Fire Regulations Governing Marine Composite Construction

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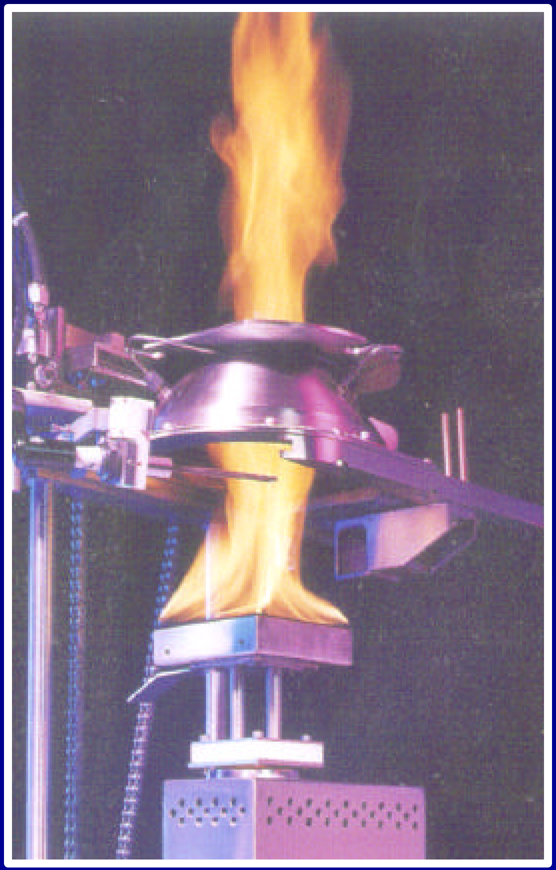
Presentation Overview

- Fire Performance Characteristics
- Material Performance
- Recreational Boats
- Commercial Vessels
- U.S. Navy Use of Composites
- Fire Protection Schemes

Fire Performance Characteristics

- Time-to-Ignition
- Flame Spread
- Burn Through Resistance
- Rate of Heat Release
- Smoke Production

Time-to Ignition and Flame Spread



Time-to Ignition Testing with Cone Calorimeter

Flame Spread Testing with
ISO 9705 Room Corner test

Burn Through Resistance

Test Arrangement for Burn Through Resistance of 10 x 10 - foot Panel

Hot Surface During 2000º Test

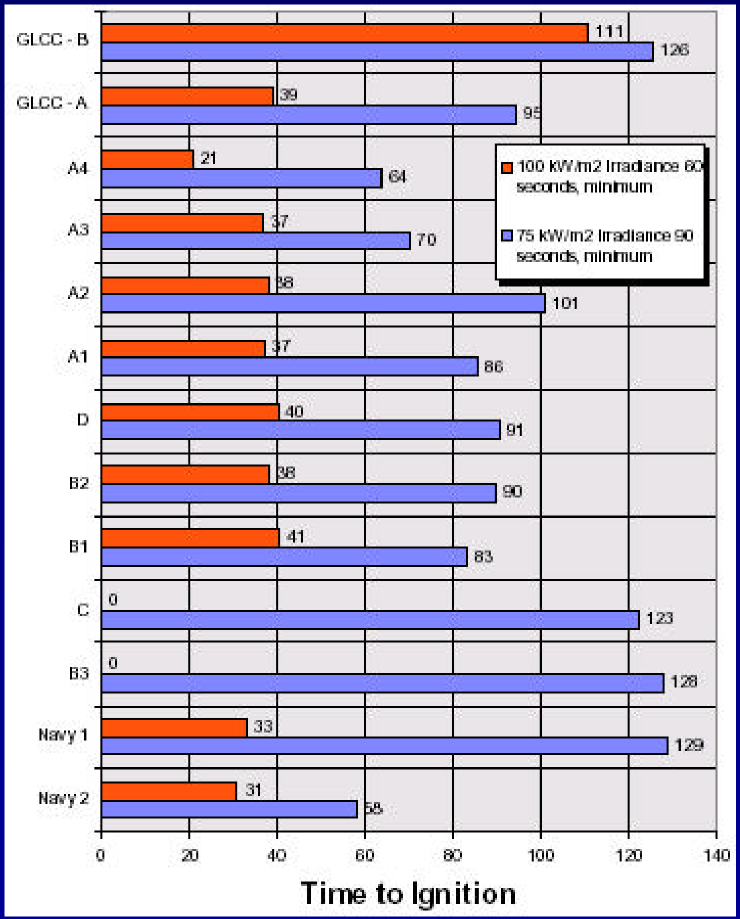
Smoke Produced During Test

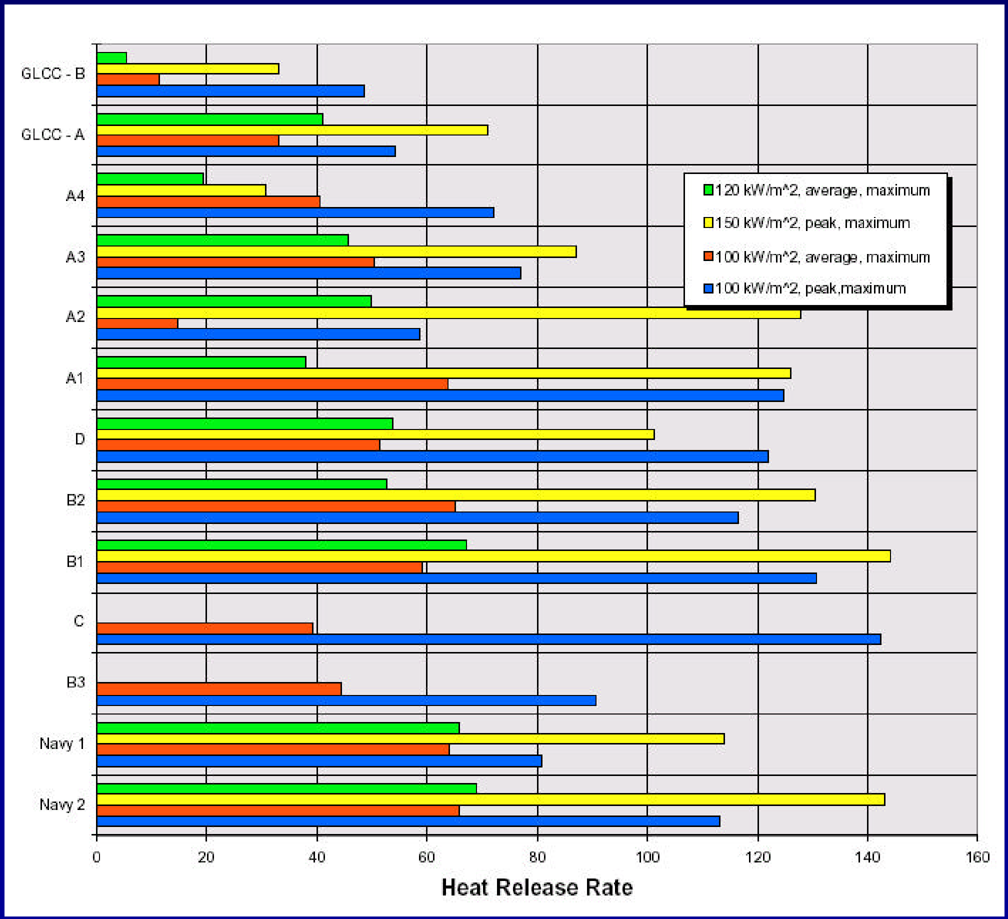
Material Performance

- Resin
- Reinforcement
- Core Material

Fire Regulations Governing Marine Composite Construction

Resin





Reinforcement

E-Glass Vinyl Ester Laminate Tested Without Insulation for Burn Through Resistance

