N-CLASS DIVISIONS IN U.S. NAVAL SHIPS

Carderock Division

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ABS Naval Vessel Rules

- The American Bureau of Shipping and the United States Navy formalized their established strategic partnership through a Cooperative Agreement in 2003.
- ABS Naval Vessel Rules was published in 2004.
- PEO Ships decided that the ABS classification process using Naval Vessel Rules (NVRs) would form a core part of the certification process for the DD(X), LCS and all future non-nuclear Navy surface ships.

ABS Naval Vessel Rules

- Part 1-Hull and Structures
- Chapter 2-Structural Fire Protection
- The requirements for structural fire protection are based on traditional Navy fire zone boundary and also includes SFP for primary structural members such as stanchions and girders supporting decks and superstructures.

N-Class Division

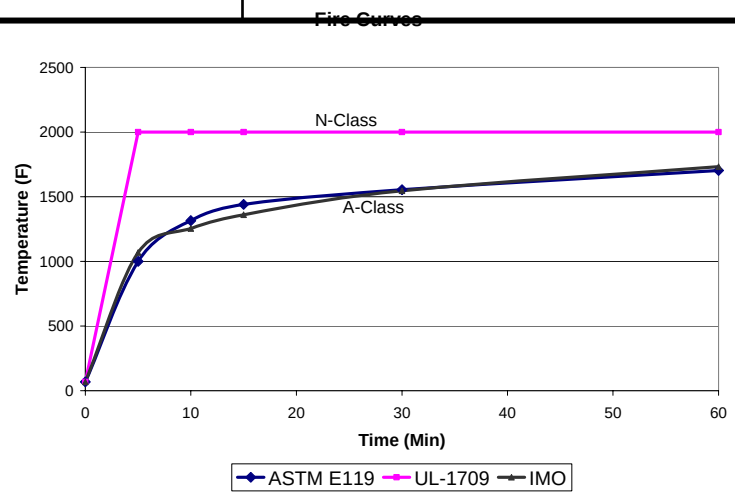
- For classification of fire resistant boundaries, Navy has introduced N-Class Division system.
- N-Class Division.- N-Class Divisions are those divisions formed by bulkheads and decks that: are designed to protect against structural failure and prevent the passage of fire and smoke when exposed to a hydrocarbon (class B) fire, **after shock testing**, for the designated test period. In addition N Class Divisions shall be designed to prevent prescribed temperature rise for the classification period.
- The N-Class Division is analogous to the commercial International Maritime Organization (IMO) system (e.g., A-Class divisions). However, some changes and modifications have been made to accommodate fire threats and combat environment.

N-Class Divisions

N-Class:	A-Class:
• Constructed of steel or other equivalent material; "other equivalent material" includes polymer composite (FRP) construction for topside structures when they pass the fire test requirements of DDS-078-1.	• Constructed of steel or other equivalent material. • Polymer composite construction permitted IAW High Speed Craft Code.

N-Class Divisions

N-Class:	A-Class:
• UL 1709 Fire Curve •heat flux of 204 ± 16 kW/m2; •temperature of 1,093 ± 111°C (2,000 ± 200°F). •Minimum duration of fire test is 30 minutes.	• ISO 834 Standard fire curve •Minimum duration of fire test is 60 minutes

