

Overview of Firemen Program at Ames Research Center

Demetrius A. Kourtides

ABSTRACT

The Ames Firemen Program is described. The key elements of the program involve (a) the development and evaluation of aircraft interior composite panels (b) the thermochemical and flammability characterization of thermoset and thermoplastic resins and (c) the evolution of fire resist aircraft seat components. The first two elements are described in this paper.

In the first area of interior panels, the processing and evaluation of composites fabricated from currently used resins and advanced fire resistant resins is described. Laboratory test methodology used to qualify candidate composite materials includes thermochemical characterization of the polymeric compounds and evaluation of the completed composite assemblies for flammability, fire endurance and smoke evolution. The use of these test methods will be discussed in comparing advanced lamination resins and composites consisting of modified phenolics, bismaleimide and polyimide, with conventional baseline materials consisting of epoxy. Particular attention is given to the development of assessment criteria such as fire endurance, or fire containment capability, and smoke produced when these composites are subjected to a fire environment.

In the second area of thermoplastic resins, the thermochemical and flammability characteristics of some typical thermoplastic materials currently in use and others being considered for in aircraft interiors are described. The properties studied included (1) thermomechanical properties such as glass transition and melt temperature, (2) changes in polymer enthalpy, (3) thermogravimetric analysis in anaerobic and oxidative environments, (4) oxygen index, (5) smoke evolution, (6) relative toxicity of the volatile products of pyrolysis, and (7) selected physical properties. The generic polymers that were evaluated included: acrylonitrile butadiene styrene, bisphenol A polycarbonate, 9,9 bis (4-hydroxyphenyl) fluorene polycarbonate-poly (dimethylsiloxane) block polymer, phenolphthalein-bisphenol A polycarbonate, phenolphthalein polycarbonate, polyether sulfone, polyphenylene oxide, polyphenylene sulfide, polyaryl sulfone, chlorinated polyvinyl chloride homopolymer, polyvinyl fluoride, and polyvinylidene fluoride. Processing parameters, including molding characteristics of some of the advanced polymers, are described. Test results and relative rankings of some of the flammability, smoke, and toxicity properties are presented. Under these test conditions, some of the advanced polymers evaluated were significantly less flammable and toxic or equivalent to polymers in current use.

Overview of Firemen Program at Ames Research Center

Presented at the FIREMEN Program Review

by D. A. Kourtides

April 14, 1978

- Figure 1. I will give a brief overview of the Firemen Program at Ames. Before I begin, I would like to acknowledge Boeing Commercial Airline Co. for providing some of the data to be presented here.
- Figure 2. The objectives of the program as stated here are to provide an understanding and certain selection criteria for the development and use of fire-resistant materials for aircraft interiors. The primary objective is to reduce flame propagation, smoke, and toxicity in the cabin and to increase fire containment capability in selected areas such as lavatories and cargo compartments. In this presentation I will summarize primarily 2 areas:
- (a) Aircraft interior panels
 - (b) Thermoplastics--which would be useable either as moldings or films in aircraft interiors.
- Figure 3. The present contractual activities are shown here. We have an ongoing program at Boeing for the development of fire-resistant films. A program has just been initiated also for the development of fire-resistant inks for possible replacement of the acrylic inks. The details of these programs will be described by Gerald Johnson. We are presently in phase II for the evaluation of fire-resistant aircraft seat components at Douglas. We are contemplating efforts for flashover laboratory tests for the decorative surface and we are initiating an effort for the evaluation of fire-resistant polyimide foam as an edge closeout for panels.

Figure 4. The program plan is shown here. Phase I and Phase II of the program involved the development and evaluation of composite panels. This program is essentially completed. We are presently in Phase III and Phase IV at Boeing for the development of fire-resistant films and inks. These programs will be discussed in detail by Gerald Johnson. The program is supported by our R & T program for the development of phosphorylated epoxy adhesives (Dr. Bilow will be describing these), transparent films and edge closeouts. In addition, we are conducting fire containment and flashover tests at the University of California. Boeing will be fabricating both baseline and advanced panels, which eventually will be tested by FAA-NAFEC in the C-133 aircraft.

Figure 5. The program on thermoplastics has been transferred to JSC. At the present time, we are in Phase II of the aircraft seat program. We hope to start a program on the use of advanced materials for post-crash fire protection.

Figure 6. I will briefly discuss the aircraft interior panels work.

Figure 7. The purpose of this program was to assess the relative flammability and thermochemical properties of some typical state-of-the-art and candidate experimental aircraft interior composite panels, and to develop an understanding of the relationship of flammability and thermochemical properties of these systems. Specifically, aircraft interior composite panels were characterized as to their thermal stability, oxygen index of the composite components, smoke evolution from the panels, fire containment capability or fire endurance,

identification of the pyrolysis effluents, relative toxicity of the degradation products and mechanical properties.

Figure 8. The integration of the composite panel program is shown here. A panel has been selected jointly by ARC and Boeing and these panels will be tested by JSC at the Douglas Cabin Fire Simulator. Once the film and ink development work is completed, we hope to be able to develop materials and process specification for an advanced panel configuration which could be useable to all the airfram manufacturers. In addition, the information generated on the performance of these materials could be useful to FAA for consideration in the rule making process.

Figure 9. The composite panels used by most airframe manufacturers as interior paneling are sandwich panels that vary slightly in configuration, component composition, thickness, and density depending on the type of aircraft in which they are used and the specific application. In general, the panel consists of a clear polyvinyl fluoride film which is bonded to a polyvinyl fluoride decorative film bonded to a fiberglass epoxy resin laminate. The complete laminate is bonded to an aromatic polyamide honeycomb core either when the prepreg is uncured or with a suitable adhesive bond ply depending on the resin used in the prepreg. The current method of bonding the skins to the core consists of using an epoxy resin-impregnated bond ply over which is applied the 181 E glass cloth/polyvinyl fluoride decorative laminate. The resin in the bond ply provides the adhesives to bond the skin to the honey comb and the decorative laminate to the bond ply. Curing is accomplished at approximately 100°C with vacuum bag pressure. For panels requiring decorative laminates on one side

only, the bond ply provides the backside skin. The epoxy resin used in these panels is a fire-retardant bisphenol A type epoxy resin cured with methylene dianiline.

Figure 10. Three types of advanced resin systems were used for the fabrication of the laminates used in these composites: bismaleimide, polyimide and phenolic resins. Exact formulation for the polyimide and phenolic resins was not available from the manufacturers. The bismaleimide is an addition type polyimide. The resin is produced by mixing a bismaleimide with a diamine at a specified ratio resulting in a resin with controlled crosslink density. The resin polymerizes thermally without loss of volatiles. The core of this panel was filled with a quinone dioxime or polyquinoxaline foam to provide additional fire containment capability. The polyimide and phenolic panels were fabricated from commercially available resins. All composites fabricated were 2.54 cm thick. The laminates were adhered to the honeycomb structure using the various types of resin-fiberglass adhesive plys indicated. It can be seen that in general, longer processing times were required for the bismaleimide and polyimide panels than the phenolic panels. Density of the panels was approximately the same (90-100 Kg/m³).

Figure 11. In this slide we compare the oxygen index of the laminating resins with their relative anaerobic char yield. Thermo analyses of the facesheet resins were conducted on a Dupont 950 thermogravimetric analyzer (TGA) using nitrogen atmosphere at a heating rate of 10⁰C/min. The polyimide resin was the most thermally stable resin followed by the modified phenolic, bismaleimide. The char yield indicated is that of the resin cured to an optimum condition. The oxygen indexes

(OI) of the components comprising the composites were determined in accordance with ASTM D-2863. The oxygen index was measured using one ply laminates consisting of the 181 glass with 30-47 resin. The OI indicated is calculated based in the fraction of the resin present in the fibergalss and the fiberglass having an LOI of 100%. The specimans again were cured to an optimum condition. It can be seen that the OI increases as the char yield of the laminating resin increases. The polyimide system had the highest oxygen index followed by the phenolic system, the bismaleimide system and the baseline epoxy syste.

Figure 12. The amount of heat released from the various panels was measured using the OSU heat release rate apparatus at Boeing run at heat fluxes of 2.5 to 5.0 W/cm^2 and with specimans mounted vertically. The total heat released from the facesheet laminates is plotted against the incident heat flux on the specimans. There was a significant difference between the epoxy and polymide systems at 5.0 W/cm^2 . The differences are due to the chemical structure, char formation, and amount of resin consumed in the two systems. The differences in the total heat released are greater in the higher heat flux range than the lower heat flux range.

Figure 13. The smoke emission for the systems was measured in the NBS smoke chamber. In this slide the specific optical density at 4 minutes is plotted against the heat flux to the panels. The samples were tested at 1, 2.5, and 5.0 W/cm^2 under flaming conditions. It can be seen that the smoke release rate is increased as the

heat flux was increased. This increase is due to more material becoming involved in the combustion at the higher heat fluxes. The smoke release for the epoxy system was the greatest, followed in order by the bismaleimide, modified phenolic and polyimide. It is desirable to have a D_s value of less than 100 at 2.5 W/cm^2 for materials that are proposed for aircraft interiors.

