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MICROWAVE LIMB SOUNDER, GRAPHITE EPOXY SUPPORT STRUCTURE

Final Report

Prepared by:

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ABSTRACT

The manufacturing and processing procedures which were used to fabricate a precision graphite/epoxy support structure for a spherical microwave reflecting surface are described. The structure was made from GY-70/930 ultra-high modulus graphite prepreg, laminated to achieve an isotropic in plane thermal expansion of less than ±0.1 PPM/F. The structure was hand-assembled to match the interface of the reflective surface, which was an array of 18 flexure supported, aluminum, spherically contoured tiles. Structural adhesives were used in the final assembly to bond the elements into their final configuration. A eutectic metal coating was applied to the composite surface to reduce dimensional instabilities arising from changes in the composite epoxy moisture content due to environmental effects. Basic materials properties data is reported and the results of a finite element structural analysis are referenced.

1.0 INTRODUCTION

The Microwave Limb Sounder Graphite/Epoxy Support structure is a lightweight, precision, dimensionally stable composite truss which supports the aluminum reflective first surface of the microwave antenna. The support structure must, therefore, be capable of (1) withstanding the launch loads induced by the reflective aluminum tiles without permanent deformation, (2) maintaining the alignment of the tiles under changing humidity conditions (launch to orbit) and (3) maintain the precise alignment of the tiles over a wide thermal range ($\approx$-100F to +150F).

This report covers the manufacturing tasks associated with the fabrication of a segment of the full size primary reflector. For this exercise, a segment of one-fourth of the antenna was fabricated for subsequent testing and evaluation. This segment consisted of 18 aluminum tiles, each 5-1/4" x 5-1/4" with three integral aluminum flexures extending 2" from the rear surface. The front surfaces of the tiles were machined to a spherical contour of six meters. The graphite/epoxy support structure consists of an array of interlocking curved beams, 16" x 36" in overall size, which support the tiles through the flexures.

The aluminum tiles were provided by JPL, attached to a tooling base assembly fixture which held each tile in its spherical contour location. The graphite/epoxy support structure was then built up on this tooling to interface with the tile flexures using essentially a hand fitting procedure. The support structure is held together with structural adhesive with a mechanical fastener at the tile flexure/graphite composite interface.

The completed graphite composite structure was removed from the array of tiles and plated with an overcoat of indium tin eutectic to provide a moisture barrier. It was then reassembled to the tiles (which were still attached to the base assembly fixture) and delivered to JPL where the antenna was separated from the tooling.

2.0 APPLICABLE DOCUMENTS

The support structure was manufactured in compliance with JPL drawings 10091464 through 10091468. Assembly procedures were written by Composite Optics, Incorporated (COI) and approved by JPL. They are designated COI specification COS 80-006 Rev. A.

3.0 SCOPE

The following tasks represent the manufacturing program task breakdown for the purposes of this report.

1. Materials and Properties.
2. Analysis.
3. Element Fabrication.
4. Assembly.
5. Moisture Barrier Application.

Each of these topics is discussed in detail in the following sections.

4.0 MATERIALS AND PROPERTIES

The support structure was manufactured from a single production lot of pre-impregnated GY-70/930 tape purchased from the Fiberite Corporation. Procurement was made by JPL to COI material specifications. Copies of these specifications and the vendor's certification are contained in Appendix 1.

The structure was bonded together with Hysol EA-934 adhesive. The vendor's certification of compliance for this material is also contained in Appendix 1.

Receiving Inspection Tests. Both the prepreg and adhesive were subjected to the following tests, upon receipt, to verify their basic mechanical and thermal properties. These measurements were performed prior to releasing the materials for manufacturing.

A sample of the GY-70/930 prepreg was cured in an 8 ply pseudoisotropic flat, test laminate from which thermal expansion (CTE) coupons were cut in the 0° and 90° directions. Tensile coupons were also fabricated from this laminate and were used to measure the tensile modulus (E_t) and the ultimate tensile strength (F_{tu}). A 16 ply pseudoisotropic laminate was also cured and then plated with the indium-tin eutectic coating to verify the plating process compatibility. This plated coupon was then measured for CTE and hygrodimensional response to verify compliance with the JPL structural specifications.

Single lap shear bond line strengths of the EA-934 adhesive were measured as a function of bond line thickness. These adhesive test coupons were made with GY-70/930 material in accordance with the applicable COI bonding specification, a copy of which is included in Appendix 1.

The results of these measurements are as follows:

1. GY-70/930 Laminate Measurements

A. Thermal Expansion

Laminate, Layup	Nominal Thickness	CTE @ R.T. (PPM/F)	Msmt. Direction
R.I. 1 (0,45,90,135)s	.04"	-0.01	90°
"	"	0.06	0°
R.I. 2 (0,45,90,135)2s In/Sn Coated	.08	0.09	0°

The complete expansion curves are contained in Appendix 2.

B. Mechanical Properties, Layup (0,45,90,135)s

Msmt. Direction	E_t MSI	F_{tu} KSI
0°	14.65	28.4 (Failed at doubler)
90°	14.25	41.7

C. Hygrodimensional Sensitivity

Sample: 16 ply, (0,45,90,135)2s,
In/Sn coated

Exposed to 95% relative Humidity

Exposure Time: 72 hours

Measured Strain: Less than 1 PPM.

2. GY-70/930 and EA-934 Single Lap Shear Strengths at Room Temperature

Sample #	Bond Thickness (inches)	Shear Strength (PSI)
1	Less than .001	877
2	" " "	1101
3	" " "	1187
4	" " "	970
5	.002	802
6	.004	1260
7	.004	875
8	.004	1354
9	.004	1295

5.0 ANALYSIS

A finite element stress analysis of the support structure was performed, prior to the manufacturing of composite material stock, to validate the design. CDC/NASTRAN was used to model the structure and 3 axis uncombined loads corresponding to 80g's were applied. Strength assessments of each structural member were made, including local buckling analysis and the loads through the bonded joints.

The results of this analysis indicated that there are positive margins of safety everywhere, for strength, stability and joint load transfer.

A detailed discussion of this analysis is contained in COI report number COI-80-067, Analysis of Microwave Limb Sounder.

6.0 ELEMENT FABRICATION

All of the elements comprising the support structure, with the exception of the angle ties, were fabricated from flat stock cures of GY-70/930. The angle ties were laminated and cured on aluminum tooling which had been machined to the angles required. All of the material was laminated in pseudoisotropic layups corresponding to the nominal thickness required. The angle ties and gussets at a thickness of 0.06 inches have a stacking sequence of (0,30,60,90,120,150)s and the remainder of the material at a nominal thickness of 0.08 inches, has a stacking sequence of plys at (0,45,90,135)2s.

The layups were cured at a nominal temperature of 250F in accordance with COI specification COMP-009 contained in Appendix 1.

A total of 7 cures were required to fabricate the composite material. Individual elements were machined from this material as shown in the following Table.

Element Cure Schedule

Cure #	Elements from Cure
1 - 3	Angle Ties
4	(a) Main Beam Assembly, All Components. (b) Flexure Interface Tabs, Qty. 22. (c) Diagonal Beam Webs, Qty. 2. (d) Diagonal Beam Bottom Cap strips, Qty. 5. (c) CTE Test Coupon.
5	(a) Flexure Interface Tabs, Qty 38. (b) Diagonal Beam Webs, Qty. 29. (c) Diagonal Beam Bottom Cap Strips, Qty. 27. (d) Diagonal Beam Top Cap strips, Qty. 26. (c) CTE Test coupons.

Element Cure Schedule (cont.)

Cure #	Elements from Cure
6	(a) Curved Beam Cap strips, All (b) Diagonal Beam Webs, Qty. 29. (c) Diagonal Beam Top Cap Strips, Qty. 26. (c) CTE Test Coupon.
7	(a) Curved Beam Webs, All. (b) Diagonal Beam Webs, Qty. 5. (c) CTE Test Coupon.

Work-In-Process Thermal Expansion Measurements. Thermal expansion measurement coupons were taken from each of the flat stock cures, numbered 4 through 7 above. The measurements of these CTE coupons provided a method of control and verification of the quality and thermal performance of the composite stock going into the support structure.

The results of these measurements are contained in the following Table and in Appendix 2.

Work-In Process CTE Results

Cure #	CTE @ R.T. (PPM/F)
4	+0.06
5	-0.04
6	-0.03
7	-0.05

Element Assembly. The graphite epoxy support structure consists of the following principal elements: the main beam, four curved beams, 36 diagonal beams, 60 tabs, and angle ties.

Each of these components were manufactured in accordance with detailed assembly procedures, contained in Appendix 3. A brief description of these operations is presented in the following paragraphs and the interested reader is referred to Appendix 3 for additional information.

Main Beam Assembly. The main beam is a box structure of 8 interlocking elements which attaches to the 4 curved beams and thereby supports the array of curved and diagonal beams. The top and bottom plates are curved to fit the nominal 240 inch radius of curvature of the antenna. It was fabricated entirely of flat stock which, in the case of the top and bottom plates, was deformed to the radius of curvature. The interlocking design allowed the assembly to be entirely self-fixturing, ie no assembly tools were required with the exception of clamping devices.

Each element of the main beam was machined to net dimensions prior to assembly except for the interfacing surfaces to the curved beams. These surfaces were match-machined to fit the curved beam locations during final assembly.

The structure was bonded together and then subjected to three thermal cycles between -100F and 30F. The thermal cycling improves the dimensional stability of the assembly by allowing internal stresses within the adhesive bonds to dissipate themselves before the assembly is attached to the remainder of the support structure.

Curved Beams and Diagonal Beams. The four curved beams, and the 36 diagonal beams were assembled, minus tabs, as separate units. The slots for the tabs in the inner cap plate were machined prior to bonding the cap plates to the web. The openings in the web to accommodate the diagonal beams were not machined at this time. After bonding the beams were also subjected to three thermal cycles between -100F and 30F.

