NTIS #

SSC-439

COMPARATIVE STRUCTURAL REQUIREMENTS FOR HIGH SPEED CRAFTS

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2005

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Technical Report Documentation Page

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16. Abstract

The report contains a general overview and comparison of the application, requirements and methods for the structural design of high speed craft used the International Maritime Organization, The American Bureau of Shipping, Bureau Veritas, Det Norske Veritas, Germanischer Lloyd, Lloyd's Register of Shipping, Nippon Kaiji Kyokai, and Register Italiano Navale. The comparison included:

- Types of craft classed
- Service restrictions or categories
- Speed and size ranges covered by the codes/rules
- Performance based or prescriptive design standards
- Key parameters specified (hull pressure loads, section modulus requirements, etc.)

Specific calculations are presented for a large, high speed monohull using the rules from The American Bureau of Shipping (ABS) and Det Norske Veritas (DNV) in order to provide a meaningful quantitative comparison.

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CONVERSION FACTORS
(Approximate conversions to metric measures)

To convert from	to	Function	Value
LENGTH			
inches	meters	divide	39.3701
inches	millimeters	multiply by	25.4000
feet	meters	divide by	3.2808
VOLUME			
cubic feet	cubic meters	divide by	35.3149
cubic inches	cubic meters	divide by	61,024
SECTION MODULUS			
inches^2 feet^2	centimeters^2 meters^2	multiply by	1.9665
inches^2 feet^2	centimeters^3	multiply by	196.6448
inches^4	centimeters^3	multiply by	16.3871
MOMENT OF INERTIA			
inches^2 feet^2	centimeters^2 meters	divide by	1.6684
inches^2 feet^2	centimeters^4	multiply by	5993.73
inches^4	centimeters^4	multiply by	41.623
FORCE OR MASS			
long tons	tonne	multiply by	1.0160
long tons	kilograms	multiply by	1016.047
pounds	tonnes	divide by	2204.62
pounds	kilograms	divide by	2.2046
pounds	Newtons	multiply by	4.4482
PRESSURE OR STRESS			
pounds/inch^2	Newtons/meter^2 (Pascals)	multiply by	6894.757
kilo pounds/inch^2	mega Newtons/meter^2 (mega Pascals)	multiply by	6.8947
BENDING OR TORQUE			
foot tons	meter tons	divide by	3.2291
foot pounds	kilogram meters	divide by	7.23285
foot pounds	Newton meters	multiply by	1.35582
ENERGY			
foot pounds	Joules	multiply by	1.355826
STRESS INTENSITY			
kilo pound/inch^2 inch$^{1/2}$(ksi√in)	mega Newton MNm$^{3/2}$	multiply by	1.0998
J-INTEGRAL			
kilo pound/inch	Joules/mm^2	multiply by	0.1753
kilo pound/inch	kilo Joules/m^2	multiply by	175.3

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COMPARATIVE STRUCTURAL REQUIREMENTS FOR HIGH SPEED CRAFT

The report contains a general overview and comparison of the application, requirements and methods for the structural design of high speed craft used by the following: International Maritime Organization, American Bureau of Shipping, Bureau Veritas, Det Norske Veritas, Germanischer Lloyd, Lloyd's Register of Shipping, Nippon Kaiji Kyokai, and Register Italiano Navale. The comparison included:

- Types of Craft Classed
- Service Restrictions or Categories
- Speed and Size Ranges Covered by the codes/rules
- Performance based on Prescriptive Design Standards
- Key Parameters Specified (Hull Pressure Loads, Section Modulus Requirements, etc.)

Specific calculations are presented for a large, high speed monohull using the rules from the American Bureau of Shipping (ABS) and Det Norske Veritas (DNV) in order to provide a meaningful quantitative comparison.

This study was limited to the calculation of the scantlings required by the rules. Both societies' rules would require additional global and local finite element analyses to verify the adequacy of the design as well as fatigue studies of critical areas.

T. H. Gilmour

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Chairman, Ship Structure Committee

Executive Summary

The report contains a general overview and comparison of the application, requirements and methods for the structural design of high speed craft used the International Maritime Organization, The American Bureau of Shipping, Bureau Veritas, Det Norske Veritas, Germanischer Lloyd, Lloyd's Register of Shipping, Nippon Kaiji Kyokai, and Register Italiano Navale. The comparison included:

- Types of craft classed
- Service restrictions or categories
- Speed and size ranges covered by the codes/rules
- Performance based or prescriptive design standards
- Key parameters specified (hull pressure loads, section modulus requirements, etc.)

Specific calculations are presented for a large, high speed monohull using the rules from The American Bureau of Shipping (ABS) and Det Norske Veritas (DNV) in order to provide a meaningful quantitative comparison. A similar comparison for catamaran hull forms would be useful but was not performed due to a lack of complete design information for a representative catamaran.

This study was limited to the calculation of the scantlings required by the rules; both societies' rules would require additional global and local finite element analyses to verify the adequacy of the design as well as fatigue studies of critical areas.

In summary, the structural design requirements for ABS and DNV are comparable for a high speed monohull in commercial cargo service. A patrol craft designed and built to DNV's HSLC Rules with the Patrol R0 service notation would be heavier than one designed and built to the ABS HSNC Guide's naval craft requirements.

Table of Contents

1. Introduction

The purpose of this study was to review and compare the application, requirements and methods for the structural design of high speed craft used by a variety of classification societies. The comparison included:

- Types of craft classed
- Service restrictions or categories
- Speed and size ranges covered by the codes/rules
- Performance based or prescriptive design standards
- Key parameters specified (hull pressure loads, section modulus requirements, etc.).

The study also included the calculation of the loads and required scantlings for a large, high speed catamaran using the rules from two major societies in order to provide a meaningful quantitative comparison.

This report provides a summary of the study's results to date. It is organized as follows:

1) Introduction

2) Comparison of the Class Society Rules
The application and overall requirements for High Speed Craft rules of the International Maritime Organization, American Bureau of Shipping, Bureau Veritas, Det Norske Veritas, Germanischer Lloyd, Lloyd's Register of Shipping, Nippon Kaiji Kyokai, and Register Italiano Navale are described and compared.

3) High Speed Monohull Design Calculations and Comparison
The design loads, hull girder strength, and scantlings are calculated and compared for a 61 m, 60 knot aluminum monohull in accordance with The American Bureau of Shipping's "Guide for Building and Classing High-Speed Craft", The American Bureau of Shipping's "Guide for Building and Classing High Speed Naval Craft", and Det Norske Veritas' "Rules for Classification of High Speed, Light Craft and Naval Surface Craft".

4) Conclusions

5) References

2. Comparison of Class Society Rules

2.1 International Maritime Organization (IMO)

The IMO developed the "International Code of Safety of High-Speed Craft" (HSC Code) in 1994 as follow-on to the earlier Code of Safety for Dynamically Supported Craft. It was prepared "in recognition of the of the growth, in size and types, of high speed craft, and (was) intended to facilitate the future research and development of fast sea transportation while maintaining a high degree of safety for passengers and crews." [1] The HSC Code was revised in 2000 but did not change the structural requirements.

The code applies to:

- High-speed craft which are engaged in international voyages; and
- Passenger craft which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden; and
- Cargo craft of 500 gross tonnage and upwards which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden.

The code specifically excludes, among others, craft of war and troopcraft, pleasure craft, and fishing craft.

For the purpose of the IMO HSC Code, a *high-speed craft* is a craft capable of:

$$V \geq 3.7\nabla^{0.1667}$$

where V is speed in meters per second and ∇ is the displacement in m^3 at the design waterline in saltwater. This is equivalent to the more commonly used:

$$V \geq 7.16\,\Delta^{0.1667}$$

where V is in knots and Δ is the displacement in saltwater in tonnes, see figure 2-1.

The structural requirements of the HSC Code are not specific and cannot be used for design or the comparison of Class Rules to the HSC Code for compliance. Extracted here, the HSC Code's structural requirements are:

> "Materials used for the hull and superstructure … should be adequate for the intended use of the craft.
>
> The structure should be capable of withstanding the static and dynamic loads which can act on the craft under all operating conditions in which a craft is permitted to operate, without such loading resulting in inadmissible deformation and loss of watertightness or interfering with the safe operation of the craft" [1, Chapter 3]

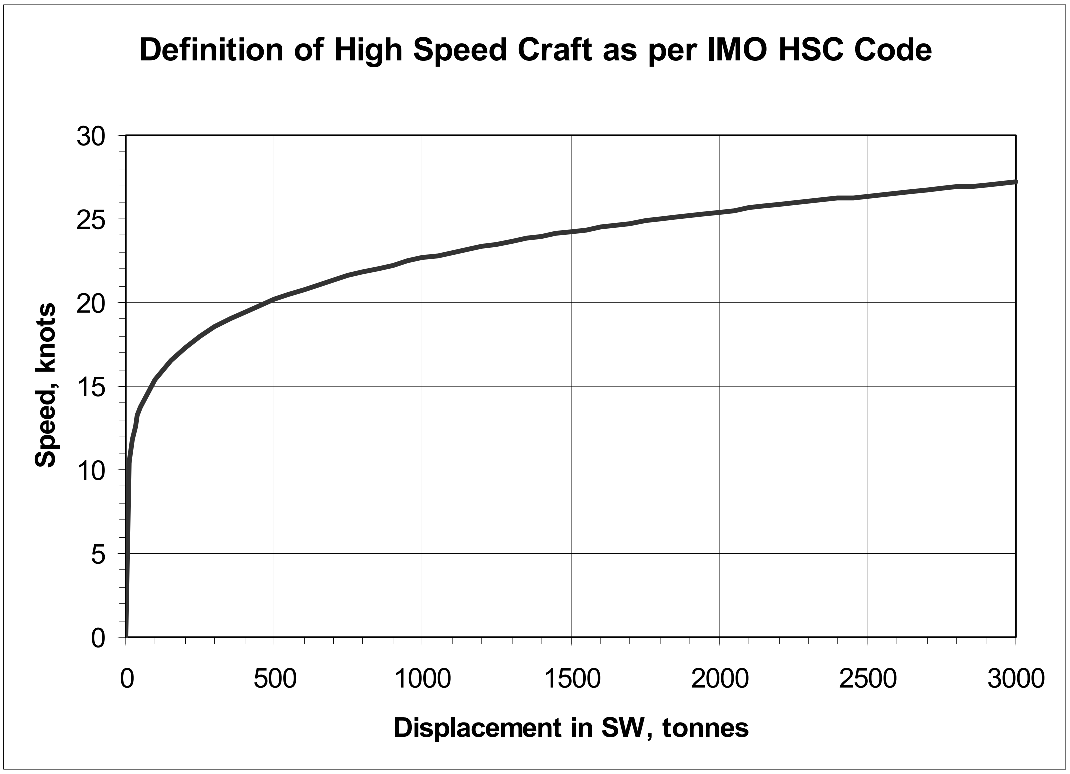


Figure 2-1. Definition of HSC as per IMO HSC Code

2.2 The American Bureau of Shipping (ABS)

ABS has two sets of rules for high speed craft, the "Guide for Building and Classing High-Speed Craft" (October 2001) [2] which was first issued in 1990, and the more recently issued "Guide for Building and Classing High Speed Naval Craft 2003" [3]. The latter is applicable to naval craft only. Each will be described here.

Guide for Building and Classing High-Speed Craft (HSC Guide) The ABS HSC Guide is applicable to high speed craft for commercial or governmental use constructed of steel, aluminum, or FRP and having $V/\sqrt{L}$ not less than 2.36 where L is the length (meters) on the design waterline in the displacement mode and V is the craft design speed in knots. The applicability is further defined for craft type and length:

Vessel Type	Applicable Length
Mono-hull	< 130 m
Multi-hull	< 100 m
Surface Effects Ship (SES)	< 90 m
Hydro Foil	< 60 m

Figure 2-2 shows the dividing line of the required speed for a vessel of a given length to be classified by ABS under the regular ship rules or as a high speed craft.

Unrestricted service is defined by ABS as operating in sea states with a significant wave height, $h_{1/3}$, greater than or equal to 4.0m. Vessels which are to be restricted in their operations as per the IMO HSC Code may be classed as “Passenger Craft” or “Cargo Craft”. In addition, a craft may be restricted to operations in a geographical area such as the Gulf of Mexico, Inter-Island Service, etc.

Direct analyses are required for steel or aluminum vessels when the length exceeds 61 m, for FRP vessels when the length exceeds 50 m, or for all vessels when the operating speed exceeds 50 knots.

If desired, a ‘Dynamic Load Approach’ (DLA) notation of the classification may be obtained. This requires additional finite element analyses to validate the design. This may require that the design be strengthened but it cannot reduce the scantlings below that required by the HSC Guide.

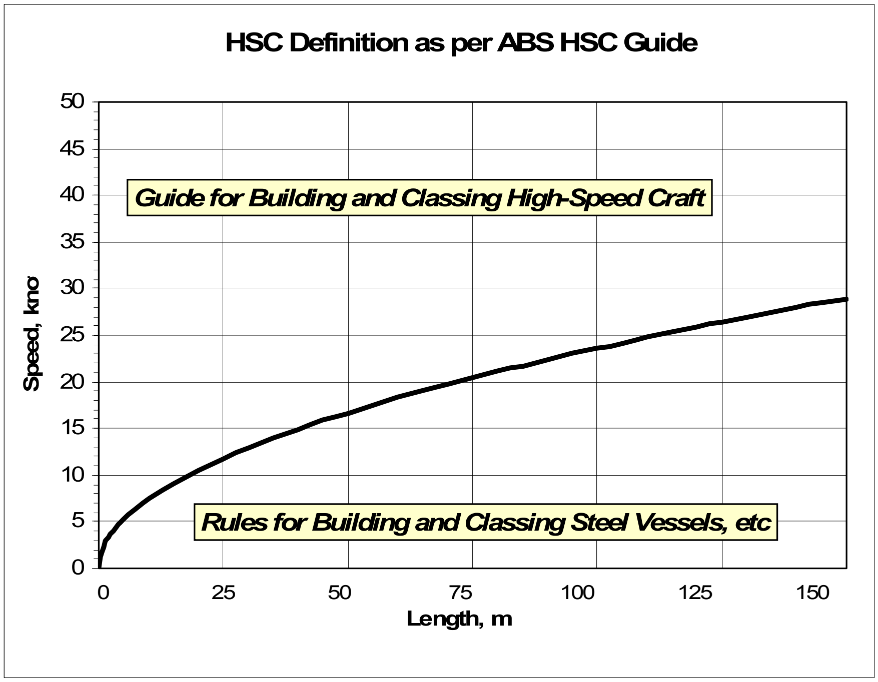


Figure 2-2. Definition of HSC as per ABS HSC Guide

<u>Guide for Building and Classing High Speed Naval Craft (HSNC Guide)</u> The ABS HSNC Guide is applicable to high speed naval craft constructed of steel, aluminum, or FRP and having $V/\sqrt{L}$ not less than 2.36 where L is the length (meters) on the design waterline in the displacement mode and V is the craft design speed in knots (and as further defined in the Guide). The applicability for the differing vessel types (mono-hulls, etc.) is the same as the ABS HSC Rules; however, the ABS HSNC Guide has four additional types of classification as shown in Table 2-1.

Further structural notations are optionally applicable: several notations for operations in ice, an "Operational Envelope" (OE) notation that provides an envelope of speeds and wave heights within which the vessel must operate, and "Dynamic Load Approach" (SH-DLA) wherein the vessel's structural behavior has been evaluated under dynamic loading conditions.

Direct analyses are required for all vessels with the Naval Craft notation, for Coastal Naval Craft when the length equals or exceeds 45 m and any operational speed, and for Coastal Naval Craft of any length when the operational speed is equal to or greater than 40 knots. Direct analyses are not required for Riverine Naval Craft.

The structural requirements of the ABS HSNC Rules differ from the HSC Rules in that the HSNC Rules require calculation of the vertical acceleration in both "design condition" and "survival condition". For example, the ABS HSC Rules require the calculation of the design acceleration with a wave height of L/12 meters (and not less than 4.0 meters) at the design speed. The HSNC Rules require the calculation of the design acceleration with a wave height of 4.0 meters at the design speed as well as at 6.0 meters wave height and 10 knots craft speed.

TYPE	***DESCRIPTION***
HSC	Unrestricted service
Naval Craft	Assigned to a naval vessel that is intended to operate in the littoral environment, but is capable of ocean voyages. Naval Craft are limited to a maximum voyage of 300 miles from safe harbor when operating in the Winter Seasonal Zones as indicated in Annex II of the International Conference on Load Lines, 1966 (see Appendix A to this report). When operating on an open ocean voyage, craft are to avoid tropical cyclones and other severe weather events.
Coastal Naval Craft	Assigned to a naval vessel that is intended to operate on a coastal voyage with a maximum distance from safe harbor of 300 miles and a maximum voyage of 150 miles from safe harbor when operating in the Winter Seasonal Zones as indicated in Annex II of the International Conference on Load Lines, 1966. Coastal Naval Craft are not permitted to perform transoceanic movements.
Riverine Naval Craft	Assigned to a naval vessel that is intended to operate in rivers, harbors, and coast lines with a maximum distance from safe harbor of 50 miles. Riverine Naval Craft are not permitted to perform transoceanic movements.

Table 2-1. ABS HSNC Classification Types

2.3 Det Norske Veritas (DNV)

The "Rules for Classification of High Speed, Light Craft, and Naval Surface Craft", July 2002 (DNV HSLC) defines the acceptance criteria for design, construction, survey and testing of high speed, light craft and naval surface craft constructed in steel, aluminum or fiber reinforced composites. The DNV HSLC Rules define a light craft as one with a full load displacement not greater than:

$$\Delta = (0.13\ L\ B)^{1.5}$$

where L and B are the craft length and breadth are in meters and Δ is the displacement in saltwater in tonnes.

A high speed craft is defined as a craft capable of a maximum speed in knots equal to or exceeding:

$$V \geq 7.16\ \Delta^{0.1667}$$

where V is in knots and Δ is the displacement in saltwater in tonnes.

A high speed and light craft, in addition to the above, has a maximum speed of not less than 25 knots.

Vessels will usually have a special service classification; Passenger, Car Ferry, Cargo, Crew, Yacht, Patrol, or Naval, depending upon the intended service. This distinction has a significant impact upon the structural design as will be shown later.

Vessels must have a service restriction notation as a part of their classification. The restrictions are defined as in table 2-2. Craft with a length greater than 50 meters must also have a global finite element analysis submitted.

Condition	*Notation*	*Sea state Beaufort*	*Hs (m)*	*Max. distance from shelter (nm)* (1)		
				Winter	*Summer*	*Tropical*
Ocean	None	-	-	(2)	(2)	(2)
Ocean	R0	> 6	> 6	300	(2)	(2)
Ocean	R1	> 6	> 6	100	300	300
Offshore	R2	6	< 6	50	100	250
Coastal	R3	5	< 4	20	50	100
Inshore	R4	4	< 2.5	5	10	20
Inshore	R5	3	< 1.25	1	2	5
Sheltered	R6	n/a	n/a	0.2	0.3	0.5

Note (1): Seasonal zones are as per Annex II of the International Conference on Load Lines, 1966 (Appendix A)
(2): Unrestricted service is not permitted for craft designated as Passenger, Car Ferry or Cargo

Table 2-2. DNV HSLC Rule Service Notation

2.4 Bureau Veritas, Germanischer Lloyd and Registro Italiano Navale (UNITAS)

Bureau Veritas, Germanischer Lloyd, and Registro Italiano Navale have jointly established “Rules for the Classification of High Speed Craft” [5] as the members of the co-operative classification society group called European Economic Interest Grouping (EEIG) UNITAS. The rules are closely modeled on the IMO HSC Code in that the entire HSC Code is embodied within the UNITAS HSC Rules with exceptions and/or modifications to the IMO HSC Code specifically called out.

The UNITAS HSC Rules apply to:

- High-speed craft which are engaged in international voyages; and
- Passenger craft which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden and
- Cargo craft of 500 gross tonnage and upwards which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden.

As described before, the IMO HSC specifically excludes, among others, craft of war and troopcraft, pleasure craft, and fishing craft; however, the UNTIAS Rules state that they may be considered. In addition, the UNITAS Rules may apply to craft on national voyages as opposed to the IMO code which applies only to those on international voyages.

As per the IMO HSC Code, the UNITAS HSC Rules are applicable to a craft capable of a maximum speed, in meters per second (m/s), equal to or exceeding $3.7\nabla^{0.1667}$ where ∇ is the displacement in m^3 in saltwater corresponding to the design waterline. The UNITAS HSC Rules state, however, that craft with a speed to length ratio ($V/\sqrt{L}$) greater than 10 must be individually considered.

Similar to the DNV HSLC Rules, the UNITAS HSC Rules’ calculation of the design vertical acceleration is dependent upon the type of craft and the operational area restrictions:

$$a_{cg} = f_{oc}\, S_{oc}\, V/\sqrt{L}$$

where f_{oc} varies from 0.666 for passenger, ferry and cargo vessels, 1.333 for patrol vessels, and to 1.666 for rescue vessels. Similarly, S_{oc} ranges from 0.14 for “Smooth sea” areas to 0.30 for “Restricted open sea” operations. For “Open sea” operations $S_{oc} = 0.2 + 0.6/(V/\sqrt{L})$ but not less than 0.32. Thus for our example 61 m, 50 knot corvette ($V/\sqrt{L} = 6.4$) cited earlier, the design acceleration for unrestricted operations would be:

$$\begin{aligned} a_{cg} &= f_{oc}\, S_{oc}\, V/\sqrt{L} \\ &= 1.333 \cdot 0.32 \cdot 6.4 \\ &= 2.73 \text{ g's} \end{aligned}$$

As will be shown later, this is similar to the DNV requirements for unrestricted patrol vessel.

2.5 Lloyd's Register of Shipping (LR)

The Lloyd's Register "Rules and Regulations for the Classification of Special Service Craft" [6] (SSC) applies to the following constructed of steel, aluminum, composites materials or combinations of these materials:

- High speed craft
- Light displacement craft
- Multi-hull craft
- Yachts of overall length 24m or greater
- Craft with draft to depth ratios less than or equal to 0.55.

A high speed craft is defined as having a speed greater than or equal to:

$$V = 7.19\ \nabla^{0.1667}\ (V \text{ in knots, } \nabla \text{ in m}^3)$$

This is equal to the more commonly used $V \geq 7.16\ \Delta^{0.1667}$ (V in knots, Δ in saltwater in tonnes). A light displacement craft is defined as a craft with a displacement in saltwater not exceeding:

$$\Delta = 0.04(LB)^{1.5} \text{ tonnes}$$

All craft classed under the LR SSC Rules are assigned a service area restriction and a service type notation as follows:

- **G1**: Craft intended for service in sheltered waters adjacent to sandbanks, estuaries, etc. and in reasonable weather where the range to refuge is, in general, 5 nm or less
- **G2**: Craft intended for service in reasonable weather, in waters where the range to refuge is 20 nm or less, e.g. craft operating in defined coastal waters
- **G3**: Craft intended for service where the range to refuge is 150 nm or less
- **G4**: Craft intended for service where the range to refuge is 250 nm or less
- **G5**: Craft intended for service where the range to refuge is over 250 nm
- **G6**: Yachts having unrestricted service.

The service type notations are:

- Passenger: passenger craft which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden

- Cargo: craft of 500 gross tonnage and upwards which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden

- Patrol, Pilot, and Workboat: Craft complying with the relevant requirements of the Rules

- Yacht.

2.6 Nippon Kaiji Kyokai (NK)

The Nippon Kaiji Kyokai "Rules for High Speed Craft" [7] apply to the following constructed of steel, aluminum, or composites materials:

- Passenger craft which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge, and
- Cargo craft which do not proceed in the course of their voyage more than 8 hours at operational speed from a place of refuge when fully laden.

The NK HSC Rule definition of a high-speed craft is the same as the IMO HSC criteria, i.e.:

$$V \geq 7.19\ \nabla^{0.1667}$$

The NK Rules appear to be more restrictive than others in that they specify that "the craft will not operate in a rough sea condition" and that "the craft will at all times be in reasonable proximity to a place of refuge". The latter restriction is noteworthy in that the NK definitions of passenger and cargo craft are in accordance with the IMO HSC Code. In addition, the design loads are for monohull craft with a length less than or equal to 50 m; the design loads for all other craft are considered on a case basis. Craft may have two area restrictions as a part of classification: "Coasting Service" and "Smooth Water Service".

2.7 Summary of Classification Society HSC Definition and Operating Restrictions

Table 2-3 summarizes the definition of a "high speed craft" and "light craft" as well as the major operating restrictions for IMO and the classification societies examined (ABS, DNV, BV/GL/RINA (UNITAS), LR and NK.

Society	High speed definition (kts)	Light craft definition (tonnes)	Operating Restrictions
IMO	$7.16\Delta^{0.1667}$	None	4 hrs from refuge for passenger craft, 8 hours for cargo
ABS HSC	$2.36\sqrt{L}$	None	Case basis
ABS Naval HSC	$2.36\sqrt{L}$	None	Seasonal zone limits
DNV	$7.16\Delta^{0.1667}$	$(0.13\ LB)^{1.5}$	Seasonal zone limits
LR	$7.16\Delta^{0.1667}$	$(0.04\ LB)^{1.5}$	Sheltered only to >250 nm from shelter
BV/GL/RINA (UNITAS)	$7.16\Delta^{0.1667}$	None	4 hrs from refuge for passenger craft, 8 hours for cargo
NK	$7.16\Delta^{0.1667}$	None	4 hrs from refuge for passenger craft, 8 hours for cargo

Table 2-3. Classification Society Comparison

<u>Definition of a High-Speed Craft</u>. The classification societies considered in this study have two different definitions of a high speed craft, the one used by ABS and the other as defined by IMO and the other class societies. Figure 2-3 compares the two versions. As can be seen, while it is not possible to directly compare the definitions as the IMO criteria is displacement vs. speed and the ABS criteria is length vs. speed it is nonetheless useful to show the two criteria together and to compare a specific vessel. Consider a corvette sized vessel that is classed as a HSC under the DNV Rules. It is 61 m long with a full load displacement of 950 tonnes. Under the IMO criteria a 950 tonnes vessel must have a design speed of at least 22.5 knots to be considered a high speed vessel. The same vessel, 61 m long, can have a design speed of only 18.4 knots under the ABS Rules and still be considered a high speed craft.

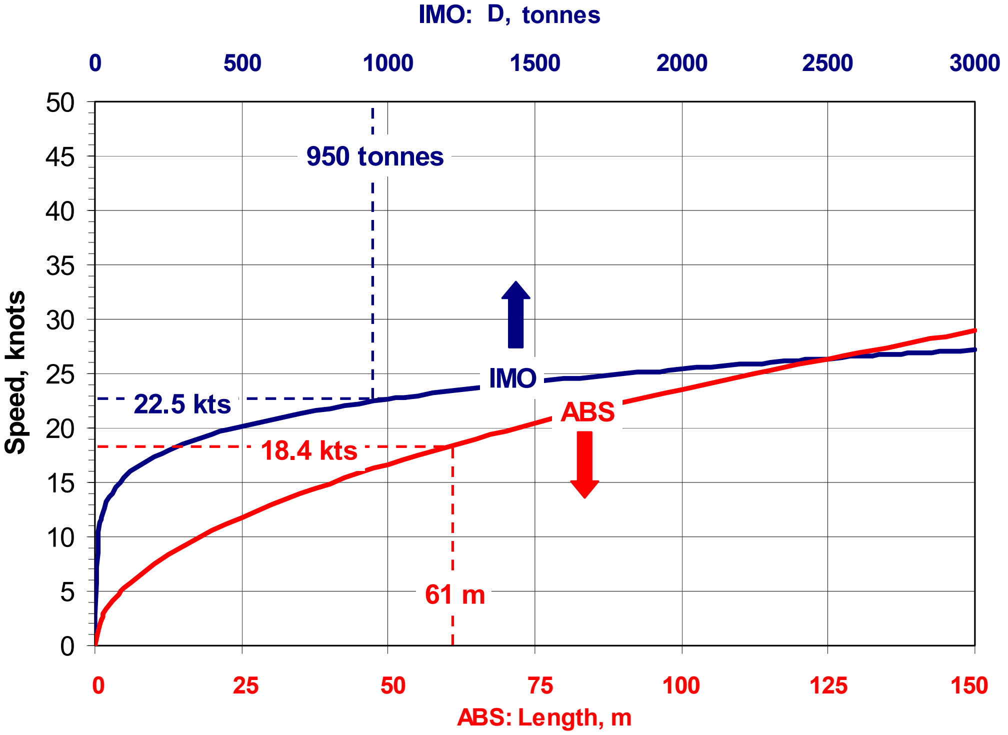


Figure 2-3. IMO and ABS Definitions of High Speed Craft

<u>Operating Restrictions</u>. The classification societies and IMO have two types of operating limits: time and distance. IMO, BV/GL/RINA and NK each restrict the craft to be no more than a certain allowable time, dependent upon vessel type, from safe refuge at operational speed when fully laden. For passenger craft this is four hours, e.g. for a 30 knot passenger ferry a distance of 120 nm. The ABS HSC Rules allow for unrestricted operations, limits as per the IMO HSC Code, or specific geographical limits. The ABS

HSNC Guide, the DNV HSLC Rules and the LR SSC Rules all require a distance limit from safe refuge. The ABS HSNC and DNV HSLC limits are based upon the seasonal zones established by the International Conference on Load Lines, 1966. Appendix A to this report shows these zones. Some of the areas of winter seasonal zones are effective only at certain times of the year; they are summer zones during the other times. The assignment of a service notation can have profound effects upon the operation of a HSC. For instance, a high speed passenger ferry classed in accordance with the DNV HSLC Rules to the R1 service notation (the least restrictive possible for a passenger ferry) is limited to operations, with passengers, of only 100 nm from safe harbor in winter zones and 300 nm in summer/tropical zones. These restrictions are reflected in the calculation of the design loads and thus the structural integrity of the craft is tied to these service notations.

3. Calculation of Design Loads and Required Scantlings

A comparison of the structural requirements for high speed craft by the different classification society rules and codes is not useful or instructive unless the rules are applied to a sample high speed craft. This report will compare the structural requirements of the ABS HSC Guide, the ABS HSNC Guide and the DNV HSLC Rules for a nominal 61 m long, 35-50 knot large high speed aluminum monohull suitable for use as a yacht, passenger ferry, cargo vessel, or patrol craft. The vessel's full load displacement is 950 tonnes. The bottom dead rise angle varies from 17 degrees at the longitudinal center of gravity (LCG) to 48 degrees at 0.875L forward of the after perpendicular (AP). The design/hull form characteristics are taken from an actual vessel but slightly modified to preserve anonymity.

The hull girder's strength requirements, design pressures for the bottom and side at the LCG and two locations forward, and the resulting local scantlings for the plating, stiffeners and transverse frames were calculated for each set of rules. These locations were chosen in order to determine the difference between the Rules for the vessel overall as well as how the LCG requirements were distributed longitudinally and at the fore end.

The ABS HSC Guide was used to calculate the hull girder strength, design pressures and scantlings required for a vessel in unrestricted service. The ABS HSNC Guide was used to calculate these same requirements for the vessel classed as a "naval craft". In the case of the DNV HSLC Rules, these requirements were calculated for four different types of vessels and/or service notations; patrol R0 and R1, cargo R0, and ferry R1. Four different design speeds were used in the ABS calculations; 35, 40, 45 and 50 knots. In the case of the DNV calculations, the rules do not require the use of a value of $V/\sqrt{L}$ greater than 3, which in this example is equates to speed of 23.4 knots. Thus the same design is required by the DNV HSLC Rules for all design speeds greater than 23.4 knots.

The following sections provide the requirements for design acceleration, hull girder strength, design pressures, and required scantlings. The complete calculations of the ABS HSC requirements are contained in Appendix B, the ABS HSNC requirements are in Appendix C, and the DNV calculations are in Appendix D. Table 3-1 summarizes the results of the calculations of the required hull girder bending moments and section modulus at amidships; and the required bottom and side design pressures and scantlings for the plating, stiffeners and transverse frames at the LCG, 0.75L forward of the AP and 0.875L forward of the AP. These same results are shown graphically throughout this section with a brief explanation of the rule requirements.

