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DEVELOPMENT OF FIRE RESISTANT, NONTOXIC AIRCRAFT INTERIOR MATERIALS

by: G. Haley, B. Silverman, Y. Tajima

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16. ABSTRACT

All available newly developed nonmetallic polymers were examined for possible usage in developing fire resistant, nontoxic nonmetallic parts or assemblies for aircraft interiors. Specifically, feasibility for the development of clear films for new decorative laminates, compression moldings, injection molded parts, thermoformed plastic parts, and flexible foams were given primary considerations.

Efforts were directed toward promoting the development of pilot plant polymers by the chemical companies, to be used in the development of the above end applications, in order to upgrade the interiors of the next generation of airplanes for resistance to fire and the reduction of smoke and toxic by-products when subject to a fire environment.

Preliminary data on the flame resistant characteristics of the materials were obtained. Preliminary toxicity data was generated by the AMES Research Center from samples of materials submitted from the contractor.

Preliminary data on the physical characteristics of various thermoplastic materials to be considered for either compression molded, injection molded, or thermoformed parts were obtained.

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CONTENTS

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CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

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I SUMMARY

New polymers were studied to identify those that offered promise to reduce significantly the fire and associated hazards when used in producing typical aircraft interiors. Specifically, the study was directed toward advancing the development of paints or coatings, decorative films, compression and injection molded parts, thermoforming materials, fabrics, and foams. The program was also undertaken to provide stimulation for further product development by providing close interchange between polymer manufacturers and users to make certain that a product has the desired characteristics for production consideration.

During the program it was established that the feasibility of producing a clear coating or paint material to prevent the outgassing of smoke and toxic by-products from presently used interior materials was beyond the technology of the presently available polymers. Unavailability of certain resins and the unstable solutions of other resins considered as candidates for coatings caused the contractor to stop work on trying to develop barrier type coatings.

Certain new polymers for casting films were not available during the study program, however, three different film materials were obtained and typical decorative laminates were manufactured by Polyplastex from the new films. Data on these laminates as well as feasibility of their application, and expected service life were investigated during the program.

Several research materials were evaluated for their feasibility as compression moldable or injection moldable materials. Two materials appeared to be developed sufficiently to warrant further consideration for designs predicated on these types of molded parts. The two polymers which appeared to offer the most promise as replacements for regular polycarbonate and Noryl type injection molded parts are polyethersulfone and polyphenylene sulfide.

Various modified polymers were examined as replacements for the high smoking thermoplastic materials, namely, ABS and Noryl, presently used for almost all thermoformed parts around seats, doors, and lavatories. These materials examined were a new modified polycarbonate from G.E., a modified polysulfone from Uniroyal and a chlorinated PVC from General Tire (basic polymers from Rhodia). In addition, initial samples of thermoforming grade of polyether sulfone was examined and some data are presented.

Development of new foam materials for replacement of FR polyurethane foams presently employed in seats manufactured for airplanes is progressing more slowly than anticipated. Only two materials appear to offer some degree of success. The polyphosphazene materials being developed by Horizons under NASA-AMES contract and a polymide foam material being developed by Solar under NASA-JSC contract. Only large samples of polyphosphazene material available in quantity for evaluation appeared to be too heavy 80.2 kg/M^3 to 144.6 kg/M^3 (5 to 9 lb/ft^3) for use in aircraft seat construction. Present seats use foam at 32.2 kg/M^3 (2 lb/ft^3). Initial samples of polyimide foam supplied to JSC looked very promising at the 32.2 kg/M^3 (2 lb/ft^3) density. Development of large bun production for use in making seats is being pursued by Solar. Little data have been obtained under this contract on these foams.

Samples of new fabric materials which offer some promise for use in upholstery and drapery production are proban treated wool, FR nylon, Nomex, Kynol, and PBI fibers. The proban treated wool, FR nylon, and Nomex are presently available in production. However, the reduction of toxic by-products in the event of fire gained by use of these materials is still questionable. The use of Kynol for seat upholstry is questionable since its wear qualities are not good. This material would, however, be satisfactory for drapery material providing it is not exposed directly to sunlight.

The PBI fiber material needs further development by the Celanese Corporation and a commitment to produce pigmented fibers to alleviate the lack of ultra-violet resistance experienced with the dyed fabric made from the original PBI fiber. Little Data are presented concerning these advanced fabric materials. Some data on the proban-wool and FR nylon, and Nomex type fabrics are presented in the report.

II INTRODUCTION

This is the final report of "Development of Fire Resistant Nontoxic Aircraft Interior Materials" conducted by the Lockheed-California Company under Contract NAS 2-8835 with the National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California. This report documents all research activities conducted during the study, which extended from June 16, 1975, through June 16, 1976.

A. Background

This study is one of several being sponsored by the NASA-AMES Chemical Research Projects Office as part of its Aircraft Interior Fire Protection Program. Other studies include an evaluation of combustion detectors, mass spectroscopic analysis of pyrolysis and combustion processes, animal toxicology studies, as well as full-scale fire testing.

B. Objectives

The prupose of this study was to provide information which would identify new polymers that promise significant reduction in fire and associated hazards and that have sufficiently advanced state of the development to merit consideration and evaluation for use in aircraft interiors. Qualifying materials were characterized chemically to identify applicability is specific end-usages (paints, decorative films, compression and injection molded parts, thermoformed parts, fabrics, and foams). Laboratory tests were performed to identify the materials most suitable for use in these applications. This evaluation considered the material behavior under the fire environment, the ability of the material to be processes into the intended end products, and the ability of the end products to withstand typical aircraft environment and service abuse.

C. Method of Approach

To meet the objectives of the program, this contractor established a program that included six technical tasks.

Task 1 Industrial Survey

Task 1 was the industrial survey which included trips to the various chemical industry research facilities to explain the purpose of the NASA-AMES FIREMEN Program and to promote the development of research polymers designed to yield materials of interest for reducing aircraft fire and associated hazards. Development of polymers for barrier coatings, film compression molding compounds, injection molding compounds, thermoforming sheet materials, foams, and fibers for fabrics were stressed in the presentations given at the various companies.

Task 2 Chemical Characterization

Materials of industrial origin, identified under Task 1, were subjected to chemical characterization to supplement, as necessary, supplier furnished data and to pinpoint the specific end-usage for which the materials were later tested. Materials qualifying for end-uses other than in paints, decorative films, compression molded, and/or injection molded parts were identified and the information brought to the attention of the companies, together with some recommendations for further evaluation.

Task 3 Evaluation of Paints and Coatings

On the basis of results from Tasks 1 and 2, selected resins were considered as possible basis for the development of barrier type coatings. Consideration was given to developing a clear type coating which when applied over existing type interior materials, would act as a flame barrier material. This material would prevent or restrict the evolution of smoke and toxic by-products for a period of time when subjected to fire, thereby allowing additional time for passenger evacuation. It was intended for the large number of older passenger jets now in service, since complete refurbishment of all interiors on the older jets appears to be economically unfeasible.

Task 4 Films on Decorative Laminates

From the polymers identified in Task 1 and considered as potential film material in Task 2, three polymers or combinations of polymers were selected for further evaluation. Decorative laminates were procured from Polyplastex Inc., made of PVF_2 over substrates of PVF_2, polycarbonate and polyether sulfone.

Data were obtained on the decorative laminates themselves and also on the serviceability of the decorative laminates bonded to substrates typical of the presently used sandwich type panels. Final data on fire testing and toxic by-product evaluations with animal studies will be done by NASA-AMES.

Task 5 Compression Molded Parts

From the candidate materials identified under Task 2, several new polymers were considered for further screening for potential use in the fabrication of compression molded parts. During the screening period, the thermochemical properties were studied in more detail to identify the processing parameters on small samples in a laboratory press. Based on initial test results and overall physical, chemical, processing, and cost aspects of the polymers, the two leading candidates were selected for further studies. Data gathered on the two most promising polymers and their flame, smoke, and toxicity ratings have been presented. Suitability of the polymers for use in injection molding equipment was of prime importance in the decision for selection, as a large quantity of thermoplastic parts in present day jets are injection molded. During this task, newly developed thermoplastic sheet materials were examined for possible substitutes for the existing high smoking Noryl and ABS materials. Limited data are presented on these thermoplastic sheet materials as it appears they were developed primarily to meet the intended FAA flame and smoke emission standards, and were not intended to meet any toxic by-product limitations when subjected to flame exposure.

Task 6 Foams and Fabrics

New foam developments and new fiber developments which offer significant improvements in upgrading the fire safety aspects are indicated. Only limited data are provided in this report on the foam materials as both research programs covering the foam developments are sponsored under separate NASA contracts. Work on development of polyphosphazene foam and data concerning this material are being supplied to NASA-AMES under contract.

Work and data on the second candidate foam, namely, polyimide type, are being supplied by Solar to NASA-JSC under contract.

Samples of Kynol fabrics indicate that the usefulness of this type of fabric will be limited, in its present state of development, to drapery material as its abrasion resistance to wear as upholstery material is far less than present upholstery type materials. Data presented are limited to published material and were not generated by this program. Data on other presently available fabrics for upholstery material, namely, proban treated wool, FR nylon, Nomex, and blends of these fibers are presented. Limited data are available on PBI fiber developed by Celanese. Work on producing individually dyed fibers to produce ultraviolet stable fabrics is just started. This polymer appears to have good characteristics for upholstery material, however, it must be produced economically before it becomes useful to the airline industry.

Task 7 Material Specifications

Preliminary material specifications covering some of the usable materials are provided in the report.

D. Acknowledgements

The Materials and Producibility Department gratefully acknowledges the assistance provided by the following organizations and personnel in obtaining the information and creating the data used in this study:

- Edward Lopez - Rye Canyon Test Facility
- C. Fong - Rye Canyon Test Facility
- Personnel at NASA-AMES and NASA-JSC in providing some of the fire safety properties data on some of the materials.
- NASA-AMES in developing test method for determining the toxicity-level rating of various materials examined during the study period.

III INDUSTRY SURVEY

A. Introduction

Task 1 was a literature survey and an industry survey, the results of which are presented in this section. The industry survey consisted of visiting various chemical companies for an interchange of ideas for development of polymers to meet the program objectives.

At each company, Lockheed personnel presented a two-hour program which described the intent and scope of the NASA-FIREMEN Program, and how the fire resistant nontoxic aircraft materials development work related to the overall FIREMEN Program. Detailed material requirements and processing restrictions were outlined to each chemical company. Results of these visits and information received are presented in this section.

B. Research Facilities Visited

1. First Trip	2. Second Trip
Phillips Petroleum Company	Celanese Corporation
Monsanto Chemical Company	ICI, USA, Incorporated
General Tire Company	E. I. Du Pont DeNemours & Company
General Electric Company	Rhodia, Incorporation
3M Company	Ciba-Geigy Corporation
Dow Chemical Company	Stauffer Chemical Company
Dow Corning	American Kynol Incorporated

C. Results of Visits

1. First Trip

a. Phillips Petroleum Company, Bartlesville, Oklahoma

Recent developments of polyphenylene sulfide (Ryton) polymer included lighter color for injection molding, surface preparation for bonding and painting, a sintered Ryton foam, extruded films and fibers (pigmented, not dyed), and wire coatings were presented.

A new flame retardant, IFR, capable of controlling the flammability of normally flammable polymers such as polypropylene, was discussed. (Since this contains phosphorus and nitrogen, a study of toxic effects is required.)

General impression: Aggressive, well managed research team, excellent facilities, limited product line.

b. Monsanto Chemical Company, St. Louis, Missouri

Heavy involvement in fire safety of consumer products such as clothing and carpets, did not appear to have much application to NASA-FIREMEN program. No new polymer work was discussed and little interest in the aircraft market, except for an off-the-shelf material, was shown. Most of discussion was on test methods, especially controversial toxicity tests.

c. General Tire Company, Newcomerstown, Ohio

Basic supplier of rigid thermoplastic sheet and extrusions. Primarily a processor of resins made by others but with high competence in blending and special properties. Well aware of industry flammability requirements and capable of extensive development work.

General impression: Good practical background in industry requirements, and excellent development and production facilities. No basic polymer work in house.

d. General Electric Company, Chicago, Illinois

Visit to Indiana production facility as originally planned was not approved by G.E. management, a meeting was held at the O'Hare Hilton instead. No new developments were discussed but an update on polycarbonate was presented. G.E. appears to be committed to further development of their present product line and were unwilling to discuss new polymers.

General impression: No assessment of facilities was possible. General lack of interest in new polymers but much interest in present products and state of industry/FAA/NASA programs.

e. 3M Company, St. Paul, Minnesota

Excellent response to the NASA-FIREMEN presentation and several individual meetings with various specialists. New products including a ceramic fiber with handling properties like glass but with a much greater temperature resistance, new adhesives, foams, and films were discussed. Great interest in program objectives was evident and a number of contacts with future promise were made.

General impression: A very wide range of products with possible application areas were uncovered. Personnel and facilities both of very high quality.

f. Dow Chemical Company/Dow Corning, Midland, Michigan

Discussion of program objectives quickly centered on toxicity and extensive work by Dow in this area was reviewed. Several new polymers were mentioned but no details were available. Toxicity test facility was visited and test methods observed and discussed. Very extensive scale of test program and personnel and equipment was apparent.

Major message so far is that chemical composition of polymer and toxicity cannot be emperically related. Dow Corning group did not have any new developments of promise in elastomer and silicone areas.

General impression: Work on new polymers is under way but data not available. Personnel highly competent and facilities first rate.

General Comments on First Trip: While the response of various companies was highly variable, in each case the comment was made that the purpose of the NASA-FIREMEN program had been clearly presented. Overall response was very encouraging and several very promising leads were uncovered. More important, however, was the establishment of lines of communication with groups that are in a position to help the program in the future.

2. Second Trip

a. Celanese Corporation, Summit, New Jersey

Discussion centered around polyimides and PBI fiber developments. Availability of light colors of the PBI fiber appears unlikely and development work has been slow because no decision to scale up production has been made. A foamed polyimide was described but tooling requirements would be expensive. Several promising polymers were discussed but no data was available.

General impression: Objectives of the NASA-FIREMEN program were well understood. Practical aspects of quantities of materials needed were discussed in light of PBI fiber experience.

b. ICI United States, Incorporated, Wilmington, Delaware

Very active program in polyethersulfone was major subject of discussion. Outstanding flame resistance and no drip combined with low potential for toxic products make it a prime candidate. In addition to injection moldings, clear films, pigmented fibers, and thermoform sheet were shown. Solubility of PES in epoxy resins seen as a potential to reduce their smoke contribution. Several advanced resin systems were alluded to but no data available as yet.

General impression: Very good understanding of our objective. High quality research efforts combined with good practical materials background should allow ICI to make a significant contribution.

c. E.I. Du Pont DeNemours and Company, Wilmington, Delaware

After a general meeting for our presentation, separate meetings with various departments were held. The fibers department suggested use of Nomex paper to act as a barrier to panel and film outgassing but no new fiber developments were presented. The film department showed some interesting new developments in Tedlar/Teflon/Kapton films but did not offer any totally new polymers. The resins and polymers department is working on a flexible phenolic as well as polyimide variants. The plastics department discussed Tefzel film for insulation batt covers but had no new polymers.

The Haskel Laboratory was toured and discussion of Du Pont efforts on toxicity was held, with emphasis on recent work on short-time exposure. A program involving modification of theater seat construction with a thin layer of neoprene foam bonded to the standard fabrics was shown. Fire spread and intensity was drastically reduced.

General impression: Very cooperative attitude and tremendous depth and variety of effort apparent. Widespread use of various Du Pont polymers in present designs appeared to surprise many.

d. Rhodia, Incorporated, New York, New York

Discussion centered on Kerimid polyimide and chlorinated PVC thermoplastic. No Kerimid Fiber or film is available but use in high temperature tooling and interior panels was discussed. Potential of CPVC appears limited due to potential toxicity and weight penalty. They are working on new polymers but have nothing to offer at present.

General impression: Major effort by Rhodia appears to be in promoting present products. Their interest in the aerospace market did not seem very active.

e. Ciba-Geigy Corporation, Ardsley, New York

A large group attended our presentation and separate meetings with several groups were held. Very active research on polymers was reviewed and variants on epoxies, phenolics, and modified polyimides. Lower curing temperatures and lower cost polyimides are being investigated. Low smoke epoxies, NCNS resins, and solvent-soluble polyimides are within reach.

General impression: Very strong research-oriented efforts in basic polymers. A number of very promising long-range potential programs were identified. Excellent feel for needs of the NASA-FIREMEN program was established.

f. Stauffer Chemical Company, Dobbs Ferry, New York

Discussion centered on foam materials and flame inhibitors for various resin systems. Toxicity and smoke requirements were presented and tradeoffs were evaluated. No new materials were available for evaluation. A review of fire-resistant phosphate ester hydraulic fluid developments was included in this visit.

General impression: Work in flame inhibitors and additives for resin systems aimed at commercial areas. Little understanding or interest in aerospace market at present, except in area of hydraulic fluid.

g. American Kynol Incorporated, Niagara Falls, New York

Development of Kynol fiber was discussed at length. Progress in area of woven and nonwoven fabrics, blankets, and upholstery were reviewed. Encasing cushions in a Kynol cover could control drip and flame of polyurethane foam. Progress in colors and dyeing has been promising. Flame and smoke characteristics of the basic fiber are outstanding.

General impression: An impressive effort is being made to investigate additional properties and applications for the Kynol fiber.

General Comments: The intent of the NASA FIREMEN program seemed to be well understood and was received with active interest by most of the companies visited. A number of important leads were uncovered and samples of materials and more data were requested. It is apparent that the tradeoff between fire resistance, smoke, and toxicity must be coordinated so that polymers and materials can be selected for a combination of properties which will promote the safety of aircraft interiors in the event of fire.

D. Potential Candidate Polymers

During the visits and throughout the entire study period, various new candidate research polymers were reviewed for potential usage in future interior designs. Initial samples of some of the polymers considered did not materialize during the program due to development problems. In addition, during the evaluation of the initial samples of new polymers, certain difficulties were uncovered which would indicate that further polymer development was needed.

Listed in Table I are the polymers considered or examined during the study period and the present status of the polymer development.

Listed in Table II are the actual materials examined, their identification, and form of sample submitted.

TABLE I. - LIST OF POTENTIAL CANDIDATE MATERIALS

Material Category	Basic Polymer Type	Development Status
Coating Resins	Phenolphthalein polycarbonate	Research development problems
	Polyimide	Research development problems
	Polyethersulfone	Unstable solutions
Film	Phenolphthalein polycarbonate	Research development problem, none available
	Polyvinyl fluoride	Present material used
	Polyethersulfone	Under production feasibility program
	Polycarbonate	Under production feasibility program
	Polyvinylidene fluoride	Production material available
		Application feasibility in process
Injection Molding Materials	Polyethersulfone	Production feasibility study required
	Polyphenylene sulfide	Production feasibility study required
	Mod-polycarbonate	Production material available for most parts
	Polysulfone	Production feasibility study required
	Polyarylsulfone	Production feasibility study required - very costly
	Polyarylene	Polymer development stop
	Bis-Phenol "A" Modified polycarbonate	Polymer development problems
Fabrics	Kynol	Further dye stability required Not feasible for upholstery
	PBI	Under Research development to produce stable dyed fabric
	Nomex	Further dye stability required
	Fr-Nylon	Production material available
	Treated Wool	Production material available
Foams	Polyphosphazone	Further research development required
	Polyimide	Further research development required
	Treated Polyurethane	Increases weight 50% - Toxicity effect needs study

TABLE II. - IDENTIFICATION OF MATERIAL EXAMINED

Potential Usage	Generic Name	Trade Name	Material Source	Material Form	Code Ident. No.
Film (Decorative Laminate)	Polyvinyl fluoride	Tedlar	E. I. Du Pont	Film	
	Polyvinylidene fluoride	Kynar	Pennwalt	Film	
	Polycarbonate	Lexan	General Electric	Film	
	Polyethersulfone	- - - -	ICI	Film	
Compression Moldings or Injection Moldings	Polycarbonate	Lexan	General Electric	Pellets	2816
	Polyethersulfone	- - - -	ICI 212P	Pellets	30991-1
	BPF Polycarbonate	- - - -	General Electric	Powder	30991-8
	Polyphenylene sulfide	Ryton R-4	Phillips Pete	Pellets	30991-6T
	Polyarylsulfone	Astre 360	Carborundum	Pellets	30991-7T
Thermoforming Plastic	Polycarbonate	Lexan	General Electric	Sheet	SL 1000
	FR-polycarbonate	Lexan	General Electric	Sheet	F 6000
	Mod-polysulfone	- - - -	Uniroyal Inc.	Sheet	XP779
	Chlorinated-PUC	- - - -	Boltiron	Sheet	8000
	Mod-polyphenylene oxide	Noryl	General Electric	Sheet	N-1000
	Acrylo-nitrile Butadiene styrene	ABS	Boltiron	Sheet	6800
	Polyethersulfone	- - - -	ICI 212P	Sheet	30991-1
Fabrics	FR-polyamide	FR-Nylon	Collins & Aikman Airgard	Fabric	
	Treated wool	- - - -	Langenthal	Fabric	
	Aromatic polyamide	Nomex	E. I. Du Pont	Fabric	
	Phenolic	Kynol	Carborundum	Fabric	

IV CHEMICAL CHARACTERIZATION OF POLYMERS

A. Introduction

The polymers and plastics selected following the survey of the chemical industry and the materials specified in NASA RFP 2-25471 were characterized physicochemically and evaluated for application as paints, decorative films, and molded parts. All the materials were tested for physical and chemical stability in high temperature air.

Physical stability was characterized by means of the Du Pont Thermal Mechanical Analyzer (TMA), Model 941, in conjunction with the Du Pont Thermal Analyzer, Model 900. Transition temperatures were determined by changes in the coefficient of thermal volimetric expansion with temperature. Heat distortion temperatures, which may coincide with the transition temperatures, were determined by the penetration (hardness) mode.