7.0 ASSEMBLY

The goal during the assembly phase was to build up the support structure to match the aluminum tile flexure locations without introducing stresses into the tile flexures. To achieve this, the tiles were held in position on a spherical tooling fixture (JPL Dwg. 10091471) with a low temperature melting point wax. This tooling, with the tiles affixed, was assembled by JPL and delivered to COI for the final assembly of the support structure. Additional tooling, in the form of nylon pins was also provided by JPL. The pins were dimensioned to replace the fastener at the flexure-tab interface and hold the tab in alignment by maintaining concentricity between these two holes.

Additional tooling was made by COI to position and hold the curved beams with respect to the flexures. This tooling attached to the spherical base assembly fixture.

Initial Fitting. Each of the curved and diagonal beams were individually hand-machined to fit the corresponding flexures at each location prior to adhesive bonding of any elements of the structure.

The first step of this sequence was to fit the curved beams to the corresponding row of flexures. Each curved beam was held in position by the locating fixture and the tabs were numbered by location and held to the beam web by clamps. The beam position was then adjusted to provide a clearance of 0 to 3 mils between the outboard flexures and their interfacing tabs. The intermediate flexures were then bent, where necessary, to achieve a clearance of 0 to 3 mils with their tabs. This operation was monitored with dial indicators and the bending of the flexures in no case exceeded 0.02 inches.

After each curved beam was located in this manner, the intersections of the diagonal beams with the curved beams were marked on the curved beam webs. The openings were then machined and the diagonal beams were hand-fitted to match these openings with a clearance of about 10 mils. This clearance was achieved with the diagonal beams entirely supported by the corresponding flexures.

Adhesive Bonding. The structure was bonded together in the following manner with Hysol EA-934 structural adhesive. This adhesive has a pot life of about 40 minutes and will cure at room temperature in about ten hours (a post cure at 275F is required).

The tabs were first bonded to the beam webs. In the case of the curved beams, the tabs were bolted to the flexures with 3 mil shim stock between the flexure and tab to ensure this positive standoff distance between the flexure and tab. The tab-web bond line was then allowed to cure with no clamping force between the tab and web. Alignment variations of between 0 and 3 mils were then taken up in the bond line.

The diagonal beam tabs were bonded in a similar way except in this case the tab was clamped to the beam web with the beam properly indexed in the curved beam openings.

After the tab bond lines had cured at room temperature the clearance was rechecked at the diagonal to curved beam interface. The diagonal beams were then very lightly bonded to the curved beams at the top and bottom of the openings. This bond was intended to provide just enough strength for the beams to withstand the subsequent gusset bonding clamping forces without stressing the fab-flexure interface.

The gussets were then bonded in place, followed by the array of angle ties.

The main beam was then machined at the interface to match the curved beam locations and was bonded to the curved beams.

This completed the bonding operations.

Post Cure and Plating Preparation. The completed structure was then unbolted and removed from the tile flexures and assembly tooling. The entire structure was subjected to an adhesive post cure cycle of four hours at 275F.

The structure was then subjected to 7 thermal cycles between -100F to 30F to precondition the bonded joints.

At this point, the structure was lightly abraided by sandblasting, washed in an Alconox-water solution and thoroughly vacuum oven dried at 200F. It was then subjected to a visual examination and repair, where necessary, in preparation for the moisture barrier coating application.

8.0 MOISTURE BARRIER COATING

The moisture barrier coating reduces by orders of magnitude, the hygrodimensional response of the composite material by limiting the rate of moisture exchange of the epoxy matrix with the surrounding environment. This is accomplished by coating the exterior surfaces of the material with a metallic layer. The detailed procedures by which this is accomplished are considered proprietary to COI. The coating used on the graphite support structure has the following characteristics and composition.

The initial layer is electroless nickel deposited to a nominal thickness of 0.1 mils. The second layer is gold immersion plated to a thickness of 5-8 millionths of an inch. These coatings are rather porous and do not present a significant moisture barrier. The structure can, therefore, be dried under thermal vacuum conditions following these steps. This was accomplished with the support structure which was dried at 185F for 18 hours under a vacuum of about one torr.

The final coating on the support structure is Indalloy Number 8 from the Indium Corporation of America. This is a eutectic alloy of indium, tin and cadmium with a melting point of 200F.

Weights. Prior to plating, the graphite/epoxy support structure weight was 3079.9 grams. After plating the weight was 3291.7 grams.

9.0 FINAL ASSEMBLY

After the eutectic coating was completed and the structure was weighed, it was reassembled to the reflective tile flexures which were still attached to the assembly tooling. The assembly tooling was equipped with a screw mechanism for raising and lowering the structure with respect to the tiles. With this mechanism and dial indicators, between the structure and assembly fixture, it was possible to lower the structure in a uniform controlled manner while measuring the clearance between the tabs and flexures.

Teflon coated shim stock was placed between each flexure and tab interface to monitor the clearance and to guide the structure laterally into position. The structure was then bolted to the flexures and RTV was injected into the inner cavity of the bolt and allowed to cure.

This completed the assembly and the entire tool and antenna combination was shipped to JPL where the antenna was removed from the tooling.

10.0 RECOMMENDATIONS

We feel that serious consideration should be given to replacing the array of aluminum reflective tiles with a graphite epoxy reflective surface. Such a replacement would offer the following advantages:

1. Elimination of the thermal expansion mismatch between the support structure and the reflective surface. Both components would have a CTE of less than 0.1 PPM/F.

2. Allow the reflective surface to be a continuous member, ie not broken up into small segments (tiles).

3. The continuous graphite/epoxy reflector can be precisely mated to the supporting structure at a machined interface. The laborious task of fitting the support structure to the tile flexures would in effect be replaced by a machining operation in which the ends of the graphite/epoxy tabs are machined to a spherical radius of curvature, matching that of the reflective surface.

4. The reflector-support structure interface as described in (3) would yield: an improved stress-free transition, a more easily controlled and verifiable manufacturing operation and a reduction of manufacturing costs.

5. Lower thermal conductivity with an improvement in dimensional stability.

6. Reduced weight and moments of inertia. With a graphite/epoxy design, the reflective surface weight could be held to approximately one pound per ft.^{2} vs about three pounds per ft.^{2} for the current design. Additional weight could also be saved by reducing the sections of the support structure elements to match the lower loads in these elements.

We would propose that the reflective surface design incorporate a sandwich construction comprised of a front facesheet reflective surface, a lightweight interlocking core of graphite/epoxy, and a back capsheet matching the radius of curvature of the facesheet. All elements should be manufactured from ultra-high modulus graphite fibers such as GY-70 or P75S in a stable epoxy matrix of either 930 or an equivalent. The fibers would be required in a woven form in a balanced lightweight pattern. The face and back sheets would probably be 10-20 mils in thickness and would be cured on ultra-stable graphite tooling to the required radius of curvature. The constant depth would be machined to match this radius. Bonding of the face and backsheets to the core would be done on the graphite tooling as would the bonding of the support structure to the backsheet of the completed reflector.

We feel confident that a graphite/epoxy reflector of the required size for the MLS can be produced with a surface accuracy of one mil RMS or better.

APPENDIX 1.

a. Specification; Prepreg, Ultra High Modulus Tape.

b. Vendor Material Certification.

c. Vendor Adhesive Certification.

d. Bonding Procedures, EA-934 Adhesive

e. Cure Procedures, GY-70/X-30 Composite Systems.

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COMPOSITE OPTICS INCORPORATED SAN DIEGO, CALIFORNIA	SPECIFICATION NO. COS-79-005	REV
	DATE 21 Nov. 1979	
	CONTRACT NO.	

PREPREG, ULTRA HIGH
MODULUS TAPE

PREPARED BY [signature]

APPROVED BY [signature]

APPROVED BY ______________________

SPECIFICATION CHANGES

INCORP.	CHECK	APPROVED	DATE	REV	REV. PACKAGE	RELEASE

1.0 SCOPE.

This specification, together with the purchase order or procurement document applicable, establishes the requirements for epoxy impregnation of ultra high modulus, graphite filament tape. In instances where the purchase order or procurement document is in variance or modifies the detail requirements of this specification, the instruction of the purchase order or procurement document shall take precedence over those of the specification .

2.0 APPLICABLE DOCUMENTS.

The following documents form a part of this specification to the extent specified herein.

Composite Optics Specifications.

COS-77-003 Procedures and methods for test of Graphite epoxy prepreg and Laminates. Specification for.

Military Specifications.

MIL-B-131 Barrier Material: Water Vaporproof, Flexible.

Publications.

General Industry Safety Orders, State of California, Department of Industrial Relations, Article 85, "Labeling of Injurious Substances".

Manufacturing Chemists Association, Labels and Precautionary Information Committee. "Guide to Precautionary Labeling of Hazardous Chemicals". Manual L1.

3.0 REQUIREMENTS.

3.1 Material. The material shall consist of ultra-high modulus graphite filament impregnated with a catalyzed epoxy resin. The material may be supplied as a continuous length of tape of a specified width or broadgoods of a specified length and width.

3.2 Prepreg Physical Properties. The uncured prepreg shall meet the following requirements when tested according to the applicable paragraphs of COS-77-003.

a. Volatile Content - 2% by weight maximum.

b. Resin Solids - 40 ± 3% by weight.

c. Resin Flow - 15 to 30% by weight.

d. Tack - 30 minutes adherence.

e. Drape - No breaking, splitting or tear.

3.3 Prepreg Cosmetics. There shall be no splices in the tows or tapes. Gaps between tows, twists in the tows and overlaps of tows shall be to a minimum and shall not degrade the mechanical properties.

