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Design Loads for Fiberglass Bulkhead and Deck Structures

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16. Abstract

In order to determine suitable loadings to be applied during fire endurance testing of fiber reinforced plastic (FRP) bulkhead and deck structures, a number of sources were reviewed to determine whether generally-accepted published design load values were available for these structures.

Few published listings of design load values were found. It appears that the main reason is widespread reliance on classification society design rules. Also, design loads are often established on an individual basis for specific sea state conditions and operational requirements.

It was concluded that the most suitable method of establishing loadings for fire endurance testing would be to require the structure's designer to provide actual design load information for each test specimen. Suggested loading values are also provided for use in cases where the actual design load values are not available.

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METRIC CONVERSION FACTORS

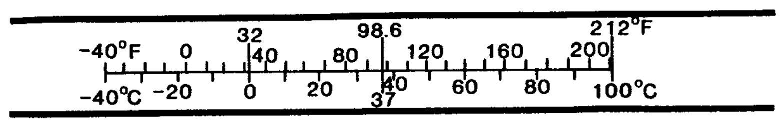
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



DESIGN LOADS FOR FIBERGLASS BULKHEAD AND DECK STRUCTURES

1.0 Background

Recently, a draft proposed standard was prepared for the International Maritime Organization, covering testing of fire endurance of loaded fiber reinforced plastic (FRP) vessel structures. Following preparation of the proposed standard, a number of sources were reviewed to determine whether a rationale could be found for establishing standard loadings to be imposed on FRP bulkhead and deck structure specimens during fire endurance testing.

This review focused on an examination of design loads (i.e., the loadings which are assumed to act on a structure for the purposes of sizing the structure's scantlings).

The following is intended neither as a design guide nor as recommendations regarding design load selection for specific structures. It is merely a discussion of available design load information applicable to bulkhead and deck structures, which could be used to establish standardized loadings to be applied during fire endurance testing.

2.0 Design Loads

For the purposes of this review, the term "design load" is taken to mean the assumed loading that is used to determine the minimum requirements (e.g., plating thickness and stiffener spacing and cross-section configuration) of a vessel's structure. The design load can also be considered to be the maximum load that a structure can be expected to carry without risking damage.

As discussed below, available sources differ as to procedures for combining various possible loading conditions in order to develop specific design load values. Design loads are often established for vessel designs on an individual basis, taking into account the probability, magnitude and frequency of an assumed maximum sea state, slamming or other expected loading conditions. Again based on available sources, there appears to be no generally-accepted method of developing design loads (or the associated design stresses and margins of safety, which involve material strength properties as well). Consequently, there are few published listings of numerical design load values suitable for general applications.

Reference 1, which is concerned primarily with small craft such as yachts, includes the following discussion of a method of establishing design load for hull structure:

> Design Load - It will be apparent by now that, whether the ABS "Guide for Building and Classing Offshore Racing Yachts" is used, or some other method derived from basic principles, the sum of the heads* multiplied by some slamming factor will be used as the design load. It is important to note, however, that most design methods utilize the head described above in conjunction with mechanical properties for the construction material usually reduced by a "safety factor." In fact, it is important for the designer to make certain that the finally derived design load is an "accurate estimate" involving the best information available regarding loadings and incorporating a positive or conservative margin between the real load and the estimated design load. The more accurate and detailed the information above, the smaller the margin may be between the real load and the design load. Nevertheless, this margin must never be negative...

In Reference 2, design loads for hull structure are discussed in general terms as follows (Chapter VI, Section 4):

> To establish the required sizes or scantlings of the structure, it is necessary to determine first the maximum

*described previously in this reference as hydrostatic head augmented by wave height and velocity pressure head.