B. Paints and Coating Materials

The solubility of polyethersulfones was checked in solvents suggested for use in paints by the manufacturer (ICI). The resins were not soluble to the required extent in the solvents. The solubility of PES 200P was less than 25 percent in methylene chloride and less than 30 percent in dimethyl formamide. The solubility of PES 212P was at least 30 percent in dimethyl formamide but the 30 percent solution was quite viscous and gelled on standing. The BPF polycarbonate powder shows poor resistance to solvents that may come in contact with it during manufacturing processes or in maintenance. Solvent solubility in various solvents was as follows:

Solubility of BPF polycarbonate (Silicone Block Copolymer) in some common solvents:

Solvent	Solubility
Acetone	very slightly soluble
Isopropanol	insoluble
Toluene	soluble
Xylene	soluble
Methylene chloride	soluble

C. Films and Decorative Laminates

Four laminated films were evaluated.

1. PVF_2/0.0508 mm PVF_2
2. PVF_2/0.127 mm PC
3. PVF_2/0.076 mm PES
4. PVF_2/0.127 mm PES

PVF_2 is polyvinylidene fluoride manufactured by Pennwalt (Kynar). PC is a film of polycarbonate manufactured by General Electric Company. PES is a polyethersulphone manufactured by ICI. The laminates were fabricated by Poly Plastex United, Inc.

1. Uniformity of Thickness

The uniformity of the films was determined by taking 25 measurements of the thickness at the points of a 127 x 127 mm matrix.

	Thickness of Film - mm	
Sample	Average	Std. Dev.
0.0508 (0.002 in.)PVF_2/PVF_2	0.200	0.0076
0.0508 (0.002 in.)PVF_2/PC	0.225	0.0051
0.0508 (0.002 in.)PVF_2/PES	0.152	0.0051
0.0508 (0.002 in.)PVF_2/PES	0.210	0.0051

The laminated films exhibited very high uniformity.

2. Thermophysical Stability

The transition temperatures of thin films cannot be determined with the Du Pont TMA dilatometer. The heat distortion temperatures were determined using a 2.54 mm hemispherical tip penetration probe. TMA thermograms of PES 212P were also recorded for reference. The polycarbonate film was not available so that the thermomechanical properties of the film could not be measured separately.

The thermogram of a laminate was found to be a composite of the constituent films. The laminates do not have a true glass temperature, T_g. They undergo viscous flow when the most stable component softens or has melted,

T_m (not true melting). Thus, the heat distortion temperatures are tabulated in order with numerical subscripts, Table III. Thermograms typical of each material are shown in Figures 1 through 5.

As noted above, the thermogram of a laminated film is a composite of the thermograms of the constituent films. Minor transitions, e.g., T_1, also appear. These transitions may be due to the adhesive used to fabricate the laminate. The critical transition of each film is tabulated as T_3. The thermophysical stability of the PVF_2/PES laminates is determined by the softening point of PVF_2. It appears that the critical transition temperature of PVF_2/PC is determined by a transition of the polycarbonate.

3. Thermochemical Stability

Results of the thermogravimetric analysis of the laminated films are summarized in Table IV. Thermogravimetric analytical results of the constituent polymers are given to facilitate analysis of the results. Data on Tedlar, a polyvinyl fluoride polymer, currently in use, is also given for comparison with Kynar. Thermograms typical of each of the materials are shown in Figures 6 through 12.

Kynar is slightly more stable thermally than Tedlar. However, rapid thermal decomposition of both films ensues at approximately 300 °C.

The rate of thermal decomposition of polycarbonate is somewhat slower than that of the polyethersulfones. However, both materials start to undergo rapid thermal decomposition at approximately 440 °C.

The residue remaining after thermal decomposition of the PVF_2/PES decorative films is probably due to pigments and fillers present. The residue of the PVF_2/PC laminated film is significantly greater because polycarbonate itself leaves a residue of 14-15W percent, whereas the residue from PES is negligible.

The thermogram of a laminated film is practically a composite of the thermograms of the constituent plies. There is no evidence of imcompatibility. Lamination of PES to PVF_2 decreases the thermal decomposition of

TABLE III. - HEAT DISTORTION TEMPERATURES OF LAMINATED FILMS

Run No.	Sample	Temperature, °C				
		T_1	T_2	T_3	T_4	T_5
115	PES 200P			208 (T_g)		
116				218 (T_g)		
TMA-3	PES 212P			218 (T_g)	227 (T_m)	
TMA-4				218 (T_g)		
TMA-5				220 (T_g)	228 (T_m)	
TMA-6				225 (T_g)		
108	PVF_2/PVF_2[1]			32 (T_g)	138 (T_m)	
109				50 (T_g)	155 (T_m)	
110				38 (T_g)	155 (T_m)	
111	PVF_2/PES 0.076mm		23	138	251	
113		-15	42	125	248	
117		-32	36	135	256	
118	PVF_2/PES 0.127mm	- 9	42	137	254	
119		-39	37	120	251	
120		- 4	39	135	239	
121	PVF_2/PC		40	111		
122		20	62	118	150	163
278		26	45	107	138	147

1. Minor ill-defined transitions at 119 °C and 180 °C.

PART NO. 941017

DU PONT INSTRUMENTS

SAMPLE: Polyethersulfone 212 P	SAMPLE HEIGHT c 0287	X-AXIS SCALE 50 °C/DIV	RUN NO. TMA - 3
LAC ID 30991-1 T	LOADING ON TRAY 10 gm	Y-AXIS SCALE 0.04 mV/IN	DATE 12-15-75
	PROBE: EXPANSION/PENETRATION	Y-AXIS SENSITIVITY	OPERATOR KW. Cox
ORIGIN: TMA Penetration	HEATING RATE 5 °C/MIN	IN. PROBE DISPL / IN. OF CHART	

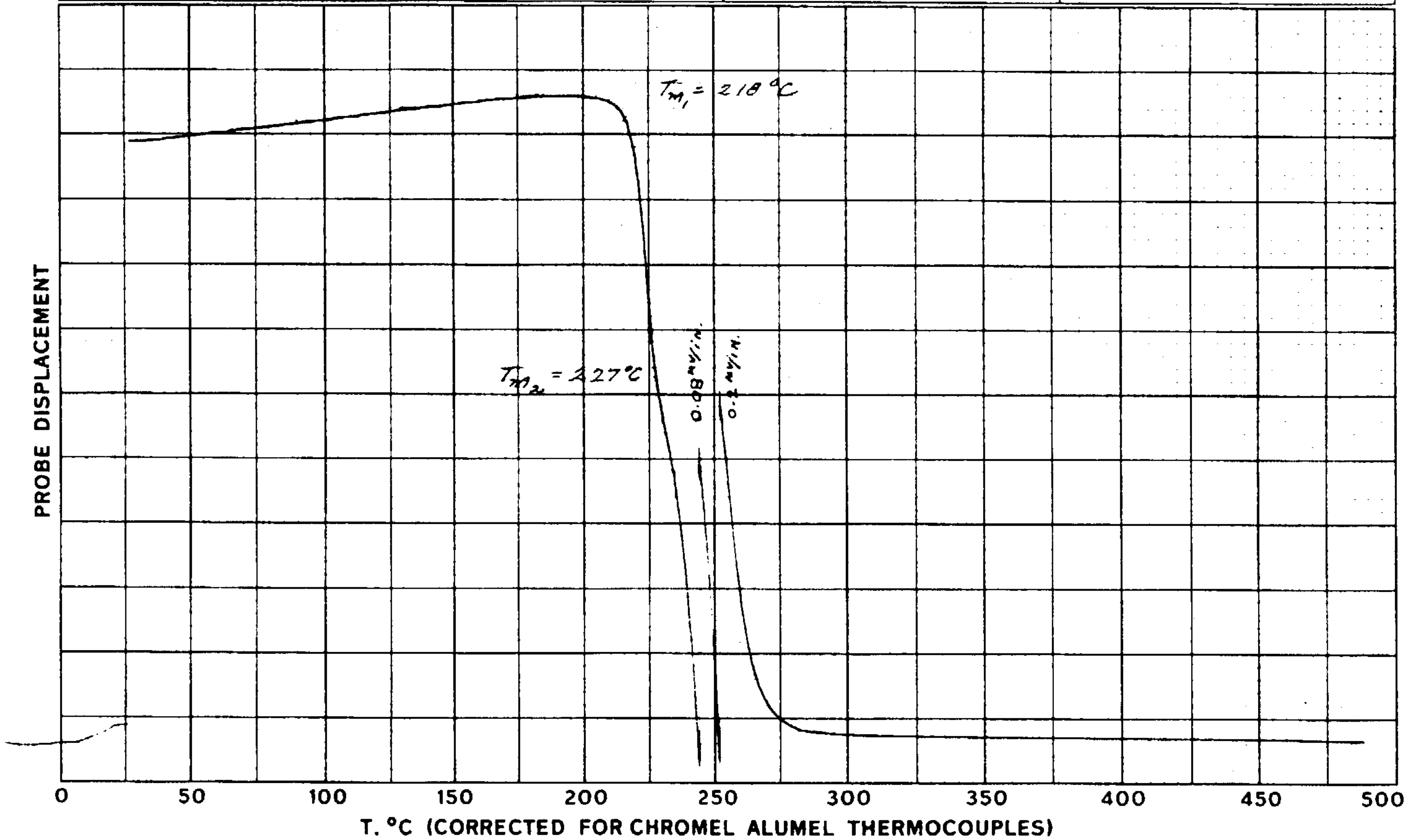


Figure 1. - Polyethersulfone 212P

PART NO. 941017

INSTRUMENTS

SAMPLE: PVF2 / PVF2 HEMI PROBE TMA PENETRATION
ORIGIN:

SAMPLE HEIGHT 0.0079
LOADING ON TRAY 10gm
PROBE: EXPANSION/PENETRATION
HEATING RATE 25 °C/min

X-AXIS SCALE 50 °C/div.
Y-AXIS SCALE 0.04 mv/in
Y-AXIS SENSITIVITY
in. probe displ./in. of chart

RUN NO. 110
DATE 4-13-76
OPERATOR KW Cox
Zero Shift +2

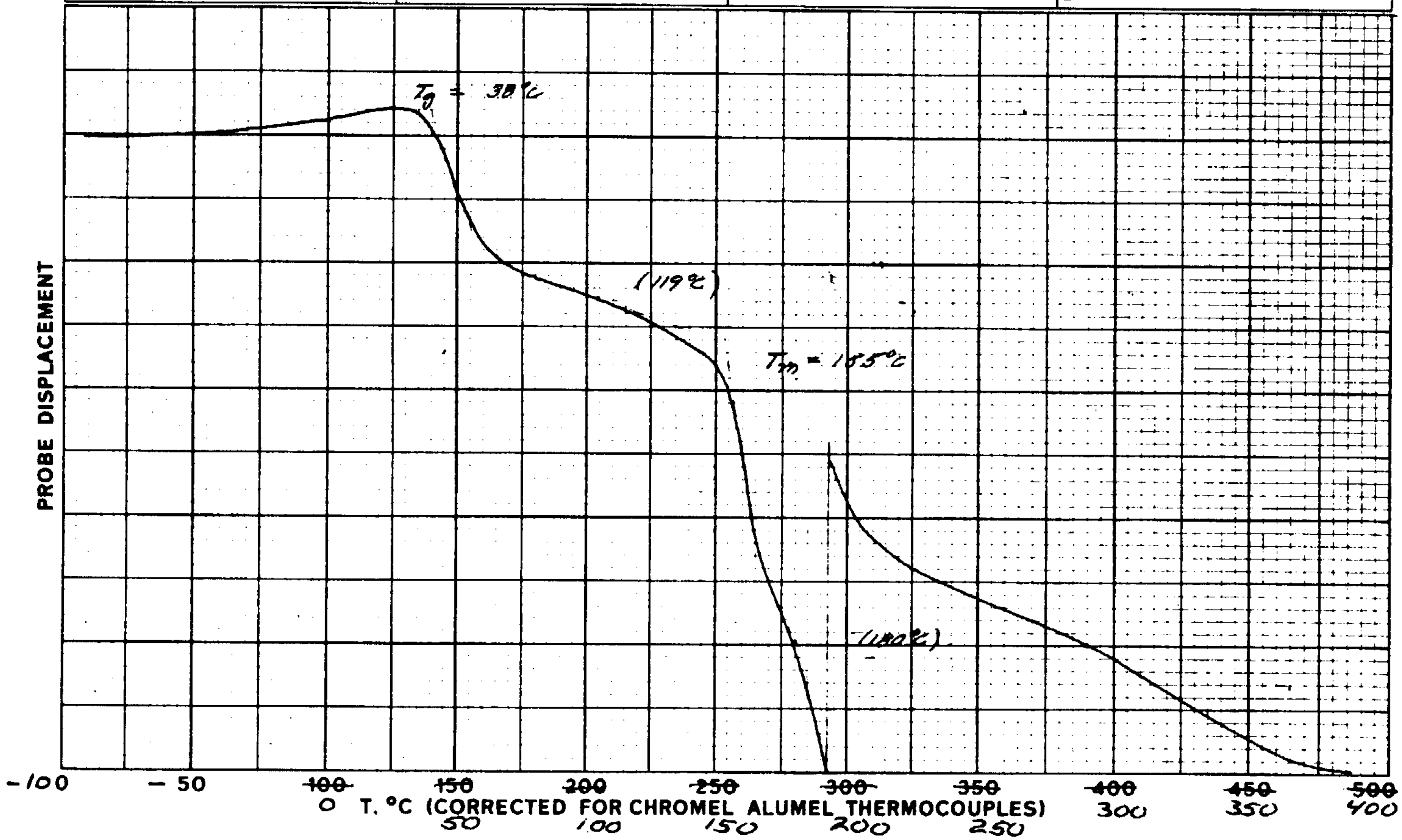
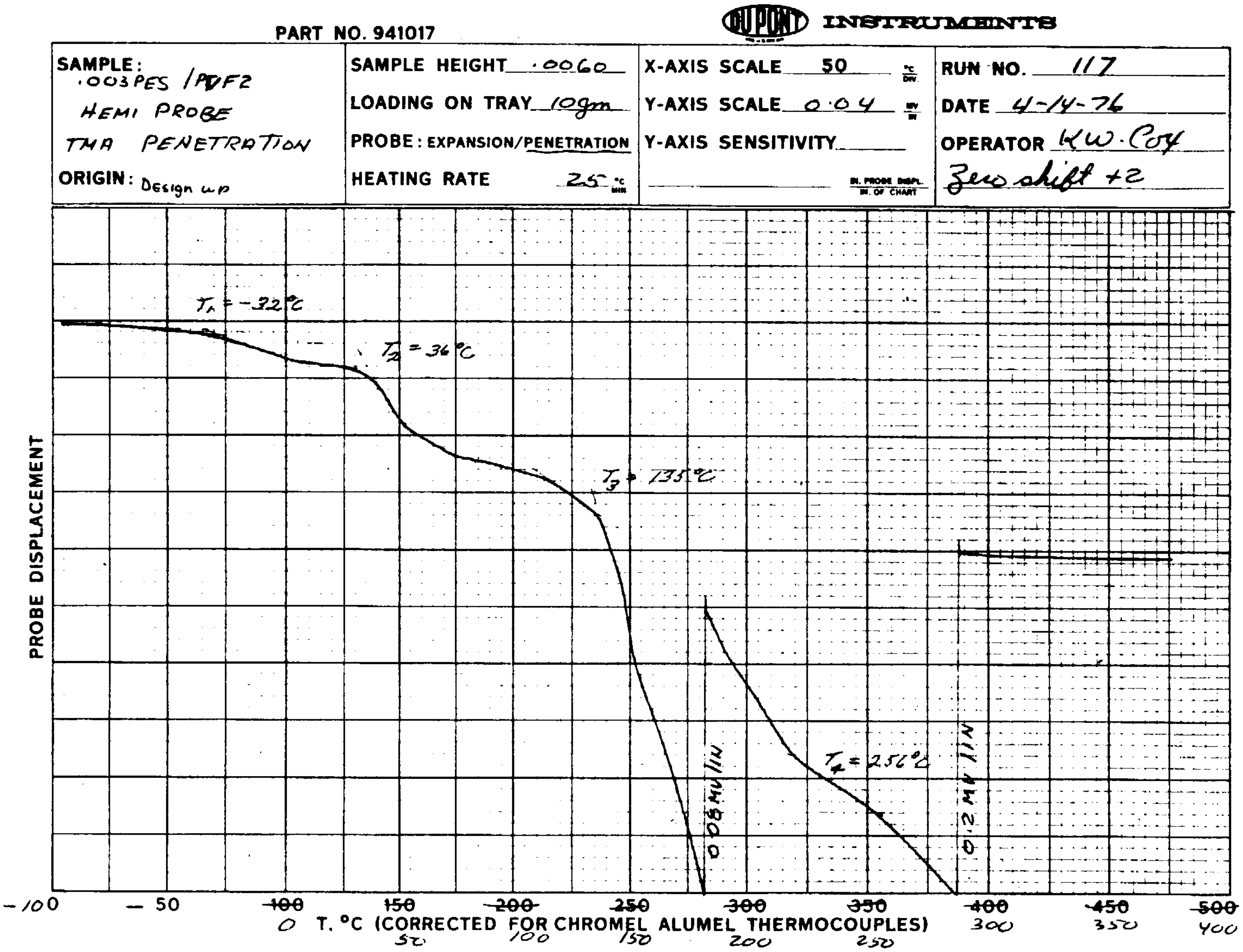


Figure 2. - PVF_2/PVF_2 hemi probe TMA penetration



PART NO. 941017

DUPONT INSTRUMENTS

SAMPLE: .003 PES /PVF2 HEMI PROBE TMA PENETRATION

ORIGIN: Design up

SAMPLE HEIGHT .0060

LOADING ON TRAY 10gm

PROBE: EXPANSION/PENETRATION

HEATING RATE 25 °C/MIN

X-AXIS SCALE 50 °C/DIV.

Y-AXIS SCALE 0.04 MV/IN

Y-AXIS SENSITIVITY

IN. PROBE DISPL./IN. OF CHART

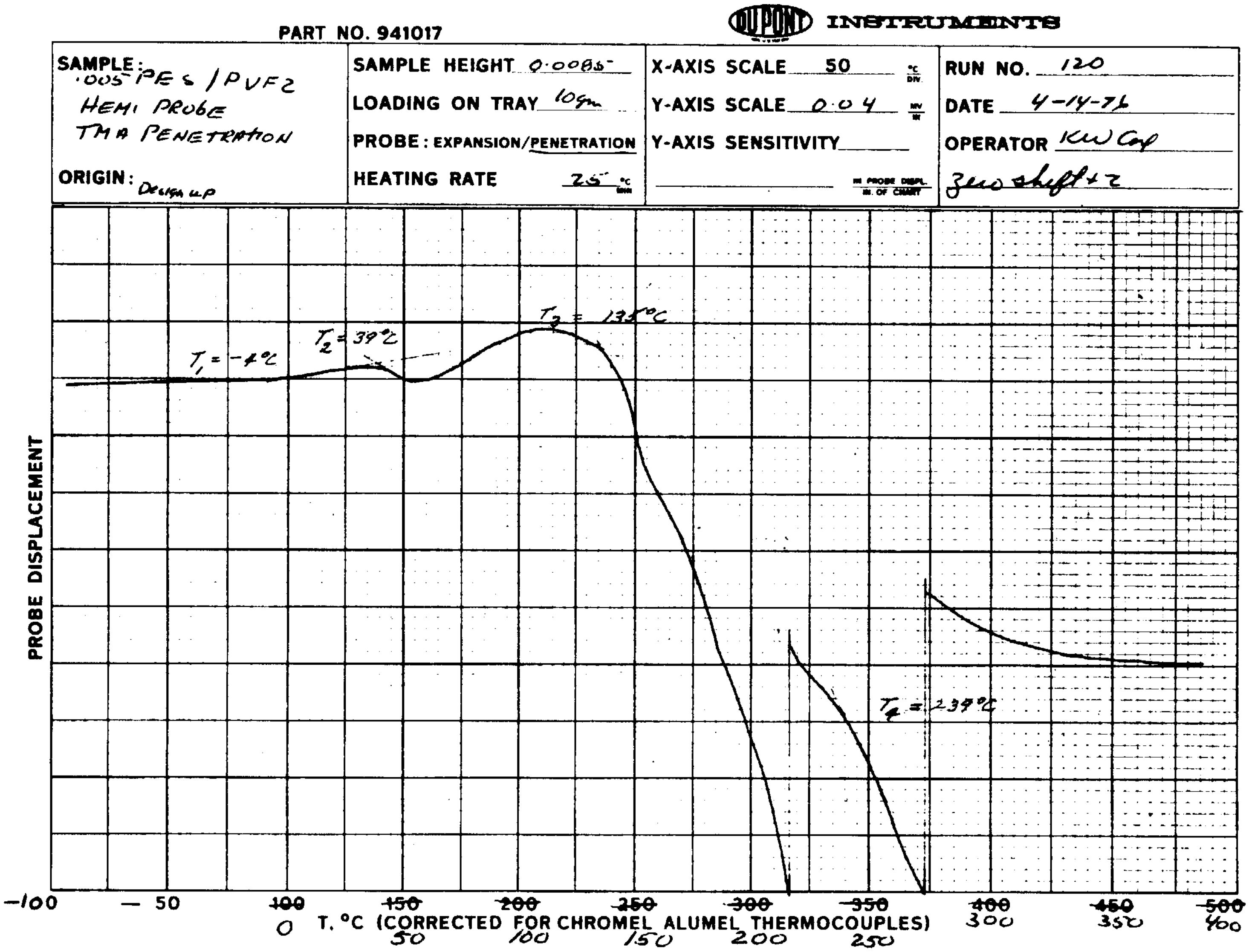
RUN NO. 117

DATE 4-14-76

OPERATOR KW. Coy

Zero shift +2

Figure 3. - 0.003 PES/PVF_2 hemi probe TMA penetration



PART NO. 941017

DUPONT INSTRUMENTS

SAMPLE: .005 PES/PVF2 HEMI PROBE TMA PENETRATION

ORIGIN: Design up

SAMPLE HEIGHT 0.0085"

LOADING ON TRAY 10gm

PROBE: EXPANSION/PENETRATION

HEATING RATE 25 °C/min

X-AXIS SCALE 50 °C/DIV.

