

ADVANCED PHENOLIC SYSTEMS FOR AIRCRAFT INTERIORS

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ABSTRACT

Recent advances in the phenolic prepreg systems suitable for aircraft interior's applications are described. The current state of the art phenolic systems achieve a balance of properties and comfortably meet heat release and smoke emission requirements of various regulatory agencies such as FAR 25.853 and ATS 1000.001. A recent commercially available phenol formaldehyde resin based prepreg product SPH 2400 is reviewed. A single ply SPH 2400 sandwich laminates fabricated from Nomex honeycomb core and 7781 style fiberglass show Ohio State University (OSU) test peak heat release characteristics as low as 18 KW/M² and an average OSU heat release of 15 KW-Min/M² over a period of two minutes. The optical density of smoke emission measured by NBS method in flaming mode was found to be only 6 when measured over four minutes. The product SPH 2400 can be processed by using a variety of techniques such as vacuum bag molding, multiple opening press (MOP) molding and crushed core (CC) press molding. The prepreg system possesses outstanding self adhesive characteristics to a variety of core substrate and does not require an additional adhesive layer for core bonding. A proprietary latent catalysis technology enables rapid cures at temperature as low as 132°C (270°F) while maintaining excellent out time at room temperature.

■ INTRODUCTION

In the recent past, composite materials have gained acceptance as materials of choice for many aircraft interior applications including side walls, partitions, ceiling panels, floor panels, seat backs and overhead stowage bins. Besides their light weight advantage, current composites meet or exceed stringent regulatory requirements of FST (Fire, Smoke and Toxicity) [1,2] and offer strength, excellent aesthetics and serviceability.

In the United States, the Federal Aviation Agency (FAA) and its predecessor, the Civil Aeronautics Administration (CAA), have had the statutory responsibility to establish minimum safety standards for aircraft design and safety. The federally mandated requirements for aircraft are contained in the part 14 of the Code of Federal Regulations commonly known as FAR's (Federal Air Regulation). The FAR PART's 25 covers the design of large transport category aircraft. The relevant section is paragraph 25.853 which describe regulatory statutes for compartment interiors.

The current FST regulatory requirements have evolved over the last three decades, however, major changes have taken place only in the past five years or so. During this period, the FAA has adopted an unprecedented series of new standards designated to improve transport aircraft fire safety [3,4]. The most stringent FAA requirements apply to large area cabin liners such as sidewalls, ceilings, partitions, stowage bins, etc. These requirements are discussed in details in references 3 and 4. New regulatory requirements are typically released by FAA through amendments to FAR PART 25. A summary of various amendments [3] in the recent past is shown in table 1. The present standards have been internationally anchored in

specifications such as Airbus Technical Specifications (ATS) 1000.001.

The earliest requirement was that cabin materials had to pass the horizontal burn Bunsen burner test. A vertical Bunsen burner test was introduced in 1967 which involved a 12 second exposure to the flame. The exposure time was increased to 60 seconds in 1972. Materials such as polyvinyl chloride (PVC), acrylonitrile butadiene styrene (ABS) copolymers met these requirements and were widely used. High performance applications also involved phenolics, epoxy on glass and Kevlar and polycarbonates. It was later recognized that a direct flammability test was not fully representative of cabin fire. A more realistic simulation would involve the introduction of a radiant heat source into the test. A new test developed at Ohio State University (OSU) was introduced in 1986 and new standards were adopted in 1988. All aircraft certified from 1988 had to meet the "100/100" requirements for the 2 minutes average heat release and the peak heat release respectively which became progressively stringent to the "65/65" for aircraft certified from 1990. These standards were further tightened by incorporating the smoke density and toxicity standards. The underlying philosophy was simple. In a cabin fire scenario, more often occupants die through asphyxiation by smoke or breathing toxic smoke. If cabin materials could resist spread of fire along with emission of low smoke during a post crash fire scenario, the occupants will have additional time to evacuate. The current FAA requirements for airplane cabin liner are listed in table 2. Among all the regulatory requirements, incorporation of quantitative limits on heat release, smoke density and toxicity in a simulated combustion scenario [5 - 9] has influenced the material