While reviewing the requirements it should be noted that the following pairs of ABS and DNV service restrictions are reasonable for direct comparison to each other:

- DNV Patrol R0 to ABS HSNC with "Naval Craft" notation
- DNV Cargo R0 to ABS HSC, unrestricted service

		ABS								DNV			
service		**HSC unrestricted**				**HSNC Naval Craft**				**patrol R0**	**patrol R1**	**cargo R0**	**ferry R1**
speed (kts)		**35**	**40**	**45**	**50**	**35**	**40**	**45**	**50**	**50**	**50**	**50**	**50**
V/?L		**4.5**	**5.1**	**5.8**	**6.4**	**4.5**	**5.1**	**5.8**	**6.4**	**? 3.0**	**? 3.0**	**? 3.0**	**? 3.0**
design accleration @ LCG, g's		0.59	0.77	0.98	1.21	0.49	0.64	0.80	0.99	2.95	2.11	1.69	1.00
Hull girder bending moments, kNm:													
Slamming wave sagging		calculation not required				70,695	77,781	85,812	94,788	35,509	41,147	41,276	37,637
Slamming wave hogging										191,354	165,267	149,219	114,088
Sagging Wave + Stillwater		50,923				51,157				52,288			
Hogging Wave + Stillwater		28,028				61,555				27,065			
Section Modulus (cm^{2}m)		6,718	7,022	7,325	7,629	7,340	7,516	7,516	7,800	12,286	10,611	9,581	7,325
Design pressure, bottom plating (kN/m^2)	LCG	212.0	236.2	263.6	294.2	197.9	217.8	240.2	265.4	603.9	431.4	345.1	204.4
	0.75L	194.5	222.6	254.3	289.9	178.2	201.2	227.3	256.4	417.7	298.4	238.7	141.4
	0.875L	112.6	130.1	150.0	172.2	186.1	212.3	241.9	275.1	397.8	284.2	227.3	134.6
Design pressure, side plating (kN/m^2)	LCG	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	26.0	26.0	26.0	26.0
	0.75L	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	40.1	40.1	40.1	40.1
	0.875L	61.0	70.5	81.3	93.4	142.3	160.6	180.0	200.5	101.9	101.9	101.9	101.9
Design pressure, bottom stiffeners (kN/m^2)	LCG	212.0	236.2	263.6	294.2	197.9	217.8	240.2	265.4	603.9	431.4	345.1	204.4
	0.75L	194.5	222.6	254.3	289.9	178.2	201.2	227.3	256.4	417.7	298.4	238.7	141.4
	0.875L	112.6	130.1	150.0	172.2	186.1	212.3	241.9	275.1	397.8	284.2	227.3	134.6
Design pressure, side stiffeners (kN/m^2)	LCG	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	25.0	25.0	25.0	25.0
	0.75L	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	39.1	39.1	39.1	39.1
	0.875L	61.0	70.5	81.3	93.4	43.8	49.4	55.4	61.7	99.3	99.3	99.3	99.3
Design pressure, bottom frames (kN/m^2)	LCG	201.4	224.4	250.4	279.5	166.2	182.9	201.8	222.9	485.6	346.8	277.5	164.3
	0.75L	184.8	211.4	241.6	275.4	149.7	169.0	190.9	215.4	335.9	239.9	191.9	113.7
	0.875L	107.0	123.6	142.5	163.6	156.3	178.3	203.2	231.1	319.9	228.5	182.8	108.3
Design pressure, side frames (kN/m^2)	LCG	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	21.0	21.0	21.0	21.0
	0.75L	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	26.0	26.0	26.0	26.0
	0.875L	53.7	62.1	71.6	82.2	43.8	49.4	55.4	61.7	47.4	47.4	47.4	47.4
Thickness, bottom plating (mm)	LCG	6.95	7.33	7.75	8.18	6.71	7.04	7.39	7.77	10.73	9.07	8.11	6.24
	0.75L	6.65	7.12	7.61	8.12	6.37	6.77	7.19	7.64	8.92	7.54	6.74	5.19
	0.875L	6.47	6.47	6.47	6.47	6.17	6.59	7.04	7.51	8.71	7.36	6.58	5.07
Thickness, side plating (mm)	LCG	6.47	6.47	6.47	6.47	4.80	4.80	4.80	4.80	5.02	5.02	5.02	5.02
	0.75L	6.47	6.47	6.47	6.47	4.80	4.80	4.80	4.80	5.02	5.02	5.02	5.02
	0.875L	6.47	6.47	6.62	7.09	8.76	9.30	9.85	10.39	7.15	7.15	7.15	7.15
SM, bottom stiffeners (cm^3)	LCG	38.7	43.1	48.1	53.7	30.6	33.6	37.1	41.0	62.44	44.60	35.68	21.13
	0.75L	35.5	40.6	46.4	52.9	27.5	31.1	35.1	39.6	43.19	30.85	24.68	14.62
	0.875L	20.6	23.8	27.4	31.5	28.8	32.8	37.4	42.5	41.13	29.38	23.50	13.92
SM, side stiffeners (cm^3)	LCG	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	4.5	4.5	4.5	4.5
	0.75L	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	7.0	7.0	7.0	7.0
	0.875L	15.7	18.2	20.9	24.0	11.3	12.7	14.3	15.9	17.8	17.8	17.8	17.8
SM, bottom frames (cm^3)	LCG	336.8	375.2	418.7	467.3	278.0	305.9	337.5	372.8	903.58	645.41	516.33	305.81
	0.75L	309.1	353.6	404.1	460.5	250.3	282.6	319.3	360.2	625.00	446.43	357.14	211.53
	0.875L	178.8	206.7	238.3	273.6	261.3	298.2	339.9	386.5	595.24	425.17	340.14	201.45
SM, side frames (cm^3)	LCG	93.6	93.6	93.6	93.6	78.0	78.0	78.0	78.0	69.37	69.37	69.37	69.37
	0.75L	100.4	100.4	100.4	100.4	83.6	83.6	83.6	83.6	92.17	92.17	92.17	92.17
	0.875L	219.7	254.0	292.8	336.2	179.2	202.2	226.6	252.4	215.66	215.66	215.66	215.66

Table 3-1. Summary of Structural Design Requirements as per ABS HSC Guide, ABS HSNC Guide, and DNV HSLC Rules

3.1 Vertical acceleration

ABS HSC Guide. The design vertical acceleration is given by:

$$n_{cg} = N_2\left[\frac{12h_{1/3}}{B_w}+1.0\right]\tau\left[50-\beta_{cg}\right]\frac{V^2(B_w)^2}{\Delta}\ \text{g's}$$

As detailed in Appendix B the acceleration is dependent upon the hull form (L, L_b, dead rise angle β_{cg}), displacement, running trim angle (τ), wave height ($h_{1/3}$) and speed. The wave height for unrestricted service is 4.0m but not less than L/12, i.e. 5.08m. It should be noted that the ABS HSC Guide specifies a minimum trim angle of 3 degrees but will give special consideration to model test data. Our example uses a trim angle of only 2.1 degrees which was obtained from full scale tests. Using the lower value results in design accelerations from 0.59 g's to 1.21 g's for speeds from 35 to 50 knots whereas using the 3 degree trim angle would result in design accelerations of 0.85 to 1.73 g's. We will use the lower value as it is based on actual experience.

ABS HSNC Guide. The design vertical acceleration is given by the same formula as for HSC:

$$n_{cg} = N_2\left[\frac{12h_{1/3}}{B_w}+1.0\right]\tau\left[50-\beta_{cg}\right]\frac{V^2(B_w)^2}{\Delta}\ \text{g's}$$

However the wave height, $h_{1/3}$, is limited to 4.0m for naval craft; this results in design accelerations as per the ABS HSC Guide are from 0.99 g's to 0.99 g's for speeds from 35 to 50 knots. The trim angle used is the same as for the HSC calculations, 2.1 degrees. The HSNC rules also require calculation of the accelerations in a survival sea state of 6.0m at a speed of 10 knots. This results in an acceleration of only 0.06g's.

DNV HSLC Rules. The design vertical acceleration is given by:

$$a_{cg} = \frac{V}{\sqrt{L}}\frac{3.2}{L^{0.76}}f_g\ \text{g's}$$

where $V/\sqrt{L}$ need not be considered greater than 3.0. As explained previously, this means that for our example 61 m long vessel, the same value of $V/\sqrt{L}$ is used for all speeds greater than 23.4 knots. Thus, for a given hull form and design speed/length ratio greater than 3, the acceleration becomes a function of the acceleration factor, f_g. For example, a Ferry R1 notation has an f_g value of 1, whereas for a Cargo R0 the value is 4 and for a Patrol R0 notation the value is 7.

The minimum value allowable of a_{cg} is 1.0 g's for service restrictions R0-R4, and 0.5 g's for R5. The calculated values range from the required minimum of 1.0 for a Ferry R1 notation to 2.95 for a Patrol R0 notation.

Comparison of ABS and DNV requirements. Figure 3-1 compares the ABS and DNV design accelerations. As can be seen, with a single exception, the ABS requirements are lower than the DNV value for all speeds and service restrictions however, as will be seen later, this difference in design accelerations does not translate into much heavier scantlings.

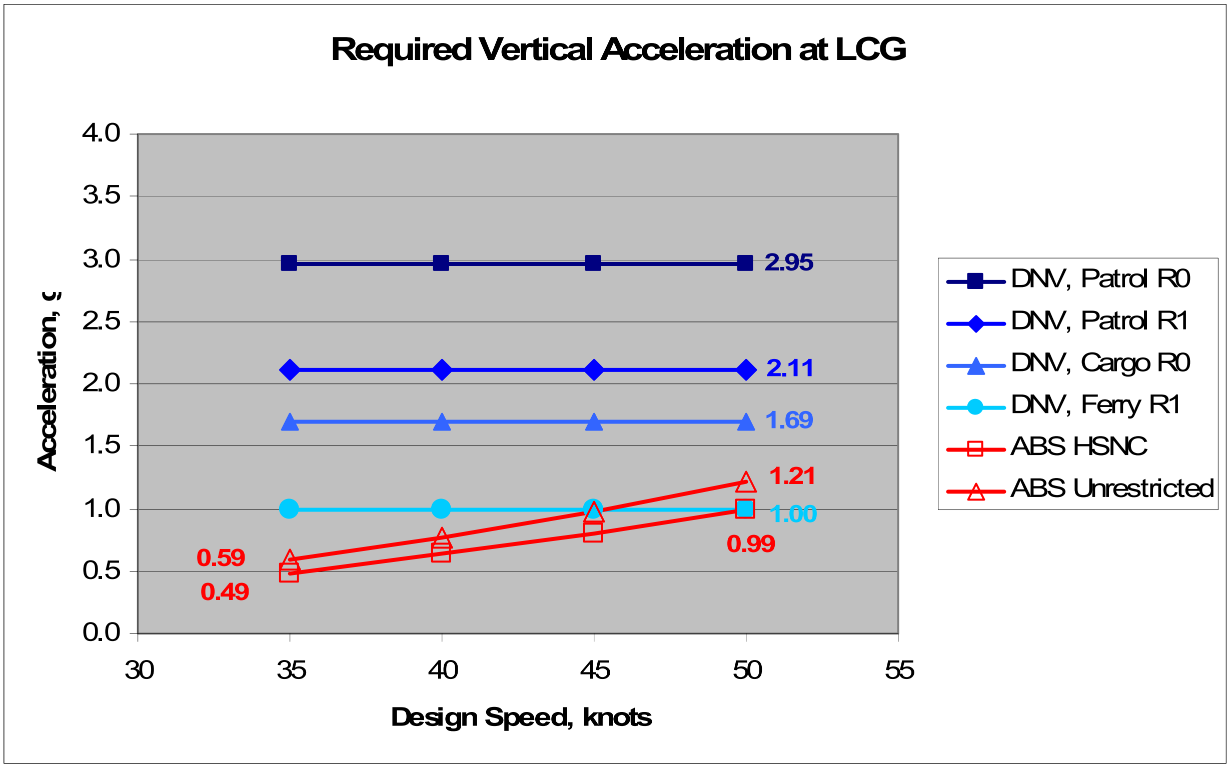


Figure 3-1. Design Accelerations

3.2 Hull girder strength

ABS HSC Guide. The required hull girder section modulus is the greater of a general requirement for all craft, the wave bending moment requirement for vessels > 61 m in length, and a third requirement for planning/semi-planing craft (if applicable). In this vessel's case the general requirement dominates for all speeds. It is given by:

$$SM = C_1 \, C_2 \, L^2 \, B \, (C_b + 0.7) \, K_3 \, K_4 \, CQ$$

As detailed in Appendix B the section modulus is dependent upon the hull form (C_2, L, B, C_b), the speed to length ratio (K_3), the intended service (K_4, restricted, unrestricted) and the hull material (Q).

ABS HSNC Guide. The required hull girder section modulus is the greater of a general requirement for all craft, the wave bending moment requirement for vessels > 24 m, and a slamming induced bending moment.. In this vessel's case the slamming requirement dominates for all speeds. It is given by:

$$M_{sl} = C_3 \Delta (1 + n_{cg})(L - l_s)$$

The required section modulus is given by:

$$SM = M_t CQ / f_p$$

As detailed in Appendix C the slamming moment is dependent upon the hull form (Δ, L, B, draft), the design acceleration (and hence speed) and the hull material (Q).

DNV HSLC Rules. The required hull girder section modulus is given by:

$$Z = \frac{10 \times M}{175 f_1} (\mathrm{cm}^2\mathrm{m})$$

where M is the maximum design bending moment and f_1 is a material factor, in this case 0.89 for 5083-H116 plate. The design bending moment is the greater of a slamming moment or seaway bending moment. The DNV wave slamming moment calculation, as shown in Appendix D, assumes that the craft is landing on either a wave crest or in a wave hollow. As with the ABS HSNC Guide, the DNV hull girder strength is driven by the wave slamming moment.

Comparison of ABS and DNV requirements. Figure 3-2 compares the ABS and DNV required hull girder strength. As can be seen, with a single exception, the ABS HSC requirement is lower than the DNV values for all speeds and service restrictions and the ABS HSNC requirement is comparable to the DNV Ferry R1 requirement.

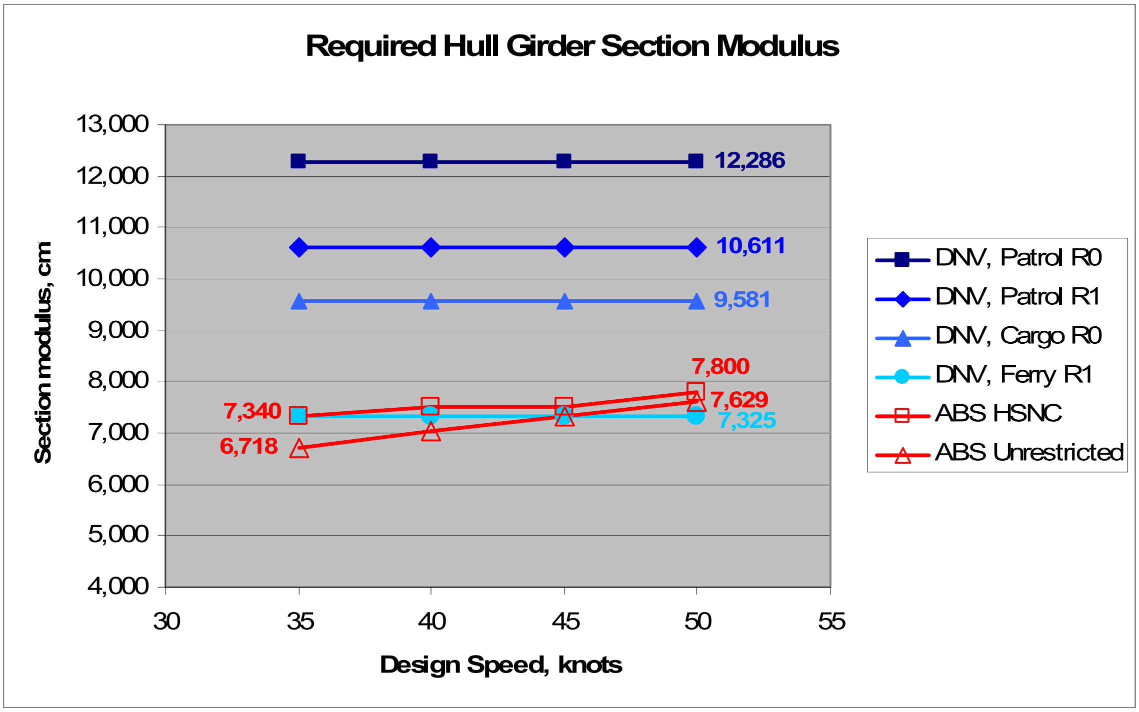


Figure 3-2. Hull Girder Section Modulus

3.3 Design pressures

The design pressures were calculated for bottom and side plating, stiffeners and transverse frames at three longitudinal locations: at the LCG, 0.75L forward of the AP, and at 0.875L forward of the AP. The calculations for all of these pressures as per the ABS HSC Guide, the ABS HSNC Guide and the DNV HSLC Rules are contained in Appendices B, C, and D, respectively.

ABS HSC Guide. The design pressure for the bottom and side is the greater of the hydrostatic pressure, slamming pressure, or the fore end slamming pressure. The slamming pressure is given by:

$$p_{bxx} = \frac{N_1 \Delta}{L_w B_w}[1 + n_{xx}]\left[\frac{70 - \beta_{xx}}{70 - \beta_{cg}}\right] F_D \ \text{kN/m}^2$$

As detailed in Appendix B the pressure is a function the hull form (Δ, L, B, dead rise angle of the bottom or side β), the vertical acceleration at the design speed, and the size of the area under pressure (F_D).

The slamming pressure is larger for the bottom throughout but the side slamming pressure is zero as the dead rise angle of the side is greater than 70 degrees. The slamming pressure for the fore end sides (stem to 0.125L aft of the stem) is given by:

$$p_{sf} = 0.28 F_s C_F N_3 (0.22 + 0.15 \tan a)(0.4 V \sin b + 0.6\sqrt{L})^2$$

where the angles β and α are the entry angle of the side shell at the waterline and the flare (dead rise) angle of the side shell, respectively.

ABS HSNC Guide. The formulae for the bottom and side design pressures as per the HSNC Guide are nearly identical to that of the HSC Guide. The HSNC limits the side's deadrise angle to no more than 30 degrees whereas the HSC Guide allows up to 50 degrees. In addition, the design area factor, F_D, is different for the two rules. The dominat difference between the HSNC and HSC requirement s is driven by the differing requirements for the design acceleration. The complete requirements as per the HSNC Guide are given in Appendix C

DNV HSLC Rules. The design pressure for the bottom is the greater of the hydrostatic pressure, slamming pressure, or fore end slamming pressure. The slamming pressure is given by:

$$p_{sl} = 1.3 k_l \left(\frac{\Delta}{nA}\right)^{0.3} T_O^{0.7} \frac{50 - \beta_x}{50 - \beta_{cg}} a_{cg} \ (\text{kN/m}^2)$$

As detailed in Appendix D the slamming pressure is a function of the displacement Δ, draft T_O, dead rise angle β at the LCG and location of interest (k_l), the vertical acceleration and the area of the element loaded.

The fore end (0.4L) slamming pressure on the bottom and side is given by:

$$p_{sl} = \frac{0.7L \times C_L \times C_H}{A^{0.3}} \Bigg[0.6 + 0.4 \frac{V}{\sqrt{L}} \sin\gamma \cos(90° - \alpha)$$
$$+ \frac{2.1 a_0}{C_B} \sqrt{0.4 \frac{V}{\sqrt{L}} + 0.6} \sin(90° - \alpha) \left(\frac{x}{L} - 0.4 \right) \Bigg]^2$$

where the angles γ and α are the entry angle of the side shell and the flare (dead rise) angle of the side shell, respectively.

The side structure must be designed for the greater of the hydrostatic pressure or, in the case of the fore end, the fore end slamming pressure (above).

Comparison of ABS and DNV requirements. The design pressures calculated for the bottom and side plating, stiffeners, and framing at the LCG, 0.75L forward of the AP and 0.875L forward of the AP are given in Table 3-1 and are shown graphically in figures 3-3 through 3-17. It is important to note that the design pressures are not, in and of themselves, a valid basis for comparison; it is the resulting scantlings that can be fairly compared.