> loads imposed on it. The major loads imposed on a ship structure may be conveniently divided into the following groups:
>
> - Stillwater bending moments and shearing forces;
> - wave-induced moments and shearing forces;
> - springing and impulsive loads;
> - thermal loads;
> - dynamic loads, i.e., hydrodynamic pressures, sloshing;
> - other loads, i.e., launching, docking, grounding, mooring, and collision
>
> A combination of the most severe loads is usually selected as the nominal design load for a given structure. The other important loads may be either accounted for in the assigned safety margin or treated statistically in conjunction with all the load components in a refined analysis of the final design...[1]

In some design methods, individual loads are grouped into load categories. One such category might include the loads that are assumed to act on a vessel's structure continuously (e.g., weight of cargo or stores, loads due to liquids in tanks, dead weight of structure), and which may therefore be considered normal operating loads. Other categories might include loads assumed to occur only under unusual operating conditions (e.g., sea slap or slamming loads in high sea states), or loads resulting from casualty conditions such as flooding (Reference 3). Typically, each of these unusual loads is assumed to act independently (but concurrent with the normal operating loads), one load at a time.

With other design methods, a single design load value is assumed, covering all operating conditions.

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[1] No specific values for design loads are given, either in the general section quoted above, or in subsequent sections dealing with deck and bulkhead design.

Regarding the predictability of actual loads, it should be remembered that, as stated in a number of sources, it is extremely difficult to determine accurately the actual loadings on a vessel due to wave action such as sea slap and green seas on deck. Even where actual forces have been measured, the results are strictly accurate only for the hull shape, vessel speed and sea conditions that existed when the measurements were made.[2]

3.0 Special Considerations Regarding Design of FRP Structures

In Section 2.0, design loads are discussed in general terms, without regard to the structural materials used. As stated above, it is important that the selected design load value includes an adequate margin over and above the best estimate of actual load.

Equally important, especially in the case of FRP structures, is the factor used to obtain allowable design stress values. Reference 1 states that:

> Mechanical properties are usually reduced by a factor of 2 or more, depending upon the reliability of information available regarding the material in question and some judgment on the part of the designer as to the benefits gained versus risks taken in reducing the size and weight of a structural component. An obvious example here is that a small margin of safety is inappropriate in ballast keel bolts, as weight savings is not particularly critical in this area of the boat.

Compared with materials such as steel and aluminum, FRP mechanical properties may be subject to great variation due to the basic nature of the material. This variation can result

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[2] For a discussion of design loads and their relationship to design stresses and safety margins, see Chapters 3 and 13 of Reference 4.

from several causes: (a) each layer of an FRP laminate will have highly directional strength properties; (b) it is possible to use a variety of resin and mat materials, as well as fiber fractions, all of which can significantly affect strength; (c) quality of workmanship during FRP manufacture and thickness variations.

In addition, according to Reference 5, FRP is particularly susceptible to creep or fracture when subjected to long-term loads. Also, static fatigue of glass fibers can reduce their load-carrying capacity by as much as 70 to 80 percent, depending on load duration, temperature, moisture conditions and other factors.

Because of these uncertainties regarding FRP strength properties, great care must be exercised when selecting both the margin used to define the design load value and the strength properties reduction factor used to define the design stress value.[3]

4.0 Design Load Information

When loaded structural specimens are tested for fire endurance, the applied loadings should at least approximate the conditions that the structures will experience in service. In order to establish reasonable loading conditions, several sources were reviewed to obtain information on the design loads typically used for designing these types of structures. These sources included documents related to Coast Guard design approval, classification society design rules, marine structure design manuals, naval architectural texts, and technical papers. In addition, technical personnel of the American Bureau of Shipping and several naval architectural firms were contacted.

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[3] For a detailed discussion of FRP vessel structural design approaches, including different approaches for large vessels and small craft, see Chapters 3 and 4 of Reference 3.

Design load information obtained from various sources is summarized below. Since many different vessel design methods are in use, it is important to understand, for each method, (a) what types of loadings are included in a given design load value, and (b) the types of vessels for which the design method is intended. For this reason, brief descriptions of individual design methods have also been included.

5.0 Design Methods Acceptable to the Coast Guard

Reference 6 states that, in general, the Coast Guard will approve fiber reinforced plastic (FRP) vessel designs which meet applicable rules of the American Bureau of Shipping (ABS) or Lloyd's Register of Shipping. These directly acceptable classification society rules are:

(1) ABS Rules for Building and Classing Reinforced Plastic Vessels 1978 (Reference 7). According to Reference 6, these rules apply to vessels of normal form, up to 200 feet in length; special consideration is required for vessels of unusual form or design features.)