Y-AXIS SCALE 0.04 mv/in

Y-AXIS SENSITIVITY

in PROBE DISPL./in. OF CHART

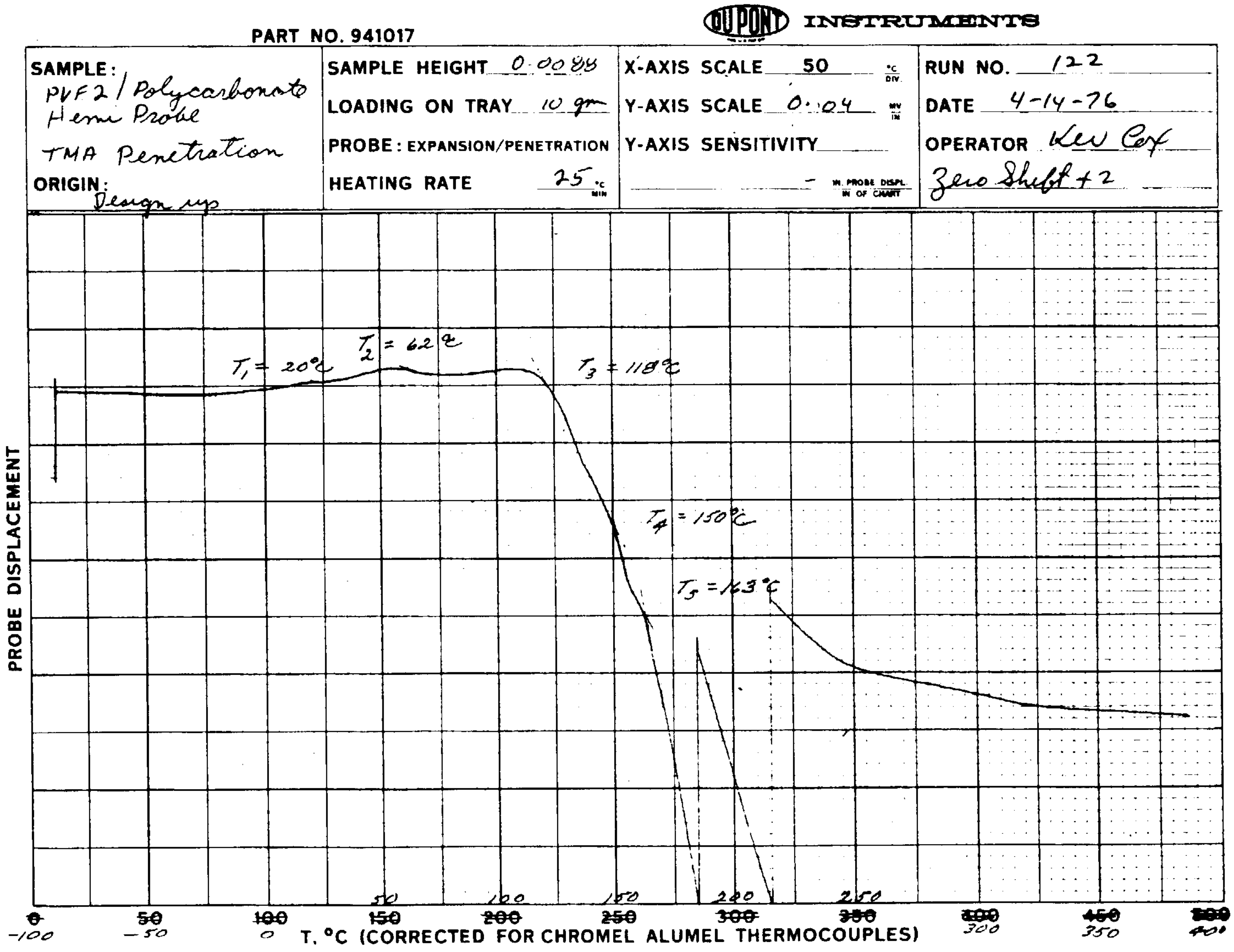
RUN NO. 120

DATE 4-14-76

OPERATOR KW Coy

Zero shift +2

Figure 4. - 0.005 PES/PVF_2 hemi probe penetration



DUPONT INSTRUMENTS

PART NO. 941017

SAMPLE: PVF2/Polycarbonate Hemi Probe TMA Penetration
ORIGIN: Design up
SAMPLE HEIGHT 0.0088
LOADING ON TRAY 10 gm
PROBE: EXPANSION/PENETRATION
HEATING RATE 25 °C/MIN
X-AXIS SCALE 50 °C/DIV.
Y-AXIS SCALE 0.04 MV/IN
Y-AXIS SENSITIVITY
IN. PROBE DISPL. / IN OF CHART
RUN NO. 122
DATE 4-14-76
OPERATOR Kev Cox
Zero Shift +2

Figure 5. - PVF_2/Polycarbonate hemi probe TMA penetration

TABLE IV. - THERMOGRAVIMETRIC ANALYSIS[1] OF PVF_2 LAMINATED FILMS

Run No.	Sample	Onset Temperature									
		T_1		T_2		T_3		T_4		Residue	
		°C	Loss W %	°C	Loss W %	°C	Loss W %	°C	Loss W %	°C	W %
14	Tedlar			325	85.5	500	14.5			600	0
15				350	80.5	515	19.5			607	0
11-76	PVF_2/PVF_2	150	2.0	311	63.0	503	24.0			700	11.0
15-76		133	1.0	285	66.0	482	24.0			677	9.0
3	PES 200P					500	45.5	630	54.5	778	0
8		170	3.0			440	48.5	587	48.5	802	0
5	PES 212P					440	52.0	603	46.5	780	1.5
7		170	2.5			440	46.5	608	47.0	790	2.0
22-76	PVF_2/PES 0.076mm	150	2.0	300	15.0	437	33.0	520	42.0	680	8.0
23-76		150	2.0	300	16.0	435	30.0	512	42.0	670	10.0
19-76	PVF_2/PES 0.127mm	120	2.0	296	10.0	435	22.0	533	61.0	740	5.0
20-76		110	2.0	302	8.0	438	20.0	520	52.0	725	18.0
22	PC					438	18.0	560	68.0	790	14.0
23						440	20.0	570	65.0	767	15.0
16-76	PVF_2/PC	100	1.0	310	64.0			515	28.0	600	7.0
17-76		125	2.0	335	53.0			512	22.0	593	23.0
18-76		130	2.0	335	53.0			515	22.0	595	20.0

[1] Heating Rate - 15 °C/min and 1 cfh Air Flow

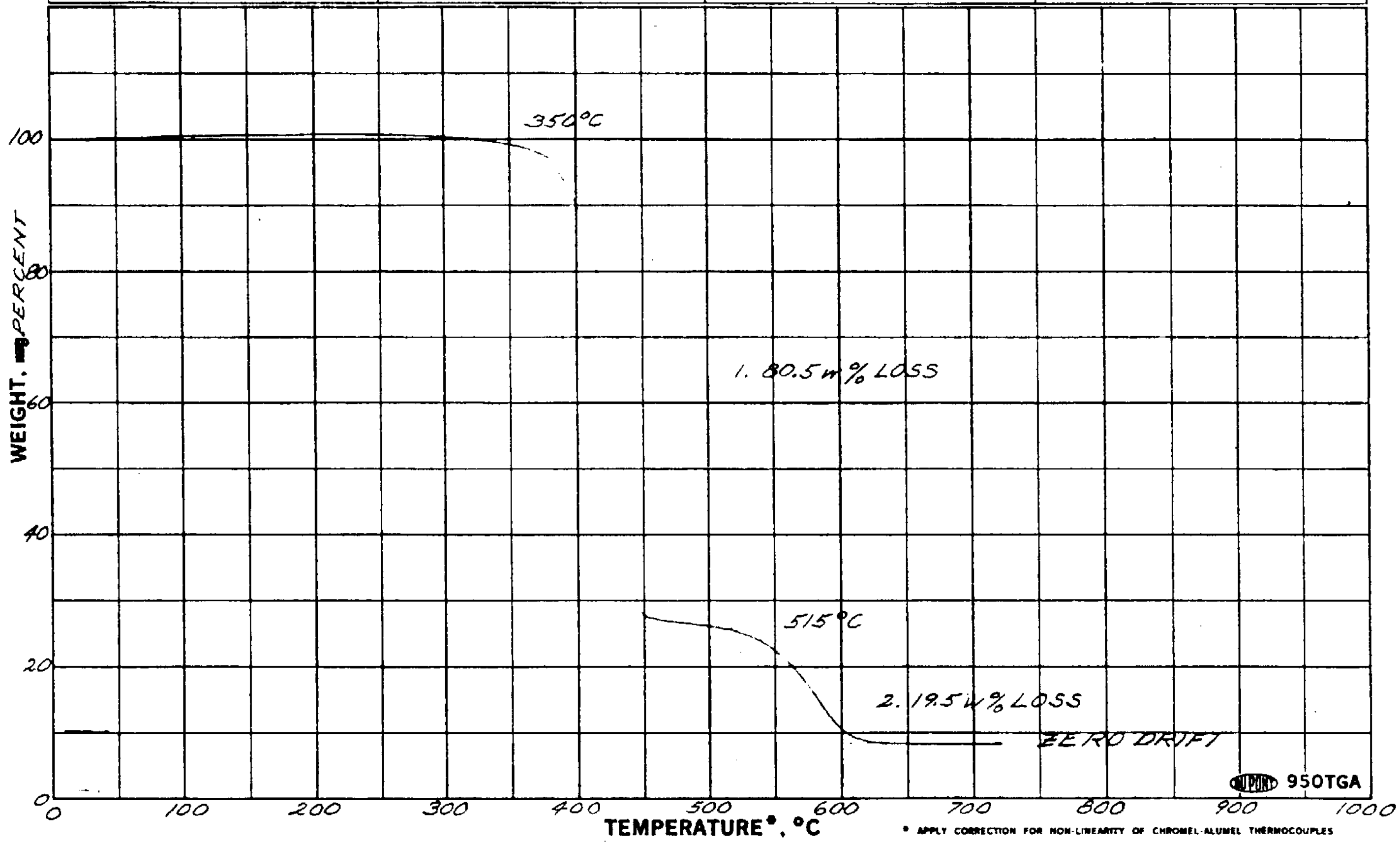
E. I. DU PONT DE NEMOURS & CO. (INC.)
INSTRUMENT PRODUCTS DIVISION
WILMINGTON, DELAWARE

SAMPLE: (sheet)
TEDLAR
PVF / PVF
SIZE ~~14~~ 6.6 **mg.**
AMB TEMP 25°C

X-AXIS
TEMP. SCALE 100 **°C/inch**
SHIFT -3 **inch**
TIME SCALE (ALT.)

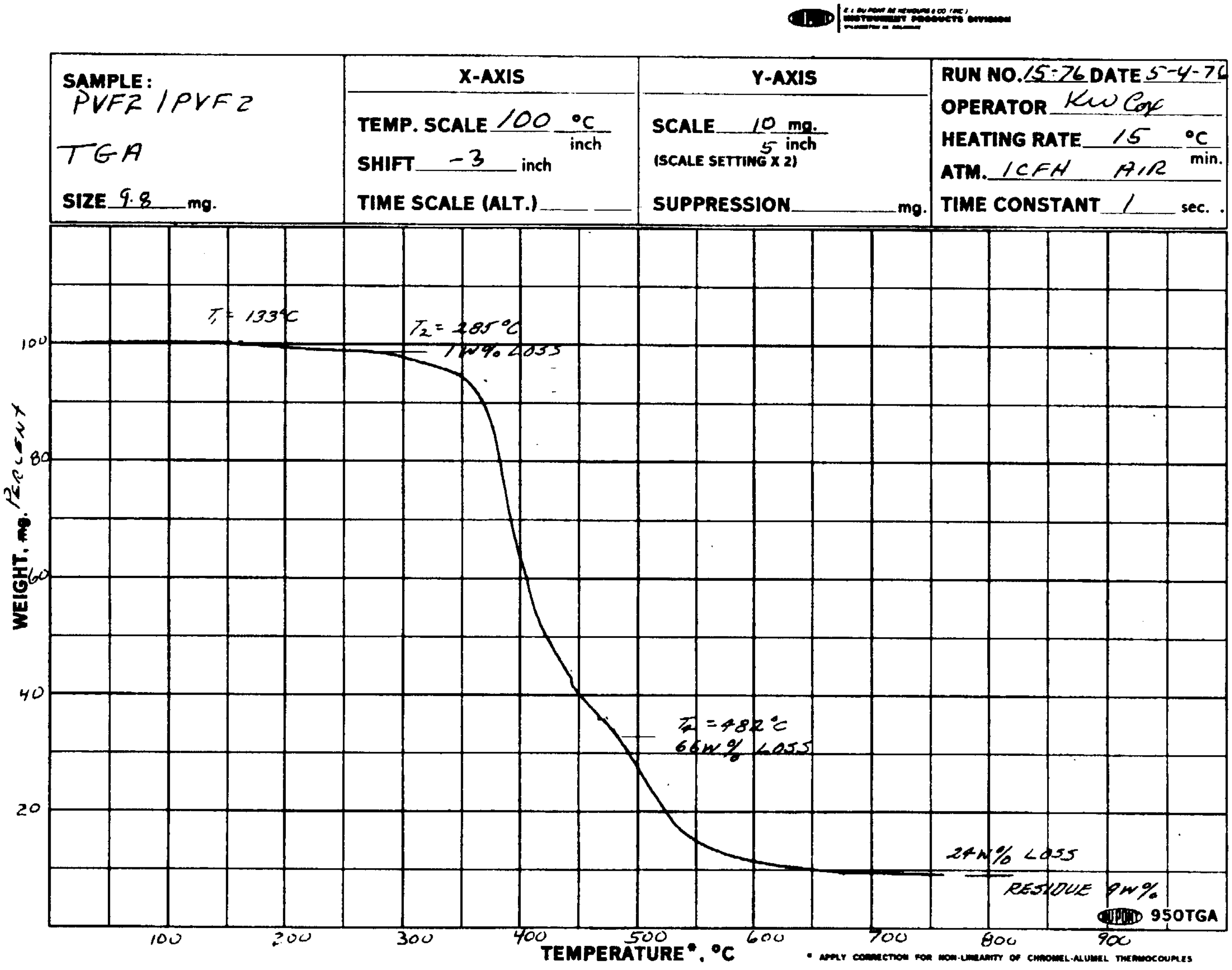
Y-AXIS
SCALE 5 **mg./5 inch**
(SCALE SETTING X 2)
SUPPRESSION 0 **mg.**

RUN NO. 15 **DATE** 12-9-75
OPERATOR K.W. Cox
HEATING RATE 15 **°C/min.**
ATM. AIR 1 CFH
TIME CONSTANT 1 **sec.**



* APPLY CORRECTION FOR NON-LINEARITY OF CHROMEL-ALUMEL THERMOCOUPLES

Figure 6. - Tedlar PVF/PVF



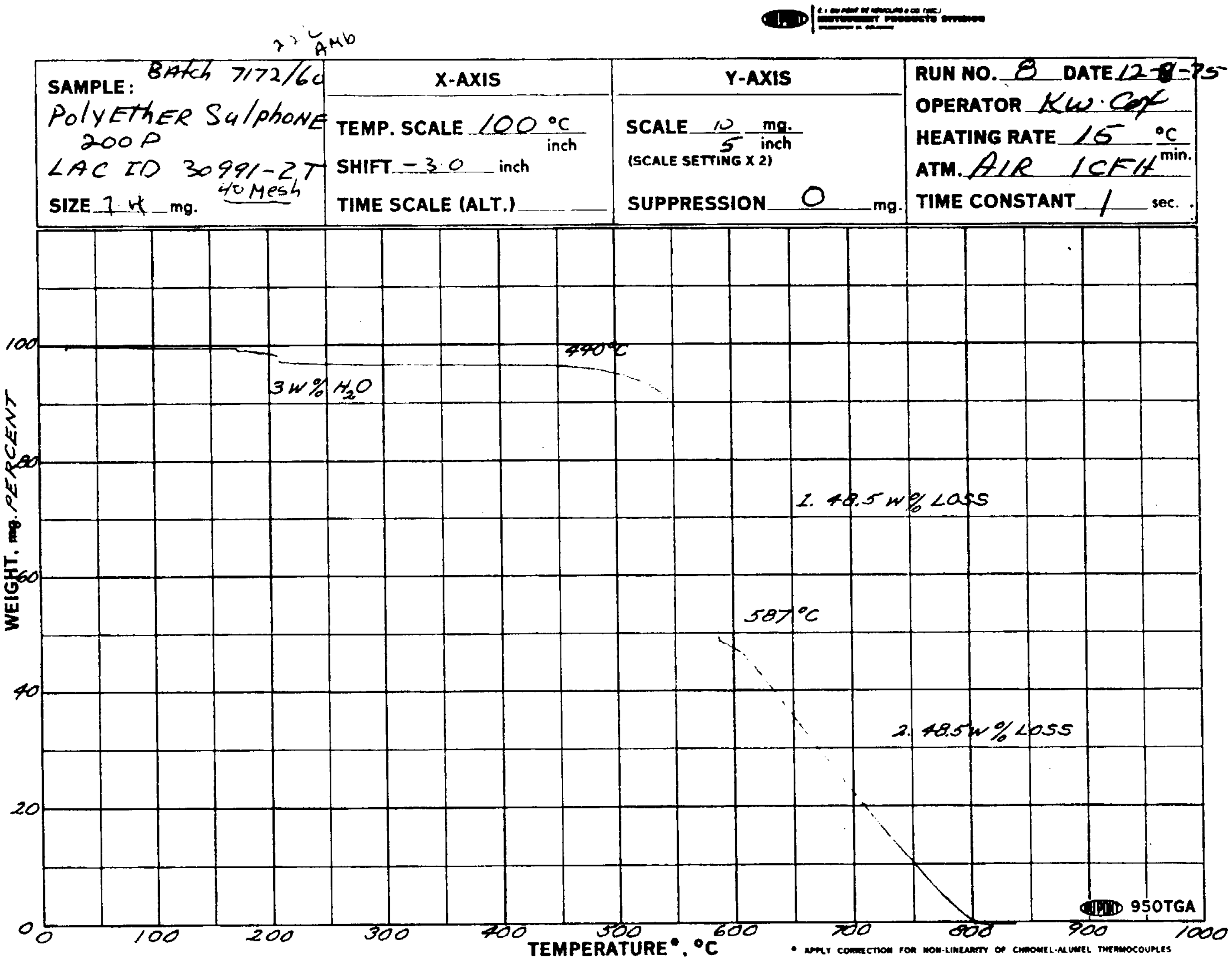
SAMPLE: PVF2 / PVF2
TGA
SIZE 9.8 mg.

X-AXIS
TEMP. SCALE 100 °C/inch
SHIFT -3 inch
TIME SCALE (ALT.)

Y-AXIS
SCALE 10 mg./5 inch
(SCALE SETTING X 2)
SUPPRESSION mg.

RUN NO. 15-76 DATE 5-4-76
OPERATOR KW Coy
HEATING RATE 15 °C/min.
ATM. 1CFH AIR
TIME CONSTANT 1 sec.

Figure 7. - PVF_2/PVF_2 TGA



SAMPLE: Batch 7172/60 22°C AMb

Polyether Sulphone 200P

LAC ID 30991-2T

SIZE 7 ~~4~~ mg. 40 Mesh

X-AXIS

TEMP. SCALE 100 °C/inch

SHIFT -3.0 inch

TIME SCALE (ALT.)

Y-AXIS

SCALE 10 mg./5 inch (SCALE SETTING X 2)

SUPPRESSION 0 mg.

RUN NO. 8 DATE 12-8-75

OPERATOR KW·Cof

HEATING RATE 15 °C/min.

ATM. AIR 1CFH

TIME CONSTANT 1 sec.

Figure 8. - Polyethersulfone 200P

SAMPLE:
PolyEther Sulfone
212 P
LAC ID 30991 -1T
SIZE 8.9 mg.
AM 6 Temp 2/5°C

X-AXIS
TEMP. SCALE 100 °C/inch
SHIFT -3.0 inch
TIME SCALE (ALT.)

Y-AXIS
SCALE 10 mg./5 inch
(SCALE SETTING X 2)
SUPPRESSION 0 mg.

RUN NO. 7 **DATE** 12-8-75
OPERATOR KW. Cox
HEATING RATE 15 °C/min.
ATM. AIR 1 CFH
TIME CONSTANT 1 sec.