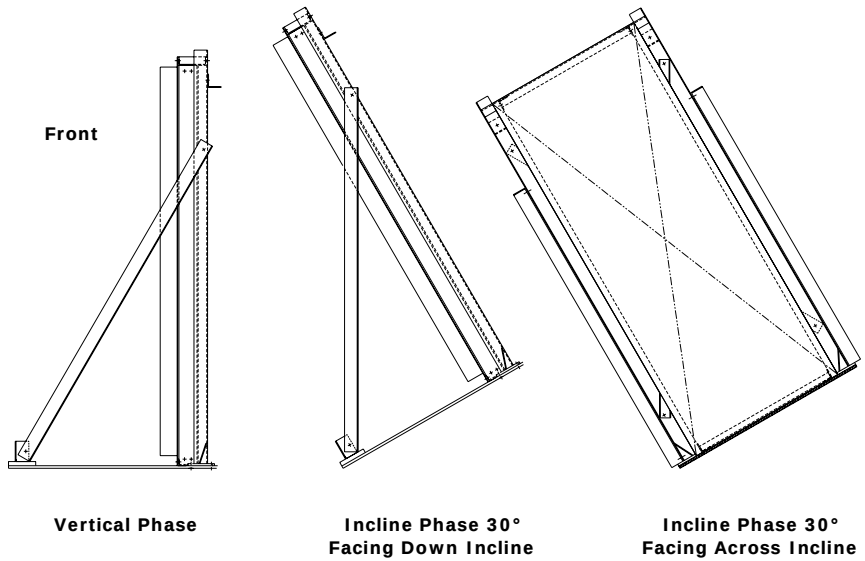


N-Class Division

N-Class:	A-Class:
•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. •Grade A –No delamination or cracking of SFP –No failure of SFP attachment method –No degradation in performance during fire test after shock test	•No requirement

N-Class Division

- The shock test (medium weight, Grade A) prior to fire resistance test is conducted in general accordance with MIL-S-901D [2] with intermediate scale 3048 x 1219 mm (10 feet x 4 feet) insulated bulkhead or deck test specimen.
- The intermediate scale test specimen size for shock testing was selected to reduce the cost of shipping to the fire test laboratory.
- The medium weight shock test is a mechanical impact of a 1,361 kg (3,000 pound) hammer swinging through an arc and then hitting the anvil mounted on the underside of the table which holds the specimens.



N-Class Divisions

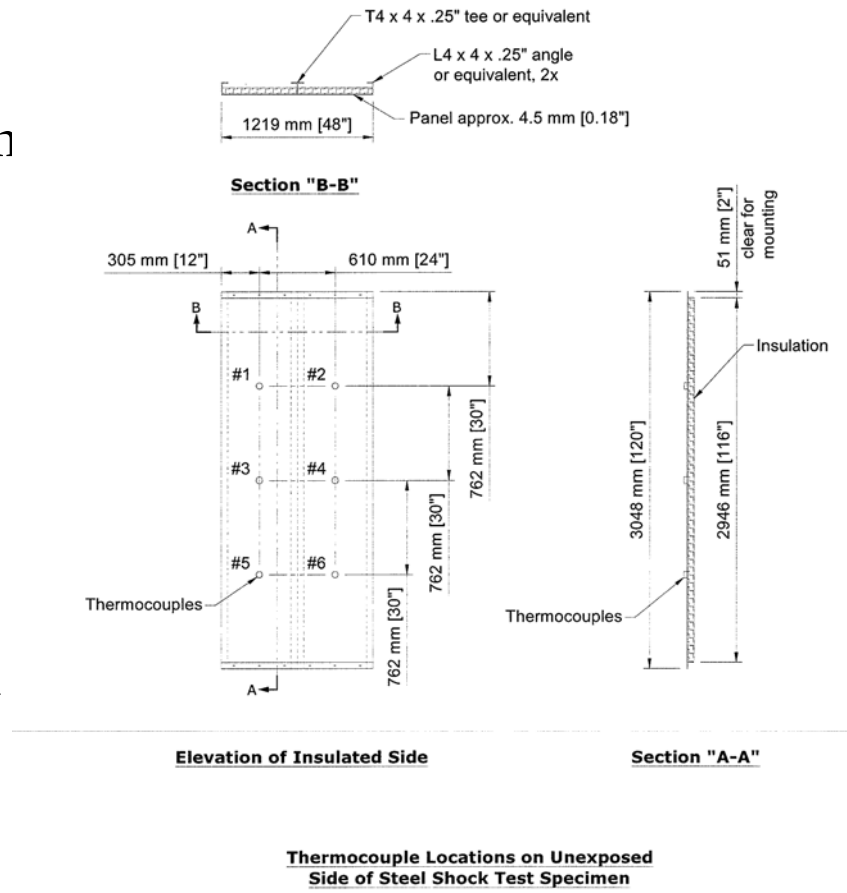
- The bulkhead/deck is subjected to one vertical/horizontal phase and two 30 degree inclined phases, turned 90 degrees from each other on the inclined surface.
- A full test for each specimen (bulkhead or deck) requires a total of nine (9) blows, three (3) blows for each orientation of the sample.
- After shock testing, the test items are visually inspected to ensure;
  - (1) no portion of the test items, or fixing devices came adrift which, when installed on a ship, could strike and injure personnel;
  - (2) no significant impairment or malfunction of Grade A items or systems;
  - (3) no detectable change of state of materials that may affect fire performance. The factors which would degrade the performance of the insulation include:
    - (1) large number of attachment pins (used for holding the insulation) becoming loose from the bulkhead or deck specimen;
    - (2) the insulation cracks or delaminates from the specimen visually exposing the face of the specimen;
    - (3) the insulation develops a noticeable gap or void between the bulkhead and insulation interface or within the insulation itself.