Figure 14. The panels were tested in the Ames T-3 Fire Test Facility at a heat flux of approximately 10 W/cm^2 . This test provided a comparison of the fire endurance capability of the composite panels. The backface temperature rise of the panel is plotted as a function of time when the samples are subjected to this type of fire. (This is shown by the solid lines and indicated on the left side of the slide.) It can be seen that the backface temperature of the conventional epoxy composite B reached 200°C in 2.5 minutes; whereas, it took as long as 8 minutes for the foam filled bismaleimide composite A to reach a comparable backface temperature. The other composite panels, C and D, were slightly better than A. The broken line represents the front face temperature of the sample exposed to the fire and is shown on the right side of the slide. Samples were 8" x 8" x 1" thick.

Figure 15. Based on processability, cost and flammability properties, the modified phenolic facesheets were selected as the optimum system to be used in the fabrication of the advanced panel. In this slide, the comparative flammability properties of the epoxy and phenolic facesheets are summarized. It can be seen that a significant

decrease in propensity to burn, smoke evolution and heat release was achieved by the use of the modified phenolic resin in the facesheet. In addition, the amount of hydrogen fluoride was decreased by the use of polyvinyl fluoride/polycarbonate decorative film.

Figure 16. I will briefly discuss the thermoplastics work. This task has been transferred to JSC but work is continuing at ARC in the development of transparent films based on some of the thermoplastics studied.

Figure 17. The thermoplastic polymers evaluated included both state-of-the-art and other high temperature polymers. The typical polymer structure of the polymers is shown here. Polymers were evaluated as injection molded or extruded sheets and as films. The polymers that were evaluated included: acrylonitrile butadiene styrene, bisphenol A polycarbonate, 9,9 bis (4-hydroxyphenyl) fluorene polycarbonate-poly (dimethylsiloxane) block polymer, phenolphthalein-bisphenol A poly-carbonate, and phenolphthalein polycarbonate.

Figure 18. Polyether sulfone, poly-phenylene oxide, polyphenylene sulfide, polyaryl sulfone, chlorinated polyvinyl chloride homopolymer, polyvinyl fluoride, and polyvinylidene fluoride are shown here. Processing parameters, including molding characteristics of some of the advanced polymers, were also studied.

Due to the shortness of time, I will only summarize some of the flammability properties of these polymers.

Figure 19. The char yield of the polymers was determined at 800°C in nitrogen and air. Vc is defined as the percent weight remaining at the temperature indicated. The anaerobic Vc is considered to be more relevant since it represents more likely the fire environment.

Figure 20. In this slide, we compare the relative anaerobic char yield of the polymers at 800°C with the oxygen index at 23°C. Parker and Winkler in 1968 and later in 1972 and 1975 with other coauthors have shown a direct relationship of OI of thermoset polymers to their anaerobic char yield. Van Krevelen has shown a similar relationship with other thermoplastic polymers such as polyethylene and polypropylene. The same relationship can be observed in this study. It can be seen that, in general, polymers with high char yield exhibit a high oxygen index. Chlorinated polyvinyl chloride homopolymer (samples 17 and 25) exhibit a high oxygen index and a relatively low char yield. The char yield shown here has been adjusted to include the equivalent of 0.539 g of HCl per 1.0 g of initial sample of polymer combusted. It is known (47) that HCl is a flame inhibitor and the high oxygen index is attributed to the quenching effect of the HCl during the test. The relationship of char yield and OI indicates that possibly char yield is a key criterion for the selection of thermally stable polymers for critical applications such as aircraft interiors.

Figure 21. The relative flammability characteristics of these polymers are shown here. For comparative purposes, the values of the material properties are indicated in terms of percent, 100% indicating the most desirable fire-safe material properties.

The properties indicated are char yield, percent light transmittance at 4 minutes, oxygen index and relative toxicity as measured using the NASA-USF toxicity chamber.

To rank materials, it is desirable to develop a "fire safety equation" that would assign weight to specific measurements of each variable. That is, oxygen index, smoke evolution, toxicity and char yield of each polymer. Development of such an equation is dependent on the identification of the variables to be measured, determination of the importance of each variable to the real aircraft fire situation, selection of measurement techniques for each variable, and determination of the weight to be assigned to the measurement of each specific variable to reflect the real fire situation. This is an extremely difficult task and will be discussed later.

Figure 22. In this case we assumed equal weight assignment to each flammability parameter and used the percent values indicated previously for an over simplified relative ranking of the polymers. The relative fire resistance of the polymers is shown against their relative char yield. It is shown that polymers with high char yield possess high relative fire resistance.

Figure 23. In summary, we have completed jointly with Boeing the evaluation of 13 types of composite panels based on the following four laminating resins: epoxies, modified phenolics, polyimides and bismaleimides. Based on processing, cost and combined flammability properties, the phenolic norolac resin has been selected as the optimum laminating resin for fabricating advanced panels. These advanced panels are

currently being constructed by Boeing into lavatory structure for testing at the Douglas Cabin Fire Simulator. The thermoplastics program is currently being sponsored by JSC. The screening of candidate seat materials has been completed.

Figure 24. Our plan is to complete the panel development in the area of:

(a) fire-resistant films which can be used either in combination or without PVF.

(b) Phosphorylated epoxy adhesive and

(c) fire resistant inks.

We anticipated to provide material and process specifications for these materials systems in addition to materials which can be tested under full scale conditions.

**AERONAUTICAL MATERIALS AND STRUCTURES
SYSTEMS TECHNOLOGY**

OVERVIEW

FIREMEN—FIRE RESISTANT MATERIALS

RTOP 510-56-01

D. A. KOURTIDES

FIREMEN PROGRAM REVIEW
NASA AMES RESEARCH CENTER
APRIL 13, 14, 1978

Fig. 1

**PROGRAM OBJECTIVE: AERO MATERIALS & STRUCTURES SYSTEMS
TECHNOLOGY
SPECIFIC OBJECTIVE: FIREMEN—FIRE RESISTANT MATERIALS**

- **RTOP OBJECTIVE (510-56-01)** TO PROVIDE THE MATERIALS TECHNOLOGY REQUIRED TO MAKE FUTURE AIRCRAFT MATERIALS, STRUCTURES AND SUBSYSTEMS AS FIRE RESISTANT AS FEASIBLE, AND TO ACCELERATE THE TRANSFER OF THIS TECHNOLOGY TO AIRCRAFT MANUFACTURERS.

- **TARGETS**
 - PROVIDE MATERIALS TECHNOLOGY FOR REDUCING FLAME PROPAGATION, SMOKE, AND TOXICITY IN CABIN
 - INCREASE FIRE CONTAINMENT CAPABILITY IN SELECTED AREAS OF THE CABIN/CARGO
 - EVALUATE FIRE-RESISTANT TRANSPARENT DUST COVERINGS
 - DEVELOP ADVANCED SEAT CUSHION SYSTEMS
 - PROVIDE MATERIALS TECHNOLOGY FOR FIRE- RESISTANT FILMS, ADHESIVES AND INKS

Fig. 2

**PROGRAM OBJECTIVE: AERO MATERIALS AND STRUCTURES
SYSTEMS TECHNOLOGY
SPECIFIC OBJECTIVE: FIRE RESISTANT MATERIALS
RTOP: 510-56-01**

