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(NASA-CR-151862) DEVELOPMENT OF PROCESSES  
AND TECHNIQUES FOR MOLDING THERMALLY STABLE,  
FIRE-RETARDANT, LOW-SMOKE-EMITTING POLYMERIC  
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## Development of Processes and Techniques for Molding Thermally Stable, Fire- Retardant, Low-Smoke- Emitting Polymeric Materials

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DEVELOPMENT OF PROCESSES AND TECHNIQUES  
FOR MOLDING THERMALLY STABLE, FIRE-RETARDANT,  
LOW-SMOKE-EMITTING POLYMERIC MATERIALS

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SUMMARY

During this study, data was gathered on the use of new polymers as material for compression molding, injection molding, and thermoforming. An evaluation was made as to which materials offer the best potential for significantly reducing fire and associated hazards when used for typical aircraft interior parts. Several materials in each molding category were selected for further development and possible utilization in production type parts. Specifically, the study was directed toward developing the processing and molding techniques of advanced, thermally stable, fire-retardant, low-smoke-emitting polymers.

The following determinations were made:

- Compression molding. - Three phenolic-type resin systems are available which would produce serviceable production parts with excellent fire-resistant properties.

Initial examination of fluorel polymer impregnated on fiberglass mat or fabric, determined that it can be compression molded into parts. Improvement in high humidity resistance or methods of preventing water absorption in the cured polymer is needed.

- Injection molding. - Two polymers, polyethersulfone and polyphenyl sulfone, offer good potential. However, material costs are approximately four times and seven times, respectively, that of presently available polycarbonate resin materials.
- Thermoforming. - The only polymer sheet material with good flame resistant properties is polyethersulfone (PES). The material costs approximately six times more than the ABS material presently in use. Initial sheets of the PES-KM-1 with textured surface, to be supplied by Rohm and Haas, were not available for making evaluation as of December 15, 1978.

INTRODUCTION

This is the final report of "Development of Processes and Techniques for Molding Thermally Stable, Fire-Retardant, Low-Smoke-Emitting Polymeric Materials" conducted by the Lockheed-California Company under Contract



NAS 9-15406 with the National Aeronautics and Space Administration, Johnson Space Center, Houston, Texas. This report documents all the development activities conducted during the study from October, 1977, through December 1978.

### Background

This development effort is one of several being sponsored by the NASA-JSC Fireman Program to develop more fire-resistant materials to be considered for use in the construction of aircraft interior parts and subassemblies.

### Objectives

The purpose of this study was to evaluate newly developed fire-resistant, low-smoke-emitting polymers for use in producing molded aircraft interior parts. This study effort specifically examined the new materials with regard to their behavior under flame impingement, their adaptability to processing into end products, and the endurance of the end products under typical aircraft environment and service abuse.

### Approach

To meet the objectives of this investigation, the contractor established a program that included seven technical tasks:

Task 1 - Industry Survey and Chemical Characterization. - Task 1 surveyed the state of the art for new polymers which could be considered for either compression molding, injection molding, or thermoforming sheet materials. Data on the polymers under consideration were gathered and analyzed to determine their potential in producing usable aircraft interior plastic parts.

Task 2 - Fire Hazard Evaluation. - From the data analyzed in Task 1, various molding materials were selected for evaluation. Promising materials mutually agreed upon between the contractor and NASA-JSC were obtained for flame resistance, smoke emission, and thermogravimetric analysis (TGA).

Compression-molded specimens were evaluated with and without added decorative Tedlar for possible improvements over presently constructed interior cabin parts. Subsequently, during the last three months of the programs actual production parts and simulated parts were molded and supplied to NASA-Houston for possible use in their fire-test program.

Task 3 - Decorative Laminates. - The NASA-AMES program with Boeing pertaining to the development of new films and decorative laminate constructions or possible replacements for Tedlar-type decorative materials was followed closely. A newly constructed decorative material had not yet been developed during this program. Consequently the present Tedlar construction was used on parts so as to provide a basis for comparison of new materials with known capabilities of standard production materials.

Task 4 - Compression Molded Parts. - Based on initial fire-test results and the overall physical and chemical properties of various new resin and modified resin systems, large compression-molded parts were produced in order to assess the processing cost aspects of the resin systems. After final analysis of the fire-resistant properties, and material and processing costs of all the candidate resin systems was made, three resin systems were selected and four production sidewall panels of each resin were produced and delivered to NASA-JSC. Two of the parts made from each resin system delivered to NASA-JSC were furnished with the decorative Tedlar laminate covering presently used on production parts. Finally 40 Tedlar covered Fiberite MXB6032 molded sidewall parts were produced for NASA.

Task 5 - Injection Molded Parts. - Based on information obtained from chemical companies and initial data analysis on plastic resins identified under Tasks 1 and 2, three newly developed materials were selected for further investigation. One of the resins was in the initial production phase and another in the pilot plant stage. The third material was in the early development stage but offered a potential for improved fire resistance at only a moderate increase in material cost over presently used injection-molding materials. In this task, data were gathered relating to the overall physical and chemical fire-resistant properties. Processing parameters and costs for producing finished parts were also established for two of the candidates based on small production parts of the passenger service modules on production tooling. The third material required a heated die to be produced on an experimental mold. Finally, over 60 injection-molded parts of two materials were produced and supplied to NASA-JSC.

Task 6 - Thermoformed Parts. - Development of new thermoforming sheet materials for replacement of the presently used high-smoke-emitting ABS, Noryl or Abskyn-type materials did not progress as well as expected. In view of restraints on fire-resistant and smoke-emission limits, it was difficult to obtain three materials for evaluation that were economically feasible. Only two true thermoforming-type materials were procured during the study period and neither had sufficient resistance to cleaner and solvent crazing to be a candidate replacement for the ABS-type and Abskyn decorative materials. During the last three months of the program, an initial sample of polyether-sulfone with improved resistance to stress cracking looked promising and several sheets of this material were ordered for evaluation.

Task 7 - Processing Instruction. - Preliminary processing and fabrication instructions covering the various molding materials, which were made into usable parts, were prepared and are presented in the Appendices to this report.

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- Gilbert Echt - Lockheed Manufacturing Research Facility
- Personnel at NASA-JSC for providing fire-safety data on some of the initial material samples.

#### DATA ANALYSIS

Three different types of molding materials were to be evaluated in this study. The available physical, chemical, and flammability data for all of the materials initially examined are presented in Tables I through III. For each category of molding material, candidate materials were selected based on availability and development potential. Final selection of the materials was made with the approval of the NASA Technical Monitor.

After reviewing the data on compression-molding materials in Table I, four modified phenolics and a polyimide foam resin system were selected for further evaluation.

Data compiled on injection molding materials, Table II, were examined and three new polymer materials, polyphenyl sulfone, aromatic polyester, and a new polycarbonate resin were initially selected for further evaluation. Production part injection molding feasibility was the area to be evaluated. Later in the program a new polyethersulfone was obtained where cost was estimated to be one-half that of the polyphenylsulfone Radel material.

Data on the potential new candidate thermoforming sheet materials are listed in Table III. A review of the data indicated that material developments to replace the high-smoke-emitting thermoplastic materials, such as ABS, and an early version of polycarbonate sheet were limited. It appeared that any new polymers developed to meet the tentative material physical property goals would be extremely expensive in sheet form. In addition to the increased material costs, projected tooling and processing costs appeared appreciably higher than the presently used thermoplastic sheet materials.

TABLE I. - PRELIMINARY DATA - COMPRESSION MOLDING MATERIALS

	Properties			
General	Chemical Name	<u>Phenolic-Glass 50%</u>	<u>Polymide (Solar)</u>	<u>Low Smoke Polyester-Glass</u>
	Trade Name	MIL-M-14F (GPI-100)	Foamed/Chopped Glass	LCM 22-2152
	Vendor	Various	Solar Turbines Int.	Various
	Finished Form	Comp Molded	Comp Molded-Foam	Compress Molded
	Raw Material Cost, \$/lb	1.50 Dark	3.00 - ?	1.50
	Colors Available	Tan to Brown	Yellow-Brown	Light to Varied
	Paint Systems	Available for Colors	Yes	Available
	Adhesive Bonding	Epoxy or Urethane	Yes-Epoxy	Epoxy
	Availability	Production Supplies	Limited Pilot Devel	Production Available
Processing	Drying	None	*Foaming-260°C 1/2 hr	None
	Cure Cycle °C	149°C (300°F) 1/2 hr	288°C (550°F)	132°C (270°F) 15 min
	Post Cure Cycle °C	177°C (350°F) 2 hr	315°C (600°F)	None
	Annealing °C	None		None
Physical	Density, kg/m <sup>3</sup>	1.75	Δ1.50	1.95
	Water Absorption, % in 24 Hours 23°C	0.15		0.25
	Rockwell Hardness	M 115	R-102	M 95
Mechanical	Tensile Strength MPa (psi)	51.8 (7500)	48.5 (7000)	69 (10,000)
	Tensile Elongation, %	.5	1.1	.5
	Flexural Strength, MPa (psi)	113 (16,000)		206 (30,000)
	Flexural Modulus, MPa (psi)	16500 (2.4 x 10 <sup>6</sup> )		11045 (1.6 x 10 <sup>6</sup> )
	Compressive Strength, MPa (psi)	186 (27,000)		145 (21,000)
	IZOD Impact, Notched, ft lb/in.	12.0	7.3	15.0
Thermal and Fire Safety	Heat Deflection, °C-1820 KPa (264 psi)	280°C (500 <sup>+</sup> °F)	204°C (400°F)	175°C (348°F)
	Maximum Service Use, °C	175°C (348°F)	190°C	130°C (266°F)
	Oxygen Index	40	60	30
	Flammability Resistance ASTM	Passes	Passes	Passes
	Far 853-60 sec Vertical Test -			
	Flame-out	0	0	4
	Glow Time	0	0	0
	Burn Length	2 cm	1 cm	5 cm
	Smoke Ignition D <sub>s</sub> -6 min (D <sub>m</sub> )	15	3	100
	TGA	400°C	400°C	300°C
Toxic Gas Emissions	Very Low	Minimal	Fair	
Servicability	Solvent Resistance	Excellent	Excellent	Good
	Humidity Stability	Good	Good	Good
	Stress Crack Resistance	Good	Good	Good
	Cleanability			
	Common Maintenance	Depends on Paint System	Depends on Paint System	Depends on Paint System
	Commercial Cleaners with Ammonia	Depends on Paint System	Depends on Paint System	Depends on Paint System
	Trichloroethane	Depends on Paint System	Depends on Paint System	Depends on Paint System
Ultra-Violet Light Resistance	Depends on Paint System	Depends on Paint System	Depends on Paint System	
Abrasion Resistance	Depends on Paint System	Depends on Paint System	Depends on Paint System	
Misc	Cost of Processing	20% Over Polyester Requires Press for Cure Matched Dies	*Foam Process Limit by Gasses Produced Cost of Foaming May Be Prohibitive Requires Press for Cure and Matched Dies	Cheapest Requires Press for Cure and Matched Dies
	Remarks		ΔOffers Possible Weight Saving	

TABLE I. - PRELIMINARY DATA - COMPRESSION MOLDING MATERIALS (Continued)

Properties				
General	Chemical Name	<u>Modified Phenolic/Glass</u>	<u>Polyimide/Glass</u>	<u>Phenolic-/Glass Fabric</u>
	Trade Name	#8250 #9250	AMS-3845/2	Fiberite MKB 6032
	Vendor	Narmco Prepreg	Prepreg	Various Prepreg
	Finished Form	Vac Bag or Comp Mold	Vac Bag Autoclave or pres	Vac Bag or Comp Mold
	Raw Material Cost, \$/lb	3.50	3.50	2.25
	Colors Available	Dark Brown	Brown	Dark Brown
	Paint Systems	Available	Available	Available
	Adhesive Bonding	Epoxy	Epoxy	Epoxy
	Availability	Limited Production	Limited Production	Production
Processing	Drying	None	None	None
	Cure Cycle °C	122°C (251°F)	290°C (554°F) 1.5 hrs	149°C (300°F) 3/4 hr
	Post Cure Cycle °C		None	177°C (350°F) 2 hrs
	Annealing °C		None	None
Physical	Density, kg/m <sup>3</sup>	1.90	1.90	1.90
	Water Absorption, % in 24 hours 23°C			
	Rockwell Hardness			
Mechanical	Tensile Strength MPa (psi)	345 (50,000)	310 (45,000)	310 (45,000)
	Tensile Elongation, %	1.0	1.0	1.0
	Flexural Strength, MPa (psi)		372 (54,000)	
	Flexural Modulus, MPa (psi)		17,240 (2.5 x 10 <sup>6</sup> )	17,240 (2.5 x 10 <sup>6</sup> )
	Compressive Strength, MPa (psi)	372 (54,000)		207 (30,000)
	IZOD Impact, Notched, ft lb/in.	20	20	20
Thermal and Fire Safety	Heat Deflection, °C-1820 kPa (264 psi)	175°C (348°F)	260°C (500°F)	200°C (391°F)
	Maximum Service Use, °C	149°C (300°F)	232°C (450°F)	185°C (348°F)
	Oxygen Index		60	40
	Flammability Resistance ASTM	Passes	Passes	Passes
	Far 853-60 sec Vertical Test -			
	Flame-out	0	0	0
	Glow Time	0	0	0
	Burn Length	2 cm	1 cm	2 cm
	Smoke Ignition D <sub>s</sub> -6 min (D <sub>m</sub> )	8	5	8
	TGA	400°C	450°C	400°C
Toxic Gas Emissions	Very Low	Minimal	Very Low	
Servicability	Solvent Resistance	Good	Good	Good
	Humidity Stability	Good	Good	Good
	Stress Crack Resistance	Excellent	Excellent	Excellent
	Cleanability			
	Common Maintenance	Depends on Paint System	Depends on Paint System	Depends on Paint System
	Commercial Cleaners with Ammonia	Depends on Paint System	Depends on Paint System	Depends on Paint System
	Trichloroethane	Depends on Paint System	Depends on Paint System	Depends on Paint System
Ultra-Violet Light Resistance	Depends on Paint System	Depends on Paint System	Depends on Paint System	
Abrasion Resistance	Depends on Paint System	Depends on Paint System	Depends on Paint System	
Misc	Cost of Processing	25% Over Polyester *Appears to be modified phenolic May be Cured with Vac Pressure and Oven	50% Over Polyester Requires Press or Autoclave for Pressure to Cure (50-100 psi)	25% Over Polyester May be Cured with Vac Pressure and Oven
Remarks				

TABLE II. - PRELIMINARY DATA - INJECTION MOLDING MATERIALS

	Properties					
General	Chemical Name	<u>Polycarbonate</u>	<u>Polyethersulfone</u>	<u>Polyphenylsulfone</u>	<u>Aromatic Polyester</u>	<u>Polyphenylene Sulfide</u>
	Trade Name	Lexan 940	200P	Radel	E-200 3Z	Ryton
	Vendor	General Electric	ICI (USA)	Union Carbide	Monsanto	Phillips Pete
	Finished Form	Small Pellets	Small Pellets	Small Pellets	Small Pellets	Small Pellets
	Raw Material Cost, \$/lb	2.50	8.00	*15.00	8.00	4.00
	Colors Available	Clear Tan Colors	Transparent Colors	All Colors	One Light Color	Darker Colors
	Paint Systems	Yes - Urethane	Possible - Devel Revived	?	?	?
	Adhesive Bonding - Available Availability	Yes - Urethane In Production	? - Devel Revived Limited Production	? Limited Production	? Developmental	? In Production
Processing	Drying Requirements	4 hrs @ 100°C	4 hrs - 150°C	3 hrs - 150°C	None	None
	Cure Cycle Injection Temp. °C - Mold Temp. °C	320°C - R.T.	*350°C I.T. - 170°C H.T.	375°C I.T. - 165°C H.T.	350°C I.T. - 100°C H.T.	300°C I.T. - 100°C H.T.
	Post Cure Cycle °C	None	None	None	None	None
	Annealing °C	None	Required for Larger Parts	None	None	None
Physical	Density, kg/m <sup>3</sup>	1.21	1.37	1.29	1.19	*1.40
	Water Absorption, % in 24 Hours	0.15	0.43		0.15	0.05
	Rockwell Hardness	70M 118R	M 88			R 123
Mechanical	Tensile Strength MPa (psi)	58.6 (8500)	82.7 (12 000)	71.7 (10 400)	69 (10 000)	79.1 (10 800)
	Tensile Elongation, %	50	8	60	66	*1.0 Colors
	Flexural Strength, MPa (psi)	82.7 (12 000)	113 (16 000)	85.5 (12 400)		143.4 (20 000)
	Flexural Modulus, MPa (psi)	2070 (3.0 x 10 <sup>5</sup> )	2415 (3.5 x 10 <sup>5</sup> )	2280 (3.3 x 10 <sup>5</sup> )	1900 (2.9 x 10 <sup>5</sup> )	4140 (6 x 10 <sup>5</sup> )
	Compressive Strength, MPa (psi)	87.2 (12 500)	82.7 (12 000)			113 (16 000)
	IZOD Impact, Notched, ft lb/in	Δ12	*1.6		3.0	*0.8
Thermal and Fire Safety	Heat Deflection, °C - 1820 kPa (264 psi)	132°C (270°F)	203°C (398°F)	204°C (400°F)	172°C (340°F)	138°C (278°F)
	Maximum Service Use, °C	110°C (230°F)	175°C (348°F)	290°C (554°F)	160°C (318°F)	
	Oxygen Index	35	37	39		48
	Flammability Resistance - ASTM F501-77	(0.30) Passes	Passes (0.030)	(0.039) Passes	(0.090) Passes	(0.030) Passes
	FAR 853 - 60 sec Vertical Test - Flame Out	5	3	0		1
	Glow Time	0	Δ0	Δ0		0
	Burn Length	8 cm	3 cm	1.5 cm		1.5 cm
	Smoke Ignition D <sub>s</sub> - 6 min (D <sub>m</sub> )	(060) 110	20	5	80 - 100	100
	TGA °C		440°C	500°C		430°C
	Toxic Gas Emissions	Very Low	Low	Minimal	Minimal	Low
Serviceability	Solvent Resistance	Poor	Poor	Good	Fair	Excellent
	Humidity Stability	Good	Good	Excellent	Good	Good
	Stress Crack Resistance	Good	Fair	Good	?	Fair
	Cleanability					
	Common Maintenance	Fair	Good	Good	Good	Good
	Commercial Cleaners with Ammonia	Fair	Fair	Good	Good	Good
	Trichloroethane	Poor	Fair	Good	Fair	Good
	Ultra-Violet Light Resistance	Good	Good	Good	?	Good
Abrasion Resistance	Fair	?	?	?	?	
Misc	Cost of Processing	Equal to present type polycarbonate	May require heated dies	Requires heated dies and high temperature equipment	May be used can present equipment	
	Remarks	• May be substituted directly in system Δ• Impact resistance greatly improved	*Impact strength very low ΔDoes not drip	*May be prohibitive but offers other good features with respect to fire safety ΔDoes not drip		*Very brittle 17% heavier than present material

TABLE II. - PRELIMINARY DATA - INJECTION MOLDING MATERIALS (Continued)

Properties					
General	Chemical Name	<u>Polyamide-Imide</u>	<u>Polyvinylidene Fluoride</u>	<u>Polyimide Alloy</u>	<u>Polyaryl-sulfone</u>
	Trade Name	Torlon 4203	Kynar	Tribolen XT-1211	Astrel #360
	Vendor	Amoco Chemicals	Penwalt	Fluorocarbon	
	Finished Form	Small Pellets	Small Pellets	Small Pellets	
	Raw Material Cost, \$/lb	4.00		*12.50	*\$75.00/lb
	Colors Available	Dark Brown	Black	Dark Brown	
	Paint Systems	?	No	? Possible	
	Adhesive Bonding - Available	Epoxy	*No	? Possible	
Availability	Limited Production	Limited Production	Limit Small Parts		
Processing	Drying Requirements	6 hrs at 120°C	None	2 hrs - 130°C	
	Cure Cycle Injection Temp. °C - Mold Temp. °C	360°C I.T. - 260°C M.T.	300°C - R.T.	370°C I.T. - 180°C M.T.	
	Post Cure Cycle °C	*96 hrs (130°C to 260°C)	None	12 hrs 20°C to 260°C	
	Annealing °C		None		
Physical	Density, kg/m <sup>3</sup>	1.40	*1.80	*1.45	
	Water Absorption, % in 24 Hours	0.28			
	Rockwell Hardness		109		
Mechanical	Tensile Strength MPa (psi)	186 (27 000)	41.6 (6000)	48.5 (7000)	
	Tensile Elongation, %	12	50 - 200	8	
	Flexural Strength, MPa (psi)	207 (30 000)		72.4 (10 500)	
	Flexural Modulus, MPa (psi)	1720 (2.5 x 10 <sup>5</sup> )	1380 (2.0 x 10 <sup>5</sup> )	4147 (6.1 x 10 <sup>5</sup> )	
	Compressive Strength, MPa (psi)	275 (40 000)	59.4 (8600)	87.2 (12 500)	
	IZOD Impact, Notched, ft lb/in	2.5	5	*1.1 to 2.5	
Thermal and Fire Safety	Heat Deflection, °C 1820 kPa (264 psi)	274°C (525°F)	82°C (180°F)	250°C (472°F)	
	Maximum Service Use, °C	250°C	70°C	225°C	
	Oxygen Index	41	45		
	Flammability Resistance - ASTM F501-77	(0.30) Passes	Passes	Passes	
	FAR 853 - 60 sec Vertical Test - Flame Out	0	0	0	
	Glow Time	0	0	0	
	Burn Length	1.2 cm	2 cm	1 cm	
	Smoke Ignition D <sub>5</sub> - 6 min (D <sub>m</sub> )	10		3	
	TGA °C	450°C	350°C	450°C	550°C
	Toxic Gas Emissions	Minimal	High HF	Minimal	Minimal
Serviceability	Solvent Resistance	Excellent	Good	Excellent	
	Humidity Stability	Good	Good	Good	
	Stress Check Resistance	Good	Good	Good	
	Cleanability				
	Common Maintenance	Depends on Paint	Depends on Paint	Depends on Paint	
	Commercial Cleaners with Ammonia	Depends on Paint	Depends on Paint	Depends on Paint	
	Trichloroethane	Depends on Paint	Depends on Paint	Depends on Paint	
Ultra-Violet Light Resistance	Depends on Paint	Depends on Paint	Depends on Paint		
Abrasion Resistance	Depends on Paint	Depends on Paint	Depends on Paint		
Misc	Cost of Processing	*Processing costs for stress relief would be prohibitive		High material and processing costs	
Remarks			*Prohibitive weight cost  *Is not bondable	*Low impact strength  *Higher density	*Too costly to be considered

TABLE III. - PRELIMINARY DATA - THERMOFORMING MATERIALS

Properties				
General	Chemical Name	<u>Abs - Polysulfone</u>	<u>Polyphenylsulfone</u>	<u>Aromatic Polyester</u>
	Trade Name	XP-779	Radel	E200 - 32
	Vendor	Uniroyal	Union Carbide	Monsanto
	Finished Form	Thermo-Sheet	Thermo-Sheet	Thermo-Sheet
	Raw Material Cost, \$/lb.	5.00	*\$30/lb	5.00
	Colors Available	Some -	Yes	Possible
	Paint Systems	Yes	?	?
	Adhesive Bonding	Yes	?	?
	Availability	Limited Production	Limited	In Development
Processing	Drying Required	120°C for 10 hrs	150°C 4 hrs	None
	Cure Cycle (Forming) °C	250°C	250°C	250°C
	Post Cure Cycle °C	None	None	None
	Annealing	None	None	None
Physical	Density, kg/m <sup>3</sup>	1.26	1.29	1.20
	Water Absorption, % in 24 hours			0.15
	Rockwell Hardness	119		
Mechanical	Tensile Strength MPa (psi)	55.2 (8000)	71.7 (10 400)	69 (10 000)
	Tensile Elongation, %	40%	60%	60%
	Flexural Strength, MPa (psi)	86.0 (12 500)	85.5 (12 400)	
	Flexural Modulus, MPa (psi)	2205 (320 000)	2280 (330 000)	
	Compressive Strength, MPa (psi)			
	IZOD Impact, Notched, ft lb/in	9	12.0	3-5
Thermal and Fire Safety	Heat Deflection, °C 1820 kPa (264 psi)	149°C (300°F)	204°C (400°F)	170°C (338°F)
	Maximum Service Use, °C	135°C	185°C	160°C
	Oxygen Index	30	39	35
	Flammability Resistance ASTM FAR 853-60 sec Vertical Test -	(0.060) Passes	(0.030) Passes	(0.080) Passes
	Flame-Out	5 sec	0	
	Glow Time	0	0	
	Burn Length	7.5 cm	1 cm	
	Smoke Ignition P <sub>s</sub> - 6 min (D <sub>m</sub> )	(0.060) 105	4	80-100
	TGA	400°C	450°C	
	Toxic Gas Emissions		Very Minor Only Co Co 4 SO	Minimal
Serviceability	Solvent Resistance	Better Than Standard Polycarb	Fair	Fair
	Humidity Stability	Good	Good	Good
	Stress Crack Resistance	Good	Better Than Standard Polycarbonate	Better Than Polycarbonate
	Cleanability	Good	Good	Good
	Common Maintenance	Good	Good	Good
	Trichloroethane	Poor	Good	Fair
	Ultra-Violet Light Resistance	Good	?	?
Abrasion Resistance	Fair	?	?	
Misc	Cost of Processing	Minimal	Requires heated dies and high temperature equipment.	May require heated die for some deep draw parts.
	Remarks	<ul style="list-style-type: none"> <li>• Does not offer any advantage over present F600 polycarb</li> <li>• Material costs about 50% higher than F-6000</li> </ul>	*Cost may be prohibited except for special areas.	



