Applicability of Thermoplastic Composites For Space Structures

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Presented At
Large Space Systems Technology Seminar
Langley Research Center, Virginia

January 17-19, 1978

TEXT

APPLICABILITY OF THERMOPLASTIC COMPOSITES FOR SPACE STRUCTURES

INTRODUCTION (Figure 1)

THERMOPLASTIC COMPOSITES FOR USE IN THE DESIGN AND MANUFACTURE OF AEROSPACE HARDWARE ARE A RELATIVELY NEW DEVELOPMENT IN COMPOSITE TECHNOLOGY. THERMOPLASTIC COMPOSITES OFFER THE DESIGNER ANOTHER DIMENSION IN DESIGN ALTERNATIVES PHASED TOWARD A COST-EFFECTIVE, DESIGN-TO-COST APPROACH TO THE USE OF HIGH STRENGTH, HIGH MODULUS, LIGHTWEIGHT COMPOSITES FOR THE ACQUISITION OF AEROSPACE HARDWARE. THE BOEING COMPANY HAS BEEN A PIONEER IN THIS FIELD AND HAS SUCCESSFULLY DESIGNED, FABRICATED, AND ENVIRONMENTALLY TESTED THERMOPLASTIC COMPOSITE MAJOR HARDWARE. THE DISCUSSION, HEREIN, DEFINES A THERMOPLASTIC RESIN AND COMPARES THE STRUCTURAL AND ENVIRONMENTAL PROPERTIES AND THE FABRICATION AND REPAIRABILITY OF THE THERMOPLASTIC COMPOSITE WITH A TYPICAL EPOXY COMPOSITE. LOW LABOR COSTS EXHIBITED BY THE THERMOPLASTIC COMPOSITES MAKE THEM A PRIORITY CONSIDERATION FOR USE IN SPACE STRUCTURE.

Thermoplastic Composites Introduction

- COMPARISON OF THERMOPLASTIC vs THERMOSETTING RESINS AND COMPOSITES
- WHY THERMOPLASTIC COMPOSITES FOR SPACE APPLICATIONS
  - MANUFACTURING METHODS
  - REPAIRABILITY
  - COST SAVINGS
  - STRUCTURAL PROPERTIES
  - ENVIRONMENTAL STABILITY

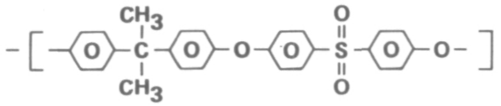
Figure 1

TEXT THERMOPLASTIC vs. THERMOSETTING COMPOSITE (Figure 2)

THE TWO FORMULATIONS ARE GENERAL FOR A POLYSULFONE AND AN EPOXY RESIN. THE POLYSULFONE, A THERMOPLASTIC, TYPICALLY UNDERGOES A REVERSIBLE VISCOUS MELT AT 350°F, WHEREAS THE EPOXY, A THERMOSET, MAY SOFTEN SLIGHTLY BUT WILL DECOMPOSE RATHER THAN APPRECIABLY SOFTEN WITH INCREASED TEMPERATURE. CURRENTLY, TOP TEMPERATURE FOR THERMOPLASTICS IS 300°F OPERATIONAL USE. AS WE WILL SEE LATER, ENVIRONMENTAL AND SOLVENT RESISTANCE IS GOOD FOR SPACE HARDWARE USE.

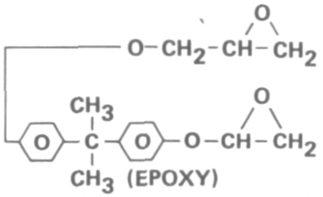
Thermoplastic vs Thermosetting Resin

THERMOPLASTIC



(POLYSULFONE)

THERMOSETTING



(EPOXY)

350°F	SOFTENING TEMPERATURE (Tg)	DOES NOT SOFTEN
TO 300°F	OPERATIONAL SERVICE TEMPERATURE	TO 350°F
GOOD	ENVIRONMENTAL RESISTANCE	GOOD
GOOD EXCEPT FOR SELECTED SOLVENTS	SOLVENT RESISTANCE	GOOD
SINGLE COMPONENT	COMPOSITION	MULTIPLE COMPONENT

Figure 2

TEXT GENERAL INFORMATION AND PREPREGS (Figure 3)

GLASS, KEVLAR,AND GRAPHITE CLOTH, TAPE OR UNIDIRECTIONAL FIBER REINFORCEMENTS ARE IMPREGNATED WITH THE THERMOPLASTIC RESIN BY SOLVENT OR HOT MELT TECHNIQUES. THEY ARE PURCHASED FROM THE MAJOR RESIN/IMPREGNATOR COMPANIES WHO SHIP USING STANDARD NONREFRIGERATED TECHNIQUES. THEY ARE THEN STORED AND HANDLED IN THE SHOP AT AMBIENT CONDITIONS UNTIL READY FOR USE.

FINISHED PARTS OR SUBASSEMBLIES ARE MACHINED AND FINISHED USING ESTABLISHED PROCEDURES.

Thermoplastic Composite General Information

IMPREGNATION TECHNIQUE	– SOLVENT OR HOT MELT
REINFORCEMENT AVAILABLE	– GLASS OR KEVLAR OR GRAPHITE CLOTH OR UNIDIRECTIONAL FIBERS
HOW PURCHASED	– RAW RESIN OR PREPREG REINFORCEMENT OR SHEET STOCK
HOW SHIPPED	– STANDARD PROCEDURES, NO REFRIGERATION REQUIRED
HOW STORED	– AMBIENT CONDITIONS, NO REFRIGERATION REQUIRED
HOW MACHINED	– STANDARD GRAPHITE COMPOSITE PROCEDURES
HOW PAINTED OR TOPCOATED	– STANDARD PAINTING PROCEDURES

Figure 3

TEXT

THERMOPLASTIC PREPREGS (Figure 4)

LIST OF AVAILABLE THERMOPLASTIC PREPREGS

Thermoplastic Prepregs

- HERCULES 3004 A-S 3-IN-WIDE TAPE
- DUPONT A-S/P1700 POLYSULFONE 6-IN-WIDE TAPE
- HEXCEL/T300 181 GRAPHITE FABRIC/P1700
- FIBERITE/T300 181 GRAPHITE FABRIC/P1700
- U.S. POLYMERIC T300/P1700 POLYSULFONE 12-IN-WIDE TAPE

Figure 4

TEXT

WHY THERMOPLASTIC COMPOSITES FOR SPACE APPLICATIONS (Figure 5)

THE FOLLOWING CHARTS ATTEMPT TO PORTRAY BRIEFLY THE ADVANTAGES OF THERMOPLASTIC COMPOSITES OVER EPOXY COMPOSITES FOR SPACE HARDWARE APPLICATIONS. THEY WILL SHOW A POTENTIAL FOR LOWER COSTS, INCREASED DESIGN EFFICIENCY AND EASE OF REPAIR. THIS COMBINED WITH GOOD STRUCTURAL PROPERTIES AND ENVIRONMENTAL STABILITY SHOULD MAKE THERMOPLASTIC COMPOSITES DESIRABLE FOR SPACE USE.

Why Thermoplastic Composites For Space Applications

- LOWER COMPONENT COSTS
    - LOWER FABRICATION COSTS
    - LOWER QUALITY ASSURANCE COSTS
    - LOWER SCRAPPAGE RATES
- INCREASED DESIGN EFFICIENCY
- EASE OF REPAIR
- GOOD STRUCTURAL PROPERTIES
- GOOD ENVIRONMENTAL STABILITY
- SINGLE COMPONENT SYSTEM

Figure 5

TEXT

LOWER COMPONENT COSTS (Figure 6)

THERMOPLASTIC COMPOSITE MATERIALS NEED NO REFRIGERATION. THEY ARE STORED AND HANDLED AT NORMAL SHOP CONDITIONS. CUTTING, SHAPING, PLY POSITIONING, APPLICATION OF PRESSURE AND TEMPERATURE, POST-FORMING AND ASSEMBLY METHODS ARE MORE LIKE FABRICATING WITH METALS LIKE ALUMINUM SHEET THAN LIKE "WET" EPOXY PREPREGS.