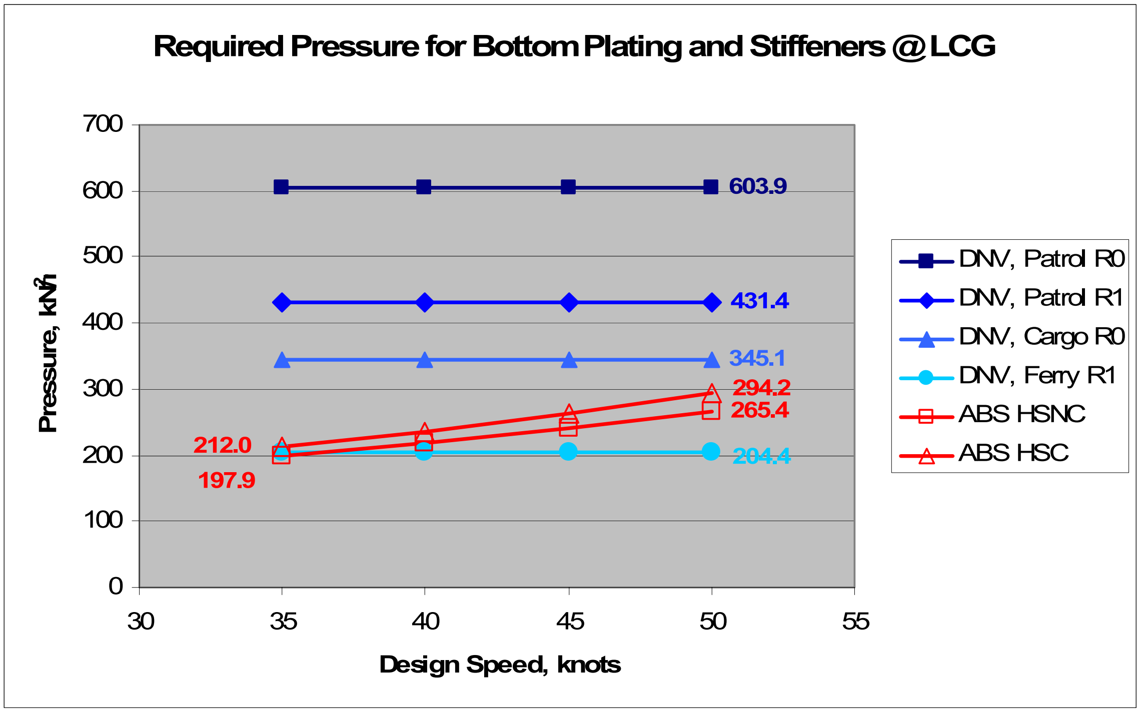


Figure 3-3. Bottom plating and stiffener design pressures @ LCG

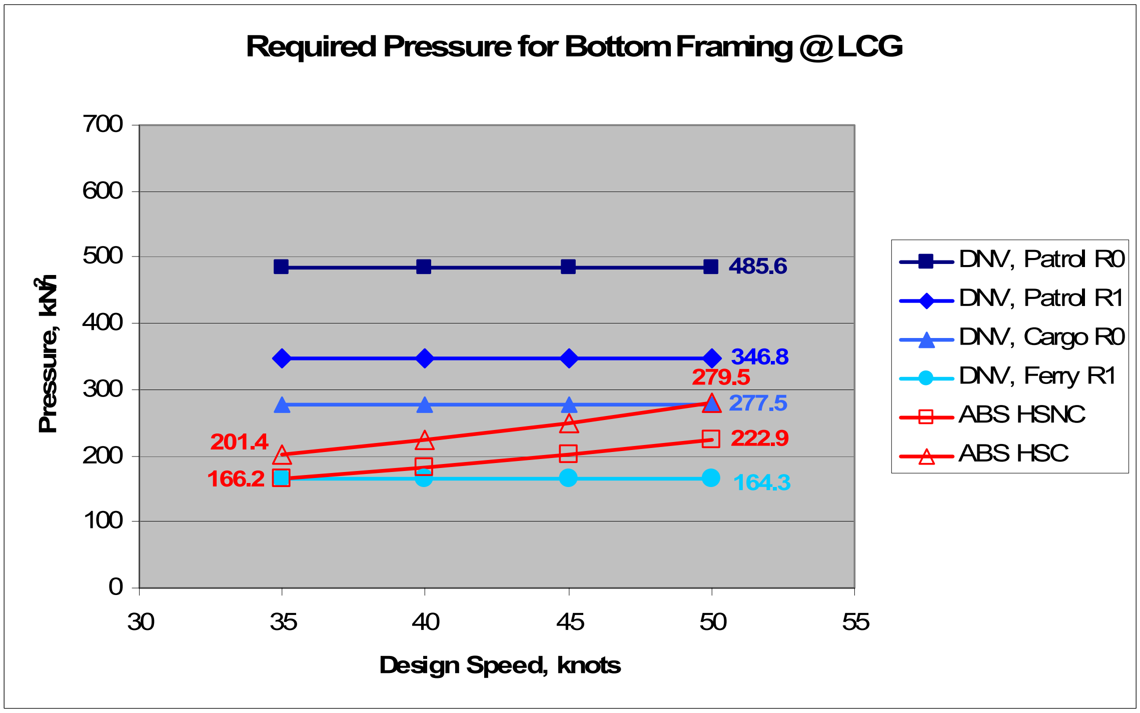


Figure 3-4. Bottom framing design pressures @ LCG

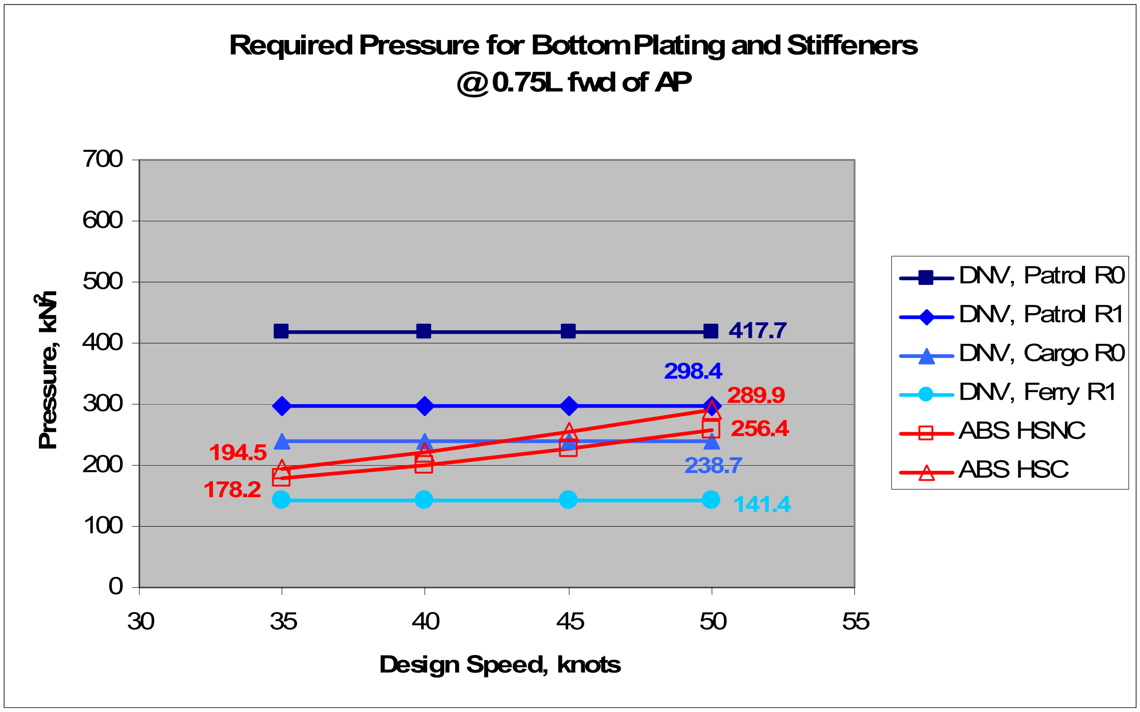


Figure 3-5. Bottom plating and stiffener design pressures @ 0.75L fwd of AP

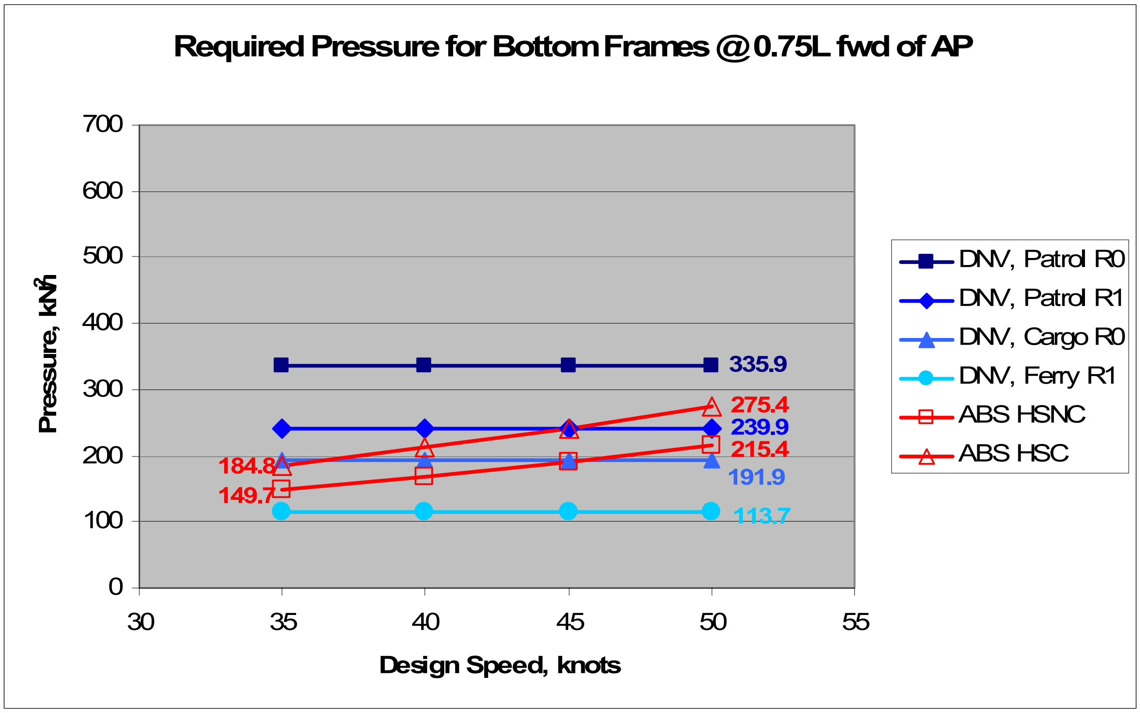


Figure 3-6. Bottom framing design pressures @ 0.75L fwd of AP

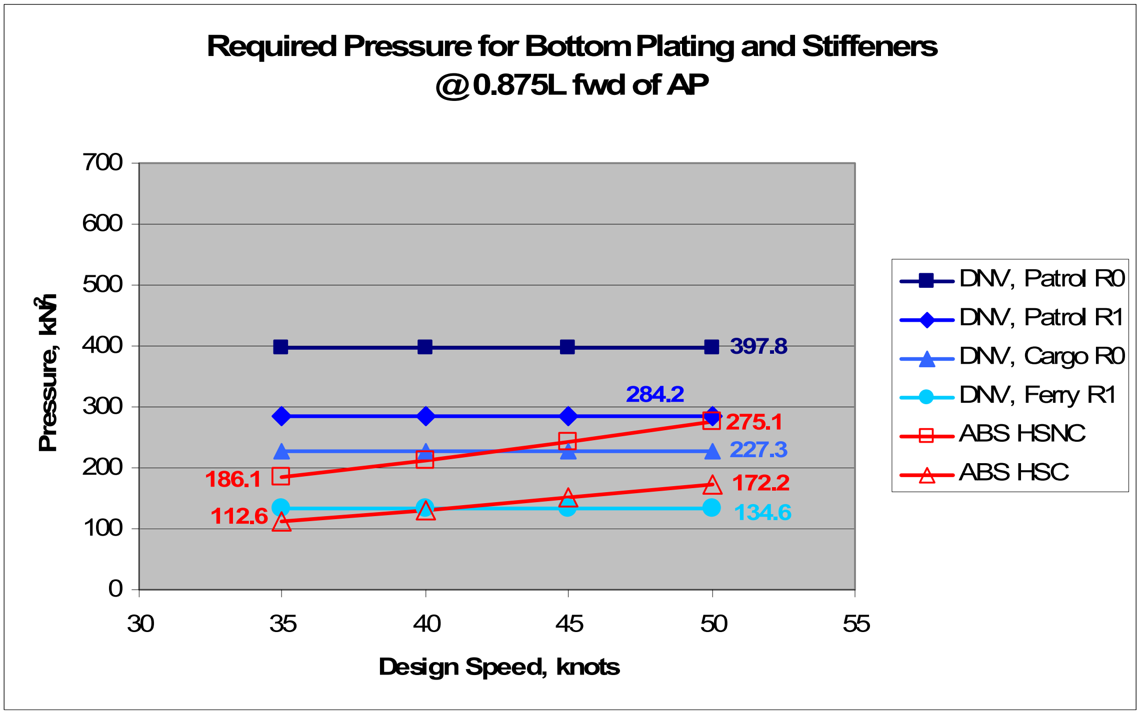


Figure 3-7. Bottom plating and stiffener design pressures @ 0.875L fwd of AP

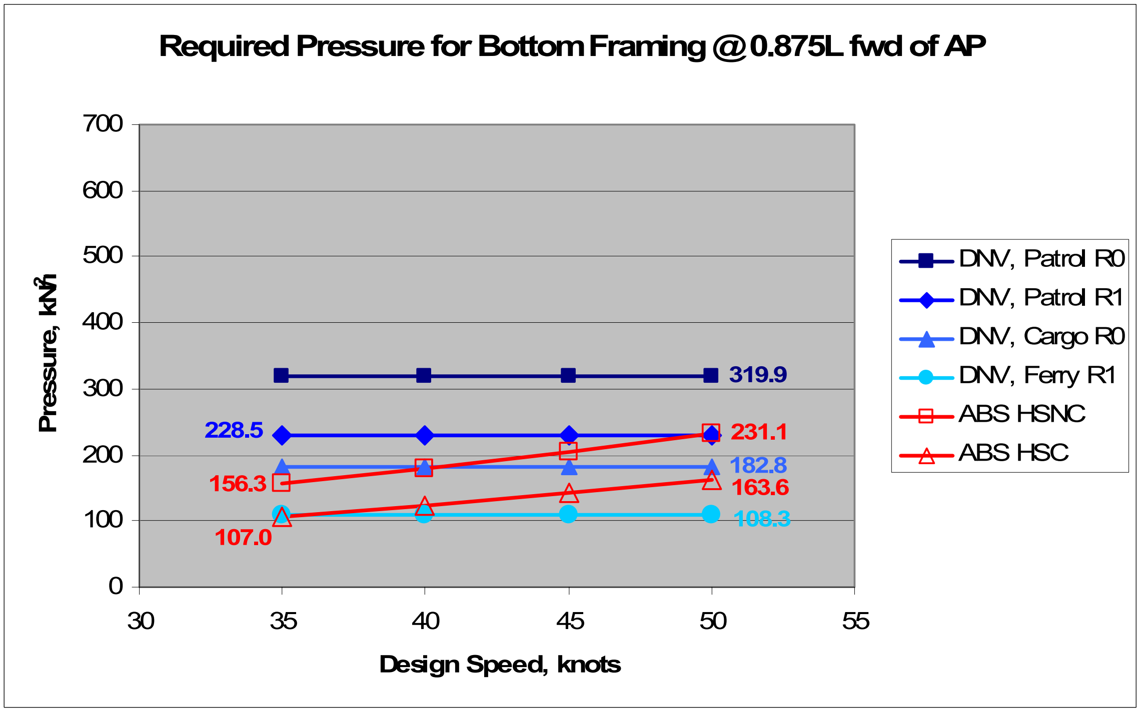


Figure 3-8. Bottom framing design pressures @ 0.875L fwd of AP

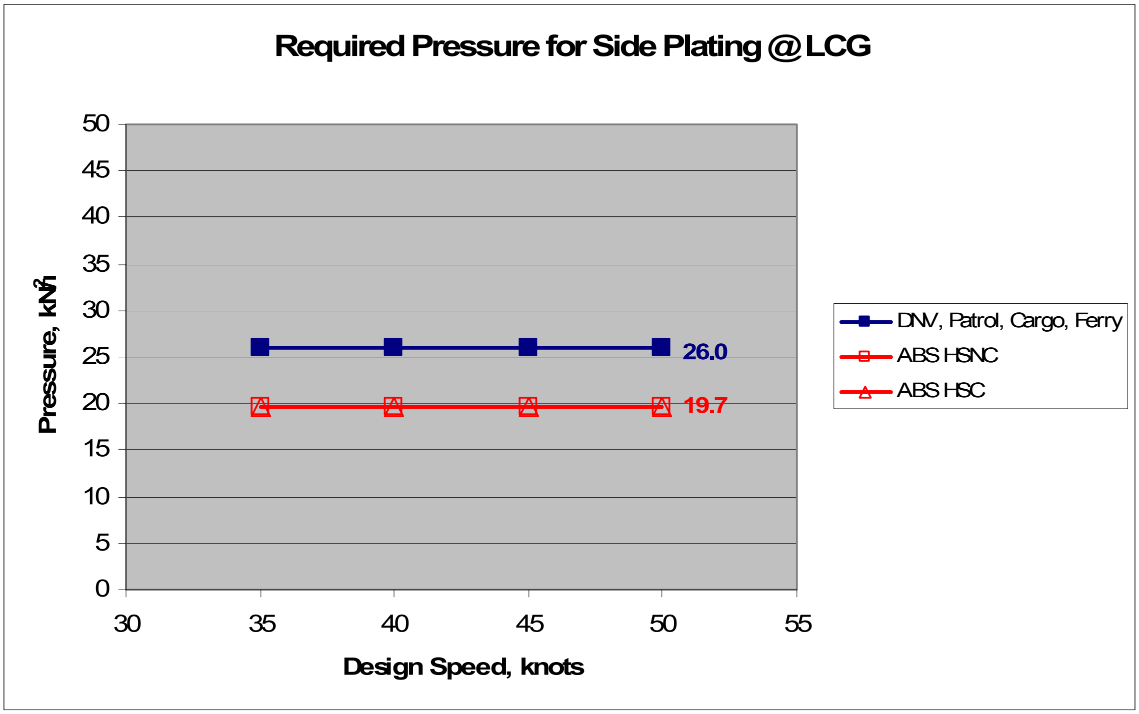


Figure 3-9. Side plating design pressures @ LCG

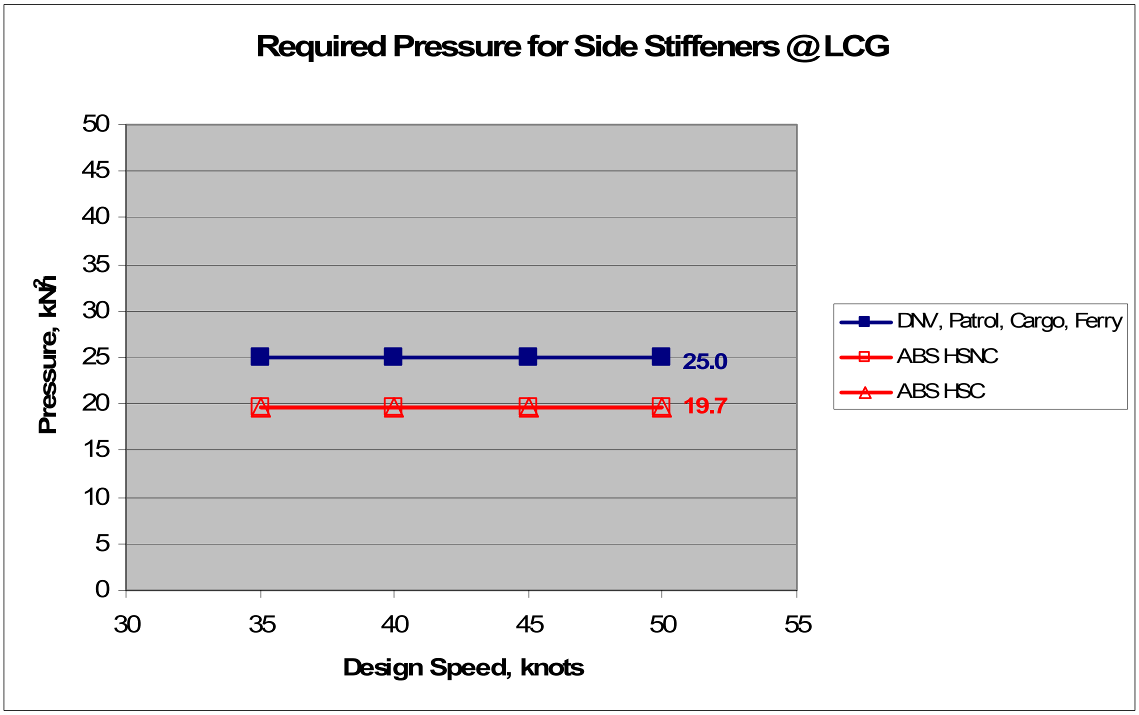


Figure 3-10. Side stiffener design pressures @ LCG

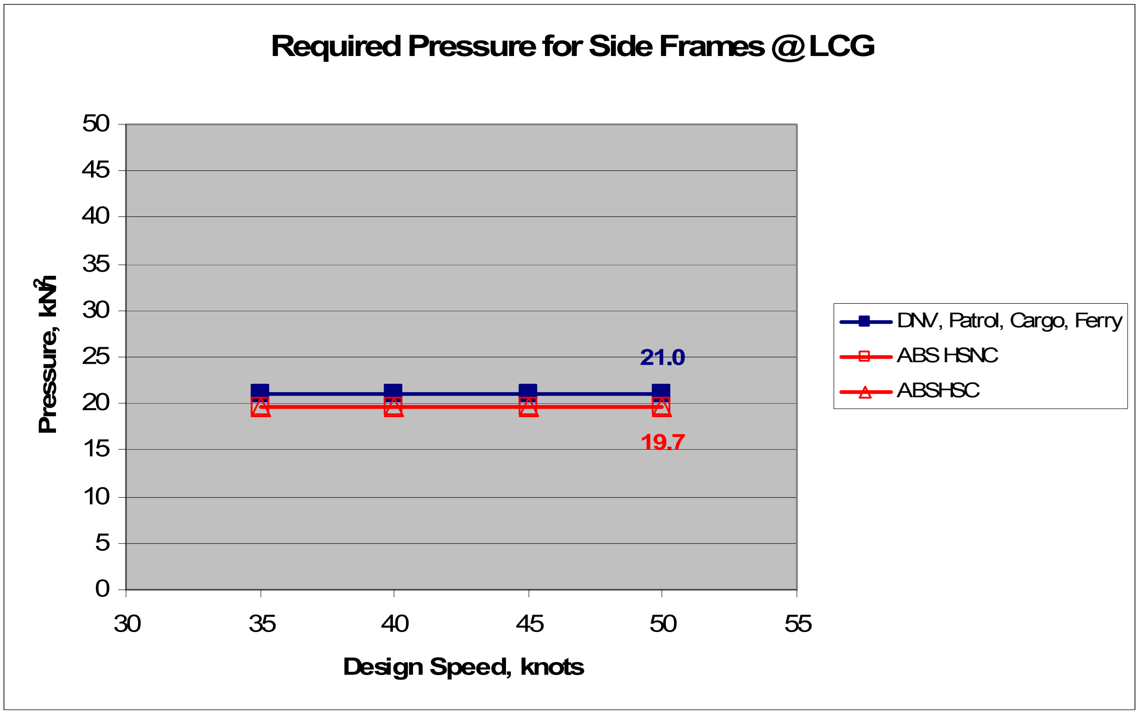


Figure 3-11. Side framing design pressures @ LCG

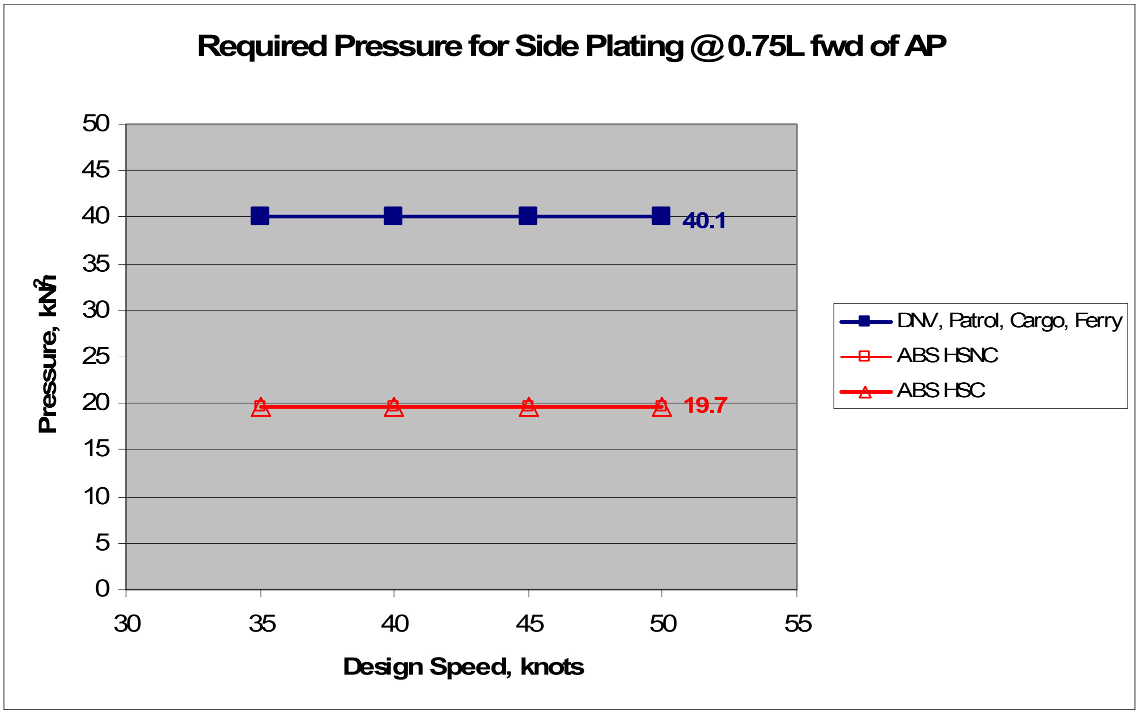


Figure 3-12. Side plating design pressures @ 0.75L fwd of AP

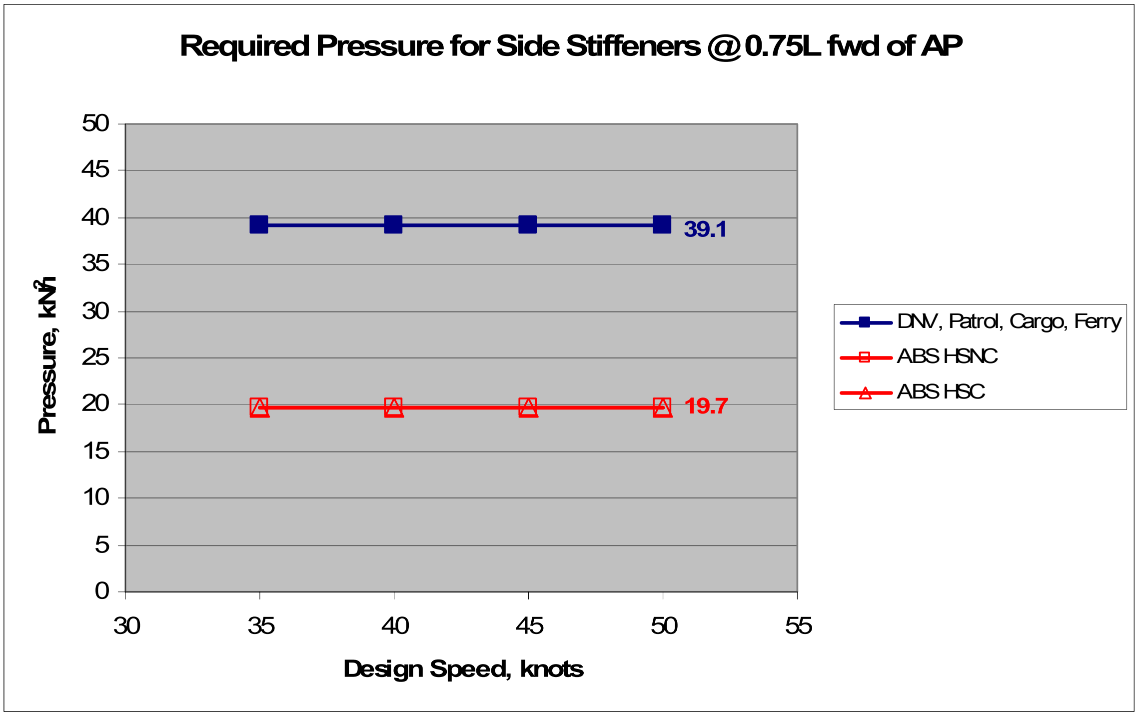


Figure 3-13. Side stiffener design pressures @ 0.75L fwd of AP

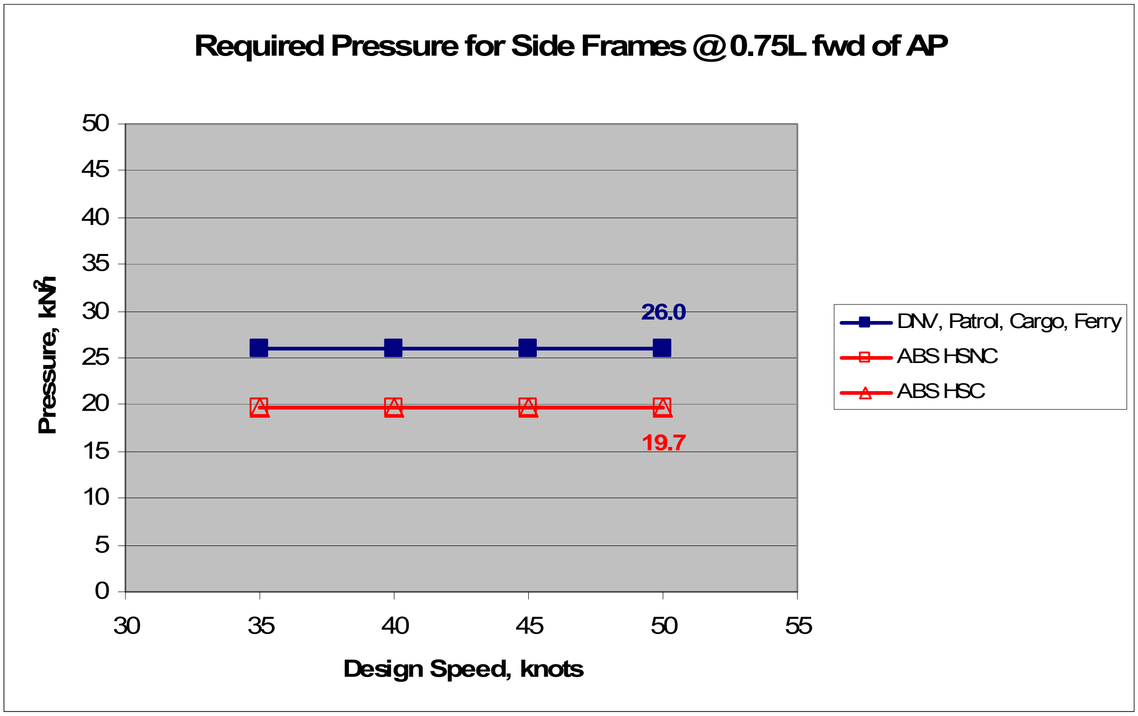


Figure 3-14. Side framing design pressures @ 0.75L fwd of AP

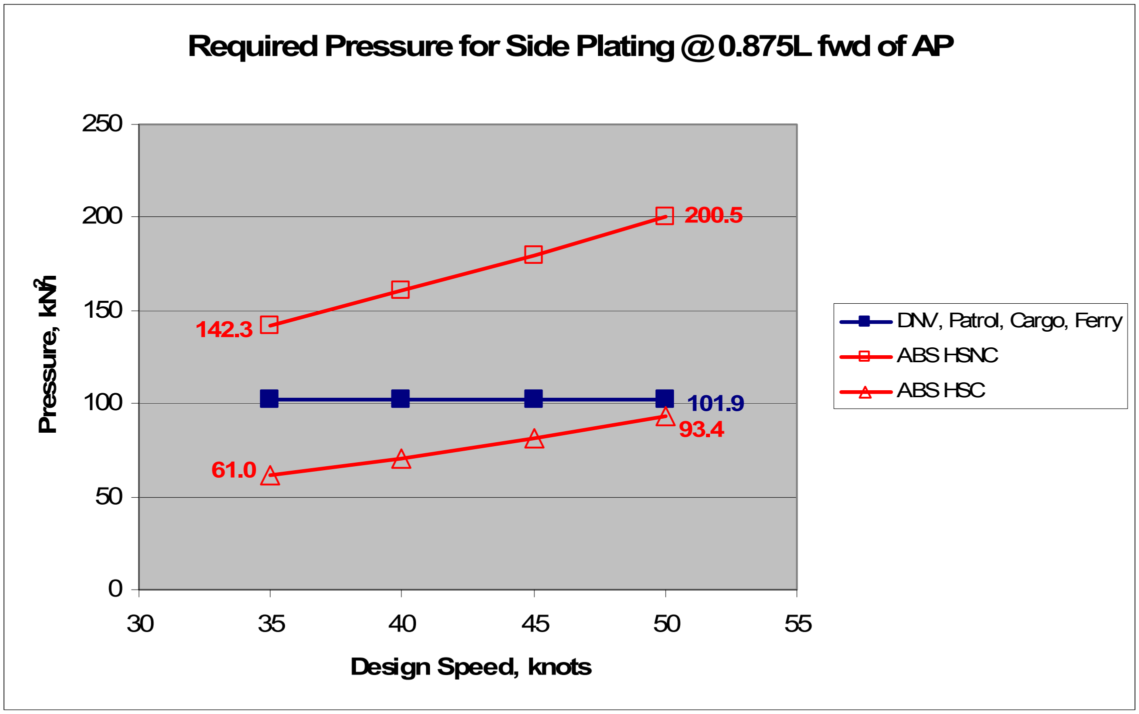


Figure 3-15. Side plating design pressures @ 0.875L fwd of AP

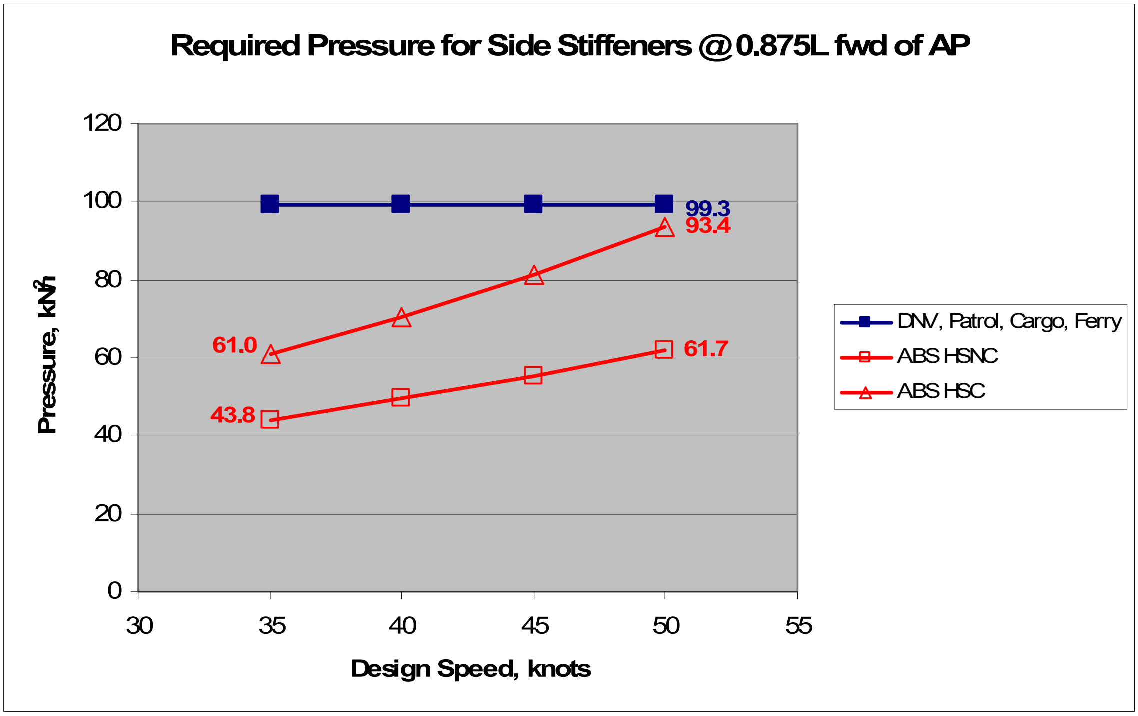


Figure 3-16. Side stiffener design pressures @ 0.875L fwd of AP

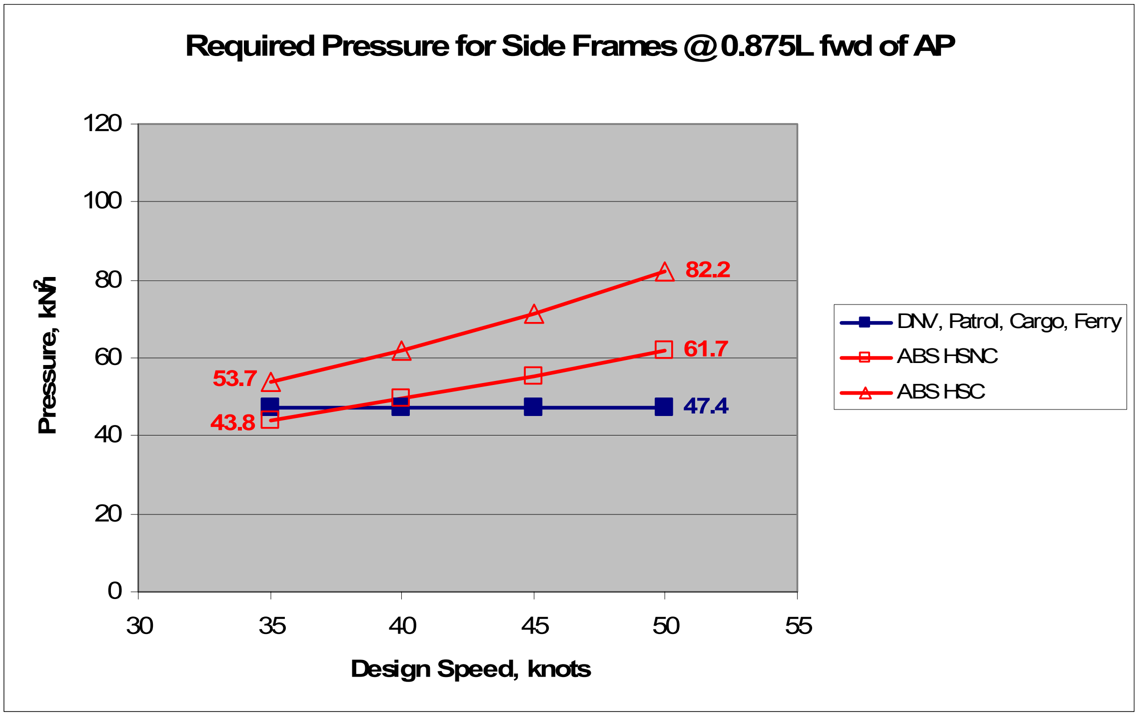


Figure 3-17. Side framing design pressures @ 0.875L fwd of AP

3.4 Required plating thickness

ABS HSC Guide. The required thickness for plating subjected to lateral pressure is given by:

$$t = s\sqrt{\frac{pk}{1000\sigma_a}}$$

where s is the stiffener spacing in mm, k is dependent upon the panel aspect ratio, p is the design pressure in kN/mm^2, and σ_a is the allowable stress and is dependent upon the location and nature of the design pressure. There is a minimum thickness requirement given by:

$$t = 0.70\sqrt{L} + 1.0 \text{ mm for bottom shell and}$$
$$t = 0.62\sqrt{L} + 1.0 \text{ mm for side shell}$$

For the example vessel this is 6.5 mm for the bottom shell and 5.8 mm for the side shell.

ABS HSNC Guide. As with the HSC Guide the HSNC required thickness for plating subjected to lateral pressure is given by:

$$t = s\sqrt{\frac{pk}{1000\sigma_a}}$$

where s and k are the same as per the HSC Guide. The magnitude of the design pressures, as seen earlier, are different. The allowable stress, σ_a, dependent upon the panel location and the nature of the design pressure, is also different in some cases from the HSC requirements:

Location, design pressure	HSC Guide	HSNC Guide
Bottom, slamming	$0.90\sigma_y$	$0.90\sigma_y$
Bottom, slamming, outside of 0.4L	not specified	σ_y
Bottom, hydrostatic pressure	$0.40\sigma_y$	$0.55\sigma_y$
Side, slamming	$0.90\sigma_y$	$0.90\sigma_y$
Side, hydrostatic pressure	$0.50\sigma_y$	$0.55\sigma_y$

The minimum thickness requirement is given by:

$$t = 0.70\surd(Lq_a) + 1.0 \text{ mm for bottom shell and}$$
$$t = 0.62\surd(Lq_a) + 1.0 \text{ mm for side shell}$$

where q_a is 115/ σ_{ya} (σ_{ya} is the unwelded yield strength). This results in minimums of 5.0 mm for the bottom shell and 4.55 mm for the side shell.

DNV HSLC Rules. The required thickness for plating subjected to lateral pressure is given by:

$$t = \frac{s\sqrt{Cp}}{\sqrt{\sigma}}$$

where s is the stiffener spacing in m, C is dependent upon the panel aspect ratio, p is the design pressure in kN/mm^2 and σ is the nominal allowable bending stress. The minimum required thickness is given by:

$$t = \frac{t_0 + kL}{\sqrt{f}} \frac{s}{S_R} \text{ (mm)}$$

For the example vessel this is 5 mm for the bottom and side.

Comparison of ABS and DNV requirements. The plating thicknesses calculated for the bottom and side plating at the LCG, 0.75L forward of the AP and 0.875L forward of the AP are given in Table 3-1 and are shown graphically in figures 3-18 through 3-23. As can be seen the bottom shell plating required by the ABS HSC and HSNC Guides at are between those required by the DNV HSLC Rules for Ferry R1 and Cargo R0 service at the LCG, and the Cargo R0 and Patrol R1 service at 0.75L and 0.875L positions. The ABS HSNC and DNV HSLC requirements for the side shell are similar and less than those required by the HSC Guide at the LCG and 0.75L positions. Forward, at the 0.875L position, the ABS HSNC side shell requirements are substantially higher than the ABS HSC or any of the DNV requirements.

