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NAVSEA TECHNICAL PUBLICATION

COMPOSITE MATERIALS, SURFACE SHIPS, TOPSIDE STRUCTURAL AND OTHER TOPSIDE APPLICATIONS – FIRE PERFORMANCE REQUIREMENTS

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FOREWORD

Under the authority of NAVSEAINST 5400.111, NAVSEA Engineering and Technical Authority Policy, this manual identifies NAVSEA design practices and criteria for ship design throughout the ship's life cycle including new construction and conversions/modernizations. This manual is issued by the NAVSEA enterprise and associated technical authorities for use by the Navy and the Navy's industry partners in ship design.

This manual does not apply to systems under the cognizance of the Deputy Commander, Nuclear Propulsion Directorate (NAVSEA 08).

Comments, suggestions, or questions on these procedures should be addressed to: Commander, Naval Sea Systems Command, ATTN: NAVSEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to CommandStandards@navy.mil, with the subject line "DPC Comment".

TMDER INSTRUCTIONS

Ships, training activities, supply points, depots, Naval Shipyards and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA and SPAWAR technical manuals (TMs). All errors, omissions, discrepancies, and suggestions for improvement to NAVSEA and SPAWAR TMs shall be submitted as a Technical Manual Deficiency/Evaluation Report (TMDER). All feedback comments shall be thoroughly investigated and originators will be advised of action resulting there from.

The NAVSEA/SPAWAR Technical Manual Deficiency/Evaluation Report form, NAVSEA 4160/1 is included at the back of the TM.

Copies of form NAVSEA 4160/1 may also be downloaded from:
https://nsdsa.nmci.navy.mil/nsdsarepository/TMDER_BLANK_REV_9-2010-1.pdf.

The following methods are available for generation and submission of TMDERs against unclassified TMs:

- For those with a Technical Data Management Information System (TDMIS) account, the most expedient and preferred method of TMDER generation and submission is via the TDMIS website at: https://mercury.tdmis.navy.mil.
- For those without a TDMIS account, generate and submit TMDER via the Naval Systems Data Support Activity (NSDSA) website at: https://mercury.tdmis.navy.mil/def_external/pubsearch.cfm. (TDMIS accounts may be requested at https://nsdsa.nmci.navy.mil.)
- When internet access is not available, submit TMDER via hardcopy to:

  COMMANDER
  CODE 310 TMDERs
  NAVSURFWARCENDIV NSDSA
  4363 MISSILE WAY, BLDG 1389
  PORT HUENEME, CA 93043-4307

- TMDERs against classified/restricted (includes all NOFORN) TMs must be submitted using the hardcopy method cited above.
- Urgent priority TM deficiencies shall be reported by naval message with transmission to Port Hueneme Division, Naval Surface Warfare Center (Code 310), Port Hueneme, CA. Local message handling procedures shall be used. The message shall identify each TM deficiency by TM identification number and title. This method shall be used in those instances where a TM deficiency constitutes an urgent problem, (i.e., involves a condition, which if not corrected, could result in injury to personnel, damage to the equipment, or jeopardy to the safety or success of the mission).

Complete instructions for TMDER generation and submission are detailed on the NSDSA website at:
https://nsdsa.nmci.navy.mil/tmder/tmder.asp?lvl=1.

DDS 078-1

DESIGN DATA SHEET

COMPOSITE MATERIALS, SURFACE SHIPS, TOPSIDE STRUCTURAL AND OTHER TOPSIDE APPLICATIONS – FIRE PERFORMANCE REQUIREMENTS

11 August 2004

FOREWORD

Fiber Reinforced Plastic (FRP) composites, also referred to herein as composites, are one of the options being considered for the design of the next generation of naval surface combatants. Fire performance is one of the safety risks associated with the application of composite materials aboard ships. The material fire performance requirements described in this design data sheet are intended to provide consistent safety criteria for the application of composites aboard ships. These requirements have been developed based on Navy fire safety policy and international maritime standards for fire safety. Fire performance requirements for surface flammability, fire growth, smoke generation, fire gas toxicity, fire resistance, and structural integrity under fire have been established.

The requirements of this document are intended to supplement the structural fire protection section 1-2-1 of the ABS Naval Vessel Rules (NVR).

The Navy N-Class Division system is used to classify fire resistant boundaries. The N-Class Division is analogous to the commercial International Maritime Organization (IMO) system (e.g., A-Class divisions). The key difference is the N-Class fire exposure, which uses the more severe temperature and heat flux requirements of a hydrocarbon (class B) fire exposure in accordance with the fire curve of UL-1709. The N-30 Class (30-minute) Division is designated for most applications to enable personnel escape from the fire area and provide time for a concerted firefighting effort by the crew.

The use of a fire protective cover, such as fire insulation, is acceptable over combustible materials which fail the fire performance requirements alone. NAVSEA accepts this practice because we expect naval shipboard configuration control will assure the presence of the fire protective cover over the life of the ship. However, the use of intumescent coatings as a fire protective cover is not acceptable because current technologies have been demonstrated to be unreliable in the naval combat environment.

U.S. Navy approval of material fire performance is based on full scale tests. Appendix A of this document presents a low-cost protocol for fire safety screening of candidate composite systems. Fire growth potential of new composite systems and designs can be screened by using small-scale test data from cone calorimeter (ASTM E-1354), and LIFT (ASTM E-1321) in conjunction with the Navy's Composite Fire Hazard Analysis Tool (CFHAT). The small-scale Burn-Through test was shown capable of screening fire resistance performance determined in furnace testing with a UL 1709 fire curve. These screening techniques provide cost-effective approaches for evaluating fire performance of new technologies, which in turn aids in the product development process. Full-scale fire testing in accordance with the main body of this document is required for approval for use on U.S. Navy surface ships.

The qualification or certification of a composite topside structure is a multi-disciplinary process. Several NAVSEA codes may be involved in this process, such as, but not necessarily limited to, SEA 05D (Design Integration), SEA 05M (Materials) and SEA 05P (Survivability, Fire Protection, Shock). In the area of fire safety, it is recommended that interested parties should contact their NAVSEA Technical Point of Contact (TPOC) very early in their design process. Interaction and communication very early in the certification process will lead to a better understanding of the mutual needs and will expedite the certification process. It is envisioned that the certification process will consist of the following steps:

1. Introduction of the design philosophy by the contractor to the NAVSEA TPOC.
2. Review of the design drawings.
3. Approval of the Test Plan
4. Conduct Fire Tests.
5. Review of the fire test reports by NAVSEA
6. Final approval and certification.