N-Class Division

- Shock Test

N-Class Division

- Successful shock testing (medium weight, Grade A) is followed by fire testing of shocked test specimen and unshocked test specimen side by side in the same furnace.
- The fire test is conducted in general accordance with NAVSEA 05P4 Test Method 02-2006 [1].
- The fire insulation material and its attachment method is evaluated for degradation in fire resistance by analyzing the average and maximum temperature rise on the unexposed face of the shock tested assembly compared to the average and maximum temperature rise of the control assembly at the end of the time period equal to that for which classification is desired.



Thermocouple Locations on Unexposed Side of Steel Shock Test Specimen

N-Class Division

- There should be no flaming on the unexposed face of shock tested assembly.
- The average and maximum temperature rise of shock tested and unshocked assemblies should not exceed 140 and 180 deg C IAW IMO acceptance criteria.
- The temp rise difference between shock tested assembly should not be more than 15% higher than the average and maximum temperature rise of the control assembly.
- The full scale fire resistance test in accordance with NAVSEA 05P4 Test Method 02-2006 [1], at the same insulation thickness and with the same attachment method, is still required to obtain final NAVSEA approval for the designated N-Class qualification.

Fire Resistance

- For bulkheads, overheads, decks, doors, hatches and penetrations):
  - MIL-PRF-32161 (NAVSEA 05P4 TM 02-2006)
  - Test Methods similar to IMO A.754(18)-Fire Resistance Tests for “A, “B, and “F” Class Divisions
  - Navy modified to address combat environment
- ACCEPTANCE CRITERIA:
  - Same as IMO A. 754(18)

  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 140^{o}C.

  c. Peak temperature rise on the unexposed surface shall not exceed 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.