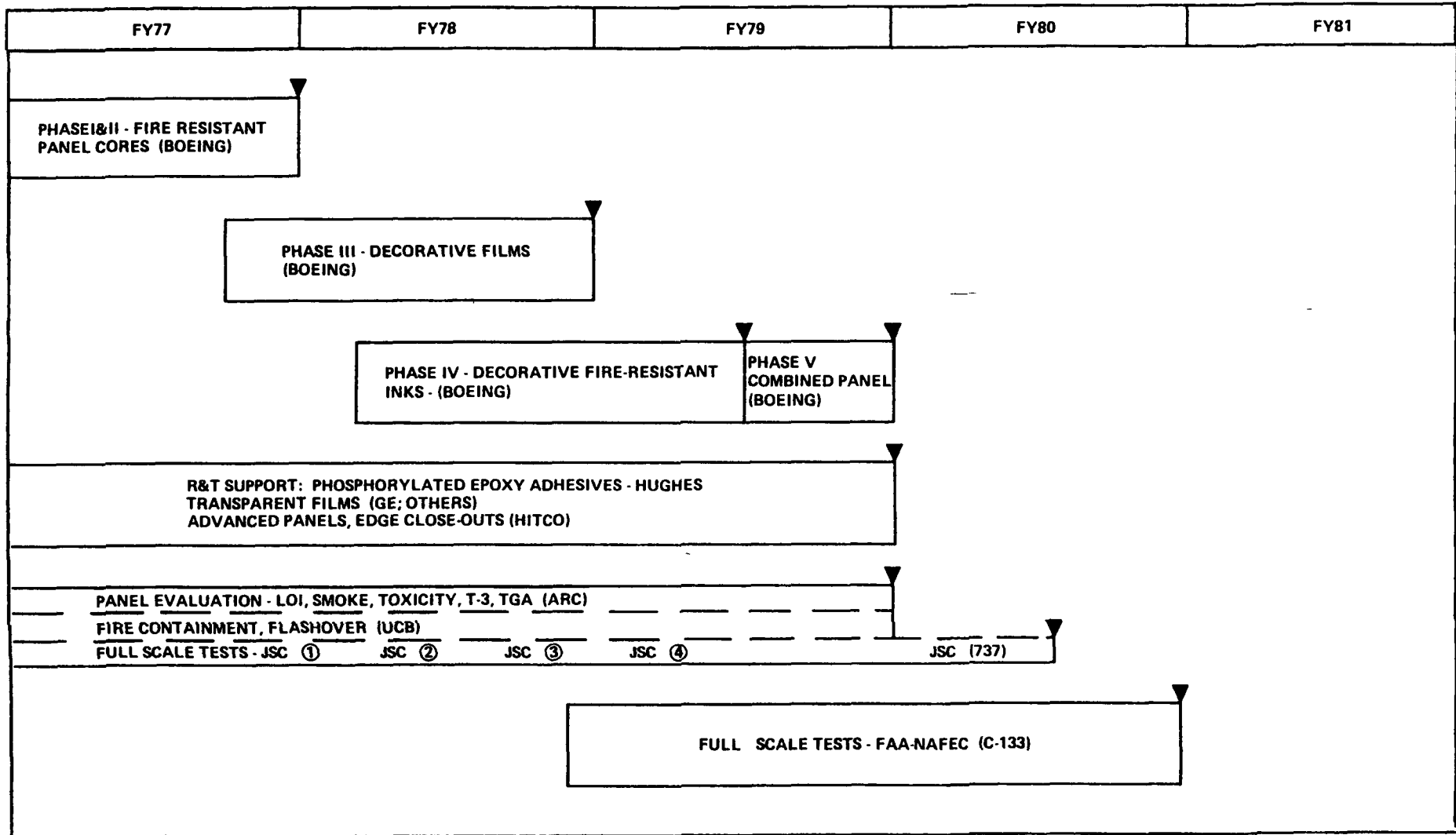
PROGRAM PLAN, FY '78

NO.	ACTIVITY	NET R&D \$K		DURATION
1.	NAS2-7978, MOD. NO. 3, "DEVELOPMENT AND EVALUATION OF INTERIOR PANEL COMPOSITES AND FILMS," BOEING.	99(PY77)		9/77-9/78
2.	RFP 2-27132, "DEVELOPMENT AND EVALUATION OF INKS," BOEING.	99		1/78-1/79
3.	NAS2-9337, "DEVELOPMENT OF FIRE-RESISTANT AIRCRAFT SEAT," DOUGLAS.	99		10/77-10/78
4.	RFP 2- , "FLAME PROPAGATION, FLASHOVER TESTS OF DECORATIVE FILMS/INKS," BOEING.	32		3/78-3/79
5.	NAS-2-7980, "EVALUATION OF FIRE-RESISTANT EDGE SEALS FOR PANELS," HITCO.	35		3/78-3/79

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Fig. 3

PROGRAM OBJECTIVE: AERO MATERIALS & STRUCTURES SYSTEMS TECHNOLOGY
SPECIFIC OBJECTIVE: FIRE RESISTANT MATERIALS - FIREMEN



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Fig. 4

**PROGRAM OBJECTIVE: AERO MATERIALS & STRUCTURES SYSTEMS TECHNOLOGY
 SPECIFIC OBJECTIVE: FIRE RESISTANT MATERIALS - FIREMEN**

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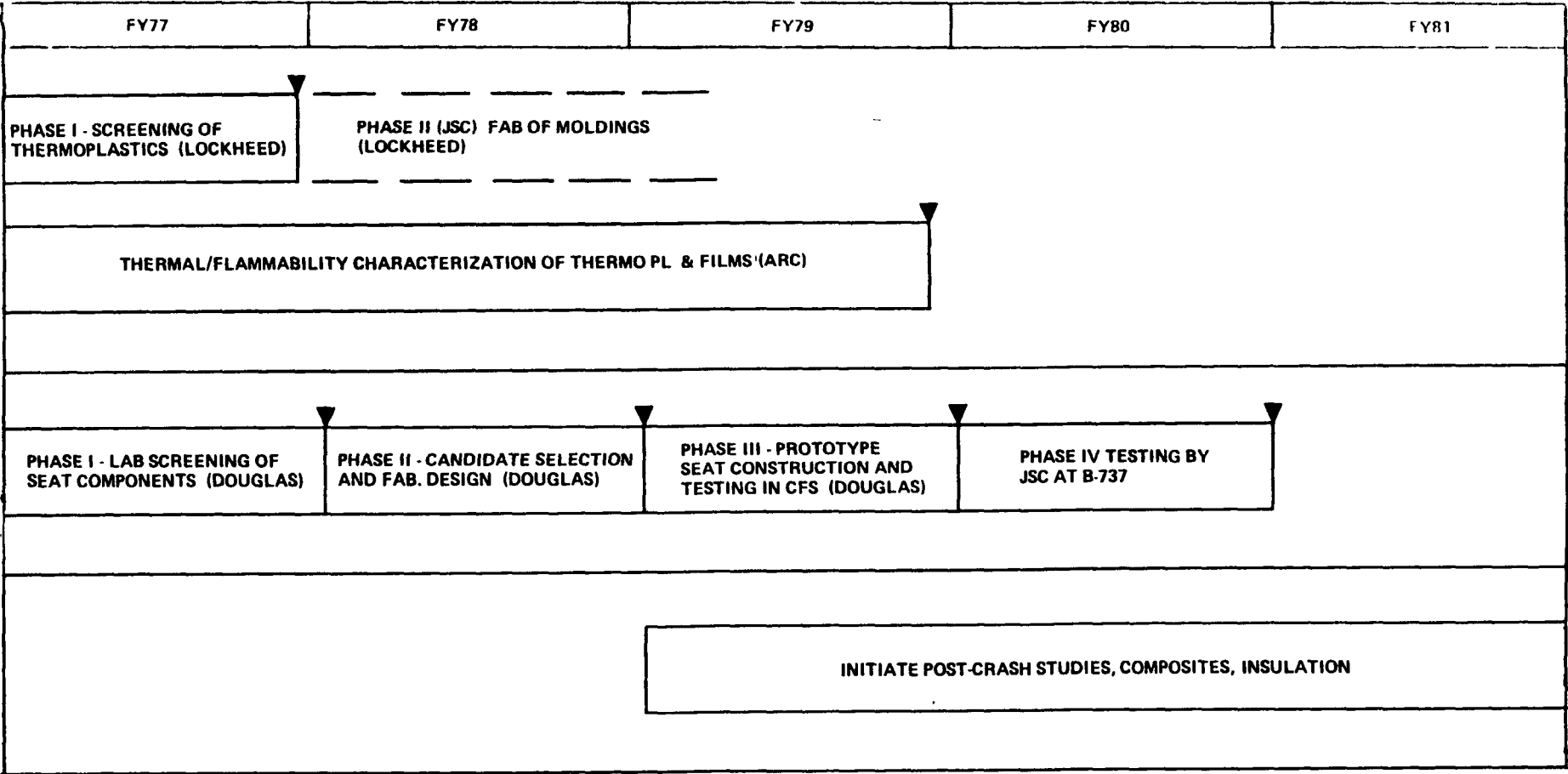