The technical content of this document is controlled by NAVAL SEA SYSTEMS COMMAND, Code SEA 05P4. The requirements and test procedures are primarily drawn from “Fire Performance Goals and Qualification Procedures for Composite Material Systems used in Topside Structure and Other Topside Applications in Surface Ships”, NSWCCD-64-TR-2003/06 of June 2003.

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1 SCOPE

1.1 General. This DDS provides the fire performance requirements for various Fiber Reinforced Plastic (FRP) composite materials, also referred herein as composites, used in the construction of U.S. Navy surface ship topside structures, and other topside applications. An asterisk (*) immediately after the paragraph number indicates additional non-mandatory information is provided in Appendix A.

1.2 Classification.

1.2.1 Material shipboard location. This document applies to composite materials used in topside structure and other topside applications. Topside structure is defined as the structure above the upper most strength deck. Strength decks are defined as those continuous decks included as part of the hull girder inertia. Other topside applications include material applications, which are mounted onto the topside structure, but are not necessarily integral structural members, such as life rail stanchions, vent screens, and ventilation ducts.

1.2.2 Material Composition. This document applies to shipboard materials which may be generally described as FRP composites, which are engineered materials in which the major component is a high strength fibrous reinforcement and the minor component is an organic resin binder. U.S. Navy structural composite applications have typically been a composite sandwich made up of fiberglass or carbon-reinforced brominated vinyl ester resin face sheets, bonded to a balsa wood core. New composite systems with significantly different mechanical and physical properties will need to be assessed for the need of additional fire performance criteria.

1.2.3 Material shipboard usage. Shipboard components fabricated from composites covered by this document, include, but are not limited to:

a. Lightweight foundations
b. Deckhouses, superstructure and helicopter hangars
c. Masts
d. Doors and Hatches
e.. Valves
f. Gratings
g. Structural stanchions
h. Weather Vent screens
i. Ventilation ducts in proximity to weather
j. Louvers at ventilation duct weather openings
k. Pumps

1.2.4 Limits of Application. This document is not intended to apply to composite components in pumps, in portable equipment, and minor items which would not add measurably to the fire hazard in the space and which are not critical to the proper functioning of the system in which they are located. It also doesn't apply to more

traditional combustible materials which are already regulated elsewhere, such as habitability materials listed in MIL-STD-1623.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in the main body of this document. This section does not include documents cited in Appendix A.

2.2 Government documents.

2.2.1 Specifications, standards and handbooks. The following specifications, standards and handbooks form part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are as listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, or as cited in the solicitation.

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-P-24608	Pipe, Fittings, & Adhesive Kits, Glass Reinforced Thermosetting Epoxy Resin for Shipboard Piping Systems
MIL-P-24705	Penetrators, Multiple Cable, for Electric Cables, General Specification for
MIL-PRF-32161	Performance Specification, Insulation, High Temperature Fire Protection, Thermal And Acoustic
MIL-S-901	Shock Tests. H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-777	(Design Criteria Standard) Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships.

Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094, www.daps.dla.mil.

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

NAVAL SEA SYSTEMS COMMAND
Drawing, NAVSEA 803-5184182, Insulation, Passive Fire Protection, Installation Details

2.3 Non-Government standards and publications. The following specifications, standards and handbooks form part of this document to the extent specified herein.

AMERICAN PETROLEUM INSTITUTE (API)

API 607	Fire Test for Soft-Seated Quarter-Turn Valves

(Applications for copies should be addressed to: API Publications, Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO, 80112-5776, 1-800-854-7179, www.global.ihs.com)

ASTM INTERNATIONAL

ASTM E-84	Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM E-162	Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source
ASTM E-662	Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials
ASTM E-800	Standard Guide for Measurement of Gases Present or Generated During Fires
ASTM E-1354	Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

(Applications for copies should be addressed to: ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, 1-610-832-9585, www.astm.org)

FACTORY MUTUAL

FM 4922	"Fume Exhaust Ducts—Fume and Smoke Exhaust Ducts," Norwood MA, April 2002

(Applications for copies should be addressed to: FM Global, 1151 Boston-Providence Turnpike, PO Box 9102, Norwood MA 02060 , www.fmglobal.com)

INTERNATIONAL MARITIME ORGANIZATION (IMO)

A.754(18)	"Recommendation on Fire Resistance Tests for "A", "B" and "F" Class Division," FTP Code – International Code for Application of Fire Test Procedures, International Maritime Organization, London, 1998

(Applications for copies should be addressed to: New York Nautical Instrument & Service Corp., 140 West Broadway, NY, NY 10013, 212-962-4522, fax 212-406-8420, email info@newyorknautical.com)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

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

(Copies are available through The American National Standards Institute, and requests should be addressed to: ANSI, 25 West 43rd St., 4th floor, NY, NY, 10036, 1-212-642-4980, fax 212-398-0023, www.ansi.org)

UNDERWRITERS LABORATORY (UL)

UL 1709	"Rapid Rise Fire Tests of Protection Materials for Structural Steel," Underwriters Laboratories, Inc., Northbrook, IL, (1991)
UL 2079	"Tests for Fire Resistance of Building Joint Systems," First Edition, Underwriters Laboratories, Inc., Northbrook, IL, (1994).

(Applications for copies should be addressed to: Underwriters Laboratory, comm2000, 1414 Brook Drive, Downers Grove, IL, 60515, 1-415-352-2168, fax 1-888-853-3512, www.ul.com)

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein (except for related associated specifications or specification sheets), the text of this document takes precedence. Nothing in this document, however, supercedes applicable laws and regulations unless a specific exemption has been obtained.