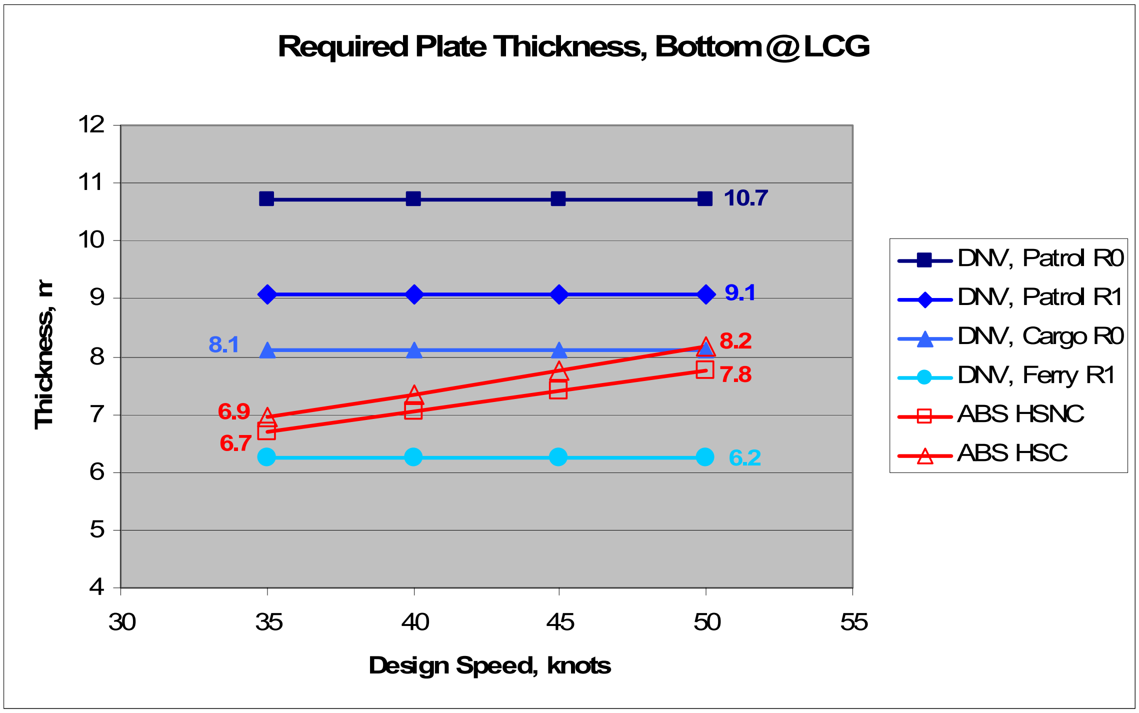


Figure 3-18. Required bottom plating @ LCG

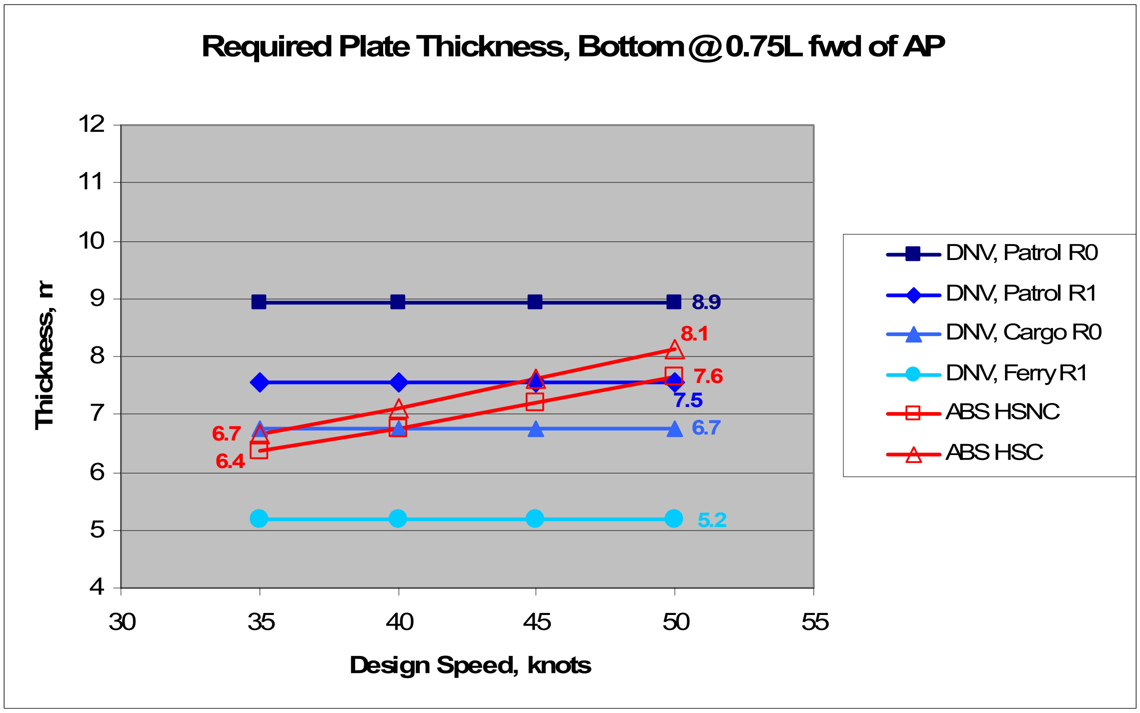


Figure 3-19. Required bottom plating @ 0.75L

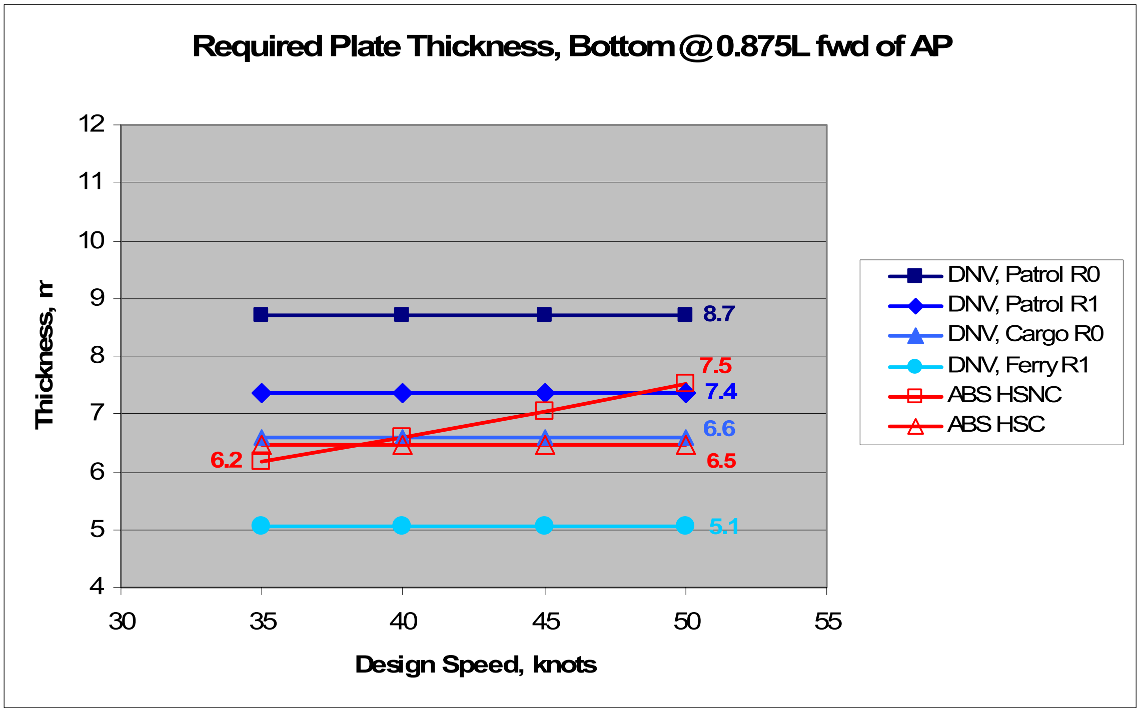


Figure 3-20. Required bottom plating @ 0.875L

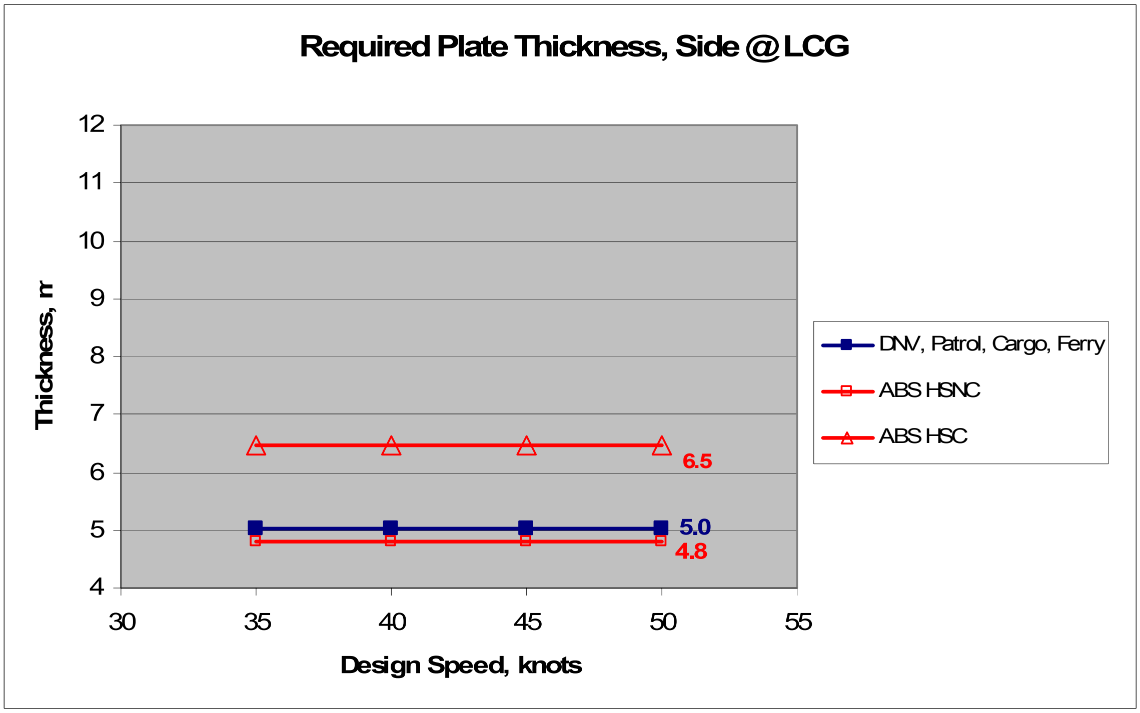


Figure 3-21. Required side plating @ LCG

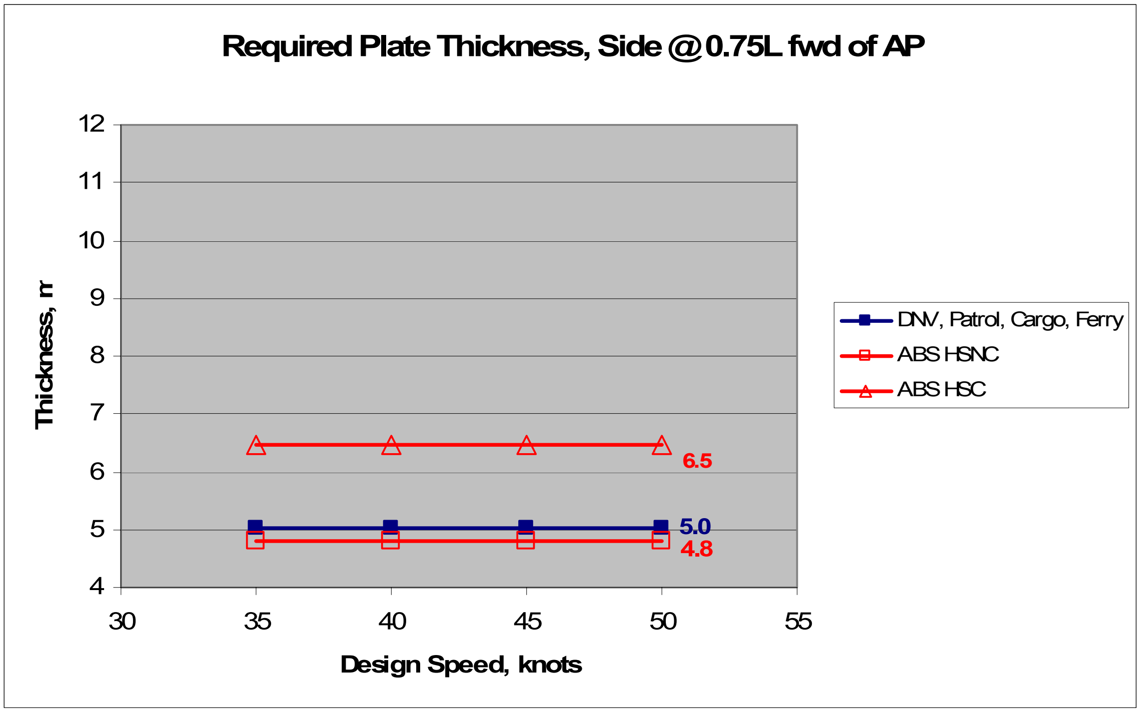


Figure 3-22. Required side plating @ 0.75L

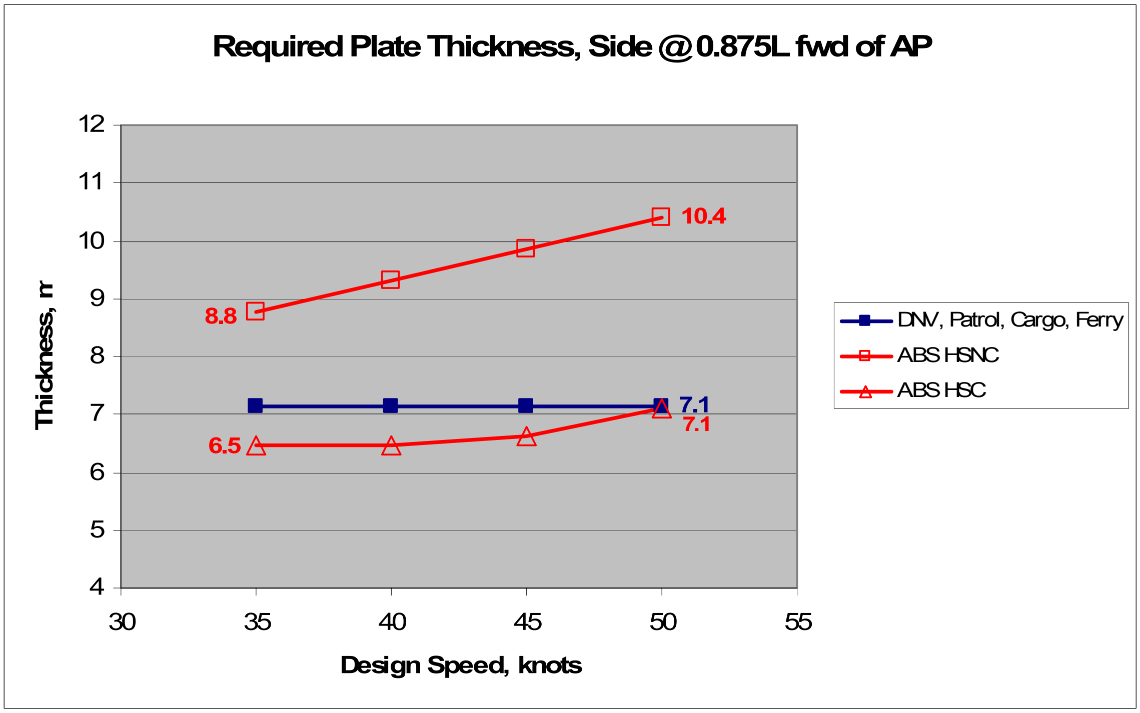


Figure 3-23. Required side plating @ 0.875L

3.5 Required internals (stiffeners, frames)

ABS HSC and HSNC Guides. The section modulus of longitudinals and transverse framing, for both the HSC and HSNC Guides, is given by:

$$\mathrm{SM} = \frac{83.3 \times \mathrm{psl}^2}{\sigma_a}\ \mathrm{cm}^3$$

where p is the design pressure and the allowable stress, σ_a, is as follows:

Location, design pressure	HSC Guide	HSNC Guide
Bottom longitudinals, slamming	$0.55\sigma_y$[1]	$0.65\sigma_y$
Bottom longitudinals, sea pressure	$0.30\sigma_y$	$0.50\sigma_y$
Side longitudinals, slamming	$0.60\sigma_y$	$0.60\sigma_y$
Side longitudinals, sea pressure	$0.50\sigma_y$	$0.50\sigma_y$
Bottom transverses, slamming	$0.80\sigma_y$	$0.80\sigma_y$
Bottom transverses, sea pressure	$0.50\sigma_y$	$0.60\sigma_y$
Side transverses, slamming	$0.80\sigma_y$	$0.80\sigma_y$
Side transverses, sea pressure	$0.50\sigma_y$	$0.60\sigma_y$

Note 1: σ_y is the welded yield stress

As can be seen, the HSC allowable stresses are more conservative for the bottom longitudinals for all pressures and for the bottom and side transverse for sea pressures.

DNV HSLC Rules. The section modulus of continuous longitudinals and transverse framing is given by:

$$Z = \frac{85\, psl^2}{\sigma}\ \mathrm{cm}^3$$

where *p* is the design stress, and *s* and *l* are the stiffener spacing and length, respectively. The allowable stress, *σ*, is 136.8 N/mm^2 for bottom longitudinals and 121.6 N/mm^2 for side longitudinals.

The section modulus of transverse framing is given by:

$$Z = \frac{100\, pbS^2}{\sigma}\ \mathrm{cm}^3$$

where *p* is the design stress, and *b* and *S* are the frame spacing and length, respectively. The allowable stress, *σ*, is 160.2 N/mm^2 for slamming loads and 142.4 N/mm^2 for hydrostatic loads.

Comparison of ABS and DNV requirements. The required section modulus calculated for the bottom and side shell stiffeners, and framing at the LCG, 0.75L forward of the AP and 0.875L forward of the AP are given in Table 3-1 and are shown graphically in figures 3-24 through 3-35.