Fig. 5

AIRCRAFT PANELS

PROGRAM OBJECTIVES

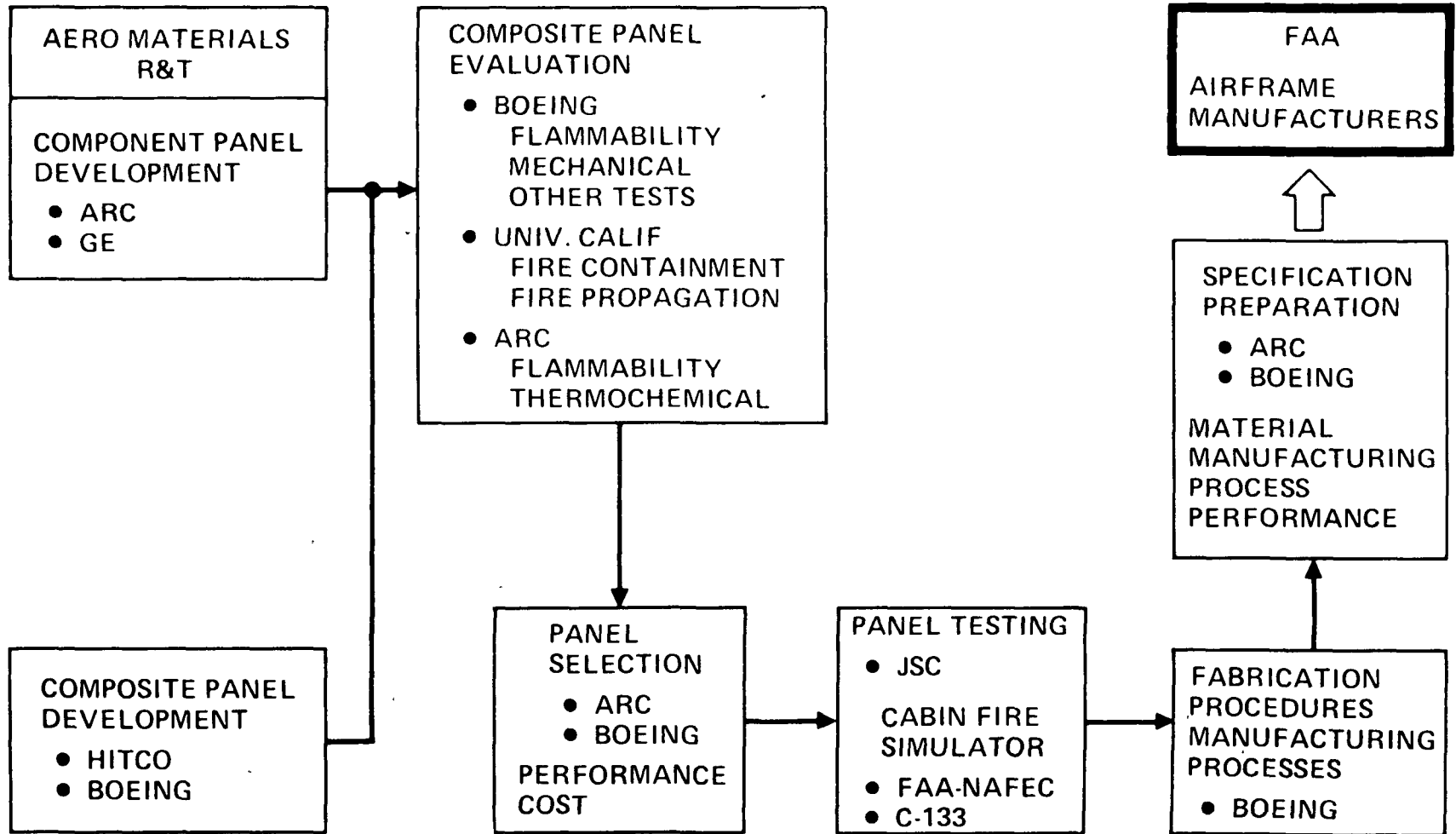
OBJECTIVE

DETERMINE THERMAL-CHEMICAL AND FLAMMABILITY PROPERTIES OF TYPICAL STATE-OF-THE-ART AND OTHER ADVANCED AIRCRAFT INTERIOR COMPOSITE PANELS IN ORDER TO ASSESS THEIR RELATIVE FIRE RESISTANCE.

SCOPE

- DETERMINE PROPERTIES OF PANEL COMPONENTS AND PANELS
 - THERMOMECHANICAL
 - THERMOGRAVIMETRIC ANALYSIS
 - DIFFERENTIAL THERMAL ANALYSIS
 - PROCESSING
 - TEMPERATURE, PRESSURE (MOLDING) AND CURE PARAMETERS
 - FLAMMABILITY
 - OXYGEN INDEX
 - SMOKE EVOLUTION (NBS AND OSU APPARATUS)
 - PHYSICAL-MECHANICAL
 - FLATWISE TENSION
 - COMPRESSION
 - WEAR
 - PEEL STRENGTH
 - ELONGATION
 - THERMAL
 - THERMAL EFFICIENCY
 - HEAT RELEASE
 - TOXICITY
 - APPARENT LETHAL CONCENTRATION
 - TOXIC GAS EVOLUTION

INTEGRATION OF COMPOSITE PANEL PROGRAM



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Fig. 8

BASELINE EPOXY PANEL CONFIGURATION

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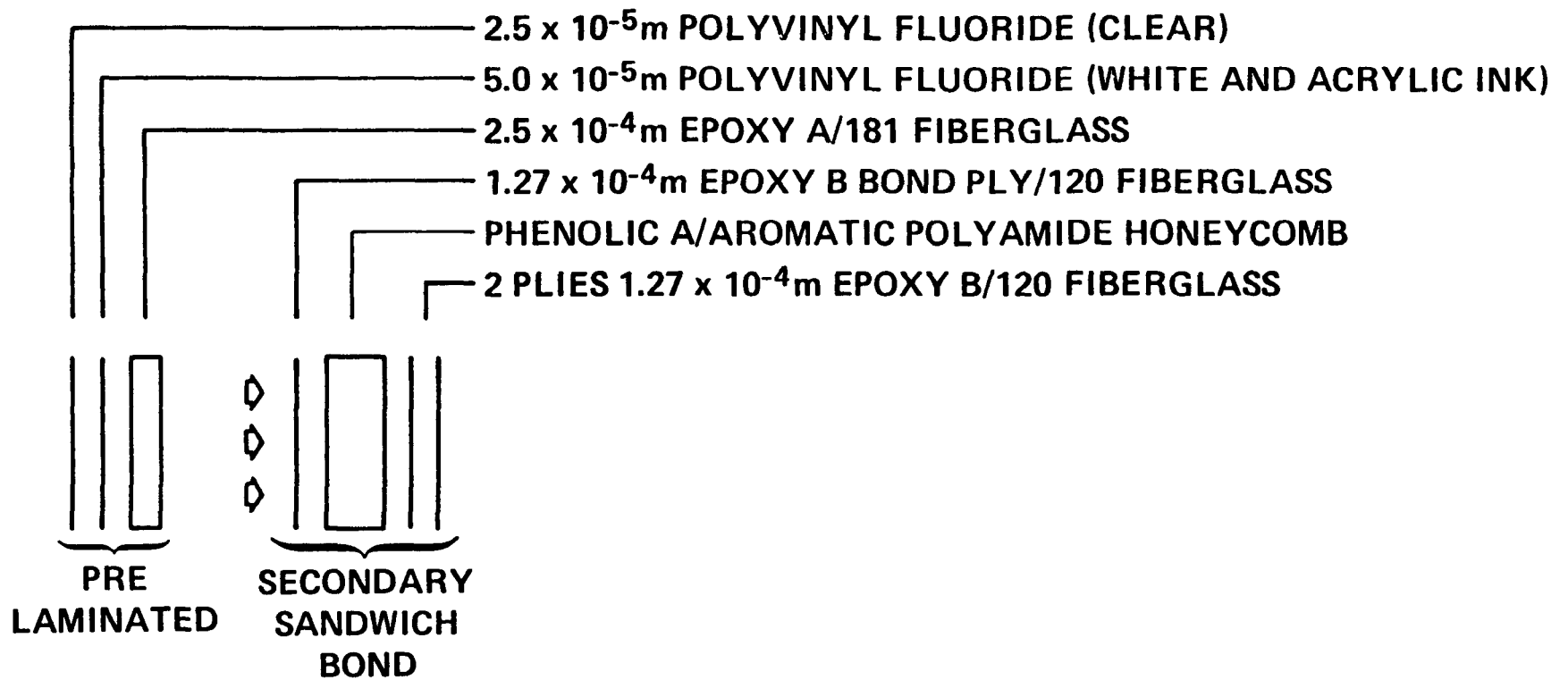
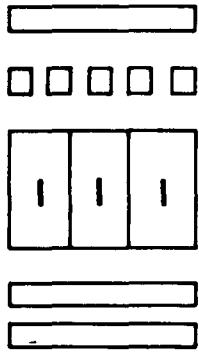


Fig. 9

ADVANCED PANEL CONFIGURATION



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	BISMALEIMIDE	POLYIMIDE	PHENOLIC
	<p>BISMALEIMIDE/181 FIBERGLASS BISMALEIMIDE/120 FIBERGLASS POLYIMIDE A ADHESIVE</p> <p style="text-align: center;">PHENOLIC A/ AROMATIC POLYAMIDE 29 kg/m³ 32 kg/m³ QDO FOAM</p> <p>POLYIMIDE A ADHESIVE</p> <p>2 PLIES BISMALEIMIDE/ 120 FIBERGLASS</p>	<p>POLYIMIDE B/181 FIBERGLASS POLYIMIDE B/120 FIBERGLASS POLYIMIDE C ADHESIVE</p> <p style="text-align: center;">POLYIMIDE C/ AROMATIC POLYAMIDE 48 kg/m³</p> <p>POLYIMIDE C ADHESIVE</p> <p>2 PLIES POLYIMIDE B/ 120 FIBERGLASS</p>	<p>PHENOLIC B/181 FIBERGLASS PHENOLIC B/120 FIBERGLASS</p> <p style="text-align: center;">PHENOLIC A/ AROMATIC POLYAMIDE 48 kg/m³</p> <p>2 PLIES PHENOLIC B/ 120 FIBERGLASS</p>
CURE CYCLE:			
PRESSURE	5.76 x 10 ⁴ sec, 68.9 kN/m ² , 160°C	3.60 x 10 ³ sec, 68.9 kN/m ² , 177°C	720 sec, 68.9 kN/m ² , 160°C
BOND	5.76 x 10 ⁴ sec, 68.9 kN/m ² , 177°C	3.60 x 10 ³ sec, 68.9 kN/m ² , 177°C	3.60 x 10 ³ sec, 68.9 kN/m ² , 127°C