TABLE III. - PRELIMINARY DATA - THERMOFORMING MATERIALS (Continued)

	Properties			
General	Chemical Name	<u>Acrylic/PVC</u>	<u>Chlorinated PVC</u>	<u>Polycarbonate</u>
	Trade Name	DKE 500X	Boltiron 8000	Lexan EF-6000
	Vendor	E. I. Dupont	General Tire	General Electric
	Finished Form	Thermoformed	Thermoformed	Thermo-Sheet
	Raw Material Cost, \$/lb.	2.50	2.50/lb	3.00
	Colors Available	Yes-Light to Dark	*Some - Thickness limited	Opaque Colors and texture
	Paint Systems	Yes - Available	Yes	Yes - Urethane
	Adhesive Bonding	? Yes	Available - Good	Yes - Urethane
Availability	Limited Production	Back in Development	Limited Production	
Processing	Drying Required	None	None	120°C for 6 hrs
	Cure Cycle (Forming) °C	190°C (374°F)	190°C (374°F)	190°C (390°F)
	Post Cure Cycle °C	None	None	None
	Annealing	None	None	None
Physical	Density, kg/m <sup>3</sup>	1.26	*1.57	1.21
	Water Absorption, % in 24 hours	0.09		0.19
	Rockwell Hardness	106		1949
Mechanical	Tensile Strength, MPa (psi)	41.4 (6000)	37.9 (5500)	66.2 (9600)
	Tensile Elongation, %	120%	40%	75%
	Flexural Strength, MPa (psi)	69 (10 000)	69 (10 000)	92 (13 500)
	Flexural Modulus, MPa (psi)	2565 (370 000)	2280 (330 000)	2130 (308000)
	Compressive Strength, MPa (psi)	58.6 (8500)		
	IZOD Impact, Notched, ft lb/in	6,6	6,6	14,0
Thermal and Fire Safety	Heat Deflection, °C 1820 kPa (264 psi)	87.5°C (190°F)	87.5°C (190°F)	121°C (252°F)
	Maximum Service Use, °C	82°C (180°F)	82°C (180°F)	110°C (230°F)
	Oxygen Index	28	45	34
	Flammability Resistance ASTM FAR 853-60 sec Vertical Test - Flame-Out	Passes	Passes	Passes (030)
	Glow Time		0	5 sec
	Burn Length		0	0
	Smoke Ignition D <sub>5</sub> - 6 min (D <sub>m</sub> )		10 cm	10 cm
	TGA	*(0.063) 200	(0.060) 140	(0.060) 124
	Toxic Gas Emissions	(HCL?)	(HCL?)	Minor
Serviceability	Solvent Resistance	Fair	Fair	Fair
	Humidity Stability	Good	Good	Good
	Stress Crack Resistance	Good	Good	Fair (Better Than Standard Polycarbonate)
	Cleanability	Good	Good	Good
	Common Maintenance	Good	Good	Good
	Trichloroethane	Fair	Fair	Poor
	Ultra-Violet Light Resistance	?	Good 60 hr	Good
Abrasion Resistance	Good	Good	Fair	
Misc	Cost of Processing	Minimal	Minimal	Minimal
Remarks		No New Tooling *May be too high but much better than ABS presently used in high wear areas.	No New Tooling *Density Wt Cost (40%) *Limited thickness - colors width and texture	* Still questionable for areas where continuous cleaning required.

One elastomeric type resin material, fluorel from the 3M Company was added to the thermoplastic category by the NASA Technical Monitor. This material is in a very early development stage. However, in work done previously by NASA-JSC, excellent fire resistant properties are indicated.

#### SELECTION OF POLYMERS

Selection of polymers to be further evaluated was based on their ability to most closely meet the tentative material specification goals listed in Table IV, with the following added premises regarding development status:

- A material in production which most closely approaches the tentative program specification goals.
- A polymer in pilot plant development which most closely approaches the tentative specification goals although present costs may be prohibitive.
- A polymer in early research development which offers potential to meet the goals with minor economic impact.

Materials selected for further evaluation for each category made with the technical monitor's concurrence were as follows:

##### Compression Molding Materials

- Production Phenolic Resin System - Fiberite MXB 6032 (LAC-C-22-1339)
- Ciba Geigy Fiberdux 917
- NARMCO 8250 and 9252
- Fiberite MXB 607L
- Polyimide foam/glass (Solar)

##### Injection Molding Materials

- G.E. Lexan #940, polycarbonate
- Monsanto #E200-3Z, aromatic polyester
- Union Carbide Radel 5010N, polyphenyl sulfone

TABLE IV. - TENTATIVE MATERIAL GOALS

Chemical or Physical Property	Type of Molding			Test Method FED. STD. -406, Except as Noted
	Thermoformed	Injection	Compression	
Tensile Strength MPa min (psi)	41.3 (6000)	41.3 (6000)	55.2 (8000)	1011 Speed C
Impact Strength (notched Izod) N.m/m min (ft lb/in of notch)	(3.0)	(3.0)	(3.0)	1071
	153	153	153	
Flexural Strength MPa min (psi)	55.2 (8000)	55.2 (8000)	69.0 (10000)	1031
Elongation % min at break	20	5	5	1011 Speed C
Mod of Elasticity MPa (psi)	2070 (300000)	2070 (300000)	2070 (300000)	1031
Specific Gravity max	1.40	1.30	1.30	5011
Heat of Deflect Temp °C(°F) min @ 1820 kPa (264 psi)	121°C (250°F)	121°C (250°F)	148.5°C (300°F)	ASTM D648
Color Fastness Fade-0-Meter	50 hr min	50 hr min	50 hr min	Fed. Std. 191 5060
Stress Cracking Resistance Solvent Test	No visible cracks	No visible cracks	No visible cracks	LAC C-22-1115 D Method 4.1.1.1
Oxygen Index (LOI) min	40	40	40	ASTM D-2863
Smoke Optical Density (DMS) max (6 minutes)	75	75	75	NBS Smoke Chamber AMINEO COT #4-5800
Thermal Stability (TGA) min°C (°F)	205°C (400°F)	205°C (400°F)	205°C (400°F)	Thermogravimetric Analysis
Flammability Screening Test 60 sec vertical Test Method	5 sec extingh. max no drip	5 sec extingh. max no drip	5 sec extingh. max, no drip	FAA 25.853a Appendix F
Bondable Lap Shear MPa min (psi)	3.55 (500)	3.55 (500)	3.55 (500)	1.27 cm overlap (1200-1400 psi) 8.27 - 9.58 MPa
180° Peel N/m	1400 (8 ppi)	1400 (8 ppi)	1400 (8 ppi)	5.1 cm/min (2 in/min) jaw sep.

### Thermoforming Sheet Materials

- G.E. Lexan EF-6000, polycarbonate
- 3M Fluorel Polymer
- Monsanto E200-3Z or Polymide/Glass (Solar)

About the middle of the contract period, and after working with some of the development materials, it was established that certain resin or polymer materials could only be made by the compression molding process. Work was continued on both the Solar polymide/glass foam material and the 3M Fluorel by compression molding with heat and pressure to form the materials. Also, during the last half of the contract it became apparent that the injection molding material from Monsanto, E200-3Z, did not possess the same degree of flame resistance in thinner sections as it initially appeared to have in thicker samples examined at JSC and at Lockheed. Therefore, another injection molding material was obtained for evaluation from ICI, a new version of polyethersulfone, KM-1. ICI stated that the new version of PES had eliminated the earlier objections to its low stress crazing property without any reduction in its flame resistant properties. Also, the estimated material cost of PES was approximately 1/2 that of Radel 5010N injection molding material.

Efforts to obtain additional samples of EF-6000 thermoplastic sheet material from General Electric were unsuccessful during the remainder of the contract period due to production problems at G.E.. Instead, G.E. F-6000 was substituted as the only available production status sheet material for fabrication of production parts. Two developmental sheet materials were ordered from Rohm and Hass, a sheet version of PES KM-1 resin and another polycarbonate material.

The PES polymer does not melt and drip as does the F-6000 polycarbonate sheet material, and also, the PES smoke emission is much lower. However, the material cost is 5 times that of the F-6000 polycarbonate sheet material presently used in production. In addition, tooling and processing costs are higher due to the requirement for heated dies and higher-temperature processing cycles.

The samples of polycarbonate from Rohm and Hass was obtained since it was stated that it had lower smoke emission than the presently used polycarbonate, and that it had been modified to obtain better service-cleaner resistance.

### TRADE-OFF DATA

Data generated for the trade-off analysis covering the materials examined during the development program are shown in Tables V, VI, and VII. Flame and associated hazards data are covered in Figures 1 through 18 indicating the flame resistance characteristics and smoke emission levels of all the candidate materials. The material code for the test results is listed in Table VIII.

TABLE V. - COMPRESSION MOLDING MATERIALS  
(Trade-Off Data - Candidates)

Property	Basic LAC 22-1339 Phenolic/Glass	Ciba/Geigy Fiberdux 917	Narmco 9252/Glass	Narmco 8250/Glass	Fiberite MXB 6072	Solar Polyimide/Glass
Density	X	X	X	X	X	Varied
Flame Test Flame Ext. and Glow 60 Sec Vert	3 - 11*	0 - 3*	3 - 4*	3 - 9*	1 - 10*	0 - 25.0*
Burn Length (CM)	3.3 - 11.3*	6.1 - 10.2*	8.4 - 16.7*	3.8 - 11.9*	3.6 - 11.4*	3.0 - 8.6*
Smoke Test	2.0	8.8	3.0	3.0	5.8	0.5
D <sub>s</sub> (6 Min) (Flaming)	70.0*	97.0*	60.0*	105.0*	58.0*	67.0*
TGA	390°C	390°C	290°C	390°C	390°C	590°C
Matl Cost	X	3X	2.5X	2.5X	2X	5X
Processing Costs	X	X	X	X	X	2X plus Expensive Tooling
Handling Properties	Adequate	Adequate	Adequate	Adequate	Adequate	Limited as supplied to simple Parts
Part Interply Strength	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
Impact Resistance	Good	Good	Good	Good	Good	Good

\*Tested with adhesively bonded decorative Tedlar

TABLE VI. - INJECTION MOLDING MATERIALS  
(Trade-Off Data - Candidates)

Property	Lexan 940	E200-3Z	Radel 5010N	ICI, PES KM-1
Density	1.21	1.19	1.29	1.37
LOI	35	33	38	36
TGA °C	440°C	?	570°C	570°F
Smoke Ds, (6 Minutes)	110	90	3.2	20
Material Cost	1.5X	2X	6X	3.0X
Processing Cost	X	1.3X	2X + Heated Die	2X + Heated Die
Impact Izod Notch J/mm	5.33J/mm (10 ft lb/in)	2.1J/mm (3 ft lb/in)	6.4J/mm (12 ft lb/in)	0.86J/mm (1.6 ft lb/in)
Availability	Production/Colors	Development	Limit Pilot Plant	Limited Production
Elongation %	90	60	60	10
Heat Deflection °C @ 1820kPa	132°C	170°C	204°C	190°C
Cleaner & Solvent Resistance	Fair	Good	Good	Good
Flame Test-60 Sec Vert 0 Flame Ext. + Glow	4 sec	2 sec	1 sec	1 sec
Melt, Drip, Burn	Melts - Drips, would feed fire ~ 2 sec	Melts - Drips and Burns - 7 sec	Chars - Does not drip - 0	Chars - Does not drip - 0
0 Burn Length	7.5 cm	6.2 cm	7 cm	8.50 cm

TABLE VII. - THERMOFORMING MATERIALS  
(Trade-Off Data - Candidates)

Property	F-6000	EF-6000	Polyethersulfone KM-1	*Fluorel (3M)
Density g/cc	1.21	1.21	1.37	?
Flame Test 50 sec Vert.				
• Flame Out	4 sec	97. sec	1 sec (glow)	8 sec (glow)
• Melt and Drip	1 sec	1 sec	0	0
• Burn Length	7.5 cm	18.5 cm	8.5 cm	2.7 cm
TGA °C	440°C	440°C	550°C	
LOI	33.5	33	36	?
Smoke D <sub>s</sub> (6 min)	110	120	20	10
Impact IZOD Notch J/mm (ft lb/in)	5.35 (10)	6.42 (12)	0.867 (1.6)	
Heat Deflection - 1820 kPa °C	132°C	122°C	190°C	
Cleaner and Solvent Resistance	Fair	Fair	Good	Good
Elongation %	90	90	20	?
Material Cost	X	1.33 X	3X	?
Availability	Production	Limited Production (on hold)	Limited Production Rohm and Hass	Development
Processing Costs	X	X	2X + Heated Dies Required	*Compression Molded not Thermoformed
Surface 180° Peel Bondable N/M (lb/in)	1750 (10)	1750 (10)	1225 (7.0)	?

\*Must be reinforced with glass fibers and compression molded to limited shapes.

TABLE VIII. - MATERIAL CODE

Test No.	Lab No.	Material
Material Test 1247	FN501	Ciba Geigy Fiberdux 917
Material Test 1248	FN503	NARMCO 9252
Material Test 1249	FN505	NARMCO 8250
Material Test 1250	FN507	Fiberite MXB607L
Material Test 1251	FN510	Fiberite 6032
Material Test 1252	FN501T	FN501 + Tedlar Covering
Material Test 1253	FN503T	FN503 + Tedlar Covering
Material Test 1254	FN505T	FN505 + Tedlar Covering
Material Test 1255	FN507T	FN507 + Tedlar Covering
Material Test 1256	FN510T	FN510 + Tedlar Covering
Material Test 1273	FN30877-11A	Polyimide/glass
Material Test 1274	FN30877-11B	Polyimide/glass + Tedlar
Material Test 1258	FN30877-10	E200 - 3Z
Material Test 1279	FN30877-11C	Rohm & Haas 4360Z
Material Test 1280	FN30877-11D	Rohm & Haas KM-1 (PES)
Material Test 1277	FN30877-11E	Radel 5010N
Material Test 1278	FN30877-11F	EF-6000
Material Test 1283	FN30877-15A	Fluorel 7-5



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CHECKED		RYE CANYON RESEARCH LABORATORY						MODEL
APPROVED		FLAMMABILITY/SMOKE TEST REPORT						REPORT NO.
MATERIAL TEST NO: <i>1247</i>								
MATERIAL DESCRIPTION: <i>FN501 Ciba-Gelby Fiberdax 917 Paper, Nomex</i>								
USE/APPLICATION: <i>Handy Comb cont. / Window Panel / Window Panel</i>								
FLAMMABILITY TEST						METHOD: 501ST		
Spec. No.	Ign. Time	After Flame Time	Flow Time	Total Ext. Time	Drip Ext. Time	Burn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>None</i>	<i>2.7</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>2.5</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>2.1</i>	<i>Yes</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>None</i>	<i>2.4</i>	<i>Yes</i>	<i>Passes Method 1</i>

SMOKE TEST	NPS TYPE CHAMBER			COMMENTS
Specimen No.	1	2	3	
Thickness - in.	<i>.08</i>	<i>.08</i>	<i>.08</i>	
Weight - grams	<i>71</i>	<i>71</i>	<i>89</i>	
Exposed Area - sq.in.	<i>6.56</i>	<i>6.56</i>	<i>6.56</i>	
Gas Pressure - psig	Pilot	Pilot	Pilot	
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5	

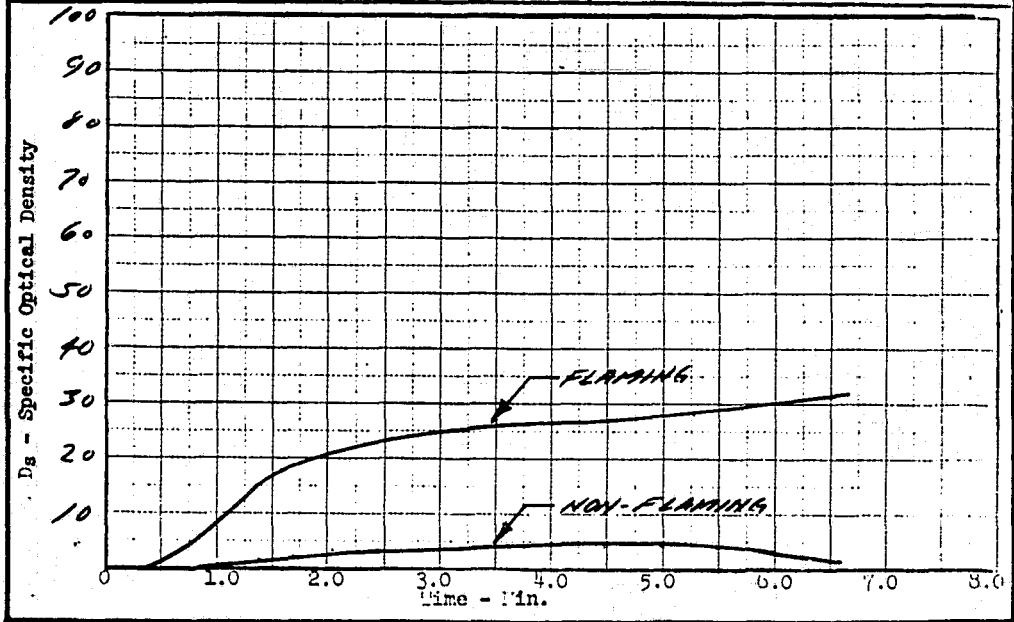
The graph plots Specific Optical Density (Ds) on the y-axis (0 to 20) against Time in minutes on the x-axis (0 to 8.0). Two curves are shown: 'FLAMING EXPOSURE' and 'NON-FLAMING (Smoldering) EXPOSURE'. The flaming curve rises to a peak of approximately 10 at 4.0 minutes and then gradually declines. The non-flaming curve rises to a peak of approximately 4 at 3.5 minutes and then declines.

Time (Min)	Flaming Exposure (Ds)	Non-Flaming Exposure (Ds)
0.0	0.0	0.0
1.0	3.0	2.5
2.0	5.0	3.0
3.0	7.0	3.5
4.0	10.0	3.5
5.0	9.0	3.0
6.0	8.0	2.5
7.0	7.0	2.0
8.0	6.0	1.5

Figure 1. - Flame and smoke data - FN501 (material test 1247).

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CHECKED	T Y P E	RYE CANYON RESEARCH LABORATORY		MODEL				
APPROVED		FLAMMABILITY/SMOKE TEST REPORT		REPORT NO.				
MATERIAL TEST NO: <i>1248</i>								
MATERIAL DESCRIPTION: <i>FN503, NARMCO 9252 Resin, Honey Hk core</i>								
USE/APPLICATION: <i>Sidewall Panel/Window Revell</i>								
FLAMMABILITY TEST			METHOD: <i>SO. 1T</i>					
Spec. No.	Ign. Time	After flame Time	Flow Time	Actual Ext. Time	Drip Ext. Time	Burn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>2</i>	<i>2</i>	<i>None</i>	<i>2.8</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>5</i>	<i>5</i>	<i>"</i>	<i>3.7</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>"</i>	<i>3.4</i>	<i>Yes</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>None</i>	<i>3.3</i>	<i>Yes</i>	<i>Passes Method 1</i>

SMOKE TEST	17'S TUBE CHAMBER			COMMENTS
Specimen No.	1	2	3	
Thickness - in.	<i>.08</i>	<i>.08</i>	<i>.08</i>	
Weight - grams	<i>6.565</i>	<i>6.819</i>	<i>7.470</i>	
Exposed Area - sq.in.	<i>6.56</i>	<i>6.56</i>	<i>6.56</i>	
Gas Pressure - psig	<i>Pilot</i>	<i>Pilot</i>	<i>Pilot</i>	
Irradiance - watts/cm <sup>2</sup>	<i>2.5</i>	<i>2.5</i>	<i>2.5</i>	



FORM 3620-2

Figure 2. - Flame and smoke data - FN503 (material test 1248).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION						PAGE
CHECKED	TITLE	RYE CANYON RESEARCH LABORATORY						MODEL
APPROVED		FLAMMABILITY/SMOKE TEST REPORT						REPORT NO.
MATERIAL TEST NO: <i>1249</i>								
MATERIAL DESCRIPTION: <i>FN505, Narmco 8250 Resin, Normy H/C core</i>								
USE/APPLICATION: <i>Sidewall Panel/Windshield Panel</i>								
FLAMMABILITY TEST METHOD: <i>ASTM D 568</i>								
Spec. No.	Ign. Time	After flame Time	Flow Time	Total ext. Time	Drip ext. Time	burn length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>4</i>	<i>4</i>	<i>None</i>	<i>1.5</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>2</i>	<i>2</i>	<i>"</i>	<i>1.5</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>2</i>	<i>2</i>	<i>"</i>	<i>1.6</i>	<i>Yes</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>None</i>	<i>1.5</i>	<i>Yes</i>	<i>Passes Method 1</i>

SMOKE TEST	NPS TEST CHAMBER			COMMENTS
Specimen No.	1	2	3	
Thickness - in.	<i>.07</i>	<i>.07</i>	<i>.07</i>	
Weight - grams	<i>7.1/64</i>	<i>6.2/64</i>	<i>6.2/63</i>	
Exposed Area - sq.in.	<i>6.56</i>	<i>6.56</i>	<i>6.56</i>	
Gas Pressure - psig	Pilot	Pilot	Pilot	
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5	

FORM 382B-2

Figure 3. - Flame and smoke data - FN505 (material test 1249).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION					PAGE	
CHECKED	T Y P E	RYE CANYON RESEARCH LABORATORY					MODEL	
APPROVED		FLAMMABILITY/SMOKE TEST REPORT					REPORT NO.	
MATERIAL TEST NO: <i>1250</i>								
MATERIAL DESCRIPTION: <i>FN 507 Fiberite MXB 607 L Pre-imp, Nomex</i>								
USE/APPLICATION: <i>HC core sidewall Panel/Window Panel</i>								
FLAMMABILITY TEST						METHOD: <i>CG 17</i>		
Spec. No.	Ign. Time	After Flame Time	Flow Time	Total Ext. Time	Drip Ext. Time	Burn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>2</i>	<i>2</i>	<i>None</i>	<i>1.9</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>1.5</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>1.4</i>	<i>Yes</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>None</i>	<i>1.9</i>	<i>Yes</i>	<i>Passes Method 1</i>

SMOKE TEST	NPS TYPE CHAMBER			CORRECTIONS
Specimen No.	1	2	3	
Thickness - in.	<i>.08</i>	<i>.08</i>	<i>.08</i>	
Weight - grams	<i>5.962</i>	<i>6.060</i>	<i>5.961</i>	
Exposed Area - sq.in.	<i>6.56</i>	<i>6.56</i>	<i>6.56</i>	
Gas Pressure - psig	Pilot	Pilot	Pilot	
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5	

The graph plots Specific Optical Density (Ds) on the y-axis (0 to 10) against Time in minutes on the x-axis (0 to 8.0). Two curves are shown: 'FLAMING' and 'NON-FLAMING EXPOSURE'. The 'FLAMING' curve starts at (0,0), rises to approximately 4.5 at 4.0 minutes, then jumps to 6.0 at 5.0 minutes and remains constant. The 'NON-FLAMING EXPOSURE' curve starts at (0,0), rises to a peak of about 1.5 at 4.0 minutes, and then gradually declines to about 0.5 at 8.0 minutes.