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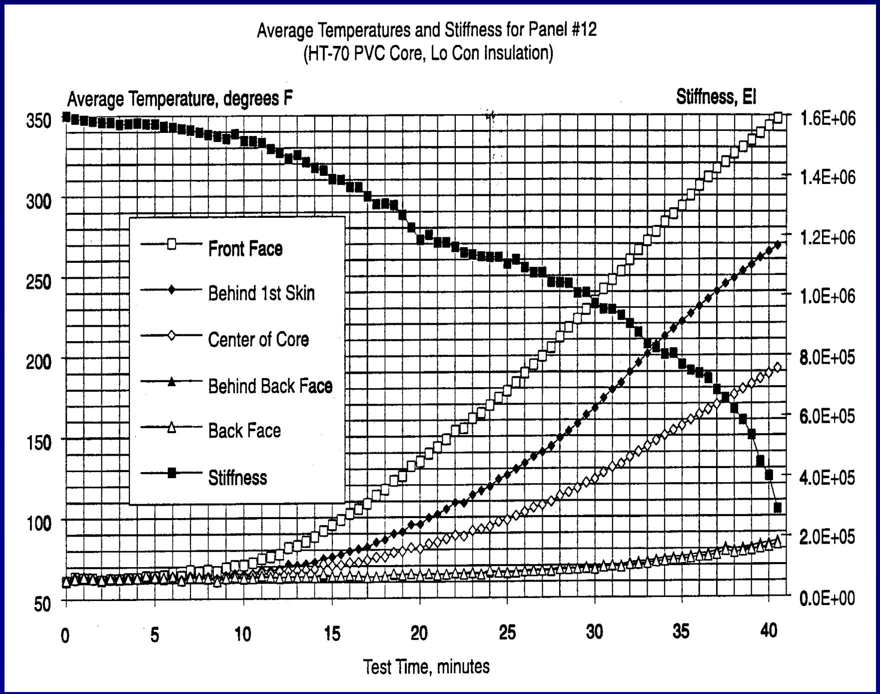
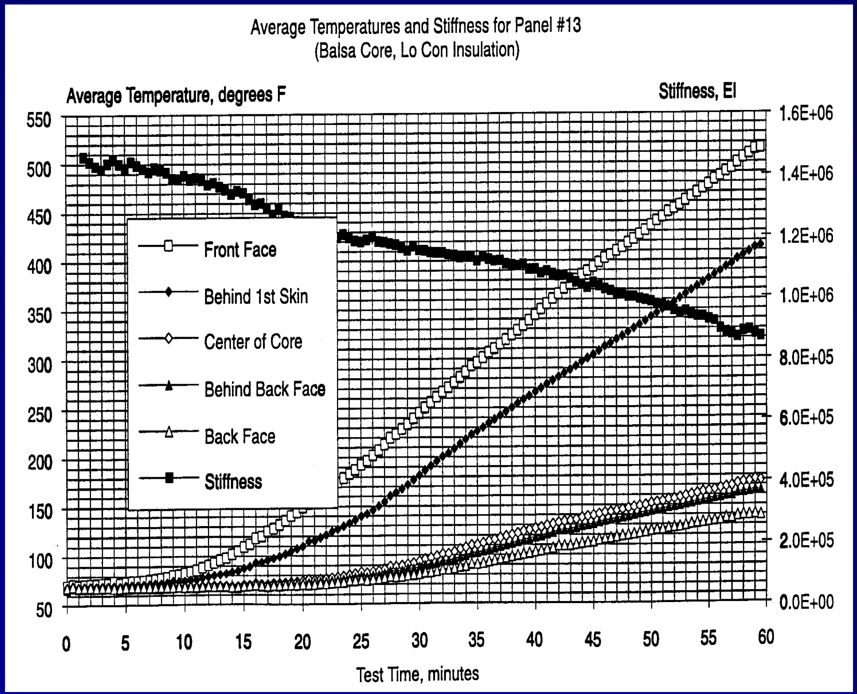
Core



Temperature Distribution and Stiffness
of PVC-Cored Panel During SOLAS Fire Test



Temperature Distribution and Stiffness
of Balsa-Cored Panel During SOLAS Fire Test

Recreational Boats

- Major Fire Threats
  - Engine Room
  - Galley
- Boats Less than 50 Feet
  - Suppression of Fires from Gas Engines
  - No Structural Fire Protection
- Large Mega-Yachts
  - Marine Coastguard Agency (UK) Inspected
  - Unclassed Vessels

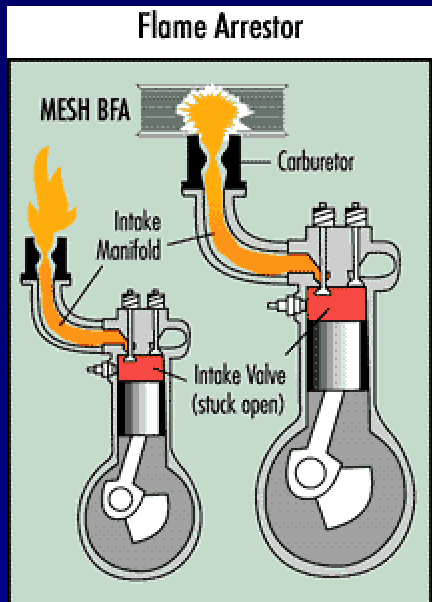
Fires on Recreational Boats

A Thick Tower of Smoke Rises From a Burning Boat on Folsom Lake (Democrat photo by William A. Scales)

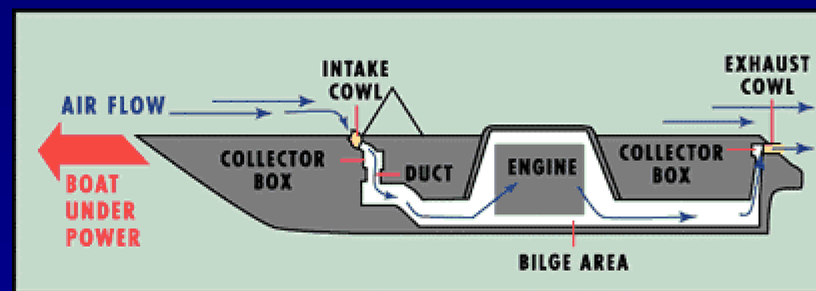
A Parked Speedboat and Trailer on Fire in the UK

Images from Fire Safety & Training in the United Kingdom

Federal Regulations for Recreational Boats



Gasoline engines installed in a vessel after April 25, 1940, except outboard motors, must be equipped with an acceptable means of backfire flame control. The device must be suitably attached to the air intake with a flame tight connection and is required to be Coast Guard approved or comply with SAE J-1928 or UL 1111 standards and marked accordingly.



