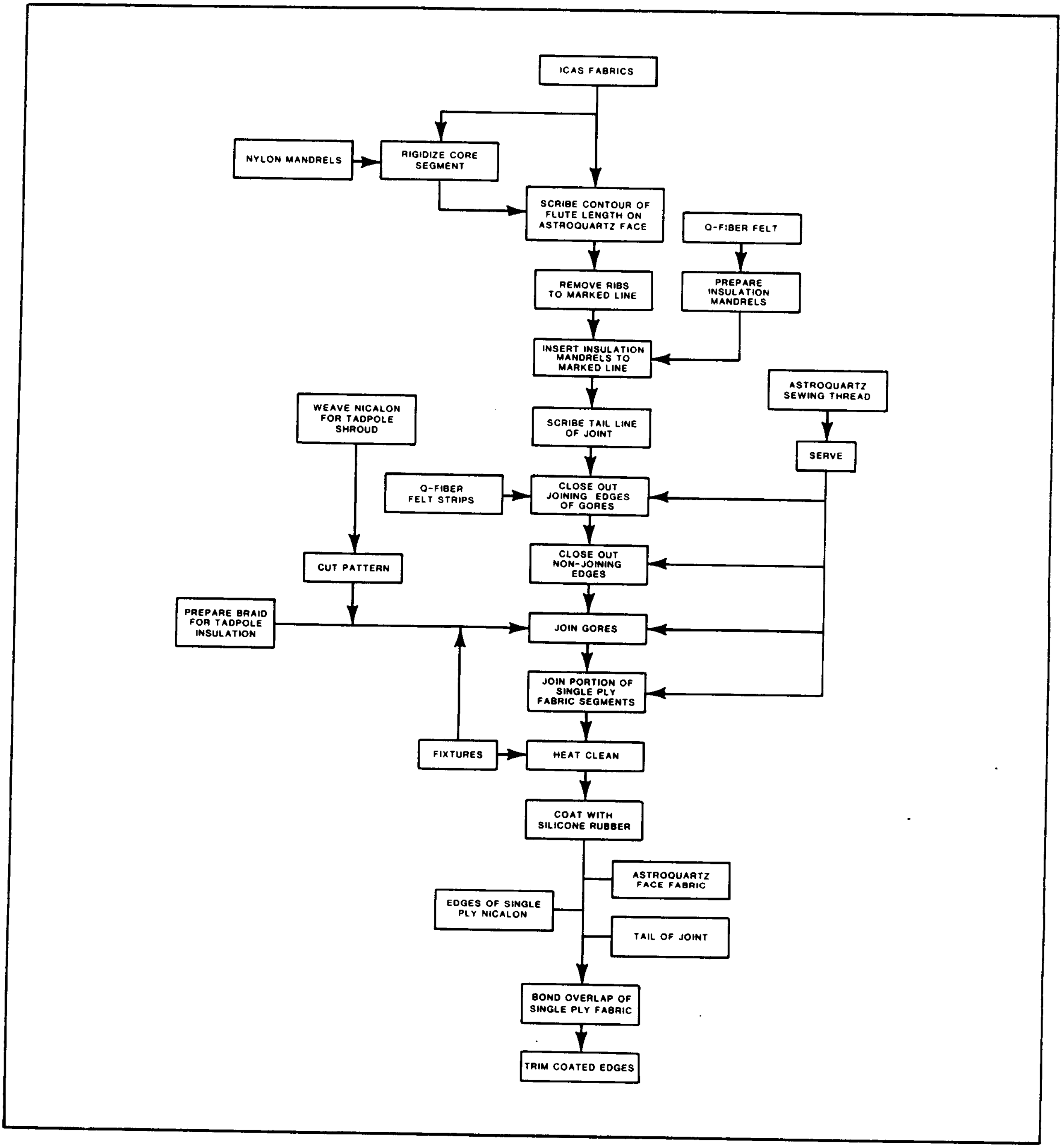

Figure 3-25

PROCEDURE FOR MAKING TWO-GORE CONTOURED TABI ASSEMBLY

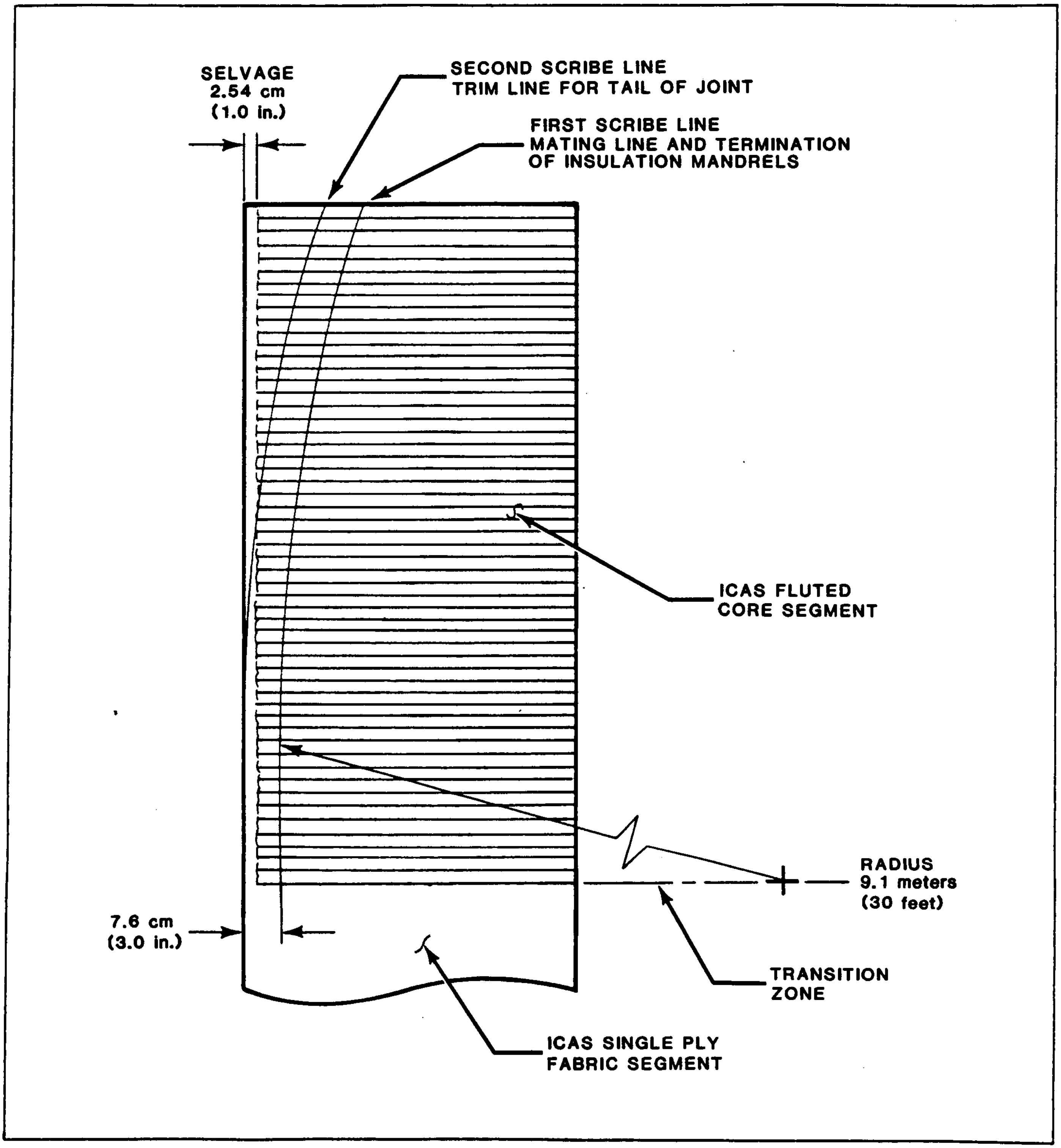

Figure 3-26

SCRIBING LAYOUT FOR ICAS FABRICS

FIGURE 3-27
RESIN-STIFFENED NICALON RIBS PARTIALLY REMOVED

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OF POOR QUALITY

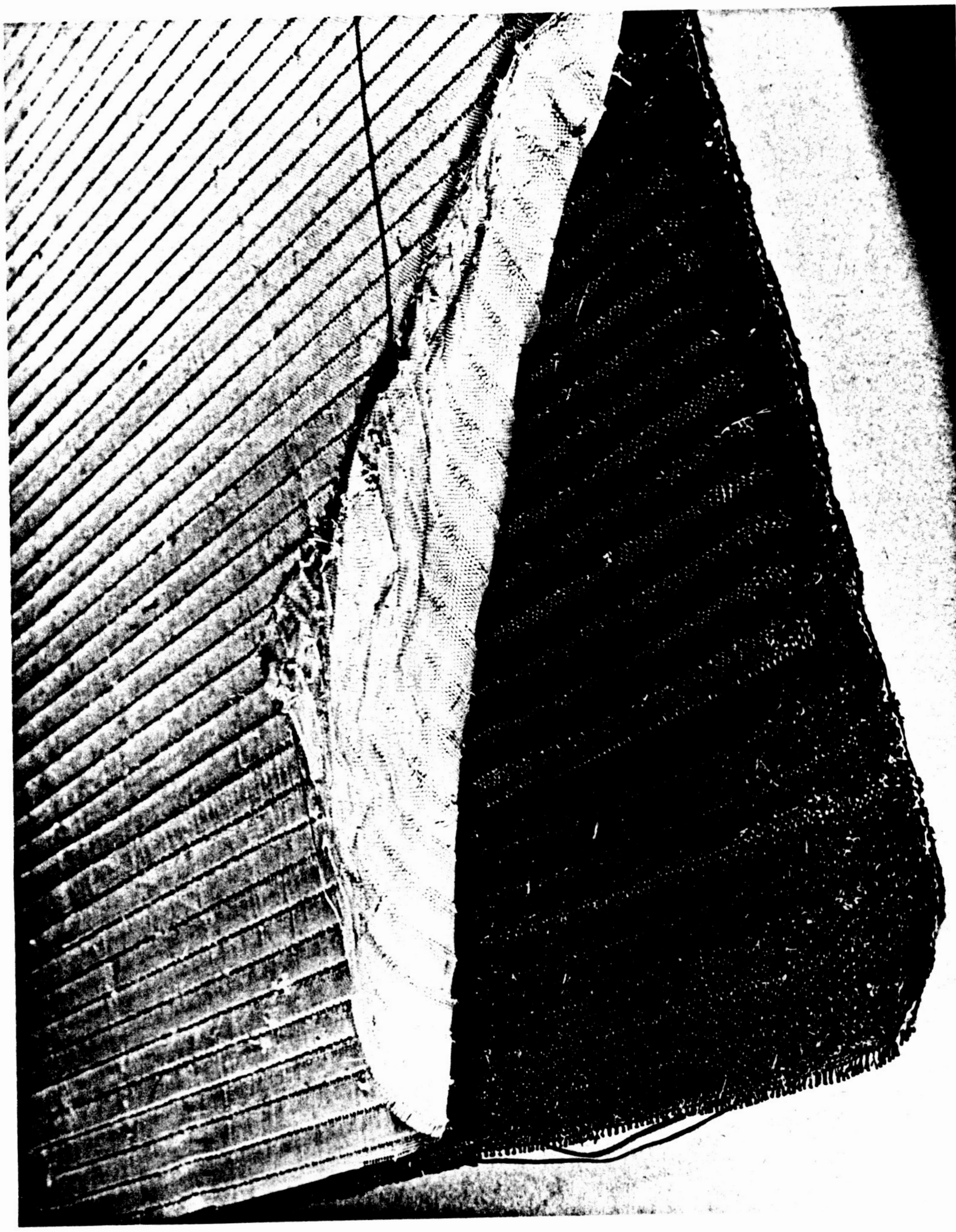

FIGURE 3-28
RIBS REMOVED FROM FABRIC EDGE TO SCRIBE LINE

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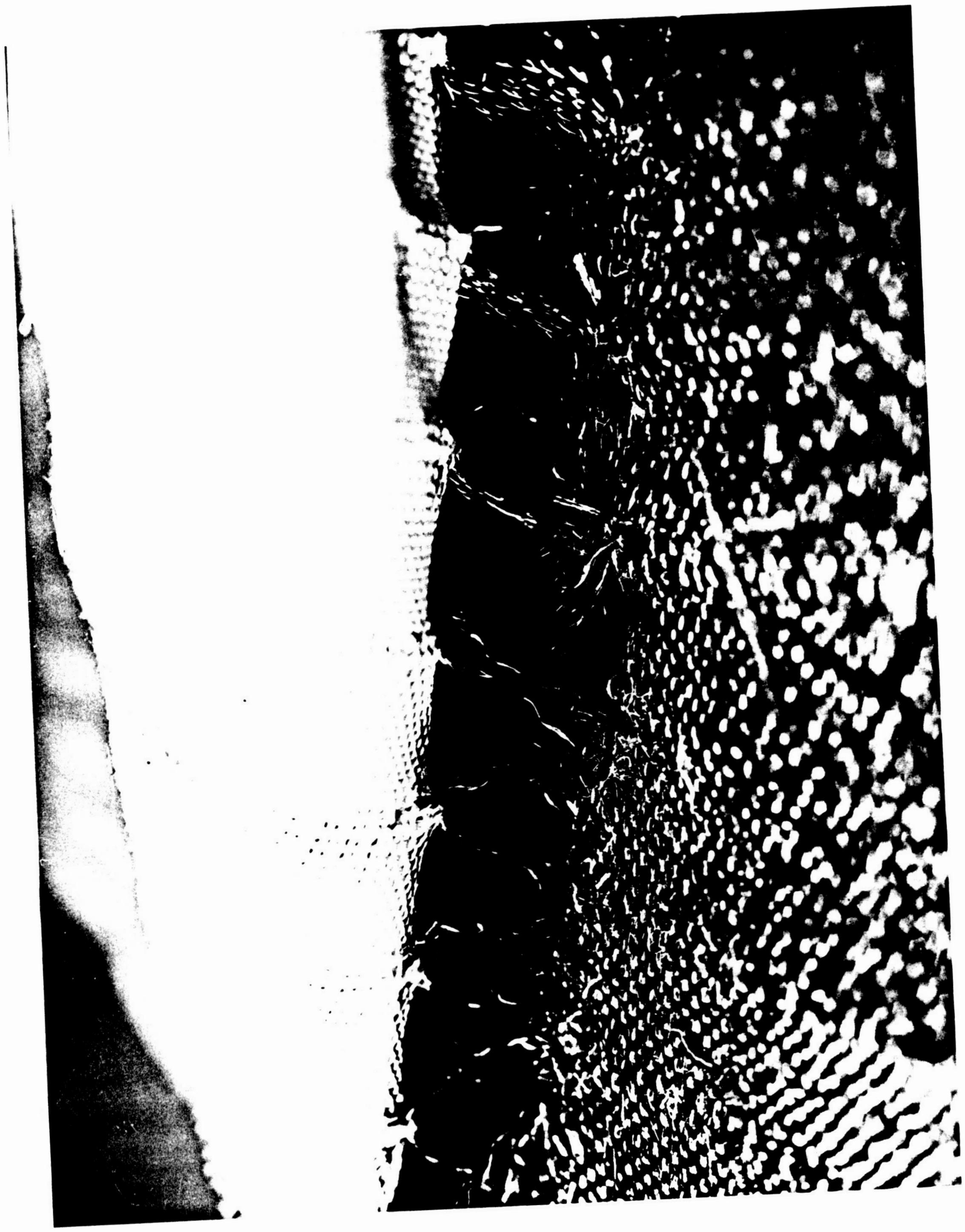

FIGURE 3-29
CLOSE-UP OF RIBS REMOVED

(3) Inserting Insulation Mandrels. Insulation mandrels prepared as described previously were inserted into the flutes up to the scribed line. The first ICAS insulated length completed is shown in Figure 3-30. Both insulated ICAS lengths to be joined are pictured in Figure 3-31. Figure 3-32 is a close-up view of insulation mandrels terminating at the scribed line.

(4) Scribing Trim Line. A second marking template similar to the first was used to scribe the trim line for the tail of all the fabrics forming the tadpole joint. The radius of this template was 7.6 cm (3 inches) greater than the first in order to provide a constant curved border of fabric on each mating edge. The Astroquartz fabric faces of the two insulated ICAS lengths were marked then cut to form the border, see Figure 3-26.

(5) Closing out Non-Mating Edges. The outer edges of the fluted core segments were closed out by sewing the selvages of Astroquartz and Nicalon faces with Astroquartz sewing thread. Figure 3-33 illustrates the close-out construction.

(6) Joining Mating Edges. The mating edges were closed out and joined as depicted in Figures 3-34A and B. Basically five steps were involved to combine the two trimmed, insulated fluted core segments and produce a Model D joint. For the sake of discussion, the segments will be identified as A and B in these figures.

Step 1). Astroquartz sewing thread was used to sew the 15.2 cm (6 inch) wide tadpole shroud fabric to the border area of the Nicalon face fabric with the stitch line 3 cm (1.2 inches) from the ends of the insulation mandrels. This distance was required for the proper length of shroud to cover the braided core later, and to allow optimum joint flexibility.

Step 2). Q-Fiber Felt gap filler was placed adjacent to the insulation mandrels' ends and the filled cavity closed off. This was accomplished by sewing all three fabric layers together, Astroquartz, Nicalon and shroud, stitched as closely as possible to the filled cavity.

Step 3). Segment A was placed over B with the Nicalon fabric faces of the segments contacting each other. The Nicalon fabric of face B was attached to the shroud fabric by sewing 3 cm (1.2 inches) from the ends of the insulation mandrels.

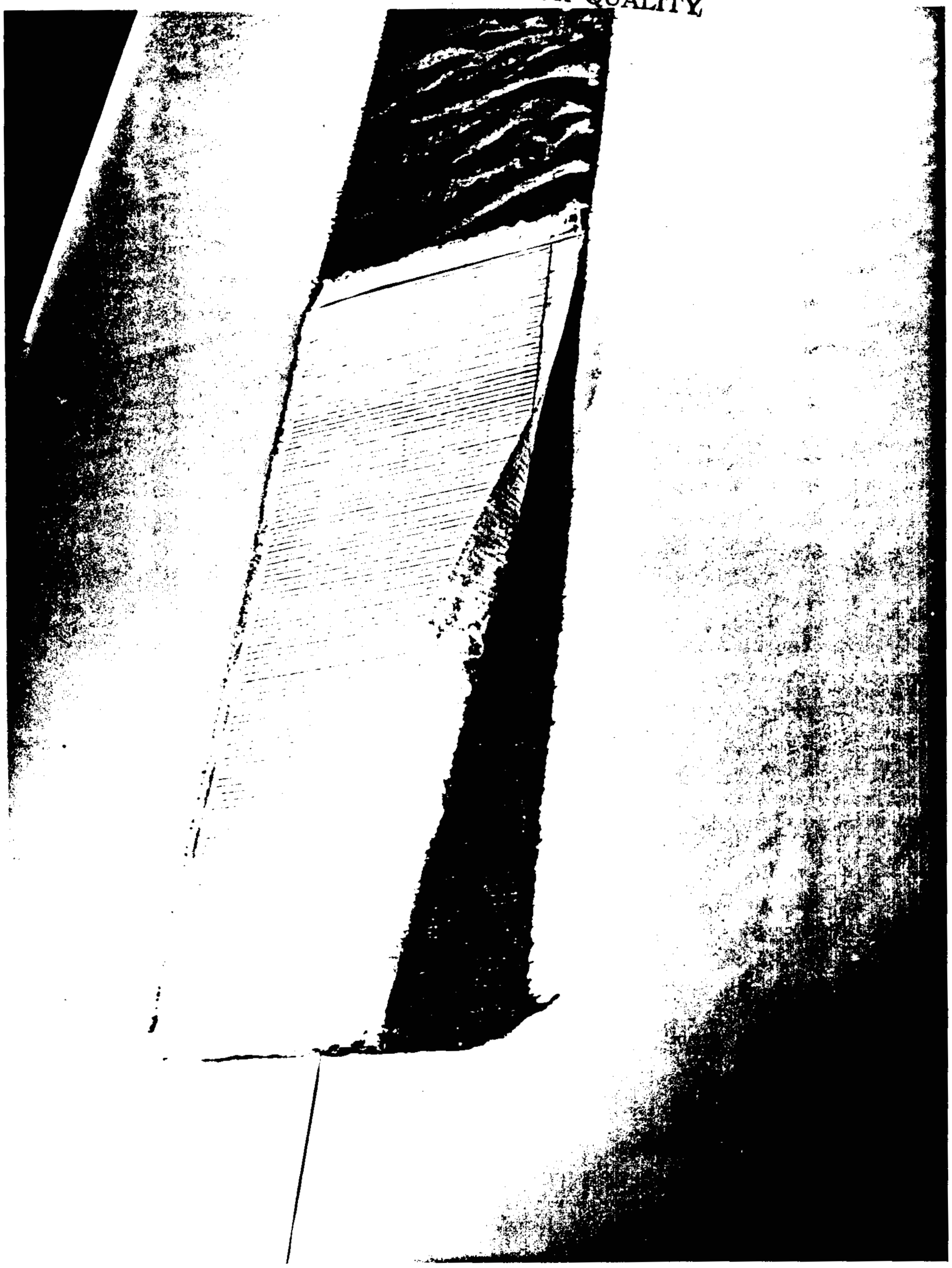

FIGURE 3-30
INSULATED ICAS FLUTED CORE SEGMENT

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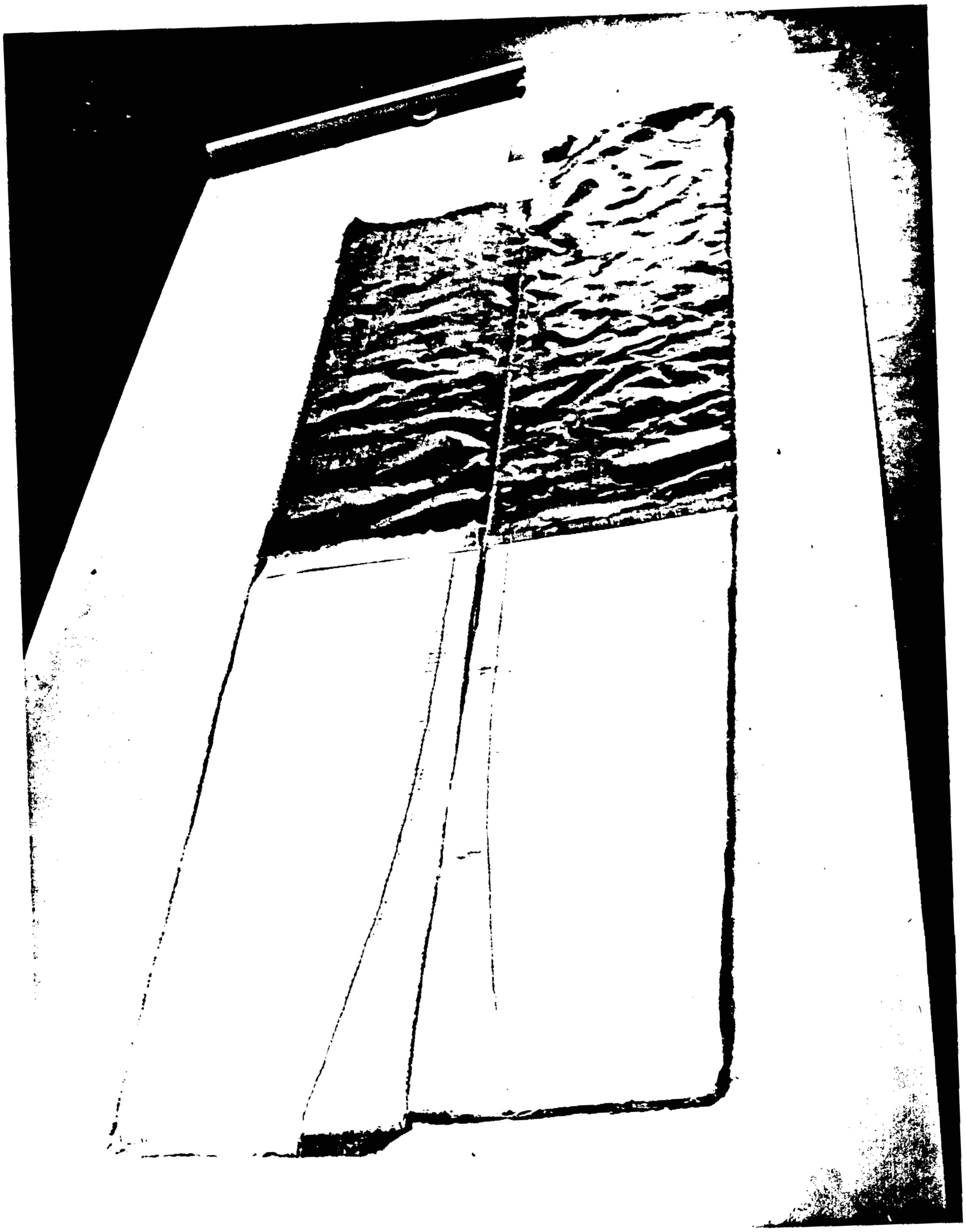

