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Manufacturing Methods and Technology

PRODUCIBILITY AND SERVICEABILITY OF KEVLAR-49 STRUCTURES MADE ON HOT LAYUP TOOLS

May 1975

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Hughes Helicopters - Division of Summa Corporation
Culver City, California

Final Report, Contract DAAG46-74-C-0100

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This report covers work performed under contract DAAG46-74-C-0100, "Producibility and Serviceability of Kevlar-49 structures made on Hot Layup Tools." The pruposes of this program were:

- Evaluate the producibility of a helicopter structural component made from Kevlar-49 fibers.

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- Demonstrate the low cost aspects of using Hot Layup Tools (HLT) to fabricate composite structures.
- Evaluate the serviceability of the Kevlar-49 structure in actual field operations.

These purposes were achieved by redesigning of the aft air inlet fairing of the OH-6A to be built from Kevlar-49 fibers on an HLT. The costs of the tool and part fabrication were monitored to demonstrate the low cost aspects of this manufacturing approach. The fairing was installed on a bailed OH-6A helicopter and flight tested to evaluate the serviceability of the Kevlar-49 structure. The HLT was easily fabricated. It performed very satisfactorily and showed good cost savings over the existing fabrication methods. The fairing's serviceability during flight test was judged comparable to the existing fiberglass fairing.

SUMMARY

The U. S. Army Materials and Mechanics Research Center (USAMMRC) has recognized the potential benefits that could be realized in manufacturing aircraft components on a new type of tool, a Hot Layup Tool (HLT). Accordingly, AMMRC awarded Hughes Helicopters (HH) a development program to investigate this improved manufacturing technology. The contract (DAAG46-74-C-0100) included the development of a tool, fabrication of the upper fairing of the OH-6A helicopter and its evaluation in flight. Another requirement of the contract was the application of Kevlar-49 in the fabrication of typical airframe components and determination of its associated producibility characteristics. The HLT is a low cost tool fabricated from wire-reinforced concrete matrix cast with copper tubing for alternate heating with live steam and cooling with cold water to achieve a rapid cure cycle for composite layups. It is nickel-lined for permanence.

The program resulted in a reduction in manhours for fabrication of the fairing of approximately 70% (10 hours in lieu of 32.2 hours). A large portion of this manhour saving was due to fairing design changes in adapting it to the process. The use of HLT also resulted in an energy cost saving (oven curing vs steam) of approximately $15.00 per fairing. In addition, it was determined that a tooling and facilities cost saving of $4.14 per fairing would result in a production rate of 250 fairings per year, (HLT vs standard plastic tool). These savings are summarized as follows:

Labor, 22.4 hours @ 20.00	$448. 00
Energy	15.00
Tooling and Facilities (Based on 250 parts/year)	4.14
TOTAL SAVING	$467.14

The portion of the above saving ascribed entirely to use of the HLT is estimated to be approximately $86.34 per fairing [15% of labor Δ($67.20) + energy saving ($15.00) + tooling and facilities savings ($4.14)]

This program also successfully applied Kevlar-49 cloth, replacing the standard E glass used in the existing fairing. Methods were successfully developed for drilling, routing and sawing Kevlar-49. The fairing assembly was judged equal to the standard fairing during handling and flight test evaluations. In addition to the part design revision, tooling development, and flight test, a materials strength evaluation was made and a total of nine fairings were manufactured, of these, five were flightworthy.

Substitution of the Kevlar-49 for fiberglass as the primary material for the fairing reduced the fairing weight 0.67 pounds (3.89 lb vs 4.56 lb) but increased the material cost approximately $53.00. This results in a weight saving cost of $79.10 per pound of weight saved. This cost per pound of weight saved would not normally be considered cost effective by HH.

The details of the program development are described in this report along with the rationale for the cost effectiveness estimates described above. Dr. Bernard Halpin of AMMRC was the Government technical advisor and coordinator for the program.

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INTRODUCTION

Advanced composite materials have been given more and more emphasis in recent years because of their versatility and potential weight and cost savings. This has led to a steady improvement in composite design and manufacturing techniques. Hughes Helicopters developed a new technique for assembling and curing composite structures called the Hot Layup Tool (HLT). This resulted in a contract award from USAMMRC in Watertown, Massachusetts, to demonstrate the effectiveness of a low-cost, low-lead time, metal reinforced concrete mold (HLT) in the fabrication of an aircraft component from the advanced composite material, Kevlar-49. The part chosen for evaluation was the engine inlet aft fairing on the Army OH-6A helicopter (Figures 1a and 1b).

The detailed scope of the program was:

- Design and fabricate a low-cost, low-lead time Hot Layup Tool on which to build the fairing. The tool has a metal face to facilitate part removal, and incorporates integral heating and cooling capabilities.
- Fabricate the OH-6A engine inlet aft fairing from the advanced composite Kevlar-49.
- Develop the techniques on small samples for machining, drilling, trimming and cutting Kevlar-49 epoxy needed to fabricate the inlet fairing.
- Fabricate nine fairings.
    - The first four were for contractor evaluation.
    - The remaining five were flightworthy and complete in all hardware details.
    - One of these five was flight tested on an OH-6A.
    - Deliver all assemblies, including the one flight tested, to the Army.
- Submit a final report.

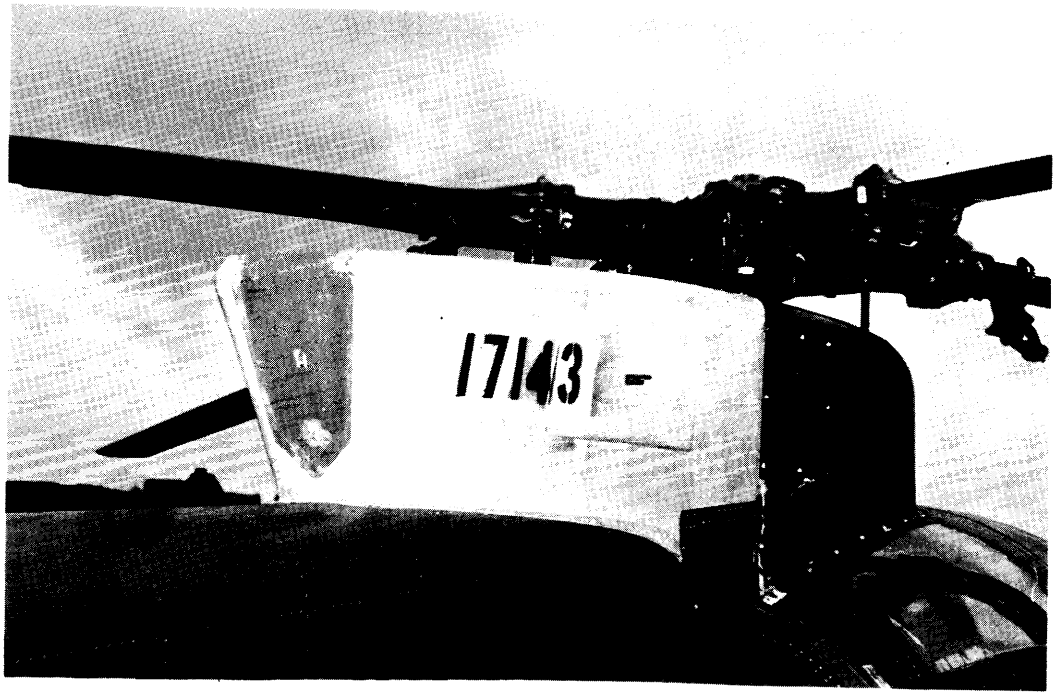


Figure 1a. Kevlar-49 Fairing on an OH-6A.

Figure 1b. Kevlar-49 Fairings Fabricated in HLT.

The program was broken down into ten tasks for easy monitoring and reporting. Figure 2 is a pictorial summary of the major tasks that made up the total program.

The program started by determining the stress allowables and core thickness in Kevlar-49/Nomex homeycomb structures by testing coupons representative of the facing and core configuration intended for use. The fairing was designed to use Nomex core and Kevlar-49 facings. The HLT was designed and fabricated from nickel-faced reinforced concrete. Copper tubing embedded in the concrete gave the tool an integral heating and cooling capability. Nine fairings were manufactured. The sixth fairing was installed on an OH-6A to assess serviceability by flight testing. A thorough trim and drilling evaluation was conducted late in the program. The delay in performing this task was due to difficulty in procuring the recommended tools. The cost effectiveness study was finalized using manufacturing data recorded throughout the fabrication of the fairings.

This final report together with delivery of nine fairings to USAMMRC concludes the effort under contract DAAG46-74-C-0100.

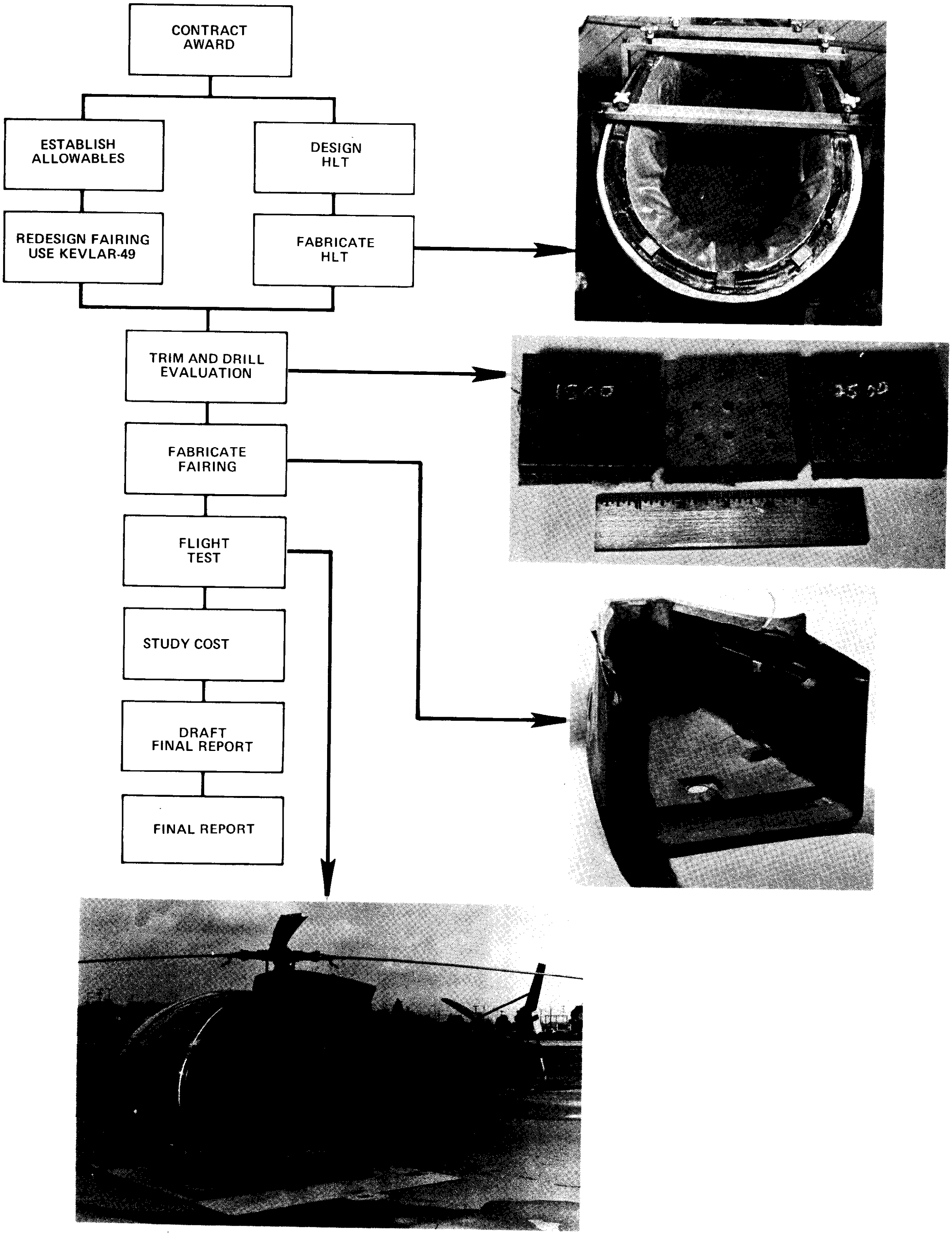


Figure 2. Program Summary of Events.

FAIRING LOADS AND DESIGN ALLOWABLES

The critical fairing loading occurs in a yawed flight condition combined with internal inlet pressure. This is the same condition that designed the present OH-6A fairing. Figure F-1 in Appendix F shows the loading, shear, and bending moment diagrams. The fairing has been found to be critical in compressure bending. The design limit loads are:

$$M = -42.2 \text{ inch-pounds}$$

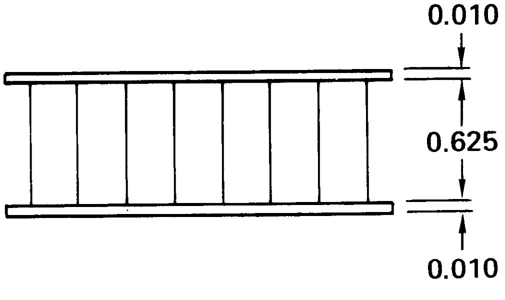
$$P = 5.61 \text{ pounds}$$

The test panels shown in F-2, Appendix F, were made from an 0.40-inch thick Nomex honeycomb and faced with a variety of Kevlar-49 epoxy prepreg cloth. These panels were subjected to bending tests to determine bending allowables. See Figure F-3, Appendix F, for the loading method. Table 1 lists the results of the tests.

The allowable stress is as follows:

$$\begin{aligned} \text{Mean Value} &= 14,743 \text{ psi} \\ 3\sigma \text{ (St'd Deviation)} &= \underline{\ 4,227\ } \text{ psi} \\ F_{c_{ult}} &= 10,516 \text{ psi} \end{aligned}$$

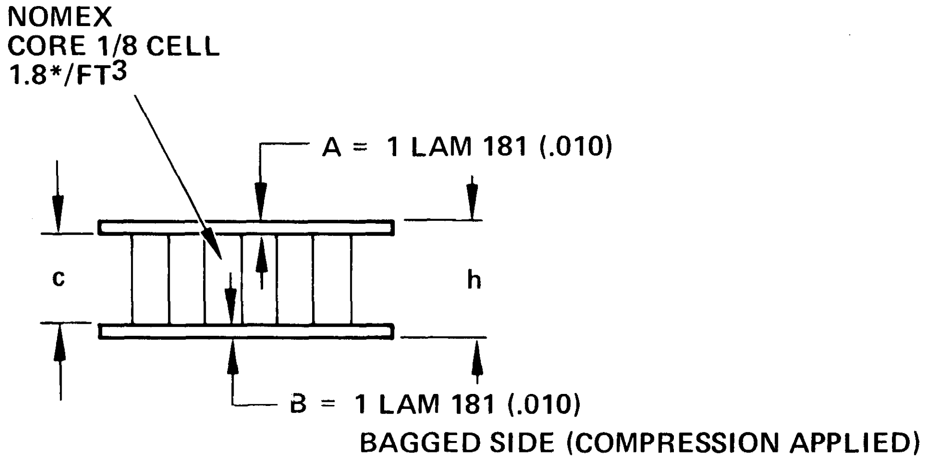
Other tests were performed using a variety of facings and type of cloth. Table F-1, Appendix F, tabulates the results. As can be seen, none of these variables gave any increase of allowable compressive bending stress over the least expensive configuration, one laminate 181 cloth on both faces of the Nomex core. The height of the core was sized to withstand the applied moment thusly:



$$f_c = \frac{42.2 \times 1.5}{0.635 \times 0.01} = 9921 \text{ psi}$$

$$MS = \frac{10,516}{9921} - 1 = 0.06$$

TABLE 1. COMPRESSIVE BENDING FINAL TEST RESULTS



Config	P* (lbs)	h (in.)	A or B (in.)	W* (in.)	c (in.)	M/Inch*	f_c or f_t
1A1	337	0.430	0.010	7.00	0.420	72	17143
1A2	247	0.380		7.00	0.370	53	14324
1A3	202	0.342		6.44	0.332	47	14156
1A4	247	0.393		6.44	0.383	58	15143
1C1	288	0.420		7.00	0.410	62	15121
1C2	284	0.420	↓	7.00	0.410	61	14878
1C3	239	0.420	0.010	7.00	0.410	51	12439

*For P, M, and W see Figure F-3, Appendix F.

The radius in the upper corner of fairing could limit the thickness of Nomex honeycomb (see Figure 3). However, it was shown that 0.625-inch thick core could be formed into these corners, so this with 0.010-inch thick single laminate facings of 181-type Kevlar-49 was selected.

For comparison purposes, typical composite material properties are compared in Table 2. These values are for the fiber with 50 percent volume of epoxy resin.

TABLE 2. TYPICAL COMPOSITE MATERIAL PROPERTY

	E-Glass	S-Glass	Kevlar-49
Density, lb/in.^{3}	0.0666	0.0656	0.0468
Fiber volume fraction	0.50	0.50	0.50
Unidirectional Properties			
Tension strength, psi	138,000	163,000	190,000
Compression strength, psi	138,000	163,000	40,000
Shear strength, psi	9,000	9,000	8,000
Tension modulus, 10^6 psi	5.3	6.3	9.5
Shear modulus, 10^6 psi	0.52	0.53	0.22
μ_{12} Poisson's ratio	0.285	0.285	0.285
μ_{21} Poisson's ratio	0.098	0.080	0.023
Crossply (±45°) Properties			
Tension strength, psi	34,000	40,000	16,400
Compression strength, psi	29,100	34,400	6,000
Shear strength, psi	36,700	12,000	10,000
Tension modulus, 10^6 psi	1.6	1.7	0.8
Shear modulus, 10^6 psi	1.7	1.8	2.5

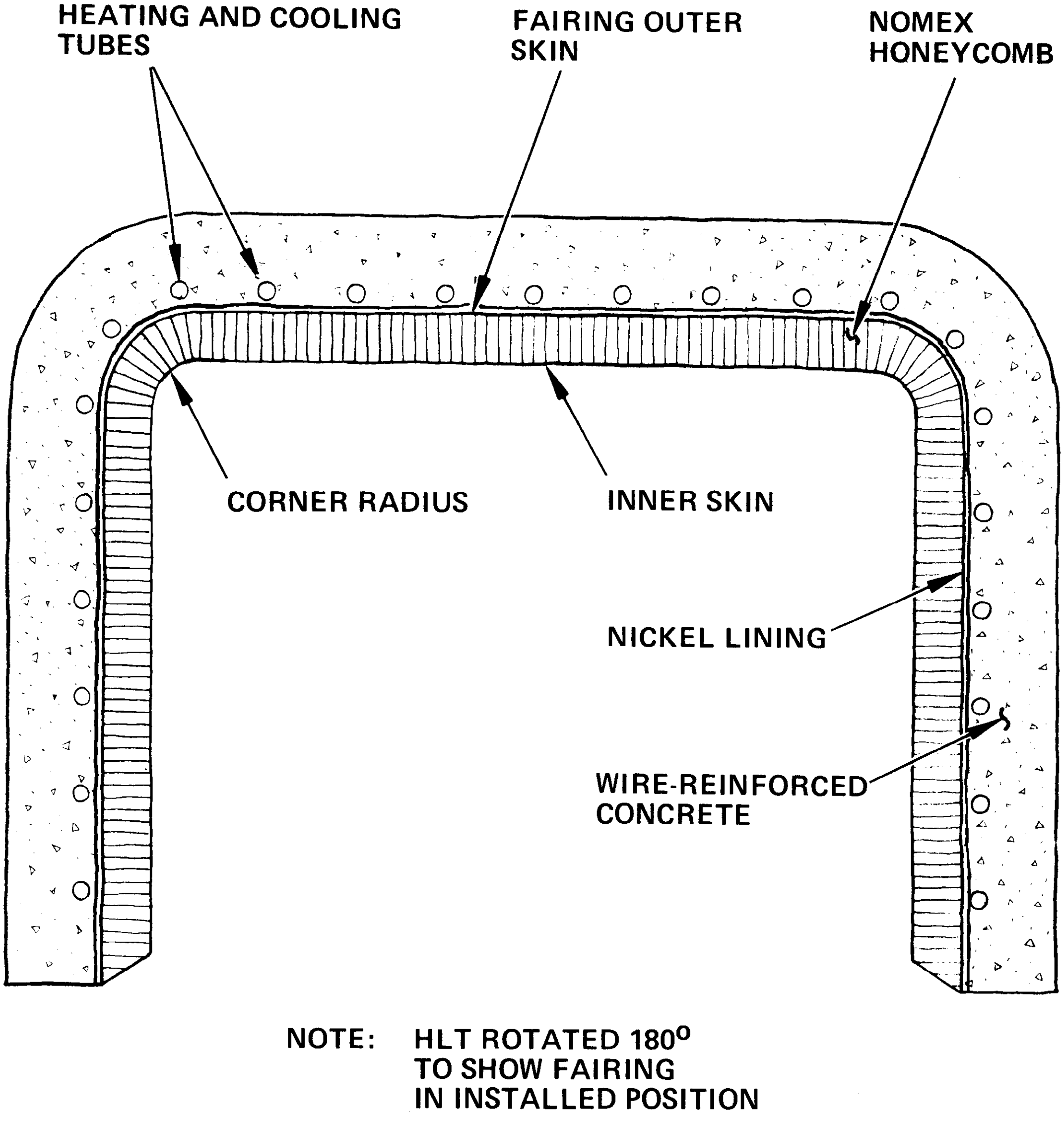


Figure 3. Section Through HLT and Fairing.

FAIRING DESIGN AND ANALYSIS

The OH-6A aft inlet fairing is a good candidate for experimenting with new materials and new manufacturing techniques. It is 35 inches long, 21 inches wide, 15 inches high, and its weight is approximately 5 pounds. The standard fiberglass fairing in production for the Hughes Helicopters Model 500 is made of fiberglass and foam construction.

The fairing is a lightly loaded secondary structure with a relatively large surface area and has second degree contours. This fairing is located behind the rotor mast above the fuselage. It fairs the aft end of the air inlet for the OH-6A engine (see Figure 1) and performs the following functions (also see Figure 4):

- Shape and position reduces aerodynamic drag.
- Supplies the mounting surface for two types of air filters: inertial particle separator or a barrier filter.
- Scavenge door for the inertial particle separator is installed on the right-hand side.
- Contains an air bypass door that serves as an alternate inlet when the filter is plugged.
- Mounts one flashing aircraft warning light.
- Contains an integral VHF/UHF antenna in the rear portion.
- Has a static pressure port in the aft surface.

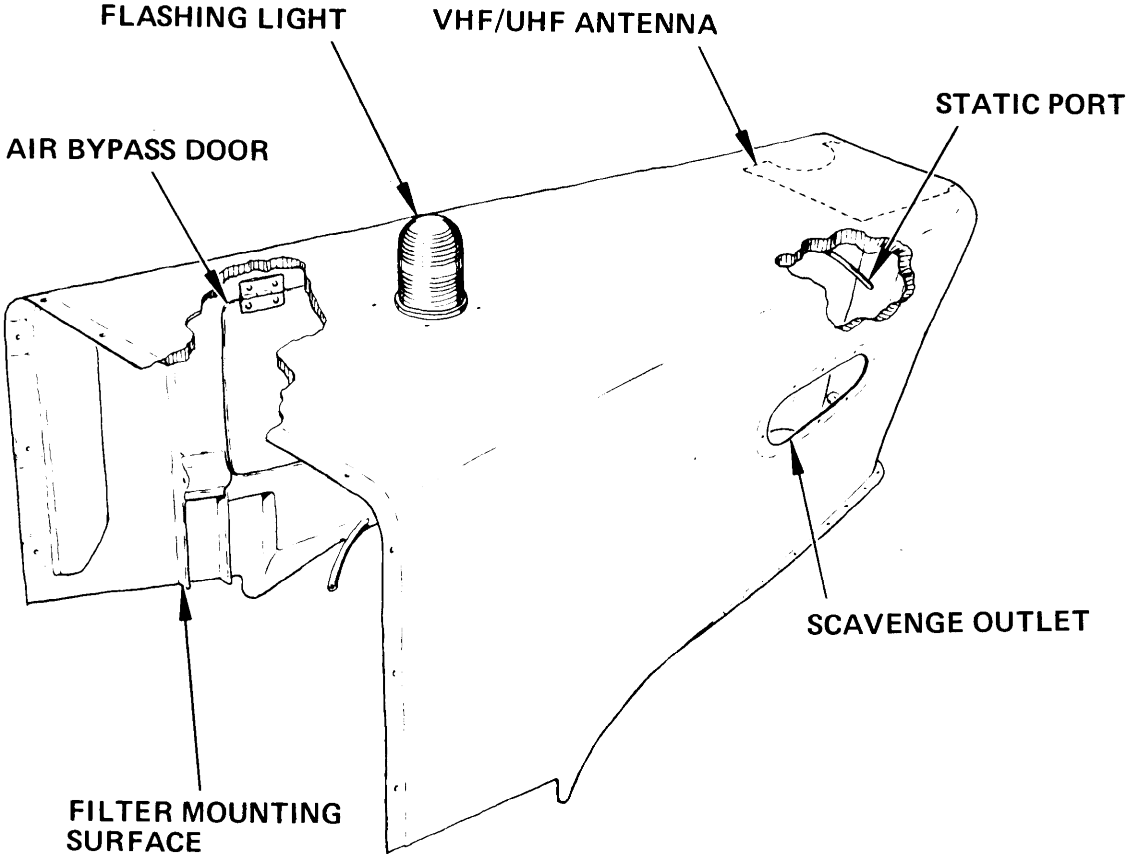


Figure 4. Functions Performed by the Fairing.

The fairing was redesigned as part of this program for the following reasons:

- Replace foam with Nomex honeycomb to allow better heat transfer from HLT to inner skin; see Figure 3.

- Reduce number of parts, thus simplifying the overall fairing. Take advantage of the Nomex honeycomb by incorporating integral integral conduits for wires, pressure lines, and control cables.

- Decrease manufacturing costs.

Tables 1 and F-1 of Appendix F show that 1/8-inch cell Nomex has higher compressive allowables than 1/4-inch cell Nomex. They also show that the addition of one or two more laminates to the compressive side of the test samples does not increase the allowables. Commercial 281 Kevlar-49 cloth was considered for use because of its low cost, but it has lower strength allowables than 181 cloth and has a very porous surface when cured as a single laminate. Therefore, it was discarded in favor of 181-type cloth which has the following characteristics:

- Cures with a sealed surface.
- Gives the highest allowable compressive stress with 1/8-inch Nomex core.
- Is the least expensive since it requires only one laminate per face.
- Has minimum weight.

These good traits together with the fact that the 0.625-inch thick Nomex can form into the corner radius of the fairing (see Figure 3) determined the configuration: one laminate of 181-type Kevlar-49/epoxy cloth on each side of a 0.625-inch thick 1/8-inch cell Nomex honeycomb core. Prior to the fabrication of the bending test specimens, it was also found that solvent-deposited rather than hot-dipped prepreg cloth gave a better bond to the Nomex core. Solvent-deposited prepreg was used exclusively thereafter.

The layout drawing for the new inlet fairing is shown in Appendix A. Figure 5 shows a breakdown of all parts that make up the inlet fairing. New parts designed and fabricated in this program are the Kevlar-49 parts; i.e., the fairing skins, filter attach frame, and door skins. The Nomex honeycomb (a new part) replaced the existing foam that stiffens the skin. The remaining parts are the same as those used in the existing fairing: sheet metal antenna, aluminum doublers bonded between the skins for rivet and screw edge support, door hinges, and epoxy blocks for filter attach bolts.

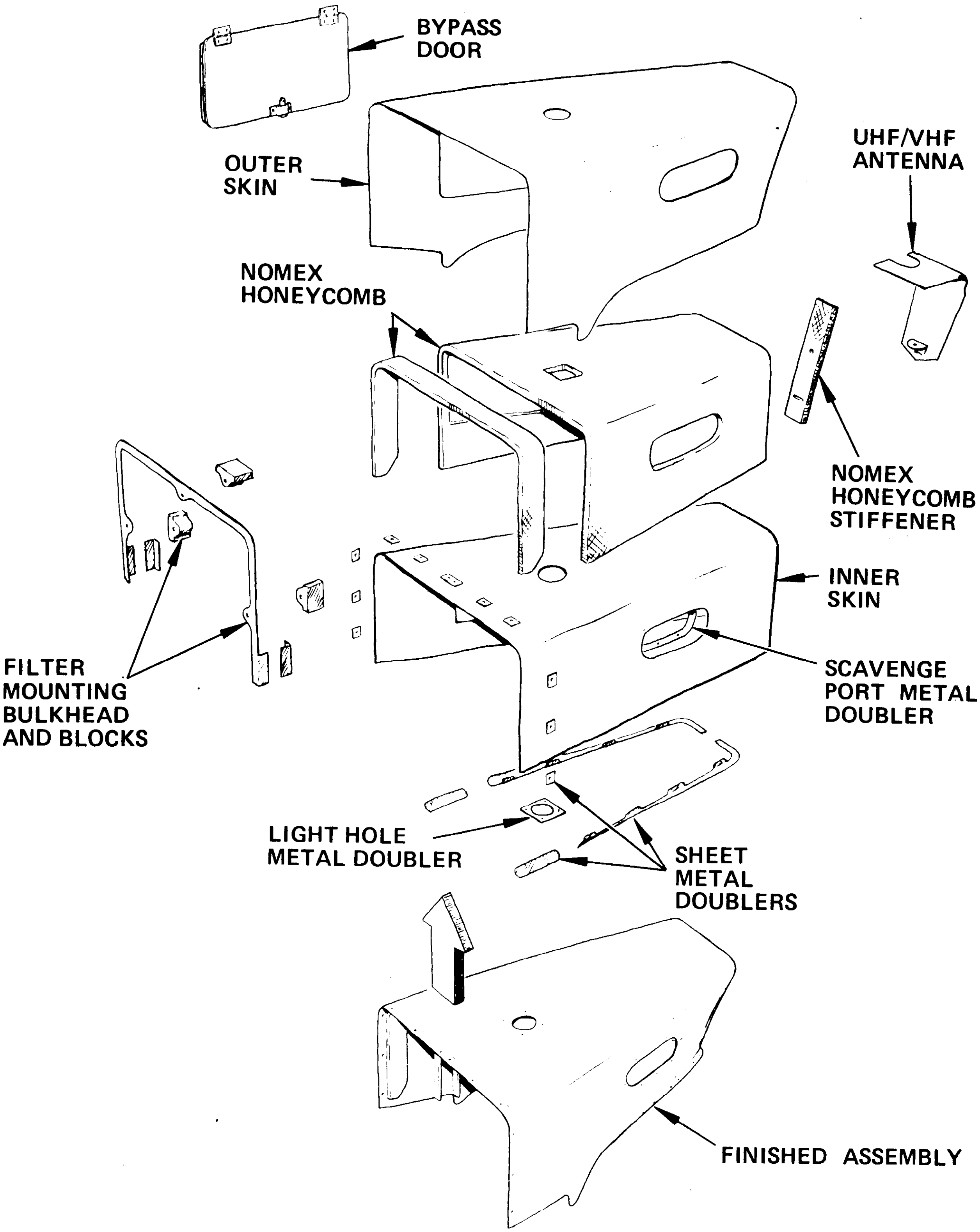


Figure 5. Exploded View of Fairing.

TOOLING DESIGN AND FABRICATION

The Hot Layup Tool (HLT) is shown schematically in Figure 6. It is a female mold that forms the outer contour of the inlet fairing. The cavity of the HLT is lined with an electro-deposited nickel skin 0.10 inch thick. The outside of the nickel liner has a wire-reinforced concrete backing with imbedded copper tubes. The concrete is reinforced with tiny steel wires (WIRAND*). The copper tubes circulate either steam or cold water to cure or cool the composite structure in the most expeditious cycle. The nickel liner gives the tool a hard smooth surface into which composite parts are laid, vacuum-bagged, and heat cured. An insulating blanket around the complete tool decreases the heat losses, thus improving the curing cycle efficiency and protecting workers from the hot tool. Figure 7 shows a schematic of the HLT plumbing system. This heating/cooling system uses steam from the factory's boiler and cold water from the plant's water supply.

The principal advantages of the HLT are

- Provides a very accurate, highly finished surface to cure parts against.
- Reduce cycle time for curing and unloading by using the heating/cooling feature provided by the imbedded coils.
- Uses minimum factory floor space by eliminating the need for a curing oven. Further, the tool does not require room to move to and from the oven.
- Costs substantially less than core-drilled or hole-cored-and-cast metal molds.
- Reduces lead time for fabricating the tool and setting it into operation, versus the all metal mold.
- Requires fewer personnel to operate the tool and fabricate composite parts.

The disadvantages are

- Steam may not be available
- Normally would not be cost effective for low production quantities.

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*TM — Batelle Memorial Institute.

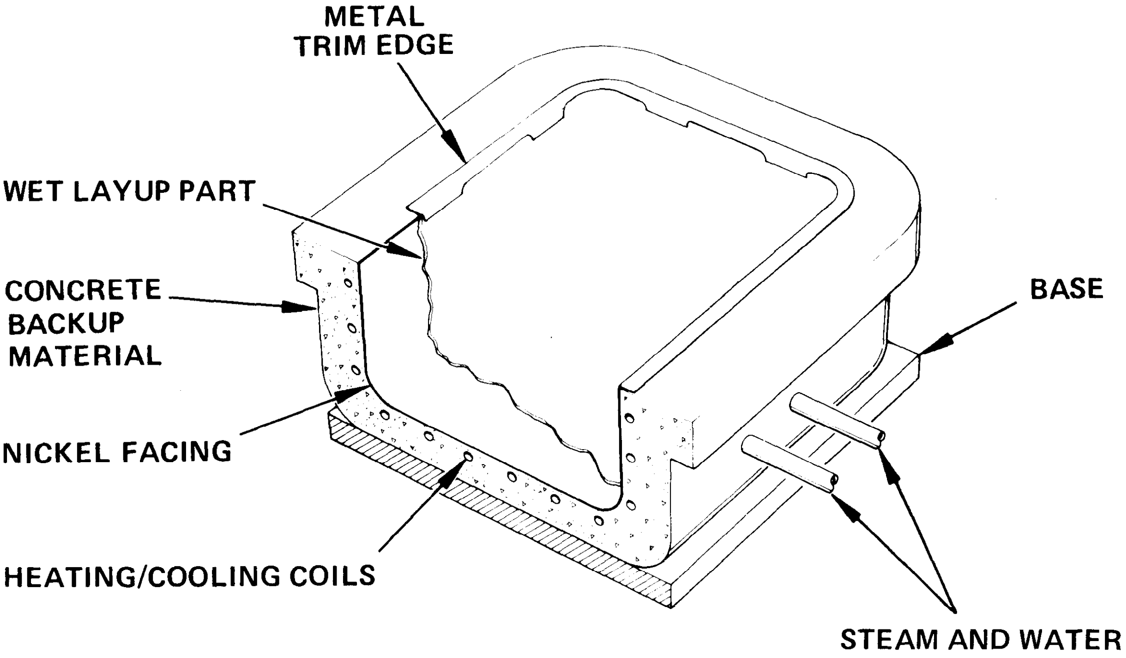


Figure 6. Hot Layup Tool (HLT)

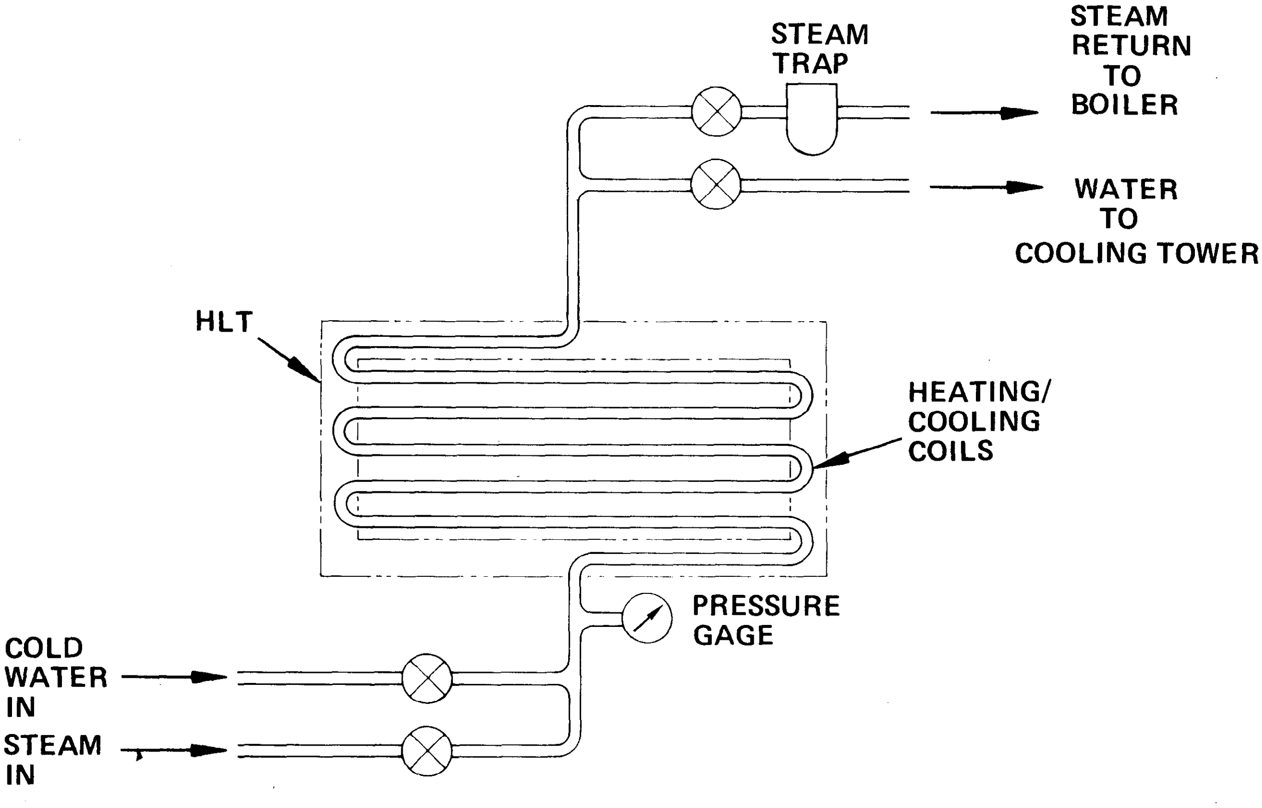


Figure 7. HLT Plumbing Schematic.