Rule	Final Rule Published	Compliance Date	Parts Effected	Am'd't No.
1. Seat Fire Blocking Layers	26 Oct. 84	26 Nov. 87	25, 29, 121	25 - 29
2. Floor Proximity Lighting	26 Oct. 84	26 Nov. 86	25, 121	25 - 58
3. Cabin Fire Protection A. Lavatory Smoke Detectors B. Lavatory Auto. Fire Extinguishers C. Halon 1211 Hand Extinguishers D. Hand Extinguishers	29 Mar. 85	29 Oct. 86 29 Apr. 87 29 Apr. 86 29 Apr. 85	121	121 - 185
4. Cargo Compartment Fire Protection	16 May 86	16 Jun. 86	25	25 - 60
5. Cabin Material Flammability A. 100/100 Heat B. 65/65 Heat, 200 Smoke	21 Jul. 86 & 25 Aug. 88	20 Aug. 88 20 Aug. 90	25, 121	25 - 61 & 25 - 66
6. Crew Protective Breathing	03 Jun. 87	06 Jul. 89	121	121 - 193
7. Cargo Compartment Fire Protection	17 Feb. 89	20 Mar. 91	121, 135	121 - 202

Table 1: Transport Aircraft Safety Rulemaking [3]

selection process in perhaps the most notable way. Even though the majority of older technologies fell short in conforming to these strict standards, phenol formaldehyde resin technology emerged as a technology of choice. Today, a proper selection of resin and flame retardants enables many commercial systems to far exceed these requirements.

Besides meeting safety criteria, the interior parts must be functional. From the part manufacturer's perspective, the parts should be rapidly processable, cost competitive and reproducible in sufficient quantities. From the airlines perspective, cabin furnishing in the aircraft interior must be sturdy, durable with pleasant and comfortable architecture. These usually translate in enhanced performance and design standards for the materials of construction. For example, comfortable and pleasing interior designs often involve complex contours for which lay-up techniques often require specific handling characteristics of the prepreg such as tack. The prepreg product, then, must be able to be manufactured at different desired tack levels while maintaining processability.

TEST TYPE	MINIMUM PASS CRITERIA
IGNITABILITY FAR 25 Appendix F, Part I 60 - SEC BUNSEN BURNER includes flooring parts	< 6 - INCH BURN LENGTH < 15 SEC EXTINGUISHING TIME FOR SPECIMENS < 3 SEC EXTINGUISHING TIME FOR DRIPS
HEAT RELEASE FAR 25 Appendix F, Part IV OSU CALORIMETER above floor parts only OSU CALORIMETER above floor parts only	< 65 Kw/M ² PEAK RATE DURING 4 - MIN. TEST < 65 Kw - MIN/M ² TOTAL DURING FIRST 2 MIN.
SMOKE RELEASE FAR 25 Appendix F, Part V NBS SMOKE CHAMBER above floor parts only	< 200 SPECIFIC OPTICAL DENSITY DURING 4 - MIN. TEST

Table 2: The FAA Flammability Requirements for Airplane Cabin Liners [4].

A widely used composite panel design for aircraft interiors involves Nomex honeycomb core based sandwich structures. Good adhesion of the composite skin is necessary to the honeycomb core for secondary operations. In general, phenolic have poor adhesion to Nomex honeycomb and other core materials frequently used for aircraft interiors. This can be overcome by employing an additional adhesive layer to facilitate better bonding. Current prepreg composites, however, are self adhesive and may not require additional adhesive layer to improve the peel strengths. This translates into material and process cost savings. However, improvement in peel strength may be accompanied by a compromise in flame, heat release and smoke release characteristics. Achieving a balance of desirable properties in a composite material system is still practiced as a proprietary art. In this presentation we describe a commercial prepreg system SPH 2400 that achieves this balance.