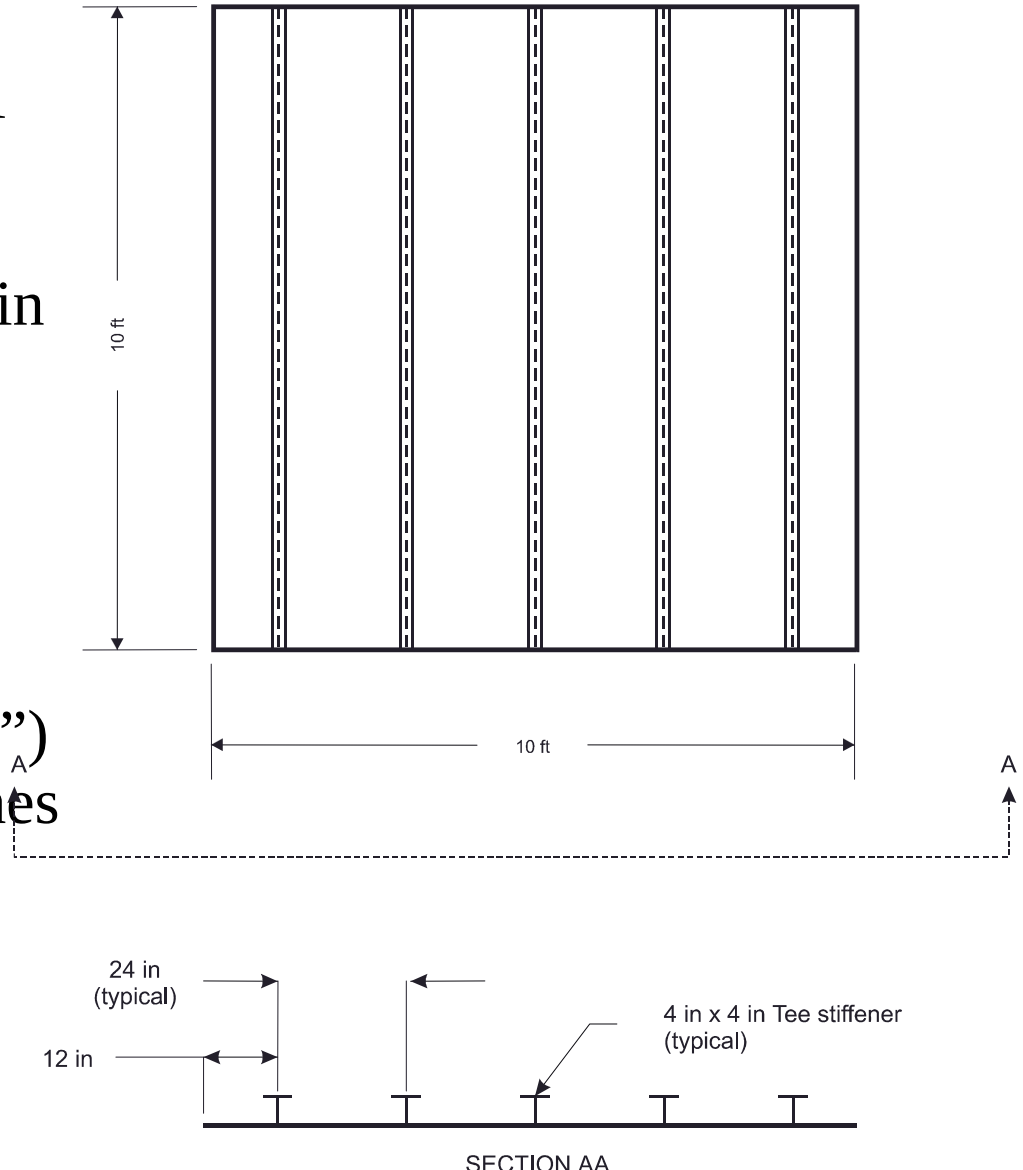
  g. Penetrations in N-class divisions shall be classified consistent with the rating of the boundary which they penetrate except where specified otherwise

Structural Integrity Under Fire

- Steel: Not required to be tested under load. For steel, structural integrity under fire may be demonstrated by analysis to illustrate that under the prescribed temperature rise the stresses will not exceed values acceptable to the Naval Technical Authority.
- Aluminum: Not required to be tested under load. For aluminum, the average temperature of the structural core shall not rise more than 200°C above its initial temperature at any time within the classification period.
- Polymer composites: Testing for structural integrity under fire shall be conducted in accordance with the fire resistance test method with the maximum load. 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
    - 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.

Test Specimen

- The bkhd assembly shall have a structural core of stiffened flat steel designed and fabricated in accordance with the specification shown in Figure A.5.
- T stiffeners are constructed on 101.6 mm(4”) by 101.6 mm (4”) stiffeners spaced 24 inches (0.61m) on center.

