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IACS Documentation Package for the IMO GBS Pilot Project

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Submitted to:

INTERNATIONAL MARITIME SAFETY ORGANIZATION
Maritime Safety Committee

IMO Pilot Project
(MSC 82/24, Paragraph 5.29 and Annex 15)

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1. General

At the 81st session of the IMO Maritime Safety Committee held in May 2006, IACS agreed to use the recently developed common structural rules as basis for a pilot to conduct a trial application of the IMO *Goal-based New Ship Construction Standards* (GBS). While IACS has published common rules for both tankers and bulk carriers, in order to limit the scope for the pilot, only the common rules for tankers will be used. Therefore, the IACS 2006 "*Common Structural Rules for Double Hull Oil Tankers*"(referred to as CSR or Rules in this report), which entered into force on 1 April 2006 have been used.

2. Objective

2.1 Objective of the Pilot Project

The objective of the pilot project is to conduct a trial application of Tier III of the *GBS for oil tankers and bulk carriers* with the intention of validating the Tier III verification framework, identifying shortcomings and making proposals for improvement. Note, the pilot project will test the IMO GBS Tier III Verification Framework and not actually carry out the verification of the IACS CSR at this time.

2.2 **Objective of the** submission from IACS

The objective of the submission from IACS is to provide to the pilot panel a working example of how IACS in the future may provide the background documentation illustrating how classification rules meet the GBS. The intention has been to provide this to the pilot panel in order for them to start their work with an example at hand, and thereby contribute to making the work more concrete.

3. Structure of this report

To assist the pilot panel members, a self assessment has been prepared by the IACS team summarising the extent to which IACS CSR meet each of the GBS Tier II functional requirements. This self assessment can be found in the table on the next page.

The self assessment indicates where the GBS are covered and where the GBS are not fully covered in the CSR. Possible reasons why the CSR do not fully cover the GBS include;

- the subject area is not normally covered in class newbuilding construction rules,
- the subject area is implicitly covered and not explicitly covered,
- the subject area is covered by other rules or regulations,
- the subject area is only partially covered,
- etc.

Wherever an item is indicated as not being fully covered in the CSR an accompanying comment is given.

A list of references to CSR for each of the functional requirements is provided in section 4.

Further commentary for each of the GBS functional requirements is included in Section 5 of this document.

Self Assessment Summary Table

Item	Fully covered in CSR	Partially covered in CSR	Not covered in CSR	Comment
DESIGN				
II.1 Design life	✓			
II.2 Environmental conditions	✓			
II.3 Structural strength	✓			
II.4 Fatigue life	✓			
II.5 Residual strength		✓		Implicitly addressed in rules.
II.6 Protection against corrosion	✓			
II.6.1 Coating life	✓			
II.6.2 Corrosion addition	✓			
II.7 Structural redundancy		✓		Implicitly addressed in rules.
II.8 Watertight and weathertight integrity	✓			
II.9 Human element considerations		✓		Partially covered. May be addressed in future SOLAS Reg.
II.10 Design transparency		✓		Also addressed by other rules or conventions.
CONSTRUCTION				
II.11 Construction quality procedures	✓			
II.12 Survey	✓			
IN-SERVICE CONSIDERATIONS				
II.13 Survey and Maintenance		✓		Addressed with respect to design and construction requirements to allow adequate survey of the structure.
II.14 Structural accessibility			✓	Addressed in SOLAS Reg II-1/3 on PMA.
RECYCLING CONSIDERATIONS				
II.15 Recycling			✓	Will be addressed in future IMO Reg. on Recycling of Ships.

4. Cross reference Table

The following table includes a quick cross reference to the CSR for each of the GBS Tier II functional requirements.