■ EXPERIMENTAL

A) MATERIALS

The commercial prepreg products SPH 2400 is a fire retardant prepreg product manufactured by SP Systems. The product consists of a proprietary resin system based on phenol formaldehyde resin technology on a woven reinforcement. The prepreg material is obtained by impregnation and subsequent B-staging of the impregnated reinforcement in a tower. The conditions of impregnation are kept as proprietary. The product SPH 2400 is extremely amenable to customization. There are two types of custom variations that are normally introduced for a given basic product chemistry. The first variation involves changes in the handling characteristics such as tack of the prepreg. This usually results from changing conditions of drying or B-staging subsequent to impregnation. As a standard nomenclature, up to two letters following SPH 2400 describe the custom variations in the handling characteristics of the prepreg. A moderate tack version of the prepreg is designated as SPH 2400M. A lower tack version results with increasing the degree of

drying and/or B-staging. This prepreg product is named as SPH 2400L. A very low tack version is produced by further staging the product and is designated as SPH 2400LC.

A complete product designation involves a description of the reinforcement. The designation of the reinforcement style follows the matrix description after a slash. Depending on the application, various styles of fiberglass or graphite may be used. As an example, the product nomenclature SPH 2400L/7781 reflects the L version of SPH 2400 prepreg product on fiberglass style 7781.

An experimental variation of the product SPH 2400 was prepared in a laboratory simulated impregnation tower with the objective to optimize peel strengths in Nomex honeycomb core and fiberglass sandwich structures. This experimental variation is designated as XSPH 2400B4/7781. The prepreg physical properties of this product are considered as proprietary and an X before normal product assignment reflects its experimental product status.

Nomex honeycomb core of 3 lb density with 1/8" cell size was obtained from Ciba Geigy Corporation. For OSU data thickness of the Nomex honeycomb core used was 1/8" while the core used for peel strength panels was 1/2" thick.

B) PANEL FABRICATION

Configuration

Different configurations were standardized for different test evaluations. For peel strength evaluations a 2 ply of 7781 glass prepreg, 1/2" Nomex honeycomb core and 2 plies of 7781 glass prepreg was utilized. For OSU data 1 ply of 7781 glass, 1/8" of Nomex honeycomb core and 1 ply of 7781 fiberglass configuration. For NBS smoke density determination the configuration used involved 1 ply of 7781 fiberglass, 1/8" Nomex honeycomb and 1 ply of 7781 fiberglass. For all the configurations, the fill side faced the core and the direction of the fill yarn was parallel to the ribbon direction.

Cure

For panels cured by press molding process, 12" by 12" specimens of the desired configurations were loaded in a preheated press at 127°C (260°F) in between two 1/4" thick release coated caul sheets and kept there for 45 minutes under 50 psi pressure. Subsequently the press was opened and the panels were removed hot.

For panels cured by crushed core press molding process, 12" by 12" specimens in the desired configurations were loaded in a preheated press at 160°C (320°F) in between two 1/4" thick release coated caul sheets. The platens were closed to the desired thickness using a set of crush rails. The panels were isothermally kept for 8 minutes and subsequently removed hot.

C) PREPREG PHYSICALS, CHEMICAL CHARACTERIZATION & MECHANICAL TESTING

Various methods of chemical characterization, heat release and mechanical testing were employed to under-

stand chemical, thermal and mechanical behavior of the new SPH 2400 system.

Prepreg Physicals

The percent volatile (Vols) in the prepreg was measured by evaluating the weight loss in the prepreg after curing at 121°C (250°F) for 10 minutes in an air circulating oven. The volatile were calculated as follows:

$$\text{Vols} = 100 \times (W1 - W2) / W1 \quad (1)$$

where

W1 Weight of the prepreg

W2 Weight of the cured prepreg

Resin content (RC) of the prepreg samples was evaluated by using a burn off technique. A known weight of a cured prepreg ply 4" by 4" in dimensions was kept in the muffled furnace at 593°C (1100°F) for 60 minutes. The resin content was evaluated by using the following formula:

$$\text{RC} = 100 \times (W2 - W3) / W2 \quad (2)$$

where

W2 Weight of the cured prepreg

W3 Weight of the prepreg after burn off

The percent flow in the prepreg was measured as the amount of resin flowed out of a stack of four plies of 4" by 4" prepreg when kept at 121°C (250°F) for 10 minutes in a preheated press at 50 psi pressure.

