NASA Contractor Report 181873

PROCESS DEVELOPMENT AND FABRICATION OF SPACE STATION TYPE ALUMINUM-CLAD GRAPHITE EPOXY STRUTS

L. R. Ring

Lockheed Missiles & Space Company, Inc.
Sunnyvale, California

Contract NAS1-18229
January 1990

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

Table of Contents

1. Introduction

The Space Station structure has been identified as a truss of 5m bays, assembled from struts that are stiff, tough, dimensionally stable and resistant to space· environment. The overall characteristics of aluminum-clad graphite epoxy tubes meet these requirements for these struts.

The aluminum-clad graphite epoxy tube concept was conceived as a result of a study performed by the NASA Langley Research Center. Graphite-epoxy (Gr/E) strut elements which were manufactured of longitudinal fiber with a thin circumferential wrap inside and out exhibited a tendency to unwrap circumferentially when subjected to a severe handling impact, such as one tube being struck by another.

The NASA studies indicated that the compressive stresses in the outer fibers could be reduced by using a circumferential wrap of a material with a low modulus of elasticity, and a high coefficient of thermal expansion (CTE) relative to the Gr/E core, such as glass or aluminum. Early development of this concept was in the manufacture of metal surfaced unidirectional Gr/E bars and 1/2-inch diameter Gr/E tubing wrapped inside and out with aluminum foil. The latter tubes were developed as slender struts 10 ft. long for deployable antennas. In all cases the manufacturing method was by dry fiber placement with resin injection and subsequent cure. The current Gr/E tubular concept with seamless aluminum surfaces is the culmination of this development. In addition to the features generally accepted with Gr/E structural elements, such as high specific strength and stiffness, and very low CTE it became apparent that there were other benefits from this concept not normally available in conventional Gr/E structure.

The continuous aluminum surface encapsulating the Gr/E provides moisture and outgassing control, dramatically improves the circumferential thermal conductivity, provides a surface on which various coatings are easily applied, and offers the potential of using mechanical attachment methods. The manufacturing method makes it possible to provide aluminum walls which are locally thicker at the ends than for the rest of the tube. For dimensionally stable structures the CTE of the tube can be precisely tuned, perhaps more accurately than it can be measured, by removing a predetermined amount of aluminum after fabrication.

Atomic oxygen effects on Gr/E structures in low earth orbit, such as Space Station, have been shown to be significant, and indicate the need for a protective surface, such as aluminum. Although the genesis of this material concept was to enhance the toughness of the tube, a large number of benefits have accrued from this development.

This report presents a description of a task to manufacture and deliver 5 m and 7 m aluminum-clad graphite epoxy struts for the assembly of a full scale truss bay. These efforts include material selection rationale, development of strut manufacturing processes, fabrication and end-fitting design and installation procedures. The report also includes a description of each strut with pertinent data.

2. Strut Requirements

The specific requirements for the struts are:

- Length : 5 m and 7 m long
- Diameter : 50.8 mm (2 in.)
- Nominal wall thickness : 1.52 mm (0.060 in.)
- Seamless aluminum surface inside and outside
  Aluminum thickness : 0.15 mm (0.006 in.)
- High modulus fiber : 517 GPa (75 Msi)

- Aluminum scarf type end fittings
- Straightness : 0.03% Length
- Fiber Content : 60% ±5%
- Longeron Weight : 7.0 lb max
- Diagonal Weight : 9.0 lb
- Axial Modulus of Elasticity : 33 Msi (compression)
- CTE : < 0.5 $\mu\varepsilon/°F$
- Axial Limit Load (Compression)
  Longeron : 2000 lb
  Diagonal : 1160 lb

3. Material Selection Rationale

Aluminum-clad graphite epoxy tubes were developed to meet the cost, weight, structural integrity, high stiffness and thermal dimensional stability requirements of space structures in general.

The initial study had included light-weight structural materials such as aluminum, magnesium and titanium for the clad surfaces. Among fibers, P75 and P100 (commercially available pitch fibers with 75 Msi and 100 Msi modulus of elasticity, respectively) were selected to meet the stiffness challenge and the low thermal expansion requirements.

Table 1 lists properties of various metal-clad graphite epoxy tubes. The clad thickness of each tube has been adjusted for zero CTE response. The first three columns represent the tube modulus of elasticity, the total tube density and the corresponding specific modulus of elasticity, respectively. The last column represents a temperature range at which the clad material remains elastic. As a result, the thermal deformation of the tube is free from hysteresis effects.

Table 1 - Properties of Zero-Expansion Metal-Clad Tubes (Fiber Volume Fraction = 0.65)

Material	E_t (Msi)	ρ (lb/in.^{3})	E_t/ρ (in.x10^6)	ΔT (°F)
Al/P75/E	42.5	0.069	616	480
Al/P100/E	49.7	0.076	654	480
Mg/P75/E	39.6	0.063	628	180
Mg/P100/E	44.3	0.066	671	180
Ti/P75/E	40.6	0.087	467	>600
Ti/P100/E	46.1	0.103	448	>600

where,

E_t - longitudinal tensile modulus of elasticity

ρ - total density

ΔT - operating temperature differential for elastic thermal deformation

Comparison of the results listed in Table 1 indicates that the aluminum metal, in general, is the best choice for the cladding material in terms of weight, stiffness and thermal dimensional stability. With the use of a high strength aluminum alloy such as the 7075-T73 for cladding, these tubes can operate elastically within a temperature range of 480 °F. Most operations in space usually fall within such a temperature range. Tubes with P75 fiber tend to be slightly lighter at the expense of the stiffness provided by the P100 fibers. P100 fibers, however, are very expensive at the present time because of their special manufacturing requirements and low quantities of fiber production.

Fiber-Resin Corporation formulated the FR 8703 system specifically for resin injection processing. This resin permits full vacuum deairation without low-boiling-diluent loss while providing the low injection viscosity (25-30 centipoise) at the 170 ±5°F isothermal process temperature.

4. Manufacturing Process

4.1 Process Description and Rationale

Operations Instructions for manufacturing the Aluminum-clad graphite epoxy struts are presented in Appendix A, "Detailed Manufacturing Procedure".* The elements of the procedure, with some discussion, are presented here.

The process used in the manufacture of the aluminum-clad struts is described below. The prespooled collimated fiber, attached to an end plug in the inside metallic tube, is drawn into an outer larger diameter tube. Resin is injected into the annulus between the two tubes containing the dry fiber and cured with the use of electric strip heaters on the outside of the tube. Following cure, both metallic wall thicknesses (inner and outer tubes) are reduced to the desired size by chemical processing. A close-up end view of a 2-inch diameter tube is shown in Fig. 1.

4.2 Drawing of Fiber

Prior to fiber draw the inside surface of the outer tube and the outside surface of the inner tube are FPL (Forest Products Laboratories) etched and primed. A pull cone is attached to the inside

* A set of these instruction sheets were prepared for each tube manufactured.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 1. End view of a 2-in. Diameter Aluminum-Clad Tube

of, and aligned with, the inner tube. 1024 tows of fiber, mounted on a creel, are threaded through a collimating plate, and attached to the pull cone. A photograph of the collimated fiber attached to the pull cone is shown in Fig. 2.

The fiber is attached by bonding and wrapping shrink tape to the cone, which also acts as a guide to help maintain the concentricity of the inner and outer tubes. A chain is attached to the cone, and the cone, with the fiber and inner tube attached is pulled through the outer tube.

4.3 Resin Injection and Cure

The concentric tubes, with the dry fiber filling the annulus, are mounted on the injection stand. Four electrical strip heaters, are attached longitudinally to the surface of the tube 90° apart, and the unit is wrapped with insulation. The insulated tube mounted on the stand, and the injection pump are shown in Fig. 3.

Epoxy resin, Fiber Resin 8703, is mixed, de-aired, and preheated to 125°F. The resin pump is filled, and a vacuum is attached to the upper end of the tube, and a vacuum drawn on the annulus. All injection hardware and the tubes are heated to 170 ±5°F before starting to pump the resin. Minimum viscosity and reasonable pot life are obtained at 175° F. Pumping is continued at a slow rate, under vacuum, until the resin runs clear at the vacuum (upper) end. All resin valves are closed and the tube is cured for 10 hours at 175 °F.