All boats which use gasoline for electrical generation, mechanical power or propulsion are required to be equipped with a ventilation system.

http://www.uscgboating.org/

Marine Coastguard Agency (UK) Code for Megayachts

The UK based Marine Safety Agency has developed guidelines that are being adopted by megayachts (over 80 feet). Much of the language follows SOLAS requirements, especially for vessels of 50 meters in length or 500 gross tons and over. The following summarizes some key points of the MSA Code:

14A STRUCTURAL FIRE PROTECTION - VESSELS OF LESS THAN 50 METERS IN LENGTH AND UNDER 500 GT

14A.1 The boundaries of any space containing internal combustion propulsion machinery or oil fired boilers on a new vessel should comply with the following:

.1 they should be gas tight;

.2 they shall be capable of preventing the passage of smoke and flame at the end of the 60 minute standard fire test, and

.3 they should be so insulated where necessary with a suitable non combustible material, that if the division is exposed to a standard fire test, the average temperature on the unexposed side of the division should not increase by more than 139°C (282°F) above the initial temperature within a period of 30 minutes.

Where such boundaries are constructed of materials other than steel or aluminum, calculation methods may be used where appropriate to determine compliance with .2 and 3.

Marine Coastguard Agency (UK) Code for Megayachts

14B STRUCTURAL FIRE PROTECTION - VESSELS OF 50 METERS LENGTH AND OVER OR 500 GT AND OVER

Spaces	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Control stations	A-0_c	A-0	A-60	A-0	A-15	A-60	A-15	A-60	*
(2) Corridors		C_e	B-0_e	A-0_a B-0_e	B-0_e	A-60	A-0	A-15 A-0_d	*
(3) Accommodation Spaces			C_e	A-0_a B-0_e	B-0_e	A-60	A-0	A-15 A-0_d	*
(4) Stairways				A-0_a B-0_e	A-0_a B-0_e	A-60	A-0	A-15 A-0_d	*
(5) Service spaces (low risk)					C_e	A-60	A-0	A-0	*
(6) Machinery spaces of category A						*	A-0	A-60	*
(7) Other machinery spaces							A-0	A-0	*
(8) Service spaces (high risk)								A-0_b	*
(9) Open decks									*

Fire Integrity of Bulkheads Separating Adjacent Spaces

Marine Coastguard Agency (UK) Code for Megayachts

Other subjects covered by MSA to ensure an adequate level of fire protection include:

14B.3.6	Means of escape
14B.3.7	Protection of stairways and elevators in accommodation and service spaces
14B.3.8	Openings in "A" class divisions
14B.3.9	Openings in "B" class divisions
14B.3.10	Windows and side scuttles
14B.3.11	Restricted use of combustible materials
14B.3.12	Details of construction

Commercial Vessels

- Subchapter T Vessels
- Subchapter K Vessels
    - NAVIC 03-01 on Equivalency
- High Speed Craft Code
    - Fire Resisting Divisions
    - Fire-Restricting Materials
- Large Passenger Ships
    - Non-Combustibility Standard

USCG Inspected Passenger Vessels

The commercial designer is primarily concerned with the following general restrictions and excerpts from the Code of Federal Regulations (see appropriate Code of Federal Regulation for detail):

- Subchapter T - Small Passenger Vessels: Use of low flame spread (ASTM E 84 <100) resins;

- Subchapter K - Small Passenger Vessels Carrying More Than 150 passengers or with overnight accommodations for 50 - 150 people: must meet SOLAS requirement with hull structure of steel or aluminum conforming to ABS or Lloyd's;

? Subchapter I - Cargo Vessels: Use of incombustible materials - construction is to be of steel or other equivalent material; and

? Subchapter H - Passenger Vessels: SOLAS requires noncombustible structural materials and insulated with approved noncombustible materials so that the average back face temperature will not rise above designated values.

Subchapter T Vessels

§177.410 Structural Fire Protection

(a) *Cooking areas*. Vertical or horizontal surfaces within 910 millimeters (3 feet) of cooking appliances must have an American Society for Testing and Materials (ASTM) E-84 "Surface Burning Characteristics of Building Materials" flame spread rating of not more than 75. Curtains, draperies, or free hanging fabrics must not be fitted within 910 millimeters (3 feet) of cooking or heating appliances.

(b) *Fiber reinforced plastic*. When the hull, decks, deckhouse, or superstructure of a vessel is partially or completely constructed of fiber reinforced plastic, including composite construction, the resin (*laminate*) used must have an ASTM E-84 flame spread rating of not more than 100.

(c) *Use of general purpose resin*. General purpose resins may be used in lieu of those having an ASTM E-84 flame spread rating of not more than 100 provided that the following additional requirements are met:

(1) *Cooking and Heating Appliances*.
(3) *Fire Detection and Extinguishing Systems*.
(4) *Machinery Space Boundaries*.
(5) *Furnishings*.

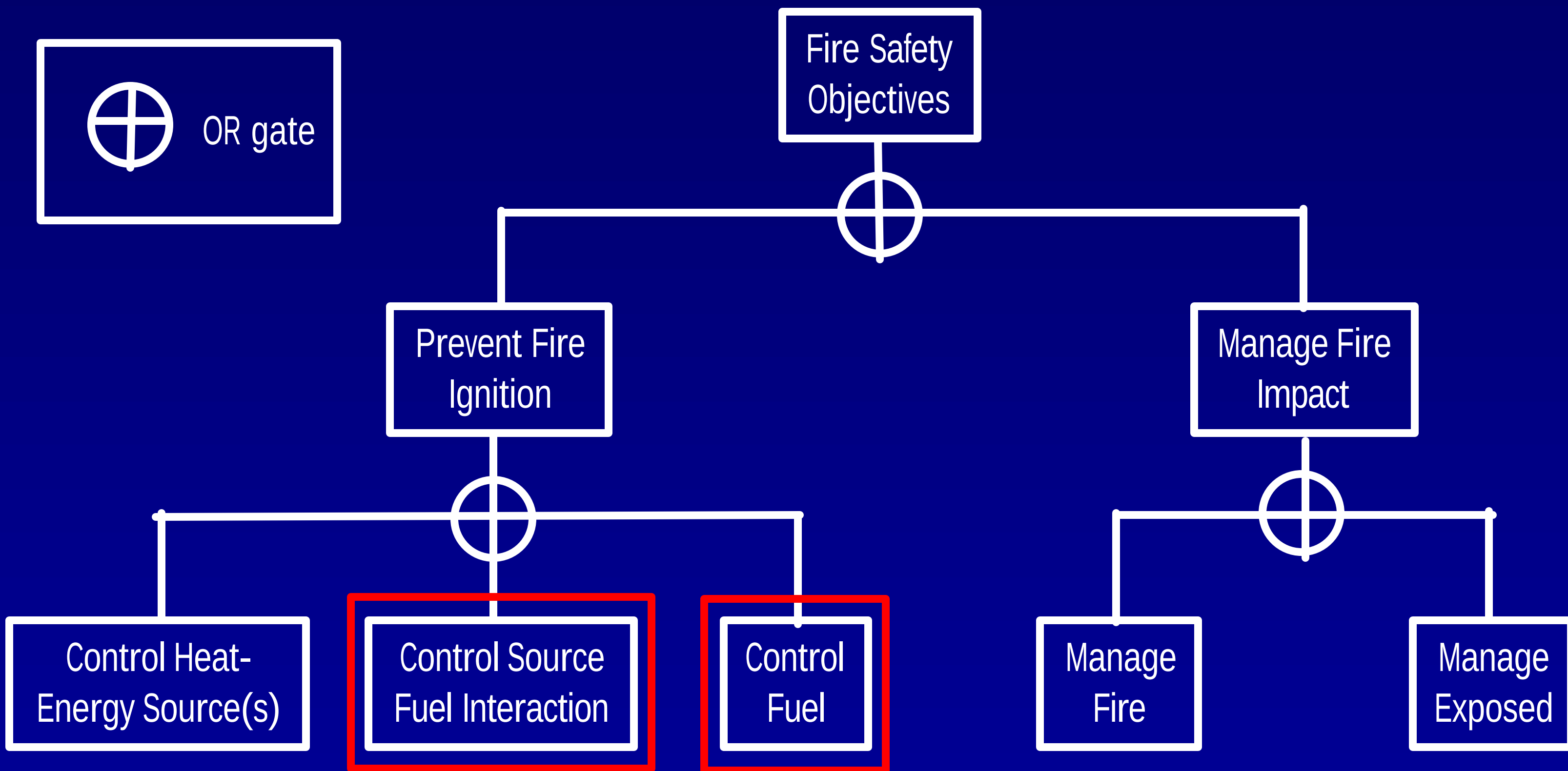
(d) Limitations on the use of general purpose resin.

