

## Performance of Composite Construction Products in Reaction-to-Fire Tests

by

J. Huczek, M. Mehrafza and M. Janssens  
Southwest Research Institute®  
6220 Culebra Road, Building 143  
San Antonio, TX 78238-5166

### ABSTRACT

A glass-fiber reinforced plastic panel construction product was tested at SwRI in the ASTM E 84 Steiner tunnel, the ISO 9705 room and the EN 13823 single burning item (SBI) test apparatus. Most of the tests were conducted in duplicate or triplicate to assess the repeatability of the measurements. The same product was also tested in the Cone Calorimeter (ASTM E 1354 and ISO 5660) at different heat flux levels to obtain ignition, heat release and smoke production properties. This paper summarizes the results from the tests and compares the corresponding reaction-to-fire classification in the United States, Australia, Europe and Japan. In addition to the data acquired in the SwRI project, additional available literature data are provided for similar materials (fiber reinforced plastic panels) to illustrate the range of product performance in a given standard fire test.

### INTRODUCTION

In July 2004 Southwest Research Institute (SwRI) initiated a research program to evaluate and improve mathematical models to predict the performance of construction products in a number of commonly used intermediate- to large-scale reaction-to-fire tests. For this purpose, eight products were tested according to ASTM E 84 (Steiner tunnel test), ISO 9705 (room/corner test) and EN 13823 (single burning item test). Some tests were performed in duplicate or triplicate to obtain repeatability information. The models rely primarily on material properties such as time to ignition, heat release rate and smoke production rate. The eight products were therefore also tested at different heat flux levels in the Cone Calorimeter (ASTM E 1354 and ISO 5660).

ASTM E 84, ISO 9705, EN 13823 and ISO 5660-1 are used for reaction-to-fire classification of construction products in the United States, Australia, the European Union and Japan, respectively. There are additional regulatory uses of most of these test methods for the United States Navy (USN), United States Coast Guard (USCG) and the International Maritime Organization (IMO).

This paper provides a summary of the results obtained in the SwRI program for a glass-fiber reinforced plastic panel material and compares the corresponding reaction-to-fire classification in these four areas of the world. In addition to the data acquired in the SwRI project, additional available literature data are provided for similar materials (fiber reinforced plastic panels) to illustrate the range of product performance in a given standard fire test. The outcome of the modeling effort is not addressed in this paper and will be discussed elsewhere.

### TEST METHODS

#### The Steiner Tunnel Test (ASTM E 84)

The Steiner tunnel test is the primary test method for evaluating reaction to fire of interior finish materials in the United States. The method is described in ASTM E 84. The apparatus, consists of a tunnel-like enclosure measuring  $8.7 \times 0.45 \times 0.31$  m ( $25 \times 1\frac{1}{2} \times 1$  ft). The test specimen is 7.6 m (24 ft) long and 0.46 m (18 in.) wide and is mounted in the ceiling position. It is exposed at one end, designated as the burner end, to an 88-kW (5000-Btu/min) gas burner. There is a forced draft through the tunnel from the burner end with an average initial air velocity of 1.2 m/s (240 ft/min). The measurements consist of flame spread over the surface and smoke obscuration in the exhaust duct of the tunnel. Test duration is 10 minutes.

A flame spread index (FSI) is calculated on the basis of the area under the curve of flame tip location versus time. The FSI is 0 for an inert board, and is normalized to approximately 100 for red oak flooring. A smoke developed index (SDI) is calculated on the basis of the area under the light obscuration vs. time curve, and is equal to 100 for red oak flooring.

#### The Room/Corner Test (ISO 9705)

The ISO 9705 test apparatus consists of a room measuring 3.6 m (12 ft) deep by 2.4 m (8 ft) wide by 2.4 m (8 ft) high, with a single ventilation opening (doorway) measuring approximately 0.8 m (30 in.) wide by 2 m (80 in.) high in the front wall. In the standard configuration the interior surfaces of all walls (except the front wall) and the ceiling are

covered with the test product. The product is exposed to a propane burner ignition source located on the floor in one of the rear corners of the room opposite the doorway.