Cross Reference Table

TIER II (FUNCTIONAL REQUIREMENTS) <from MSC 82/WP.5, 6 Dec 2006>	**CSR for Tanker** Associated Rule Reference
DESIGN	
II.1 Design life The specified design life is not to be less than 25 years.	2/3.1.3 – Design life 9/3.2.3.1 – Design fatigue life B/2.4.7.2 – Design life C/1.4.1.3 – Fatigue life C/1.4.1.4 – Fatigue life
II.2 Environmental conditions Ships should be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams.	2/3.1.7.1 - External environment 2/4.2.6.2(d) – Environmental loads 9/3.2.2.1 – Fatigue loads
II.3 Structural strength Ships should be designed with suitable safety margins: .1 to withstand, at net scantlings**, in the intact condition, the environmental conditions anticipated for the ship's design life and the loading conditions appropriate for them, which should include full homogeneous and alternate loads, partial loads, multi-port and ballast voyage, and ballast management condition loads and occasional overruns/overloads during loading/unloading operations, as applicable to the class designation; and .2 appropriate for all design parameters whose calculation involves a degree of uncertainty, including loads, structural modelling, fatigue, corrosion, material imperfections, construction workmanship errors, buckling and residual strength. The structural strength should be assessed against excessive deflection and failure modes, including but not limited to buckling, yielding and fatigue. Ultimate strength calculations should include ultimate hull girder capacity and ultimate strength of plates and stiffeners. The ship's structural members should be of a design that is compatible with the purpose of the space and ensures a degree of structural continuity. The structural members of ships should be designed to facilitate load/discharge for all contemplated cargoes to avoid	Net scantlings: 2/4.3.4 4/2.4 6/3 Intact structure: 2/4.3.5 Environmental loads: 2/3.1.7 2/4.2 7/ Loading conditions: 2/3.1.5 2/3.1.6 2/3.1.8 Tab 2.4.1 2/4.2.5 2/5.4.1.1 thru 5 2/5.4.2 7/2.1, 7/2.2, 8/1.1.2, 8/Tab 8.2.7 thru 9 B/Tab B.2.3 and 4 Accidental loads: 2/4.2.7 Tab 2.4.1 7/2.2.3.2 7/5 Yield acceptance criteria: 2/4.5 2/5.4.1.5 thru 10 2/Tab2.5.1 thru 3 2/5.4.5 and 6 8/Tab 8.1.3 (BM) 8/Tab 8.1.4 (shear) 8/Tab 8.2.4 and 5 (local)

TIER II (FUNCTIONAL REQUIREMENTS) <from MSC 82/WP.5, 6 Dec 2006>	CSR for Tanker Associated Rule Reference
damage by loading/discharging equipment which may compromise the safety of the structure. ** The net scantlings should provide the structural strength required to sustain the design loads, assuming the structure in intact condition and excluding any addition for corrosion.	8/Tab 8.2.10 (PSM) 9/2.2.5 (FEM) 9/Tab 9.2.1 (FEM) Deflection criteria: 2/5.3.1.1(b) 2/5.4.5.1 3/5.3.3.4 8/2.6.1.7 plus individual reqts. 10/2 Buckling criteria: 2/4.5 2/Tab 2.5.2 and 3 8/1.2.1.4 8/1.4 8/2.6.1.6 9/2.2.5.3 10/ D/ Fatigue criteria: 2/4.3.3 Tab 2.5.1 2/5.4.3 2/5.6.5 8/1.5 9/3 B/4 C/ Hull girder ULS: 2/5.6.3 9/1 A/ Compatibility: 2/3.1.7 2/3.1.8 Continuity: 4/3.2 thru 4 8/1.6 8/1.6.5 and 6 8/2.1.4.7 8/2.3.1.3 8/3.1.3 8/4.1.3 8/5.1.3 Loading / Unloading 2/4.2.1 2/Tab 2.5.1 8/1.1.2.2(b)
II.4 Fatigue life The design fatigue life should not be less than the ship's design life and should be based on the environmental conditions in II.2.	9/3.2.3.1 C/
II.5 Residual strength Ships should be designed to have sufficient strength to	General principle: 2/4.1.2.2(a) and (d) Hull girder ULS:

TIER II (FUNCTIONAL REQUIREMENTS) <from MSC 82/WP.5, 6 Dec 2006>	CSR for Tanker Associated Rule Reference
withstand the wave and internal loads in specified damaged conditions such as collision, grounding or flooding. Residual strength calculations should take into account the ultimate reserve capacity of the hull girder, including permanent deformation and post-buckling behaviour. Actual foreseeable scenarios should be investigated in this regard as far as is reasonably practicable.	A/ which contains post-buckling investigations.
II.6 Protection against corrosion Measures are to be applied to ensure that net scantlings required to meet structural strength provisions are maintained throughout the specified design life. Measures include, but are not limited to, coatings, corrosion additions, cathodic protection, impressed current systems, etc.	(See details below in II.6.1 and 2)
II.6.1 Coating life Coatings should be applied and maintained in accordance with manufacturers' specifications concerning surface preparation, coating selection, application and maintenance. Where coating is required to be applied, the design coating life is to be specified. The actual coating life may be longer or shorter than the design coating life, depending on the actual conditions and maintenance of the ship. Coatings should be selected as a function of the intended use of the compartment, materials and application of other corrosion prevention systems, e.g. cathodic protection or other alternatives.	6/2 Coatings: 6/2.1.1 11/5.1.8 and 9 Corrosion: 6/3 Cathotic protection: 6/2.1.2 Measurements in service: 12/
II.6.2 Corrosion addition The corrosion addition should be added to the net scantling and should be adequate for the specified design life. The corrosion addition should be determined on the basis of exposure to corrosive agents such as water, cargo or corrosive atmosphere, or mechanical wear, and whether the structure is protected by corrosion prevention systems, e.g. coating, cathodic protection or by alternative means. The design corrosion rates (mm/year) should be evaluated in accordance with statistical information established from service experience and/or accelerated model tests. The actual corrosion rate may be greater or smaller than the design corrosion rate, depending on the actual conditions and maintenance of the ship.	6/3
II.7 Structural redundancy Ships should be of redundant design and construction so that localized damage of any one structural member will not lead to immediate consequential failure of other	General principle: 2/4.1.2.2 (a) and (d)

TIER II (FUNCTIONAL REQUIREMENTS) <from MSC 82/WP.5, 6 Dec 2006>	**CSR for Tanker** Associated Rule Reference
structural elements leading to loss of structural and watertight integrity of the ship.	
II.8 Watertight and weathertight integrity Ships should be designed to have adequate watertight and weathertight integrity for the intended service of the ship and adequate strength and redundancy of the associated securing devices of hull openings.	References to other rules: 2/2.1.1, 3/3.1.1.2, 3/3, 5/2.1.2.3 watertight subdivision: 5/2 bulkheads: 8/2.5 watertight boundaries: 8/3.6, 8/4.7, 8/5.6 hull openings and closing arrangements: 11/1
II.9 Human element considerations Ships should be designed and built using ergonomic design principles to ensure safety during operations, inspection and maintenance of ship's structures. These considerations should include stairs, vertical ladders, ramps, walkways and standing platforms used for permanent means of access, the work environment and inspection and maintenance considerations.	reference to other regulations: 3/3.1.1.2 size of access openings: 5/5.1.1.4 crew protection: 11/2
II.10 Design transparency Ships should be designed under a reliable, controlled and transparent process made accessible to the extent necessary to confirm the safety of the new as-built ship, with due consideration to intellectual property rights. Readily available documentation should include the main goal-based parameters and all relevant design parameters that may limit the operation of the ship.	3/2 Novel designs: 3/4.1.2
CONSTRUCTION	
II.11 Construction quality procedures Ships should be built in accordance with controlled and transparent quality production standards with due regard to intellectual property rights. The ship construction quality procedures should include, but not be limited to, specifications for material, manufacturing, alignment, assembling, joining and welding procedures, surface preparation and coating.	2/4.4 Materials: 6/4.1.2 Fabrication: 6/4.1.2 Welding and joint preparation: 6/4.4 6/5
II.12 Survey A survey plan should be developed for the construction phase of the ship, taking into account the ship type and design. The survey plan should contain a set of requirements, including specifying the extent and scope of the construction survey(s) and identifying areas that need special attention during the survey(s), to ensure compliance of construction with mandatory	2/2.1.2.1 2/2.1.3.1(a) and (c) 2/3.1.9 3/2.2.3.1(g) 11/5