4.4 Chemical Milling Operation

The inner and outer aluminum surface thickness are chemically reduced after the epoxy cure to achieve the design CTE, and reduce the tube weight. For all tubes prior to those manufactured under this Task the chemical milling was performed in the LMSC Chem Mill Facility. However, at the beginning of 1988, a decision was made to close the

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

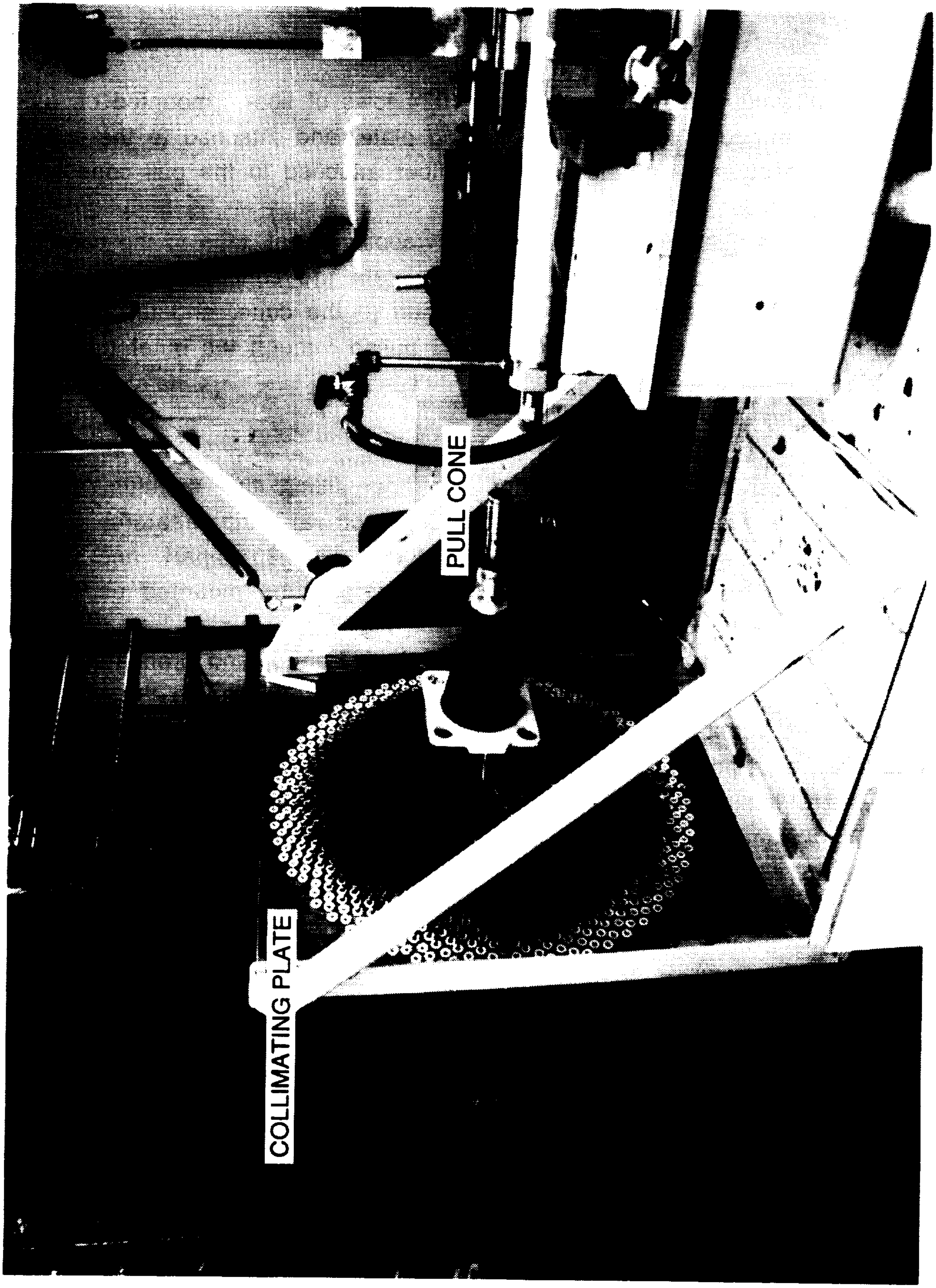


Figure 2. Fiber Attached to Tube for Draw

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

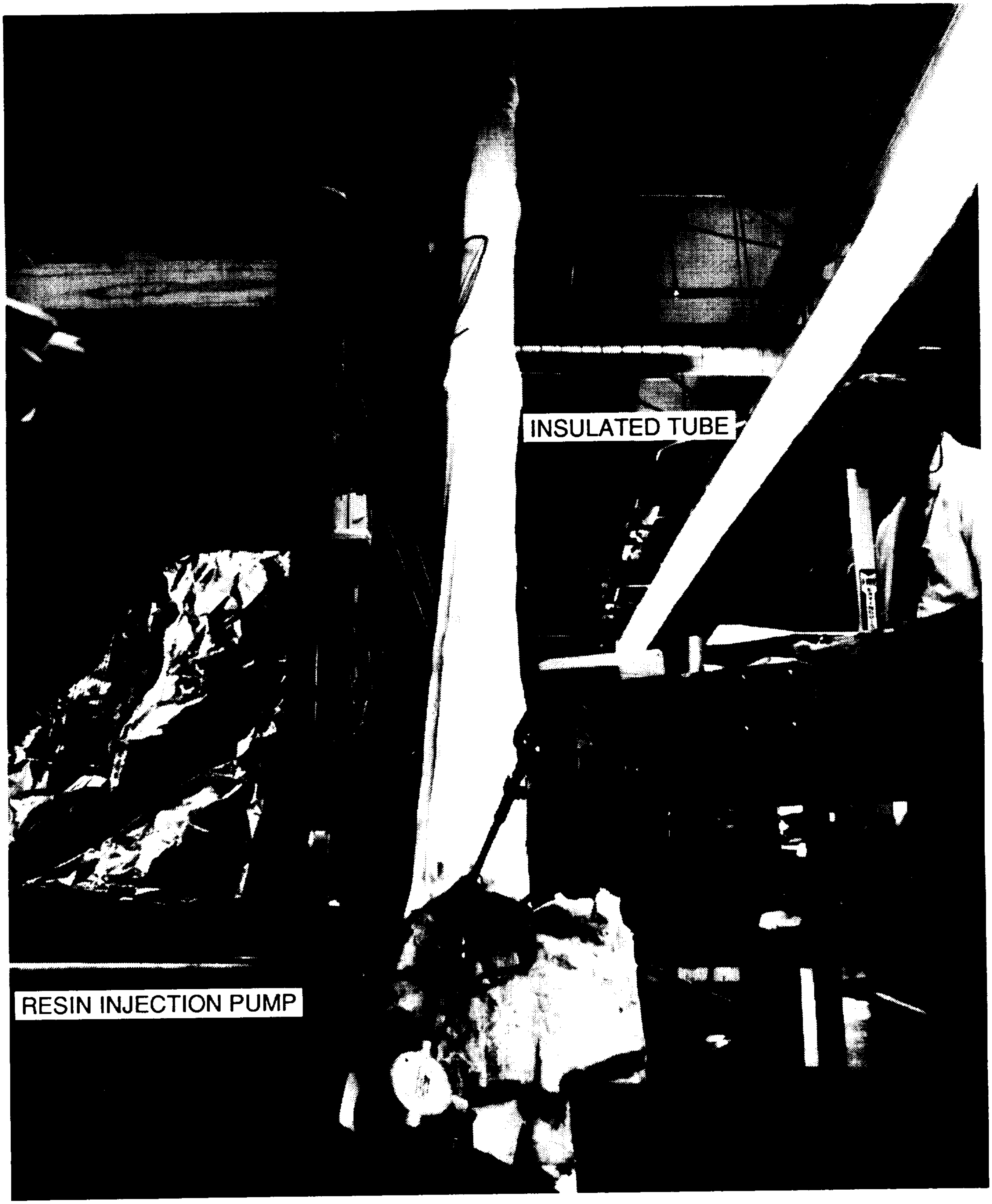


Figure 3. Tube on Injection/Cure Stand

LMSC tanks, making it necessary to find an alternate chem milling facility. Aerochem, Inc., in Adelanto, California was selected, and the facility was developed using LMSC facility and fixed asset funding. The tubes, being guided into the chemical milling tank, are shown in Fig. 4. The Aerochem tanks are 23 ft. deep, and modifications were made for chem milling the 24 ft. long tubes. A vertical cylinder, capable of processing 4 or 5 tubes simultaneously was developed. The cylinder, which can be seen in the photograph, was made at LMSC, was installed in one corner of the tank and extends above the etchant in the tank. The etchant is pumped up through the chamber using Aerochem's existing 200 gpm Wilden air diaphragm pump. A sample chem-mill data sheet prepared for each tube/run is presented in Appendix A.

4.5 End Fittings

Load transfer into a tube of laminated construction presents problems not encountered with metallic tubes. These problems are associated with the unique failure modes of laminates by interlaminar shear and tension. These failure modes are especially predominant in joint configurations that make use of lap geometry for load transfer.