3.4 Resin Identification. The supplier shall provide COI with a reference spectrum of his impregnating resin taken over a range of 2.5 through 15.0 microns. An IR spectrum analysis shall be made from a sample of each resin premix lot and compared with the reference spectrum. The sample shall produce results which have the same peaks as the reference spectrum.

3.5 Laminate Properties.

3.5.1 Mechanical and Physical Properties. Test laminates prepared from the prepreg lot in accordance with COS-77-003 shall meet the physical and mechanical property requirements of Table 1 or Table 2.

3.5.2 Test Value Normalization. Laminate test values shall be normalized to 60% fiber volume for comparison with the requirements of Tables 1 and 2 by multiplying the test value by the factor:

(60%/Actual Fiber Volume, %)

3.6 Reports. With each batch or shipment of prepreg, the supplier shall furnish two copies of the certified acceptance test results specified in paragraph 4.6.

TABLE 1. MECHANICAL AND PHYSICAL PROPERTIES OF CURED 8 PLY PSEUDOISOTROPIC LAMINATES

(All data except fiber volume and short beam shear normalized to 60% Fiber Volume)

	PROPERTY	MINIMUM AVG. VALUE	MINIMUM VALUE	AVERAGE VALUE*
a.	Longitudinal Tensile Strength, ksi.	28.0	26.0	(35.0)
b.	Longitudinal Tensile Modulus, Msi.	14.0	13.7	(15.4)
c.	Longitudinal Flexural Strength, ksi.	42.0	40.0	(45.0)
d.	Short beam Shear Strength, ksi.	3.6	3.6	(4.5)
e.	Resin Content, % by Weight.	33	33	(31)
f.	Fiber Volume, %.	57.0	57.0	(60.0)
g.	Cured Ply Thickness, inches.	0.0055		(0.0065)
h.	Microstructure.	Essentially void free and without inter or translaminar fractures.		

TABLE 2. UNIDIRECTIONAL LAMINATE PROPERTIES

	PROPERTY	MINIMUM AVG. VALUE	MINIMUM VALUE	AVERAGE VALUE
a.	Tensile Strength, ksi.	95	90	109
b.	Tensile Modulus, Msi.	40	39	42.5
c.	Flexure Strength, ksi.	95	90	109
d.	Short Beam Shear Strength, ksi.	8	7.5	9.7

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4.0 QUALITY ASSURANCE TESTS

4.1 On-Site Inspection. The supplier shall allow witness by COI or COI customer representatives of any or all testing performed to establish compliance with this specification. In such instances, a minimum of 48 hours prior notice of the on-site inspection requirement will be provided.

4.2 Test Responsibility. The supplier shall be responsible for the performance of all acceptance inspections and tests called for by this specification. In the performance of such tests, the supplier may use his own facilities or any certified commercial laboratory. COI reserves the priviledges of repeating any or all of the prescribed testing as may be necessary to assure that the material conforms to the requirements of the specification.

4.3 Inspection Certification. The supplier shall maintain records of all inspections and tests performed to establish compliance with the requirements of this specification and shall make such records available to COI or COI customer representatives. Certified records of test results shall be provided to COI as indicated herein.

4.4 Fiber Properties. Fiber supplier information consisting of ultimate tensile strength, modulus, density, original spool number and lot number of yarn shall be furnished to COI for each roll or section of roll impregnated.

4.5 Qualification Tests. Qualification tests shall consist of all of the tests and examinations specified herein.

4.6 Acceptance Tests. Prepreg acceptance tests shall consist of resin verification per paragraph 3.4 and the following tests performed in accordance with COI-77-003.

a. Volatiles content.
b. Resin solids content.
c. Resin flow.
d. Tack
e. Drape
f. Longitudinal Flexural Strength.
g. Short Beam Shear Strength.

The results of these tests shall be within the limits specified by Table 1 and Table 2.

4.7 Receiving Inspection Tests. Receiving inspection tests shall be performed by COI and, as a minimum, shall consist of the following:

a. Laminate Longitudinal Tensile Strength.

b. Laminate Longitudinal Tensile Modulus.

c. Fiber Volume.

d. Microstructure.

The results of these tests shall be with the range specified in Table 1 and Table 2.

4.8 Quality Assurance Sampling Plan. Sample material for testing shall be taken from each order as a function of lot or number or rolls as defined by Table 3. A lot shall be defined as the product of one manufacturing run or order produced under relatively stable and continuous conditions. A roll shall be defined as one continuous section of prepreg weighing up to approximately 9 pounds, and separately packaged.

4.9 Rejection and Retreat. If a sample fails to meet the requirements of this specification, new material may be prepared and tested. If test of the new samples again fails to meet the specifiction requirements, the quantity of prepreg represented by the samples shall be rejected.

5.0 DELIVERY PREPARATION, HANDLING AND STORAGE

5.1 Prepreg Carrier Sheet. The prepreg shall be backed with and rolled with a thin plastic or equivalent carrier sheet of width greater than of the prepreg. The carrier material will be such that the prepreg will adhere to it but be easily removable by technicians working at room temperature (70°F ± 10°F) without distortion or mis alignment of yarn. Previsions shall be made to prevent the surface of the prepreg from adhering to the back of the carrier sheet as it is rolled or unrolled. The carrier/prepreg sheet in combination shall be such that they are easily cut with conventional paper cutting devices.

TABLE 3. PREPREG QUALITY ASSURANCE SAMPLING PLAN

TEST OR INSPECTION	NUMBER OF ROLLS SAMPLED PER LOT	NUMBER OF SAMPLES PER ROLL
Prepreg Quality	100% visual exam.	-
Resins Solids Content	All rolls	3
Volatiles Content	20%	3
Resin Flow	20%	3
Tack	20%	3
Drape	20%	3
* Flexural Strength	10%	5
* Shear Strength	10%	5
* Tensile Strength	10%	5
* Cured Ply Thickness	20%	5
* Microstructure	20%	4 from each Test panel
* Thermal Performance	20%	1 - 0°, 1 - 90°(Iso panel)
* Fiber Volume	20%	2 - from CTE specimens

Notes: Average values of multiple samples shall be reported.
* Properties of laminates prepared and tested per COS-77-003.

The number of rolls sampled per lot shall be randomly selected.
Fractional numbers of rolls in percentage determination shall be interpreted as the next highest whole number.

5.2 Prepreg Life. The prepreg shall be capable of meeting the requirements of this specification after storage for 90 days after delivery in a sealed package at 0°F with intermittent or continuous exposure to 75±10°F for seven days while in a sealed, moisture-proof bag. If not sealed in a bag during the 75±10°F exposure, the exposure time, after which specification values shall be met, is reduced to 72 hours cumulative.

5.3 Prepreg Storage. Prepreg shall be stored in a moisture-proof bag at a temperature of 0°F or lower. Rolls shall be stored with the axis of the roll vertical and with no side pressure acting on the roll. When material is removed from storage for inspection.use, the sealed material shall be allowed to warm to a temperature where moisture condensation is avoided before the sealed bag is opened. Material not immediately necessary for operations shall be resealed and returned to storage as quickly as possible.

5.4 Storage History. A log of the storage history of each prepreg roll shall be maintained. Material that has exceeded the storage time allowed shall be retested to show conformance to the requirements for resin flow, tack and drape.

5.5 Packaging for Delivery. The individual prepreg rolls shall be wrapped in a manner preventing their loosening on the spool and sealed within a moisture proof bag per Specification MIL-B-131. The bag shall be designed to allow a minimum of 4 cycles of opening, prepreg removal and return and resealing before bag replacement becomes necessary. Each sealed prepreg roll shall be marked or tagged with the following information:

a. COS-77-005.
b. Supplier's designation.
c. Supplier's name.
d. Supplier's Lot and Section (roll) identification.
e. Date of manufacture.
f. Lineal length of fully conforming prepreg within the roll.
g. Recommended storage conditions.
h. Hazardous warnings as applicable.

9950-484 JPL MTL

PHONE (507) 454 3611

FIBERITE CORPORATION

CERTIFICATION

hy-E® By FIBERITE

(Composite Optics)
Jet Propulsion Laboratories
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91103

MAIN OFFICE 501 WEST THIRD ST.
WINONA, MINNESOTA 55987

Date: March 3, 1980

ATTENTION: R. S. Howitt

Gentlemen:

We certify that Fiberite hy-E 1530 tape ordered on your Purchase Order KS-717781 has been tested in accordance with the applicable specification procedures and found to possess the following properties, therefore meeting the requirements of COS-77-003 & COS-79-005 specification.