(2) Lloyd's Register of Shipping Rules and Regulations for the Classification of Yachts and Small Craft, Part 2, Chapter 2: Glass Reinforced Plastics. (According to Reference 6, these rules apply to vessels not more than 30 meters (100 feet) in length.)

Reference 6 also states that other classification society rules or other design standards may also be acceptable to the Coast Guard. If other design methods are used, the designer must prove, to the Coast Guard's satisfaction, that a proposed design meets a level of safety at least equivalent to that prescribed by ABS or Lloyd's Rules.

As regards to FRP vessels intended to carry passengers, Reference 6 contains the following information:

> The process of certificating an FRP vessel to carry passengers under the United States flag is regulated by Title 46, Code of Federal Regulations (CFR), Subchapter T (T-boat regulations). FRP is prohibited as a construction material for vessels carrying 150 or more total passengers (46 CFR 177.10-5(a-1)) or 50 or more passengers with overnight accommodations. FRP is also prohibited for carrying 13 or more passengers on international voyages covered by SOLAS (Chapter II-2, Regulation 23.1 of SOLAS '74 as amended) unless equivalencies or exemption determinations have been granted by the cognizant OCMI. Regulations for cargo and miscellaneous vessel construction are found in 46 CFR, Subchapter I...[4]

6.0 Design Load Information Included in ABS Rules

Reference 7 provides design methods for determining minimum allowable plating thickness and stiffener geometry requirements (section modulus and area moment of inertia) for various types of FRP vessel structure, including watertight bulkheads (Section 10) and decks (Section 11).

The formulas used in Reference 2 for calculating minimum thickness, etc., do not include a design load term as such. Instead, the design load, the safety factor (generally 4.0) and any necessary unit conversion factors are combined into a numerical coefficient for each formula. In addition to the coefficient, the formulas typically include one or more structure dimension terms and a vertical (hydrostatic head) dimension term.

While Reference 7 does not include specific design load values, Section 11.2 indicates that ABS considers "normal" cargo density to be 717.7 kg/m^3 (44.8 lb/ft^3), and implies that "normal" loading on exposed decks due to deck cargo is assumed to be 2636 kg/m^2 (540 psf or 25.9 kPa).

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4 None of the above CFR references contain design load information.

The ABS design guide for offshore racing yachts (Reference 8) uses a different approach, in that it includes a design stress term in the design formulas, as well as a term identified as design head. Design stresses for reinforced plastic are given in the guide as a portion of either minimum ultimate tensile strength or minimum flexural strength. Design loads and safety factors are not mentioned specifically. Reference 8 is also organized differently; its two major design sections are Plating (Section 7) and Internals (Section 8). This guide does not have separate sections on watertight bulkheads and decks, as does Reference 7. According to Reference 6, the ABS offshore racing yacht design guide

> ...is not alone sufficient as a standard for a sailing passenger vessel. This guide contains many design features which may be appropriate for limited purpose racing vessels but not for commercial passenger vessels. However, some design details in the ABS Yacht Guide are appropriate for any vessel and will be directly referenced...

7.0 Design Load Information from Other Published Sources

Most naval architecture texts deal primarily with the design of relatively large vessels, and few contain structure design loading data identified as such. Possibly one reason for the scarcity of published design load data is the fact that such data is unnecessary if classification society (e.g., ABS) design methods are used.[5] Also, actual loads due to waves (e.g., deck loading imposed by shipping green seas) are highly dependent upon vessel configuration and operating conditions. As stated in Reference 1, it is extremely difficult to determine the actual wave-induced loadings on vessel structures except by direct experimental measurement. Even when experimental data is taken, it is nearly impossible to isolate the effects of variables such as wave height, vessel shape, and impact. Test results are thus directly applicable to the specific structure under test and for the specific conditions (wave height, vessel speed, etc.) of the test.