Fig. 10

EFFECT OF CHAR YIELD ON OXYGEN INDEX OF FACESHEET LAMINATING RESINS

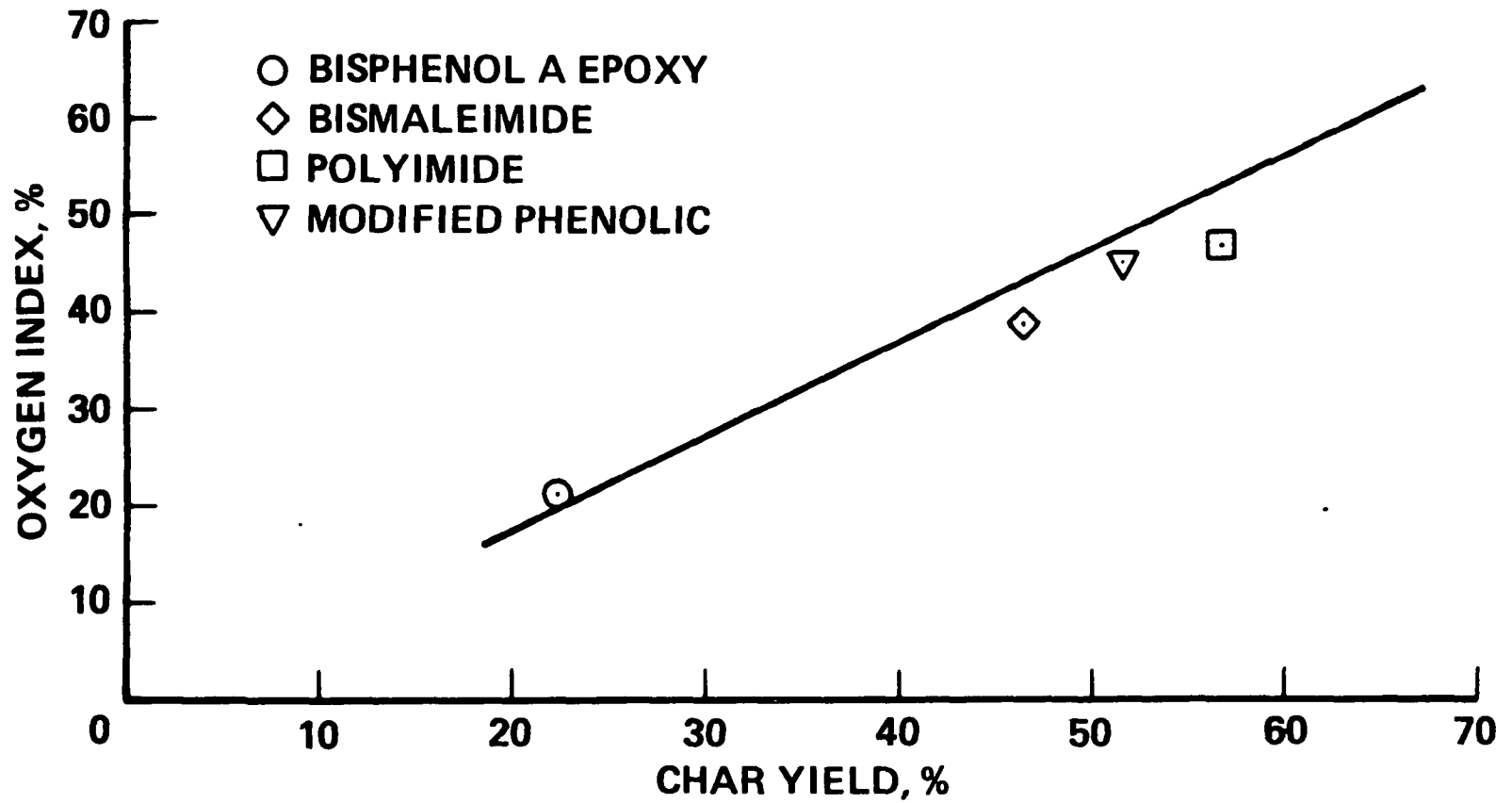


Fig. 11

EFFECT OF HEAT FLUX ON TOTAL HEAT RELEASED FROM PANELS

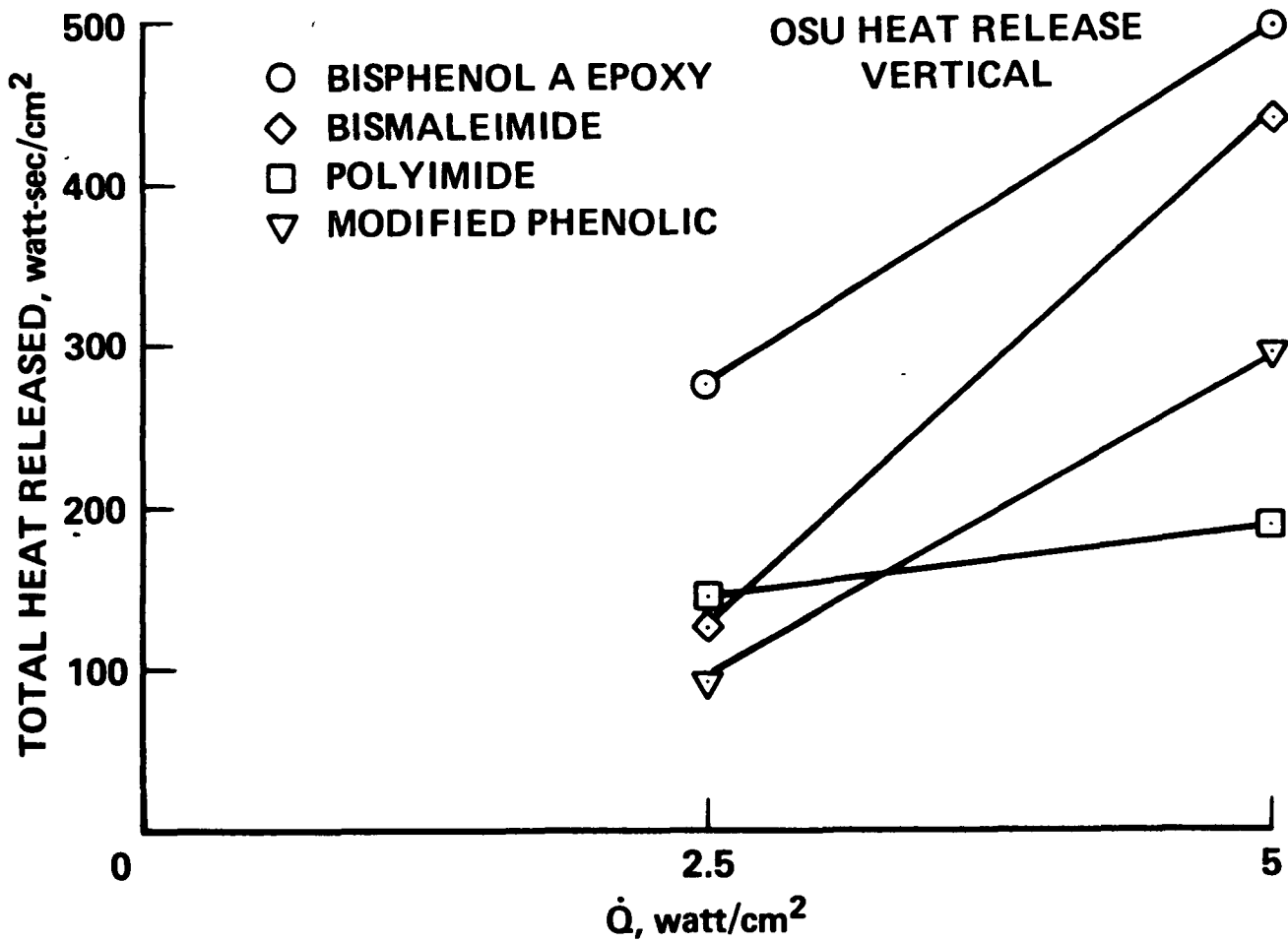


Fig. 12

EFFECT OF HEAT FLUX ON SMOKE DENSITY

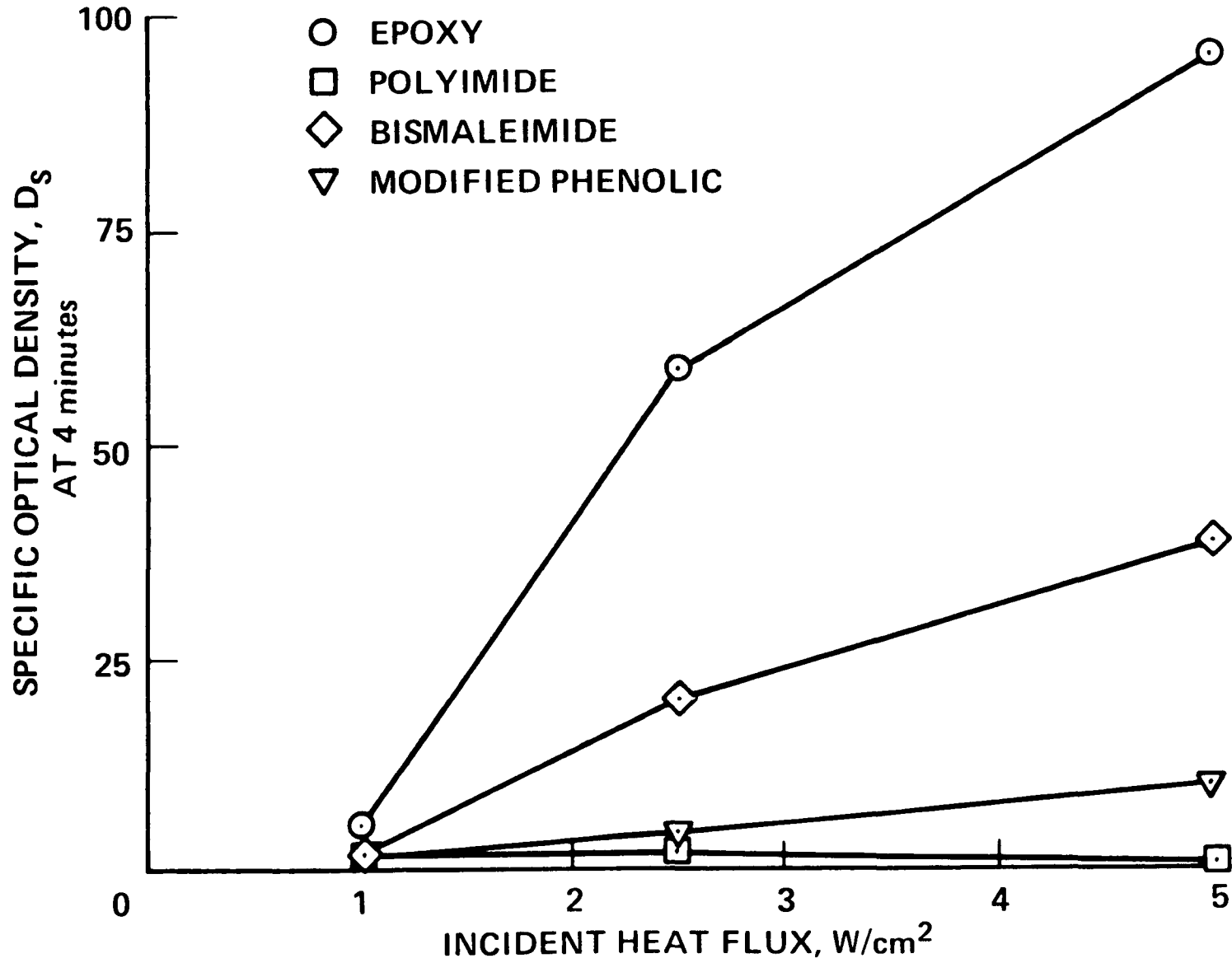


Fig. 13

THERMAL EFFICIENCY OF PANELS

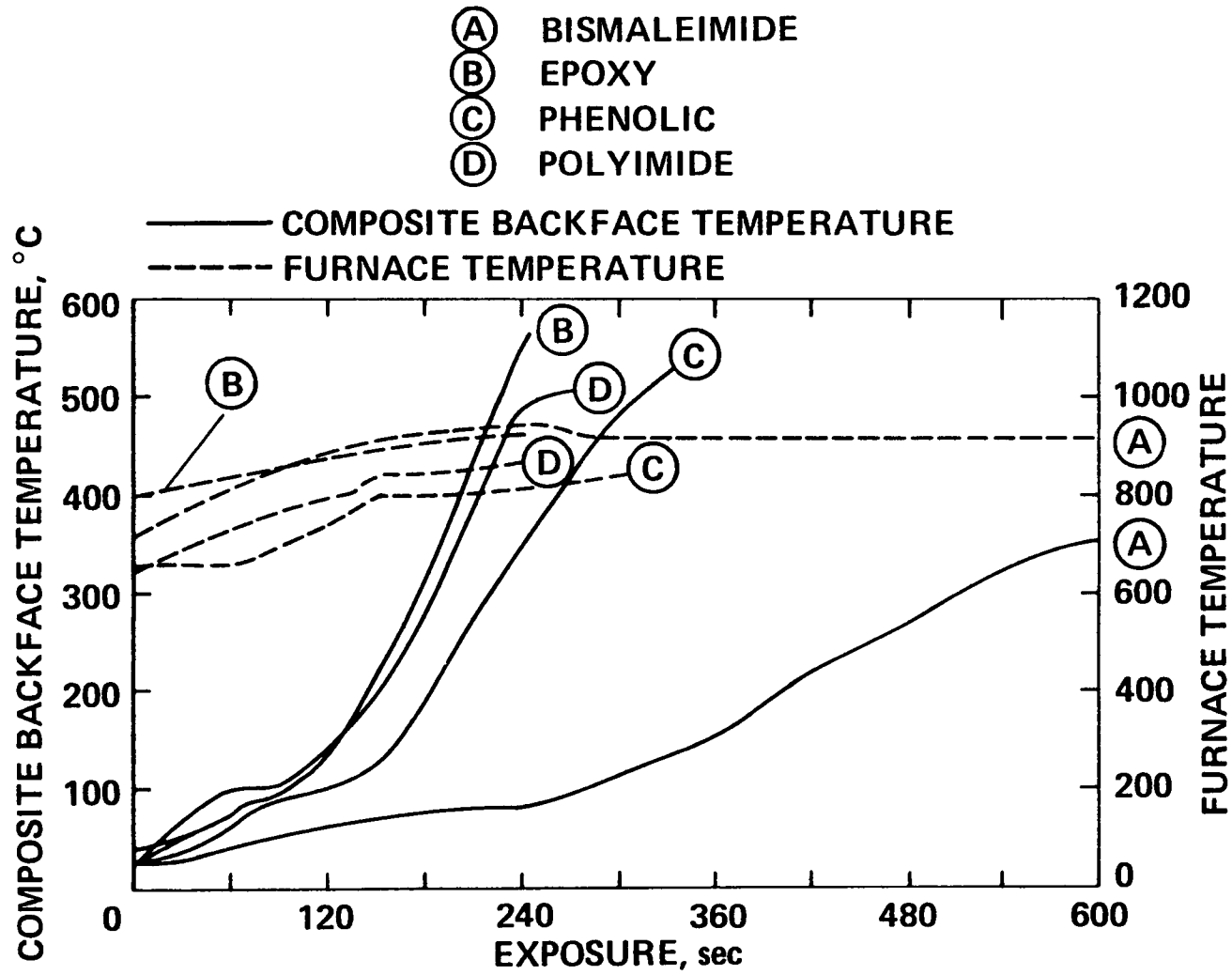


Fig. 14

COMPARATIVE FLAMMABILITY PROPERTIES OF EPOXY AND PHENOLIC FACE SHEETS

	<u>EPOXY</u>	<u>PHENOLIC</u>
PROPENSITY TO BURN (LOI)		
FACE SHEET	29.0	100
ADHESIVE	27.7	53.5
SMOKE EMISSION (D_s, 4 min), NBS		
2.5 W/cm²	62.8	2.5
5.0 W/cm²	96.5	8.4
HEAT RELEASE (W-sec/cm²) OSU		
\dot{Q} 2.5 W/cm²	--	120
\dot{Q} 5.0 W/cm²	500	320
FILM	<u>PVF/PVF</u>	<u>PVF/PC</u>
GAS RELEASE (HF mg/g)		
MONEL TUBE PYROLYSIS	74.1	27.5