At the start of a test, the propane gas burner is ignited and the material system is exposed to a 100-kW flame. After ten minutes of exposure to 100 kW, the gas flow to the burner is increased to 300 kW and maintained at that level for an additional ten minutes.

The products of combustion emerging through the doorway are collected in a hood and extracted through an exhaust duct by a fan. A gas sample is drawn from the exhaust duct to measure the concentrations of oxygen, carbon dioxide and carbon monoxide. The gas temperature and differential pressure across a bi-directional probe are measured to determine the mass flow rate of the exhaust gases. The gas concentrations and duct flow rate measurements are used to calculate heat release rate based on the oxygen consumption technique [1]. Smoke production rate is determined based on the measured light obscuration in the duct using a white-light extinction photometer located close to the gas sampling point.

The primary measurements are heat release rate, smoke production rate and heat flux to the floor in the room. The test is generally terminated when flashover occurs during the 20-minute test period. Different criteria are used to define flashover. A total heat release rate of 1000 kW is the most commonly used criterion when the results are compared to model predictions.

#### **The Single Burning Item Test (EN 13823)**

The new reaction-to-fire classification system for construction products in the European Union is based primarily on performance in the Single Burning Item (SBI) test. Two specimens of the material to be tested are positioned in a specimen holder frame at a 90° angle to form an open corner section. Both specimens are 1.5 m (60 in.) high. One specimen is 1 m (40 in.) wide, and is referred to as the long wing. The other specimen is 0.5 m (20 in.) wide and is referred to as the short wing.

During a test, the specimens are exposed for 20 minutes to the flame of a triangular diffusion propane gas burner operating at 30 kW. The products of combustion are collected in a hood, and are extracted through an exhaust duct. Instrumentation is provided in the duct to measure temperature, velocity, gas composition (oxygen, carbon dioxide and carbon monoxide concentrations) and light obscuration. The velocity and gas

composition data are used to determine heat release rate on the basis of the oxygen consumption technique [1]. Smoke production rate is determined based on the measured flow rate and light obscuration in the duct. During the test observations are made of lateral flame spread (LFS) over the specimen surface and the presence of flaming droplets or particles.

#### **The Cone Calorimeter (ASTM E 1354 and ISO 5660)**

The Cone Calorimeter is a sophisticated small-scale test apparatus that is capable of measuring heat release rate of materials and products under a wide range of thermal exposure conditions. Other useful information obtained from Cone Calorimeter tests includes time to ignition, mass loss rate, smoke production rate and effective heat of combustion. The Cone Calorimeter apparatus, calibration procedure and test protocol are standardized in the United States as ASTM E 1354. ISO 5660-1 is functionally identical to ASTM E 1354 except that it does not include smoke production measurements. The latter form the subject of ISO 5660-2.

At the start of a test, a square specimen of 100 × 100 mm (4 × 4 in.) is placed on the load cell and exposed to a preset radiant heat flux from the electric heater. The heater is in the shape of a truncated cone and is capable of providing heat fluxes to the specimen in the range from 0 to 100 kW/m<sup>2</sup>. An electric spark ignition source is used for piloted ignition of the pyrolysis gases produced by the heated specimen. The products of combustion and entrained air are collected in a hood and extracted through a duct by a blower. A gas sample is drawn from the exhaust duct and analyzed for oxygen. Smoke production is determined on the basis of the measured light obscuration in the duct using a laser photometer located close to the gas sampling point. Gas temperature at and differential pressure across an orifice plate are used for calculating the mass flow rate of the exhaust gases. The oxygen concentration and mass flow rate measurements are used to calculate heat release rate based on the oxygen consumption technique [1].

### **REACTION-TO-FIRE CLASSIFICATION SYSTEMS**

#### **United States**

U.S. model building code fire safety requirements for interior finish materials are based primarily on performance in the Steiner tunnel test (ASTM E 84). The corresponding FSI and SDI

classification is given in Chapter 8, Section 803 of the 2003 International Building Code® (IBC) and Chapter 10, Section 10.3 of NFPA 5000. Table 1 provides this classification structure.