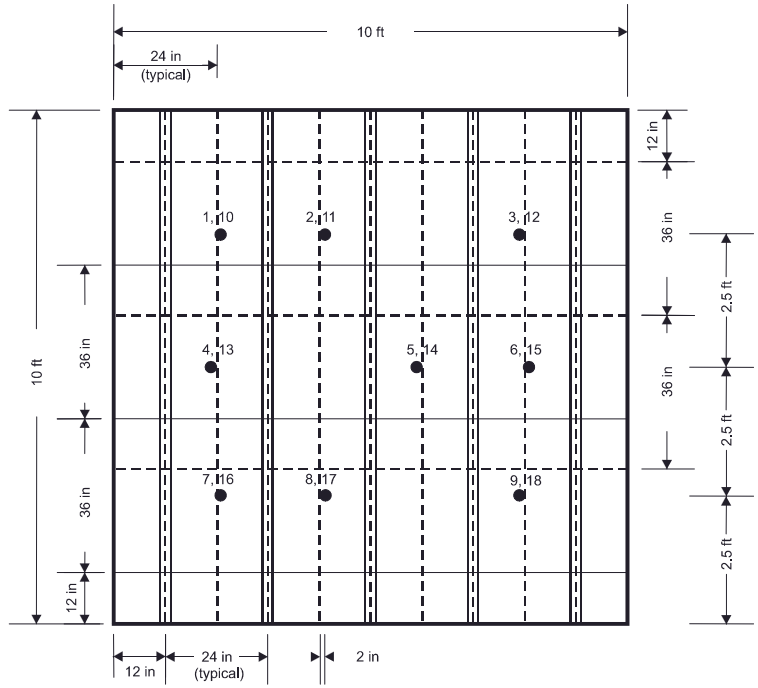


Fire Insulation

- For insulation on non fire side (“general application”):
  - For A-Class bulkhead, IMO permits bulkhead to be tested in the most onerous manner, which is considered to be with the insulation on the unexposed face and the stiffeners also on that side.
  - MIL-PRF-32161 does not address this issue. IMO is the Default guidance.
- For insulation on fire side only (“restricted application”)
  - For A-Class bulkheads for “restricted application”, insulated on fire side only, IMO requires the bulkhead to be tested with the insulation on the exposed face and with stiffeners also on that side.
  - For N-Class bulkheads, the stiffened face shall be exposed to the fire.
- For insulation (same material, equal thickness) on both sides (“double-sided application”)
  - For A-Class bulkheads, IMO requires the bulkhead to be tested with the stiffeners on the unexposed side of the bulkhead.
  - For N-Class bulkheads, the stiffened face shall be exposed to the fire.

Average Temperature Thermocouples

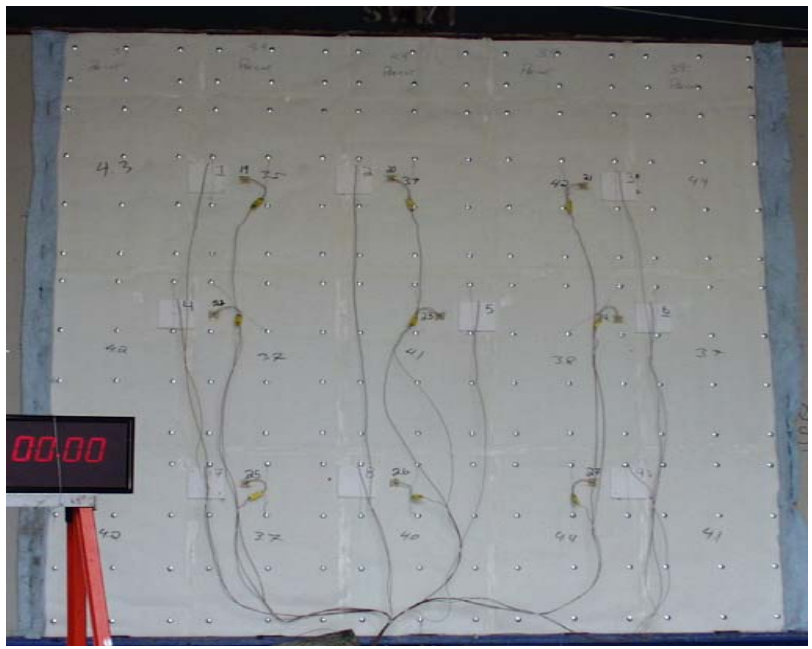
- Temperature measurement on unexposed face
  - IMO:
    - measured by 12 mm diameter copper disc (0.2 mm thick) thermocouples.
    - the average temperature rise on the unexposed face is calculated from Five thermocouples;
    - one TC is located at the center of the test specimen and one at the center of each of the four quarters
  - For N-Class bulkheads:
    - measured using Type K (Chromel-Alumel) thermocouples.
    - Nine thermocouples are used as shown centered between the frame bays.



TC#	LOCATION
1 – 9	Unexposed face, centered in frame bay
10 – 18	Unexposed face, centered in frame bay, under insulation

TC Pads

- IMO:
  - Each thermocouple should be covered with a 30 mm square insulating pad (2 mm thick).
- For N-Class bulkheads:
  - The thermocouples on the unexposed face shall be placed under dry felted pads as described in ASTM E 119 (6” x 6 ”x 0.375 ” thick).