The drawings showing the HLT are in the Appendix A. A pictorial HLT fabrication sequence is shown in Figure 8. The plastic plating pattern was made from existing Tool Masters that define the shape of the fairing. Special care was taken to produce a smooth surface for electrodepositing the nickel on the pattern, which was the next operation. Copper tubing was positioned around the outside of the plated pattern in contact with the nickel surface.

Stacrete #8 cement was used to cover the tubes and nickel surfaces. Then 533 pounds of concrete reinforced with chopped wire was poured into the mold built around the plated pattern (see Table 3 for WIRAND Mortar Proportions). The mold was agitated and cured in a wet steam atmosphere maintained at 130° F for 24 hours. The plaster pattern was removed and the nickel surface was cleaned and polished. The sealing ring for the vacuum disphragm and positioning pins for locating the door openings were installed. This completed the tool with one exception: To keep on schedule, the filter bulkhead positioning fixture was not installed. Instead, the existing standard tool was used to position the blocks and bulkheads during the cure cycle.

The finished HLT weighed 816 pounds with overall dimensions: 5 feet long, 2.5 feet wide, and 2 feet high. The total installation, including incoming and outgoing steam and water lines and work area, was 90 square feet. Two people could easily work around the periphery loading or unloading the tool.

A record of the time to heat up, cure, and cool down is shown in Figure 9. Stabilization temperatures were 304° F for the outer skin and 282° F for inner skin. The steam temperature was supplied at 328° F and 80 psig. These measurements were made with Kevlar/Nomex honeycomb panels instrumented with thermocouples while they were cured in the HLT. A typical time-history of the temperatures of the two surfaces, Figure 9, measured during the curing of the panels proved that the HLT has an effective cure cycle.

The HLT cure cycle was further evaluated after the fairings were fabricated by comparison with the oven cycle. Figure 10 shows two HLT curves (X and Y) and one typical oven cure cycle. The HLT curves reflect 100 psig saturated steam with curve X allowed to stabilize at 308° F, while curve Y had the steam pressure reduced to 60 psig at 236° F approximately 23 minutes into the heating cycle.

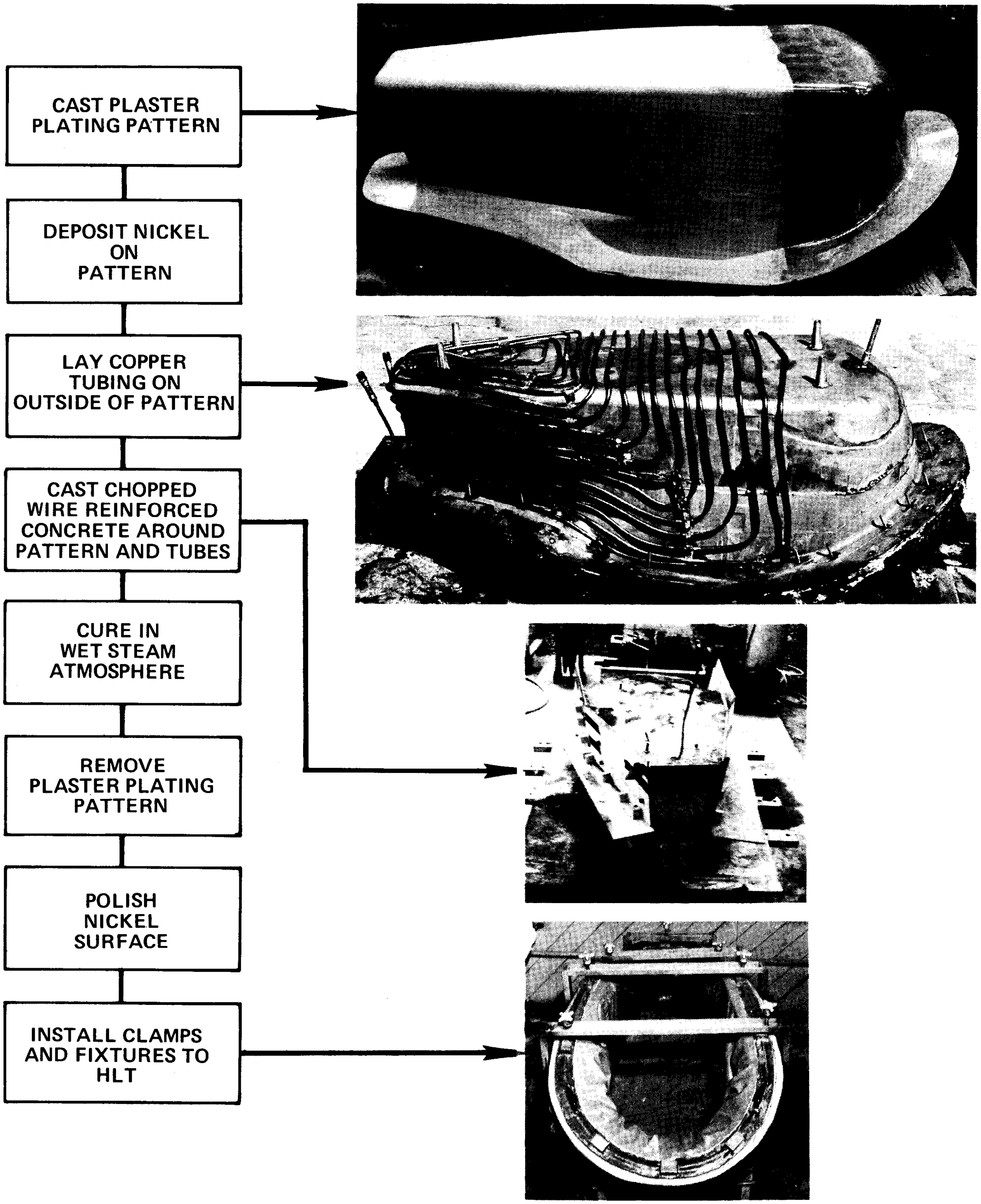


Figure 8. Fabrication Sequence for HLT.

TABLE 3. WIRAND MORTAR PROPORTIONS (1 MIX)

Item No.	Material	Weight Fraction	Weight, lb	Estimated Cost
1	Cement (Chem Comp brand)	0.248	32.2	\$0.45 at 1.40¢/lb
2	Water	0.106	13.8	\$0
3	Sand #16	0.388	50.5	\$0.73 at 1.45¢/lb
4	Sand #60	0.191	24.8	\$0.36 at 1.45¢/lb
5	Chopped wire 0.010 in. dia x 1.0 in. long	0.067	8.7	\$3.48 at 0.40¢/lb
Totals		1.000	130.0	\$5.02 at 3.86¢/lb avg

The thermocouple monitoring the temperature was positioned on the top of the inner skin approximately 12 inches aft of the forward fairing flange. The heatup cycle in all cases is shown from A to B, while the cure cycle from B to C is followed by a cooling cycle C to D. The HLT curing cycle was shorter by approximately 50 minutes. The steam flow used was measured for curve X by weighing the condensed steam on the boiler side of the HLT. The total flow was 41.3 pounds of water at position C prior to turning on the cooling water.

The HLT cure time could undoubtedly be reduced after conducting a more extensive temperature survey over the HLT surface area. But for this program the fairings were subjected to a cure time of approximately 70 minutes to ensure that no uncured areas would exist.

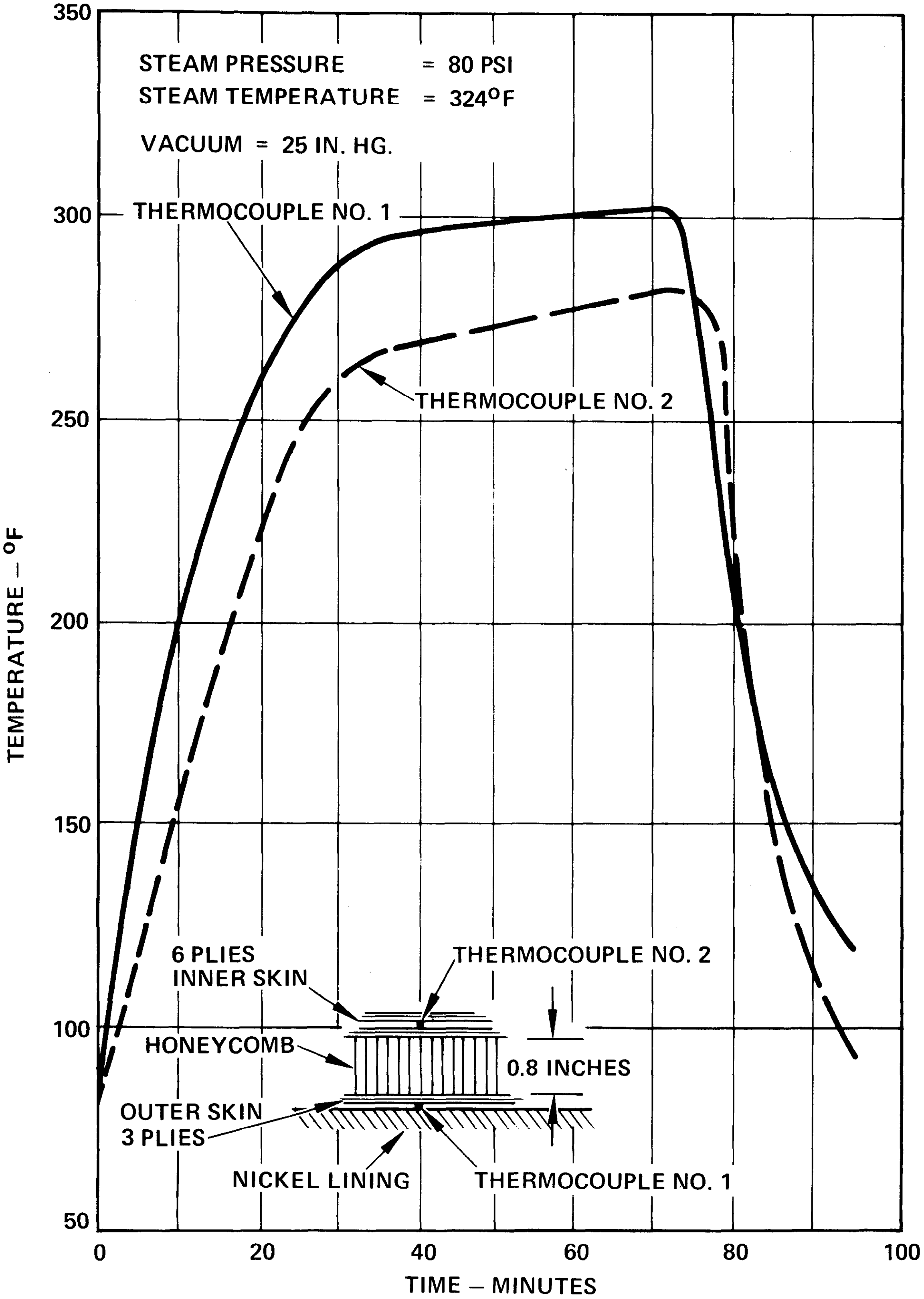


Figure 9. HLT Temperature Evaluation.

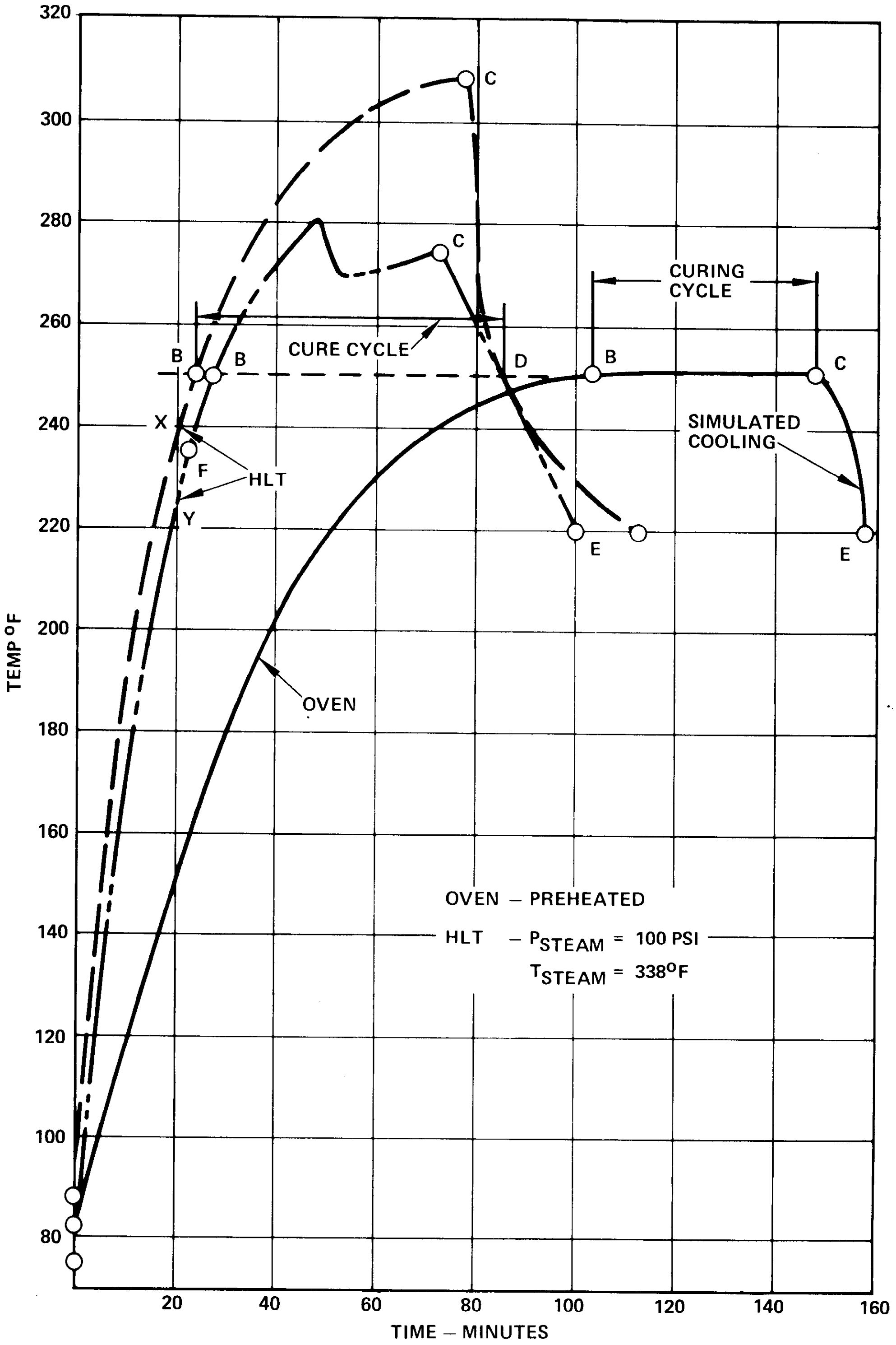


Figure 10. Curing Cycle Comparisons.

EVALUATION OF TRIMMING DRILLING AND CUTTING

An evaluation of the trimming, drilling, and cutting operations used in fabricating the inlet fairings was conducted. The evaluation was made on specimens fabricated from Kevlar-49 to match the fairings built under this contract and on fiberglass (E-glass) for comparison. Figure 11 shows these operations and where they occur on the fairing. Tables 4 and 5 describe the results of this evaluation. Their headings are generally self-explanatory, i. e., define the operation and tool used, etc. The quality rating has this definition:

- Excellent - cut edges and surfaces need little or no sanding
- Good - cut edges and surfaces need light sanding similar to fiberglass
- Poor - cut edges and surfaces need much sanding
- Inferior - cut edges and surfaces burned -- need heavy sanding

The sanding operation for composites is not too much unlike deburring sheet metal. The sanding cleans up the surface and removes protruding fibers which, if left, could lead to delamination resulting from easier water absorption, or be caught while handling, thus prying the laminates apart. The best sanding method found for Kevlar-49 was using aluminum oxide paper, grit 80 to 120, and sanding under a flow of water. In general, cutting, drilling, and trimming Kevlar-49 takes more time than a similar operation on standard fiberglass.

The best drilling was accomplished with Technology Associates spade drill. (See Appendix A.) This drill required the use of a drill bushing and was easily broken, but it produced excellent holes. The jig saw gave the best results for sawing and required a minimum amount of sanding. The jig saw cut on the downstroke, cooled and cleaned itself on the upstroke. Both the spade drill and jig saw need more tooling than are needed for the drilling and routing procedures currently used on fiberglass.

In making the nine fairings for this program, the standard tools used in producing the current production fiberglass fairings were used. The finished product was a very acceptable fairing.

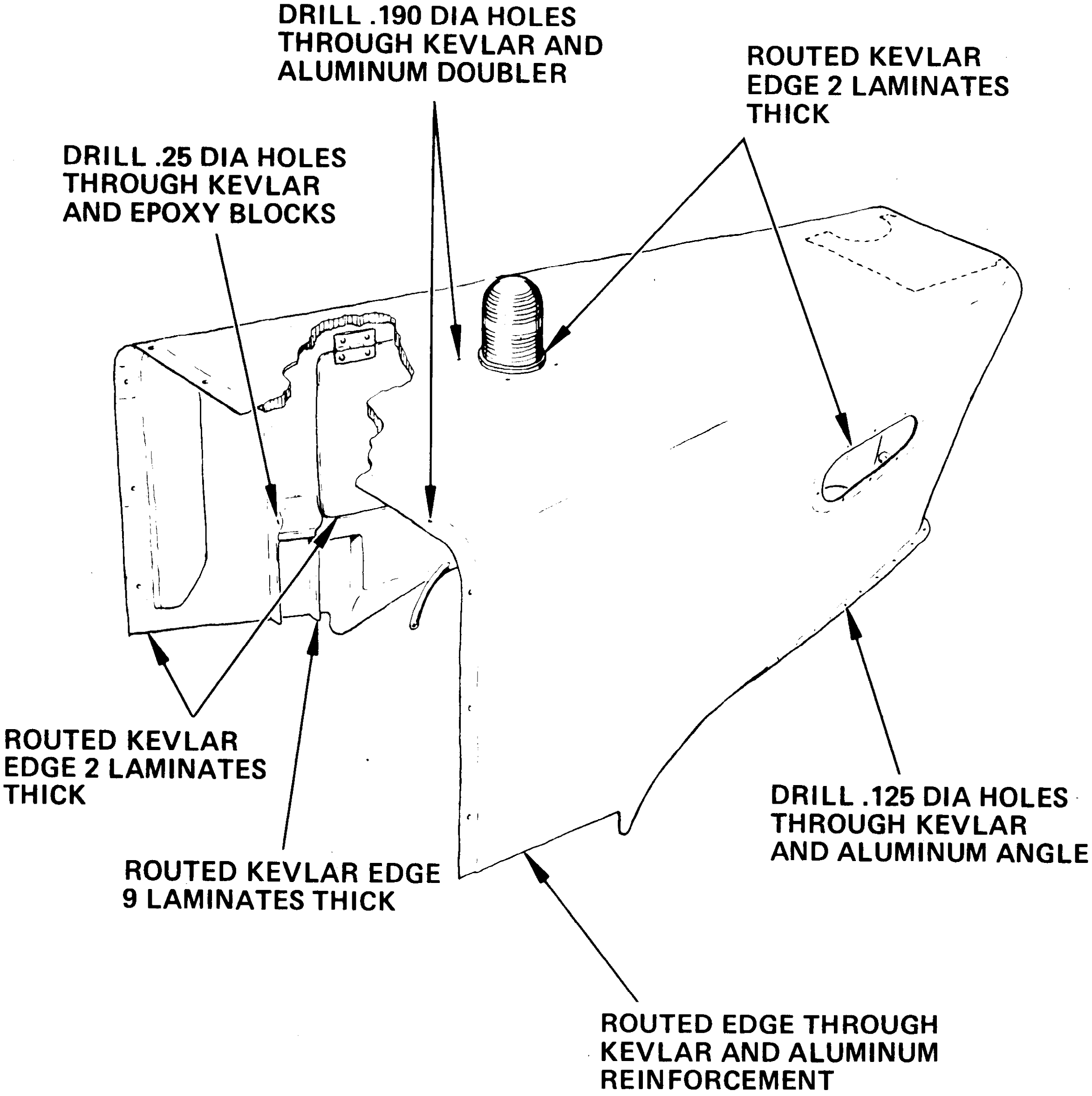


Figure 11. Cutting, Trimming, and Drilling Operations on Fairing.

Routing and sawing Kevlar-49 resulted in overheated tools and burned edges of the composite. Cooling was obviously indicated to prevent burning. Air cooling was tried unsuccessfully. A liquid coolant would have been satisfactory but would have required additions to the existing routing fixtures. This would have disrupted the program to build nine fairings, and the idea was dismissed.

Evaluation of the tools recommended in the DuPont handbook and in Tables 4 and 5 did not take place until after the fairings were completed because of tool delivery problems. The description of the fairing fabrication describes in more detail the problems and their solutions regarding fabrication of a Kevlar part.

The photographs of the samples shown in Appendix D are grouped as described below unless otherwise specified.

- The first seven photographs show samples of sandwich construction having two laminates of 181 style Kevlar-49 on each side of 0.40 thick Nomex Honeycomb core. The drill speeds used were 1500, 2000 and 2500 RPM.
- Photographs 8 through 19 inclusive show samples of 9 laminates of 181 Kevlar-49 or 9 laminates of 181 Polyester fiberglass. The drill speeds were also 1500, 2000 and 2500 RPM.
- The remaining photographs are the same as 8 through 19 except the samples are routed or saber sawed.
- The remaining photograph, #25, shows the different saw blades used to saw the samples in the successful power jig saw.

TABLE 4. DRILLING AND COUNTERSINKING EVALUATION

Operation	Tool	Sample	Photo No. in Appendix D	Quality	Remarks
Drilling	Technology Assoc. Spade Drill	Kevlar - Nomex Sandwich	1, 2, 5, 6	Excellent	Very clean holes
Drilling	59° Standard Drill	Kevlar - Nomex Sandwich	3, 4, 7	Poor	Fuzzy hole edges
Drilling	Technology Assoc. 0. 250 Dia Spade Drill	9 laminates Kevlar	8, 15	Good	Fairly clean holes with little fuzzing
Drilling	59° Standard Drill	9 laminates Kevlar	9	Poor	Fuzzy holes both on entering and leaving
Drilling	Technology Assoc. 0. 190 Dia Spade Drill	9 laminates Kevlar	10, 16	Poor	Fairly clean holes on entering, fuzzy on leaving
Drilling	59° Standard Drill	9 laminates Fiberglass	11, 12, 13, 14	Good	Clean holes with some delamination (feed too fast)
Drilling	59° Standard Drill	9 laminates Kevlar Plywood Support	17 and 18	Good	Holes show small amounts of fuzzing
Drill and CSK	59° Std Drill, Std countersinking tool	9 laminates Kevlar	19	Poor	CSK holes very fuzzy

TABLE 5. ROUTING AND SAWING EVALUATION

Operation	Tool	Sample	Photo No. in Appendix D	Quality	Remarks
Routing	Tool No. 501 - 1/4" Fullerton Router Bit	9 laminates Fiberglass	20	Good	Small amount of delamination on edges
Routing	Std 2600-1 Fullerton Router Bit	9 laminates Kevlar	21	Inferior	Fuzzy areas with burned edges. Replace tool after 30" cut
Routing	Std 2600-1 Fullerton Router Bit	9 laminates Fiberglass	21	Good	Fairly clean edges
Routing	Technology Assoc. No. TAI-1/4 Router	9 laminates Kevlar	22	Inferior	Edges fuzzy and burnt. Tool clogs and overheats
Routing	Technology Assoc. No. TAI-1/4 Router	9 laminates Fiberglass	22	Good	Fairly clean edge
Saber Sawing	Technology Assoc. No. 49491-321 Blade	9 laminates Kevlar	23	Good	Little fuzziness. Slightly burnt edges
Power Jig Saw	Tungsten Carbide Tipped Blade	9 laminates Kevlar	24	Excellent	Excellent. Clean edges
Sawing	Std Band Saw	Kevlar-Nomex sandwich	1, 2	Poor	Much fuzziness with Kevlar strands

TABLE 5. ROUTING AND SAWING EVALUATION (CONT)

Operation	Tool	Sample	Photo No. in Appendix D	Quality	Remarks
Sawing	Tungsten Carbide Tipped Band Saw	Kevlar-Nomex Sandwich	3, 4, 5, 6, 7	Poor	Much fuzziness on edges with many Kevlar strands
Sawing	Std Band Saw	9 laminates of Kevlar	8, 9	Poor	Small burned areas, fuzzy edges with Kevlar strands
Sawing	Tungsten Carbide Tipped Band Saw	9 laminates Kevlar	10	Poor	Fuzzy edges with many Kevlar strands
Sawing	Std Band Saw	9 laminates Fiberglass	11	Good	Edges have some fabric strands
Sawing	Std Band Saw	9 laminates Fiberglass	12	Good	Edges good except for some delamination
Sawing	Tungsten Carbide Tipped Band Saw	9 laminates Fiberglass	13, 14	Poor	Edges have some strands with some delamination
Sawed	Std Band Saw	9 laminates Kevlar supported by 1/4 plywood both sides	15, 16, 17,	Inferior	Edges burned. Fuzzy with Kevlar strands
Routing	Tool #501-1/4 in. Fullerton Router Bit	9 laminates Kevlar	20	Inferior	Fuzzy and burnt edges. Overheated tool

FABRICATION OF INLET FAIRING

The fabrication task consisted of manufacturing nine fairings. The first four were used to develop the process so that the last five fairings could be certificated for flight.

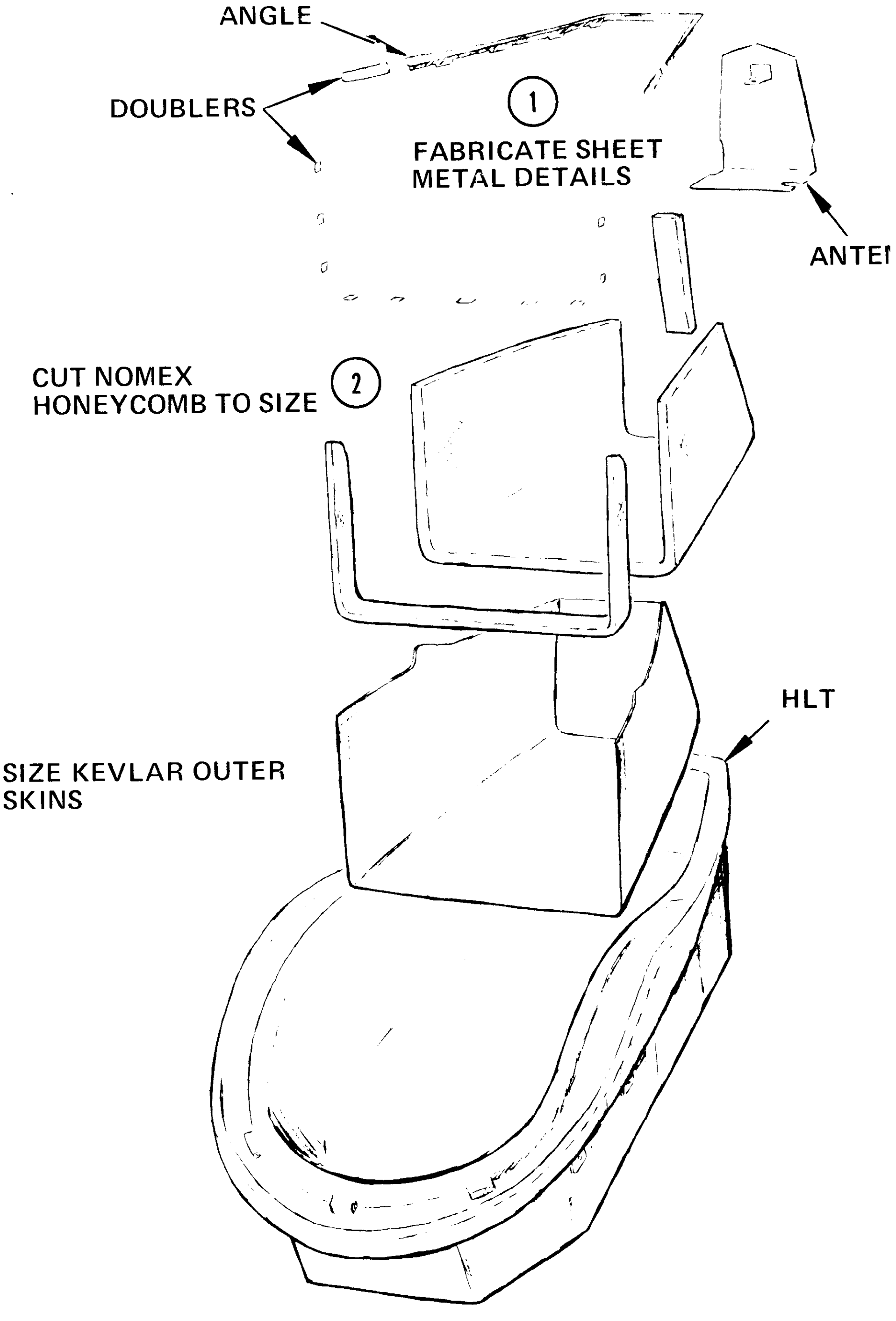
The fabrication sequence is depicted in Figure 12, which shows the eleven basic steps to build the fairing, with a minimum pressure of 22 inches of Mercury per Hughes Process 15-42 shown in Appendix C. Each fairing had a thermocouple attached to the fairing inner skin line and a time temperature recording was made. This assured each fairing was properly monitored and cured completely.

The first fairing was sectioned and tested in the Process Laboratory to prove the effectiveness of the HLT and the cure cycle. The laboratory report is shown in Appendix C. The curing cycle, as shown in Figure 10, was conservatively altered to increase time at 250°F to 70 minutes. The minimum required time per HP 15-42 is 45 minutes. This extra 25 minutes ensured a total cure and was done expeditiously to eliminate the many hours needed to survey the tool, time-history-wise and determine through fabrication experience a shorter curing time.

The fabrication of the fairing, pictorially represented in Figure 12, started by cutting the Nomex honeycomb and dinking the uncured prepreg Kevlar-49 outer skin to size. The HLT is loaded with the outer skin, honeycomb, and sheet metal parts. These are cured. The filter bulkhead and attach blocks were then secondary bonded into the assembly. The final operation has the tubes and conduits set into the honeycomb and the inner skin laid over the part, and cured. The fairing is removed from the tool; trimmed, routed, and drilled. The air bypass door, controls, anchor nuts, and inserts are added to complete the assembly.

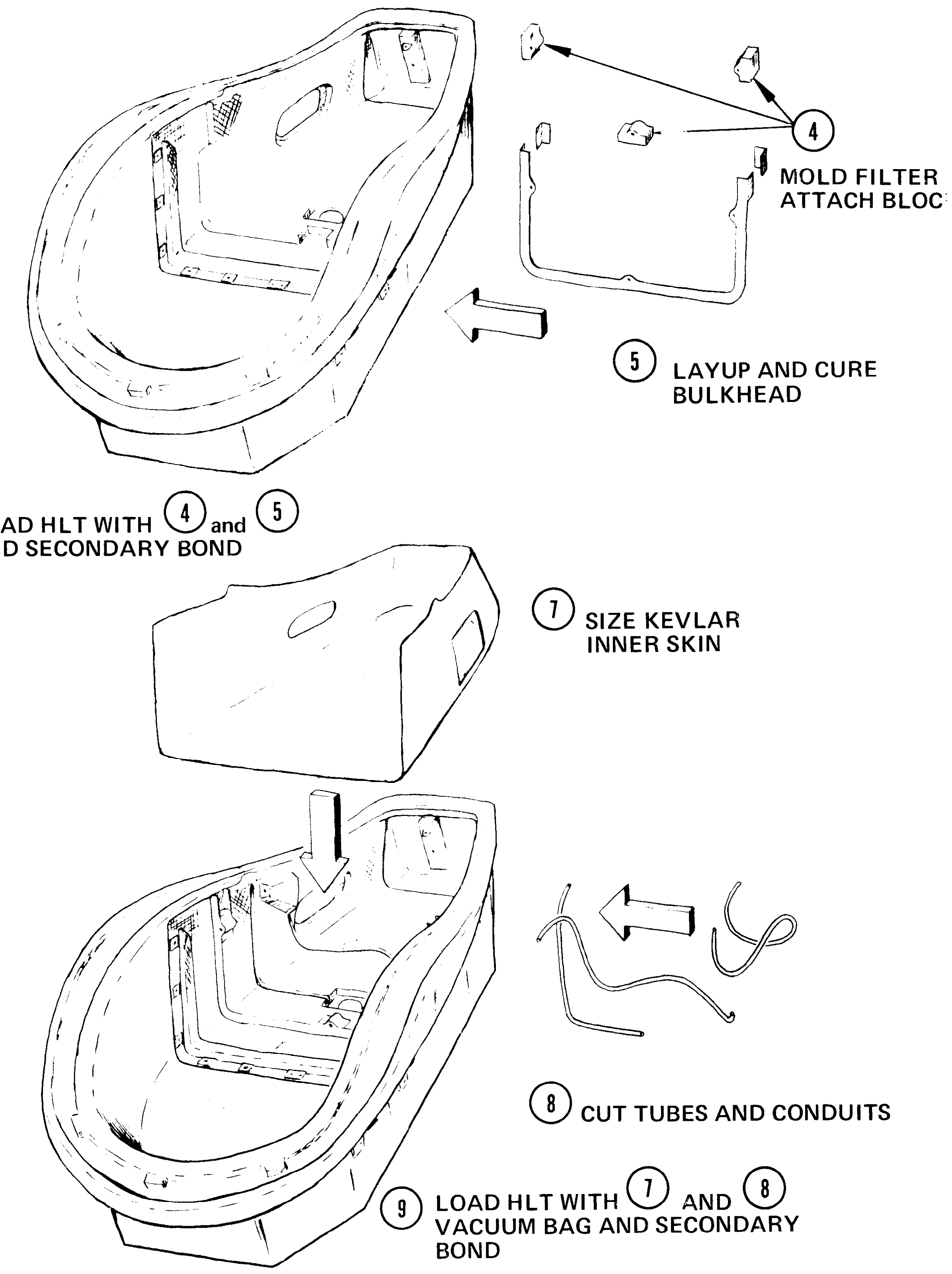
The fabrication of the first four fairings presented several problems. The majority were minor dimensional differences with the drawing and were easily corrected. The two problems of significance were:

- The outer skin would not set down firmly into the corner radius shown in Figure 5. This condition was termed skin bridging and the problem was solved by setting the outer skin tight to the nickel surface prior to adding the honeycomb (see Operation 080 in detailed planning Appendix B) and using a two step honeycomb cure as shown in steps 3 and 9 in Figure 12.