Figure 4. - Flame and smoke data - FN507 (material test 1250).

PREPARED BY <i>E. Leffer</i>	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION					PAGE	
CHECKED	T T L E	RYE CANYON RESEARCH LABORATORY					MODEL	
APPROVED		FLAMMABILITY/SMOKE TEST REPORT					REPORT NO.	
MATERIAL TEST NO: <i>1251</i>								
MATERIAL DESCRIPTION: <i>FN510 Fibriltex MKB 6030 Nomex 4/8 core</i>								
USE/APPLICATION: <i>LAG C-22-1339 TYP II</i>								
USE/APPLICATION: <i>Small Panel/Window Board</i>								
FLAMMABILITY TEST						METHOD: <i>SOFT</i>		
Spec. No.	Ign. Time	After flame Time	Jew Time	Local Ext. Time	Drip Ext. Time	Turn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>None</i>	<i>1.2</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>5</i>	<i>5</i>	<i>"</i>	<i>1.5</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>"</i>	<i>1.4</i>	<i>Yes</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>None</i>	<i>1.3</i>	<i>Yes</i>	<i>Passes Method 1</i>
SMOKE TEST			IRS TYPE CHAMBER			COMMENTS		
Specimen No.	1	2	3					
Thickness - in.	<i>.08</i>	<i>.08</i>	<i>.08</i>					
Weight - grams	<i>6.765</i>	<i>6.765</i>	<i>6.645</i>					
Exposed Area - sq.in.	<i>6.56</i>	<i>6.56</i>	<i>6.56</i>					
Gas Pressure - psig	Pilot	Pilot	Pilot					
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5					

FORM 3628-2

Figure 5. - Flame and smoke data - FN510 (material test 1251).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION					PAGE	
CHECKED	T I T L E	RYE CANYON RESEARCH LABORATORY					MODEL	
APPROVED		FLAMMABILITY/SMOKE TEST REPORT					REPORT NO.	
MATERIAL TEST NO: <i>1252</i>								
MATERIAL DESCRIPTION: <i>FN5017 Ciba-Geigy Fiberdux 917 Paper</i>								
USE/APPLICATION: <i>Navy Air core Tubular covering Sidewall Panel / Bladder Panel</i>								
FLAMMABILITY TEST METHOD: <i>30 sec</i>								
Spec. No.	Ign. Time	After flame Time	Slow Time	Ignition Ext. Time	Drip Ext. Time	Turn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>None</i>	<i>4.1</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>4</i>	<i>4</i>	<i>"</i>	<i>4.3</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>2</i>	<i>2</i>	<i>"</i>	<i>3.7</i>	<i>Yes</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>None</i>	<i>4.0</i>	<i>Yes</i>	<i>Passes Method 1</i>

SMOKE TEST	IPS TEST CHAMBER			CASELS
Specimen No.	1	2	3	
Thickness - in.	<i>.08</i>	<i>.08</i>	<i>.08</i>	
Weight - grams	<i>10.964</i>	<i>10.968</i>	<i>10.977</i>	
Exposed Area - sq.in.	<i>6.56</i>	<i>6.56</i>	<i>6.56</i>	
Gas Pressure - psig	<i>Pilot</i>	<i>Pilot</i>	<i>Pilot</i>	
Irradiance - watts/cm <sup>2</sup>	<i>2.5</i>	<i>2.5</i>	<i>2.5</i>	

The graph plots Specific Optical Density (Ds) on the y-axis (0 to 100) against Time in minutes on the x-axis (0 to 8.0). Two curves are shown: 'FLAMING' and 'NON-FLAMING'. The 'FLAMING' curve rises steeply from (0,0) to approximately (1.0, 40) and then continues to rise more gradually to about 70 at 8.0 minutes. The 'NON-FLAMING' curve rises more slowly from (0,0) to about 20 at 1.0 minute, then continues to rise to about 40 at 8.0 minutes.

FORM 382B-2

Figure 6. - Flame and smoke data - FN501 (material test 1252).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION		PAGE				
CHECKED	T I T L E	RYE CANYON RESEARCH LABORATORY		MODEL				
APPROVED		FLAMMABILITY/SMOKE TEST REPORT		REPORT NO.				
MATERIAL TEST NO: <i>1253</i>								
MATERIAL DESCRIPTION: <i>FN5037, Nomex 9352 Paper, Nomex 4K and</i>								
USE/APPLICATION: <i>W/Fedlog Coating/Windward Reseal</i>								
FLAMMABILITY TEST			METHOD: <i>90, 91</i>					
Spec. No.	Ign. Time	After flame Time	Blow Time	Total Ext. Time	Drip Ext. Time	Burn Len. in.	Flame Out	Comments
	sec.	Sec.	Sec.	Sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>1</i>	<i>1</i>	<i>None</i>	<i>6.2</i>	<i>4/5</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>"</i>	<i>6.8</i>	<i>"</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>8</i>	<i>8</i>	<i>"</i>	<i>6.9</i>	<i>"</i>	
<i>NG</i>	<i>60</i>	<i>0</i>	<i>4</i>	<i>4</i>	<i>None</i>	<i>6.6</i>	<i>4/5</i>	<i>Fail Method 1 (BURN LENGTH)</i>

SMOKE TEST	SPE. TYPE CHARACTER			COMMENTS
Specimen No.	1	2	3	
Thickness - in.				
Weight - grams	<i>10.0/99</i>	<i>9.7/101</i>	<i>9.9/</i>	
Exposed Area - sq.in.	<i>6.58</i>	<i>6.58</i>	<i>6.56</i>	
Gas Pressure - psig	Pilot	Pilot	Pilot	
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5	

Figure 7. - Flame and smoke data - FN503 (material test 1253).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION					PAGE	
CHECKED	T Y L E	RYE CANYON RESEARCH LABORATORY					MODEL	
APPROVED		FLAMMABILITY/SMOKE TEST REPORT					REPORT NO.	
MATERIAL TEST NO: <i>1254</i>								
MATERIAL DESCRIPTION: <i>FN505, Norinco 8250 Propag, Honey Alk core</i>								
USE/APPLICATION: <i>Tedlar Covering / Sidewall Panel / Window Revial</i>								
FLAMMABILITY TEST					METHOD: <i>501ST</i>			
Spec. No.	Ign. Time	After flash Time	Blow Time	Initial Ext. Time	Drip Ext. Time	Burn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>2</i>	<i>2</i>	<i>NONE</i>	<i>4.7</i>	<i>4/5</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>24</i>	<i>24</i>	<i>"</i>	<i>4.9</i>	<i>"</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>1</i>	<i>1</i>	<i>"</i>	<i>4.6</i>	<i>"</i>	
<i>AVC</i>	<i>60</i>	<i>0</i>	<i>9</i>	<i>9</i>	<i>NONE</i>	<i>4.7</i>	<i>4/5</i>	<i>Passes Method 1</i>

SMOKE TEST	INS FIRE CHAMBER			COMMENTS
Specimen No.	1	2	3	
Thickness - in.	<i>.08</i>	<i>.08</i>	<i>.08</i>	
Weight - grams	<i>957.6</i>	<i>934.3</i>	<i>949.0</i>	
Exposed Area - sq.in.	<i>6.52</i>	<i>6.56</i>	<i>6.56</i>	
Gas Pressure - psig	<i>Pilot</i>	<i>Pilot</i>	<i>Pilot</i>	
Irradiance - watts/cm <sup>2</sup>	<i>2.5</i>	<i>2.5</i>	<i>2.5</i>	

The graph plots Specific Optical Density (y-axis, 0 to 100) against Time in minutes (x-axis, 0 to 8.0). Two curves are shown: 'Flaming Exposure' and 'Non-Flaming Exposure'. The flaming exposure curve rises sharply from 0 at 0 minutes to approximately 55 at 4 minutes, then continues to rise slowly to about 60 at 8 minutes. The non-flaming exposure curve rises more gradually, reaching approximately 20 at 8 minutes.

Figure 8. - Flame and smoke data - FN505 (material test 1254).



PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION						PAGE
CHECKED	Y T L E	RYE CANYON RESEARCH LABORATORY						MODEL
APPROVED		FLAMMABILITY/SMOKE TEST REPORT						REPORT NO.
MATERIAL TEST NO: <i>1255</i>								
MATERIAL DESCRIPTION: <i>FN507 Fiberglass MIB 6072 Prepreg, Nomex HB Core Tedlar Covering</i>								
USE/APPLICATION: <i>5.5 inch Panel / Hinged Panel</i>								
FLAMMABILITY TEST METHOD: <i>ASTM D 568</i>								
Spec. No.	Ign. Time	After flame Time	Blow Time	Flame ext. Time	Drip ext. Time	burn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>2</i>	<i>2</i>	<i>None</i>	<i>4.5</i>	<i>Y/S</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>29</i>	<i>29</i>	<i>"</i>	<i>4.7</i>	<i>"</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>4.2</i>	<i>"</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>10</i>	<i>10</i>	<i>None</i>	<i>4.5</i>	<i>Y/S</i>	<i>Passes Method 1</i>

SMOKE TEST	NBS TYPE CHAMBER			COMMENTS
Specimen No.	<i>1</i>	<i>2</i>	<i>3</i>	
Thickness - in.	<i>.09</i>	<i>.09</i>	<i>.09</i>	
Weight - grams	<i>8.794</i>	<i>8.786</i>	<i>8.796</i>	
Exposed Area - sq.in.	<i>6.57</i>	<i>6.57</i>	<i>6.57</i>	
Gas Pressure - psig	<i>Pilot</i>	<i>Pilot</i>	<i>Pilot</i>	
Irradiance - watts/cm <sup>2</sup>	<i>2.5</i>	<i>2.5</i>	<i>2.5</i>	

Figure 9 is a line graph showing Specific Optical Density (Ds) on the y-axis (ranging from 0 to 200) versus Time in minutes on the x-axis (ranging from 0 to 8.0). Two curves are plotted: one labeled 'FLAMMING' and one labeled 'NON-FLAMMING'. The 'FLAMMING' curve starts at (0,0), rises steeply to about 80 at 1.5 minutes, reaches a peak of approximately 100 at 4.5 minutes, and then slightly declines. The 'NON-FLAMMING' curve starts at (0,0) and rises more gradually, reaching about 60 at 7.0 minutes.

Figure 9. - Flame and smoke data - FN507 (material test 1255).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION	PAGE					
CHECKED	TITLE	RYE CATION RESEARCH LABORATORY	MODEL					
APPROVED		FLAMMABILITY/SMOKE TEST REPORT	REPORT NO.					
MATERIAL TEST NO: <i>1256</i>								
MATERIAL DESCRIPTION: <i>FN510T, FIBERITE HMB6032 Prepreg, Nomex</i>								
USE/APPLICATION: <i>HE core, Teller containing</i> <i>Current Prod. Material Subpanel/Windon Panel</i>								
FLAMMABILITY TEST		METHOD: <i>TOAST</i>						
Spec. No.	Ign. Time	After flame Time	Flow Time	Total Ext. Time	Drip Ext. Time	burn Length	Flame Out	Comments
	SEC.	SEC.	SEC.	SEC.	SEC.	IN.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>15</i>	<i>15</i>	<i>NONE</i>	<i>4.5</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>2</i>	<i>2</i>	<i>"</i>	<i>4.0</i>	<i>"</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>18</i>	<i>18</i>	<i>"</i>	<i>4.6</i>	<i>"</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>11</i>	<i>11</i>	<i>NONE</i>	<i>4.4</i>	<i>Yes</i>	<i>Passes Method 1</i>

SMOKE TEST	M'S PIPE CHAMBER			COMMENTS
Specimen No.	1	2	3	
Thickness - in.	<i>.08</i>	<i>.08</i>	<i>.18</i>	
Weight - grams	<i>8.440</i>	<i>8.269</i>	<i>8.361</i>	
Exposed Area - sq.in.	<i>6.56</i>	<i>6.56</i>	<i>6.56</i>	
Gas Pressure - psig	Pilot	Pilot	Pilot	
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5	

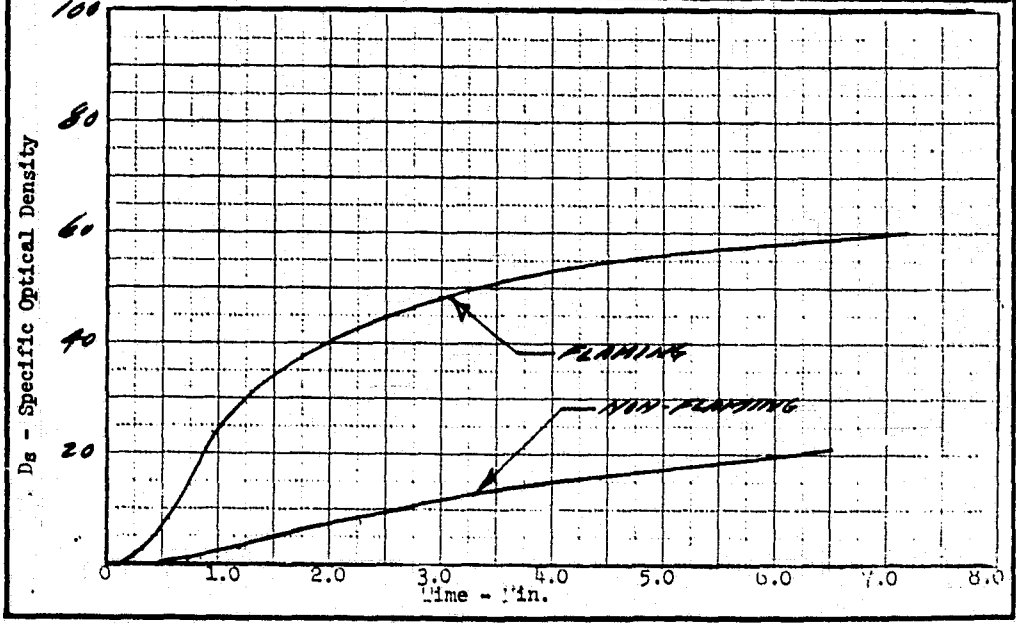


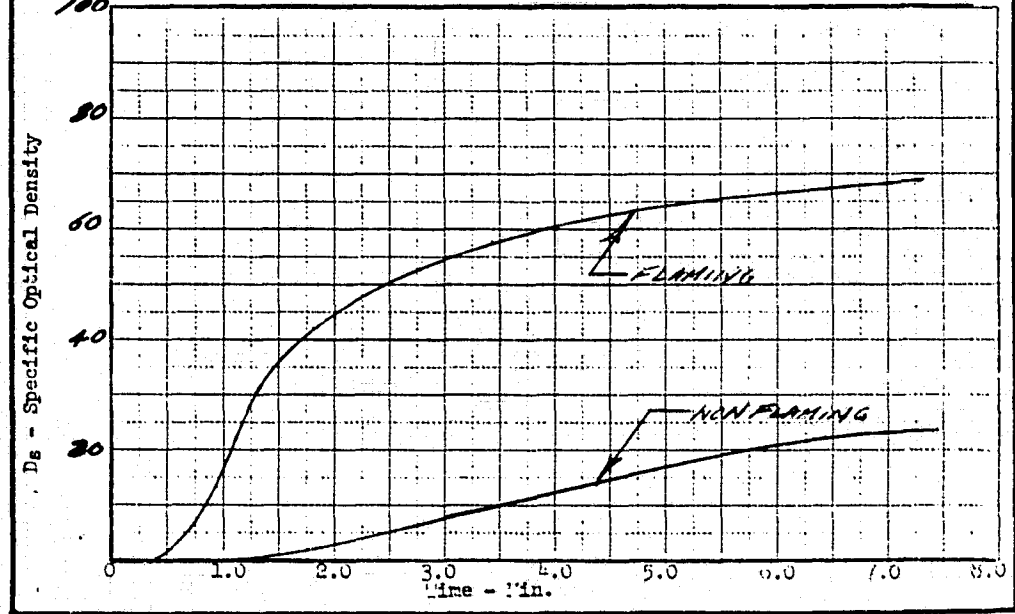
Figure 10. - Flame and smoke data - FN510 (material test 1256).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION						PAGE
CHECKED		RYE CANYON RESEARCH LABORATORY						MODEL
APPROVED		FLAMMABILITY/SMOKE TEST REPORT						REPORT NO.
MATERIAL TEST NO: <i>1273</i>								
MATERIAL DESCRIPTION: <i>FN30877-11A Solar glass reinforced polyimide</i>								
USE APPLICATION: <i>Form, 1.5 to 2.0 thick compressed to .180 in. 530 psi</i>								
VARIANTS: <i>VARIOUS</i>								
Spec. No.	Ign. Time	After Burn Time	Disc Time	LOTTA EXT. Time	DRIP EXT. Time	Burn Length	Flame Out	Comments
1	60	0	0	0	None	1.2	Yes	
2	60	0	0	0	"	1.1	Yes	
3	60	0	0	0	"	1.2	Yes	
M6	60	0	0	0	None	1.2	Yes	Passes Method 1
*1	12	0	0	0	None	0.3	Yes	* opposite end
Specimen No.	1	2	3					
Thickness - in.	.13	.13						
Weight - grams	20.6/2	20.3/2						
Exposed Area - sq.in.	6.56	6.56						
Gas Pressure - psig	Pilot	Pilot	Pilot					
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5					
10								
8								
6								
4								
2								
0								
0								
1.0								
2.0								
3.0								
4.0								
5.0								
6.0								
7.0								
8.0								

Figure 11. - Flame and smoke data - FN30877-11A (material test 1273).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION					PAGE
CHECKED	T I T L E	RYE CATION RESEARCH LABORATORY					MODEL
APPROVED		FLAMMABILITY/SMOKE TEST REPORT					REPORT NO.
MATERIAL TEST NO: <i>1274</i>							
MATERIAL DESCRIPTION: <i>FN30877-11B similar to FN30877-11A with additional Tedlar covering (C-22-127154E)</i>							
USE/APPLICATION: <i>Various</i>							
Spec. No.	Age	Al. Spec. Weight	Spec. Area	Initial Wt.	Final Wt.	Flame Out	Remarks
1	60	0	30	30	None	3.4	Yes
2	60	0	34	34	"	3.4	Yes
3	60	0	12	12	"	3.5	Yes
AVG	60	0	25	25	None	3.4	Yes
<p><i>FAILS METHOD 1</i>  <i>High glow time,</i>  <i>exceeds 4.5 min.</i>  <i>High criteria</i>  <i>passes (see 2.5.3.2)</i>  <i>Fails (see 609, spec. No. 8)</i></p>							

Specimen No.	1	2	3
Thickness - in.	.13	.13	.13
Weight - grams	19.8/20.5	19.9/21.9	19.3/20.7
Exposed Area - sq.in.	6.56	6.56	6.56
Gas Pressure - psia	Pilot	Pilot	Pilot
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5



FORM 3628-2

Figure 12. - Flame and smoke data - FN30877-11B (material test 1274).

PREPARED BY <i>E. Lopez</i>	DATE <i>7/2/58</i>	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION						PAGE
CHECKED	T Y L E	RYE CANYON RESEARCH LABORATORY						MODEL
APPROVED		FLAMMABILITY/SMOKE TEST REPORT						REPORT NO.
MATERIAL TEST NO: <i>1258</i>								
MATERIAL DESCRIPTION: <i>FN 30877-10, Monsanto Thermoplastic poly-ester E-200-37</i>								
USE/APPLICATION: <i>Various thermoplastic applications</i>								
FLAMMABILITY TEST						METHOD: 10.17		
Spec. No.	Ign. Time	After Flame Time	Flow Time	Total Ext. Time	Drip Ext. Time	Burn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>2</i>	<i>0</i>	<i>2</i>	<i>7</i>	<i>2.2</i>	<i>Yes</i>	<i>Fails Method 1. During 190. time material burns and drips. Drips continue burning</i>
<i>2</i>	<i>60</i>	<i>2</i>	<i>0</i>	<i>2</i>	<i>6</i>	<i>2.1</i>	<i>"</i>	
<i>3</i>	<i>12</i>	<i>2</i>	<i>0</i>	<i>2</i>	<i>None</i>	<i>1.2</i>	<i>Yes</i>	
<p><i>Material exceeds FAA &amp; CAA requirements</i></p> <p><i>chip ext. time</i></p>								
SMOKE TEST				SPEE TYPE STANDARD			COMMENTS	
Specimen No.	<i>1</i>			<i>2</i>	<i>3</i>			
Thickness - in.								
Weight - grams								
Exposed Area - sq.in.								
Gas Pressure - psig	Pilot			Pilot	Pilot			
Irradiance - watts/cm <sup>2</sup>	2.5			2.5	2.5			
<p><i>Da - Specific Optical Density</i></p> <p><i>Not Available</i></p>								

Figure 13. - Flame and smoke data - FN30877-10 (material test 1258).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION					PAGE	
CHECKED		RYE CANYON RESEARCH LABORATORY					MODEL	
APPROVED		FLAMMABILITY/SMOKE TEST REPORT					REPORT NO.	
MATERIAL TEST NO: <i>1279</i>								
MATERIAL DESCRIPTION: <i>FN30877-11C, Polycarbonate, ~.05 in. thick, Rohm &amp; Haas 4360</i>								
USE/APPLICATION: <i>Thermoforming</i>								
FLAMMABILITY TEST						VELOCITY: <i>30.5 ft</i>		
Spec. No.	Ign. Time	After flame Time	Flow Time	Local Ext. Time	Drip Ext. Time	burn Length	Flame Out	Comments
	sec.	sec.	sec.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>None</i>	<i>3.3</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>13</i>	<i>0</i>	<i>13</i>	<i>"</i>	<i>3.4</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>5</i>	<i>5</i>	<i>"</i>	<i>3.0</i>	<i>Yes</i>	
<i>AVG</i>	<i>60</i>	<i>4</i>	<i>1</i>	<i>5</i>	<i>None</i>	<i>3.2</i>	<i>Yes</i>	<i>Passes Method 1</i>

SMOKE TEST		NBS TYPE CHAMBER			COMMENTS
Specimen No.		1	2	3	
Thickness - in.		<i>.054</i>	<i>.054</i>		
Weight - grams		<i>10.2/1.2</i>	<i>9.85/1.6</i>		
Exposed Area - sq.in.		<i>6.56</i>	<i>6.56</i>		
Gas Pressure - psig		Pilot	Pilot	Pilot	
Irradiance - watts/cm <sup>2</sup>		2.5	2.5	2.5	

FORM 3428-2

Figure 14. - Flame and smoke data - FN30877-11C (material test 1279).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION						PAGE
CHECKED	T I T L E	RYE CANYON RESEARCH LABORATORY						MODEL
APPROVED		FLAMMABILITY/SMOKE TEST REPORT						REPORT NO.
MATERIAL TEST NO: <i>1280</i>								
MATERIAL DESCRIPTION: <i>FN30877-11D, Polyethersulfone, 205 in thickness, Rohm &amp; Haas, K4-1 Clear</i>								
USE/APPLICATION: <i>Flame Retardant Clear</i>								
FLAMMABILITY TEST						METHOD: <i>ASTM</i>		
Spec. No.	Ign. Time	After flame Time	Flow Time	Local Ext. Time	Drip Ext. Time	burn Length	Flame Out	Comments
	sec.	sec.	min.	sec.	sec.	in.		
<i>1</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>None</i>	<i>2.9</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>2.7</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>3.3</i>	<i>Yes</i>	
<i>N/A</i>	<i>60</i>	<i>0</i>	<i>1</i>	<i>1</i>	<i>None</i>	<i>2.9</i>	<i>Yes</i>	<i>Passes Method 1</i>

SMOKE TEST	M'S TEST CHAMBER			COMMENTS
Specimen No.	1	2	3	
Thickness - in.	<i>.042</i>	<i>.042</i>		
Weight - grams	<i>8.942</i>	<i>8.765</i>		
Exposed Area - sq.in.	<i>6.56</i>	<i>6.56</i>		
Gas Pressure - psig	Pilot	Pilot	Pilot	
Irradiance - watts/cm <sup>2</sup>	2.5	2.5	2.5	

FORM 3828-2

Figure 15. - Flame and smoke data - FN30877-11D (material test 1280).