FIGURE 3-31

TWO MARKED ,INSULATED ICAS FABRICS TO BE JOINED

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C-2

FIGURE 3-32

CLOSE UP OF INSULATION MANDRELS TERMINATING AT SCRIBE LINE

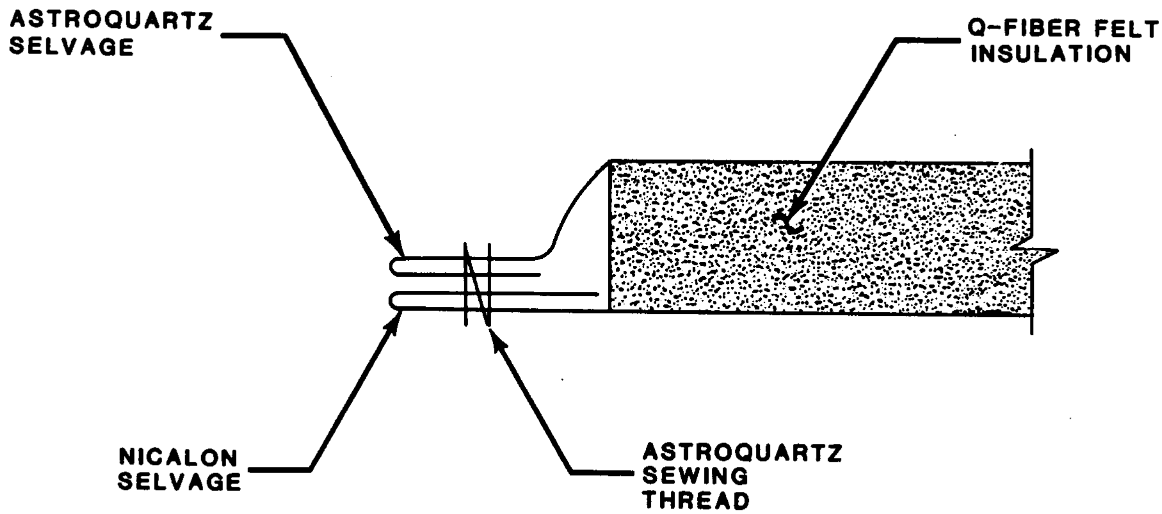


Figure 3-33

CLOSE OUT CONSTRUCTION FOR NON-MATING EDGES

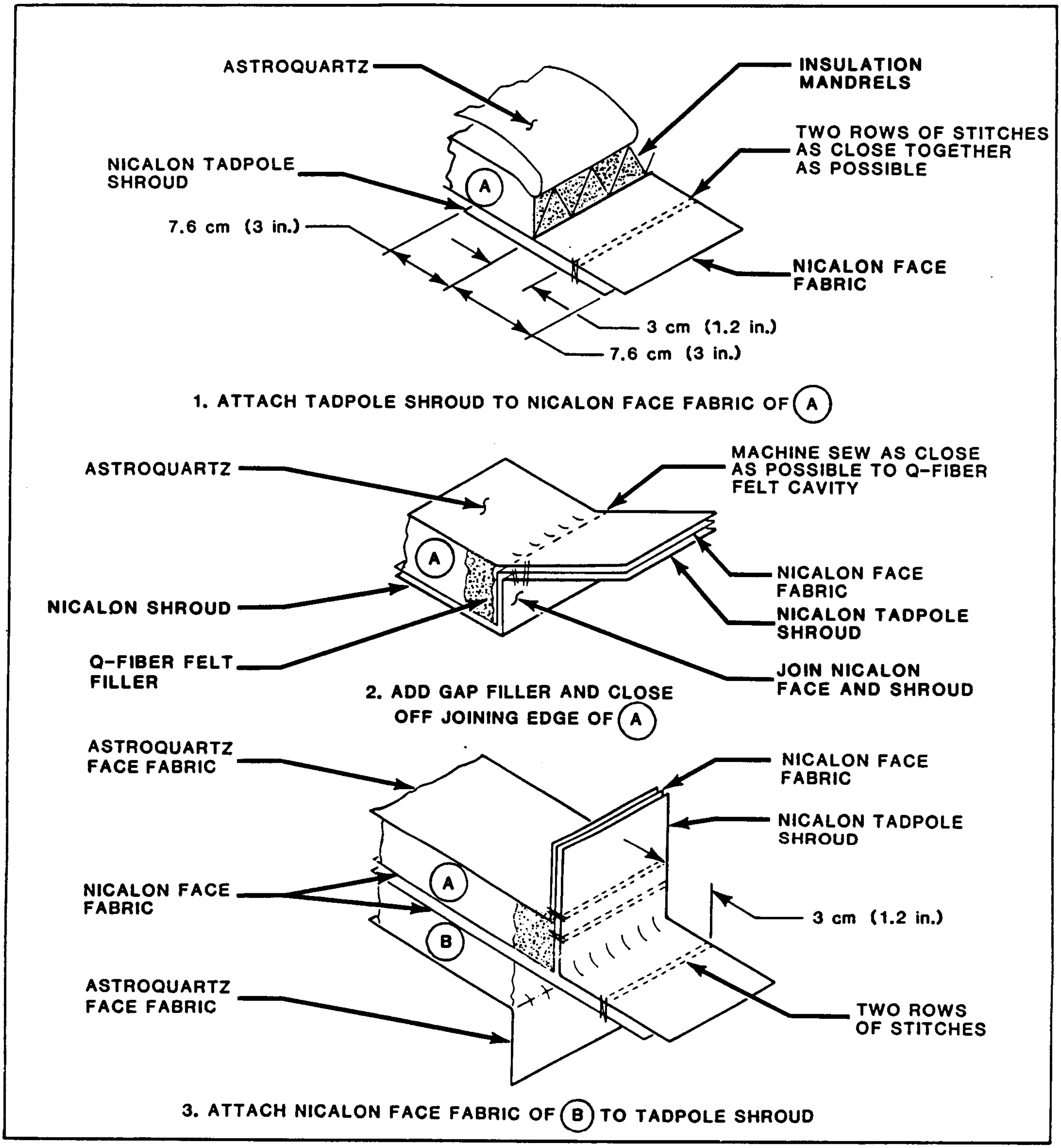
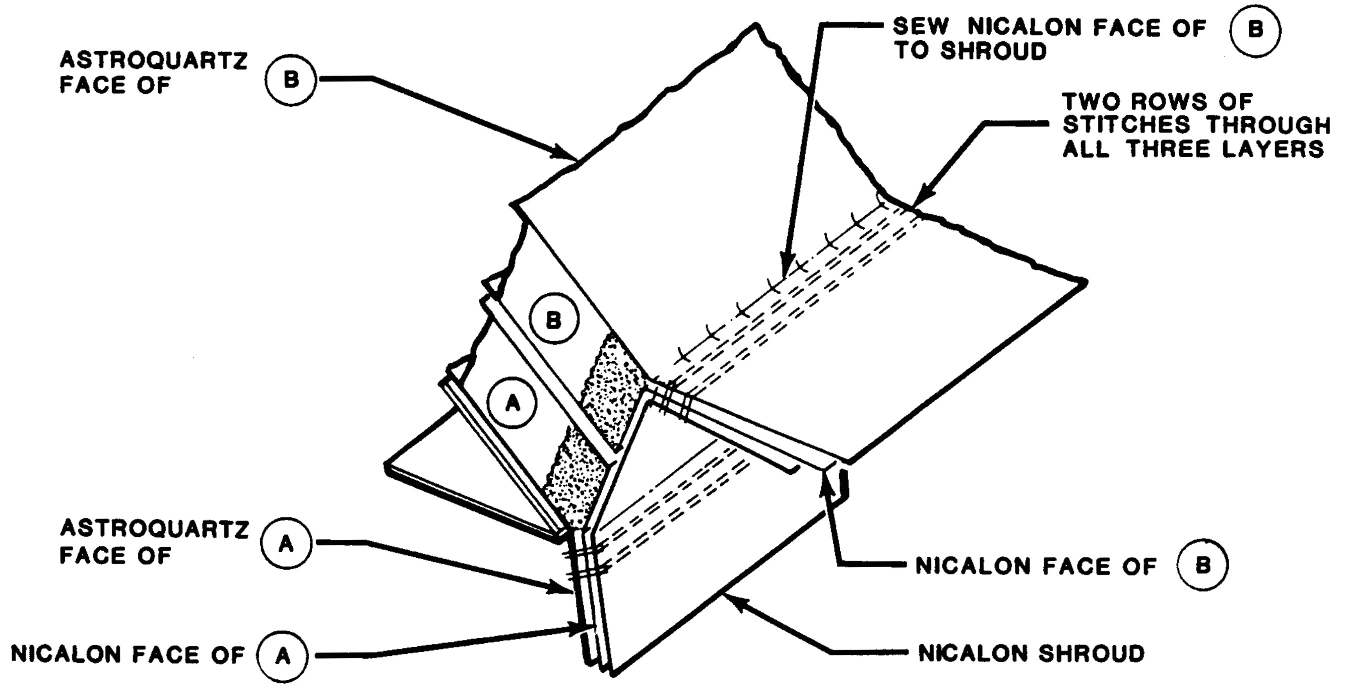
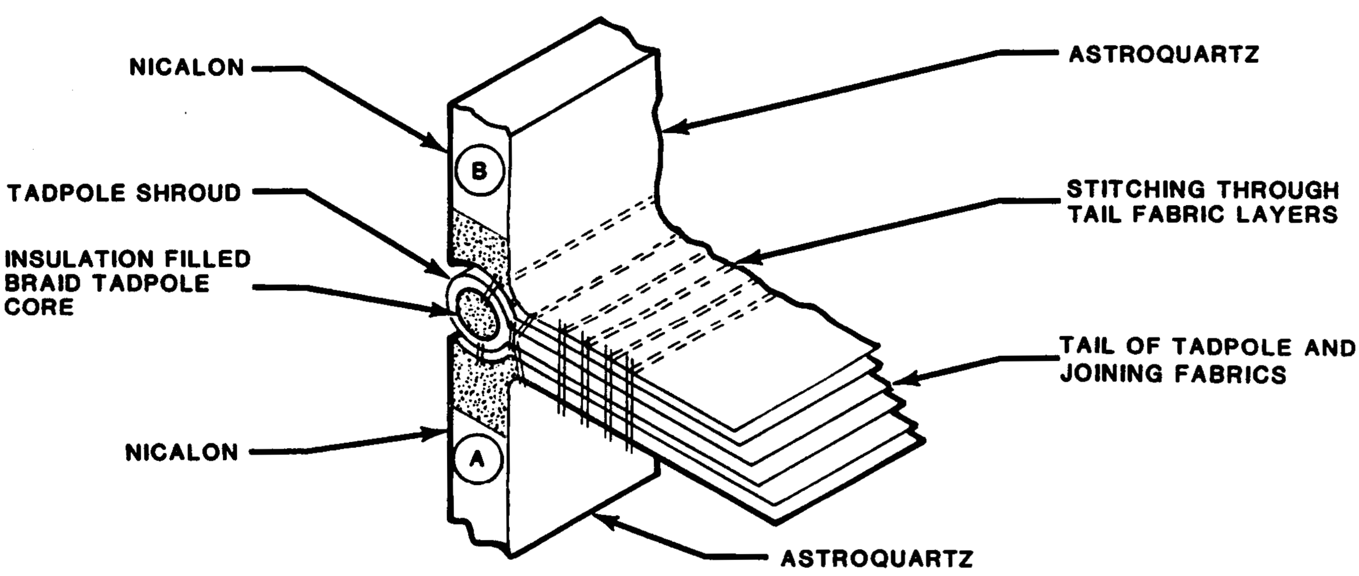


Figure 3-34A

STEPS FOR JOINING MATING EDGES OF GORES



4. ADD GAP FILLER TO B, AND CLOSE OFF JOINING EDGE OF



5. ASSEMBLE (A) AND (B) TO COMPLETE MODEL D JOINT

Figure 3-34B

STEPS FOR JOINING MATING EDGES OF GORES, (CONTINUED)

Step 4). The stack was inverted so that segment B was now above A. As in Step 2), Q-Fiber Felt gap filler was placed in the cavity and encapsulated by stitching the three fabric layers together.

Step 5). The two-gore subassembly was placed on a contoured fixture and the braided core of the tadpole positioned in the shroud fabric previously attached to the mating edges. The fabric tails of each gore were brought together and hand stitched with Astroquartz sewing thread to temporarily secure the tadpole configuration. The Model D joint was completed by vertically mounting insulated ICAS segments A and B in a fixture to facilitate machine sewing. The integral single ply segments of the two gores were rolled up and supported behind the fixture during the sewing operation. All layers of fabric forming the joint tail were sewn together, and the temporary hand stitching removed. The joining operation set up with the vertical fabric segments in the fixture and the sewing machine are pictured in Figure 3-35. Because of the inability to position the needle of the sewing machine close to the fabric in the fixture, it was necessary to remove the protruding front plate and tension device of the machine as shown in Figure 3-36. Stitching of the gore fabrics being joined with the modified sewing machine is seen in Figure 3-37. As sewing proceeded from one end of the joint toward the center, the curvature of the panels and the height of the machine made it increasingly difficult to stitch close to the joint's base. Near the center of the joint's length it was necessary to sew the innermost row of stitches by hand, Figure 3-38.

The assembly of the fluted core segments and tadpole joint is viewed from the Nicalon fabric side of the fixture in Figure 3-39. Figure 3-40 is a close-up view of this surface.

(7) Joining Single Ply Nicalon Fabric Segments. The 1.8 meters (6 feet) long single ply segments of ICAS overlapped each other approximately 7.6 cm (3 inches) after joining the fluted core segments into the contoured shape. The first 0.6 meters (2 foot) section of Nicalon beyond the ICAS transition zone was to be joined by stitching, the second 0.6 meter (2 feet) by adhesive bonding, and the remainder left unbonded. Before stitching the first section, the excess tadpole protruding from the joined gores, Figure 3-41, was trimmed and closed out. Q-Fiber Felt was removed from the tadpole, the braid flattened,

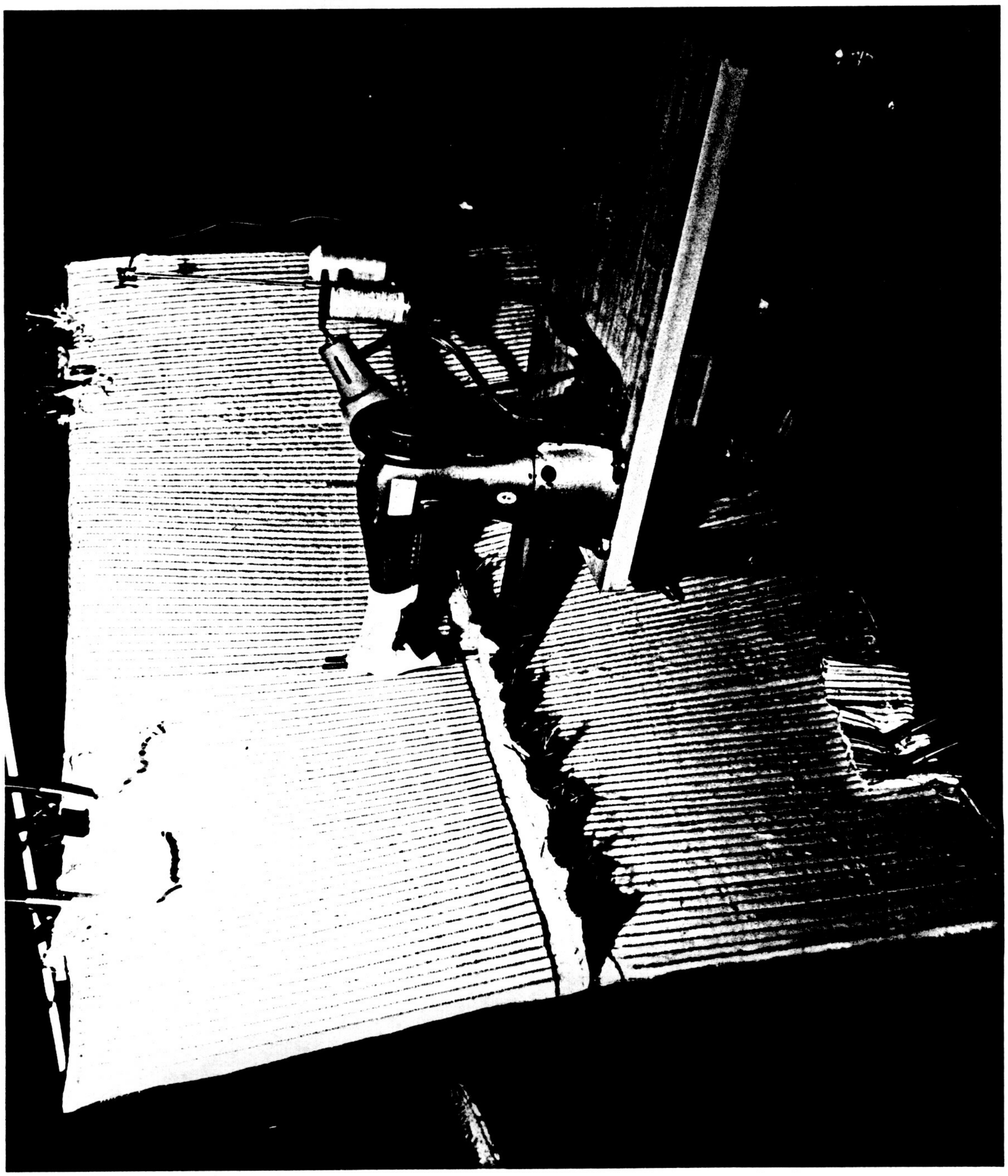


FIGURE 3-35
JOINING OPERATION SET UP

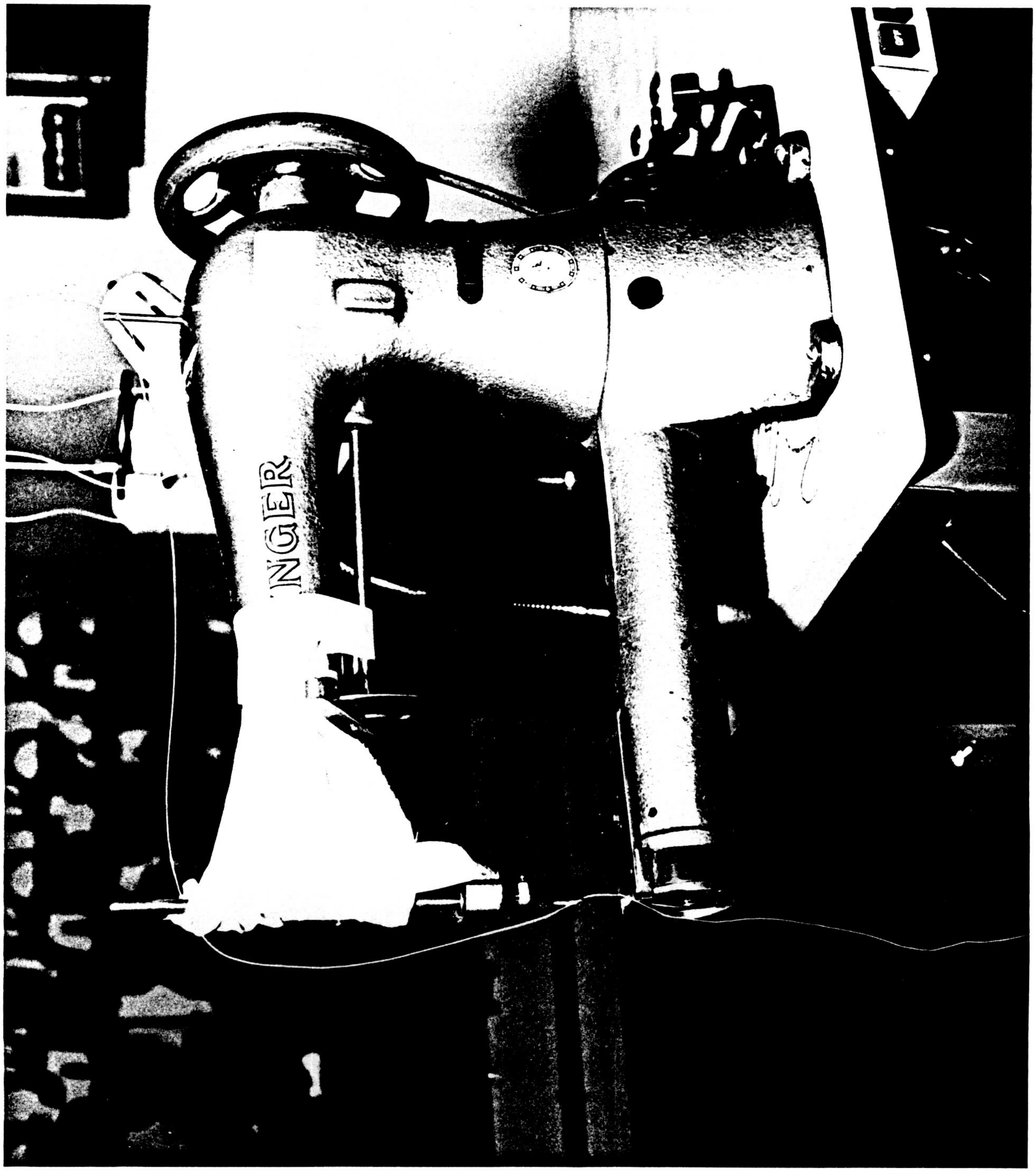


FIGURE 3-36
SEWING MACHINE WITH FRONT PLATE
& TENSION DEVICE REMOVED

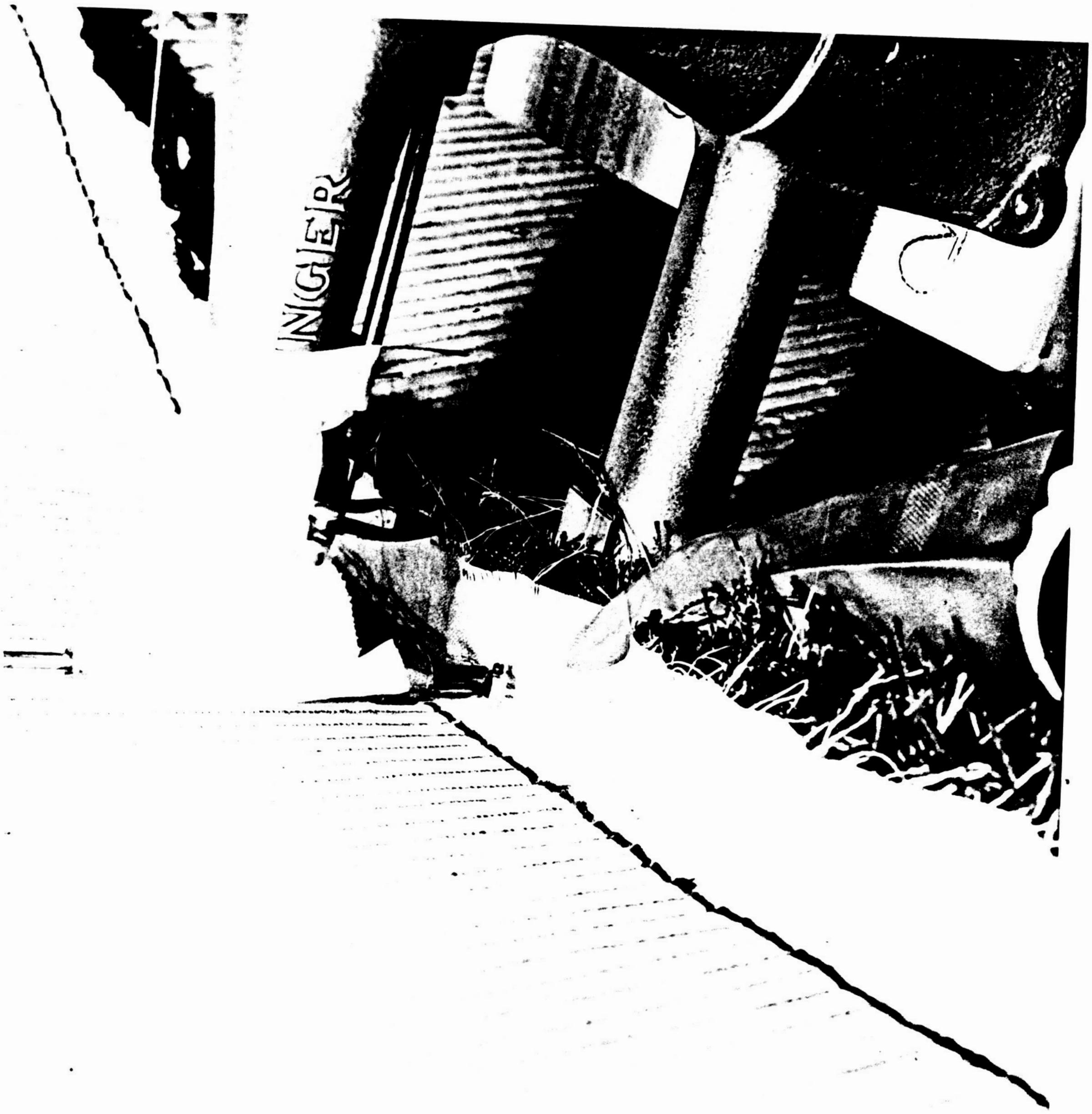


FIGURE 3–37
STITCHING OF JOINT WITH MODIFIED
SEWING MACHINE

[redacted]