④ LOAD HLT WITH DETAILS ①②③
VACUUM BAG AND CURE

JNA


④
MOLD FILTER ATTACH BLOC
⑤ LAYUP AND CURE BULKHEAD
⑥ LOAD HLT WITH ④ and ⑤ AND SECONDARY BOND
⑦ SIZE KEVLAR INNER SKIN
⑧ CUT TUBES AND CONDUITS
⑨ LOAD HLT WITH ⑦ AND ⑧ VACUUM BAG AND SECONDARY BOND

KS

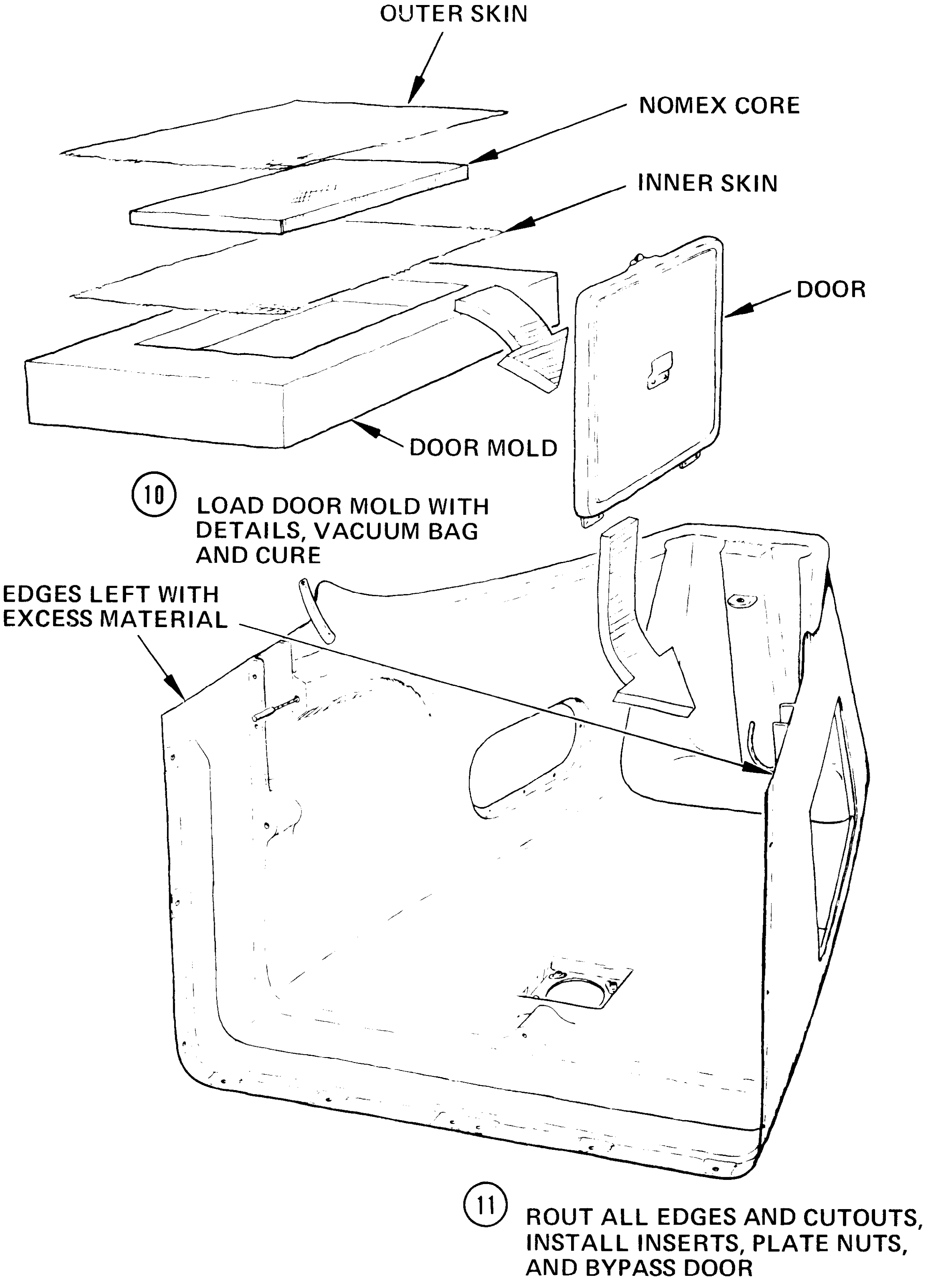


Figure 12. Fabrication Sequence.

- The edge of the Nomex honeycomb creeped during cure. This condition was caused by the vacuum pressure on the Nomex edge causing it to creep along the skin line, collapsing the honeycomb cells and wrinkling the skin as shown in Figure 13. This problem was solved by adding supports to the honeycomb edges during the curing cycles 3 and 9 Figure 12, which bond the skin to the honeycomb.

This two-step skin/honeycomb cure solved these two problems, but for future work a single-step cure should be worked out in the interest of economy. With these problems solved by the two-step cure process, the HLT could be used to fabricate the remaining assemblies. The step by step procedure is outlined in the detailed planning found in Appendix B.

The routed forward edges of the fairing where they mate with the fuselage (see Figure 12, step 11) were left long to facilitate installation on the helicopter.

The HLT functioned perfectly during the fabrication phase of this program. Loading and unloading the HLT was accomplished easily with little lost motion. The different fabrication phases were time monitored giving good basic information for the effectiveness in the Cost Analysis Section.

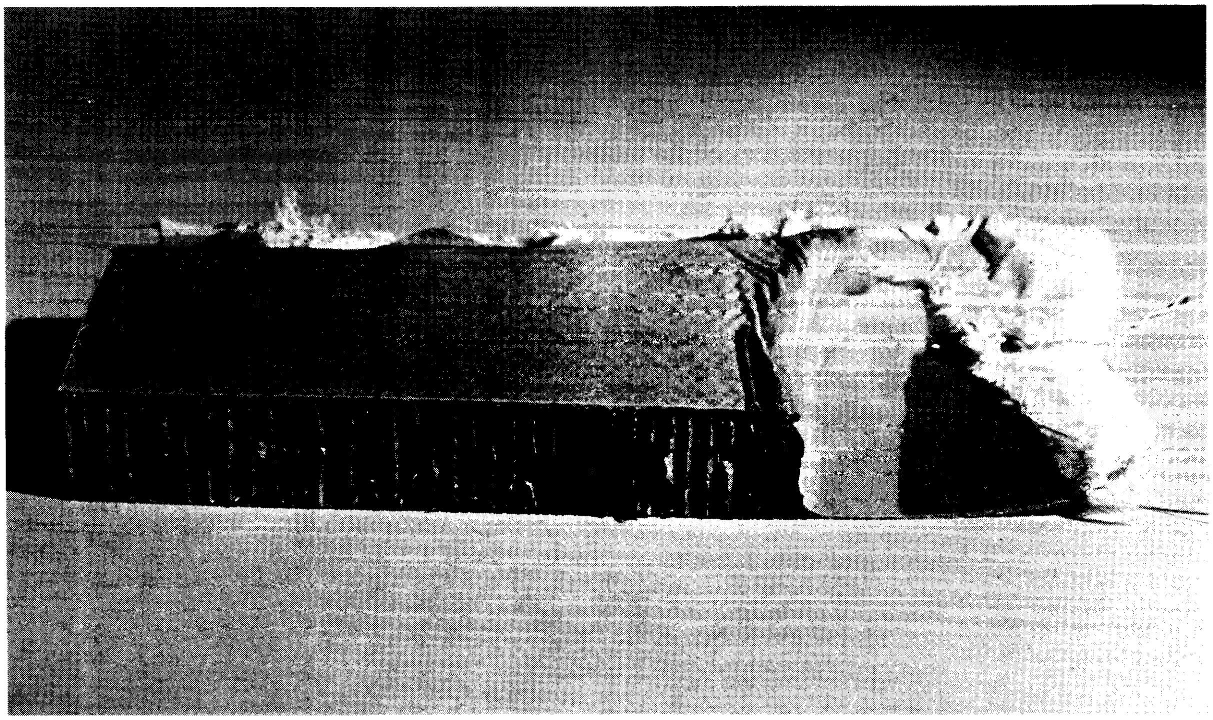


Figure 13. Collapsed Honeycomb Edge.

FLIGHT TESTING

The sixth fairing was installed on an OH-6A helicopter (S/N 17143) at Hughes Helicopters' flight test facility. The helicopter with its Kevlar-49 fairing is shown being flight tested in Figure 14. The only installation problem was obtaining clean rivet holes using the standard tools normally used with sheet metal and fiberglass. The hole edges were quite fuzzy and required much clean up. This typical edge fuzziness was found in the drilling evaluation as outlined on page 20. However, it is very difficult to drill unbushed holes with the recommended spade drill; so, rather than make drill bushings, the standard tools were used necessitating the extra clean up time.

The flight testing was conducted at Hughes Helicopters' flight test center at Hughes Airport, Culver City, California. The tests were conducted in the ambient conditions prevailing at Culver City in January. No special effort was made to fly in extremes of temperature or weather.

The flight test program consisted of 5 hours of flight conducted to the spectrum given in Table 6. The basis of this table is the unpublished report USAAMRDL TR 74-74. The flight portion was conducted successfully. The Kevlar fairing performed excellently as attested by the flight test report in Appendix C. It was subjected to the same type of ground handling as that of the standard fairing. No problems occurred. The Kevlar fairing performed with the following systems installed and operational:

- Air filter
- Filter bypass door
- Warning light
- Static port for airspeed.

The flight test program can be summed up by stating that the Kevlar fairing performed both in the flight test and ground handling conditions equally as well as the standard fiberglass fairing.

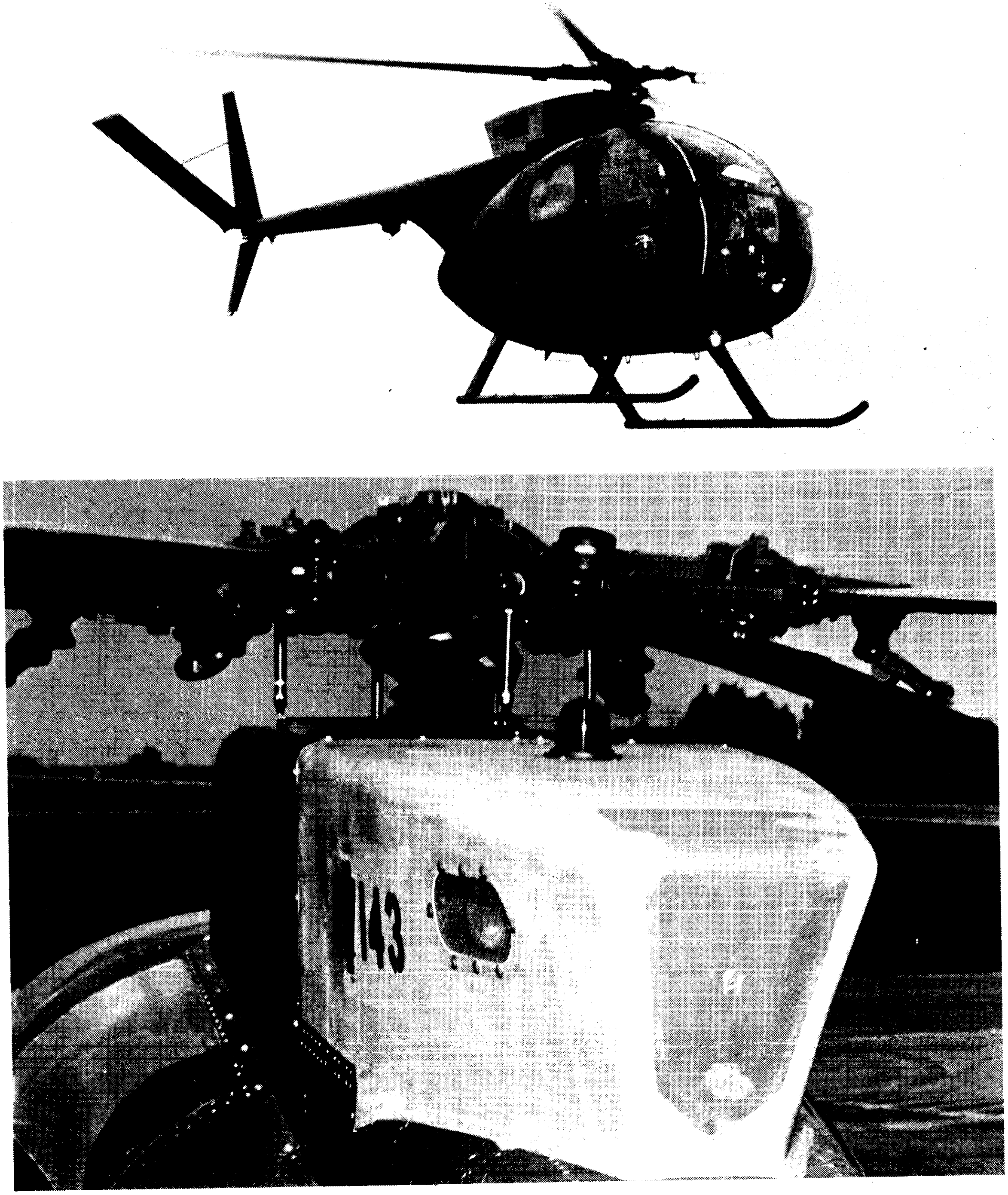


Figure 14. Flight Testing Kevlar Fairing.

TABLE 6. FLIGHT SPECTRUM

Flight Condition	Airspeed (knots)	Percent - Time	Elapsed Time Minutes
Hover	0	2	6
Air Taxi	10	2	6
Left Sideward Flight	10, maximum	2, 2	6, 6
Right Sideward Flight	10, maximum	2, 2	6, 6
Rearward Flight	10, maximum	2, 2	6, 6
Pop-up	0	1	3
Left Hover Turn	Maximum Rate	2	6
Right Hover Turn	Maximum Rate	2	6
Vertical Climb	Maximum Rate	3	9
Maximum Rate Climb	Best Climb Speed	8	24
Level Flight	5, 100, V_{NE}	10, 15, 15	30, 45, 45
Acceleration	Hover to V_{NE}	2	6
Deceleration	V_{NE} to Hover	2	6
Left Yawed Flight	50, 100, V_{NE}	2, 2, 2	6, 6, 6
Right Yawed Flight	50, 100, V_{NE}	2, 2, 2	6, 6, 6
Dive	V_{NE}	3	9
Autorotation	Minimum Descent	4	12
Autorotation Power Recover	Minimum Descent	1	3
Autorotation Flare and Land		1	3
		97	291
Bypass Door Operation			
Dive	V_{NE}	1	3
Right Sideward Flight	Maximum	1	3
Hover-Filter Blocked	0	0	0
		100	300

COST ANALYSIS

The effectiveness of the HLT to cure and produce flightworthy parts for helicopters has been demonstrated in the preceding sections entitled "Flight Test" and "Fairing Fabrication." This section establishes quantitative cost comparisons for fabrication in the HLT and by the present oven method using the plastic tool shown in Figure 14. For comparison purposes the part rate is assumed to be 250 units per year. The two major cost savings attributable to the HLT are labor and heat energy. The HLT is more thermodynamically efficient since the heat energy is used directly and only when needed. The oven wastes much heat energy since it is maintained at the high cure temperatures whether fully utilized or not. See the analysis in Appendix E.

Table 7 compares the recurring and Table 8 the nonrecurring costs for fabricating the aft inlet fairing by the HLT and oven-cured methods using the same composite material in both cases.

TABLE 7. BURDENED FACILITY AND MAINTENANCE COSTS

Item	Burden Cost Items HLT Cure	Burden Cost Items Oven Cure
Tool Maintenance	Negligible - Mold Life estimate at 10,000 Parts	$ 0. 50/Part
Floor Space	$0. 40/Part	3. 38/Part
Equipment (Prorated Amortization 10, 000 Parts	0. 27/Part	0. 42/Part
Total	$0. 67/Part	$ 4. 30/Part

TABLE 7A. ENERGY COST

Item	HLT Cure	Oven Cure
Natural Gas (Domestic Rate 1974-75)	$1. 11/Part	$16. 10/Part

TABLE 8. COST OF MOLDS

Item	HLT Mold	Oven Cure Plastic Mold
Mold Life	10, 000 Parts	1250 Parts
Assumed Quantity Per Year	250 Parts	250 Parts
Rate/Tool	4/Shift	1/Shift
Number of Molds Required* for 250 Units Per Year	1	3
Mold Cost/Part	$\frac{933}{10000}$ = \$0. 93	$\frac{8 \times 1800}{10000}$ \$1. 44

*For comparison purposes daily rate of 4/day is held constant and tools are amortized for 10000 part life.

In addition to the preceding costs the overall labor savings due to the redesign and the more efficient HLT was (22. 4 hours @ \$20. 00/hr) = \$448. 00. The total savings of the HLT over the present plastic tool is summarized as follows.

Labor		\$448. 00
Facilities and Maintenance	(\$4. 30 - \$0. 67) =	3. 63
Energy	(\$16. 10 - \$1. 11) =	15. 00
Mold Costs	(\$1. 44 - \$0. 93) =	0. 51
HLT total savings per fairing		\$467. 14

The labor savings attributed to the HLT alone was (\$448. 00 x 0. 15) = \$67. 20 giving a total savings of \$86. 34 per fairing (\$67. 20 + \$15. 00 + \$4. 14).

The use of Kevlar-49 versus fiberglass to fabricate the redesigned fairing has shown that either material can be used with either tooling approach. The only difference would be the approximately 10 percent additional labor needed for trimming, routing, and drilling the Kevlar fairing. A full study of ways and means to reduce this additional labor was felt to be beyond the scope of this contract. However, integrally cooled routers, drills, etc, together with more tooling for accurate drilling with the spade drill would go a long way toward reducing the labor difference.

The fabrication lead time for the HLT and for the present plastic tooling used in Model 500 production is about the same, based on the tools constructed for this contract and those procured for the present Model 500 production fairing. The lead time for making the HLT is estimated to be approximately one-half the lead time needed for an aluminum cored tool. This estimate is based on a preliminary review with casting vendors who stated that close dimensional control equal to that of the HLT would be difficult to achieve, thus limiting the accuracy of the finished part. In comparison, the plaster used for the HLT plating pattern has a very low shrinkage rate, and the nickel, which is electrodeposited, duplicates the outer surface of the plating pattern very accurately.

Kevlar-49 is a much more costly material than fiberglass ($8.00 per pound versus $0.75 per pound). To show cost effectiveness, material cost, labor costs, and weight savings must be considered.

Measured weights of fiberglass and Kevlar-49 fairings, both made to the improved configuration shown in Appendix A, show that weight difference is:

$$\Delta W = W_{\text{fiberglass}} - W_{\text{Kevlar-49}}$$

$$\Delta W = 4.56 - 3.89 = 0.67 \text{ pounds}$$

In computing material costs, a realization factor of 80 percent must be included since approximately 20 percent of the initial material is wasted. Then the cost increase, using Kevlar for the fairing, would be:

$$\left[\text{Added Cost} = \begin{matrix}\text{Added Labor for}\\ \text{Trimming, etc.}\end{matrix} + \begin{matrix}\text{Kevlar Material}\\ \text{Cost}\end{matrix} - \begin{matrix}\text{Fiberglass}\\ \text{Cost}\end{matrix}\right]$$

$$\text{Added Cost} = \left[.9 \text{ Hr} \times \$20.00 + \frac{3.89 \times 8.00}{0.80} - \frac{4.56 \times 0.75}{0.80}\right] = \$53/\text{Fairing}$$

$$\left[\frac{\text{Added Kevlar Cost}}{\text{Weight Saved}}\right] = \frac{\$53}{0.67 \text{ lb}} = \$79.10/\text{pound}$$

The estimated cost as shown ($79.10 per pound) would be considered high. Values of $30 to $40 per pound are normally the price most companies will pay to meet their helicopter empty weight. Projected Kevlar-49 price decreases due to future increased use could easily make this excellent material very competitive with the presently used composite materials.

The preceding cost analysis was performed by using the redesigned fairing as a constant parameter in comparing costs, either using the HLT versus the standard plastic tool or in comparing costs due to materials by substituting fiberglass for Kevlar-49. The cost comparison between the standard design and the redesigned fairing shows significant savings due to the simplification of the design itself. The average number of hours to fabricate the standard aft fairing (Figure 15) in 1974 was 33.19 hours. The redesigned fairing which is based on the use of a honeycomb sandwich construction instead of a foam-block reinforced shell, and substitutes buried conduits for pulleys, pulley brackets, and wire ties required only 10.80 hours to fabricate. This represents a saving of 22.39 man-hours for each fairing.

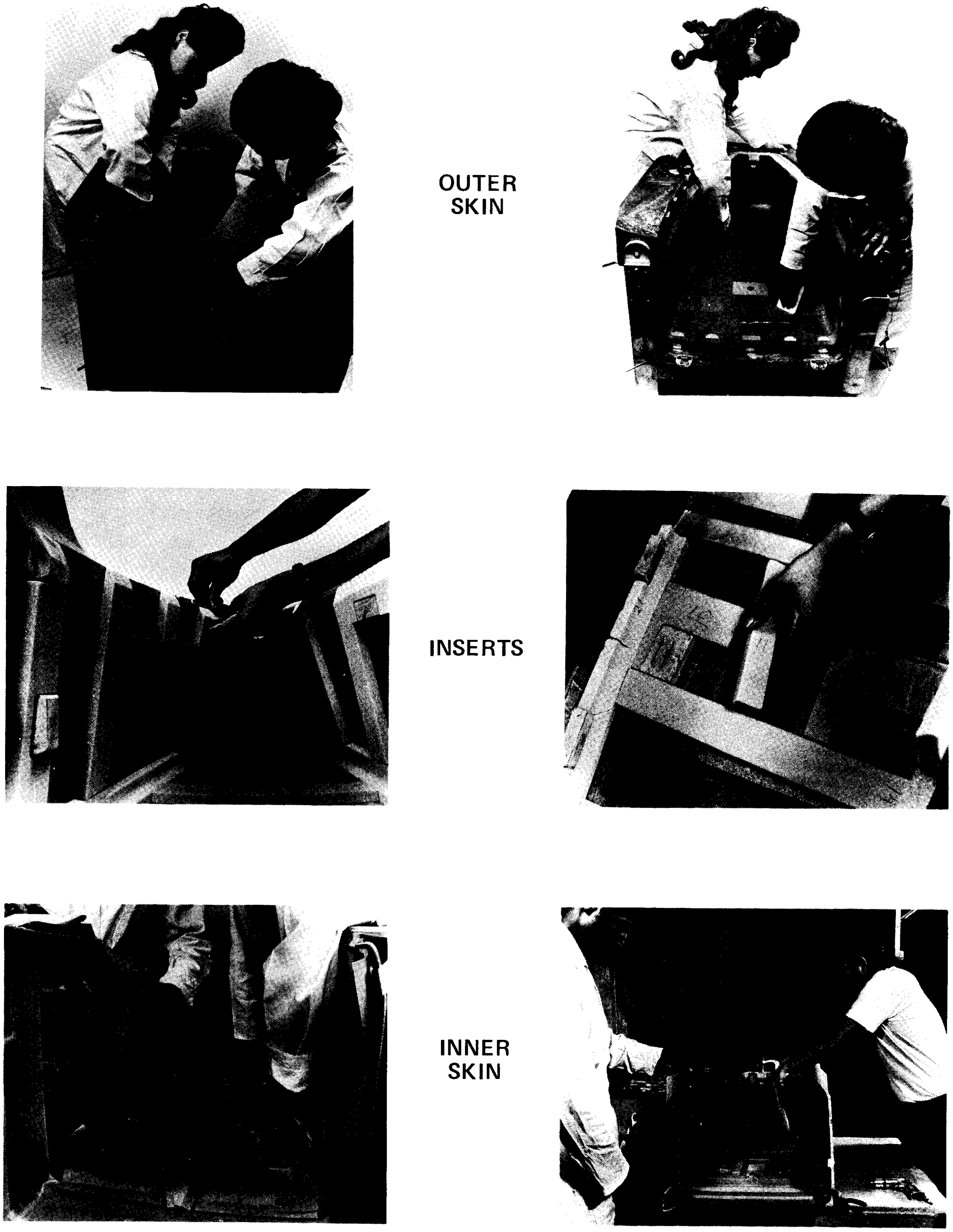


Figure 15. Assembly Procedures for the Standard Fairing

CONCLUSIONS

It is concluded that the HLT program was highly successful in that it resulted in the identification of significant cost savings that can be achieved by use of a newly developed tool. It also initiated cost saving design changes for a typical airframe composite part and established improved machining practices for Kevlar-49. Some of the more significant conclusions are further amplified as follows:

1. The Kevlar-49 fairing performed as well as the conventional fiberglass fairing in the flight testing and ground handling environment; thus it can replace fiberglass for equivalent types of structures if allowance is made for its compressive strength characteristics.

2. The HLT would have a relatively long production life since the nickel is wear resistant and the coefficient of thermal expansion of the concrete and nickel are very close to the same. This reduces the possibility of cracking and separation between the nickel and concrete mating surfaces.

3. HLT lead time versus existing plastic tool is the same. The lead time for HLT is one-half that of comparable cast aluminum tools.

4. The HLT is easily made to excellent shape and size accuracy because of the low shrinkage of the plaster pattern used for plating the interior of the die.

5. Without proper tooling Kevlar-49 composite parts can have unique problems compared with fiberglass components. Cutting, routing and drilling can leave very fuzzy and burned edges unless the proper tool and process is used. However, the following processes were established:

   - Dink dies used for cutting uncured Kevlar-49 prepreg gives an excellent sheared edge.
   - Heat problems when cutting Kevlar-49 (tool and stock burning) can be alleviated by using a coolant.
   - Hole drilling can easily be accomplished with a spade drill, but requires a bushing for drill support and accurate drilling.

6. The process is already being adopted on the production line of the fairing for the commercial version of the OH-6A, the Model 500, now being manufactured at HH.

RECOMMENDATIONS

It is recommended that the HLT process be considered for other helicopter components, both at HH and at other helicopter companies. The process should also be expanded in its capability and applications. The following programs are suggested:

1. Develop a single cure process for fabricating the aft fairings to further demonstrate the effectiveness of the HLT.
2. Investigate HLT applications to a filament winding mandrel or curing mold with heatup and cooling capabilities.
3. Investigate extending HLT technology to the matched multiple die tooling approach. This would produce more accurate parts cured from both sides without use of a vacuum bag.
4. Investigate the application of HLT's in the manufacture of composite fuselages, blades, landing gears, stabilizers, etc.
5. Investigate optimum heating/cooling tube configuration in the HLT, i. e., tube diameter limitations, manifolding with two or more tubing systems, etc.
6. Develop alternate methods for reducing the cost of depositing the hard nickel surface on the HLT. Deposition methods that should be evaluated include vapor deposition, metal spraying, and electron beam metal melt for drip casting of the nickel shell onto a water cooled pattern. Determine HLT size limitations by considering nickel deposition limitations, rigidity of the reinforced concrete die, dimensional accuracy of the HLT, etc.
7. Investigate and develop special tools that incorporate a cooling capability for working Kevlar-49. Improve the use of spade drills by incorporating a bushing with the drill motor to give drill support and allow accurate hole drilling.

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5. Development of a Low-Cost Composite Die Using High-Energy-Rate-Forming (HERF) AMMRC CRT 73-43, November 1973.

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APPENDIX A

FAIRING AND TOOLING DRAWINGS

Hughes Helicopters

	REV	DESCRIPTION		
	A	CHANGED BACK TO 7-18-74 [illegible] - CHANGED CORE FROM .400 TO .625 - ADDED TRIM [illegible]		[illegible]
	B	REVISED FWD END TO ORIGINAL CONFIGURATION - ADDED PLATES & DOUBLERS AS REQ ADDED NUTPLATES & RIVETS - ADDED SLOT ON LH SIDE FOR ANT INSTALLATION & REVISED 369A3053-57 SPACER		[illegible]

		-21	-1		PART NO.	NAME	SIZE	DESCRIPTION	
			7		369A2061	DOUBLER			
		—	12		NAS 697A3	NUTPLATE			
③		6	14		[illegible] 607 3-6-C	INSERT	SHUR-LOK CORPORATION 1300 E NORMANDY PLACE SANTA ANA CALIF		
③	—	2	-		[illegible] 607 06 6-C	INSERT			
			AR		MS 20470 AD3	RIVET			
			32		MS 20426 AD3	RIVET			
		AR	AR			FOAMING TAPE	②		
		2			NAS 623-3-3	SCREW			
	—	1			[illegible] 30156-078-4.06	BUSHING			
	—	2			[illegible] 936-302 L	WASHER			
	—	4	4		NAS 697A06	NUT PLATE			
	—	6	6		AN 960PD10L	WASHER			
	—	6	6		NAS 623-3-1	SCREW			
	—	1			MS 24665-153	COTTER PIN			
	—	2			[illegible] 958-28	SCREW			
	—	1			369H2087-7	CLIP			
	—	—	1		369A3014-63	ANGLE			
	—	—	1		369A3014-53	ANTENNA			
	—	—	1		369A8461	CLIP			
	—	1			369A8442	LATCH ASSY			
	—	2			369A8437	HINGE			
	—	—	1		369A3053-113	SEAL			
	—	—	2		-111	PLATE			
②	—	—	1		-53	SPACER			
②			1		-51	SPACER			
②		—	1		-49	SPACER			
	—	—	1		-36	ANGLE			
	—	—	1		-35	ANGLE			
	—	—	1		-33	PLATE			
	—	—	1		-31	PLATE			
	—	—	2		-27	PLATE			
	—	—	2		-25	PLATE			
	—	—	1		369A3053-23	PLATE			
	—	—	1		-35	ANGLE	9 PLY 181 (.090)	KEVLAR 49	[illegible]
	—	—	1		-33	ANGLE	9 PLY 181 (.090)	KEVLAR 49	[illegible]
	—	—	1		-31	BULKHEAD	9 PLY 181 (.090)	KEVLAR 49	[illegible]
			1		-29	DOUBLER	2 PLY 181 (.010)	KEVLAR 49	[illegible]
	—	1			-27	FILLER	[illegible] × .140	HRH-10 [illegible]	[illegible] CORE
	—	1			-25	SKIN (INNER)	2 PLY 181 (.010)	KEVLAR-49	[illegible]
	—	1			-23	SKIN (OUTER)	2 PLY 181 (.010)	KEVLAR 49	[illegible]
			1		-21	DOOR ASSY			
			1		-19	CABLE ASSY	SIMILAR TO 369A8435		
			1		-17	TUBE	.175 O.D. × .035 WALL × 30.0	⑥	[illegible]
			1		-15	TUBE	.175 O.D. × .035 WALL × 22	⑥	[illegible]
			1		-13	HOUSING	①	⑤	
			1		-11	FILLER (AFT)	[illegible] × 1.10	HRH-10 [illegible]	[illegible]
			1		-9	FILLER (FWD)	[illegible] × 16 [illegible]	HRH-10 [illegible]	[illegible]
			1		-7	FILLER (MAIN)	[illegible] × 140-.400	HRH-10 [illegible]	[illegible]
	—		1		-5	SKIN (INNER)	1 PLY 181 (.010)	KEVLAR-49	[illegible]
	—		1		-3	SKIN (OUTER)	1 PLY 181 (.010)	KEVLAR-49	[illegible]
● ①					-1	FAIRING ASSY			

QTY REQD

LIST OF MATERIAL

CRITICAL ITEM

MBLIES ARE TO

NT OF TECHNIQUES
OVERALL APPEARANCE
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D IN A FLIGHT TEST
LIGHT EVALUATION
BE DELIVERED TO THE ARMY

ANGLE IS IDENTICAL TO
3-35 EXCEPT FOR MATERIAL

TERIAL & PROCESSING)

93-3

NO CLASS

[illegible]

& TEFLON LINER

CEPTIONS ARE:
LAR 49
NOMEX HONEYCOMB
LOK INSERTS
TS FOR CABLE TO
BY CONDUIT TUBES

Hughes Helicopters

FAIRING ASSY- HOT [illegible]
KEVLAR 49 FIBERS

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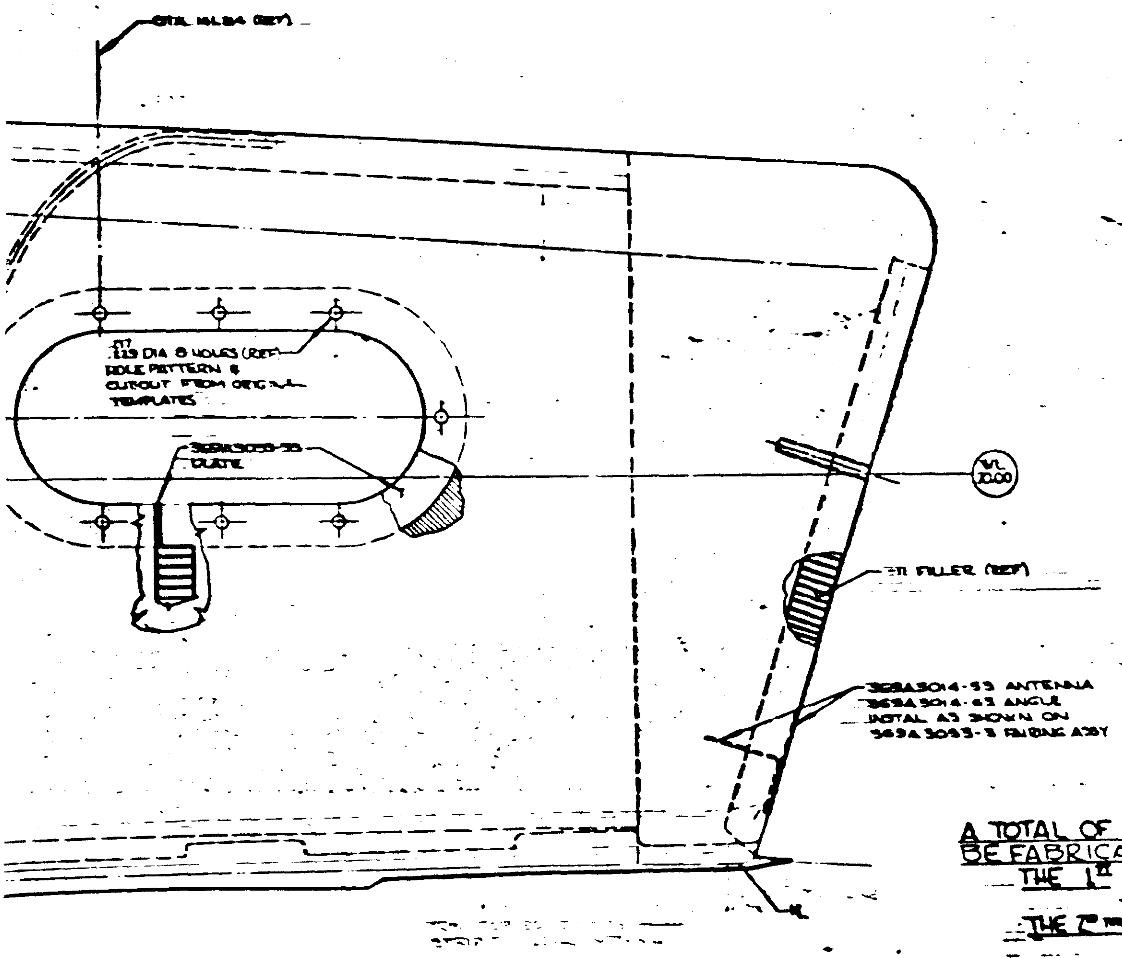
369ASK2000