Fig. 15

THERMOPLASTICS

Fig. 16

TYPICAL CHEMICAL STRUCTURES OF POLYMERS

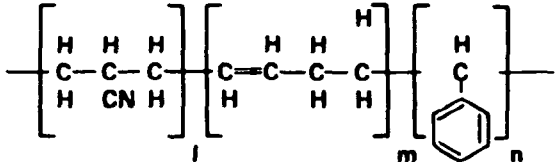
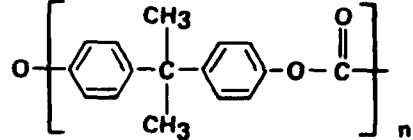
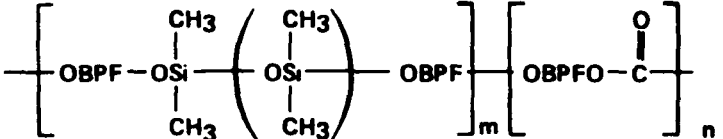
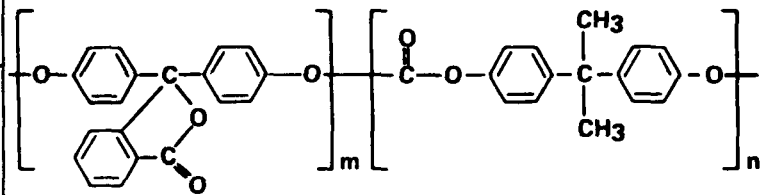
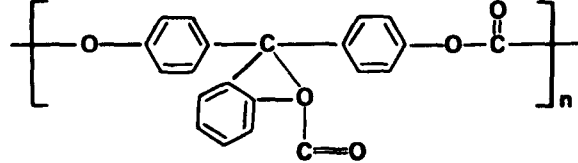
SAMPLE NUMBER	SAMPLE DESCRIPTION	POLYMER	POLYMER STRUCTURE
18	SHEET	ACRYLONITRILE BUTADIENE STYRENE (ABS)	
14	SHEET	BISPHENOL A POLY-CARBONATE (BPAPC)	
19	FIRE RETARDANT; SHEET		
21	FILM; SOLVENT CAST FROM CHLOROFORM, 21% DMS	9,9 BIS (4-HYDROXYPHENYL) FLUORENE POLYCARBONATE-POLY (DIMETHYLSILOXANE) BLOCK POLYMER (BPFC-DMS)	
23	INJECTION MOLDED DISCS, 10.16 cm. DIA. by 0.3175 cm, 15% DMS		
27	UNCURED, MOLDING POWDER		
28	MOLDING POWDER, CURED AT 315.56°C		
30	80% MOLE PHENOLPHTHALEIN, FILM	PHENOLPHTHALEIN-BISPHENOL A POLYCARBONATE COPOLYMER (PH-BPAPC)	
31	70% MOLE PHENOLPHTHALEIN, FILM		
55	FILLED WITH 10% Al ₂ O ₃ , 5% TiO ₂ ; FILM	PHENOLPHTHALEIN POLY-CARBONATE (PHPC)	

Fig. 17

TYPICAL CHEMICAL STRUCTURES OF POLYMERS

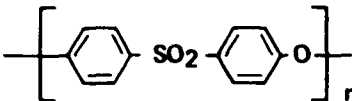
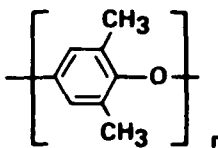
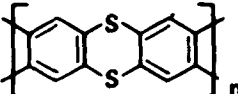
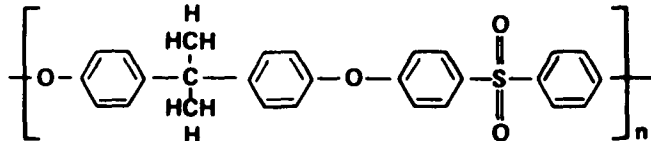
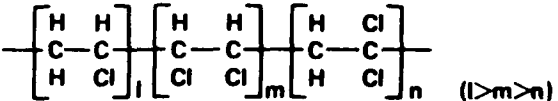
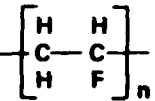
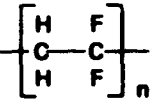
SAMPLE NUMBER	SAMPLE DESCRIPTION	POLYMER	POLYMER STRUCTURE
12 13 22	MOLDING PELLETS MOLDING PELLETS 0.0127 cm FILM	POLYETHER SULFONE (PES)	
16	MODIFIED; SHEET	POLYPHENYLENE OXIDE (PPO) (POLY-2,6-DIMETHYL-PHENYLENE OXIDE)	
11 20 24	MOLDING PELLETS MOLDED PART SECTION, 0.3175 cm THICK 0.3175 cm SHEET	POLYPHENYLENE SULFIDE (PPS)	
10 15	MOLDING PELLETS MODIFIED, SHEET	POLYARYLSULFONE (PAS)	
17 25	SHEET SHEET	CHLORINATED POLYVINYL CHLORIDE HOMOPOLYMER (CPVC)	
32	0.0051 cm FILM	POLYVINYL FLUORIDE (PVF)	
58	0.0127 cm FILM	POLYVINYLIDENE FLUORIDE (PVF2)	

Fig. 18

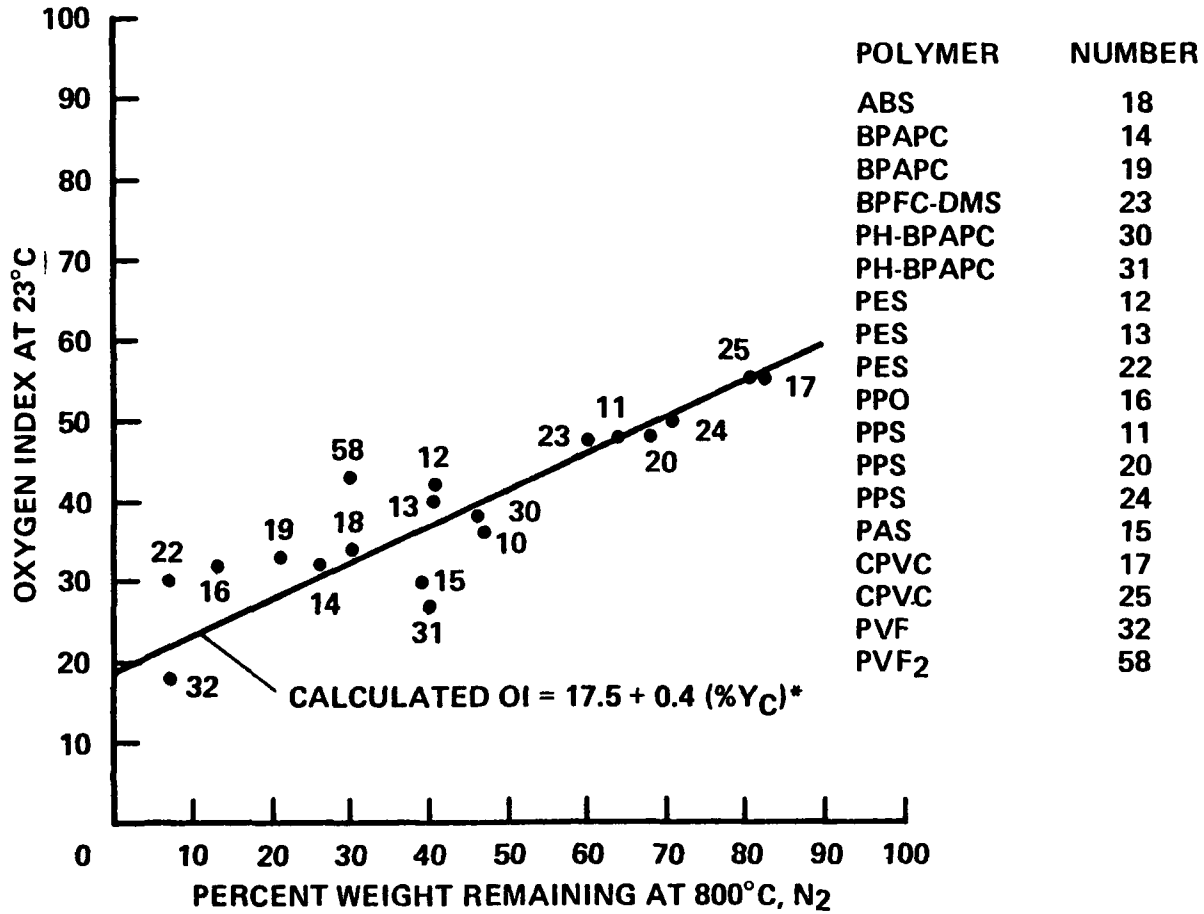
TABLE 5.- CHAR YIELD OF THERMOPLASTICS IN NITROGEN AND AIR

SAMPLE NO.	POLYMER	γ_c , 800°C, N ₂	γ_c , 800°C, AIR
18	ABS	18	5
14	BPAPC	30	3
19	BPAPC	27	5
21	BPFC-DMS	58	*
23	BPFC-DMS	61	19
27	BPFC-DMS	58	19
30	PH-BPAPC	47	2
31	PH-BPAPC	43	2
55	PHPC	50	*
12	PES	44	10
13	PES	43	10
22	PES	9	0
16	PPO	17	17
11	PPS	66	42
20	PPS	68	47
24	PPS	72	47
10	PAS	50	5
15	PAS	42	10
17	CPVC	29	5
25	CPVC	28	5
32	PVF	8	3
58	PVF ₂	30	5

*NOT DETERMINED

Fig. 19

EFFECT OF CHAR YIELD OF THERMOPLASTIC POLYMERS ON OXYGEN INDEX



*D.W. VAN KREVELEN, SOME BASIC ASPECTS OF FLAME RESISTANCE OF POLYMERIC MATERIALS, VOL. 6, POLYMER (AUG. 1975)

Fig. 20

Relative Flammability Characteristics of Thermoplastics.