The gel time was measured as the time required for the sneezed prepreg resin to undergo gelation at 121°C (250°F). The gelation was measured by an event when stringiness of the resin ceases to exist.

Tack of the prepreg was measured only qualitatively under ambient conditions of 25°C (77°F) and relative humidity of 65%. A low tack prepreg showed no adherence to itself whereas a moderate tack prepreg showed self adherence.

Thermal Analysis (TA)

A Dupont Thermogravimetric Analyzer TGA model 951 and thermal analysis work station (model TA 9900), has been used throughout this study. All the experiments were performed under isothermal conditions in a nitrogen environment with the gas flowing at 40 cc/Min.

Chemorheology

Dynamic mechanical testing was performed on an RDS II, Rheometrics dynamic spectrometer, using a rectangular torsion accessory. All the experiments were conducted with 'auto tension on'. This feature is necessary to prevent samples from buckling under compression due to the thermal expansion. Dynamic mechanical parameters such as G' , G'' and η^* were calculated from equations 3 to 5.

$$G' = K \cdot \text{Real}(\tau/\theta) \quad (3)$$

$$G'' = K \cdot \text{Imag}(\tau/\theta) \quad (4)$$

$$\eta^* = [(G'^2 + G''^2) / \omega] / w \quad (5)$$

of rectangular torsion accessory.

$$K = L \cdot 980.7 / [(T / 10)^3 \cdot W \cdot (1/3 - .21 \cdot (T/W))] \quad (6)$$

- T : Sample thickness
- L : Sample length
- θ : Shearing angle
- τ : Shearing Torque
- w : Test frequency

Two plies prepreg samples were cut at 45° orientation w.r.t warp axis for all products. A frequency of 40 Rads/sec was used along with a 0.4% strain rate. The samples were heated at specified heat rate from room temperature to 180°C (356°F).

Peel Strength

A United Calibration Smart-1 mechanical tester was used throughout the study. All the mechanical testing was performed in accordance with Climbing Drum peel test method outlined in MIL-STD-401.

OSU Heat Release & NBS Smoke Testing

Samples were sent to Delsen laboratory for evaluation. The heat release characteristics were evaluated based on Ohio State University (OSU) test method in accordance with requirements of FAR 25.853. The optical density of the smoke emission was measured as per the National Bureau of Standard (NBS) specification adopted by FAR 25.853.

RESULTS AND DISCUSSION

The physical characteristics of three commercial versions of the product SPH 2400 are shown in table 3. Resin content of the L and the M version is targeted to be around 40%, however, flow and volatile in the L version are targeted to be lower than the M version. Resin content of the LC version, in contrast, is targeted to be only 32% and the prepreg has low flow characteristics. These differences in prepreg physical properties manifest significant differences in the handling performance of the prepreg product. The M version has moderate tack in comparison to the L version which has low tack and the LC version has even lighter tack. In general, prepreg physicals are controlled by regulating various operational parameters of the impregnation tower. For a given reinforcement, resin content of the prepreg is a function of line speed, gap setting of metering bars and resin dilution. Flow characteristics and residual volatile percents are complex quan-

ties and usually depend on resin content as well as the extent of drying and B-staging subsequent to impregnation. In the impregnation tower, drying and B-staging are mainly controlled by a combination of tower temperatures and the line speed. With increasing temperature and residence time in the tower, prepreg is drier, less tackier and more B-staged. The tack characteristics may be quite important from the application stand point. By virtue of moderate tack levels, the M version is more suitable for lay-ups involving complex contours where tackiness of the prepreg is desired. The product version L, on the other hand, is suitable for flat laminates and sandwich structure. The LC version is most suitable for crushed core or high pressure press molding processes.