3. NAVY N-CLASS DIVISIONS

3.1 Navy N-Class Divisions. The Navy N-Class system for classifying fire resistant boundaries is analogous to the commercial IMO system (e.g., A-Class divisions). Fire resistance is the property of a material or assemblage to withstand fire or give protection from it, principally to prevent fire spread to adjoining compartments. Structural integrity is the ability to continue to carry a structural load. The key difference is the Navy N-Class fire exposure, which uses the more severe temperature and heat flux requirements of a hydrocarbon (class B) fire exposure in accordance with the fire curve of UL-1709. An N-Class division boundary shall comply with the following:

a. Constructed of steel or other equivalent material; "other equivalent material" includes composite construction for topside structures when they pass the fire test requirements.

b. Prevent passage of smoke and flame to the end of the N-Class Division Fire Test, conducted in accordance with paragraph 5.5.1.2, for the specified period.

c. For composites, they shall be capable of supporting the maximum load (as defined in paragraph 5.5.1.3) for structural integrity fire testing to the end of the specified period.

d. Limit the average and peak unexposed face temperature rise during the fire test within the time listed below:

Class N-60	60 min
Class N-30	30 min
Class N-0	0 min

Note: Per paragraph 4.5.1, for N-0 Class boundaries, there are no requirements for unexposed face temperature rise. However, there shall be no flaming on the unexposed face for a minimum of 30 minutes when tested in accordance with paragraph 5.5.1.2.

4 PERFORMANCE REQUIREMENTS

4.1 Surface Flammability. All exposed interior and exterior composite surfaces, including bulkheads, decks, overheads, doors and hatches, shall meet the surface flammability requirements (flame spread and smoke).

4.1.1 Interior applications:

a. Maximum flame spread index: 25;

b. Maximum smoke developed index: 15.

4.1.2 Exterior applications:

a. Maximum flame spread index: 25;

b. Smoke data shall be submitted for review by NAVSEA 05P4.

4.2 Fire Growth. All exposed interior composite surfaces, including bulkheads and overheads, but excluding decks, doors and hatches, shall meet the fire growth requirements:

a. Net peak heat release rate over any 30 second period less than 500 kW;

b. Net average heat release rate for test less than 100 kW;

c. Flame spread must not reach 0.5 meter above the floor excluding the area 1.2 meters from the corner with the ignition source;

d. No flaming droplets or flaming material at any location, which fall from the test specimen during the fire test, shall continue flaming after reaching the test platform or floor;

e. These requirements are not applicable to exterior weather surfaces.

4.3 Smoke Production. All exposed interior composite surfaces, including bulkheads and overheads, but excluding decks, doors and hatches, shall meet the smoke production requirements:

a. Peak smoke production rate less than 8.3 m^2/s over any 60 second period of test;

b. Test average smoke production rate less than 1.4 m^2/s.

4.4 Fire Gas Toxicity. All exposed interior composite surfaces, including bulkheads, overheads, decks, doors and hatches, shall meet the fire gas toxicity requirements below. Tests shall be conducted in both flaming and non-flaming modes.

a. CO: 350 ppm (max);

b. HCl: 30 ppm (max);

c. HCN: 30 ppm (max);

d.* Fire Gas IDLH Index, $I_{IDLH} <$ (less than) 1;
where $I_{IDLH} = (C_{CO}/IDLH_{CO} + C_{HCl}/IDLH_{HCl} + C_{HCN}/IDLH_{HCN} + C_X/IDLH_X)$;
and $IDLH_{CO}$ = 1200 ppm, $IDLH_{HCl}$ = 50 ppm and $IDLH_{HCN}$ = 50 ppm;

e. If candidate materials have a potential for significant concentrations of other toxic fire gases (C_X in the above formula), those gases will be included in the fire gas IDLH index. To determine $IDLH_X$, use the Immediately Hazardous to Life and

Health (IDLH) concentration of fire gases published by the National Institute of Occupational Safety and Health (NIOSH) in "Immediately Hazardous to Life and Health (IDLH) Concentrations" revised in 1995. <http://www.cdc.gov/niosh/idlh/intridl4.html>

4.5 Fire Resistance and Structural Integrity Under Fire: Fire resistance and structural integrity under fire are applicable to N-Class Division boundaries designated for each ship design. Fire resistance and structural integrity shall always be required for fire zone bulkheads. These requirements are normally not required for non-tight boundaries. Approval of an assembly is limited to the system configuration, orientation(s), and attachment method in which it was tested.

4.5.1 Fire Resistance (for bulkheads, overheads, decks, doors, hatches and penetrations):

a. There shall be no passage of flames, smoke, or hot gases on the unexposed face.

b. Average temperature rise on the unexposed surface shall not exceed 250^{o}F (rise of 140^{o}C).

c. Peak temperature rise on the unexposed surface shall not exceed 325^{o}F (rise of 180^{o}C).

d. There shall be no ignition of the cotton wool pad.

e. Gap sizes shall not permit the introduction of gap gages into any openings of the specimen.

f. For N-0 Class boundaries, there are no requirements for unexposed face temperature rise. However, there shall be no flaming on the unexposed face for a minimum of 30 minutes when tested in accordance with paragraph 5.5.1.2.

g. Penetrations in N-class divisions shall be classified consistent with the rating of the boundary which they penetrate except where specified otherwise

4.5.1.1 Structural integrity under fire (under load): shall be required for all composite N-Class Divisions and other designated structural elements.

4.5.1.1.1 Testing for structural integrity under fire shall be demonstrated in accordance with the fire resistance test of paragraph 5.5.1.2 with the maximum load (see paragraph 5.5.1.3) for structural integrity fire testing.

4.5.1.1.2* There shall be no collapse of the structure or joint, or rupture of the structure for the period specified. The maximum average temperature on the unexposed side of the composite system shall not exceed the critical temperature of the composite

where structural properties degrade rapidly (see Appendix A). This applies if the critical temperature is less than the average temperature rise of 250°F (rise of 140°C).

4.5.2 Fire Resistance (for composite joints):

a. There shall be no passage of flames, smoke, or hot gases on the unexposed face.

b. Average temperature rise on the unexposed surface shall not exceed 250°F (rise of 140°C).

c. Peak temperature rise on the unexposed surface shall not exceed 325°F (rise of 180°C).

d. There shall be no ignition of the cotton wool pad.

e. Gap sizes shall not permit the introduction of gap gages into any openings of the specimen.

4.5.2.1 Structural integrity under fire (under load): Structural integrity under fire shall meet the requirements of paragraph 4.5.1.1.2.

4.5.3 Fire Integrity (for attachments and hangers): Attachments and hangers installed more than 6 feet above the floor or located where they would threaten personnel safety, such as over hatchways, shall remain intact for the entire period of the test. Tests shall be performed with a load typical of that carried by the attachment or hanger.