TIER II (FUNCTIONAL REQUIREMENTS) <from MSC 82/WP.5, 6 Dec 2006>	CSR for Tanker Associated Rule Reference
ship construction standards.	
IN-SERVICE CONSIDERATIONS	
II.12 Survey and Maintenance Ships should be designed and constructed to facilitate ease of survey and maintenance, in particular avoiding the creation of spaces too confined to allow for adequate survey and maintenance activities. The survey plan in II.11 should also identify areas that need special attention during surveys throughout the ship's life and in particular all necessary in-service survey and maintenance that was assumed when selecting ship design parameters.	2/2.1.3.1(d) 2/3.1.9.3 renewal criteria 3/2.2.3.1plans to be on board 5/5 access arrangements 11/2 crew protection 12/1.2 thickness measurements
II.14 Structural accessibility The ship should be designed, constructed and equipped to provide adequate means of access to all internal structures to facilitate overall and close-up inspections and thickness measurements.	3/2.2.2.1(d) 5/5
RECYCLING CONSIDERATIONS	
II.15 Recycling Ships should be designed and constructed of materials for environmentally acceptable recycling without compromising the safety and operational efficiency of the ship.	2/2.1.1 3/3.3

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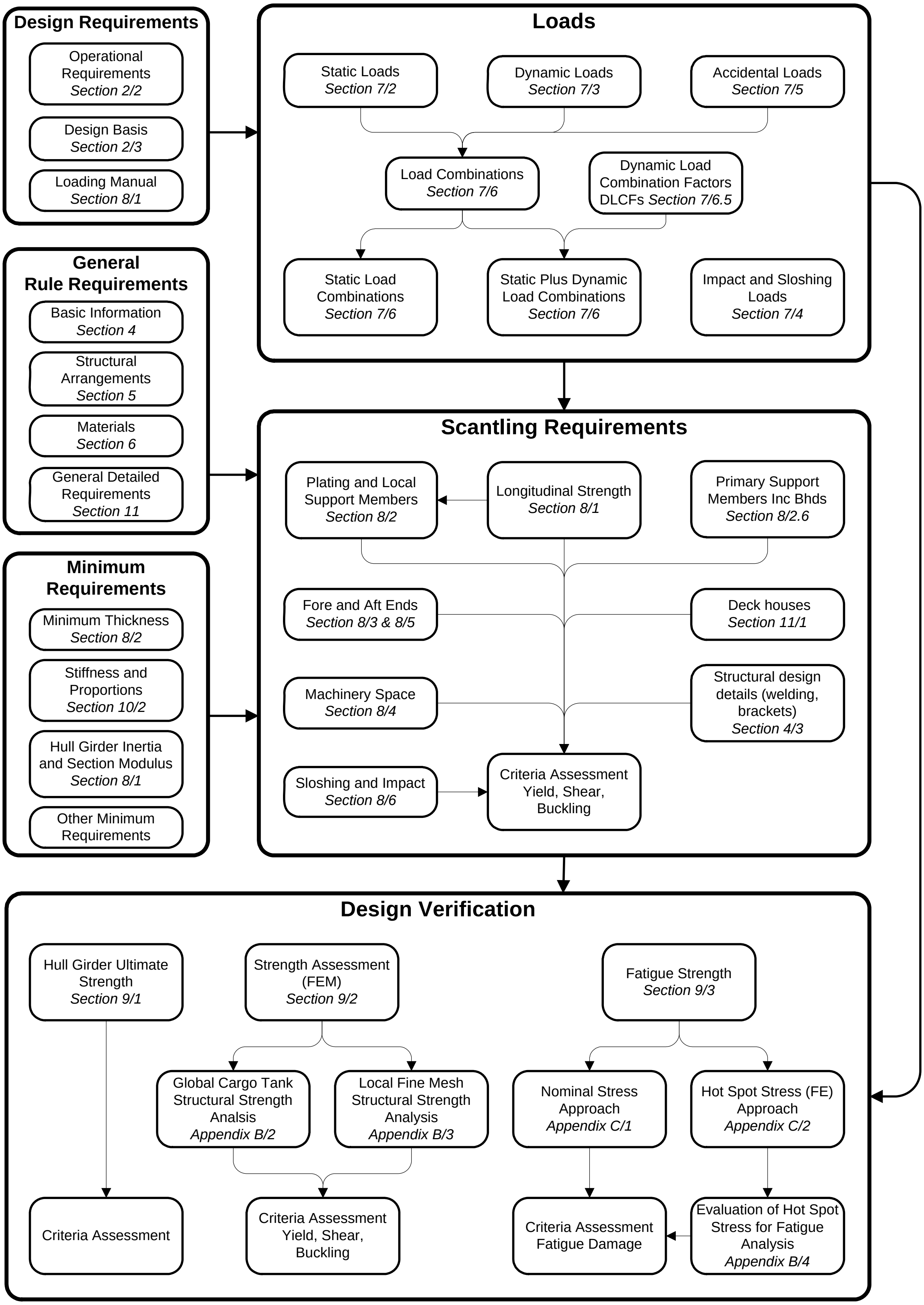
5. Commentary