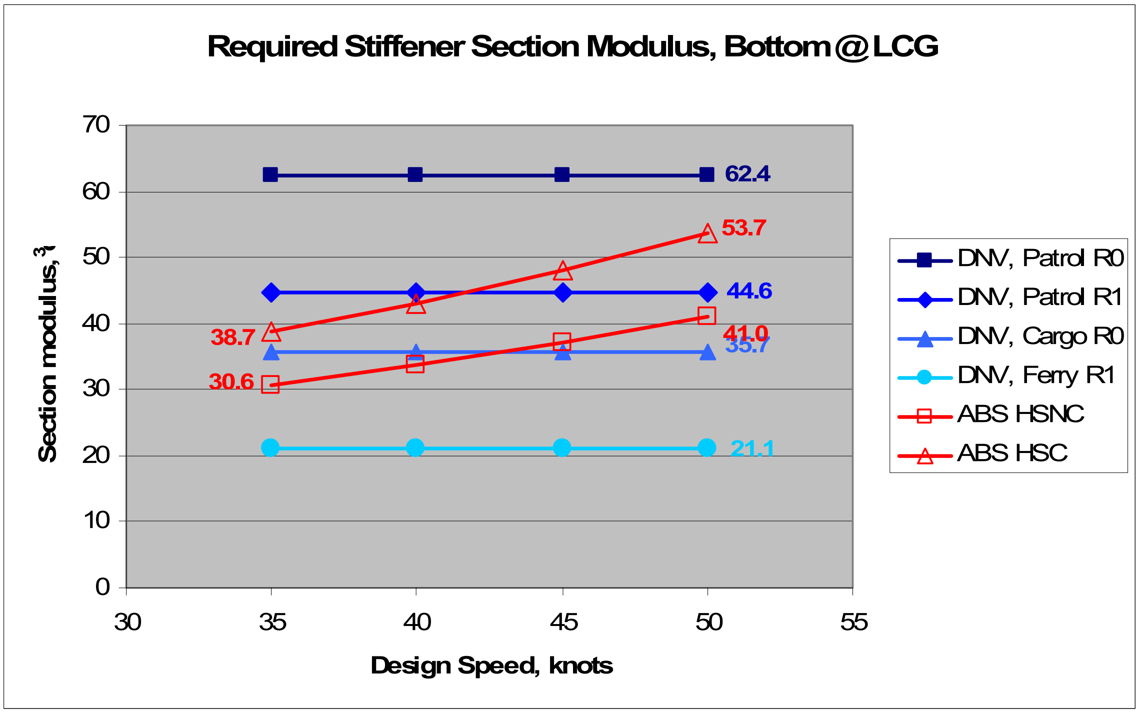


Figure 3-24. Required bottom shell stiffener section modulus @ LCG

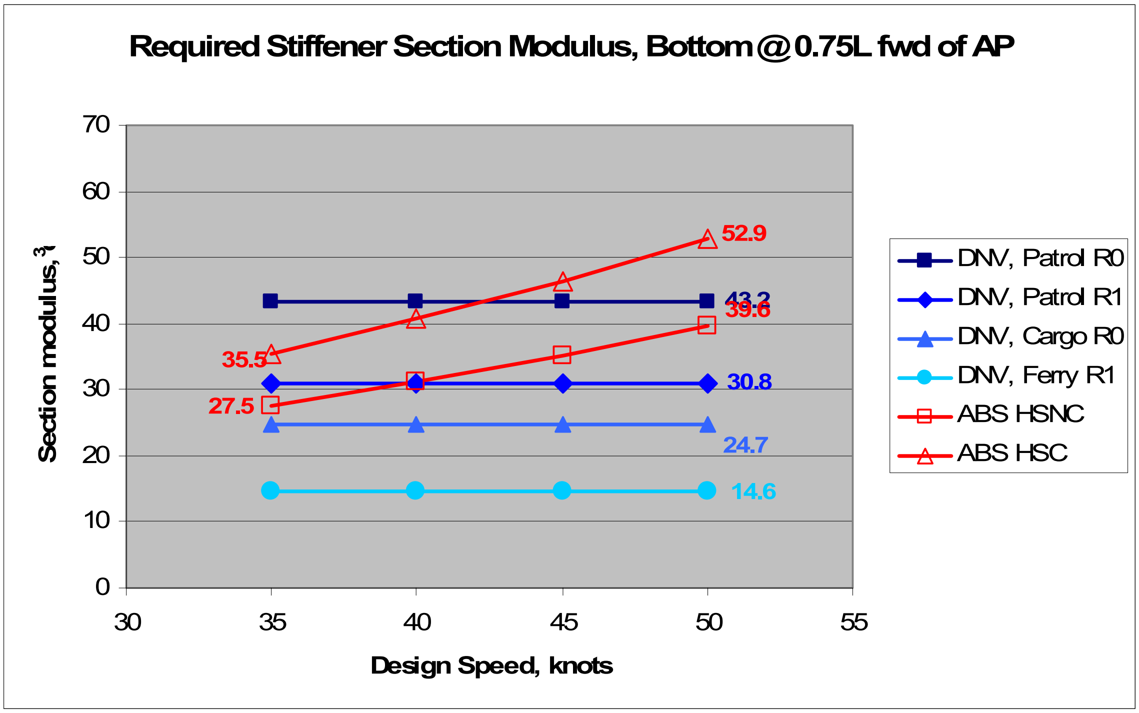


Figure 3-25. Required bottom shell stiffener section modulus @ 0.75L

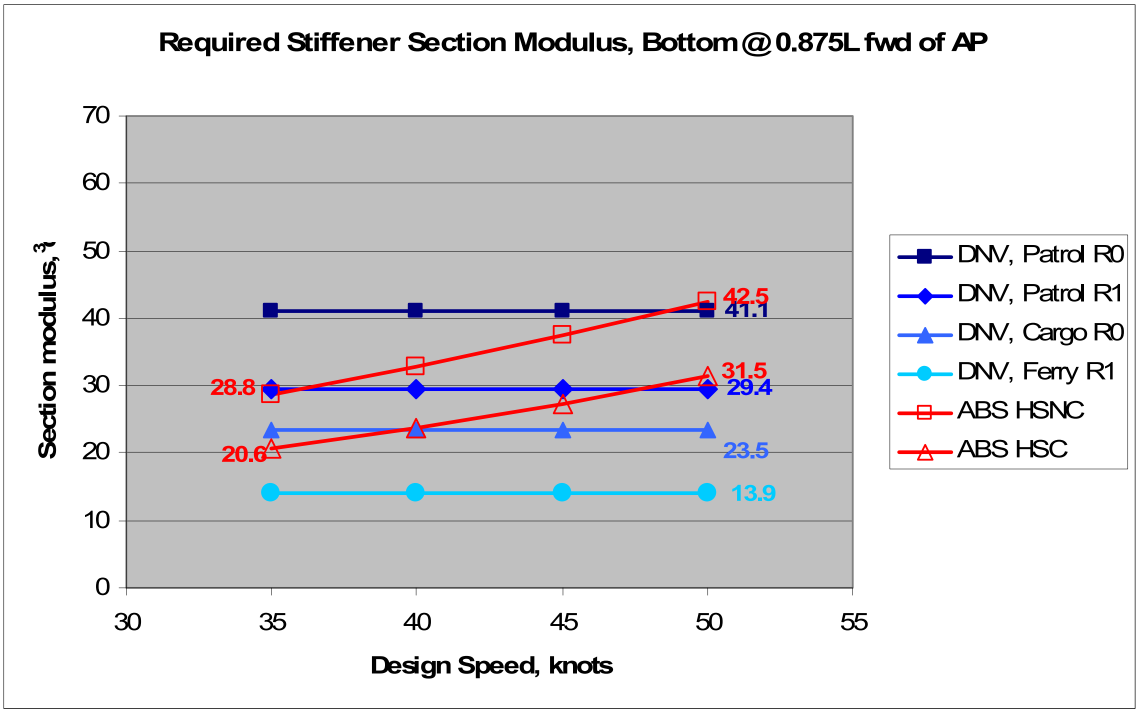


Figure 3-26. Required bottom shell stiffener section modulus @ 0.875L

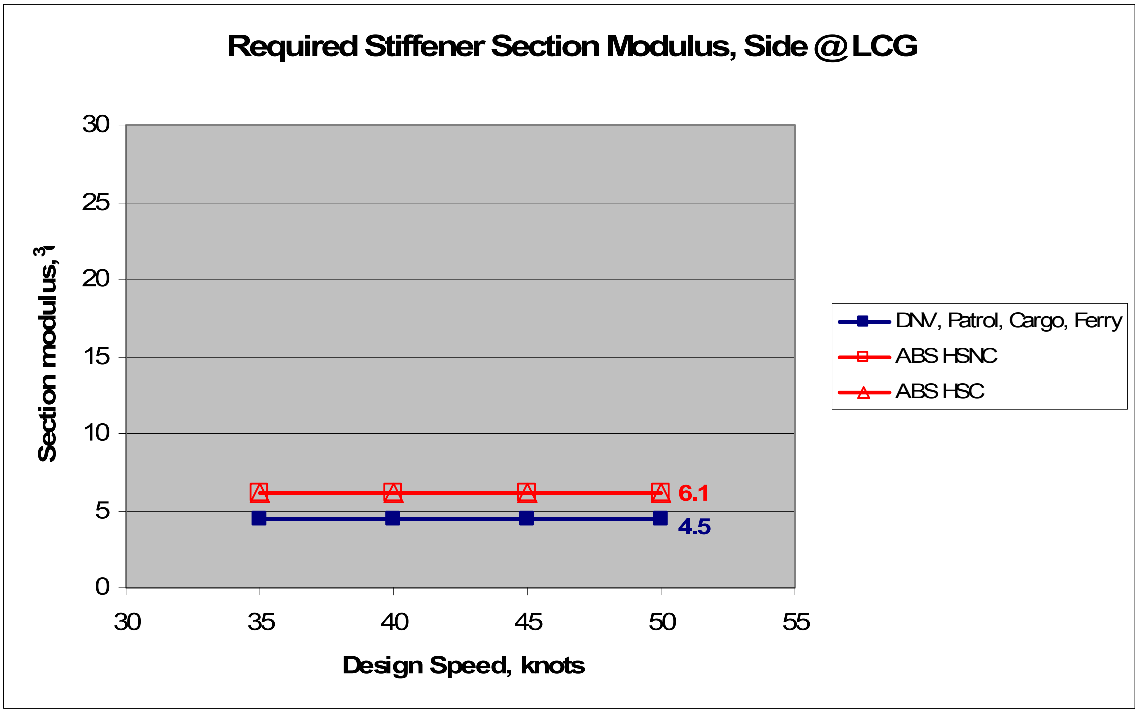


Figure 3-27. Required side shell stiffener section modulus @ LCG

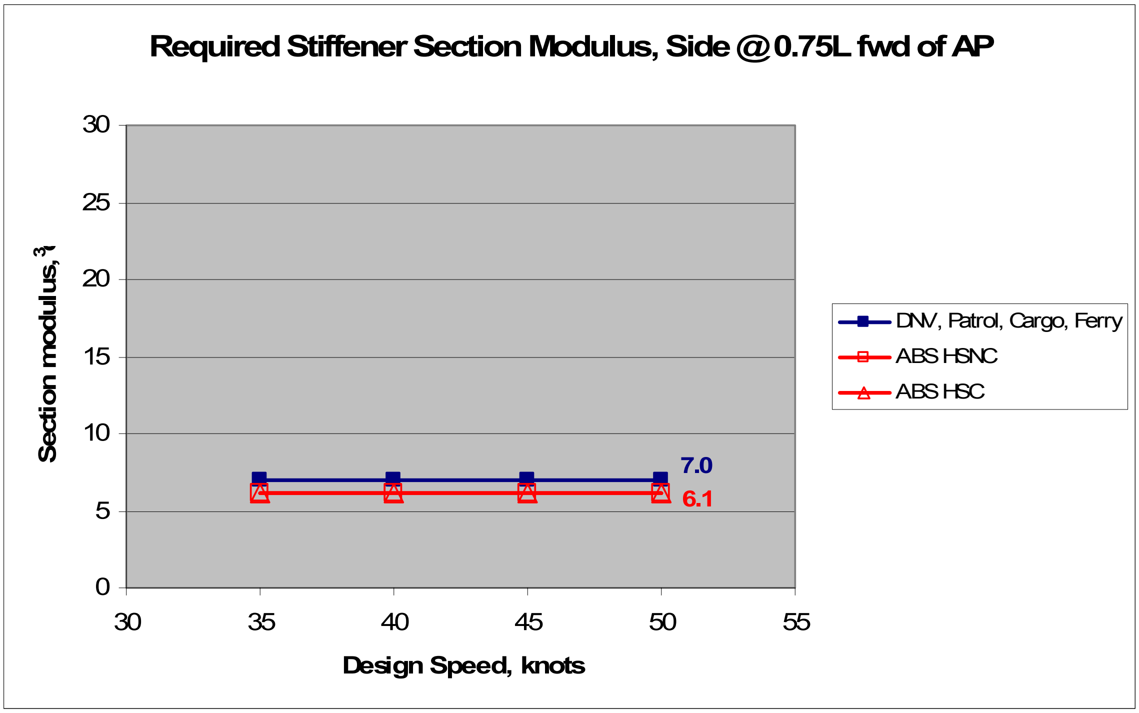


Figure 3-28. Required side shell stiffener section modulus @ 0.75L

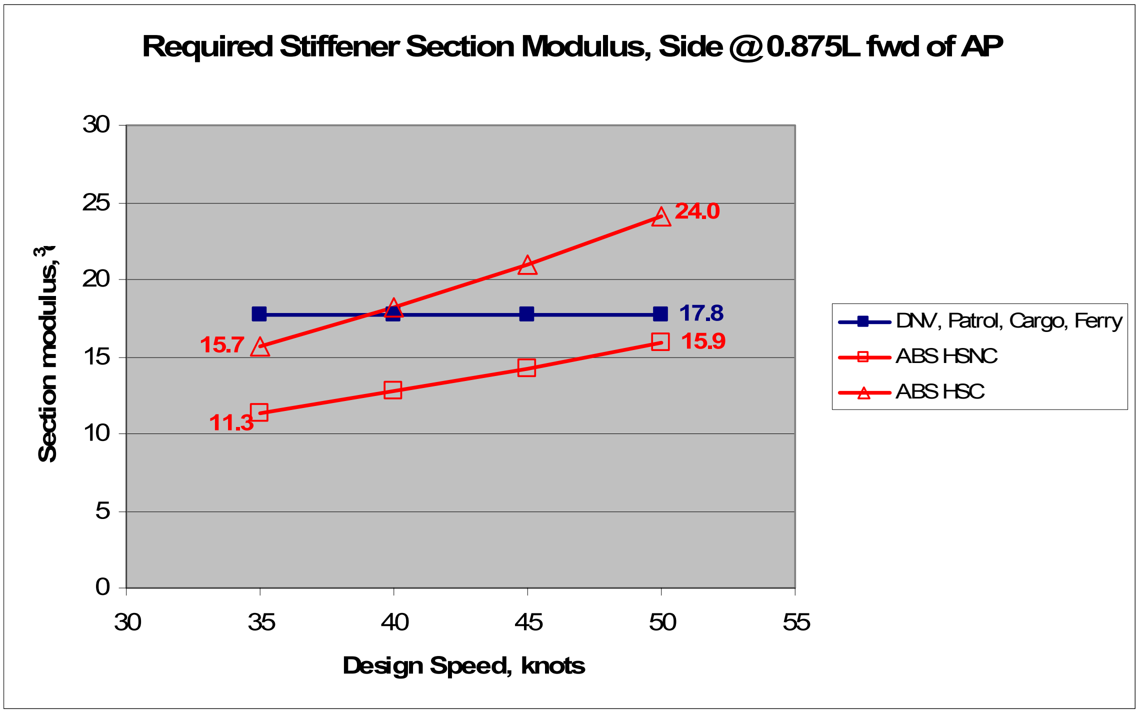


Figure 3-29. Required side shell stiffener section modulus @ 0.875L

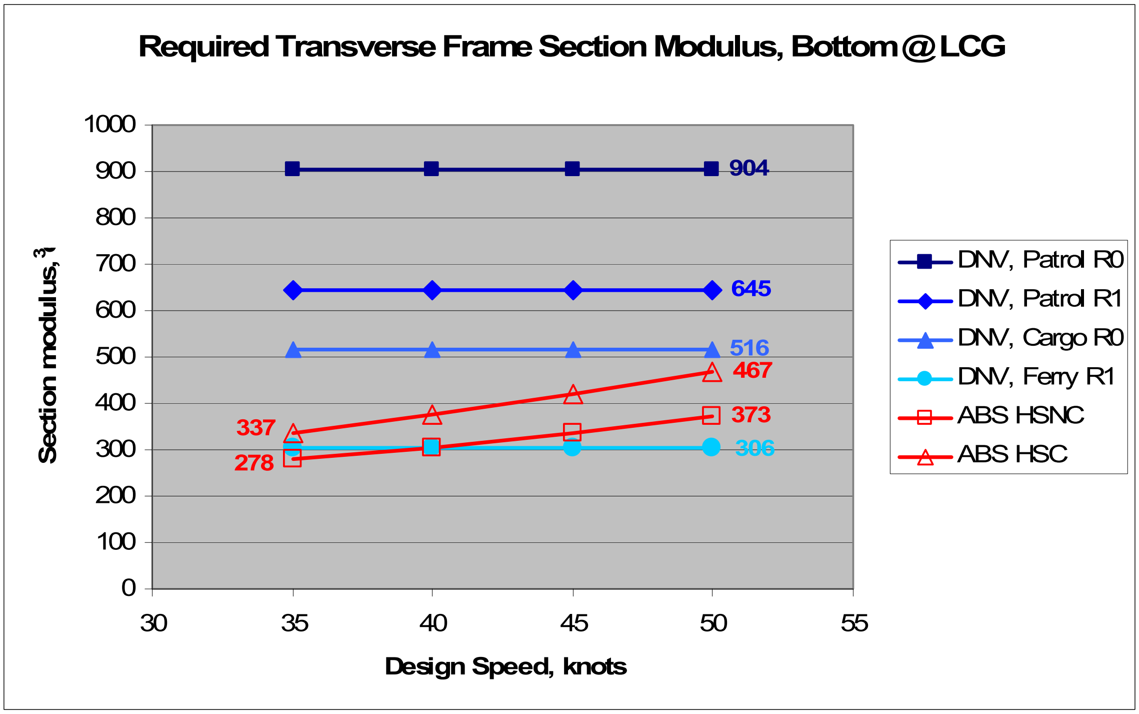


Figure 3-30. Required bottom framing section modulus @ LCG

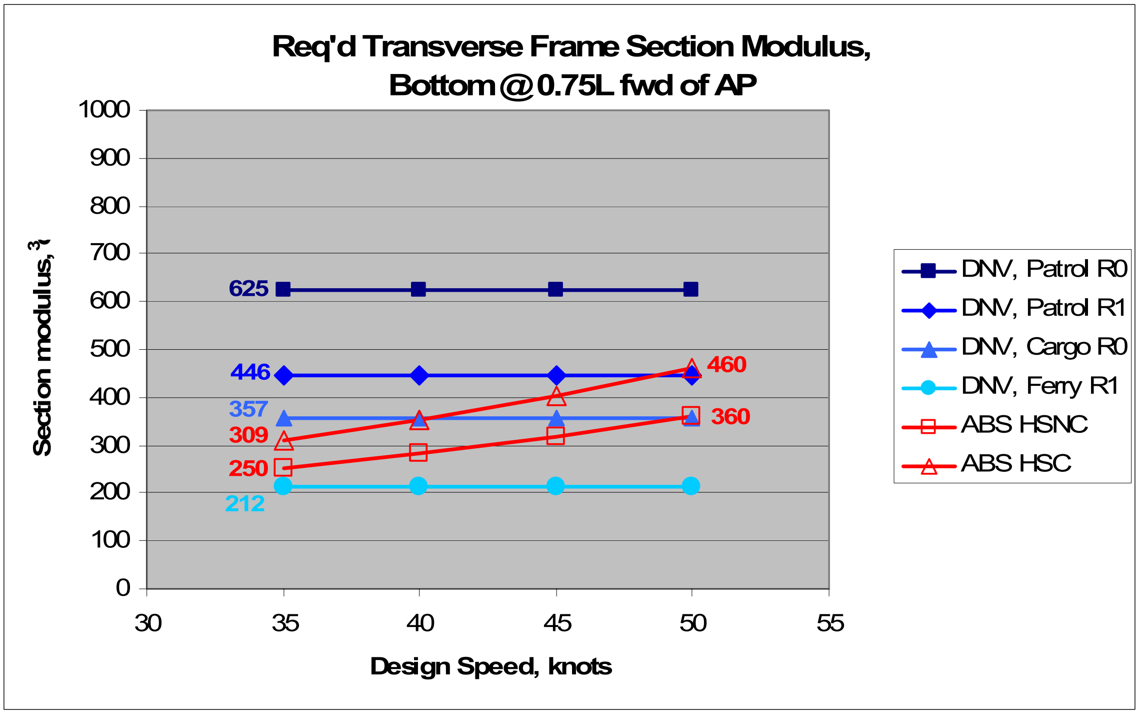


Figure 3-31. Required bottom framing section modulus @ 0.75L

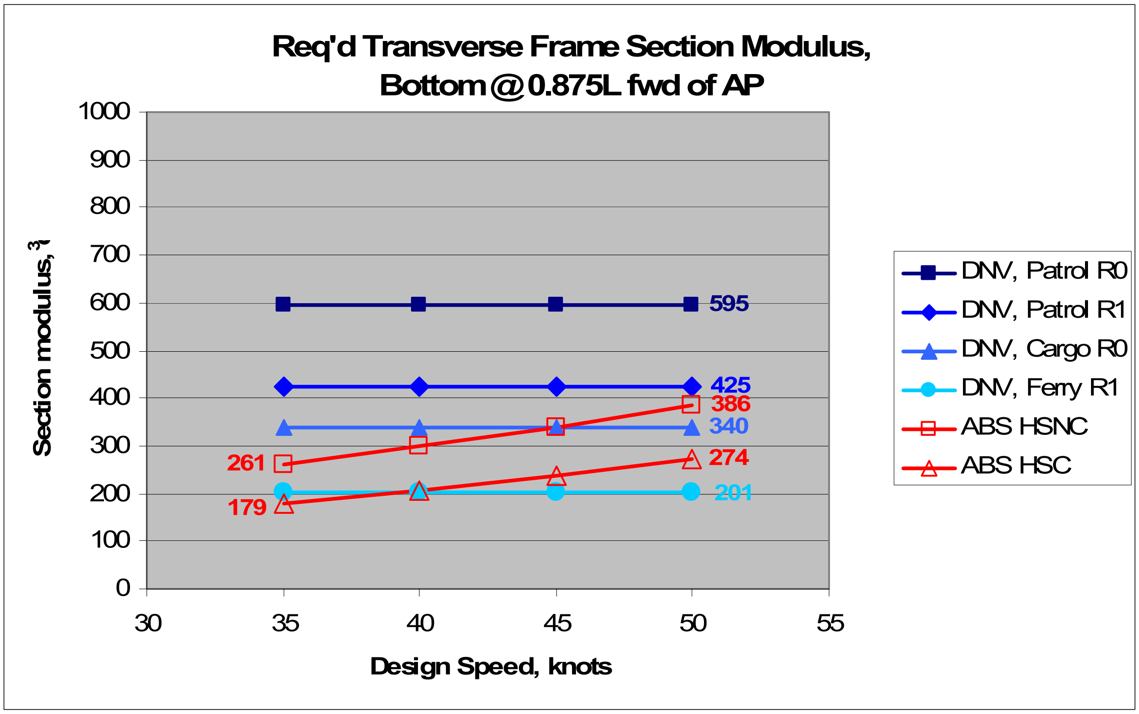


Figure 3-32. Required bottom framing section modulus @ 0.875L

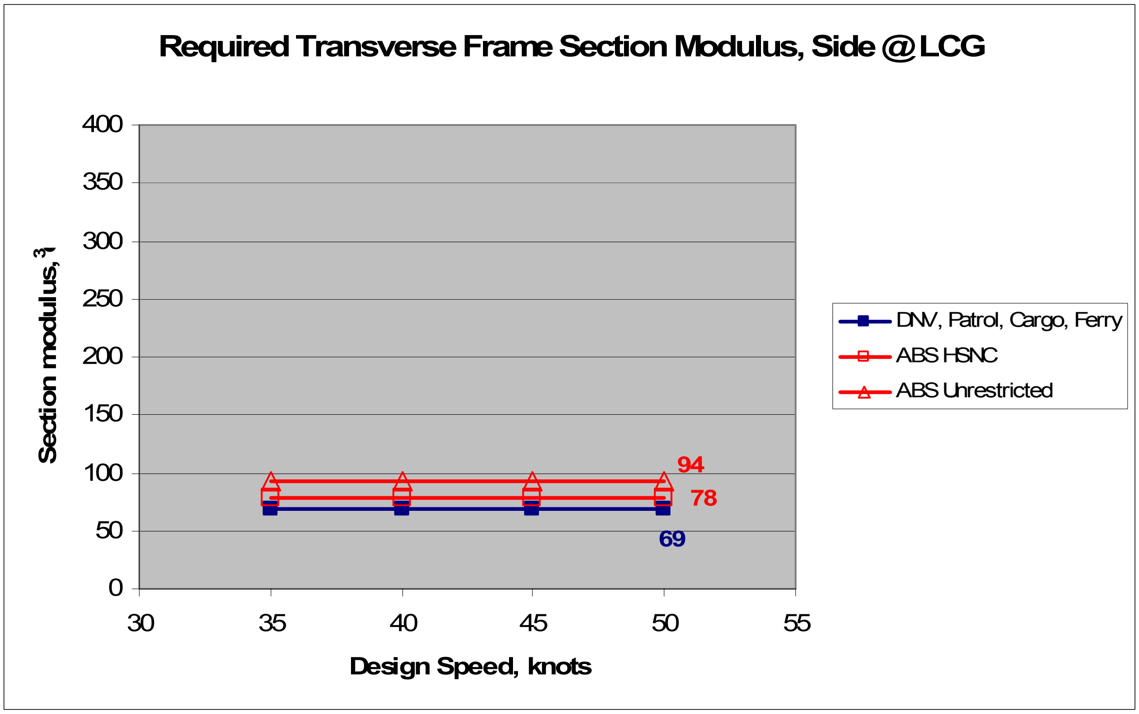


Figure 3-33. Required side framing section modulus @ LCG

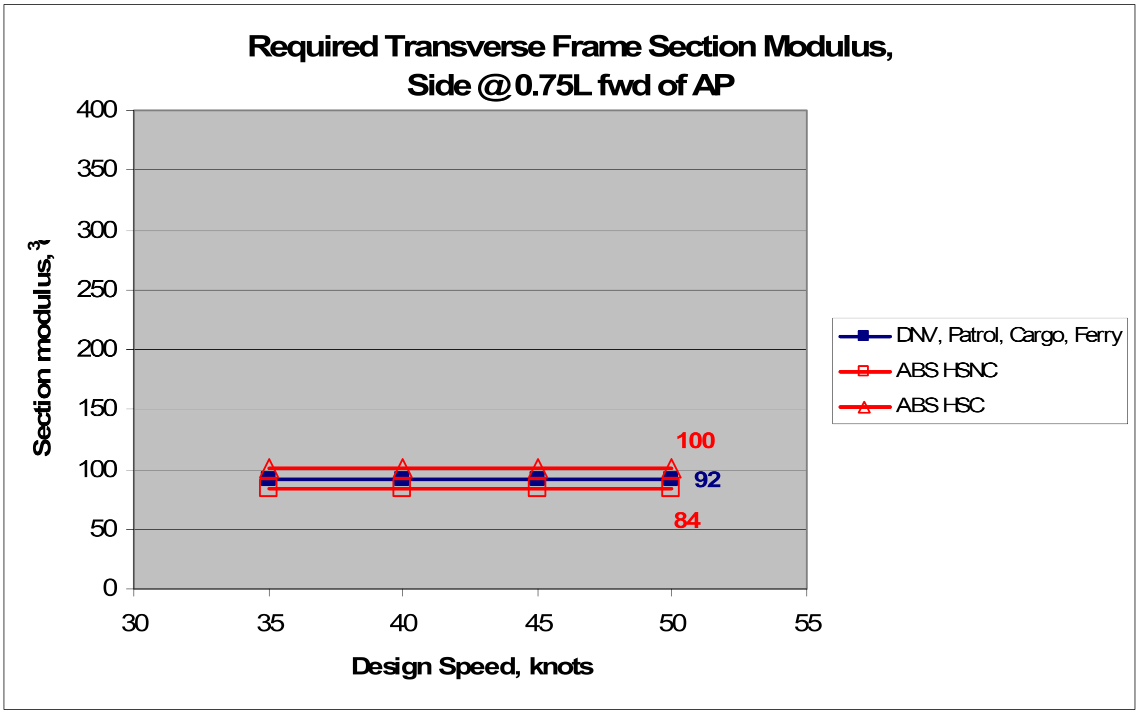


Figure 3-34. Required side framing section modulus @ 0.75L

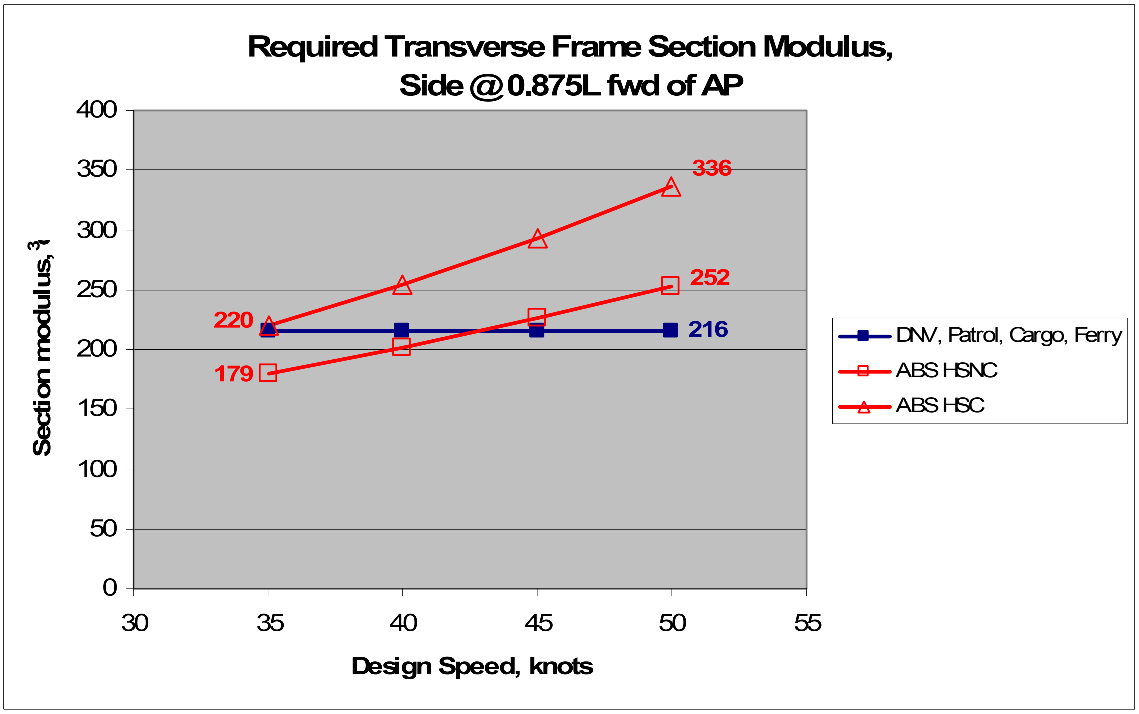


Figure 3-35. Required side framing section modulus @ 0.875L

4. Conclusions

The calculation of the required accelerations, loads, and subsequent scantlings for an example high speed monohull in accordance with three different sets of rules from two different class societies allowed for a quantitative comparison of those requirements.

It appears that a monohull cargo ferry designed for unrestricted operations in accordance with the ABS HSC Guide has, in general, slightly greater local scantlings than one designed to the DNV HSLC Rules with a notation of Cargo R1. The ABS hull girder section modulus requirement is less but the plating and internals are slightly heavier. The DNV requirements for a patrol craft are, overall, more stringent. For example, as seen in figure 3-2 the required hull girder section modulus in accordance with the ABS HSNC Guide varies from 7,340 to 7,800 cm^2m for a 35-50 high speed craft; the DNV HSLC Rules require a similar section modulus of 10,611 cm^2m for a Patrol R1 notation. A Patrol craft built for unrestricted operations (Patrol R0) in accordance with DNV's Rules requires approximately 60 percent more section modulus than the ABS Guide, 12,286 cm^2m.

This study was limited to the calculation of the scantlings required by the rules; both societies' rules would require global and local finite element analyses to verify the adequacy of the design, buckling checks and fatigue studies of critical areas. A similar comparison for catamaran hull forms would be useful but was not performed due to a lack of complete design information for a representative catamaran.

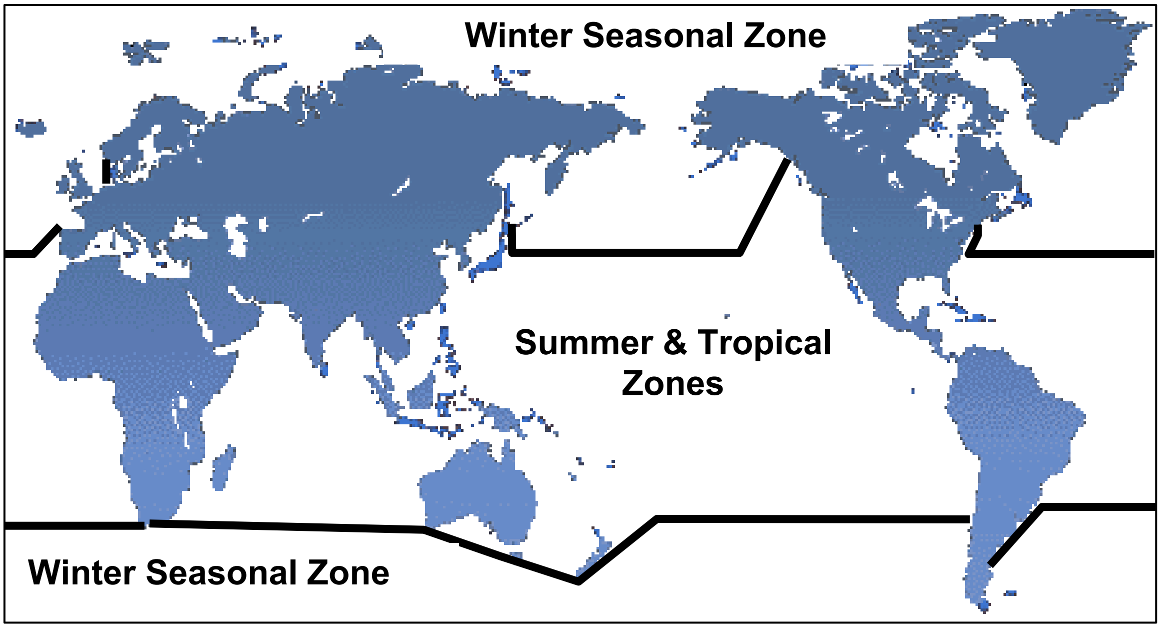
In summary, the structural design requirements for ABS and DNV are comparable for a high speed monohull in commercial cargo service. A patrol craft designed and built to DNV's HSLC Rules with the Patrol R0 service notation would be heavier than one designed and built to the ABS HSNC Guide's naval craft requirements.

5. References

1. "International Code of Safety for High-Speed Craft", International Maritime Organization, London
2. "Guide for Building and Classing High-Speed Craft", The American Bureau of Shipping, Houston, October 2001 with Corrigenda, April 2003
3. "Guide for Building and Classing Naval High Speed Craft", The American Bureau of Shipping, Houston, 2003
4. "Rules for Classification of High Speed, Light Craft, and Naval Surface Craft", Det Norske Veritas, Høvik, Norway, July 2002
5. "Rules for Classification of High Speed Craft", published jointly by Bureau Veritas, Germanischer Lloyd and Registro Italiano Navale as members of EEIG UNITAS, July 2002
6. "Rules and Regulations for the Classification of Special Services Craft", Lloyd's Register of Shipping, London, July 2002
7. "Rules for High Speed Craft", Nippon Kaiji Kyokai, Tokyo, July 2002

APPENDIX A

Zones, areas and seasonal periods as defined in Annex II of the International Conference on Load Lines, 1966



IMO: Passenger craft, 4 hours to refuge
Cargo craft, 8 hours to refuge

ABS: Naval Craft < 300 nm to refuge in Winter Seasonal Zone
Coastal Naval Craft < 300 nm to refuge in Summer/Tropical Zones, 150 nm to refuge in Winter Zones

DNV: R0 restriction < 300 nm to refuge in Winter Seasonal Zone
R1 restriction < 100 nm to refuge in Winter Seasonal Zone, 300 nm to refuge in Summer/Tropical Zones

LR: G4 restriction < 250 nm to refuge
G5 restriction > 250 nm to refuge

APPENDIX B

Calculation of the hull girder strength, design pressures and local scantlings for a 61m, 50 knot high speed craft in accordance with the American Bureau of Shipping's "Guide for Building and Classing High-Speed Craft", April 2003

PART 3, SECTION 6
Primary Hull Strength

3/6.1 Longitudinal Hull Girder Strength - Monohulls

The equations are, in general, valid for craft having breadths, B, not greater than twice their depths, D, as defined in 3/1.

3/6.1.1 Section Modulus

a. All Craft. The required hull girder section modulus SM at amidships is to be not less than given by the following equation:

$$SM = C_1 C_2 L^2 B\,(C_b + 0.7)\,K_3 K_4 C Q \quad \text{cm}^2\text{m}$$

where:

C_1 = 6.4 $\quad 45 \le L \le 61$m
C_2 = 0.01
L = length of craft on summer load line, m, as defined in section 3/1
= 61.0 m
B = breadth of craft, m
= 12.9 m
V = maximum speed for the desired sea state, knots
= varies from 35 to 50 knots
C_b = block coefficient but not less than 0.45 for L < 35m or 0.6 for L ≥ 61m. The minimum C_b for lengths between 35m and 61m is to be determined by interpolation
= 0.451 design (actual)
= 0.6 minimum required

$$K_3 = 0.70 + 0.30\left[\frac{V/\sqrt{L} + 1.20}{3.64}\right]$$

but not less than 1.0

= 1.16824 for V = 35 knots
= 1.221 for V = 40 knots
= 1.27376 for V = 45 knots
= 1.32653 for V = 50 knots

K_4 = 1.0 for unrestricted ocean service
C = 0.9 for aluminum craft
Q = $0.9 + q_5$ but not less than Q_o
σ_u = 276 = minimum tensile strength of welded aluminum, Mpa
σ_y = 165 = minimum yield strength of welded aluminum, Mpa
q_5 = $115/\sigma_y$
= 0.69697
Q_o = $635/(\sigma_y + \sigma_u)$
= 1.43991
Q = 1.59697 calculated
= 1.6 minimum required

therefore:

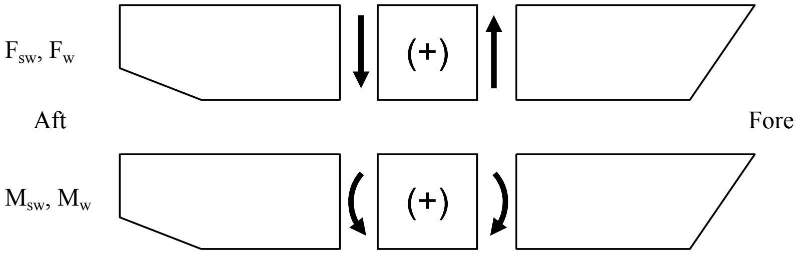
$SM = C_1 C_2 L^2 B (C_b + 0.7) K_3 K_4 CQ$
= 6.4 x 0.01 x 61^2 x 12.9 x (0.6 + 0.7) x K3 x 1.0 x 0.9 x 1.6
= 5751 x K_3

SM = 6718 cm^2m for V = 35 knots
= 7022 cm^2m for V = 40 knots
= 7325 cm^2m for V = 45 knots
= 7629 cm^2m for V = 50 knots

b Craft 61m in Length and Over. In addition to meeting the above criteria in 3/6.3.1a, craft of 61m in length or greater are to comply with the following requirements.

1. *Sign Convention of Bending Moment and Shear Force.* The sign convention of bending moment and shear force is as shown in Figure 3/6.1.

Figure 3/6.1
Sign Convention



2. *Wave Bending Moment Amidships.* The wave bending moment, expressed in kN-m, may be obtained from the following equations.

$M_{ws} = -k_1 C_1 L^2 B (C_b + 0.7) \times 10^{-3}$ Sagging moment

$M_{wh} = +k_2 C_1 L^2 B C_b \times 10^{-3}$ Hogging moment

k_1 = 110
k_2 = 190

and C_1, L, B, and C_b are as defined in 3/6.1.1a

therefore:

M_{ws} = -43,930 kN-m
M_{wh} = 35,021 kN-m

3. *Section Modulus.* The required hull-girder section modulus for $0.4L$ amidships is to be obtained from the following equation:

$$SM = \frac{M_t K_3 C Q}{f_p} \text{ cm}^2\text{m}$$

K3, C, Q are as defined in 3/6.1.1a and where

M_t = $M_{sw} + M_w\ F_s$
M_{sw} = maximum still-water bending moment in the hogging condition and the sagging condition in kN-m, generally M_{sw} is not to be taken less than 0.5 M_{ws}.
M_{sw} = -6,993 kN-m (actual value)
M_{sw} = -21,965 kN-m (greater of actual value and $0.5M_{ws}$)
M_w = maximum wave induced bending moment in kN-m, as determined in 3/6.1.1(b)(2)
= -43930 kN-m
f_p = 17.5 kN/cm^2
F_s = 1.0 for unrestricted service ($h_{1/3} \geq 4.0$m)

therefore:

M_t = -21965 + -43930 x 1
-65896 kN-m

SM = 6335 cm^{2}m for V = 35 knots
= 6621 cm^{2}m for V = 40 knots
= 6907 cm^{2}m for V = 45 knots
= 7193 cm^{2}m for V = 50 knots

c Planing and Semi-planing Craft. Where the craft speed exceeds 25 knots, the hull-girder section modulus is also to be not less than obtained by the following equations, whichever is greater:

$$SM = \frac{\Delta L_w}{C_2}(128Y_F - 178Y_{cg} - 50)CQ \text{ cm}^2\text{m}$$

or

$$SM = \frac{\Delta L_w}{C_2}(78Y_F - 128Y_A - 50)CQ \text{ cm}^2\text{m}$$

where:

Δ = maximum displacement of craft in metric tons
= 950 mt
L_w = length of craft at the design waterline in meters
= 61.0 m
Y_F = vertical acceleration at the forward end, generally taken as $1.2n_{cg}$, however where L is greater than 61meters, or where V_k is greater than 35 knots, it is to be determined by model tests and submitted for review.

n_{cg} = as defined in 3/8.1
= 0.847 g's for V = 35 knots
= 1.106 g's for V = 40 knots
= 1.400 g's for V = 45 knots
= 1.728 g's for V = 50 knots

therefore:
Y_F = 1.016 g's for V = 35 knots
= 1.327 g's for V = 40 knots
= 1.680 g's for V = 45 knots
= 2.074 g's for V = 50 knots

Y_{cg} = vertical acceleration at longitudinal center of gravity, average 1/10th highest accelerations, in g's. Where Y_{cg} is not submitted by the designer, it is generally to be taken as not less than $0.6n_{cg}$, where n_{cg} is as given in 3/8.1.1a. However where L is greater than 61meters, or where V_k is greater than 35 knots, it is to be determined by model tests and submitted for review.

= 0.508 g's for V = 35 knots
= 0.664 g's for V = 40 knots
= 0.840 g's for V = 45 knots
= 1.037 g's for V = 50 knots

Y_A = vertical acceleration at the aft end, generally taken as 0, however where L is greater than 61meters, or where V_k is greater than 35 knots, it is to be determined by model tests and submitted for review.
= 0.0 g's
C_2 = 1320
C = coefficient given in 3/6.1.1a
= 0.9
Q = material coefficient given in 3/6.1.1a
= 1.6

therefore SM equals the greater of :

$$SM = \frac{\Delta L_w}{C_2}(128Y_F - 178Y_{cg} - 50)CQ\,\mathrm{cm}^2\mathrm{m}$$

= -655 cm^2m for V = 35 knots
= 112 cm^2m for V = 40 knots
= 981 cm^2m for V = 45 knots
= 1953 cm^2m for V = 50 knots

or

$$SM = \frac{\Delta L_w}{C_2}(78Y_F - 128Y_A - 50)CQ\,\mathrm{cm}^2\mathrm{m}$$

= 1851 cm^2m for V = 35 knots
= 3385 cm^2m for V = 40 knots
= 5124 cm^2m for V = 45 knots
= 7067 cm^2m for V = 50 knots

The minimum required section modulus as per each of the above sections is:

	all craft	**craft 61m and over**	**planing or semi-planing craft**		
SM =	6,718	6,335	-655	1,851	cm^{2}m for V = 35 knots
=	7,022	6,621	112	3,385	cm^{2}m for V = 40 knots
=	7,325	6,907	981	5,124	cm^{2}m for V = 45 knots
=	7,629	7,193	1,953	7,067	cm^{2}m for V = 50 knots

therefore the minimum required section modulus is:

SM = 6,718 cm^{2}m for V = 35 knots
= 7,022 cm^{2}m for V = 40 knots
= 7,325 cm^{2}m for V = 45 knots
= 7,629 cm^{2}m for V = 50 knots

PART 3, SECTION 8
Design Pressures

3/8.1 Monohulls

3/8.1.1 Bottom Structure Design Pressure

The minimum bottom design pressure is to be the greater of a or b as given in the following equations, for the location under consideration. Bottom structure design pressures are dependent upon the service in which a craft operates. The bottom pressure herein calculated applies to hull bottoms below the chines or the turn of the bilge.

a ***Bottom Slamming Pressure***

$$p_{bcg} = \frac{N_1 \Delta}{L_w B_w}[1 + n_{cg}]F_D \ \text{kN/m}^2$$

$$p_{bxx} = \frac{N_1 \Delta}{L_w B_w}[1 + n_{xx}]\left[\frac{70 - \beta_{xx}}{70 - \beta_{cg}}\right]F_D \ \text{kN/m}^2$$

for craft less than 61m, p_{bxx} may be taken as:

$$p_{bxx} = \frac{N_1 \Delta}{L_w B_w}[1 + n_{cg}]F_D F_V \ \text{kN/m}^2$$

b ***Hydrostatic Pressure***

$$p_d = N_3(F_s H + d) \ \text{kN/m}^2$$

where:

p_{bcg} = bottom design pressure at LCG, kN/m^2
p_{bxx} = bottom design pressure at any section clear of LCG, kN/m^2
p_d = bottom design pressure based on hydrostatic forces, kN/m^2
n_{cg} = average of the 1/100th highest vertical acclerations at LCG, corresponding to the sea state, in g's. G's are the dimensionless ratio of the accleration to gravitational acceleration at sea level (9.8 m/s^2). Can be determined by the following equation:

$$n_{cg} = N_2\left[\frac{12h_{1/3}}{B_w} + 1.0\right]\tau[50 - \beta_{cg}]\frac{V^2(B_w)^2}{\Delta} \ \text{g's}$$

n_{xx} = average of the 1/100th highest vertical acclerations at any section clear LCG, corresponding to the sea state, in g's. Can be determined by the following equation:
= $n_{cg} K_v$
N_1 = 0.1
N_2 = 0.0078
N_3 = 9.8
Δ = displacement at the design waterline in kg
= 950,000 kg
L_w = craft length at the design waterline, displacement mode, m
= 61.0 m

B_w = maximum waterline beam, m
= 11.7 m
H = wave parameter, $0.0172L + 3.653$m
= 4.7022
$h_{1/3}$ = significant wave height, m, for the sea state being considered, generally not to be taken as less than $L_w/12$ except for restricted service operations as given in Table 3/8.1
= 5.08 m (greater of $L_w/12$ or 4.0m (unrestricted service))
τ= running trim at V, in degrees, but generally not to be taken as less than 4 deg. for craft L<50m nor less than 3 deg. for L<125m. Special consideration will be given to desgner's values predicted from model tests.
= 3.0 degrees (sea trial data) 2.1
β_{cg} = deadrise at LCG, degrees, generally not to be taken less than 10 deg. or more than 30 degrees.
= 17 degrees
β_{xx} = deadrise at any section clear of LCG, degrees, generally not to be taken less than 10 deg. or more than 50 degrees.
$\beta_{0.75L}$ = 29 degrees
$\beta_{0.875L}$ = 48 degrees
V = craft design speed in knots, generally the maximum speed in calm water
= varies from 35 to 50 knots
F_S = 1.0 for unrestricted service, table 3/8.1
F_D = design area factor given in Figure 3/8.1 for given values of A_D and A_R. Generally not to be taken less than 0.40.
K_V = vertical acceleration distribution factor given in Figure 3/8.2
= 1.50 at 0.75L forward of AP
= 1.75 at 08.75L forward of AP
F_V = vertical acceleration distribution factor given in Figure 3/8.3
= 1.00 at 0.75L forward of AP
= 1.00 at 0.875L forward of AP
s = spacing of longitudinals or stiffeners, cm
= 26 cm
l = length of unsupported span of internals, see 3/10.1.2a
l_{st} = 80 cm, stiffeners
l_{tr} = 182 cm, transverses (assume 7s)
d = stationary draft, in m, vertical distance from outer surface of shell measured at centerline to design waterline at middle of the design waterline length, but generally not to be taken as less than 0.04L.