(1) *Overnight Accommodations*. Vessels with overnight passenger accommodations must not be constructed with general purpose resin.

(2) *Gasoline Fuel Systems*. Vessels with engines powered by gasoline or other fuels having a flash point of 43.3° C (110° F) or lower must not be constructed with general purpose resin, except for vessels powered by outboard engines with portable fuel tanks stored in an open area aft, if, as determined by the cognizant OCMI, the arrangement does not produce an unreasonable hazard.

(3) *Cargo*. Vessels carrying or intended to carry hazardous combustible or flammable cargo must not be constructed with general purpose resin.

Subchapter K Vessels - NAVIC 03-01 on Equivalency



Upper Level of Fire Safety Tree

Subchapter K Vessels - NAVIC 03-01 on Equivalency

Development of Performance Criteria

- Life Safety Criteria - These address the survivability of passengers and crew and may represent the effects of heat, smoke, toxicity, reduced visibility, and evacuation time.

- Criteria for Damage to Ship Structure and Related Systems - These address the impact that fire and its effluents might have on the ship structure, mechanical systems, electrical systems, fire protection systems, evacuation systems, propulsion and maneuverability, etc. These criteria may represent thermal effects, fire spread, smoke damage, fire barrier damage, degradation of structural integrity, damage to environment, etc.

? Criteria for Damage to the Environment - These address the impact of heat, smoke and released pollutants on the atmosphere and marine environment.

High Speed Craft Code - Fire Resisting Divisions

Fire-resisting divisions are defined as those divisions formed by bulkheads and decks which comply with the following:

.1 They should be constructed of noncombustible or fire-restricting materials which by insulation or inherent fire-resisting properties satisfy the requirements of .2 to .6.

.2 They should be suitably stiffened.

.3 They should be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the appropriate fire protection time.

.4 Where required, they should maintain load-carrying capabilities up to the end of the appropriate fire protection time.

.5 They should have thermal properties such that the average temperature on the unexposed side will not rise more than 139° C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 180° C above the original temperature during the appropriate fire protection time.

.6 A test in accordance with the test procedures for a prototype bulkhead and deck should be required to ensure that it meets the above requirements.

High Speed Craft Code - Fire Resisting Divisions

After Bulkhead Test at Omega Point Laboratories

Weights Being Positioned for Deck Test at Omega Point Laboratories

High Speed Craft Code - Fire Resistive Materials

IMO Resolution MSC 40(64) on ISO 9705 Test: Tests should be performed according to the standard *ISO 9705, the Room/Corner Test*. This standard gives alternatives for choice of ignition source and sampling mounting technique. For the purpose of testing products to be qualified as *"fire restricting materials"* under the IMO High-Speed Craft Code, the following should apply:

Ignition source: Standard ignition source according to Annex A in ISO 9705, i.e. 100 kW heat output for 10 minutes and thereafter 300 kW heat output for another 10 min. *Total testing time* is 20 minutes.

100 kW Fire

300 kW Fire

High Speed Craft Code - Fire Resistive Materials

Criteria for Qualifying Products as *"Fire Restricting Materials"*

? The *time average of HRR* excluding the ignition source does not exceed *100 kW*;

? The *maximum HRR* excluding the HRR from the ignition source does not exceed *500 kW* averaged over any 30 second period of the test;

? The time *average of the smoke production rate* does not exceed *1.4 m2/s*;

? The *maximum value of smoke production rate* does not exceed *8.3*m^2*/s* averaged over any period of 60 seconds during the test;

? *Flame spread* must not reach any further down the walls of the test room than *0.5 m* from the floor excluding the area which is within 1.2 meter from the corner where the ignition source is located;

- *No flaming drops or debris* of the test sample may reach the floor of the test room outside the area which is within 1.2 meter from the corner where the ignition source is located

Large Passenger Ships - Noncombustibility Standard

INTERNATIONAL MARITIME ORGANIZATION - NON-COMBUSTIBILITY TEST

1.2 If a material passes the test as specified in section 2, it shall be considered as "non-combustible" even if it consists of a mixture of inorganic and organic substances.

2 Fire test procedure

2.1 The non-combustibility shall be verified in accordance with the test procedure in the standard ISO 1182:1990 except that instead of Annex A "Criteria for evaluation" of this standard all the following criteria shall be satisfied:

.1 the average furnace thermocouple temperature rise as calculated in 8.1.2 of ISO 1182 does not exceed 30ºC;

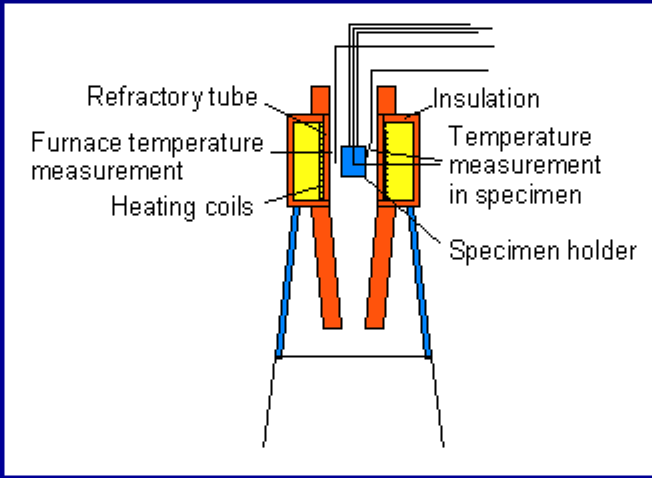
.2 the average surface thermocouple temperature rise as calculated in 8.1.2 of ISO 1182 does not exceed 30 ºC;

.3 the mean duration of sustained flaming as calculated in 8.2.2 of ISO 1182 does not exceed 10 s; and

.4 the average mass loss as calculated in 8.3 of ISO 1182 does not exceed 50%.

TEST PROCEDURE

The testing is performed in an open, vertically positioned cylindrical furnace. The furnace is preheated to 750 °C before the test specimen is introduced. The specimens are cylindrical with diameter 45 mm and height 50 mm.