Tier II Functional Requirements

To demonstrate how the CSR/Tankers address the IMO GBS Tier II Functional Requirements, each of the functional requirements is listed followed by a description of how the CSR/Tanker relates.

This report has been organized by sections according to the GBS functional requirements, however the Rules themselves are organized similar to a typical design flow as illustrated in the figure below, which is Figure 2.5.1 from the CSR.

Overview of Structural Design Process



DESIGN

II.1 Design life

Rating: The functional requirement is **covered** by CSR.

Comment:
In Tier II.1 of the Goal based standards the design life, defined in Goal 5 of Tier I, is to be 25 years.

CSR definitions of design life are given in Section 2/3.1.3. These definitions are essentially the same as the one provided in Tier I.

The design life of 25 years is an input parameter for the determination of the values of the scantling loads, fatigue loads, expected fatigue life and corrosion wastage allowances:

.1 In CSR, the characteristic value of loads used in ultimate strength analysis is the expected maximum load likely to be encountered during the design life, i.e. 25 years. With a mean wave period of about 9 seconds, 25 years corresponds to 10^8 cycles. Influence of design life variations on characteristic loads is negligible: less than 1% variation for a life increase of five years from 20 to 25 years as compared to typical pre-CSR requirements.

.2 The increase of design fatigue life from the past practice of 20 years to 25 years has an important influence on the fatigue checking of the structure, see section 5.II.4 Fatigue of this report.

.3 To take into account general uniform corrosion of the structure of the ships, values of wastage allowances are given in CSR Rules. The wastage allowances were determined such that 95% of the measured thicknesses present in the IACS statistics are larger than the renewal thickness given in the rules at the end of the design life (25 years of service).

CSR Reference:

CSR-reference	content	comment
Sec 2/3.1.3	Design life	
Sec 2/5.4.2.4	Description regarding the 10^8 cycles	

II.2 Environmental conditions

Rating: The functional requirement is **covered** by CSR.

Comment:
The functional requirement II.2 is covered by CSR for Tankers. The rule text explicitly specifies that the rule requirements are based on a ship trading in the North Atlantic wave environment for its entire design life.

.1 Sea state data
It is specified in the rule text that wave loads are derived using the sea state data given in IACS Recommendation No. 34. This recommendation gives the wave data using a

scatter diagram where the probability of sea-states is described as occurrences per 100000 observations. The area covered by the scatter diagram is also specified. The scatter diagram given in Rec. 34 is developed based on wave data obtained from British Marine Technology.

The sea-state data that the rule requirements are based on, and background documentation of the scatter diagram used, can be found in the following publications:
- IACS Recommendation No. 34, “Standard Wave Data”
- British Marine Technology (Primary contributors Hogben N., Da Cunha, L.F. and Oliver, H.N.). “Global Wave Statistics”, Unwin Brothers Limited, London 1986.
- Bitner-Gregersen, E.M., Cramer, E.H., Korbijin, F., “Environmental Description for Long-term Load Response of Ship Structures”, ISOPE June 1995, The Hague, The Netherlands.