The USN requires that composites used on the topside of USN surface ships meet surface flammability and smoke requirements. For interior non-load bearing composite surfaces and composite surfaces on the exterior of the ship, surface flammability and smoke are regulated through ASTM E 84. The USN surface flammability requirement in both interior and exterior applications is a FSI  $\leq$  25. In addition, materials for use in the interior of a ship must also have a SDI  $\leq$  15 [2].

The use of structural composites in Naval submarines is discussed in MIL-STD-2031 (SH). This method identifies several flammability requirements for materials used in submarines and some of the performance criteria is based on testing in accordance to ASTM E 1354 at several irradiances. Table 2 provides a summary of the Cone Calorimeter fire performance criteria for materials on Naval submarines.

#### Australia

Alternative requirements for the reaction to fire of interior finish materials in the Building Code of Australia (BCA) are based on performance in the ISO 9705 room corner test. Products are classified in four groups based on the time to flashover (see Table 3).

#### European Union

Classification is based primarily on a fire growth rating (FIGRA), total heat released over the first 10 minutes of the test (THR600s), and lateral flame spread (LFS) across the long wing of the specimen. A smoke development index (SMOGRA), as well as visual observations of flaming droplets and/or particles are used for additional classification. The FIGRA index is equal to the maximum value of (heat release rate)/(elapsed time). To reduce the noise, the FIGRA is calculated based on the 30-second running average heat release rate. In addition, only heat release rates that exceed a class-dependent minimum value are considered in the calculations. The SMOGRA is equal to the maximum value of (smoke production rate)/(elapsed time). The smoke production rate is based on a 60-second running average. Smoke production rate and cumulative smoke production must exceed specified values.

Table 4 provides an excerpt (Class B, C and D) of the classification table from EN 13501-1. It is important to note that the official Euroclass (B, C or

D) of a material is subject to performance in EN 13823 as well as in EN ISO 11925-2 (small open flame test). This testing was not conducted for these materials, so the reported Euroclass is based solely on the EN 13823 test results.

#### Japan

The Building Standards Law (BSL) in Japan recognizes three classes of interior finish materials based on heat release rate measurements in the Cone Calorimeter (ISO 5660-1). The criteria are identical for the three classes, but the test duration is different. Peak heat release rate can exceed the limit for a maximum period of 10 seconds. Table 5 provides this classification structure.

#### United Nations (UN)

The UN doesn't have regulatory authority in terms of building codes or even transportation industries, strictly speaking. However, formation of the UN basically facilitated the formation of the IMO, due to collateral infrastructure and a common vision of maritime safety. The IMO does pass down regulations and all the member countries of the UN that have signed the Safety of Life at Sea (SOLAS) Treaty have to meet these regulations.

The IMO provides requirements for materials installed on passenger vessels, high-speed craft and numerous other applications. For the purpose of this paper, only the requirements for materials used in high-speed craft will be discussed.

Surface materials on high-speed craft must be "fire-restricting." Materials that will serve as bulkhead, wall and ceiling linings are tested in accordance with ISO 9705 and materials used for furniture and other components are tested in accordance with ISO 5660 (ASTM E 1354). The criteria for the ISO 9705 and 5660 test are provided in Table 6 and 7, respectively. The criteria for ISO 5660 was developed in support of a project for the USCG in 1998, and expanded upon by SwRI in 2004 [3]. In addition, these Cone Calorimeter criteria may be used as a screening tool to predict ISO 9705 high-speed craft code compliance.

### **EXPERIMENTAL**

#### Product Tested

Table 8 provides some information concerning the composite product that was tested. The literature data for some additional composite materials tested in accordance with ASTM E 84, E 1354 and ISO 9705, will be described in the Test Results section. The density and thicknesses of these

materials are generally unknown. They are submitted to help understand how the product that SwRI tested compares to previous literature data to materials of the same class.

### Summary of Test Results

The results of the tests according to ASTM E 84, ISO 9705, EN 13823 and ASTM E 1354 are presented in Tables 9-14.