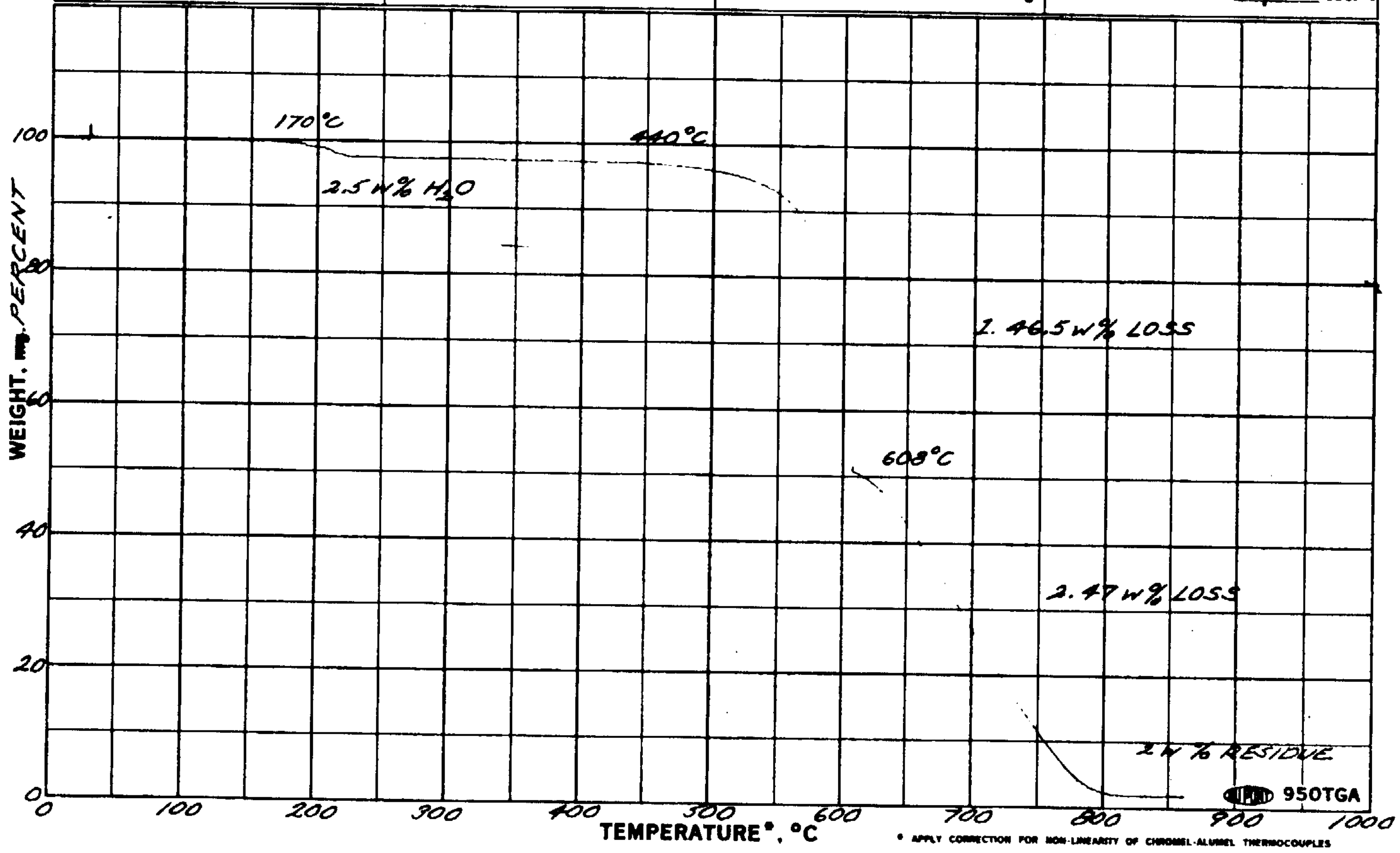


Figure 9. - Polyethersulfone 212P

E. I. DU PONT DE NEMOURS & CO. (INC.)
INSTRUMENT PRODUCTS DIVISION

SAMPLE: .003 PES / PVF 2 T G A	**X-AXIS**	**Y-AXIS**	**RUN NO.** 22-76 **DATE** 5-7-76
	TEMP. SCALE 100 °C/inch	**SCALE** 10 mg./5 inch (SCALE SETTING X 2)	**OPERATOR** KW Cox
	SHIFT -3 inch		**HEATING RATE** 15 °C/min.
			ATM. 1 CFH AIR
SIZE 9.95 mg.	**TIME SCALE (ALT.)**	**SUPPRESSION** mg.	**TIME CONSTANT** 1 sec.

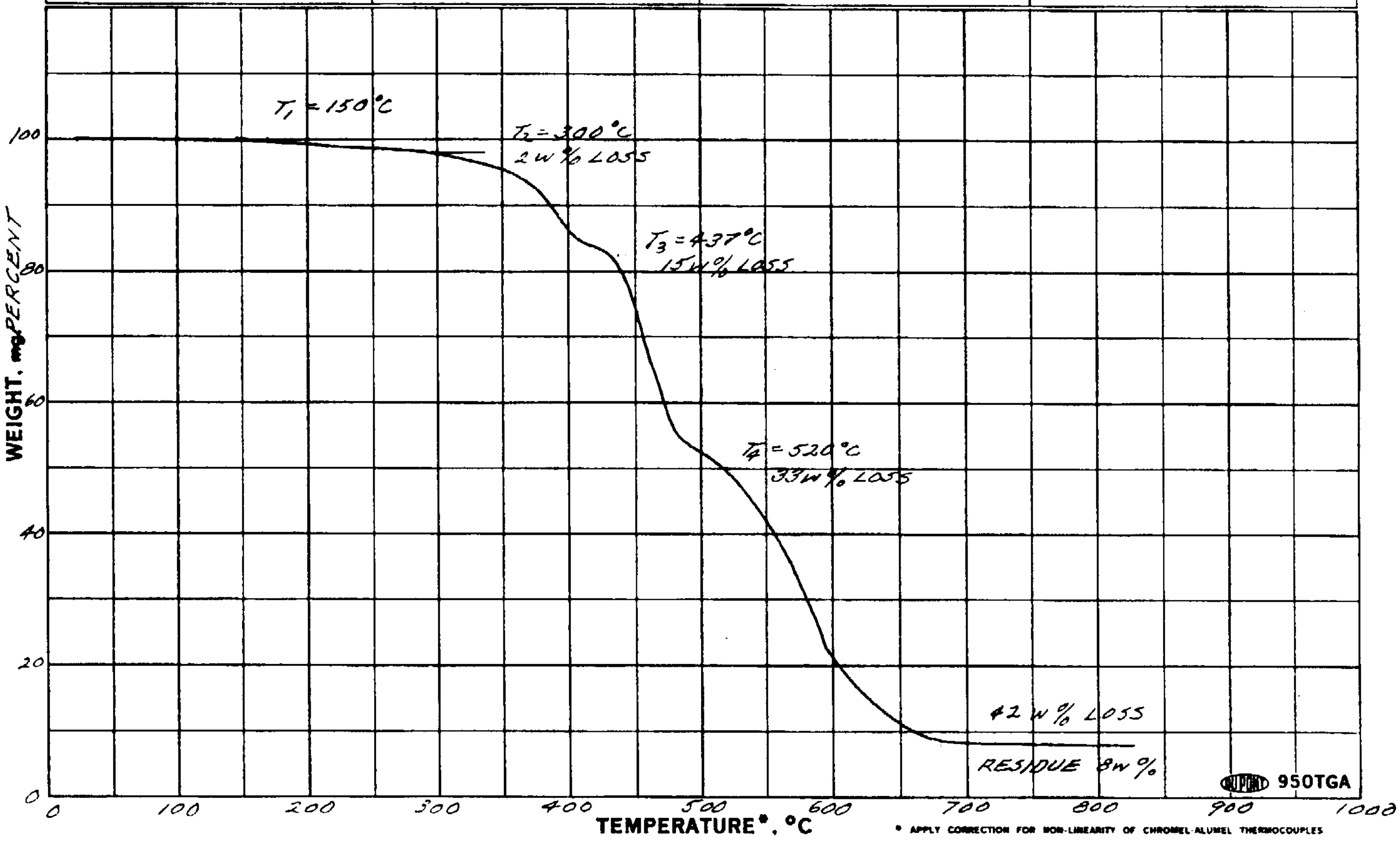


Figure 10. - 0.003 PES/PVF_2 TGA

SAMPLE: .005 PES / PVF2 TGA A SIZE 9.5 mg.	X-AXIS TEMP. SCALE 100 °C/inch SHIFT -3 inch TIME SCALE (ALT.)	Y-AXIS SCALE 10 mg./5 inch (SCALE SETTING X 2) SUPPRESSION mg.	RUN NO. 15-76 DATE 5-6-76 OPERATOR [illegible] HEATING RATE 15 °C/min. ATM. 1 CFH AIR TIME CONSTANT 1 sec.

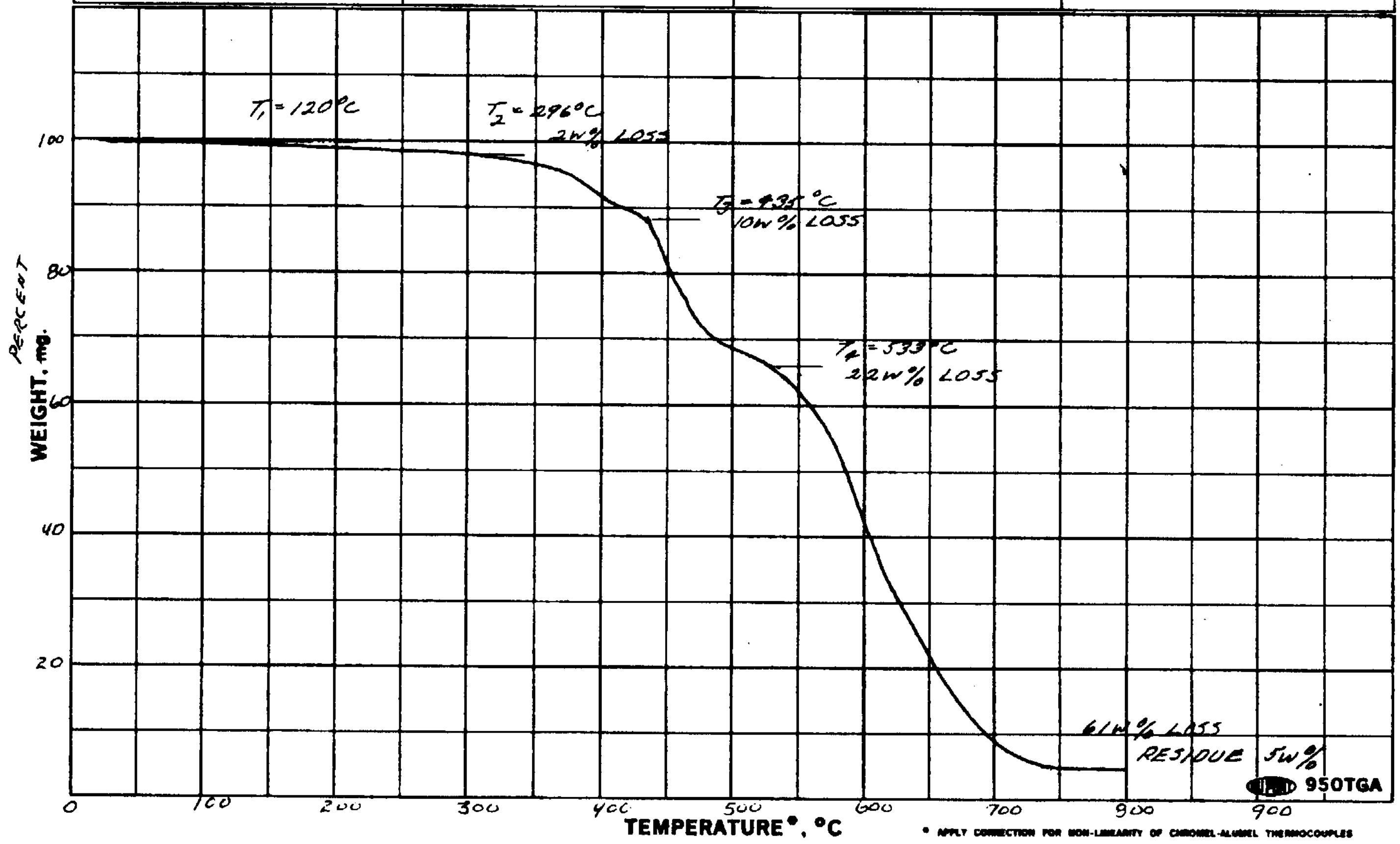


Figure 11. - 0.005 PES/PVF$_2$ TGA

E. I. DU PONT DE NEMOURS & CO. (INC.)
INSTRUMENT PRODUCTS DIVISION

SAMPLE: PVF2 / Poly Carbonate TGA	**X-AXIS**	**Y-AXIS**	**RUN NO.** 18-76 **DATE** 5-6-76
	TEMP. SCALE 100 °C/inch	**SCALE** 10 mg./5 inch (SCALE SETTING X 2)	**OPERATOR** KW Eg
	SHIFT -3 inch		**HEATING RATE** 15 °C/min.
			ATM. 1CFH AIR
SIZE 9.95 mg.	**TIME SCALE (ALT.)**	**SUPPRESSION** mg.	**TIME CONSTANT** 1 sec.

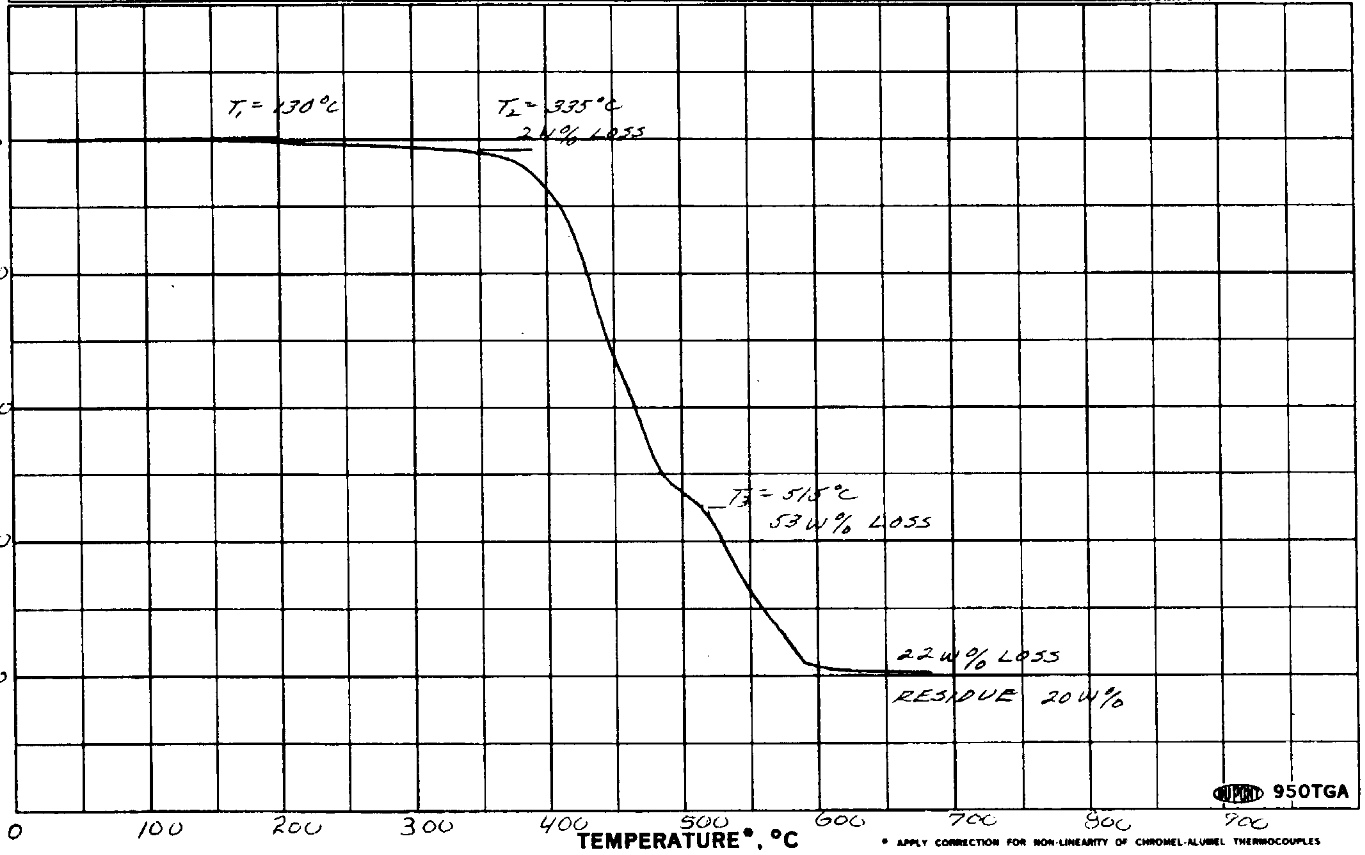


Figure 12. PVF_2/Polycarbonate TGA

PVF_2 up to 440 °C from 63-66W percent to 8-10W percent. In contrast, the polycarbonate film has little effect on the thermal stability of the PVF_2 film.

D. Compression Molding or Injection Molding Polymers and Thermoplastic Sheet Materials.

The following thermoplastic resins have been evaluated:

Polyethersulfone 200P (PES 200P), Batch No. 7172/60, LAC ID.30991-2T, ICI
Polyethersulfone 212P (PES 212P), Batch No. 7172/45, LAC ID.30991-IT, ICI
Polyphenylene Sulfide, Ryton 50962 (PPS), LAC ID. 30991-6T, Phillips Petroleum Company
BFP - Polycarbonate Silicone Block Copolymer LAC ID. 10563-87D, General Electric Company.
Polyarylsulfone (PAS), LAC ID. 30991-7T, U. S. Carborundum

1. Thermochemical Stability

The results of the thermogravimetric analysis are summarized in Table V. Typical thermograms are shown in Figures 8, 9, 13, 14, and 15. The critical thermal degradation of the resins starts at approximately 460 °C. One to five percent loss of weight occurs below this temperature. The resins do not differ significantly in thermal stability.

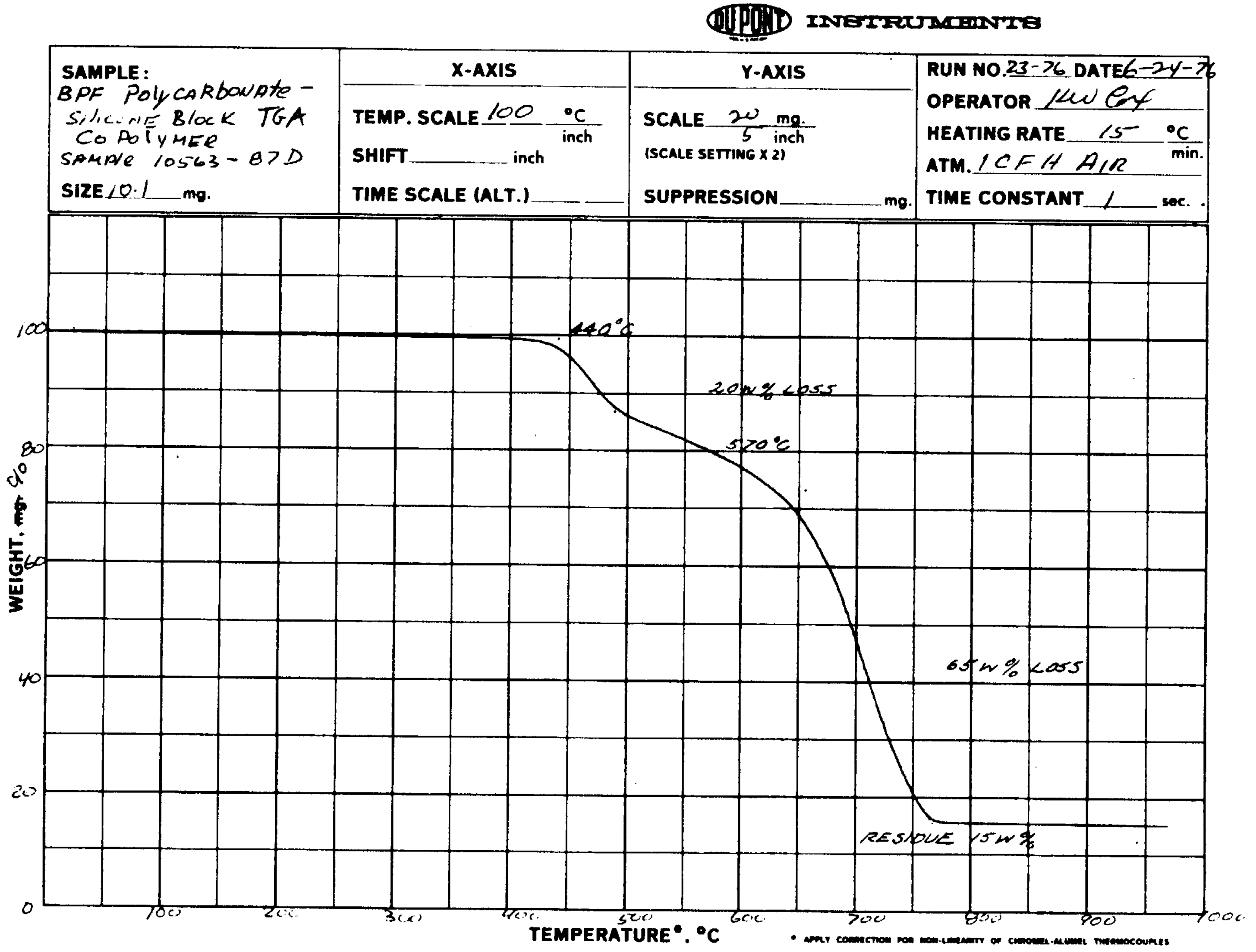
2. Thermophysical Stability

The heat distortion temperatures, determined by thermochanical analysis, are tabulated in Table VI. Typical thermograms are shown in Figures 1 and 16 through 18. The polyethersulfones soften at 218-225 °C. Polyarylsulfone softens at 282 °C. It is thermophysically the most stable of the five thermoplastic resins. The thermogram of polyphenylene sulfide appears to be that of a typical viscoelastic resin. The first transition occurs at 86-92 °C followed by the second transition at 260-275 °C. The transitions appear to be the glass and melting or softening temperatures. However, polyphenylene sulfide actually has two glass regions. T_1 is the softening

TABLE V. - THERMOGRAVIMETRIC ANALYSIS[1] OF THE THERMOPLASTICS FOR COMPRESSION MOLDING

Run No.	Sample	Onset Temperature, °C							
		T_1		T_2		T_3		Residue	
		°C	Loss W %	°C	Loss W %	°C	Loss W %	°C	W %
1	PES 200P	N.R.		500	45.5	630	54.5		
8		170	3.0	440	48.5	587	48.5		
5	PES 212P			440	52.0	603	46.5	780	1.5
7		170	2.5	440	46.5	608	47.0	780	2.0
9	PPS	90	5.0	430	24.0	630	50.0	850	23.0
10		135	2.0	470	21.0	610	44.5	775	30.0
11				425	22.0	600	54.5	780	23.5
12	PAS	90	1.0	490	34.0	640	62.0	840	3.0
13		75	1.5	440	34.0	600	62.5	840	2.0

1. Heating Rate - 15 °C/min, and 1 cfh Air Flow



DUPONT INSTRUMENTS

SAMPLE: BPF Polycarbonate - Silicone Block TGA CoPolymer Sample 10563 - 87D	**X-AXIS**	**Y-AXIS**	**RUN NO.** 23-76 **DATE** 6-24-76
	TEMP. SCALE 100 °C/inch	**SCALE** 20 mg./5 inch (SCALE SETTING X 2)	**OPERATOR** KW Cnf **HEATING RATE** 15 °C/min.
	SHIFT ____ inch		**ATM.** 1 CFH Air
SIZE 10.1 mg.	**TIME SCALE (ALT.)** ____	**SUPPRESSION** ____ mg.	**TIME CONSTANT** 1 sec.