CSR reference:

CSR-reference	content	comment
Sec 2/3.1.7.1	External environment	

.2 Environmental loads
The basis for the development of load formulations using the specified wave environment is explained in the following.

The Rule formulations for the wave loads are based on envelope values calculated by numerical wave load analysis and regression analysis, and calibrated with feedback from service experience and model tests. The envelope value is the long term value, at a given probability level, taking into consideration the effect of all wave headings.

The general principles for the derivation of the wave load values are:
(a) the application of load values is consistent for all similar load scenarios
(b) the characteristic load value is selected to suit the purpose of the application of the load and the selected structural assessment method, e.g. for strength assessment the expected lifetime maximum load is applied while for fatigue assessment an average value representing the expected load history is applied
(c) load calculations are performed using 3-D linear hydrodynamic computational tools. The effects of speed are considered
(d) the derivation of characteristic wave loads is based on a long term statistical approach which includes representation of the wave environment (North Atlantic scatter diagram), probability of ship/wave heading and probability of load value exceedance based on IACS Rec. 34. All of which result in envelope values
(e) non-linear effects are considered for the expected lifetime maximum loads.

The hydrodynamic calculations are based on:
(a) the Pierson-Moskowitz wave spectrum
(b) a wave energy-spreading of $\cos^2$
(c) an equal probability on all wave headings
(d) a 30 degree step of ship/wave heading

The speed and loading condition are chosen based on the corresponding application of load and the structural assessment method. Thus, for:
(a) strength evaluation; a heavy ballast condition and a full load condition at scantling draught have been used for the assessment, applying no forward speed, as tankers are

full-form ships with negligible manoeuvring speed in extreme heavy weather due to voluntary and involuntary reasons;
(b) fatigue assessment; normal ballast and full load condition at design draught have been evaluated as the two most common sailing conditions. A speed of 75% of service speed has been taken as the average speed over the lifetime, taking into account effects of slamming, bow submergence, added wave resistance and voluntary speed reduction.

The considered wave-induced loads include:
(a) hull girder loads (i.e., vertical and horizontal bending moments)
(b) dynamic wave pressures
(c) dynamic tank pressures.

The probability of occurrence is selected based on the purpose of application of the load and the selected structural assessment method to be as follows:
(a) the loads for fatigue assessment are based on a probability of exceedance of 10^{-4}, which means loads which occur frequently. The 10^{-4} is the reference probability level that together with a Weibull shape parameter and average zero-crossing period define the expected load history.
(b) the loads for strength evaluation are based on a probability of exceedance of 10^{-8}. The probability level represents the expected maximum load during the design life. The exception is the sloshing loads, where a probability level of 10^{-4} is used, which is a load that occurs frequently.

General formulae for linear wave induced ship motion, acceleration, hull girder loads and wave pressures are given at both 10^{-8} and 10^{-4} probability levels.

The design load combinations corresponding to the identified load scenarios produce realistic design load sets suitable for the design and verification of the structural capability. Design load sets apply all the applicable simultaneously acting static and dynamic local load components and static and dynamic global load components for the design of a particular or group of structural members.

The combination of dynamic loads considers all simultaneously occurring dynamic load components. In deriving the simultaneously occurring loads, one particular load component is maximised or minimised and the relative magnitude of all simultaneously occurring dynamic load components is specified by the application of dynamic load combination factors (DLCF) based on the envelope load value. These dynamic load combination factors are based on the application of the equivalent design wave approach and are given as tabulated values.

For scantling requirements and strength assessments, correction factors to account for non-linear wave effects and operational considerations in heavy weather are applied to the linear loads. In beam sea condition a heading correction factor of 0.8 to account for operational considerations are applied to the linear loads. This is done because the assumption of equal probability of all wave headings is not considered to be correct for extreme conditions, since the ship in such weather will be steered up against the waves.