The results for the epoxy panel with glass-phenolic cladding materials, as well as the epoxy vinyl ester material are taken from a paper published by Lattimer [4]. The results for the acrylic resin panels are taken from a paper published by Stevens, et. al. [5].

The results for all the composites in Tables 10-11, except the GRP-SwRI IR material, are taken from the paper published by Grenier, et. al. [6].

Please note that for SBI testing, additional tests according to EN ISO 11925-2 are needed to verify the classification. The classification for all the composites in Table 12, except the GRP-SwRI IR material, have been estimated based on the ISO 9705 data taken from the paper published by Grenier, et. al. [6].

The results for the composites numbered 2-9 in Table 13 are taken from the paper published by Grenier, et. al. [6]. The results for the composites numbered 10-12 in Table 13 are taken the paper published by Lattimer [4]. Cone Calorimeter data are reported in reference [5], however, there was not enough information available in the paper to determine the classification according to the Japanese BSL.

The results for all the composites in Table 14, except the GRP-SwRI IR material, are taken from the paper published by Grenier, et. al. [6]. Cone Calorimeter data are reported in references 4 and 5, however, there is not enough information available in the paper to determine acceptance according to the IMO criteria. No comparison was made between Cone Calorimeter data and USN criteria for installation of materials on Naval submarines, due to lack of sufficient data at the four different required heat fluxes.

### **COMPARISON OF CLASSIFICATION IN DIFFERENT COUNTRIES**

A comparison of the reaction-to-fire classification in the United States, Australia, the European Union and Japan for the products tested is shown in Table 15. In addition, where possible, it is noted if a material would meet the requirements of a

fire-restricting material per IMO. Construction products appear to be classified in a comparable manner in different countries, although some products do not follow the general trends. For example, two materials with the best classification in the US system have the worst classification in the Japanese system.

Table 16 provides a comparison of the classification systems. This illustrates that, regardless of the nomenclature, the US uses three classes, Australia uses four classes, Europe uses five classes (actually more, but five that utilize the SBI), and Japan uses four classes. The US method is arguably the least severe and the European system is arguably the most severe.

### **CONCLUSIONS**

A glass-reinforced plastic panel construction product was tested at SwRI in the ASTM E 84 Steiner tunnel, the ISO 9705 room and the EN 13823 single burning item (SBI) test apparatus. Most of the tests were conducted in duplicate or triplicate and the repeatability of the measurements was very good. The same product was also tested in the Cone Calorimeter (ASTM E 1354 and ISO 5660) at different heat flux levels to obtain ignition, heat release and smoke production properties.

This paper summarizes the test results and compares the corresponding reaction-to-fire classification in the United States, Australia, Europe and Japan. In addition to the data acquired in the SwRI project, additional available literature data are provided for similar materials (fiber reinforced plastic panels) to illustrate the range of product performance in a given standard fire test. Construction products appear to be classified in a comparable manner in different countries, although some products, such as GRP-clad sandwich panels, do not follow the general trends.

Efforts to model performance of construction products in the ASTM E 84 Steiner tunnel test, the ISO 9705 room/corner test and the EN 13823 single burning item test based on Cone Calorimeter data are currently underway. These model calculations will be validated on the basis of the current data set and will give insight in the underlying reasons for the discrepancies between the different test methods.

### **REFERENCES**

#### List of Test and Classification Standards

**ASTM E 84** *Standard Test Method for Surface Burning Characteristics of Building Materials*

**ASTM E 1354** *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*

**EN ISO 11925-2** *Reaction to fire tests for building products—Ignitability*

**EN 13501-1** *Fire classification of construction products and building elements – Part 1: Classification using test data from reaction to fire tests*

**EN 13823** *Reaction to fire tests for building products—Building products excluding flooring exposed to the thermal attack of a single burning item*

**ISO 5660-1** *Reaction-to-fire tests—Heat release, smoke production and mass loss rate—Part 1: Heat release rate (cone calorimeter method)*

**ISO 5660-2** *Reaction-to-fire tests—Heat release, smoke production and mass loss rate—Part 2: Smoke production rate (dynamic measurement)*

**ISO 9705** *Fire Tests – Full-Scale Room Test for Surface Products*

MIL-STD-2031 (SH), *Fire and Toxicity Methods and Qualification Procedure for Composite Material Systems Used in Hull, Machinery, and Structural Applications on Naval Submarines*

Referenced Publications

[1] Janssens, M., "Measuring Rate of Heat Release by Oxygen Consumption," *Fire Technology*, Vol. 27, pp. 234-249, 1991.