PREPARED BY <i>E. Lopez</i>		DATE		LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION				PAGE	
CHECKED		T I T L E		RYE CANYON RESEARCH LABORATORY				MODEL	
APPROVED				FLAMMABILITY/SMOKE TEST REPORT				REPORT NO.	
MATERIAL TEST NO: <i>1277</i>									
MATERIAL DESCRIPTION: <i>Poly phenylsulfone, Radcl 5010, Union Carbide</i>									
USE/APPLICATION: <i>Thermforming</i> <i>Approx. .054, Beige</i>									
FLAMMABILITY TEST					METHOD: <i>50.17</i>				
Spec. No.	Ign. Time	After flame Time	Flow Time	Total ext. Time	Drip ext. Time	Turn Length	Flam. Char	Comments	
	sec.	sec.	sec.	sec.	sec.	in.			
<i>1</i>	<i>60</i>	<i>0</i>	<i>3</i>	<i>3</i>	<i>None</i>	<i>27</i>	<i>Yes</i>		
<i>2</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>2.6</i>	<i>Yes</i>		
<i>3</i>	<i>60</i>	<i>0</i>	<i>0</i>	<i>0</i>	<i>"</i>	<i>2.5</i>	<i>Yes</i>		
<i>APL</i>	<i>60</i>	<i>0</i>	<i>1</i>	<i>1</i>	<i>None</i>	<i>2.6</i>	<i>Yes</i>	<i>Passes Method 1</i>	
SMOKE TEST			N'S PIPE CHAMBER			COMMENTS			
Specimen No.			1	2	3				
Thickness - in.			<i>.054</i>	<i>.054</i>					
Weight - grams			<i>10.4/9.8</i>	<i>9.8/9.7</i>					
Exposed Area - sq.in.			<i>6.56</i>	<i>6.56</i>					
Gas Pressure - psig			Pilot	Pilot	Pilot				
Irradiance - watts/cm <sup>2</sup>			2.5	2.5	2.5				

FORM 342B-2

Figure 16. - Flame and smoke data - FN30877-11E (material test 1277).



PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION					PAGE	
CHECKED		RYE CANYON RESEARCH LABORATORY					MODEL	
APPROVED		FLAMMABILITY/SMOKE TEST REPORT					REPORT NO.	
MATERIAL TEST NO: <i>1278</i>								
MATERIAL DESCRIPTION: <i>FN30877-11B, Polycarbonate ~0.5 in thick, Lexan</i>								
USE APPLICATION: <i>EF6000, General Electric, Engine</i>								
TEST METHOD: <i>Flame</i>								
Spec. No.	Ign. Time	ALERT TIME	IGN. TIME	TOTAL EXT. TIME	DRIP EXT. TIME	WURN LENGTH	Flame Out	Comments
1	60	120	0	120	None	8.5	Yes	
2	60	154	0	154	"	9.5	Yes	
3	60	16	0	16	"	3.8	Yes	
AVG	60	97	0	97	None	7.3	Yes	<i>Fails Method 1</i>
Specimen No.		1	2	3				
Thickness - in.								
Weight - grams								
Exposed Area - sq.in.								
Gas Pressure - psig		Pilot	Pilot	Pilot				
Irradiance - watts/cm <sup>2</sup>		2.5	2.5	2.5				
D <sub>s</sub> - Specific Optical Density Not Available								

FORM 367B-2

Figure 17. - Flame and smoke data - FN30877-11F (material test 1278).

PREPARED BY <i>E. Lopez</i>	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED AIRCRAFT CORPORATION						PAGE
CHECKED	T	RYE CANYON RESEARCH LABORATORY						MODEL
APPROVED	T L E	FLAMMABILITY/SMOKE TEST REPORT						REPORT NO.
MATERIAL TEST NO: <i>1283</i>								
MATERIAL DESCRIPTION: <i>FN30877-15A .05 to .06 in thick, 3M 7-5</i>								
USE/APPLICATION: <i>Fluorel resin reinforced w/ chopped glass 3M Co</i>								
FLAMMABILITY TEST						METHOD: <i>90-11</i>		
Spec. No.	Ign. Time sec.	After flame Time sec.	Flow Time sec.	Total Ext. Time sec.	Drip Ext. Time sec.	Burn Length in.	Flame Out	Comments
<i>1</i>	<i>60</i>	<i>0</i>	<i>6</i>	<i>6</i>	<i>None</i>	<i>1.2</i>	<i>Yes</i>	
<i>2</i>	<i>60</i>	<i>0</i>	<i>10</i>	<i>10</i>	<i>"</i>	<i>1.1</i>	<i>Yes</i>	
<i>3</i>	<i>60</i>	<i>0</i>	<i>8</i>	<i>8</i>	<i>"</i>	<i>1.1</i>	<i>Yes</i>	
<i>AVG</i>	<i>60</i>	<i>0</i>	<i>8</i>	<i>8</i>	<i>None</i>	<i>1.1</i>	<i>Yes</i>	<i>Fails Method 1 Passes FAA 25.533(c) Passes CAA Spec 2</i>
SMOKE TEST			ING PIPE DIAMETER			COMMENTS		
Specimen No.	<i>1</i>		<i>2</i>		<i>3</i>			
Thickness - in.	<i>~.055</i>		<i>~.055</i>					
Weight - grams	<i>7.9/g</i>		<i>8.0/g</i>					
Exposed Area - sq.in.	<i>6.57</i>		<i>6.57</i>					
Gas Pressure - psig	Pilot		Pilot		Pilot			
Irradiance - watts/cm <sup>2</sup>	2.5		2.5		2.5			

Figure 18. - Flame and smoke data - 3M 7-5 Fluorel (material test 1283).

## THERMOGRAVIMETRIC ANALYSIS DATA

### Introduction

The thermogravimetric analytical (TGA) thermograms were recorded with a DuPont Model 900 Differential Thermal Analyzer and the accessory Model 950 thermogravimetric analyzer operating at a heating rate of 15°C/min. and air flow rate of 1 cfh.

### Results and Discussion

Eleven samples consisting of five crushed core sandwich panels, two glass fiber reinforced plastics, and four neat plastics were analyzed. Typical thermograms are presented in Figures 19 through 29. Schematic thermograms of the crushed core panels, glass fiber reinforced plastics and neat plastics are grouped together in Figures 30, 31 and 32, respectively, for ready reference and comparison. The principal temperatures and corresponding weight losses are tabulated in Table IX.

Thermo-oxidative degradation of the eleven samples proceeded in two to five or more stages. The most volatile product, which probably was water, accounted for a weight loss of 0 to w%. GFR sample No. 1273 (FN 30877-11A) underwent thermo-oxidative degradation in one stage, Figure 23. In contrast, the degradation of the crushed core panels was quite complex, due, probably, to the heterogeneous composition.

The data on the compression-molded crushed core phenolic resin systems are covered by the sample designations F501 through F510.

Except for the FN503 sample, the principal thermal decomposition, probably of the resin, started at approximately 390 C and was almost complete at approximately 650°C. The pyrolysis of FN503 started gradually at 290°C and the rate increased sharply at 495°C.

FN501 began to lose weight at an appreciable rate at 210°C and had lost 7w% after 395°C compared to 2-4w% lost by FN505, FN507 and FN510. The initial weight loss of approximately 2w% may be due to moisture in the panels. The residue varied between a low of 47w% (FN510) and a high of 56w% (FN507).

The most stable samples of the thermoplastics were the 1277 (Radel 5010N) and 1280 (R & H KM-1-(ICI) polymers and the compression-molded polyimide/glass laminate, 1273, is also very stable. These samples were stable to 570°C to 580°C. The least stable material, 1274 appears to be the Tedlar covering which is adhesively bonded to the polyimide/glass laminate. Degradation started at 260-270°C.

PART NO. 950017

**DUPONT** INSTRUMENTS

SAMPLE: <b>FN501</b>  SIZE <b>20.5</b> mg.	X-AXIS		Y-AXIS		RUN NO. <b>110</b> DATE <b>6-30-78</b>
	TEMP. SCALE <b>100</b> $\frac{^{\circ}\text{C}}{\text{inch}}$		SCALE <b>4</b> $\frac{\text{mg.}}{\text{inch}}$		OPERATOR <b>Kad Caf</b>
	SHIFT <b>0</b> inch		(SCALE SETTING X 2)		HEATING RATE <b>15</b> $\frac{^{\circ}\text{C}}{\text{min.}}$
	TIME SCALE (ALT.) <b>-</b>		SUPPRESSION <b>0</b> mg.		ATM. <b>1 GEN AIR</b>
					TIME CONSTANT <b>1</b> sec.

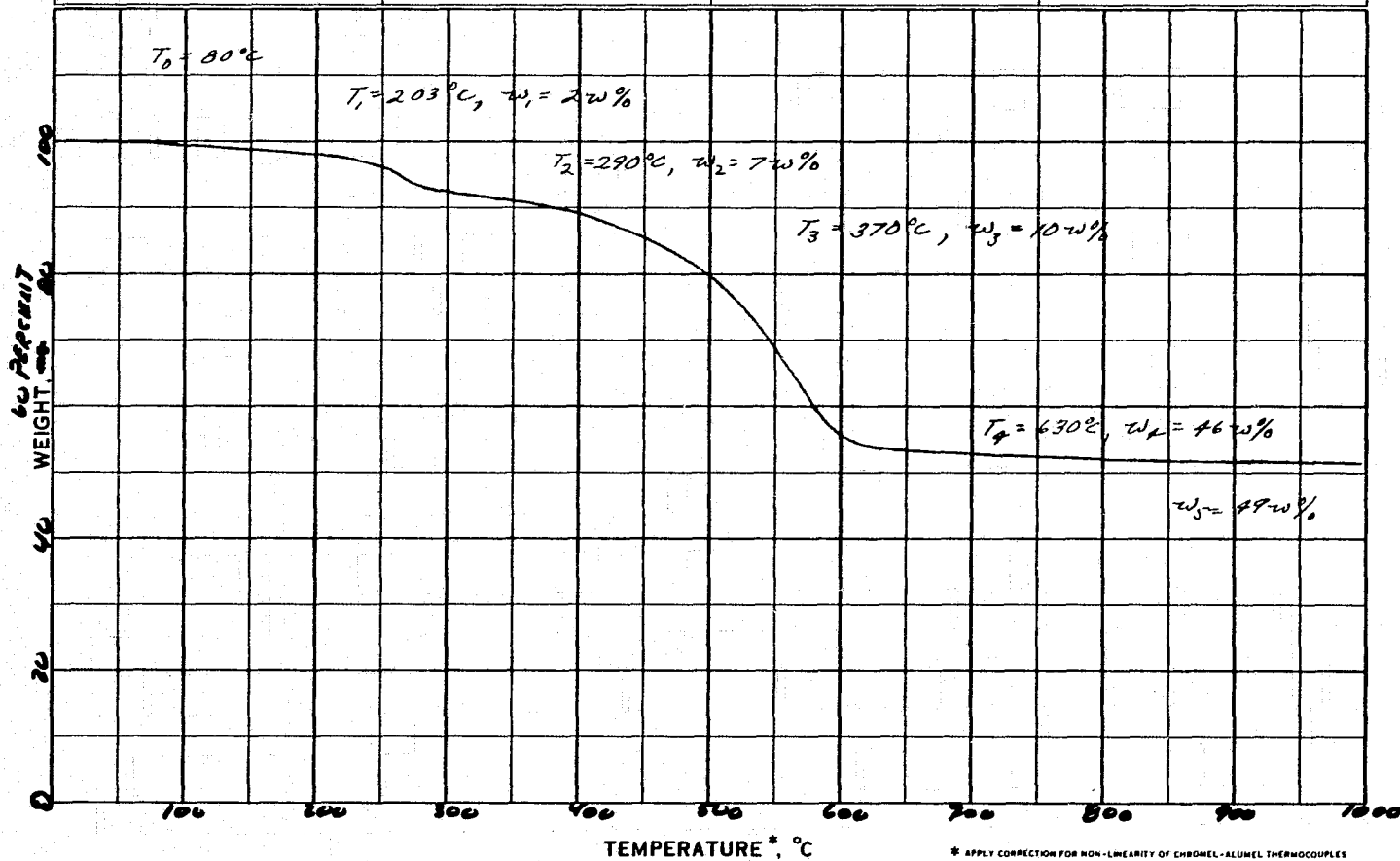


Figure 19. - Thermogram F501 (Ciba Geigy Fiberdux 917).

PART NO. 950017


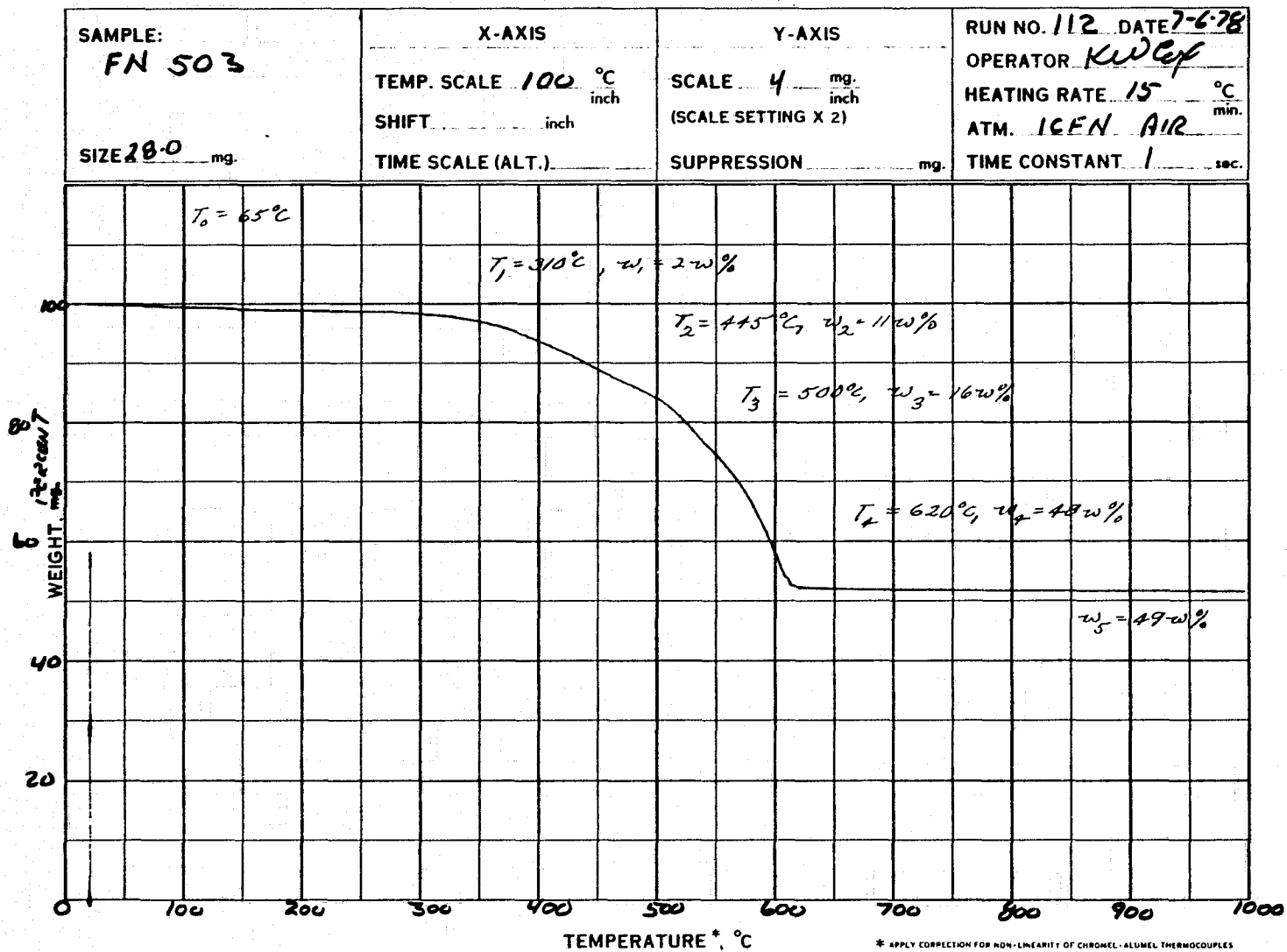

**DU PONT INSTRUMENTS**


Figure 20. - Thermogram F503 (Narmco 9252).

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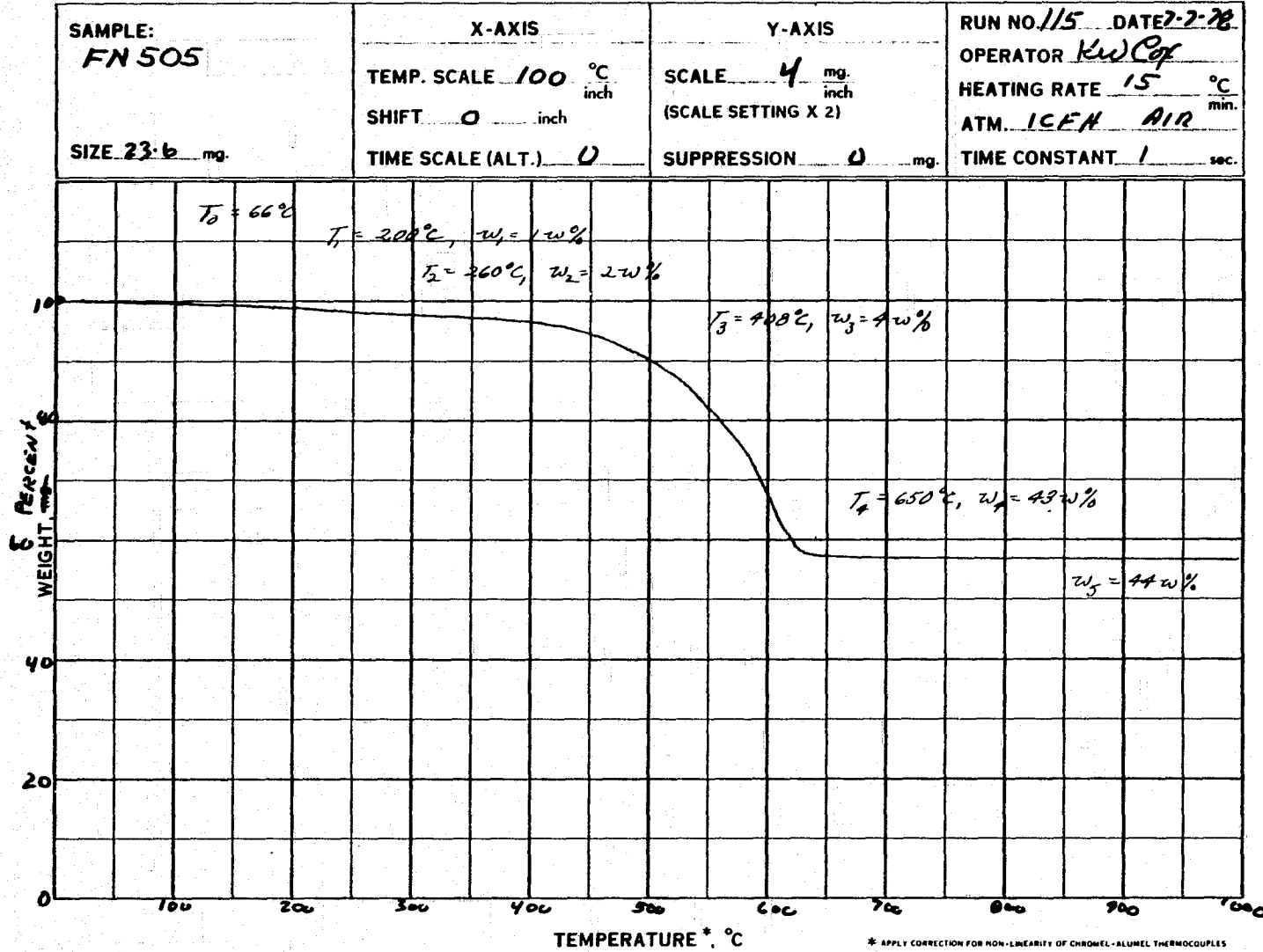
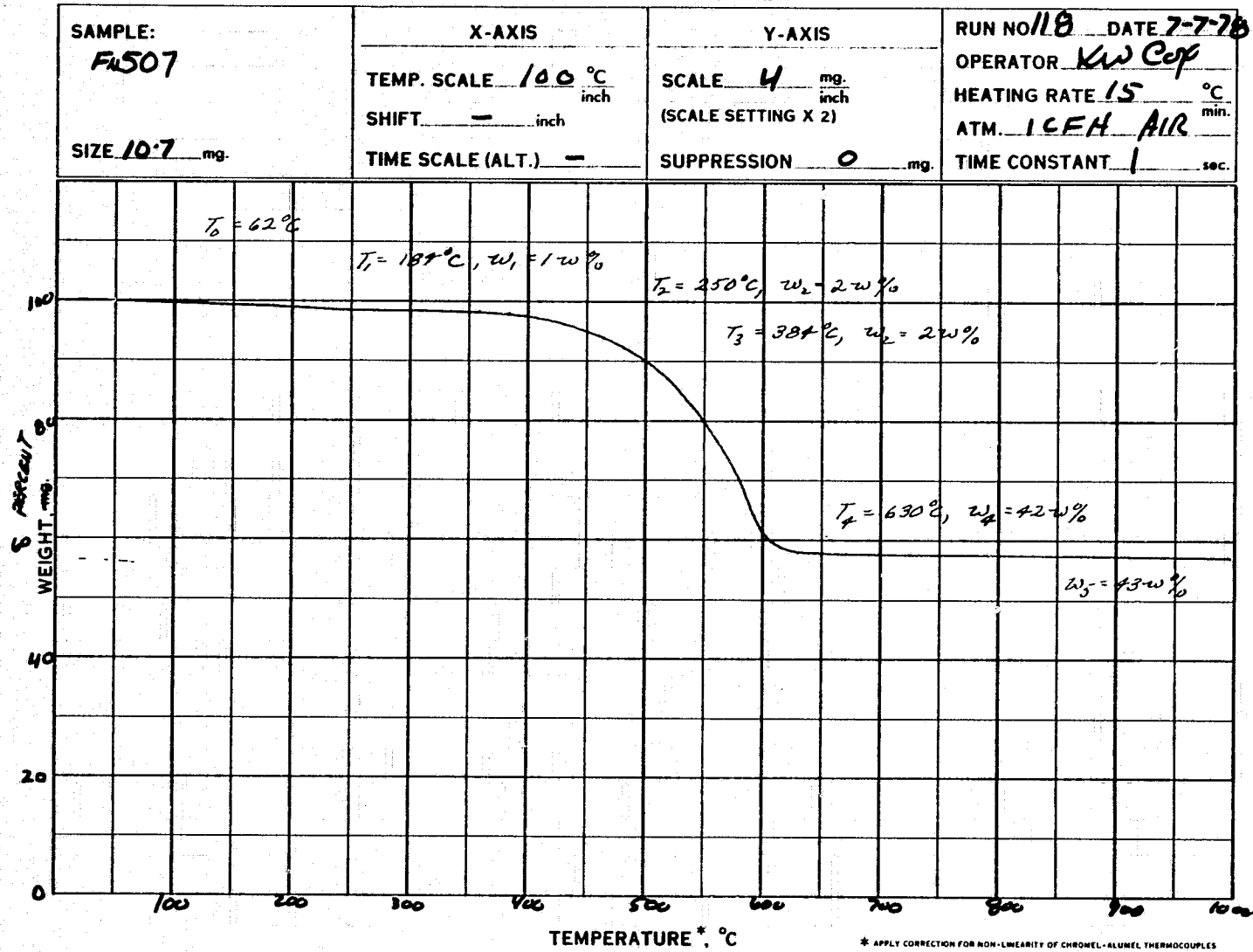
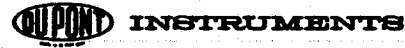


Figure 21. - Thermogram F505 (Narmco 8250).

PART NO. 950017



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Figure 22. - Thermogram F507 (Fiberite MXB 607L).