FIGURE 3-38
HAND-STITCHED PORTION OF JOINT
(BOTTOM ROW)

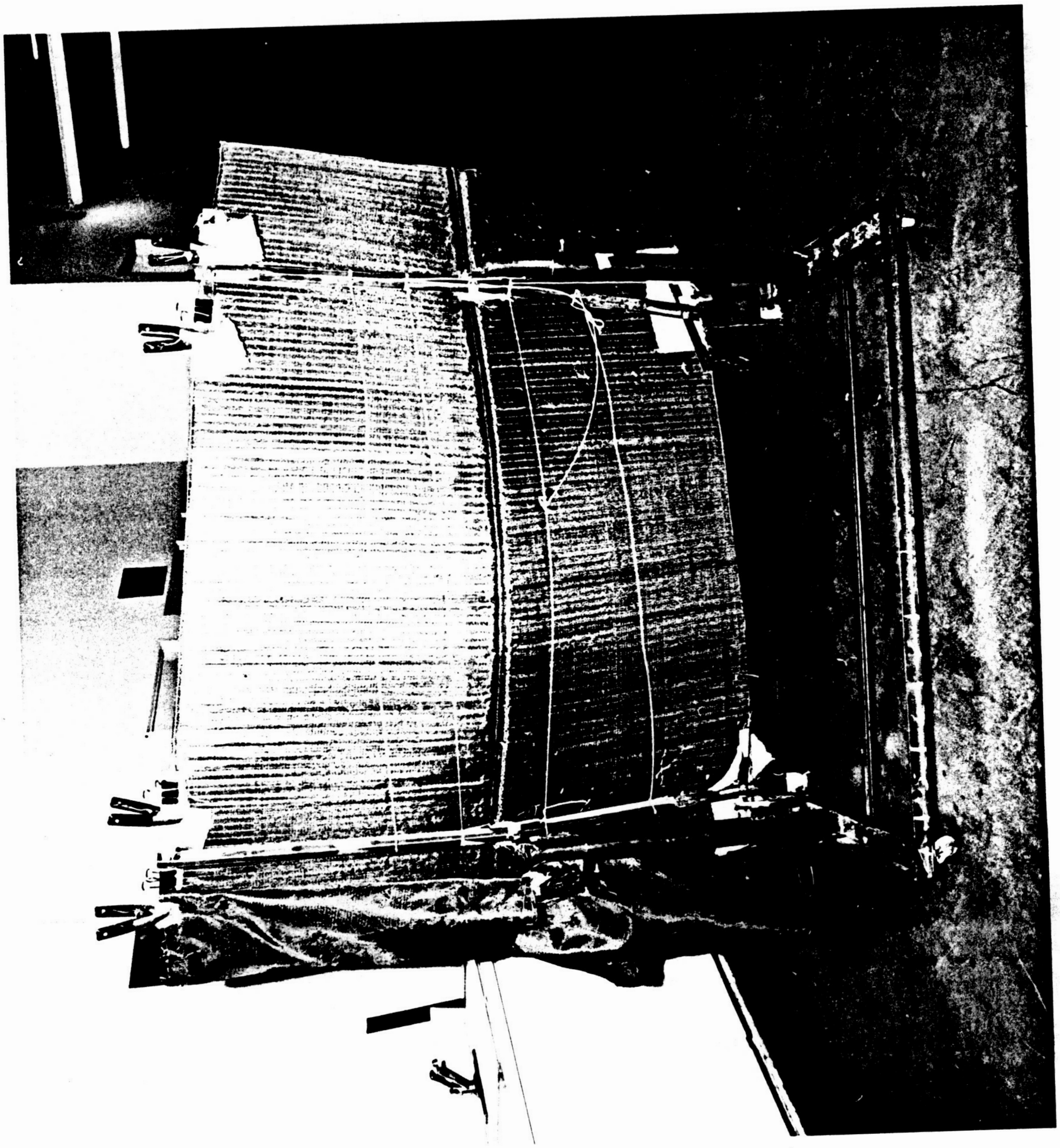


FIGURE 3-39
JOINED GORES IN FIXTURE VIEWED FROM NICALON FABRIC SIDE

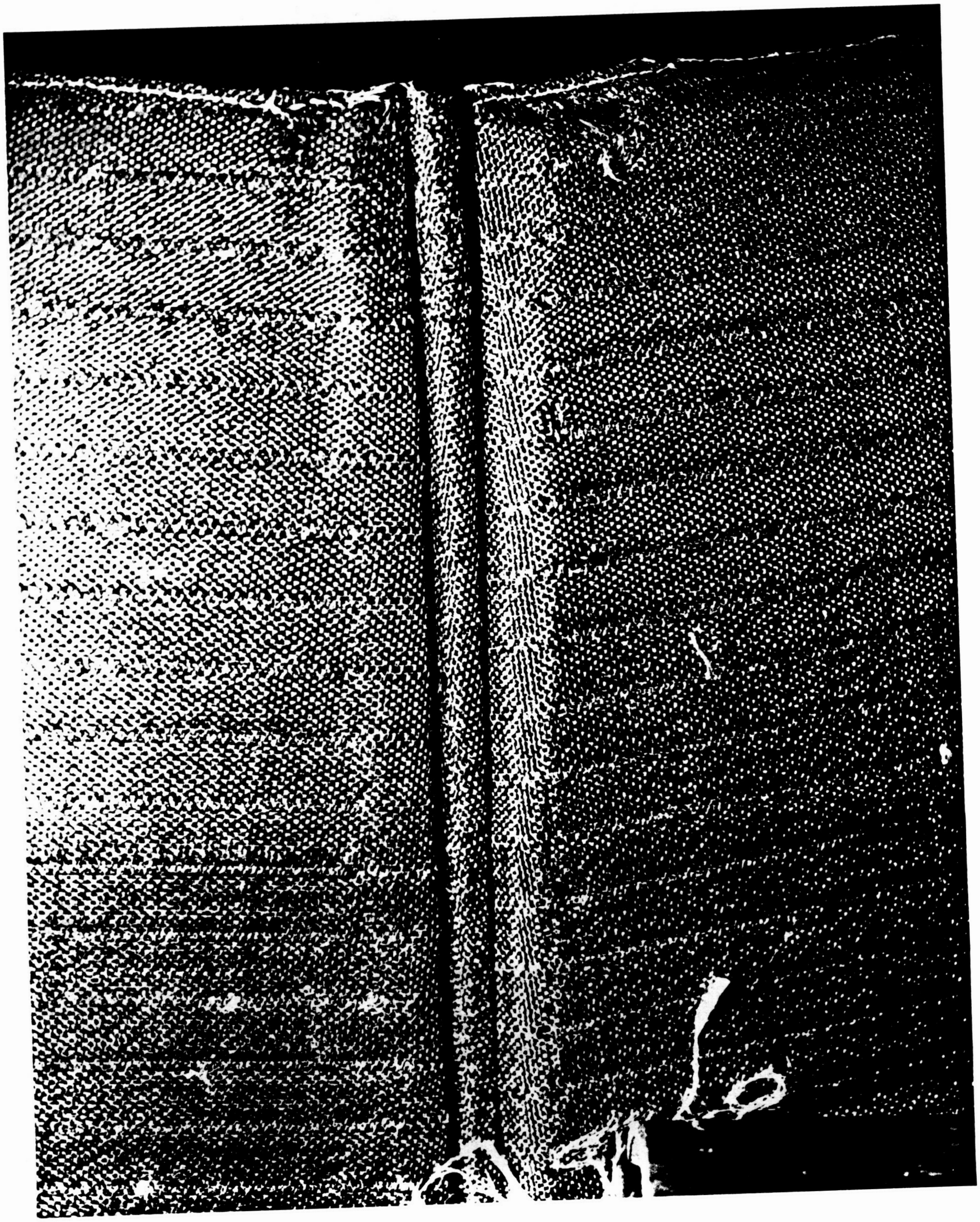


FIGURE 3-40
CLOSE UP OF NICALON FABRIC AND TADPOLE JOINT

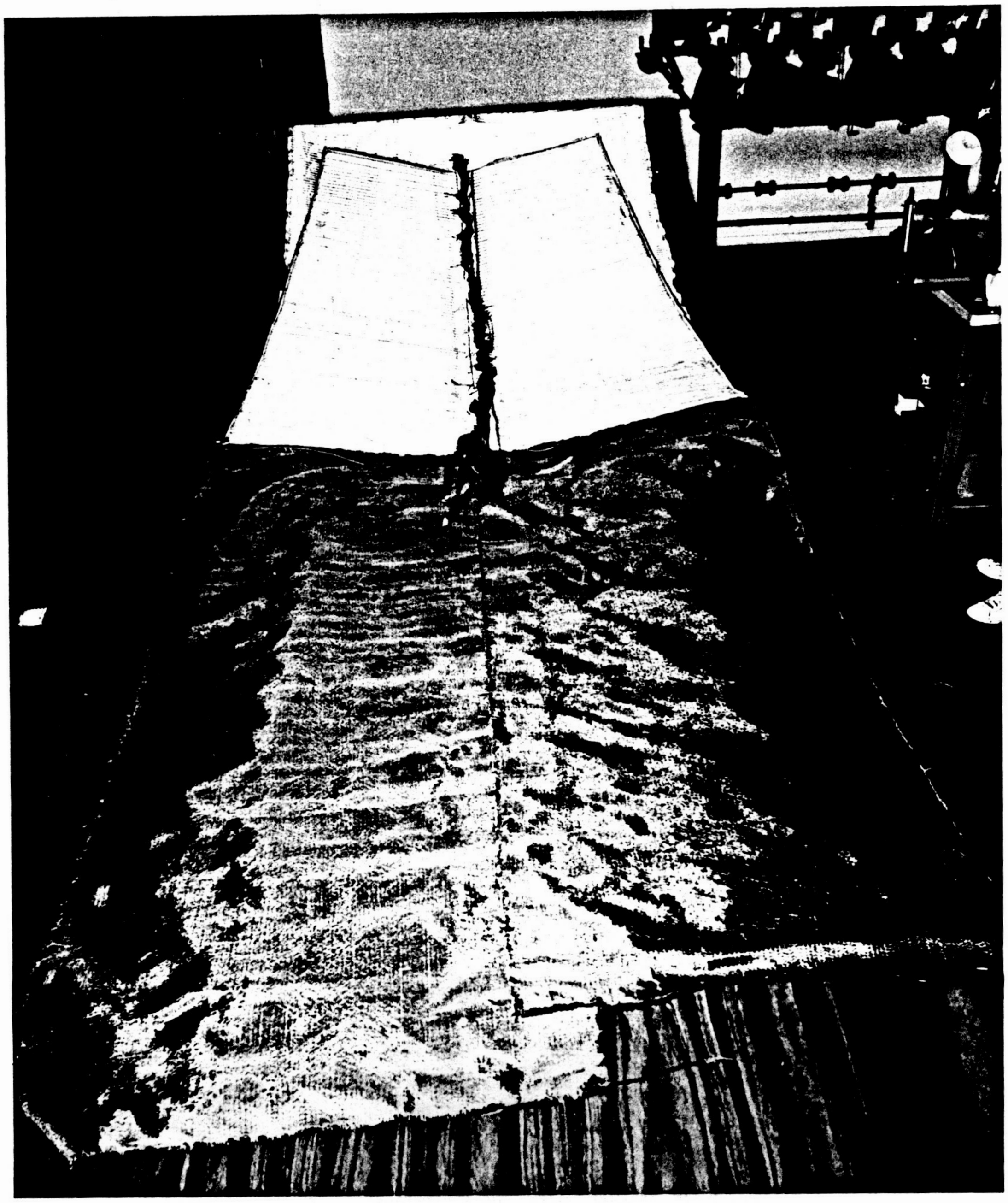


FIGURE 3-41

EXCESS TADPOLE PROTRUDING FROM JOINED GORES

folded back, and sewn to the shroud fabric. The terminated tadpole extended beyond the fluted core segment by 10.2 cm (4 inches). The first section of single ply fabric was then hand stitched as pictured in Figure 3-42. Adhesive bonding of the second section was accomplished after heat cleaning.

(8) Heat Cleaning. The two gore assembly of fluted core segments was positioned on a fixture, Figure 3-43, which had been covered with a clean layer of glass cloth. The single ply segment was folded back to rest on the core segment, and the assembly heat cleaned in a large recirculating oven using the same temperature cycle as for Item 1, see paragraph 2.2.7.

(9) Coating With Silicone Rubber. After heat cleaning, the same fixture supported the contoured assembly while coating the Astroquartz with RTV. A flat table adjacent to the fixture's end supported the single ply Nicalon. Small batches of catalyzed RTV rubber were mixed and applied by brushing following the procedure selected in the coating development task, Figure 3-44. The fabric tails of the tadpole joint were also coated, Figure 3-45, and trimmed. RTV was then applied for bonding the second section of overlapped single ply Nicalon fabrics. A portion of the adhesive bonded section adjacent to the stitched section is illustrated in Figure 3-46. Finally, all edges of the single ply Nicalon fabric were masked, coated and trimmed, Figure 3-47. The nearly completed gore assembly is shown in Figure 3-48.

3.2.9 Characterization. Measurements were made on representative heat cleaned samples of ICAS units and the results are presented in Table 3-2. Except for the desirable higher pick count Astroquartz fabric, discussed previously, and the higher pick count of the Nicalon rib, the target fabric characteristics were achieved. There was concern that unusual handling might damage the assembly so no attempt was made to weigh the completed unit on the devices available in the plant. However, based on various measured samples produced during the program, the finished article weight was estimated at 6.8 kb (15 lbs), a value believed to be reasonably accurate.

3.2.9.1 Theoretical areal weights of both segments of ICAS were calculated on the basis of yarn yields and fabric construction. These agreed quite closely with actual values measured on large sample segments.