[2] Sorathia, U., Ziv, M., and Lattimer, B.Y., "Fire Performance Requirements for the Composite Helicopter Hanger," NSWCCD\_TR\_2001/22, Naval Surface Warfare Center-Carderock Division, West Bethesda, Maryland.

[3] Huczek, J.P., Janssens, M.L., *Application of a Methodology to Predict Room-Scale Fire Performance from Bench-Scale Testing*, Interflam 2004, 10th International Conference on Fire Science and Engineering, Edinburgh, Scotland, July 5-7, 2004.

[4] Lattimer, B.Y., *Composite Claddings for Reduced Surface Flammability and Smoke Production on Shipboard Composites*, Fire and Materials 2003, 8th International Conference on Fire and Materials, San Francisco, CA, January 27-28, 2003.

[5] Stevens, M., *Cone Calorimeter as a Screening Test for ASTM E-84 Tunnel Test*, Fire and Materials 1998, 5th International Conference on Fire and Materials, London, England, February 23-24, 1998.

[6] Grenier, A.T., Nash, L., Janssens, M.L., *Developing Cone Calorimeter Acceptance Criteria for Materials Used in High-Speed Craft*, Fire and Materials 1999, 6th International Conference on Fire and Materials, San Antonio, TX, February 22-23, 1998.

**Table 1. U.S. Building Code Classification Based on ASTM E 84**

Classification	Flame Spread Index	Smoke Developed Index
A	0 – 25	0 – 450
B	26 – 75	0 – 450
C	76 - 200	0 – 450

**Table 2. USN Submarine Acceptance Based on ASTM E 1354**

Irradiance (kW/m <sup>2</sup> )	Minimum Time to Sustained Ignition (s)	Maximum Heat Release Rate (kW/m <sup>2</sup> )	
		Peak	5-min Average
25	300	50	50
50	150	65	50
75	90	100	100
100	60	150	120

**Table 3. BCA Classification Based on ISO 9705**

Classification	t <sub>flashover</sub> (s)
Group a	0-120
Group b	120-600
Group c	600-1200
Group d	No flashover

**Table 4. European Reaction-to-Fire Classification System**

Classification	Test Method	Classification Criteria	Additional Classification
B	EN 13823, and	FIGRA $\leq 120$ W/s, and LFS < edge of specimen, and THR <sub>600s</sub> $\leq 7.5$ MJ	Smoke production*, and Flaming droplets/particles**
	EN ISO 11925-2	F <sub>s</sub> $\leq 150$ mm within 60 s	
C	EN 13823, and	FIGRA $\leq 250$ W/s, and LFS < edge of specimen, and THR <sub>600s</sub> $\leq 15$ MJ	Smoke production*, and Flaming droplets/particles**
	EN ISO 11925-2	F <sub>s</sub> $\leq 150$ mm within 60 s	
D	EN 13823, and	FIGRA $\leq 750$ W/s	Smoke production*, and Flaming droplets/particles**
	EN ISO 11925-2	F <sub>s</sub> $\leq 150$ mm within 60 s	

\* s1 = SMOGRA  $\leq 30\text{m}^2/\text{s}^2$  and TSP<sub>600s</sub>  $\leq 50\text{m}^2$ ; s2 = SMOGRA  $\leq 180\text{m}^2/\text{s}^2$  and TSP<sub>600s</sub>  $\leq 200\text{m}^2$ ; s3 = not s1 or s2

\*\* d0 = No flaming droplets/ particles in EN 13823 within 600 s; d1 = No flaming droplets/ particles persisting longer than 10s in EN 13823 within 600 s; d2 = not d0 or d1