PART NO. 950017



SAMPLE: <b>FN 510</b>  SIZE <b>18.2</b> mg.	X-AXIS		Y-AXIS		RUN NO. <b>121</b> DATE <b>7-1-70</b>
	TEMP. SCALE <b>100</b> °C inch		SCALE <b>4</b> mg. inch (SCALE SETTING X 2)		OPERATOR <b>KW COY</b>
	SHIFT <b>-</b> inch		SUPPRESSION <b>0</b> mg.		HEATING RATE <b>15</b> °C min.
	TIME SCALE (ALT.) <b>0</b>		TIME CONSTANT <b>1</b> sec.		ATM. <b>1CFH AIR</b>

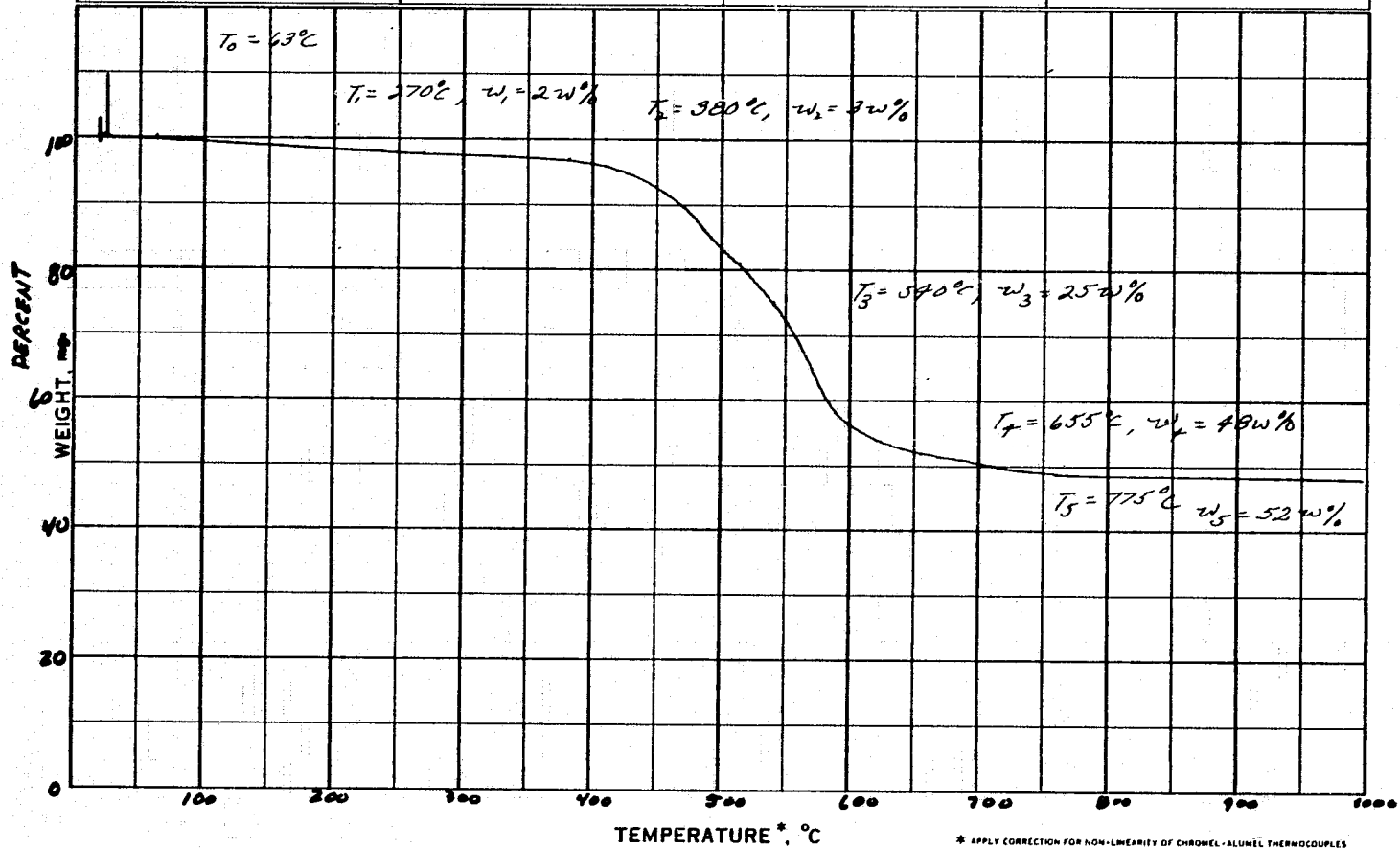


Figure 23. - Thermogram F510 (Fiberite MXT 6032).



PART NO. 950017


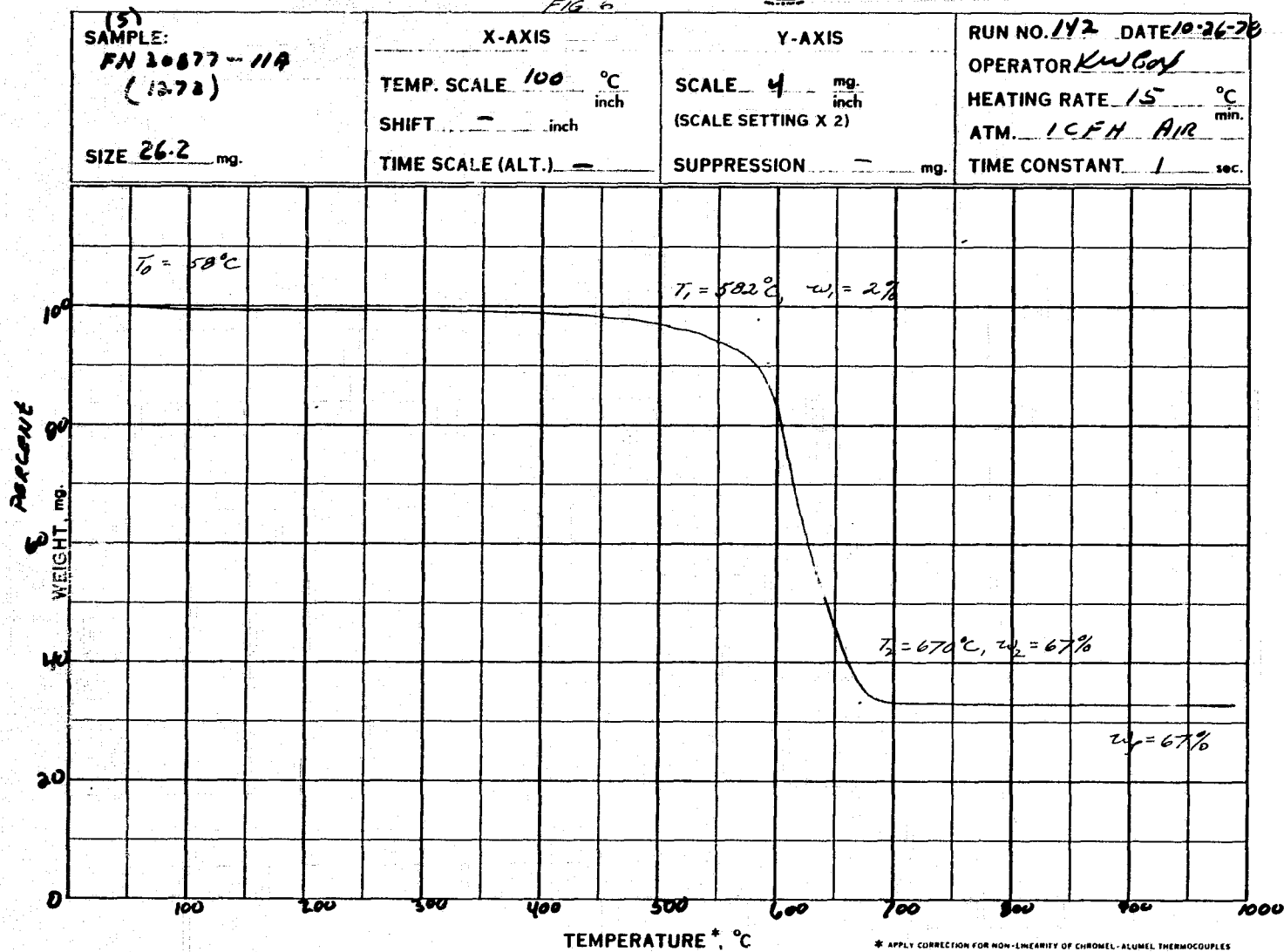

**DU PONT INSTRUMENTS**


Figure 24. - Thermogram FN308/7-11A (Polyimide/Glass).

PART NO. 950017

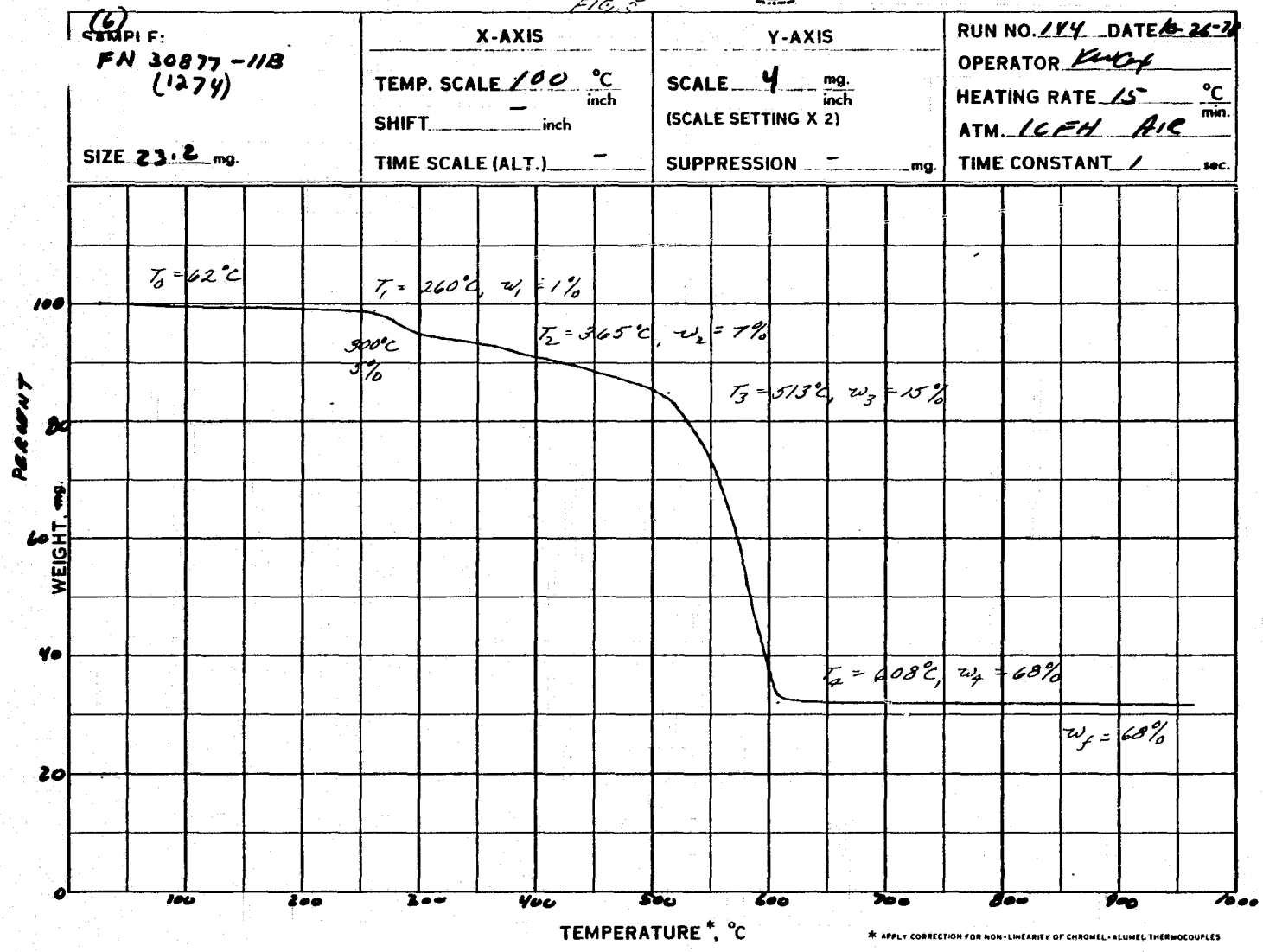


Figure 25. - Thermogram FN 30877-11B (Polyimide/Glass-Tedlar).

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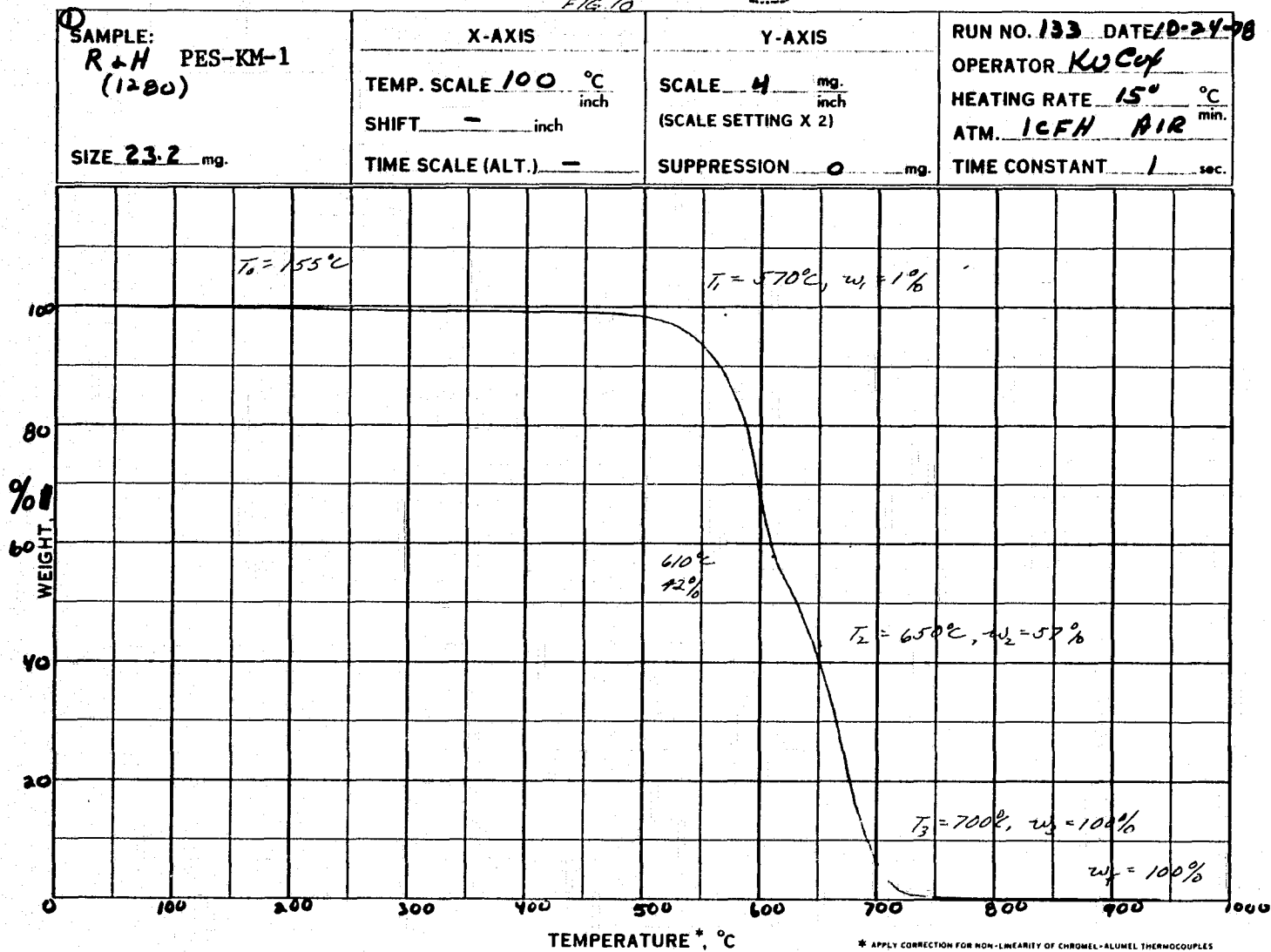

 DUPONT INSTRUMENTS


Figure 26. - Thermogram PES-KM-1.

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PART NO. 950017



FIG. B

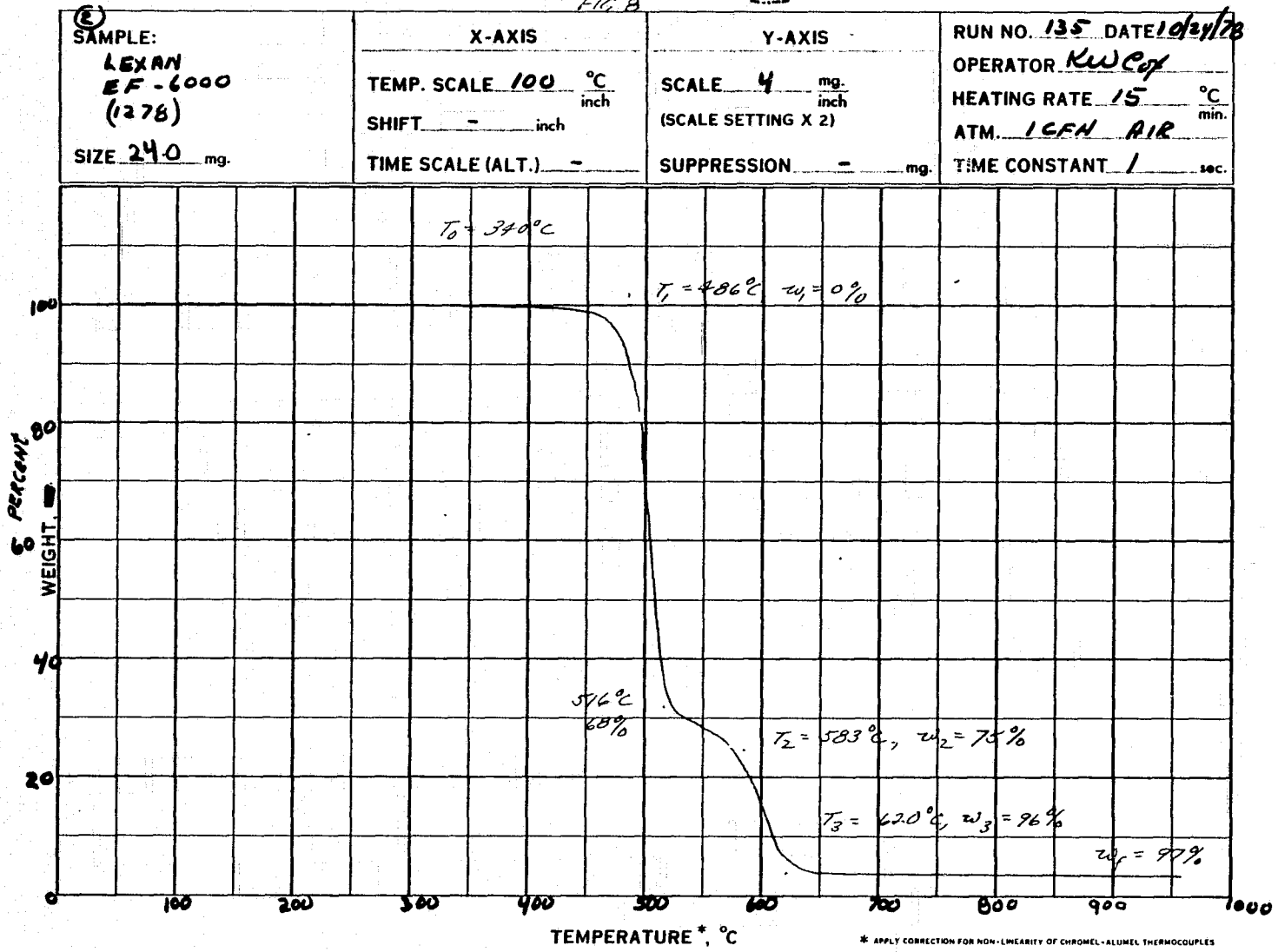


Figure 27. - Thermogram Lexan EF-6000.

PART NO. 950017

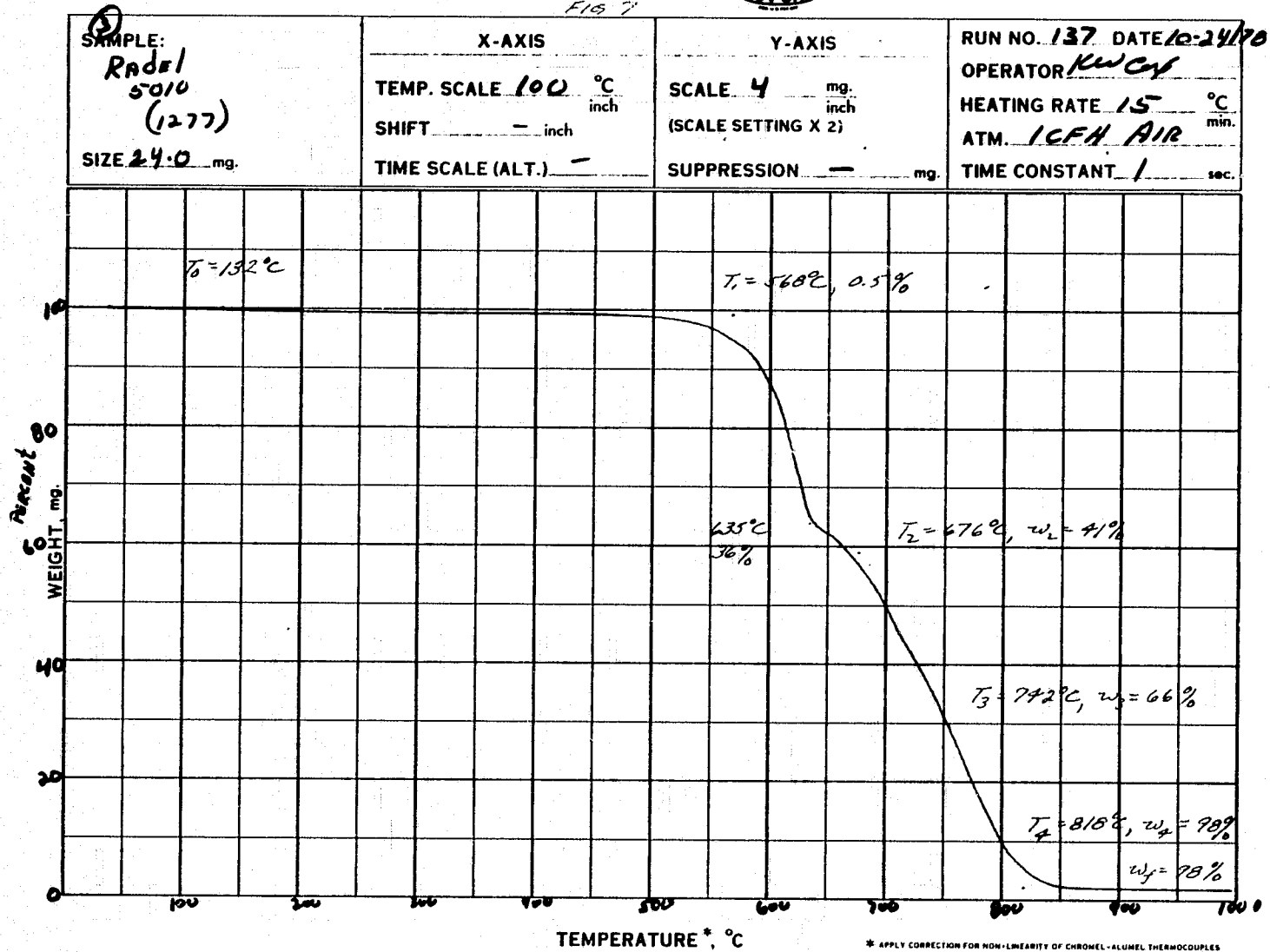

**INSTRUMENTS**

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Figure 28. - Thermogram Radel 5010N.