Thermoplastic Composites Lower Component Costs

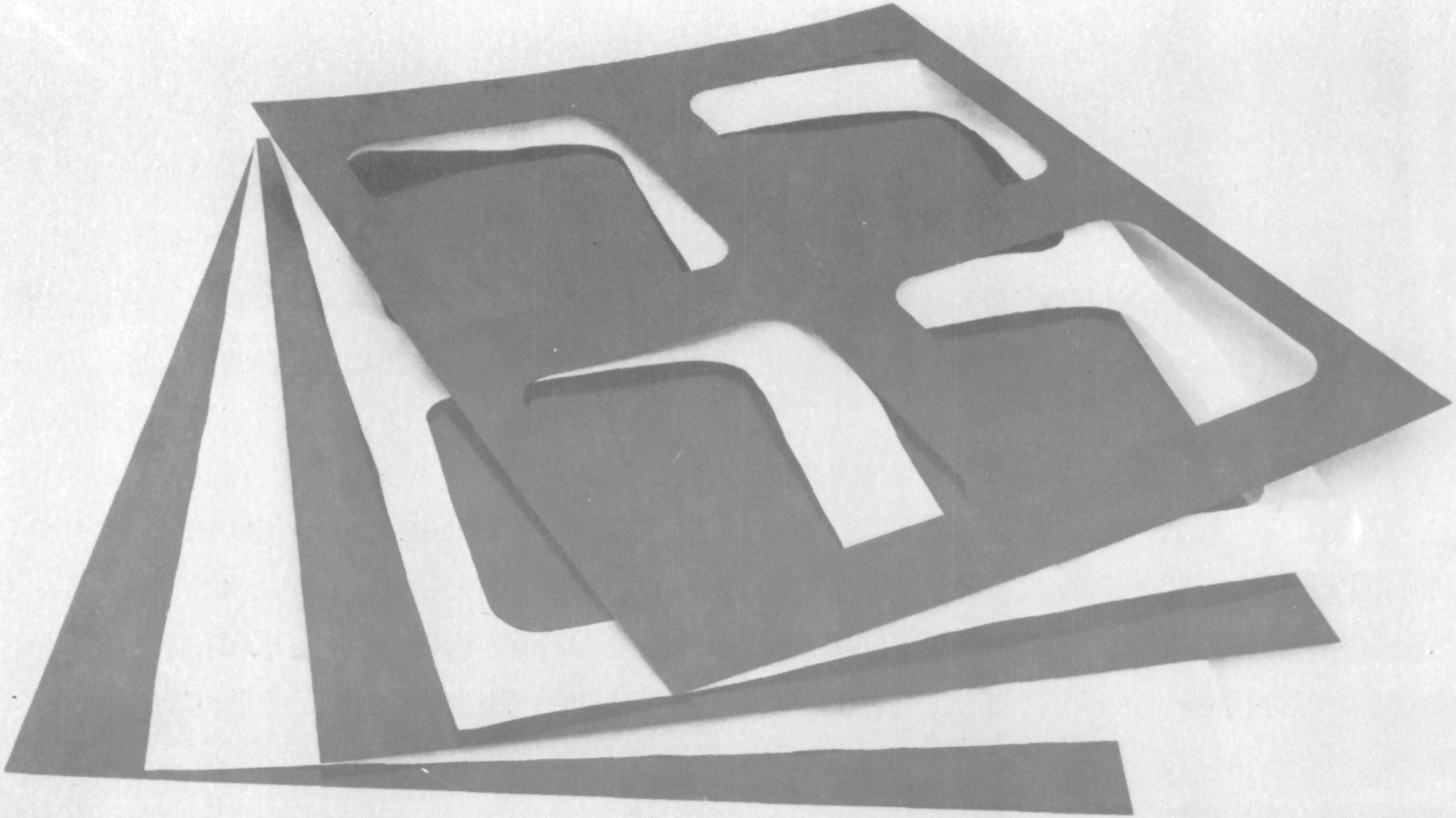
- STORAGE
    - AMBIENT CONDITION LIKE ALUMINUM SHEET
- LAMINATE CONSOLIDATION
    - CUTTING AND SHAPING
    - PLY POSITIONING
    - PRESSURE AND TEMPERATURE APPLICATION
- POST FORMING AND HANDLING
- ASSEMBLY METHODS

Figure 6

TEXT

PICTURE PREPREG CUT-OUT (Figure 7)

THIS PICTURE SHOWS HOW PLIES CAN BE CUT OUT AND LAYED UP IN PREPARATION TO FABRICATION OF A LAMINATE WITH DOUBLER OR REINFORCED AREAS. SUBSEQUENT APPLICATION OF PRESSURE (100 - 200 PSI) AND HEAT (425 - 650°F) WILL FORM THE PART READY FOR THE FINISHING OPERATION.



PREPREG CUT OUT

Figure 7

TEXT MANUFACTURING METHODS (Figure 8)

(FIGS. 8, 9 AND 10) LAMINATE CONSOLIDATION CAN BE ACCOMPLISHED USING TECHNIQUES CAPABLE OF APPLYING PRESSURE AND TEMPERATURE SIMULTANEOUSLY. FLAT SHEETS, FORMED PARTS, OR CONTINUOUS TAPE-LIKE ROLLS CAN BE FORMED. THESE PARTS CAN BE POST-FORMED BY HEATING AND PRESSING AGAIN AS MANY TIMES AS NECESSARY TO OBTAIN THE FINISHED SHAPE. (FIGS. 8, 11 AND 12) THE FINISHED SHAPE CAN BE MACHINED AS REQUIRED AND SUBSEQUENTLY BONDED OR MECHANICALLY ASSEMBLED INTO A SUBASSEMBLY. (FIGS. 8, 13 AND 14) PARTS SUCH AS TUBE FITTINGS CAN BE INJECTION MOLDED AND ASSEMBLED WITH THERMOPLASTIC COMPOSITE TUBING IN PRIME STRUCTURE SUCH AS SPACE METERING TRUSS.

Thermoplastic Composites Manufacturing Methods

Laminate consolidation:

- Roll-lamination
- Pultrusion
- Autoclave-lamination
- Press-lamination

Post-forming methods:

- Press (matched-die)
- Autoclave-molding
- Vacuum-forming
- Pultrusion

Bonding/joining methods:

- Fusion
- Adhesive-bonding
- Mechanical-fastening

Chopped fiber molding:

- Injection-molding
- Matched-die

Assembly methods:

- Fusion
- Adhesive-bonding

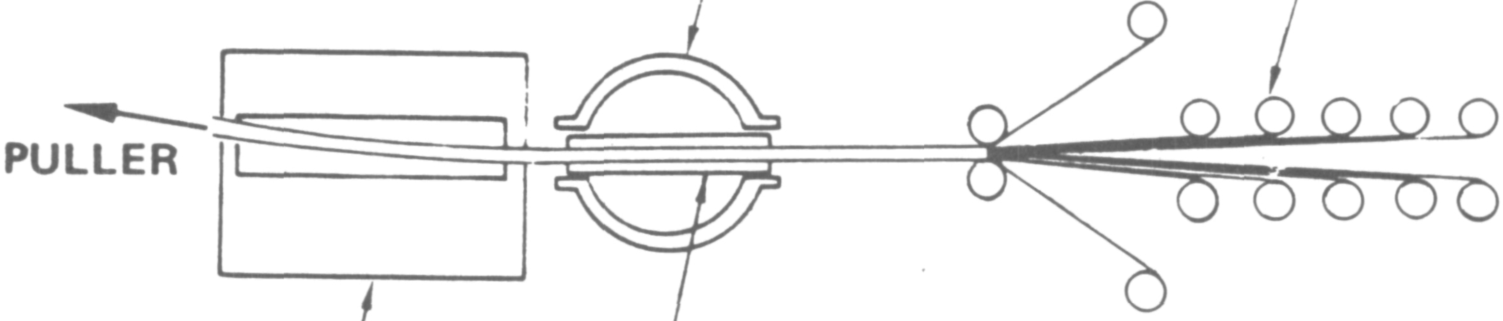
Figure 8

TEXT

PULTRUSION (Figure 9)

THIS IS A TYPICAL PULTRUSION MANUFACTURING FACILITY WHEREIN TAPE PASSES THROUGH A MICROWAVE PREHEAT CHAMBER, THEN TO A PRESSURE-TEMPERATURE COMPACTION CHAMBER AT 200 PSI AND 600°F.

Thermoplastic Composite Pultrusion Facility



EXISTING 12" WIDE
MW PRE–HEAT
CHAMBER

PREPREG TAPES
WIDTHS TO 12"

PULLER

NON–PRESSURIZED
PLATENS
TEMPERATURE TO 600°F

COMPACTION CHAMBER
METAL PLATENS
PRESSURE TO 200 PSI
TEMPERATURE TO 600°F

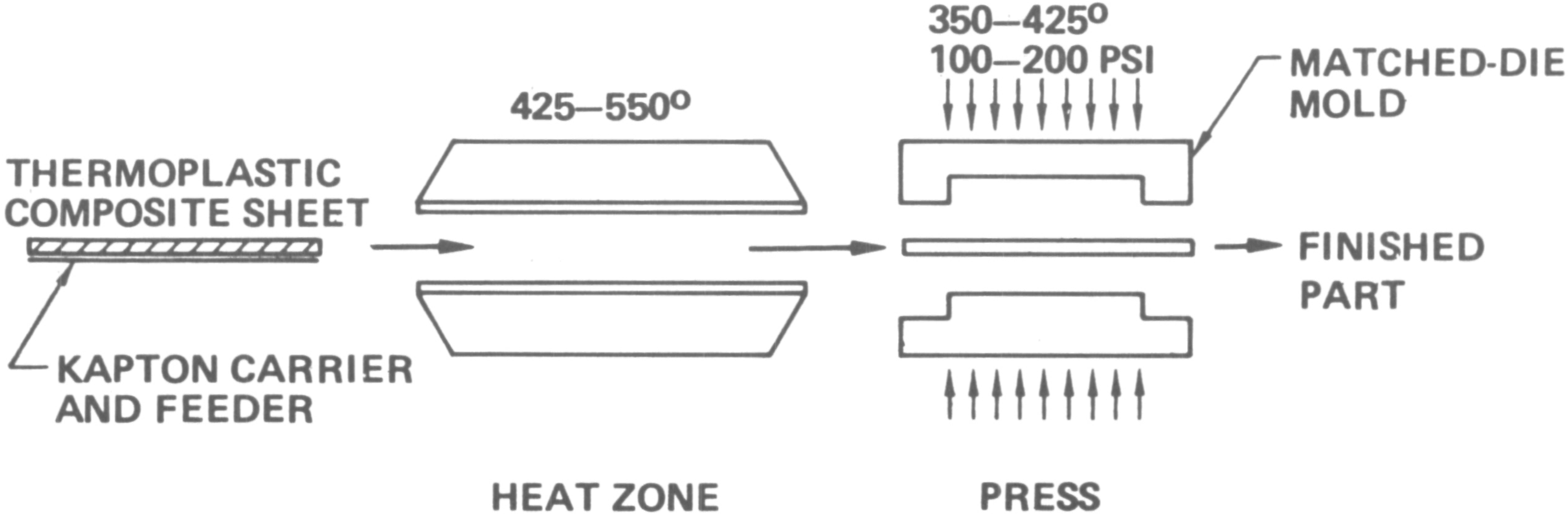
Figure 9

TEXT

PRESS FORMING (Figure 10)

STANDARD METHODS OF APPLICATION OF PRESSURE AND HEAT CAN BE USED FOR LAMINATE CONSOLIDATION. A PREHEAT ZONE IS USUALLY USED TO SOFTEN THE THERMOPLASTIC SO THAT IT WILL DRAPE WELL ON THE FINISHED MOLD WHEN FINISHED SHAPED PARTS ARE TO BE MADE AT THE SAME TIME LAMINATE CONSOLIDATION IS ACCOMPLISHED. THE PART CAN ALSO BE CONSOLIDATED IN A SHEET FORM, AND POST-FORMED BY A REPEAT OF THIS PRESS PROCESS.