= 2.7 m
A_R = reference area, cm^2.
= $6.95\Delta/d$ cm2.
= 2.E+06 cm^2
A_D = design area, cm^2. for plating it is the actual area of the shell plate panel but not to be taken as more than $2s^2$. For longitudinals, stiffeners, transverses and girders it is the shell area supported by the longitudinal, stiffener, transverse or girder; for thransverses and girders the area used need not be taken less than $0.33l^2$.

for plating:

$2s^2$ = 1352 cm^2
sl_{st} = 2080 cm^2
$\therefore A_D$ = 1352 cm^2
A_D/A_R = 0.001
$\therefore F_D$ = 1.00 greater of 0.4 or value from figure 3/8.1

for stiffeners:

A_D = 2080 cm^2 (spacing x length)
A_D/A_R = 0.001
$\therefore F_D$ = 1.00 greater of 0.4 or value from figure 3/8.1

for transverses:

$0.33l_{tr}^{\;2}$ = 10930.9 cm^2
$l_{tr}l_{st}$ = 14560 cm^2
$\therefore A_D$ = 14560 cm^2
A_D/A_R = 0.006
$\therefore F_D$ = 0.95 greater of 0.4 or value from figure 3/8.1

therefore:

n_{cg} = 0.847	$n_{0.75L}$ = 1.270	$n_{0.875L}$ = 1.482	g's for V = 35	knots
= 1.106	= 1.659	= 1.936	g's for V = 40	knots
= 1.400	= 2.100	= 2.450	g's for V = 45	knots
= 1.728	= 2.593	= 3.025	g's for V = 50	knots

therefore the design pressures as per 3/8.1.1.a *Bottom Slamming Pressure*, are:

$$p_{bcg} = \frac{N_1\Delta}{L_w B_w}[1+n_{cg}]F_D \text{ kN/m}^2$$

$$p_{bxx} = \frac{N_1\Delta}{L_w B_w}[1+n_{xx}]\left[\frac{70-\beta_{xx}}{70-\beta_{cg}}\right]F_D \text{ kN/m}^2$$

for plating:

p_{bcg} = 245.85	$p_{b0.75L}$ = 233.79	$p_{b0.875L}$ = 137.15	kN/m^2 ,V = 35	knots
= 280.36	= 273.84	= 162.22	kN/m^2 ,V = 40	knots
= 319.47	= 319.22	= 190.63	kN/m^2 ,V = 45	knots
= 363.19	= 369.95	= 222.38	kN/m^2 ,V = 50	knots

for stiffeners:

p_{bcg} = 245.85	$p_{b0.75L}$ = 233.79	$p_{b0.875L}$ = 137.15	kN/m^2 ,V = 35	knots
= 280.36	= 273.84	= 162.22	kN/m^2 ,V = 40	knots
= 319.47	= 319.22	= 190.63	kN/m^2 ,V = 45	knots
= 363.19	= 369.95	= 222.38	kN/m^2 ,V = 50	knots

for transverses:

$p_{bcg} = 233.55$ $p_{b0.75L} = 222.10$ $p_{b0.875L} = 130.29$ kN/m^2 ,V = 35 knots
$= 266.34$ $= 260.14$ $= 154.11$ kN/m^2 ,V = 40 knots
$= 303.50$ $= 303.26$ $= 181.10$ kN/m^2 ,V = 45 knots
$= 345.03$ $= 351.45$ $= 211.27$ kN/m^2 ,V = 50 knots

and the design pressures as per 3/8.1.1.b *Hydrostatic Pressure* are:

$p_d = N_3(F_s H + d)$ kN/m^2
$= 72.54$ kN/m^2

The minimum design pressure for the bottom is the greater of that calculated by 3/8.1.1.a and 3/8.1.1.b, therefore the minimum bottom design pressures are as follows:

for plating:

$p_{bcg} = 245.85$ $p_{b0.75L} = 233.79$ $p_{b0.875L} = 137.15$ kN/m^2 ,V = 35 knots
$= 280.36$ $= 273.84$ $= 162.22$ kN/m^2 ,V = 40 knots
$= 319.47$ $= 319.22$ $= 190.63$ kN/m^2 ,V = 45 knots
$= 363.19$ $= 369.95$ $= 222.38$ kN/m^2 ,V = 50 knots

for stiffeners:

$p_{bcg} = 245.85$ $p_{b0.75L} = 233.79$ $p_{b0.875L} = 137.15$ kN/m^2 ,V = 35 knots
$= 280.36$ $= 273.84$ $= 162.22$ kN/m^2 ,V = 40 knots
$= 319.47$ $= 319.22$ $= 190.63$ kN/m^2 ,V = 45 knots
$= 363.19$ $= 369.95$ $= 222.38$ kN/m^2 ,V = 50 knots

for transverses:

$p_{bcg} = 233.55$ $p_{b0.75L} = 222.10$ $p_{b0.875L} = 130.29$ kN/m^2 ,V = 35 knots
$= 266.34$ $= 260.14$ $= 154.11$ kN/m^2 ,V = 40 knots
$= 303.50$ $= 303.26$ $= 181.10$ kN/m^2 ,V = 45 knots
$= 345.03$ $= 351.45$ $= 211.27$ kN/m^2 ,V = 50 knots

3/8.1.2 Side and Transom Structure, Design Pressure

The side pressure, P_s, is to be not less than given by equations:

a ***Slamming Pressure***

$$p_{sxx} = \frac{N_1\Delta}{L_w B_w}[1 + n_{xx}]\left[\frac{70 - \beta_{Sxx}}{70 - \beta_{Scg}}\right]F_D \text{ kN/m}^2$$

b ***Hydrostatic Pressure***

$$p_s = N_3(F_s H + d - y) \text{ kN/m}^2$$

c ***Fore End (stem to 0.125L aft of stem)***

$$p_{sf} = 0.28F_s C_F N_3(0.22 + 0.15 \tan a)(0.4V \sin b + 0.6\sqrt{L})^2$$

where $N_1, N_3, \Delta, L_w, V, n_{xx}, b_{cg}, H, d,$ and F_d are as defined in 3/8.1.1:

N_1 = 0.1
N_3 = 9.8
Δ = 950,000 kg
L_w = 61.0 m
V = craft design speed in knots, generally the maximum speed in calm water
= varies from 35 to 50 knots
n_{cg} = 0.847 $n_{0.75L}$ = 1.270 $n_{0.875L}$ = 1.482 g's for V = 35 knots
= 1.106 1.659 1.936 g's for V = 40 knots
= 1.400 2.100 2.450 g's for V = 45 knots
= 1.728 2.593 3.025 g's for V = 50 knots
$\beta_{S\text{-cg}}$ = deadrise of side shell at LCG, degrees, generally not to be taken less than 10 deg. or more than 30 degrees.
= 30 degrees
H = 4.702
d = 2.7 m
F_D = design area factor given in Figure 3/8.1 for given values of A_D and A_R. Generally not to be taken less than 0.40.
A_R = reference area, cm^2.
= $6.95\Delta/d$ cm2.
= 2.E+06 cm^2
A_D = design area, cm^2. for plating it is the actual area of the shell plate panel but not to be taken as more than $2s^2$. For longitudinals, stiffeners, transverses and girders it is the shell area supported by the longitudinal, stiffener, transverse or girder; for transverses and girders the area used need not be taken less than $0.33l^2$.
s = spacing of longitudinals or stiffeners, cm
= 40 cm
l = length of unsupported span of internals, see 3/10.1.2a
l_{st} = 80 cm, stiffeners
l_{tr} = 242.4 cm, transverse @ CG
= 251.0 cm, transverse @ 0.75L
= 284.7 cm, transverse @ 0.875L

for plating:

$2s^2$ = 3200 cm^2
sl_{st} = 3200 cm^2
$\therefore A_D$ = 3200 cm^2
A_D/A_R = 0.001
$\therefore F_D$ = 1.00 greater of 0.4 or value from figure 3/8.1

for stiffeners:

A_D = 3200 cm^2 (spacing x length)
A_D/A_R = 0.001
$\therefore F_D$ = 1.00 greater of 0.4 or value from figure 3/8.1

for transverses:

$0.33l_{tr}^2$ =	19383.4	cm^2 @ CG	20784.7	cm^2, 0.75L	26746.9	cm^2, 0.875L
$l_{tr}l_{st}$ =	19388.7	cm^2 @ CG	20077.3	cm^2, 0.75L	22775.6	cm^2, 0.875L
$\therefore A_D$ =	19388.7	cm^2 @ CG	20784.7	cm^2, 0.75L	26746.9	cm^2, 0.875L
A_D/A_R =	0.008	@CG	0.008	@ 0.75L	0.011	@ 0.875L
$\therefore F_D$ =	0.92	@CG	0.92	@ 0.75L	0.88	@ 0.875L

and:

B_w = maximum waterline beam, m
= 11.7 m
β_{Sxxx} = deadrise of side shell at any section clear of LCG, degrees, generally not to be taken less than 10 deg. or more than 70 degrees.
$\beta_{S0.75L}$ = 70 degrees
$\beta_{S0.875L}$ = 61 degrees
p_{sxx} = side design pressure at any section clear of LCG, kN/m^2
p_s = side design pressure due to hydrostatic forces, in kN/m^2, but is not to be less than the following:
= $0.05N_3L$ kN/m^2 at or below $L/15$ above BL or at any height forward of $0.125L$ from the stem
= 29.89 kN/m2 at or below 4.07 m above BL or at any height forward of 0.51 m from the stem
= $0.033N_3L$ kN/m^2 above $L/15$ above BL and aft of $0.125L$ from the stem
= 19.73 kN/m2 above 4.07 m above BL and aft of 0.51 m from the stem
p_{sf} = side design pressure forward of $0.125L$ from the stem
y = distance above baseline, m, of location being considered
= 5.80 m @ CG
= 5.80 m @ 0.75L
= 5.845 m @ 0.875L
L = craft length as defined in section 3/1.1
= 61.00 m
F_S = 1.0 for unrestricted service, table 3/8.1
C_F = 0.0125L for L<80 m
= 0.7625
β = entry angle of side shell, the angle between a longitudinal line parallel to the centerline and the
= 15 degrees
α = flare angle, the angle between a vertical line and the tangent to the shell plating, measured in a vertical plane at 90 degrees to the horizontal tangent to the shell
= 29 degrees

therefore the design pressures as per 3/8.1.2.a *Side and Transom Slamming Pressure*, are:

$$p_{sxx} = \frac{N_1 \Delta}{L_w B_w}[1 + n_{xx}]\left[\frac{70 - \beta_{Sxx}}{70 - \beta_{Scg}}\right] F_D \ \text{kN/m}^2$$

for plating:

p_{Scg} = 0.00 $p_{S0.75L}$ = 0.00 $p_{S0.875L}$ = 74.34 kN/m^2, V = 35 knots
= 0.00 = 0.00 = 87.93 kN/m^2, V = 40 knots
= 0.00 = 0.00 = 103.33 kN/m^2, V = 45 knots
= 0.00 = 0.00 = 120.54 kN/m^2, V = 50 knots

for stiffeners:

p_{Scg} = 0.00 $p_{S0.75L}$ = 0.00 $p_{S0.875L}$ = 74.34 kN/m^2, V = 35 knots
= 0.00 = 0.00 = 87.93 kN/m^2, V = 40 knots
= 0.00 = 0.00 = 103.33 kN/m^2, V = 45 knots
= 0.00 = 0.00 = 120.54 kN/m^2, V = 50 knots

for transverses:

p_{Scg} = 0.00 $p_{S0.75L}$ = 0.00 $p_{S0.875L}$ = 65.42 kN/m^2, V = 35 knots
= 0.00 = 0.00 = 77.38 kN/m^2, V = 40 knots
= 0.00 = 0.00 = 90.93 kN/m^2, V = 45 knots
= 0.00 = 0.00 = 106.08 kN/m^2, V = 50 knots

and the design hydrostatic pressures as per 3/8.2.1.b *Hydrostatic Pressure* are:

$p_s = N_3(F_s H + d - y)$ but not less than $0.033 N_3 L$ kN/m2
p_{scg} = 15.70 but not less than 19.73 kN/m^2
$p_{s0.75L}$ = 15.70 but not less than 19.73 kN/m^2
$p_{s0.875L}$ = 15.26 but not less than 19.73 kN/m^2

The design side shell pressure at 0.875L and forward as per 3/8.2.2.c *Fore End Pressure* is:

$p_{sf} = 0.28 F_s C_F N_3 (0.22 + 0.15 \tan\alpha)(0.4V \sin\beta + 0.6\sqrt{L})^2$
= 43.80 kN/m^2, V = 35 knots
= 49.42 kN/m^2, V = 40 knots
= 55.39 kN/m^2, V = 45 knots
= 61.70 kN/m^2, V = 50 knots

The minimum design pressure for the side shell is the greater of that calculated by 3/8.2.1.a, b, and c, therefore the minimum side shell design pressures are as follows:

for plating:

$p_{bcg} = 19.73$ $p_{b0.75L} = 19.73$ $p_{b0.875L} = 74.34$ kN/m^2 ,V = 35 knots
$= 19.73$ $= 19.73$ $= 87.93$ kN/m^2 ,V = 40 knots
$= 19.73$ $= 19.73$ $= 103.33$ kN/m^2 ,V = 45 knots
$= 19.73$ $= 19.73$ $= 120.54$ kN/m^2 ,V = 50 knots

for stiffeners:

$p_{bcg} = 19.73$ $p_{b0.75L} = 19.73$ $p_{b0.875L} = 74.34$ kN/m^2 ,V = 35 knots
$= 19.73$ $= 19.73$ $= 87.93$ kN/m^2 ,V = 40 knots
$= 19.73$ $= 19.73$ $= 103.33$ kN/m^2 ,V = 45 knots
$= 19.73$ $= 19.73$ $= 120.54$ kN/m^2 ,V = 50 knots

for transverses:

$p_{bcg} = 19.73$ $p_{b0.75L} = 19.73$ $p_{b0.875L} = 65.42$ kN/m^2 ,V = 35 knots
$= 19.73$ $= 19.73$ $= 77.38$ kN/m^2 ,V = 40 knots
$= 19.73$ $= 19.73$ $= 90.93$ kN/m^2 ,V = 45 knots
$= 19.73$ $= 19.73$ $= 106.08$ kN/m^2 ,V = 50 knots

PART 3, SECTION 9
Plating

3/9.1 Aluminum or Steel

3/9.1.1 Thickness

The thickness of the shell, deck or bulkhead plating is to be not less than obtained by the following equaqtions, whichever is greater:

a ***Lateral loading***

$$t = s\sqrt{\frac{pk}{1000\sigma_a}}$$

s = the spacing, in mm, of the longitudinals or stiffeners

p = design pressure in kN/mm^2 given in section 3/8

k = plate panel aspect ratio factor, given in Table 3/9.1

σ_a = design stress, in N/mm^2 given in Table 3/9.2

= $0.9\sigma_y$

σ_y = as-welded yield strength

= 165 N/mm^2, 5083-H116 Al

$\therefore \sigma_a$ = 148.5 N/mm^2

c Minimum thickness

1 Bottom Shell

$t_{al} = 0.70\sqrt{L} + 1.0$ mm

2 Side Shell

$t_{al} = 0.62\sqrt{L} + 1.0$ mm

The required thicknesses for the bottom and side shell plating due to lateral loading at the LCG, 0.75L and 0.875L positions as per 3/9.1.2.a are:

Bottom:

	V	p	l	s	l/s	k	σ_a	t
	knots	kN/m^2	mm	mm	-	-	N/mm^2	mm
LCG	35	245.85	800	260	3.08	0.5	148.5	7.48
	40	280.36	800	260	3.08	0.5	148.5	7.99
	45	319.47	800	260	3.08	0.5	148.5	8.53
	50	363.19	800	260	3.08	0.5	148.5	9.09
0.75L	35	233.79	800	260	3.08	0.5	148.5	7.29
	40	273.84	800	260	3.08	0.5	148.5	7.89
	45	319.22	800	260	3.08	0.5	148.5	8.52
	50	369.95	800	260	3.08	0.5	148.5	9.18
0.875L	35	137.15	800	260	3.08	0.5	148.5	5.59
	40	162.22	800	260	3.08	0.5	148.5	6.08
	45	190.63	800	260	3.08	0.5	148.5	6.59
	50	222.38	800	260	3.08	0.5	148.5	7.11

Side:

	V	p	l	s	l/s	k	σ_a	t
	knots	kN/m^2	mm	mm	-	-	N/mm^2	mm
LCG	35	19.73	800	400	2.00	0.5	148.5	3.26
	40	19.73	800	400	2.00	0.5	148.5	3.26
	45	19.73	800	400	2.00	0.5	148.5	3.26
	50	19.73	800	400	2.00	0.5	148.5	3.26
0.75L	35	19.73	800	400	2.00	0.5	148.5	3.26
	40	19.73	800	400	2.00	0.5	148.5	3.26
	45	19.73	800	400	2.00	0.5	148.5	3.26
	50	19.73	800	400	2.00	0.5	148.5	3.26
0.875L	35	74.34	800	400	2.00	0.5	148.5	6.33
	40	87.93	800	400	2.00	0.5	148.5	6.88
	45	103.33	800	400	2.00	0.5	148.5	7.46
	50	120.54	800	400	2.00	0.5	148.5	8.06

The Required minimum thicknesses as per 3/9.1.2.c are:

1 Bottom Shell

$t_{al} = 0.70\sqrt{L} + 1.0$ mm

$= 6.47$ mm

2 Side Shell

$t_{al} = 0.62\sqrt{L} + 1.0$ mm

$= 5.84$ mm

Therefore the required thickness for the bottom and side shell at LCG, 0.75L and 0.875L are:

	bottom plating	side plating
LCG	7.48 mm @ 35 knots	6.47 mm @ 35 knots
	7.99 mm @ 40 knots	6.47 mm @ 40 knots
	8.53 mm @ 45 knots	6.47 mm @ 45 knots
	9.09 mm @ 50 knots	6.47 mm @ 50 knots
0.75L	7.29 mm @ 35 knots	6.47 mm @ 35 knots
	7.89 mm @ 40 knots	6.47 mm @ 40 knots
	8.52 mm @ 45 knots	6.47 mm @ 45 knots
	9.18 mm @ 50 knots	6.47 mm @ 50 knots
0.875L	6.47 mm @ 35 knots	6.47 mm @ 35 knots
	6.47 mm @ 40 knots	6.88 mm @ 40 knots
	6.59 mm @ 45 knots	7.46 mm @ 45 knots
	7.11 mm @ 50 knots	8.06 mm @ 50 knots

PART 3, SECTION 10
Internals

3/10.1 Aluminum or Steel
3/10.1.2 Strength and Stiffness

a *Section Moulus* The section modulus of each longitudinal, stiffener, transverse web, stringer and girder is to be not less than given by the following equation:

$$\mathrm{SM} = \frac{83.3 \times \mathrm{psl}^2}{\sigma_a}\ \mathrm{cm}^3$$

where:

p = design pressure in kN/m^2, given in 3/8.1
s = the spacing, in m, of the longitudinals or stiffeners
l = the length, in m, of the longitudinals, stiffener, transverse web or girder, between supports
σ_a = design stress, in N/mm^2 given in Table 3/10.1
= $0.55\sigma_y$, bottom longitudinals, slamming, craft L>50m
= $0.30\sigma_y$, bottom longitudinals, sea pressure
= $0.80\sigma_y$, bottom transverses, slamming
= $0.50\sigma_y$, bottom transverses, sea pressure
= $0.60\sigma_y$, side longitudinals, slamming
= $0.50\sigma_y$, side longitudinals, slammingea pressure
= $0.80\sigma_y$, side transverses, slamming
= $0.50\sigma_y$, sidetransverses, sea pressure
σ_y = as-welded yield strength
= 165 N/mm^2, 5083-H116 Al (built up framing)
= 138 N/mm^2, 6061-T6 (stiffeners)

$\therefore \sigma_a$ = 75.9 N/mm^2, bottom longitudinals, slamming
= 41.4 N/mm^2, bottom longitudinals, sea pressure
= 132.0 N/mm^2, bottom transverse, slamming
= 82.5 N/mm^2, bottom transverse, sea pressure
= 82.8 N/mm^2, side longitudinals, slamming
= 69.0 N/mm^2, side longitudinals, sea pressure
= 132.0 N/mm^2, side transverses, slamming
= 82.5 N/mm^2, side transverses, sea pressure

therefore, the required section modulus is:

Bottom Longitudinals

	p	s	l	σ_a	SM	
	kN/m^2	m	m	N/mm^2	cm^3	
LCG						
sea press	72.54	0.26	0.8	41.4	24.3	cm^3
slamming	245.85	0.26	0.8	75.9	44.9	cm^3 @ 35 knots
	280.36	0.26	0.8	75.9	51.2	cm^3 @ 40 knots
	319.47	0.26	0.8	75.9	58.3	cm^3 @ 45 knots
	363.19	0.26	0.8	75.9	66.3	cm^3 @ 50 knots
0.75L						
sea press	72.54	0.26	0.8	41.4	24.3	cm^3
slamming	233.79	0.26	0.8	75.9	42.7	cm^3 @ 35 knots
	273.84	0.26	0.8	75.9	50.0	cm^3 @ 40 knots
	319.22	0.26	0.8	75.9	58.3	cm^3 @ 45 knots
	369.95	0.26	0.8	75.9	67.6	cm^3 @ 50 knots
0.875L						
sea press	72.54	0.26	0.8	41.4	24.3	cm^3
slamming	137.15	0.26	0.8	75.9	25.0	cm^3 @ 35 knots
	162.22	0.26	0.8	75.9	29.6	cm^3 @ 40 knots
	190.63	0.26	0.8	75.9	34.8	cm^3 @ 45 knots
	222.38	0.26	0.8	75.9	40.6	cm^3 @ 50 knots

Bottom Transverse Framing

	p	s	l	σ_a	SM	
LCG	kN/m^2	m	m	N/mm^2	cm^3	
sea press	72.54	0.8	1.82	82.5	194.1	cm^3
slamming	233.55	0.8	1.82	132.0	390.6	cm^3 @ 35 knots
	266.34	0.8	1.82	132.0	445.4	cm^3 @ 40 knots
	303.50	0.8	1.82	132.0	507.5	cm^3 @ 45 knots
	345.03	0.8	1.82	132.0	577.0	cm^3 @ 50 knots
0.75L						
sea press	72.54	0.8	1.82	82.5	194.1	cm^3
slamming	222.10	0.8	1.82	132.0	371.4	cm^3 @ 35 knots
	260.14	0.8	1.82	132.0	435.0	cm^3 @ 40 knots
	303.26	0.8	1.82	132.0	507.1	cm^3 @ 45 knots
	351.45	0.8	1.82	132.0	587.7	cm^3 @ 50 knots
0.875L						
sea press	72.54	0.8	1.82	82.5	194.1	cm^3
slamming	130.29	0.8	1.82	132.0	217.9	cm^3 @ 35 knots
	154.11	0.8	1.82	132.0	257.7	cm^3 @ 40 knots
	181.10	0.8	1.82	132.0	302.8	cm^3 @ 45 knots
	211.27	0.8	1.82	132.0	353.3	cm^3 @ 50 knots

Side Longitudinals

	p	s	l	σ_a	SM	
	kN/m^2	m	m	N/mm^2	cm^3	
LCG						
sea press	19.73	0.40	0.80	69.0	6.1	cm^3
slamming	-	-	-	-	6.1	cm^3 @ 35 knots
	-	-	-	-	6.1	cm^3 @ 40 knots
	-	-	-	-	6.1	cm^3 @ 45 knots
	-	-	-	-	6.1	cm^3 @ 50 knots
0.75L						
sea press	19.73	0.40	0.80	69.0	6.1	cm^3
slamming	-	-	-	-	6.1	cm^3 @ 35 knots
	-	-	-	-	6.1	cm^3 @ 40 knots
	-	-	-	-	6.1	cm^3 @ 45 knots
	-	-	-	-	6.1	cm^3 @ 50 knots
0.875L						
sea press	19.73	0.40	0.80	69.0	6.1	cm^3
slamming	74.34	0.40	0.80	82.8	19.1	cm^3 @ 35 knots
	87.93	0.40	0.80	82.8	22.6	cm^3 @ 40 knots
	103.33	0.40	0.80	82.8	26.6	cm^3 @ 45 knots
	120.54	0.40	0.80	82.8	31.0	cm^3 @ 50 knots

Side Transverse Framing

	p	s	l	σ_a	SM	
	kN/m^2	m	m	N/mm^2	cm^3	
LCG						
sea press	19.73	0.8	2.42	82.5	93.6	
slamming	-	-	-	-	93.6	cm^3 @ 35 knots
	-	-	-	-	93.6	cm^3 @ 40 knots
	-	-	-	-	93.6	cm^3 @ 45 knots
	-	-	-	-	93.6	cm^3 @ 50 knots
0.75L						
sea press	19.73	0.8	2.51	82.5	100.4	
slamming	-	-	-	-	100.4	cm^3 @ 35 knots
	-	-	-	-	100.4	cm^3 @ 40 knots
	-	-	-	-	100.4	cm^3 @ 45 knots
	-	-	-	-	100.4	cm^3 @ 50 knots
0.875L						
sea press	19.73	0.8	2.85	82.5	129.2	
slamming	65.42	0.8	2.85	132.0	267.7	cm^3 @ 35 knots
	77.38	0.8	2.85	132.0	316.6	cm^3 @ 40 knots
	90.93	0.8	2.85	132.0	372.1	cm^3 @ 45 knots
	106.08	0.8	2.85	132.0	434.1	cm^3 @ 50 knots

APPENDIX C

Calculation of the hull girder strength, design pressures and local scantlings for a 61m, 50 knot high speed craft in accordance with the American Bureau of Shipping's "Guide for Building and Classing High Speed Naval Craft", 2003

PART 3, CHAPTER 2, SECTION 1
Primary Hull Strength

1 Longitudinal Hull Girder Strength - Monohulls

The equations are, in general, valid for craft having breadths, B, not greater than twice their depths, D, as defined in Section 3-1-1.

1.1 Section Modulus

1.1.1 All craft. The required hull girder section modulus SM at amidships is to be not less than given by the following equation:

$$SM = C_1 C_2 L^2 B (C_b + 0.7) K_3 CQ \quad \text{cm}^2\text{m}$$

where:

C_1 = 0.044L + 3.75 L ≤ 90m
= 6.434
C_2 = 0.01
L = length of craft on summer load line, m, as defined in section 3/1
= 61.0 m
B = breadth of craft, m
= 12.9 m
V = maximum speed in calm water, knots
= varies from 35 to 50 knots
C_b = block coefficient but not less than 0.45 for L < 35m or 0.6 for L ≥ 61m. The minimum C_b for lengths between 35m and 61m is to be determined by interpolation
= 0.451 design (actual)
= 0.6 minimum required

$$K_3 = 0.70 + 0.30\left[\frac{V/\sqrt{L}}{2.36}\right]$$

= 1.270 for V = 35 knots
= 1.351 for V = 40 knots
= 1.432 for V = 45 knots
= 1.514 for V = 50 knots
However, K_3 is not to be taken less than 1, nor more than 1.30
$\therefore K_3$ = 1.27 for V = 35 knots
= 1.30 for V = 40 knots
= 1.30 for V = 45 knots
= 1.30 for V = 50 knots

C = 0.9 for aluminum craft
Q = $0.9 + q_5$ but not less than Q_o
σ_y = 165 = minimum yield strength of welded aluminum, Mpa
σ_u = 276 = minimum tensile strength of welded aluminum, Mpa
q_5 = $115/\sigma_y$
= 0.69697

Q_o = $635/(\sigma_y + \sigma_u)$
= 1.44
Q = 1.60 calculated value ($0.9 + q_5$ but not less than Q_o)
$\therefore Q$ = 1.60 minimum required

therefore:

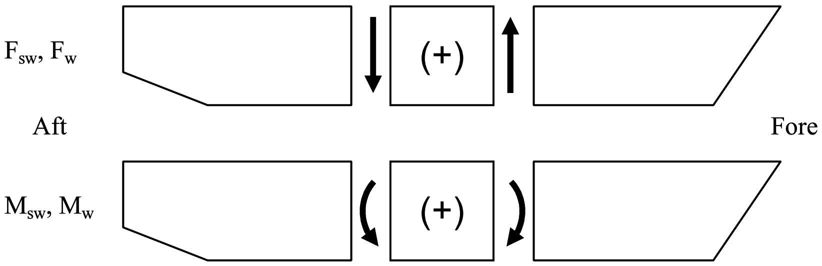
$$SM = C_1 C_2 L^2 B (C_b + 0.7) K_3 CQ$$
= 6.434 x 0.01 x 61^2 x 12.9 x (0.6 + 0.7) x K3 x 0.9 x 1.6
= 5,781 x K_3

SM = 7,340 cm^2m for V = 35 knots
= 7,516 cm^2m for V = 40 knots
= 7,516 cm^2m for V = 45 knots
= 7,516 cm^2m for V = 50 knots

1.1.2 Craft 24m in Length and Over. In addition to meeting the above criteria in 3-2-1/1.1.1, craft of 24m in length or greater are to comply with the following requirements.

1.1.2(a) Sign Convention of Bending Moment and Shear Force. The sign convention of bending moment and shear force is as shown in Figure 3-2-1/Figure 1.

Figure 1
Sign Convention



1.1.2(b) Wave Bending Moment Amidships. The wave bending moment, expressed in kN-m, may be obtained from the following equations.

M_{ws} = $-k_1 C_1 L^2 B (C_b + 0.7)$ x 10^{-3} Sagging moment
M_{wh} = $+k_2 C_1 L^2 B C_b$ x 10^{-3} Hogging moment

k_1 = 110
k_2 = 190

and C_1, L, B, and C_b are as defined in 3-2-1/1.1.1

therefore:

M_{ws} = -44,164 kN-m Sagging moment
M_{wh} = 35,208 kN-m Hogging moment

1.1.2(c) Still Water Bending Moment. The still water bending moment in the hogging and sagging is to be submitted. In case detailed information is not yet available the still water bending moment can be determined from the following:

$M_{sws} = 0$ Sagging moment

$M_{sws} = 0.375 f_p C_1 C_2 L^2 B (C_b + 0.7)$ Hogging moment

where:

f_p = 17.5 kN/cm^2
C_1, C_2, L, B, C_b are as defined in 3-2-1/1.1:
C_1 = 6.43
C_2 = 0.01
L = 61.0 m
B = 12.9 m
C_b = 0.6

therefore:

M_{sws} = -6,993 kN-m Sagging moment (from design information)
M_{swh} = 26,348 kN-m Hogging moment

1.1.2(d) Slamming Induced Bending Moment. The slamming induced bending moment in kN-m, can be determined from the following equation:

$M_{sl} = C_3 \Delta (1 + n_{cg})(L - l_s)$

where:
C_3 = 1.25
Δ = full load displacement, metric tons
= 950 metric tonnes
l_s = length of slam load, m
= A_R / B_{wl}
$A_R = 0.697 \Delta / d$ m^2
d = full load draft, m
= 2.7 m
$\therefore A_R$ = 245.241 m^2
B_{wl} = waterline breadth at LCG, m
= 11.7 m
$\therefore l_s$ = 20.96 m
n_{cg} = maximum acceleration as defined in 3-2-2/1.1, but $(1+n_{cg})$ is not to be taken less than indicated in 3-2-1/Table 1.

TABLE 1 Minimum Vertical acceleration

Δ (mt)	$1+n_{cg}$ (g)	
180	3	
400	2	
950	*1.3125*	*(by interpolation)*
≥ 1200	1	

$\therefore$ minimum n_{cg} = 0.3125

acceleration as defined in 3-2-2/1.1:

$\therefore$ n_{cg} = 0.69551 g's for V = 35 knots, $h_{1/3}$ = 4.00 m

= 0.90842 g's for V = 40 knots, $h_{1/3}$ = 4.00 m

= 1.14972 g's for V = 45 knots, $h_{1/3}$ = 4.00 m

= 1.41941 g's for V = 50 knots, $h_{1/3}$ = 4.00 m

therefore:

$M_{sl} = C_3\Delta(1+n_{cg})(L\text{-}l_s)$

= 80,616 kNm, V = 35 knots, $h_{1/3}$ = 4.00 m

= 90,739 kNm, V = 40 knots, $h_{1/3}$ = 4.00 m

= 102,212 kNm, V = 45 knots, $h_{1/3}$ = 4.00 m

= 115,035 kNm, V = 50 knots, $h_{1/3}$ = 4.00 m

3. *Section Modulus.* The required hull-girder section modulus for 0.4*L* amidships is to be obtained from the following equation:

$$SM = \frac{M_t C Q}{f_p}\ \text{cm}^2\text{m}$$

where

M_t = maximum total bending moment. To be taken as the greatest of:

= $M_{swh} + M_{wh}$

= $-M_{sws} - M_{ws}$

= M_{sl}

M_{swh} = maximum still-water bending moment in the hogging condition, in kN-m, as determined in 3-2-1/1.1.2c

= 26,348 kN-m

M_{sws} = maximum still-water bending moment in the sagging condition, in kN-m, as determined in 3-2-1/1.1.2c

= -6,993 kN-m

M_{wh} = maximum wave induced bending moment in the hogging condition, in kN-m, as determined in 3-2-1/1.1.2b

= 35208 kN-m

M_{ws} = maximum wave induced bending moment in the sagging condition, in kN-m, as determined in 3-2-1/1.1.2b

= -44164 kN-m

M_{sl} = maximum slamming induced bending moment in the sagging condition, in kN-m, as determined in 3-2-1/1.1.2d

= 80,616 kNm, V = 35 knots, $h_{1/3}$ = 4.00 m
= 90,739 kNm, V = 40 knots, $h_{1/3}$ = 4.00 m
= 102,212 kNm, V = 45 knots, $h_{1/3}$ = 4.00 m
= 115,035 kNm, V = 50 knots, $h_{1/3}$ = 4.00 m

f_p = 17.5 kN/cm^2
C, Q are as defined in 3-2-1/1.1.1

$M_{swh} + M_{wh}$ = 61,555 kN-m
$-M_{sws} - M_{ws}$ = 51,157 kN-m

therefore:

M_t = 80,616 kNm, V = 35 knots, $h_{1/3}$ = 4.00 m
= 90,739 kNm, V = 40 knots, $h_{1/3}$ = 4.00 m
= 102,212 kNm, V = 45 knots, $h_{1/3}$ = 4.00 m
= 115,035 kNm, V = 50 knots, $h_{1/3}$ = 4.00 m

therefore, the section modulus required craft over 24m by 3-2-1/1.1.2:
SM = 6,634 cm^{2}m for V = 35 knots, $h_{1/3}$ = 4.0m
= 7,467 cm^{2}m for V = 40 knots, $h_{1/3}$ = 4.0m
= 8,411 cm^{2}m for V = 45 knots, $h_{1/3}$ = 4.0m
= 9,466 cm^{2}m for V = 50 knots, $h_{1/3}$ = 4.0m

The minimum required section modulus as per each of the above sections is:

3-2-1/1.1.1 all craft	3-2-1/1.1.2 craft 61m and over	
7,340	6,634	cm^{2}m for V = 35 knots
7,516	7,467	cm^{2}m for V = 40 knots
7,516	8,411	cm^{2}m for V = 45 knots
7,516	9,466	cm^{2}m for V = 50 knots

therefore the minimum required section modulus is:
SM = 7,340 cm^{2}m for V = 35 knots
= 7,516 cm^{2}m for V = 40 knots
= 8,411 cm^{2}m for V = 45 knots
= 9,466 cm^{2}m for V = 50 knots

PART 3, CHAPTER 2, SECTION 2

Design Pressures

1 Monohulls

The bottom and side pressures are to be checked using the displacement (D), speed (V), draft (d), and running trim (τ) in the full load, half load, and light load conditions. If the craft is receiving a freeboard assignment, the parameters used in the full load condition are to coincide with the assigned freeboard. If the craft is not receiving a freeboard assignment, the parameters used in the full load condition are to correspond to the condition of the craft with the maximum operating deadweight. The parameters used in the half load condition are to correspond to the condition of the craft with 50% of the maximum operating deadweight, and the parameters used in the light load condition are to correspond to the condition of the craft with 10% of the maximum operating deadweight plus the maximum speed of the craft.