4.6 General Applications.

4.6.1* Allowance of fire protective covers. The use of a fire protective cover, such as fire insulation, over combustible composite structures is acceptable to achieve the fire performance requirements of this document. However, the use of intumescent coatings as a fire protective cover is not acceptable because current technologies have been demonstrated to be unreliable in the naval combat environment.

4.7 Special Applications.

4.7.1* Weather Deck Gratings. Composite deck gratings may be used in the weather. They shall pass the following:

a. Weight Drop Test: Support specified drop load after 5-minute exposure to flowing fuel fire with no structural failure;

b. Surface Flammability Test:

1) Flame Spread Index (Radiant Panel Test) = 25 or less;

2) No pooling or flaming droplets;

c. Heat and Smoke Release Test (Cone Calorimeter): The test results shall be in accordance with Table 4-1.

TABLE 4-1. Heat and Smoke Release Test (Cone Calorimeter) (for GRP deck gratings)

FLUX (kW/m^2)	50	75	100
T ignition (sec) (minimum)	90	30	20
Peak Heat Release (kW/m^2) (maximum)	160	170	210
Avg. Heat Release (kW/m^2) (maximum)	90	100	120
Specific Ext. Area (m^2/Kg)	130	190	260

4.7.2 Weather Vent Screens. Composite vent screens may be used in the weather. They shall pass the following:

a. Surface Flammability Test:

1) Flame Spread Index (Radiant Panel Test) = 25 or less;

2) No pooling or flaming droplets.

b. Heat and Smoke Release Test (Cone Calorimeter): The test results shall be in accordance with Table 4-2.

TABLE 4-2. Heat and Smoke Release Test (Cone Calorimeter) (for GRP vent screens)

FLUX (kW/m^2)	25	50	75
T ignition (sec) (minimum)	360	110	60
Peak Heat Release (kW/m^2) (maximum)	190	210	220
Avg. Heat Release (kW/m^2) (maximum)	110	130	140
Specific Ext. Area (m^2/Kg)	190	210	280

4.7.3 Weather Louvers. Composite louvers may be used in the weather. They shall pass the following:

a. Surface Flammability Test: Flame Spread Index (Radiant Panel Test) = 35 (max);

b. Smoke Generation Test: The corrected optical density (D_m) shall be less than 240 in both flaming and non-flaming mode;

c. Fire gas toxicity limits of 4.4 apply.

4.7.4* Near-Weather Ventilation Ducting. Installation of composite ventilation ducting is limited to ventilation ducts within 15 ft. from weather deck openings, and is restricted from use in high fire risk spaces. For this application, high fire risk spaces are those in which flammable liquids are stored or dispensed, and spaces in which flammable liquids exist under pressure and ignition sources are present.

a. Smoke Generation Test: The corrected optical density (D_m) shall not exceed 200.

b. Internal Fire Test:

1) Flaming shall not spread on the interior of the duct from the fire-exposed end to the 12 ft. point in 15 minute test;

2) The interior duct temperature recorded at the 12 ft. point shall not exceed 1250^{o}F;

3) There shall be no holing or structural sagging.

4.7.5 Electric Junction Boxes. Composite electric junction boxes shall pass the following:

a. Surface Flammability Test: Flame Spread Index (Radiant Panel Test) shall be 25 or less;

b. Smoke Generation Test: The corrected optical density (D_m) shall not exceed 200;

c. Heat and Smoke Release Test (Cone Calorimeter): The test results shall be in accordance with Table 4-3.

d. Fire Containment Test: (RESERVED).

TABLE 4-3. Heat and Smoke Release Test (Cone Calorimeter) (for composite electric junction box)

FLUX (kW/m^2)	25	50	75
$T_{Ignition}$ (sec) (minimum)	300	100	50
Peak Heat Release (kW/m^2) (maximum)	250	250	250
Avg. Heat Release (kW/m^2)	150	150	150

maximum)			
Specific Ext. Area (m^2/Kg)	200	250	300

4.7.6 Quarter-turn Valves in flammable fluid, oxidizer or fire extinguishing systems. When used in flammable fluid or oxidizer systems, composite quarter-turn valves shall pass the following:

a. Fire test (Composite Quarter turn Valves in flammable fluids or oxidizer systems): Through-valve leakage & external valve leakage criteria per API 607 for 30 min.

b. Composite valves are prohibited in fire extinguishing systems, other than a firemain with adequate redundancy and segregation.

4.7.7 Piping. Composite piping, if used, shall be in accordance with MIL-STD-777.

a. Fire test: (RESERVED).

b. Fire loading: As specified in MIL-STD-777 and it's related documents, the total amount of GRP piping in a space shall not exceed 25 lbs/1000 ft^3 of volume for non-liquid pipe situations and 50 lbs/1000 ft^3 of volume for flowing or stagnant pipe situations.

5 TEST METHODS

5.1 Surface Flammability. ASTM E-84, "Standard Test Method for Surface Burning Characteristics of Building Materials."

5.2 Fire Growth. ISO 9705 "Fire Tests-Full-Scale Room Test for Surface Products", Annex A (100 kW for 10 minutes followed by 300 kW for 10 minutes, utilizing a 0.17 square meter burner).

5.3 Smoke Production: ISO 9705, Annex A (100 kW for 10 minutes followed by 300 kW for 10 minutes).

5.4 Fire Gas Toxicity. ASTM E-662, "Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials" (flaming and non-flaming). Gas sampling and concentrations measured in accordance with ASTM E-800, "Standard Guide for Measurement of Gases Present or Generated During Fires."

5.5 Fire Resistance and Structural Integrity Under Fire.

5.5.1 Fire Resistance (for bulkheads, overheads, decks, doors, hatches and penetrations).

5.5.1.1 Grade A Shock: Where Grade A shock requirements have been invoked and if the N-Class Division includes non-structural components or attachments, such as fire insulation, the assembly shall pass a medium weight Grade A shock test in accordance with MIL-S-901 prior to conducting the fire resistance test. The shock tested assembly shall then pass the fire resistance test.

5.5.1.2* Fire Resistance Test Method (for bulkheads, overheads, decks, doors, hatches and penetrations): The N-Class Division test method shall be in accordance with IMO A.754(18), as modified herein. The fire exposure shall be a rapid rise fire, representing a hydrocarbon pool fire exposure, in accordance with the fire curve of UL 1709. The total number of thermocouples and their placement on unexposed side shall be in accordance with MIL-PRF-32161. Additionally, IMO App. A. III & A.IV shall apply, and the hose stream test (IMO) shall apply. Passive fire protective cover, if used, shall be attached so as to survive for the period specified.