U.S. Navy Use of Composites

- Applications
  - Hull Structure
  - Topside Structure
  - Components
- Surface Ship Criteria
  - UL 1709 Burn-Through Resistance
  - Room Corner Test
- MIL STD 2031 (SH) for Submarines
- Component Testing

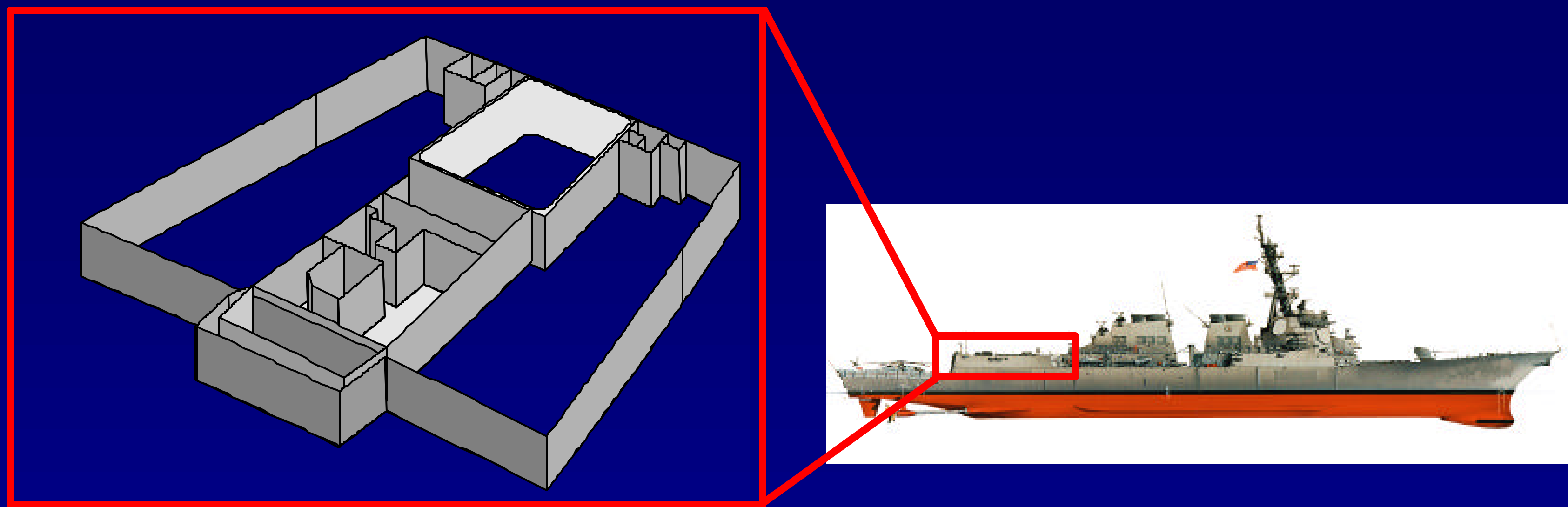
U.S. Navy Use of Composites - Hull Structure

MHC 51 Osprey Coastal Mine Hunter

11-Meter RIB Used by the U.S. Navy SEALS

50-Foot Navy Utility Boat - One of 1500 Fiberglass Boats Built for the Navy by Uniflite

U.S. Navy Use of Composites - Topside Structure



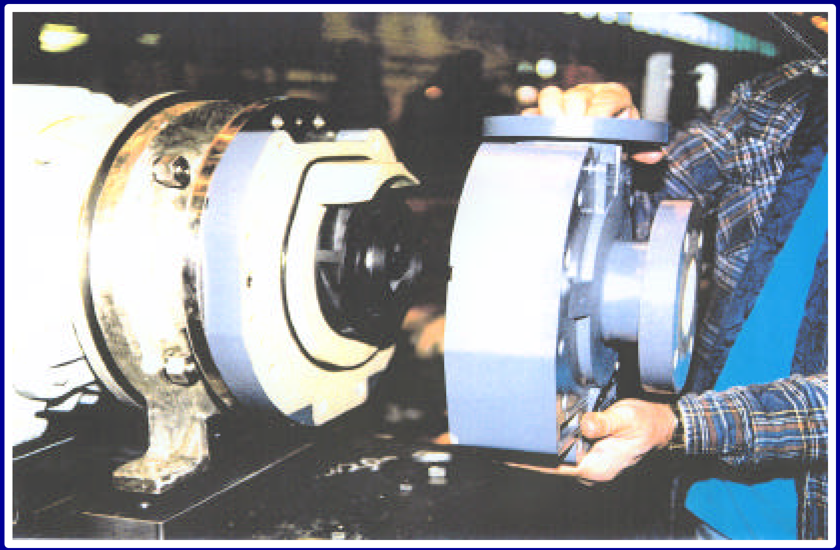
Composite Helicopter Hanger for DDG 51 Flight IIA Destroyer Built at Northrop Grumman Gulfport Facility

Forward Director Room
Built by Northrop Grumman
as Technology
Demonstrator for DDG 51

U.S. Navy Use of Composites - Components

Composite Ventilation Ducts on FFG 58
built by Structural Composites

Phenolic Deck Grating Installed on
Aircraft Carrier



Family of Composite Pumps Developed
by
the U.S. Navy to Reduce Maintenance
Cost and Reduce Parts Inventory

U.S. Navy Use of Composites - Surface Ship Criteria

- Small Fires (<200 kW) should not grow quickly.
- Fire and Smoke should not generate untenable conditions quickly.
- Bulkheads, decks and structural members should resist post flashover UL 1709 fire for 30 minutes under load with No holing, and far side average temperatures rise less than 250ºF.
- Fire should be capable of being extinguished by agents on board ship.
- Melting, and dripping spreads fire, and are considered unacceptable.
- Passive fire protection system shall be attached so as to survive the fire and other loads.

Source: Usman Sorathia, NSWCCD Code 643

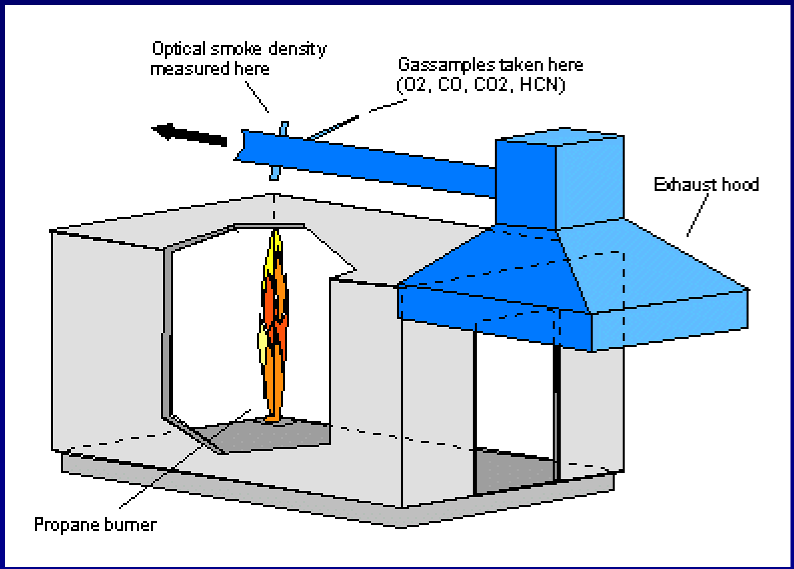
U.S. Navy Use of Composites - Summary of Surface Ship Test Requirements