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[5] See Section 4.0 above

7.1 "Fiberglass Boat Design and Construction" (Reference 9)

Reference 9 lists types of loads which must be considered in the design of boat structures:

For weather decks:

- Hydrostatic loads
- Static loads from equipment and cargo
- Footprint loads
- Snow and ice loads
- Impact against docks at edges
- Impact of cargo or gear (workboats)
- Abrasion

For interior decks:

- Static loads from equipment and cargo
- Footprint loads
- Flooding loads (if watertight)
- Hydrostatic loads for tank boundaries
- Impact from cargo or gear (workboats)
- Abrasion

For bulkheads:

- Flooding loads
- Loads transferred from decks supported

Reference 9 states that:

> The magnitude of the design loads is highly dependent on the size of the hull and its anticipated service...
>
> ...Many of the loads in the foregoing list are dynamic in nature, and a classical engineering approach to design would analyze the dynamic response of the structure to these load-time inputs. However, it is generally acceptable to develop simpler equivalent static loads since load inputs are usually not well enough defined to warrant the more complex dynamic analysis.

The following design load values are recommended by Scott for use in designing small FRP boats. These values were obtained from several other published sources.

Recommended Design Loads for Structural Design			
Exterior Decks*	Yachts 125 PSF (5.99 kPa)	Workboats 200 PSF (9.58 kPa)	Sailboats 125 PSF (5.99 kPa)
Interior Decks*	50 PSF (2.39 kPa)	100 PSF (4.79 kPa)	50 PSF (2.39 kPa)
Watertight Bulkheads	Hydrostatic head 1.0 feet above uppermost continuous deck		

* In addition to the specified uniform loads, walking surfaces should be designed for a load of 150 pounds (Yachts and Sailboats) or 250 pounds (Workboats) concentrated on an area of 6" x 12". This is generally only critical for single skin panels. If more severe concentrated loads are anticipated, they must be considered.

(For tanks, the recommended design loads are given as "Same as Watertight Bulkheads or to height of overflow, whichever is greater".)

Scott also discusses safety factors:

The safety factors used in designing FRP small boats are based upon the ultimate strength of the laminate or the core material and are generally higher than for steel or aluminum to account for any loss of strength due to life-cycle environment, fatigue, creep and the variability in laminate thickness and properties... The following safety factors are recommended for conventional FRP boat design for both laminates and cores of sandwich panels:

Hydrostatic and equipment loads on the hull and weather deck	4.0
Rigging and foundation loads (normal operating)	4.0
Impact loads on hull and weather deck	1.5
Static and equipment loads on interior decks	3.0
Flooding loads on bulkheads and tight decks	2.0

Another matter of concern is the possibility of excessive deflection of FRP structures. Reference 9 states that:

> The low modulus of elasticity of fiberglass laminates results in larger deflections than metal structures of equivalent strength, which can be objectionable in some cases. Most boat owners object to "soft" decks and equate noticeable hull side or bottom panel deflections with structural weakness. Excessive panel deflections can be objectionable since the rotation between the panel edge and the stiffener can weaken the bonded joint and excessive stiffener deflection can cause misalignment of shafting.
>
> As a general guideline, the deflection of panels and stiffeners subjected to the loads discussed previously should not exceed the following, where L is defined as the length of a stiffener between supports or the minimum unsupported span of a panel:

Bulkheads - flooding loads	L/50
Decks - uniform loads	L/100
Decks - footprint loads	L/100

7.2 "Structural Design Manual for Naval Surface Ships", NAVSEA 0900-LP-097-4010 (REFERENCE 3)

Reference 3 includes a section dealing with ship structural loads in naval vessel design. The manner in which these loads are considered is much more complex than the ABS approach in References 7 and 8.

In the Reference 3 approach, there are two basic types of ship structural loads: loads to be combined (i.e., superposed), and individual or independent loads which are not normally combined with other loads, or with each other.

Non-combat loads on bulkheads and decks are categorized in Reference 3 as:

Basic Loads (assumed to act on the structure regardless of environmental influences and special operational conditions)

Sea Environment Loads (including hull girder, weather and ship motion loads)

Operational Environment Loads (normally not combined with other loads or with each other; represent extreme cases or unusual situations unlikely to occur simultaneously with other loads in this category)

An outline of these loads and their applicability to bulkhead and deck structures appears in Table 1, "Bulkhead and Deck Loads (Adapted from Reference 3)".