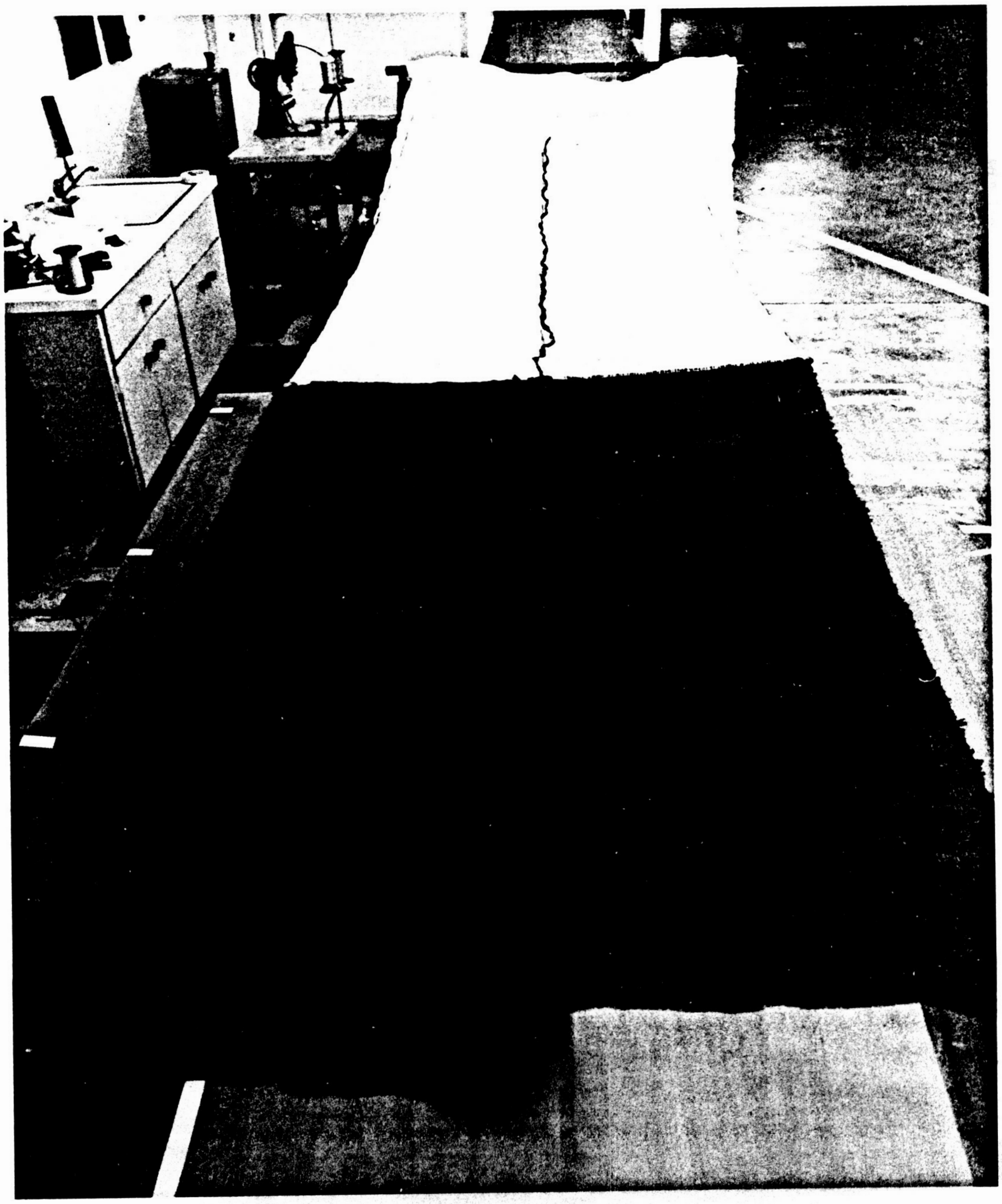


FIGURE 3-42
FIRST SECTION OF STITCH-BONDED SINGLE PLY FABRIC

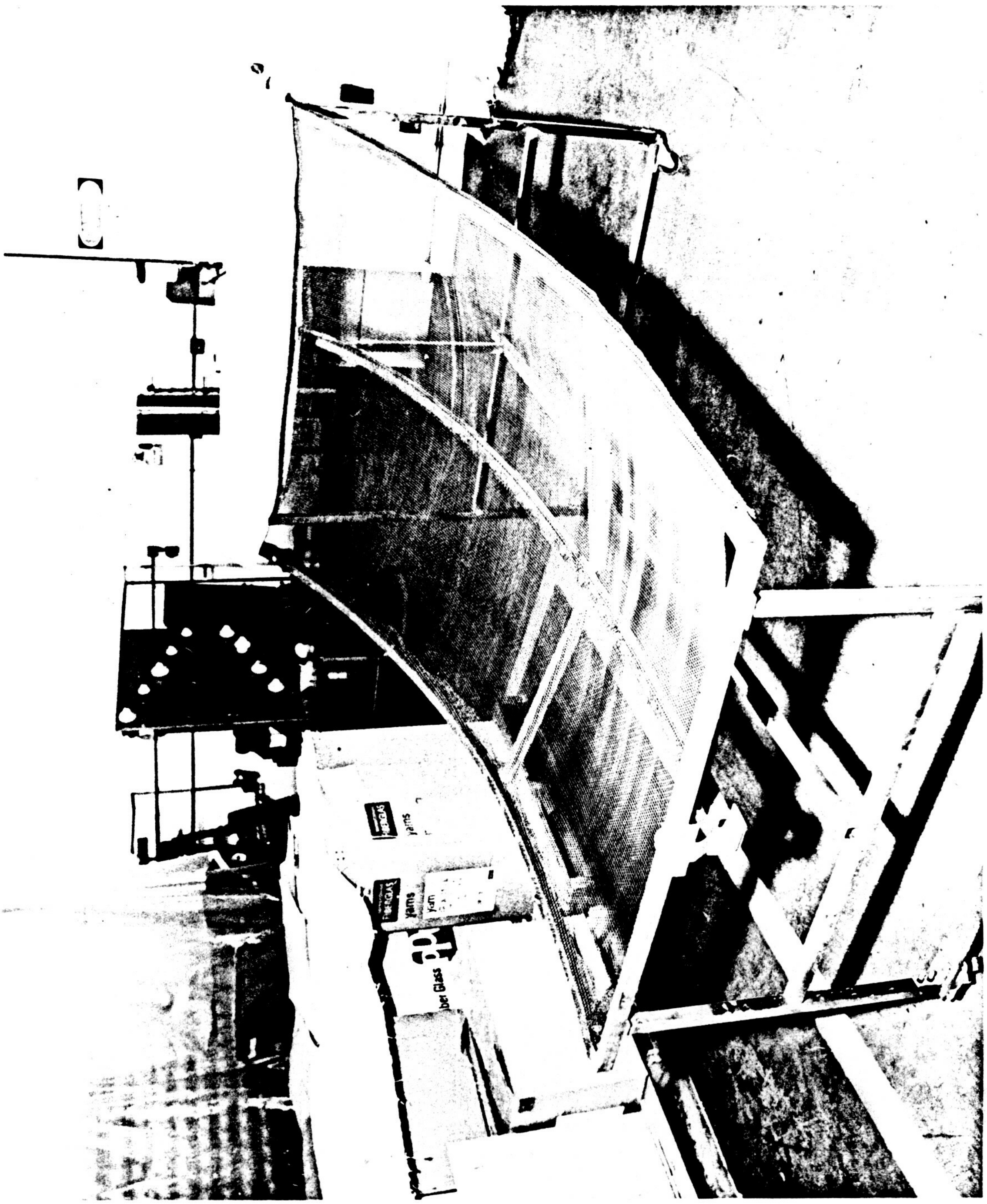


FIGURE 3-43
FIXTURE FOR HEAT CLEANING AND COATING

FIGURE 3-44
BRUSH COATING ASTROQUARTZ FABRIC

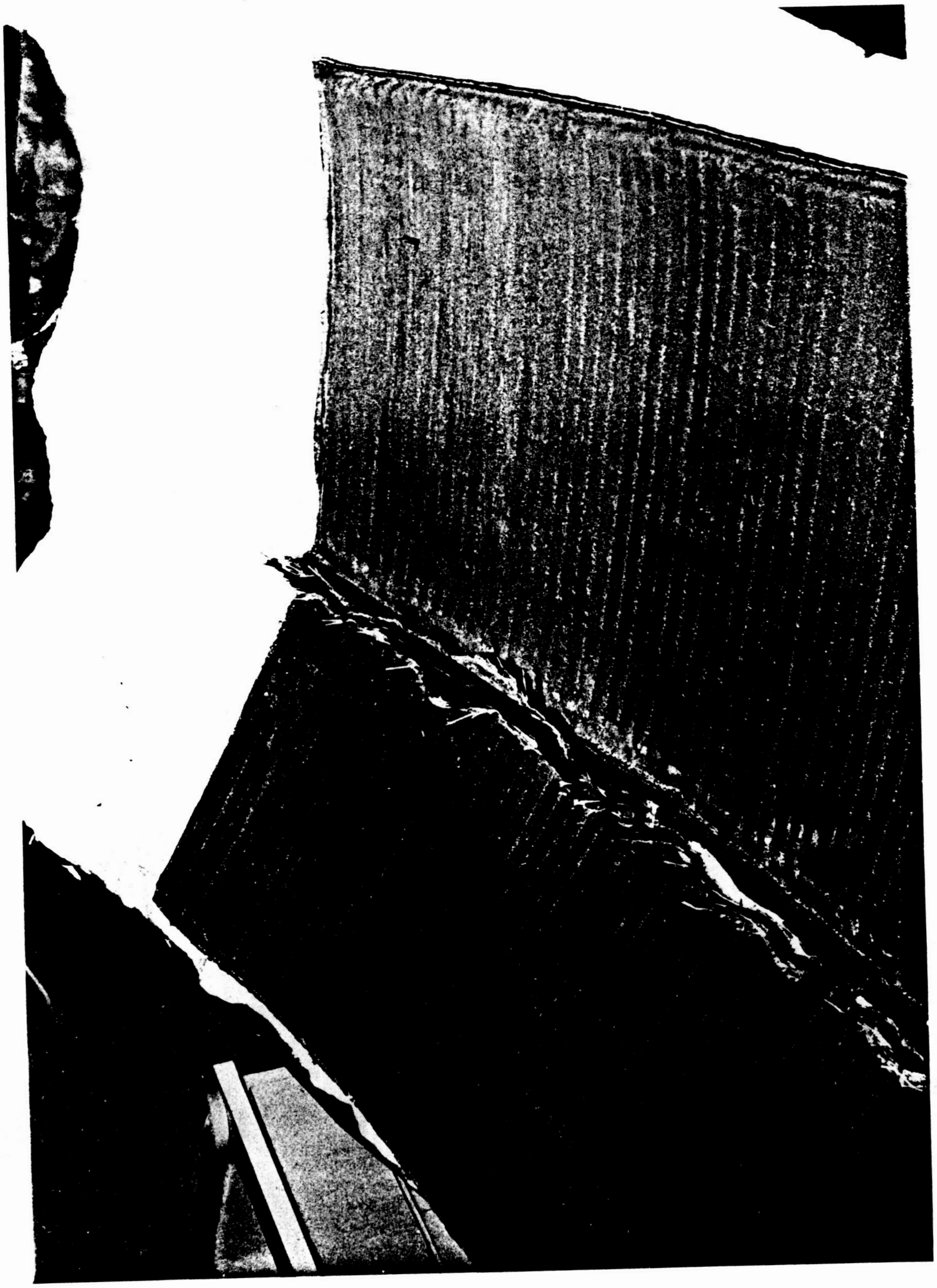


FIGURE 3-45
COATED TAILS OF TADPOLE JOINT. COATING OF
ASTROQUARTZ FABRIC IS COMPLETE

ORIGINAL PAGE IS
OF POOR QUALITY

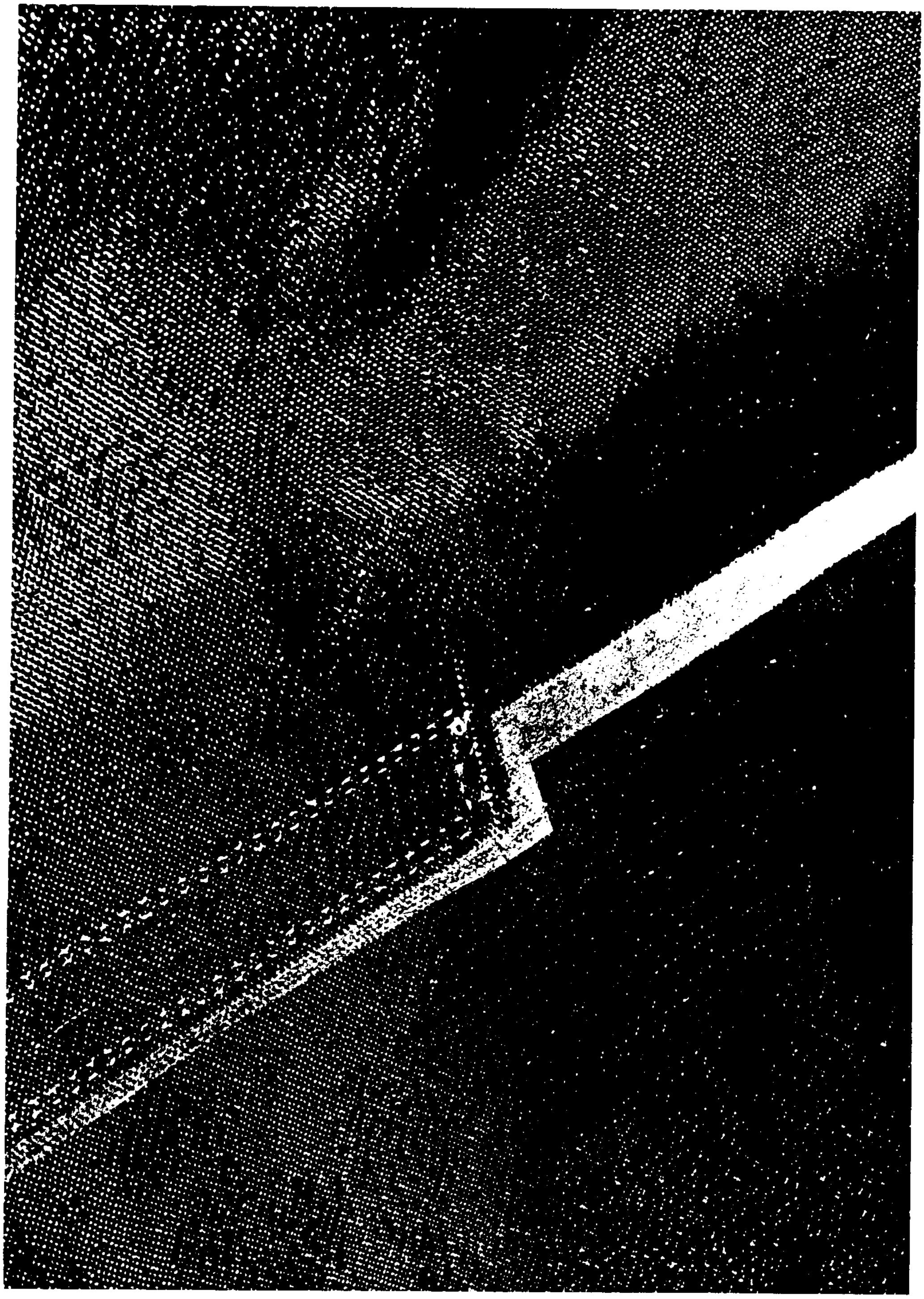


FIGURE 3-46
BONDED SINGLE PLY SECTION OF NICALON.
PORTION OF STITCHED SECTION IS ALSO SEEN

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BLACK AND WHITE PHOTOGRAPH

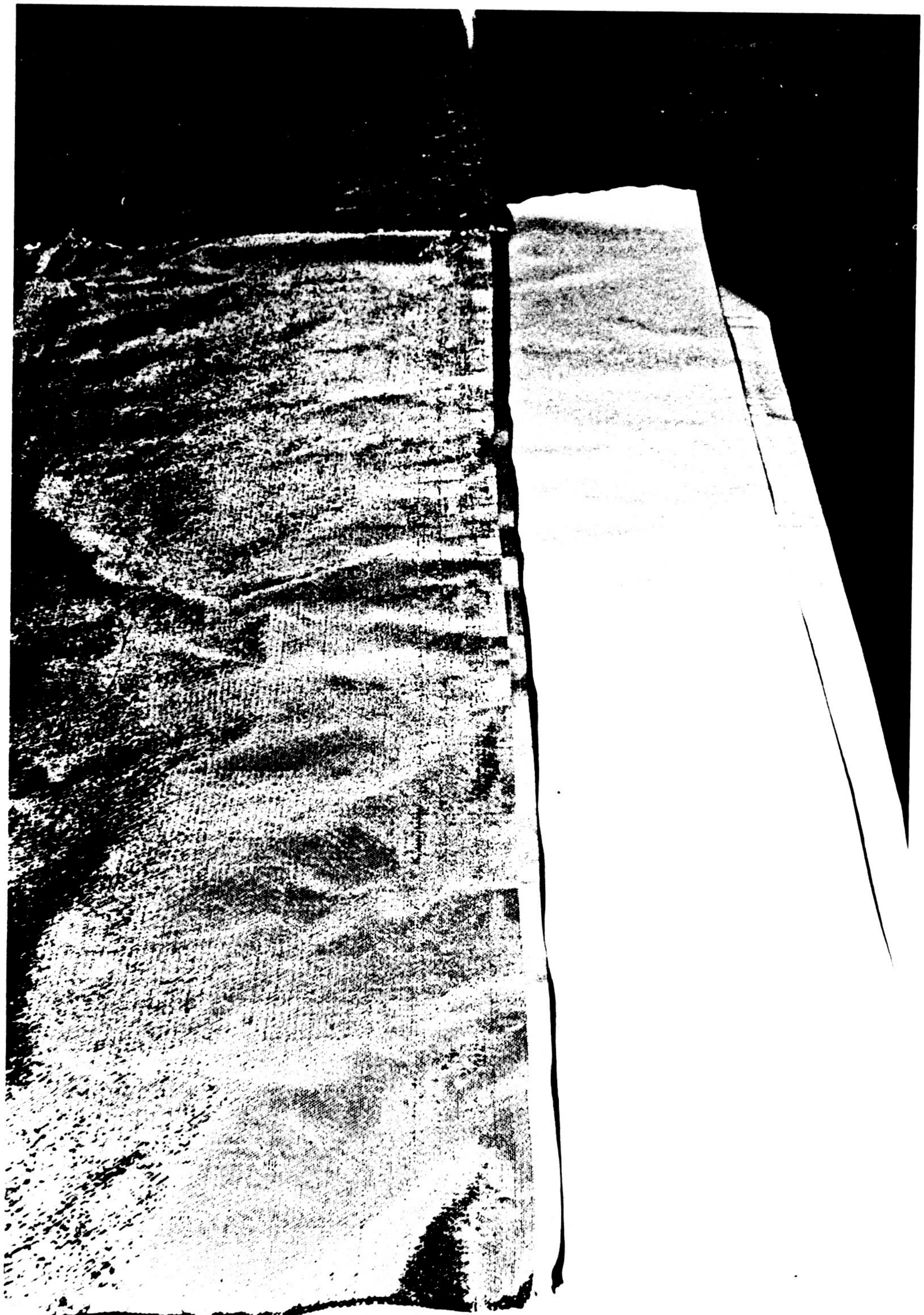


FIGURE 3-47
TRIMMED, COATED EDGE OF SINGLE PLY FABRIC

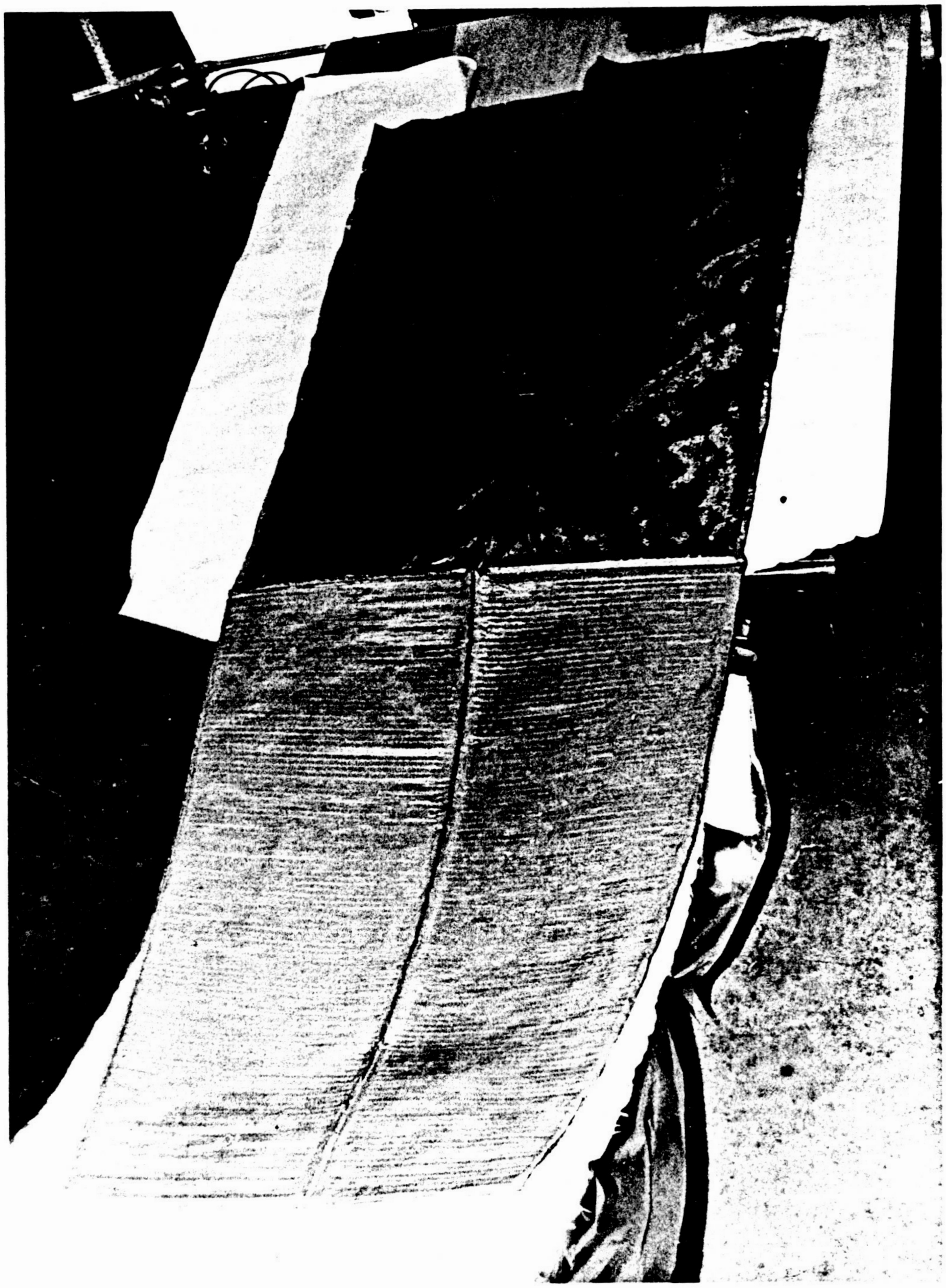
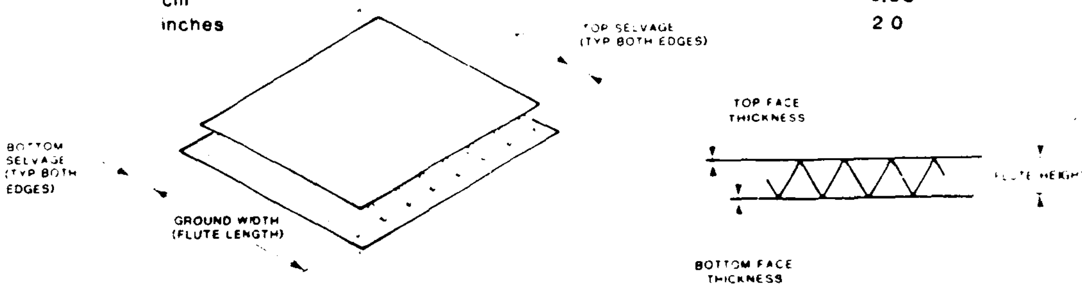


FIGURE 3-48
GORE ASSEMBLY, NEARLY COMPLETED

Table 3-2

CHARACTERISTICS AND DIMENSIONS OF ICAS FABRIC

FLUTED CORE SEGMENT	
FABRIC YARN COUNT (WARP X FILL)	MEASURED VALUES
ASTROQUARTZ FACE	
ENDS/cm X PICKS/cm	9.4 X 10.6
ENDS/inch X PICKS/inch	24.0 X 27.0
NICALON RIBS	
ENDS/cm X PICKS/cm	6.3 X 7.9
ENDS/inch X PICKS/inch	16.0 X 20.0
NICALON FACE	
ENDS/cm X PICKS/cm	6.3 X 9.4
ENDS/inch X PICKS/inch	16.0 X 24.0
FABRIC FACE THICKNESS	
ASTROQUARTZ FACE	
cm	0.025
inches	0.010
NICALON RIB	
cm	0.036
inches	0.014
NICALON FACE	
cm	0.038
inches	0.015
FLUTE HEIGHT (OR CELL HEIGHT)	
cm	1.27
inches	0.5
GROUND WIDTH	
cm	71.1
inches	28.0
EACH SELVAGE, TOP FACE	
cm	2.54
inches	1.0
EACH SELVAGE, BOTTOM FACE	
cm	5.08
inches	2.0



SINGLE PLY SEGMENT (NICALON)	
FABRIC YARN COUNT	
(WARP X FILL)	
ENDS/cm X PICKS/cm	6.3 X 8.7
ENDS/inch X PICKS/inch	16.0 X 22.0
FABRIC THICKNESS	
cm	0.036
inches	0.014
TOTAL WIDTH INCLUDING SELVAGE	
cm	76.2
inches	30.0

Table 3-3 lists these results, and also includes information useful for estimating the total weight of assemblies where dimensions are known.

3.2.9.2 Qualitative judgements were made on flexibility of the TABI fabric used to produce the two-gore assembly. As expected, flexibility of insulation-filled core in the direction where flutes remain essentially straight and parallel to each other, Figure 3-49, (A), is considerably greater than that of core where the flutes are curved, (B). The insulated fluted core segment of the Item 2 ICAS could be curved to a minimum radius of approximately 0.38 meters (1.25 feet) in the (A) direction, and about 1.2 meters (4 feet) in (B). After assembling the two gores, the joint between gores and the closed-out non-mating edges restricted the flexibility in the (A) direction. For example, the TABI assembly with an original radius of nearly 1.5 meters (5 feet) could only be expected to achieve a radius of approximately 0.9 meters (3 feet) without visible damage to the joint stitching. In the (B) direction, the material could not be appreciably flexed beyond its fabricated contour without risking damage to the fabric faces and insulation. Each of the joined gores, however, could be hinged about the tadpole to the extent that the non-mating edges were nearly touching each other, Figure 3-50. The larger the radius of the curvature, the greater the resulting hinge effect. The flexibility characteristics and hinge action will ultimately have a bearing on the design of hardware.

3.2.10 Shipping. After completion, the two-gore assembly was wrapped with polyethylene film. The assembly was placed in a wood crate, protected with a generous quantity of cushioning, sealed and shipped to NASA Ames Research Center.

3.2.11 Health and Safety. During the program, precautions were taken to minimize health risks presented by handling of the materials involved. Potential problems in scaling up to larger assemblies were also considered. Of all the materials, Nicalon and Q-Fiber Felt required the most attention; Nicalon because of its high modulus and fragility, Q-Fiber Felt because of its small filament diameter fibers. When working with silicon carbide yarns and fabrics, especially after heat cleaning almost any contact by the hands, or other skin area, resulted in penetration of irritating slivers. It was important for operators to avoid rubbing other areas

Table 3-3
WEIGHT MEASUREMENTS
FOR ESTIMATING FABRICATED ASSEMBLY WEIGHTS

		THEORETICAL	ACTUAL
FLUTED CORE SEGMENT OF ICAS NICALON FACE & RIBS & ASTROQUARTZ FACE (HEAT CLEANED)			
	kgs/sq meter	1.10	1.11
	oz/sq yd	32.45	32.67
SINGLE PLY NICALON SEGMENT OF ICAS (HEAT CLEANED)			
	kgs/sq meter	0.315	0.322
	oz/sq yd	9.29	9.49
Q-FIBER FELT INSULATION (1/2" NOMINAL THICKNESS)			
	kgs/sq meter	1.22	-
	oz/sq yd	36.0	-
TADPOLE INSULATION NICALON SHROUD WITH NICALON BRAID & Q-FIBER FELT CORE. (HEAT CLEANED)			
	kgs/ lineal meter	0.0594	-
	oz/lineal yd	2.07	-
RTV SILICONE, 0.038 cm (0.015 inch)thick			
	kgs/sq meter	0.54	-
	oz/sq yd	15.95	-

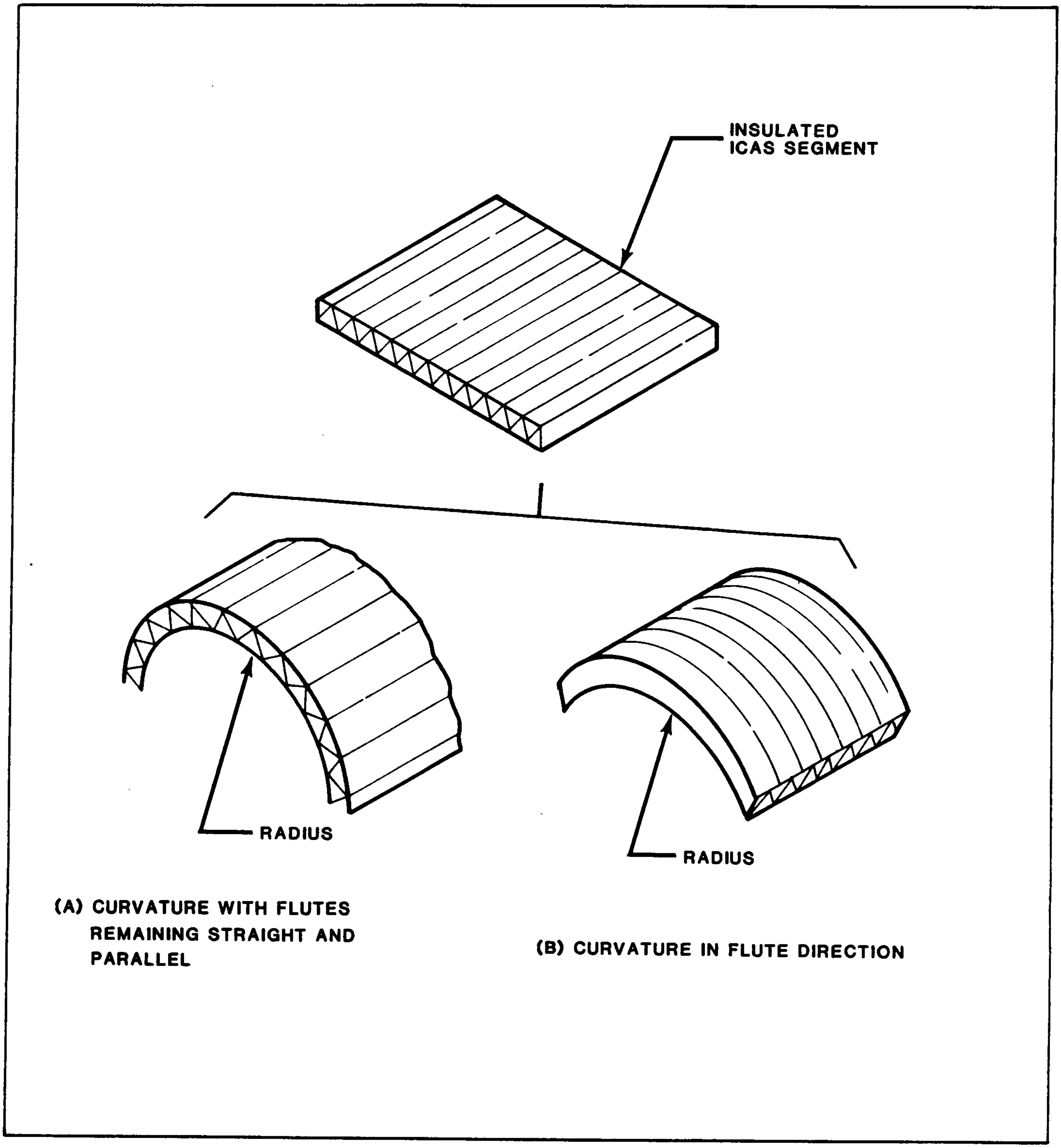


Figure 3-49
FLEXIBILITY OF INSULATED FLUTED CORE FABRIC

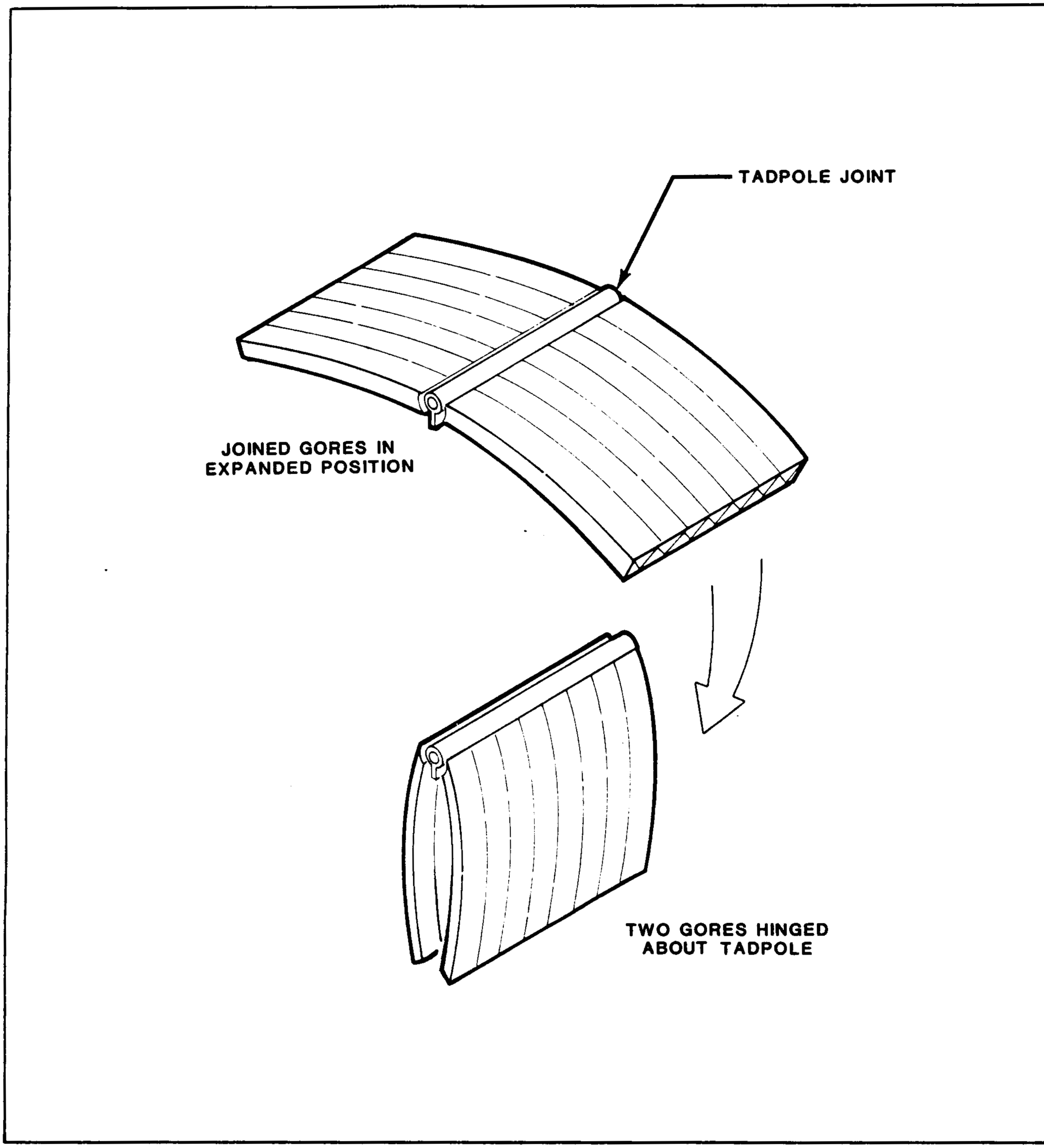


Figure 3-50

HINGED ACTION OF JOINED GORES

of their bodies, especially their eyes. Nitrile rubber gloves were worn by operators during all process steps that required contact with the Nicalon, from yarn preparation to packaging for shipping. Protective sleeves were worn to protect bare arms from exposure. The precautions taken greatly minimized the potential health hazards of handling silicon carbide fibers. Personnel involved with subsequent handling and fabricating should be aware of this hazard. When producing larger assemblies, it may be necessary to provide extensive protection by covering most of the operators' bodies. During sewing, for example, personnel would be working in close proximity to many Nicalon surfaces. It may be desirable, if the application permits, to apply a protective coating to the silicon carbide fabrics.