Figure 13. - BPF polycarbonate-silicone block TGA copolymer

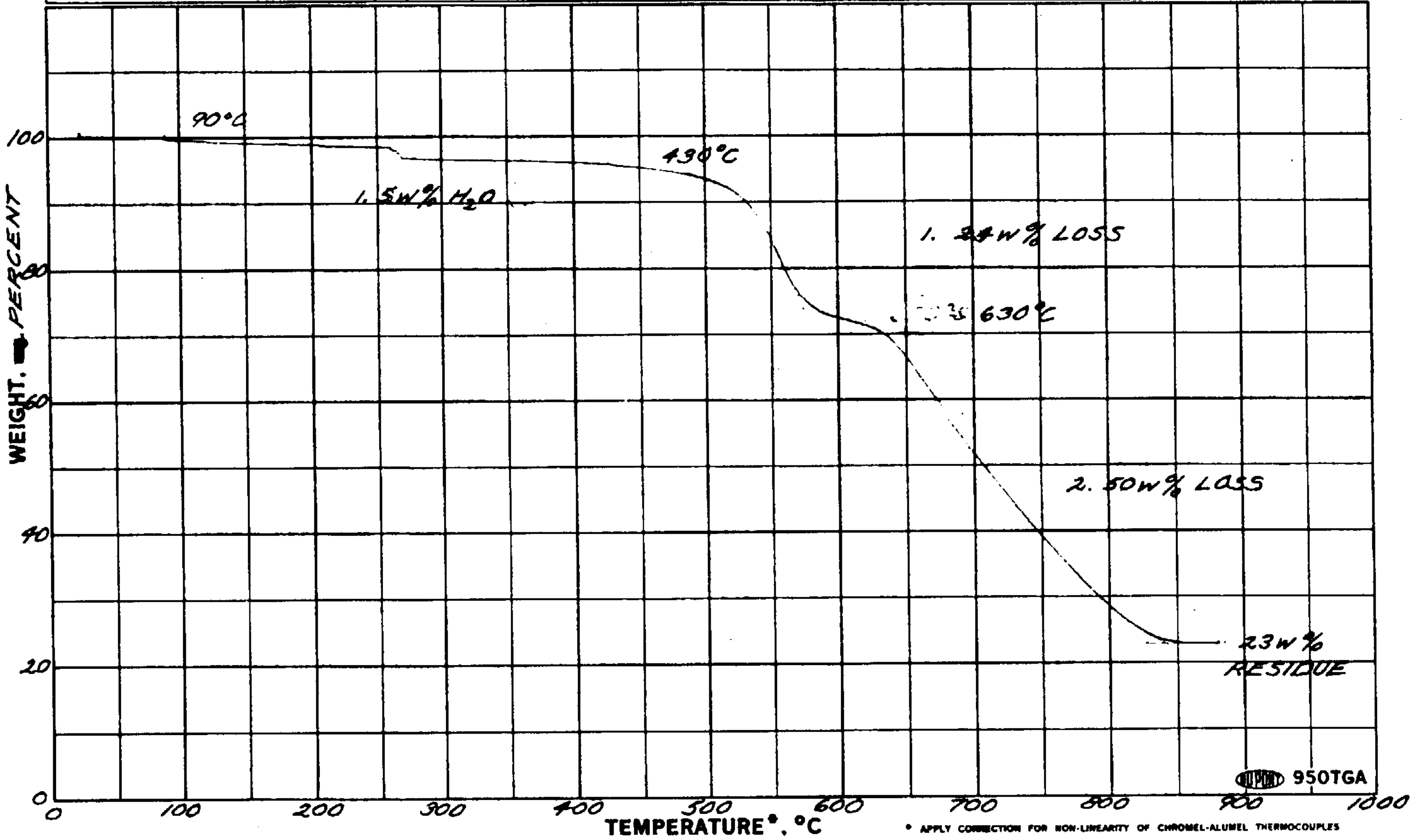
E. I. DU PONT DE NEMOURS & CO. (INC.)
INSTRUMENT PRODUCTS DIVISION

SAMPLE: Poly Phenylene Sulfide
LAC code # 30991-6T
40 Mesh
22° C
SIZE [illegible] mg.

X-AXIS
TEMP. SCALE 100 °C/inch
SHIFT -30 inch
TIME SCALE (ALT.)

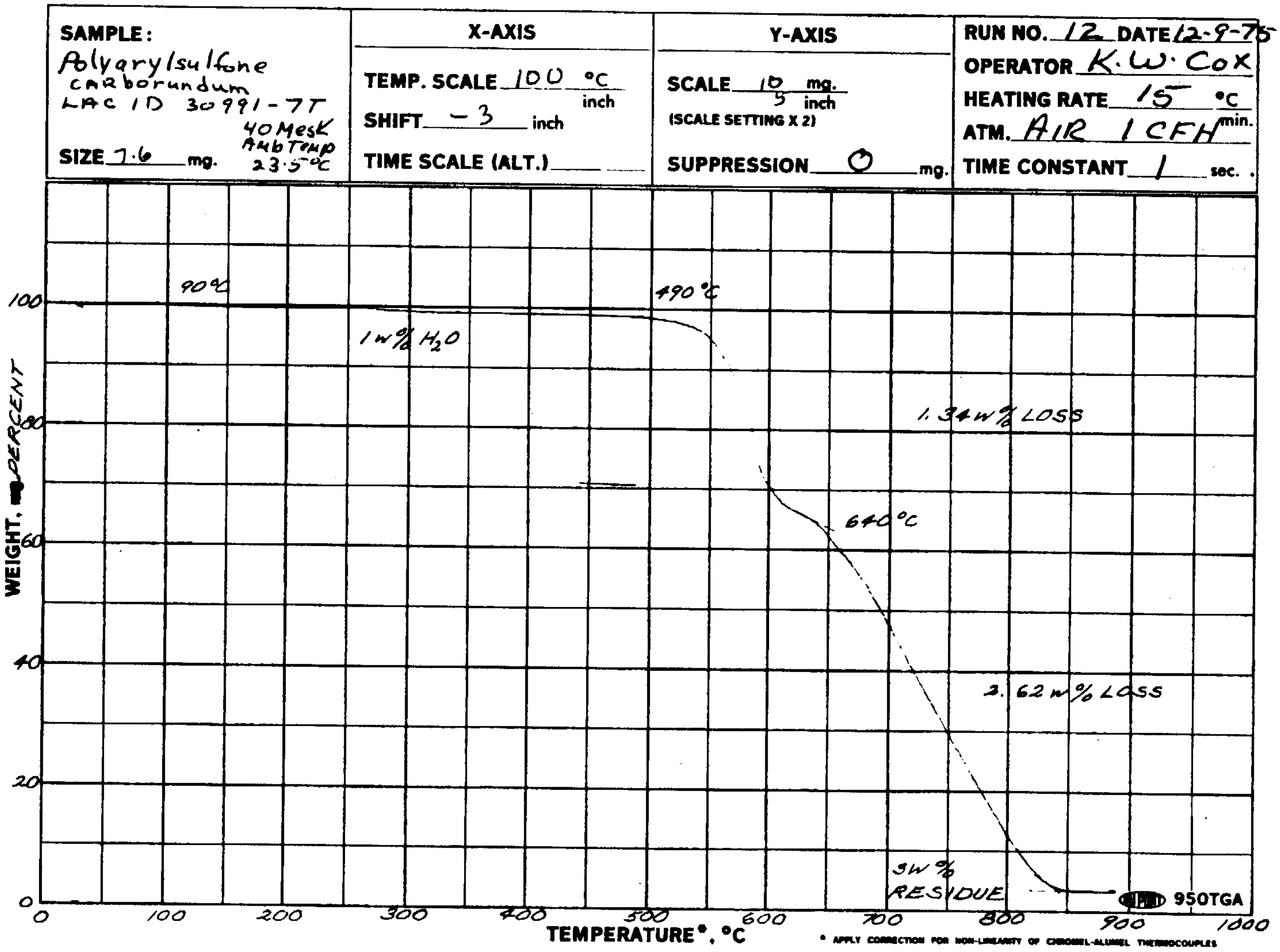
Y-AXIS
SCALE 10 mg./5 inch
(SCALE SETTING X 2)
SUPPRESSION 0 mg.

RUN NO. 9 **DATE** 12-8-75
OPERATOR KW Cox
HEATING RATE 15 °C/min.
ATM. AIR 1CFH
TIME CONSTANT 1 sec.



* APPLY CORRECTION FOR NON-LINEARITY OF CHROMEL-ALUMEL THERMOCOUPLES

Figure 14. - Polyphenylene sulfide



SAMPLE: Polyarylsulfone carborundum LAC ID 30991-7T 40 Mesh Amb Temp 23.5°C
SIZE 7.6 mg.

X-AXIS
TEMP. SCALE 100 °C/inch
SHIFT −3 inch
TIME SCALE (ALT.)

Y-AXIS
SCALE 10 mg./5 inch
(SCALE SETTING X 2)
SUPPRESSION 0 mg.

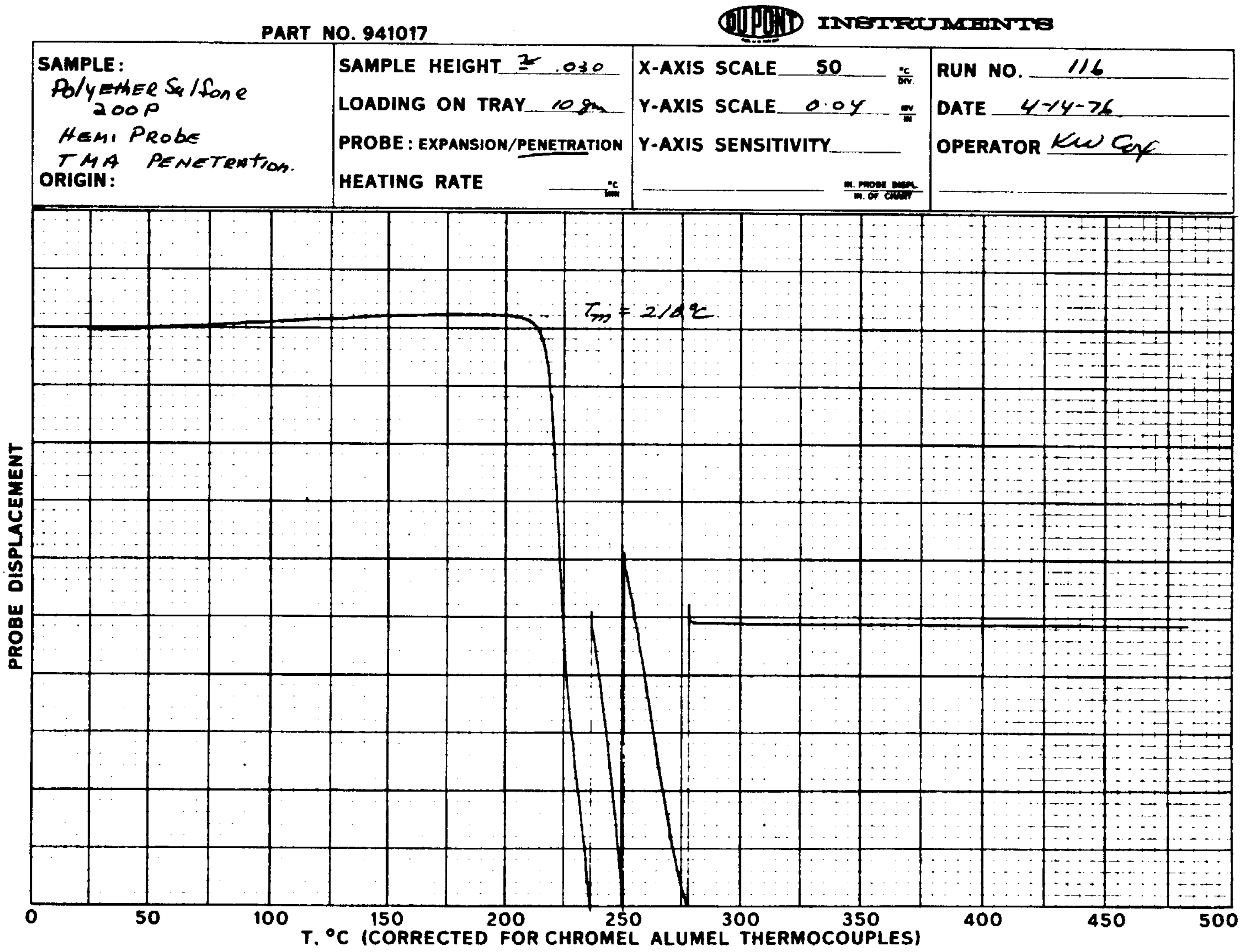
RUN NO. 12 DATE 12-9-75
OPERATOR K. W. Cox
HEATING RATE 15 °C/min.
ATM. AIR 1 CFH
TIME CONSTANT 1 sec.

Figure 15. - Polyarylsulfone carborundum

TABLE VI. - HEAT DISTORTION TEMPERATURES[1] OF THERMOPLASTICS FOR COMPRESSION MOLDING

Run No.	Sample	Temperature, °C				
		T_1	T_2	T_3	T_4	T_5
116	PES 200P		218			
3	PES 212P		218	227		
5			220	228		
6			225	---		
7	PPS	89			271	
8		92			275	
9		86			270	
10		82			260	
11		88			267	
12	PAS				283	310
13					282	---

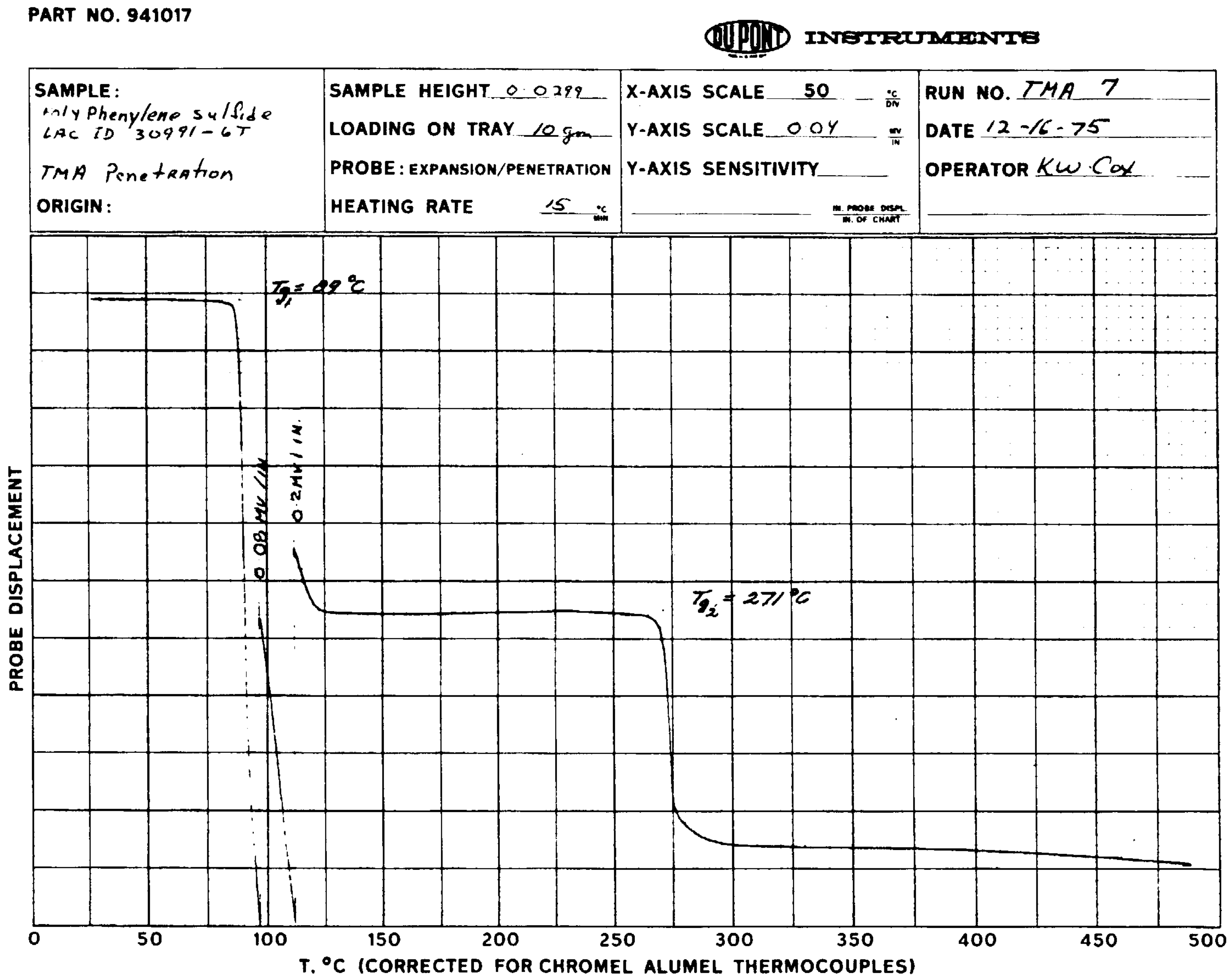
1. 10G load, 15 °C/min Heating Rate except Run No. 3 (5 °C/min).


PART NO. 941017

DUPONT INSTRUMENTS

SAMPLE: Polyether Sulfone 200P Hemi Probe TMA Penetration. ORIGIN:	SAMPLE HEIGHT ≥ .030 LOADING ON TRAY 10 gm PROBE: EXPANSION/PENETRATION HEATING RATE ___ °C/min	X-AXIS SCALE 50 °C/DIV Y-AXIS SCALE 0.04 mv/in Y-AXIS SENSITIVITY ___ ___ in. PROBE DISPL./in. OF CHART	RUN NO. 116 DATE 4-14-76 OPERATOR KW Cox

Figure 16. - Polyethersulfone 200P hemi probe



PART NO. 941017

INSTRUMENTS

SAMPLE: Poly Phenylene sulfide LAC ID 30991-6T TMA Penetration	SAMPLE HEIGHT 0.0299	X-AXIS SCALE 50 °C/DIV	RUN NO. TMA 7
	LOADING ON TRAY 10 gm	Y-AXIS SCALE 0.04 mv/IN	DATE 12-16-75
	PROBE: EXPANSION/PENETRATION	Y-AXIS SENSITIVITY	OPERATOR KW Cox
ORIGIN:	HEATING RATE 15 °C/MIN	IN. PROBE DISPL. / IN. OF CHART	

Figure 17. - Polyphenylene sulfide TMA penetration

PART NO. 941017

DUPONT INSTRUMENTS

SAMPLE: Polyarylsulfone
LAC ID 30991-7T
TMA Penetration Hemi Probe
ORIGIN:

SAMPLE HEIGHT 0.0294
LOADING ON TRAY 10 gm
PROBE: EXPANSION/PENETRATION
HEATING RATE 15 °C/MIN

X-AXIS SCALE 5° 50 °C/DIV.
Y-AXIS SCALE 0.04 MV/IN
Y-AXIS SENSITIVITY ______ IN. PROBE DISPL./IN. OF CHART

RUN NO. TMA 12
DATE 12-17-75
OPERATOR KW Coy

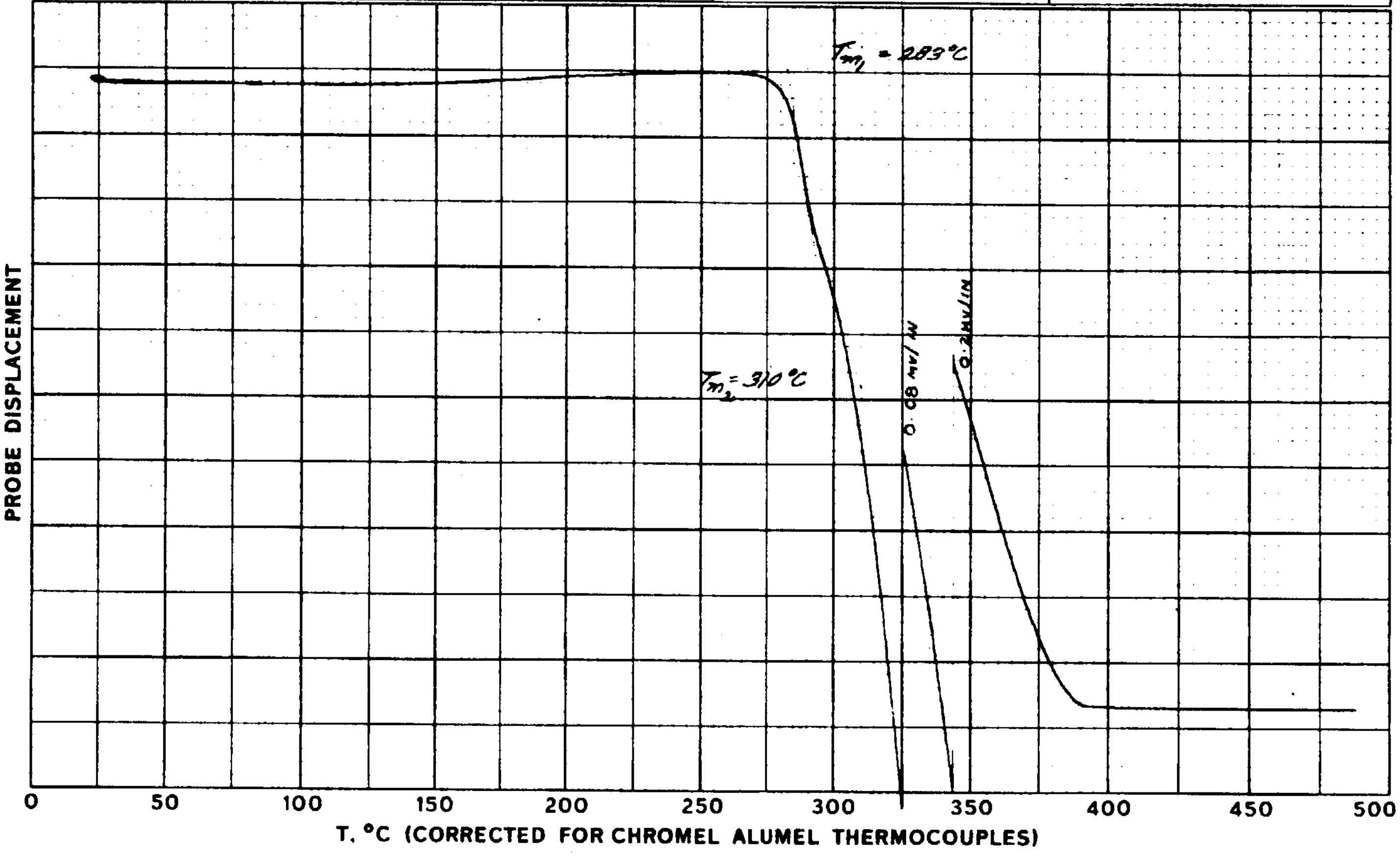


Figure 18. - Polyarylsulfone TMA penetration hemi probe

temperature of the neat resins. Crosslinking occurs as the temperature is raised with the formation of a second glass region which softens at 260-275 °C. The data supporting this conclusion follows.