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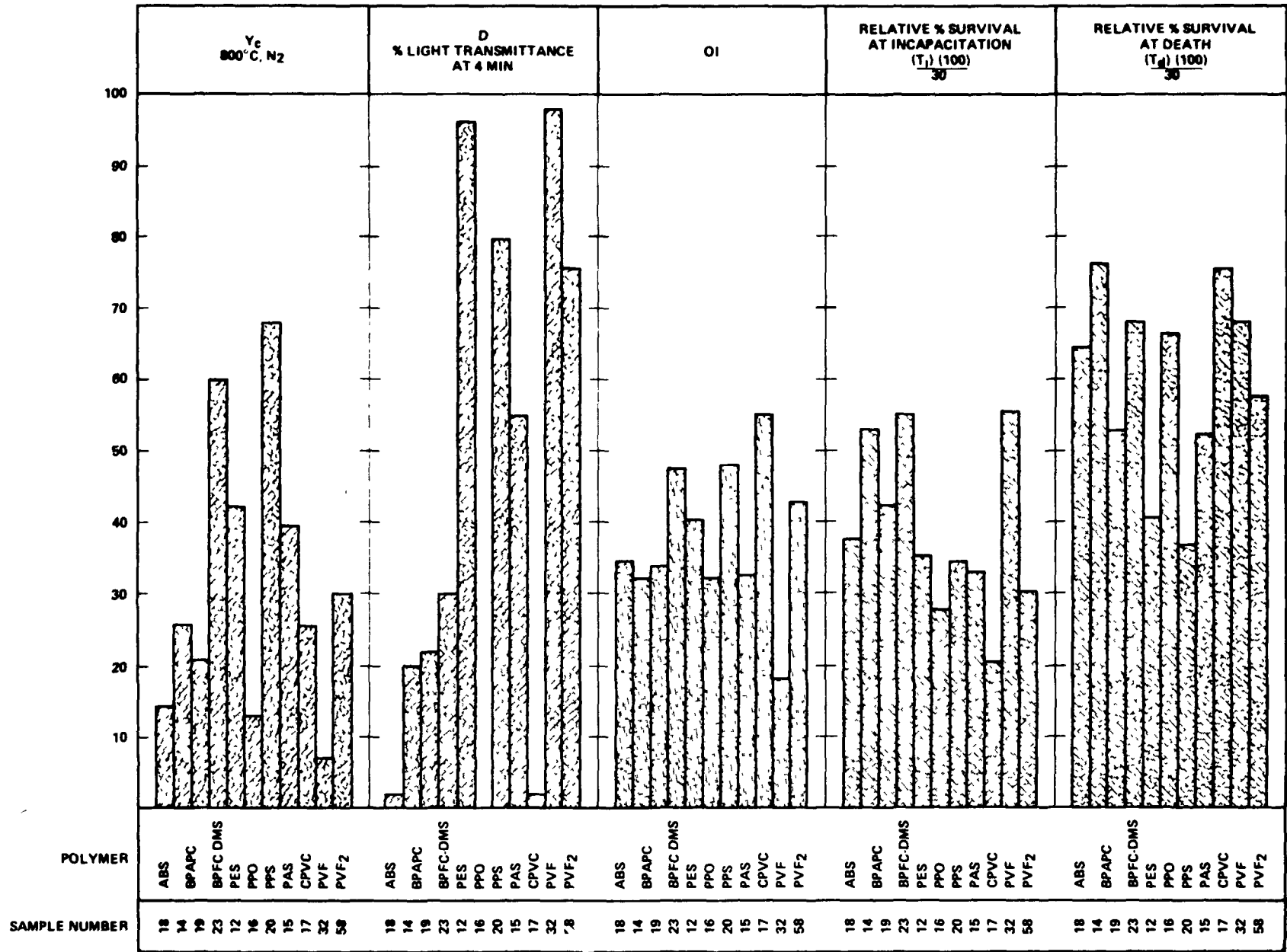


Fig. 21

RELATIVE FIRE RESISTANCE OF SOME THERMOPLASTIC POLYMERS

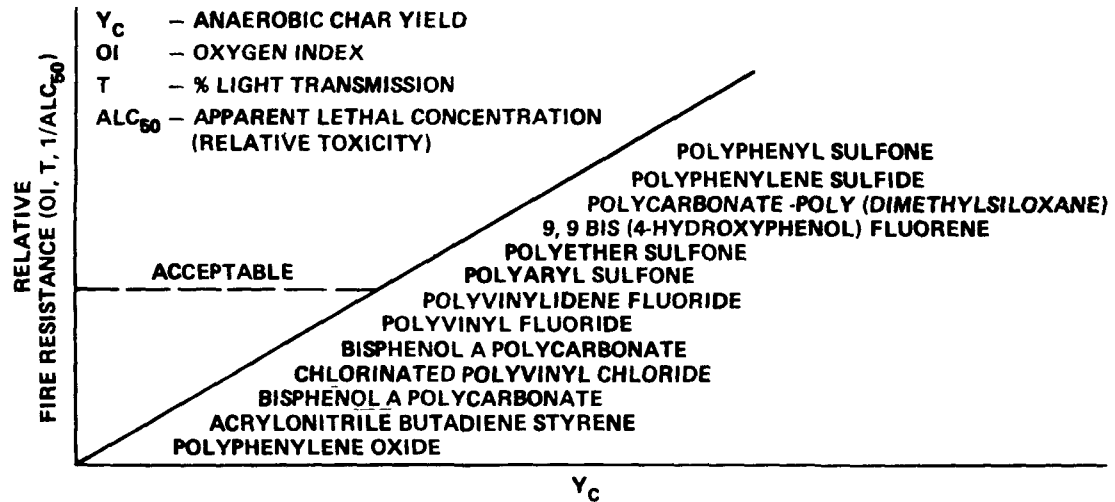
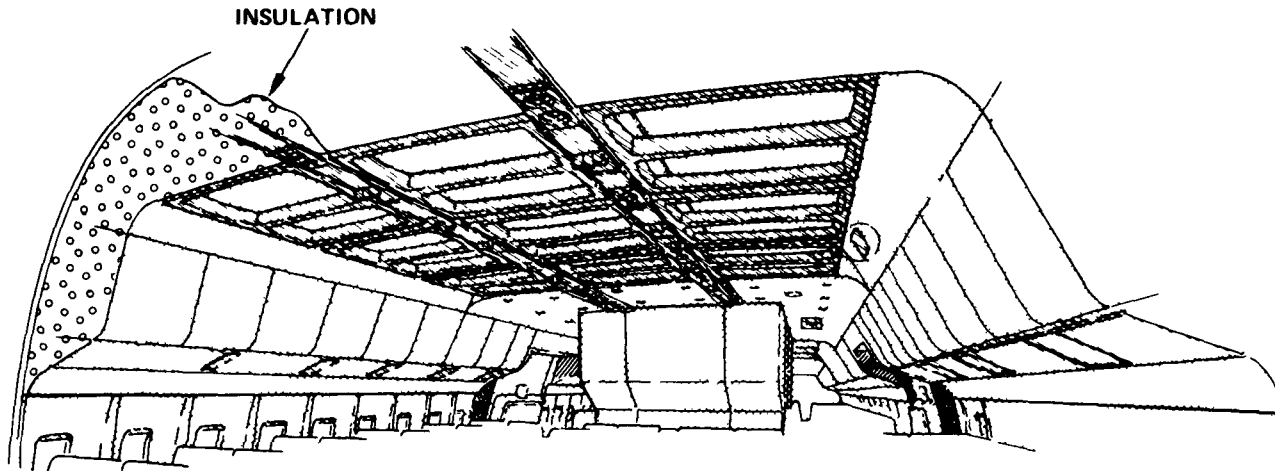


Fig. 22

FIREMEN

ACCOMPLISHMENTS

FY 1977-1978

- **COMPOSITE PANELS**
 - **COMPLETED EVALUATION OF 13 TYPES OF COMPOSITE (CORE) PANELS FROM 4 LAMINATING RESINS**
 - **EPOXIES**
 - **PHENOLICS**
 - **POLYIMIDES**
 - **BISMALEIMIDE**
 - **SELECTED 2 CANDIDATE PANELS FOR LARGE SCALE TESTING BY JSC BASED ON PHENOLIC RESINS**
- **THERMOPLASTICS**
 - **COMPLETED THERMOCHEMICAL/FLAMMABILITY CHARACTERIZATION**
 - **TRANSFER MOLDING TECHNOLOGY TO JSC**
- **SEATS**
 - **COMPLETED LABORATORY SCREENING**

FIREMEN PLANS FY 1978, 1979

- **COMPOSITE PANELS**
 - **DECORATIVE FILM - ON GOING DEVELOPMENT AND CANDIDATE SCREENING**
 - **ADHESIVES - PHOSPHORYLATED EPOXIES**
 - **INKS - PROGRAM INITIATED**
- **SEATS**
 - **FABRICATION DESIGN STUDIES OF ADVANCED SEATS INITIATED**
 - **TESTING IN CFS**
- **PROVIDE ADVANCED MATERIALS SYSTEMS TO JSC, & FAA-NAFEC FOR FULL-SCALE TESTING**

Fig. 24