Quantity Shipped On 3/3/80	15.5#		
Lot No.	CO-349		
Roll No.	1	2	3
Tape Size, Inches	3.0	3.0	3.0
Resin Solids, %	42.3	42.0	42.4
Volatile Content, %	1.0	0.9	0.9
Laminate Flow, % @ 100 p.s.i.	16.0	15.0	19.7
Gel Time, Minutes @ 163°C	14.6	14.4	14.5
Tack	Pass	Pass	Pass
Drape	Pass	Pass	Pass

Specific Gravity	
Tensile Strength (p.s.i.)	122,887*
Tensile Modulus (10⁶ p.s.i.)	45.91*
Flexural Strength (p.s.i.)	145,073*
Flexural Modulus (10⁶ p.s.i.)	
Compression Strength (p.s.i.)	
Horizontal Beam Shear (p.s.i.)	8,864
Cured Ply Thickness, Inches	.00493
Date of Manufacture:	2/19/80
Shelf Life	6 months @ 0°F Max.
Ref: Packing List No.:	013500

* Values normalized to 60% fiber volume

I.R. scan attached

9950-404

PHONE (507) 454 [illegible]

FIBERITE CORPORATION

515 WEST THIRD
WINONA, MINNESOTA

hy-E® By FIBERITE

Hy-E Tape Inspection Sheet

Hy-E 7630
Lot No [illegible]
Roll No 3
Project No 13-4156
Date 2-19-80
Remarks:

Total Weight 65#
Total Length 480'
Length Allowance 13'
Weight Allowance 2#
Net Weight 63#
Net Length 467'

DEFECT CODE

- A. Fullsplice
- B. Towsplice
- C. Contamination
- D. Dry Area
- E. Fisheye
- F. Wrinkle
- G. Crossover
- H. Gaps
- I. Buckle
- J. Pucker
- K. Width
- L. Heavy
- M. Missel
- N. Other

Location [illegible]	Tape Width, in	Defect (See Code)	Defect Length	Defect Location	Remarks
0	3"				
12	2 3/4"	K	5'		
24	2 3/4"	K	30"		
118	3"	K	1'		
127	3"	"	18"		
178	2 3/4"	K	1'		
182	2 3/4	K	2'		
480	END				

9950-484

PHONE (507) 454-3611

FIBERITE CORPORATION

515 WEST THIRD ST
WINONA, MINNESOTA

hy-E® By FIBERITE

Hy-E Tape Inspection Sheet

Hy-E: 1570
Lot No.: CU-379
Roll No.: 2
Project No.: 17-4156
Date: 2-19-80
Remarks:

Total Weight 4.5#
Total Length 352'
Length Allowance 5'
Weight Allowance .1#
Net Weight 4.4#
Net Length 347'

DEFECT CODE

A. Fullsplice
B. Towsplice
C. Contamination
D. Dry Area
E. Fisheye
F. Wrinkle
G. Crossover
H. Gaps
I. Buckle
J. Pucker
K. Width Variation
L. Heavy Resin
M. Misalignment
N. Other (note)

Location FT	Tape Width, in	Defect (See Code)	Defect Length	Defect Location	Remarks
0	3"				
1	2 3/4"	K	5'		
352	END				

9950-484

PHONE (507) 454-3611

Hy-E® By FIBERITE

FIBERITE CORPORATION

515 WEST THIRD ST.
WINONA, MINNESOTA 55987

Hy-E Tape Inspection Sheet

Hy-E: 1570
Lot No.: CO-249
Roll No.: 1
Project No.: 17-4156
Date: 2-19-80
Remarks.

Total Weight 5.6#
Total Length 396'
Length Allowance 62' 6"
Weight Allowance .5#
Net Weight 4.5#
Net Length 335' 6"

DEFECT CODE

A. Fullsplice
B. Towsplice
C. Contamination
D. Dry Area
E. Fisheye
F. Wrinkle
G. Crossover
H. Gaps
I. Buckle
J. Pucker
K. Width Variat...
L. Heavy Resin
M. Missalignme...
N. Other (note)

...ation FT	Tape Width, in.	Defect (See Code)	Defect Length	Defect Location	Remarks
0	3"				
5	3"	H	1'		
?	3"	D-H-K	12'		
	2 7/8	K	8"		
	2 7/8	K	3'		
?	2 7/8	K	5"		
	2 ¾	K	10'		
	3"	D-H	3'		
	2 7/8	K	7'		
	3"	H+K	12'		
	3"	H	6'		
(	3"	H	8'		
	3"	H	9"		
	3"	H	5"		
?	END				

PURCHASE ORDER NO. - 7003
CERTIFICATION DATE 04-18-80
ORDER DATE: 04-18-80 PACKING LIST 34559

HYSOL EA 934 A/B 1 LB
MANUFACTURED BY HYSOL DIV.
LOT: CWAS91061. DOM: 03-80.
S.L. 3 MOS @ 80 /12 MOS @ 40 FROM DOS

Ray Darby
RAY DARBY, QUALITY CONTROL MANAGER

THIS IS TO CERTIFY THAT MATERIAL LISTED SHIPPED AGAINST THIS PURCHASE ORDER WAS MANUFACTURED IN ACCORDANCE WITH STANDARD SPECIFICATIONS AND QUALITY CONTROL PROCEDURES. THIS INFORMATION IS BASED ON DATA RECEIVED FROM THE MANUFACTURER. HOWEVER NO WARRANTY IS EXPRESSED OR IMPLIED. THE USER SHOULD CONDUCT HIS OWN TEST TO DETERMINE THE SUITABILITY OF THIS MATERIAL FOR HIS PARTICULAR APPLICATION

E. V. ROBERTS & ASSOCIATES
DIVISION EVRA, INC.
8500 STELLER DRIVE · CULVER CITY, CA. 90230
213-870-9561

9950-484

COMPOSITE OPTICS INCORPORATED SAN DIEGO, CALIFORNIA	SPECIFICATION NO. COMP-012	REV
	DATE 27 SEPTEMBER, 1977	
	CONTRACT NO.	

PREPARATION AND USE OF EA-934 ADHESIVE IN COMPOSITE BONDING OPERATIONS

-

General Procedure For:

PREPARED BY [signature]

APPROVED BY [signature]

APPROVED BY ______________________

SPECIFICATION CHANGES

INCORP.	CHECK	APPROVED	DATE	REV	REV. PACKAGE	RELEASE

Unless otherwise specified by Traveler or engineering directive, the following procedures shall be observed in the preparation and application of EA-934 adhesive in composite material assembly operations.

1. Material: EA-934 Parts A/B Structrual Adhesive
   Hysol Division - The Dexter Corp.
   Pittsburg, CA 94565

2. Mixing:
   2.1 Mixing Ratio - 33% Catalyst by weight (part B)
   2.2 Mixing Temp - 75±10°F
   2.3 Mixing Time - Dependent on amount - but in no case shall be shorter than five (5) minutes.

3. Shelf Life: Twelve (12) months from date of manufacture.

4. Storage:
   4.1 Parts "A" and "B" shall be stored at 40±10°F until ready for mixing. Both components shall be 75±10°F prior to mixing.
   4.2 After mixing, adhesive may be put in syringes or small containers. These syringes/containers must be stored below 0°F until ready for use. Caution shall be used to seal syringes/containers from moisture. Each syringe/container shall be identified as to batch and preparation date. Mixed components may be kept for a maximum of two (2) months.

5. Pot Life: The adhesive maybe used as long as consistency is such that it is workable, but in no case longer than forty (40) minutes after mixing.

6. Cure Cycle: All joints shall be exposed to a minimum of (4) hours at 120F. Adhesive maybe allowed to cure at room temperatures. All evaluated temperature exposures will be monitored.

7. Joints
   7.1 All areas to be bonded shall be abraided and cleaned with Methyl Ethyl Keytone, Acetone or Alcohol. The abraided area is to include the estimated fillet area.
   7.2 Bond line thickness not to exceed .015 inches.

7.3 All bond fillets shall be cleaned and struck with Methyl Ethyl Keytone, Acetone or Alcohol applied with cure tip or appropriate absorbent material, prior to adhesive settings.

7.4 Fillet size shall not exceed .04 radius. This requirement my be negated in particular cases by Cognizant Engineering personnel.

7.5 Once the bond has been cured it is acceptable to apply more adhesive if required. The cure cycle shall be repeated for all added adhesive.

7.6 If feasible a minimum of 5 PSI pressure shall be applied to all bond joints.

9950-404

COMPOSITE OPTICS INCORPORATED SAN DIEGO, CALIFORNIA	SPECIFICATION NO. COMP-009	REV
	DATE 23 SEPTEMBER 1977	
	CONTRACT NO.	

CURE PROCEDURE FOR GY-70/X-30 COMPOSITE SYSTEM

PREPARED BY

APPROVED BY

APPROVED BY

SPECIFICATION CHANGES

INCORP.	CHECK	APPROVED	DATE	REV	REV. PACKAGE	RELEASE

CURE PROCEDURE FOR GY-70/X-30 COMPOSITE SYSTEM

Laminates will be cured using the following procedures:

1. A minimum of 24"Hg. will be maintained throughout the cure. If no constant recording device exists, vacuum shall be read off of a gauge and recorded in intervals of no more than 10 minutes prior to pressure application and at intervals not exceeding 20 minutes thereafter. A maximum of 3"Hg. drop in 3 minutes is allowed.