1.1 Bottom Structure Design Pressure

The minimum bottom design pressure is to be the greater of those given in the following equations, for the location under consideration. Bottom structure design pressures are dependent upon the service in which a craft operates. The bottom design pressure applies to hull bottoms below the chines or the upper turn of the bilge.

1.1.1 Bottom Slamming Pressure

$$p_{bcg} = \frac{N_1 \Delta}{L_w B_w}[1 + n_{cg}]F_D \ \text{kN/m}^2$$

$$p_{bxx} = \frac{N_1 \Delta}{L_w B_w}[1 + n_{xx}]\left[\frac{70 - \beta_{xx}}{70 - \beta_{cg}}\right]F_D \ \text{kN/m}^2$$

1.1.2 Bottom slamming for Craft Less Than 61m (200ft)

The design pressure may be:

$$p_{bxx} = \frac{N_1 \Delta}{L_w B_w}[1 + n_{cg}]F_D F_V \ \text{kN/m}^2$$

1.1.3 Hydrostatic Pressure

$$p_d = N_3(0.64H + d) \ \text{kN/m}^2$$

where:

p_{bcg} = bottom design pressure at LCG, kN/m^2

p_{bxx} = bottom design pressure at any section clear of LCG, kN/m^2

p_d = bottom design pressure based on hydrostatic forces, kN/m^2

n_{cg} = the vertical acceleration of the craft as determined by a model test, theoretical computation, or service experience (see Section 3-1-3). If this information is not readily avaliable during the early stages of design, the following formula utilizing the average 1/100th highest vertical acclerations at LCG can be used:

$$n_{cg} = N_2\left[\frac{12h_{1/3}}{B_w} + 1.0\right]\tau\left[50 - \beta_{cg}\right]\frac{V^2(B_w)^2}{\Delta} \ \text{g's}$$

Note that g's are the dimensionless ratio of the accleration to gravitational acceleration at sea level (9.8 m/s2). The vertical acceleration, n_{cg}, is typically not to be taken greater than the following:

$$n_{cg} = 1.39 + 0.256\frac{V}{\sqrt{L}}$$

= 2.537 g's for V = 35 knots

= 2.701 g's for V = 40 knots

= 2.865 g's for V = 45 knots

= 3.029 g's for V = 50 knots

n_{xx} = average of the 1/100th highest vertical acclerations at any section clear LCG, corresponding to the sea state, in g's. Can be determined by the following equation:

= $n_{cg}\ K_v$

N_1 = 0.1

N_2 = 0.0078

N_3 = 9.8

Δ = displacement at the design waterline in kg

= 950,000 kg

L_w = craft length at the design waterline, displacement mode, m

= 61.0 m

B_w = maximum waterline beam, m

= 11.7 m

H = wave parameter, 0.0172L + 3.653m, generally not to be taken less than the maximum survival wave height for the craft (see 3-2-2/Table 1)

$\therefore H$ = 6.00 m (greater of (0.0172L + 3.653m), L/12, or survival wave height (3-2-2/Table 1)

$h_{1/3}$ = significant wave height, m, see 3-2-2/Table 1

= 4.00 m, Operational

Table 1: Design Significant Wave Heights and Speeds

	Operational		Survival	
	$h_{1/3}$	V	$h_{1/3}$	V
Naval Craft	4.0m	$V_m^{(2)}$	6.0m $^{(1)}$	10 kts$^{(3)}$
Coastal Naval Craft	2.5m	$V_m^{(2)}$	4.0m	10 kts$^{(3)}$
Riverine Naval Craft	0.5m	$V_m^{(2)}$	1.25m	10 kts$^{(3)}$

Notes 1: Not to be taken less than L/12 = 5.08 m

2: V_m = maximum speed for the craft in the design condition specified in 3-2-2/1

3: This speed to be verified by the Naval Admninistration

τ= running trim at V, in degrees, but generally not to be taken as less than 4 deg. for craft L<50m nor less than 3 deg. for L<125m. Special consideration will be given to desgner's values predicted from model tests.

= 3.0 degrees (sea trial data) 2.1

β_{cg} = deadrise at LCG, degrees, generally not to be taken less than 10 deg. or more than 30 degrees.

= 17 degrees

β_{xx} = deadrise at any section clear of LCG, degrees, generally not to be taken less than 10 deg. or more than 30 degrees.

$\beta_{0.75L}$ = 29 degrees

$\beta_{0.875L}$ = 30 degrees

V = craft design speed in knots, see 3-2-2/Table 1
= varies from 35 to 50 knots
F_D = design area factor given in 3-2-2/Figure 6 for given values of A_D and A_R. Generally not to be taken less than 0.40. See 3-2-2/Table 2 for minimum values of F_D for craft less than 24 m (79 ft) in length.

F_V = vertical acceleration distribution factor given in 3-2-2/Figure 8
= 1.00 at 0.75L forward of AP
= 1.00 at 0.875L forward of AP
K_V = vertical acceleration distribution factor given in 3-2-2/Figure 7
= 1.50 at 0.75L forward of AP
= 1.75 at 0.875L forward of AP
A_D = design area, cm^2. for plating it is the actual area of the shell plate panel but not to be taken as more than $2s^2$. For longitudinals, stiffeners, transverses and girders it is the shell area supported by the longitudinal, stiffener, transverse or girder; for thransverses and girders the area used need not be taken less than $0.33l^2$.
A_R = reference area, cm^2.
= $6.95\Delta/d$ cm2.
= 2.E+06 cm^2
s = spacing of longitudinals or stiffeners, cm
= 26 cm
l = length of unsupported span of internals, see 3-2-4/1.3.1
l_{st} = 80 cm, stiffeners
l_{tr} = 182 cm, transverses (assume 7s)
d = stationary draft, in m, vertical distance from outer surface of shell measured at centerline to design waterline at middle of the design waterline length, but generally not to be taken as less than 0.04L. See 3-2-2/1
= 2.7 m

for plating:
$2s^2$ = 1352 cm^2
sl_{st} = 2080 cm^2
$\therefore A_D$ = 1352 cm^2
A_D/A_R = 0.001
$\therefore F_D$ = 1.00 greater of 0.4 or value from 3-2-2/Figure 6

for stiffeners:
A_D = 2080 cm^2 (spacing x length)
A_D/A_R = 0.001
$\therefore F_D$ = 1.00 greater of 0.4 or value from 3-2-2/Figure 6

for transverses:
$0.33l_{tr}^2$ = 10930.9 cm^2
$l_{tr}l_{st}$ = 14560 cm^2
$\therefore A_D$ = 14560 cm^2
A_D/A_R = 0.006
$\therefore F_D$ = 0.84 greater of 0.4 or value from 3-2-2/Figure 6

Since

$$n_{cg} = N_2\left[\frac{12h_{1/3}}{B_w}+1.0\right]\tau\left[50-\beta_{cg}\right]\frac{V^2(B_w)^2}{\Delta}\ \text{g's}$$

and

$$n_{xx} = n_{cg}\,K_v$$

therefore:

n_{cg} = 0.696 $n_{0.75L}$ = 1.043 $n_{0.875L}$ = 1.217 g's for V = 35 knots, $h_{1/3}$ = 4.00 m
= 0.908 = 1.363 = 1.590 g's for V = 40 knots, $h_{1/3}$ = 4.00 m
= 1.150 = 1.725 = 2.012 g's for V = 45 knots, $h_{1/3}$ = 4.00 m
= 1.419 = 2.129 = 2.484 g's for V = 50 knots, $h_{1/3}$ = 4.00 m

Summarizing, the design pressures as per 3-2-2/1.1.1 *Bottom Slamming Pressure*, are:

$$p_{bcg} = \frac{N_1\Delta}{L_wB_w}[1+n_{cg}]F_D\ \text{kN/m}^2$$

$$p_{bxx} = \frac{N_1\Delta}{L_wB_w}[1+n_{xx}]\left[\frac{70-\beta_{xx}}{70-\beta_{cg}}\right]F_D\ \text{kN/m}^2$$

and F_D = 1.00 plating
= 1.00 stiffeners
= 0.84 transverses

Therefore, the design pressures as per 3-2-2/1.1.1 *Bottom Slamming Pressure*, for plating are:

p_{bcg} = 225.69 $p_{b0.75L}$ = 210.40 $p_{b0.875L}$ = 222.73 kN/m^2, V = 35 knots, $h_{1/3}$ = 4.00 m
= 254.03 = 243.28 = 260.16 kN/m^2, V = 40 knots, $h_{1/3}$ = 4.00 m
= 286.15 = 280.55 = 302.59 kN/m^2, V = 45 knots, $h_{1/3}$ = 4.00 m
= 322.04 = 322.21 = 350.00 kN/m^2, V = 50 knots, $h_{1/3}$ = 4.00 m

for stiffeners:

p_{bcg} = 225.69 $p_{b0.75L}$ = 210.40 $p_{b0.875L}$ = 222.73 kN/m^2, V = 35 knots, $h_{1/3}$ = 4.00 m
= 254.03 = 243.28 = 260.16 kN/m^2, V = 40 knots, $h_{1/3}$ = 4.00 m
= 286.15 = 280.55 = 302.59 kN/m^2, V = 45 knots, $h_{1/3}$ = 4.00 m
= 322.04 = 322.21 = 350.00 kN/m^2, V = 50 knots, $h_{1/3}$ = 4.00 m

for transverses:

p_{bcg} = 189.58 $p_{b0.75L}$ = 176.73 $p_{b0.875L}$ = 187.10 kN/m^2, V = 35 knots, $h_{1/3}$ = 4.00 m
= 213.38 = 204.36 = 218.54 kN/m^2, V = 40 knots, $h_{1/3}$ = 4.00 m
= 240.36 = 235.66 = 254.17 kN/m^2, V = 45 knots, $h_{1/3}$ = 4.00 m
= 270.52 = 270.65 = 294.00 kN/m^2, V = 50 knots, $h_{1/3}$ = 4.00 m

and the design pressures as per 3-2-2/1.1.3 *Hydrostatic Pressure* are:

$p_d = N_3(0.64H + d)$ kN/m^2

$= 64.09$ kN/m^2

The minimum design pressure for the bottom is the greater of that calculated by 3-2-2/1.1.1 and 3-2-2/1.1.3, therefore the minimum bottom design pressures are as follows:
for plating:

p_{bcg} =	225.69	$p_{b0.75L}$ =	210.40	$p_{b0.875L}$ =	222.73	kN/m^2 ,V =	35	knots, $h_{1/3}$ =	4.00 m
=	254.03	=	243.28	=	260.16	kN/m^2 ,V =	40	knots, $h_{1/3}$ =	4.00 m
=	286.15	=	280.55	=	302.59	kN/m^2 ,V =	45	knots, $h_{1/3}$ =	4.00 m
=	322.04	=	322.21	=	350.00	kN/m^2 ,V =	50	knots, $h_{1/3}$ =	4.00 m

for stiffeners:

p_{bcg} =	225.69	$p_{b0.75L}$ =	210.40	$p_{b0.875L}$ =	222.73	kN/m^2 ,V =	35	knots, $h_{1/3}$ =	4.00 m
=	254.03	=	243.28	=	260.16	kN/m^2 ,V =	40	knots, $h_{1/3}$ =	4.00 m
=	286.15	=	280.55	=	302.59	kN/m^2 ,V =	45	knots, $h_{1/3}$ =	4.00 m
=	322.04	=	322.21	=	350.00	kN/m^2 ,V =	50	knots, $h_{1/3}$ =	4.00 m

for transverses:

p_{bcg} =	189.58	$p_{b0.75L}$ =	176.73	$p_{b0.875L}$ =	187.10	kN/m^2 ,V =	35	knots, $h_{1/3}$ =	4.00 m
=	213.38	=	204.36	=	218.54	kN/m^2 ,V =	40	knots, $h_{1/3}$ =	4.00 m
=	240.36	=	235.66	=	254.17	kN/m^2 ,V =	45	knots, $h_{1/3}$ =	4.00 m
=	270.52	=	270.65	=	294.00	kN/m^2 ,V =	50	knots, $h_{1/3}$ =	4.00 m

1.3 Side and Transom Structure, Design Pressure

The side pressure, P_s, is to be not less than given by equations:

1.3.1 Slamming Pressure

$$p_{sxx} = \frac{N_1\Delta}{L_w B_w}[1 + n_{xx}]\left[\frac{70 - \beta_{Sxx}}{70 - \beta_{Scg}}\right]F_D \ \text{kN/m}^2$$

1.3.2 Hydrostatic Pressure

$p_s = N_3(H_s - y)$ kN/m^2

1.3.3 Fore End

$p_{sf} = 0.28F_a C_F N_3(0.22 + 0.15 \tan\alpha)(0.4V \sin\beta + 0.6\sqrt{L})^2$

where

p_{sxx} = side design slamming pressure at any section clear of LCG, in kN/m^2. For craft greater than 24m (79 ft) in length, the side design slamming pressure only applies to locations below L/12 above baseline and forward of 0.125L

p_s = side design pressure due to hydrostatic forces, in kN/m^2, but is not to be taken less than the following:

= $0.05 N_3 L$ kN/sq.m at or below L/15 above the base line or any height above base line forward of 0.125L from the stem
= 29.89 kN/sq.m at or below 4.07 m above BL or at any height fwd of 0.125L from the stem
= $0.033 N_3 L$ kN/sq.m above L/15 above the base line, aft of 0.125L from the stem
= 19.73 kN/sq.m above 4.07 m above BL and aft of 0.125L from the stem
p_{sf} = side design pressure for forward of 0.125L from the stem
H_s = $0.64H + d$ in meters where H and d are defined in 3-2-2/1.1
H = 6.00 m
d = 2.70 m
$\therefore H_s$ = 6.54 m
y = distance above baseline, m, of location being considered
= 5.80 m @ CG
= 5.80 m @ 0.75L
= 5.845 m @ 0.875L
L = craft length as defined in section 3-1-1/3
= 61.00 m
β_{sx} = deadrise of side shell at any section clear of LCG, degrees, generally not to be taken greater than 55 degrees.
$\beta_{S0.75L}$ = 55 degrees
$\beta_{S0.875L}$ = 55 degrees
C_F = $0.0125L$ for L<80 m
= 0.7625
F_a = 3.25 for plating
= 1.0 for longitudinals, transverses and girders
α = flare angle, the angle between a vertical line and the tangent to the shell plating, measured in a vertical plane at 90 degrees to the horizontal tangent to the shell, see 3-2-2/Figure 1.
= 29 degrees
β= entry angle of side shell, the angle between a longitudinal line parallel to the centerline and the horizontal tangent of the side shell, see 3-2-2/Figure 1.
= 15 degrees
$N_1, N_3, \Delta, L_w, B_w, V, n_{xx}$, b_{cg}, $H, d,$ and F_d are as defined in 3-2-2/1.1:
N_1 = 0.1
N_3 = 9.8
Δ = 950,000 kg
L_w = 61.0 m
B_w = 11.7 m
V = craft design speed in knots, generally the maximum speed in calm water
= varies from 35 to 50 knots
n_{cg} = 0.696 $n_{0.75L}$ = 1.043 $n_{0.875L}$ = 1.217 g's for V = 35 knots, $h_{1/3}$ = 4.00 m
= 0.908 1.363 1.590 g's for V = 40 knots, $h_{1/3}$ = 4.00 m
= 1.150 1.725 2.012 g's for V = 45 knots, $h_{1/3}$ = 4.00 m
= 1.419 2.129 2.484 g's for V = 50 knots, $h_{1/3}$ = 4.00 m
$\beta_{s\text{-cg}}$ = deadrise of side shell at LCG, degrees, generally not to be taken greater than 55 degrees.
= 55 degrees

F_D = design area factor given in 3-2-2/Figure 6 for given values of A_D and A_R. Generally not to be taken less than 0.40. See 3-2-2/Table 2 for minimum values of F_D for craft less than 24 m (79 ft) in length.

A_R = reference area, cm^2.
= $6.95\Delta/d$ cm2.
= 2.E+06 cm^2
A_D = design area, cm^2. for plating it is the actual area of the shell plate panel but not to be taken as more than $2s^2$. For longitudinals, stiffeners, transverses and girders it is the shell area supported by the longitudinal, stiffener, transverse or girder; for transverses and girders the area used need not be taken less than $0.33l^2$.
s = spacing of longitudinals or stiffeners, cm
= 40 cm
l = length of unsupported span of internals, see 3/10.1.2a
l_{st} = 80 cm, stiffeners
l_{tr} = 242.4 cm, transverse @ CG
= 251.0 cm, transverse @ 0.75L
= 284.7 cm, transverse @ 0.875L

for plating:

$2s^2$ = 3200 cm^2
sl_{st} = 3200 cm^2
$\therefore A_D$ = 3200 cm^2
A_D/A_R = 0.001
$\therefore F_D$ = 1.00 greater of 0.4 or value from 3-2-2/Figure 6

for stiffeners:

A_D = 3200 cm^2 (spacing x length)
A_D/A_R = 0.001
$\therefore F_D$ = 1.00 greater of 0.4 or value from 3-2-2/Figure 6

for transverses:

$0.33l_{tr}^2$ =	19383.4	cm^2 @ CG	20784.7	cm^2, 0.75L	26746.9	cm^2, 0.875L
$l_{tr}l_{st}$ =	19388.7	cm^2 @ CG	20077.3	cm^2, 0.75L	22775.6	cm^2, 0.875L
$\therefore A_D$ =	19388.7	cm^2 @ CG	20784.7	cm^2, 0.75L	26746.9	cm^2, 0.875L
A_D/A_R =	0.008	@CG	0.008	@ 0.75L	0.011	@ 0.875L
$\therefore F_D$ =	greater of 0.4 or value from 3-2-2/Figure 6					
=	0.80	@CG	0.8	@ 0.75L	0.74	@ 0.875L

The design pressures as per 3-2-2/1.3.1 *Side and Transom Structure, Slamming Pressure*, are applicable below L/12 (5.08m) above baseline. The locations considered are above this point so 3-2-2/1.3.1 does not apply.

The design hydrostatic pressures as per 3-2-2/1.3.2 *Hydrostatic Pressure* are:

p_s = $N_3(H_s - y)$ but not less than $0.033N_3L$ kN/m^2
p_{scg} = 7.25 but not less than 19.73 kN/m^2
$p_{s0.75L}$ = 7.25 but not less than 19.73 kN/m^2
$p_{s0.875L}$ = 6.81 but not less than 19.73 kN/m^2

The design side shell pressure at 0.875L and forward as per 3-2-2/1.3.3 *Fore End Pressure* is:

$$p_{sf} = 0.28 F_a C_F N_3 (0.22 + 0.15 \tan\alpha)(0.4V \sin\beta + 0.6\sqrt{L})^2$$

for plating, $F_a = 3.25$

$p_{sf} =$ 142.3 kN/m^2 ,V = 35 knots
= 160.6 kN/m^2 ,V = 40 knots
= 180.0 kN/m^2 ,V = 45 knots
= 200.5 kN/m^2 ,V = 50 knots

for beams, $F_a = 1.00$

$p_{sf} =$ 43.8 kN/m^2 ,V = 35 knots
= 49.4 kN/m^2 ,V = 40 knots
= 55.4 kN/m^2 ,V = 45 knots
= 61.7 kN/m^2 ,V = 50 knots

The minimum design pressure for the side shell is the greater of that calculated by 3-2-2/1.3.1-3, therefore the minimum side shell design pressures are as follows:

for plating:

p_{bcg} = 19.7	$p_{b0.75L}$ = 19.7	$p_{b0.875L}$ = 142.3	kN/m^2 ,V = 35	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 160.6	kN/m^2 ,V = 40	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 180.0	kN/m^2 ,V = 45	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 200.5	kN/m^2 ,V = 50	knots, $h_{1/3}$ = 4.00 m

for stiffeners:

p_{bcg} = 19.7	$p_{b0.75L}$ = 19.7	$p_{b0.875L}$ = 43.8	kN/m^2 ,V = 35	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 49.4	kN/m^2 ,V = 40	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 55.4	kN/m^2 ,V = 45	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 61.7	kN/m^2 ,V = 50	knots, $h_{1/3}$ = 4.00 m

for transverses:

p_{bcg} = 19.7	$p_{b0.75L}$ = 19.7	$p_{b0.875L}$ = 43.8	kN/m^2 ,V = 35	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 49.4	kN/m^2 ,V = 40	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 55.4	kN/m^2 ,V = 45	knots, $h_{1/3}$ = 4.00 m
= 19.7	= 19.7	= 61.7	kN/m^2 ,V = 50	knots, $h_{1/3}$ = 4.00 m

PART 3, CHAPTER 2, SECTION 3
Plating

1 Aluminum or Steel

1.1 General

The bottom shell is to extend from the keel to the chine or upper turn of bilge. In general the side shell is to be of the same thickness from its lower limit to the gunwale.

All plating is to meet the requirements for thickness as given in 3-2-3/1.3.

In addition those areas of plating associated with primary hull strength are to meet the buckling criteria as given in 3-2-3/1.5. Where plate panels are subjected to other bending, biaxial, or a combination of stresses, they will be specially considered.

The thickness of the shell plating in way of skegs, shaft struts, hawse pipes, etc. is to be increased by 50% over that obtained from 3-2-3/1.3.

The thickness of water jet tunnels and transverse thruster tubes is to be in accordance with 3-2-3/1.7.

Where the plating forms decks for the access, operation or stowage of vehicles, the plating is in addition to meet the requirements of 3-2-3/1.9.

1.3 Thickness

The thickness of the shell, deck or bulkhead plating is to be not less than obtained by the following equaqtions, whichever is greater:

1.3.1 Lateral loading

$$t = s\sqrt{\frac{pk}{1000\ \sigma_a}}$$

s = the spacing, in mm, of the longitudinals or stiffeners
p = design pressure in kN/mm^2 given in section 3-2-2
k = plate panel aspect ratio factor, given in 3-2-2/Table 1
σ_a = design stress, in N/mm^2 given in 3-2-3/Table 2
= $0.9\sigma_y$ = 148.5 N/mm^2, bottom slamming, 0.4L
= σ_y = 165 N/mm^2, bottom slamming, outside of 0.4L
= $0.55\sigma_y$ = 90.75 N/mm^2, bottom hydrostatics
= $0.9\sigma_y$ = 148.5 N/mm^2, side slamming, 0.4L
= $0.55\sigma_y$ = 90.75 N/mm^2, side hydrostatics
σ_y = as-welded yield strength
= 165 N/mm^2, 5083-H116 Al

1.3.2 Thickness Based on Secondary Stiffening

t_{al} = 0.012s mm
s = stiffener spacing, mm

1.3.3 Minimum thickness

1.3.3(a) Bottom Shell

$t_{al} = 0.70 \sqrt{(L q_a)} + 1.0$ mm, but not less than 4.0mm

1.3.3(b) Side Shell

$t_{al} = 0.62 \sqrt{(L q_a)} + 1.0$ mm, but not less than 3.5mm

where

$q_a = 115/\sigma_{ya}$

σ_{ya} = minimum unwelded yield strength, N/mm^2

= 214 N/mm^2, 5083-H116 Al

$\therefore q_a = 0.537$ N/mm^2

The required thicknesses for the bottom and side shell plating due to lateral loading at the LCG, 0.75L and 0.875L positions as per 3-2-3/1.3.1 are:

Bottom:

	V	p	l	s	l/s	k	σ_a	t
	knots	kN/m^2	mm	mm	-	-	N/mm^2	mm
LCG								
hydrostatics		64.09	800	260	3.08	0.5	90.75	4.89
slamming	35	225.69	800	260	3.08	0.5	148.50	7.17
	40	254.03	800	260	3.08	0.5	148.50	7.60
	45	286.15	800	260	3.08	0.5	148.50	8.07
	50	322.04	800	260	3.08	0.5	148.50	8.56
0.75L								
hydrostatics		64.09	800	260	3.08	0.5	90.75	4.89
slamming	35	210.40	800	260	3.08	0.5	148.50	6.92
	40	243.28	800	260	3.08	0.5	148.50	7.44
	45	280.55	800	260	3.08	0.5	148.50	7.99
	50	322.21	800	260	3.08	0.5	148.50	8.56
0.875L								
hydrostatics		64.09	800	260	3.08	0.5	90.75	4.89
slamming	35	222.73	800	260	3.08	0.5	165.00	6.75
	40	260.16	800	260	3.08	0.5	165.00	7.30
	45	302.59	800	260	3.08	0.5	165.00	7.87
	50	350.00	800	260	3.08	0.5	165.00	8.47

Side:

	V	p	l	s	l/s	k	σ_a	t
	knots	kN/m^2	mm	mm	-	-	N/mm^2	mm
LCG								
hydrostatics		19.73	800	400	2.00	0.5	90.75	4.17
slamming	35	-	800	400	2.00	0.5	n/a	n/a
	40	-	800	400	2.00	0.5	n/a	n/a
	45	-	800	400	2.00	0.5	n/a	n/a
	50	-	800	400	2.00	0.5	n/a	n/a
0.75L								
hydrostatics		19.73	800	400	2.00	0.5	90.75	4.17
slamming	35	-	800	400	2.00	0.5	n/a	n/a
	40	-	800	400	2.00	0.5	n/a	n/a
	45	-	800	400	2.00	0.5	n/a	n/a
	50	-	800	400	2.00	0.5	n/a	n/a
0.875L								
hydrostatics		19.73	800	400	2.00	0.5	90.75	4.17
slamming	35	142.34	800	400	2.00	0.5	148.5	8.76
	40	160.62	800	400	2.00	0.5	148.5	9.30
	45	180.01	800	400	2.00	0.5	148.5	9.85
	50	200.51	800	400	2.00	0.5	148.5	10.39

The required thickness as per 3-2-3/1.3.2, Secondary Stiffening

t_{al} = 0.012s mm
s = stiffener spacing, mm
= 3.12 mm, bottom (s = 260)mm
= 4.80 mm, side (s = 400)mm

The Required minimum thicknesses as per 3-2-3/1.3.3 are:

1.3.3(a) Bottom Shell

$t_{al} = 0.70\sqrt{(Lq_a)} + 1.0$ mm, but not less than 4.0mm
= 5.01 mm

1.3.3(b) Side Shell

$t_{al} = 0.62\sqrt{(Lq_a)} + 1.0$ mm, but not less than 3.5mm
= 4.55 mm

Therefore the required thickness for the bottom and side shell at LCG, 0.75L and 0.875L are:

	bottom plating	side plating
LCG	7.17 mm @ 35 knots	4.80 mm @ 35 knots
	7.60 mm @ 40 knots	4.80 mm @ 40 knots
	8.07 mm @ 45 knots	4.80 mm @ 45 knots
	8.56 mm @ 50 knots	4.80 mm @ 50 knots
0.75L	6.92 mm @ 35 knots	4.80 mm @ 35 knots
	7.44 mm @ 40 knots	4.80 mm @ 40 knots
	7.99 mm @ 45 knots	4.80 mm @ 45 knots
	8.56 mm @ 50 knots	4.80 mm @ 50 knots
0.875L	6.75 mm @ 35 knots	8.76 mm @ 35 knots
	7.30 mm @ 40 knots	9.30 mm @ 40 knots
	7.87 mm @ 45 knots	9.85 mm @ 45 knots
	8.47 mm @ 50 knots	10.39 mm @ 50 knots

PART 3, CHAPTER 2, SECTION 4
Internals

1 Aluminum and Steel

1.3 Strength and Stiffness

1.3.1 Section Moulus

The section modulus of each longitudinal, stiffener, transverse web, stringer and girder is to be not less than given by the following equation:

$$SM = \frac{83.3 \times psl^2}{\sigma_a} \text{cm}^3$$

where:

p = design pressure in kN/m^2, given in 3-2-2/1 or 3-2-2/3
s = the spacing, in m, of the longitudinals or stiffeners
l = the length, in m, of the longitudinals, stiffener, transverse web or girder, between supports
σ_a = design stress, in N/mm^2 given in 3-2-3/Table 2
= $0.65\sigma_y$ = 89.7 N/mm^2, bottom longitudinals - slamming pressure
= $0.50\sigma_y$ = 69 N/mm^2, bottom longitudinals - sea pressure
= $0.80\sigma_y$ = 132 N/mm^2, bottom transverses - slamming pressure
= $0.60\sigma_y$ = 99 N/mm^2, bottom transverses - sea pressure
= $0.60\sigma_y$ = 82.8 N/mm^2, side longitudinals - slamming pressure
= $0.50\sigma_y$ = 69 N/mm^2, side longitudinals - sea pressure
= $0.80\sigma_y$ = 132 N/mm^2, side transverses - slamming pressure
= $0.60\sigma_y$ = 99 N/mm^2, side transverses - sea pressure
σ_y = as-welded yield strength
= 138 N/mm^2, 6061-T6 (stiffeners)
= 165 N/mm^2, 5083-H116 Al (built up framing)

therefore, the required section modulus is:

Bottom Longitudinals

	V knots	p kN/m^2	s m	l m	σ_a N/mm^2	SM cm^3
LCG						
sea pressure	-	64.09	0.26	0.8	69.00	12.9
slamming	35	225.69	0.26	0.8	89.70	34.9
	40	254.03	0.26	0.8	89.70	39.3
	45	286.15	0.26	0.8	89.70	44.2
	50	322.04	0.26	0.8	89.70	49.8
0.75L						
sea pressure	-	64.09	0.26	0.8	69.00	12.9
slamming	35	210.40	0.26	0.8	89.70	32.5
	40	243.28	0.26	0.8	89.70	37.6
	45	280.55	0.26	0.8	89.70	43.4
	50	322.21	0.26	0.8	89.70	49.8

0.875L						
sea pressure	-	64.09	0.26	0.8	69.00	12.9
slamming	35	222.73	0.26	0.8	89.70	34.4
	40	260.16	0.26	0.8	89.70	40.2
	45	302.59	0.26	0.8	89.70	46.8
	50	350.00	0.26	0.8	89.70	54.1

Bottom Transverse Framing

	V	p	s	l	σ_a	SM
	knots	kN/m^2	m	m	N/mm^2	cm^3
LCG						
sea pressure	-	64.09	0.80	1.82	99.00	142.9
slamming	35	189.58	0.80	1.82	132.00	317.0
	40	213.38	0.80	1.82	132.00	356.8
	45	240.36	0.80	1.82	132.00	402.0
	50	270.52	0.80	1.82	132.00	452.4
0.75L						
sea pressure	-	64.09	0.80	1.82	99.00	142.9
slamming	35	176.73	0.80	1.82	132.00	295.5
	40	204.36	0.80	1.82	132.00	341.7
	45	235.66	0.80	1.82	132.00	394.1
	50	270.65	0.80	1.82	132.00	452.6
0.875L						
sea pressure	-	64.09	0.80	1.82	99.00	142.9
slamming	35	187.10	0.80	1.82	132.00	312.9
	40	218.54	0.80	1.82	132.00	365.5
	45	254.17	0.80	1.82	132.00	425.0
	50	294.00	0.80	1.82	132.00	491.6

Side Longitudinals

	V	p	s	l	σ_a	SM
LCG	knots	kN/m^2	m	m	N/mm^2	cm^3
sea pressure	-	19.73	0.40	0.80	69.00	6.1
slamming	35	-	-	-	-	6.1
	40	-	-	-	-	6.1
	45	-	-	-	-	6.1
	50	-	-	-	-	6.1
0.75L						
sea pressure	-	19.73	0.40	0.80	69.00	6.1
slamming	35	-	-	-	-	6.1
	40	-	-	-	-	6.1
	45	-	-	-	-	6.1
	50	-	-	-	-	6.1
0.875L						
sea pressure	-	19.73	0.40	0.80	69.00	6.1
slamming	35	43.80	0.40	0.80	82.8	11.3
	40	49.42	0.40	0.80	82.8	12.7
	45	55.39	0.40	0.80	82.8	14.3
	50	61.70	0.40	0.80	82.8	15.9

Side Transverse Framing

	V	p	s	l	σ_a	SM
LCG	knots	kN/m^2	m	m	N/mm^2	cm^3
sea pressure	-	19.73	0.80	2.42	99.0	78.0
slamming	35	-	-	-	-	78.0
	40	-	-	-	-	78.0
	45	-	-	-	-	78.0
	50	-	-	-	-	78.0
0.75L						
sea pressure	-	19.73	0.80	2.51	99.0	83.6
slamming	35	-	-	-	-	83.6
	40	-	-	-	-	83.6
	45	-	-	-	-	83.6
	50	-	-	-	-	83.6
0.875L						
sea pressure	-	19.73	0.80	2.85	99.0	107.6
slamming	35	43.80	0.80	2.85	132.0	179.2
	40	49.42	0.80	2.85	132.0	202.2
	45	55.39	0.80	2.85	132.0	226.6
	50	61.70	0.80	2.85	132.0	252.4

APPENDIX D

Calculation of the hull girder strength, design pressures and local scantlings for a 61m, 50 knot high speed craft in accordance with Det Norske Veritas' "Rules for Classification of High Speed, Light Craft and Naval Surface Craft", July 2002

PART 3 CHAPTER 1
DESIGN PRINCIPLES, DESIGN LOADS

SECTION 2 DESIGN LOADS

B. Accelerations

B 200 Design vertical acceleration

201 Design vertical acceleration at the craft's centre of gravity a_{cg} is to be specified by the builder, and is normally not to be less than:

$$a_{cg} = \frac{V}{\sqrt{L}} \frac{3.2}{L^{0.76}} f_g g_0 \; (m/s^2)$$

The design vertical acceleration is an approximation for the average 1/100 highest accelerations.