5.5.1.3* Structural Integrity under Fire: For all composite N-Class Divisions and other designated structural elements, structural integrity under fire shall be conducted in accordance with the fire resistance test method provided in paragraph 5.5.1.2. The maximum load for structural integrity fire testing is two times the sum of the dead load, the design live load, and the firefighting live load. The dead load is the weight of the structure. The live load is the weight of equipment and personnel. The firefighting live load is assumed to be 50 pounds per square foot.

5.5.2 Fire resistance test method (for composite joints): The test shall be conducted in accordance with UL 2079 “Tests for Fire Resistance of Building Joint Systems,” with the fire test curve of UL-1709 and the maximum fire test load (see paragraph 5.5.1.3), for the period specified. The fire test shall be followed by a hose stream test.

5.5.3 Fire integrity test method (for attachments and hangers): The test shall be conducted with the fire curve of UL 1709 , with load typical of that carried by the attachment or hanger, for the period specified.

5.6 Special Applications.

5.6.1 Weather Deck Grating.

a. Flowing fuel fire, weight drop test: Test Procedure for NRL Full Scale (2 ft by 2 ft) Flowing Fuel Fire Test on GRP Deck Gratings (Appendix B). Drop weight: 150 pounds dropped from 5 feet above top surface of grating.

b. Surface Flammability Test: ASTM E –162, “Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source”

c. Heat and Smoke Release Test: ASTM E-1354, "Standard Test Method for Heat and Visible Smoke Release Using an Oxygen Consumption Calorimeter"

5.6.2 Weather Vent Screens.

a. Surface Flammability Test: ASTM E –162, "Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source"

b. Heat and Smoke Release Test: ASTM E-1354, "Standard Test Method for Heat and Visible Smoke Release Using an Oxygen Consumption Calorimeter"

5.6.3 Weather Louvers.

a. Surface Flammability Test: ASTM E –162, "Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source"

b. Smoke Generation Test: ASTM E-662, "Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials".

c. Fire Gas toxicity limits (flaming and non-flaming): ASTM E-662, "Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials". Gas sampling and concentrations measured in accordance with ASTM E-800, "Standard Guide for Measurement of Gases Present or Generated During Fires."

5.6.4 Near-Weather Ventilation Ducting.

a. Smoke Generation Test: ASTM E-662, "Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials".

b. Internal Fire Test: Navy Modified Factory Mutual 4922 (Internal fire); (RESERVED).

5.6.5 Electric Junction Boxes.

a. Surface Flammability Test: ASTM E-162, "Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source"

b. Smoke Generation Test: ASTM E-662, "Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials".

c. Heat and Smoke Release Test: ASTM E-1354, "Standard Test Method for Heat and Visible Smoke Release Using an Oxygen Consumption Calorimeter"

d. Fire Containment Test: (RESERVED).

5.6.6 Composite Quarter Turn Valves in flammable fluid, oxidizer or fire extinguishing systems.

a. Fire Test: API 607, “Fire Test for Soft-Seated Quarter-Turn Valves”

5.6.7 Piping.

a. Fire Test: (RESERVED)

b. Fire Loading: MIL-STD-777 and its’ related documents, drawing review, or analysis.

6 CROSS REFERENCE - PERFORMANCE REQUIREMENT TO TEST METHOD

6.1 Cross Reference. A paragraph cross reference of performance requirement to test method is provided in TABLE 6-1

TABLE 6-1. Cross reference – Performance Requirement to Test Method

PERFORMANCE REQUIREMENT	TEST METHOD
4.1	5.1
4.1.1	5.1
4.1.2	5.1
4.2	5.2
4.3	5.3
4.3.a	5.3
4.3.b	5.3
4.4	5.4
4.5.1	5.5.1.1, 5.5.1.2, 5.5.1.3
4.5.1.1.1	5.5.1.1, 5.5.1.2, 5.5.1.3
4.5.1.1.2	5.5.1.1, 5.5.1.2, 5.5.1.3
4.5.2	5.5.2
4.5.2.1	5.5.2
4.5.3	5.5.3
4.7.1.a	5.6.1.a
4.7.1.b	5.6.1.b
4.7.1.c	5.6.1.c
4.7.2.a	5.6.2.a
4.7.2.b	5.6.2.b
4.7.3.a	5.6.3.a
4.7.3.b	5.6.3.b
4.7.3.c	5.6.3.c
4.7.4.a	5.6.4.a
4.7.4.b	5.6.4.b
4.7.5.a	5.6.5.a
4.7.5.b	5.6.5.b
4.7.5.c	5.6.5.c
4.7.5.d	5.6.5.d
4.7.6.a	5.6.6.a
4.7.7.a	5.6.7.a
4.7.7.b	5.6.7.b

7 NOTES

7.1 Parenthetical Note: This section contains information of a general or explanatory nature, which may be helpful, but is not mandatory.

7.2 Acronyms used in this document

ABS American Bureau of Shipping
CFHAT: Composite Fire Hazard Analysis Tool
DMTA: Dynamic Mechanical Thermal Analysis
FRP: Fiber Reinforced Plastic
GRP: Glass Reinforced Plastic
IMO: International Maritime Organization
ISO: International Standards Organization
KW: Kilowatt

NAVSEA: Naval Sea Systems Command
NAVSEA 05D: Naval Sea Systems Command, Surface Ship Design and Systems Engineering Group
NAVSEA 05M3: Naval Sea Systems Command, Materials and Environmental Engineering Group, Non-Metallic Materials Division
NAVSEA 05P4: Naval Sea Systems Command, Platform Systems Group, Damage Control and Fire Protection Division
NAVSEA PMS 500: DD (X) Program Office
NFPA: National Fire Protection Association
NRL: Naval Research Laboratory
NSWCCD: Naval Surface Warfare Center, Carderock Division
NSWCCD-C643: Fire Protection Branch
NSWCCD-C65: Marine Composites and Structures
NVR Naval Vessel Rules
ppm: Parts Per Million
UL: Underwriters Laboratory
USCG: United States Coast Guard
USN: United States Navy

APPENDIX A

GENERAL NOTES

Paragraph numbers below, after the "A.", coincide with the referenced paragraphs in the main body of this document. Corresponding paragraphs in the main body are annotated with an asterisk (*).