PART NO. 950017

**DUPONT** INSTRUMENTS

FIG 9

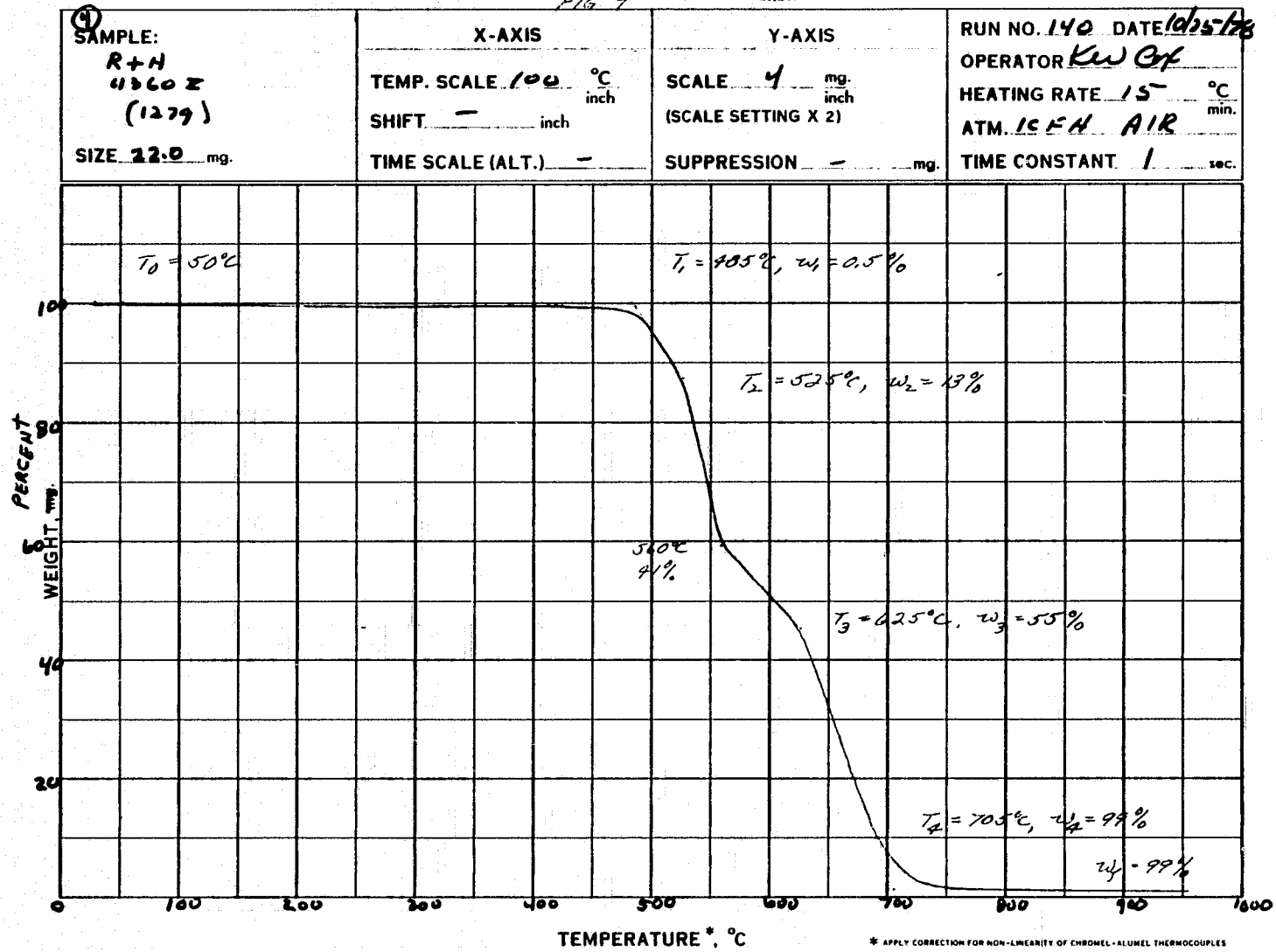


Figure 29. - Thermogram Rohm and Haas 4360Z.

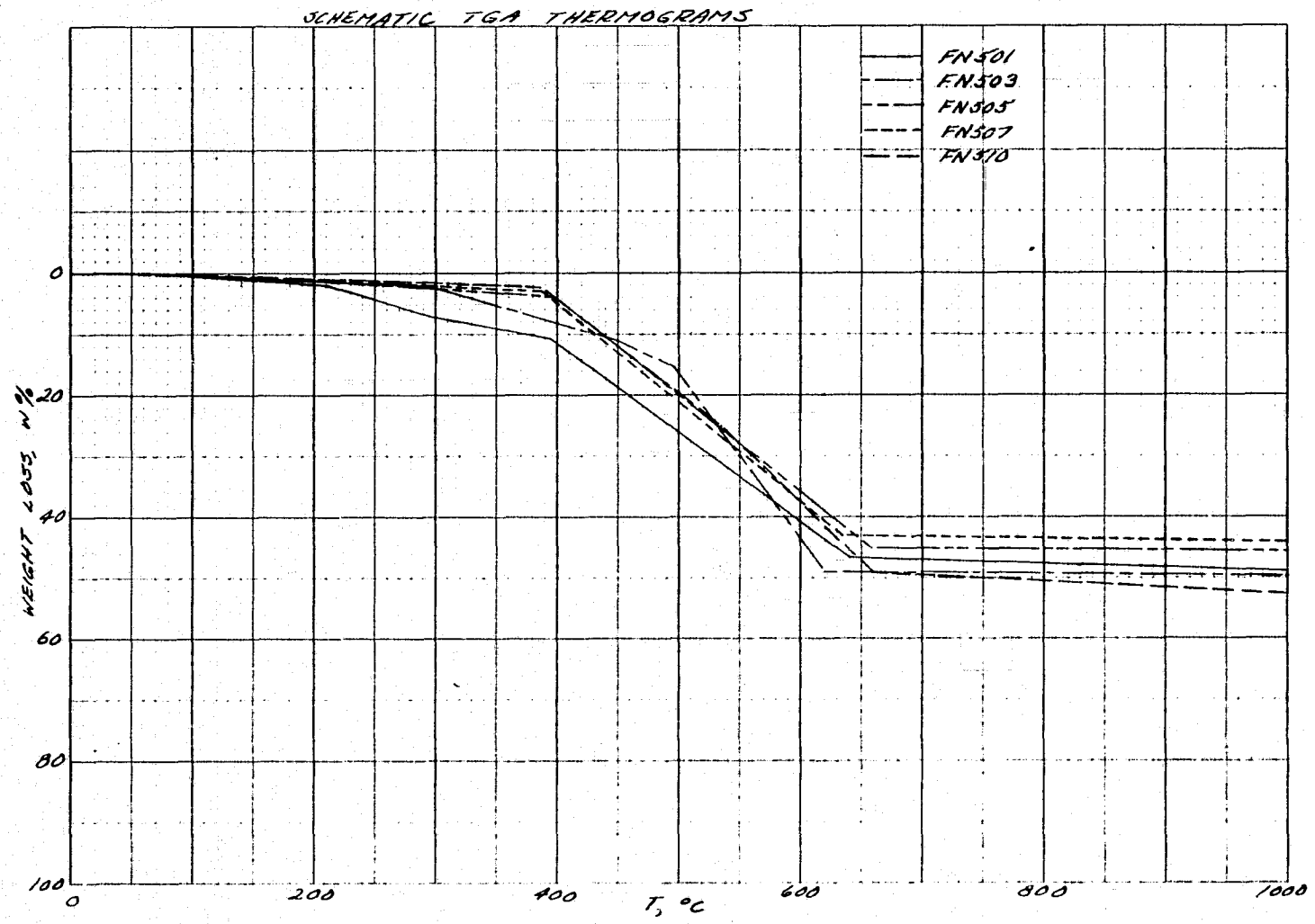
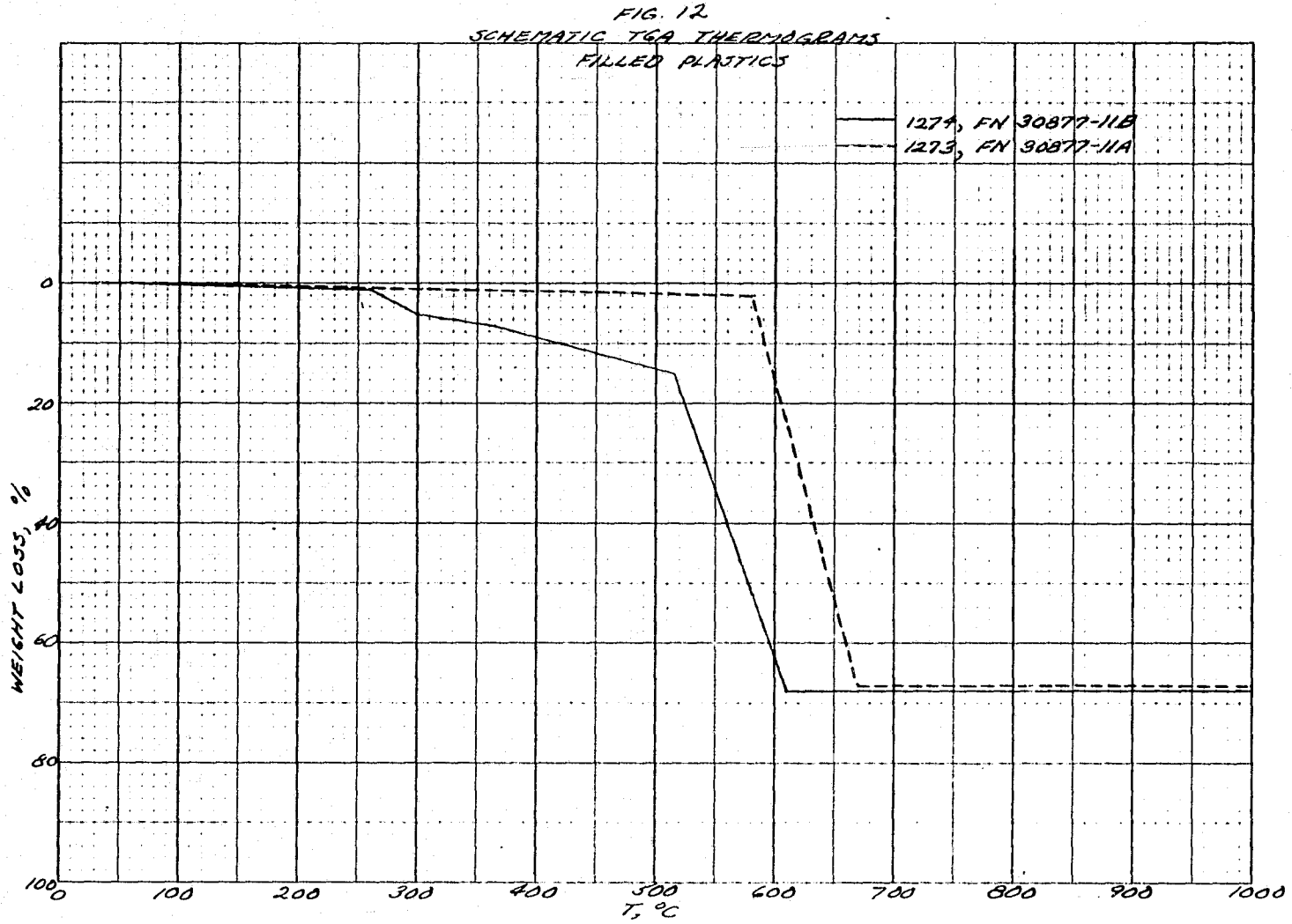


Figure 30. - TGA Thermograms - Compression molded sidewalls.



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Figure 31. - TGA Thermograms - Compression molded polyimide/glass.



FIG. 13  
SCHEMATIC TGA THERMOGRAMS  
PLASTICS

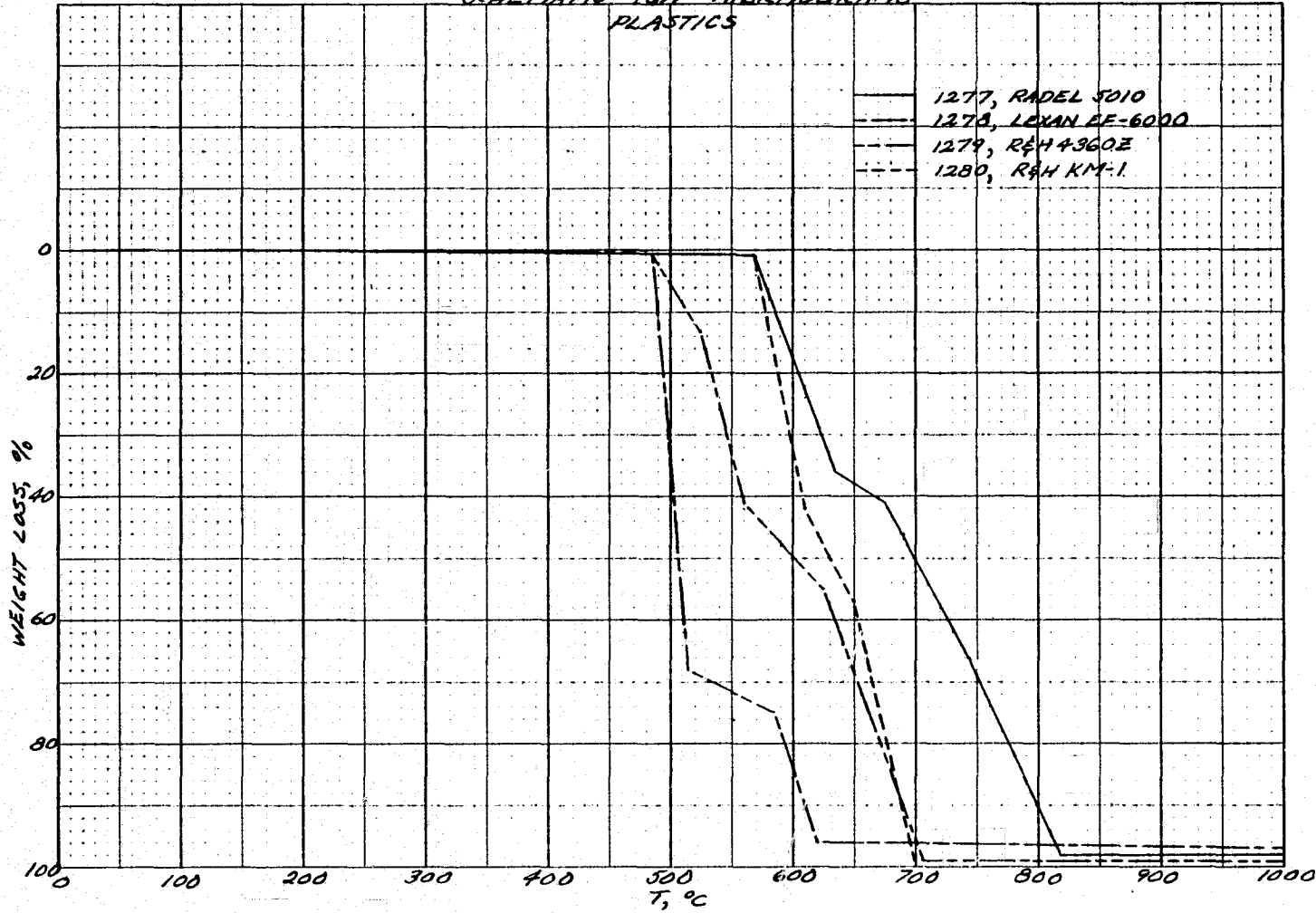


Figure 32. - TGA Thermograms - Thermoplastics

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TABLE IX. - RESULTS OF THERMOGRAVIMETRIC ANALYSIS

Material Sample and Number	T <sub>0</sub>	T <sub>1</sub>	W <sub>1</sub>	ΔW <sub>1</sub>	T <sub>2</sub>	W <sub>2</sub>	ΔW <sub>2</sub>	T <sub>3</sub>	W <sub>3</sub>	ΔW <sub>3</sub>	T <sub>4</sub>	W <sub>4</sub>	ΔW <sub>4</sub>	T <sub>5</sub>	W <sub>5</sub> or W <sub>f</sub>
	°C	°C	WZ	WZ	°C	WZ	WZ	°C	WZ	WZ	°C	WZ	WZ	°C	WZ
<b>FN501</b>															
(1247) 110	80	203	2	2	290	7	5	370	10	3	630	46	36	1000	49
111	50	220	2	2	300	7	5	407	11	4	650	47	36	1000	49
<b>FN503</b>															
(1248) 112	65	310	2	2	445	11	9	500	16	5	620	48	32	1000	49
113	65	268	1	1	450	11	10	490	14	3	610	45	31	1000	46
114	66	297	2	2	455	12	10	500	16	4	635	54	38	1000	44
<b>FN505</b>															
(1249) 115	66	200	1	1	260	2	1	408	4	2	650	43	39	1000	44
116	60	185	1	1	275	2	1	392	3	1	660	46	43	1000	47
117	45	162	1	1	243	2	1	390	4	2	665	45	41	1000	46
<b>FN507</b>															
(1250) 118	62	184	1	1	250	2	1	384	4	0	630	42	40	1000	43
119	55	175	1	1	245	2	1	385	3	1	640	43	40	1000	44
120	68	203	1	1	263	2	1	392	3	1	640	44	41	1000	46
<b>FN510</b>															
(1251) 121	63	270	2	2	380	3	1	540	25	22	655	48	23	775	52
122	65	276	2	2	386	3	1	535	26	23	664	49	23	735	51
123	62	262	2	2	390	4	2	533	24	20	655	50	26	790	55
(1273) 142	58	582	2	2	670	67	65							1000	67
FN-30872 11A 143	50	575	3	3	660	74	71								74
159	25	585	2	2	650	68	66								
(1274) 144	62	260	1	1	365	7	6	513	15	8	608	68	53		67
FN-30877-11B 145	85	268	1	1	365	6	5	522	14	8	590	62	48	1000	62
156	65	260	1	1	350	4	3	515	10	6	635	68	58		68
(1277) 137	132	568	0.5	0.5	676	41	40	742	66	25	818	98	32	1000	98
RADEL 5010 138	70	590	1	1	675	44	43	740	66	23	815	100	34		100
139	150	590	1	1	670	44	43	720	61	18	798	98	37		99
(1278) 135	340	486	0	0	583	75	75	620	96	21				1000	97
<b>LEXAN</b>															
EF-6000 136	235	475	1	1	560	74	73	610	97	23					98
(1279) 140	50	485	0.5	0.5	525	13	12	625	55	42	705	99	44	1000	99
R&D 43602 141	85	495	0.5	0.5	530	17	16	630	55	39	700	99	44		99
(1280) 133	155	570	1	1	650	57	56	700	100	43				1000	100
R&D KM-1 134	80	545	1	1	620	52	51	685	100	48					100
<p>W<sub>1</sub> = Cumulative Weight Loss                  ΔW<sub>1</sub> = Incremental Weight Loss                  W<sub>f</sub> = Final (Total) Weight Loss at 1,000°C.</p>															

## PART FABRICATION

### Sidewall Compression Molded Parts

Sidewall compression molded parts were made from the three different resin systems and are shown in Figure 33. All three systems were processed in the same manner on production tooling and equipment. Handling characteristics and cure cycles were equivalent and therefore, processing of each was carried out without difficulty by manufacturing personnel.

### Injection-Molded Parts

Injection-molded segments of a production section of the passenger service modules were made from both G.E. 940 and Monsanto 200-3Z resins and are shown in Figures 34 and 35, respectively. The G.E. 940 material handled without difficulty on the production dies and injection equipment. The present formulation of Monsanto 200-3Z did not process as well as expected. The material appears to be too brittle to mold for this type of part. Simpler parts with thicker sections may mold easier without cracking problems, but this material could not be used for the type of injection-molded thinwall parts used in typical interior aircraft designs. Efforts to mold Radel 5010 were not successful. The material batch was considered bad by Union Carbide. Efforts to mold PES were not attempted by the injection molder by December 15, 1978.

### Thermoformed (Vacuum Formed)

Production parts made from G.E. F-6000 polycarbonate are shown in Figure 36. The polycarbonate material was processed at ambient temperature with production tooling and fairly low temperature heating equipment. The polyethersulfone requires higher heating equipment, longer drying cycles, and requires a heated die to prevent chilling marks when forming to deep contours. Sheet materials were not obtained to work out processing techniques as of December 15, 1978.

### Compression-Molded 3M Fluorel Polymer

Parts made in a simple development die are shown in Figure 37. Parts molded out of four layers of 3M fluorel polymer coated on 120 fiberglass fabric appear to make a much better looking part than those made from random mat fiberglass. One part made from 1 layer of mat glass plus 1 layer of 120 fiberglass made a usable part and offers the potential to reduce the weight of the large production part.

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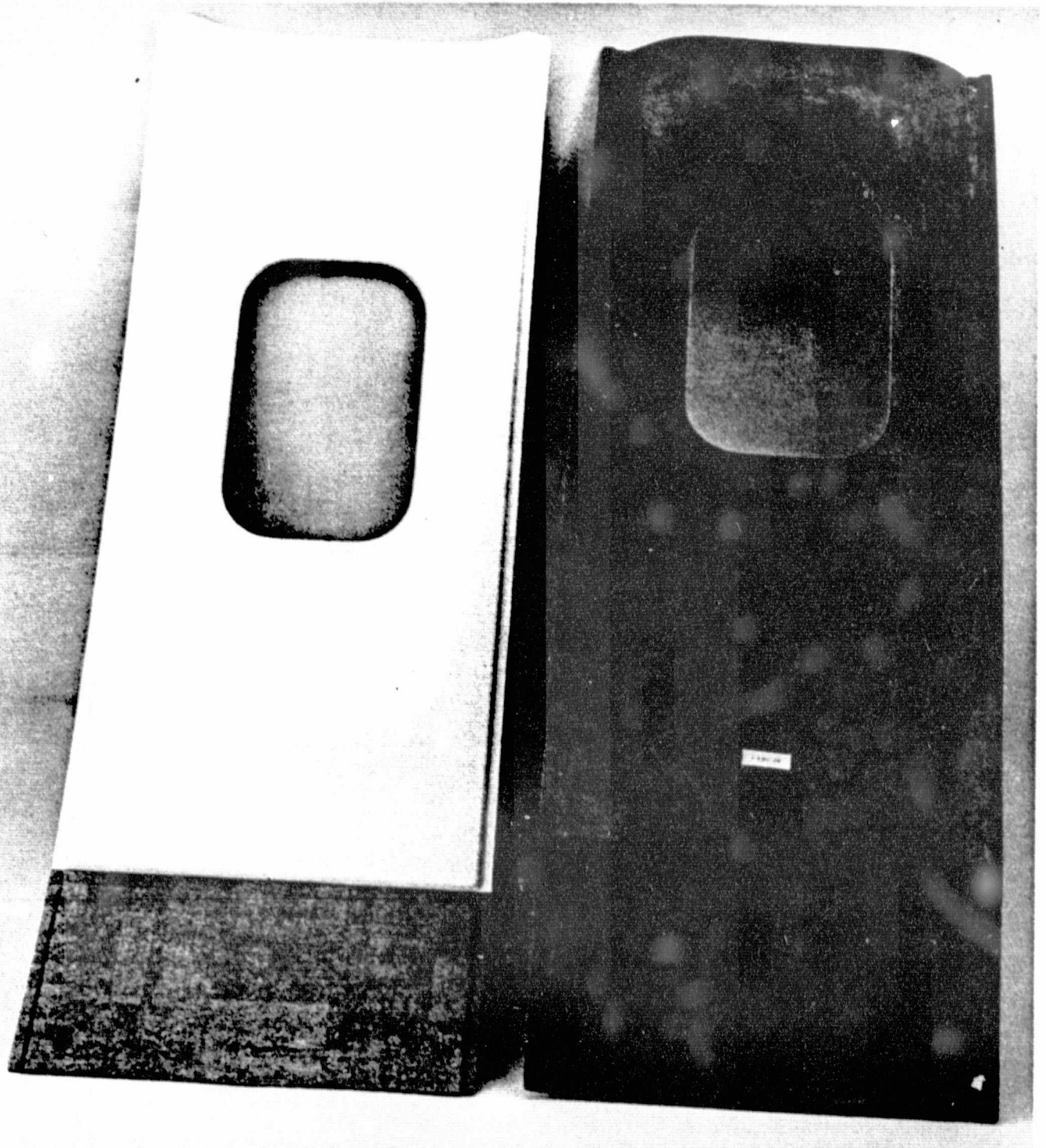


Figure 33. - Sidewall molded (Phenolic/Glass-Typical)

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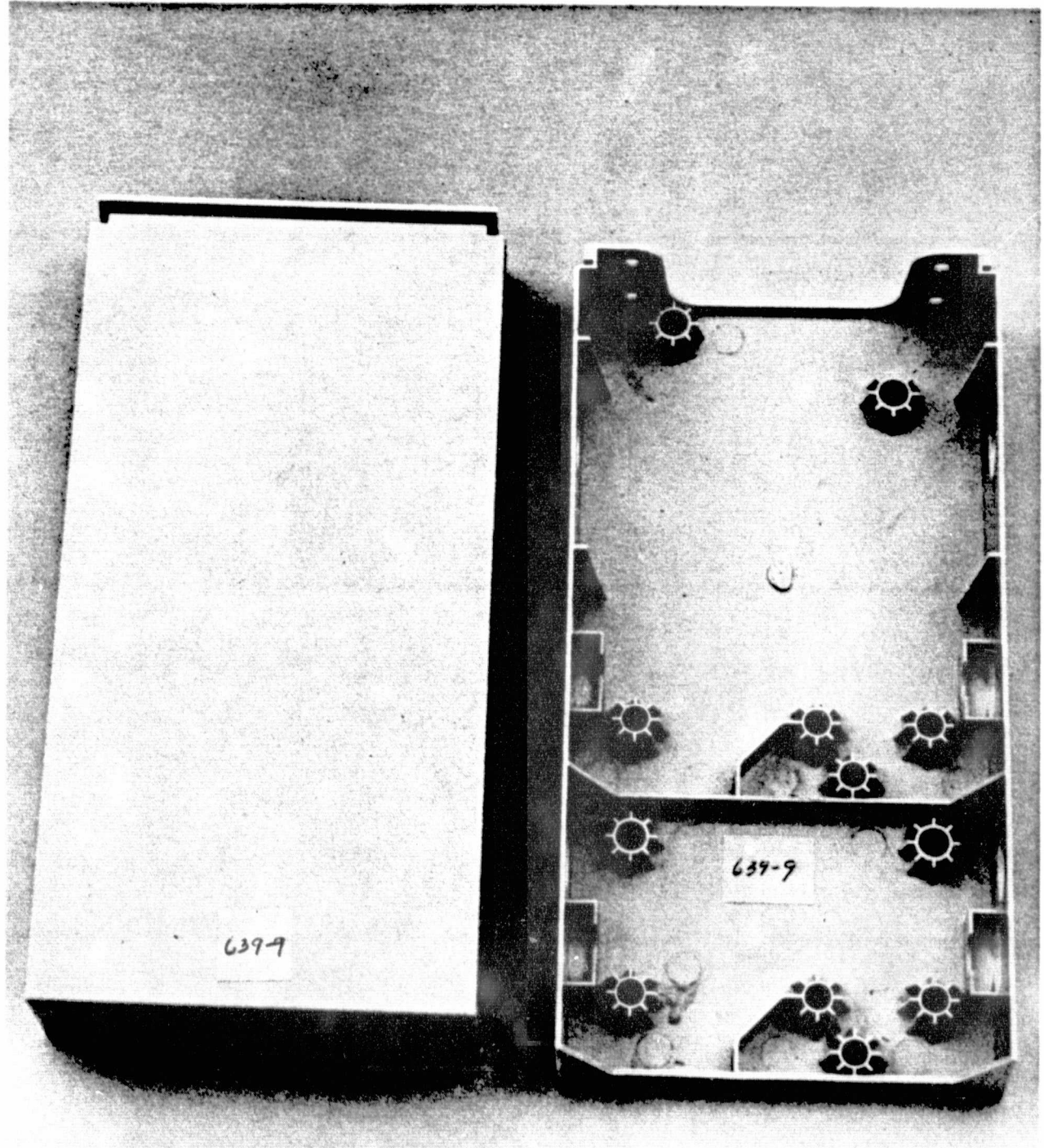


Figure 34. - G.E. 940 molded.