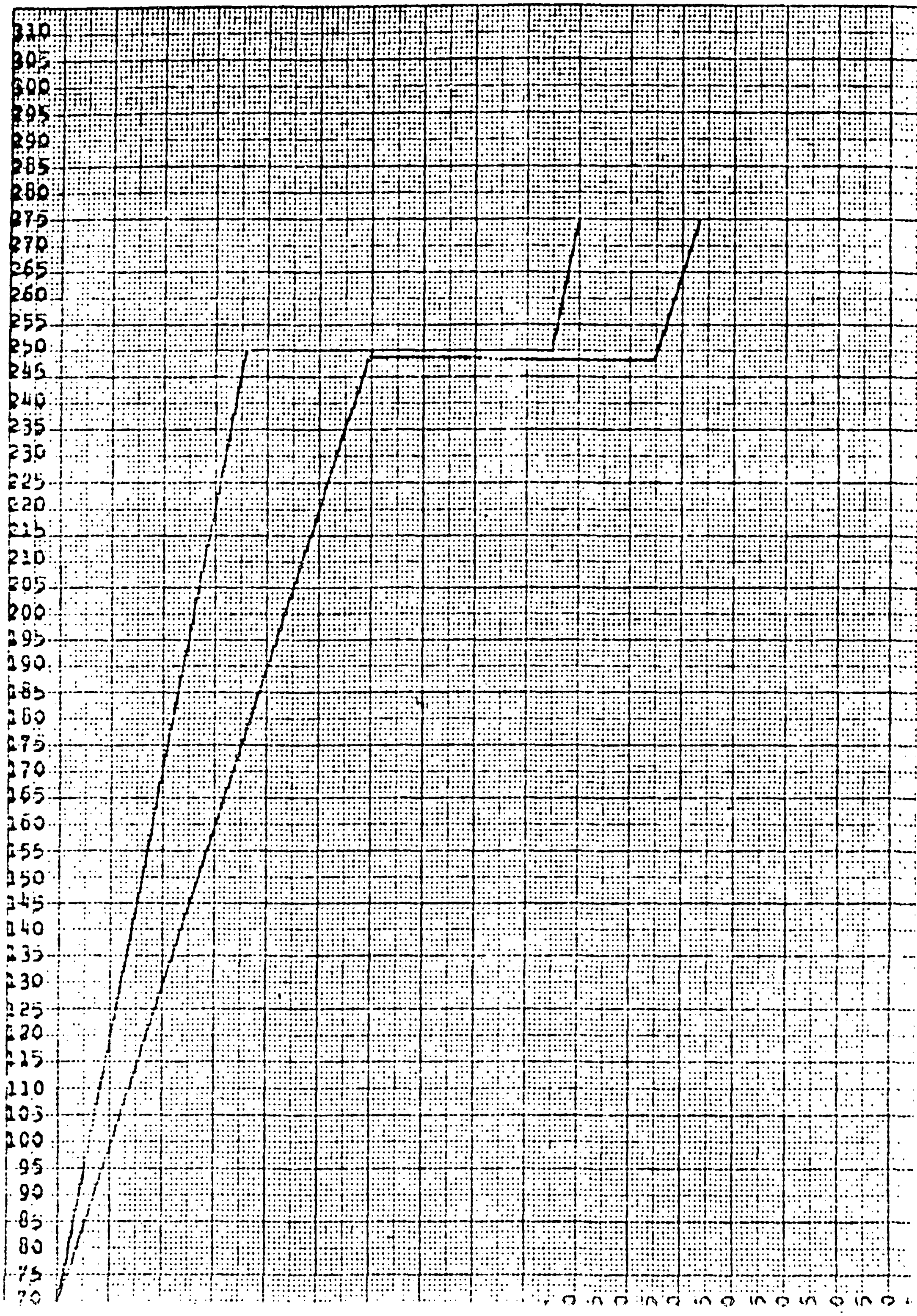
2. A minimum of two (2) part, two (2) tool and one (1) ambient thermocouples will be used for each part. Each thermocouple will be tested to be accurate to within $\pm 3°$ at 212°F.

3. Under vacuum, heat part at a rate of 3-5°F per minute to 250 ± 5°F, hold 30 minutes, apply 100 psig pressure and hold an additional 30 minutes. Heat part at a rate of 3-5°F per minute to 275^{+10}_{-5}°F, hold a minimum of two (2) hours, part temperature shall be recorded at intervals of no more than 10 minutes prior to reaching 275°F and no more than 20 minutes after 275°F obtained.

4. The part shall cool down under vacuum and 100 psig pressure to below 175°F. This requirement shall not apply to parts of an internal nature requiring removal from tool while hot. Precautions shall be taken not to allow rapid cooling of parts removed above 175°F.

5. All temperature data shall be recorded on an automatic printing device or on form COMP-009-A.

COMP-009-A



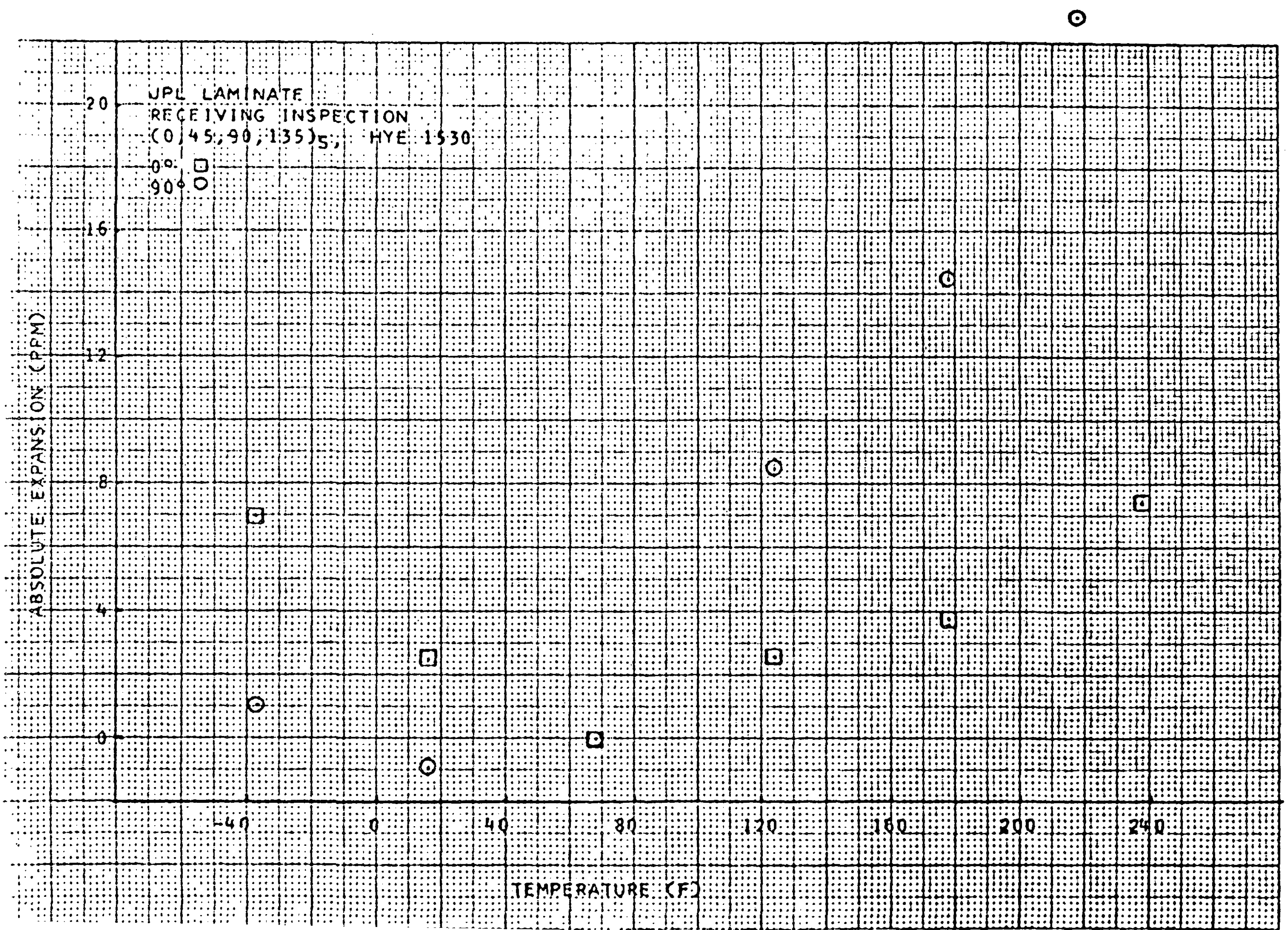
46 1516

K-E

APPENDIX 2.

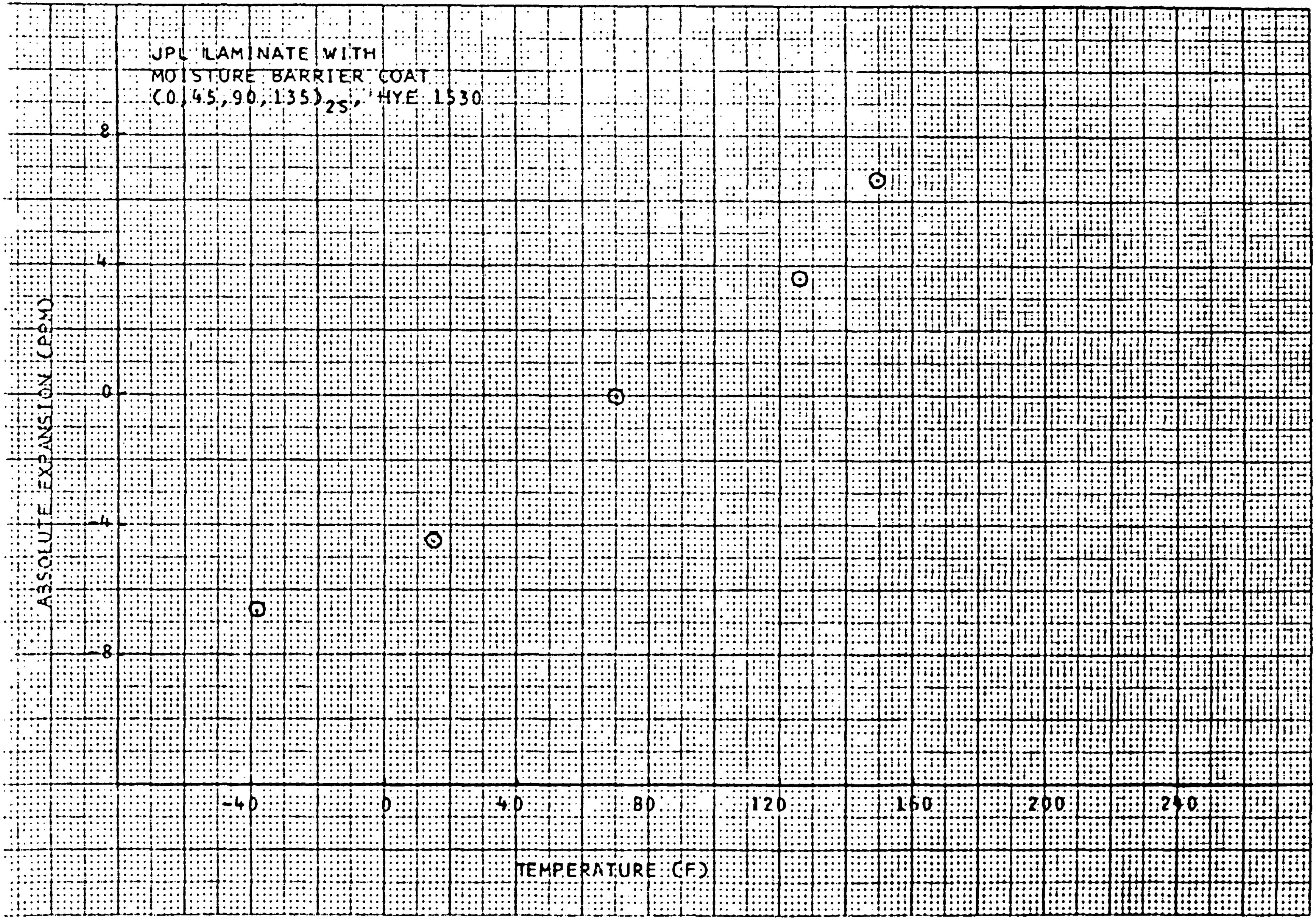
a. Receiving Inspection Thermal Expansion Data.