SCALE FULL



OUP THIS AREA TO ENCASE
OUSING AS REQ
N NO. NOT ASSIGNED)
NDARY STRUCTURE
BONDING ALLOWED

VIEW A~A
LEFT HAND SIDE
FWD

A TOTAL OF 9 FAIRING ASSE
BE FABRICATED -
THE 1ST IS FOR DEVELOPME
-TUBE ROUTING &
THE 2ND THRU 4TH ARE FOR FU
& EVALUATION
THE 5TH IS TO BE INSTALLE
AIRCRAFT FOR F
THE 6TH THRU 9TH ARE TO

9 -31 BULKHEAD IS IDENTICAL TO 369A 3053-21, -33
369A 3053-93 & -37 ANGLE IS IDENTICAL TO 369A305

8 FABRICATE FAIRING PER 15-42 (ALSO APPLICABLE TO M

7 INSTALL FAIRING TO FUSELAGE AS SHOWN ON 369A30

6 MATERIAL: NYLON PRESSURE TUBING CONFORMING TO LP4
POLYHEXAMETHYLENE ADIPAMIDE

5 MAY BE PURCHASED FROM TUBE FLEX INC. NORTHWALES.

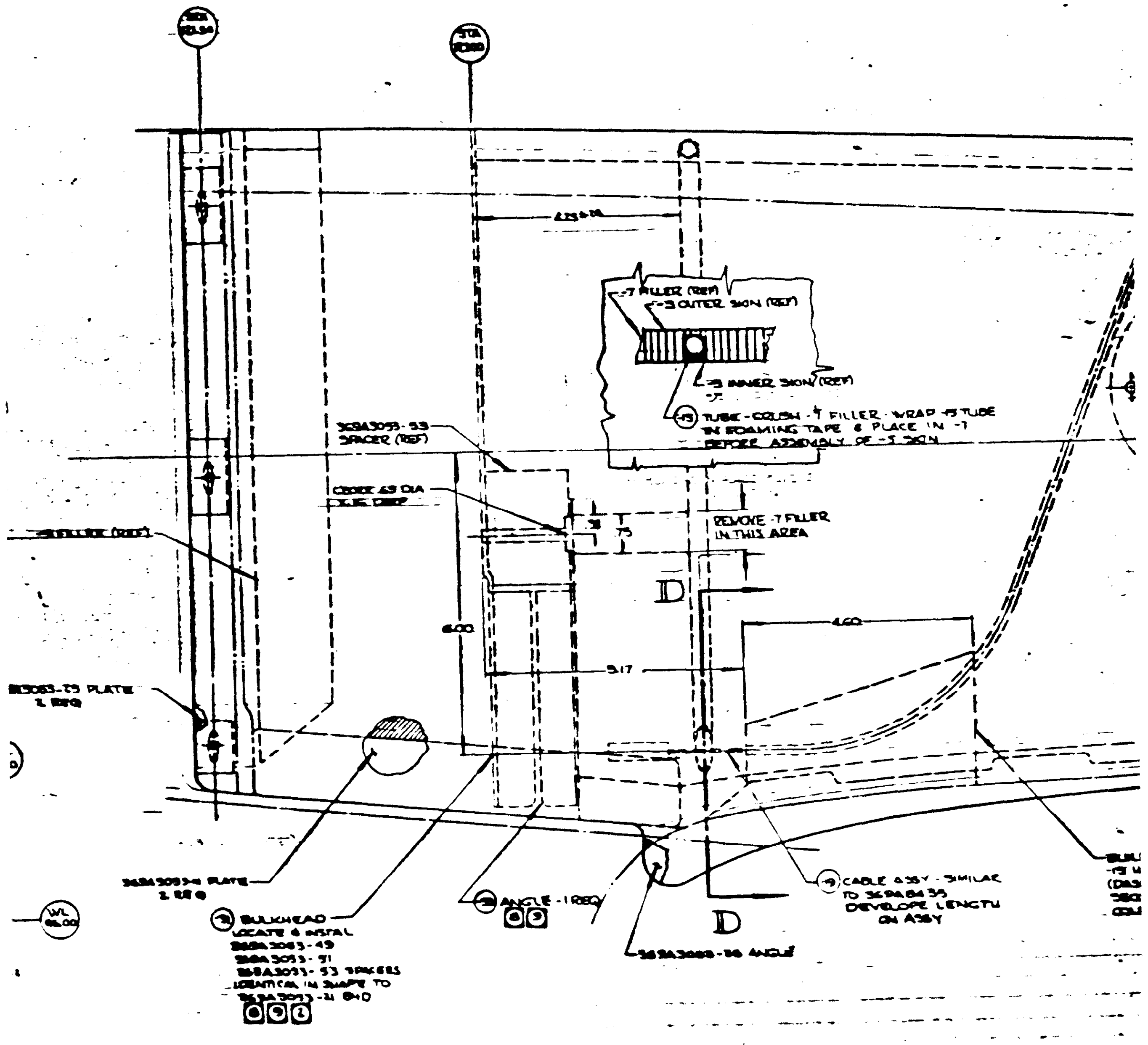
4 MAKE FROM 3/16 DIA NYLON TUBING WITH .080 ID DELRON C

3 INSTALL SHUR LOK INSERTS PER HP 15-32

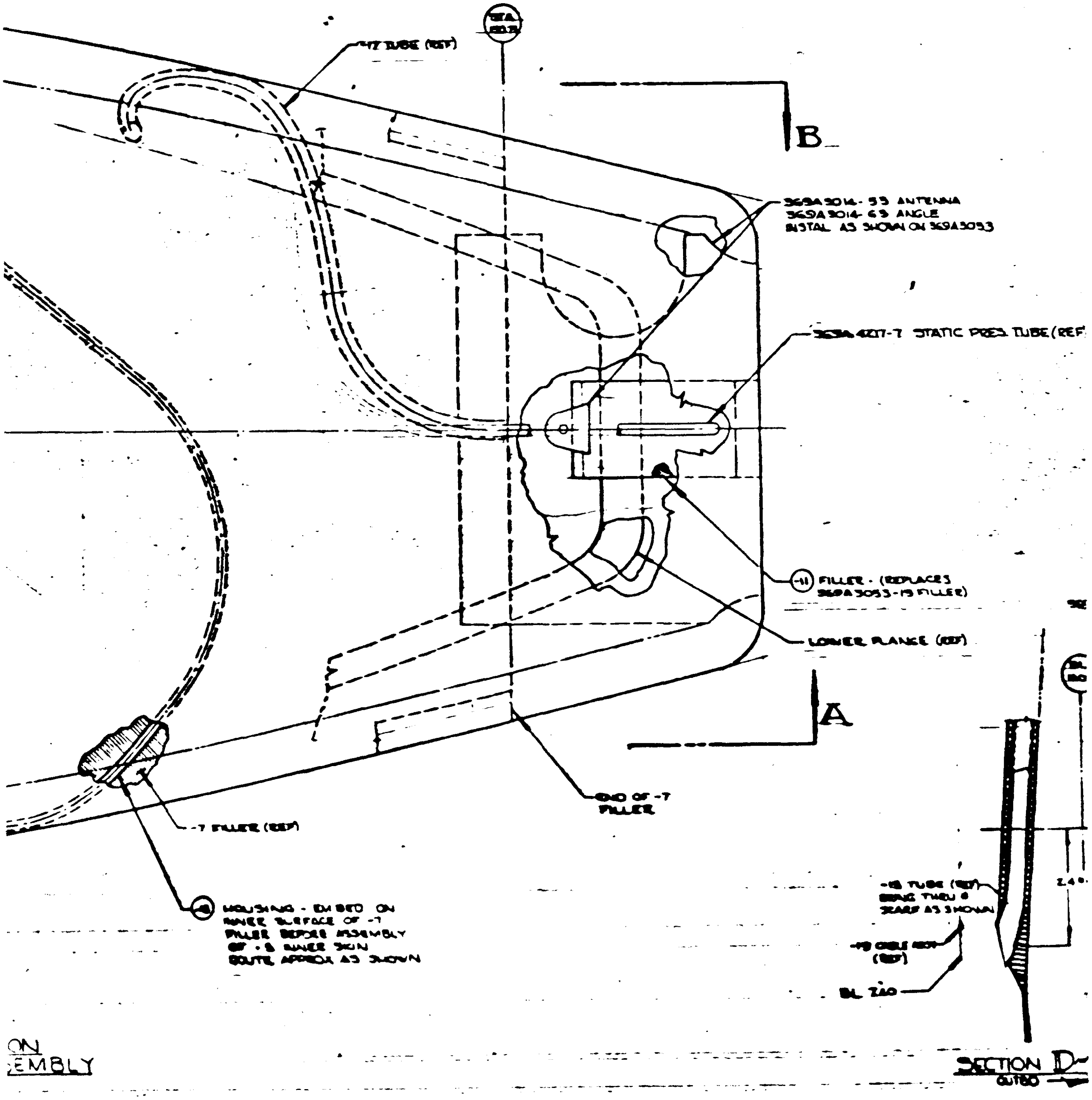
2 USE FOAMING TAPE AS REQ PER HMS 16-1111 TYPE IX

1 THIS PART IS SIMILAR TO 369A3053-3 THE MAJOR
A. FIBERGLASS SKINS HAVE BEEN REPLACED BY KEV
B. FOAM FILLERS & DOUBLERS HAVE BEEN REPLACED BY
C. ANCHOR NUTS HAVE BEEN REPLACED BY SHUR-L
D. ELECTRICAL & STATIC TUBE CLIPS - PLUS PULLE
OPERATE BY-PASS DOOR - HAVE BEEN REPLACED

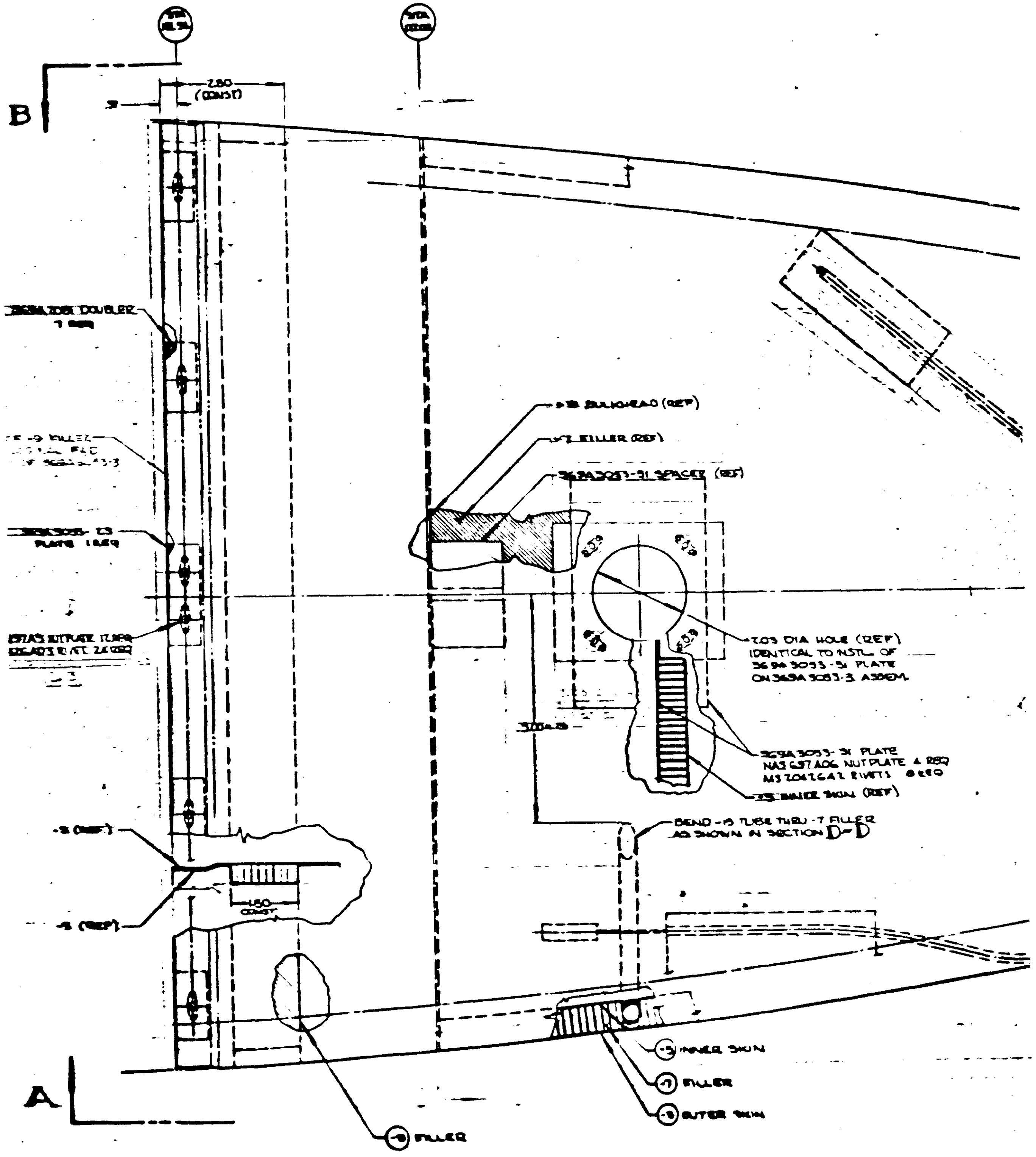
NOTE:


STA
STA
4.25±.12
-7 FILLER (REF)
-3 OUTER SKIN (REF)
-5 INNER SKIN (REF)
-13 TUBE - CRUSH - 7 FILLER - WRAP -13 TUBE IN FOAMING TAPE & PLACE IN -7 BEFORE ASSEMBLY OF -5 SKIN
36BA3053-53 SPACER (REF)
.63 DIA
.38
.75
REMOVE -7 FILLER IN THIS AREA
D
6.00
5.17
4.60
PLATE 2 REQ
36BA3053- PLATE 2 REQ
WL
BULKHEAD LOCATE & INSTAL
36BA3053-49
36BA3053-51
36BA3053-53 SPACERS
IDENTICAL IN SHAPE TO
36BA3053-21 BHD
8 9 2
ANGLE - 1 REQ
8 9
36BA3053-36 ANGLE
D
-9 CABLE ASSY - SIMILAR TO 36PA8435 DEVELOPE LENGTH ON ASSY
BUL
-13
(DAS

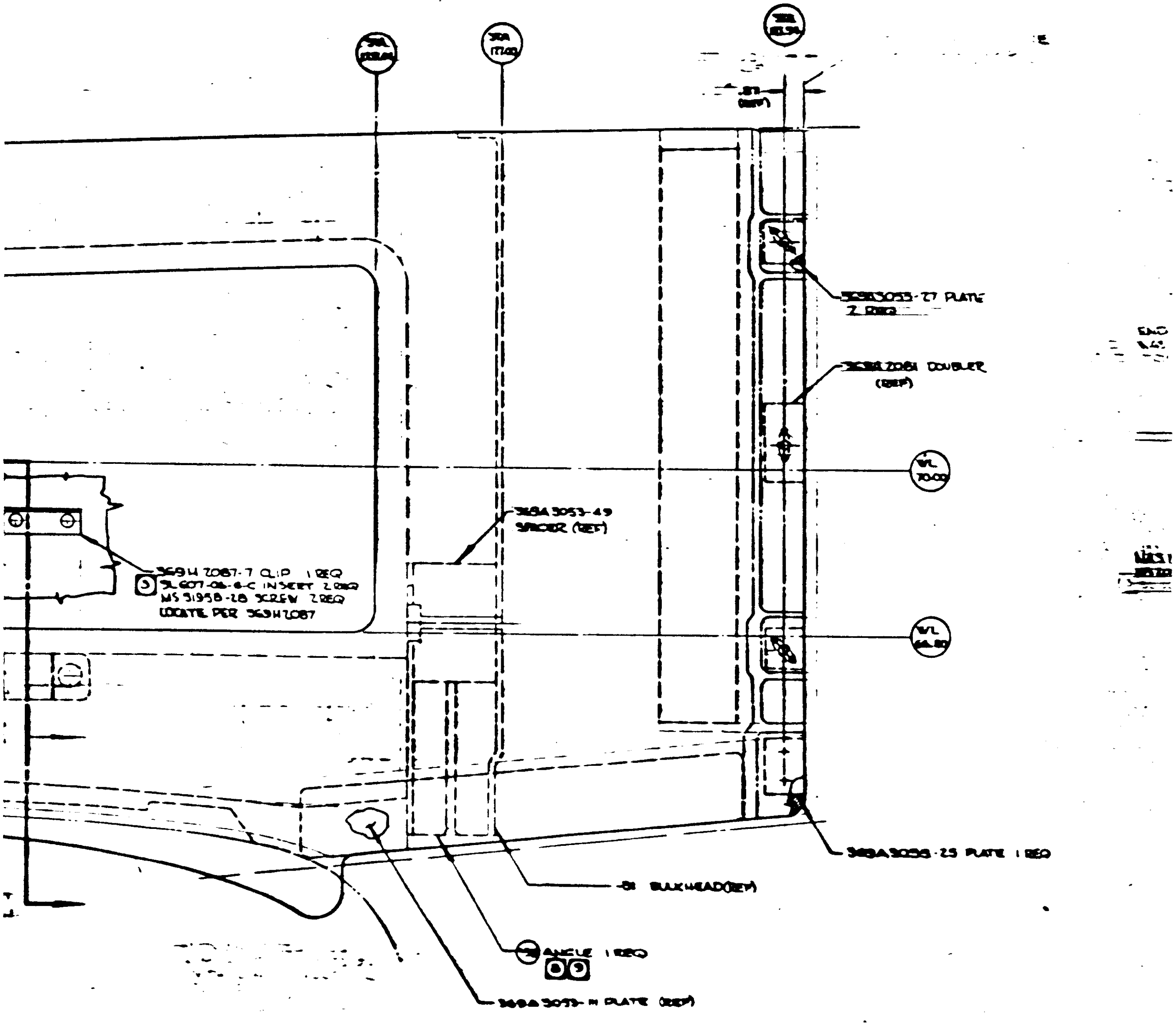
D

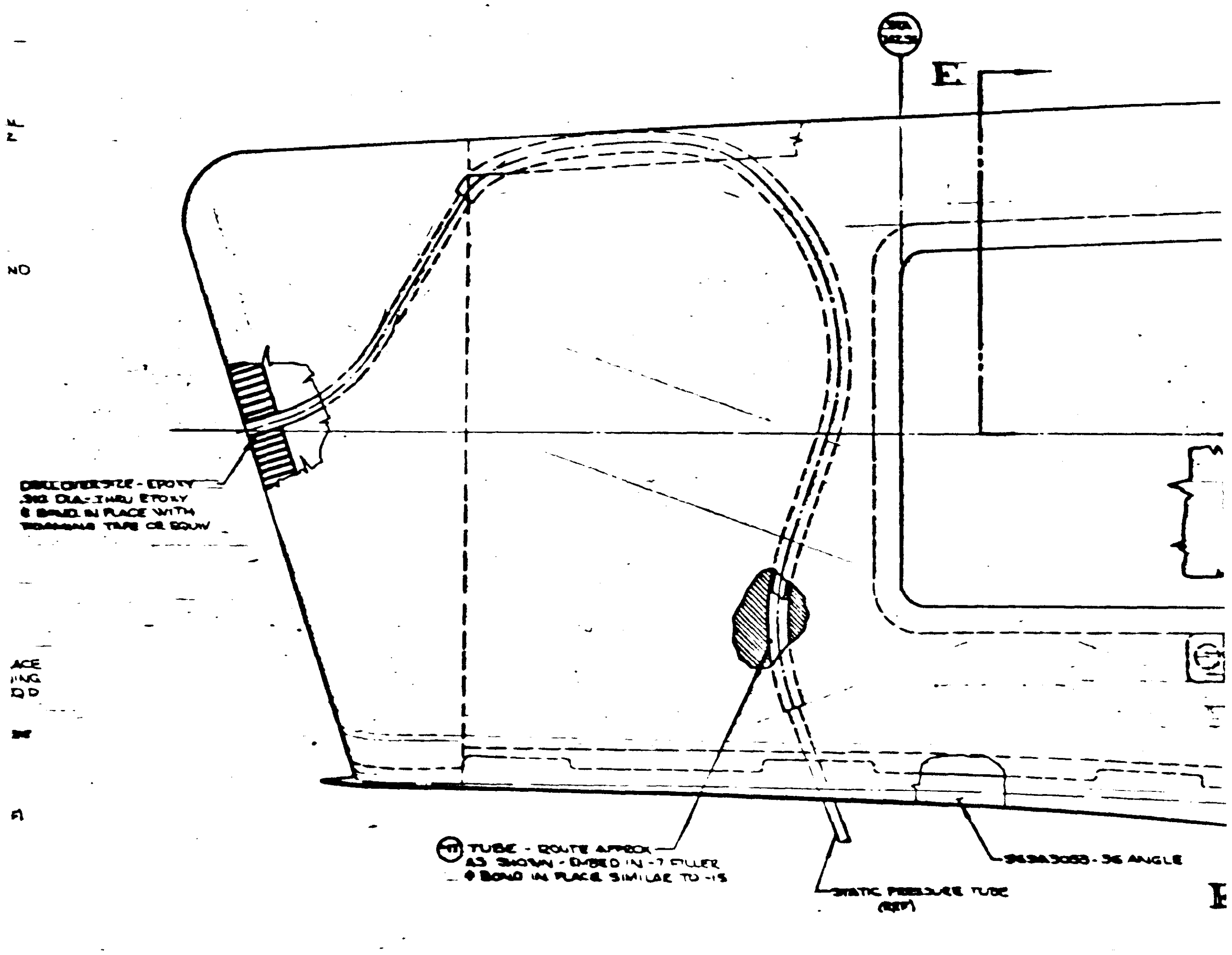


STA 180.75
-17 TUBE (REF)
B
369A3014-53 ANTENNA
369A3014-63 ANGLE
INSTAL AS SHOWN ON 369A3053
369A4217-7 STATIC PRES TUBE (REF
-11 FILLER - (REPLACES
369A3053-19 FILLER)
LOWER FLANGE (REF)
A
END OF -7
FILLER
-7 FILLER (REF)
-13 HOUSING - EMBED ON
INNER SURFACE OF -7
FILLER BEFORE ASSEMBLY
OF -5 INNER SKIN
ROUTE APPROX AS SHOWN
ON
EMBLY
-13 TUBE (REF)
BRING THRU &
SCARF AS SHOWN
-19 CABLE ASSY
(REF)
BL 23.0
2.4
SECTION D
ROTATED



PLAN VIEW - AFT SECTI
ENGINE INLET FAIRING ASS


369A3053-27 PLATE
2 REQ
369A2081 DOUBLER
(REF)
W.L. 70.00
W.L. 64.50
369A3053-49
SPACER (REF)
369H2087-7 CLIP 1 REQ
5
SL607-08-6-C INSERT 2 REQ
MS51958-28 SCREW 2 REQ
LOCATE PER 369H2087
369A3055-25 PLATE 1 REQ
-51 BULKHEAD(REF)
ANGLE 1 REQ
8 9
369A3053-11 PLATE (REF)

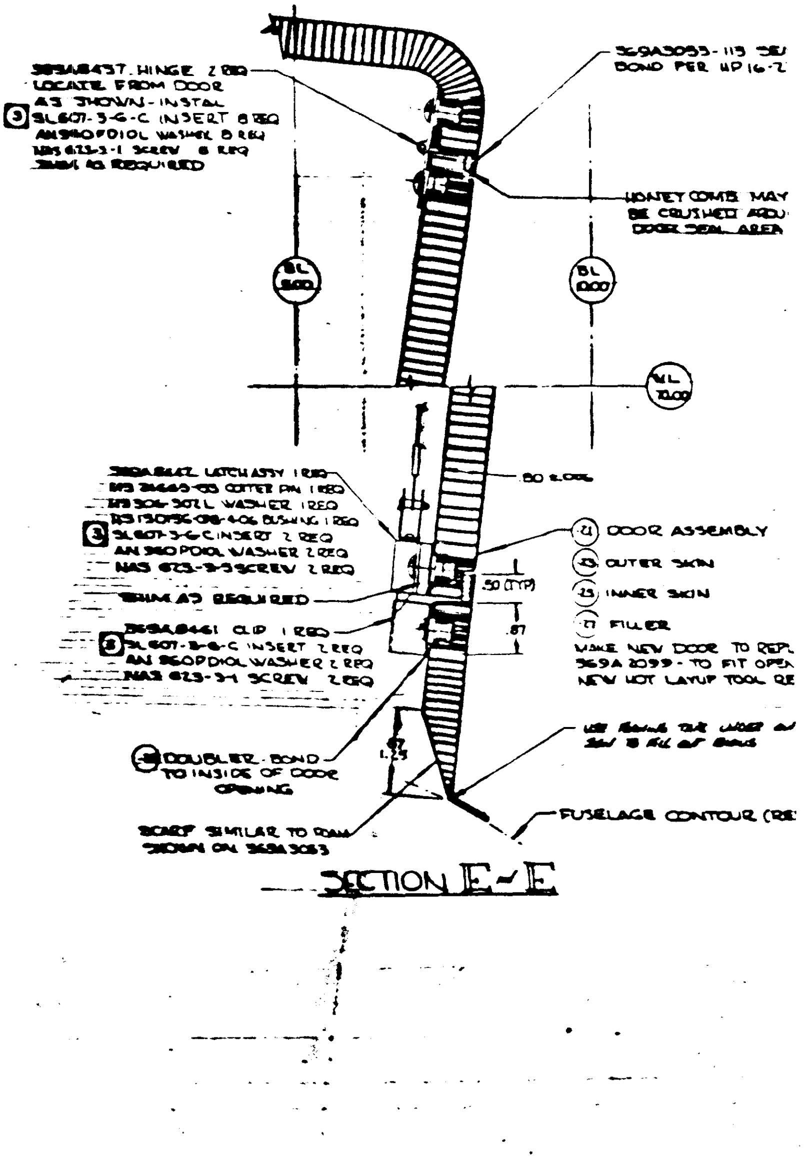


VIEW B-B

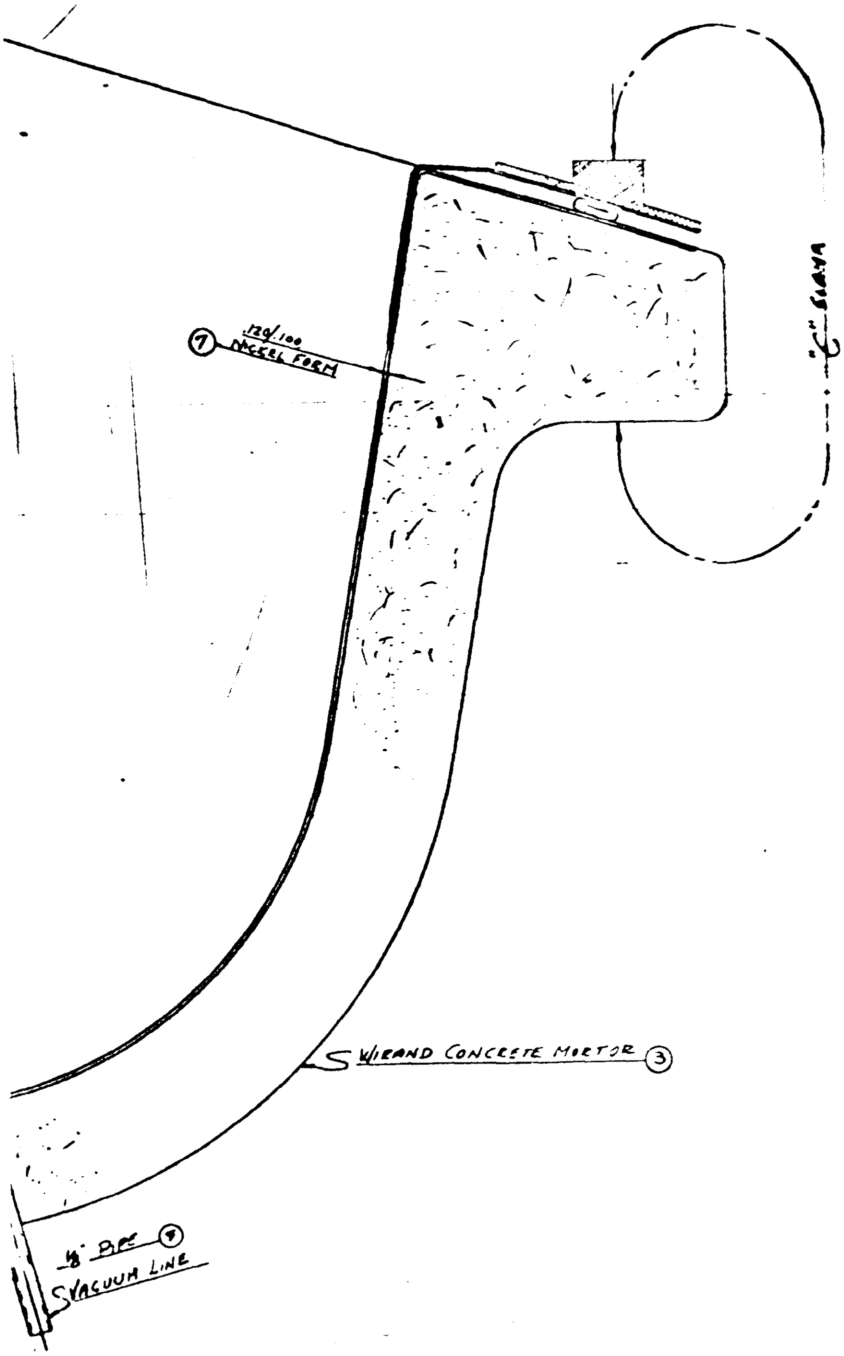
RIGHT HAND SIDE - ROTATED 90° CW

FWD →

-31 DOOR ASSEMBLY NOT SHOWN


369A8437 HINGE 2 REQ
LOCATE FROM DOOR
AS SHOWN - INSTAL
3 SL607-3-6-C INSERT 8 REQ
AN960PD10L WASHER 8 REQ
NAS 623-3-1 SCREW 8 REQ
SHIM AS REQUIRED
369A3053-115 SE
BOND PER HP16-2
HONEYCOMB MAY
BE CRUSHED ARO
DOOR SEAL AREA
BL 5.00
BL 10.00
WL 20.00
369A8462 LATCH ASSY 1 REQ
MS 24665-153 COTTER PIN 1 REQ
MS 306-30ZL WASHER 1 REQ
RS130756-08-4-06 BUSHING 1 REQ
3 SL607-3-6-C INSERT 2 REQ
AN960PD10L WASHER 2 REQ
NAS 623-3-5 SCREW 2 REQ
.80 ±.006
-21 DOOR ASSEMBLY
-23 OUTER SKIN
-25 INNER SKIN
-27 FILLER
.50 (TYP)
SHIM AS REQUIRED
369A8461 CLIP 1 REQ
3 SL607-3-6-C INSERT 2 REQ
AN960PD10L WASHER 2 REQ
NAS 623-3-4 SCREW 2 REQ
.87
MAKE NEW DOOR TO REPL
369A 2099 - TO FIT OPEN
NEW HOT LAYUP TOOL RE
DOUBLER - BOND
TO INSIDE OF DOOR
OPENING
.87
1.25
SCARF SIMILAR TO FOAM
SHOWN ON 369A3053
FUSELAGE CONTOUR (RE

SECTION E~E
)



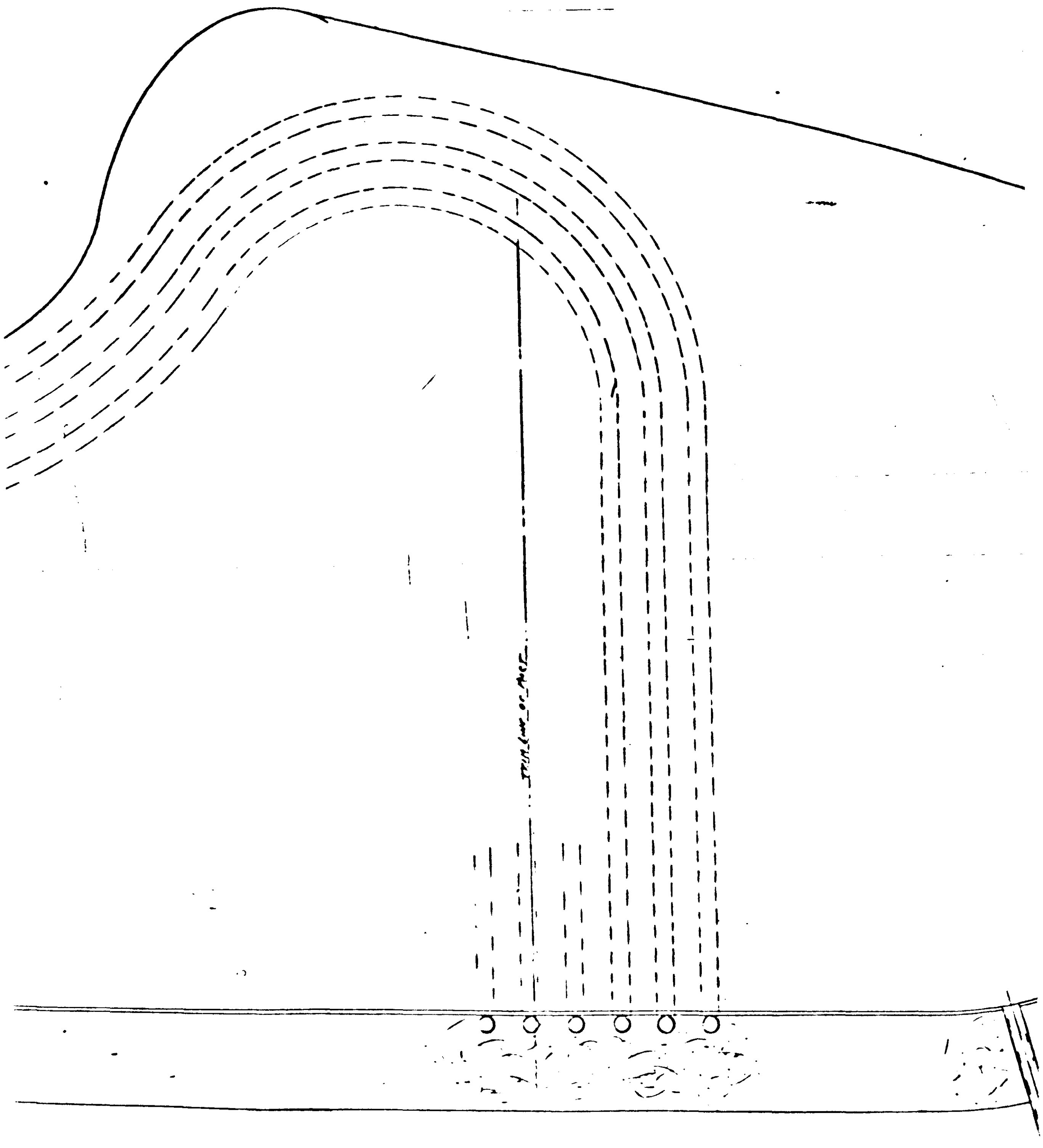
17	2	⅜-3" Nipple
16	20"	[illegible]
15	2	[illegible] -24" MS
14	24	½-13 FN [illegible]
13	24	½-13 Concrete Anchor
12	3	Stainless [illegible]
11	1/2	Silicone [illegible]
10	—	[illegible] Frame
9	200	Silicone [illegible]
8	—	Fabricated Stand
7	—	.100/.120 [illegible]
6	4	Fabricated [illegible]
5	2	[illegible]
4	1	[illegible]
3	2.2	W/ and Mortar
2	40	[illegible] Sheet
1	175	[illegible]

HUGHES TOOL CO. [illegible] DIVISION
TOOL DESIGN
DEPT.