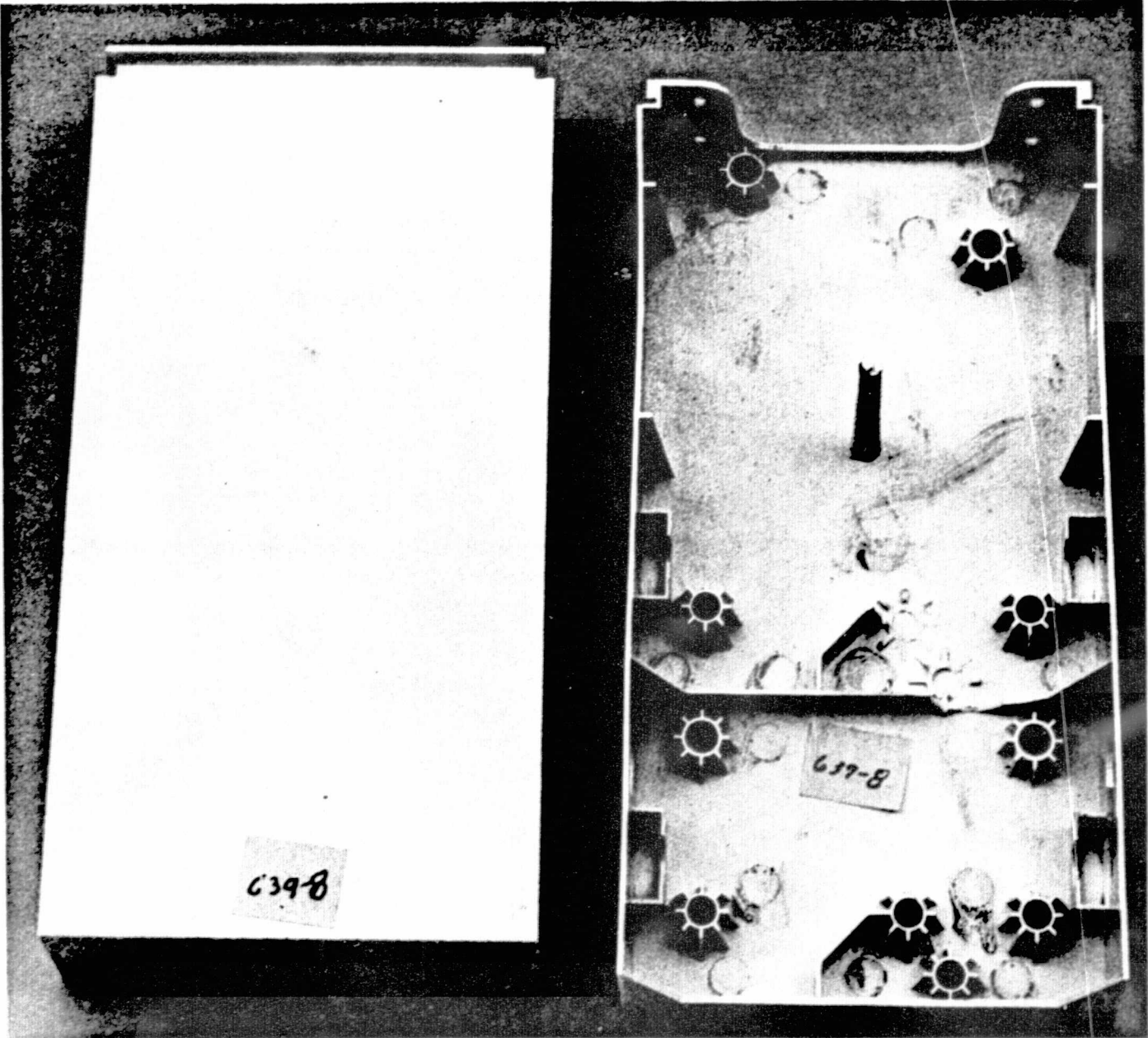


Figure 35. - Monsanto 200-3Z molded.

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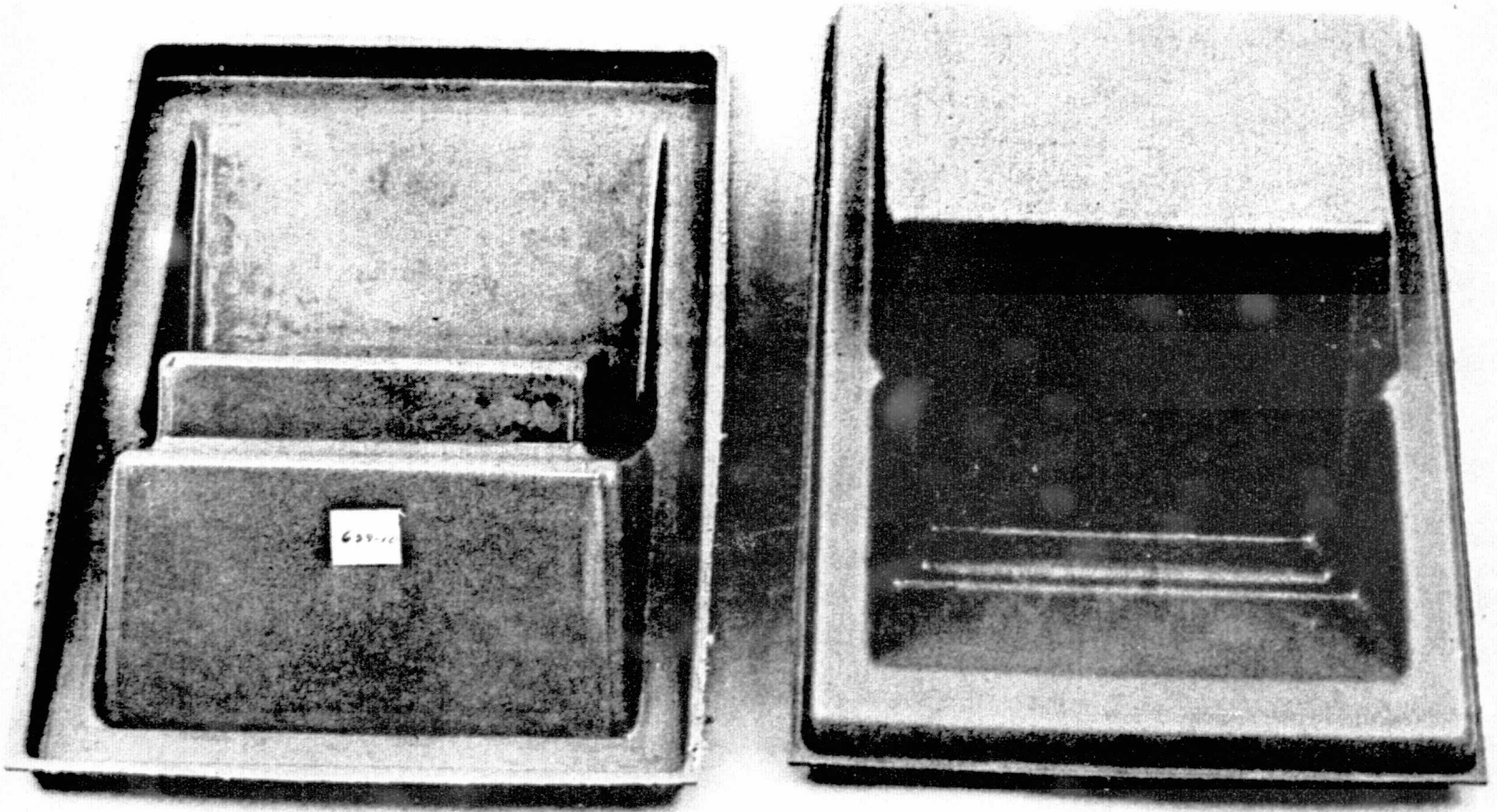


Figure 36. - Lexan F-6000 formed parts.

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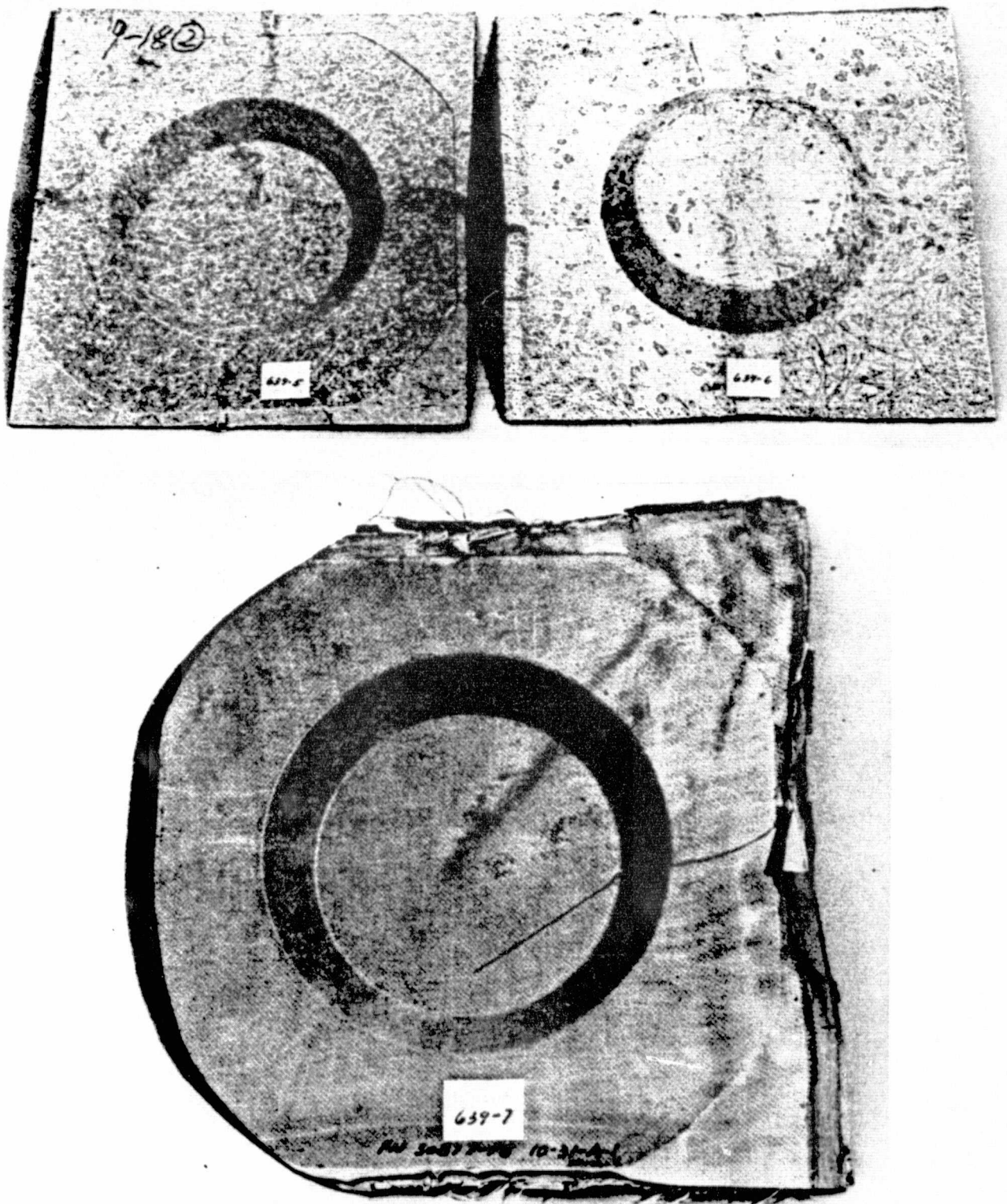


Figure 37. - 3M fluorel molded parts



## PROCESSING PARAMETERS AND ASSOCIATED COST COMPARISONS

### Compression Molding

Molding of the compounds has indicated that the three selected resin systems Ciba Geigy 917, Narmco 8250 and Fiberite MXB 6032 which were compression-molded into the production sidewall parts are similar. Processing details, as a preliminary processing document for fabrication of these resins into types of compression-molded parts are covered by Appendix A.

### Injection Molding

Table X presents the injection molding parameters covering the two different materials which were made into injection molded type parts. Processing details for each material are described in Appendix B.

### Thermoforming (Vacuum Forming)

Table XI compares the thermoforming aspects of two different thermoplastic sheet materials. Processing details for the two materials are covered in Appendix C.

TABLE X. - INJECTION MOLDING PARAMETERS

Parameter	Lexan 940	E200-3Z	Radel 5010N	PES KM-1
Material Cost	\$2.50/lb	\$5.00/lb est	\$22/lb	\$9.00/lb
Scrap Rate	10%	10%	10%	10%
Material Prep	Oven Dry 6 hrs	0	Oven Dry 3 hrs	Oven Dry 6 hrs
Material Temp °C(°F)	127°C (260°F)	Room	150°C (302°F)	127°C (260°F)
Tooling Cost	Minimal	Minimal	Expensive	Expensive
Die Requirements	No Change	No Change	Heated & Cooled Die	Heated & Cooled Die
Injection Temp °C(°F)	260 (500)	360 (680)	390 (735)	350-390 (660-735)
Injection Pressure MPa (psi)	103 (15 000)	103 (15 000)	124 (18 000)	124 (18 000)
Injection Cycle	Fast	Fast	Medium	Medium
Protective System Required	Required	None	Maybe	Maybe
Adhesive Bonding	Good	Good	?	?
Process Costs Comparison	X	X	2X	2X

TABLE XI. - THERMOFORMING (VACUUM FORMING) PARAMETERS

Parameter	F-6000	EF-6000	PES KM-1
Material Cost	\$3.50/lb	*\$4.50/lb est	\$13.00/lb
Scrap Rate	60 %	65%	70%
Material Prep	Oven Dry 4 hrs	Oven Dry 4 hrs	Oven Dry 6 hrs
Tooling Required	Available	Available	Req Higher Temp Heating
Die Required	Available	Available	Heated & Cooling Die
Forming Temp °C	193°C	193°C	230°C
Forming Cycle	Fast	Fast	Very Fast
Forming Ratio Limit	8:1	8:1	6:1
Material Limit Texture Retention	Good	Good	?
Totals Cost Comparisons	1	1.4	4.3
		*Not Available	

## RESULTS

The object of this study was to promote the development of fire-retardant, low-smoke-emitting polymeric molding materials used in the design of cabin interior parts. Efforts were directed toward developing the processes and techniques for molding aircraft interior parts within the latest state-of-the-art in a practical and economical manner.

The study program examined the material behavior under flame exposure, the ability of the material to be processed into end products, and the ability of the end products to withstand typical aircraft interior environment and service abuse.

The approach adopted was to review all available data and information covering the potential candidate polymers which could be molded into usable parts in interior cabin designs. Specifically, materials which could be compression molded, injection molded, and thermofomed in a practical and economical manner were examined. Handling characteristics, preliminary service evaluation, possible cost and weight impact, and anticipated development schedule for each new polymer were also considered during the study period.

### Summary of Results

Although much of the data obtained and verified during the study were on initial pilot plant samples of most of the newer polymers, various pertinent observations were verified. The more important results are summarized below:

- Three modified phenolic resin systems, Ciba Geigy 917, Narmco 8250 and Fiberite MXB 6032, produced good quality fire-retardant, low-smoke-emitting compression molded parts with minimal cost, and no weight increase when compared to presently used polyester or epoxy resin molded parts.
- Although the polyimide/glass foam compression-molded material is flame resistant and low-smoke-emitting, it does not offer much improvement over the phenolic resins. The resin system is more costly, the processing more costly and tooling more expensive. The type of parts which could be molded from the thick foam material as applied by Solar is also limited.
- The addition of decorative laminate Tedlar inked film, bonded to the compression-molded parts greatly increased the quantity of smoke emitted, and lengthened the flame-out time and burn length when exposed to the flame test and smoke-evaluation test.
- Two pilot plant injection molding resins, polyethersulfone and polyphenylsulfone, exhibited better flame-resistant properties than the production-available Lexan 940. The Monsanto 200-3Z, aromatic polyester resin, does not meet the required flame resistance in thin sections. The resin dripped and continued to burn up to 7 seconds when exposed to the 60° vertical flame test.

- Both the polyethersulfone, PES KM-1, and the polyphenylsulfone, Radel 5010N, resins are much more costly than the Lexan 940. In addition, because of higher injection temperatures, they require high-cost tooling and expensive heated dies to produce quality molded parts.
- Development of thermoforming material EF-6000 polycarbonate has not progressed as expected. Initial exposure of material to service conditions indicated that it was more resistant to service cleaning than F-6000 material; however, G.E. production scrap rate is excessively high and no additional material for this program could be obtained. Also, initial exposure of 0.050 sheet of EF-6000 to 60-second flame test indicates that the flame resistance has been degraded in the modification from F-6000 to EF-6000.
- F-6000 polycarbonate is the only production material available in colors which approach the tentative flame resistant and smoke-emitting goals set for this development program. However, F-6000 still lacks adequate cleaner and solvent resistance for parts subjected to service contamination. In addition, the material still sags and drips on exposure to heat and flame which is objectionable.
- The PES, TQ 103, supplied in sheet form made from KM-1, appears to have the necessary fire retardant properties; however, material cost is approximately six (6) times that of the F-6000 sheet material. Since the average scrap loss of sheet material is approximately 60% on each part, the PES material cost could be prohibitive except for special parts.
- The PES sheet material requires heated dies with cooling fixtures to accept the formed parts to prevent chilling marks on the decorative surface. Forming parameter limits of the PES, and the heat-up rates and cooling cycles still need to be developed for different thicknesses of the PES sheet material.
- Parts molded from 3M Fluorel polymer coated, 120 fiberglass fabric produced much better parts than the polymer coated on random mat fiberglass, however combining of mat and fabric layers offers a potential weight reduction.
- Although the Fluorel polymer does not appear to burn or support combustion in flame, on removal of flame, the material appears to glow as punk on fiberglass mat.
- If parts are to be molded from the present Fluorel polymer, then a method must be developed to prevent absorption of moisture by the polymer after molding into parts. In a simple ambient water exposure test, The polymer lost much of its rigidity and part of its adhesion to the random fibers within one week.

## CONCLUSIONS

- Compression-molded parts made from phenolic resins appear to meet all the requirements for improved flame resistance, reduced smoke emission, and minimal degradation up to 500°F.
- Replacement for decorative Tedlar laminate covering for large surface areas still appears to offer potential for improving the flame resistance of cabin interior panels.
- Cost of Radel 5010N polymer for making injection or thermoformed parts appears prohibitive.
- New PES KM-1, polyethersulfone polymer may be the only logical candidate to replace polycarbonates for injection-molded parts in upper areas of cabin interiors.
- Use of higher cost PES for thermoforming parts may be prohibitive due to the 60% scrap rate experienced on most of these molded parts.
- A flame-resistant low-smoking serviceable, moderate-cost thermoforming sheet material to replace ABS parts presently used around seats, doors, and flight stations is still not available.

## RECOMMENDATIONS

- Further efforts to develop the PES for injection-molded parts should be continued.
- Further development of serviceable, moderate-cost thermoforming material should be continued.
- Further development of the Fluorel molding polymer with either better moisture resistance or with a means of protection should be continued.
- Molding of large sidewall panels from combination of glass mat and fabric with Fluorel resin should be continued.

APPENDIX A

COMPRESSION MOLDING OF LOW-SMOKING MODIFIED  
PHENOLIC RESIN LAMINATE OR CRUSHED CORE PARTS

1. SCOPE

1.1 Scope - This Process Specification establishes the requirements and processes for the compression molding of glass fabric reinforced, low smoking resin.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the cause and effect on date of content or purchase order, form a part of this process specification to the extent specified herein.

Specifications:

Federal	TT-M-261 Methyl Ethyl Ketone
Military	MIL-R-9299 Resin, Phenolic Laminating
	MIL-C-9084 Cloth, Glass, Finished For Resin Laminates
	MIL-T-81533 (1-1-1 Trichloro Ethane)
	MIL-STD-401 Sandwich Constructions and Core Material: General Test Methods
SAE	AMS 3711 Core, Honeycomb, Fibrous Aramid Base, Phenolic Coated
	AMS 3824 Cloth, Type "E" Glass, Finished For Resin Laminates
Commercial	Glass Fabric, Preimpregnated with Phenolic For Molding of Parts.
	(a) Ciba-Geigy Corp Fibredux 917 High Performance FST Adhesive Pre-Preg
	(b) Narmco 8250 Pre-Preg
	(c) Fiberite Corp. MXB 6032 3M Spray Adhesive No. 44

3. REQUIREMENTS

3.1 Materials

3.1.1 Nomex Core - Shall be 1/8 in. cell size 3.0 pcf density 0.125 in. thick and should conform to the requirements of AMS 3711.

3.1.2 Glass Cloth Reinforcement - Shall be style 1581 or 7781 conforming to AMS 3824. Finish shall be suitable to meet the requirements of this specification.

3.1.3 Preimpregnated Gloss Cloth - Shall be Ciba Geigy Fibredux 917, Fiberite Corp. MXB 6032 or Narmco 8250

3.1.4 Material Control - The initial storage period shall be in accordance with the material specification or vendor specification as applicable. After the initial storage period, the material shall be tested for flow and gel time prior to production cure.

The maximum allowable out-time during processing shall be five days.

3.1.5 Preparation of Materials

3.1.5.1 Preimpregnated fabrics which are removed from cold storage shall be warmed sufficiently in closed containers or wrapper to avoid moisture condensation on or into the material.

3.1.5.2 Nomex honeycomb shall be oven dried for a minimum of two hours at 225°F immediately prior to fabrication.

3.2 Tool preparation

3.2.1 Compression molding tools shall be thoroughly cleaned of any protective films or molding residue.

3.2.2 Parting agents shall have no detrimental effect on the curing, mechanical properties, surface finish, or subsequent processing of the part. When a part surface must be painted or have decorative film applied by adhesives, the parting agent shall be removed by solvent cleaning.