Press Forming of Thermoplastic Composites



TOTAL ELAPSED PROCESSING TIME = 6–12 MINUTES

Figure 10

TEXT

PICTURE - POST-FORMED GRTP SHEETS (Figure 11)

THESE ARE TYPICAL PARTS WHICH HAVE BEEN POST-FORMED BY HEATING IN A VACUUM USING AN AIR ASSIST TO APPLY PRESSURE. THE PARTS WERE FORMED ON THE METAL TEMPLATE SHOWN.

Vacuum Formed Shear Web $[0^{\circ}/90^{\circ}]_{s}$ Sheet Stock

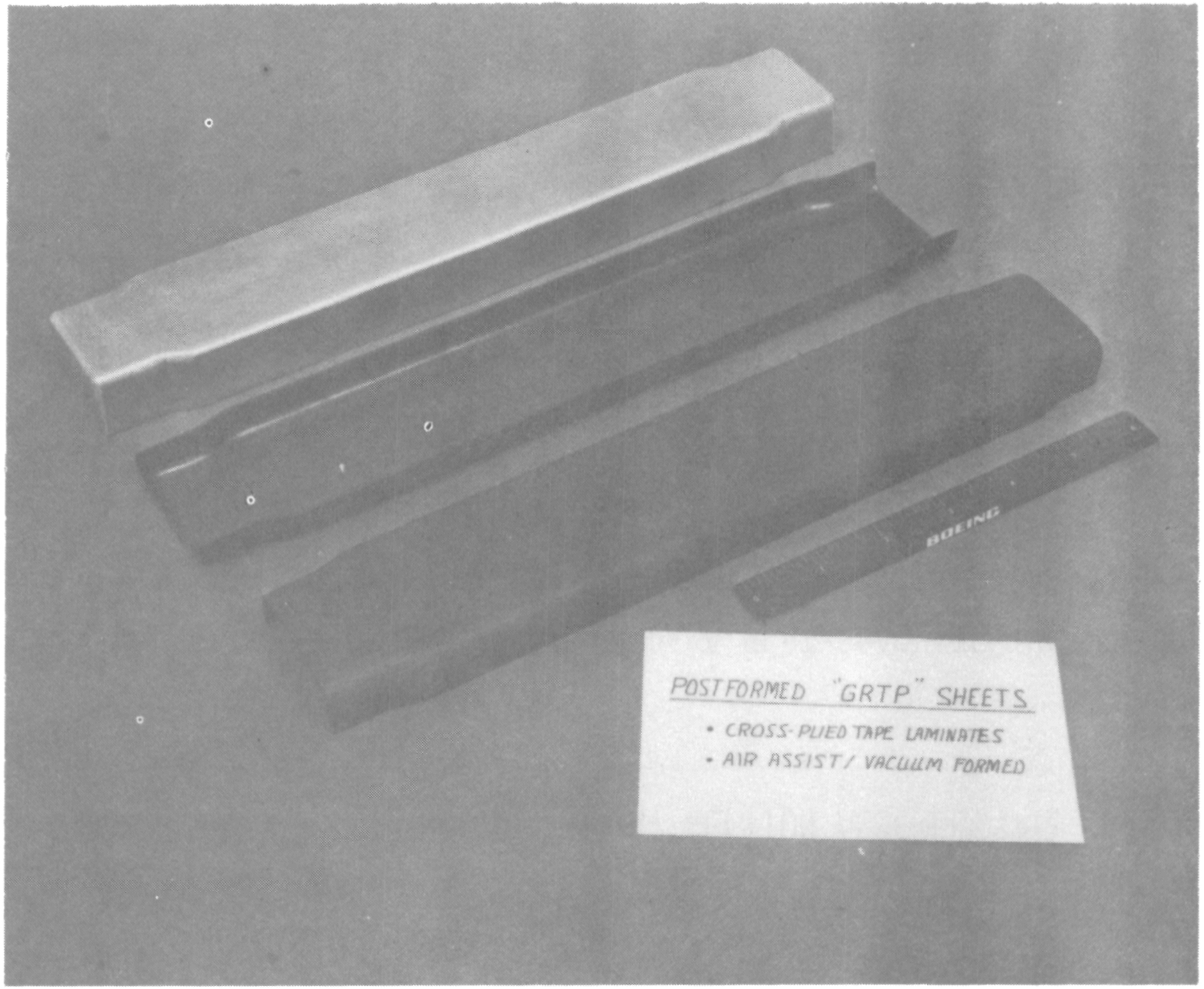
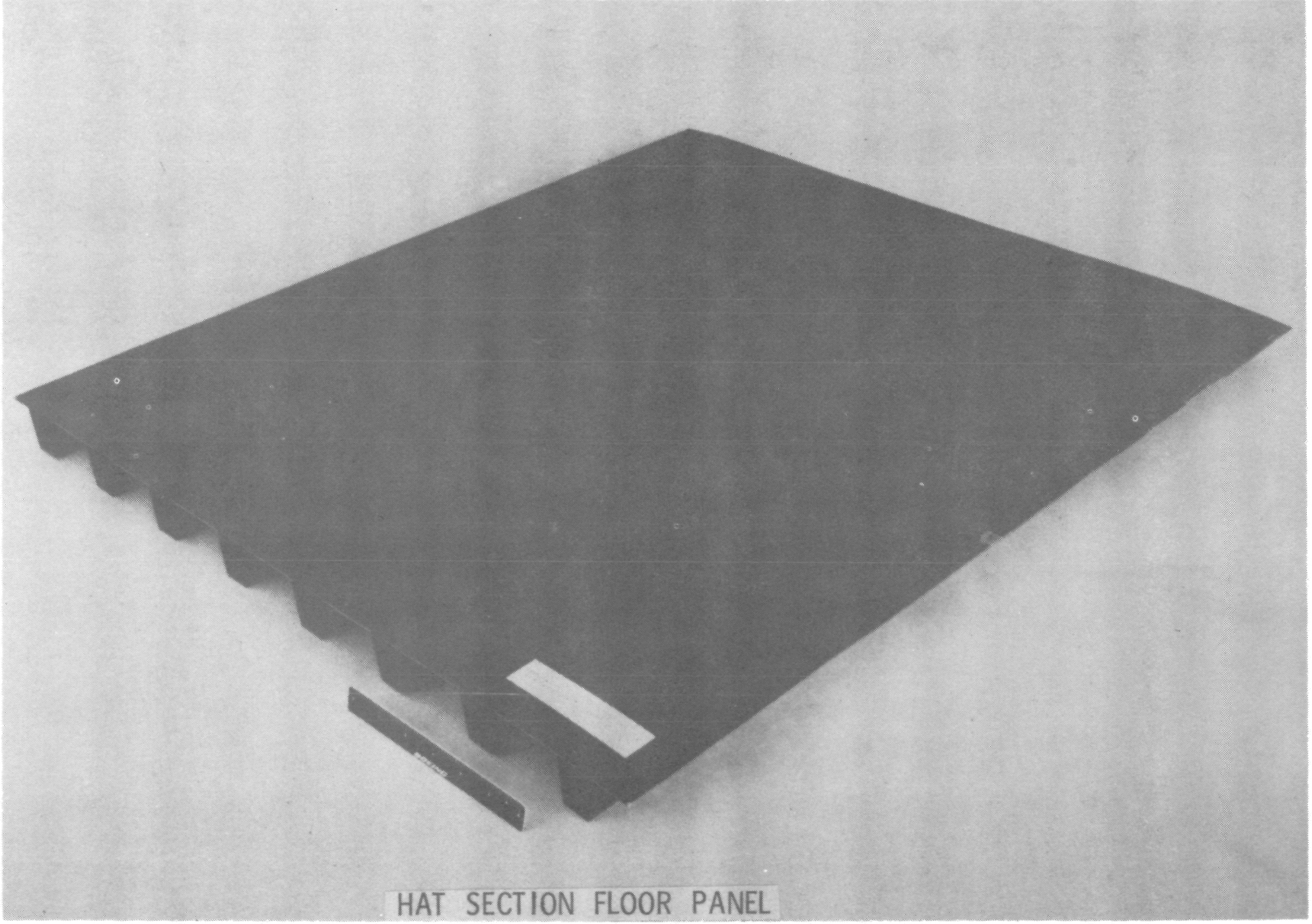


Figure 11

TEXT

PICTURE - HAT SECTION ASSEMBLY (Figure 12)

THIS IS A PICTURE OF AN ASSEMBLY COMPOSED OF A FLAT GRAPHITE THERMOPLASTIC COMPOSITE SHEET BONDED TO GRAPHITE THERMOPLASTIC COMPOSITE CORRUGATED PANEL FOR RIGIDITY. THE FACE SHEET AND THE CORRUGATED PANEL WERE INTEGRALLY CONSOLIDATED AND FUSED TOGETHER IN ONE OPERATION. THE PROCESS ELIMINATED THE APPLICATION OF ADHESIVES AND THE SUBSEQUENT BONDING OPERATION. REMOVABLE CORES WERE USED TO FORM THE CORRUGATIONS.