For the fatigue requirements given, the load assessment is based on the expected load history and an average approach is applied. The expected load history for the design life is characterised by the 10^{-4} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding stresses.

The fatigue analysis is calculated for two representative loading conditions covering the ship's intended operation. These two conditions are:
(a) full load homogeneous conditions at design draught
(b) normal ballast condition.

The ships life is divided into three operational phases with 42.5% in full load at sea, 42.5% in ballast at sea and the remaining 15% in harbour or sheltered waters.

Correction factors to account for speed effects are applied to the linear loads for fatigue assessment. Also factors to calculate the loads at probability levels 10^{-8} and 10^{-4} are applied.

CSR references:

CSR-reference	content	comment
Sec 2/4.2.6	Environmental loads	
Sec 2/5.4.2	Design loads for scantling requirements and strength assessment	
Sec 2/5.4.3	Design loads for fatigue assessment	
Sec 7/3	Dynamic load components	
Sec 7/6	Combination of loads	

II.3 Structural Strength

Rating: The functional requirement is **covered** by CSR.

Comment:
The GBS Tier II.3 criteria calls for the documentation of the structural requirements included in the class rules.

.1 Safety Margins

The GBS lists various items which should be taken into account when establishing suitable safety margins in the rules. The items mentioned are each discussed as follows:

a) Environmental conditions:
The environmental loads included in the CSR, which are used during the assessment of structural strength, have been based on a 25 year exposure to the North Atlantic environment. The probability of exceedance levels for the various individual design environmental loads are included in Section 5.II.2 of this report.

While the design loads of the North Atlantic have been used to formulate the design loads, most vessels do not typically trade exclusively in the North Atlantic. Therefore there is a safety factor associated with relating the actual environment under which the vessel trades versus the North Atlantic environment, as the CSR have not included reductions to the design loads to account for actual benign environments. The safety margin varies based on the future trading patterns of the vessels.

These environmental conditions are used to develop the dynamic wave-induced components of the design loads for longitudinal hull girder strength and the strength evaluation of local structural members.

CSR references:

CSR-reference	content	comment
Sec 2/3.1.7	External environment	
Sec 7/3	Dynamic loads	

b) Loading conditions:
Representative design cargo and ballasting loading conditions are specified to envelope the actual vessel loading conditions. The design loading conditions include various combinations of full and empty tanks to represent homogeneous, alternate, partial, multi-port, ballast, and ballast management conditions. If actual vessel loading conditions include non-typical conditions such as asymmetric loading or simultaneously emptying all cargo tanks across a section, the Rules state that they also have to be used in the structural evaluation.

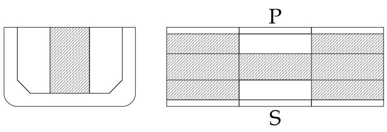
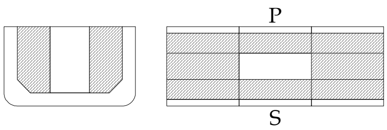
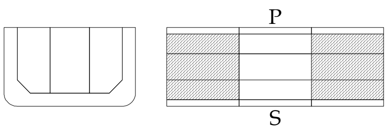
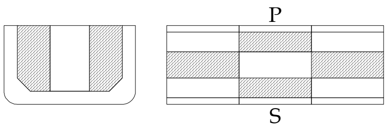
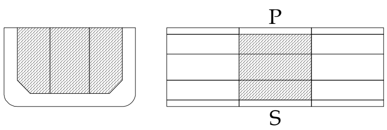
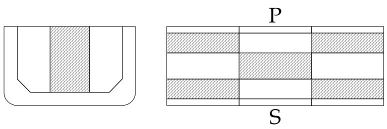
While the Rule specified loading conditions which include checkerboard or alternate tank loading have been used to formulate the design loads, most vessels typically trade in homogeneous full load or ballast load conditions. Therefore there is a safety factor associated with relating the actual loading conditions under which the vessel trades versus the Rule conditions. As this depends on the unknown future loading patterns of the vessels, there is no way of actually quantifying the safety margin attributed to this.