Studies concerning joints for aluminum-clad Gr/E tubes have indicated that a scarf geometry at the tube/fitting interface could minimize joint problems associated with laminated tubes. Load transfer in well designed scarf joints is accomplished by pure shear through the adhesive between the tube and the fitting. The investigation on the strength of scarf joints in aluminum-clad Gr/E tubes considered various adhesives and fitting materials. Results indicated that 7075-T73 aluminum for the end fittings and EA9321 adhesive for the joint gave satisfactory results under static load applications and thermal environment. A drawing of the end fitting is given in Appendix B.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

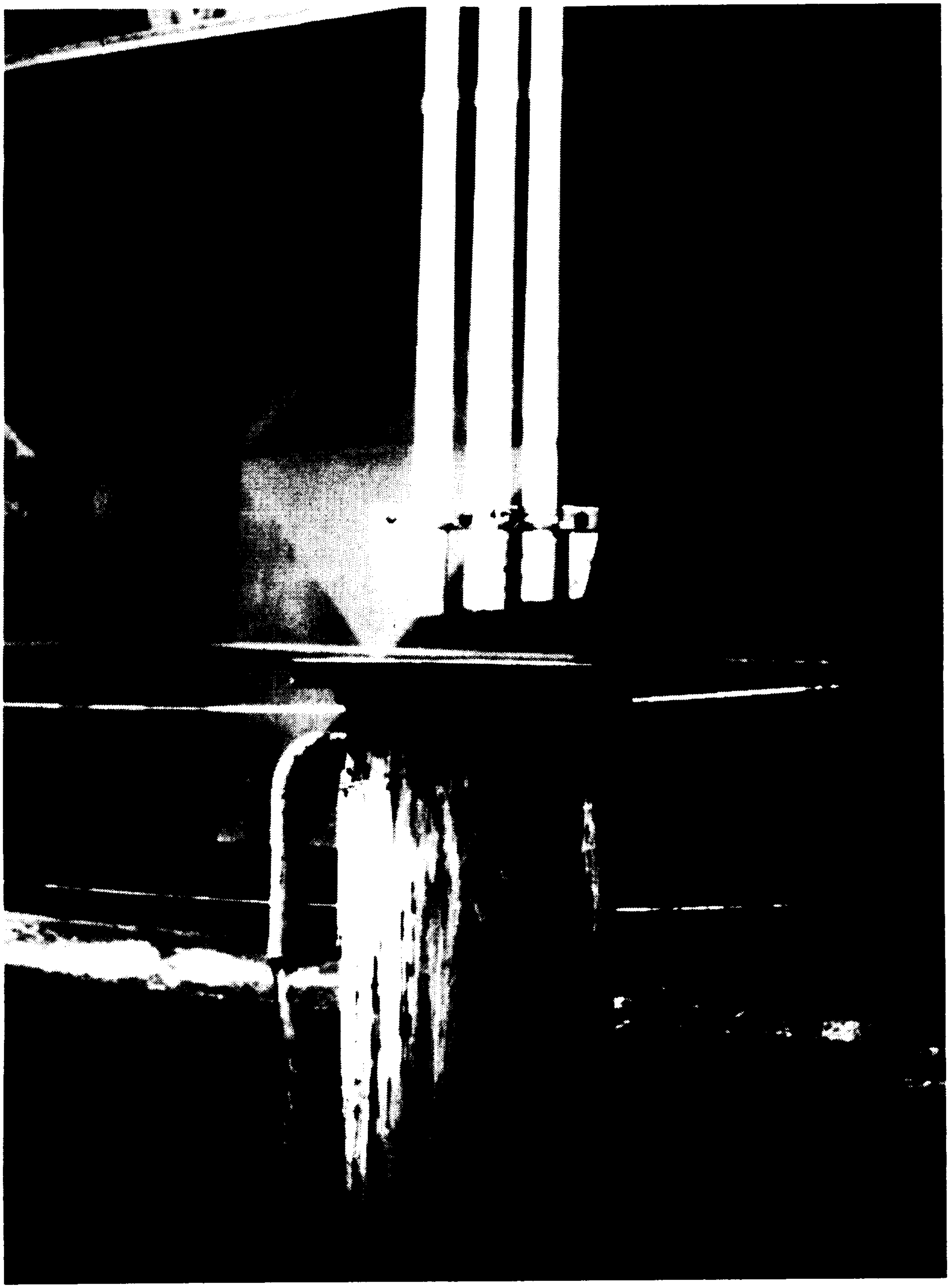


Figure 4. Tubes Being Guided into Chem-milling Tank

Each tube was fitted at the ends with these fittings and subjected to 200 lb tension acceptance load after a typical strut was subjected to a 2,000 lb qualification load. The predicted load capability of the joint is much higher than the qualification tension value. It is estimated that the joint will take 43,000 lb in tension and 19,500 lb in compression for thermally uncycled struts. Analysis and limited testing indicates that the allowable joint load for the thermally cycled struts would be about one third of the strength of uncycled specimens

4.6 Description of Strut Elements

A summary of the characteristics of the 13 tubes manufactured under this Task and shipped to the NASA Langley Research Center is presented in Table 2. In addition to the weight and geometry of each tube the bow, or lack of straightness, is also presented. The effect of bow on strut stiffness is shown in Fig. 5. Except for tube No. 7, which has a bow of over an inch, the maximum bow is in tube No. 2, 0.348 in. Although this curvature is quite severe the decrease of stiffness is about 10 percent. General characteristics of the tubes are listed in the right hand column of the table. All tubes were carefully examined, and all imperfections or anomalies noted.

ORIGINAL PAGE IS
OF POOR QUALITY

Table 2 – NASA Tubes Characteristics Summary

CHARACTERISTIC:

S/N	LENGTH	WEIGHT (POUNDS)	BOW	DIAMETER S/N END 0 DEG.	DIAMETER S/N END 90 DEG.	DIAMETER MIDDLE 0 DEG.	DIAMETER MIDDLE 90 DEG.	DIAMETER OPPOSITE 0 DEG.	DIAMETER OPPOSITE 90 DEG.	GENERAL CHARACTERISTICS
#2	263.588	8.75	0.348	2.124	2.122	2.125	2.120	2.128	2.120	2 RIDGES, ENTIRE LENGTH, AT 45' & 270', .020H,.2-.25W PINHOLES ENTIRE LENGTH, ROUGH SURFACE (ALODINE) OD SKIN FLAP NON-S/N END 160', MATL FROM PREVIOUS WORK
#7	263.590	9.75	MORE THAN ONE INCH	2.136	2.138	2.135	2.131	2.137	2.131	
#9	263.591	10.75	0.243	2.138	2.132	2.145	2.145	2.134	2.132	
#12	263.600	11.00	0.160	2.138	2.132	2.147	2.146	2.140	2.144	
#6	182.022	8.25	0.195	2.140	2.140	2.148	2.150	2.140	2.137	TWO DINGS: 14" AT 10'
#8	182.036	7.75	0.228	2.141	2.146	2.144	2.140	2.128	2.130	SMALL VOID: 25" 130', PIT: 68" 100' GROUP OF PITS: 130.23" 10'
#10	182.040	8.25	0.063	2.148	2.152	2.147	2.152	2.125	2.144	PINHOLE 181" 0', VESTIGE OF TOOL CLAMP MARK AT 5"
#11	182.049	8.25	0.308	2.140	2.125	2.151	2.146	2.150	2.152	TOOLING CLAMP VESTIGE AT 177"
#13	179.687	7.75	0.075	2.131	2.126	2.147	2.149	2.136	2.137	(2) 1/8" CRATERS AT 29" 265'
#14	182.028	7.25	0.203	2.132	2.139	2.136	2.138	2.139	2.142	PITS AT 17" 180', & 18.25" 280'
#17	182.050	8.13	0.143	2.126	2.125	2.153	2.151	2.130	2.129	VOID: 170' FROM 2.5" TO 177.5" OD ETCHED THROUGH 170' FROM 11.5" TO 18.5"
#19	182.038	8.75	0.203	2.125	2.126	2.149	2.150	2.138	2.137	
#22	182.020	6.00	0.255	2.126	2.123	2.130	2.120	2.128	2.123	FLAT RIDGE AT 330' INDICATES VOID ID ALUMINUM ETCHED AWAY

NOTES:

ALL END FITTING BONDS PROOF TESTED AT 200 POUNDS TENSION

NOTATION FOR DEGREES IS ('): 170' = 170 DEGREES

ALL LOCATIONAL DIMENSIONS ARE FROM SERIAL NUMBERED END

ALL RADIAL LOCATION IS LOOKING AT SERIAL NUMBERED END

SERIAL NUMBERS ARE LOCATED AT ZERO DEGREES AND COINCIDE WITH OUTSIDE OF BOW

THE FOUR SEVEN METER STRUTS ARE IN THE 25 FOOT LONG BOX

FIVE METER STRUTS NUMBER 6, 8, 10, 11, &13 ARE IN BOX 17A

FIVE METER STRUTS NUMBER 14, 17, 19, & 20 ARE IN BOX 17C

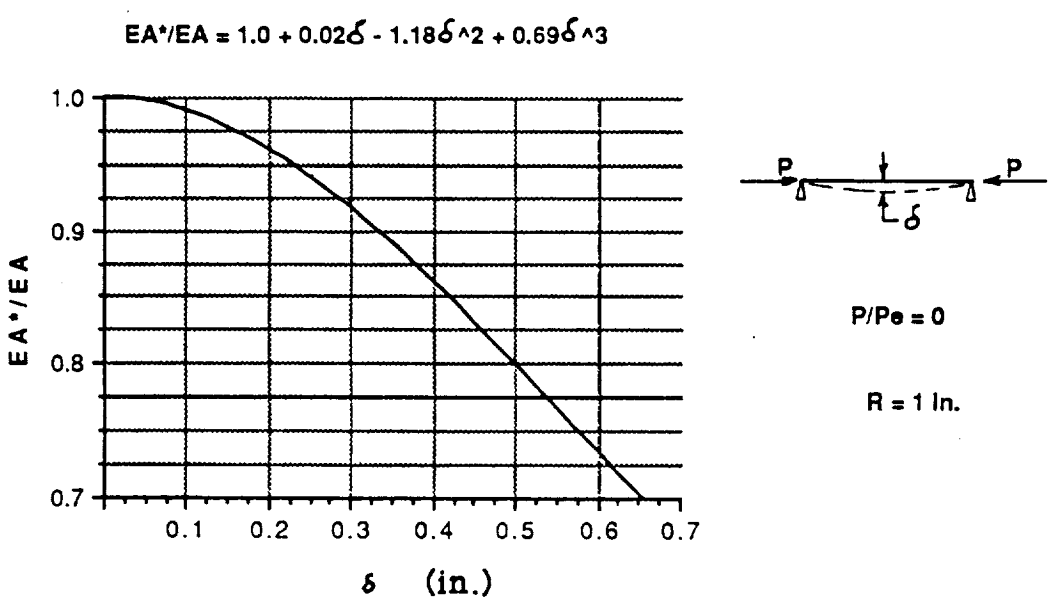


Figure 5. Effects of Bow on the Axial Stiffness of 2-in. dia. Aluminum-Clad Graphite Epoxy Tube

APPENDIX A

DETAILED MANUFACTURING PROCEDURE

SPACETUBE DATA SHEET-CHEM MILLING (AEROCHEM)

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	INSTRUCTION SHEETS REVISED 8-8-88 (L. BECK)			
10	IDENTIFY STRUT ASSEMBLY COMPONENTS:			
	RECORD DIMENSIONS BEFORE PRIME:			
	ASSEMBLY NUMBER	..XX...		
	INNER TUBE: SERIAL NUMBER	....		
	at s/n / 90 off s/n			
	O.D: s/nEND 1: _______ END 1: _______			
	CENTER: _______ CENTER: _______			
	END 2: _______ END 2: _______			
	avg:	....		
	OUTER TUBE: SERIAL NUMBER	....		
	at s/n / 90 off s/n			
	I.D: s/nEND 1: _______ END 1: _______			
	END 2: _______ END 2: _______	....		
	avg:	....		
	CALCULATED ANNULUS:	....		
	**			
	* PREPARE TUBE SET FOR ETCH & PRIME *			
	**			
20	MEASURE OUTER TUBE LENGTH			
	OUTER TUBE LENGTH:	....		
	CUT INNER TUBE TO OUTER TUBE LENGTH MINUS 7.43 INCHES			
	INNER TUBE LENGTH:	....		
	DEBURR ENDS			
	CHAMFER I.D AND O.D. OF BOTH ENDS			
30	DRILL SIX 3/8 DIA RADIAL PULL HOLES IN 2" TUBE IN SMALLER O.D. END (IF DIFFERENCE EXITS)			
	DEBURR INSIDE AND OUTSIDE OF HOLES			
40	RUN COLLAR ALONG ENTIRE LENGTH OF 2" TUBE TO CONFIRM CONSISTENT SIZE			
50	TEST PULL CONE FIT IN 2" TUBE I.D.			
	POLISH FOR SLIP FIT IF NECESSARY			
60	FLARE AND POLISH INPUT END I.D. OF 2-1/4" TUBE			
	USE LARGER END IF ANY DIFFERENCE EXISTS			

continue operations for STRUT XX on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	CHAMFER O.D. OF INPUT END DEBURR I.D. AND O.D. OF CHAIN DRIVE END PULL I.D. GAUGE THROUGH TUBE TO ASSURE CLEARANCE			
70	PACKAGE TUBES AND SEND OUT FOR FPL ETCH AND BR127 PRIME			
	** * PREPARE FOR FIBER DRAW * **			
100	MEASURE TUBES AGAIN AFTER PRIME			
	INNER TUBE:			
	at s/n 90 off s/n			
	O.D: s/nEND 1: _______ END 1: _______			
	CENTER: _______ CENTER: _______			
	END 2: _______ END 2: _______			
	avg:	....		
	OUTER TUBE:			
	at s/n 90 off s/n			
	I.D: s/nEND 1: _______ END 1: _______			
	END 2: _______ END 2: _______	....		
	avg:	....		
	CALCULATED ANNULUS:	....		
	BEFORE PREVIOUS TUBE IS FIBER DRAWN:			
105	INSTALL THREE 2-131 O-RINGS ON PULL CONE USING VACUUM GREASE INSERT PULL CONE INTO TUBE INSPECT FOR ANY O-RING PARTICLES AT RADIAL HOLES (IF ANY TRACE, REPEAT OPERATION) CLEAN RADIAL HOLES FOR PULL PLUGS COAT PLUG THREADS WITH ANTI-SIEZE COMPOUND INSTALL PULL PLUGS THROUGH TUBE INTO PULL CONE ORIENTING ROUND SURFACES TO BE FLUSH WITH TUBE O.D. OBSERVE PLUG/CONE MATCHMARKING FILE PROTRUDING PLUGS FLUSH AS REQUIRED FORCE EA956 ADHESIVE INTO PLUG HEAD CRACKS USING VIGOROUS RUBBING MOTION COAT PULL PLUG LINE WITH EA956 ADHESIVE, 1/16 THICK, 1/2 WIDE			

continue operations for STRUT XX on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI- TIAL	DATE
	WRAP SHRINK TAPE AROUND PLUG LINE 3" WIDE, USE CLOSE WRAPS, WRAP TIGHTLY AT ENDS, SNUGLY OVER ADHESIVE			
	INSTALL SHRINK TUBING OVER CONE/TUBE JOINT			
	MARK LINE 9-3/16 FROM CONE NOSE TO INDICATE PLUG LINE			
	HEAT SHRINK TAPE AND TUBING TO SQUEEZE ADHESIVE INTO PLUG HOLES, WORKING EVENLY TOWARD PLUG LINE			
	SLIP ON 3 HOSE CLAMPS, CENTERED ON PLUG LINE			
	TIGHTEN OUTER CLAMPS TIGHTLY, THEN TIGHTEN CENTER CLAMP			
	SCREW PULL NOSEPIECE ONTO PULL CONE, ASSURING EQUAL STUD ENGAGEMENT			
	SET RADIAL ORIENTATION OF TUBE FOR CHAIN LINK			
	SCRIBE MARK TOP OF 2" TUBE			
	RECORD PULL NOSE NUMBER...............	....		
110	PROTECT TUBE WITH PLASTIC WRAP			
	AFTER PREVIOUS TUBE SET IS PARTIALLY DRAWN:			
120	CLEAN DELRIN COLLARS ON INPUT END OF FIXTURE			
	CLEAN 2 INCH TUBE O. D.			
	CHECK FIT OF PULL CONE, FLUSH FIT OF 6 PLUGS, LEADING EDGE OF TUBE, AND FOR BURRS			
	APPLY MOLD RELEASE TO PULL CONE FROM RADIAL PLUGS TO NOSE, USING LINT-FREE WIPER			
130	INSTALL 2 INCH TUBE WITH PULL CONE IN INPUT END OF PULL FIXTURE FOR NEXT FIBER DRAW			
	ORIENT SCRIBE LINE UP			
	ADVANCE TO CONTACT TUBE IN DRAW PROCESS			
	TIGHTEN DELRIN COLLARS			
	SECURE COLLAR CLAMP BLOCKS WRENCH TIGHT			
140	SLIDE GUIDE COLLAR BLOCK BACK ONTO NEW 2 INCH TUBE			
150	UNPIN AND GENTLY SLIDE CONDENSER BOARD BACK FROM CONVERGENCE COLLAR TO STOP			
160	SLIDE CONDENSER RING BACK PAST PULL CONE AND SECURE			
170	WIPE DOWN A 2 FOOT PIECE OF TYGON TUBING WITH MOLD RELEASE			
	USING A COMPLETE WRAP OF TYGON TUBING, GENTLY PULL FIBERS DOWN TO FRONT OF PULL CONE AT THE SEVENTH STEP FROM THE LARGE END (10-1/2" FROM CONVERGENCE COLLAR FACE)			
	WRAP TUBING SECURLEY TYING A KNOT ON THE THIRD WRAP			