Thermal history of the impregnated reinforcement in the tower affects chemorheology of the SPH 2400 products. The influence is seen both on minimum dynamic viscosity as well as initial dynamic viscosity. Figure 1 compares dynamic complex viscosity of the three commercial versions on 7781 style fiberglass reinforcement as a function of temperature. Lower minimum and initial viscosity attained by the M version are attributed to lower degree of B-staging during impregnation operation. The LC version attains the highest initial viscosity and minimum viscosity among the three commercial grades. This reduced ability to flow limits the LC grade to be processable only under high pressures. The flow behavior of the SPH 2400 products is also affected by the rate at which the heat is applied. Figure 2 and 3 show the effects of heat rate on the dynamic viscosity of the M and L versions of

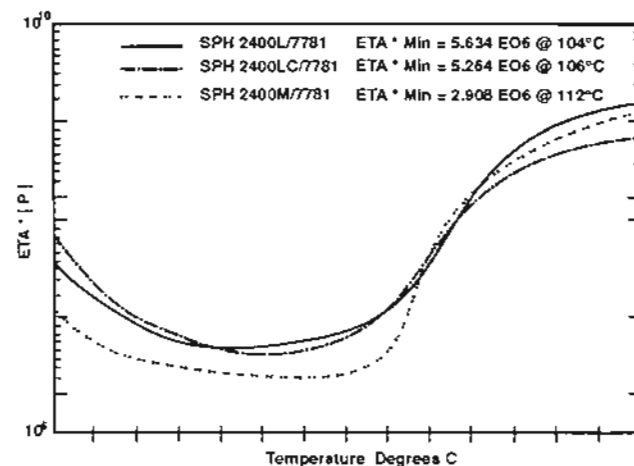


Figure 1. Dynamic Complex Viscosity of SPH 2400 Product M, L & LC Versions on 7781 Style Woven Fiberglass Reinforcement.

	Resin Content		Flow %		Volatiles %		Gel Time (Minutes)
	Specification	Actual	Specification	Actual	Specification	Actual	
SPH 2400L/7781	38 - 43	39	8 - 18	15.5	3.2 max	2.9	6'
SPH 2400 LC/7781	29 - 35	33	10 - 20	12.9	6 max*	4.7	2'
SPH 2400 M/7781	38 - 43	40	15 - 25	22.5	5 max	3.8	9'
X SPH 2400 (84)/7781	-	P**	-	P	-	P	P

* Volatile % was measured at 160° C for 10 minutes

P** Proprietary Data

Table 3. The Physical Characteristics of Various Versions of SPH 2400 Prepreg Product

the prepreg. As the heat rate increases, the minimum viscosity reduces irrespective of the initial viscosity of different versions of SPH 2400 products. Temperatures at which the minimum viscosity is achieved, on the other hand, increasing the rate of heating. This is important in designing a cure cycle specially for processes where resin flow is a critical parameter.

The sequence of chemorheological changes that take

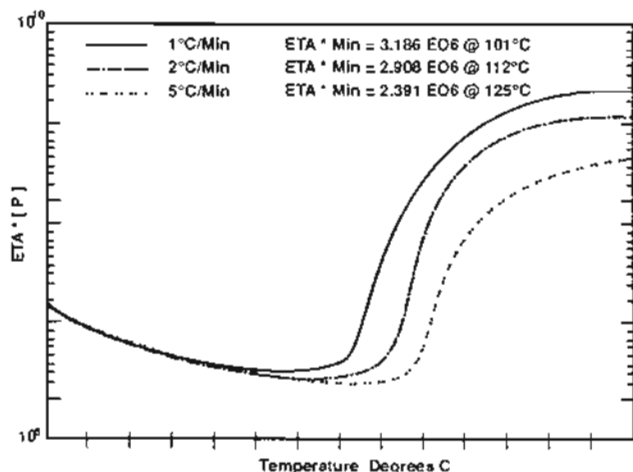


Figure 2: Dynamic Complex Viscosity of SPH 2400M/7781 as a Function of Heat Rate.