**Table 5. BSL Classification Based on ISO 5660-1**

Classification	Test Duration (min)	Peak Heat Release Rate (kW/m <sup>2</sup> )	Total Heat Released (MJ/m <sup>2</sup> )
Noncombustible	20	200	8
Quasi Noncombustible	10	200	8
Fire Retardant	5	200	8

**Table 6. IMO Performance Criteria for Fire Restricting Materials Based on ISO 9705**

IMO LIMIT	HRR <sub>p,t</sub>	HRR <sub>n</sub>	SPR <sub>p</sub>	SPR	Flame Spread	Flaming Droplets or Debris
	(kW)	(kW)	(m <sup>2</sup> /s)	(m <sup>2</sup> /s)		
	$\leq 500$	$\leq 100$	$\leq 8.3$	$\leq 1.4$	None within 0.5 m of floor, 1.2 m from burner corner	None within 1.2 m from burner corner

**Table 7. IMO Performance Criteria for Fire Restricting Materials Based on ISO 5660**

<b>IMO LIMIT</b>	<b>t<sub>ig</sub> (s)</b>	<b>HRR<sub>30,max</sub> (kW/m<sup>2</sup>)</b>	<b>THR (MJ/m<sup>2</sup>)</b>	<b>SPR<sub>avg</sub> (m<sup>2</sup>/s)</b>	<b>ISO 9705 Prediction</b>
	≥ 20	≤ 60	≤ 20	≤ 0.005	Pass

**Table 8. Product Tested**

<b>Product</b>	<b>Density (kg/m<sup>3</sup>)</b>	<b>Thickness (mm)</b>
GRP - SwRI IR	1420	2.79

**Table 9. ASTM E 84 Flame Spread and Smoke Developed Indices**

<b>Product</b>	<b>FSI</b>	<b>SDI</b>	<b>Class</b>
GRP- SwRI IR	130	380	C
Epoxy Coated Sandwich Panel w/o Cladding	40	650	B*
Epoxy Coated Sandwich Panel w/ Cladding	0	5	A
Epoxy Vinyl Ester	20	750	A*
Acrylic Resin Panel #1	15	35	A
Acrylic Resin Panel #2	10	55	A

\* Class given based on FSI alone, as SDI is over 450

**Table 10. ISO 9705 Flashover Times**

<b>Product</b>	<b>Time to Flashover (sec)</b>	<b>Class</b>
GRP - SwRI IR	134	Group b
FR Phenolic	*	Group d
Fire Restricting Material	*	Group d
FR Polyester	372	Group b
FR Vinylester	318	Group b
FR Epoxy	990	Group c
Coated FR Epoxy	*	Group d
Polyester	108	Group a
FR Modified Acrylic	666	Group c

\* No Flashover

**Table 11. ISO 9705 IMO Criteria Results**

PRODUCT ID	HRR <sub>p,n</sub> (kW)	$\overline{\text{HRR}}_n$ (kW)	SPR <sub>p</sub> (m <sup>2</sup> /s)	$\overline{\text{SPR}}$ (m <sup>2</sup> /s)	Meets IMO
GRP – SwRI IR	3265	143	24.9	2.1	No
FR Phenolic	198	48	9.4	2.2	No
Fire Restricting Material	144	26	0.8	0.2	Yes
FR Polyester	1516	139	49.4	10.3	No
FR Vinylester	1436	197	54.7	14.8	No
FR Epoxy	686	114	42.9	10.2	No
Coated FR Epoxy	166	29	5.8	2.1	No
Polyester	1735	274	22.3	4.9	No
FR Modified Acrylic	963	132	8.7	1.1	No

**Table 12. EN 13823 Results**

Product	FIGRA (W/s)	THR <sub>600s</sub> (MJ)	SMOGRA (m <sup>2</sup> /s <sup>2</sup> )	TSP <sub>600s</sub> (m <sup>2</sup> )	Class
GRP - SwRI IR	1511	64.1	325	1258	E or F
FR Phenolic	120 < F < 250	< 15	NE	NE	B or C
Fire Restricting Material	120 < F < 250	< 15	NE	NE	B or C
FR Polyester	< 750	> 15	NE	NE	D
FR Vinylester	< 750	> 15	NE	NE	D
FR Epoxy	< 250	< 15	NE	NE	C
Coated FR Epoxy	< 120	< 7.5	NE	NE	B
Polyester	> 750	> 15	NE	NE	E or F
FR Modified Acrylic	< 250	< 7.5	NE	NE	C