A.4.4.d The Fire Gas IDLH Index, I_{IDLH}, provides a reasonable threshold to screen out material systems which produce excessive fire gases to provide more time for escape of unprotected personnel. However, it does not assure that a specific fire aboard ship will not create hazardous concentrations when a sufficiently large material surface burns in an enclosed space.

A.4.5.1.1.2 Critical temperature is defined as the temperature at which the rapid loss of modulus occurs when determined in accordance with Dynamic Mechanical Thermal Analysis (DMTA) as discussed in NSWCCD-64-TR-2003/06, "Fire performance Goals and Qualification Procedures for Composite Material Systems Used in Topside Structure and other Topside Applications in Surface Ships", Volume II, Appendix A, Page 64.

A.4.6.1 The common US naval sandwich composite of brominated vinyl ester and balsa core is an example of a composite system which fails the fire performance requirements alone, but has been accepted with the use of a fire protective cover.

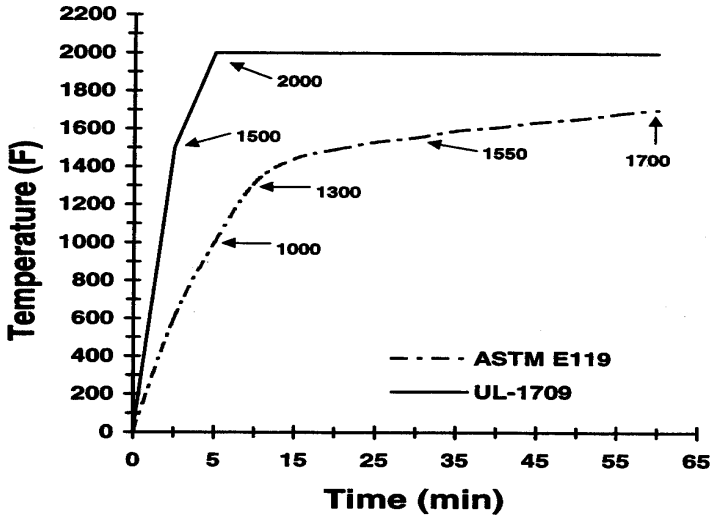
A.4.7.1 Modified acrylic resin with alumina trihydrate (60% by weight), trade name Fibergrate ELS (extra low smoke) has been tested and found to be satisfactory.

A.4.7.4 A specific glass/phenolic composite has been tested and found to be satisfactory.

A.5.5.1.2 With reference to the Naval N-class division fire resistance test method after a large weapon effects induced fire aboard the USS STARK (FFG 31) in 1992, NRL performed post flashover fire tests in ex-USS Shadwell. The results indicated that UL-1709 fire curve more closely approximated the thermal conditions in the Navy compartment during the post flashover fire. As such, the U.S. Navy is now using the fire exposure of UL 1709 fire curve as a benchmark for evaluating fire resistance. As shown in Figure A-1, this fire exposure is more severe than the ISO 834 (similar to ASTM E-119) fire curve used by the IMO for commercial vessels. One of the distinguishing features of a UL-1709 (post flashover fire, hydrocarbon pool fire) is the rapid development of high temperatures and heat fluxes that can subject exposed structural members to thermal shock much more rapidly than they see in ASTM E119. The UL 1709 fire curve rises to an average temperature of $2000 \pm 200^{o}F$ ($1093 \pm 111^{o}C$) within 5 minutes from start of the test. This temperature is to be maintained throughout the remainder of the fire test. The heat flux to the sample during $2000^{o}F$ part of the UL 1709 exposure must be $204\ kW/m^2 \pm 16\ kW/m^2$ which is more severe than ASTM E-119.

Unprotected steel or aluminum is not expected to support it's load during the fire test and will typically require fire insulation to achieve an N-30 or N-60 rating.

FIGURE A-1 Comparison of UL1709 and ASTM E-119 Fire Curve



A.5.5.1.3 With reference to structural integrity under fire load, the maximum fire test load includes a safety factor of 2 which accounts for uncertainties associated with the introduction of new materials.

APPENDIX B

GUIDELINES FOR USE OF SMALL-SCALE SCREENING TESTS

B.1 SCOPE

B.1.1 This Appendix contains discussion of small-scale fire performance screening testing as they may be applied to composite materials. This Appendix is not a mandatory part of the DDS. The information contained herein is for information and guidance only.

B.2 General Guidelines for Use of Small-Scale Screening Tests: Most of the tests required to qualify the fire performance of composite systems are larger scale tests as given in this document. When developing new composite systems, it is expensive to repeatedly conduct these tests to determine the performance of the most recent design. Instead, more cost-effective small-scale testing is preferable to intermittently evaluate performance. To facilitate the introduction of new and modified fire tolerant materials/systems/designs, guidance is provided in this section for some aspects of a candidate systems' fire performance.

The small-scale screening test methodology is shown in Figure B-1. The two most important fire test parameters in the evaluation of new organic matrix based composite materials are the fire growth (ISO 9705) and fire resistance (UL-1709 fire curve, Navy N-Class). For fire growth, the small-scale screening test methodology involves the use of the small-scale heat release test method (cone calorimeter, ASTM E-1354) and the lateral flame spread (LIFT, ASTM E-1321) in conjunction with an Excel spreadsheet based Composite Fire Hazard Analysis Tool (CFHAT). For fire resistance, the small-scale screening test methodology involves the use of 2-ft x 2-ft modified UL-1709 fire resistance test method.