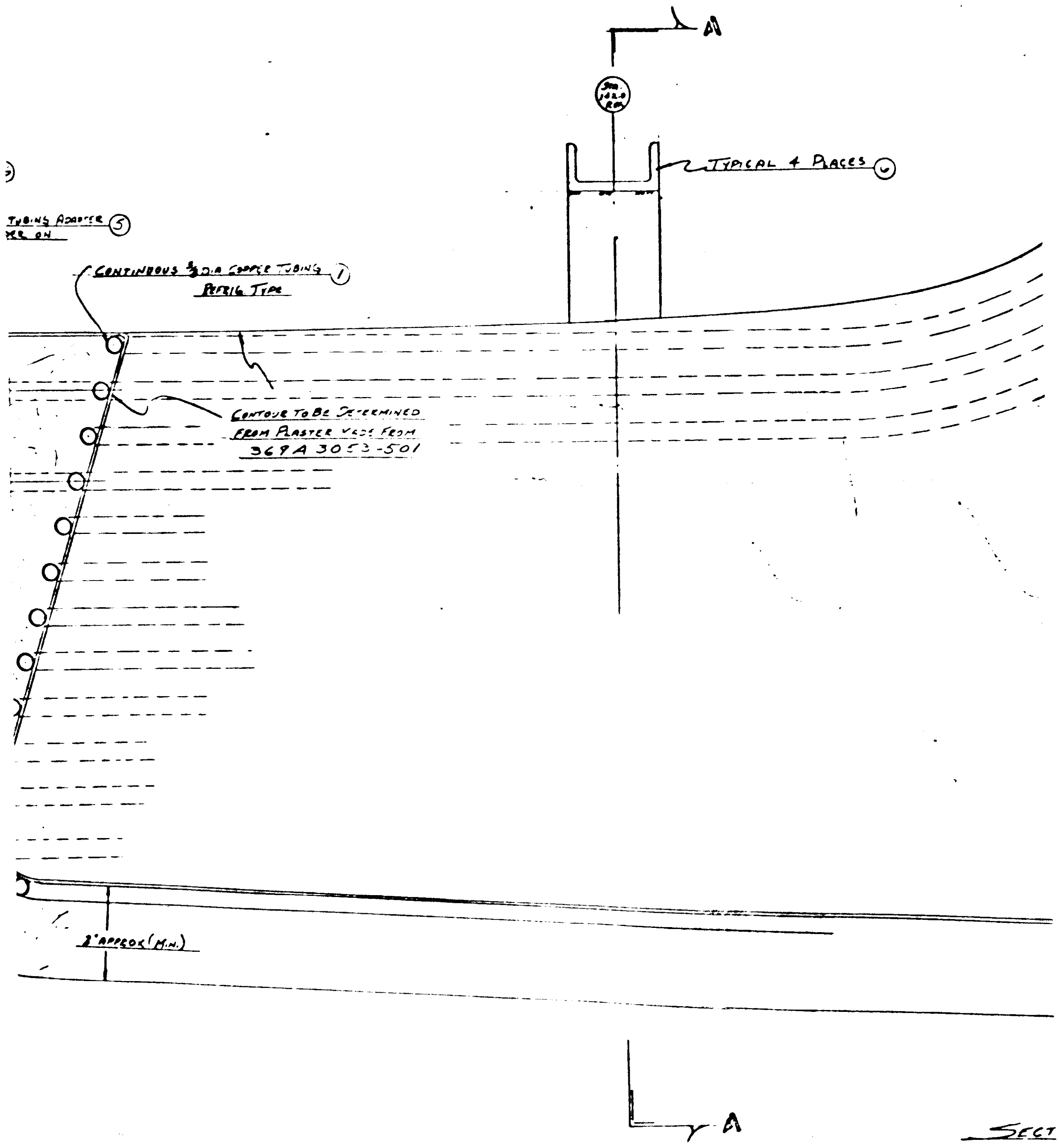
Curing Mold for Fairing
Assy, Engine Inlet Aft Section

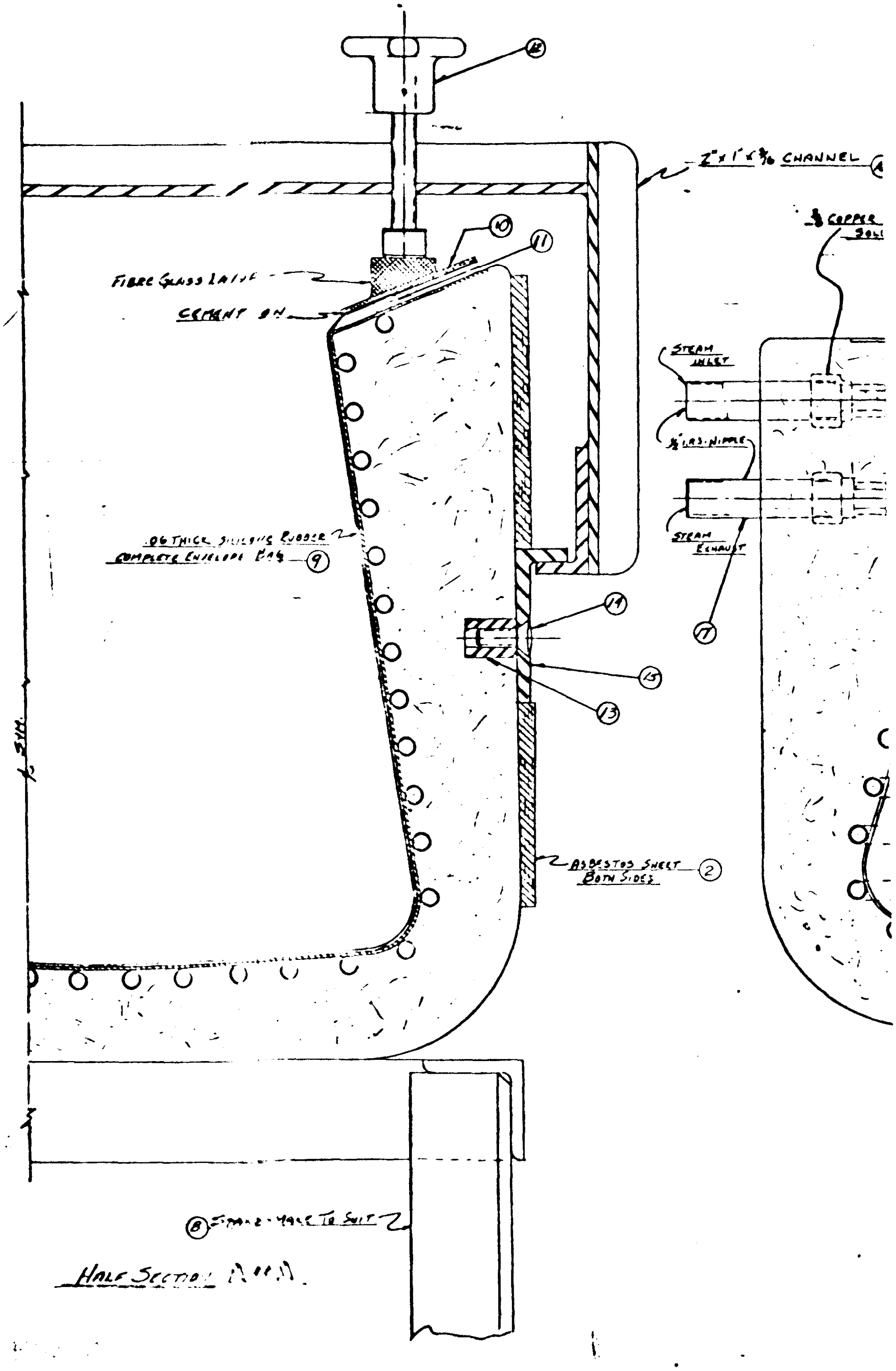
Smith
1/3
1 = 1
Full
369ASK2000-21201

Record Drawing



ION THRU ℄ OF MOLD


A
STA. 142.0 REF
TYPICAL 4 PLACES ⑥
TUBING ADAPTER ⑤
ER ON
CONTINUOUS ⅜ DIA COPPER TUBING ①
REFRIG TYPE
CONTOUR TO BE DETERMINED
FROM PLASTER MODS FROM
369A 3053-501
3" APPROX (MIN.)
A
SECT



HALF SECTION A-A.

Hughes Helicopters PLANNING SHEET

VALUE CODE		PROJECT 369A	DWG. LTR A	PART NUMBER 369ASK 2000-1		SHEET 1/8
PART TYPE		ENGINEERING ORDERS		NAME FAIRING ASSY- HOT LAYUP-KEVLAR 49		REV. NO. 1.
COST CENTER REV. LTR.	F					

OPER NO.	DEPT CC	WORK STA	OPERATIONS PERFORMED	SET UP	RUN	TOOL NO.	REV. NO.
010	1303		FURNISH PARTS PER 9270 A		R		
020	1304		FURNISH MATL. PER 9270 A		R		
030	1300		INSPECT		I		
040	2825		MOLD 369A3053-49-51 & 53 USING A1177B MOLDING COMPOUND	00.1	0.060	369A3053-21202	
			TRIM EXCESS COMPOUND AS REQ'D				
			DRILL (1) .25 DIA. HOLE IN EACH 369A3053 -49-51 & -53			369A3053-71201	
050	2823		LAYUP (9) PLIES OF 181 KEVLAR 49 TO -31 BLK'HD AND -33 & -35 ANGLE	00.2	0.378	369A3053-21-01001	
			APPLY BLEEDER & VACUUM BAG-CURE PER HP 15-42				

NEXT ASSEMBLY END ITEM R&D PROGRAM.	QTY.	CHANGE EFFECTIVE FROM / TO	R1 REASON FOR CHANGE PRODUCTION PLANNING RELEASE	PLANNED BY L. MEEKS DATE 2-3-75 REVISED BY DATE I.E. D.S. 2-5-75

FORM NO. 9733. REV. 6/74

Hughes Helicopters PLANNING SHEET

VALUE CODE		PROJECT	DWG. LTR	PART NUMBER 369ASK 2000-1	SHEET 2/8
PART TYPE		ENGINEERING ORDERS		PART NAME	REV. NO. 1
COST CENTER REV. LTR.					

OPER NO.	DEPT CC	WORK STA	OPERATIONS PERFORMED	SET UP	RUN	TOOL NO.	REV. NO.
060	2823		ROUT PART TO SIZE AND DRILL (3) .260/.271 DIA. HOLES DEBURR	00.1	0.246	369A3053-21-00301	
						369A3053-21-71201	
			TRIM 369ASK 2000-7-9 & -11 HONEYCOMB FILLERS TO SIZE				
070	2823		CLEAN MOLD AND APPLY MOLD RELEASE	00.1	0.021	369ASK 2000-21201	
			1ST STAGE				
080	2823		LAYUP (2) PLIES OF 181 KEVLAR 49 OVER 369A3014-53 ANTENNA AND	00.3	1.588	369ASK 2000-21201	
			POSITION IN TOOL				
			COVER BALANCE OF TOOL WITH (1) PLY OF 181 KEVLAR 49 (REF-3 OUTER SKIN)				
			POSITION (4) 369A3053-25 PLATES (7) 369A2081 DOUBLERS AND (1) EACH				
			369A3053-23 PLATE,369A3053-31 PLATE,369A3053-33 PLATE,369A3053-35 ANGLE				
			(CONT)				

NEXT ASSEMBLY	QTY.	CHANGE EFFECTIVE FROM	TO	REASON FOR CHANGE	PLANNED BY DATE
					REVISED BY DATE
					I.E.

Hughes Helicopters PLANNING SHEET

VALUE CODE

PART TYPE

COST CENTER REV. LTR.

PROJECT

DWG. LTR

ENGINEERING ORDERS

PART NUMBER 369ASK 2000-1

PART NAME

SHEET 3/8

REV. NO. 1

OPER NO.	DEPT CC	WORK STA	OPERATIONS PERFORMED	SET UP	RUN	TOOL NO.	REV. NO.
080	(CONT)		369A3053-36 ANGLE AND (2) 369A3053-111 PLATES				
			COVER METAL DETAILS WITH (1) PLY 181 KEVLAR 49				
			APPLY BLEEDER AND VACUUM BAG TO SET MATL. AGAINST MOLD				
			REMOUE VACUUM BAG AND BLEEDER				
			POSITION -7-9 & -11 HONEYCOMB FILLERS				
			COVER -11 FILLER WITH 181 KEVLAR 49 (INNER SKIN)				
			APPLY BLEEDER & VACUUM BAG				
			CURE PER HP 15-42				
			STRIP BLEEDER & VACUUM BAG FOR NEXT ASSY.				

NEXT ASSEMBLY

QTY.

CHANGE EFFECTIVE FROM TO

REASON FOR CHANGE

PLANNED BY DATE

REVISED BY DATE

I.E.

Hughes Helicopters PLANNING SHEET

VALUE CODE

PART TYPE

COST CENTER REV. LTR.

PROJECT

DWG. LTR

ENGINEERING ORDERS

PART NUMBER 369ASK 2000-1

NAME

SHEET 4/8

REV. NO. 1.

OPER NO.	DEPT CC	WORK STA	OPERATIONS PERFORMED	SET UP	RUN	TOOL NO.	REV. NO.
			2ND STAGE				
090	2833		ROUT DOOR, AIR OUTLET AND LIGHT OPENING AREAS THRU OUTER SKIN AND FILLER	00.1	0.177		
			TRIM FILLER BACK TO DOUBLER EDGES AS REQ'D				
100	2823		LOCATE ASSY. IN FIXTURE FOR LOCATING POSITIONING AND BONDING -31 BULK HEAD -33 & -35 ANGLES AND 369A3053 -49-51 & 53 SPACERS				
			SECONDARY BOND DETAILS PER HP16-25 CLASS 2 (SCOTCHWELD)				
			REMOVE FROM MOLD				
			POSITION & IMBED -15 TUBE -17 TUBE & -13 HOUSING IN HONEYCOMB PER ENG. DWG.				
			REMOVE TUBES AND WRAP WITH FOAMING TAPE AND REINSTALL.				

NEXT ASSEMBLY

QTY.

CHANGE EFFECTIVE FROM TO

REASON FOR CHANGE

PLANNED BY DATE

REVISED BY DATE

I.E.

FORM NO. 9733, REV. 6/74

Hughes Helicopters PLANNING SHEET

VALUE CODE		PROJECT	DWG. LTR	PART NUMBER 369ASK 2000-1	SHEET 5/8
PART TYPE		ENGINEERING ORDERS		PART NAME	REV. NO. 1
COST CENTER REV. LTR.					

OPER NO.	DEPT CC	WORK STA	OPERATIONS PERFORMED	SET UP	RUN	TOOL NO.	REV. NO.
100	(CONT)		BUILD UP AREA AT (REF.) SECT. DD AS REQ'D TO ENCASE -13 HOUSING				
			NOTE: -15 TUBE EXTENDS THRU -5 INNER SKIN (REF.) SECT. DD.				
			LAYUP (1) PLY OF 181 KEVLAR 49 OVERALL (REF.) -5 INNER SKIN				
			APPLY BLEEDER AND VACUUM BAG.				
			CURE PER HP15-42				
			STRIP BLEEDER & VACUUM BAG AND REMOVE ASSY. FROM MOLD				
110	2823		ROUT PERIPHERY AND CUTOUTS PER RTB	00.3	1.043	369A3053-00301	
			DRILL (4) .165/.177 DIA. HOLES (8) #49 (.073) DIA. &				
			(3) #40 DIA. (.098) DIA. HOLES IN 369A3053-31 DOUBLER AREA.				

NEXT ASSEMBLY	QTY.	CHANGE EFFECTIVE FROM	CHANGE EFFECTIVE TO	REASON FOR CHANGE	PLANNED BY	DATE
					REVISED BY	DATE
					I.E.	

FORM NO. 9733, REV. 6/74

Hughes Helicopters PLANNING SHEET

VALUE CODE

PART TYPE

COST CENTER REV. LTR.

PROJECT

DWG. LTR

ENGINEERING ORDERS

PART NUMBER 369ASK 2000-1

NAME

SHEET 6/8

REV. NO. 1

OPER NO.	DEPT CC	WORK STA	OPERATIONS PERFORMED	SET UP	RUN	TOOL NO.	REV. NO.
110	(CONT)		DRILL (2) .198/.204 DIA. HOLES IN LWR. AFT SECTION				
			DRILL (3) .280 /.291 DIA. HOLES (K DRILL) (3) .217/.229 DIA. HOLES				
			(#2 DRILL) AND (6) #40 DIA. HOLES IN -31 BULKHEAD				
			POSITION INSIDE SECTION OF DRILL FIXTURE AND PIN TO -31 BULKHEAD				
			DRILL (16) .205/.212 DIA. HOLES. COUNTER SINK (16) PLC'S .43 DIA. X				
			100°				
120	2823		SAND AND BLEND ASSY AS REQ'D	00.1	0.083		
130	2823		INSTALL (4) NAS697 A06 NUTPLATES WITH (18) MS20426 A2-4 RIVETS	00.1	0.153		
			COMMON 369A3053-33 DOUBLER				
			TRIM AND INSTALL 369A3053-113 SEAL ON DOOR OPENING. BOND PER HP16-22				

NEXT ASSEMBLY

QTY.

CHANGE EFFECTIVE FROM TO

REASON FOR CHANGE

PLANNED BY DATE

REVISED BY DATE

I.E.

FORM NO. 9733. REV. 6/74

Hughes Helicopters PLANNING SHEET

VALUE CODE		PROJECT	DWG. LTR	PART NUMBER 369ASK 2000-1	SHEET 7/8
PART TYPE		ENGINEERING ORDERS		NAME	REV. NO. 1
COST CENTER REV. LTR.					

OPER NO.	DEPT CC	WORK STA	OPERATIONS PERFORMED	SET UP	RUN	TOOL NO.	REV. NO.
			(REF.) -21 DOOR ASSY.-				
140	2823		TRIM -27 FILLER AND ROUT RECESS	00.2	0.596	369ASK 2000-27-20901	
			LAYUP (1) PLY #181 KEVLAR 49 (REF.) -23 SKIN			369ASK 2000-21-21201	
			POSITION -27 FILLER & (1) PLY 181 KEVLAR 49 (REF.) -25 INNER SKIN				
			LAYUP (2) PLIES 181 KEVLAR 49 (REF.) -29 DOUBLER				
			BAG & CURE PER HP 15-42				
			LOCATE AND DRILL (2) .452/.457 DIA. HOLES THRU -23 SKIN ONLY PER 369H2087 DWG.				
			INSTALL & BOND (2) SL 607-06-6-C INSERTS PER HP15-32				
			INSTALL 369H2087-7 CLIP TO DOOR ASSY. WITH (2) MS 51958-28 SCREWS				

NEXT ASSEMBLY	QTY.	CHANGE EFFECTIVE FROM	CHANGE EFFECTIVE TO	REASON FOR CHANGE	
					PLANNED BY DATE
					REVISED BY DATE
					I.E.

FORM NO. 9753, REV. 6/74

Hughes Helicopters PLANNING SHEET

VALUE CODE

PART TYPE

COST CENTER REV. LTR.

PROJECT

DWG. LTR

ENGINEERING ORDERS

PART NUMBER 369ASK 2000-1

NAME

SHEET 8/8

REV. NO. 1

OPER NO.	DEPT CC	WORK STA	OPERATIONS PERFORMED	SET UP	RUN	TOOL NO.	REV. NO.
150	2823		INSTALL & BOND (12) SL 607-3-6-C INSERTS COMMON HINGES & LATCHES PER	00.2	0.500		
			HP15-32				
			ASSEMBLE HINGES AND LATCH ASSY. PER SECT. E-E OF ENG. DWG.				
			ASSEMBLE AND INSTALL -19 CABLE ASSY. NOTE: USE 369A8435 DWG. AS REF.				
			IDENTIFY - INK STAMP HP 8-5				
160	2800		INSPECT		I		
170	1301		CLOSE ORDER				

NEXT ASSEMBLY

QTY.

CHANGE EFFECTIVE FROM TO

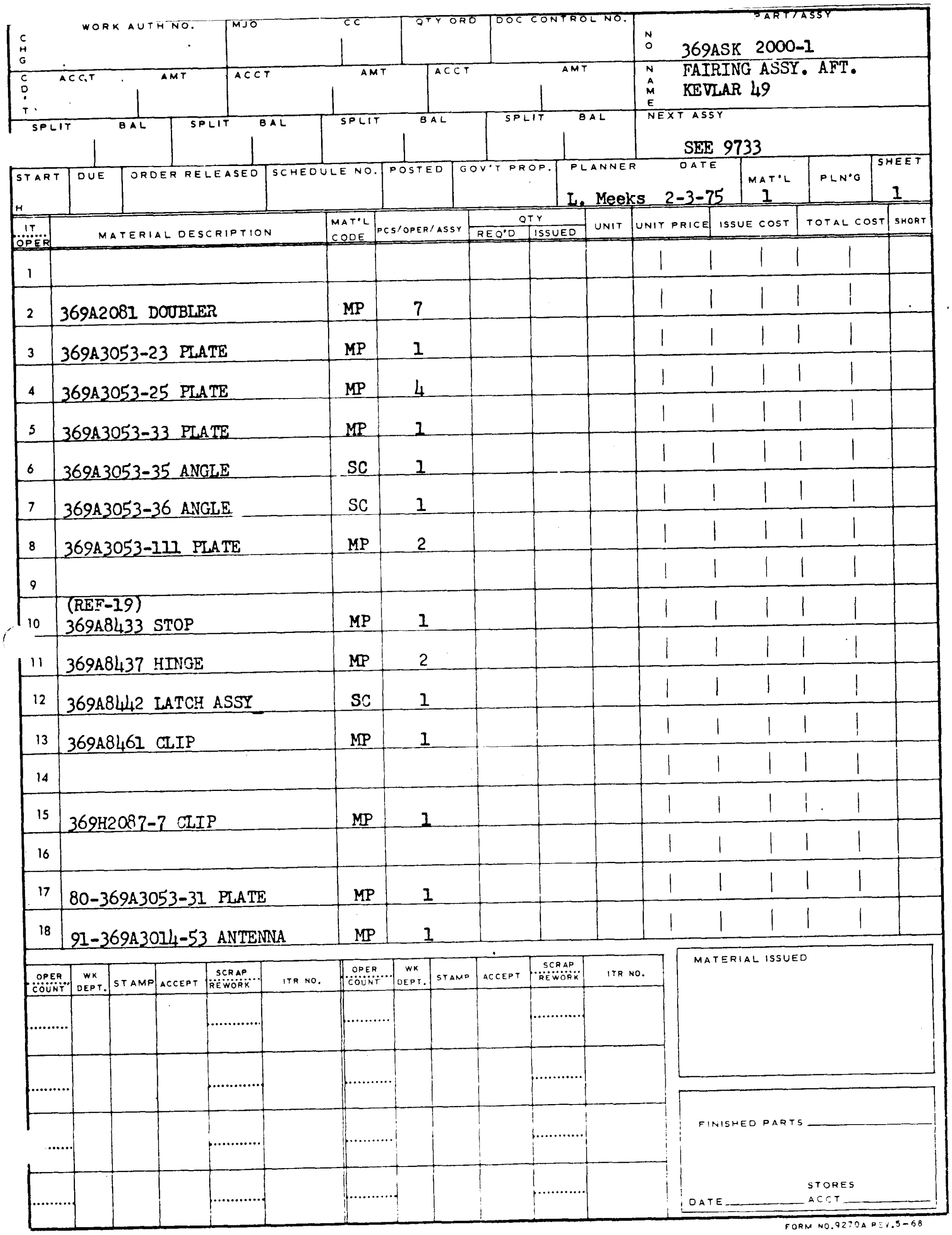
REASON FOR CHANGE

PLANNED BY DATE

REVISED BY DATE

I.E.

FORM NO. 9733, REV. 6/74



WORK AUTH NO. | MJO | CC | QTY ORD | DOC CONTROL NO.

CHG / CDT — ACCT AMT | ACCT AMT | ACCT AMT

SPLIT BAL | SPLIT BAL | SPLIT BAL | SPLIT BAL

PART/ASSY NO: 369ASK 2000-1

NAME: FAIRING ASSY. AFT. KEVLAR 49

NEXT ASSY: SEE 9733

START | DUE | ORDER RELEASED | SCHEDULE NO. | POSTED | GOV'T PROP.

PLANNER: L. Meeks DATE: 2-3-75 MAT'L: 1 PLN'G SHEET: 1

IT OPER	MATERIAL DESCRIPTION	MAT'L CODE	PCS/OPER/ASSY	QTY REQ'D	QTY ISSUED	UNIT	UNIT PRICE	ISSUE COST	TOTAL COST	SHORT
1										
2	369A2081 DOUBLER	MP	7							
3	369A3053-23 PLATE	MP	1							
4	369A3053-25 PLATE	MP	4							
5	369A3053-33 PLATE	MP	1							
6	369A3053-35 ANGLE	SC	1							
7	369A3053-36 ANGLE	SC	1							
8	369A3053-111 PLATE	MP	2							
9										
10	(REF-19) 369A8433 STOP	MP	1							
11	369A8437 HINGE	MP	2							
12	369A8442 LATCH ASSY	SC	1							
13	369A8461 CLIP	MP	1							
14										
15	369H2087-7 CLIP	MP	1							
16										
17	80-369A3053-31 PLATE	MP	1							
18	91-369A3014-53 ANTENNA	MP	1							

OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.	OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.

MATERIAL ISSUED

FINISHED PARTS ______

DATE ______ STORES ACCT ______

FORM NO.9270A REV.5-68

MANUFACTURING SHOP ORDER

CHG WORK AUTH NO.
MJO
CC
QTY ORD
DOC CONTROL NO.
PART/ASSY NO 369ASK 2000-1
NAME FAIRING ASSY. AFT.
KEVLAR 49
CD.T ACCT AMT ACCT AMT ACCT AMT
SPLIT BAL SPLIT BAL SPLIT BAL SPLIT BAL
NEXT ASSY SEE 9733
START H
DUE
ORDER RELEASED
SCHEDULE NO.
POSTED
GOV'T PROP.
PLANNER L. MEEKS
DATE 2-3-75
MAT'L 1
PLN'G
SHEET 2

IT OPER	MATERIAL DESCRIPTION	MAT'L CODE	PCS/OPER/ASSY	QTY REQ'D	QTY ISSUED	UNIT	UNIT PRICE	ISSUE COST	TOTAL COST	SHORT
1										
2	AN664C2 TERMINAL (REF 19)	PP	2		A/R					
3	AN 960PD 10L WASHER	PP	12		A/R					
4										
5	MS 24665-153 PIN	PP	1		A/R					
6	MS 51958-28 SCREW	PP	2		A/R					
7	MS 20426 A2-4 RIVET	PP	8		A/R					
8	MS 20426 AD3-3 RIVET	PP	24		A/R					
9	HS 13D156-078-406	SC	1		A/R					
0	HS 306-302L WASHER	SC	2		A/R					
11										
12	NAS 623-3-1 SCREW	PP	10		A/R					
13	NAS 623-3-3 SCREW	PP	2		A/R					
14	NAS 697A06 NUT PLATE	PP	4		A/R					
15	NAS 697A3 NUTPLATE	PP	12		A/R					
16	SC 607-06-6-C INSERT	PP	2		A/R					
17	SC 607-3-6-C INSERT	PP	10		A/R					
18										

OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.	OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.

MATERIAL ISSUED

FINISHED PARTS ______

DATE ______ STORES ACCT ______

FORM NO. 9270A REV. 5-68

MANUFACTURING SHOP ORDER

CHG	WORK AUTH NO.	MJO	CC	QTY ORD	DOC CONTROL NO.
					PART/ASSY NO. 369ASK 2000-1

CDT	ACCT	AMT	ACCT	AMT	ACCT	AMT	NAME FAIRING ASSY. AFT. KEVLAR 49

SPLIT	BAL	SPLIT	BAL	SPLIT	BAL	SPLIT	BAL	NEXT ASSY

START	DUE	ORDER RELEASED	SCHEDULE NO.	POSTED	GOV'T PROP.	PLANNER	DATE	MAT'L	PLN'G	SHEET
						L. MEEKS	2-3-75	1		3

IT OPER	MATERIAL DESCRIPTION	MAT'L CODE	PCS/OPER/ASSY	QTY REQ'D	QTY ISSUED	UNIT	UNIT PRICE	ISSUE COST	TOTAL COST	SHORT
1			SQ. IN.							
2	181 PREIMPREGNATED	RM	14,000							
3	ORGANIC FIBER									
4	KEVLAR 49									
5	HMS 16-1112									
6	(REF-3-5-23-25-29-31-33-35)									
7	(CORLAR 5134/ PRD-49 III-181 STYLE EPOXY-250°F CURE									
8			SQ. IN.							
9	.400±.006 NOMEX (REF-9)	RM	200							
10	HONEYCOMB									
11	1/8 HRH-10 @ 1.8# DEN									
12										
13			SQ. IN.							
14	.625±.006 NOMEX	RM	1700							
15	HONEYCOMB									
16	1/8 HRH-10 @ 1.8# DEN									
17										
18										

OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.	OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.

MATERIAL ISSUED

FINISHED PARTS ________

DATE ________ STORES ACCT ________

FORM NO.9270A REV.5-58

MANUFACTURING SHOP ORDER

CHG	WORK AUTH NO.	MJO	CC	QTY ORD	DOC CONTROL NO.	PART/ASSY NO.
						369ASK 2000-1

CDT	ACCT	AMT	ACCT	AMT	ACCT	AMT	NAME
							FAIRING ASSY. AFT. KEVLAR 49

SPLIT	BAL	SPLIT	BAL	SPLIT	BAL	SPLIT	BAL	NEXT ASSY
								SEE 9733

START	DUE	ORDER RELEASED	SCHEDULE NO.	POSTED	GOV'T PROP.	PLANNER	DATE	MAT'L	PLN'G	SHEET
H						L. MEEKS	2-3-75	1		4

IT OPER	MATERIAL DESCRIPTION	MAT'L CODE	PCS/OPER/ASSY	QTY REQ'D	QTY ISSUED	UNIT	UNIT PRICE	ISSUE COST	TOTAL COST	SHORT
1			SQ. IN.							
2	.80 ± .006 NOMEX	RM	150							
3	HONEYCOMB									
4	1/8 HRH-10 @ $1.8^{\#}$ DEN.									
5	(REF-27)									
6										
7										
8	.19 X .50 ENSOLITE TYPE-M	RM	LIN. FT. 4.0							
9	MIL-P-15280 TYPE 1									
10	(REF. 369A3053-113)									
11										
12	.375 OD X .03 WALL	RM	LIN. FT. 5.0							
13	SPEC. 1101 NYLON									
14	PRESSURE TUBING									
15	CONFORMING TO LP410	CLASS								
16	POLYHEXAMETHYLENE	ADIPAMIDE								
17	(REF-15-17)									
18										

OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.	OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.

MATERIAL ISSUED

FINISHED PARTS ____________

DATE ____________ STORES ACCT ____________

FORM NO.9270A REV.5-68

MANUFACTURING SHOP ORDER

Hughes Helicopters

CHG: WORK AUTH NO. | MJO | CC | QTY ORD | DOC CONTROL NO.

PART/ASSY NO. 369ASK 2000-1

CDOT: ACCT | AMT | ACCT | AMT | ACCT | AMT

NAME FAIRING ASSY. AFT.
KEVLAR 49

SPLIT | BAL | SPLIT | BAL | SPLIT | BAL | SPLIT | BAL

NEXT ASSY

START | DUE | ORDER RELEASED | SCHEDULE NO. | POSTED | GOV'T PROP.

PLANNER L. MEEKS | DATE 2-3-75 | MAT'L 1 | PLN'G | SHEET 5

IT OPER	MATERIAL DESCRIPTION	MAT'L CODE	PCS/OPER/ASSY	QTY REQ'D	QTY ISSUED	UNIT	UNIT PRICE	ISSUE COST	TOTAL COST	SHORT
1			LIN. FT.							
2	.063 CABLE-NON-MAG.	RM	6.0							
3	STAINLESS STL.									
4	MIL-C-18375									
5	(REF-19)									
6										
7										
8	A1177 B MOLDING COMPOUND	OS	2 LBS.			A/R				
9	(REF 369A3053-49-51-53)									
10										
11										
12	.187 DIA. NYLON CASING	RM	6.0 LIN. FT.							
13	WITH .080 ID DELCRON									
14	(OR) TEFLON LINER.									
15	(REF-13)									
16										
17	FOAMING TAPE-	OS	A/R		A/R					
18	HMS 16-1111 TYPE III END OF LIST									

OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.	OPER COUNT	WK DEPT.	STAMP	ACCEPT	SCRAP REWORK	ITR NO.

MATERIAL ISSUED

FINISHED PARTS ______

DATE ______ STORES ACCT ______

FORM NO.9270A REV.5-68

MANUFACTURING SHOP ORDER

APPENDIX C

HUGHES PROCESS 15-42

LABORATORY REPORT

FLIGHT TEST REPORT

	REVISIONS		
LTR	DESCRIPTION	DATE	APPROVED
A	Released on E. O. 114178	4/2/69	
B	Released on E. O. 119620	1/6/70	
C	Released on E. O. 125990	4/12/74	
D	Released on E. O. 127397	2/7/75	

SCOPE: This specification provides the requirements and and procedures for fabrication of fiberglass laminated parts.

CHANGES:

Revised 3. 5. 1. 3; WAS:

HMS 16-112 material 60, 000 psi (413. 7 MPa)

Change bars indicate changes.

PREP	S. Schultz
APPD	
1/31/75	
2/3/75	McDermott
2-3-75	S M Jacobson
2/3/75	M Vague
[illegible]	
2/5/75	
2/5/75	

Hughes Helicopters division of summa corporation

TITLE
FABRICATION OF REINFORCED PLASTICS

SIZE	CODE IDENT NO.	NO.
A	02731	HP 15-42 D

SHEET 1 of 12

FORM 565 REV. 8/73

1. SCOPE

1.1 This specification provides the requirements and procedure for fabrication of reinforced plastic laminated parts.

2. APPLICABLE DOCUMENTS

2.1 The following documents form a part of this specification to the extent specified herein. In case of conflict between these documents and this specification, the requirements of this specification shall prevail.