Design Consideration	Method for Evaluating Performance	Areas Required
Fire Growth		
Flashover Potential	ISO 9705	All Boundaries*
Visibility	ISO 9705	All Boundaries*
Gas Toxicity (CO)	ISO 9705	All Boundaries*
Fire Resistance		
Heat Transmission	UL 1709 (ASTM E119 protocol)	Fire Zone Boundaries
Structural Integrity	UL 1709 (ASTM E119 protocol)	All Boundaries and Joints
Attachment Integrity during Fire		
Doors / Hatches	UL 1709 (NFPA 252 protocol)	Structural Doors/Hatches
Equipment Mounts	UL 1709 (nonstandard furnace test)	Three Classes of Mounts
Penetrations		
Heat Transmission/Flame Passage	UL 1709 (ASTM E814 protocol)	Fire Zone Boundaries
Prevent Ignition of Composite	UL 1709 (ASTM E814 protocol)	Non-Fire Zone Boundaries

*except for boundaries in spaces shown through the FHA to not require protection

From Dr. Brian Lattimer, Hughes Associates

U.S. Navy Use of Composites - Surface Ship Criteria - Room Corner Test



Schematic of ISO 9705 Room Corner Test to Determine Flame Spread and Smoke Generation

Lighting of Burner to Start Modified ISO 9705 Room Corner Test at VTEC Laboratories

Fire Regulations Governing Marine Composite Construction

U.S. Navy Use of Composites - Submarine Criteria - MIL-STD-2031 (SH)

Fire Test/Characteristic		Requirement		Test Method
Oxygen-Temperature Index (%)	The minimum concentration of oxygen in a flowing oxygen nitrogen mixture capable of supporting flaming combustion of a material.		Minimum	ASTM D 2863 (modified)
		% oxygen @ 25°C	35	
		% oxygen @ 75°C	30	
		% oxygen @ 300°C	21	
Flame Spread Index	A number or classification indicating a comparative measure derived from observations made during the progress of the boundary of a zone of flame under defined test conditions.		Maximum 20	ASTM E 162
Ignitability (seconds)	The ease of ignition, as measured by the time to ignite in seconds, at a specified heat flux with a pilot flame.		Minimum	ASTM E 1354
		100 kW/m^2 Flux	60	
		75 kW/m^2 Flux	90	
		50 kW/m^2 Flux	150	
		25 kW/m^2 Flux	300	
Heat Release Rate (kW/m^2)	Heat produced by a material, expressed per unit of exposed area, per unit of time.		Maximum	ASTM E 1354
		100 kW/m^2 Flux		
		Peak	150	
		Average 300 secs	120	
		75 kW/m^2 Flux		
		Peak	100	
		Average 300 secs	100	
		50 kW/m^2 Flux		
		Peak	65	
		Average 300 secs	50	
		25 kW/m^2 Flux		
		Peak	50	
		Average 300 secs	50	
Smoke Obscuration	Reduction of light transmission by smoke as measured by light attenuation.		Maximum	ASTM E 662
		D_s during 300 secs	100	
		D_{max} occurrence	240 secs	

Fire Regulations Governing Marine Composite Construction

U.S. Navy Use of Composites - Component Testing

Fire Testing of Phenolic Ventilation Ducts
to Navy-Modified FM 4922 Test at VTEC Labs

Fire Protection Schemes

- Resins with Improved Fire Performance Characteristics
    - Fire Retardant Additives
    - Phenolic Resins
- Structural Fire Protection
    - Insulation Blankets
    - Intumescent Coatings
    - Spray Insulation Systems
- Fire Hazard Analysis
    - Fire Characteristics of Room Lining Material and Geometry
    - Fire Detection and Suppression

Fire Retardant Additives

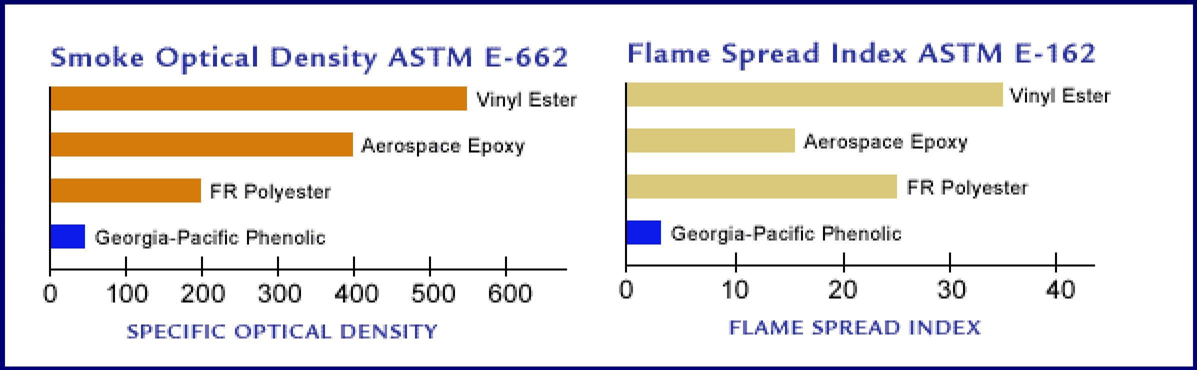
There are three main families of flame-retardant chemicals:

1. The main inorganic flame retardants are aluminium trihydroxide, magnesium hydroxide, ammonium polyphosphate and red phosphorus. This group represents about 50% by volume of the worldwide flame retardant production. Some of these chemicals are also used as flame retardant synergists, of which antimony trioxide is the most important.

2. Halogenated products are based primarily on chlorine and bromine. This group represents about 25% by volume of the worldwide production.

3. Organophosphorus products are primarily phosphate esters and represent about 20% by volume of the worldwide production. Products containing phosphorus, chlorine and/or bromine are also important.