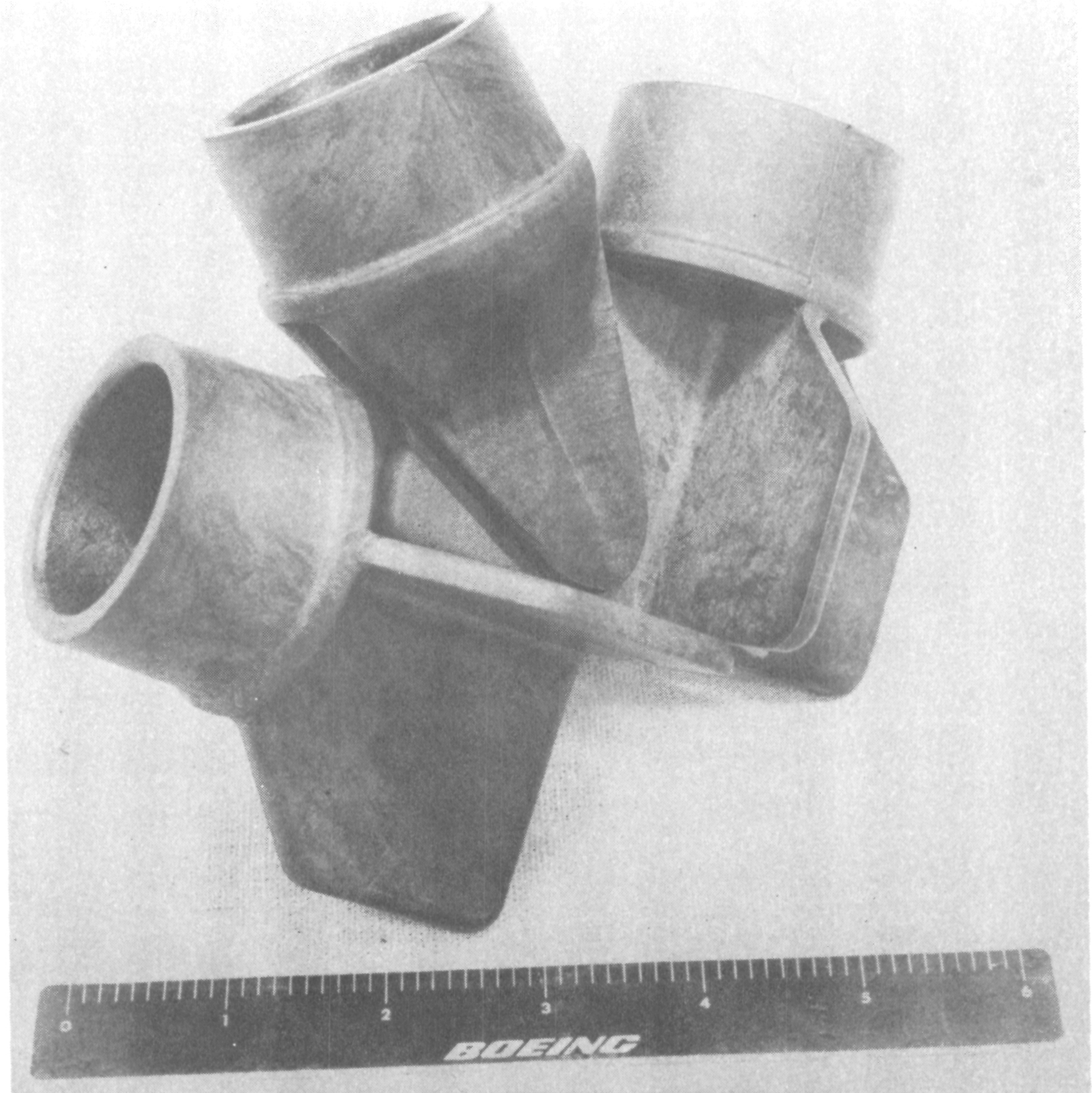
HAT SECTION FLOOR PANEL

Figure 12

TEXT

PICTURE - INJECTION MOLDED PARTS (Figure 13)

THIS IS A PICTURE OF GRAPHITE THERMOPLASTIC COMPOSITE MOLDED TUBE FITTINGS MANUFACTURED USING STANDARD INJECTION MOLDING TECHNIQUES FOR REINFORCED THERMOPLASTICS.



INJECTION MOLDED TUBE FITTINGS
(Figure 13)

TEXT

PICTURE - METERING TRUSS (Figure 14)

THIS PICTURE EXHIBITS TWO METERING TRUSSES. THE SHORTER OF THE TWO IS FABRICATED FROM GRAPHITE THERMOPLASTIC TUBES ASSEMBLED USING LAMINATED GRAPHITE FABRIC/POLYSULFONE COMPOSITE FITTINGS. THE LARGER TRUSS IS AN EPOXY STRUCTURE. THE TWO STRUCTURES WERE FABRICATED PER THE SAME DESIGN.

Figure 14

TEXT

METHODS OF REPAIR (Figure 15)

(FIGS. 15, 16 AND 17) DAMAGED PARTS CAN BE RATHER EASILY REPAIRED BY REMOVING THE DAMAGE AND APPLYING REPLACEMENT MATERIAL BY ADHESIVE BONDING OR BY FUSING THE THERMOPLASTIC RESIN BY RADIANT, CONVECTIVE OR RESISTANCE HEATING OR BY ELECTROMAGNETIC BONDING. TENSILE TESTS OF REPAIRED SPECIMENS INDICATE SATISFACTORY STRUCTURAL PROPERTIES.

Methods Of Repair

- ADHESIVE BONDING
- FUSION
  - RADIANT HEATING
  - CONVECTION HEATING
  - ELECTROMAGNETIC BONDING
  - RESISTANCE HEATING

Figure 15

TEXT PICTURE - REPAIR METHOD (Figure 16)

THIS PICTURE SHOWS PATCHES USED AFTER DAMAGE HAS BEEN REMOVED AND HOLE PREPARED SO THAT A TAPERED PLUG CAN BE INSERTED PLY BY PLY. FINAL FUSION IS ACCOMPLISHED BY HEAT AND PRESSURE APPLICATION. ROOM-TEMPERATURE AND CONTACT PRESSURE BONDS HAVE ALSO BEEN MADE; HOWEVER, THE STRENGTH OF THE REPAIR IS NOT AS HIGH AS WITH HIGH TEMPERATURE - HIGH PRESSURE BONDING.