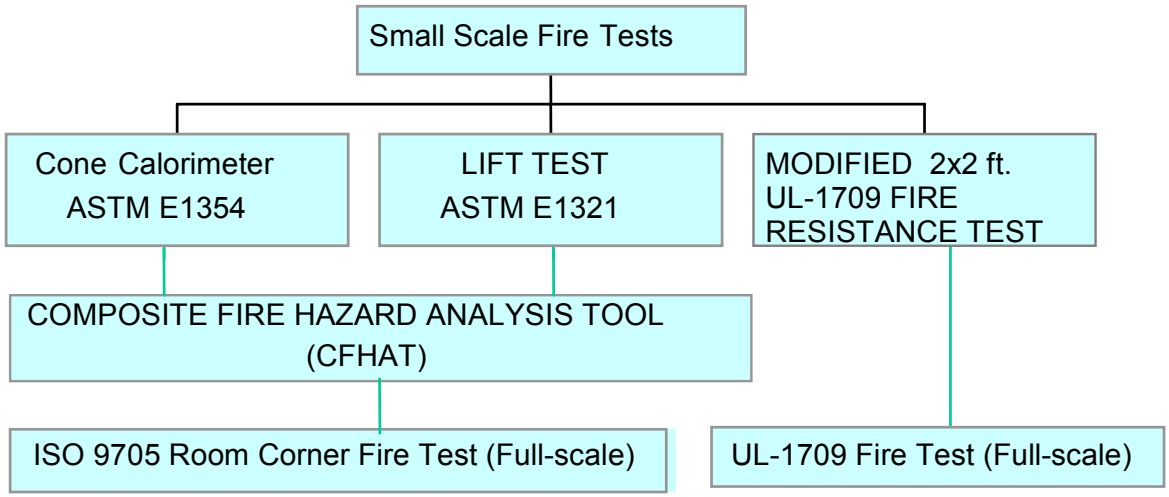


FIGURE B-1: Small-scale Screening Test Methodology

B.2.1 Small-Scale Testing for Fire Growth: The growth of a compartment fire depends on the rate at which the initiating source fire ignites other items in the compartment and the heat release rate of the ignited items. Of interest here is how bulkheads and overheads constructed of a composite system affect the fire growth during an ISO 9705 room/corner test. The rate at which combustible boundaries become involved in the fire depends on several variables. For this reason, computer fire models are necessary to adequately predict the composite system performance in an ISO 9705 test. Input data for these models can be developed from small-scale tests. Heat release rate and lateral ignition flame spread tests are two small-scale tests, which have been shown to lead to successful full-scale fire predictions in existing applications. To this end, a Composite Fire Hazard Analysis Tool (CFHAT) has been developed to assist in the screening of new or modified materials. CFHAT is an Excel spreadsheet based tool developed for estimating fire conditions inside a compartment constructed with composite material, and uses small-scale data as input. This tool uses a flame-spread model to determine the rate at which the composite system is involved in the fire and the total heat release rate of the fire in the compartment. This heat release rate is used by a compartment fire model to determine the gas temperature, visibility and toxicity levels inside the compartment. The tool requires input data on the ignitability, heat release rate, combustion product formation, and lateral flame spread propensity of the composite system. Two standard small-scale tests can be used to develop this data. ASTM E 1354-94 "Standard Test Method for Heat and Visible Smoke Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter" can be used to determine the ignitability, heat release rate, and combustion product levels of the combustible surface. Data to determine lateral flame spread can be acquired from ASTM E1321-97a "Standard Test Method for Determining Material Ignition and Flame Spread Properties". Inquiries regarding CFHAT should be directed to: NSWCCD, Code 643, (301-227-5588).

B.2.2 Small-Scale Testing for Fire Resistance: The Navy N-Class Division test for fire resistance of composite structures is based on the UL-1709 fire curve, using the protocol described in IMO Resolution A.754 "Recommendation on Fire Resistance Tests for "A", "B" and "F" Class Division". Fire resistance is measured by the heat transmitted through the sample (measured using thermocouples mounted on the unexposed side of the sample) and the transmission of hot gases through the assembly (sufficient to ignite cotton pad by hot gases leaking through the assembly). The current NAVSEA guidelines for acceptable fire resistance of composite structures is that a structure should withstand a post flashover fire (UL 1709) for a period specified without holing or having the unexposed face average temperature rise exceed 250^{o}F. The current NAVSEA guidelines for acceptable performance of structural integrity during fire are that composite structures shall withstand a post flashover fire for 30 minutes with no collapse or rupture of the structure when tested under the conditions of maximum fire test load (see 6.3.2). A standard U.S. Navy Burn-Through Test has been modified for small-scale fire resistance testing. The sample size used in this test is 2 ft. x 2 ft. which is mounted in the test frame. A flame leaves the torch roughly 18 inches away from the sample, and the flame temperature as it reaches the sample face is between 1800ºF and 2200ºF. The heat flux on the exposed surface is 180 ± 10 kW/m^2. There are eight thermocouples attached to the unexposed face of the sample positioned 3 inches radially from the center. A ½"

maranite board is placed over the thermocouples to prevent false temperature readings due to drafts. Adequate performance would be expected when average unexposed face temperature rise is below 250^{o}F after the specified exposure period.

APPENDIX C

TEST PROCEDURE FOR NRL FULL-SCALE (2 FT BY 2FT) FLOWING FUEL FIRE TEST ON GRP DECK GRATINGS

C.1 Background

Glass-reinforced plastic (GRP) deck gratings are being used for catwalks located outboard of flight decks on air capable ships. Gratings in these locations are often more than 50 feet above the water, posing a personnel fall hazard if the grating failed. Deck gratings are expected to be capable of supporting a person jumping down onto the gratings after exposure to a fire produced on the flight deck. Two potential flight deck fire scenarios are (1) a fuel spill fire on the flight deck where burning fuel runs over the side onto these deck gratings or (2) a three-dimensional fuel fire, produced by a ruptured fuel cell of a wing overhanging the deck, impinging on the deck gratings. A fire test was developed by the Naval Research Laboratory (NRL) to evaluate the structural performance of GRP deck gratings after a three-dimensional fire exposure.

C.2 Test Description

The GRP deck grating flowing fuel fire test setup is shown in Figure C-1. The setup includes the deck grating sample, walls to support the edges of the grating, fuel supply system for the three-dimensional spray fire, a water coated pan to contain unburned fuel from the spray fire, a thermocouple to measure the flame temperature at the grating, and a weight for impact testing.

The GRP deck grating sample shall have dimensions of 0.60 m by 0.90 m (2.0 ft by 3.0 ft). The deck grating sample is supported on two sides by two 0.90 m (3.0 ft) high, 0.60 m (2.0 ft) wide parallel masonry walls, which are spaced 0.60 m (2.0 ft) apart. The deck grating sample shall be placed on top of these walls so that there is a 0.15 m (6.0 in.) wide section of the grating on top of the walls. This results in a 0.60 m by 0.60 m (2.0 ft by 2.0 ft) unsupported area of grating.