In the TMA dilatometer, the probe displacement is directly proportional to the specific volume of the sample. As the temperature increases linearly, the slope is directly proportional to the coefficient of thermal volumetric expansion. A break in the curve is a temperature transition due to changes in the molecular orientation and motions. A representative dilatometer thermogram of polyphenylene sulfide is shown in Figure 19. Four transitions are evident. The first transition at 88 °C appears to be an isothermal change. The flat curve following this transition is due to a very low coefficient of thermal expansion such as is found with glasses. Three transitions follow at 118, 200, and 250 °C.

A representative thermogram developed on analyzing polyphenylene sulfide by differential scanning calorimetry (DSC) is shown in Figure 20. The heat of fusion of idium was used to calibrate the thermal changes. The numerical values were calculated from thermograms recorded simultaneously on an 11-inch strip chart recorder. The chart speed was varied during a run to optimize the shap of the peaks.

The first transition A, 0.39 cal/g, at 90 °C corresponds to the transition temperature T_g, found by dilatometry. Thus, T_g is a true first-order transition due to melting of a crystalline phase. The exotherm B at 119 °C, 2.09 cal/g, is due to crosslinking. According to the manufacturer, this crosslinking is catalyzed by air (oxygen). The specific volume decreased on crosslinking, T_B in the dilatometer thermogram, with formation of a glass as indicated by the very low coefficient of thermal expansion, Figure 19.

The drawn out endotherm E is due to loss of water, 95 °C to 280 °C, Figure 14. The endotherm C at 271 °C, 2.88 cal/g, may be due to the sharp loss in weight evident in the TGA thermogram, Figure 14. The thermal decomposition then proceeds slowly as evident from endotherm D and the TGA thermogram.

PART NO. 941017

DU PONT INSTRUMENTS

SAMPLE: Polyphenylene Sulfide LAC CODE # 30991-64 TMA DilatomETER **ORIGIN:**	**SAMPLE HEIGHT** ____ **LOADING ON TRAY** 5 **PROBE:** EXPANSION/PENETRATION **HEATING RATE** 2 °C/MIN.	**X-AXIS SCALE** 50 °C/DIV. **Y-AXIS SCALE** 0.02 MV/IN. **Y-AXIS SENSITIVITY** ____ IN. PROBE DISPL./IN. OF CHART	**RUN NO.** 77 **DATE** 2-18-76 **OPERATOR** KW Cox

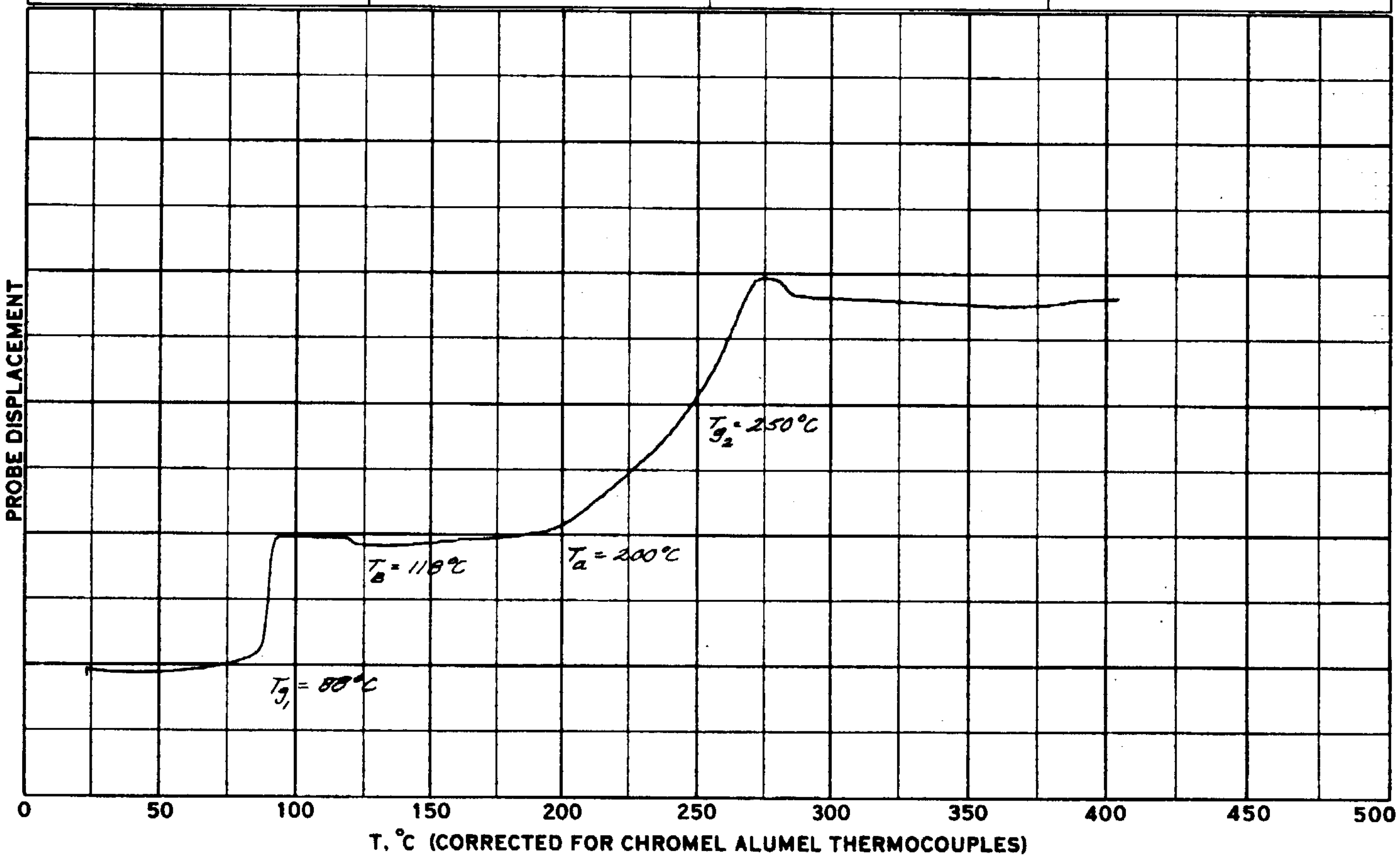
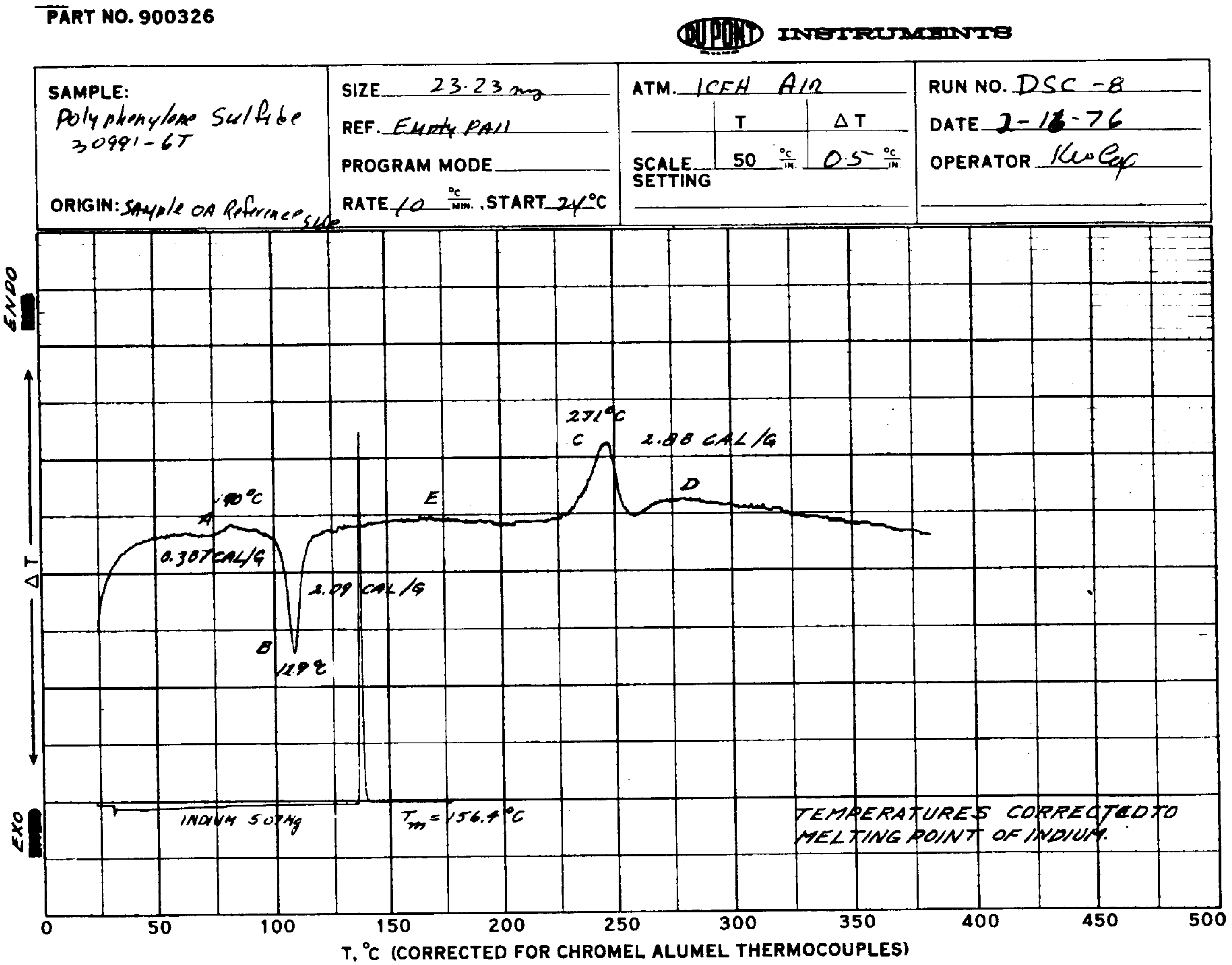


Figure 19. - Polyphenylene sulfide TMA dilatometer



PART NO. 900326

DU PONT INSTRUMENTS

SAMPLE: Polyphenylene Sulfide 30991-6T

ORIGIN: Sample on Reference Side

SIZE 23.23 mg

REF. Empty Pan

PROGRAM MODE

RATE 10 °C/MIN., START 24°C

ATM. ICEH Air

SCALE SETTING T 50 °C/IN. ΔT 0.5 °C/IN.

RUN NO. DSC-8

DATE 2-16-76

OPERATOR

Figure 20. - Polyphenylene sulfide

The secondary transition T_a at 200 °C, dilatometer thermogram, is followed by the second glass temperature at approximately 250 °C. The polyphenylene sulfide finally softens at 271 °C, Figure 17.

In summary, polyphenylene sulfide undergoes a true first-order transition, melting of a crystalline phase, at 86-92 °C. With continued heating, it crosslinks in the presence of air and forms a second glass which finally softens at 260-275 °C and undergoes viscous flow.

3. Compression Molding

Polyethersulfone 212P was successfully molded at 316 °C and 27.58 MPa psi followed by a holding pressure of 20.98 MPa. The data indicates that this resin can be injection molded at 400 to 427 °C. This temperature range is well above the melting temperature and just below the thermal decomposition point.

Polyphenylene sulfide was molded with difficulty at 327 °C and 41.37 MPa (6,000 psi) followed by a holding pressure of 27.58 MPa (4,000 psi). The processing would have been less difficult and the product of better quality with a temperature of 343 to 371 °C. Polyphenylene sulfide should be injection moldable at 370 to 427 °C or just below the temperature of thermal decomposition.

V PHYSICAL, CHEMICAL AND MECHANICAL PROPERTIES OF POLYMERS

A. Introduction

The data indicating the physical, mechanical, chemical, and fire safety characteristics of the various polymers or materials which were examined during the study period are presented in this section. The data presented in table form are a compilation of information supplied by the developer and by examination of the initial samples of polymer or material received during the program. The tables are set up to cover each category of materials studied under the contract. The values and data shown are typical of what could be expected with production lots of material. Much of the preliminary data were developed by the supplier with selected spot evaluation of physicals. Fire safety data were obtained during the program by the contractor and NASA Laboratories on one research batch of material. Comparative advantages or disadvantages of the different materials are also discussed.

B. Decorative Laminates

The decorative laminate materials were made from various combinations of available film materials thought to offer the best approach to replace the presently used PVF/PVF (Tedlar). Development of some of the films thought possible for this purpose did not materialize during this study period. Samples of decorative laminates were made using PVF_2 for the outer film for serviceability. This clear 0.0508 mm (0.002 in.) film was then laminated to various other types of available films which had been inked to typical interior patterns. Films which had the ability for accepting ink, and which appear to be feasible for application to various flat and contoured parts were polyvinylidene fluoride, polycarbonate, and polyethersulfone. Limited square footage of the initial finished decorative laminates were procured for evaluation however, only the PVF_2/PVF_2 laminate was textured to the required finish similar to the presently used PVF/PVF type laminate. The polyethersulfone film was only available in small 0.0929 sq m (1 sq ft) samples and therefore the finished laminate supplied was limited to 0.3048 m (1 ft) squares.

From the preliminary evaluation of the various laminates, the development of the PVF_2/PVF_2 for Tedlar replacement appears feasible. Whether its advantage of better flame resistance to prevent flame propagation exceeds its disadvantages of increased weight and other fire safety aspects must still be determined. In order to utilize the advantages of the PVF_2 film and to minimize the above disadvantages, other substitute films were employed to reduce the quantity of PVF_2 in the finished laminate. The use of other film materials necessitated developing new inks since the forming temperatures of the new films are above the heat stability of the presently used inks. Also, ultraviolet resistance of the ink used in the PVF_2/PES laminate is considered questionable and further development is required. In addition, application techniques for both the PVF_2/polycarbonate and PVF_2/PES must still be developed. The actual fire safety aspects of the laminates applied over various substrates must still be determined before a comparison can be made and their usage considered. Costs of the basic new film constructions range from 25 percent to 50 percent higher for similar patterns. If handling and application costs are not excessive, the increase costs may be justified if the material substitution can sufficiently improve the fire safety aspects of the interior surface of the cabins. Table VII lists the various properties of the finished decorative laminates compared to the presently used Tedlar type.

C. Compression Molding for Injection Molding Materials

Various new polymers considered for end use in injection type molded parts were evaluated for possible replacement for presently used polymers, namely, polyphenylene oxide and polycarbonate. Since larger quantities of materials are required to produce injection moldings, evaluation of these polymers was made utilizing compression molding techniques. Small compression buttons were first made to obtain processing parameters before making larger flat sheets for fabrication of specimens to obtain physical properties data.

Ideally, the injection molding material needed for future aircraft should have the flame resistance of polyphenylene sulfide; the smoke density rating and nondripping characteristics of polyether sulfone; the specific gravity, notch impact strength and fabrication ease of the modified

TABLE VII. - PRELIMINARY PROPERTIES OF CANDIDATE DECORATIVE LAMINATES

Property	PVF/PVF	PVF/PVC/PVF	PVF_2/PVF_2	PVF_2/PES	PVF_2/Polycarbonate
Thermal Stability	Good	Good	Excellent	Excellent	Excellent
Light Stability	Excellent	Excellent	Excellent	Fair	Excellent
Stain Resistance	Excellent	Excellent	Excellent	Excellent	Excellent
Odor	None	None	None	None	None
Formability	Good	Good	Excellent	?	?
Abraison Resistance	Excellent	Excellent	Good	Good	Good
Cleaner Resistance	Excellent	Excellent	Excellent	Excellent	Excellent
LOI	16 to 20	20 to 24	44	?	?
TGA °C	340				
Smoke D_s (6 min)	60	90	20	20	110
Shrinkage Resistance	Fair	Good	Good	?	?
Tear Strength Initial (gm/mil)	500	500	300	?	?
Specific Gravity	1.50	1.45	1.80	1.44	1.40
Elongation %	200	200	?	?	?
ALC_{50} at 700 °C* mg/liter					

*Data being developed at NASA-Ames

polycarbonate; the TGA and elongation of polyarylene; and the soil and cleaner resistance of polyarylsulfone. However, since the ultimate polymer material is not available today, data must be obtained covering all physical, chemical, mechanical, and fire safety aspects on candidate polymers.

After compiling initial data, it appears that tradeoff studies may indicate that possibly two or more polymers could be used for injection molded parts. Use of one or the other would depend on the degree of fire safety to be gained for a certain cost figure. In order to accomplish this it appears that a fire safety rating system must be established for all types of materials. The relative value placed upon fire resistance, smoke emission, versus toxicity rating must still be determined. A program or committee to determine the parameters of materials fire safety and to determine a rating system has not been established as yet.

Preliminary data for the various candidate injection molding materials is shown in Table VIII. From the data, one can depict advantages and disadvantages for the use of each of the materials. If one ignores the cost aspects, one should continue the evaluation of polyarylsulfone; however, with all its good features one cannot disregard the initial material cost of 15 times the price of modified polycarbonate material. In addition, the polymer requires the use of heated dies to mold the material, and the electrical heated dies run from $3000 for a small simple die to around $10 000 for a large complex die for the size of the passenger service modules. Until further fire testing and toxicity testing is accomplished on actual parts made from the materials one must continue to evaluate all the potential candidates.

D. Thermoforming Sheet Materials

ABS, polyphenylene oxide, and polycarbonate sheet materials which are presently used to produce the complex thermoformed molding parts in the design of cabin interiors, produce excessive smoke when subjected to flame. The total weight of material used in the plastic parts employed in design for use in door surrounds, window frames and shade assemblies, passenger seats, crew seats, attendant seats, lavatories, and cockpit trim and

TABLE VIII. - PROPERTIES OF CANDIDATE INJECTION MOLDING MATERIALS (PRELIMINARY)

Property	Polyethersulfone	Polyphenylene Sulfide	Polyarylsulfone	Polyarylene	Polysulfone	F 6000 Mod-Polycarbonate	(2816) Polycarbonate
Tensile Strength (psi) MPa	(11 000) 75.8	(9500) 65.4	(12 000) 82.7	(13 000) 88.6	(10 000) 8.9	(8500) 58.6	(8000) 55.2
Elongation % of R.T.	?	1.5	10%	140%	40%	50%	30
Flexural Strength (psi) MPa	(16 000) 113.0	(13 000) 88.6	(16 000) 113.0	(9000) 62.1	(15 000) 103.0	(12 000) 82.7	(12 000) 82.7
Heat Deflection Temp of @ (264 psi) 1820 kPa	(390 °F) 199 °C	(275 °F) 135 °C	(500 °F) 260 °C	(330 °F) 165 °C	(330 °F) 165 °C	(270 °F) 132 °C	(270 °F) 132 °C
Specific Gravity	1.37	1.3	1.36	1.30	1.25	1.20 to 1.26	1.20 to 1.26
Impact Strength (Notched Izod) (ft-lb/in) of Notch N·m/m	(1.6) 85.4	(1.2) 64.2	(3.0) 153.0	(2.0) 107.0	(1.3) 69.5	(9.0) 480.0	(2.0) 107.0
Mod of Elasticity (psi) MPa	(350 000) 2415	(500 000) 3550	(350 000) 2415	(230 000) 1585	(340 000) 2340	(300 000) 2070	(280 000) 1930
Compressive Strength (psi) MPa	(12 000) 82.7	(15 000) 103.0	(16 000) 113.0	?	(13 500) 92.0	(12 000) 82.7	(12 000) 82.7
Smoke Density Flaming D_s (6 min) 0.060	20 (0.060)	100 (0.070)	?	>20 (0.060)	80 (0.060)	130 (0.060)	180 (0.069)
TGA °C	440	430	490	580			
Ultraviolet Fade-O-Meter	50 hr	50 hr	?	?	60 hr	60 hr	60 hr
Liming Oxygen Index (LOI)	30.0	48.0	?	36.0	30.0	33.5	32.0
Surface Bonding Acceptance 180° Peel N/m	?	?	?	?	(7 lb/in) 1226	(10 lb/in) 1751	(10 lb/in) 1751
Soil and Cleaner Resistance	Fair	Excellent	Excellent	Fair	Fair	Fair	Fair
ALC_{50} at 700°/mg/liter*							
COST RATING	3.5x	2.5x	15x	(?)x	1.5x	x	x

*Data being developed by NASA-Ames.

glareshields is large. Therefore, effort to develop new thermoforming sheet materials is required to reduce the potentially large source of smoke-producing materials in the event of a fire. During the past two years only one new sheet material has been made available for evaluation, and two modification of formerly used polymers have been produced to basically reduce the smoke emissions. Recently some small sheets of polyethersulfone have been made available in 1.524 mm (.060 in.) thickness by ICI for preliminary evaluation.