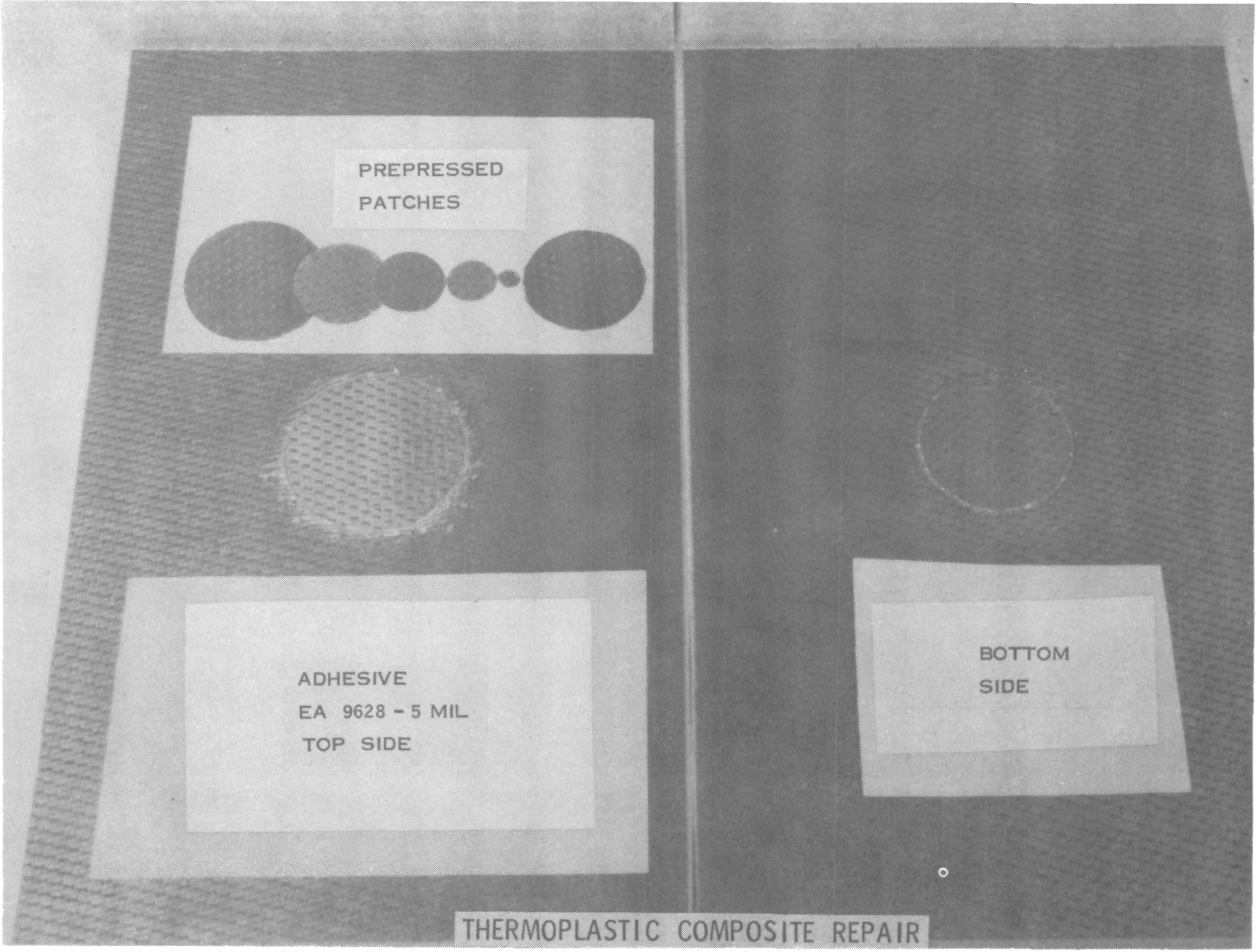

PREPRESSED
PATCHES
ADHESIVE
EA 9628 - 5 MIL
TOP SIDE
BOTTOM
SIDE
THERMOPLASTIC COMPOSITE REPAIR

Figure 16

TEXT PICTURE - REPAIR TEST SPECIMENS (Figure 17)

THESE ARE TYPICAL TEST SPECIMENS WITH VARYING SIZES OF REPAIRS AT THE CENTER OF THE SPECIMEN.

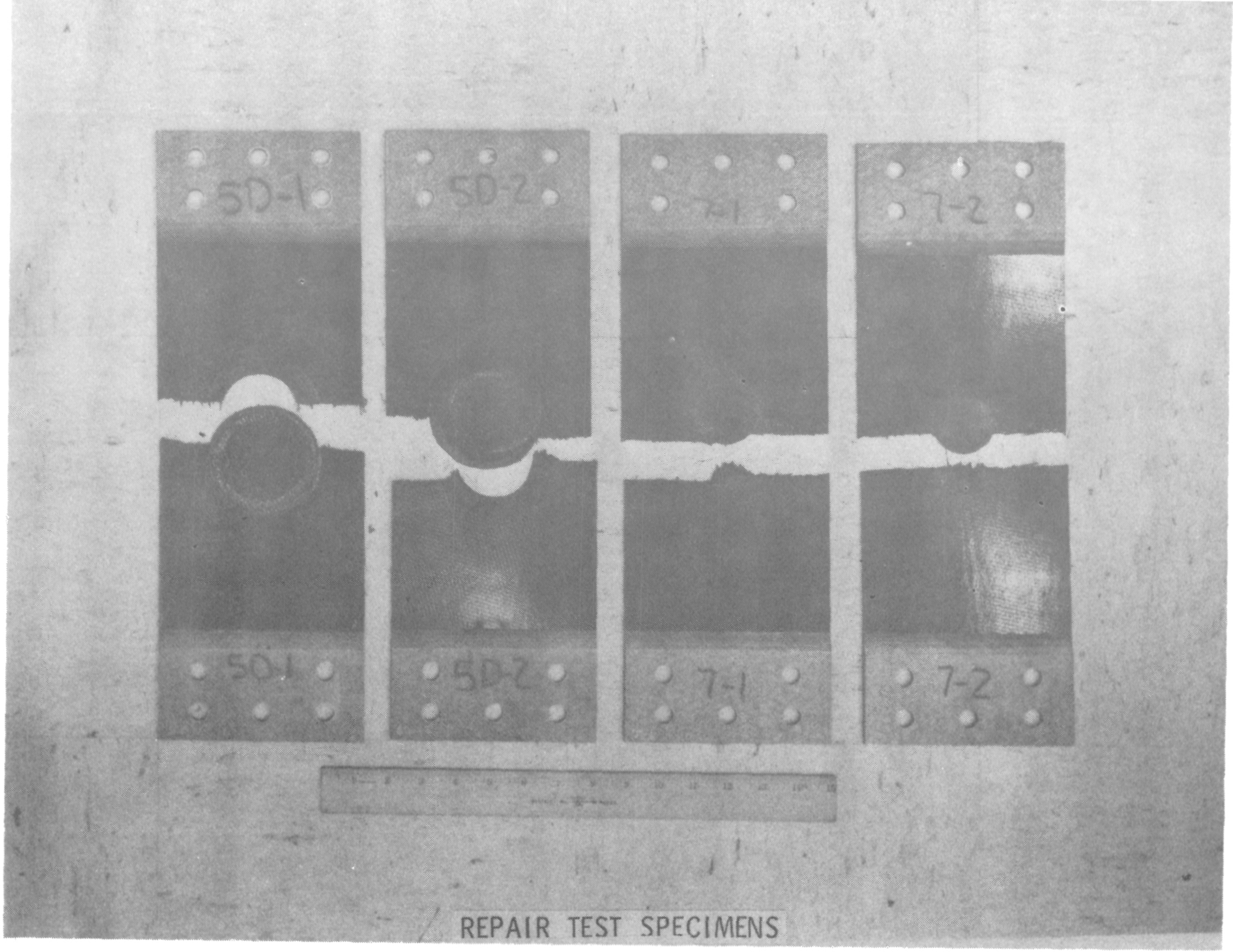


Figure 17

TEXT REPAIR PANELS (Figure 18)

THE DATA HERE INDICATE THE EXCELLENCE OF ONE, TWO, AND THREE-HOLE FUSION AND BONDED REPAIRS. THEY COMPARE FAVORABLY WITH THE CONTROL (NO HOLE) SPECIMEN AND SUPERIOR TO THE SECOND CONTROL (ONE HOLE - NOT REPAIRED) SPECIMEN.

Repair Panels[a]

Panel	Area (in²)	Load (lb)	Gross stress (psi)	Net stress (psi)
Control No. 1	0.1635	8,330[b]	50,948	50,948
Control No. 2 (1-in hole, no repair)	0.3276	8,830	26,593	32,343
1-in hole repair—fusion	↓	16,540	50,488	60,585
1-in hole repair—fusion		17,100	52,197	62,636
2-in hole repair—fusion		9,260	28,266	42,399
2-in hole repair—fusion		9,600	29,304	43,956
3-in hole repair—fusion		7,420	22,649	45,298
3-in hole repair—fusion		6,720	20,512	41,024
1-in hole repair—bond		17,250	52,655	63,186
1-in hole repair—bond		16,220	49,511	59,413
1-in hole repair—fusion		Fatigue 7.0 x 10^6 at 15,000 psi N.F., increase load		
1-in hole repair—fusion		Fatigue 3.8 x 10^6 at 20,000 psi increased to 25,000 psi		

[a] Four plies of fabric at (0, 90)

[b] First test failed in grips at 66,000 psi, measured to 3 in width for second test.

Figure 18

TEXT

ELEMENT COST SAVING WITH GR/TP (Figure 19)

(FIGS. 19 AND 20) COST SAVINGS IN LABOR ARE SIGNIFICANT WHEN COMPARING GRAPHITE REINFORCED EPOXY COMPOSITE LAYUP, CURE AND STANDARD MANUFACTURING TECHNIQUES TO SIMILAR OPERATIONS IN GRAPHITE-REINFORCED THERMOPLASTIC COMPOSITES. THE POSITIONING OF DOUBLERS, LOCAL HARD POINTS, AND THE FABRICATION OF NEAR NET DIMENSION PARTS ARE MUCH EASIER IN THERMOPLASTICS THAN IN EPOXY COMPOSITES.

THE ELEMENT COST SAVING IS CARRIED OVER INTO THE ASSEMBLY AS A SIGNIFICANT LABOR COST SAVING. HOWEVER, TO OVERCOME THE INCREASED MATERIAL AND TOOLING COSTS, OVERALL COST SAVINGS CAN BE APPRECIATED ONLY AFTER MULTIPLE ASSEMBLIES ARE PRODUCED.

Element Cost Savings With Gr/T.P.

			Savings*
Elements	T–Stiffeners		60%
	Hat–Stiffeners		65%
	L–Channel		72%
	Honeycomb Panels		30%
	Flat Panels		42%
	Complex Shapes	(Small)	70%
		(Large)	18%
Operations	Bonding		0
	Drilling		59%

*Over Gr/E (Labor)

Figure 19

TEXT

EFFECT OF LABOR SAVING ON COST (Figure 20)

THE GRAPHITE THERMOPLASTIC ASSEMBLY, AS TYPIFIED BY A STUDY OF THE COMPASS COPE HORIZONTAL STABILIZER, LABOR COSTS ARE LESS THAN THAT OF THE EPOXY GLASS ASSEMBLY. HOWEVER, DUE TO THE HIGHER COSTS OF MATERIALS AND TOOLING, MULTIPLE UNIT PRODUCTION MUST BE ACCOMPLISHED TO REALIZE A TOTAL COST SAVING. IT'S WORTH NOTING THAT EVEN WITH THE SIGNIFICANTLY HIGHER TOOLING COSTS THE THERMOPLASTIC COMPONENT BECOMES COST EFFECTIVE BY THE 10TH UNIT.