place on heating phenol formaldehyde resin based prepreg systems are in general complicated by evaluation of volatile. This volatile may further affect the fabrication of honeycomb type sandwich structures by exerting internal pressure on the face skin. This is especially critical for press molding processes where placing a lay-up in a hot press and removing hot, results in a considerable time saving. For a system to be suitable for this process variation, the bondline needs to be strong enough at the process temperature, at the time of removal, to withstand the internal pressure of the volatile, or the skin will peel off the core. The rate of volatile liberation is a strong function of the resin content of the prepreg and the temperature of the final cure. The effect of temperature on volatile generation was investigated on SPH 2400 products using TGA analysis. Figure 4 summarizes the weight loss characteristics of the M version as a function of the cure time at various temperatures. It is clear that the rate of

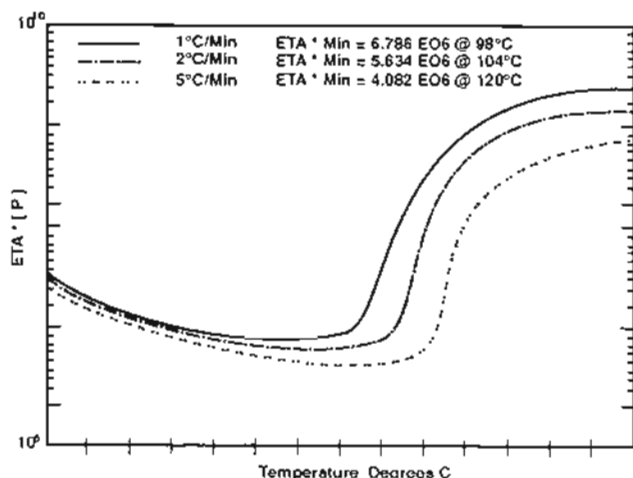


Figure 3: Dynamic Complex Viscosity of SPH 2400L/7781 as a Function of Heat.

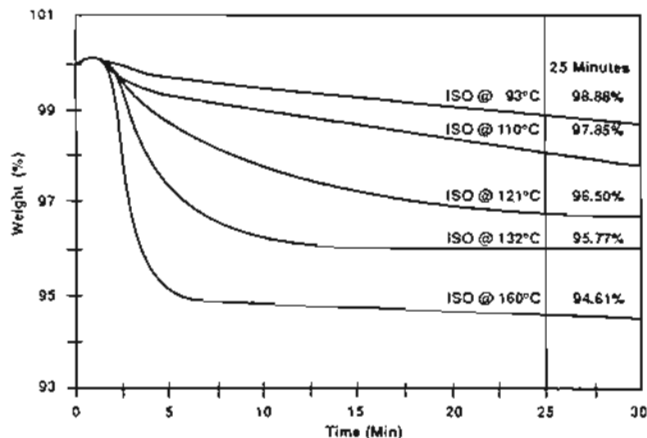


Figure 4: Isothermal Thermogravimetric Analysis of SPH 2400M/7781 at Various Temperatures.

volatile generation significantly change as the temperature increases. At lower temperatures of 93°C (200°F) and 110°C (230°F), the loss of weight is gradual and does not achieve an equilibrium within 30 minutes of observation. At temperatures of 121°C (250°F) or higher, volatile evolve rapidly during the initial isothermal phase and then asymptotically approach to an equilibrium level. Noteworthy is the equilibrium amount of volatile that the system finally approaches to at various temperatures. The equilibrium weight loss at 160°C (320°F) is 94.61% in comparison to 95.77% at 132°C (270°F) and 96.5% at 121°C (250°F). This remarkable difference may be due to different temperature dependent mechanisms that the system may follow [10]. The L version shows similar weight loss profile as a function of time at different temperatures as shown in figure 5. The two products, however, show a marginal difference between the abso-