Furnace Pressure

- For A-Class::
  - Bulkhead: Pressure of zero is established at a height of 500 mm above the notional floor level to the test specimen.
  - Deck: Pressure of 20 pa is established at 10 mm below the underside of the specimen.
- For N-Class:
  - Bulkhead: The neutral plane (zero pressure differential) shall be maintained at the base assembly for the entire test duration. This method places the entire assembly under a positive pressure.
  - Deck: the average pressure within the furnace shall be maintained at a minimum of 2.5 pa during the test at 25 mm below the sample.

SFP Installation

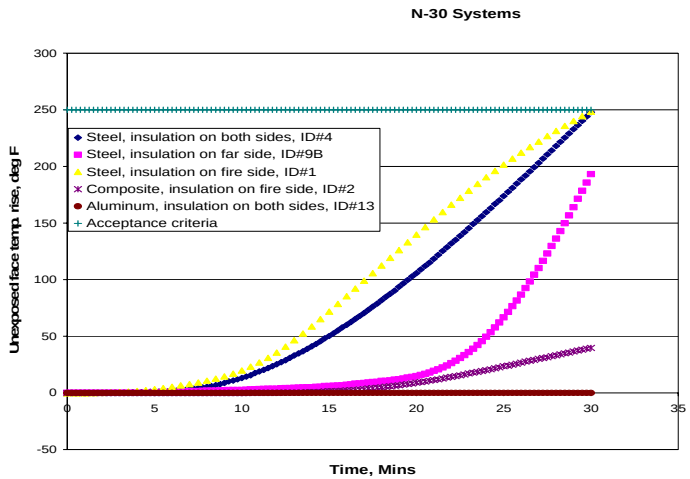
- Installation details for fire insulation are contained in MIL-PRF-32161.
- Details for studs and caps are contained in NAVSEA Dwg 803-518-4182
- Adhesively bonded fire insulation, or intumescent coatings not allowed for SFP.
- Approval of the material being fire tested will be limited to shipboard use with the assembly on which it was tested including attachment methods.