NE: not estimated

**Table 13. ISO 5660-1 Results**

Product No.	Product	Duration	HRR <sub>max</sub>	THR	Classification
		(min)	(kW/m <sup>2</sup> )	(MJ/m <sup>2</sup> )	
1	GRP - SwRI IR	5	449	51.8	Unclassified
2	FR Phenolic	20	34	4.6	Noncombustible
3	Fire Restricting Material	20	34	7.1	Noncombustible
4	FR Polyester	5	116	20.2	Unclassified
5	FR Vinylester	5	135	20.3	Unclassified
6	FR Epoxy	20	163	5.4	Noncombustible
7	Coated FR Epoxy	20	42	0.9	Noncombustible
8	Polyester	5	361	64.6	Unclassified
9	FR Modified Acrylic	5	129	15.7	Unclassified
10	Epoxy Coated Sandwich Panel w/o Cladding	5	125	30.0	Unclassified
11	Epoxy Coated Sandwich Panel w/ Cladding	10	10	4.2	Quasi-Noncombustible
12	Epoxy Vinyl Ester	5	115	24.0	Unclassified

**Table 14. ISO 5660 IMO Criteria Results**

<b>PRODUCT ID</b>	<b>t<sub>ig</sub> (s)</b>	<b>HRR<sub>30,max</sub> (kW)</b>	<b>THR (MJ/m<sup>2</sup>)</b>	<b>SPR<sub>avg</sub> (m<sup>2</sup>/s)</b>	<b>Meets IMO</b>
GRP – SwRI IR	39	431	52.9	0.0536	No
FR Phenolic	324	28	4.6	0.0012	Yes
Fire Restricting Material	NI	-	-	-	Yes
FR Polyester	65	101	44.7	0.0268	No
FR Vinylester	75	116	65.6	0.0312	No
FR Epoxy	123	59	5.4	0.0063	No
Coated FR Epoxy	68	15	0.9	0.0005	Yes
Polyester	30	334	68.5	0.0540	No
FR Modified Acrylic	93	105	47.7	0.0020	No

NI: no ignition

**Table 15. Comparison of Reaction-to-Fire Classification in Different Countries**

<b>Product</b>	<b>United States</b>	<b>Australia</b>	<b>Europe</b>	<b>Japan</b>	<b>IMO</b>
GRP - SwRI IR	C	Group b	E or F	Unclassified	No
FR Phenolic	ND	Group d	B or C	Noncombustible	No
Fire Restricting Material	ND	Group d	B or C	Noncombustible	Yes
FR Polyester	ND	Group b	D	Unclassified	No
FR Vinylester	ND	Group b	D	Unclassified	No
FR Epoxy	ND	Group c	C	Noncombustible	No
Coated FR Epoxy	ND	Group d	B	Noncombustible	No
Polyester	ND	Group a	E or F	Unclassified	No
FR Modified Acrylic	ND	Group c	C	Unclassified	No
Epoxy w/o Cladding	B	ND	ND	Unclassified	ND
Epoxy w/ Cladding	A	ND	ND	Quasi-Noncombustible	ND
Epoxy Vinyl Ester	A	ND	ND	Unclassified	ND
Acrylic Resin Panel #1	A	ND	ND	ND	ND
Acrylic Resin Panel #2	A	ND	ND	ND	ND

ND: not determined; Yes: meets IMO requirements; No: does not meet IMO requirements

**Table 16. Comparison of Reaction-to-Fire Classification Systems**

RANKINGS FROM BEST TO WORST FIRE PERFORMANCE	CLASSIFICATION LEVELS			
	US	Australia	Europe	Japan
1	A	Group D	B	Noncombustible
2	B	Group C	C	Quasi- Noncombustible
3	C	Group B	D	Flame Retardant
4	-	Group A	E	Unclassified
5	-	-	F	-