Specifications

Federal

O-T-620	Trichloroethane - 1, 1, 1, Technical

Military

MIL-P-265	Polyvinyl Alcohol, Granular
MIL-R-7575	Resin, Polyester, Low-Pressure Laminating
MIL-R-9300	Resin, Epoxy, Low-Pressure Laminating
MIL-P-8116	Putty, Zinc Chromate, General Purpose
MIL-C-23377	Primer Coating, Epoxy-Polyamide, Chemical-and Solvent-Resistant

Hughes Helicopters

HP 4-57	Chemical Films for Aluminum and Aluminum Alloys
HP 4-100	Adhesive Primer, Application and Control

HP 9-26	Etch for Corrosion-Resistant Steel
HMS 15-1100	Catalyzed Epoxy Primer
HMS 16-1072	Polyester, Preimpregnated Fiberglass
HMS 16-1079	Epoxy, Preimpregnated Fiberglass
HMS 16-1112	Laminating Epoxy Preimpregnated High Strength Organic Fiber (Kelvar)
HMS 16-1113	Uni-directional Glass Cloth/Epoxy Resin Prepreg

Standards

Federal

FED-STD-406	Methods of Testing Plastics

3. REQUIREMENTS

3.1 General

3.1.1 The laminates shall be within the tolerances of the engineering drawing and shall be of uniform quality and good workmanship. High quality and good workmanship are evidenced by conformance to the condition defined by requirements of this specification.

3.1.2 All laminating and fabrication operations shall be performed in a clean area designated for the fabrication of reinforced plastic laminates. All details, primed parts and laminating materials shall be kept covered or wrapped in plastic or Kraft paper when not is use.

3.2 Thickness

3.2.1 The thickness dimension requirements for the laminated plastic parts fabricated to this specification shall meet the requirements of Table I, except that along the surface of radii or 0.50 inch (12.7 mm) or less, the thickness shall not exceed double the thickness for the number of laminates.

Table I. Thickness Requirements for Plastic Laminates

Number of Plies	181 Prepreg Fabric	120 Prepreg Fabric	181 Wet Construction	120 Wet Construction
1	0.0115 ±0.005	0.0065 ±0.005	0.0115 ±0.005	0.0035 ±0.005
2	0.0207 ±0.005	0.0105 ±0.005	0.0200 ±0.005	0.0065 ±0.005
3	0.0308 ±0.005	0.0140 ±0.005	0.0275 ±0.005	0.0100 ±0.005
4	0.0420 ±0.008	0.0175 ±0.005	0.0365 ±0.008	0.0128 ±0.005
5	0.0520 ±0.010	0.0210 ±0.005	0.0450 ±0.010	0.0165 ±0.005
6	0.0640 ±0.012	0.0250 ±0.005	0.0535 ±0.012	0.0200 ±0.005

3.3 Resins

3.3.1 The polyester resins used shall conform to the requirements of MIL-R-7575, Grade A, Class O, Forms A and B.

3.3.2 The polyester/glass prepreg materials shall conform to HMS 16-1072.

3.3.3 The epoxy resins used shall conform to the requirements of MIL-R-9300, Type I, Grade O, Forms A and B.

3.3.4 The epoxy/glass prepreg materials shall conform to HMS 16-1079.

3.3.5 The epoxy/organic fiber prepreg shall conform to HMS 16-1112.

3.3.6 The epoxy/uni-directional glass cloth prepreg shall conform to HMS 16-1113.

3.4 Testing

3.4.1 The Durometer hardness shall be determined in a minimum of three locations on each part. The measurement on parts fabricated of less than three plies shall be a tag-along area or a trim portion. The minimum acceptable value is 75 when tested according to 5.1.1.2.

NOTE: A Barcol hardness of 55 minimum is acceptable.

3.5 Minimum Requirements and Allowable Defects

3.5.1 The minimum tensile strength when tested according to 5.1.1.1 shall be:

3.5.1.1 HMS 16-1072 material 25,000 psi (172.4 MPa)

3.5.1.2 HMS 16-1079 material 40,000 psi (275.8 MPa)

3.5.1.3 HMS 16-1112 material 60,000 psi (413.7 MPa), 40,000 psi (275.8 MPa), when cured with less than 40 psi (275.8 kPa) pressure.

3.5.1.4 HMS 16-1113 material 150,000 psi (1034 MPa)

3.5.2 The laminated parts shall be within the tolerances of the engineering drawing and shall be of high quality workmanship.

3.5.3 The laminate shall be fully cured and free of surface tackiness.

3.5.4 The final surface of the part shall not be sanded or abraded in such a manner that the outer layer of glass fabric is damaged to the extent that the continuity of the woven fiber is broken.

4. PROCEDURE

4.1 General

4.1.1 The selection of the manufacturing methods will depend upon the type of tooling required for a particular part and the required properties of the part. Several factors may influence this; for example, configuration or size of part, quantity to be manufactured, and specific requirements of finished part.

4.2 Metal Treatment

4.2.1 Metal inserts of aluminum and aluminum alloys shall be processed in accordance with HP 4-57 and then coated with either MIL-P-23377 primer, HMS 15-1100 Type I or adhesive primer per HP 4-100. Large sheets may be prepared and sheared into small detail parts.

4.2.2 Corrosion-resistant steel alloys shall be etched and primed in accordance with HP 9-26.

4.2.3 Prepared parts shall be wiped with O-T-620 trichlorethane or equivalent immediately prior to fabrication.

4.3 Laminate Fabrication

4.3.1 Apply release agents to the tooling; use carnauba-based wax or 5-to 10-percent MIL-P-265 polyvinyl alcohol or equivalent. Wax should be buffed smooth.

4.3.2 The laminated parts may be fabricated with a gel resin overlay, 0.010 inch thick maximum, integrally molded or otherwise fabricated with the part.

4.3.3 Preimpregnated glass cloth shall be fabricated as follows:

4.3.3.1 Place the impregnated cloth in or on the tool, one ply at a time, and smooth out wrinkles and airpockets in each ply before addition of the next ply.

4.3.3.2 Necessary laps shall be 0.5 to 1.0 inch (12.7 to 25.4 mm) wide and shall not be superimposed, except when the contour of the part required crosslapping.

4.3.3.3 Tailoring shall be done prior to addition of each succeeding ply, and no gaps shall be allowed between cut or matched edges.

4.3.3.4 Preimpregnated cloth may be warmed to provide greater flexibility.

4.3.4 Wet layup or nonpreimpregnated fiberglass cloth shall be fabricated as follows:

4.3.4.1 Place fiberglass cloth in or on tool one ply at a time.

4.3.4.2 Apply resin (mixed with catalyst, as required) to the cloth with a brush or squeegee.

4.3.4.3 Continue adding cloth and resin until desired thickness has been achieved.

NOTE

As an option, cloth may be prewet with the resin prior to placement on the tooling.

4.3.5 Vacuum bag pressure shall be applied as follows.

4.3.5.1 Place bleeder material or wire spring around the edge of the tool in a manner that the layup is not touched.

4.3.5.2 Enclose the entire assembly (mold, layup, and bleeder material) in MIL-P-265 polyvinyl alcohol (PVA) sheet or equivalent sealed to the mold surface with MIL-P-8116 zinc chromate compound or equivalent. As an alternate, the bag may be sealed by mechanical methods, in the event the tool is so designed.

4.3.5.3 Connect and seal a vacuum line to the bag opening, taking care to protect the end of the line from possible clogging by excess resin. Additional bleeder strips or flexible tubing may be installed at this time, if necessary.

4.3.5.4 Evacuate the bag gradually.

4.3.5.5 Keep wrinkles from forming as much as possible by working the bag surface with the fingers. Prevent any small wrinkles that do develop from bridging the gap between the laminate and the bleeder strips or any other direct connection to the vacuum line. Care shall be exercised to prevent formation of a seal between the lay-up and the bleeder strips.

4.3.5.6 After the PVA sheet has completely contacted the laminate and mold, slowly wipe air and excess resin out of the laminate, using rollers, paddles, spatulas, or hands. Sweep the air bubbles (visible through the transparent bag) from the laminate in the waves of excess resin. Continue this wiping process until all entrapped air has moved past the edge of the laminate and the impregnated fabric plies are firmly pressed together. Wiping should not be carried to the point of resin starvation as evidenced by whitening and loss of transparency of the laminate. Care should be exercised during wiping to avoid puncturing the bag. If a leak should develop, repair the hole with Scotch cellophane tape or zinc chromate compound, and work any air that may have penetrated into the bag away from the laminate.

NOTE

Mineral oil may be used to provide lubrication on the vacuum bag surface during the void-free processing of the laminate. This use of oil shall be carefully controlled, since even small quantities of oil, if allowed to work into the laminate, either through a pin hole in the bag or from the operator' s hands, during layup will seriously affect the quality of the part.

4.3.5.7 Vacuum pressure of 10 psig (69 kPa) minimum shall be maintained throughout the entire curing cycle and as required until the laminate has cooled to 130°F (54.4°C) or lower or has been removed from the ultraviolet lamps.

WARNING

> Care shall be exercised in using ultraviolet lamps, as burns are possible from either direct or reflected light. Special caution is required in protecting the operator's eyes. Special goggles must be worn during operation of curing units.

4.3.6 Matched metal molds shall be used for simple designs and flat panels. The layup may be made outside the mold and then placed in position while the dies are hot. Close dies immediately. For complicated designs, the layup may be made directly on the cool dies.

4.4 Curing of Laminates

4.4.1 Laminates requiring vacuum bag pressure shall be cured in an oven, or under heat lamps, sunlamps, or ultraviolet, depending on the resin system. Laminates made with an expandable punch or matched metal molds shall be cured by direct heated dies.

4.4.2 The cure temperature for oven-cured laminates shall be 250° to 275° F (121.1° to 135°C) and the time shall be established as follows:

4.4.2.1 A cure temperature curve shall be established for all laminates at the time of curing of the initial unit during prototype development. The part shall be cured with a minimum of three calibrated thermocouples contacting the surface of the laminate at representative points. Temperature readings shall be taken at suitable time intervals so that a smooth time-temperature curve may be plotted indicating the start of the exothermic polymerization reaction and the subsequent curing time. Oven or die temperature shall be recorded at the same intervals. Subsequent parts shall be cured according to the temperature schedule established by the curve.

4.4.3 Molding pressure shall be maintained throughout the entire cure cycle.

4.4.4 Laminates cured using ultraviolet lamps shall have a time cycle established for each design during prototype development. Subsequent units shall be cured according to the time cycle established.

4.5 Removing Laminates

4.5.1 The laminates should be allowed to cool below 130°F (54.4°C) whenever practical, before removal from the tooling to minimize distortion. Suitable apparatus may be used for force cooling.

4.5.2 Removal of the laminates from the tooling shall be accomplished without damage to either the part or the tooling. Air jets may be used to aid separation between the tooling surface and the laminate.

4.6 Secondary Bonding

4.6.1 Areas for secondary bonding may be prepared by incorporating a tear ply of type-128 fabric or light weight nylon on the surface of the laminate during the layup operation. Prior to bonding, the tear ply is removed and the surface wiped lightly with an approved solvent.

4.6.2 Surfaces for secondary bonding may also be prepared by sanding the area free of gloss with 180-grit emery and wiping with an approved solvent.

4.7 Trimming

4.7.1 All parts shall be trimmed to the required engineering dimensions, unless otherwise specified. Laminate surfaces in contact with PVA film may be uneven and require minor smoothing. Sanding, as required, shall be performed with care to avoid damaging the glass fabric.

4.8 Repairs and Rework

4.8.1 Repairs and rework shall be accomplished in such a manner that the repaired or reworked part meets all the requirements stated in 3.4.1. Repairable defects shall consist of those that can be repaired without adversely affecting the serviceability of the part. Laminates may be repaired using only the same materials as in the original laminates, with minimum overlap of 0.5 inch (12.7 mm).

4.8.1.1 Surface defects such as starved areas, cracks, checks, and porosity not extending through the part may be repaired by lightly sanding the surface, taking care to avoid damage to the glass fabric, and applying a light coat of applicable resin mixture or prepreg fiberglass cloth to the sanded area. The part shall then be recured in accordance with 4.4.

4.8.1.2 Major surface defects such as blisters, delamination, and excessive starved areas or porosity may be repaired by carefully stripping off the outer layer of glass fabric after cutting around the defective area with a sharp knife. Extreme care shall be taken not to damage the next glass fabric layer during this operation. The exposed area shall then be sanded and a contoured piece of glass fabric fitted into place, with 0.5-inch (12.7 mm) overlap, and the part then recured in accordance with 4.4.

4.8.1.3 Defects such as small blisters, delaminated areas, air or gas pockets, and dry spots may be repaired by drilling several small holes into (not through) the defective area and injecting a catalyzed resin mixture by use of a hypodermic needle. The part shall then be recured, with application of pressure if possible, in accordance with 4.4.

4.8.1.4 Repair of Delaminations

a. Using a sharp knife, carefully cut around the area to be repaired, leaving a margin of 1/4 inch (6.35 mm) for each ply of fabric to be removed. The depth of cut produced by the knife shall be adjusted in such a manner that no more than the uppermost single ply of glass fabric will be cut. Remove this layer by inserting the knife blade under the cut edge and carefully prying the fabric loose.

b. Repeat the operation above, moving the cut margin in 1/4 inch (6.35 mm) toward the center of the area to be repaired.

c. Continue the above "step-stripping" procedure until all damaged plies have been removed.

d. Sand the exposed plies to remove excess cured resin and wipe with a cloth dampened (not saturated) with O-T-620 trichloroethane or equivalent.

e. Cut glass fabric patches to fit each of the step-stripping openings in the laminate, with minimum overlap of 0.5 inch (12.7 mm). Impregnate the tailored patches. Fit each successively larger patch into its respectively larger opening until all patches are in place. Lay a piece of cellophane over the wet layup, apply pressure, and cure in accordance with 4.4

5. QUALITY ASSURANCE PROVISIONS

5.1 First Article Qualifications

5.1.1 The first article (cure temperature curve part) shall be tested completely for conformance to paragraphs 3.2 and 3.5.

5.1.1.1 Tensile strength shall be determined according to method 1011 (type 2 specimen) of FED-STD-406.

5.1.1.2 The Durometer hardness shall be determined by a direct Type D Durometer.

5.1.2 Finished parts shall be inspected for conformance to the requirements of 3.

6. NOTES

6.1 Fiberglass laminated parts require careful handling.

6.1.2 Completed assemblies shall be cushioned or supported in adequate racks, storage bins, or boxes to prevent damage.

6.2 In case of conflict, the engineering drawing takes precedence over this specification.

7. APPROVED VENDORS

7.1 Only vendors listed in AVL 15-42 shall perform this process.

HUGHES TOOL COMPANY--AIRCRAFT DIVISION

TEST MACHINE DATA AND RESULTS

45464 SHT 2
74-12-1322

REQUESTED BY Pmc. lab
DATE TEST IS MADE 12-11-74
TEST MACHINE OPERATOR K. Crist

DESCRIPTION OR TITLE OF TEST 369 ASK 2000 Aft inlet fairing Fiberglass tensile

Spec.	W	T	Area		Ult. load	Ult. P.S.I.		
IB	.504	.0115	.00580		233	40,200		
OB	.503	.012	.00604		261	43,200		
IR	.504	.0122	.00615		281	45,700		
OR	.5025	.0117	.00589		335	56,900		
IL	.504	.0116	.00585		294	50,300		
OL	.502	.012	.00602		294	48,800		
I-	inside							
O-	outside							
B-	bottom							
L-	left							
R-	right							

REMARKS

J Leach
File

HUGHES TOOL COMPANY - AIRCRAFT DIVISION
CULVER CITY, CALIFORNIA
STANDARDS, MATERIALS AND PROCESS ENGINEERING

LABORATORY REPORT

No. 45464
S#71

PART NUMBER 369ASK2000 PART NAME Aft Inlet Fairing
SUBMITTED BY J Bailer ORG. CODE 41-20 EXTENSION
NUMBER OF SAMPLES 1 LOT SIZE 1 MJO 9436 CC 862
FORM 9778 DATE 12/10/74 ITR NO. P.O. R.R.
VENDOR HH HEAT TREAT CO.
WHY IS LABORATORY EXAMINATION DESIRED? Test conformance HP 15-42
First Article

BLUE PRINT REQUIREMENTS	RESULTS OF LABORATORY EXAMINATION
MS 16-1112 Tensile Shear 40,000 psi	Tensile Shear, psi 40,200 43,200 45,700 56,900 50,300 48,800

rocessing conforms to
quirements.

PREPARED BY
PHOTOS ATTACHED
SHEETS ATTACHED

APPROVED BY Smith DATE 1/15/75 APPROVED BY French DATE 1-15-75

FORM 9130

No. 45464 SHT 3

February 3, 1975

Ralph Goodall,

369HSK2000, Aft Inlet Fairing bond was 100% with no void areas. Fairing was sectioned so that bond areas could be observed.

Resin showed good cure as evidenced by the test values listed in Lab Report 45464. Tensile test values are very good considering that the skins tested were (1) ply.

Schultz

HUGHES HELICOPTERS

ENGINEERING FLIGHT TEST REPORT

5336A

A/C No.:	68-17143		Date:	1/29,1/30,1/31/75	Pilot:	Ferry/Zimmerman
	(491103)		Flt. No.:	326 & 327	FTE:	Bardell
Model:	OH-6A					
	326	327	OAT Range:	40-70° F.	Total Time:	5.6 Hr.
TOGW:	1817	1887	Bar.:	-------	Test Request:	F-369-1227
TOCG:	Mid	Mid	Wind:	-------	MJO:	9436

Purpose: Flight Evaluation of Kevlar-49 Aft Engine Inlet Fairing

Pilot's Comments:

Zimmerman (5.4 Hr):

1. Aircraft handling characteristics were satisfactory and unchanged by installation of the Kevlar -49 Aft Engine Inlet Fairing.

Ferry (0.2 Hr):

1. Concur with Zimmerman.

FTE's Comments:

1. The aircraft was in standard OH-6A configuration with the Kevlar-49 Engine Inlet Aft Fairing installed in place of the standard fairing. The fairing installation included the engine inlet particle separator with cockpit operated by pass door, static system line and port and upper flashing anticollision light.
2. Installation of the Kevlar fairing was routine and no major problems were experienced. It was noted that the Kevlar material tended to powder when drilled but otherwise had similar working characteristics to fiberglass.
3. The five hour flight test program specified in the flight test plan attachment to E.T.R. F-369-1227 was satisfactorily completed. Post test inspection of the Kevlar-49 Fairing revealed no discrepancies.

Pilot

Pilot

APPENDIX D

PHOTOS OF TRIMMING, DRILLING AND CUTTING SAMPLES

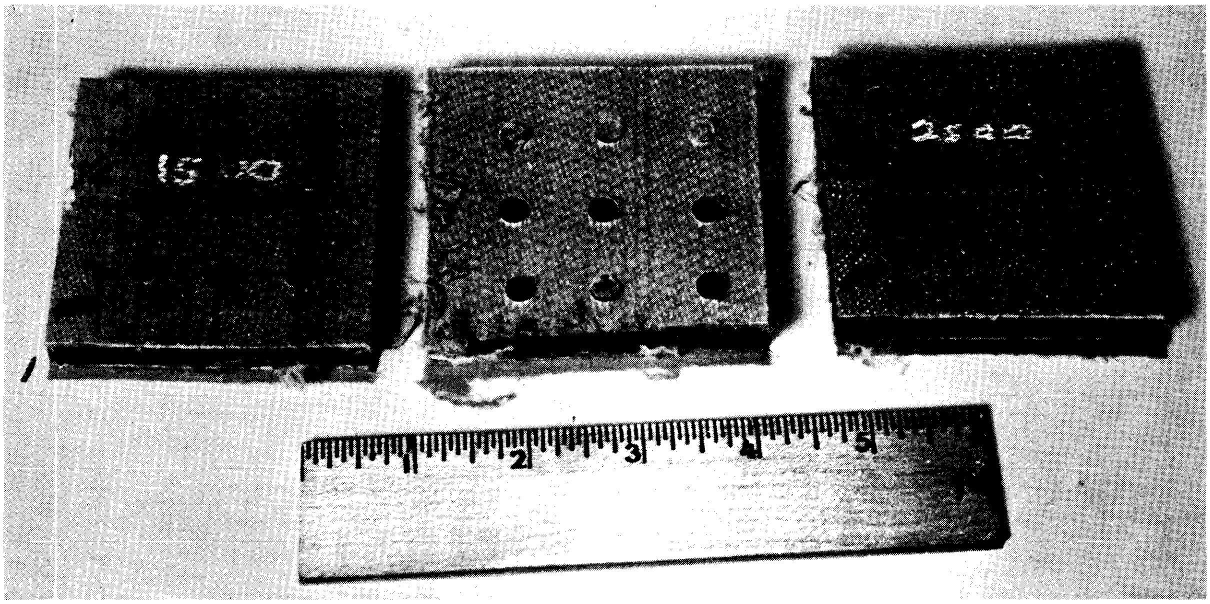


PHOTO NO. 1 – DRILL: .250 DIA TECHNOLOGY ASSOCIATES SPADE DRILL
SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN
NOTE. TREPANNING OF EXIT HOLES

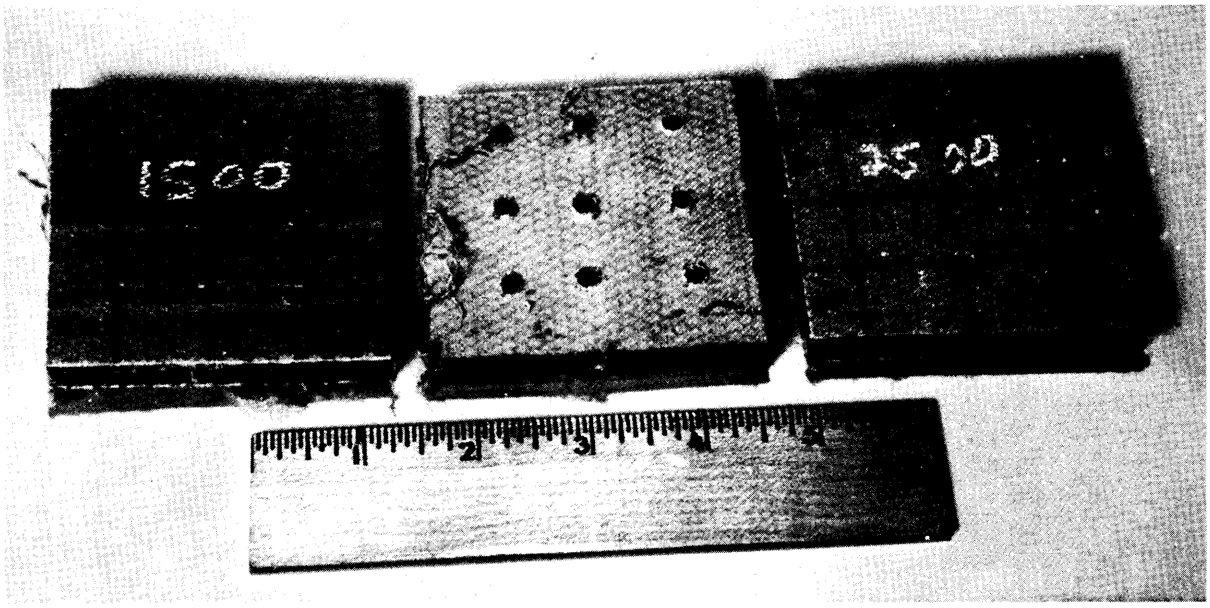


PHOTO NO. 2 – DRILL: .190 DIA TECHNOLOGY ASSOCIATES SPADE DRILL
SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

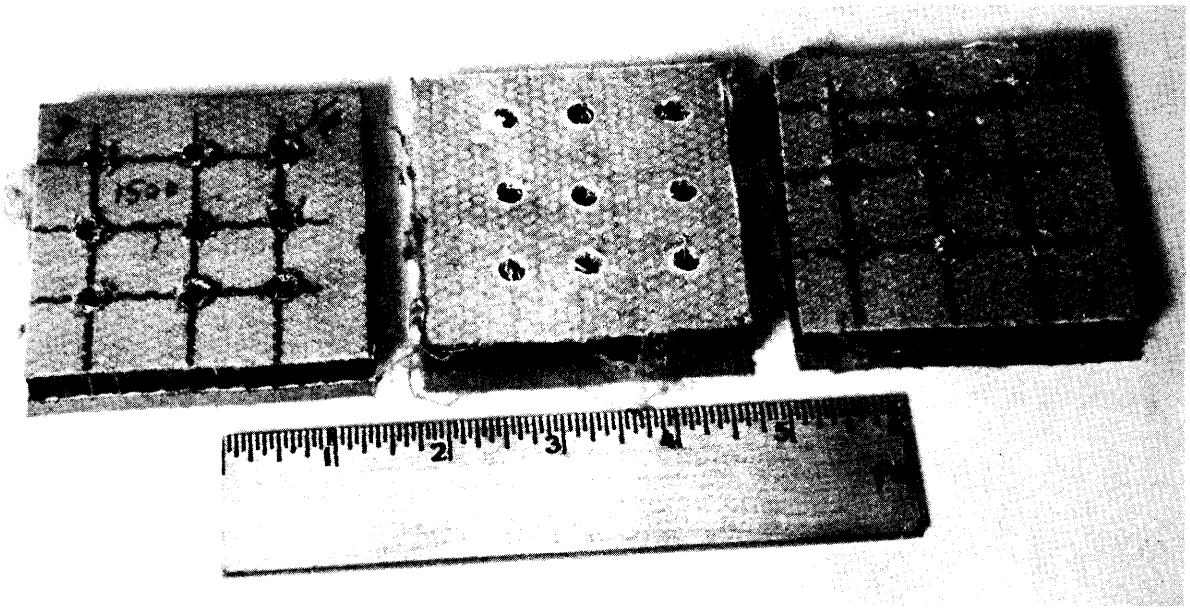


PHOTO NO. 3 – DRILL: .250 DIAMETER STANDARD DRILL
SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN

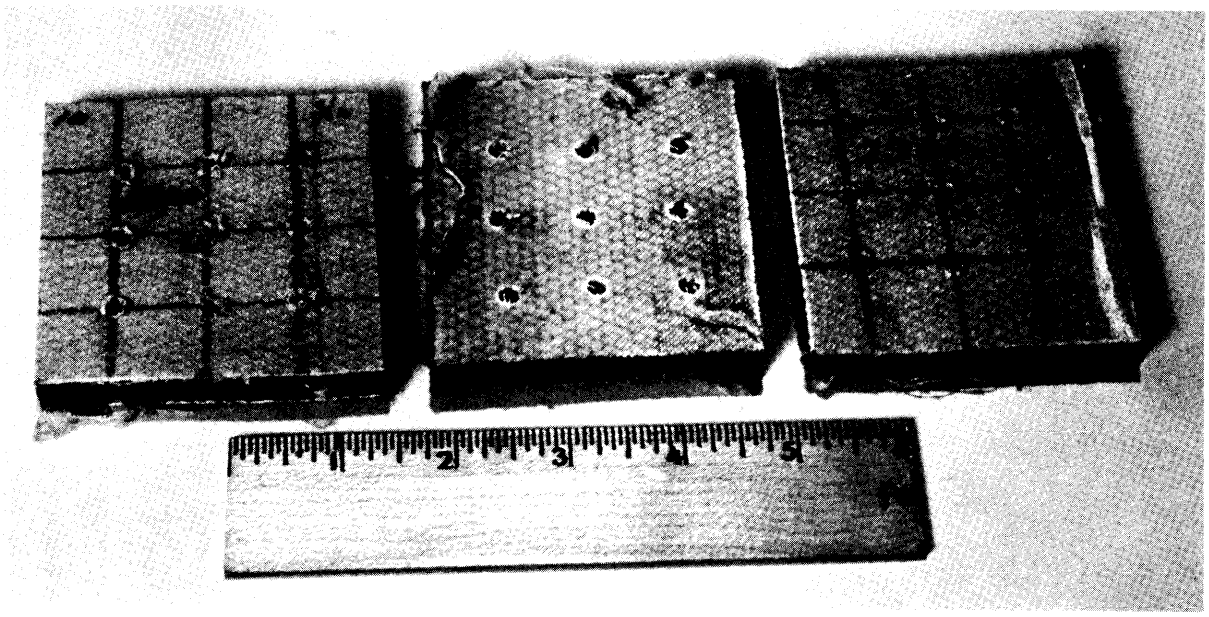


PHOTO NO. 4 – DRILL: .190 STANDARD DRILL
SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN

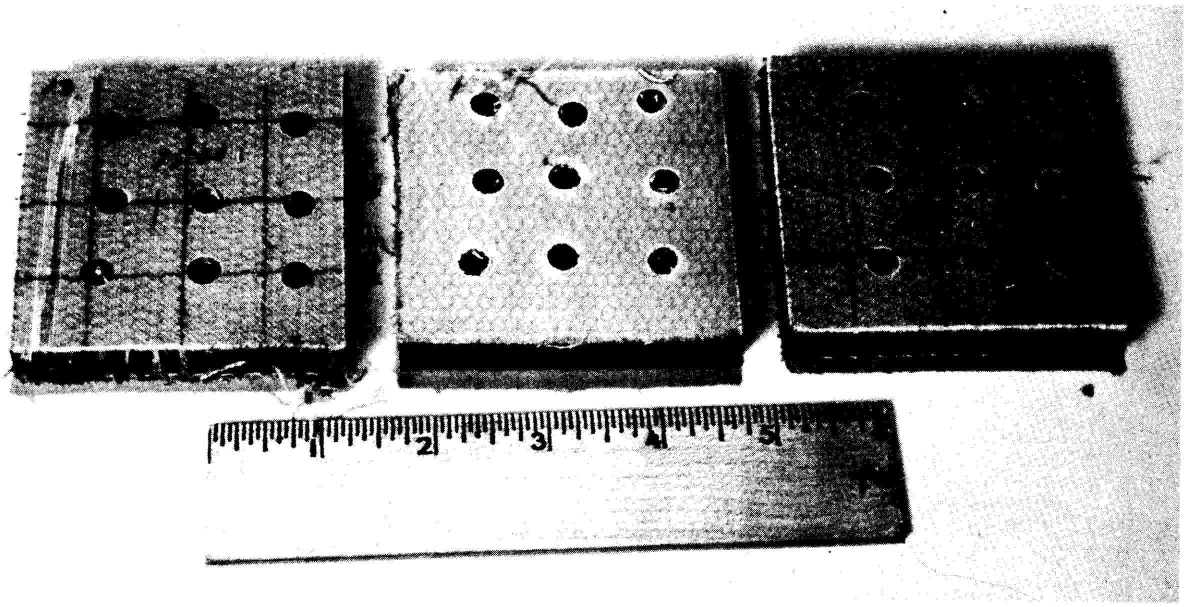


PHOTO NO. 5 – DRILL: .250 SPADE DRILL

SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN

NOTE: KEVLAR SAMPLE SUPPORTED BOTH SIDES WITH .25 PLYWOOD

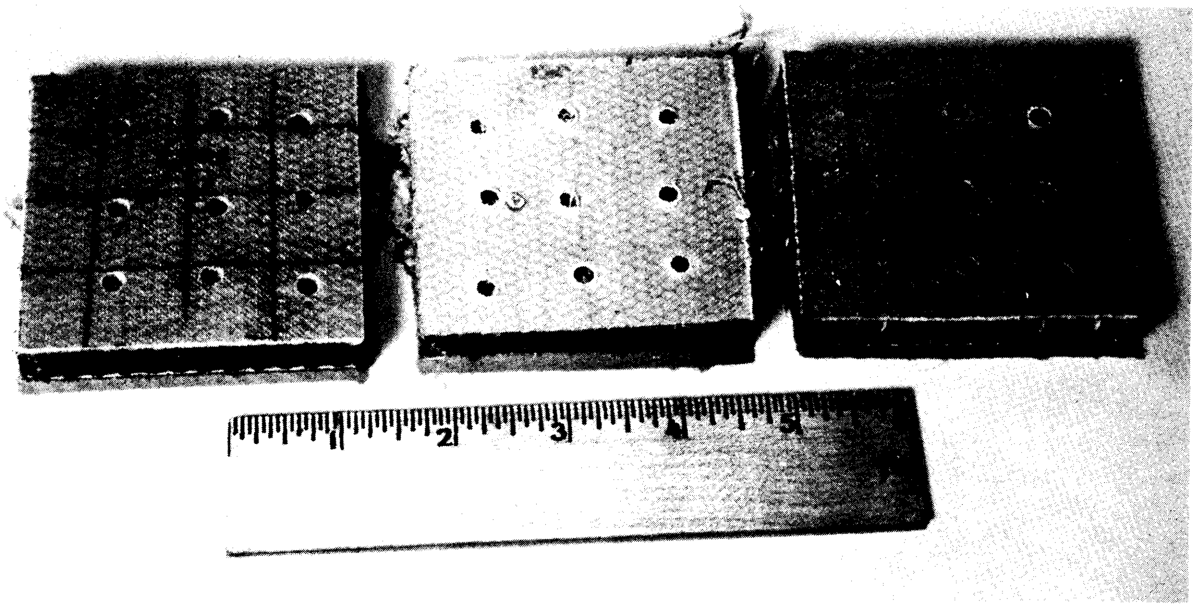


PHOTO NO. 6 – THESE SAMPLES SAME AS PHOTO NO. 5 EXCEPT .190 SPADE DRILL WAS USED

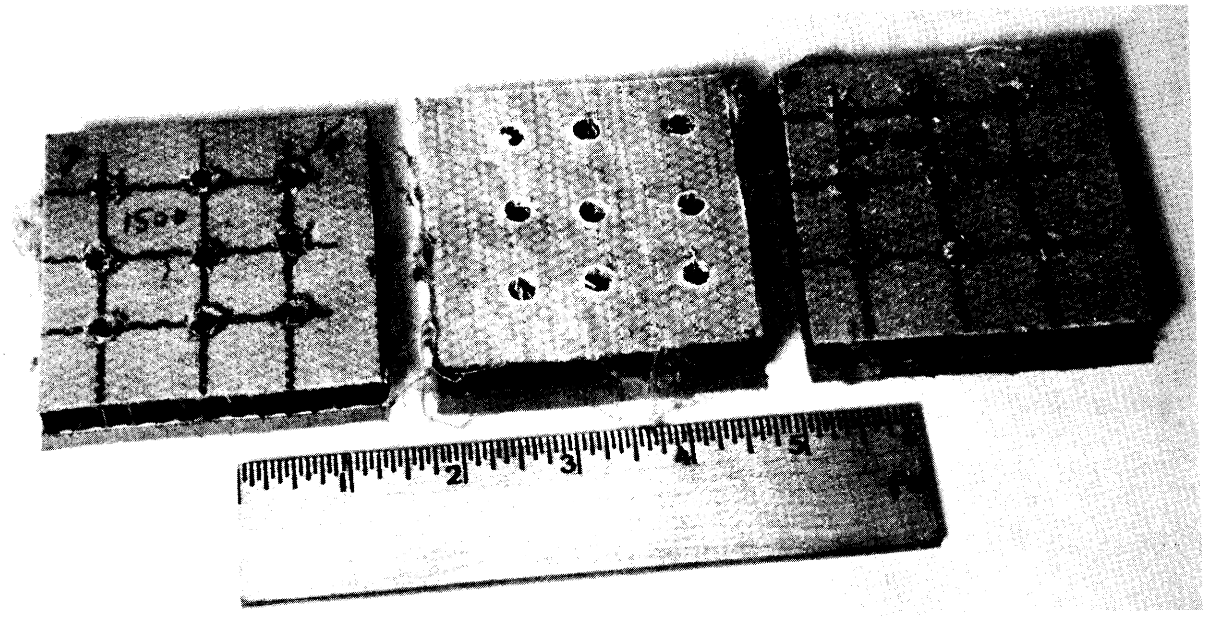


PHOTO NO. 3 – DRILL: .250 DIAMETER STANDARD DRILL
SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN

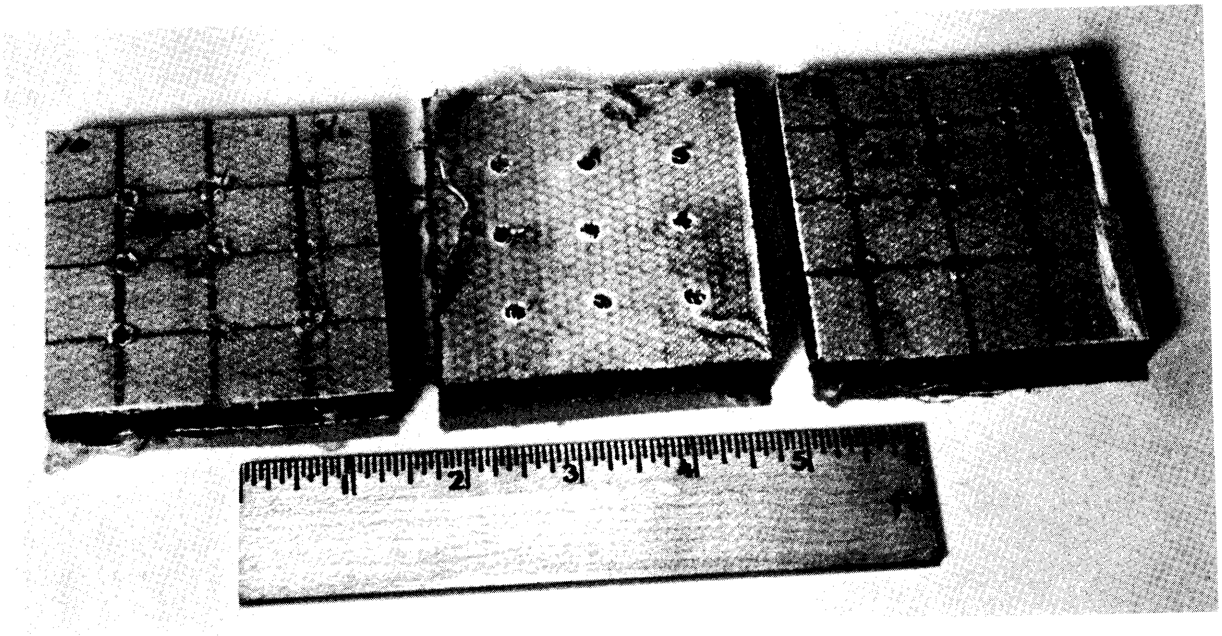


PHOTO NO. 4 – DRILL: .190 STANDARD DRILL
SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN

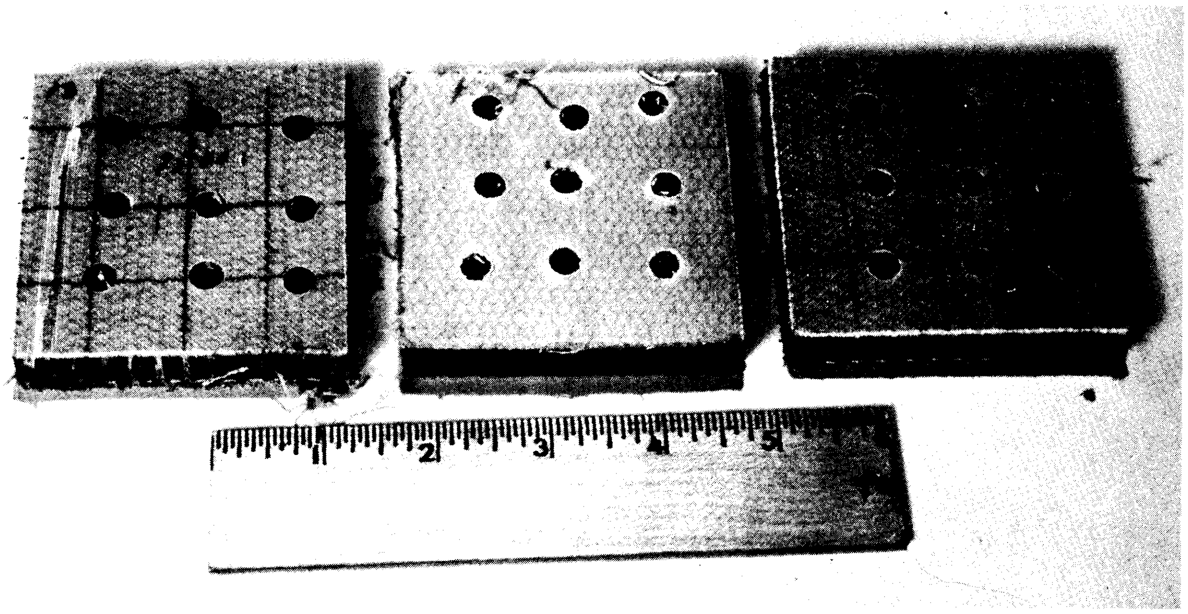


PHOTO NO. 5 – DRILL: .250 SPADE DRILL
SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN
NOTE: KEVLAR SAMPLE SUPPORTED BOTH SIDES WITH .25 PLYWOOD

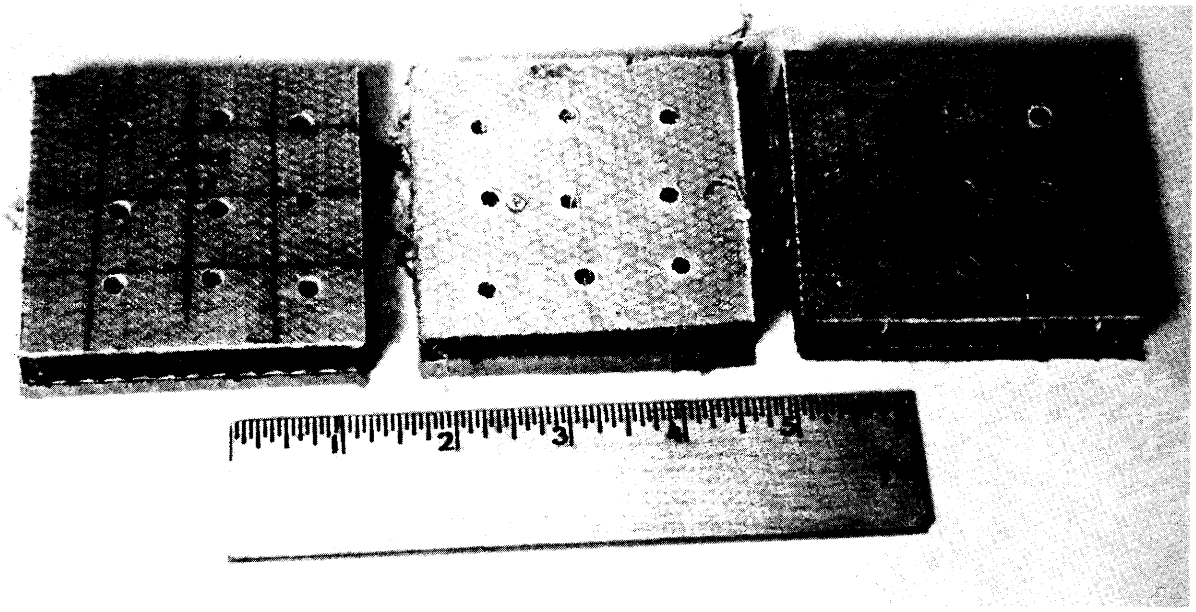


PHOTO NO. 6 – THESE SAMPLES SAME AS PHOTO NO. 5 EXCEPT .190 SPADE DRILL WAS USED

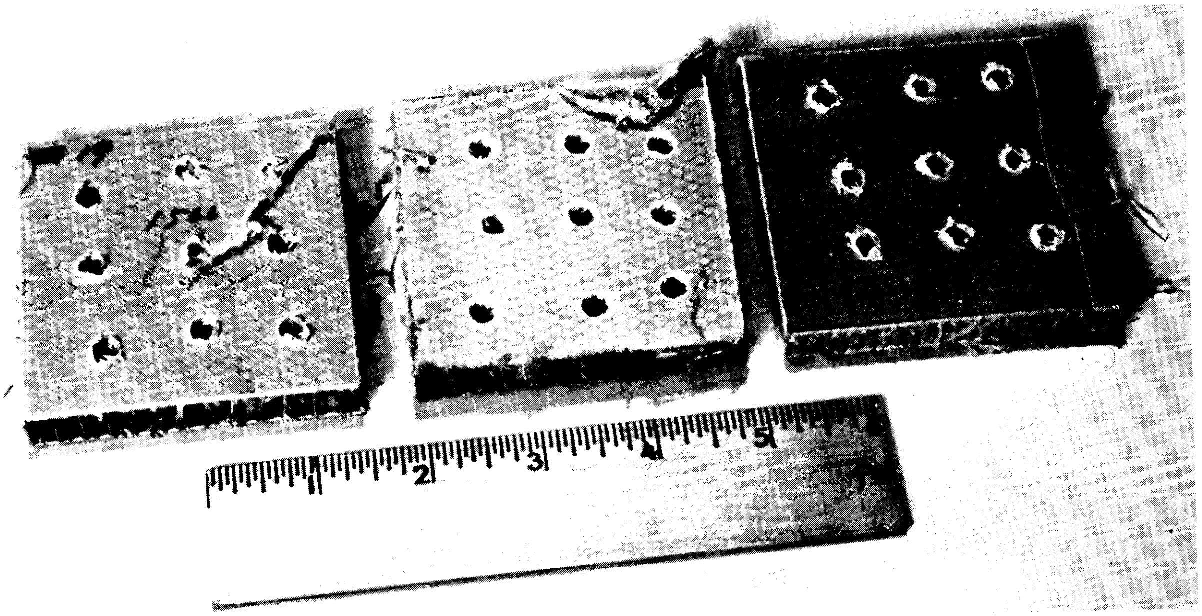


PHOTO NO. 7 – THESE SAMPLES SAME AS PHOTO NO. 5 EXCEPT .250 STANDARD DRILL WAS USED

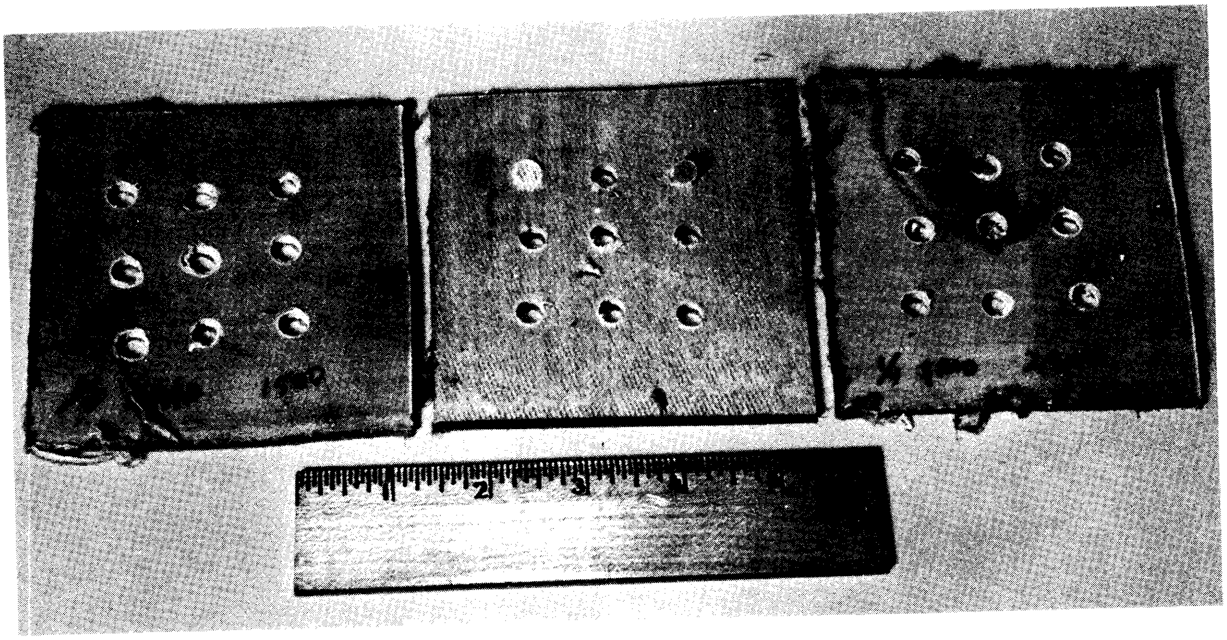


PHOTO NO. 8 – DRILL: .250 SPADE DRILL

SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

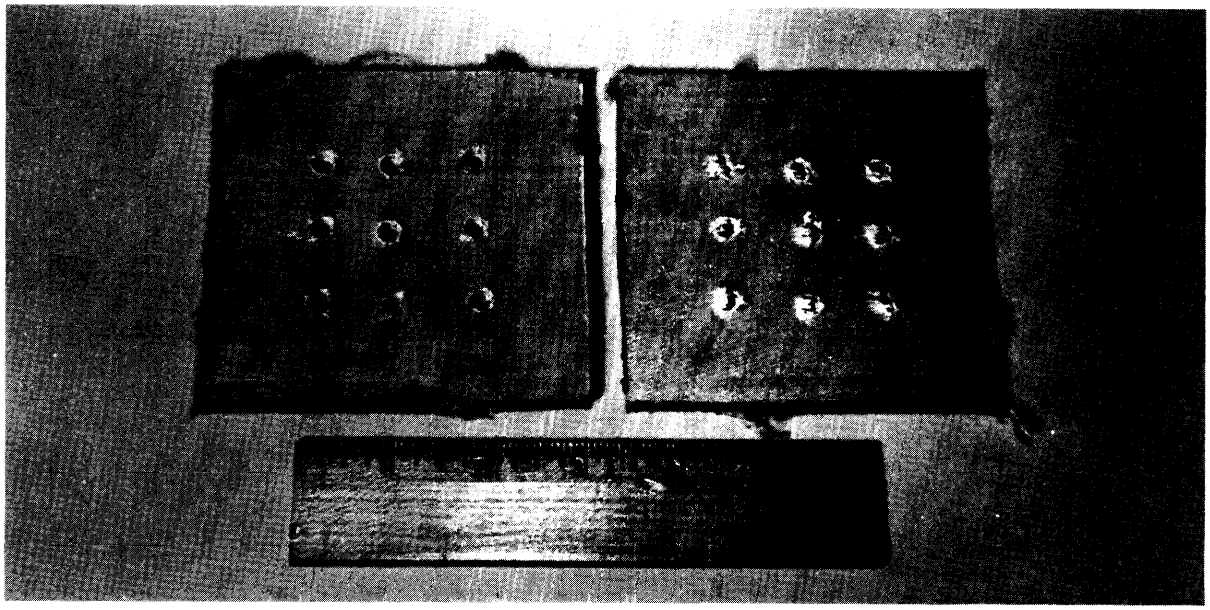


PHOTO NO. 9 – THESE SAMPLES SAME AS PHOTO NO. 8 EXCEPT .25 STANDARD DRILL AT SPEEDS OF 2000 AND 3000 RPM WAS USED

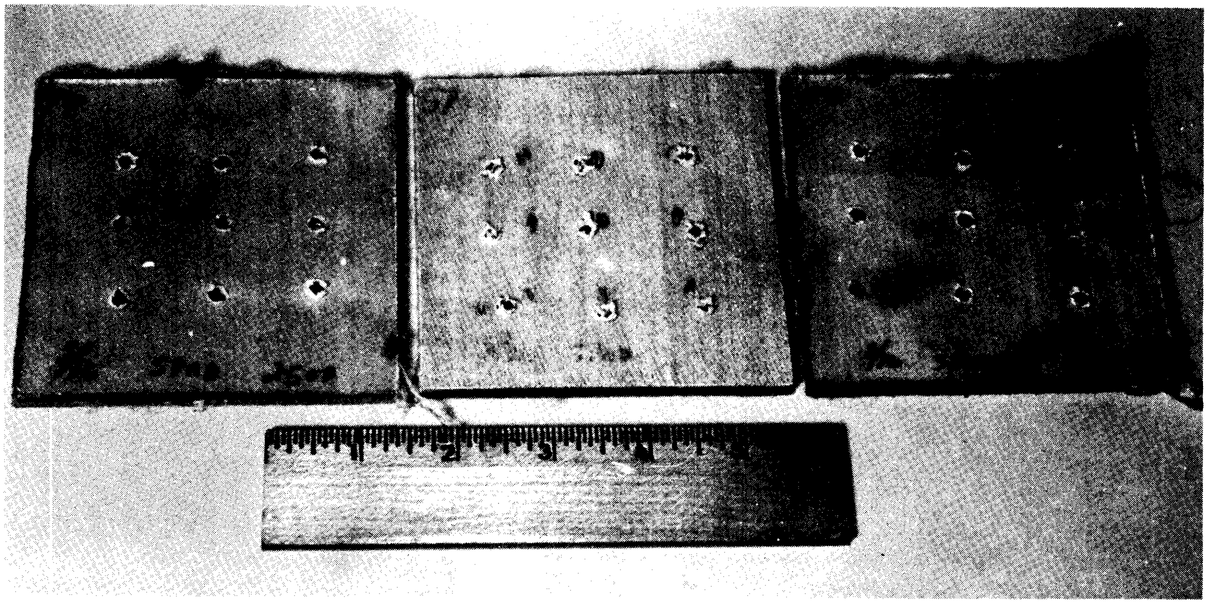


PHOTO NO. 10 – DRILL: .190 SPADE DRILL

SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN

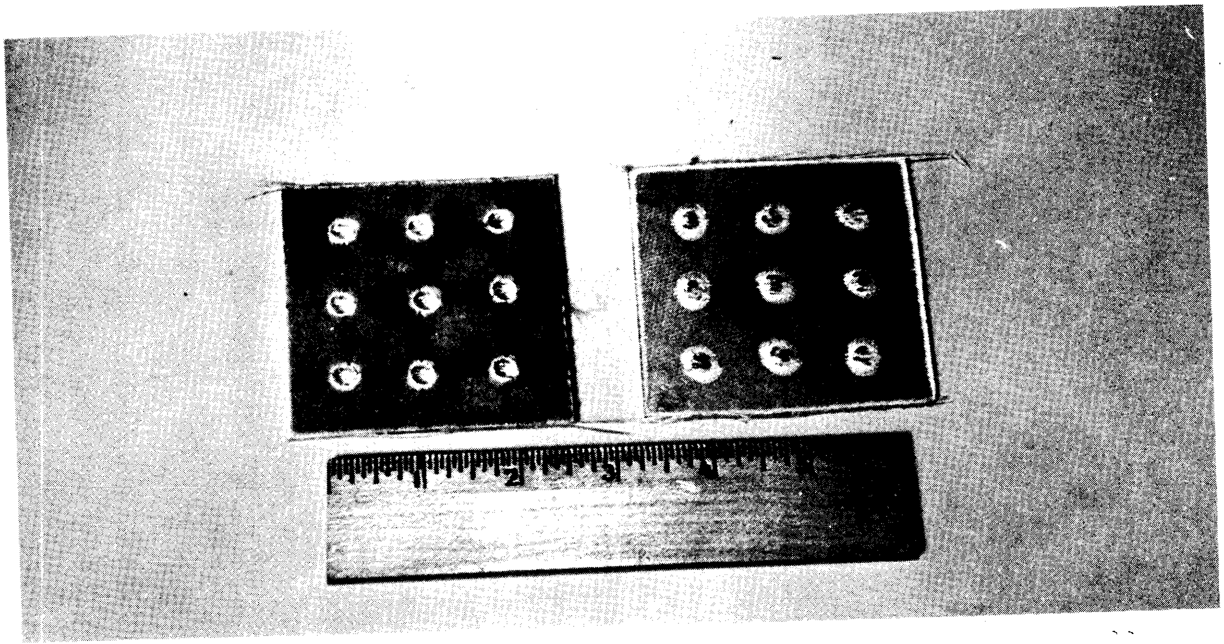


PHOTO NO. 11 – MATERIAL: 9 PLY 181 FIBERGLASS
DRILL: .25 STANDARD DRILL
SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

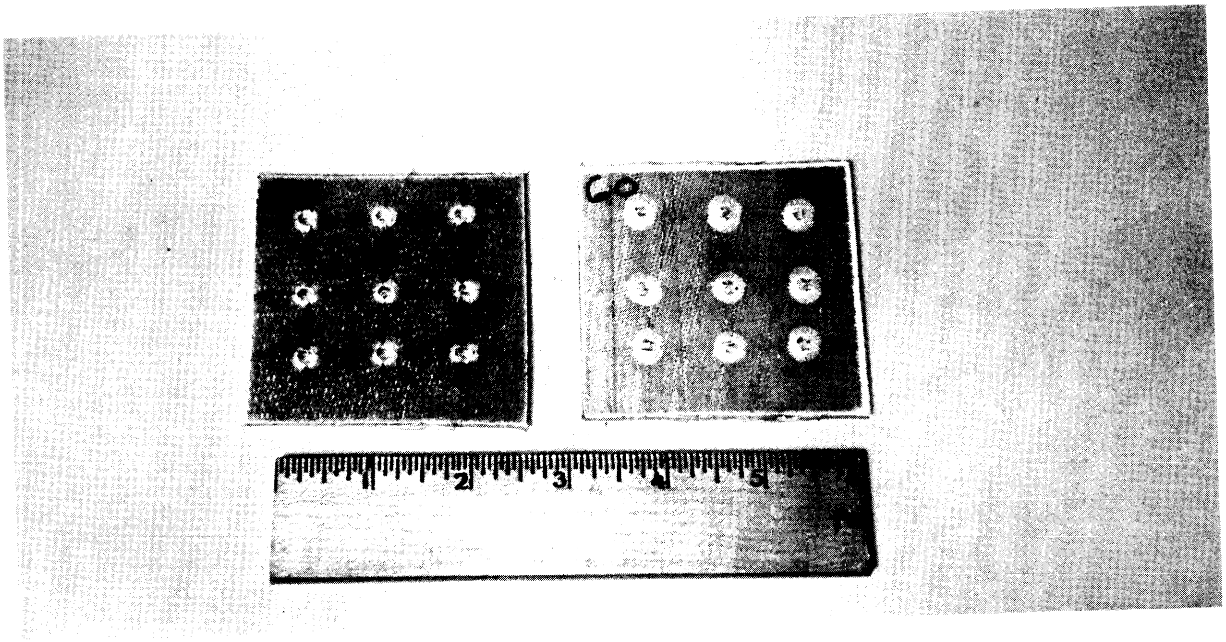


PHOTO NO. 12 – MATERIAL: 9 PLY 181 FIBERGLASS
DRILL: .190 STANDARD DRILL
SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

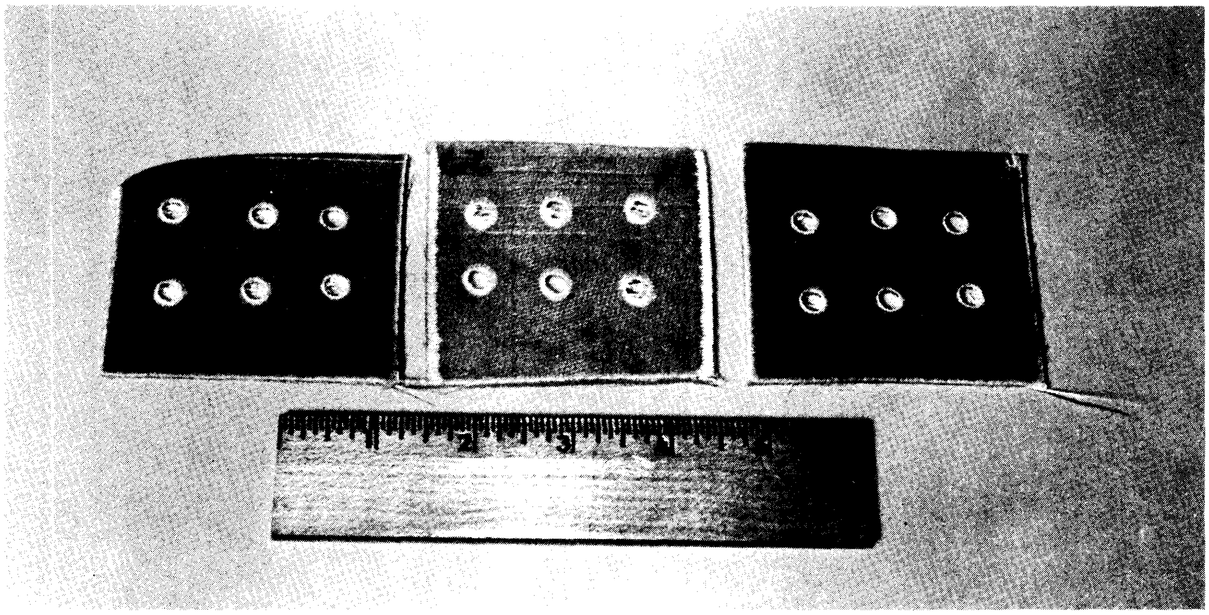


PHOTO NO. 13 – MATERIAL: 9 PLY 181 FIBERGLASS
DRILL: .250 STANDARD DRILL
SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN

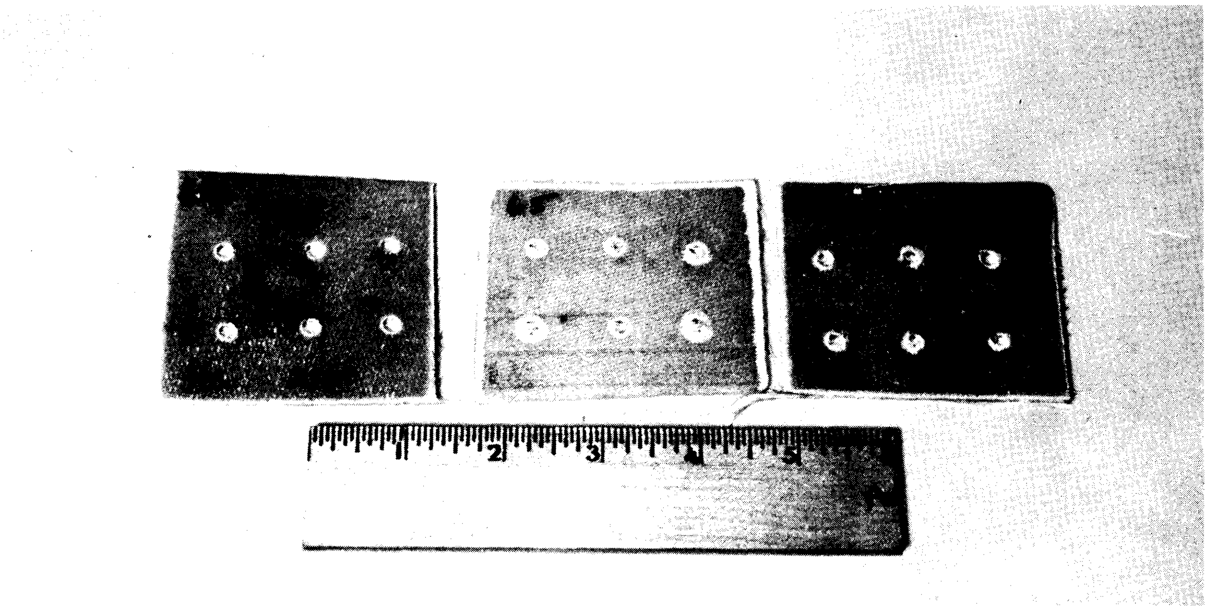


PHOTO NO. 14 – MATERIAL: 9 PLY 181 FIBERGLASS
DRILL: .190 STANDARD DRILL
SAW: TUNGSTEN CARBIDE TIPPED BAND SAW AT SAW SPEED OF 2000 FT/MIN