Effect Of Labor Saving On Cost Of Complete Assembly

Compass Cope Horizontal Stabilizer Cost Estimate - Glass/Epoxy and Graphite/Polysulfone

ADVANCED COMPOSITE MATERIAL	NO. OF UNITS	PRODUCTION HOURS	MATERIAL DOLLARS	TOOLING HOURS	TOTAL COST DOLLARS
GLASS/EPOXY ($12/LB)	1	1,068	600	810	56,940
	10	7,600	6,000	810	258,296
	100	46,730	60,000	810	1,486,178
GRAPHITE/POLYSULFONE ($65/LB)	1	775	2,760	1,690	76,710
	10	5,515	27,600	1,690	243,747
	100	33,909	276,000	1,690	1,343,980

Figure 20

TEXT

P-1700/GRAPHITE FABRIC LAMINATE STRUCTURAL PROPERTIES (Figure 21)

(FIGS.21, 22 AND 23) GRAPHITE REINFORCED THERMOPLASTIC COMPOSITES EXHIBIT SIGNIFICANT TENSILE STRENGTH AND TENSILE MODULUS FROM -50^{0} TO 300^{0}F.

(FIGS.21, 24 AND 25) COMPRESSION AND FLEXURAL STRENGTH DECREASES WITH TEMPERATURE TO 300^{0}F; HOWEVER, THE MODULUS REMAINS FAIRLY CONSISTENT.

(FIGS.21 AND 26) INTERLAMINAR SHEAR DECREASES WITH INCREASE IN TEMPERATURE TO 300^{0}F.

IN GENERAL, STRUCTURAL PROPERTIES ARE KNOWN AND AVAILABLE FOR DESIGN UTILIZATION.

P-1700/Graphite Fabric Laminate Structural Properties

PROPERTY	TEST TEMPERATURE		
	+70 °F	+180 °F	+300 °F
TENSION			
STRENGTH, PSI	77,000	–	61,400
MODULUS, 10^6 PSI	10.0	–	10.4
COMPRESSION			
STRENGTH, PSI	56,000	–	36,000
MODULUS, 10^6 PSI	9.2	–	10.6
FLEXURAL (0°)			
STRENGTH, PSI	107,000	92,000	69,000
MODULUS, 10^6 PSI	7.7	7.1	7.2
FLEXURAL (90°)			
STRENGTH, PSI	97,000	80,000	66,000
MODULUS, 10^6 PSI	7.7	6.8	6.7
INTERLAMINAR SHEAR			
STRENGTH, PSI	8,740	–	4,390

Figure 21

TEXT

TEMPERATURE vs. TENSILE STRENGTH (Figure 22)

THE TENSILE STRENGTH VARIES ONLY SLIGHTLY FROM -50° TO 300°F. THIS IS ON A LAMINATE WHOSE FIBER VOLUME IS 60%.

Effect of Temperature on Tensile Strength

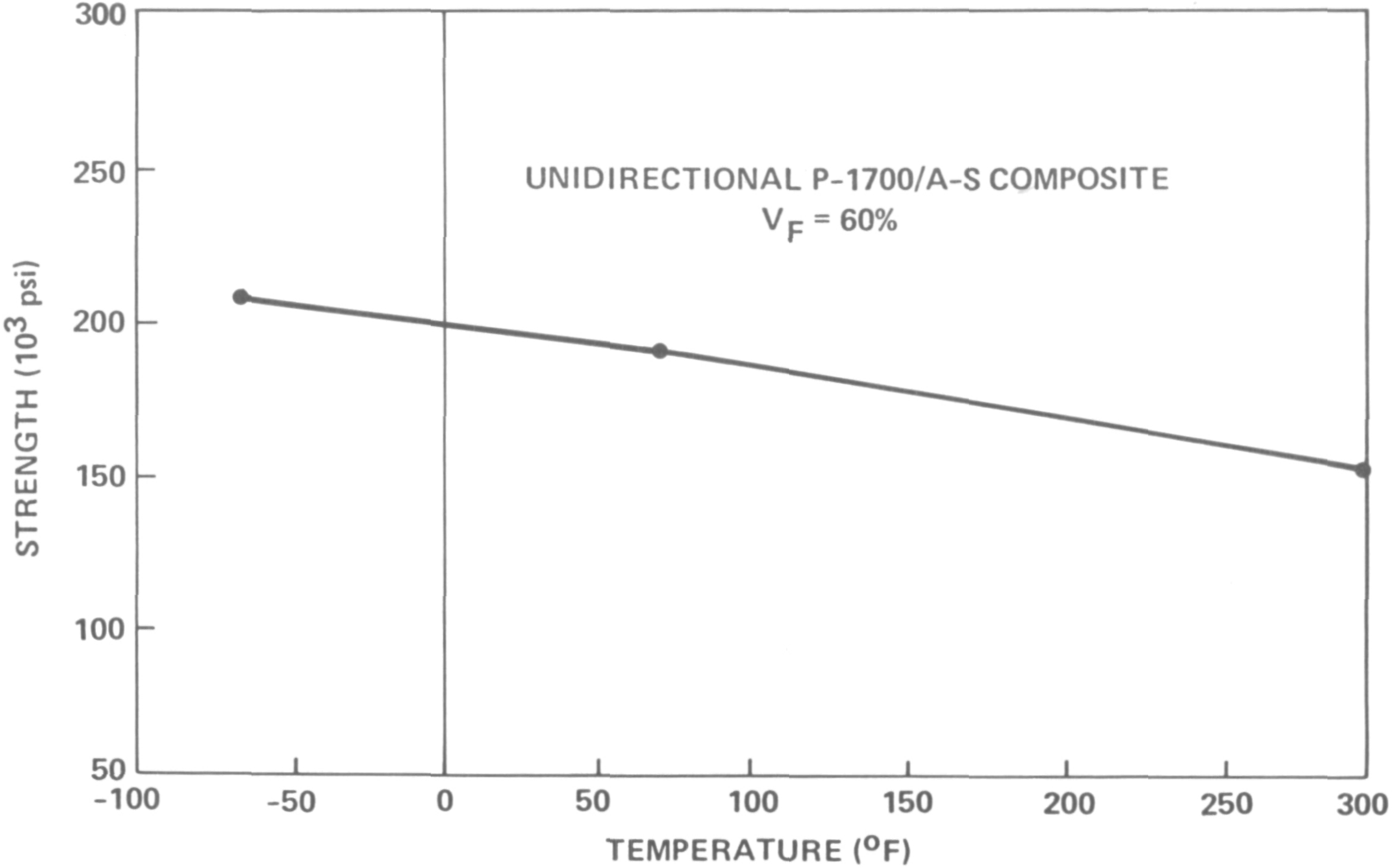


Figure 22

TEXT

TEMPERATURE vs. TENSILE MODULUS (Figure 23)

THE TENSILE MODULUS IS NOT APPRECIABLY AFFECTED BY TEMPERATURE EXPOSURES -50° TO 300°F. THIS IS ON A LAMINATE WHOSE FIBER VOLUME IS 60%.