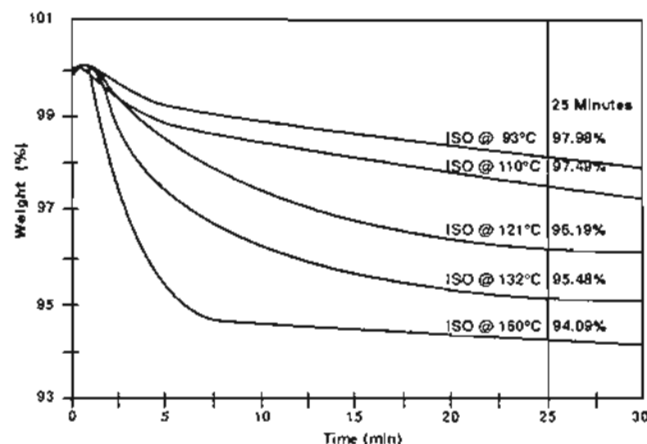


Figure 5: Isothermal Thermogravimetric Analysis of SPH 2400L/7781 at Various Temperatures.

lute magnitude of the weight loss characteristics. A lower weight loss by the L version may be attributed to higher degree of B-staging during the manufacturing process. From the weight loss curves, it is clear that SPH 2400 prepregs can be cured at temperatures as low as 93°C (200°F) and temperatures as high as 160°C (320°F) by varying the isothermal cure time [11]. At temperatures of 160°C (320°F) the system requires as little as 12 minutes for complete cure whereas at 93°C (200°F) time required for complete cure is 180 minutes. Despite their fast reactivity, SPH 2400 systems show excellent outlife. A roll of SPH 2400M/7781 prepreg was laid out at room

	LYING ON THE TABLE WITHOUT COVER					ROLLED AND SEALED IN POLY BAGS				
	FRESH	8 DAYS	12 DAYS	15 DAYS	19 DAYS	FRESH	8 DAYS	12 DAYS	15 DAYS	19DAYS
Resin Solid (Dry) %	40.0	39.5	39.3	39.7	39.4	41.7	40.0	39.4	39.5	39.5
Volatiles @ 121° C 10' %	4.6	4.7	4.0	4.3	4.0	4.6	4.7	4.0	4.3	4.3
Flow @ 121° C 50 PSI %	23.1	21.0	18.5	19.9	19.9	23.1	21.0	18.0	19.9	20.2
Gel Time @ 121° C	4' 58"	4' 41"	4' 36"	4' 32"	4' 24"	4' 58"	4' 41"	4' 36"	4' 32"	4' 19"
Tack & Drape	Med.	Med.	Med.	Med.	Med.	Med.	Med.	Med.	Med.	Med.

Table 4: Room Temperature aging of SPH 2400M/7781 Product

temperature with and without the polyfilm and the prepreg physical characteristics were monitored for 18 days. The results are compiled in table 4. It is clear that no appreciable changes in the physical properties of the prepreg were noted over 18 days of observations.

In general, unmodified phenol formaldehyde resins do not bond very well to the core materials. This may be because of the condensation volatile that may stay trapped in the resin as flaws and weaken the bondline. If honeycomb core is used, the bonding is even more difficult due to the low area of adhesion. The peel strengths of a Nomex sandwich panel with self adhesive SPH 2400/7781 face sheet was investigated using a climbing drum technique for the three commercial versions of the product. Table 5 lists the peel strengths of the selected configurations. Clearly SPH 2400 systems show excellent peel strengths to the honeycomb core. It is evident

Product	Molding Conditions		Configuration	Peel Strength in-lb/3 in Width
	Press (PSI)	Crushed Core (degree of crush)		
SPH 2400M/ 7781	50 PSI		2 / H / 2	12
SPH 2400L/ 7781	50 PSI		2 / H / 2	13
SPH 2400LC/ 7781		0.5" to 0.08"	1 / H / 1	56
SPH 2400LC/ 7781		0.125 to 0.08	1 / H / 1	35

Table 5: Climbing Drum Peel Strengths of SPH 2400 Product

that peel strengths are a strong function of prepreg physicals, panel configuration and process conditions. Depending on the panel configuration and process conditions, the peel strengths vary from 12 in-lb/3 in width to 56 in-lb/3 in width. Panels fabricated with cores crushed from 0.5" to 0.08" thick showed peel strengths as high as 56 in-lb/3 in width. As the degree of crush reduced, as in case of panel crushed from .125" to 0.08", the peel strength dropped to 35 in-lb/3 in width. The flat panels process by the press molding process under 50 psi show a modest peel strength of 12 to 13 in-lb/3 in width. The

outstanding peel strengths obtained using a crushed core process may be attributed to the additional core surface available for bonding due to the crush. As the degree of crush reduces, core surface available for bonding may be less resulting in lower peel strengths.