3.2.11.1 The two operations of most concern involving Q-Fiber Felt were cutting insulation panels into mandrels, and inserting mandrels into the flutes, both of which created dust of short, small diameter filaments. The precautions for these operations involve using a vacuum system on the cutting equipment and requiring the operators to wear adequate dust respirators. While no difficulties were encountered with Astroquartz in this program, it should be recognized that some personnel are susceptible to skin rashes. These can often be prevented by wearing protective clothing. Use of the small quantities of toluene to thin the RTV required a well ventilated area free of ignition sources and presented no problem. Material Safety Data Sheets supplied by the manufacturers are included in the appendices.

4.0 SUMMARY AND CONCLUSIONS

4.1 There were no major problems in producing the forty Item 1 TABI panels prepared from Nicalon woven fluted core. Use of rayon-served Nicalon yarn for filling was found to be unnecessary and this facilitated the production of more tightly woven fluted core fabric. A method was developed for bonding two layers of Q-Fiber Felt to provide insulation panels of the proper thickness and density. Unfortunately, many mandrels cut from the panels separated at the bond during insertion into the core flutes. A procedure for rigidizing the fluted core to reduce the insertion time of insulation mandrels was effective. Insulated panels were heat cleaned at a different time-temperature cycle than in previous programs to reduce the level of smoke generated.

4.1.1 The insulated fluted core segments of two ICAS lengths were cut into gores and assembled into a spherical shape incorporating a tadpole joint. The ICAS fluted core segment consisted of a Nicalon top face and rib, and an Astroquartz bottom face. The single ply segment was woven from Nicalon. Procedures were developed to prepare the gores for assembly, to sew the fabric layers of the joint together with served Astroquartz thread, and to coat the Astroquartz fabric with RTV silicone rubber. After solving mechanical problems on the loom, the fluted core segment wove very well. The Astroquartz face fabric was woven more tightly than planned to reduce porosity. A satisfactory transition zone between the fluted core and single ply segments was designed and incorporated. Development included an effort to braid a Nicalon tube around Q-Fiber Felt, encase the braid in a silicon carbide fabric shroud attached to the mating gores, and stitch the tails of the fabric together. The stitching was accomplished with a modified industrial sewing machine. The resulting tadpole joint exhibited a desirable hinge action. Heat cleaning the Astroquartz sewing thread reduced its strength considerably but not sufficiently to cause separation at the joints. Several methods for coating with RTV were investigated, and brushing proved the most effective. A third of the overlapping length of single ply Nicalon fabrics was joined together by stitching, a third by bonding with RTV, and the final third left unbonded. Both items of the effort were characterized. Weaving ICAS fabric, insulating the flutes to form TABI, and joining gores to form contoured shapes appears to be feasible. The program to achieve the objectives of both items was successful.

5.0 RECOMMENDATIONS

5.1 Recommendations to be considered for future efforts are as follows:

(1) If future TABI panels are to be made with flute heights requiring multiple plies of Q-Fiber Felt, an effort should be made to develop an improved method for bonding the layers. Some modification of the technique already developed may be successful.

(2) Additional efforts to develop and improve assemblies with tadpole joints should include the following:

1) Investigate alternate methods for fabricating the joints. For example, some advantages may be gained by

preassembling the tadpole before sewing the joint. Using a bias fabric shroud for the braid to improve flexibility should be evaluated.

2) Rigidizing fluted core fabric prior to inserting insulation mandrels was beneficial to this operation. However, this resin treatment resulted in greater difficulty when removing ribs from the joining areas of the gores. Rigidizing the core only in areas to be filled with insulation should be attempted.

3) Because of the deterioration of heat cleaned Astroquartz sewing thread, other materials and procedures should be investigated. A heavier Astroquartz thread may be adequate and should be evaluated, as should other high temperature ceramic candidates. If a small amount of high thermal conductivity material is permissible, metal thread should be considered. Stainless steel, or other high temperature metal sewing thread, would provide stronger, more abrasion resistant stitching for the joints. Conceivably new ceramic yarns now under development may also become available for evaluation as sewing thread.

4) While the modified sewing machine used in the program was able to stitch most of the requirements, accessibility to all parts of the seam lines was impossible because of the unit's remaining protrusions and physical size. A future program should include the search for a more suitable machine.

5) The brush coating process for applying RTV was effective, but tedious. Other silicone rubber materials should be evaluated as should potentially faster application methods.

6) Although the insulation mandrel insertion rate was increased, considerably more improvement is necessary. A program should be considered to develop undersized mandrels that can be inserted into flutes with a minimum of resistance caused by friction or tight ends. The mandrels should be capable of expanding to fill the flutes when heat treated. Other methods for filling flutes with insulation should also be considered.

7) Consideration should be given to a program that addresses the stowage requirements of the potential end applications. Design and feasibility studies should be made on methods to provide compaction of TABI. This would probably include developing techniques to form different types of joints, or by other means, to

allow the assembly to be packaged into a relatively small space, and then expanded to its final shape upon demand. It is conceivable that joints, or other connecting means, may be required to permit TABI panels to be folded accordian style. Joints normal to the flutes may also be required. A program of this type would probably be of significant magnitude, and would undoubtedly involve coordination with those involved in the development of the expanding mechanisms.

6.0 LIST OF APPENDICES

A. Manufacturer's Literature and Material Safety Data Sheet for Nicalon Yarn.

B. Manufacturer's Literature and Material Safety Data Sheet for Q-Fiber Felt.

C. Manufacturer's Literature and Material Safety Data Sheet for Astroquartz Yarn.

D. Manufacturer's Literature and Material Safety Data Sheet for Astroquartz Sewing Thread.

E. Manufacturer's Literature and Material Safety Data Sheet for Carboset.

F. Manufacturer's Literature and Material Safety Data Sheet for RTV 560 Silicone Rubber Compound.

Appendix A

Manufacturer's Literature and Material Safety Data Sheet for Nicalon.

New Product Information

DOW CORNING

DESCRIPTION

NICALON® fiber is a new type of silicon carbide fiber manufactured through a polymer pyrolysis process by Nippon Carbon Co., Ltd., of Japan. It is homogeneously composed of ultrafine β-SiC crystals with excess carbon. The fiber has excellent strength and modulus properties. It retains its properties at high temperatures. NICALON fiber is highly resistant to oxidation and chemical attack. The fiber is readily wet by organic resins and metals.

USES

NICALON fiber can be used as a reinforcement for plastic, metal and ceramic matrices to form high performance composite materials. It can also be used to form fibrous products such as high temperature insulation, belting, curtains, gaskets, etc. Its resistance to chemical attack allows it to be used in highly corrosive environments.

NICALON® is a registered trademark of Nippon Carbon Co., Ltd., Japan.

NICALON® SILICON CARBIDE FIBERS

Type	Silicon carbide
Physical Form	Fiber
Primary Uses	Reinforcement for plastic, metal or ceramic matrices; to form fibrous material

NOMINAL PROPERTIES OF NICALON FIBER
These values are not intended for use in preparing specifications.

Filament Diameter	10~20 μm
Cross Section	Round
Filaments/Tow	500
Count	200 tex
Density	0.092-0.094 lb/in³ (2.55-2.56 g/cm³)
Tensile Strength	360~470 ksi (250~330 kg/mm²)
Tensile Modulus	26~29 × 10³ ksi (18~20 × 10³ kg/mm²)
Strain to Failure	1.5% Average
Thermal Conductivity	10 Kcal/mhr °C (Along fiber axis @ RT)
Specific Resistivity	~10³ ohm cm
Coefficient of Thermal Expansion	3.1 × 10⁻⁶/°C (Along fiber axis, 0-200°C)

Specification Writers: Please contact Dow Corning Corporation, Midland, Michigan, before writing specifications on this product.

Plastic Matrix Composites

NICALON fiber may be utilized to reinforce plastic matrix materials. The fiber is nonelectrically conductive so corrosion of metals is not enhanced when in contact with its composites nor should electrical grounding problems arise from free fibers. NICALON fiber/epoxy composites show improved compressive, impact and interlaminar sheer strength and thermal expansion compatibility over common graphite/epoxy composites. The unique electrical properties of NICALON fiber may lead to specialized aerospace applications. The oxidation resistance of NICALON fiber makes it a candidate for high temperature plastic composites. (See Tables 2 and 3.)

Metal Matrix Composites

NICALON fiber is an excellent choice as a reinforcement for metal matrix composites. The fiber is readily wet by metals. The fiber can easily be woven into cloth and preformed shapes. This allows composite design and manufacturing methods to be tailored to best suit potential applications. NICALON fiber's good specific strength and modulus, and the retention of these properties as high temperatures, result in improved metal composite properties. Since the fiber is nonelectrically conductive it does not enhance metal corrosion. NICALON chopped fiber used as discontinuous reinforcement for metals could enable composites to be postformed by conventional metal-working techniques. (See Table 4.)

TABLE 2: TYPICAL PROPERTIES OF NICALON FIBER/EPOXY RESIN COMPOSITES*

Tensile Strength(0°)	215 ksi (150 kg/mm²)
Tensile Modulus	18.5 × 10³ ksi (13 × 10³ kg/mm²)
Flexural Strength (0°)	285 ksi (200 kg/mm²)
Flexural Modulus	17.1 × 10³ ksi (12 × 10³ kg/mm²)
Compressive Strength	257 ksi (180 kg/mm²)
Interlaminar Shear Strength	17.1 ksi (12 kg/mm²)
Charpy Impact Strength	1450 lb-in/in² (260 kg-m/mm²)
Coefficient of Thermal Expansion,	
(0°)	2.6 × 10⁻⁶/°C
(90°)	20 × 10⁻⁶/°C
Density	0.073 lb/in³ (2.0 g/cm³)

*Shell DX 210 epoxy, 60 v/o fiber.

TABLE 3: TYPICAL NICALON 8 HARNESS SATIN/POLYIMIDE COMPOSITE PROPERTIES

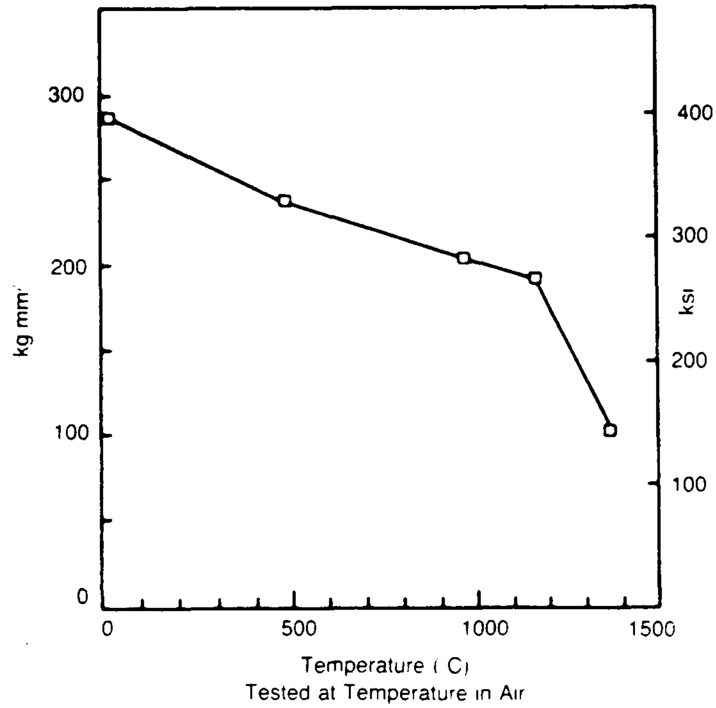
	SHELL DX 210 EPOXY	*POLYIMIDE*
Fiber Volume Fraction, %	45	45
Density, g/cc	1.80	1.85
Tensile Strength, kg/mm²	57	52
Flexural Strength, kg/mm²	95	92
I.L.S.S., kg/mm²	6.7	5.6

TABLE 4: TYPICAL PROPERTIES OF NICALON FIBER/UNIDIRECTIONALLY REINFORCED 1100 ALUMINUM COMPOSITES ($V_f = 35\%$)

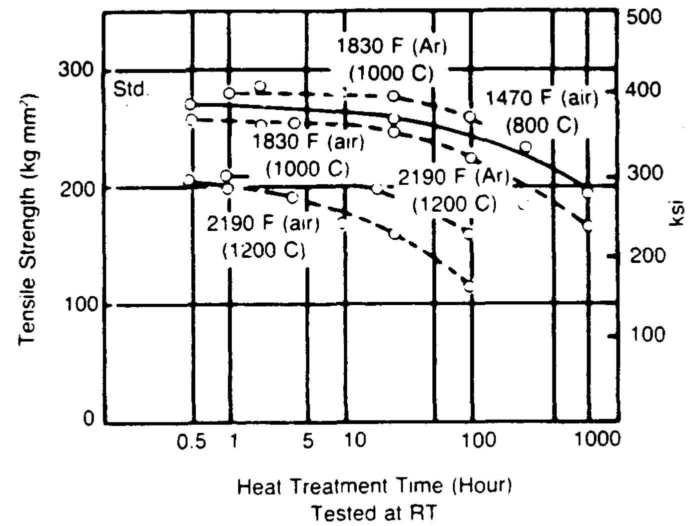
Tensile Modulus (0°)[1]	14~16 × 10³ ksi (10~11 × 10³ kg/mm²)
Tensile Strength	
(0°)	114~129 ksi (80~90 kg/mm²)
(90°)[2]	10~11 ksi (7~8 kg/mm²)
Flexural Strength[3]	143~157 ksi (100~110 kg/mm²)
Flexural Fatigue Strength (10⁷ cycle)	57 ksi (40 kg/mm²)
Coefficient of Thermal Expansion[4]	
(0°)	3.2 × 10⁻⁶/°C
(90°)	25 × 10⁻⁶/°C
Density	0.095 lb/in³ (2.6 g/cm³)
Poisson Ratio	0.18

[1] Fiber axis direction.
[2] Perpendicular direction to fiber axis.
[3] Three-point method.
[4] 212~392°F (100~200°C)

GRAPH 1: TENSILE STRENGTH OF NICALON FIBER



GRAPH 2: TENSILE STRENGTH OF NICALON FIBER AFTER HEAT TREATMENT



Ceramic Matrix Composites

NICALON silicon carbide fiber should be considered as a reinforcement for ceramic matrices. Its combination of high strength, high modulus, low density, oxidation resistance, chemical resistance and retention of properties at high temperatures make it ideal for ceramic composites to be used in severe environments.

Present work in NICALON fiber glass composites has shown encouraging results. NICALON fiber could potentially be used to form oxidation resistant composites. (See Table 1.)

TABLE 1: PROPERTIES OF 50 VOL % NICALON FIBER REINFORCED LITHIUM ALUMINUM SILICATE (LAS) COMPOSITES

Property	*0*	*0/90*
Density (g cm ³)	2.5	2.5
Flexural Strength (MPa)		
RT	600	380
800 C (1472 F)	800	410
1000 C (1832 F)	850	480
Fracture Toughness – K_{IC} (MN m)		
RT	17	10
1000 C (1832 F)	25	12
Thermal Expansion (10 C)	2.2	1.6 (90)
Thermal Conductivity		
(cal sec cm C)	3.5 · 10	3.5 · 10
(W m K)	1.465	1.465

Source: Karl M. Prewo, John J. Brennan, *J. Mat. Sci.*, XVII, (1982), 2371-2383

IMPORTANT INFORMATION ON STORAGE AND HANDLING

NICALON fiber products have indefinite shelf life.

Handling (Caution)

No special precautions need to be taken when handling NICALON fiber products other than those normally associated with inorganic fibers. Gloves and safety glasses are recommended.

PACKAGING

NICALON fiber is available as continuous yarn wound on bobbins. Each bobbin holds a minimum of 0.1 kg of fiber. All NICALON fiber products are shipped in cardboard containers with appropriate packing.

PRODUCT AVAILABILITY

NICALON silicon carbide fiber products are presently available through Dow Corning Corporation. Continuous fiber, chopped fiber and woven goods are available.

ORDERING

For information, please contact:
Michael Ladenburger
Product Market Supervisor
Dow Corning Corporation
Midland, MI 48686-0995
(517) 496-4814

USERS PLEASE READ

The information and data contained herein are believed to be accurate and reliable; however, it is the user's responsibility to determine suitability of use. Since Dow Corning cannot know all of the uses to which its products may be put or the conditions of use, it makes no warranties concerning the fitness or suitability of its products for a particular use or purpose.

You should thoroughly test any proposed use of our products and independently conclude satisfactory performance in your application. Likewise, if the manner in which our products are used requires governmental approval or clearance, you must obtain it.

Dow Corning warrants only that its products will meet its specifications. There is no warranty of merchantability or fitness for use, nor any other express or implied warranty. The user's exclusive remedy and Dow Corning's sole liability is limited to refund of the purchase price or replacement of any product shown to be otherwise than as warranted. Dow Corning will not be liable for incidental or consequential damages of any kind.

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DOW CORNING CORPORATION
MIDLAND, MICHIGAN 48640-0994

DOW CORNING

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WS-8817

NIPPON CARBON CO., LTD.

6-1, HACHI-CHOBORI 2-CHOME, CHUO-KU, TOKYO, JAPAN
TELEPHONE: 552-6111, CABLE ADDRESS: NCKCARBON TOKYO
TELEX: 252-2868 NCK J

Inspection Sheet of SiC Fiber "NICALON"

To Messrs. Dow Corning Corporation

1. Product identification: Ceramic Grade NLP-201
2. Quantity: 100 Kg
3. Date of manufacture: Jan. Apr. 1985
4. Date of shipment: May. 1985
5. PO number: 38082
6. NCK invoice number: —
7. Lot number: 021B 022 022B 029B 030 031
8. Spool number:

Lot number	021B	022	022B	029B	030	031
Spool number	502158 ~502174	502989 ~503094	502175 ~502244	502245 ~502553	502554 ~502761 503095 ~503157	502762 ~502968

9. Specification:

Filaments/yarn : 500
Length of yarn : 500m
Density : 2.55g/cm3
Weigth percent of sizing resin : 1.5±0.5 %

10. Test data:

Test identification \ Lot No.		021B	022	022B	029B	030	031
Tex count	(gr/1000m)	219	210	200	206	210	208
Tensile Strength‡	(ksi)	399	398	382	433	432	423
	(kg/mm2)	281	280	269	305	304	298
Tensile Modulus‡	(×1000 ksi)	29.2	28.5	29.2	28.2	28.8	29.7
	(×1000 kg/mm2)	20.5	20.0	20.5	19.8	20.2	20.8
Oxygen Content	(%)	12.0	11.9	13.0	9.8	10.5	9.7

‡ by resin impregnated strand method (JIS R 7601, ASTM D 2344, AMS 3892)

Nippon Carbon Co., Ltd. Yokohama Plant
NICALON Products

by T. Kobayashi
T. Kobayashi Manager

NIPPON CARBON CO., LTD.

6-1, HACHI-CHOBORI 2-CHOME, CHUO-KU, TOKYO, JAPAN
TELEPHONE: 552-6111, CABLE ADDRESS: NCKCARBON TOKYO
TELEX: 252-2665 NCK J

Inspection Sheet of SiC Fiber "NICALON"

To Messrs. Dow Corning Coporation

1. Product identification: Ceramic Grade NLP-201
2. Quantity: 60 Kg
3. Date of manufacture: jul.Nov.1984. Jan.1985.
4. Date of shipment: Mar. 1985
5. PO number:
6. NCK invoice number: -
7. Lot number: 017 019B 022
8. Spool number: 501094~501585 501586~501662 501663~501693

9. Specification:

Filaments/yarn : 500
Length of yarn : 500m
Density : 2.55g/cm3
Weigth percent of sizing resin : 1.5±0.5%

10. Test data:

Test identification \ Lot No.		017	019B	022
Tex count	(gr/1000m)	207	218	208
Tensile Strength*	(ksi)	444	403	398
	(kg/mm2)	313	284	280
Tensile Modulus*	(×1000 ksi)	28.2	27.9	28.2
	(×1000 kg/mm2)	19.8	19.6	19.8
Oxygen Content	(%)	11.4	10.5	11.9

* by resin impregnated strand method (JIS R 7601, ASTM D 2344, AMS 3892)

Nippon Carbon Co., Ltd. Yokohama Plant
NICALON Products

by T. Kobayashi
T. Kobayashi Manager

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TAG # 27365

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- 6

HITCO
WOVEN STRUCTURES DIV
618 W CAROB ST
COMPTON, CA 90220

DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

MATL NAME: NICALON(R) CONTINUOUS FIBER P
EMERGENCY TELEPHONE NO. (517) 496-5900

SECTION I - GENERAL INFORMATION

MANUFACTURERS NAME: DOW CORNING CORPORATION
ADDRESS: SOUTH SAGINAW ROAD, MIDLAND MI 48686

PROPER SHIPPING NAME(49CFR 172.101): NONE
D.O.T. HAZARD NAME(49CFR 172.101): NONE
D.O.T. ID NO(49CFR 172.101): NONE
D.O.T. HAZARD CLASS(49CFR 172.101): NONE
RCRA HAZARD CLASS(40CFR 261)(IF DISCARDED): NONE
E.P.A. PRIORITY POLLUTANTS(40CFR 122.53): NONE
NFPA = NATIONAL FIRE PROTECTION ASSOCIATION - 704
HEALTH (NFPA): 1 FLAMMABILITY (NFPA): 0 REACTIVITY (NFPA): 0
CAS NO: ARTICLE DOW CORNING WARNING CODE: NONE
GENERIC DESCRIPTION: SILICON CARBIDE

SECTION II - HAZARDOUS INGREDIENT

NONE PRESENT % TLV (UNITS):

ONLY THOSE INGREDIENTS LISTED IN THIS SECTION HAVE BEEN DETERMINED TO BE HAZARDOUS AS DEFINED IN 29 CFR 1910.1200. AN INGREDIENT MARKED WITH AN ASTERISK(*) IS ALSO LISTED IN 29 CFR 1910.1200(D) #4 AS KNOWN OR SUSPECTED CARCINOGEN.

COMMENT:NONE

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DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

MATL NAME: NICALON(R) CONTINUOUS FIBER P

SECTION III - EFFECTS OF OVEREXPOSURE

EYES: FIBERS MAY CAUSE SLIGHT MECHANICAL IRRITATION IF RUBBED INTO THE EYE.

SKIN: LIKE MOST SHARP FIBER MATERIAL, SLIGHT SKIN IRRITATION MAY OCCUR.