Table 1. Bulkheads and Deck Loads (Adapted from Reference 3)

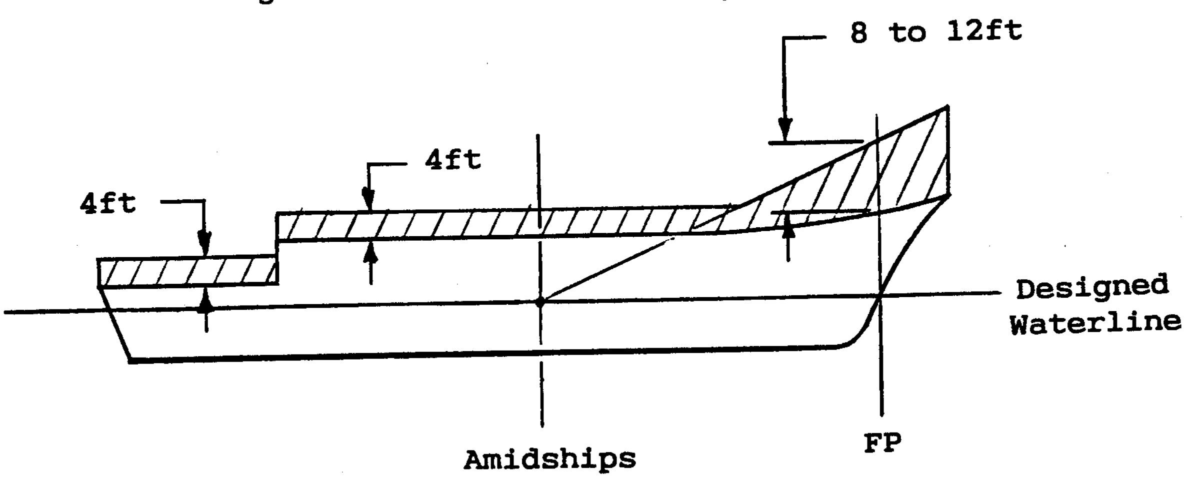
LOADS	APPLICATION			
	Bulkheads		Decks	
	Longitudinal	Transverse	Interior	Exterior
LOADS TO BE COMBINED				
<u>Basic Loads</u>				
Standard live loads	(N/A)	(N/A)	Note 1	Note 1
Dead loads	Note 2	Note 2	Note 2	Note 2
Liquid/tank loads	Note 2	Note 2	Note 2	(N/A)
Loads from equipt/cargo	(N/A)	(N/A)	Note 2	Note 2
<u>Sea Environment Loads</u>				
Hull girder loads	Note 2	(N/A)	Note 2	Note 2
Sea loads (hydrostatic)	(N/A)	(N/A)	(N/A)	Note 3
Weather loads (ice and snow)	(N/A)	(N/A)	(N/A)	7.5 lb/ft^2
Ship motion loads	Note 4	Note 4	Note 4	Note 4
INDIVIDUAL LOADS				
<u>Operational Environment Loads</u>				
Slamming loads	(N/A)	(N/A)	(N/A)	Note 5
Flooding loads	Note 2	Note 2	Note 2	(N/A)
Tank overfill loads	Note 2	Note 2	Note 2	Note 2

Notes: 1. Live load values depend upon type and location (deck level) of compartment, as follows:

TYPE OF COMPARTMENT	LIVE LOADING (LBS/SQ.FT.)	kPa (kN/m^2)
Living and control spaces, offices and passages, main deck and above	75	3.6
Living spaces below main deck	100	4.8
Offices and control spaces below main deck	150	7.2
Shop Spaces	200	9.6
Storerooms	300*	14.0
Weather portions of main deck and 01 level	250**	12.0

*Or stowage weight, whichever is greater
**Or maximum vehicle operating load, whichever is greater

2. Magnitude of design loading will depend on specific vessel/compartment/structure configuration.
3. Hydrostatic head on the weather deck due to pitching/green seas is assumed to be 8 to 12 feet at the Forward Perpendicular. The head is assumed to decrease linearly toward the stern, to a minimum of 4 feet, remaining constant over the after part of the vessel. (See the diagram below, which is based on Figure 4.5 of Reference 3.)