continue operations for STRUT XX on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
180	SPREAD PAPER BELOW PULL CONE MIX 956 ADHESIVE 10g PART A, 5.8g PART B SPREAD ADHESIVE AROUND CIRCUMFERENCE OF FIBERS JUST BEHIND TYGON TUBING USING A 2 FOOT DOUBLED GLASS TOW, WRAP FIBERS FIRMLY BEHIND TYGON TUBING, USING ADHESIVE TO SECURE END			
190	USING 2 FOOT DOUBLED GLASS TOWS WRAP FIBERS SECURELY, STARTING ONE INCH BACK FROM FIRST GLASS WRAP AND WRAPPING TO ONE INCH WIDE			
200	SPREAD ADHESIVE ON FIBERS EXPOSED IN ONE INCH SPACE BETWEEN GLASS WRAPPINGS USE HEAT GUN TO THIN RESIN FOR SATURATION OF GRAPHITE FIBERS WRAP ADHESIVE AREA WITH SIX WRAPS OF SHRINK TAPE AND SECURE WITH MYLAR TAPE HEAT SHRINK TAPE STARTING AT REAR OF WRAP TO AVOID WETTING CONVERGING FIBERS OBSERVE FOR FULL WETTING OF FIBERS CUT AWAY FIBERS 1-1/2" FORWARD OF TYGON TUBING (CURE TIME IS 24 HOURS)			
****	RETURN TO RUNSHEET FOR PREVIOUS TUBE ASSEMBLY			
210	* * * SAFETY CRITICAL OPERATION * * * COAT INNER SUPPORT MANDREL WITH MOLD RELEASE INSTALL INNER SUPPORT MANDREL USING SPECIAL SPANNER TOOL RECORD MANDREL INSTALLATION SEQUENCE POS. 1: POS. 2: POS. 3: * * * USE 3-1/2" STUDS IN 2" DEEP MANDREL THREADS TO ASSURE FULL THREAD ENGAGEMENT	....		
220	TEST FIT INNER VACUUM PLUG INTO INNER TUBE ADD SPACERS AS REQUIRED TO MAKE A 1/16 INCH GAP BETWEEN TUBE END AND INNER PLUG SHOULDER			
225	* * * SAFETY CRITICAL OPERATION * * * INSTALL 6-1/2" MINIMUM LENGTH 1/2-13 STUD INTO MANDREL ASSURE THAT STUD IS FULLY SEATED INTO MANDREL INSERT			
230	INSTALL (4) 2-131 O-RINGS ONTO INNER VACUUM PLUG COAT INNER PLUG AND INSIDE OF TUBE WITH RTV INSTALL VACUUM END INNER PLUG INTO TUBE REMOVE EXCESS RTV RUBBER			

continue operations for STRUT XX on next sheet

ORIGINAL PAGE IS
OF POOR QUALITY

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
240	INSTALL 2 INCH INDICATOR FLAG ON VACUUM PLUG STUD			
	AFTER PREVIOUS TUBE ASSEMBLY IS TRANSFERRED TO INJECTION STAND:			
260	CLEAN I.D. OF 2-1/4" TUBE WITH M.E.K. BLOW STRING THROUGH AND PULL DAMPENED CLOTH (VERIFICATION OF PRIMER BAKE) WIPE COLLAR I.D.'s WITH M.E.K.			
270	INSTALL IN PULL STAND USE ROUND END RETAINER PLATE AT STOP BLOCK TIGHTEN DELRIN COLLARS SECURE COLLAR CLAMPS			
280	MARK LINE ON TUBE TO INDICATE TOP WHEN PULLED MAKE MARK SUFFICIENTLY FROM END TO AVOID LOSS WHEN INJECTION TOOLING IS REMOVED			
290	REMOVE SHRINK TAPE FROM PULL CONE AND INSPECT FOR FULL FIBER SATURATION REMOVE TYGON TUBING WRAP TRIM GRAPHITE FLUSH WITH FRONT EDGE OF ADHESIVE			
300	REMOVE BROKEN FIBERS FROM CREEL AND CONDENSER BOARD REPAIR FRAYED STRANDS REMOVE SPARE TOWS FROM CONDENSER BOARD, FLAG AND ROLL BACK TO CREEL FACE BOARD INSPECT FOR MISSING TOWS SPLICE BROKEN TOWS TO COMPANION TOWS FORWARD OF CREEL FACE BOARD RETHREAD TOWS IF BOTH IN A PAIR ARE BROKEN USE POTEYE LOCATOR TABLES			
310	CLEAN AND POLISH CONVERGENCE COLLAR AND PULL NOSEPIECE			
320	CLEAN CHAIN, SPROCKET, AND CHAIN SUPPORTS WITH M.E.K. INSTALL STRAIN GUAGE LINK TO CHAIN WRAP LINK,NUT, AND PIN WITH MYLAR TAPE TO AVOID SCRATCHING TUBE I. D. INSTALL CONVERGENCE BLOCK ON PULL FIXTURE PULL CHAIN THROUGH TUBE, INSTALLING NYLON CHAIN SUPPORTS EVERY THIRD OPENING IN CHAIN KEEP GAUGE WIRE ON TOP OF CHAIN SPACE LAST 10 SUPPORTS EVERY 4TH OPENING			
330	ATTACH PULLING NOSEPIECE TO PULL CONE USE 3" MINIMUM LENGTH 1/2-13 STUD, FULLY			

continue operations for STRUT XX on next sheet

ORIGINAL PAGE IS OF POOR QUALITY

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	SEATING IT INTO NOSEPIECE BEFORE TIGHTENING ONTO PULL CONE HOOKUP LOAD CELL AND CHAIN TO NOSEPIECE TAKE UP CHAIN SLACK			
335	POWER UP LOAD CELL INDICATOR BOX (WARM-UP IS REQUIRED)			
340	CLEAN O.D. OF 2 INCH TUBE WITH M.E.K. (VERIFICATION OF PRIMER BAKE)			
350	ADVANCE CONDENSER BOARD TOWARD CONVERGENCE COLLAR GENTLY DIVIDE FIBERS INTO MARKED QUADRANTS TO CLEAR ALIGNMENT POSTS			
360	LOCK CONDENSER BOARD SLIDE WITH PIN			
370	LOOSEN 2" TUBE COLLARS TO HAND TIGHT			
380	CONNECT VIBRATOR AIR HOSES			
	** * FIBER DRAW * **			
400	PULL FIBERS AND INNER TUBE INTO OUTER TUBE MOTOR CONTROL SETTING TURN ON VIBRATORS AT 4000 POUNDS OF PULL FORCE RECORD START TIME.......... RECORD FIRST PAUSE TIME.....	....		
420	RECORD PULL DISTANCE, ELAPSED TIME, AND FORCE:			

inches	e.t.	force	inches	e.t.	force
6			150		
12	1+t		156	13	
18			162		
24	2		168	14	
30			174		
36	3		180	15	
42			186		
48	4		192	16	
54			198		
60	5		204	17	
66			210		
72	6		216	18	
78			222		
84	7		228	19	
90			234		
96	8		240	20	
102			246		

continue operations for STRUT XX on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	108 9____ ____ 252 21____ ____ 114 ____ ____ 258 ____ ____ 120 10____ ____ 264 22____ ____ 126 ____ ____ 270 ____ ____ 132 11____ ____ 276 23____ ____ 138 ____ ____ 282 ____ ____ 144 12____ ____ 288 24____ ____			
430	PAUSE FIBER DRAW OPERATION WHEN END OF VACUUM PLUG ENTERS CONVERGENCE COLLAR TO 2 INCHES FROM BACK EDGE OF COLLAR (FLAG SET AT 2") SET CONTROL AT ZERO...DO NOT TURN OFF			
***	GO TO OPERATION INSTRUCTION FOR NEXT TUBE SET			
	AFTER NEXT TUBE PULL CONE FIBER BONDING:			
440	CONTINUE FIBER DRAW PROCESS PULL UNTIL VACUUM PLUG IS RECESSED 1 INCH INTO CONVERGENCE COLLAR			
450	PAUSE OPERATION SET CONTROL AT ZERO...DO NOT TURN OFF CAREFULLY REMOVE CONVERGENCE COLLAR TRIM FIBERS AT VACUUM PLUG TO 2 INCH TUBE JOINT			
460	TERMINATE PULL SO THAT INNER VACUUM PLUG NECK PROTRUDES 7/8 INCH FROM EDGE OF OUTER TUBE			
	*** * PREPARE FOR RESIN INJECTION * ***			
500	DISCONNECT VIBRATOR HOSES REMOVE PULL NOSE OPEN COLLAR CLAMPS REMOVE DELRIN COLLARS REMOVE END PLATE EXAMINE TUBE ASSEMBLY FOR STRAIGHTNESS			
502	CHAMFER O.D. OF INJECT END FOR O-RING ASSEMBLY INTO INJECTION CUP			
504	COAT INNER SURFACES AND THREADS OF INJECTION CUP ASSEMBLY COMPONENTS WITH MOLD RELEASE COAT CUP/CAP THREADS WITH A LIGHT COATING OF VACUUM GREASE			
506	INSTALL (1) 2-131 O-RING ONTO THREADED END OF INJECTION CUP USING VACUUM GREASE			