INHALATION: NOSE AND THROAT IRRITATION MAY OCCUR. PROLONGED OR FREQUENTLY REPEATED EXPOSURES MAY CAUSE SLIGHT INJURY.

ORAL: AMOUNTS TRANSFERRED TO THE MOUTH BY FINGERS, ETC., DURING NORMAL OPERATIONS SHOULD NOT CAUSE INJURY.

COMMENT: NO KNOWN ADVERSE CHRONIC HEALTH EFFECTS, BUT UNNECESSARY EXPOSURE TO ANY CHEMICAL SHOULD BE AVOIDED.
THIS PRODUCT, AS WITH ANY CHEMICAL, MAY ENHANCE ALLERGIC CONDITIONS ON CERTAIN PEOPLE. WE DO NOT KNOW OF ANY MEDICAL CONDITIONS THAT MIGHT BE AGGRAVATED BY EXPOSURE TO THIS PRODUCT.

SECTION IV - EMERGENCY AND FIRST AID PROCEDURES

EYES: FLUSH WITH WATER.

SKIN: FREQUENT RINSING WITH WATER TO REMOVE ACCUMULATED FIBER WILL MINIMIZE IRRITATION.

INHALATION: NO PROBLEM.

ORAL: NO PROBLEM.

COMMENT: NONE.

SECTION V - FIRE AND EXPLOSION DATA

FLASH POINT (METHOD USED): OPEN/CLOSED - NONE
AUTOIGNITION: NONE
FLAMMABILITY LIMITS IN AIR : LOWER:N UPPER: N

EXTINGUISHING MEDIA: WATER WATER FOG X CO2 X DRY CHEMICAL X FOAM X OTHER

SPECIAL FIRE FIGHTING PROCEDURES: SELF_CONTAINED BREATHING APFRARATUS AND PROTECTIVE CLOTHING SHOULD BE WORN IN FIGHTING FIRES INVOLVING CHEMICALS

UNUSUAL FIRE AND EXPLOSION HAZARDS: NONE KNOWN TO DOW CORNING.

COMMENTS: N=NOT A PROBLEM.

SECTION VI - PHYSICAL DATA

BOILING POINT(@ 760 MM HG): NOT APPLICABLE
SPECIFIC GRAVITY (AT 77 DEG F/25 DEG C): NOT APPLICABLE
MELTING POINT: NOT APPLICABLE
VAPOR PRESSURE (AT 77 DEG F/25 DEG C): NOT APPLICABLE
VAPOR DENSITY (AIR = 1 AT 77 DEG F/25 DEG C): NOT APPLICABLE
PERCENT VOLATILE BY VOLUME (%): NOT APPLICABLE
EVAPORATION RATE (ETHER = 1): NOT APPLICABLE
SOLUBILITY IN WATER(%): LESS THAN 0.1%
ODOR, APPEARANCE, COLOR: NO ODOR, THREAD, DARK COLOR.

NOTE: THE ABOVE INFORMATION IS NOT INTENDED FOR USE IN PREPARING PRODUCT SPECIFICATIONS. CONTACT DOW CORNING BEFORE WRITING SPECIFICATIONS

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DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

MATL NAME: NICALON(R) CONTINUOUS FIBER P

DEC - 6

SECTION VII - REACTIVITY DATA

STABILITY: STABLE

INCOMPATABILITY(MATERIAL TO AVOID): OXIDIZING MATERIAL CAN CAUSE A REACTION.

CONDITIONS TO AVOID: NOT APPLICABLE

HAZARDOUS DECOMPOSITION PRODUCTS: NONE

HAZARDOUS POLYMERIZATION: WILL NOT OCCUR

CONDITIONS TO AVOID: NOT APPLICABLE

COMMENTS: NONE

SECTION VIII - SPILL, LEAK AND DISPOSAL PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: NO PROBLEM.

PROTECTIVE EQUIPMENT:
EYES: USE CHEMICAL WORKER GOGGLES.

SKIN: AVOID CONTACT BY USING IMPERVIOUS PROTECTIVE CLOTHING: RUBBER OR PLASTIC GLOVES, APRONS, BOOTS, ETC. USE PROTECTIVE GLOVES AS A MINIMUM AND WASH IMMEDIATELY UPON ANY DETECTABLE CONTACT.

INHALATION: NO RESPIRATORY PROTECTION REQUIRED.

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. (49CFR 171.8)/E.P.A. (40CFR 117) SPILL REPORTING INFORMATION
HAZARDOUS SUBSTANCE: NONE REPORTABLE QUANTITY: NOT APPLICABLE
CONCENTRATION OF HAZARDOUS SUBSTANCE: NOT APPLICABLE
REPORTABLE QUANTITY OF PRODUCT: NOT APPLICABLE

COMMENTS: NONE

SECTION IX - ROUTINE HANDLING PRECAUTIONS

PROTECTIVE EQUIPMENT:
EYES: USE PROPER PROTECTION -- SAFETY GLASSES, AS A MINIMUM.

SKIN *: AVOID CONTACT BY USING IMPERVIOUS PROTECTIVE CLOTHING: RUBBER OR PLASTIC GLOVES, APRONS, BOOTS, ETC. USE PROTECTIVE GLOVES AS A MINIMUM AND WASH PROMPTLY UPON ANY DETECTABLE CONTACT.

INHALATION: NO RESPIRATORY PROTECTION REQUIRED.

VENTILATION:
LOCAL EXHAUST: NONE
MECHANICAL (GENERAL): NONE

SUITABLE RESPIRATOR: NONE SHOULD BE NEEDED.

THESE PRECAUTIONS ARE FOR ROOM TEMPERATURE HANDLING, USE AT ELEVATED TEMPERATURE MAY REQUIRE ADDED PRECAUTIONS.
* GOOD PRACTICE REQUIRES THAT GROSS AMOUNT OF ANY CHEMICAL BE REMOVED FROM THE SKIN AS SOON AS PRACTICAL, ESPECIALLY BEFORE EATING OR SMOKING.
COMMENTS: NONE

SECTION X - SPECIAL PRECAUTIONS

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

OTHER PRECAUTIONS: NONE KNOWN TO DOW CORNING.
COMMENTS: NONE.

F-022

DOW CORNING CORPORATION
MATERIAL SAFETY DATA SHEET

MATL NAME: NICALON(R) CONTINUOUS FIBER P

THESE DATA ARE OFFERED IN GOOD FAITH AS TYPICAL VALUES AND NOT AS A PRODUCT SPECIFICATION. NO WARRANTY, EITHER EXPRESSED OR IMPLIED, IS HEREBY MADE. THE RECOMMENDED INDUSTRIAL HYGIENE 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: JACK L. SHENEBERGER
LAST REVISION DATE: OCTOBER 11, 1985
PREVIOUS REVISION DATE: MARCH 19, 1984
DATE: NOVEMBER 15, 1985
(R) INDICATES REGISTERED OR TRADEMARK OF THE DOW CORNING CORPORATION.

DEC - 6

Appendix B

Manufacturer's Literature and Material Safety Data Sheet for Q-Fiber Felt.

Johns-Manville **Aerospace Insulation** **Q-Fiber® Felt**

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Type: Binderless Felt
Temp. Limit: 1800° F

Description

Q-Fiber felt is made by water deposition of fine, 98.5+% pure silica fibers. It is clean, flexible, without binder of any kind, and possesses the thermo-physical and chemical stability of pure silica. Q-Fiber felt is sufficiently strong for effective application. It is unaffected by moisture; will not accelerate or cause corrosion; is inert to most acids.

Available Forms

Q-Fiber felt is available in 36"-wide sheets in lengths of 60" and 120", and thicknesses of 3/16" and 1/2". Q-Fiber is also made in bulk form.

Advantages

Strong. The average tensile strength per inch of width for 3/16" felt, tested in either direction, is 150 grams or 1.8 pounds per square inch.

Moisture-resistant. Q-Fiber felt is unaffected by moisture.

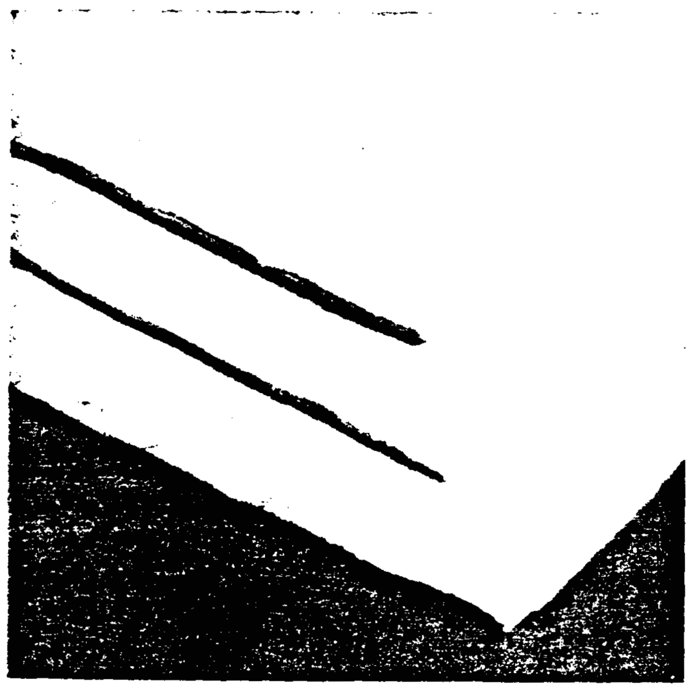
Non-corrosive. Q-Fiber felt will not accelerate or cause corrosion.

Durable. The chemical composition of Q-Fiber makes it incombustable and resistant to most acids.

Low Thermal Conductivity. Q-Fiber felt possesses the lowest kp (conductivity × density) value of any commercially available high temperature fibrous insulation.

Excellent Sound Absorption. The long, fine fibers trap and absorb undesirable sound.

High Heat Resistance. Q-Fiber felt is effective up to 1800° F for steady state applications.



Application

Q-Fiber in felted form is useful in many applications requiring high heat resistance, being effective up to, and in many cases above, 1800° F for steady state applications. It is excellent thermal insulation for aircraft, missiles, spacecraft and special industrial applications. It is also designed to provide reinforcement for high-temperature plastics such as exhaust nozzles, nose cones, and aerodynamically heated surfaces. It is particularly useful in components where the factors of space and weight are of prime importance.

[redacted]

Chemical Composition

Silica — SiO_2	98.50% Minimum
Boron — B*	.01% Maximum
Iron — Fe	.06% Maximum
Alumina — Al_2O_3	.50% Maximum
Calcium Oxide — CaO	.35% Maximum
Magnesium Oxide — MgO	.35% Maximum
Sodium Oxide — Na_2O	.15% Maximum

*The low boron content, normally less than .005%, makes Q-Fiber particularly useful for thermal control in nuclear applications.

Thermal Conductivity (Btu-In)/(Sq Ft-Hr-°F)

Density Lbs./Cu. Ft.	Mean Temp. °F							
	300	400	500	600	700	800	900	1000
3.0	.36	.43	.50	.57	.65	.73	.82	.91
3.5	.33	.39	.46	.53	.60	.67	.75	.83
6.0	.30	.34	.39	.44	.50	.56	.62	.68

Shrinkage and Weight Loss

Q-Fiber felt undergoes shrinkage and weight loss at high temperatures. The table below indicates average laboratory test values.

Temperature	Linear Shrinkage, %
1000°F	0.7
1200°F	1.4
1400°F	1.8
1600°F	2.0
1800°F	2.6
2000°F	6.2

Standard Sizes

Nominal thickness*	3/16" and 1/2"
Sheet length	60" and 120" +1/2" −0"
Sheet width	36" +1/2" −0"

*Other thicknesses down to 1/8" and up to 1" are available on special order.

Density and Weight

Nominal Thickness Inches	Nom. Den. Lbs./Cu. Ft.	Nom. Weight Lbs./Sq. Ft. ±10%
3/16	3.0	.047
1/2	3.5	.146
3/16	6.0	.094
1/2	6.0	.250

Johns-Manville
Ken-Caryl Ranch
Denver, Colorado 80217

For information on other Aerospace Insulation, write to Johns-Mansville Aerospace Department or call (303) 979-1000 Ex. 2334 or Ex. 3280.

The physical properties of Johns-Manville Q-Fiber felt represent typical, average values obtained in accordance with accepted test methods and are subject to normal manufacturing variations. They are supplied as a technical service and are subject to change without notice. Check the Johns-Manville district office to assure current information.

AI-8 4-80

Manville Sales Corporation
PO Box 517
Toledo, Ohio 43693
419 878-8111

Manville

April 9, 1986

Woven Structures
Hitco
618 W. Carob Street
Compton, CA 90220

Gentlemen:

This is to certify that Manville Sales Corp.'s standard inspection procedure has been used in the inspection of the material covered by this order. This inspection indicates that the material tested for Manville Sales Corp. Order No. G92 ZK 00525, your Order No. WS 7037 complies with the applicable finished product requirements of Manville Sales Corp.

Very truly yours,

R. J. Szymanski
Quality Control Manager

RJS/dn

Certified in triplicate

SEE WSI STATUS
TAG # 27356

Manville Building Materials Group
PO Box 517
Toledo, Ohio 43693
419 878-8111

Manville

December 4, 1985

Woven Structures
Hitco
618 W. Carob Street
Compton, CA 90220

Attn: Dick Pusch

This is to certify that we have reviewed the manufacturing records for the time periods associated with the production codes of the material supplied on Manville Order No. G92 ZK 01910, your Order No. 36160. These records of the normal inspection procedures indicate that the material was produced in accordance with the general requirements of Manville's manufacturing specification for Q Felt 4363-72. This is to further certify that the material supplied was warehoused in compliance with the applicable storage requirements of Manville.

Very truly yours,

R. J. Szymanski
Quality Control Manager

RJS/dn

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RECEIVING INSPECTION

SEE WSI STATUS
TAG # 17271

Certified in triplicate

DEC - 9 1985

MATERIAL SAFETY DATA SHEET

MC X-01046

MSDS NUMBER
FM 2822/IP 4614

PRODUCT IDENTIFICATION

TRADE NAME
Micro-Fiber/Micro-Quartz Felt, Q-Felt

GENERIC NAME
Fibrous Glass

MANUFACTURER'S NAME
Manville Building Materials Corporation

CAS NUMBER
65997-17-3

ADDRESS (STREET)
P. O. Box 5108

PHONE NUMBER
(303) 978-3120

CITY
Denver

STATE
Colorado

ZIP
80217

CHEMICAL STRUCTURE

I • PRODUCT INGREDIENTS

MATERIAL	CAS NUMBER	%	TLV
Fibrous Glass	65997-17-3	100	30*mppcf
			10 mg/m3
			Total dus

*While OSHA considers glass microfibers to be a nuisance dust (TLV 30 mppcf or 10 mg/m3 total dust), Manville recommends a TLV of 2 f/cc for fibers longer than 10 micrometers.

II • PHYSICAL DATA

BOILING POINT
N/A

SPECIFIC GRAVITY

SOLUBILITY IN WATER
Nil

PERCENT VOLATILE

APPEARANCE AND ODOR
White fibrous felt - no odor.

III • FIRE AND EXPLOSION DATA

FLASH POINT
Nonflammable

FLAMMABLE LIMITS | LEL | UEL

EXTINGUISHING MEDIA
N/A

SPECIAL FIREFIGHTING PROCEDURES

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UNUSUAL FIRE OR EXPLOSION HAZARDS
None

IV • HEALTH HAZARD INFORMATION

HAZARD BY ROUTES OF EXPOSURE (Indicate chronic or acute)

INHALATION Based on the current data available there are no known acute or chronic health hazards.

INGESTION
None

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EYE
Transient mechanical irritant.

SKIN CONTACT
Transient mechanical irritant.

SKIN ABSORPTION
None

SIGNS AND SYMPTOMS ASSOCIATED WITH EXPOSURE OVER TLV Inhalation - excessive exposure to product dust may cause upper respiratory irritation.

Eye - temporary irritation or inflammation.

Skin - temporary irritation or rash.

HEALTH HAZARD INFORMATION CONTINUED ON BACK

V • HEALTH HAZARD INFORMATION (Continued)

FIRST AID

INHALATION
Remove to fresh air.

INGESTION
N/A

EYE CONTACT
Flush with copious quantities of water. If irritation persists consult a physician.

SKIN CONTACT
Wash exposed areas with soap and warm water.

SKIN ABSORPTION

VI • CONDITIONS FOR SAFE USE (When over TLV)

RESPIRATORY PROTECTION
Use a respirator suitable for protection against nuisance dust.

EYE PROTECTION
Goggles are recommended.

PROTECTIVE GLOVES
Not normally required.

OTHER PROTECTIVE CLOTHING/EQUIPMENT

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VENTILATION REQUIREMENTS
Recommended at source of any mechanical cutting.

VII • REACTIVITY DATA

IS MATERIAL STABLE? Yes	WILL HAZARDOUS POLYMERIZATION OCCUR? No
INCOMPATIBILITY Hydrofluoric acid	CONDITIONS TO AVOID

HAZARDOUS DECOMPOSITION PRODUCTS

VIII • SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATEIAL IS SPILLED OR RELEASED
Vacuum clean dust. If sweeping is necessary use a dust suppressant.

WASTE DISPOSAL METHOD
Normal practice

LABELING REQUIRED? Yes	DOT REGULATED?	DOT NUMBER
RCRA REGULATED? No	RCRA NUMBER	

IX • SPECIAL PRECAUTIONS

SPECIAL PRECAUTIONS FOR HANDLING AND STORAGE

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OTHER PRECAUTIONS
See caution label on package.

PREPARED BY Kenneth A. Roberts	DATE 7/11/83	TITLE Mgr., Environmental Services

While the information and recommendations set forth herein are believed to be accurate as of the date hereof, THE MANUFACTURER MAKES NO WARRANTY WITH RESPECT THERETO AND DISCLAIMS ALL LIABILITY FROM RELIANCE THEREON.

Appendix C

Manufacturer's Literature and Material Safety Data Sheet for Astroquartz Yarn.

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STEVENS ASTROQUARTZ® II

ASTROQUARTZ® II YARN

TECHNICAL DATA

ASTROQUARTZ® II YARN

ASTROQUARTZ® II yarn is made from high purity, extremely fine continuous filaments of pure fused silica which exhibits excellent refractory properties and is capable of extended exposure to 2000°F. Fiber composition is 99.90% SiO_2 (silica) exclusive of binder.

ASTROQUARTZ® II yarn, with more than five times the yield of high silica leached yarn, has higher tensile strength and abrasion resistance. As a result, high production efficiencies are now possible in the production of high temperature flexible insulation.

ASTROQUARTZ® II yarn, because of its high purity, high temperature resistance, excellent electrical properties and low density, is widely used in the form of braided insulation in thermocouple wire, coaxial cables, space separators, hoop-wire and heating elements. It has proven to be far superior in physical property characteristics when compared to the comparatively thick, low strength high silica leached yarns.

ASTROQUARTZ® II YARN
PROPERTY DATA

TYPE	APPROXIMATE DIAMETER	APPROXIMATE BREAKING STRENGTH*	APPROXIMATE YIELD
300 2/0	0.008"	3.0 lb.	15,000 yds/lb.
300 2/2	0.012"	6.0 lb.	7,500 yds/lb.
300 2/4	0.018"	10.0 lb.	3,750 yds/lb.
300 2/8	0.020"	24.0 lb.	1,875 yds/lb.

These yarns are available with 9779 binder system which is compatible with phenolic, epoxy, and some polyimide resins.

For further information write to: J.P. STEVENS & CO., INC. • INDUSTRIAL PRODUCTS GROUP
33 STEVENS ST., P.O. BOX 208 • GREENVILLE, S.C. 29602

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ASTROQUARTZ® II FIBER CHARACTERISTICS

Number of filaments:

1. 300 1/0 - 120 filaments
2. 300 2/0 - 240 filaments
3. 300 2/2 - 480 filaments

Fiber diameter in microns:

Each filament is 9 microns in diameter
This is equivalent in diameter to a
fiberglass G filament.

TERMS OF SALE

PRICE: All prices shall be subject to change without notice. The effective date of a price change shall be the date stated on the Corporation's applicable price sheet.

OFFERING: Made subject to general terms and conditions of sale.

TERMS: Net 30 Days

FREIGHT: F.O.B. Slater, S.C.

MINIMUM ORDER: 1 kg or 2.2 lbs ± 10% if available from stock
10 kg ± 10% if it is a special order.

For further information write to: J.P. STEVENS & CO., INC. • INDUSTRIAL PRODUCTS GROUP
33 STEVENS ST., P. O. BOX 208 • GREENVILLE, S.C. 29602
TELEPHONE (803) 879-9091 OR (803) 239-4828

1/1/85
2100-32

NEW ASTROQUARTZ®II
A BETTER SOLUTION TO HIGH-HEAT HIGH-STRENGTH PROBLEMS.
Its strength is in numbers.

Astroquartz II and original Astroquartz are composed of identical raw materials. Through improved manufacturing and handling techniques, however, Astroquartz II represents a stronger, cleaner product with unparalleled quality, standards and specifications. Such innovation, for which Stevens has long been known, gives new flexibility to your design opportunities.

Physical and Mechanical Properties

With a tensile strength of 500,000 psi, Astroquartz II has a higher strength-to-weight ratio than virtually all other high temperature materials.

Because of its low coefficient of linear expansion, Astroquartz II offers great dimensional stability. Fibers are flexible, and function well in applications subject to torsion and flexing. Astroquartz II is transparent to ultraviolet radiation in the 2,000A and upwards range. It does not form paramagnetic centers, nor does it capture neutrons in high energy applications. Astroquartz II is an excellent electrical insulator, and retains these properties at high temperatures.

PHYSICAL PROPERTIES OF FIBERS

Filament diameter yarn and fabric	0.00035 in. (9 microns)
Filament tensile strength at room temperature (psi)	500 x 10³
Specific gravity	2.2
Hardness (Mohs' scale)	5-6
Young's modulus	10 x 10⁶
Poisson's ratio	0.17

DATA SUMMARY OF PURE FUSED SILICA(1) (2)

Mechanical Properties

Density (grams/cc)		2.20
Hardness (Mohs' scale)		5-6
Poisson's ratio		0.17
Young's modulus	daN/cm²	6.2 - 7.2 x 10⁵
Breaking stress tensile	daN/cm²	500(2)

Thermal Properties

Mean coefficient of linear expansion 0 - 1,000°C per °C		0.54 x 10⁻⁶
Mean specific heat, 0 - 500°C	cal/g°C	0.230

Thermal conductivity at 20°C	CGS	0.0033
Stress point $\log\eta = 14.6$	°C	1,070
Annealing point $\log\eta = 13$	°C	1,140
Softening point $\log\eta = 7.6$	°C	1,670

Electrical Properties

Resistivity at 20°C	Ω x cm	10¹⁸
Resistivity at 800°C	Ω x cm	2 x 10⁷ (appx.)
Dielectric constant at 20°C, 1 MHz		3.78
Dielectric strength at 20°C	kV/cm	250/400
Loss factor at 20°C, 1 MHz		1 x 10⁻⁴
Power factor at 20°C, 1 MHz		2 x 10⁻⁴

Optical Data

Refractive index at 15°C	n_D	1.4585
Dispersion	$n_C - n_F$	0.0067

Chemical Datum

SiO_2 content	%	99.99

(1) Cf. Technical leaflet S 1: "Transparent pure fused quartz." (2) The values shown relate to solid test pieces.

Chemical Properties

Astroquartz II fibers (identical to Astroquartz) are chemically stable. They are water-insoluble, imputrescible and non-hygroscopic. Halogens, common acids in either liquid or gaseous form, have no effect on Astroquartz II with the exception of hydrofluoric and hot phosphoric acids. Astroquartz II should not be used in environments where strong concentrations of alkalies are present.

TYPICAL CHEMICAL ANALYSIS OF ASTROQUARTZ II

Element		
SiO_2	exclusive of binders	99.95
Phosphorous	ppm	3
Sodium	ppm	3-4
Potassium	ppm	2-4
Lithium	ppm	1-2
Boron	ppm	<.5
Calcium	ppm	2-8
Magnesium	ppm	2
Strontium	ppm	≤.1
Iron	ppm	3-5
Titanium	ppm	<4
Aluminum	ppm	20-30
Manganese	ppm	2
Copper	ppm	1
Cadmium	ppm	2
Antimony	ppm	.5
Chromium	ppm	.2-.5

> GREATER THAN < LESS THAN ≤ LESS THAN OR EQUAL TO
≥ GREATER THAN OR EQUAL TO = EQUAL

Thermal Properties

Astroquartz II can be used at temperatures much higher than either "E" glass or "S" glass fiber, up to 1,050°C. Above this temperature slow devitrification or crystallization occurs with the loss of flexible mechanical properties. Repeatedly varied temperatures and various impurities, especially alkalies, may promote devitrification at somewhat lower temperatures.