Effect of Temperature on Tensile Modulus

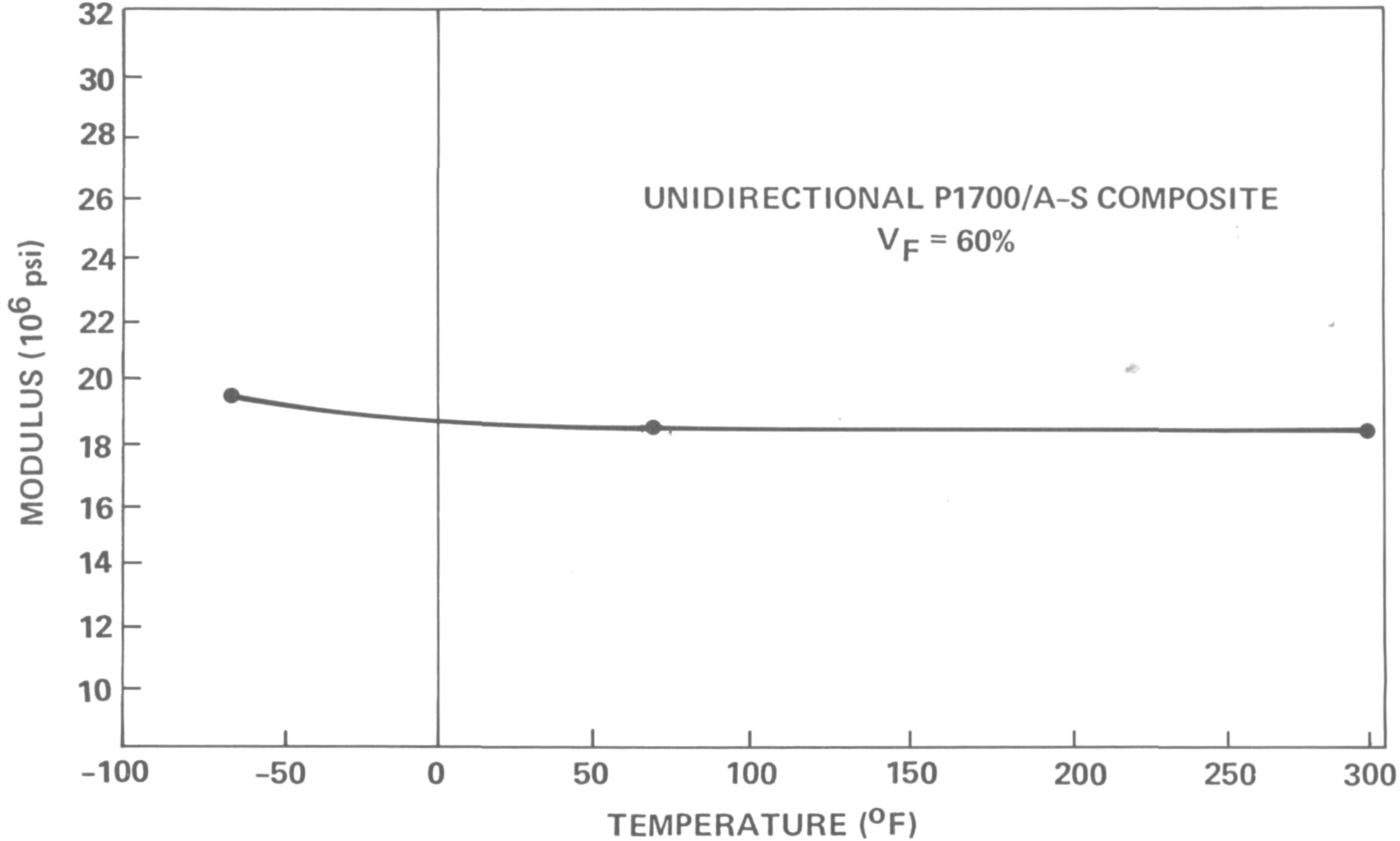


Figure 23

TEXT

TEMPERATURE vs. FLEXURAL STRENGTH (Figure 24)

FLEXURAL STRENGTH DECREASES WITH INCREASE IN TEMPERATURE FOR UNIDIRECTIONAL (0), BIDIRECTIONAL $(0 - 90)_S$, AND FABRIC LAMINATES. THIS IS TO BE EXPECTED SINCE THE RESIN SOFTENS WITH INCREASE IN TEMPERATURE.

Effect of Temperature on Flexure Strength– Graphite/ Polysulfone Composites

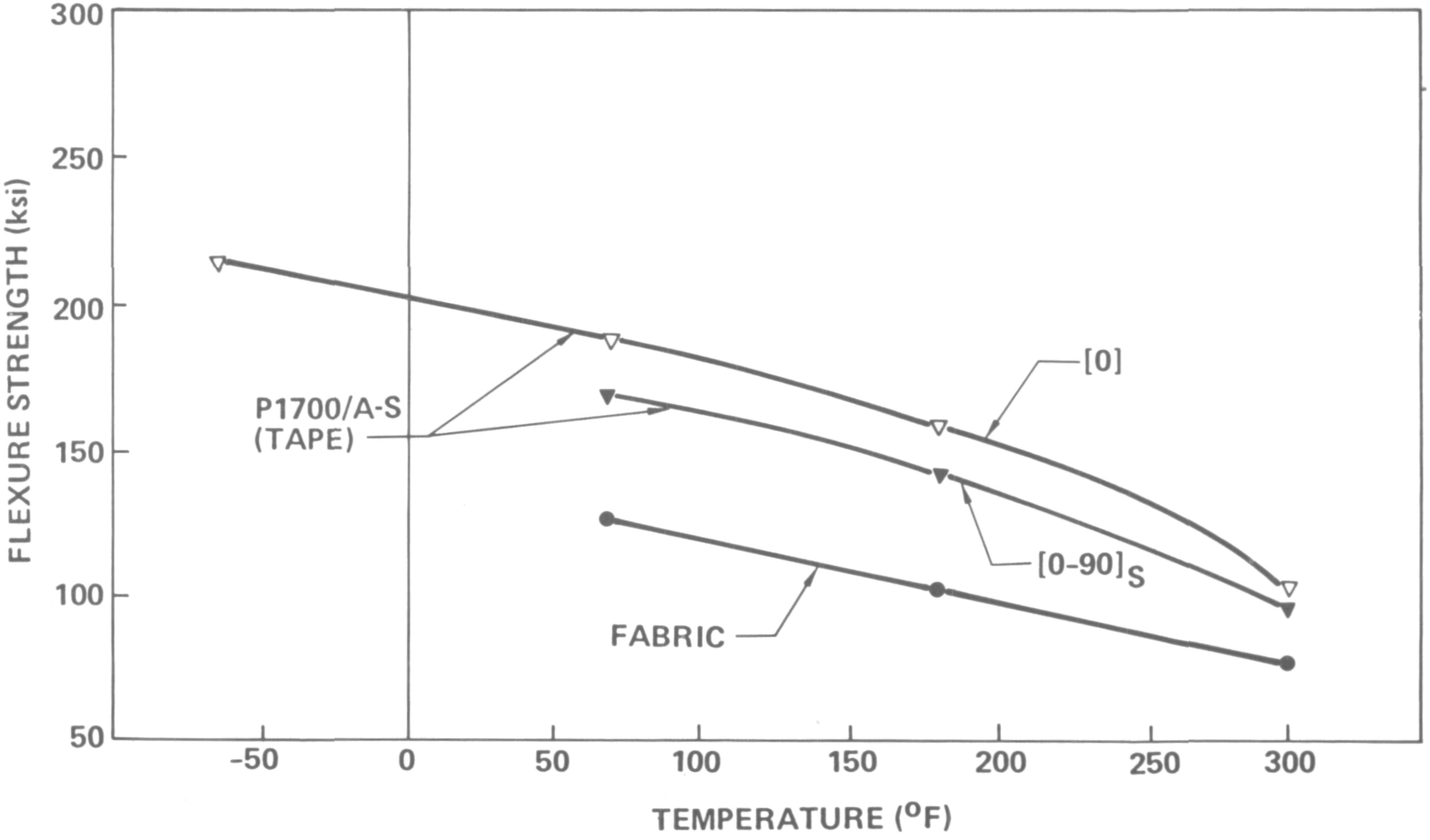


Figure 24

TEXT

TEMPERATURE vs. FLEXURE MODULUS (Figure 25)

THE FLEXURE MODULUS IS NOT AFFECTED BY RAISE IN TEMPERATURE FROM -50° TO 300°F. THIS IS TRUE OF UNIDIRECTIONAL (0), BIDIRECTIONAL $(0 - 90)_S$ AND FABRIC LAMINATES.

Effect Of Temperature On Flexure Modulus

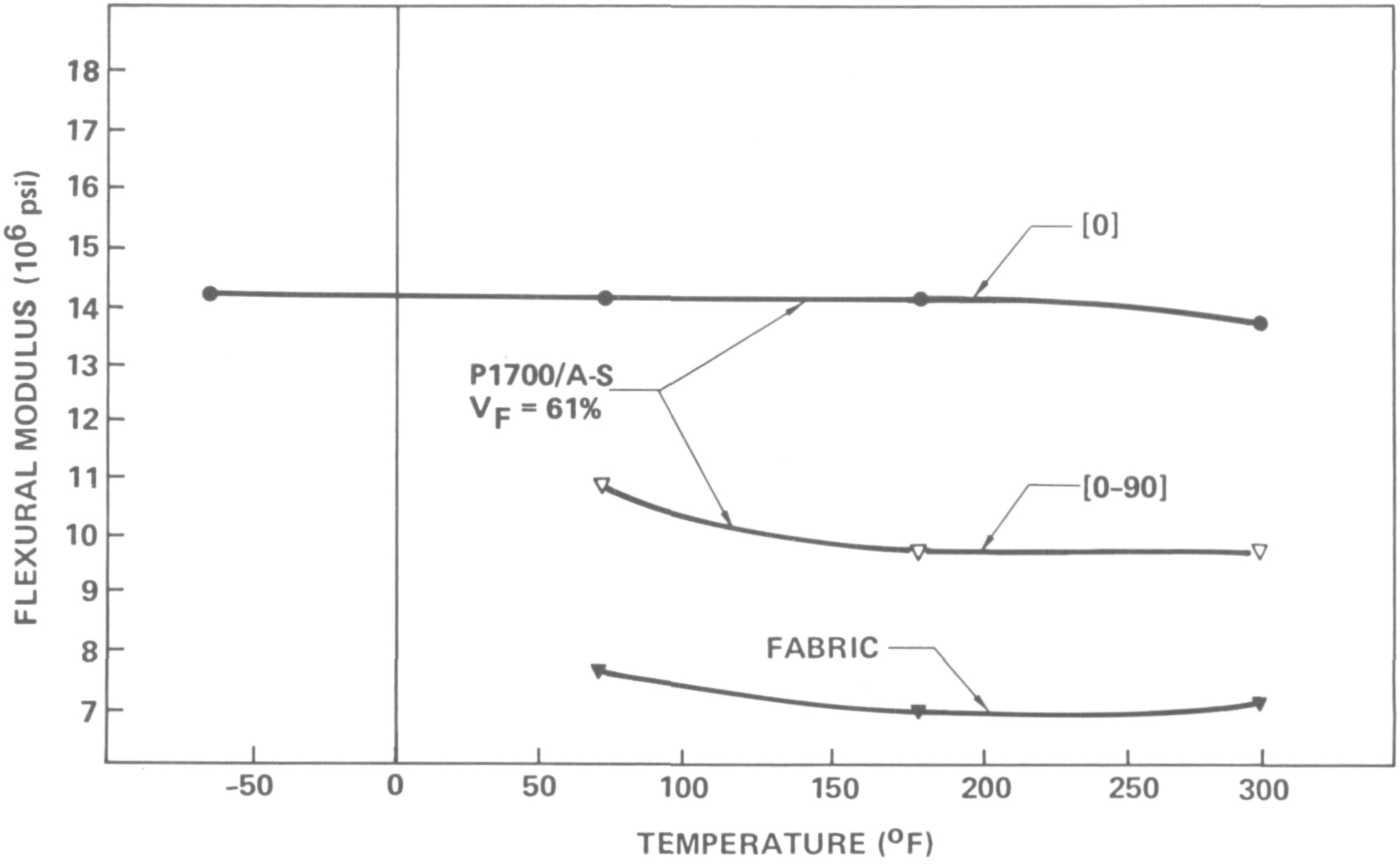


Figure 25

TEXT

TEMPERATURE vs. INTERLAMINAR SHEAR (Figure 26)

THE INTERLAMINAR SHEAR STRENGTH DECREASES WITH THE INCREASE IN TEMPERATURE TO 300°F. THIS LAMINATE HAD A FIBER VOLUME OF 58%.