APPROVED N-CLASS SYSTEMS

Fire Insulation	Substrate	N-Class Rating	Test Remarks	NAVSEA approval	Reference See Note (1)
FireMaster X 607 Marine Blanket (Thermal Ceramics) with VBD foil facing, two layers of 1.5 inch insulation on fire side	2 mm Aluminum Deck (overhead) with stiffeners	N-30 aluminum deck (overhead) or bulkhead. (Restricted application)	Stiffened face exposed to fire.	Ser 05P4/072 Jan 2007	SwRI Rpt # 01.11717.01.003, May 2006.
FireMaster X 607 Marine Blanket (Thermal Ceramics) with VBD foil facing, two layers of 1.5 inch insulation on both sides for a total of 6.0 inches	2 mm Aluminum bulkhead with stiffeners	N-30 aluminum bulkhead (Un-restricted application)	Stiffened face exposed to fire	Ser 05P4/072 Jan 2007	SwRI Rpt # 01.11717.06.002a, July 2006
Structo-Gard® (SG) insulation, 1-7/8 inch thickness on fire side. Areal weight of insulation is 1.3 lbs/sq.ft.	Steel deck 4.5 mm thick, with 4x4 in. stiffeners IAW MIL-PRF-32161	N-30 steel deck (overhead) or bulkhead (Restricted application)	Stiffened face exposed to fire. Test continued for 1 hr.	Ser 05P4/115 Nov 2006	SwRI Report # 01.12043.01.003 November 2, 2006.
Un-Insulated	Steel deck, 4.77 mm plate with MT 3x2.2 stiffeners 400 mm apart, and deep stiffeners spaced 1400 mm apart	N-0 steel deck (overhead) or bulkhead	Stiffened face exposed to fire.	Ser 05P4/034 15 May 2006	SwRI Rpt # 01.11809.01.004, February 2006
Un-Insulated	Steel deck or bulkhead, 0.18 inch (4.5 mm) plate with 4x4 inch Tee stiffeners spaced 24 inches on center.	N-0 steel deck (overhead) or bulkhead	Stiffened face exposed to fire.	Ser 05P4/055 14 June 2005	Test Article IAW MIL-PRF-32161
Structo-Gard® (SG) insulation, 1.0 inch thick on each side, for a total of 2.0 inches. Areal weight of insulation is 0.67 lbs/sq.ft per side.	Steel Bkhd, 4.5 mm thick, with 4x4 in. stiffeners IAW MIL-PRF-32161	N-30 steel Bulkhead (Un-restricted application)	Insulation on both sides. Stiffened face exposed to fire.	Ser 05P4/055 14 June 2005	SwRI Rpt # 01.10679.01.001c, May 2005
SG Insulation, 3.5 inches thick (2 layers, each layer 1.75 inches thick) on one side.	Steel bulkhead, 4.5 mm thick, with 4x4 in. stiffeners IAW MIL-PRF-32161	N-30 steel Bulkhead (Un-restricted application)	Insulation tested in worst case on stiffened non fire side. Smooth bare steel face exposed to fire.	Ser 05P4/055 14 June 2005	SwRI Rpt # 01.10679.01.001d, May 2005
SG Insulation, 3.0 inches thick (2 layers, each layer 1.5 inches thick) on each side, for a total of 6.0 inches.	Aluminum (5083-116) Bulkhead, 4 mm thick, flat plate, stiffeners not required.	N-30 aluminum Bulkhead (Un-restricted application)	Insulation on both sides. No stiffeners on either side.	Ser 05P4/055 14 June 2005	SwRI Rpt # 01.10679.01.001g, May 2005.
Structo-Gard® (SG) Insulation, 5/8 in. thick, Areal weight of insulation is 0.55 lbs/sq.ft.	Composite Deck assembly, 76 mm thick balsa core and 7 mm fiber reinforced vinyl ester skin on both sides.	N-30 Composite deck assembly (Restricted application)	Insulation on the fire side.	Ser 05P4/107 27 September 2005	SwRI Project No. 01.10679.01.003b, July 2005

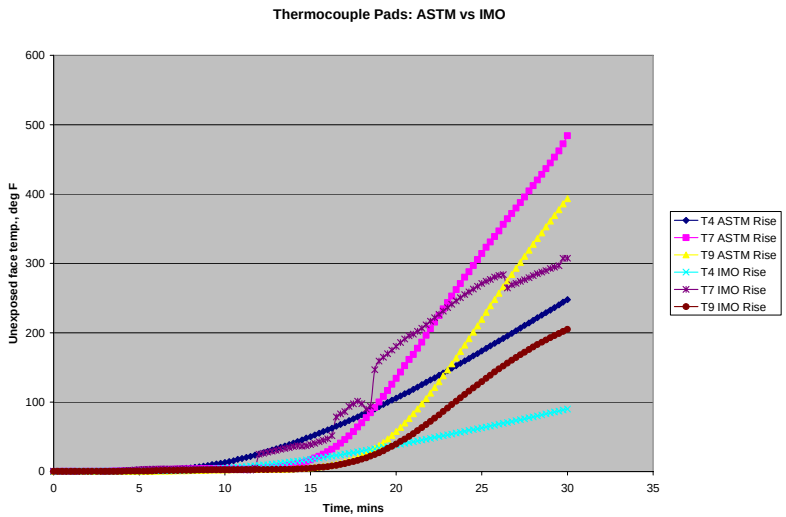
N-30 Class Divisions

- When the location of the fire threat is known and protection from only that side is required, insulation is placed on the side of the fire threat location and tested with fire on that side. This is known as Restricted application (ID#1).
- When fire threat is from both sides, and protection is required from both sides, the system must be qualified for Un-Restricted application. For steel construction, this can be achieved either by placing insulation on both sides (ID#4) or insulation on non fire side (ID#9B). 3.5 inch thick insulation on non fire side is required versus a total of 2 inch thick requirement for insulation on both sides.
- For aluminum construction, unrestricted application requires insulation on both sides since fire (appx. 2000oF) from either side could melt aluminum (appx. 1200oF) on non insulated side.
- For Navy polymer composite construction, fire resistance itself as defined by the temperature rise on the unexposed face, is not much of an issue. Typical Navy composite construction consists of 2 inch or greater balsa core sandwiched between glass or carbon reinforced vinyl ester skins. Balsa core itself provides significant fire insulation capability, and backside temperature requirements are easily met even without fire insulation on the fire side. Brominated vinyl ester based sandwich composites still require fire insulation on the fire side to meet smoke and fire growth requirements.