The commercial utility of a prepreg system used for manufacturing aircraft interior's parts depends on it's ability to meet the current "65/65/200" requirements for average heat release, peak heat release and the smoke density respectively [3,4]. Achieving lower heat and smoke release (LHSR) characteristics are extremely desirable for a variety of reasons. First is the safety consideration. Composite structures made from LHSR prepregs will be superior in fire worthiness. Secondly, lower heat release and smoke release may translate into easier compliance with the regulation. This may be critical for two reasons. First, it is now recognized that a substantial scatter is inherent in the determination of the OSU heat release results. The materials that perform marginally in OSU heat release testing may not sometimes meet the specifications simply because to inherent scatter in the test results. Secondly, a final decorative panel in general requires a number of operations that may involve materials such as paints, adhesives or decorative plies. These materials may adversely contribute to heat release and smoke release characteristics. Therefore, LHSR prepregs may translate into easier compliance of the overall panel. In fact, many fabricators frequently lower their internal acceptance specifications for qualified prepreg products. Fire worthy characteristics of SPH 2400 systems far exceed the current requirements of FAR 25.853. Table 6 lists the heat release characteristics and the smoke density of M and L version of SPH fiberglass. These values represent an average of three

Product	Configuration	Average Heat Release, 2Min HRR, 2M KW-Min/M ²	Peak Heat Release, 4Min HP, KW/M ²	Os, 4Min NBS
SPH 2400L/ 7781	1/H/1 6 ply laminate	15 19	18 12	6 6
SPH 2400M/ 7781	1/H/1	20	17	7

Table 6. Ohio State University (OSU) Heat Release Characteristics of SPH 2400 Product.

panels, the average heat release for the L and M version was only 15 and 20 KW-MIN/M² respectively and the peak heat release for these versions was 18 and 17 KW/M² respectively. The optical density in flaming mode, in both these cases was less than 10.

The heat release and smoke release characteristics determined for 6 ply laminate of SPH 2400L system were similar to the one ply sandwich panel. The average heat release marginally increased to 19 KW-Min/M² and peak heat release characteristics actually reduced to 12 KW/M².

The experimental version of SPH 2400 product designated as XSPH 2400B4/7681, created by altering prepreg physical characteristics, shows interesting combination of properties. In general, for a given system it has been noted that higher peel strength values are observed with a compromise in heat release and smoke release characteristics [12].

Table 7 shows the peel strengths, heat release and the smoke characteristics of this product. The climbing drum

	Configuration	Molding	Property
Average Heat Release, 2 Min. HRR, 2 M KW-Min./M ²	1 / H / 1	50 psi	15
Peak Heat Release, 4 Min. HP, KW/M ²	1 / H / 1	50 psi	17
Ds, 4 Min. NBS Smoke Density	1 / H / 1	50 psi	9
Climbing Drum Peel Strength in-lb/3 in width	2 / H / 2	50 psi	21

Table 7: Peel Strengths & Heat Release Characteristics of Experimental X SPH 2400 (B4) / 7781 Prepreg Product.

peel strength on Nomex honeycomb averages to 21 in-lb/3 in width. The average heat release rate is 15 KW-Min/M² and the peak heat release rate was 17KW/M².

It is clear that peel strengths are substantially increased over the L version by almost 62%. However, it is remarkable that it is achieved without sacrificing the heat release and the smoke release characteristics.

■ CONCLUSIONS

A new commercial SPH 2400 fire worthy composite prepreg system is introduced. The system represents an optimum of processing, FST and peel strengths. The system has been customized for variety processes like vacuum bag molding, press curing and crushed core processes.

■ ACKNOWLEDGMENTS

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