continue operations for STRUT XX on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	ASSEMBLE INJECTION CUP AND CAP WITH COPPER CRUSH GASKET, USING NYLON PLUG TO AVOID O-RING DAMAGE INSTALL (2) 2-140 O-RINGS INTO INJECTION CUP USING VACUUM GREASE			
508	* * * SAFETY CRITICAL OPERATION * * * INSTALL (2) 2-119 O-RINGS ONTO PULL CONE NOSE USING VACUUM GREASE INSTALL INJECTION CUP ASSEMBLY TO INJECT END OF TUBE ASSEMBLY INSTALL (1) 2-016 O-RING ONTO END RETAINER NUT USING VACUUM GREASE INSTALL NUT AND TIGHTEN * * * ASSURE THAT 1/2-13 STUD IS PROTRUDING FROM THE NUT INDICATING FULL THREAD ENGAGEMENT * * *			
510	COAT SURFACES OF VACUUM END FITTINGS WITH MOLD RELEASE INSTALL (1) 2-022 O-RING ON INNER PLUG NOSE USING VACUUM GREASE			
512	INSTALL (1) 2-135 O-RING ONTO OUTER PLUG O.D. USING VACUUM GREASE COAT TUBE I.D. AND PLUG O.D. WITH RTV			
514	INSTALL VACUUM END OUTER PLUG INTO TUBE ASSEMBLY			
516	* * * SAFETY CRITICAL OPERATION * * * INSTALL (1) 2-016 O-RING ONTO VACUUM END RETAINER NUT USING VACUUM GREASE INSTALL NUT USING HARDENED 1/8" THICK WASHER AND TIGHTEN * * * ASSURE THAT 1/2-13 STUD IS PROTRUDING FROM THE NUT INDICATING FULL THREAD ENGAGEMENT * * *			
518	ASSEMBLE INJECT END PLUMBING: INSTALL 6 INCH STAINLESS NIPPLE TO CUP CAP INSTALL BALL VALVE TO NIPPLE INSTALL VACUUM GAUGE TO BALL VALVE			
520	ASSEMBLE VACUUM END PLUMBING: INSTALL 6 INCH STAINLESS NIPPLE TO BLOCK INSTALL PRESSURE GAUGE, ISOLATOR, BALL VALVE, AND TEE, TO 6 INCH NIPPLE INSTALL BALL VALVE TO GAUGE TEE			
525	* * * SAFETY CRITICAL OPERATION * * * INSTALL NITROGEN PRESSURE TEST APPARATUS SECURE FLEX LINE WITH RIGID RETAINER			

continue operations for STRUT XX on next sheet

ORIGINAL PAGE IS
OF POOR QUALITY

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	INSTALL LEXAN SHIELD AT PRESSURE END PRESSURIZE TUBE ASSEMBLY WITH 600 PSI DRY NITROGEN. TURN OFF NITROGEN SUPPLY OBSERVE PRESSURE FOR 1 HOUR. A PRESSURE DROP OF 10 PSI IS ACCEPTABLE ***CAUTION*** FACE SHIELD AND EAR PROTECTION ARE TO BE WORN AT ALL TIMES BY ALL PERSONNEL PERFORMING THIS OPERATION ALL PERSONNEL PERFORMING THIS OPERATION ARE TO AVOID BEING IN LINE WITH THE TUBE CENTER AXIS AT ALL TIMES DURING PRESSURE TEST			
530	CONNECT VACUUM PUMP AND START PUMPING START TIME: LOG INJECT GAUGE VACUUM & TIME OF DAY: "Hg tod "Hg tod "Hg tod "Hg tod 1 ____ 8 ____ 15 ____ 22 ____ 2 ____ 9 ____ 16 ____ 23 ____ 3 ____ 10 ____ 17 ____ 24 ____ 4 ____ 11 ____ 18 ____ 25 ____ 5 ____ 12 ____ 19 ____ 26 ____ 6 ____ 13 ____ 20 ____ 27 ____ 7 ____ 14 ____ 21 ____ 28 ____			
535	MEASURE TUBE LENGTH FROM VACUUM END TO INJECTION CAP FACE.......................			
540	CLOSE VACUUM END VALVE DISCONNECT VACUUM PUMP IN PREPARATION FOR TRANSFER TO INJECT STAND			
545	INSTALL TUBE ASSEMBLY ON INJECT STAND: PLACE BOTTOM HEATER WIRE IN RECESS INSTALL TUBE ASSEMBLY LOCATE TOP HEATER LINES IN POSITION ORIENT TUBE ASSY WITH TOP MARKING LINE UP CLAMP TUBE OBSERVING CAP ALIGNMENT MARKS: INSTALL TUBE SUPPORT BLOCK AT INJECT END GREASE ALL PHENOLIC SPACERS LIBERALLY WITH VACUUM GREASE CLAMP ALL CLAMPS FINGER TIGHT			
550	INSTALL VACUUM RESIN CATCH JAR AND RESTART VACUUM			
555	SECURE HEATER WIRES AT 12 INCH INTERVALS WORK FROM ONE END TO KEEP WIRES FLAT TO TUBE USING TIE-WRAPS AND CLIPPING ENDS OFF			
557	INSTALL BAND HEATERS ON INJECTION CUP AND CAP			

continue operations for STRUT XX on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
560	INSTALL THERMOCOUPLES AT FOUR LOCATIONS: A: CENTERED BETWEEN FIRST SET OF CLAMPS B: 1/3 OF DISTANCE FROM "A" TO "D" C: 2/3 OF DISTANCE FROM "A" TO "D" D: CENTERED BETWEEN LAST SET OF CLAMPS CONNECT P.C. CONTROLLER TC's: TC# LOCATION 1 B: H9: HTR/TUBE TANGENT 2 C: HALFWAY BETWEEN H6 & H9 3 D: HALFWAY BETWEEN H3 & H6 4 D: H3: HTR/TUBE TANGENT 5 A: HALFWAY BETWEEN H12 & H3 6 C: H6: HTR/TUBE TANGENT 7 A: H12: HTR/TUBE TANGENT 8 B: HALFWAY BETWEEN H9 & H12 9 MANDREL: VACUUM END 10 ON 2-1/4 DIA. CONE BASE AT PULL PLUGS 11 AT CUP BAND HEATER 12 AT CAP BAND HEATER 13 INTO NOSE OF PULL CONE CONNECT DATALOGGER TC's: 000 A: H12: HTR/TUBE TANGENT 001 B: H3: HTR/TUBE TANGENT 002 C: H6: HTR/TUBE TANGENT 003 D: H9: HTR/TUBE TANGENT 004 MANDREL: VACUUM END 005 INTO NOSE OF PULL CONE USING 2 MIL FLASHBREAKER TAPE AND SECURING SNUGLY WITH TIE WRAP USE SPRING TENSION OF TC WIRE TO MAKE TANGENT CONTACT			
565	CONNECT TEMPERATURE CONTROL COMPUTER SYSTEM AND BACKUP DATALOGGER TEMPERATURE MONITOR OBSERVE TEMPERATURE READOUTS FOR ACCURACY			
570	SECURE THERMAL INSULATION			
580	TURN TUBE HEATERS ON TO 170 F USE 'INJECT1' PROGRAM (MONITORS MANDREL) WHEN MANDREL REACHES 170F SWITCH CONTROLLER TO MONITOR LOWEST EXTERNAL TC AND MAINTAIN 165F MINIMUM TEMPERATURE FOR INJECTION			
590	INSTALL FIVE VIBRATORS AND HOSES			

continue operations for STRUT XX on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	** * MIX RESIN * **			
600	WEIGH OUT COMPONENTS USE USE 8703 RATIO TABLE, START WITH "A" COMPONENT WEIGHT 1000 GRAMS MINIMUM RECORD "A" COMPONENT WEIGHT RECORD "B" COMPONENT WEIGHT TOTAL RESIN WEIGHT.........			
610	PREHEAT COMPONENTS TO 125 F: "A" COMPONENT RECORD TIME........ "B" COMPONENT RECORD TIME........ USE MERCURY THERMOMETER TO INDICATE FULL PREHEATING OF COMPONENTS PUMP CYLINDER UNTIL INJECTION INJECT END PLUMBING UNTIL INJECTION			
620	REMOVE RESIN COMPONENTS FROM OVEN AND MIX RETURN MIXED RESIN TO OVEN FOR 5 MINUTES RECORD HEATING TIME............ RECORD TEMPERATURE.............			
630	DE-AIR RESIN: 27" Hg UNTIL BUBBLES CEASE USING BELL JAR VACUUM SYSTEM RECORD DE-AIR TIME..... RETURN MIXED RESIN TO OVEN FOR 15 MINUTES USE MERCURY THERMOMETER TO INDICATE FULL PREHEATING OF RESIN RECORD HEATING TIME............ RECORD TEMPERATURE.............			
640	INSTALL (4) 2-222 O-RINGS ONTO PUMP END PLUGS AND PISTON BACK OFF PUMP SCREW SHAFT FULLY			
650	FILL PUMP IN VERTICAL POSITION TO 1-1/2 INCH BELOW CYLINDER LIP INSTALL INJECTION END BLOCK, TUBE, GAUGE AND VALVE INSTALL AND SECURE (3) TENSION RODS WITH TUBE HELD AT 45 DEGREE ANGLE, GAUGE DOWN, SLOWLY ADVANCE PUMP UNTIL RESIN EXITS VALVE CLOSE VALVE			
655	RECORD VACUUM GAUGE READING BEFORE REMOVAL....	....		
660	INSTALL PUMP IN PUMP BRACKET TURN OFF INJECT CUP VALVE REMOVE VACUUM GAUGE CONNECT PUMP VALVE TO INJECTION CUP VALVE WITH SWAGE-LOK FITTING			