Initial investigation of these thermoforming materials indicates that only the chlorinated PVC material would be usable in areas subjected to numerous cleanings in service. The modified polycarbonate and modified polysulfone are susceptible to stress cracking in service. The polyethersulfone appears to be slightly affected by cleaners but sufficient quantities of sheet stock have not been available for any extensive evaluation of this material. The Cl-PVC material has been made available in only three colors and only in limited thickness. Difficulty in color matching has been a problem in thicknesses over 2.286 mm (0.090 in.). These thicknesses are built up by laminating layers of sheet and the General Tire Chemical Division have not been able to match colors. Full evaluation concerning all fire safety aspects for these materials must still be accomplished. In addition, since smoke emission data are gathered to evaluate effect on visibility, for these types of materials, one should consider the effect of other combustion by-products on visibility such as lachrymator effect.

From the data, it appears that the modified polycarbonate or modified polysulfone materials are possible replacements for the presently used materials. However, since earlier version of these polymer-type materials have been cracking in service, development of textured sheet stock of modified polycarbonate or modified polysulfone protected with a layer of PVF_2 should be pursued. Parts made from these construction could then be evaluated for fire safety properties. Although preliminary polyethersulfone data is quoted, feasibility of the sheet stock to be fabricated into usable parts must be demonstrated. Data on the new thermoformed sheet materials compared to the data on the presently used materials are listed in Table IX.

E. Fabrics

Numerous fabric materials were reviewed during the study period for possible future usage for seat upholstery and drapery materials. Replacement of material in presently used jets during refurbishing of cabin interiors could also be considered if more flame resistant fabrics are not too costly. Four available fibers which offer various levels of improvements in fire safety were evaluated during the study period. Fabric made from initially dyed PBI fibers was not made available by Celanese Corporation during the past year. However, it now appears that the company has committed to producing a pilot production plant for manufacturing dyed fibers for fabric construction. Initial physical properties and flame resistant properties of the basic PBI fiber indicates that further development should be pursued to improve the fabric for resistance to ultraviolet exposure.

One of four fabrics examined made from Kynol fiber exhibited poorer resistance to abrasion than did the other three available fabrics. Its consideration for seat upholstery is, therefore, eliminated. However, its use as a fabric for curtain or drapery designs should still remain under evaluation. From the data, it appears that the newly developed FR nylon fabric offers an improved flame resistant nylon material which will give good service as upholstery fabric. Expected service would be equivalent to the nylon previously used for initial jet aircraft. The data also indicate that the Nomex and Kynol fabric dyes are not stable after 60 hours of ultraviolet exposure. Data on fabrics are shown in Table X.

F. Foams

Present flexible foams used for padding and for seat fabrication are usually made from flame resistant polyurethane foam. This polyurethane foam is made in various densities for the different applications, however, about 95 percent of the foam ends up in seat designs where it is used for comfort and float cushions. These foam applications employ the use of kg/m^3 32.2 kg/m^3 (2 lb/ft^3) or lighter density foam. Also, although the foam is flame resistant

TABLE IX. - PRELIMINARY PROPERTIES OF CANDIDATE THERMOFORMED MATERIALS

Property	(F 6000) Mod-Polycarbonate	(SL 1000) Polycarbonate	Mod-Polysulfone	Chlorinated - PVC	(212P) Polyethersulfone	(6800) ABS
Tensile Strength (psi) MPa	(8500) 58.56	(8000) 55.2	(8000) 55.2	(5400) 37.2	(11 000) 75.8	(5500) 37.9
Elongation %	70	30		40	?	5
Flexural Strength (psi) MPa	(12 000) 82.7	(12 000) 82.7	(12 500) 86.0	(10 000) 68.9	(16 000) 113.0	(9500) 65.4
Heat Deflection Temp of @ (264 psi) 1820 kPa	(220 °F) 105 °C	(230 °F) 110 °C	(300 °F) 149 °C	(200 °F) 84 °C	(390 °F) 199 °C	(170 °F) 76.5 °C
Specific Gravity	1.26	1.20 to 1.26	1.26	1.57	1.37	1.36
Impact Strength (Notched Izod) (ft-lb/in) of Notch N·m/m	10.0 534.0	2.0 107.0	9.0 480.0	6.6 352.0	1.6 85.4	8.0 427.0
Mod of Elasticity psi MPa	(300 000) 2070	(300 000) 2070	(320 000) 2205	(300 000) 2070	(350 000) 2415	(300 000) 2070
Smoke Density Flaming D_s (6 min)	130(0.060)	200 to 400	105(0.050)	140(0.060)	20(0.060)	<1000
TGA °C			400 °C		440 °C	
Ultraviolet Fade-O-Meter	60 hr	60 hr	60 hr	60 hr	50 hr	60 hr
Liming Oxygen Index (LOI)	33.5	32.0	30.0	50.0	30.0	34.0
Soil and Cleaner Resistance	Fair	Fair	Fair	Excellent	Fair	Excellent
Surface Bonding Acceptance 180° Peel lb/in N/m	10 1751	10 1751	7 1226	10 1751	Poor ?	10 1751
ALC_{50} at 700 °C Mg/Liter*						
COST RATING	x	x	2x	1.3x	4x	0.8x

*Data being developed by NASA-Ames.

TABLE X. - PRELIMINARY DATA ON FABRICS

Basic Polymer Fiber	*ALC_{50}	LOI	Flame Resistance 12 sec Vertical Total Flame & Glow Time	Smoke Density D_s(6 min) NBS Chamber	Abrasion Resistance Fed-Std-191 #5306 1000gm/1000cy	Color Stability #5660 60 hours	Cleaning Stability #5580 10 Cleanings	Specific Gravity
FR Nylon		25	3 sec	< 10	Excellent	Excellent	Excellent	1.4
Nomex (Amer.)		38	3 sec	33	Good	Fair	Good	1.38
Treated Wool		31	0 sec	>100	Fair	Good	Good	1.32
Kynol		30	2 sec	<10	Poor Fails less than 380 cy	Poor	Good	1.25
PBI		40	0 sec	<10	Good	?	?	1.34

*Toxicity data being developed by NASA-Ames.

and meets the FAA 12 second vertical flame test requirement, it melts, drips flame, produces smoke and is totally consumed in the area of the flame. Therefore, in any fairly large fire, the volume of foam available for consumption is appreciable and large amounts of smoke and combustion by-products would be produced by the foam.

At present, only two development programs are in progress to develop alternate polymers for foam material. Both these development programs are progressing with assistance from NASA contracts. One of the polymers is a polyphosphazene type. Samples of 80.2 k_g/M^3 (5 lb/ft^3) density material have been produced and examined for fire safety characteristics. Early data obtained indicate a need for continuation of foam development. Small samples of lower density foam have been produced but adequate quantity and quality of foam required for full evaluation in seat applications was not produced during the study period. The other polymer under development showing good fire safety characteristics is a polyimide type. Small samples of 32.2 k_g/M^3 (2 lb/ft^3) density foam have been made and delivered to NASA-JSC. Information out of JSC indicates that the foam looks very promising and that the cost estimates for producing the foam are fairly low compared to the polyphosphazene foam material. Work is being pursued toward producing sufficient size samples to cut foam thicknesses required to fabricate seat cushions.

Other means of limiting the effect of the foams in a fire situation are being pursued while the development work continues on new foam polymers. NASA-JSC has treated the regular polyurethane seat foam with a fire retardant. This retardant prevented flame propagation in various tests, however, the retardent increases the foam density 50 percent by weight. In addition, the combustion by-products produced in a fire must still be evaluated for toxicity. Another method under evaluation to reduce the effect of the polyurethane foam in seats, in the event of fire, is to surround the foam with a barrier of either neoprene foam or some form of Kynol mat fiber. The quantity of neoprene foam or Kynol fiber is fairly low and test work to perfect the system is limited to fire testing. Service life testing of the seat is not required since a qualified seat design is employed. Evaluation of the smoke and by-products of combustion produced in a fire test of these two methods of reducing flame propagation must still be accomplished.

Limited data on foam materials and barrier methods are shown in Table XI.

TABLE XI. - PRELIMINARY DATA ON FLEXIBLE FOAMS

Basic Foam Polymer or Concept	$^*ALC_{50}$	Smoke Density D_s (6 min) 1 in. Thick	Flame Resistance 60 sec vert. 1/2 in. Thick	LOI	Compression Set Resistance	Density kg/m^3 (lb/ft^3	Availability and Cost
FR Polyurethane (Treated - JSC)		>100	Excellent	58	Good	56 kg/m^3 (3.5)	Production Materials Available
Polyphosphazone NASA - Ames		< 50	Excellent		Good	80.2 kg/m^3 (5.0)	Horizons Limited Research Samples Available Expensive
Polyimide Foam NASA - JSC		< 20	Excellent		?	32.2 kg/m^3 (2.0)	Solar Inc. Research Samples Available - JSC
Flame Resistant Neoprene Foam		>400	Excellent		N.A.	0.64 cm only 32.2 kg/m^3 (2.0)	Pilot Plant Production Available E. I. Du Pont
Kynol Mat Fiber		<10	Excellent		N.A.	0.64 cm only 8.02 kg/m^3 (0.5)	Pilot Plant Production Available

*Toxicity data being developed by NASA-Ames.

VI PRELIMINARY MATERIAL SPECIFICATIONS

In order to control the quality of the production of the various different materials, preliminary material specifications were drafted. These material specifications cover requirements which are established to control the batch to batch quality of the types of materials covered by each typical specification.

Categories covered by proposed material specification are:

1. Decorative Plastic Sheet
2. Thermoplastic Resin Molding Compound.
3. Thermoset Resin Molding Compound, Reinforced
4. Thermoplastic Sheet, Thermoform Grade

These proposed specifications are presented in the Appendixes.

Appendix A	Proposed Material Specification Decorative Plastic Sheet
Appendix B	Proposed Material Specification Thermoset Resin Molding Compound, Reinforced
Appendix C	Proposed Material Specification Thermoplastic Resin Molding Compound
Appendix D	Proposed Material Specification Thermoplastic Sheet, Thermoform Guide

VII RESULTS AND CONCLUSIONS

A. General Remarks

The object of this study was to identify and to promote the development of new polymers which offer promise to reduce significantly the fire and associated hazards when used in producing typical aircraft interiors. Specifically, resins or polymers for use in the manufacture of barrier coatings, decorative laminates, compression or injection molding compounds, thermoforming sheet material, foams, and fabrics were of prime importance.

The study primarily was concerned with (a) the possibility of developing a clear barrier coating which could be used in the present surfaces of aircraft interiors to prevent the out gassing of smoke and toxic by-products when subjected to a flame exposure; (b) the development of new film materials to produce lower smoking and toxic by-products decorative laminate constructions for decorative interior surfaces; (c) the development of polymers to be used for thermoplastic molding materials to replace presently used materials in injection molded and thermoformed parts. In addition, the present state of the art in fabric and foam development programs was investigated in the study.

The approach adopted was to review all the literature and information supplied by various government agencies and industry. Then selection of polymers based on chemical structure and on preliminary flame tests was made in various categories. A formal presentation was then prepared, and a team of Program Material Engineers were sent to visit the research facilities of companies developing potential candidate polymers. The formal presentation and exchanges of information at the various research facilities were intended to promote the rate of development of polymers to meet a time schedule for implementation in the next generation of airplanes.

Samples of new polymers were obtained from various chemical companies and these were evaluated in the potential use areas. Data obtained during the study were sufficient to permit the selection of polymers for further consideration. Handling characteristics and preliminary service evaluation, properties, possible cost and weight impact, and anticipated development schedule were also considered during the study period.

B. Summary of Results

Although much of the data obtained during the study were on initial research or pilot plant samples, various pertinent observations were verified. A list of the more important results are summarized below:

1. None of the research polymers examined during this study period exhibited the physical or handling properties to produce usable clear barrier type coating for possible use over existing aircraft interior wall surfaces.

2. Preliminary evaluation of some research polymers was not attainable during the study period as samples of the polymers were not available due to the lack of sufficient progress in the development of phenolphlhalin polycarbonate and bis-phenol-A modified polymers.

3. Development of decorative type laminates with better flame resistance with lower production of smoke and toxic by-products appears feasible, however, at this time, better flame resistance and reduction of smoke and toxic by-products is accomplished by combining two film materials. The clear overlay film for service maintenance and flame resistance and the lower layer for producing less toxic by-products.

4. Although decorative laminates can be upgraded, the development of more flame-resistant pressure-sensitive adhesive or heat activated adhesives must be advanced before significant improvement in overall fire safety is achieved.

5. Of the several polymers examined as compression molding materials for use in injection molded parts, two appear to have favorable fire safety qualities and with further development, could possibly be used to make injection molded parts. Cost of the two polymers appears to be approximately 2 and 3 times the cost of today's injection molding materials, however if present tooling and

processing can be utilized, a one time part cost may not be more than 50 percent to double the present part cost.

6. One of the two polymers, polyphenylene sulfide, could not be controlled by compression molding as the material became liquid over a short temperature span and could not be contained. However, the material is compatible with injection molding equipment and it appears that good parts can be produced with this polymer.

7. Newly developed production thermoplastic sheet materials have been produced to meet the FAA regulations for flammability and intended requirements for smoke emission. However, reduction of toxic by-products and/or low temperature melting properties which allow materials when heated, to feed a fire source have not been greatly improved in these sheet materials.

8. Except for the chlorinated PVC material, all the other new production sheet materials are affected by solvents used for cleaning at most airline maintenance bases.

9. Initial samples of polyether sulfone sheet material appear to offer some hope for a better fire safety material to replace ABS or Noryl type sheet material, however it may be necessary to laminate a layer of Kynar over the surface to make the material serviceable in aircraft interiors.

10. Initial examination of the new injection molding and thermoforming materials indicates that adhesive bonding techniques must be developed for fabrication of assemblies.

11. Developments of new flexible foam materials to replace the presently used 32.2 kg/m^3 (2 lb/ft^3) polyurethane foam has not progressed to the point of making up seats for fatigue testing and service evaluation. Only small sections of either polyimide or polyphosphazene flexible foam have been produced in the density required to manufacture passenger seats with weight limitations listed foam materials.

12. Fabric materials made from proban treated wool, american nomex fiber, and F.R. nylon offer new materials, with some upgraded fire safety aspects, which are usable for upholstery.

13. PBI fiber, dyed as a fiber, appears to offer a definite improvement in overall fire safety with a fabric material that would be serviceable as aircraft upholstery. Commitment to proceed with a pilot production plant has just been made by Celanese Corporation.

14. Samples of Kynol fabric examined indicate that this material would be usable as drapery type fabric, however, its abrasion resistance is much poorer than presently used seat fabrics and it does not appear to be usable as upholstery material due to poor expected service life.

C. Conclusions

1. Development of a clear flame barrier type coating material to prevent presently used materials from being consumed in a fire does not appear feasible with the polymers examined.

2. Processing parameters for application and/or adhesives to adhere polyethersulfone or polycarbonate type decorative laminates to substructure must still be developed.

3. Fabrication of compression molded parts is presently feasible with phenolic and polyimide type polymers and chopped fibers, however, compression molding steel dies and high temperature and high pressure press facilities are required.

4. Substitution of compression molded designs for injection molded parts would result in 200 to 300 percent weight penalty for the parts in addition to the cost of new compression molding dies.

5. Adhesives and bonding techniques for some of the new injection and thermoforming materials need further development.

6. Development of processing parameters for the new type polymers for fabricating injection molded parts is required.

7. Thermoforming parameters for some of the candidate thermoplastic laminated sheet materials needs further development.

8. Further development is required of the two candidate foam materials made from polyphosphazene and polyimide polymers.

9. Development of stable PBI dyed fiber for fabrics is needed.

10. Fire safety aspects as well toxicity aspects of new thermoplastic type materials as finished products, compared to presently used materials, must be evaluated by standardized fire tests.

APPENDIX A

PROPOSED MATERIAL SPECIFICATION
DECORATIVE PLASTIC SHEET

1. SCOPE AND CLASSIFICATION

1.1 Scope. - Material conforming to this specification shall be suitable for application to various substrates using adhesives or integral bonding techniques. The decorative sheet shall be capable of meeting applicable FAA regulations for flame resistance and smoke generation for commercial aircraft interiors when applied to suitable substrates.

1.2 Classification. - Decorative sheet shall be furnished in the following types and classes:

Type I - Standard Service
Type II - Heavy Duty

Class (*)

* Class designations shall be assigned to each construction defining details of materials and thicknesses and special requirements such as perforations as applicable.

Grade (*)

* Grade designations shall be assigned to specify adhesives preapplied to the sheet as required.

2. APPLICABLE DOCUMENTS

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

Federal

FED-STD-191	Textile Test Methods

(Applicable Flammability and Smoke Tests)

3. REQUIREMENTS

3.1 Qualification. - The plastic sheet furnished under this specification shall be a product which has passed the qualification tests specified herein. When a product has been qualified, neither the constituent materials nor the method of manufacture of that product shall be changed without requalification.

3.2 Workmanship. - The materials shall be uniform and free of runs, wrinkles, blisters, voids, lumps, impurities, delaminations or other defects that can impair its appearance or use.

3.2.1 If detrimental specks (imbedded impurities) are visible in the material, no more than four specks, 0.08 cm (1/32 in.) maximum diameter, are allowable per 0.32 m^2 (3.5 sq ft) (approx. 3200 cm^2 <500 sq in>).

3.3 The color, design, gloss and texture of each sheet shall be inspected against the applicable color chip specified in the contract or purchase order.

3.4 Size. - When the material is ordered in rolls, it shall be supplied in a specified minimum width with a minus 0.64 cm (0.25 in.) tolerance. If the material is not ordered in rolls, the material shall be supplied in sheets of specified width and length with a tolerance of minus 0.64 cm (0.25 in.) in usable width and minus 1.28 cm (0.5 in.) in usable length. The plus tolerance is unlimited.

3.5 Thickness. - The total thickness of the material without adhesive backing shall be as specified by class in 1.2 when measured in accordance with 4.5.1.

3.6 Adhesive backing. - Preapplied adhesives shall conform to the Grade as specified in 1.2 and the applicable material specificaiton. The adhesive shall be applied uniformly and shall be protected with an easily removable protective paper or film.

3.7 Thermal stability. - The appearance, texture, gloss and color shall not change significantly after subjection to the heat cycles specified in 4.5.2.

3.8 Light stability. - The texture, gloss and color shall not be significantly changed by the exposure specified in 4.5.3.

3.9 Stain resistance. - The outer surface of the material shall exhibit no residual stain when tested as specified in 4.5.4.

3.10 Formability. - The decorative sheet shall be capable of being applied to a panel as specified in 4.5.5 with negligible loss of texture except at the corners.

3.11 Flammability. - The decorative sheet shall be self-extinguishing within 3 seconds when tested as specified in 4.5.6. Burn length shall be less than 15.2 cm (six inches).

3.12 Smoke emission. - Smoke emission of the decorative sheet shall give a D_s of less than 50 in six minutes when tested as specified in 4.5.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. - Unless otherwise specified in the contract or purchase order, the supplier shall be responsible for the performance of all inspection requirements specified herein. The supplier shall maintain adequate records of tests performed and data showing conformance to this specification.

4.2 Test reports

4.2.1 Qualification test report. - The supplier shall furnish to the purchaser two copies of a report showing the results of the qualification tests specified herein, performed to determine conformance with the requirements of this specification.

4.2.2 Acceptance test report. - With each lot, the supplier shall furnish two copies of a report showing the results of the acceptance tests specified herein. The report shall also show the purchase order number, this specification number and revision letter, date of manufacture, manufacturer's stock or lot designation, and the date tests were performed.

4.3 Qualification tests. - Qualification tests for the material to be furnished under this specification shall consist of all the tests specified herein to ensure conformance to all the requirements of Sections 3 and 5.

4.4 Acceptance tests. - Acceptance tests of random samples for each lot of material furnished under this specification shall consist of visual inspection for appearance, color and texture to match the specified color chip. The material shall be tested for flammability to the requirements of 3.11.

4.4.1 Lot. - A lot shall consist of one shipment of one type of material regardless of the number of colors.

4.5 Tests

4.5.1 Thickness. - The thickness of the material shall be measured in accordance with Method 5030 of FED-STD-191.

4.5.2 Thermal and dimensional stability. - An unmounted 25.4 by 25.4 cm (10 by 10 in.) specimen shall be measured at three marked places across the length and width to ± 0.397 mm (0.0156 in.). The specimen shall be heated in an oven for 1/2 hour at 93.3 ± 5 °C (200 ± 10 °F), cooled to room temperature and remeasured. The percentage change in dimensions shall then be calculated for both length and width directions and individually averaged.

4.5.3 Light stability. - The sample material shall be exposed for 50 hours in a standard Fadeometer in accordance with Method 5660 of FED-STD-191.

4.5.4 Stain resistance. - The outer surface shall be marked with two 5 cm (2 in.) long lines applied with a red felt marker, such as Magic Marker. After at least 30 minutes drying time, the red lines shall be wiped away with a cloth wet with acetone.

4.5.5 Formability. - The material shall be capable of being applied with a large 3-M vacuum applicator machine over a 16 cm (6 in.) minimum square at least 12.7 mm (0.5 in.) thick of a rigid laminate or wooden block with a relatively smooth surface. The cycle to apply the material to the block shall be:

8-10 inches Hg vacuum
4 to 5 minutes full heat at 104 ± 3 °C (220 ± 5 °F)
Cool to 54 °C (130 °F) before releasing vacuum

4.5.6 Flammability. - Both classes of material shall be tested in accordance with FAA FAR 25.853 (60 second Vertical Test).

4.5.7 Smoke. - When applied to an aluminum panel with adhesive, the D_s as measured in standard NBS Smoke Test Chamber shall be as specified in 3.1.2.

5. PREPARATION FOR DELIVERY

5.1 Packaging. - Packaging shall be sufficient to afford adequate protection against deterioration and physical damage during shipment from the supply source to the first receiving activity for immediate use or for controlled storage.