Astroquartz II fiber softens at approximately 1,300°C but never liquifies. Volatilization begins near 2,000°C. Because of their very high melt viscosity, Astroquartz products are often used in ablative composites.

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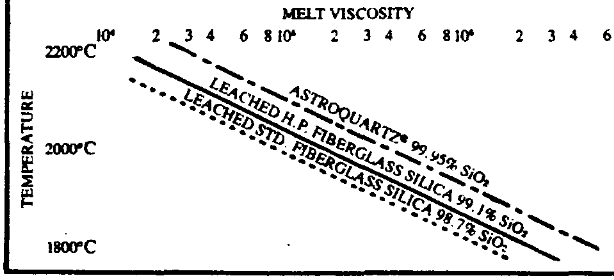
MELT VISCOSITY VS. TEMPERATURE



(CORRECTIVE COPY)
12/17/85

J. P. Stevens & Co., Inc.

SLATER, SOUTH CAROLINA

PLEASE REPLY TO:
SLATER PLANT
SLATER, S. C. 29683

"CERTIFICATION – INDUSTRIAL GLASS FABRICS"

December 6, 1985

Hitco Inc.
Woven Structures
618 West Carob Street
Compton, California 90220

CUSTOMER ORDER NO.:	WS6819
TRADE STYLE:	300-2/4/9100 Starch Oil Binder Astroq Yarn
TOTAL ~~YARDS~~: POUNDS:	22.05
B/L DATE:	12/6/85
B/L NUMBER:	-

We certify that the above material is J. P. Stevens 300-2/4/9100 Starch Oil Binder Astroquartz Yarn.

Test results are attached.

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Mill Reference
Contract 31482
Lot Number 1714

Yours very truly,

J. P. STEVENS & CO., INC.
Slater Plant, Slater, S. C.

Frances Gravley
SUPT. – QUALITY CONTROL
Frances Gravley

JPS-41902-6

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SEE WSI STATUS
TAG # 27317

J. P. Stevens & Co., Inc.

(CORRECTIVE COPY)
12/17/85

INDUSTRIAL GLASS FABRICS DEPARTMENT

TEST REPORT SLATER PLANT
Slater, South Carolina

TO: Hitco Inc.
JPS Order #31482
Customer Order #WS6819

DATE: 12/6/85

MATERIAL IDENTIFICATION: 300-2/4/9100 Starch Oil Binder Astroquartz Yarn
Lot #1714

TEST DATA:

Silica Content (%)	99.95
Finish Content (%)	.41
Yards Per Pound	3663
Breaking Strength (lbs.)	10.11

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WSI QUALITY ASSURANCE

Frances Gravley, Laboratory Manager
SIGNED Frances Gravley

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STEVENS

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MATERIAL SAFETY DATA SHEET #0011
Occupational Safety and Health Administration
OSHA 174, Sept. 1985 (Non-Mandatory Form)
OMB No. 1218-0072

IDENTITY (As Used on Label and List)

JAN - 5

ASTROQUARTZ I & II MSDS NO. 0011

SECTION I

Manufacturer's Name J. P. Stevens & Co., Inc.	Emergency Telephone Number (803) 239-4129
Address (Number, Street, City, State, and Zip Code) Stevens Industrial Division	Telephone Number for Information (803) 239-4129
33 Stevens Street, P. O. Box 208	Date Prepared Revised October 22, 1986
Greenville, SC 29602	Signature of Preparer (optional)

SECTION II - HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

Hazardous Components (Specific Chemical Identity; Common Name(s)	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)
Fused Silica CAS: 60676-86-0	80 mg/cuM % SiO_2	0.1 mg/cuM - respirable		

Astroquartz consists of amorphous fused silica fibers plus fiber surface organic binders comprising less than 1% of the total weight. Fused silica dust is amorphous and is considered to be biologically inert.

SECTION III - PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point	2000°C	Specific Gravity (H_2O = 1)	2.2
Vapor Pressure (mm Hg.)	N/A	Melting Point Fiberglass	900+°C
Vapor Density (AIR = 1)	N/A	Evaporation Rate (Butyl Acetate = 1)	N/A

Solubility in Water
Insoluble

Appearance and Odor
White Fabric - No odor.

SECTION IV - FIRE AND EXPOLOSION HAZARD DATA

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Non combustible	N/A		

Extinguishing Media
Use media appropriate for surrounding fire.

Special Fire Fighting Procedures
• This material is noncombustible. Firefighters should wear full protective gear including NIOSH approved self contained breathing apparatus.

Unusual Fire and Explosion Hazards
When heated to extreme temperatures (over 900°C) this material may crystallize or melt into glass.

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SECTION V - REACTIVITY DATA

Stability			
	Unstable		Conditions to Avoid
	Stable	X	None Known

Incompatibility (Materials to Avoid) May react with hydrofluoric acid to produce silicon tetrafluoride gas. Reacts with xenon hexafluoride to produce xenon trioxide. Avoid oxygen difluoride, chlorine trifluoride and hot phosphoric acid.

Hazardous Decomposition or Byproducts
None

Hazardous Polymerization			
	May Occur		Conditions to Avoid
	Will Not Occur	X	None Known

SECTION VI - HEALTH HAZARD DATA

Route(s) of Entry:	Inhalation?	Skin?	Ingestion?
	Yes	No	N/A

Health Hazards (Acute and Chronic)
Inhalation of large amounts may irritate upper respiratory tract.

Carcinogenicity:	NTP?	IARC Monographs?	OSHA Regulated?
	No	No	No

Signs and Symptoms of Exposure
Skin, Eye, and Respiratory Tract Irritation.

Medical Conditions
Generally Aggravated by Exposure Respiratory Ailments - as with prolonged repeated exposure to any dust.

Emergency and First Aid Procedures
Eye Contact: Flush with water for 15 minutes - get medical assistance if irritation persists. Skin contact: Wash with soap and water. Inhalation: Remove to fresh air.

SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to Be Taken in Case Material is Released or Spilled
If fused silica particles are generated then the material should be collected in a manner to minimize the generation of airborne dust. Those involved in clean up of particulates should use appropriate personal protective equipment.

Waste Disposal Method
Follow local, State, and Federal regulations.

Precautions to Be Taken in Handling and Storing
Store and use in a manner that will prevent airborne particulates in the workplace.

Other Precautions
N/A

SECTION VIII - CONTROL MEASURES

Respiratory Protection (Specify Type)
NIOSH approved respirators where dust levels exceed TLV.

Ventilation		
	Local Exhaust Recommended for processing machinary where dust generation is apparent.	Special Not normally required.
	Mechanical (General) Yes, where local exhaust ventilation is not feasible	Other Not normally required.

Protective Gloves	Eye Protection
Gloves and barrier creams if necessary.	Safety glasses with side shields/goggles.

Other Protective Clothing or Equipment Work aprons or smocks are recommended. NIOSH approved air supplied or self contained respirator for nonroutine & emergency situations.

Work/Hygienic Practices
Wash thoroughly after work. Recommend launder work clothes separately.

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Appendix D

Manufacturer's Literature and Material Safety Data Sheet for Astroquartz Sewing Thread.

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STEVENSASTROQUARTZ® II

ASTROQUARTZ® II SEWING THREAD

TECHNICAL DATA

ASTROQUARTZ® II sewing thread is made from high purity, extremely fine, continuous filaments of pure fused silica that is capable of extended exposure to 2000°F. Fiber composition is 99.90% SiO_2 (silica), exclusive of binder. Unless otherwise specified ASTROQUARTZ® II sewing threads are supplied coated with Teflon.

ASTROQUARTZ® II sewing thread, because of its high strength and flexibility, high purity and high temperature resistance, is widely used in sewing or wrapping insulation blankets, shrouds, blast curtains and separators.

The strength, smoothness and flexibility of ASTROQUARTZ® II sewing threads are far superior to any quartz sewing threads previously offered.

ASTROQUARTZ® II SEWING THREAD

WITH 9855 TEFLON COATING (20 ± 4%)

TYPE	APPROXIMATE DIAMETER	BREAKING STRENGTH (1) POUNDS		KNOT STRENGTH (2) POUNDS-TYPICAL	APPROX. YIELD (3) UNCOATED-COATED	
		TYPICAL	MINIMUM			
Q-12	0.014"	15	12	5	3,660	2,925
Q-18	0.017"	24	19	9	2,440	1,950
Q-24	0.020"	30	25	13	1,830	1,460

1. Tested in accordance with ASTM Test Method D-578
2. Tested in accordance with ASTM Test Method D-2256
3. ±10%

NOTE: ASTROQUARTZ® II properties based on limited testing. Do not use for specification purposes without consultation with J. P. Stevens.

For further information write to: J.P. STEVENS & CO., INC. • INDUSTRIAL PRODUCTS GROUP
33 STEVENS ST., P.O. BOX 208 • GREENVILLE, S.C. 29602

J. P. Stevens & Co., Inc.

SLATER, SOUTH CAROLINA

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PLEASE REPLY TO:
SLATER PLANT
SLATER S C 29683

"CERTIFICATION – INDUSTRIAL GLASS FABRICS"
October 1, 1985

Hitco Inc.
Woven Structures
618 West Carob Street
Compton, California 90220

CUSTOMER ORDER NO.: WS 6819

TRADE STYLE: Q-12/9855 Astroquartz II Sewing Thread

TOTAL XXXXXX POUNDS: 11.97

B/L DATE: 10/1/85

B/L NUMBER: -

We certify that the above material is J. P. Stevens Q-12/9855 Astroquartz II Sewing Thread.

Test results are attached.

Mill Reference
Contract 31482 Lot Number 1622

SEE WSI STATUS
TAG # 27231

Yours very truly,

J. P. STEVENS & CO., INC.
Slater Plant, Slater, S. C.

SUPT. - QUALITY CONTROL
Frances Gravley

JPS-41902-6

CLEARED THROUGH WSI
RECEIVING INSPECTION

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
OCT 1985
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J. P. Stevens & Co., Inc.

INDUSTRIAL GLASS FABRICS DEPARTMENT

TEST REPORT SLATER PLANT
Slater, South Carolina

TO: Hitco Inc.
JPS Order #31482
Customer Order #WS 6819

DATE: 10/1/85

MATERIAL IDENTIFICATION: Q-12/9055 Astroquartz II Sewing Thread
Lot #1022

TEST DATA:

Silica Content (%)	99.99
Finish Content (%)	23.32
Yards per Pound	2922
Breaking Strength (lbs.)	16.22

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Frances Gravley, Laboratory Manager
SIGNED Frances Gravley

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STEVENS

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MATERIAL SAFETY DATA SHEET #0012
Occupational Safety and Health Administration
OSHA 174, Sept. 1985 (Non-Mandatory Form)
OMB No. 1218-0072

IDENTITY (As Used on Label and List)

ASTROQUARTZ II SEWING THREAD MSDS NO. 0012

JAN - 5

SECTION I

Manufacturer's Name J. P. Stevens & Co., Inc.	Emergency Telephone Number (803) 239-4129
Address (Number, Street, City, State, and Zip Code) Stevens Industrial Division	Telephone Number for Information (803) 239-4129
33 Stevens Street, P. O. Box 208	Date Prepared Revised October 22, 1986
Greenville, SC 29602	Signature of Preparer (optional)

SECTION II - HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

Hazardous Components (Specific Chemical Identity; Common Name(s)	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)
Fused Silica CAS: 60676-86-0	80 mg/cuM % SiO_2	0.1 mg/cuM - respirable		

Astroquartz Sewing Thread consists of a yarn of fused silica fibers plus a polytetrafluoroethylene coating. Fused silica dust is amorphous and is considered to be biologically inert. Since the quartz yarn is coated, it is extremely unlikely that any condition will occur in which there is any significant airborne fiber from this material.

SECTION III - PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point	2000°C	Specific Gravity (H_2O = 1)	2.2
Vapor Pressure (mm Hg.)	N/A	Melting Point Fiberglass	900+°C
Vapor Density (AIR = 1)	N/A	Evaporation Rate (Butyl Acetate = 1)	N/A

Solubility in Water
Insoluble

Appearance and Odor
Astroquartz Thread. Tan Color. No Odor.

SECTION IV - FIRE AND EXPOLOSION HAZARD DATA

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Non combustible	N/A		

Extinguishing Media
Use that which is appropriate for surrounding fire.

Special Fire Fighting Procedures
Use procedures necessary for surrounding fire. Wear full protective gear including NIOSH approved self contained breathing apparatus to protect against toxic decomposition products.

Unusual Fire and Explosion Hazards
In extreme fire situations involving polytetrafluoroethylene, hydrogen fluoride fumes can be liberated and appropriate personal protective gear should be employed.

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SECTION V - REACTIVITY DATA

Stability			
	Unstable		Conditions to Avoid
	Stable	X	None Known

Incompatibility (Materials to Avoid) May react with hydrofluoric acid to produce silicon tetrafluoride gas. Reacts with xenon hexafluoride to produce xenon trioxide. Avoid oxygen difluoride, chlorine trifluoride and hot phosphoric acid.

Hazardous Decomposition or Byproducts

Hydrogen fluoride

Hazardous Polymerization			
	May Occur		Conditions to Avoid
	Will Not Occur	X	None Known

SECTION VI - HEALTH HAZARD DATA

Route(s) of Entry:	Inhalation?	Skin?	Ingestion?
	Yes	No	N/A

Health Hazards (Acute and Chronic)

Inhalation of large amounts may irritate upper respiratory tract.

Carcinogenicity:	NTP?	IARC Monographs?	OSHA Regulated?
	No	No	No

Signs and Symptoms of Exposure

Skin, Eye, and Respiratory Tract Irritation.

Medical Conditions

Generally Aggravated by Exposure Respiratory Ailments - as with prolonged repeated exposure to any dust.

Emergency and First Aid Procedures

Eye Contact: Flush with water for 15 minutes - get medical assistance if irritation persists. Skin contact: Wash with soap and water. Inhalation: Remove to fresh air.

SECTION VII - PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to Be Taken in Case Material is Released or Spilled

If fused silica particles are generated then the material should be collected in a manner to minimize the generation of airborne dust. Those involved in clean up of particulates should use appropriate personal protective equipment.

Waste Disposal Method

Follow local, State, and Federal regulations.

Precautions to Be Taken in Handling and Storing

Store and use in a manner that will prevent airborne particulates in the workplace.

Other Precautions

N/A

SECTION VIII - CONTROL MEASURES

Respiratory Protection (Specify Type)

NIOSH approved respirators where dust levels exceed TLV.

Ventilation		
	Local Exhaust Recommended for processing machinary where dust generation is apparent.	Special Not normally required.
	Mechanical (General) Yes, where local exhaust ventilation is not feasible	Other Not normally required.

Protective Gloves	Eye Protection
Gloves and barrier creams if necessary.	Safety glasses with side shields/goggles.

Other Protective Clothing or Equipment Work aprons or smocks are recommended. NIOSH approved air supplied or self contained respirator for nonroutine & emergency situations.

Work/Hygienic Practices

Wash thoroughly after work. Recommend launder work clothes separately.

Appendix E

Manufacturer's Literature and Material Safety Data Sheet for Carboset.

Carboset® Resins

Carboset 514H Resin
Product Specification
Commodity No. 0530H 514 0000

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General Properties

1. Appearance - Milky White Dispersion

Specifications

		Target	Limits Min.	Limits Max.	Proc. No.
1.	Total Solids (%)	40.0	39.0	41.0	1196-A
2.	Brookfield Viscosity (cps @ 25°C)*	200	100	500	764-A
3.	Contamination	None (No More Than Std.)			767-A
4.	pH of Solution	7.0	6.6	7.4	92-B
5.	Acid Number	65.0	60.0	70.0	1047-B-D
6.	Film Appearance	Clear, Glossy (Only Value Acceptable)			771
7.	Film Water Resistivity	Complete (Only Value Acceptable)			771
8.	Film Alkali Removability	Complete (Only Value Acceptable)			771

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*Run with RVF, #2 Spindle at 20 RPM

wp/0985g-15

BFGoodrich
Chemical Group

The BFGoodrich Company, Chemical Group/6100 Oak Tree Blvd., Cleveland, Ohio 44131

CARBOSET® ACRYLIC RESINS

Metal coatings, printing inks, pigment dispersions, paper coatings, cosmetics, reprographics, chemical specialities and tire cord dips are just a few of the many applications for Carboset® resins.

In metal and specialty coatings, for instance, Carboset® resins can be used as temporary or permanent coatings for protection against corrosion, weathering, and degradation during handling, processing, and shipping.

Clear, adherent, water resistant, temporary protective coatings can be removed easily with a dilute alkaline solution.

By crosslinking either the thermoplastic or thermosetting Carboset® resins or by simply using a thermosetting Carboset® resin, permanent, protective coatings can be obtained. Epoxies, formaldehyde condensation crosslinking agents, multivalent metals, and polyfunctional aziridines are crosslinking agents for Carboset® resins.

In printing inks and pigment dispersions, Carboset® resin can be used as a pigment binder, pigment dispersant, or both. Inks based on Carboset® resins work well on surfaces where adhesion is normally a problem.

The high gloss, good water resistance, and non-blocking characteristics of several Carboset® resins make them particularly suitable for paper coating applications.

Carboset® XL-19 and XL-30 resins are low acid resins which qualify under several FDA regulations concerning components of paper in contact with food.

In cosmetics, Carboset® 515, 525 and preserved versions of 514H and XL-19 resins have been used for many years because of their low toxicity and low odor characteristics along with their excellent binder properties and soap and water removability.

Carboset® 533H resins act as an adhesion retention aid by protecting dipped tire cords from degradation by ultraviolet light, humidity and ozone.

Carboset resins are recommended for reprographic applications due to their excellent dielectric properties and freedom from soaps and surfactants which interfere with commonly used additives.

Carboset® resins are available in both solution and dry form. Most of the Carboset® resins are available as dispersions in ammonia water. Carboset® 514A resin is available as a 70% total solids solution in isopropyl alcohol. Carboset® 515 is a viscous, near liquid resin offered at 100% total solids. Carboset® 525, 526, XL-27 and XL-44 are dry resins soluble in alkaline water as well as many organic solvents.

The accompanying charts and your BFGoodrich representative can help you decide which Carboset® acrylic resin best suits your application.

CARBOSET® ACRYLIC POLYMERS TYPICAL PROPERTIES

THERMOPLASTIC POLYMERS SUPPLIED AS DISPERSION IN WATER	RESIN CONCENTRATION	NEUTRALIZED WITH	pH	VISCOSITY CP	DENSITY LBS/GAL.	GLASS TRANSITION TEMPERATURE°C	SPECIAL PROPERTIES	SUGGESTED USES
XL-11	30%	AMMONIA	6.7	40	8.7	55	Forms a hard glossy tack-free film at room temperature. High boiling solvents will further improve gloss and wet out.	1,2,3,4 5,9,10
XL-19*	40%	AMMONIA	8.0	100	8.8	26	Excellent wet out and gloss on most substrates. The use of fillers, additives and crosslinkers will improve block resistance of this polymer. Qualifies under several FDA regulations calling for low acid content.	1,4,6,8,9
XL-30	35%	AMMONIA	7.8	30	8.8	55	Same low acid level as XL-19, but much harder film. A coalescing aid such as butyl Cellosolve® (Union Carbide) is needed for film formation.	1,4,5
XL-33	38%	AMMONIA AND DMEA	7.8	60	8.8	55	Same as XL-30 but neutralized with DMEA in addition to ammonia for extended "Open" time during application.	4,5
XL-37	35%	AMMONIA	7.1	400	8.8	42	Good adhesion on treated polyethylene. Excellent pigment dispersant. Broad compatibility with latex letdown polymers.	1,2,4,5 8,9,10
XL-52	37%	AMMONIA	7.1	500	8.8	2	Excellent dispersant and tackifier; imparts greater cohesive strength than 515.	4,5,8,9
514H*	40%	AMMONIA	7.0	200	8.8	28	Excellent overall combination of wet out, dispersion, gloss and adhesive properties. Excellent film former at room temperature.	1,2,3,4,5,6 8,9

*Preserved Grades Available For Cosmetics With Special Restrictions

SUGGESTED USES

1. Paper Coatings
2. Industrial Metal Coatings
3. Can Coatings
4. Pigment Dispersions
5. Printing Inks
6. Cosmetics
7. Tire Cord Dips
8. Adhesives
9. Latex Additive
10. Reprographics

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Chemical Group

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CERTIFICATE OF ANALYSIS

TO: Woven Structures, Inc.
Div. of Hitco Corp.
618 Carol Street
Compton, CA 90220
attn. Dominick Calamita

SHIPPED TO:

YOUR ORDER NO: WS 7194

OUR ORDER NO: V237060

DATE SHIPPED: 06-20-84

ANALYSIS OF: Carboset 514-H

Listed below is the quality data for the subject material:

Properties	Lot No. 262085 Data	Lot No. Data	Lot No. Data
Total Solids	40.05		
pH	7.24		
Brook. Visc.	446.		

SEE WSI STATUS
TAG # 27383

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MJM/bjs

M. J. Mannino

BFG-16365-A 9/79

APR 30

Carboset® Resins

MATERIAL SAFETY DATA SHEET

CARBOSET® RESINS **PM-002**

ISSUED: FEBRUARY, 1983*
DOC: 83046

SECTION I

Manufacturer's Name
The BFGoodrich Company
Chemical Group

Telephone Number
(216) 447-6000

Transportation Emergency Telephone
CHEMTREC: (800) 424-9300

Address
6100 Oak Tree Blvd.
Cleveland, Ohio 44131

Chemical Family
Acrylic Polymer. Varying amounts of total solids in ammonia water.

Trademark
Carboset® Resin:

514	XL-11	XL-35
514H	XL-19	XL-37
514N	XL-28	XL-40

SECTION II - HAZARDOUS INGREDIENTS

	C.A.S. NUMBER	Amount in Product**	ACGIH TLV-TWA	OSHA PEL
Ammonia	7664-41-7	0.4%	25 ppm	50 ppm

** Typical amount; not a specification.

Notes:
- TLV-TWA: Threshold Limit Value - Time Weighted Average for concentration of the chemical substance in the ambient workplace air. American Conference of Governmental Industrial Hygienists, 1982 Edition.
- OSHA PEL: OSHA Permissible Exposure Limit, 8-hour TWA. 29CFR1910.1000.

SECTION III - PHYSICAL DATA (Typical data, not specifications)

Boiling Point
212°F (100°C)

Melt Point
Not Applicable (NA)

Specific Gravity (H_2O=1)
1.1

Solubility in Water
Soluble in alkaline water.

% Volatile by Volume
Water: See Table 1

Vapor Density (Air = 1)
NA

Appearance and Odor
See Table 1

% Total Solids
See Table 1

pH and Tg
See Table 1

*Supersedes 10/81

The BFGoodrich Company, Chemical Group/6100 Oak Tree Blvd., Cleveland, Ohio 44131

BFGoodrich Chemical Group

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Flash Point
Aqueous System (not applicable)

Flammable Limits in Air
(% by volume) Lower: NA
Upper: NA

Extinguishing Media
If water is evaporated off, dry polymer could burn. Water spray, ABC dry powder and protein type air foams are effective. Carbon dioxide may be ineffective on larger fires due to a lack of cooling capacity which may result in reignition.

Special Fire Fighting Procedure
Positive pressure self-contained breathing apparatus should be used. Personnel not having suitable respiratory protection should leave the area to prevent significant exposure to toxic combustion gases from any source.

Unusual Fire and Explosion Hazards
None known.

SECTION V - HEALTH HAZARD DATA

Threshold Limit Value
None established.

Effects of Overexposure
None known.

Emergency and First Aid Procedure

IN CASE OF EYE CONTACT: Immediately flush eyes with plenty of water for an extended time, not less than five (5) minutes. Flush longer if there is any indication of residual chemical in the eye. See a physician.

IN CASE OF SKIN CONTACT: Remove contaminated clothing. Wash the affected area with plenty of soap and water. If irritation develops, see a physician.

IN CASE OF INHALATION: Move to fresh air. Obtain medical attention as soon as possible if asthmatic symptoms are evident.

IN CASE OF INGESTION: Low oral toxicity. Any treatment should be symptomatic.

SECTION VI - REACTIVITY DATA

Stability
Stable

Hazardous Polymerization
Will not occur.

Hazardous Decomposition Products
CO, CO_2, and small amounts of aromatic and aliphatic hydrocarbons.

Incompatibility (materials to avoid)
Lowering product pH by acid addition could result in precipitation.

SECTION VII - SPILL OR LEAK PROCEDURE

Steps to be taken in case material is released or spilled
Dam-up the spill area if necessary. Absorb spill with an inert material such as sand, sweeping compound or a commercial absorbent. Place into closed container for disposal. Wash the spill area with soap and water. Do not flush chemical into public sewer or water system.
CAUTION: Spill of polymer may create slippery conditions.

Waste Disposal Method
Dispose of waste in accordance with all federal, state and local health and pollution laws and regulations. These products, for waste disposal purposes, are not defined or designated as a hazardous waste under current provisions of the Federal Resources Conservation and Recovery Act (RCRA). 40CFR261.