continue operations for STRUT XX on next sheet

ORIGINAL PAGE IS
OF POOR QUALITY

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	OPEN INJECTION CUP VALVE WAIT FIVE MINUTES			
	** * RESIN INJECTION AND CURE * **			
705	RECORD PUMP SHAFT EXTENSION LENGTH............	....		
	OPEN PUMP VALVE			
	RECORD TIME OF INJECTION START................	....		
	ADVANCE PUMP UNTIL SHARP RISE IN PRESSURE OCCURS			
	RECORD NOMINAL PRESSURE BEFORE RISE...........	....		
	RECORD NOMINAL PRESSURE AT RISE...............	....		
	RECORD PUMP SHAFT EXTENSION LENGTH............	....		
710	TURN ON VIBRATORS MAINTAIN PUMPING RATE AND PRESSURE CONTROLS UNTIL RESIN IS OBSERVED AT VACUUM END CATCH JAR: PRESSURE: DO NOT EXCEED 600 PSI RATE: DO NOT EXCEED 3.5 TURNS PER MINUTE RECORD SAMPLED DATA:			

time	rate of rotation	shaft length	pump temp	tube temp

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
715	WHEN RESIN IS OBSERVED AT VACUUM END:			
	RECORD TIME OF FIRST RESIN....................	....		
	RECORD PUMP SHAFT EXTENSION LENGTH............	....		
	(20" OF TRAVEL CALCULATED TO FILL 24' TUBE) (14" OF TRAVEL CALCULATED TO FILL 17' TUBE) (PUMP BOTTOMS AT 6-3/4" OF SHAFT EXTENSION)			
720	CONTINUE PUMPING UNTIL RESIN RUNS CLEAR CLOSE VACUUM END VALVE TURN OFF VACUUM PUMP			

continue operations for STRUT xx on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	RECORD PUMP SHAFT EXTENSION LENGTH............ RECORD TIME OF VALVE CLOSING................. MAINTAIN PUMPING PRESSURE AND RATE	....		
725	OPEN VALVE TO VACUUM END PRESSURE GAUGE PRESSURIZE ENTIRE TUBE TO 600 PSI RECORD TIME AND PRESSURE: psi time psi time psi time 100 ____ 200 ____ 300 ____ 400 ____ 500 ____ 600 ____ HOLD FOR 5 MINUTES AT 600 PSI IF PRESSURE DROPS, VENT RESIN AT CATCH JAR AND REPEAT UNTIL PRESSURE HOLDS FOR 5 MINUTES RECORD NUMBER OF VENTS: RECORD EQUALIZATION PRESSURE .... RECORD EQUALIZATION TIME	....		
730	CLOSE INJECT END VALVE TURN OFF VIBRATORS RECORD PUMP SHAFT EXTENSION LENGTH............	....		
735	CURE RESIN AT 170 DEGREES F FOR 4 HOURS			
745	DISCONNECT VACUUM CATCH JAR DISCONNECT PUMP DRAIN RESIN FROM PUMP COLLECT RESIN FROM JAR, PUMP, AND MIX CONTAINER RECORD WEIGHT OF EXCESS UNUSED RESIN....... RECORD WEIGHT OF RESIN USED FOR INJECTION..	....		
750	CLEAN PUMP AND RESIN CATCH JAR COMPONENTS			
755	MEASURE TUBE LENGTH FROM VACUUM END TO INJECTION CAP FACE........................ RECORD GROWTH IN LENGTH......................	....		
760	REMOVE VACUUM END FITTING: CUT TUBE AT 3.86 INCHES FROM FACE OF OUTER VACUUM END PLUG USING HACKSAW WITH DEPTH STOP SET AT .190 INCH			
770	REMOVE INJECTION END FITTING: REMOVE INJECTION CUP/CAP ASSEMBLY CUT TUBE AT 10 INCHES FROM FACE OF PULL CONE NOSE USING HACKSAW WITH DEPTH STOP SET AT .190 INCH			

continue operations for STRUT XX on next sheet

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI- TIAL	DATE
780	REMOVE MANDREL FROM TUBE ASSEMBLY			
785	DEBURR ENDS, CLEAN INSIDE OF TUBE WITH M.E.K.			
790	EXAMINE TUBE ASSEMBLY FOR STRAIGHTNESS			
795	ENGRAVE SERIAL NUMBER ON INPUT END ON SAME LONGITUDE LINE THAT WAS UP FOR DRAW			
799	PACKAGE TUBE ASSEMBLY FOR SHIPMENT TO CHEMICAL ETCH FACILITY			
	** * Al/GrE STRUT MACHINING * **			
810	INSPECT TUBES RECEIVED FROM CHEMICAL MILLING MOVE TO BONDING AREA FOR MEASUERMENT *HANDLE WITH EXTREME CARE* AVOID ALL HANDLING DAMAGE			
820	PLACE TUBE IN BONDING FIXTURE SO THAT STOCK IS EVENLY DISTRIBUTED +/-.25" BETWEEN JAW FACES SCRIBE LINE FLUSH AT OUTSIDE FACE OF CHUCK JAWS ON EACH END			
830	REMOVE TUBE FROM BONDING FIXTURE AND TRANSFER TO HARRISON LATHE			
840	CHUCK TUBE IN LATHE PART OFF AT SCRIBE LINE CUT TAPER FROM INSIDE OUT LEAVING .006" WALL PER DRAWING SSAS-006 REVERSE TUBE AND REPEAT MACHINING ON OPPOSITE END			
850	MOVE TUBE TO STRUT BONDING FIXTURE			
	** * BOND END FITTINGS * ** 			
900	PREPARE BOND SURFACES PER HYSOL SPEC G1-600			
910	INSTALL STRUT AND END FITTING IN BONDING FIXTURE *DO NOT TOUCH TAPER SURFACES*			
920	INSTALL FITTING ON INSTALLATION KNEE TIGHTEN SO THAT END OF FITTING IS FLUSH			

continue operations for STRUT XX on next sheet

ORIGINAL PAGE IS
OF POOR QUALITY

OPRN NMBR	OPERATION DESCRIPTION	RECORD VALUE	INI-TIAL	DATE
	WITH PLUG SURFACE			
	RUN FITTING INTO TUBE TO BOTTOM			
	ZERO DIAL GAUGE			
	BACK OFF END FITTING TO CORRECT DIMENSION			
	FOR DESIRED BOND LINE			
	RECORD DIMENSION TRAVELLED.....	....		
	CLAMP STOPS FOR KNEE AND BACK OUT KNEE			
930	MIX HYSOL EA9321 ADHESIVE:			
	10 GRAMS OF PART A			
	5 GRAMS OF PART B			
940	APPLY ADHESIVE EVENLY TO SURFACE OF END FITTING			
	AND TUBE TAPER PER HYSOL SPEC 9621			
950	INSERT END FITTING INTO STRUT TO STOPS			
	REMOVE EXCESS ADHESIVE			
960	REPEAT OPERATIONS 920 THROUGH 960 FOR			
	OPPOSITE END			
	RECORD DIMENSION TRAVELLED.....	....		
	RECORD TIME OF DAY.............	....		
	ALLOW TWO HOURS FOR INITIAL ADHESIVE CURE			
965	MEASURE FINAL STRUT LENGTH			
	RECORD LENGTH......	....		
	(REF: 263.718" & 182.180")			
970	REMOVE STRUT FROM BONDING FIXTURE AND INSTALL			
	INTO CURING FIXTURE			
975	CURE AT 180 DEGREES F FOR 2 HOURS			
	RECORD START TIME.................	....		
	RECORD NOMINAL CURE TEMPERATURE...	....		
	RECORD COMPLETION TIME............	....		
980	TRIM EXCESS ADHESIVE FROM INSIDE AND OUTSIDE OF			
	STRUT ENDS			
985	INSPECT			
	FILL OUT CHARACTERIZATION SHEET LISTING ALL			
	VISUAL CHARACTERISTICS			
	PACKAGE FOR SHIPMENT TO CUSTOMER			

continue operations for STRUT XX on next sheet

LOCKHEED SPACETUBE
DATA SHEET

					DATE:			
S/N	INT. WEIGHT		FIN. WEIGHT		INT. LENGHT		FIN. LENGHT	
WALL THICKNESS DIMENSION	MEASURE SEQ. #				MEASURE SEQ. #			
	12:00	3:00	6:00	9:00	12:00	3:00	6:00	9:00
S/N END INSIDE								
OUTSIDE								
OPP. END INSIDE								
OUTSIDE								
	1/2	CENTER		3/4				