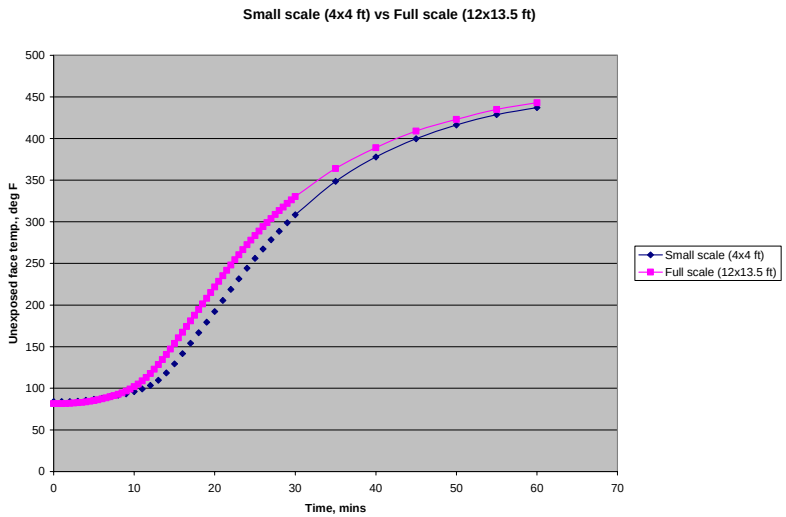
ASTM vs IMO Thermocouple Pads

- IMO uses five 12 mm (0.47 in.) diameter copper disc (0.2 mm thick) thermocouples to measure the average temperature rise on the unexposed face. The thermocouples are covered with a 30 mm (1.18 in.) square insulating pad with a thickness of 2 mm (0.08 in.).
- Navy uses nine Type K (Chromel-Alumel) thermocouples to measure the average temperature rise on the unexposed face. The thermocouples are covered with ASTM E 119 pads which have the dimensions of 152 x 152 x 9.5 mm (6 x 6 x 0.37 in.).
- Test results are show the unexposed face temperature rise is significantly higher from ASTM thermocouple pads than IMO thermocouple pads. The difference between the two temperature rise readings gets bigger approximately 15 minutes into the full scale fire test.



Small Scale Screening Test

- In the current competitive business environment, the U.S. Navy is often called upon to evaluate and qualify new materials and systems.
- For fire insulation systems, it has been found that 4x4 ft screening fire resistance tests provide a good approximation of insulation thickness required to qualify a full scale N-30 system.
- 4x4 ft steel division in deck orientation which met the unexposed face temperature rise requirements of less than 250oF (with 30 deg margin of safety) also met the N-30 requirements in full scale deck test.
- New insulation systems proposed for use by the Navy must first pass the small scale fire tests prior to the investment of resources into full scale qualification process.



SUMMARY

- U.S. Navy fire performance requirements are now governed by the ABS 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) which is non combustible. The key difference is that N-Class divisions are designed to protect against structural failure and prevent the passage of fire and smoke when exposed to a rapid rise hydrocarbon pool fire exposure for the designated test period after shock testing in accordance with MIL-S-901 [2].
- Several systems recently tested have been approved as N-30 Class. These include steel division with insulation on fire side, far side, and both sides; aluminum division with insulation on both sides; and composite division with insulation on fire side.
- Data on unexposed face temperatures measured by both ASTM and IMO thermocouple pads indicate that ASTM thermocouple pads consistently read higher temperatures due to greater size and thickness of pads.
- Data on small scale screening fire resistance test indicates that it provides a good approximation of insulation thickness required to qualify a full scale N-30 system. It provides a reliable and cost effective screening process for the new fire insulation systems.
- Due to significant differences in the IMO and MIL-PRF-32161 test procedures, IMO certifications are not accepted for N Class divisions.