Liquid waste may be disposed of by incineration. The liquid waste may be mixed with a drying or bulking agent such as fly ash or sawdust so that the resultant mixture may be disposed of in a landfill. Most states prohibit disposal of liquids in landfills.

SECTION VIII - SPECIAL PROTECTION INFORMATION

Ventilation
Efficient exhaust ventilation should always be provided to draw fumes and vapors away from workers to prevent routine inhalation. Ventilation should be adequate to maintain the ambient workplace atmosphere below the TLV listed in Section II.

Respiratory Protection
Wear a NIOSH/MSHA approved respirator whenever exposure to fumes or vapors exceed the TLV listed in Section II.

Protective Equipment
-Chemical splash goggles are recommended.
-Wear protective gloves.

APR 30

SECTION IX - SPECIAL PRECAUTIONS

-Open, handle and use under well-ventilated conditions.
-Wash thoroughly after handling. Always wash-up before eating, smoking or using toilet facilities.
-Keep container closed.
-Store products where temperatures are between 40-100°F. Avoid storing containers in direct sunlight. Vapors may be released creating pressure in the container.
-Keep from freezing.
-When neutralizing or adjusting pH, be sure to follow all safety precautions regarding the proper use of the neutralizing agents involved.
-Storage tanks, pumps, piping and fittings should all be of Number 304 stainless steel, glass lined carbon steel, glass fiber reinforced polyester, or epoxy or phenolic coated carbon steel. Avoid zinc, copper, iron, aluminum and low carbon steel (these materials will either cause a breakdown of the polymer, discoloration of the resin or reduce the pH by reacting with ammonia present in the resin).
-Other ingredients you select for compounding with these products may require special handling. It is the user's responsibility to obtain and follow the current recommendations and safety precautions of the individual additive supplier.

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PM-002

SECTION X - TRANSPORTATION

For domestic transportation purposes, these products are not defined or designated as a hazardous material by the U.S. Department of Transportation under Title 49 of the Code of Federal Regulations, 1981 edition.

USER'S RESPONSIBILITY

A bulletin such as this cannot be expected to cover all possible individual situations. As the user has the responsibility to provide a safe workplace, all aspects of an individual operation should be examined to determine if, or where, precautions, in addition to those described herein, are required. Any health hazard and safety information contained herein should be passed on to your customers or employees, as the case may be. BFGoodrich must rely on the user to utilize the information we have supplied to develop work practice guidelines and employee instructional programs for the individual operation.

DISCLAIMER OF LIABILITY

As the conditions or methods of use are beyond our control, we do not assume any responsibility and expressly disclaim any liability for any use of this material. Information contained herein is believed to be true and accurate but all statements or suggestions are made without warranty, express or implied, regarding accuracy of the information, the hazards connected with the use of the material or the results to be obtained from the use thereof. Compliance with all applicable federal, state and local laws and regulations remains the responsibility of the user.

0156b/27/4

PM- 002

Table 1

Carboset® Resin	% Total Solids	% Volatile by Volume	Appearance	Odor	pH*	Tg (°C)
514	30%	70%	Hazy liquid	Acrylic	7.0-7.6	27
514H	40%	60%	Milky white liquid	Acrylic	6.7-7.3	27
514N	30%	70%	Hazy liquid	Acrylic	7.0-7.6	27
XL-11	30%	70%	Milky white liquid	Acrylic	6.6-6.9	55
XL-19	40%	60%	Milky white liquid	Acrylic	7.6-8.0	26
XL-28	30%	70%	Hazy liquid	Acrylic	7.0-7.6	27
XL-35	30%	70%	Milky white liquid	Acrylic	6.4-6.8	56
XL-37	35%	65%	Milky white liquid	Acrylic	6.8-7.2	42
XL-40	30%	70%	Hazy liquid	Acrylic	7.0-7.6	27

*As supplied.

Carboset® Resin	Preservative
514N	0.2% Methyl Paraben (Tenneco Chemicals, Inc.)
	0.1% Propyl Paraben (Tenneco Chemicals, Inc.)
	0.2% Sodium dehydroacetate (Ganes Chemical, Inc.)
	0.02% Na_3T Sequestrene (Geige Chemical Corp.)
XL-28	0.2% Dowicil 200 (Dow Chemical Company)
XL-40	4.5% Propylene glycol
	0.3% Methyl Paraben
	0.2% Propyl Paraben

APPENDIX - WARNING STATEMENTS/PRECAUTIONARY MEASURES

CAUTION!

Use with adequate ventilation. Keep container closed. Wash thoroughly after handling. Protective gloves and splash goggles are recommended. Spilled polymer is slippery - use care to avoid falls.

0156b/27/5

Appendix F

Manufacturer's Literature and Material Safety Data Sheet for RTV Silicone Rubber Compound.

RTV SILICONE RUBBER PRODUCT DATA

THE versatiles

RTV 560

SILICONE RUBBER COMPOUND

for high temperature potting, encapsulating and sealing applications where low temperature flexibility is required

PRODUCT DESCRIPTION

General Electric RTV 560 is a two-component room temperature vulcanizing silicone rubber compound used where a combination of low temperature flexibility and high temperature resistance, is required. RTV 560 is supplied in kit form with DBT (dibutyl tin dilaurate) as a standard catalyst suitable for typical applications.

RTV 560 is red in color and has a pourable viscosity of approximately 30,000 cps.

APPLICATIONS

General Electric RTV 560 silicone rubber compound is used for potting or sealing applications where environmental temperatures range from -115C (-175F) to +260C (500F). In addition, it also is used as a thermal insulation, a firewall sealant, for fabrication of heat shields, and in ablative coatings in aerospace applications.

PRODUCT FEATURES	POTENTIAL BENEFITS
• Resistance to temperature extremes	• Retention of elastomeric properties at temperatures from -115C (-175F) up to 260C (500F) continuously and up to 316C (600F) for short periods of time
• Excellent adhesion capabilities to many materials with the use of primer	• Offers longer working time and deeper section cure than offered by one component adhesive sealants
• Simple handling procedures and equipment	• Easy to use in production applications
• Variable work life by adjusting the amount of catalyst	
• Room temperature cure	• Eliminates need for bulky and costly ovens and associated energy costs
• Composition free of solvents and solvent odor	• Contributes to worker comfort

PRODUCT DATA

RTV 560
SILICONE RUBBER COMPOUND

PRODUCT DATA

TYPICAL UNCURED PROPERTIES

	RTV 560
Color	Red
Consistency	Pourable
Viscosity, cps	30,000
Specific Gravity	1.42
Nonvolatile Content, %	100
Shelf Life, mos @ -18C (0F)	6

TYPICAL UNCURED PROPERTIES
(0.5 wt. % DBT Curing Agent Added)

Work time @ 25C, hrs	1
Cure Time @ 25C, hrs	24

TYPICAL CURED PROPERTIES
(0.5 wt % DBT Curing Agent Added, Cured 168 hrs. @ 25C and 50% R.H.)

	RTV 560
Mechanical	
Hardness, Shore A Durometer	55
Tensile Strength, kg/cm^2 (psi)	42 (600)
Elongation, %	110
Tear Strength, kg/cm (lb/in)	8.1 (45)
Shrinkage, %	0.2 - 0.6
Electrical	
Dielectric Strength, kv/mm (v/mil) (1.9 mm thick)	19.7 (500)
Dielectric Constant @ 100 Hz	4.4
Dissipation Factor @ 100 Hz	0.006
Volume Resistivity, ohm-cm	1×10^{15}
Thermal	
Useful Temperature Range, ^oC (^oF)	-115 to 260 (-175 to 500)
Thermal Conductivity, gm-cal/sec, cm^2, $^oC/cm$	0.00074
(Btu/hr, ft^2, $^oF/ft$)	(0.18)
Coefficient of Expansion, cm/cm ^oC	20×10^{-15}
(in/in, ^oF)	(11×10^{-5})
Specific Heat, cal/gm, ^oC	0.35
(Btu/lb, ^oF)	(0.35)

PRODUCT DATA

RTV 560
SILICONE RUBBER COMPOUND

SPECIFICATIONS

Properties shown in the Typical Product Data section should not be considered or used in preparing specifications. Assistance and recommendations are available by contacting General Electric Company, Silicone Products Division.

INSTRUCTIONS FOR USE

MIXING

Select a mixing container 4-5 times larger than the volume of RTV silicone rubber compound to be used. Weigh out the RTV silicone rubber base compound and add the appropriate amount of curing agent. 0.5% DBT by weight will provide a work time or pot life of about one hour and a cure time of 24 hours. The pot life may be lengthened by using less DBT. With clean tools, thoroughly mix the RTV base compound and the curing agent, scraping the sides and bottom on the container carefully to produce a homogeneous mixture. When using power mixers, avoid excessive speeds which could entrap large amounts of air or cause overheating of the mixture, resulting in shorter pot life.

DEAERATING

Air entrapped during mixing should be removed to eliminate voids in the cured product. Expose the mixed material to a vacuum of about 25 mm (29 in.) of mercury. The material will expand, crest, and recede to about the original level as the bubbles break. Degassing is usually complete about two minutes after frothing ceases. When using the RTV for potting, a deairing step may be necessary after pouring to avoid capturing air in complex assemblies.

CURING

Using DBT curing agent at a level of 0.5%, RTV 560 silicone rubber compound will cure in 24 hours at 25C (77F) and 50% relative humidity to form a durable resilient rubber. Under these conditions a pot life of about one hour will typically be available for pouring and working with the catalyzed RTV. Pot life may be increased by up to 24 hours or more by refrigerating the compound at 0C (32F) after catalyzing. Cure time may be shortened as much as 75% by using mild heat up to 93C (200F) maximum. For information on curing agents for faster cure, deep-section cure, or machine dispensing see General Electric data sheet covering curing agents.

If RTV 560 silicone rubber compound is to be used at temperatures over 150C (302F), the cured product should be properly conditioned prior to service. Following room temperature cure of 1-3 days, a typical program would be eight hours at 25C (45F) intervals from 100C (212F) to the service temperature. Longer times at each temperature will be required for larger parts or very deep sections.

BONDING

RTV 560 silicone rubber compound requires a primer to bond to non-silicone surfaces. Thoroughly clean the substrate with a non-oily solvent such as naphtha, methyl ethyl ketone, or 1,1,1-trichloroethane and allow to dry. Then apply a uniform thin film of General Electric SS 4155 silicone primer and allow the primer to air dry for one hour or more. Finally, apply freshly catalyzed RTV 560 to primed surface and cure as recommended.

When solvents are used, as described, proper safety precautions must be observed. All solvents must be considered toxic and should be used only in well-ventilated areas. Exposure to solvent vapors must be avoided. If flammable solvents are used, storage, mixing and use must be in areas away from open flames or other sources of ignition. The selection of any solvent, particularly chlorinated hydrocarbon solvents, will require consideration of applicable OSHA, EPA, and other federal, state and local regulations.

For more details on priming and adhesion please refer to General Electric data sheet on RTV primers.

STORAGE AND HANDLING

RTV 560 base compound and DBT curing agent will remain useful for six months from the date of shipment when stored in the original unopened containers at temperatures below -18C (0F). Material removed from the freezer should be allowed to return to room temperature before container is opened to prevent the condensation of moisture in the compound. At temperatures below 5C (40F), the DBT curing agent may solidify. Warm gently to liquefy before using.

PRODUCT DATA

RTV 560
SILICONE RUBBER COMPOUND

Uncured RTV 560 silicone rubber compound is not known to produce any toxic effects.

Caution: DBT (dibutyl tin dilaurate) causes eye irritation and may cause skin irritation. Avoid contact with skin and eyes. In case of contact flush with water; for eyes, call a physician.

SAFETY PRECAUTIONS

Material Safety Data Sheets defining the known hazards and describing appropriate safety precautions with respect to the product are available upon request from General Electric Company, Silicone Products Division. Similar information sheets for solvents and other chemicals used with our product may be obtained from the supplier and used accordingly.

AVAILABILITY

General Electric RTV 560 silicone rubber compound is available from General Electric Company and from authorized GE Silicone Products distributors. For the name of your nearest distributor or for more information on this product, contact General Electric Company, Silicone Products Division, RTV Products Department, Waterford, New York 12188, or the Silicone Sales Department office nearest you.

GENERAL ELECTRIC COMPANY
SILICONE PRODUCTS DIVISION
RTV PRODUCTS DEPARTMENT
WATERFORD, NEW YORK 12188
PHONE (518) 237-3330

GENERAL ELECTRIC

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REC'D NOV 10, 1986
D. Calanito

R.S. HUGHES CO. INC

Raw Material Certification

Date: Nov 6, 1986

CUSTOMER'S PURCHASE ORDER NO. WF 7352

SHIPPER'S PACKING SLIP NO. W111123

We hereby certify that the material shipped on the above packing slip conforms to all specifications requirements called out or referenced on the above purchase order.

GE RTV 560 12#
S/L: 6 mo
Dom. 11/86
Exp: 5/87

By: Janine R. Smithurst, Sales

SUNNYVALE	OAKLAND	PORTLAND	SEATTLE	SALT LAKE CITY	DENVER
1162 Sonora Court	1076 40th St.	2238 N.E. Columbia Blvd.	6520 5th Place South	3455 W. 1820 South	4880-J Ironton St
P.O. Box 3515		P.O. Box 11068	P.O. Box 81084	P.O. Box 27077	
Sunnyvale, CA 94088	Oakland, CA 94608	Portland, OR 97211	Seattle, WA 98108	Salt Lake City, UT 84127	Denver, CO 80239
(408) 739-321*	(415) 652-5044	(503) 284-0777	(206) 767-4463	(801) 973-4211	(303) 371-9440

Other warehouses in LOS ANGELES, GARDENA, SANTA ANA, SAN DIEGO, SAN BERNARDINO, PHOENIX, DALLAS, HOUSTON, AUSTIN

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SYSTEMS PRINTING OF SAN FRANCISCO

ELECTRICAL SPECIALTY CO.

ES

So. San Francisco, Calif. 94080
345 Swift Ave
Tel. (415) 589 9611

Los Angeles, Calif. 90040
7244 Condor St.
Tel. (213) 724-9600

Fullerton, Calif. 92631
1431 Orangethorpe
Tel. (714) 773-0200

Denver, Colorado 80207
3999 Holly Street
Tel. (303) 321-0226

El Paso, Texas 79935
11210 Armour Dr. Unit B1
Tel. (915) 594-8251

Phoenix, Ariz. 85034
202 South 29th St.
Tel. (602) 275-5736

Portland, Ore. 97210
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1499 South 700 West
Tel. (801) 972-4184

San Diego, Calif. 92111
9679 Distribution Ave.
Tel. (619) 586-1255

Tukwila, Wash. 98168 (Seattle)
4471 So. 134th Place
Tel. (206) 241-1010

TO: Woven Structures

DATE:

ATTN Dick

OUR PACK SHEET NO LAX65198

CERTIFICATE OF CONFORMANCE

THIS IS TO CERTIFY THAT MATERIALS SUPPLIED ON YOUR P.O. NO. WS6823
HAVE BEEN MANUFACTURED IN ACCORDANCE WITH AND CONFORM TO APPLICABLE SPECIFICATIONS AND/OR STANDARDS.

ITEM NO.	MANUFACTURER	DESCRIPTION
1	Ge silicone	RTV-560 red 12 lb kit

SEP 1985
RECEIVED

SEE WSI STATUS
TAG # 2726r

ELECTRICAL SPECIALTY CO.

FO-107

MATERIAL SAFETY DATA SHEET

MANUFACTURED BY:

GENERAL ELECTRIC CO.
SILICONE PRODUCTS DIV.
WATERFORD, NY 12188

EMERGENCY TELEPHONE: (24 HRS)
(518) 237-3330

REVISED: 1/08/86
PREPARER:DA POLSINELLI

***** I PRODUCT IDENTIFICATION *****

PRODUCT IDENTIFICATION: RTV560 CHEMICAL FAMILY:SILICONE RUBBER COMPOUND
CHEMICAL NAME: METHYLPHENYL COMPOUND FORMULA: MIXTURE

***** II PRODUCT COMPONENTS *****

PRODUCT COMPOSITION	APPROX. %	ACGIH TLV	OSHA PEL	UNITS	CAS REG NO.
A. HAZARDOUS					
ETHYLSILICATE	< 5%	10	100	PPM	78-10-4*
B. NON-HAZARDOUS					

***** III PHYSICAL DATA ******

**PRODUCT INFORMATION

BOILING POINT	: >545 (F) >285 (C)	% VOLATILE BY VOLUME	:<2
VAPOR PRESSURE(20 C)	: NEGL. MM HG	EVAPORATION RATE (BUTYL ACETATE=1	:NEGL.
VAPOR DENSITY(AIR=1)	: NEGL.		
FREEZING POINT	: NA (F) NA (C)	SPECIFIC GRAVITY (WATER=1)	:1.42
MELTING POINT	: NA (F) NA (C)		
PHYSICAL STATE	: LIQUID	DENSITY	:1414 KG/M3
ODOR	: SLIGHT	ACIDITY/ALKALINITY	:UNKN MEG/G
COLOR	: RED	PH	:NA

SOLUBILITY IN WATER(20 C):INSOLUBLE
SOLUBILITY IN ORGANIC SOLVENT:PARTIAL IN TOLUENE
(STATE SOLVENT)

***** IV FIRE AND EXPLOSION DATA *****

FLASH POINT: >200 (F) >93 (C) BY PMCC. IGNITION TEMP:>500 (F)>26(C)
FLAMMABLE LIMITS IN AIR(%): LOWER NA UPPER NA
EXTINGUISHING MEDIA:
ALL STANDARD FIREFIGHTING MEDIA
SPECIAL FIREFIGHTING PROCEDURES:
NONE KNOWN.

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MATERIAL SAFETY DATA SHEET

***** V REACTIVITY DATA *****

STABILITY: X STABLE UNSTABLE

HAZARDOUS: POLYMERIZATION WILL NOT OCCUR

HAZARDOUS DECOMPOSITION PRODUCTS:
- CARBON MONOXIDE.
- CARBON DIOXIDE.
- SILICON DIOXIDE.

INCOMPATIBILITY (MATERIALS TO AVOID):
NONE KNOWN.

CONDITIONS TO AVOID:
NONE KNOWN.

***** VI HEALTH HAZARD DATA *****

ACUTE SIGNS/EFFECTS OF OVEREXPOSURE:

INGESTION:
MAY CAUSE STOMACH DISCOMFORT.

SKIN CONTACT:
UNCURED PRODUCT CONTACT MAY IRRITATE THE SKIN.

INHALATION:
NONE KNOWN.

EYE CONTACT:
MAY CAUSE MILD EYE IRRITATION.

MEDICAL CONDITIONS AGGRAVATED:
NONE KNOWN.

OTHER:
NONE KNOWN.

CHRONIC EFFECTS OF OVEREXPOSURE:
NONE KNOWN.

EMERGENCY AND FIRST AID PROCEDURES:

INGESTION:
NONE KNOWN.

SKIN:
WASH WITH SOAP AND WATER.

INHALATION:
NONE KNOWN.

EYES:
IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES AND GET MEDICAL ATTENTION IF IRRITATION PERSISTS.

NOTE TO PHYSICIAN:
NONE KNOWN.

TOXICITY: ETHYLSILICATE
ACUTE ORAL LD50: >1000 (RAT) MG/KG
ACUTE DERMAL LD50: NONE FOUND MG/KG
ACUTE INHALATION LC50: >1000 PPM/4HR.

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OTHER: MILDLY IRRITATING TO SKIN (RBT).
AMES TEST: UNKNOWN
PRINCIPAL ROUTES OF EXPOSURE:
DERMAL - SKIN.
THIS PRODUCT OR ONE OF ITS INGREDIENTS PRESENT 0.1% OR MORE IS NOT LISTED AS A CARCINOGEN OR SUSPECTED CARCINOGEN BY NTP, IARC, OR OSHA.
PRODUCTS/INGREDIENTS:
THIS SPACE RESERVED FOR SPECIAL USE.

***** VII SPECIAL PROTECTIVE EQUIPMENT *****

RESPIRATORY PROTECTION:
NONE KNOWN.
PROTECTIVE GLOVES:
CLOTH GLOVES.
EYE AND FACE PROTECTION:
SAFETY GLASSES.
OTHER PROTECTIVE EQUIPMENT:
NONE KNOWN.
VENTILATION:
NONE KNOWN.

*** VIII SPILL, LEAK AND DISPOSAL PROCEDURES ***

ACTION TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED:
WIPE, SCRAPE OR SOAK UP IN AN INERT MATERIAL AND PUT IN A CONTAINER FOR DISPOSAL.
WASH WALKING SURFACES WITH DETERGENT AND WATER TO REDUCE SLIPPING HAZARD.
WEAR PROPER PROTECTIVE EQUIPMENT AS SPECIFIED IN THE PROTECTIVE EQUIPMENT SECTION.
DISPOSAL METHOD:
DISPOSAL SHOULD BE MADE IN ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

***** IX SPECIAL PRECAUTIONS *****

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:
CAUTION!
AVOID CONTACT WITH EYES.
ENGINEERING CONTROLS:
EYEWASH STATIONS.

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** X SHIPPING AND REGULATORY CLASSIFICATION DATA **

DOT SHIPPING NAME: NA
DOT HAZARD CLASS: NA
DOT LABEL(S): NA
UN/NA NUMBER: NA
PLACARDS: NA

EXPORT: NA

EPA HAZARD WASTE: NA
OSHA HAZARD CLASS: NA
CPSC CLASSIFICATION: NA
TRANSPORTATION CLASS: IMO NA
RID (OCTI) NA
ADR (ECE) NA
RAR (IATA) NA
NFPA/HMIS CLASSIFICATION: FLAMMABILITY 0 , REACTIVITY 0 , HEALTH 1
ADDITIONAL INFORMATION:

THIS PRODUCT OR ITS COMPONENTS ARE ON THE EUROPEAN INVENTORY OF EXISTING COMMERCIAL CHEMICALS (EINECS).
THESE DATA ARE OFFERED IN GOOD FAITH AS TYPICAL VALUES AND NOT AS A PRODUCT SPECIFICATION. NO WARRANTY, EITHER EXPRESSED OR IMPLIED, IS MADE. THE RECOMMENDED HANDLING PROCEDURES ARE BELIEVED TO BE GENERALLY APPLICABLE. HOWEVER, EACH USER SHOULD REVIEW THESE RECOMMENDATIONS IN THE SPECIFIC CONTENT OF THE INTENDED USE.

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Report Documentation Page

NASA — National Aeronautics and Space Administration

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4. Title and Subtitle	5. Report Date
DEVELOPMENT OF TAILORABLE ADVANCED BLANKET INSULATION FOR ADVANCED SPACE TRANSPORTATION SYSTEMS	April 15, 1987
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Dominic P. Calamito	
	10. Work Unit No. 506-53-31
9. Performing Organization Name and Address WOVEN STRUCTURES Division of HITCO 618 W. Carob Street Compton, CA 90220	11. Contract or Grant No. NAS2-12253
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15. Supplementary Notes
Monitor Contract:
Technical Monitor, Paul M. Sawko, M/S 234-1
NASA Ames Research Center, Moffett Field, CA 94035

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16. Abstract Two items of Tailorable Advanced Blanket Insulation (TABI) for Advanced Space Transportation Systems, were produced. The first consisted of flat panels made from integrally woven, three dimensional fluted core having parallel fabric faces and connecting ribs of Nicalon silicon carbide yarns. The triangular cross section of the flutes were filled with mandrels of processed Q-Fiber Felt. Forty panels were prepared with only minimal problems, mostly resulting from the unavailability of insulation with the proper density. Rigidizing the fluted fabric prior to inserting the insulation reduced the production time. The procedures for producing the fabric, insulation mandrels and TABI panels are described. The second item was an effort to determine the feasibility of producing contoured TABI shapes from gores cut from flat, insulated fluted core panels. Two gores of ICAS, "Integrally woven fluted Core And Single ply fabric" were insulated and joined into a large spherical shape employing a tadpole insulator at the mating edges. The fluted core segment of each ICAS consisted of an Astroquartz face fabric and Nicalon face and rib fabrics, while the single ply fabric segment was Nicalon. Although further development will be required, the success of fabricating this assembly indicates that this concept may be feasible for certain types of space insulation requirements. The procedures developed for weaving the ICAS, joining the gores, and coating certain areas of the fabrics are presented.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
OTV Aerobrake; Thermal Protection Blanket; Silica Fabric; Hi-Temp Insulation Blanket; Inflatable Ballute; Hi-temp Insualtion Blanket; TABI; Flexible Ceramic TPS Blanket; Fluted Core Fabric; Silicon Carbide Fabric; Integrally Woven Fluted Core; Flexible Insulation Blanket	Limited Distribution Star Category 27

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
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