Minimum $a_{cg} = 1.0\ g_0$ for service restrictions **R0-R4**
Minimum $a_{cg} = 0.5\ g_0$ for service restriction **R5**

$V/\sqrt{L} = 4.48$ @ 35 knots
$= 5.12$ @ 40 knots
$= 5.76$ @ 45 knots
$= 6.40$ @ 50 knots

however $V/\sqrt{L}$ need not be taken greater than 3.0 therefore
$V/\sqrt{L} = 3.00$

$f_g =$ acceleration factor (fraction of g_0) dependent of type and service notation and service area restriction notation given in Table B1.
$= 7$ patrol, **R0**
$= 5$ patrol, **R1**
$= 4$ cargo, **R0**
$= 1$ ferry, **R1**
$g_0 = 9.81$ m/s^2

therefore:
$a_{cg} = 2.955\ g_0 = 28.99\ m/s^2$ patrol, **R0**
$= 2.111\ g_0 = 20.70\ m/s^2$ patrol, **R1**
$= 1.688\ g_0 = 16.56\ m/s^2$ cargo, **R0**
$= 1.000\ g_0 = 9.81\ m/s^2$ ferry, **R1**

202 Unless otherwise established, the design vertical acceleration at different positions along the craft's length is not to be less than:

$a_v = k_v\ a_{cg}$

where

k_v = longitudinal distribution factor from Fig. 2.
= 1.0 aft of L/2
= $(L_x$-0.5L)/(L/2) + 1.0 where L_x is the distance forward of the AP in meters
= 1.5 @0.75L
= 1.75 @0.875L

therefore:

	0.75L				0.875L			
a_v = 4.432	g_0	= 43.48	m/s^2	5.171	g_0	= 50.73	m/s^2	patrol, **R0**
= 3.166	g_0	= 31.06	m/s^2	3.693	g_0	= 36.23	m/s^2	patrol, **R1**
= 2.533	g_0	= 24.85	m/s^2	2.955	g_0	= 28.99	m/s^2	cargo, **R0**
= 1.500	g_0	= 14.72	m/s^2	1.75	g_0	= 17.17	m/s^2	ferry, **R1**

C. Pressures and Forces

C 200 Slamming pressure on bottom

201 The design slamming pressure on bottom of craft with speed V/√L ≥ 3 is to be taken as:

$$p_{sl} = 1.3 k_l \left(\frac{\Delta}{nA}\right)^{0.3} T_O^{0.7} \frac{50-\beta_x}{50-\beta_{cg}} a_{cg} \ (\mathrm{kN/m^2})$$

k_l = longitudinal distribution factor from Fig.3.
= 0.5 to 1.0 aft of L/2, 1.0 forward of L/2
n = 1, number of hulls
A = design load area for element considered in m^2 but need not for any structure be < 0.002Δ/T
A_{pl} = spacing x span for plating but not greater than $2.5s^2$ but need not be < 0.002Δ/T

spacing x span = 0.208 m^2
$2.5s^2$ = 0.169 m^2
0.002Δ/T = 0.704 m^2

∴ A_{pl} = 0.704 m^2
A_{st} = spacing x span for stiffeners and girders

spacing x span = 0.208 m^2
0.002Δ/T = 0.704 m^2

∴ A_{st} = 0.704 m^2
A_{fr} = spacing x span for stiffeners and girders

spacing x span = 1.456 m^2
0.002Δ/T = 0.704 m^2

∴ A_{fr} = 1.456 m^2
T = fully loaded draft in metres with the craft floating at rest.
= 2.7 meters
T_O = draft at L/2 in m at normaloperation condition at operating speed
= 2.7 meters (assumed to be same as at rest, conservative answer)
Δ = fully loaded displacement in tonnes in salt water on draught T
= 950 tonnes

β_{cg} = deadrise angle in degrees at LCG (minimum 10^o, maximum 30^o)
= 17 degrees
β_x = deadrise angle in degrees at transverse section condidered (minimum 10^o, maximum 30^o)
$\beta_{.75L}$ = 29 degrees
$\beta_{.875L}$ = 30 degrees
a_{cg} = design vertical acceleration at LCG from B200

therefore the bottom slamming pressures as per C201 are:

						p_{sl} (kN/m^2)			
					service:	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
		k_l	A	β_x	a_{cg}:	28.99	20.70	16.56	9.81
Plate		-	(m^2)	(deg)					
	LCG:	0.92	0.704	17		603.91	431.37	345.09	204.39
	0.75L:	1.00	0.704	29		417.73	298.38	238.70	141.37
	0.875L:	1.00	0.704	30		397.83	284.17	227.33	134.64
Stiffeners									
	LCG:	0.92	0.704	17		603.91	431.37	345.09	204.39
	0.75L:	1.00	0.704	29		417.73	298.38	238.70	141.37
	0.875L:	1.00	0.704	30		397.83	284.17	227.33	134.64
Frames									
	LCG:	0.92	1.456	17		485.56	346.83	277.46	164.33
	0.75L:	1.00	1.456	29		335.86	239.90	191.92	113.67
	0.875L:	1.00	1.456	30		319.87	228.48	182.78	108.26

203 All are to be designed for a pitching slamming pressure on bottom as given below:

$$p_{sl} = \frac{21}{\tan \beta_x} k_a k_b C_W \left(1 - \frac{20 T_L}{L} \right) \text{ (kN/m}^2\text{)}$$

Above pressure is to extend within a length from FP to (0.1 + 0.15V/√L)L aft of the FP. V√L need not be taken greater than 3. p_{sl} may be gradually reduced to zero at 0.175L aft of the above length.

∴ Extent of slamming pressure = 0.45L to FP
LCG = 25.7 m forward of AP, or: 0.03 /.175
= 0.42 L
∴ Reduction of pitching slamming pressure at LCG = 0.836 p_{sl}

β_x = deadrise angle in degrees at transverse section condidered (minimum 10^o, maximum 30^o)
β_{cg} = 17 degrees
$\beta_{.75L}$ = 29 degrees
$\beta_{.875L}$ = 30 degrees

k_a = 1.00 for plating
= 1.1-20 (l_A/L), maximum 1.0, minmum 0.35 for stiffeners and girders
l_A = longitudinal extent in m of load area
= 0.80 m for stiffeners
= 0.80 m for frames
= 0.84 for stiffeners
= 0.84 for frames
k_b = 1.00 for plating and longitudinal stiffeners
= L/40l+ 0.5, maximum 1.0 for transverse girders (frames)
l = span in m of girder = 1.82 m
= 1.00
C_W = wave coefficient = 0.08L for L<100m, unrestricted service
= 1.0C_W for service notation **R0**
= 4.88
= 1.0C_W for service notation **R1**
= 4.88
T_L = lowest service speed draft in m at FP measured from waterline to entended keel line
= 2.7 meters (assumed to be same as at rest)

therefore the bottom pitching slamming pressure is:

	β_x	p_{sl} (kN/m^2)			
Plate	(deg)	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	17	32.16	32.16	32.16	32.16
0.75L:	29	21.22	21.22	21.22	21.22
0.875L:	30	20.37	20.37	20.37	20.37

	β_x				
Stiffeners	(deg)	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	17	26.94	26.94	26.94	26.94
0.75L:	29	17.77	17.77	17.77	17.77
0.875L:	30	17.06	17.06	17.06	17.06

	β_x				
Frames	(deg)	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	17	26.94	26.94	26.94	26.94
0.75L:	29	17.77	17.77	17.77	17.77
0.875L:	30	17.06	17.06	17.06	17.06

204 Pressure on bottom structure is not to be less than given in 500.

C 300 Forebody side and bow impact pressure

301 Forebody (bow to 0.4L aft of FP) side and bow impact pressure is to be taken as, in kN/m^2:

$$p_{sl} = \frac{0.7L \times C_L \times C_H}{A^{0.3}} \left[0.6 + 0.4 \frac{V}{\sqrt{L}} \sin\gamma \cos(90° - \alpha) + \frac{2.1a_0}{C_B} \sqrt{0.4 \frac{V}{\sqrt{L}} + 0.6}\, \sin(90° - \alpha)\left(\frac{x}{L} - 0.4\right) \right]^2$$

V/√L need not be taken greater than 3.0

A = design load area for element considered in m^2 but need not for any structure be < L B_{wl}/1000 (m^2)

A_{pl} = spacing x span for plating but not greater than 2.5s^2 and need not be < L B_{wl}/1000 (m^2)

spacing x span = 0.32 m^2

2.5s^2 = 0.40 m^2

LB_{wl}/1000 = 0.714 m^2

∴ A_{pl} = 0.714 m^2

A_{st} = spacing x span for stiffeners but not smaller than e^2 nor L B_{wl}/1000 (m^2)

e = vertical extent of load area, m

= 0.4 m, stiffener spacing

e^2 = 0.160 m^2

spacing x span = 0.208 m^2

LB_{wl}/1000 = 0.714 m^2

∴ A_{st} = 0.714 m^2

A_{fr} = spacing x span for frames but not smaller than e^2 nor L B_{wl}/1000 (m^2)

e = vertical extent of load area, m

= 2.4 m, deck spacing

e^2 = 5.760 m^2

spacing x span = 2.278 m^2

LB_{wl}/1000 = 0.714 m^2

∴ A_{fr} = 5.760 m^2

x = distance in meters from AP to position considered

$x_{.75L}$ = 45.75 m

$x_{.875L}$ = 53.38 m

C_L = correction factor for craft length = (250L - L^2)/15000

= 0.769

C_H = correction factor for height above the waterline to load point = 1-(0.5 h_0/C_W)

where:

h_0 = vertical distance in m from the waterline to the load point

= 2.10 m, plating (just above second deck, 4.6m abl)

= 2.30 m, stiffener (first stiffener above second deck, 4.6m abl)

= 3.10 m, frame (midpoint between main and second decks)

C_W = 4.88 for service notation **R0**
= 4.88 for service notation **R1**
∴ C_H = 0.785 plating, **R0** 0.785 plating, **R1**
= 0.764 stiffeners, **R0** 0.764 stiffeners, **R1**
= 0.682 frames, **R0** 0.682 frames, **R1**
α= flare angle (deadrise) of side shell
$\alpha_{.75L}$= 73 degrees
$\alpha_{.875L}$= 61 degrees
γ= angle between the waterline and a longitudinal line at the point considered
$\gamma_{.75L}$= 6.7 degrees
$\gamma_{.875L}$= 15 degrees
a_0 = acceleration parameter = $3C_w/L + C_V\, V/\sqrt{L}$, $C_V = \sqrt{L}/50$ (maximum 0.2)
C_V = 0.156
∴ a_0 = 0.709 for service notation **R0**
= 0.709 for service notation **R1**

therefore the forebody slamming pressure is:

p_{sl} (kN/m^2)

Plate	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
0.75L:	40.15	40.15	40.15	40.15
0.875L:	101.92	101.92	101.92	101.92

Stiffeners	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
0.75L:	39.10	39.10	39.10	39.10
0.875L:	99.26	99.26	99.26	99.26

Frames	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
0.75L:	18.66	18.66	18.66	18.66
0.875L:	47.36	47.36	47.36	47.36

C 500 Sea pressure

501 Pressure acting on the craft's bottom, side (including superstructure side) and weather decks is to be taken as:

- for load point below design waterline

$$p = 10\,h_0 + \left(k_s - 1.5\frac{h_0}{T}\right)C_W \ \ (\text{kN/m}^2)$$

- for load point above design waterline

$$p = a\,k_s\left(C_W - 0.67\,h_0\right)\ (\text{kN/m}^2)$$

Minimum sea pressures are given in Table C1 (extracted below):
Sides, notation **R0, R1** : 6.5 kN/m^2

h_0 = vertical distance in m from the waterline at draught T to the load point
= 2.70 m, bottom, all elements (assume draft for simplicity)
= 2.10 m, side plating (just above second deck, 4.6m abl)
= 2.30 m, side stiffener (first stiffener above second deck, 4.6m abl)
= 3.10 m, side frame (midpoint between main and second decks)
k_s = 7.50 aft of amidships
= $5/C_B$ = 11.09 at FP, varying linearly between amidships and FP
$\therefore k_s$ = 7.50 at LCG
= 9.29 at 0.75L
= 10.19 at 0.875L
a = 1.0 for craft sides and open freeboard deck
= 0.8 for weather decks above freeboard deck
C_W = wave coefficient according to A200
= 4.88 for service notation **R0**
= 4.88 for service notation **R1**

Therefore the calculated sea pressures are

	p (kN/m^2)			
Bottom (all elements)	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	56.28	56.28	56.28	56.28
0.75L:	65.03	65.03	65.03	65.03
0.875L:	69.41	69.41	69.41	69.41

Side plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	26.05	26.05	26.05	26.05
0.75L:	32.28	32.28	32.28	32.28
0.875L:	35.39	35.39	35.39	35.39

Side stiffeners	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	25.04	25.04	25.04	25.04
0.75L:	31.03	31.03	31.03	31.03
0.875L:	34.02	34.02	34.02	34.02

Side framing	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	21.02	21.02	21.02	21.02
0.75L:	26.05	26.05	26.05	26.05
0.875L:	28.56	28.56	28.56	28.56

SUMMARY: The maximum design pressures from C100, C200, C300, and C500 are:

Bottom plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	603.91	431.37	345.09	204.39
0.75L:	417.73	298.38	238.70	141.37
0.875L:	397.83	284.17	227.33	134.64

Bottom stiffeners	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	603.91	431.37	345.09	204.39
0.75L:	417.73	298.38	238.70	141.37
0.875L:	397.83	284.17	227.33	134.64

Bottom frames	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	485.56	346.83	277.46	164.33
0.75L:	335.86	239.90	191.92	113.67
0.875L:	319.87	228.48	182.78	108.26

Side plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	26.05	26.05	26.05	26.05
0.75L:	40.15	40.15	40.15	40.15
0.875L:	101.92	101.92	101.92	101.92

Side stiffeners	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	25.04	25.04	25.04	25.04
0.75L:	39.10	39.10	39.10	39.10
0.875L:	99.26	99.26	99.26	99.26

Side framing	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	21.02	21.02	21.02	21.02
0.75L:	26.05	26.05	26.05	26.05
0.875L:	47.36	47.36	47.36	47.36

PART 3 CHAPTER 1
DESIGN PRINCIPLES, DESIGN LOADS

SECTION 3 HULL GIRDER LOADS

A. Longitudinal Bending, Shearing and Axial Loads

A 200 Crest landing

201 For craft with $V/\sqrt{L} \geq 3$ a slamming pressure is actiong on an area equal to the reference area, A_R, given below. The area is to be situated with the load point at the LCG of the craft. The weight distribution is to be increased by the acceleration at the LCG. The hull girder is to be considered out of the water.

$$A_R = k\,\Delta \frac{\left(1 + 0.2\frac{a_{cg}}{g_0}\right)}{T} \quad (m^2)$$

where:

$k = 0.7$

$\Delta =$ displacement in tonnes

$= 950.0$ tonnes

$a_{cg} =$ vertical design acceleration at the LCG as per Section 2, B201

$= 2.955 \quad g_0 \quad = 28.99 \quad m/s^2$ patrol, **R0**

$= 2.111 \quad g_0 \quad = 20.70 \quad m/s^2$ patrol, **R1**

$= 1.688 \quad g_0 \quad = 16.56 \quad m/s^2$ cargo, **R0**

$= 1.000 \quad g_0 \quad = 9.81 \quad m/s^2$ ferry, **R1**

$T =$ design draught, m

$= 2.70$ m

$\therefore A_R = 391.844$ m^2, patrol, **R0**

$= 350.259$ m^2, patrol, **R1**

$= 329.467$ m^2, cargo, **R0**

$= 295.556$ m^2, ferry, **R1**

202 The load combination which is illustrated in Fig. 1 may be required analyzed with actual weight distribution along the hull beam.

203 The longitudinal midship bending moment may assumed to be:

$$M_B = \frac{\Delta}{2}\left(g_0 + a_{cg}\right)\left(e_w - \frac{l_s}{4}\right) \quad (kNm)$$

where:

$e_w =$ one half of the distance from LCG of the fore half body to LCG of the aft half body of the vessel, in m

$= 0.25L$ if not known

$= 10.52$ m (from vessel design data)

$l_s =$ longitudinal extension of slamming reference area

$= A_R/b_s$

b_s = breadth of slamming reference area, see fig. 2

= 11.4 m

∴ M_B = 35,509 kNm, patrol, **R0**

= 41,147 kNm, patrol, **R1**

= 41,276 kNm, cargo, **R0**

= 37,637 kNm, ferry, **R1**

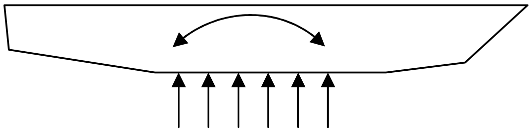


Figure 1.

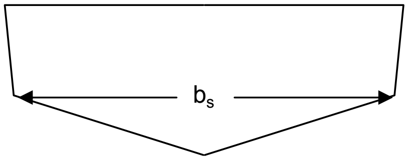


Figure 2.

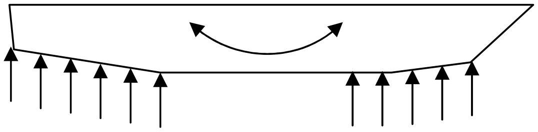


Figure 3.

A 300 Hollow landing

301 Hollow landing is similar to crest landing except that the reference area A_R is situated towards AP and FP as shown in Fig.3 and:

$$A_R = k\,\Delta \frac{\left(1 + 0.2\frac{a_{cg}}{g_0}\right)}{T} \ (m^2)$$

where:

k = 0.6

∴ A_R = 335.867 m^2, patrol, **R0**

= 300.222 m^2, patrol, **R1**

= 282.40 m^2, cargo, **R0**

= 253.333 m^2, ferry, **R1**

302 The load combination may be required analyzed with actual weight distribution along the hull beam.

303 The longitudinal midship bending moment may assumed to be:

$$M_B = \frac{\Delta}{2}\left(g_0 + a_{cg}\right)\left(e_r - e_w\right) \text{ (kNm)}$$

where:

e_w = one half of the distance from LCG of the fore half body to LCG of the aft half body of the vessel, in m
= 0.20L if not known
= 10.52 m
e_r = mean distance from the centre of the $A_R/2$ end areas to the vessel's LCG in m.
$l_{S\ (fwd)}$ = longitudinal extension of forward reference area, m
= $(A_R / 2) / b_{S\ (fwd)}$
$l_{S\ (aft)}$ = longitudinal extension of forward reference area, m
= $(A_R / 2) / b_{S\ (aft)}$
$b_{S\ (fwd)}$ = 7.5 m, avg
$b_{S\ (aft)}$ = 10.5 m, avg

Therefore the hollow landing bending moment is:

	a_{cg}	$A_R/2$	$l_{S\ (fwd)}$	$l_{S\ (aft)}$	e_r	M_B	
patrol, **R0**	28.99	167.93	22.39	15.99	20.90	191,354	kNm
patrol, **R1**	20.70	150.11	20.01	14.3	21.92	165,267	kNm
cargo, **R0**	16.56	141.20	18.83	13.45	22.43	149,219	kNm
ferry, **R1**	9.81	126.67	16.89	12.06	22.76	114,088	kNm

A 500 Hogging and sagging bending moments

501 For all craft an investigation of hogging and sagging bending moments taking into account any immersed/emerged structures may be required.

503 Tentative formulae for bending moments (still water + wave) for high speed light craft:

$M_{tot\ hog} = M_{SW} + 0.19\ C_W\ L^2\ B\ C_B$
$= M_{SW} + 20072.4$
$M_{tot\ sag} = M_{SW} + 0.14\ C_W\ L^2\ B\ (C_B + 0.7)$
$= M_{SW} + 37746.1$

M_{SW} = still water moment in the most unfavourable loading condition in kNm
= $0.11\ C_W\ L^2\ B\ C_B$ (kNm) in hogging if not known
= 0 in sagging if not known
= 6993 kNm sagging (full load, departure)

Additional correction of 20% to be added to the wave sagging moment for craft with large flare in the foreship therefore:

$M_{tot\ sag} = M_{SW} + 1.20\ [0.14\ C_W\ L^2\ B\ (C_B + 0.7)]$
$= M_{SW} + 45295.4$

therefore the total hogging and sagging moments due to seaway bending are:

$$M_{\text{tot hog}} = M_{SW} + 20072.4$$
$$= 27065 \text{ kNm}$$

$$M_{\text{tot sag}} = M_{SW} + 45295.4$$
$$= 52288 \text{ kNm}$$

A 600 Shear forces from longitudinal bending

601 A vertical hull girder shear force may be related to the hull girder bending moment from 200, 300, and 500 as follows:

$$Q_b = M_B / (0.25L)$$

SUMMARY: The maximum hogging and sagging bending moments and their associated shear forces from A200, A300, and A500 are:

Service Notation	Hogging (kNm)	Sagging (kNm)	Shear force (kN)
patrol, **R0**	35,509	191,354	12,548
patrol, **R1**	41,147	165,267	10,837
cargo, **R0**	41,276	149,219	9,785
ferry, **R1**	37,637	114,088	7,481

PART 3 CHAPTER 3
HULL STRUCTURAL DESIGN, ALUMINUM ALLOY

SECTION 4 HULL GIRDER STRENGTH

B. Vertical Bending Strength

B 100 Hull section modulus requirement

101 The hull girder section modulus is given by:

$$Z = \frac{M}{\sigma} \times 10^3 \ (\mathrm{cm}^3)$$

where:

M = the longitudinal midship bending moment in kNm from Ch.1 Sec.3
= sagging or hogging bending moment
= hollow landing or crest landing bending moment
= maximum still water + wave bending moment
σ = 175 f_l N/mm^2
f_l = material factor as per Ch.3, Sec.2, Table B1, B2, B3 or B4
= 0.89 5083-H116 plate
= 0.76 6061-T6 extrusion
= 0.60 5083-H116 plate, in the welded condition
= 0.48 6061-T6 extrusion, in the welded condition

Therefore the required section modulii, based upon the maximum design bending moments from Ch. 1 Sec 3, and for the various service notations are:

Service Notation	Required Bending Moment (kNm)		Minimum Required Section Modulus	
	Hogging	Sagging	(cm^3)	(cm^{2}m)
patrol, **R0**	35,509	191,354	1,228,595	12,286
patrol, **R1**	41,147	165,267	1,061,104	10,611
cargo, **R0**	41,276	149,219	958,066	9,581
ferry, **R1**	37,637	114,088	732,510	7,325

SECTION 5 PLATING AND STIFFENERS

A. General

A 300 Allowable stresses

301 Maximum allowable bending stresses in plates and stiffeners are to be according to Table A1.

Table A1 Allowable Bending Stresses (extract):

Item:	*Plate* (N/mm^2)		*Stiffener* (N/mm^2)	
Bottom, slamming load	$200f_1 =$	178.0	$180f_1 =$	136.8
Bottom, sea load	$180f_1 =$	160.2	$160f_1 =$	121.6
Side	$180f_1 =$	160.2	$160f_1 =$	121.6

B. Plating

B 100 Minimum thickness

101 The thickness of structures is in general not to be less than:

$$t = \frac{t_0 + kL}{\sqrt{f}} \frac{s}{S_R} \text{ (mm)}$$

where:

$f = \sigma_f/240$

$\sigma_f =$ yield stress in N/mm^2 at 0.2% offset for unwelded alloy, not to be taken greater than 70% of the ultimate tensile strength

$\sigma_Y = 214.0$ N/mm^2 but $0.7\ \sigma_U = 212.1$ N/mm^2

$\therefore\ \sigma_f = 212.1$ N/mm^2

$f = 0.884$

$t_0 = 4.0$ bottom, side to loaded waterline

$= 3.5$ side above loaded waterline

$k = 0.03$ bottom, side to loaded waterline

$= 0.02$ side above loaded waterline

$s =$ actual stiffener spacing, m

$= 0.260$ bottom

$= 0.400$ side

$S_R =$ basic stiffener spacing, m

$= 2(100 + L)/1000$

$= 0.322$

s/S_R is not to be taken less than 0.5 or greater than 1.0

$s/S_R = 0.8075$ bottom

$= 1.0000$ side

therefore the minimum thickness of plate is:

$t = 5.01$ bottom, side to loaded waterline (mm)

$= 5.02$ side above loaded waterline (mm)

B 200 Bending

201 The general requirement to thickness of plating subjected to lateral pressure is given by:

$$t = \frac{s\sqrt{C\,p}}{\sqrt{\sigma}} \quad \text{(mm)}$$

C = correction factor for aspect ratio (= *s* /*l*) of plate field and degree of fixation of plate's edges given in Table B2.

s/l = 0.325 bottom

= 0.500 side

201 The thickness requirement for a plate field clamped along all edges and with an aspect ratio ≤ 0.5:

$$t = \frac{22.4s\sqrt{p}}{\sqrt{\sigma}} \quad \text{(mm)}$$

p = design pressure in kN/m^2 as given in Ch.1 Sec. 2

σ = nominal allowable bending stress in N/mm^2 due to lateral pressure, Table A1

The design pressures (slamming except as noted) from Ch.1 Sec.2 are:

Bottom plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	603.91	431.37	345.09	204.39
0.75L:	417.73	298.38	238.70	141.37
0.875L:	397.83	284.17	227.33	134.64

Side plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**	
LCG:	26.05	26.05	26.05	26.05	(sea load)
0.75L:	40.15	40.15	40.15	40.15	
0.875L:	101.92	101.92	101.92	101.92	

Therefore the required thickness due to lateral pressure is:

Bottom plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	10.73	9.07	8.11	6.24
0.75L:	8.92	7.54	6.74	5.19
0.875L:	8.71	7.36	6.58	5.07

Side plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	3.61	3.61	3.61	3.61
0.75L:	4.49	4.49	4.49	4.49
0.875L:	7.15	7.15	7.15	7.15

B 300 Slamming

301 The bottom plating is to be strengthened according to the requirements given in the following:

301 The thickness of the bottom plating is not to be less than:

$$t = \frac{22.4 k_r s \sqrt{p_{sl}}}{\sigma_{sl}} \text{ (mm)}$$

where:

k_r = correction factor for curved plates
= (1 - 0.5 s/r) where r is the radius of curvature in m
= 1.0 for flat plates
p_{sl} = slamming pressure as given in Ch.1 Sec. 2
σ_{sl} = 200 f_1
f_1 = material factor as per Ch.3, Sec.2, Table B1, B2, B3 or B4
= 0.89 5083-H116 plate
$\therefore \sigma_{sl}$ = 178.0

Therefore the required thickness due to slamming pressure is:

Bottom plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	10.73	9.07	8.11	6.24
0.75L:	8.92	7.54	6.74	5.19
0.875L:	8.71	7.36	6.58	5.07

PLATING SUMMARY: The required plating thicknesses from B100, B200, and B300 are:

Bottom plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	10.73	9.07	8.11	6.24
0.75L:	8.92	7.54	6.74	5.19
0.875L:	8.71	7.36	6.58	5.07

Side plating	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	5.02	5.02	5.02	5.02
0.75L:	5.02	5.02	5.02	5.02
0.875L:	7.15	7.15	7.15	7.15

C. Stiffeners

C 100 Bending

101 The section modulus of longitudinals, beams, frames and other stiffeners subjected to lateral pressure is not to be less than:

$$Z = \frac{m l^2 s\, p}{\sigma} \ (\mathrm{cm}^3)$$

where:

m = bending moment factor depending degree of end constraints and type of loading
= 85 bottom and side continuous longitudinal member
l = stiffener span in m
= 0.80 bottom
= 0.80 side
s = stiffener spacing in m
= 0.26 bottom
= 0.40 side
σ = nominal allowable bending stress in N/mm^2 due to lateral pressure, Table A1
= 136.8 bottom slamming
= 121.6 side

C 200 Slamming

201 The section modulus of longitudinals or transverse stiffeners supporting the bottom plating is not to be less than:

$$Z = \frac{m l^2 s\, p_{sl}}{\sigma_{sl}} \ (\mathrm{cm}^3)$$

where:

m = bending moment factor depending degree of end constraints and type of loading
= 85 bottom and side continuous longitudinal member
l = stiffener span in m
= 0.80 bottom
s = stiffener spacing in m
= 0.26 bottom
p_{sl} = slamming pressure as given in Ch.1 Sec. 2
σ_{sl} = 180 f_1
= 136.8

The design pressures (slamming except as noted) from Ch.1 Sec.2 are:

Bottom stiffeners	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	603.91	431.37	345.09	204.39
0.75L:	417.73	298.38	238.70	141.37
0.875L:	397.83	284.17	227.33	134.64

Side stiffeners	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**	
LCG:	25.04	25.04	25.04	25.04	(sea load)
0.75L:	39.10	39.10	39.10	39.10	
0.875L:	99.26	99.26	99.26	99.26	

The required section modulii of the bottom and side stiffeners are:

Bottom stiffeners	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	62.4	44.6	35.7	21.1
0.75L:	43.2	30.8	24.7	14.6
0.875L:	41.1	29.4	23.5	13.9

Side stiffeners	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	4.5	4.5	4.5	4.5
0.75L:	7.0	7.0	7.0	7.0
0.875L:	17.8	17.8	17.8	17.8

SECTION 6 WEB FRAMES AND GIRDER SYSTEMS

A. General

A 400 Allowable stresses

401 Maximum allowable bending stresses and shear stresses in web frames and girders are to be according to Table A3.

Table A3 Allowable stresses

Item:	*Bending stress (N/mm^2)*		*Shear stress (N/mm^2)*		*Equivalent stress (N/mm^2)*	
Dynamic load	$180f_1$ =	160.2	$90f_1$ =	80.1	$200f_1$ =	178.0
Sea, static load	$160f_1$ =	142.4	$90f_1$ =	80.1	$180f_1$ =	160.2

B. Web Frames and Girders

B 400 Strength requirements

401 The section modulus for girders subjected to lateral pressure is not to be less than:

$$Z = \frac{mS^2\,b\,p}{\sigma}\ (\text{cm}^3)$$

m = bending moment factor, Table B3.
= 100 bottom, web frames
= 100 side, web frames
S = girder span in m
= 1.820 bottom
= 2.424 side @ LCG
= 2.510 side @ 0.75L
= 2.847 side @ 0.875L
b = breadth of load area, m
= 0.80 bottom
= 0.80 side
p = design pressure in kN/m^2 according to Ch.1 sec.2
σ = 160 f_1 (maximum)
= 142.4

The design pressures (slamming except as noted) from Ch.1 Sec.2 are:

Bottom frames	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	485.56	346.83	277.46	164.33
0.75L:	335.86	239.90	191.92	113.67
0.875L:	319.87	228.48	182.78	108.26

Side frames	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	21.02	21.02	21.02	21.02
0.75L:	26.05	26.05	26.05	26.05
0.875L:	47.36	47.36	47.36	47.36

The required section modulii of the bottom and side frames are:

Bottom frames	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	903.58	645.41	516.33	305.81
0.75L:	625.00	446.43	357.14	211.53
0.875L:	595.24	425.17	340.14	201.45

Side frames	patrol, **R0**	patrol, **R1**	cargo, **R0**	ferry, **R1**
LCG:	69.37	69.37	69.37	69.37
0.75L:	92.17	92.17	92.17	92.17
0.875L:	215.66	215.66	215.66	215.66

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