5.2 Marking. - Each package shall be permanently and legibly marked with the following information on the exterior and on the inner surface of the core if the material is supplied in rolls:

DECORATIVE TRIM
Material Specification_______________ Rev.________
Type__________________ Class_____________
Purchase Order No. _______________________
Color No.___________________________
No. of Sheets_________________ Net Weight_________
Manufacturer_________________ Lot No. ____________
Date of Manufacture_______________
Storage Instructions__________________
Size: Length_____________ , Width_____________

5.2.1 If the material is supplied in flat sheets the same information, except quantity and weight, shall be applied to each sheet using a label that is easy to remove.

5.2.2 Where print pattern has directionality, the specified direction fo the print shall be designated as vertical along two parallel edges using labels or tape that are easy to remove. Frequency of arrows shall be a maximum of 30 cm (12 in.) apart. In place of labels or tape a printed or silk-screened set of arrows is preferred provided they are readily removable with water.

6. NOTES

6.1 There is no Government specification covering the requirements of this material.

APPENDIX B

PROPOSED MATERIAL SPECIFICATION
THERMOSET RESIN MOLDING COMPOUND, REINFORCED

1. SCOPE AND CLASSIFICATION

1.1 This specification establishes the requirements for thermoset resin, fiber reinforced molding compounds. Molding compounds conforming to this specification meet applicable FAA regulations for flammability and smoke generation for use in commercial aircraft interiors.

1.2 Molding compounds shall be furnished in the following types and grades:

Type I - Polyester/fiberglass
Type II - Epoxy/fiberglass
Type III - Phenolic/glass
Type IV - Polyimide/glass
Grade A - High strength, moderate flow
Grade B - Moderate strength, high flow

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 herin:

STANDARDS

Federal

FED-STD-406	Plastics: Methods of Testing
TT-M-261	Methyl Ethyl Ketone

Other

FAA-FAR 25.853(a) Appendix F	Flame Resistance
FAA-NPRM-Smoke Standard Docket No. 9611, Notice 75-3, Feb. 1975, Appendix F(1)	Smoke Generation

3. REQUIREMENTS

3.1 Qualification. - The molding material furnished under this specification shall be a product which has passed the qualification tests specified herein. When a product has been qualified, neither the constituent materials nor the method of manufacture of that product shall be changed without requalification.

3.2 Materials. - The material shall be a thermoset resin, fiber reinforced molding compound, capable of meeting the requirements of this specification. The material may be furnished in sheet form suitable for cutting patterns and preforms. Unless otherwise specified, the color shall be natural.

3.2.1 Color. - When specified, the color of the molding compound shall be inspected for color match against the applicable color chip specified in the contract or purchase order. Specimen preparation shall be in accordance with 4.3.2.

3.2.2 Storage stability. - The uncured molding compound shall meet all the requirements of this specification for a period of at least 12 months following receipt at the purchaser's destination, when stored in an area protected from direct sunlight and elements with the temperature maintained below 40 °F.

3.3 Physical properties. - Materials shall conform to the requirements of Table I when tested in accordance with 4.3.

3.4 Quality. - The material shall be clean, uniform in quality, and free from contaminants detrimental to molding, appearance, or performance. Fibers shall be thoroughly impregnated and evenly distributed.

TABLE I - PHYSICAL PROPERTIES

Property	Units	Value					Test Method	
		Type I		Type II		Types III & IV	FED-STD-406	Other
		Grade A	Grade B	Grade A	Grade B	Grades A & B		
Specific gravity	Maximum	2.5	2.5	2.0	2.0	2.5	5011	
Water absorption 24 hr 23 °C	% Maximum	0.25	0.25	0.20	0.20	0.25	7031	
Impact Izod	(ft-lb/in notch minimum) No m/m	(18) 963	(15) 802	(26) 1391	(18) 963	(18) 963	1071	
Tensile strength	(psi, minimum) MPa	(18 000) 124.0	(10 000) 68.9	(23 000) 158.4	(20 000) 137.5	18 000 124.0	1011	
Flexural strength [1]	(psi, minimum) MPa	(35 000) 241.1	(30 000) 206.7	(53 000) 365.2	(50 000) 344.5	(30 000) 206.7	1031	
Flexural modulus	(psi, minimum) MPa	(1.85×10^6) 12746	(1.80×10^6) 12402	(3.3×10^6) 22737	(2.6×10^6) 17914	(1.80×10^6) 12402	1031	
Compressive Strength	(psi, minimum) MPa	26 000 179.1	21 000 144.7	32 000 220.5	30 000 206.7	(21 000) 144.7	1021	
Rockwell Hardness M Scale	Minimum	95	95	100	100	100	1081	
Resin content [2]	%	65 ± 2-1/2	70 ± 2-1/2	33 ± 3	37 ± 3		7061	
Flame resistance [3]	Seconds, max. extinguish time	5	5	5	5	5		4.3.3
Smoke Density, Flaming D_s (6 min)	Maximum							4.3.4
Solvent Resistance		Pass	Pass	Pass	Pass	Pass		4.3.5

NOTES:

[1] Specimen thickness, 3.175 ± 0.254 mm (0.125 ± 0.010 in.)

[2] Percentages noted include resin and fillers other than glass fibers.

[3] Specimen thickness, 0.762 - 1.016 mm (0.030 - 0.040 in.)

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. - The supplier is responsible for the performance of all inspection requirements specified herein, prior to submitting the material for qualification. Two copies of the test report showing the results of the qualification tests specified herein shall be submitted with materials intended for qualification testing.

4.2 Classification of tests shall be as follows:

4.2.1 Qualification tests. - Qualification tests shall consist of all tests specified herein and any other tests required to ensure conformance to all the requirements of this specification. (See Table I.)

4.2.2 Acceptance test report. - Unless otherwise specified in the purchase order, the supplier shall furnish to the purchaser, or its authorized representatives, two copies of a report showing the results of the batch acceptance tests specified herein. The report shall also show the purchase order number, this specification number and revision letter, date of manufacture, manufacturer's stock or lot designation, and the date tests were performed.

4.2.2.1 Batch acceptance tests. - The following tests (see Table I) shall be conducted on molded samples from each batch of material submitted for acceptance: (See 6.2.1).

Molding Compound

(a) Resin content

Molded Samples

(a) Flexural strength
(b) Hardness
(c) Specific gravity
(d) Color (when applicable)
(e) Flame resistance

4.3 Test methods. - The specimens shall be tested in accordance with the applicable test methods specified in Table I.

4.3.1 Test specimen preparation. - Except as otherwise noted in Table I, specimen size shall conform to the applicable FED-STD-406 test methods. Specimens shall be molded as follows: 8.27 ± 1.4 MPa (1200 ± 200 psi), 150 ± 10 °C (300 ± 20 °F), 25 ± 5 minutes at temperature.

4.3.2 When color is specified, the material supplier shall furnish a representative molded color specimen, approximately 5 x 8 x 0.10 cm (2 x 3 x 0.040 inch), prepared from the batch of material submitted for acceptance. The color specimen shall be molded as specified in 4.3.1. The specimens shall be compared for color match with the specified Engineering color standard.

4.3.3 Flame resistance. - 60-second vertical flame exposure, in accordance with FAA-FAR 25.853(a) Appendix F.

4.3.4 Smoke generation. - NBS Smoke Chamber, flaming condition, in accordance with FAA-NPRM - Smoke Standard Docket No. 9611, Notice 75-3, Feb. 1975, Appendix F (1).

4.3.5 Solvent resistance. - Subject a specimen molded in accordance with 4.3.1 to the following test:

Soak a soft cloth or paper wipe with Methyl Ethyl Ketone (TT-M-261) and place in contact with the specimen for 5 minutes, adding solvent as required to keep the cloth or paper moist. Remove cloth or paper, air dry for one minute, and check for tackiness of the surface, which constitutes failure of the test.

5. PREPARATION FOR DELIVERY

5.1 Packaging and packing. - Unless otherwise specified in the contract or purchase order, packaging and packing shall be in accordance with standard commercial practice in a manner that will ensure safe transportation at the lowest rate to the point of delivery. Containers shall meet Uniform

Freight Classification Rules or the regulations of other common carriers as applicable to the mode of transportation.

5.2 Marking. - In addition to any special marking required by the contract or purchase order, shipping containers shall be marked to include but not limited to the following information:

____________ Resin Molding Compound, __________ Fiber Reinforced
Specification, Rev. __________________
Type____________________ Class ____________________
Purchase Order ________________________
Quantity____________________
Product Designation and Batch No. __________________
Supplier's Name ____________________________________
Date of Manufacture______________________
Store at 40°F max.

6. NOTES

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

6.2 Definitions

6.2.1 Batch. - A batch is that amount of molding compound which is impregnated in a continuous production run with one resin mix and offered for delivery at one time.

APPENDIX C

PROPOSED MATERIAL SPECIFICATION
THERMOPLASTIC RESIN MOLDING COMPOUND

1. SCOPE

1.1 Scope. - This specification covers thermoplastic resin molding compounds which may be processed by injection and compression molding and extrusion (see 3.1 for type designations). Materials conforming to this specification meet applicable FAA regulations for flammability and smoke generation for use in commercial aircraft interiors.

2. APPLICABLE DOCUMENTS

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

Federal	
FED-STD-406	Plastics, Methods of Testing
Industry	
ASTM D648	Method of Test for Deflection Temperature of Plastics Under Load
Other	
PAA-FAR 25.853(a) Appendix F	Flame Resistance
FAA-NPRM-Smoke Standard Docket No. 9611, Notice 75-3, Feb. 1975, Appendix F(1)	Smoke Generation

3. REQUIREMENTS

3.1 Material. - The material shall consist of the specified polymer types and any additional ingredients required to conform to this specification.

Type I	Polycarbonate
Type II	Polysulfone
Type III	Polyethersulfone
Type IV	Polyphenylene sulfide

3.1.1 Reinforcement. - When specified by class designation, reinforcing fibers and fillers shall be blended with the resin to provide a variety of properties as determined using test methods of this specification.

3.1.2 Color and transparency. - Unless otherwise specified, the compound shall be furnished in its natural color and transparency. Added colorant (when used) shall not alter the physical, chemical, and electrical properties specified herein. When specified, the color of the molding compound shall be inspected for color match against the applicable color chip required in the contract or purchase order. Specimen preparation shall be in accordance with 4.3.1.

3.2 Quality. - The product shall be uniform in quality and condition, clean, smooth, and free from foreign materials and from imperfections detrimental to fabrication, appearance, or performance of parts.

3.3 Physical properties. - Test specimens molded from the materials covered by this specification shall conform to the requirements of Table I.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. - The supplier is responsible for the performance of all inspection requirements specified herein, prior to submitting the material for qualification. Two copies of the test report showing the results of the qualification tests specified herein shall be submitted with materials intended for qualification testing.

4.2 Classification of tests shall be as follows:

4.2.1 Qualification tests. - Qualification tests shall consist of all tests specified herein and any other tests required to ensure conformance to all the requirements of this specification. (See Table I.)

4.2.2 Acceptance test report. - Unless otherwise specified in the purchase order, the supplier shall furnish to the user, or its authorized representatives, two copies of a report showing the results of the batch acceptance tests specified herein. The report shall also show the purchase order number, this specification number and revision letter, date of manufacture, manufacturer's stock or lot designation, and the date tests were performed.

4.2.2.1 Batch acceptance tests. - The following tests (see Table I) shall be conducted on molded samples from each batch of material submitted for acceptance.

(a) Flexural strength
(b) Impact strength
(c) Hardness
(d) Specific gravity
(e) Flammability

4.2.2.2 Definition of batch. - A batch of molding material is defined as the amount which is processed in a continuous production run with one resin mix and offered for delivery at one time.

4.3 Test method. - The test specimens shall be conditioned and tested in accordance with applicable test methods of FED-STD-406 and as follows, as required by Table I and 3.1.2 and 3.2.

4.3.1 Specimen preparation. - Test specimens shall be prepared using standard injection molding equipment and processes typical of the intended use and in accordance with the suppliers recommendations.

4.3.2 Flame resistance. - 60 second vertical flame exposure, in accordance with FAA-FAR 25.853(a) Appendix F.

TABLE I Physical Properties

Property	Unit	Value				Test Method	
		Type I	Type II	Type III	Type IV	FED-STD-406	Other
Specific Gravity	Max	1.25	1.28	1.40	1.35	5010	
Water Absorption 24 hr @ 23 ^{o}C	% Max	0.20	0.27	0.50	0.15	7031	
Impact, I_{zod} (Ft-lb/in of notch) Ni m/m	Min	(10.0) 535	(1.1) 58.8	(1.4) 74.9	(1.1) 58.8	1071	
Tensile Strength	10^3psi Min	(8.0) 55.1	(9.0) 62.0	(10.5) 72.3	(8.5) 58.6	1011	
Flexural Strength	(10^3psi Min	(11.5)	(12.5)	(15.5)	(12.5)	1031	
Flexural Modulus	10^6psi Min MPa	(.30) 2067	(.35) 2412	(.35) 2412	(.40) 2756	1031	
Compressive Strength	10^3psi Min	(11.0) 75.8	(12.0) 82.7	(12.0) 82.7	(13.5) 93.0	1021	
Hardness, Rockwell, M Scale	Min	65.0	65.0	65.0	68.0	1081	
Heat Deflection, (264 psi) 1820 k Pa	(^{o}F) Min ^{o}C	(260.0) 126.7	(320.0) 160.0	(375.0) 190.6	(260.0) 126.7		ASTM D648
Flammability Seconds, Exting Time	Max △1	5	5	5	5		4.3.2
Smoke Density Flaming, D_s (6 min)	Max △1	100	100	100	100		4.3.3

△1 Specimen thickness, 0.040 ± .005 inch

4.3.3 Smoke density. - NBS Smoke Chamber, flaming condition, in accordance with FAA-NPRM-Smoke Standard Docket No. 9611, Notice 75-3, Feb. 1975, Appendix F (1).

5. PREPARATION FOR DELIVERY

5.1 Packaging and packing. - Unless otherwise specified in the contract or order, packaging and packing shall be in accordance with standard commercial practice in a manner that will ensure safe transportation at the lowest rate to the point of delivery. Containers shall meet Uniform Freight Classification Rules or regulations of the common carriers as applicable to the mode of transportation.

5.2 Marking. - In addition to any special marking required by the contract or order, shipping containers shall be marked to include but not limited to the following information:

(a) Manufacturer's name
(b) Product designation and batch number
(c) Number and revision letter of this specification
(d) Purchase order number
(e) Quantity

6. NOTES

6.1 Intended use. - The thermoplastic molding compounds covered by this specification meet or exceed all applicable requirements for use in commercial aircraft interiors.

APPENDIX D

PROPOSED MATERIAL SPECIFICATION
THERMOPLASTIC SHEET, THERMOFORM GRADE

1. SCOPE

1.1 Scope. - This specification covers thermoplastic sheets which may be processed by thermoforming techniques into interior aircraft components (see 3.1 for type designations). Materials conforming to this specification meet applicable FAA regulations for flammability and smoke generation for use in commercial aircraft interiors.

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards, of the issue in effect on the date of purchase order, form a part of this specification to the extent specified herein.

Federal	
FED-STD-406	Plastics, Methods of Testing
0-M-232	Methanol (Methyl Alcohol)
TT-E-751	Ethyl Acetate
Industry	
ASTM D 648	Method of Test for Deflection Temperature of Plastics Under Load

3. REQUIREMENTS

3.1 Material. - The material shall consist of the specified polymers and any additional ingredients required to conform to this specification in all respects.

Type I	Polycarbonate
Type II	Polyethersulfone
Type III	Modified polysulfone
Type IV	Chlorinated polyvinyl chloride
Type V	To be determined
Type VI	To be determined

3.2 Quality. - The product shall be uniform in quality and condition, clean and free from imperfections detrimental to fabrication, appearance, and performance of parts.

3.3 Color. - The color of the sheet material shall be as specified on the contract or purchase order. All colors shall remain fast when exposed to a Fade-O-Meter test for 50 hours. When color is not specified, the material shall be in the natural color.

3.4 Thickness tolerance. - Unless otherwise specified, thickness shall not vary more than 10 percent from the nominal thickness ordered.

3.5 Surface finish. - The surface finish of sheets shall be smooth, polished, semigloss or embossed, as specified.

3.6 Machinability. - The material shall be capable of machining by standard machining operations required for the specified tests herein without cracking, splitting, as otherwise impairing the material for aircraft use.

3.7 Properties. - The physical properties of the sheet shall conform to Table I.

3.8 The corner of each sheet of material shall be identified with a label, applied with a pressure sensitive adhesive, legibly marked with the following information:

TABLE I (TARGET VALUES) (MINIMUMS)

Property	Unit	Value						FED-STD-406 Test Method	Other Test Method
		Type I	Type II	Type III	Type IV	Type V	Type VI		
Tensile Strength	(psi, min.) MPa	(8500) 58.6	(8000) 55.1	(6000) 41.3	(5000) 34.5			1011 Speed C	
Flexural Strength	(psi, min.) MPa	(12 000) 82.7	(10 000) 68.9	(9500) 65.5	(9500) 65.5			1031	
Specific Gravity	Max.	1.30	1.40	1.30	1.60			5011	
Modulus of Elasticity	(psi, min.) MPa	(300 000) 2067	(300 000) 2067	(250 000) 1723	(250 000) 1723			1031	
Heat Deflection Temp., Avg.	(^{o}F) min. at (264 psi) ^{o}C 1820 kPA	(220) 104.4	(240) 115.6	(200) 93.3	(180) 82.2				4.1.2
Impact Strength (Notched Izod)	ft-lb/in [1] N.m/m	(10.0) 535	(2.0) 107	(5.0) 268	(5.0) 268			1071	
Elongation	% min.	70	10	20	30			1011 Speed C	
Flame Resistance	seconds and (inches), max. cm	5 sec (4 in.) 10.2	5 sec (4 in.) 10.2	5 sec (4 in.) 10.2	5 sec (4 in.) 10.2				4.1.4
Smoke	Ds max (6 min.)	>150	>100	>200	>200				4.1.5
Unforming Temperature	(^{o}F min.) ^{o}C	(200) 93.3	(220) 104.4	(190) 87.8	(170) 76.7				4.1.1
Stress Cracking Resistance	- - - -	Pass	Pass	Pass	Pass				4.1.3

[1] Specimen thickness shall be 0.125 inch.

(Material Description)
Resin Manufacturer______________________________
Material Specification________________ Type____________
Color__________________________
Gauge (mils)____________________________
Extruder____________________________________
Date of Extrusion______________________

4. QUALITY ASSURANCE PROVISIONS

4.1 Test methods. - The test methods used shall be as specified herein and in accordance with any additional or supplemental requirement which may be specified on the purchase order. In case of conflicting requirements, this specification shall govern.

4.1.1 Unforming test. - A 15 cm (6 in.) diameter hemisphere shall be formed from 0.318 ± 0.03 (0.125 ± 0.012 in.) thick material. The hemisphere height from its base shall be accurately determined at room temperature. Using an air circulating oven, the hemisphere shall be run through a heating cycle which increases at 3 °C (5 °F) intervals every 2 hours. The starting temperature shall be 71 °C (160 °F). At the end of each temperature interval, the hemisphere shall be cooled to room temperature and its height shall be accurately measured. The unforming temperature shall be the temperature interval in degrees Celsius (Fahrenheit) which produces a 0.7 cm (0.3 in.) decrease in height of the hemisphere from its original measured height.

4.1.2 Heat deflection temperature test. - Test in accordance with ASTM D648. For sheets less than 0.318 cm (0.125 in.) but more than 0.10 cm (0.040 in.) in thickness, test by making a hot press laminate sample having a minimum thickness of 0.318 cm (0.125 in.). The direction of loading shall be perpendicular to the edges of each laminated specimen.

4.1.3 Stress cracking resistance

4.1.3.1 Sample size and configuration. - Using sheet stock from the production lot, select three samples at random that measure at least 6 inches square.

4.1.3.2 Test equipment

(a) The solvent shall be as follows:
50/50 mixture (p.b.v.) of TT-E-751 Ethyl Acetate and
O-M-232 Methanol (Methyl Alcohol).

(b) Pontachrome Blue-Black Dye,
1.0 grams per 200 ml. of solution.

(c) Cotton gauze.

4.1.3.3 Procedure. - Thoroughly wet the cotton gauze with the test mixture specified in 4.1.3.2. Wipe the sample slowly with the gauze, allowing the solvent to wet the sample for three minutes. Allow the sample to air-dry for one minute and then carefully inspect for cracks or crazing. If more than one of the samples exhibit any stress cracking, the lot of material shall be rejected.

4.1.4 Flame resistance. - 60 second vertical flame exposure per FAA - FAR 25.853(a) Appendix F.

4.1.5 Smoke generation. - NBS Smoke Chamber, flaming condition per FAA - NPRM - Smoke Standard Docket No. 9611, Notice 75-3 Feb. 1975 Appendix F(1).

4.2 Qualification requirements. - A vendor shall not begin to submit material to this specification until tests have been successfully performed to demonstrate conformance to the requirements specified in 3.2 through 3.7, and a shop tryout has been successfully performed using production tools. Qualification shall be made only after pilot parts have met all the requirements of formability.

4.3 Acceptance requirements. - Each lot of material shall be tested for tensile strength, elongation, specific gravity, smoke generation and flame resistance as specified in Table I, and inspected for conformance to the requirements in 3.2 through 3.5.

4.4 Test report. - Unless otherwise specified, the vendor shall furnish two copies of the results of tests to determine conformance to this specification. This report shall include the purchase order number, lot number, material specification number and date of report.

5. PREPARATION FOR DELIVERY

5.1 Each package or lot of material shall be permanently and legibly marked to give the following information:

THERMOPLASTIC SHEET - (Type of Material)
Material Specification_____________ Rev.______, Type_______
Color___________________
Size____________________
Purchase Order No.________________
Manufacturer___________________________
Date of Manufacture______________________

6. Notes: This specification meets or exceeds all applicable requirements for thermoplastic sheet material to be used in commercial aircraft interiors.