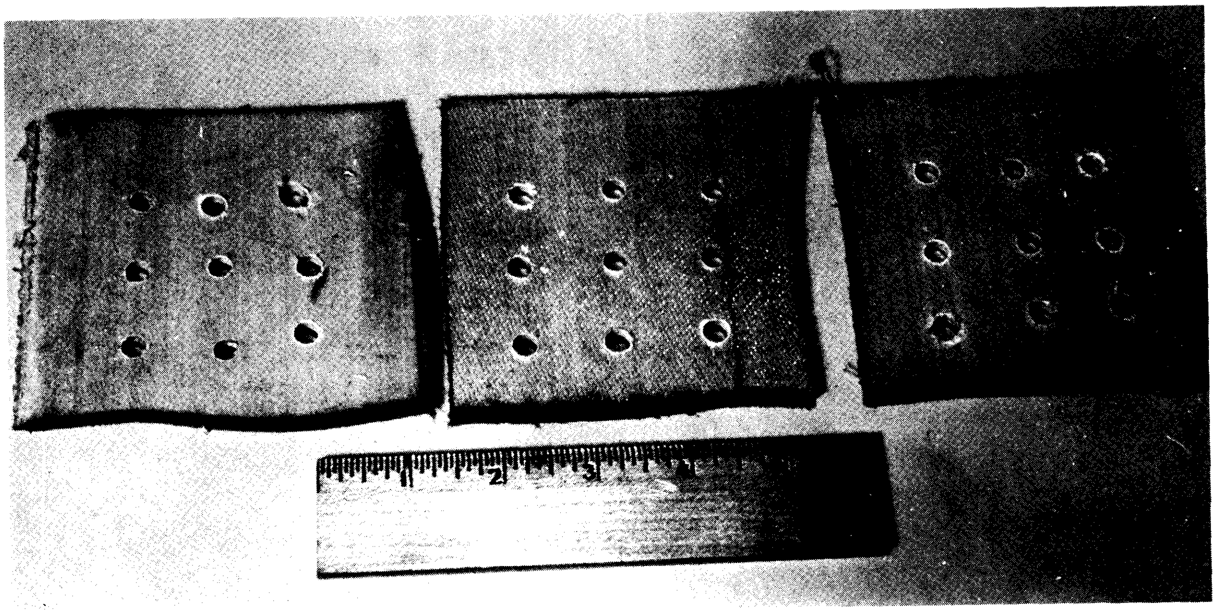


PHOTO NO. 15 – .25 PLYWOOD SUPPORT USED ON BOTH SIDES OF SAMPLE

DRILL: .25 DIA SPADE DRILL

SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

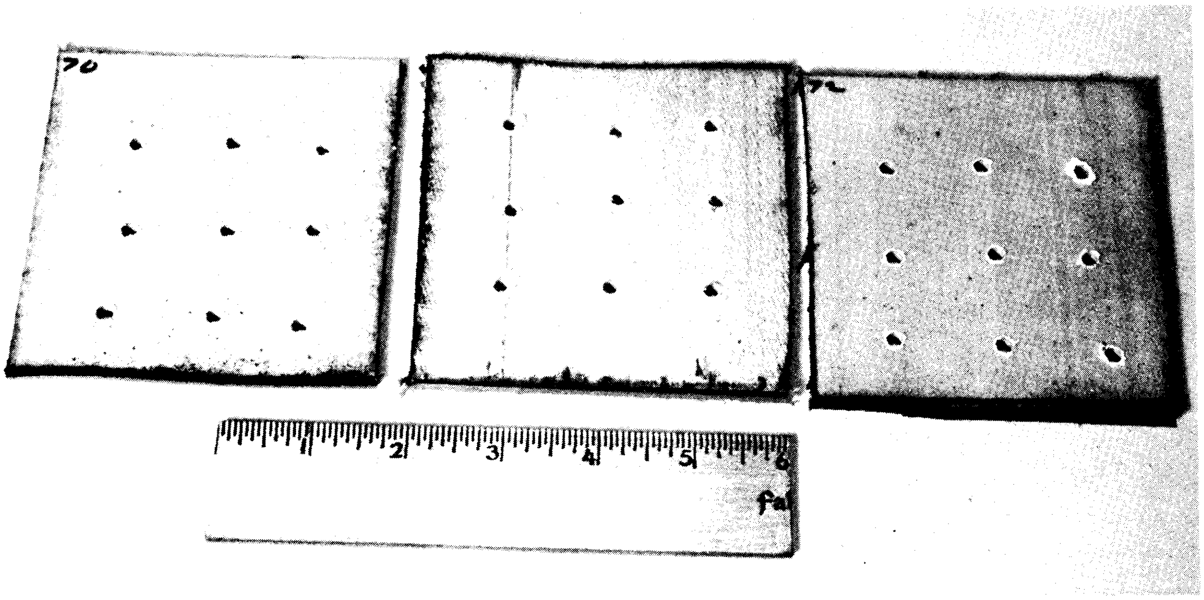


PHOTO NO. 16 – .25 PLYWOOD SUPPORT USED ON BOTH SIDES OF SAMPLE

DRILL: .190 DIA SPADE DRILL

SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

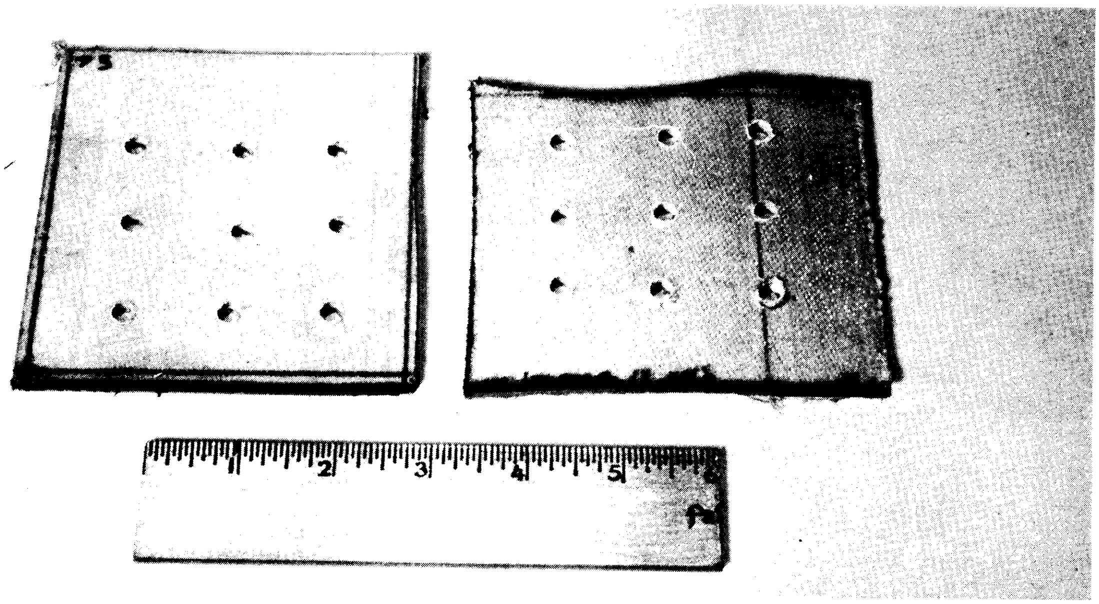


PHOTO NO. 17 – .25 PLYWOOD SUPPORT USED ON BOTH SIDES OF SAMPLE

DRILL: .250 STANDARD DRILL

SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

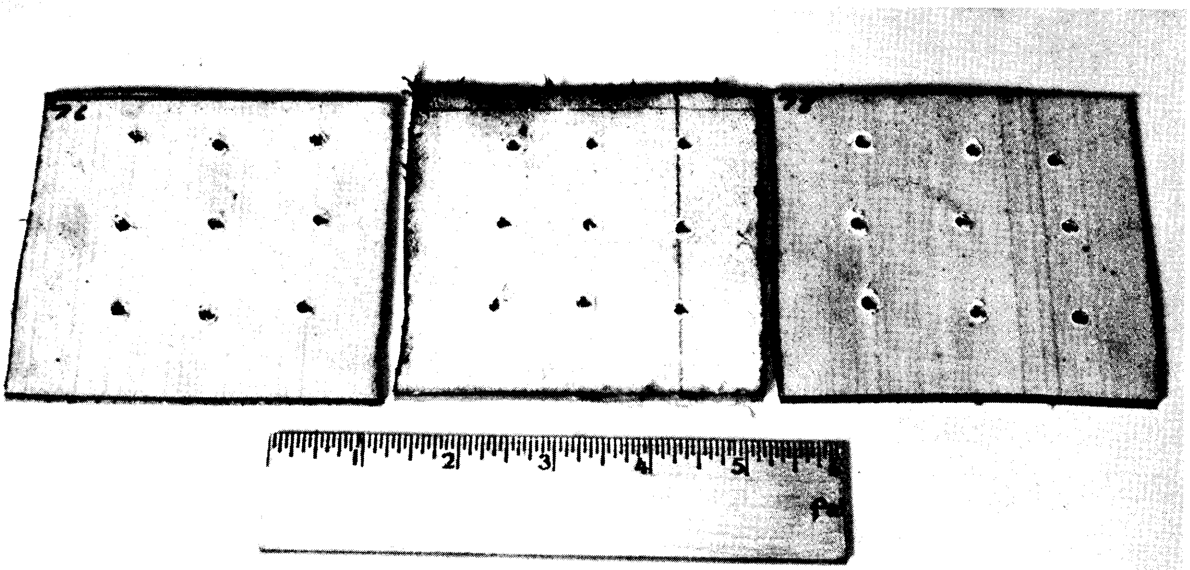


PHOTO NO. 18 – .25 PLYWOOD SUPPORT USED ON BOTH SIDES OF SAMPLE

DRILL: .190 STANDARD DRILL

SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

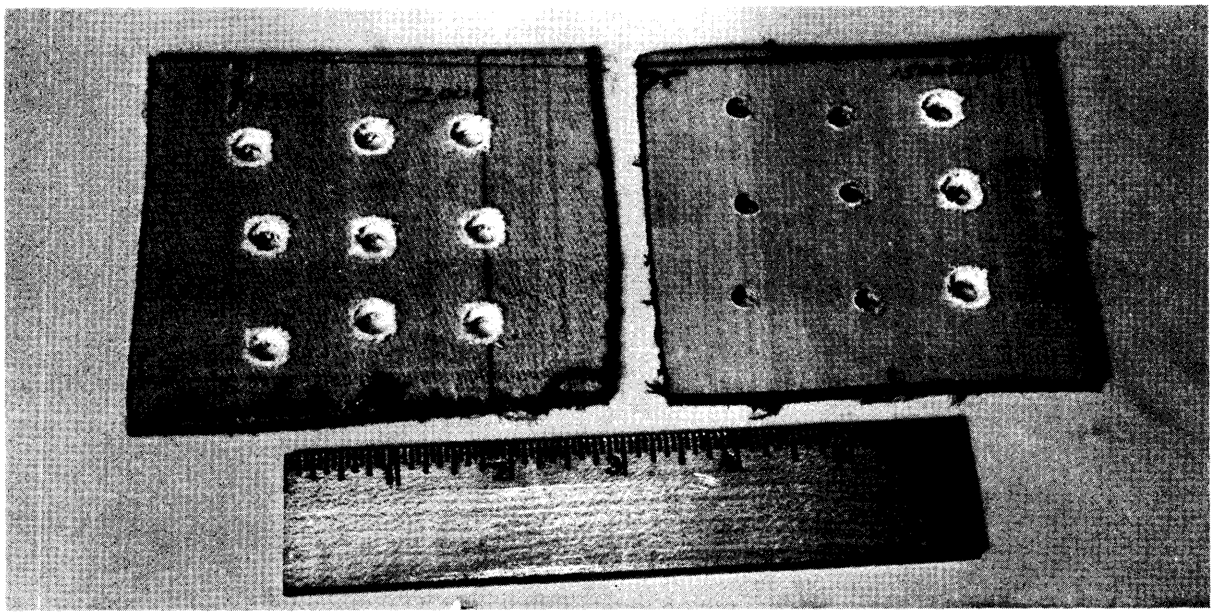


PHOTO NO. 19 – DRILL: .250 DIA STANDARD DRILL
COUNTERSINK: STANDARD
SAW: STANDARD BAND SAW AT SAW SPEED OF 4000 FT/MIN

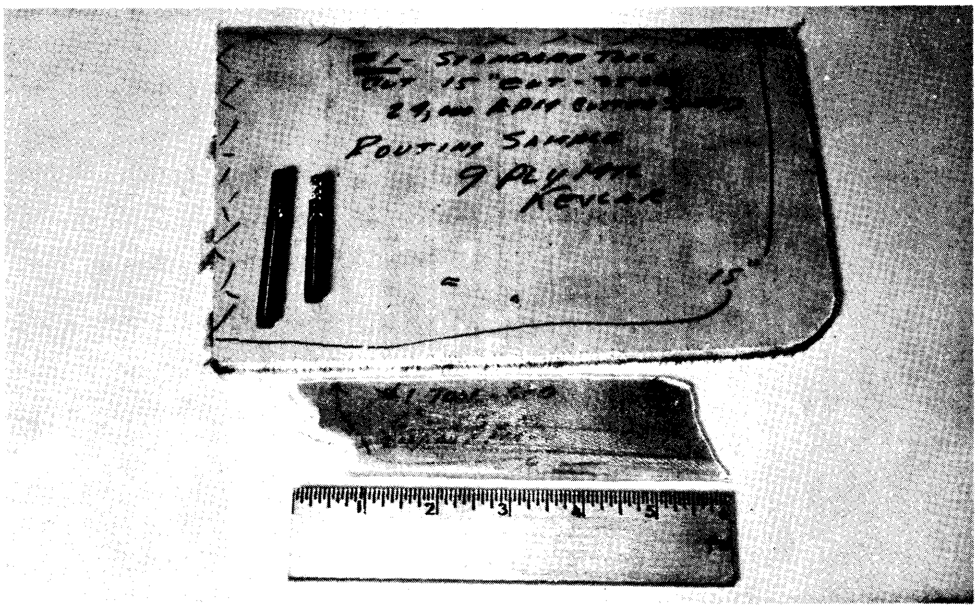


PHOTO NO. 20 – MATERIAL: TOP SAMPLE 181 KEVLAR 40
BOTTOM 181 FIBERGLASS
ROUTER: TOOL NO. 501 - 1/4 FULLERTON SPEED 24000 RPM
FEED: KEVLAR 49 - 15" IN 35 SEC
FIBERGLASS - 6" IN 15 SEC

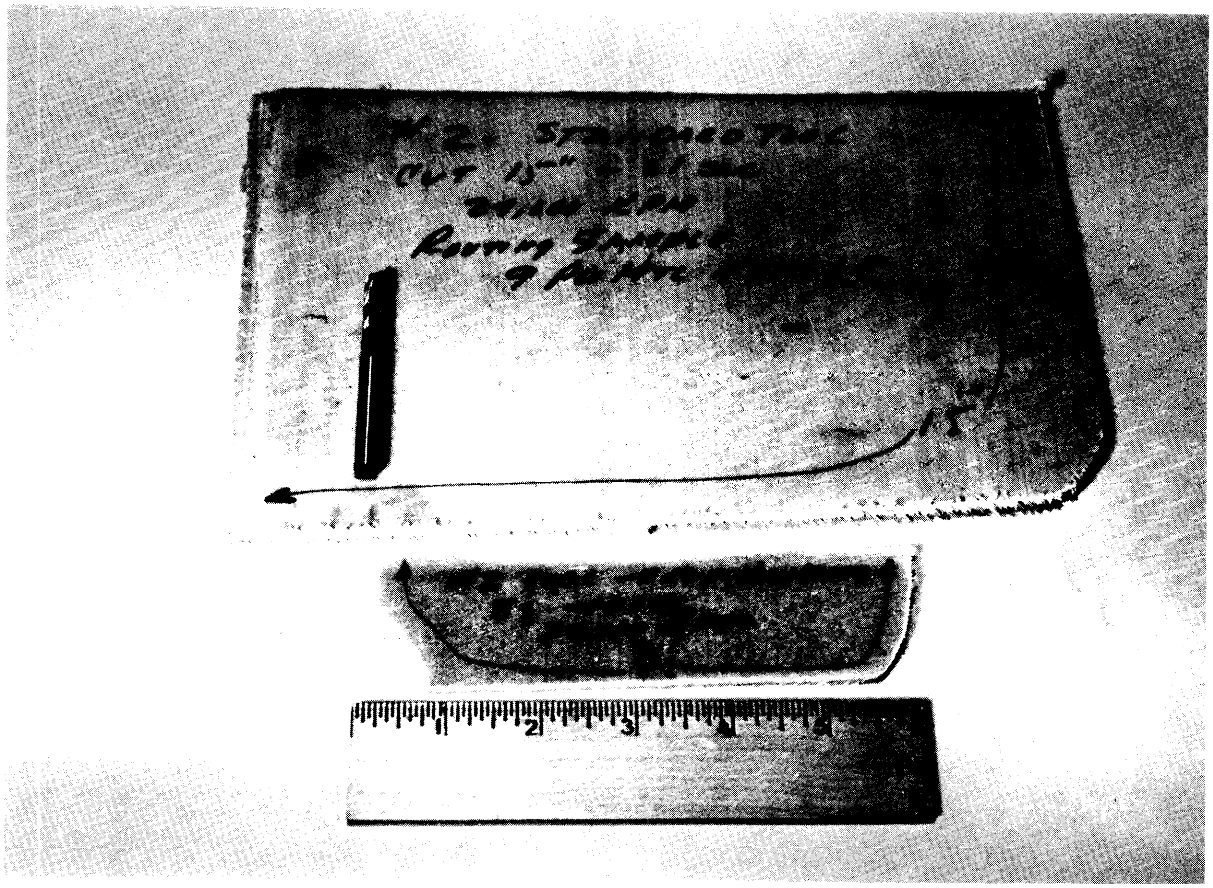


PHOTO NO. 21 – MATERIAL: TOP SAMPLE 181 KEVLAR 49
BOTTOM 181 FIBERGLASS
ROUTER: STANDARD NO. 2600-1 FULLERTON
SPEED 24000 RPM
FEED: KEVLAR 49, 15 INCHES IN 21 SEC
REPLACE TOOL AFTER 30 INCH CUT
FIBERGLASS; 8.5 INCHES IN 10 SEC

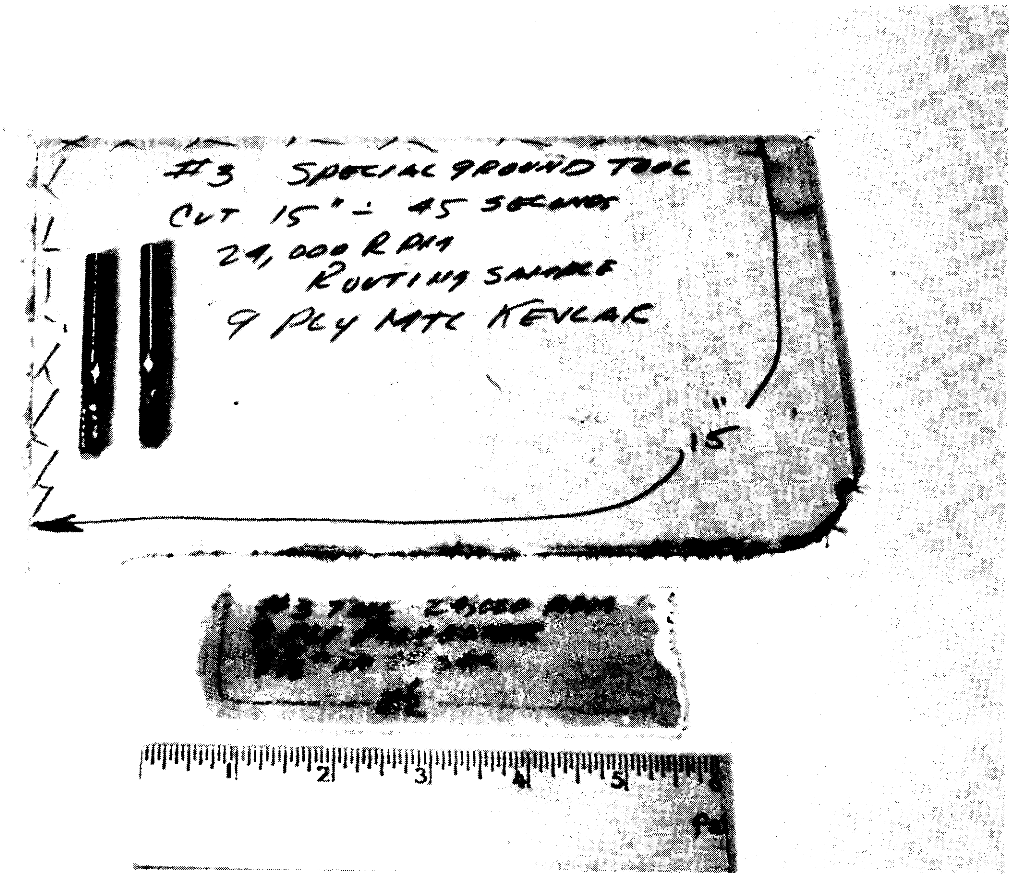


PHOTO NO. 22 – MATERIAL: TOP SAMPLE 181 KEVLAR 49
BOTTOM 181 FIBERGLASS
ROUTER: TAI - 1/4 TECHNOLOGY ASSOCIATES
SPEED 24000 RPM
FEED: KEVLAR 49 15 INCHES IN 45 SEC
FIBERGLASS 8.5 INCHES IN 15 SEC
NOTE: TOOL BADLY OVERHEATED

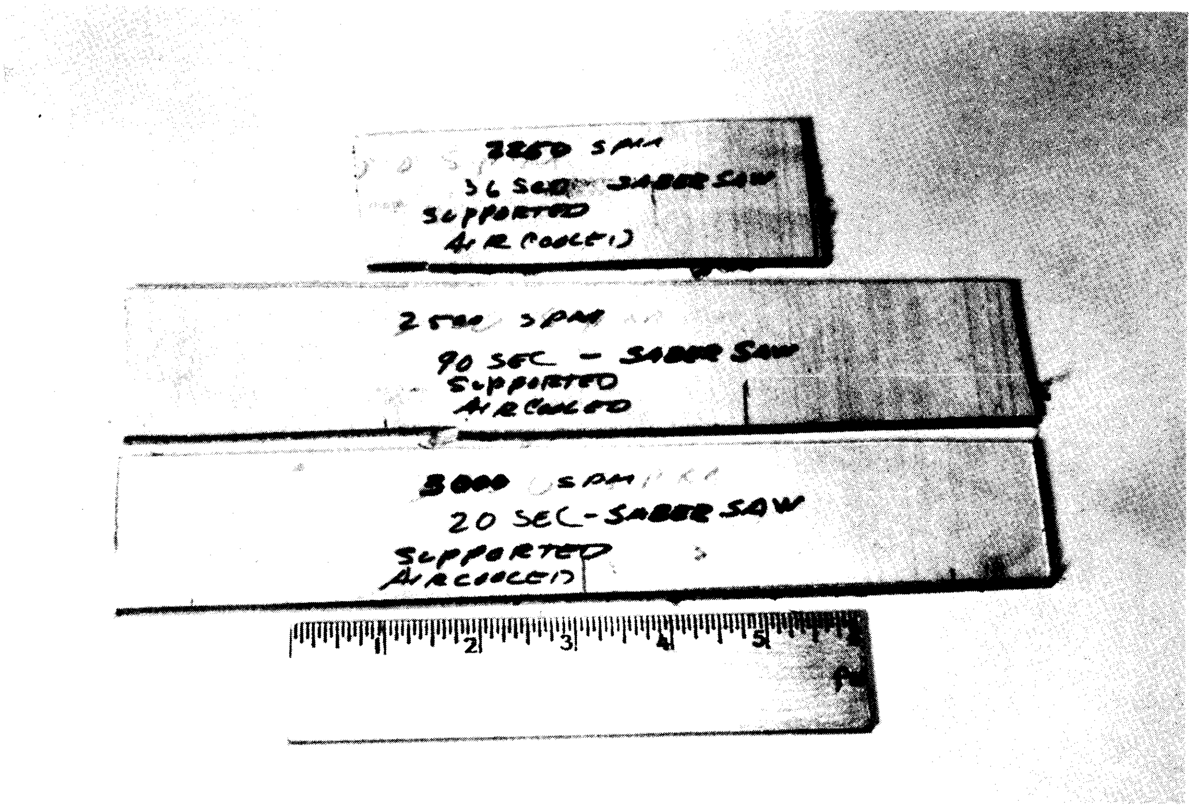


PHOTO NO. 23 — SABER SAW: NO. 49491-321 BLADE
TECHNOLOGY ASSOCIATES
SPEED - FEED: 2250 STROKES/MINUTE - 5 INCHES IN 36 SEC

2500 STROKES/MINUTE - 10 INCHES IN 90 SEC

3000 STROKES/MINUTE - 5 INCHES IN 20 SEC

REMARKS: TOOL HEATED UP EVEN WHEN AIR COOLED, CAUSING TOOL DISCOLORATION

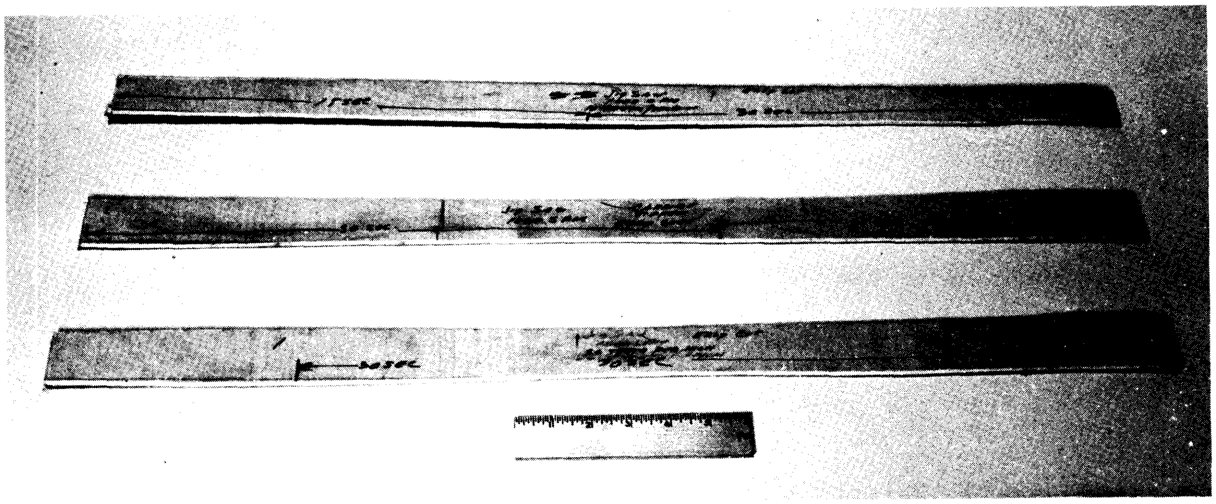


PHOTO NO. 24 – SAW: POWER JIG SAW
SPEED 1000 STROKES/MIN
BLADES: 10 TEETH/INCH, 26 TEETH/INCH
CARBIDE TIPPED BLADE
REMARKS: EXCELLENT SAWED EDGES WITH NO BLADE
HEATING OR DAMAGE

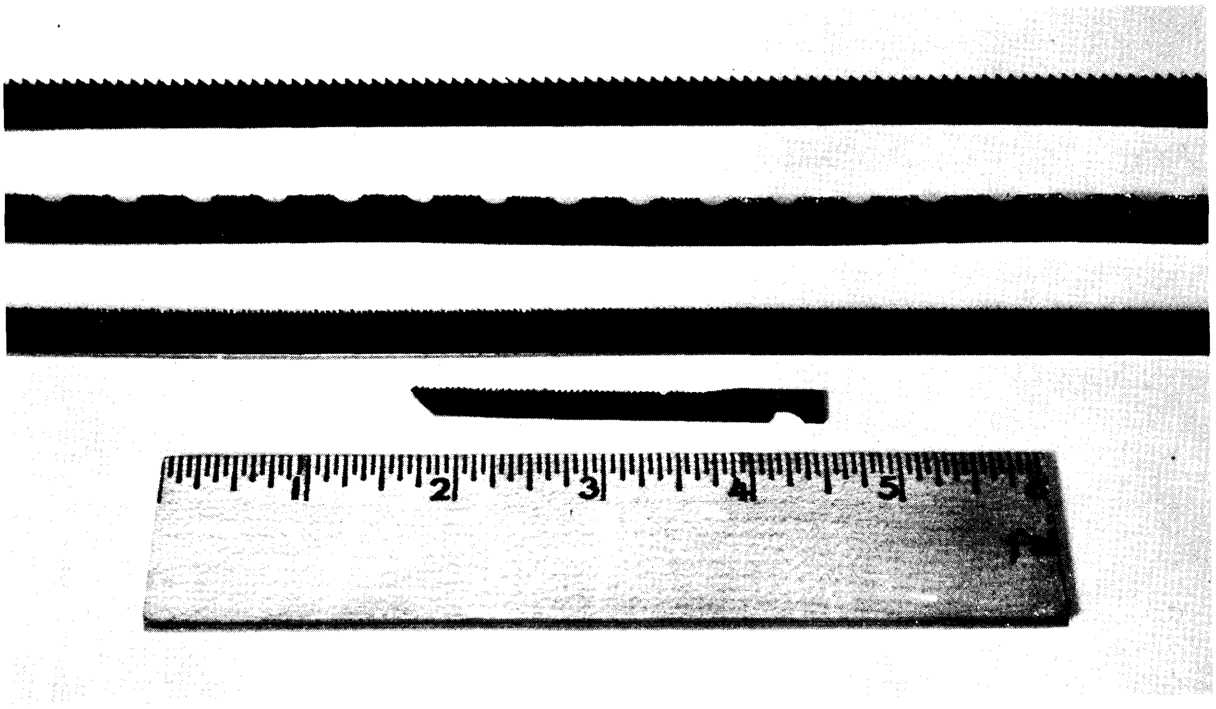


PHOTO NO. 25 – SAWS USED IN THE POWER JIG SAW

1ST (TOP) :	10 TEETH PER INCH BLADE
2ND :	TUNGSTEN CARBIDE BLADE
3RD :	26 TEETH PER INCH BLADE
4TH (BOTTOM):	TECHNOLOGY ASSOCIATES SABEL SAW BLADE

APPENDIX E

DETAILED COST BREAKDOWN

Heat Energy Cost Determination

HLT Cure

$$\text{Energy Used per cure cycle} = \frac{41.3\ \text{\#Steam} \times 879\ \text{Btu/lb}}{0.40\ \text{(Boiler Efficiency)}} = 90{,}755\ \text{Btu}$$

or

0.907 Therms* at $1.22 = $1.11 per part

Oven Cure

Oven Model DF 1587 Bacon - Blakdeslee uses 660,000 Btu per hour

Estimated Heat/Part = 660,000 x 0.5 = 330,000 Btu/hr
(use 50% of oven)

Total Heat/Part = 4 hr cure x 330,000
= 1,320,000 Btu/part

or

13.20 therms at $1.22 = $16. 10 per part.

Amortization of Capital Equipment

HLT Cure

Steam cost at Hughes is negligible on a pound basis. However, cost of a separate boiler is used for a more realistic comparison.

Small single use McKenna Marine Model #5 would cost $2,651.00, installed.

$$\text{Cost/Part over 10 years} = \frac{\$2651.00}{10,000} = \$0.27/\text{Part}$$

---

*1 Therm = 100,000 Btu's

Oven Cure

Cost of Oven Model DF 1587 Bacon-Blakeslee would be \$8,272.00 installed. Assume 50 percent use for fairing

$$\text{Cost/part over 10 years} = \$8{,}272.00 \times 0.5 \times \frac{1}{10000} = \$0.42\text{/part}$$

Mold Costs

The standard plastic tool used for the fairing and shown in Figure 14 has the following cost:

Vendor Purchased Mold = \$ 750
Plaster form supplied by HH labor = 40 hr at \$20/hr = \$ 800
Design hours amortized over 4 molds = $\frac{40\text{ hr}}{4}$ at \$20/hr = \$ 200
\$1750

Plaster Materials = \$ 50

Total standard plastic mold = \$1800

The HLT costs for materials are summarized in Table E-1.

Materials = \$2711
Labor - 251 hours at \$20.00 = \$5020
Design and Liaison 80 hr at \$20/hr = \$1600

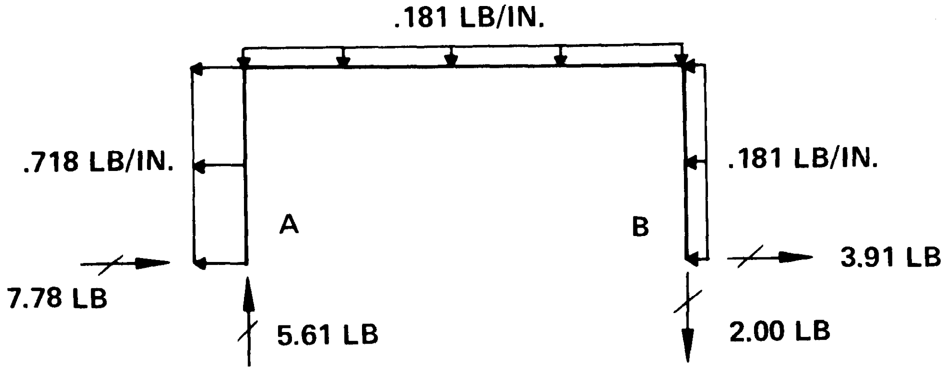
Total HLT Cost = \$9331

TABLE E-1. MOLD COST

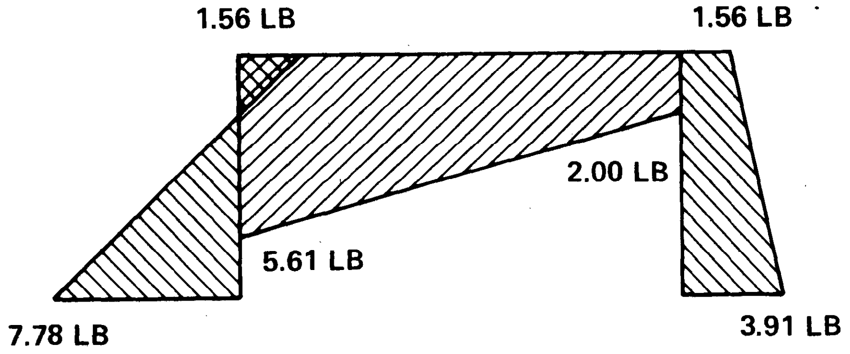
Purchased Materials	
Nickel Shell (Electroforms, Inc.) (Actual Cost)	$2,500.00
Copper Tubing and Fittings (100 ft cu 3/8 dia tubing, actual cost)	39.00
Miscellaneous Steel Fittings, Brackets, Clamps etc (estimated)	50.00
Silicone Diaphragm Material (Actual Cost)	75.00
Chopped Wire Mortar Mix (Actual Cost) 715 lb at 3.86¢ lb (5-1/2 mixes at 130 lb each)	27.60
Lumber for Forms (Casting Chopped Wire Mix) (Estimated Cost)	20.00
Total Purchased Material (Unburdened)	$2,711.60

APPENDIX F

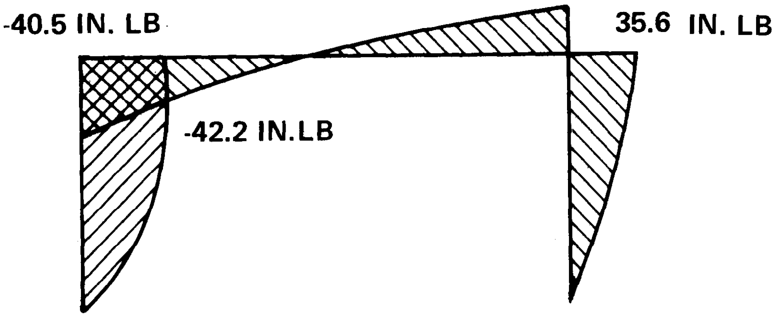
LIMIT LOADS



LOADING DIAGRAM

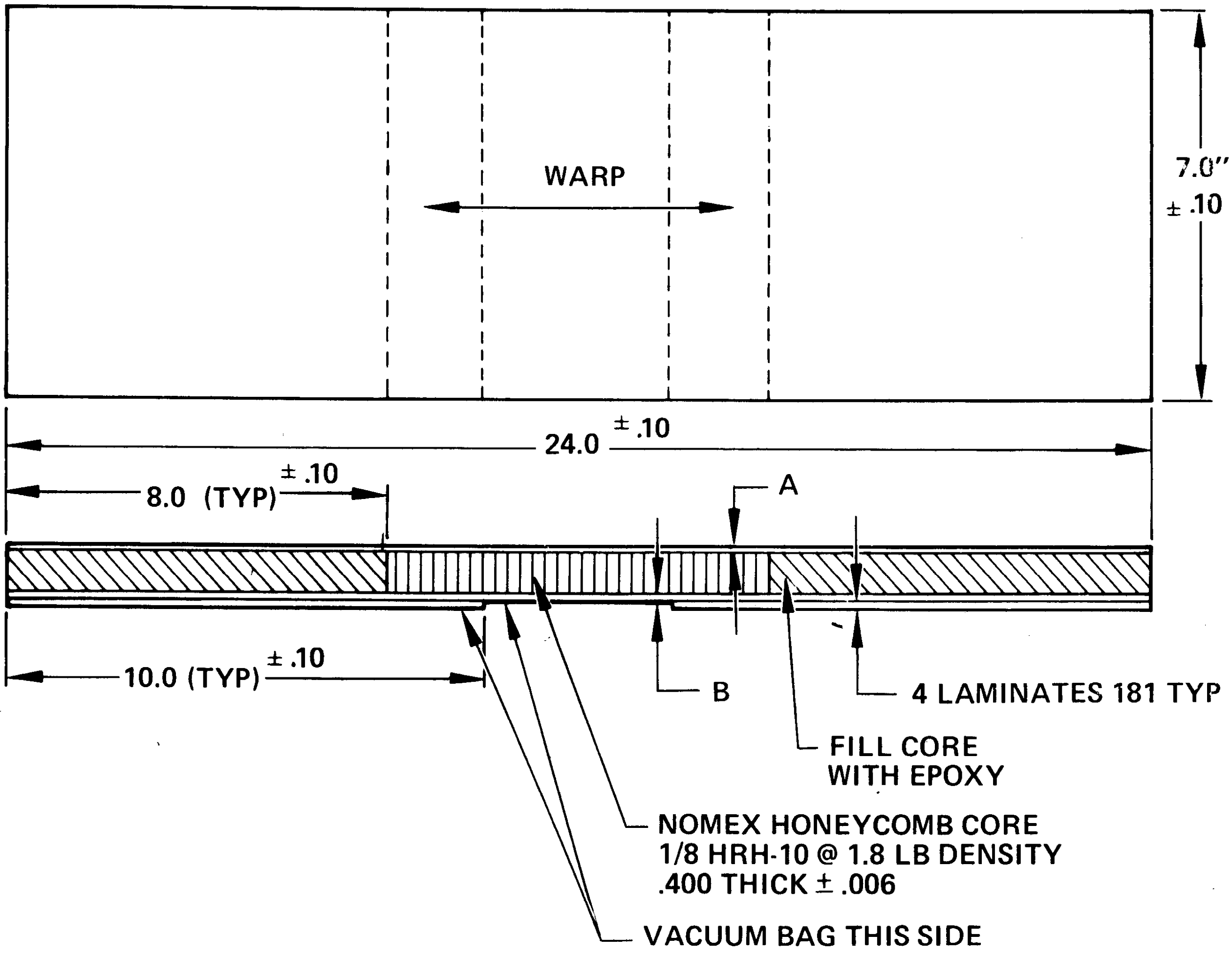


SHEAR DIAGRAM



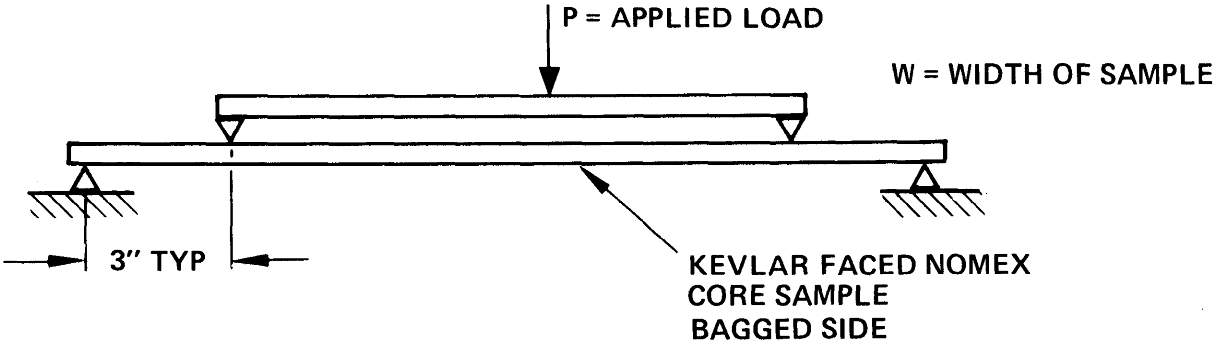
MOMENT DIAGRAM

Figure F-1. Limit Loads.



5. INSPECTION REQ'D
4. FAB PER HP 15-42 CURE TIME 1.0 TO 1.5 HRS
3. EDGES OF CORE MAY BE UNCOVERED
2. SPECIMEN TO BE VACUUM BAGGED AGAINST FLAT SURFACE AND CURED
1. FACING MATERIAL TO BE KEVLAR-49 EPOXY PREPREG

Figure F-2. Test Panels.



$$\text{M/INCH} = \frac{P}{2} \text{ X } 3 \text{ X } \frac{1}{W}$$

Figure F-3. Compressive Bending Tests Loading Method.

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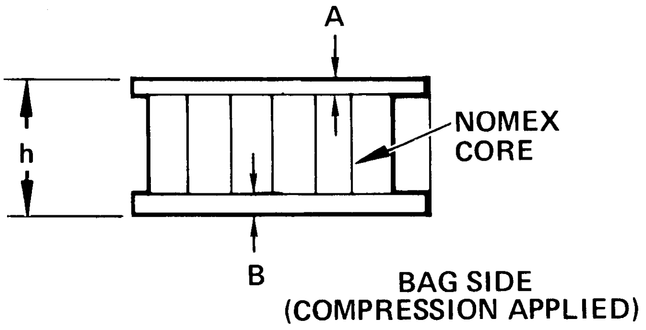
TABLE F-1. PRELIMINARY TESTS



.009 = 2 LAM 120 CLOTH
.0135 = 3 LAM 120 CLOTH
.010 = 1 LAM 181
.0145 = 1 LAM 181 + 1 LAM 120

Config	P(lb)	h(in.)	A(in.)	B(in.)	W(in.)	M/in.	f_c	f_t
The following had 181 or 120 Facings and Nomex 1/8 cell at 1.8 lb/ft.^{3}								
1B	391	0.430	0.010	0.0145	7.00	84	13620	20150
1C	213	0.500	0.009	0.009	↓	46	10409	10409
1D	443	0.470	↓	0.0135	↓	95	15119	23040
2C	110	0.344	↓	0.009	↓	31	10281	10281
2D	243	0.344	↓	0.0135	↓	57	12445	19070
3D	288	0.374	0.009	0.0135	7.00	60	12033	18410
The following had 281 Facings 1 Laminate and Nomex 1/8 cell at 1.8 lb/ft^3								
1D1	189	0.415	0.010	0.010	7.00	41	10123	10123
2D1	180	0.415	↓	↓	↓	39	9524	9524
3D1	195	0.415	0.010	0.010	7.00	42	10317	10317
The following had 120 or 181 Facings and Nomex 1/4 cell at 1.5 lb/ft^3								
1	139	0.36	0.010	0.010	7.00	28	8000	8000
2	154	0.36	0.010	0.010	↓	33	9429	9429
3	234	0.37	0.010	0.0145	↓	50	9430	13987
4	110	0.36	0.009	0.009	↓	24	7597	7597
5	235	0.37	0.009	0.0135	7.00	50	10153	15541

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