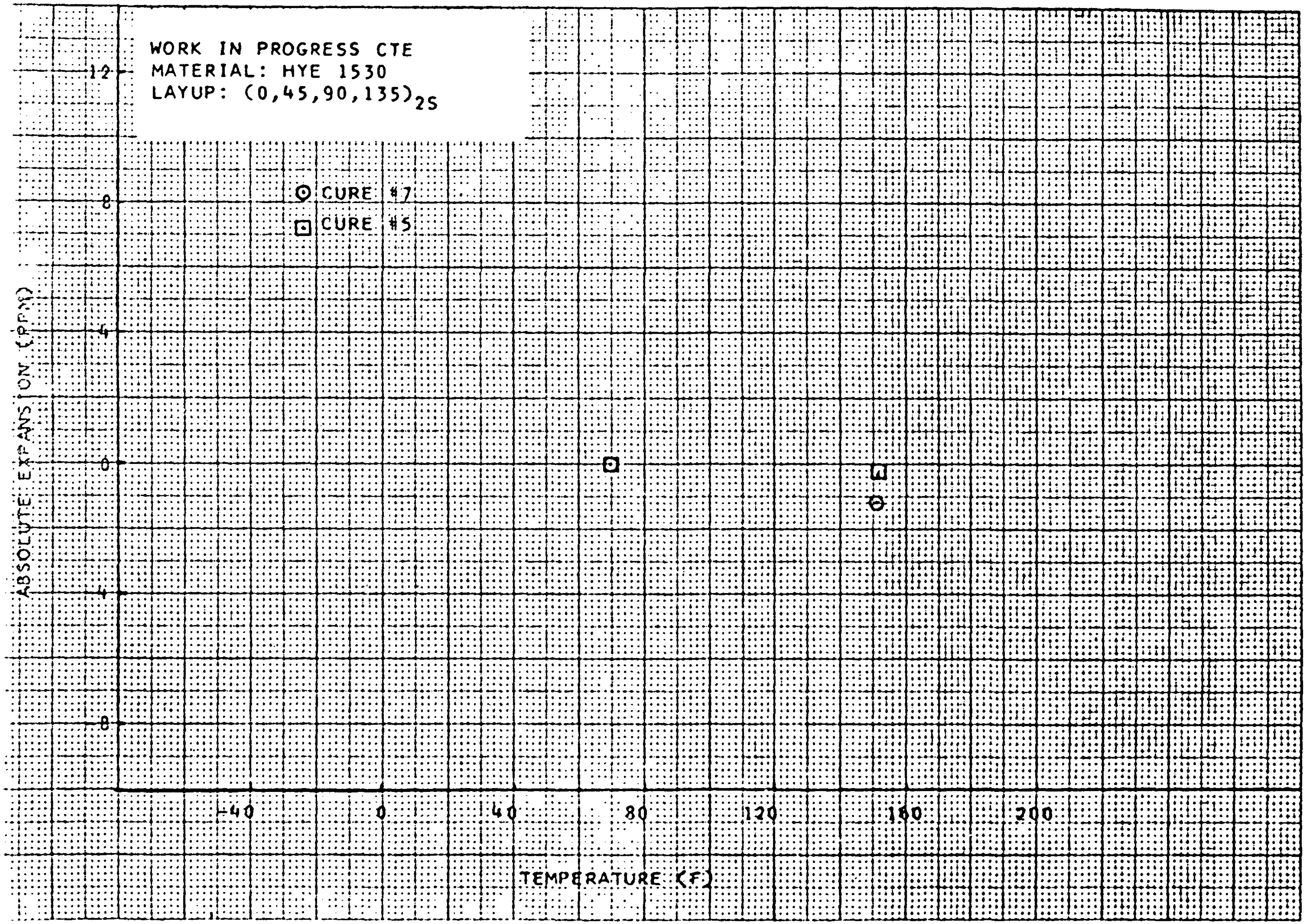
b. Work in Process, Thermal Expansion Data.


JPL LAMINATE
RECEIVING INSPECTION
(0,45,90,135)5, HYE 1530
0° □
90° ○
ABSOLUTE EXPANSION (PPM)
20
16
12
8
4
0
-40
0
40
80
120
160
200
240
TEMPERATURE (F)

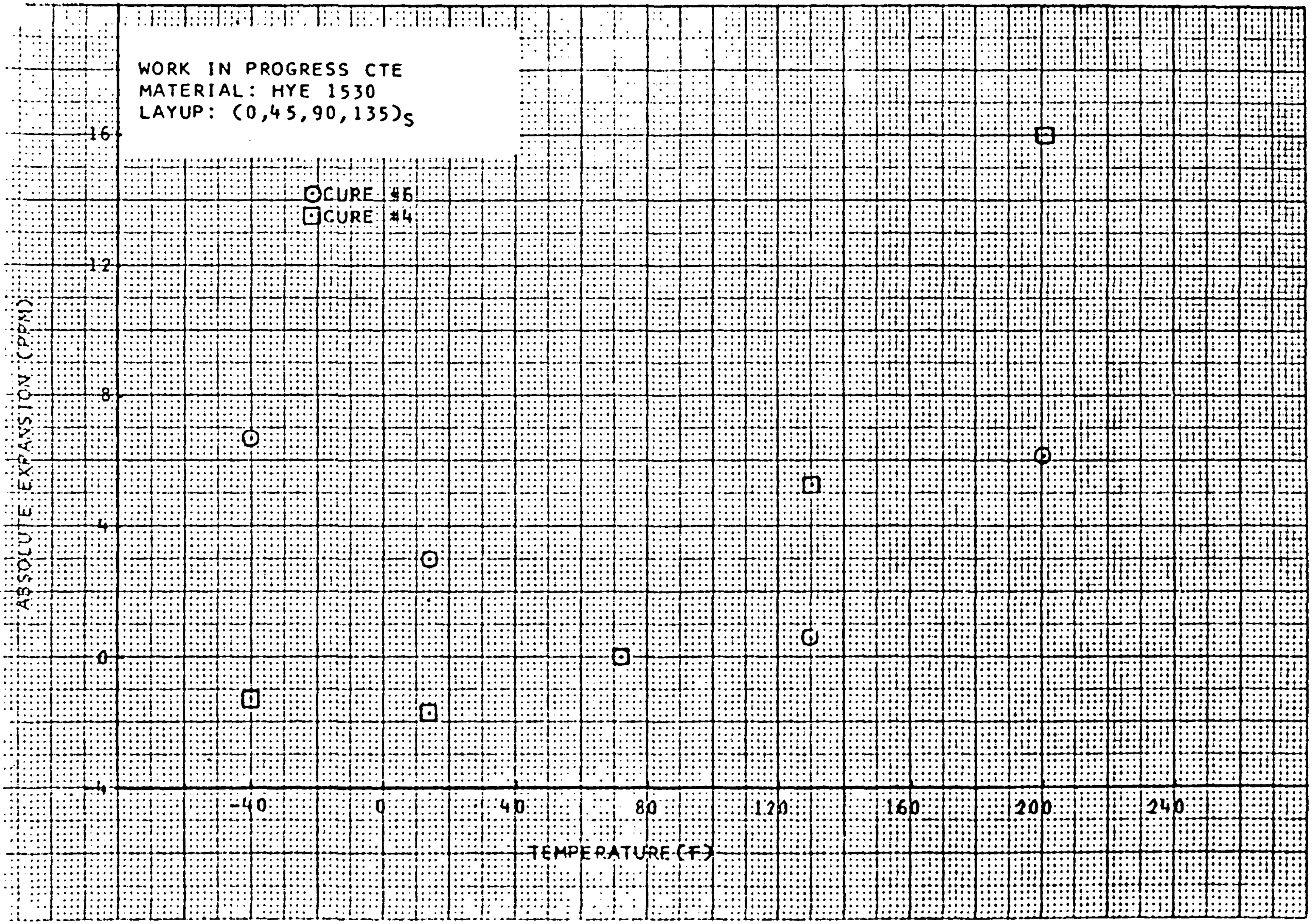
K·E 10 X 10 TO ½ INCH KEUFFEL & ESSER CO.

46 1320





WORK IN PROGRESS CTE
MATERIAL: HYE 1530
LAYUP: (0,45,90,135)2S
CURE #7
CURE #5
12
8
4
0
4
8
-40
0
40
80
120
160
200
TEMPERATURE (F)
ABSOLUTE EXPANSION (PPM)



WORK IN PROGRESS CTE
MATERIAL: HYE 1530
LAYUP: (0,45,90,135)S
CURE #6
CURE #4
16
12
8
4
0
-4
-40
0
40
80
120
160
200
240
TEMPERATURE (F)
ABSOLUTE EXPANSION (PPM)

APPENDIX 3.