4. Ship motion amplitudes and periods for moderate sea and storm sea conditions (specified for each ship design) are used to obtain equivalent static force components. The basic load used in calculating ship motion factors consists of only dead load and known stowage weights.
5. Table 4-1 of Reference 3 indicates that "Sea Slap/Slam" loadings are independent loadings applicable to weather deck design. However, it appears that these loadings are intended to be used primarily in the design of aircraft carrier sponson structures; therefore, such loads would not be appropriate for merchant vessel weather deck design.

7.3 "Structural Design and Materials for Small Warships" (Reference 10)

As part of the design criteria for fast patrol craft, Reference 10 states that:

> External decks must be able to withstand a certain head of water, together with the weight of any equipment on the deck, without collapse. The actual value to use in design is somewhat controversial. Suggested pressures are 1½ lb/in^2 (100 mbar) forward and 1 lb/in^2 (70 mbar) aft.
>
> Interior decks must withstand an arbitrary distributed loading to represent equipment and personnel. We assume an overall pressure, excluding local heavy equipment, of 1 lb/in^2 (70 mbar). As a matter of interest, this is approximately equivalent to men standing as closely packed as possible over the whole area.
>
> Watertight bulkheads in small warships should be designed to hold a head of water, either side, up to the main deck level, to allow for the case where some compartments are holed and flooded while others remain dry. For larger boats it may be worth considering reasonable flooding cases in more detail to get a more rational design case for the bulkheads.
>
> Fuel and water tanks should be able to withstand static heads of liquid up to the vent outlets, plus an allowance for flow along the vent pipes in case of accidental over-filling.

8.0 Summary of Standard Design Load Information

As mentioned previously, there is little available published standard design load information for deck and bulkhead structure. (In this case, "standard" is defined as specific numerical values generally applicable to a wide variety of individual vessel design requirements and/or structural configurations.)

In this survey, four sources containing standard design loads were found. Of these, only one gave standard total design loads; the other sources gave standard design loads for only portions of the total design loadings. In each case, the standard design loads were for deck structures.

Available standard design load recommendations for deck structures are given in Table 2.

Table 2. Standard Design Loads for Deck Structures		
Description of Structure	Type of Loading Represented	Recommended Design Load
<u>ABS</u> (Reference 7) Decks (reinforced plastic vessels)	Cargo weight	540 psf (2636kg/m^2 for "normal" cargo weight (Note 1) (25.9kPa)
<u>NAVSEC</u> (Reference 3) Decks (naval surface ships)		
Exterior	Live load	250 psf (Note 2) (12.0 kPa)
"	Ice and snow	7.5 psf (0.36 kPa)
"	Green seas	Approx. 12 ft head (768 psf) (36.8 kPa) max fwd; 4 ft head (256 psf) (12.2 kPa) aft (Note 3)
Interior (Main Deck and above Note 4)	Live load	75 psf (3.6 kPa)
(Below Main Deck) Living Spaces	" "	100 psf (4.8 kPa)
Offices and control spaces	" "	150 psf (7.2 kPa)
(Shop Spaces)		200 psf (9.6 kPa)
(Storerooms)		300 psf (Note 5) (14 kPa)
<u>Scott</u> (Reference 9) Decks (fiberglass boats)		
Exterior (yachts and sailboats)	Total	125 psf (Note 6) (6.0 kPa)
" (workboats)	"	200 psf (" ") (9.6kPa)
Interior (yachts and sailboats)	"	50 psf (" ") (2.4 kPa)
" (workboats)	"	100 psf (" ") (4.8 kPa)
<u>Kingslake</u> (Reference 10) Decks (small warships)		
Exterior	Equipment weight plus water head	216 psf fwd, (10.3 kPa) 144 psf aft, (6.89 kPa)
Interior	Equipment and personnel	144 psf (Note 7) (6.89 kPa)

Notes

1. ABS Rules for Building and Classing Steel Vessels under 61 Meters (200 feet) in length (1983 Edition) includes the 540 psf figure for "normal" cargo weight.

2. Or maximum vehicle operating load, if greater.

3. See Section 6.2 for method of determining variation of design head along length of vessel.

4. Including living and control spaces, offices and passages.

5. Or stowage weight, if greater.

6. In addition to the recommended uniform load, walking surfaces should be designed for a load of 150 pounds (yachts and sailboats) or 250 pounds (workboats) concentrated on a 6" x 12" area, except where more severe concentrated loading is expected.