3.3 Layup procedure

3.3.1 The preimpregnated fabric and honeycomb core shall be cut to the required patterns established for each part to make an optimum lay-up. Fabric patterns shall be cut in such a manner as to ensure that the fabric warp direction is in accordance with Engineering Drawing Requirements. When the warp direction of the glass reinforcement or the ribbon direction of the core is not specified on the engineering drawing, the directions are optional.



3.3.2 Foreign Material - There shall be no trash, dirt, or foreign objects introduced into the part during lay-up.

3.3.3 Local build-up - Wherever possible, local build-ups shall be introduced into the center of the lay-up. When this is not possible, the build-up shall be covered with a minimum of one layer of fabric.

3.3.4 Part build-up

3.3.4.1 When possible make a flat build-up of the glass prepreg and Nomex Core. To hold the build-up together, fasten edges using tape, heat sealing, or staples. Core sliding may be minimized by spraying with contact adhesive, 3M Spray Adhesive No. 44.

3.3.4.2 When the previous procedure is not possible, lay-up the material on a pre-form tool, then partially curing or freezing this build-up sufficiently to hold the assembly together and permit removal from the pre-form tool. There shall be no wrinkles on separation of plies within the trim area of the laid up pattern. This partially cured or frozen part shall then be placed into the compression molding tool.

3.4 Part Curing

3.4.1 Detailed standard fabrication procedure - All details as to build-up, pressure cycle, tool temperature, and curetime shall be developed during the first part qualification in accordance with 3.5. These data shall then become a part of the detail standard fabrication procedure.

3.4.2 Cure Cycle - Temperature shall be a minimum of  $300^{\circ}\text{F} + 10^{\circ}\text{F}$ . Insert build-up into compression tool. Use sufficient pressure (about 350 psi) to compact the honeycomb cure and close the compression tool to stops for the required part thickness. Cure parts for 30 minutes minimum and remove from press. Upon removal from the compression tool, post cure the parts for 1 hour at  $350^{\circ}\text{F}$ . In certain parts, fixtures may be required to reduce warping and distortion during other part cure and cooling cycles.

3.5 Detail Standard Fabrication Procedure

3.5.1 Prior to production of a part, a detail standard fabrication procedure shall be established and proven. This procedure shall cover the following:

- (a) List of raw materials
- (b) Description of patterns of impregnated fabric and honeycomb cure used for lay-up.
- (c) Special lay-up instructions, as required.

- (d) Exact cure cycles
- (e) Any other specific instructions considered necessary to obtain a satisfactory part. When the detail standard fabrication procedure is established, it shall be recorded on a suitable form. These documents shall be used as the standard for all subsequent production of the part.

### 3.6 Workmanship

3.6.1 Laminates shall be free of defects, such as air bubbles, laps, gaps, blisters, holes, starved areas, resin pockets, nonuniformity, and other defects exceeding the limits specified below.

3.6.2 Uniformity - The laminate shall be within the tolerance of the engineering drawings and shall be of high quality workmanship.

3.6.3 Gaps - There shall be no gaps between pieces of fabric in any lamination.

3.6.4 Cracks and checks - Cracks extending through the part are prohibited. Checks forming sharp discontinuities in the resin surface and exceeding 1/4 inch (6.35 mm) in length, or covering an area greater than 20 percent of any square inch (645.2 mm<sup>2</sup>), or 5 percent of the part area are not acceptable.

3.6.5 Pits - Pits exceeding 1/16 inch (1.59 mm) diameter are not acceptable.

3.6.6 Blisters - Blisters exceeding 1/4 inch (6.3 mm) in diameter are not acceptable. The total number of acceptable blisters shall not exceed an average two for each square foot (0.09 m<sup>2</sup>) of surface. No two blisters shall be closer together than 6 inches (152 mm) edge to edge. Parts having less than 1 square foot (0.09 m<sup>2</sup>) of surface area shall be limited to one blister, maximum.

3.6.7 Resin rich areas - Press molded parts - Variations in resin thickness on the glass cloth surface which may show up as discoloration or surface dryness are acceptable provided that the surface is smooth enough not to show through the Tedlar decorative surface or paint to be applied later.

3.6.8 Starved areas - Any area in which the resin content is below the amount required to ensure proper setting of the fibers is not acceptable.

3.6.9 Tackiness - The entire laminate surface shall be fully cured and free of tackiness.

3.6.10 Wrinkles - Wrinkles 1/32 inch (0.79 mm) or less in height or depth shall be allowed, provided no more than an accumulative total length of 6 inches (152.4 mm) of such wrinkles occur in an area encompassed in a 6 inch (152.4 mm) diameter circle.

3.6.11 Delaminations - Solid laminate parts shall contain no delaminations. Compacted core parts shall show no visible delamination to the core on the Tedlar side. The reverse side of the part may be delaminated from the core to a limit of four areas not exceeding three square inches each as long as this delamination is not visible from the tedlar side.

3.6.12 Porosity - Uniform surface porosity is acceptable.

3.7 Rework - Unless otherwise specified, the reworkable defects in the laminated parts are defined as those which fall within the limits specified below.

3.7.1 Rework limits - Blisters, starved areas, pits, checks, cracks, and non-uniform resin surfaces extending through no more than 10 percent of the laminate thickness or one ply may be reworked providing the defects do not affect more than 20 percent of the surface area.

3.7.2 Rework procedure.

3.7.2.1 Surface preparation - All surfaces to be reworked shall be free of oils, wax, finishes, etc. The surface shall be roughened by light sanding to remove surface gloss, and then cleaned by wiping with clean cloths saturated with TT-M-261, Methyl-Ethyl-Ketone to remove all dust.

3.7.2.2 Rework surface defects with plastic casting resin LCM 22-1029 Type IX.

3.8 Secondary Bonding - Secondary bonding to the molding may be done with any suitable epoxy or polyurethane adhesive.

3.9 Surface Preparation - When the part surface is to be prepared for painting or application of decorative Tedlar, wipe the surface with a clean cloth moistened with 1-1-1 Trichloroethane. (NOTE: Avoid prolonged or repeated breathing of vapor; avoid contact with skin.) Allow to air dry for a minimum of 15 minutes. Scuff sand as necessary to remove surface gloss. Remove dust residue with shop air, vacuum brush or dry cloth wipe. Follow with a wipe with a clean cloth saturated with 1-1-1 Trichloroethane to remove sanding residue. Allow to air-dry for a minimum of 30 minutes before further processing.

3.10 Mechanical Properties

3.10.1 Flatwise tensile - The flatwise tensile strength shall be a minimum of 100 psi (689.5 kPa) when tested in accordance with MIL-STD-401.

Specimen size shall be 2 inches (50.8 mm) square or 2 inches (50.8 mm) in diameter. Five specimens shall be tested and the average reported.

3.10.2 Peel strength - The peel strength shall be a minimum of 8 pounds (44.48 N) tested in accordance with MIL-STD-401. Specimen size shall be 3 inches (76.2 mm) by 12 inches (304.8 mm). Warp direction of cloth and ribbon direction of core shall be at random. Five specimens shall be tested dry and the average reported.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Qualification of parts, tools and process - Prior to production, each part together with the set of tools and process used to fabricate it shall be qualified as specified in 3.6. Complete or partial requalification may be required periodically or whenever quality of parts is questionable at the option of Quality Assurance.

#### 4.2 Material Control

4.2.1 All raw material used for fabricating parts shall have been qualified and accepted under the applicable material specification.

4.2.2 Raw material shall be stored at temperatures corresponding to shelf life requirements of the applicable material specification. Material in storage shall be tested periodically to determine if there is any deterioration. The initial period before the material is retested shall correspond to the shelf life requirements of the material specification.

4.3 Equipment control - All variable equipment used for storage of material, processing, and inspection shall be controlled by documented periodical checks to ensure that all process requirements such as temperature and pressure limits are consistently met as specified herein.

4.4 Process control - All critical operations in the process, such as lay-ups, cure temperatures, times, and pressures, shall be verified by recording instruments or by inspection; and documentary evidence maintained to demonstrate conformance to all the requirements of this process bulletin.

4.5 Part inspection - Each part shall be inspected for conformance to requirements of 3.2 as well as the Engineering drawing.

#### 5. HANDLING AND TRANSPORTATION

5.1 Parts and materials shall be handled and transported in such a manner as will insure that the required physical characteristics and properties are preserved. All parts in fabrication, shipment, and storage shall be protected adequately to prevent damage. Critical surfaces may require surface protection, packaging in shipping containers, or be stored on individual storage racks to protect them adequately.

## 6. NOTES

6.1 This process bulletin meets the requirements of MIL-F-9400, for preparation of a detailed process specification for the fabrication of plastic laminate parts.

## APPENDIX B

### PROCESSING OF INJECTION-MOLDING MATERIALS

#### 1. SCOPE AND CLASSIFICATION

1.1 Scope - This Process Specification establishes the requirements for the fabrication of low smoke producing injection molding materials.

1.2 Classification - This specification applies to the fabricator of parts from General Electric Lexan 940, Polycarbonate, and ICI Chemical Polyethersulfone, KM-1.

#### 2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of Contract or purchase order, form a part of this specification to the extent specified herein:

Federal	JAN-T-171 Toluene
	O-C-291 Chloroform
	TT-E-751 Ethyl Acetate
	TT-I-735 Isopropyl Alcohol
	TT-M-261 Methyl Ethyl Ketone
	TT-X-916 Xylene

#### 3. REQUIREMENTS

##### 3.1 Material

3.1.1 Material shall be shipped and stored in sealed metal or plastic containers.

3.1.2 Containers shall not be opened until the contents can be loaded into the hopper of the injection molding machine.

3.1.3 Material that has absorbed moisture shall be dried in trays in a circulating air oven for not less than three hours at 150°C (302°F) or six hours at 120°C (248°F).

3.1.4 Rework Material - Sprues and scrap parts may be utilized up to 25 percent with new polymer. Material shall be cut up and dried as in 3.1.3.

3.2 Tooling - Mold dies shall be made of hardened steel forgings, chrome plated, incorporating electric heating elements capable of heating the die to 200°C (392°F).

3.3 Mold Releases - Mold releases shall be used as sparingly as possible. They shall have no detrimental effect on the material properties, surface finish or subsequent processing of the part. Silicone mold releases shall not be used.

### 3.4 Injection Molding Machines

3.4.1 Must be capable of providing a thermally homogeneous melt with no pockets where the melt can be trapped or stagnate. Heating capacity to 400°C (752°F).

3.4.2 A reciprocating screw-type machine is recommended. Plunge-type machines are not recommended because of the possibility of local over heating.

3.4.3 Must have a variable control of pressure up to 140 MN/m<sup>2</sup> (20,000 psi.).

3.4.4 Must have hopper with heating capacity to 200°C (392°F) to pre-heat material before feeding to injection machine.

3.4.5 Must have accurate temperature controls on feed hopper.

3.4.6 Must have high screw torque.

3.4.7 Must have variable control of all phases of the molding cycle.

### 3.5 Detail Standard Fabrication Procedure

3.5.1 Prior to production a detail standard fabrication procedure shall be established and proven. This procedure shall cover the following:

- (a) Cylinder temperature
- (b) Plastic temperature
- (c) Mold temperature
- (d) Extrusion time and pressure
- (e) Mold cooling time
- (f) Mold open time

- (g) Any other specific instructions considered necessary to obtain a satisfactory part. When the detail procedure is established it shall be reworded on a suitable form. These documents shall be used as the standard for all subsequent production of the part.

3.6 Workmanship

3.6.1 Parts shall be free of the defects specified below

3.6.1.1 Shrink or Sink Marks - A shallow depression or dimple on the surface of the part due to collapsing of the surface following local internal shrinkage, after the gate seals. May also be an insufficient short shot.

3.6.1.2 Bubbles and Voids - Enclosed cavity or hole in the bulk of the molding.

3.6.1.3 Weld Lines - A mark on the surface made by the meeting of two flow fronts during the molding operation.

3.6.1.4 Flash - Extra plastic attached to a molding along the parting line which must be removed before the part can be considered finished.

3.6.1.5 Burn Marks - Discolored or charred areas of molding.

3.6.1.6 Splash Marks - A surface pattern of streaks radiating from the area of the gate.

3.6.1.7 Flow Marks - Wavy surface appearance caused by improper flow of the resin into the mold.

3.6.1.8 Poor Surface Finish - Poor or nonreproduction of the tool surface.

3.6.1.9 Distortion of the part in one or more planes.

3.6.1.10 Window - Well defined areas of different appearance approximately the size and shape of unmelted granules.

3.6.1.11 Patches - Surface defects in the same position of each molding usually close to the gate.

3.6.1.12 Crazeing - Fine cracks which may extend in a network on or under the surface. Usually occurs in the presence of an organic liquid or vapor with or without the application of mechanical stress.

3.6.1.13 Cracking - Cracking or breaking of the part by injection.

3.6.1.14 Surface Blisters - Small bulges caused by the expansion of the void under the surface.



3.6.1.15 Pressure burn discolored area caused by trapped air in the mold becoming superheated.

3.7 Secondary Bonding - Secondary bonding to the molding may be done with any suitable epoxy or polyurethane adhesive.

3.8 Surface Preparation - When the part surface is to be prepared for painting or application of decorative Tedlar, wipe the surface with a clean cloth moistened with Isopropyl Alcohol.

Note: Avoid prolonged or repeated breathing of vapor, avoid contact with skin.

Allow to air dry for a minimum of 15 minutes. Scuff sand as necessary to remove surface gloss. Remove dust residue with shop air, vacuum brush or dry cloth wipe. Follow with a wipe with a clean cloth saturated with Isopropyl alcohol to remove sanding residue. Allow to air dry for a minimum of 30 minutes before further processing.

3.9 Residual Strain - Parts shall not have a residual strain greater than A-B when tested in accordance with 4.6.1.

3.10 Annealing - When parts exhibit excessive residual strain they shall be annealed in a circulating air oven at 190°C (375°F) for five hours to release molded in stress.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Equipment Control - All variable equipment used for material processing and inspection shall be controlled by documented periodic checks to insure that all process requirements are consistently met as specified herein.

4.2 Process Control - All critical operations in the process, such as barrel material and mold temperatures, times and pressures shall be verified by recording instruments or by inspection; and documentary evidence maintained to demonstrate conformance to all the requirements of the specification.

4.3 Part Inspection - Each part shall be inspected for conformance to the Engineering Drawing and the requirements of 3.6.

4.6 Test Methods

4.6.1 Test Method for estimating residual molded in strain.

4.6.1.1 Immerse part in each of the test reagents for 100 seconds.

4.6.1.2 Wipe dry and examine for cracks. (Molding turning white is disregarded.)

4.6.1.3 Select reagent which first gives visible cracks.

Test Reagent

Xylene	D	Very Highly Strained
Toluene	C	Highly Strained
Ethyl Acetate	B	Fair Amount of Strain
75% Chloroform	A	Low Strain
25% Trichloro Ethane	AA	
Methyl Ethyl Ketone		
No Cracks With Methyl Ethyl Ketone		Strain Free

Good quality moldings should rate A-B. Annealing is usually required for AA or better.

5. HANDLING AND TRANSPORTATION

5.1 Parts and materials shall be handled and transported in such a manner to prevent damage. All parts in fabrication, shipment and storage shall be protected adequately by storage on racks, in boxes or protective bags.

6. NOTES

6.1 This Process Specification meets the requirements of MIL-P-9400 for preparation of a detail process specification for the fabrication of plastic parts.

## APPENDIX C

### FABRICATION OF LOW-SMOKING THERMOPLASTIC PARTS FROM SHEET STOCK

#### 1. SCOPE AND CLASSIFICATION

1.1 Scope - This specification details the requirements and procedures for fabricating parts from polycarbonate and polyethersulfone by thermoforming techniques.

#### 1.2 Classification

Type I Parts - Parts where the surface finish is important such as the interior trim of the flight station or passenger compartment.

Type II Parts - All other parts.

#### 2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of contract or purchase order form a part of this specification to the extent specified herein:

##### Federal

O-M-232	Methanol (methyl alcohol)
TT-E-751	Ethyl acetate
TT-I-735	Isopropyl Alcohol

##### Commercial

General Electric Polycarbonate "Lexan" F-6000 sheet

ICI Chemical Polyethersulfone KM-1 sheet supplied as Rohm and Haas TQ-103

##### Adhesives, Polyurethane

Bacon Industries	Flexobond 203-A/Flexobond
	Activator BA-400 (Fast Cure)
	Flexobond 204-A/Flexobond
	Activator BA-400 (Medium Cure)

3M Co.

3535 A/B

Seven-K Color Corp.

Dye - Pontachrome

Blue-Black AAG-13

### 3. REQUIREMENTS

3.1 Material - This specification covers the fabrication of General Electric Polycarbonate, "Lexan" F-6000, and ICI Polyethersulfone, KM-1, sheet.

3.1.1 Detail procedure - Details of forming shall be as specified by a forming machine set-up chart. Other details of fabrication shall be as specified by the manufacturing operations sheet. These shall be prepared for each part as specified in 3.4.

3.1.2 Tools - Forming tools shall be a cast plastic, laminated fiberglass, or aluminum. Where a decorative surface texture is desired, or dimensional tolerances must be maintained, electric heating shall be incorporated in aluminum tooling.

3.1.3 Cleaning - Special precautions shall be taken to keep the sheet dust-free during the heating and forming cycles to prevent marring the surface with objectionable dimples. Remove the dust from the sheet by blowing with clean air. If necessary, wipe with a clean rag dampened with isopropyl alcohol.

3.1.4 Drying - Prior to forming sheet material shall be dried as follows:

	Polycarbonate	Polyethersulfone
Thickness	120°C <u>+5°C</u> (250°F <u>+10°F</u> )	150°C <u>+10°C</u> (300°F <u>+15°F</u> )
Less than 1.5 mm (0.60 in.)		5 hours min
1.5 mm (0.60 in.) through 3 mm (0.120 in.)		6 hours min
Over 3 mm (0.120 in.)		18 hours min

Dried sheets shall be loaded into the thermoforming machine before they cool down to room temperature.

If the part bubbles during the forming operation, the drying cycle shall be repeated.

3.1.5 Heating - Heating shall be accomplished by using a circulating air oven, hot platen, or bank of radiant heaters. The heating cycle shall be specified by the forming machine set-up chart.

3.1.6 Forming - Polycarbonate shall be formed between 171°C (340°F) and 199°C (390°F). Polyethersulfone shall be formed between 270°C (525°F) and 302°C (575°F). The forming cycle shall not be started until the sheet is formable. Forming cycles must be very fast to minimize cooling of the sheet below forming temperature.

3.1.7 Cooling - The part shall be removed from the forming tool as soon as possible. Cooling may be expedited by blowing clean air over the part. A water spray shall not be used.

3.2 Machining - In general, polycarbonate sheet material shall be machined in the same manner as soft metal. Do not over heat the material during the machining operations. An air blast or water spray may be used to prevent over heating. Organic solvent type coolants shall not be used.

### 3.3 Bonding

3.3.1 Adhesives - All bonding shall be performed using polyurethane adhesives, as follows:

(a) General Purpose - Flexobond 204-A/Flexobond Activator BA-400 (medium cure)

(b) Fast Cure - Flexobond 203-A/Flexobond Activator BA-400  
3M Co. 35 35 A/B

3.3.2 Surface Preparation - Scuff sand the faying surface with abrasive paper, 150 grit maximum, as required to get satisfactory bonding. Wipe the dust off the sanded surfaces with a clean cloth or paper. If necessary, clean with a cloth or paper dampened with TT-I-735 Isopropyl Alcohol.

3.3.3 Adhesive bonding procedure - Mix the adhesive according to the manufacturer's instructions and then apply it to the faying surfaces. Assemble and clamp the surfaces lightly and evenly together. Clamps shall remain on the joined surfaces until the curing cycle has been completed. Approximate cure times for the adhesive are as follows: 4 hours at room temperature, 1 hour at 150 +10°F, or other combinations of temperature and time not exceeding 150°F are permissible.

3.4 Detail forming machine set-up chart and manufacturing operations sheet for specific parts.

3.4.1 As part of the qualification procedure, a detail forming machine set-up chart and manufacturing operations sheet shall be established and proven (see 4.1.1) which shall include the following:

- (a) Material type, thickness, and cut-out pattern.
- (b) Type of release, if any, and method of application to the tool.
- (c) Heating cycle including heater or oven settings, and description of any masks used between the heaters and the sheet.
- (d) Forming cycle sequence including vacuum and pressure setting, tool position forming sequence, cooling time, and the description of any cooling jigs if required.
- (e) Special instructions about trimming, cementing, cleaning, or protection.
- (f) Any other instructions considered necessary to make a satisfactory part.

3.4.2 The forming procedures shall be recorded on a forming machine set-up chart. Fabrication procedures shall be recorded on a detail manufacturing operations sheet. These documents shall be used as the standard for all subsequent production of parts.

### 3.5 Workmanship

3.5.1 Parts shall be free of cracks and crazing. - Pits, blisters or bubbles less than 0.060 inch in diameter are acceptable, provided they do not cover more than 20 percent of any square inch. Pits, blisters or bubbles larger than 0.060 inch but less than 0.20 inch in diameter are acceptable, provided no more than three such defects are located in any 4-inch diameter circle.

3.5.2 Where the parts surface is critical as noted on the Engineering drawing, pits, blisters or bubbles less than 0.060 inch in diameter are acceptable, provided they do not cover more than 10 percent of any square inch. The surface shall be free of pits, blisters, bubbles, discolorations or other surface imperfections exceeding 0.060 inch in diameter.

3.5.3 Bonded joints shall be free of crazing, cracks, and uncured adhesive, and shall be firmly bonded over at least 85 percent of the joint surface within any 2-inch length of the joint. The remaining 15 percent of the joint may have bubbles or dry-spots. On joints in ducts, no voids or dry-spots shall extend more than 1/3 of the width of the joint. Discoloration of adhesive bonded joints is acceptable.

3.5.4 Wrinkles are not allowed.

3.5.5 Foreign materials - There shall be no paper tape, crayon marks, or other miscellaneous materials on the parts.

3.5.6 Trimming - Sharp or frayed edges resulting from drilling, trimming, or routing shall be removed.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Prior to acceptance of parts, at least one pilot part shall be fabricated on each set of tools.

4.1.1 Destructive inspection - Inspection of parts having draw ratios of 1 to 1 (width to depth) or less, i.e. 1.5 to 1, 2 to 1 etc., shall not require destructive testing. All new parts having ratios exceeding 1 to 1 shall, during tool try and forming cycle development, have at least one part sectioned for thickness check in the thin areas and tested for stress crazing. If crazing or excessive thinning occurs, the cause, such as faulty tooling or improper processing, shall be determined and corrected. At least one part shall be formed with the necessary changes and the procedure repeated until acceptable parts can be produced. The forming procedure set up chart and shop order shall be up-dated to reflect all information necessary.

4.1.2 Stress cracking resistance.

4.1.2.1 Sample size and configuration - On flat parts, the sample size shall be at least 4 square inches by the supplied thickness. On other than flat parts, the parts shall be tested in the area of maximum curvature or complexity.

4.1.2.2 Test equipment shall be as follows:

(a) Solvent, as follows:

50/50 mixture (pbv) of TT-E-751 Ethyl Acetate and O-M-232 Methanol (Methyl Alcohol).

(b) Pontachrome Blue-Black Dye 1.0 gram per 200 ml above solvent.

(c) Cotton gauze.

4.1.2.3 Procedure - Thoroughly wet the cotton gauze with the test mixture specified in 4.1.2.2. Wipe the part slowly with the gauze, allowing the solvent to wet the sample for three minutes. Allow the part to air dry for one minute, and then carefully inspect for cracks or crazing. If the part exhibits any stress cracking, the cause shall be determined and corrected as specified in 4.1.1.

4.2 Production parts

4.2.1 Process control - Inspection shall assure conformance to the applicable forming machine set-up chart and manufacturing operations sheet (see 3.1.1).

4.2.2 Part inspection - Inspection shall verify conformance of parts to the requirements of 3.5 as applicable.

## 5. HANDLING AND TRANSPORTATION

5.1 Parts and materials shall be handled and transported in such a manner as will insure that the required physical characteristics and properties are preserved.

5.2 Sheet material - If sheets are stacked horizontally, use paper between sheets to prevent scratching. Place the smaller sheets on top of larger sheets to avoid any unsupported overhang. Sheets may be stored in a vertical position provided precautions are taken to prevent sagging or scratching of the sheet material.

5.3 Formed parts - Rough handling shall be avoided. Parts shall be stored in a manner that will prevent distortion, change of shape, or physical damage.

## 6. NOTES

6.1 There are no Government specifications covering the requirements of this specification.