ASSEMBLY PROCEDURES

9950-48

COI Specification
COS 80-006

ASSEMBLY PROCEDURES,
JPL GRAPHITE/EPOXY
LIMB SOUNDER SUPPORT
STRUCTURE

Prepared For:

THE CALIFORNIA INSTITUTE OF TECHNOLOGY

JET PROPULSION LABORATORY

By:

COMPOSITE OPTICS, INCORPORATED
SAN DIEGO, CALIFORNIA

Prepared By G E Pynchon
G. E. Pynchon (COI)

Approved By ____________________
(JPL)

1.0 INTRODUCTION This document sets forth the detailed procedures which will be followed in fabricating the JPL graphite epoxy structure, under JPL contract number 955701. When approved by JPL, it will become the effective statement of work for this phase of the contractual effort.

2.0 MATERIALS Unless stated otherwise, the structural material used to fabricate the support structure is GY-70/X-30 (Fiberite HyE 1530) graphite epoxy laminates. These laminates will be cured in pseudoisotropic laminates, the ply orientation of which will be determined by a structural analysis. It is assumed in these procedures that this material has been cured per COI standard autoclave procedures and defines the point of departure for these instructions. Unless otherwise stated the adhesive system will be EA-934 manufactured by Hysol.

3.0 SPECIFICATIONS The following specification are applicable to these assembly procedures:

1. COMP-012 Preparation and use of EA-934 adhesive in composite bonding operations.

4.0 ENVIRONMENTAL CONDITIONS All of the following operations will be performed under laboratory ambient conditions unless otherwise stated. The structure and all composite materials will be stored in a dessicated dry box when not required for assembly and during all non-working hours. The dry box time shall not be less than 12 hours of each day.

5.0 ASSEMBLY TOOLING AND FIXTURES The assembly tooling and fixtures consist of the following, in addition to the JPL furnished assembly base:

1. Curved beam locations fixtures.
2. Diagonal beam templates.
3. Diagonal beam locating fixture.

5.1 Curved Beam Locating Fixture

The curved beam locating fixture, shown in Figure 1 mounts to the JPL assembly base and provides an adjustable mounting and support location for each of the curved beams.

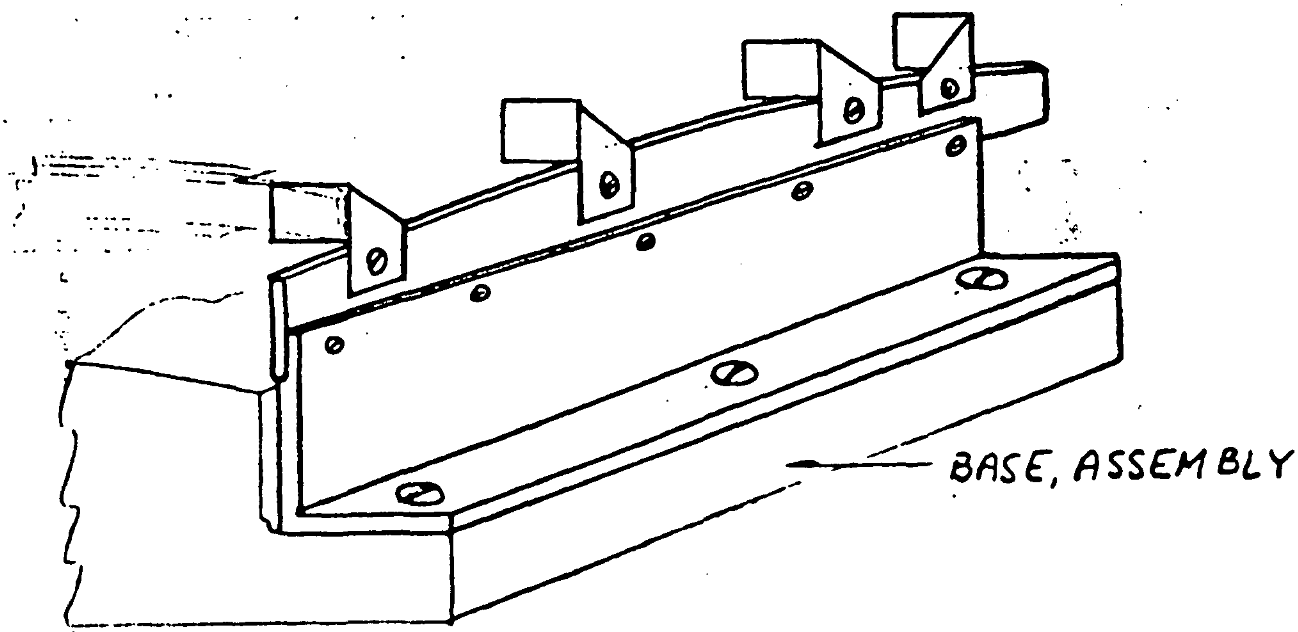


Figure 1. Curved Beam Locating Fixture

5.2 Diagonal Beam Templates
The diagonal beam templates, shown in Figure 2, are positioned on the diagonal flexures in place of the diagonal beams and are used to locate and mark the points of intersection these elements make with the curved beams. They are therefore shorter than the diagonal beams so they fit between the curved beams.

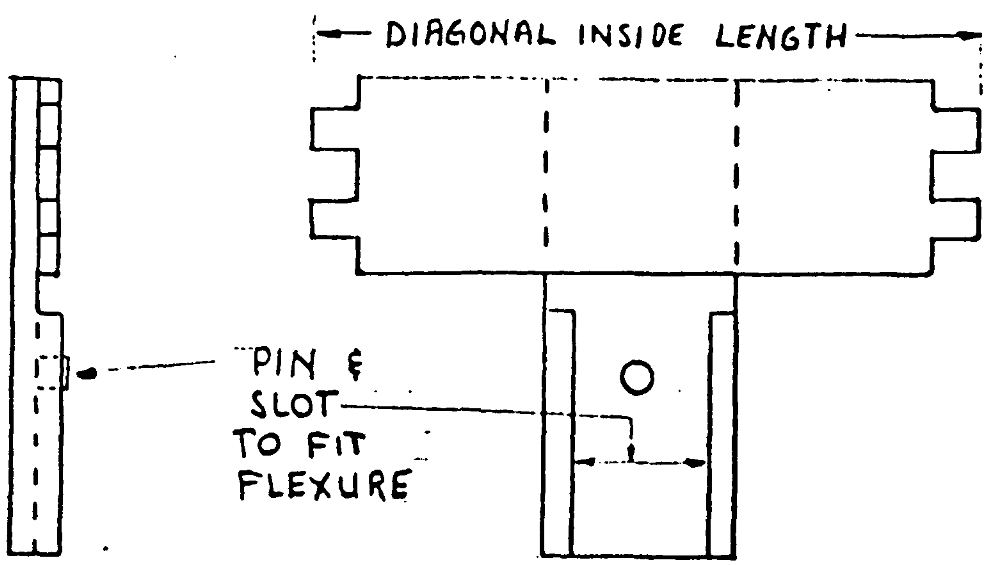


Figure 2. Diagonal Beam Templates

5.3 Diagonal Beam Locating Tool
This tool is positioned in place of a curved beam to facilitate the fitting of the diagonal beams as shown in Figure 3.

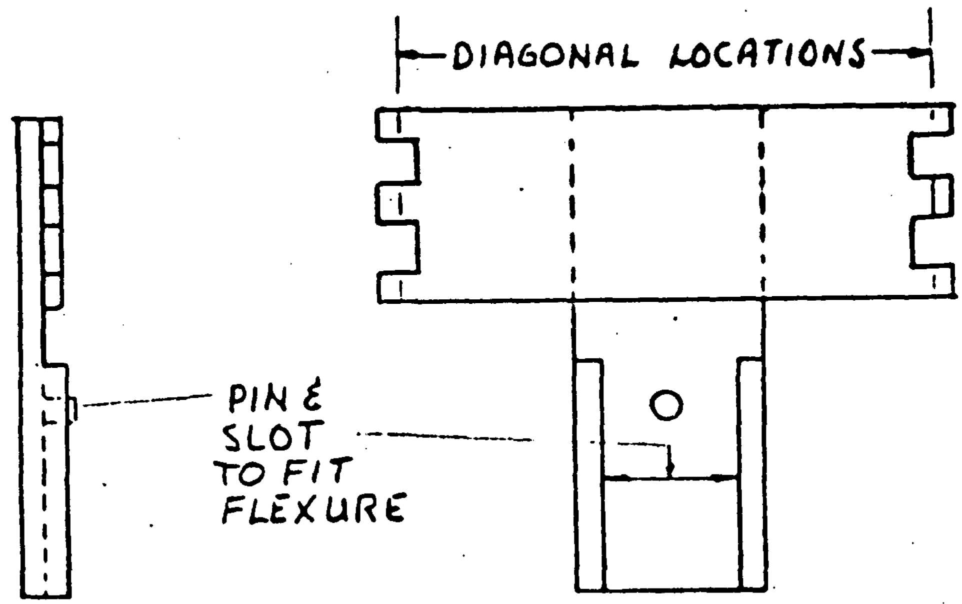


Figure 3. Diagonal Beam Locating Tool

6.0 COMPONENT ASSEMBLY The main beam, curved beams diagonal beams, and detailed parts will be fabricated as sub-units as described below.

6.1 Main Beam Assembly

1. Rout all elements to net size except the surfaces which mate with the curved beam webs. These surfaces will be left 1/8 inch oversized.

2. Fit check the assembly of the main beam filing and sanding to fit - principally at locations where router radius leaves an interference fit. Structure is self fixturing upon assembly.