Phenolic Resins



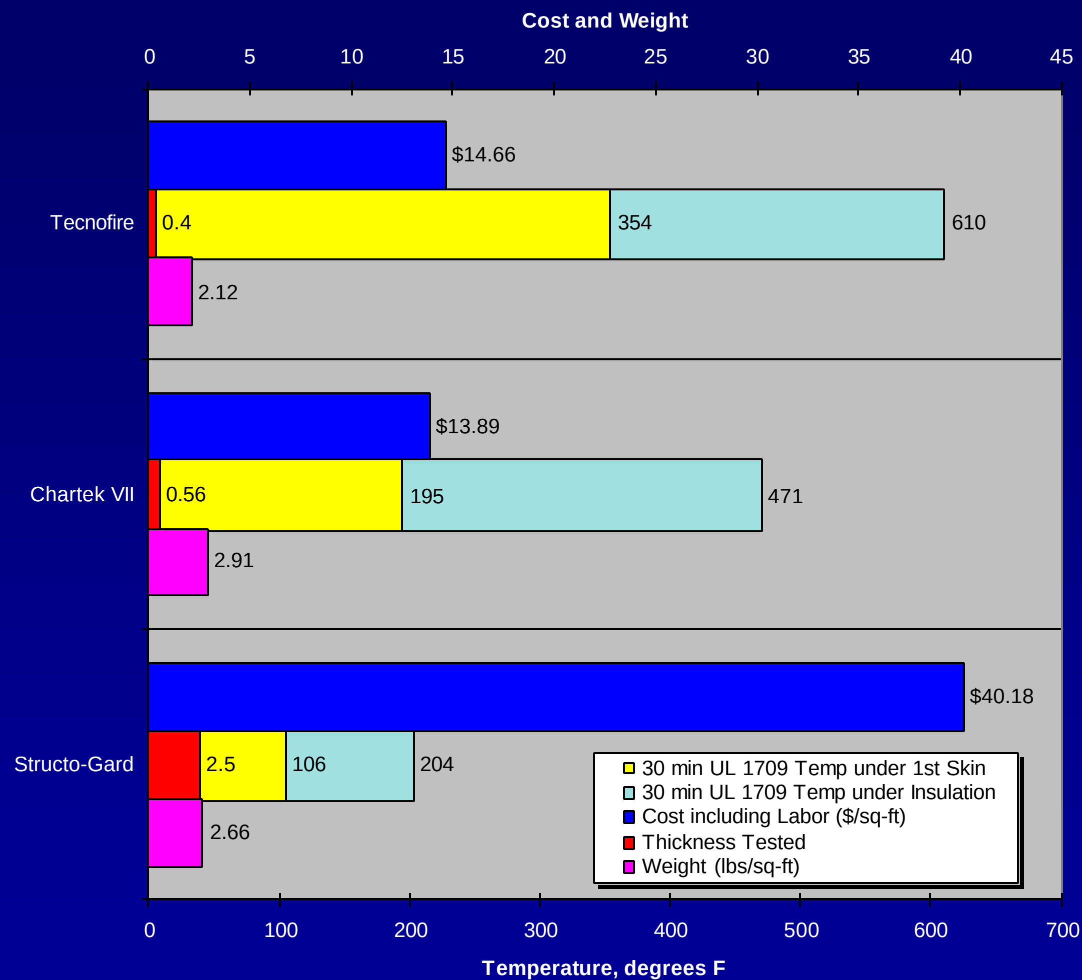
Fire Performance of Phenolic Resin from Georgia-Pacific

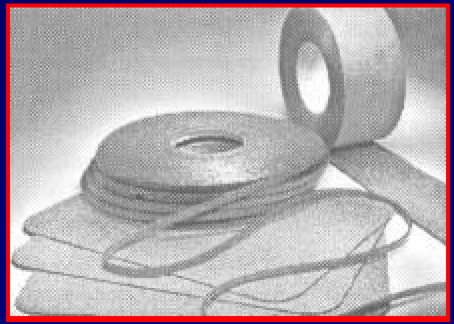
Bondstrand PSX • L3 Phenolic Pipe Passed IMO Level 3 Fire Tests That Subjected Pipe to 1000º C

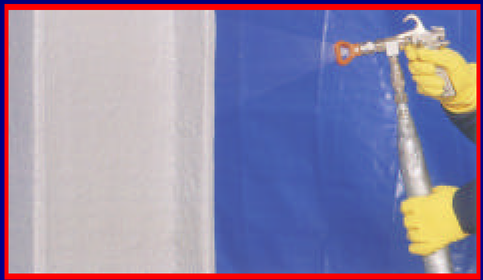
Phenolic Resin-Based Modular Panels for Offshore Topside Housing Built by Balmoral Composites

Fire Regulations Governing Marine Composite Construction

Structural Fire Protection



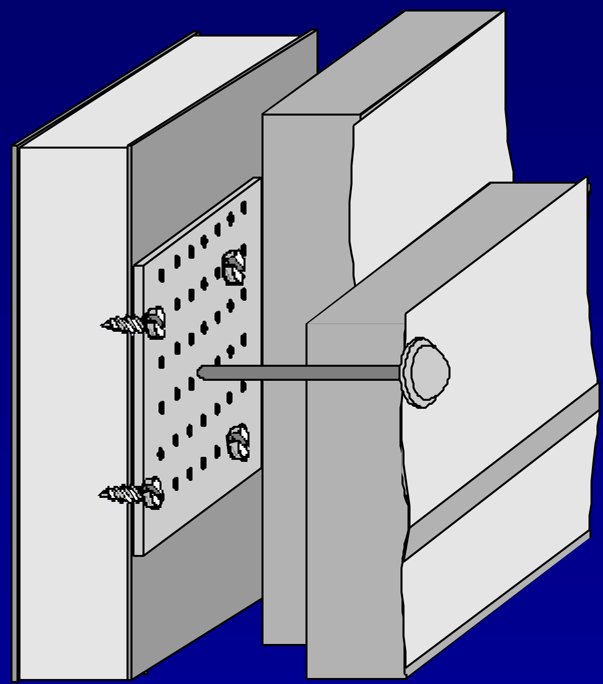




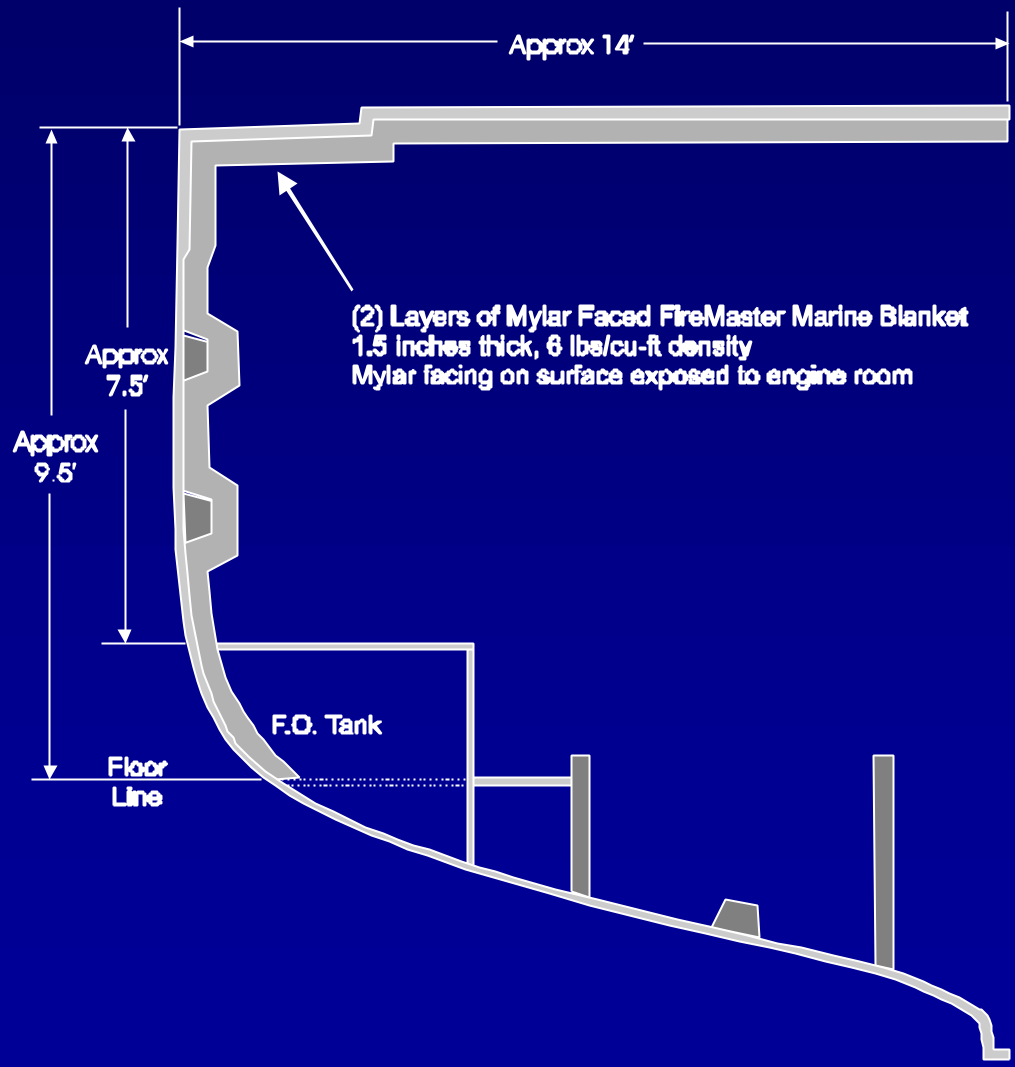
Cost data based on NG chart presented 7/28/98 at BIW