Effect of Temperature on Interlaminar Shear

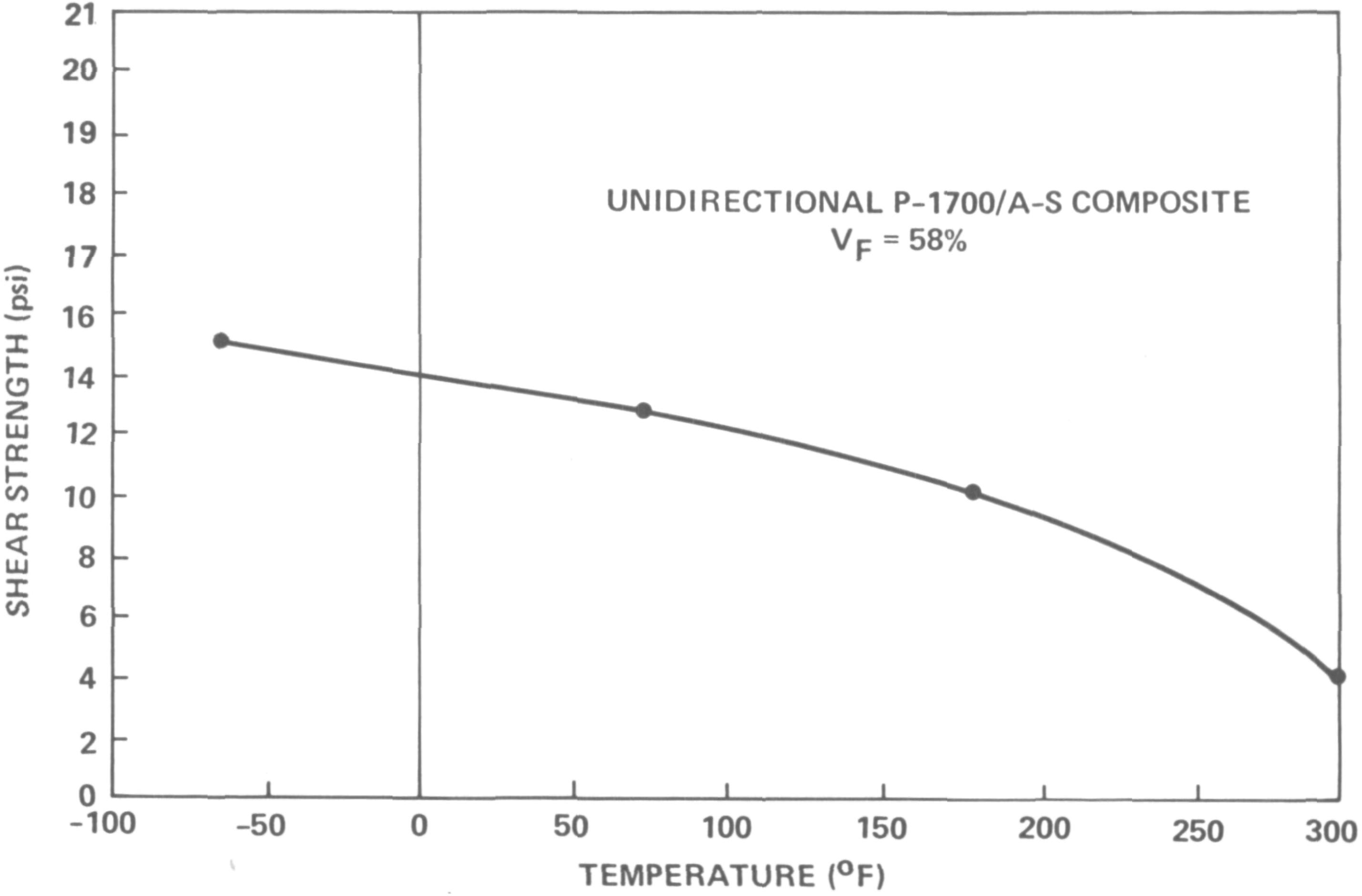


Figure 26

TEXT

ENVIRONMENTAL STABILITY (Figure 27)

THERMOPLASTIC COMPOSITES ARE ESSENTIALLY ENVIRONMENTALLY STABLE. THEY EXHIBIT LOW MOISTURE ABSORPTION, GOOD THERMAL STABILITY TO 300°F INCLUDING RESISTANCE TO MICROCRACKING WHEN EXPOSED TO SEVERE TEMPERATURE CYCLING. THEY OUTGAS IN A VACUUM ENVIRONMENT WITHIN ACCEPTABLE LIMITS OF 1% WEIGHT LOSS AND 0.1% VCM. THERE IS CURRENTLY, AS WITH EPOXY SYSTEMS, A LACK OF DATA ON RADIATION STABILITY; HOWEVER, BASED ON AVAILABLE THERMOPLASTIC RESIN RADIATION RESISTANCE DATA, IT IS SUSPECTED THAT THE COMPOSITE WILL SHOW SATISFACTORY RESISTANCE. CONTRARY TO POPULAR BELIEF, THERMOPLASTICS ARE ESSENTIALLY RESISTANT TO SOLVENT ATTACK EXCEPT FOR CERTAIN HALOGENATED SOLVENTS. THE COMPOSITES CAN BE PRIMED AND PAINTED USING STANDARD MIL-SPEC PROCEDURES AND WILL RESIST LONG TIME (28 DAY) CONTINUOUS EXPOSURE TO SUCH LIQUIDS AS JP-4 FUEL, HYDRAULIC OIL (MIL-H-5606), SYNTHETIC LUBRICANT (MIL-L-7807) AND POLYSULFIDE SEALANTS. SURFACE CLEANING OF THE THERMOPLASTIC COMPOSITES CAN BE ACCOMPLISHED WITH COMMON NON-HALOGENATED SOLVENTS (I.E., NAPHTHA, ALCOHOLS, ETC.)

Environmental Stability Thermoplastic Composites

• MOISTURE ABSORPTION	LOW (.25% @ 75°F)
• THERMAL STABILITY	GOOD TO 300°F GOOD STABILITY CYCLING -320°F TO +300°F (MINIMAL MICROCRACKING)
• VACUUM OUTGASSING	TOTAL WEIGHT LOSS = 0.38% VACUUM CONDENSIBLES = 0.06%
• SPACE RADIATION STABILITY	UNKNOWN - HOWEVER,SOME DATA ARE AVAILABLE ON RESIN PROPERTIES
• SOLVENT STABILITY	GOOD EXCEPT FOR CHLORINATED SOLVENTS

Figure 27

TEXT

SUMMARY (Figure 28)

TO SUMMARIZE, THERMOPLASTIC COMPOSITES OFFER THE SPACE SYSTEM DESIGNER A LOW-COST VERSATILE MATERIAL FOR SPACE SYSTEM HARDWARE DESIGN, CAPABLE OF BEING HANDLED, MACHINED AND ASSEMBLED IN THE SHOPS USING ESSENTIALLY STANDARD MANUFACTURING TOOLS AND PROCEDURES. THE FABRICATED STRUCTURE CAN BE READILY REPAIRED AND WILL EXHIBIT PREDICTABLE STRUCTURAL AND ENVIRONMENTAL STABILITY.

Thermoplastic Composites Summary

THERMOPLASTIC COMPOSITES FOR LARGE SPACE STRUCTURE WHEN COMPARED TO EPOXY COMPOSITES

- LOW COST
- GREATER DESIGN ALTERNATIVES
- MANUFACTURING AND ASSEMBLY VERSATILITY
- REPAIR CAPABILITY
- GOOD STRUCTURAL AND ENVIRONMENTAL STABILITY
- SINGLE COMPONENT SYSTEM

Figure 28

COMMENTS OF GENERAL INTEREST FROM QUESTIONS AND ANSWERS

Applicability of Thermoplastic Composites for Space Structures

Test Data from Materials Exposed to Space Environments

At the present time the limited understanding of the degradation modes - ultra violet as surface damage, charged particles as internal damage, has resulted in a correspondingly limited capability to perform accelerated testing on materials. Confirmatory testing from samples exposed on-orbit appear to be a real requirement in achieving such an understanding. The need exists to proceed immediately toward long term testing of material in actual orbital environments.