3. Clean all surfaces in preparation for bonding using MEK or acetone and cotton swabs.

4. Support one side in the fixture which will hold it in its normal vertical position.

5. Bond all bulkheads to this side.

6. Bond the top cap to the side and bulkheads.

7. Clean all excess adhesive from the fillets, clamp all elements together and allow the adhesive to cure at R.T.

8. Bond the remaining side and the bottom cap plate to the assembly.

9. Cure the bonds (entire assembly) at 175$\pm$5F for 4 hours.

10. Subject the main beam assembly to 3 thermal cycles between 65F and 150F.

6.2 Curved Beam Assembly

1. Machine the beam cap plates and the flexure attachment tabs to final dimension using routing templates and standard machine practices. Machine the beam webs 1/2 inch oversize in length in each direction. Drill 1/8 inch holes at the locations where the diagonal beams will penetrate the curved beam webs. Note the desired orientation of the caul plate side of each of these elements as shown in Figure 4.

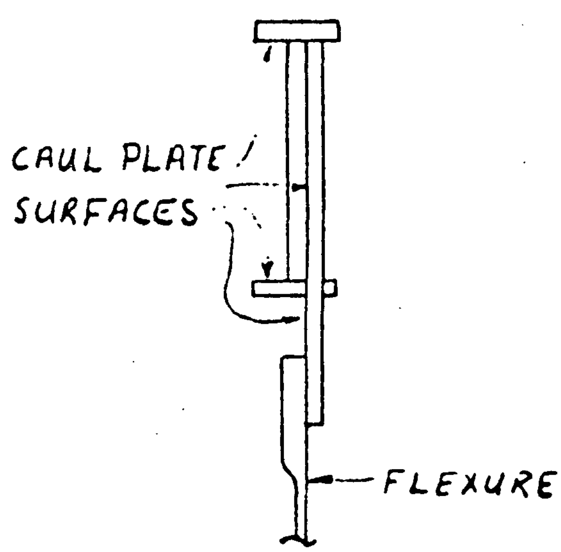


Figure 4. Cross Section of Beams at Flexure Locations.

2. Position 8 tooling blocks 1"X 1"X thickness (TBD) on a flat granite table. The thickness is equal to the cap plate extension from the caul plate surface of the web. Place the web on the tooling blocks with the caul plate surface in contact with the blocks which are located at each tab location and at each end of the web. Weight or clamp the web as necessary at each tab location to hold the web flat.

3. Bond the caps to web indexing the lower surfaces against the granite table. Clamp the caps to the web and then pick the beam up to clean the fillets. Reposition the beam to the blocks and check the fit and correct as necessary.

4. Allow the adhesive to cure at R.T. or apply heat with a heat gun to kick the adhesive into a cured state.

5. Cure at 175F for an additional 4 hours.

6. Subject to 3 thermal cycles between 65F and 150F.

6.3 Diagonal Beam Assembly

1. Machine the diagonal caps, webs and tabs to size using routing templates and standard machine practices. At this time the tabs will be machined to final dimension. The web and caps will be machined to final width but will be left oversized in length and the indexing tabs will not be machined on the webs.

2. The remaining machining operations on the diagonal beams will be accomplished during final assembly.

6.4 Detail Parts

1. Rout all of the angle ties and gussets to final dimension.

7.0 STRUCTURAL ASSEMBLY The structural assembly will be built up from the tiles while they are mounted to the assembly fixtures, (JPL Dwg. 10091471).

The curved beam locating fixtures will be attached to the assembly fixture to locate and support the curved beams during this procedure.

These procedures are intended to provide a systematic sequence for building up the beam structure without introducing stresses into the tile flexures. It is compatible with scaled up structures of the same configuration and is forgiving in the sense that individual elements are not bonded together until the entire structure is assembled. The procedures will accommodate misalignment of the tile flexures (up to about 2 mils) in the following way: The curved beams are located and held in a "best fit" position and the tabs are bolted to the flexures. The misalignment of the flexures is taken up in the bond line between the tabs and the beam web. The diagonal beams are supported on their flexures and the openings in the curved beam at the points of intersection are machined-to-fit the diagonal beams. This is accomplished the the following way.

7.1 <u>Initial Curved Beam Installation</u>

The first curved beam to be installed is that for row number 4. This beam does not attach directly to a row of tiles and therefore interfaces only with a row of diagonal beams.

1. Bring the beam minus tabs, into its approximate position supported by the curved beam locating fixture.

2. Adjust the position of the beam, using the diagonal beam templates, such that the diagonal beams will align properly with the curved beam.

3. Lock the locating tabs on the curved beam locator to maintain this final position of the curved beam.

4. Using the diagonal beam templates, mark the intersections of the diagonal beam with the curved beam web.

5. Remove the curved beam and machine the web openings at these marked locations to accommodate the diagonal beam interlocking tabs.

6. Bond the flexure tabs to the curved beam and cure.

The curved beam locating fixtures will be attached to the assembly fixture to locate and support the curved beams during this procedure.

These procedures are intended to provide a systematic sequence for building up the beam structure without introducing stresses into the tile flexures. It is compatible with scaled up structures of the same configuration and is forgiving in the sense that individual elements are not bonded together until the entire structure is assembled. The procedures will accommodate misalignment of the tile flexures (up to about 2 mils) in the following way: The curved beams are located and held in a "best fit" position and the tabs are bolted to the flexures. The misalignment of the flexures is taken up in the bond line between the tabs and the beam web. The diagonal beams are supported on their flexures and the openings in the curved beam at the points of intersection are machined-to-fit the diagonal beams. This is accomplished the the following way.

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2. Adjust the position of the beam, using the diagonal beam templates, such that the diagonal beams will align properly with the curved beam.

3. Lock the locating tabs on the curved beam locator to maintain this final position of the curved beam.

4. Using the diagonal beam templates, mark the intersections of the diagonal beam with the curved beam web.

5. Remove the curved beam and machine the web openings at these marked locations to accommodate the diagonal beam interlocking tabs.

6. Bond the flexure tabs to the curved beam and cure.

7. Reposition the curved beam on the assembly fixture and fit check, using the diagonal beam templates, adjusting as necessary.

8. Clamp the curved beam in its final location.

7.2 Diagonal Beams, Initial Fit

1. Install the diagonal beam locating tool on the curved beam flexure of tile 3-3.

2. Clamp, but do not bond, the flexure tabs to the 2 diagonal beams for tile 3-3.

3. Insert bushings in the tabs and bring the diagonal beams into position, triming the beams to fit the row 4 curved beam on one end and the opening in diagonal beam locating tool at the position of the row 3 curved beam.

4. After the diagonal beams for tile 3-3 have been completed, leave them clamped in position and repeat the procedure for tiles 3-2. 3-1, and the others of row 3.

5. When all of the diagonal beams for the rows have been completed, remove them from their flexures and identify each one with a number indicating its location.

7.3 Curved Beam, Initial Fit Row 3

1. Clamp, but do not bond, the flexure tabs to the curved beam for row 3.

2. Insert the bushings into the flexure tabs and bring the beam into position supported by the locating fixture.

3. Adjust the position of the beam for a nominal 2-3 mil clearance between the flexures and the flexure tabs.

4. Fit check the flexure bolts to insure alignment triming the tabs and/or the beam cap tab slots as necessary.

5. Lock the locating brackets of the locating fixture in position to support the beam in the final position.

6. Using the diagonal beam templates mark the intersections of the row 3 diagonals with the curved beam.

7. Remove the curved beam from the supporting fixture and remove the tabs.

8. Reposition the curved beam on the supporting fixture and mark the location of the intersections of the row 2 diagonals with the curved beam using the diagonal templates.

9. Remove the curved beam and machine the slots, as marked, to accommodate the diagonal beams.

7.4 Final Assembly, Row 3

1. Bond the tabs of the diagonal beams in place and bolt these beams in their proper locations with a 2.5 mil shim between the flexures and the tabs. Use the diagonal beam locating tool to position the beams. The tabs are clamped to the webs.

2. Bond the tabs to the curved beam and lightly clamp them together.

3. Index the curved beam against the beam support fixture and check the fit between the flexures and the tabs. Adjust as neccessary.

4. Place a 2.5 mil shim between each flexure and tab and tighten the flexure bolt while releasing the clamp which was holding the tab to the beam.

5. At this point the curved beam tabs are in their final positions spaced 2.5 mils from the flexures. The tabs are unstressed by the curved beam with a positive clearance of $\approx$ 2 mils maximum which is taken up in the bond line. The diagonal beams are attached to their flexures and there is a positive clearance of up to a 20 mils between the diagonal beams and the curved beams to insure that they are stress free.

6. Check final assembly and allow the adhesive bonds to cure at room temperature.

7.5 Remaining Row

1. Repeat the steps of 7.2 through 7.4 to assemble the beams of rows 2 and 1, in that order.

7.6 Bonding

1. Adhesively bond the diagonal beams and curved beams to one another at the locations where the diagonal beams intercept the curved beams. This is modest bond with a small contact area and serves simply to provide enough structural integrity to withstand the clamping forces of the next bonding operation.

2. Cure at room temperature.

3. Bond the gussets across the cap plates of the beam intersections. Clamp across the beams at each pair of gussets.

4. Cure at room temperature.

5. Bond the remaining angle clips at the beam intersections.

6. Final machine the main beam to fit structure.

7. Bond the main beam to the structure.

8. Cure at room temperature.

9. Bond the main beam angle ties.

10. Cure at room temperature.

7.7 Adhesive Post Cure

1. Remove the bolts from tile flexures.

2. Using JPL provided fixturing, remove the graphite support structure from the tiles.

3. Remove the tab bushings.

4. Weigh the graphite structure to the nearest ± 0.1 gm.

5. Place the structure in an oven and post-cure the adhesive bonds at 175 ± 5F for 4 hours.

6. Thermally cycle the structure for 4 cycles between 65F and 150F.

8.0 <u>SUBSEQUENT OPERATIONS</u> The assembly and bonding of the graphite support structure will be complete following the completion of the steps in Section 7.

The structure will then be coated with an electroless plating, which serves as a moisture barrier, and re-assembled to the array of tiles. These operations are covered by separate procedures.