7. Not including local heavy equipment.

In the available sources that include recommended design loads for bulkhead structures (References 3, 9 and 10), the design load is defined as a head of water, rather than as a specific load per unit area.

For naval surface ship bulkhead design, Reference 3 requires that the following loads be considered:

Loads to be combined

Primary hull girder loads (longitudinal bulkheads only)

Tank loads (A head measured to the top of the tank is considered to be the normal case, and is therefor combined with other loads. However, it is frequently assumed that a filled tank has an opposing, and therefor reducing, impact on other loads; loads which act in opposition should not be combined in the strength analysis.)

Dead loads

Independent loads

Tank loads in overfilled condition (For accidental tank overfill, the assumed load is the hydrostatic head measured to the overflow.

This is considered to be a short-term condition and is, therefore, not combined with any other load; see also the above remark concerning impact of a filled tank on other loads.)

Flooding loads (Flooding loads are likely to be critical for bulkheads and decks of vital spaces in the lower hull.)

Scott (Reference 9) indicates that the loads which must be considered in designing small boat bulkhead structures are:

Flooding loads

Loads transferred from decks supported.

Scott states that the recommended design load for structural design of watertight bulkheads for fiberglass yachts, sailboats and workboats is a hydrostatic head measured from the bottom of the bulkhead to a point 1.0 foot above the uppermost continuous deck.

(For tanks, the recommended design load is a hydrostatic head measured from the bottom of the bulkhead to a point 1.0 foot above the uppermost continuous deck (i.e., the same as for watertight bulkheads), or to the height of the tank overflow, whichever is greater.)

Kingslake (Reference 10) recommends that watertight bulkheads in small warships should be designed to hold a head of water, either side, up to the main deck level (to allow for the case where some compartments are holed and flooded while others remain dry). This reference also states that fuel and water tanks should be able to withstand static heads of liquid up to their vent outlets, plus an allowance for flow along the vent pipes in case of accidental overfilling.

9.0 Recommendations Concerning Loadings for FRP Structures Undergoing Fire Endurance Tests

As described above, determining realistic design loads for bulkhead and deck structures can be a complex process. In order to ensure structural adequacy, the designer must consider a number of environmental, operational and material factors that often vary greatly from case to case. For this reason, it seems reasonable to assume that standard, numerical values for overall design loads are seldom used in actual practice.

Therefore, the most straightforward method of determining the loading to be applied to a structure during fire endurance testing would be to require that the structure's designer provide the necessary design load information (e.g., head in feet, uniform loading in pounds per square foot, magnitude, location and direction of point or concentrated loadings, etc.) for each specific structural specimen to be tested.

If such information is not available, and it becomes necessary to estimate test loadings, the following values are suggested for deck structures:

Interior decks (other than machinery spaces)

Accommodations spaces, control spaces, offices and passageways, Main Deck and above	75 lb/ft^2 (3.6 kPa)
Accommodations spaces below Main Deck	100 lb/ft^2 (4.8 kPa)
Offices, control spaces, passageways below Main Deck	150 lb/ft^2 (7.2 kPa)
Shop spaces	200 lb/ft^2 (9.6 kPa)
Storerooms	300 lb/ft^2 (14.0 kPa)
Cargo stowage deck areas	550 lb/ft^2 (26.0 kPa)

Exterior decks

Areas subject to green seas loading but not used for cargo stowage:	
Forward one-quarter of vessel:	375 lb/ft^2 (18.0 kPa)
After three-quarters of vessel:	250 lb/ft^2 (12.0 kPa)
Cargo stowage areas:	550 lb/ft^2 (26.0 kPa)
Areas not used for cargo stowage and not subject to green seas loading:	200 lb/ft^2 (9.6 kPa)

(These suggested loadings should be adjusted upwards if the structures will be subjected to large concentrated loads or other unusual service conditions.)

Bulkheads

Test loads for bulkhead structures should simulate a hydrostatic head of seawater measured from the bottom of the bulkhead to a point 1.0 foot above the uppermost continuous deck.

For tank bulkheads, the hydrostatic head should be measured to the height of the tank overflow, or to a point 1.0 foot above the uppermost continuous deck, whichever is greater.

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