Fire Regulations Governing Marine Composite Construction

Typical Engine Room Structural Fire Protection



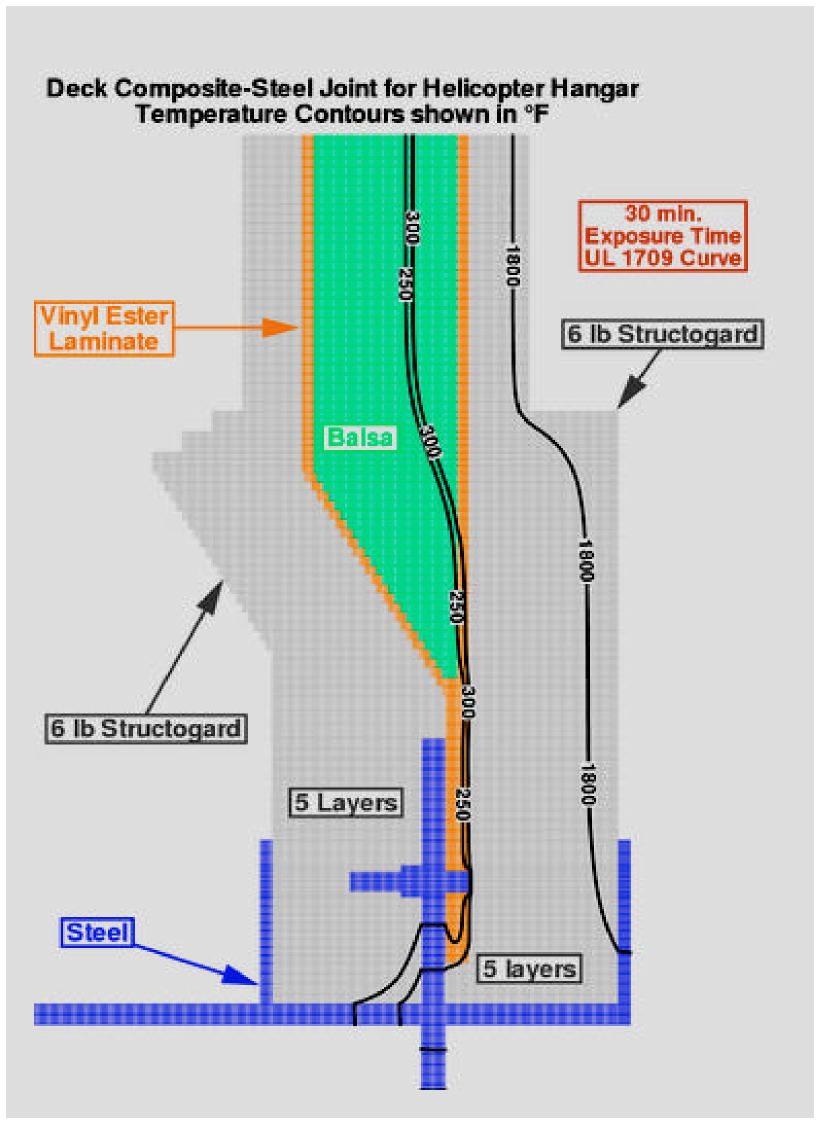
Detail of Insulation Blanket Installation

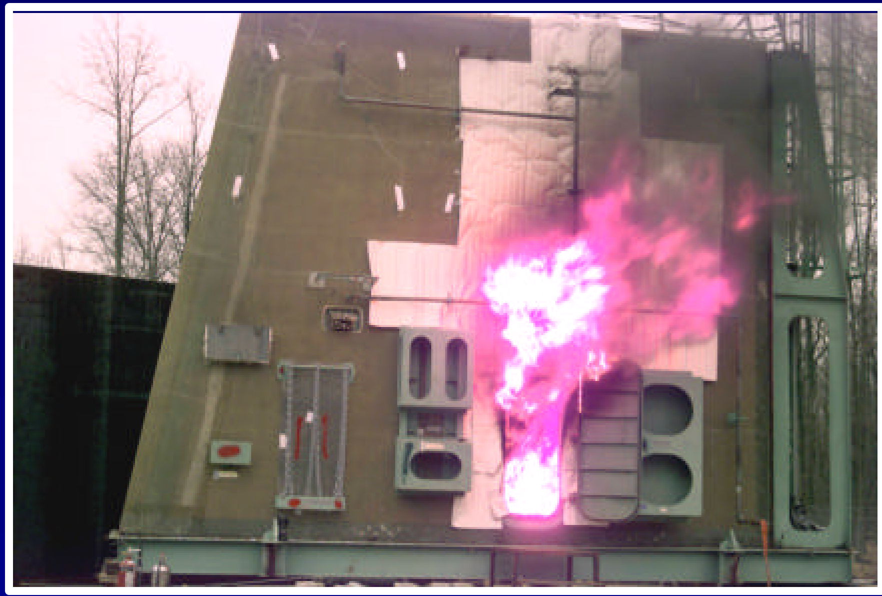


Eric Greene for 40th Annual National Marine Conference

Fire Regulations Governing Marine Composite Construction

Fire Hazard Analysis





Fire Hazard Analysis by Hughes Associates
Predicts Thermal Profile of Composite
Structure During Full-Scale Fire Test

Fire Detection and Suppression

Type of Detector	Maximum floor area per detector	Maximum distance apart between centers	Maximum distance away from bulkheads
Heat	37 m^2	9 m	4.5 m
Smoke	74 m^2	11 m	5.5 m

Required Spacing of Detectors on Ships

A Chemetron Water Mist System Provides a Fine Water Mist for Effective Protection Without the Deluge and Damage of traditional Water-Based Systems

Testing of Water Mist Systems on the ex-*USS SHADWELL*

Conclusions

- Fire Characteristics of Materials Are Unique and Require Individual Test Methods
- Resin System Overwhelmingly Determines Fire Performance
- Small Boats Currently Have No Structural Fire Protection Regulations - Sparks and Fumes from Gas Engines Biggest Risk
- Megayachts Need to be Concerned with Engine Rooms, Galleys, Stairwells, & Engine Room Ventilation Systems
- T Vessels Must Have ASTM E84 Flame Spread < 100; K Vessels Can Use Fire hazard Analysis or IMO High Speed Craft Code
- Naval Structures Must Pass Tougher 2000º F Requirements
- Insulation Blankets Currently Best Method to Provide Structural Fire Protection