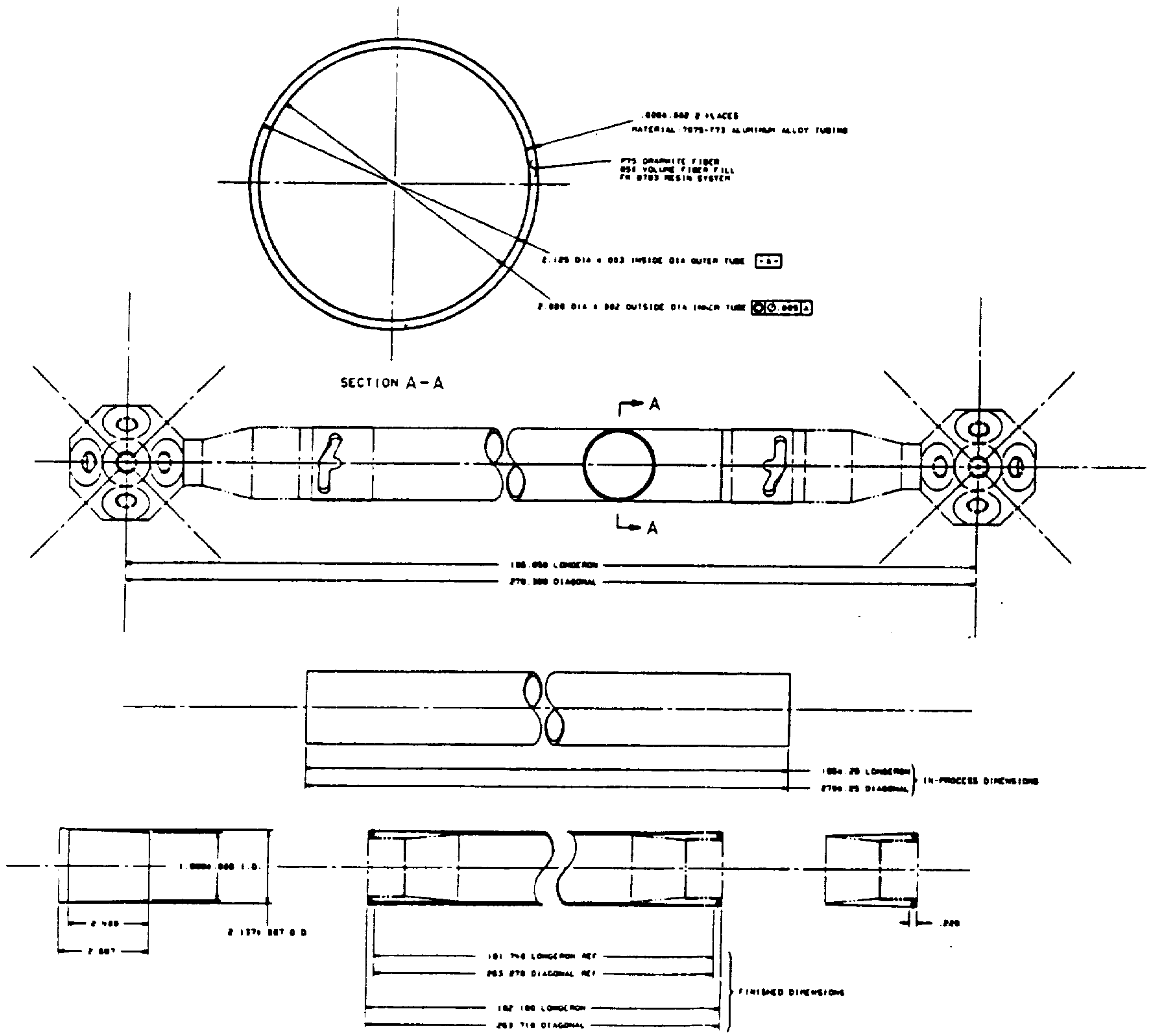
1. M.E.K. CLEAN & PIT		7. RACK & REVERSE FIXTURE	
2. MASK & SEAL TUBE ENDS		8. 2nd. MILL CUT (20 mil) TIME:	
3. RACK/RECORD SERIAL # POSITION		9. CLEAN/BENCH/PIT RECORD 2nd. MILL CUT:	
4. RECORD: PUMP FLOW (65gpm) ETCH RATE: TEMP:		10. RACK & REVERSE FIXTURE	
5. 1st. Mill CUT: (20 mil) TIME:		11. 3RD. MILL CUT (5 mil) TIME:	
6. CLEAN/BENCH/PIT RECORD 1st. MILL CUT:		12. REVERSE FIXTURE FINAL MILL CUT (to tollerance) TIME:	

APPENDIX B

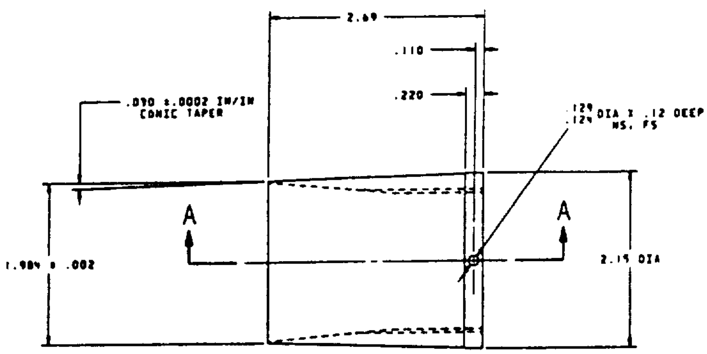
TUBE/STRUT DRAWING

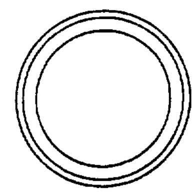
END FITTING DRAWING

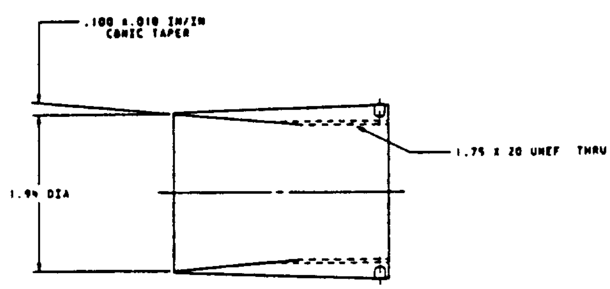
ORIGINAL PAGE IS
OF POOR QUALITY

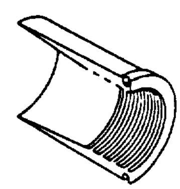


ORIGINAL PAGE IS OF POOR QUALITY









SECTION A - A

TUBE END FTNG.01

555GRAPHITE STRUT END FITTING 14AUG86 HLVOQUI

NASA
National Aeronautics and Space Administration

Report Documentation Page

1. Report No.
NASA CR-181873

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Process Development and Fabrication of Space Station Type Aluminum-Clad Graphite Epoxy Struts

5. Report Date
January 1990

6. Performing Organization Code

7. Author(s)
L. R. Ring

8. Performing Organization Report No.
LMSC/F186352

9. Performing Organization Name and Address
Lockheed Missiles & Space Company, Inc.
1111 Lockheed Way
Sunnyvale, CA 94088

10. Work Unit No.
506-43-41-02

11. Contract or Grant No.
NAS1-18229

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23665-5225

13. Type of Report and Period Covered
Contractor Report

14. Sponsoring Agency Code

15. Supplementary Notes
Langley Technical Monitor: Harold G. Bush
Contract NAS1-18229, Task Assignment No. 5

16. Abstract

The manufacture of aluminum-clad graphite epoxy struts, designed for application to the Space Station truss structure, is described in this report. The strut requirements are identified, and the strut material selection rationale is discussed.

The manufacturing procedure is described, and shop documents describing the details are included. Dry graphite fiber, Pitch-75, is pulled between two concentric aluminum tubes. Epoxy resin is then injected and cured. After reduction of the aluminum wall thickness by chemical milling the end fittings are bonded on the tubes. A discussion of the characteristics of the manufactured struts, i.e., geometry, weight, and any anomalies of the individual struts is included.

17. Key Words (Suggested by Author(s))
Aluminum-Clad, Space Station Truss Struts, Graphite Epoxy, Manufacturing Procedure

18. Distribution Statement
Unclassified - Unlimited

Subject Category 18

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	36	A03