The three-dimensional fire exposure in the test shall be a 7.57 lpm (2.0 gpm) JP-5 spray fire from a downward pointing nozzle. The nozzle is located over the center of the grating, 0.30 m (1.0 ft) above the top of the grating. JP-5 sprayed from the nozzle at this flow rate creates a 4.5 MW three-dimensional fire without the undesirable pooling of burning fuel just below the grating sample. A pan coated with water located between the masonry walls collects any excess fuel spray. The JP-5 spray fire is produced using a Bete 90^{o}, solid cone fine atomizing P-series nozzle. The nozzle is pointed downward so that fuel is being sprayed directly onto the deck grating. Fuel is fed to the nozzle from a tank pressurized with nitrogen to produce the desired flow rate. A small, 0.050 m (2 in.) square pan, heptane fire is used to ignite the spray fire. A Type K thermocouple is located just above the grating to monitor the gas temperature during the test. When the fire exposure is terminated and prior to dropping the weight onto the grating, the fuel nozzle and piping are moved from over top of the grating.

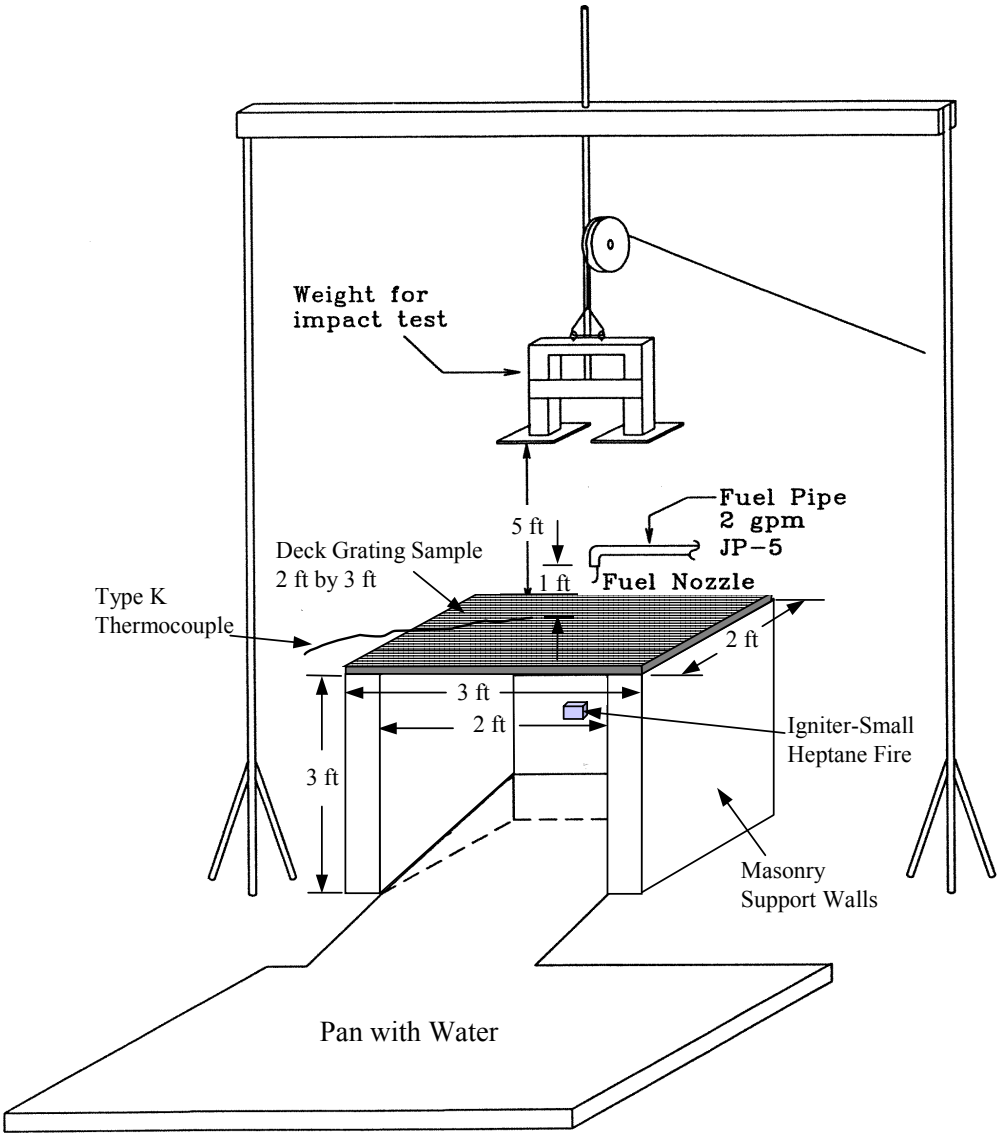


Figure C-1. Deck grating fire test setup.

The impact testing consists of dropping a weight down onto the deck grating. Using a pulley system, a 68 kg (150 lb.) weight is dropped from a height of 1.53 m (5 ft), simulating a person jumping onto the catwalk. Impact testing is conducted both before and after the fire exposure. The pulley system with the weight is removed from above the deck grating during the fire exposure.

C.3 Test Procedure

The deck grating test consists of a pre-fire exposure impact test, a five minute fire exposure, and post-fire exposure impact test. A 0.60 m by 0.90 m (2 ft by 3 ft) sample of

deck grating is placed on top of the masonry walls. The pre-fire exposure impact test is conducted on the deck grating. After inspecting the deck grating for damage from the impact test, the pulley system with the impact weight is removed from above the deck grating. The fuel nozzle and piping are then moved into position 0.30 m (1 ft) above the center of the deck grating. A thermocouple is then placed just above the deck grating to monitor gas temperature. The fuel tank is filled with nitrogen to the desired back pressure. A small pan of heptane is ignited. The spray is activated and ignited by the heptane fire. The fire is then allowed to burn for 5.0 minutes. After terminating the fire by turning off the fuel, the fuel nozzle, fuel piping, and thermocouple are removed from over top of the deck grating. The pulley system is then moved back over top of the deck grating and a second, post-fire impact test is conducted on the deck grating. Any remaining fire is then extinguished.

C.4 Acceptance Criteria

The composite deck grating shall not collapse after the post-fire exposure impact test.

Ref: NAVSEAINST 4160.3 NAVSEA S0005-AA-GYD-030/TMMP

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