These vessel loading conditions are used to develop the static components of the design loads for longitudinal hull girder strength and the strength evaluation of structural members. Additional information on the loading conditions is included in Section 5.II.2 of this report.

The Rules relate the design loading conditions to the actual operation of the vessel by specifying that loading conditions and operation instructions be included in the vessel Loading Manual and/or Loading Instrument which will be used by the vessels' operating personnel. The Rules require that the Loading Manual include design parameters and operational limitations upon which approval of the hull scantlings have been based. Limitations on permissible still water bending moment and shear forces, scantling draft, minimum draft, minimum forward draft, allowable cargo density, ballast water exchange operations, and the design speed are to be included.

The following table, which is a partial copy of Table B.2.3 from the CSR, illustrates representative loading conditions to be evaluated in the FEM analysis which are included in the Rules.

FE Load Cases for Tankers with Two Oil-tight Longitudinal Bulkheads

Loading Pattern	Figure	Still Water Loads			Dynamic load cases		
		Draught	% of Perm. SWBM(2)	% of Perm. SWSF(2)	Strength assessment (1a)	Strength assessment against hull girder shear loads (1b)	
					Midship region	Forward region	Midship and aft regions
Design load combination S + D (Sea-going load cases)							
A1		0.9 T_{sc}	100% (sag)	See note 3	1	\	\
			100% (hog)	100% (-ve fwd) See note 4	2, 5a	\	\
A2		0.9 T_{sc}	100% (sag)	See note 3	1	\	\
			100% (hog)	100% (-ve fwd) See note 4	2, 5a	\	\
A3(6)		0.55 T_{sc} see note 5	100% (hog)	100% (-ve fwd) See note 5	2	4	2
				100% (-ve fwd) See note 5	5a	\	\
A4		0.6 T_{sc}	100% (sag)	100% (+ve fwd) See note 4	1, 5a	\	\
A5(7)		0.8 T_{sc} See note 6	100% (sag)	100% (+ve fwd) See note 5	1	3	1
				100% (+ve fwd) See note 4	5a	\	\
A6		0.6 T_{sc}	100% (hog)	100% (-ve fwd) See note 4	5a	\	\

CSR references:

CSR-reference	content	comment
Sec 2/3.1.5	Operating conditions	
Sec 2/3.1.6	Operating draughts	
Sec 7/2.1	Static hull girder loads	
Sec 8/1.1	Loading guidance	
Sec 8/1.1.2	Loading manual	
Sec 8/1.1.3	Loading computer program	

c) Local loads:

The above mentioned wave-induced dynamic (D) and loading condition static (S) load components are combined in order to calculate the maximum local loads (S + D) used to evaluate structural members. Design loads included in the Rules also contain margins to cover accidental (A) loads such as occasional overruns or overloads during loading or unloading operations. This includes the height of air pipes and pressure relief vale settings. Details of the determination of the local loads are included in Section 5.II.2 of this report.

The following table, which is a copy of Table 2.4.1 from the CSR, indicates load categories included in the Rules.

Load Categorisations		
Operational Loads	Lightship weight	Steel weight and outfit Machinery and permanent equipment
	Buoyancy loads	Buoyancy of the ship
	Variable loads	Cargo Ballast water Stores and consumables Personnel Temporary equipment
	Other loads	Tug and berthing loads Towing loads Anchor and mooring loads Lifting appliance loads
Environmental loads	Cyclic loading due to wave action including inertia loads	Dynamic wave pressures
		Dynamic loads and dynamic tank pressures due to ship accelerations
	Impact loads or resonant loads	Wave impacts Bottom slamming Liquid sloshing in tanks Green sea loads
Accidental loads		Flooding of compartments
Deformation loads		Thermal loads Deformations due to construction

CSR references:

CSR-reference	content	comment
Sec 2/3.1.8	Internal environment (cargo and water ballast tanks)	
Sec 2/4.2.3	Load categorisation	
Tab 2.4.1	Load categorisation	
Sec 2/4.2.5	Operational loads	
Sec 2/4.2.7	Accidental loads	
Sec 7/2.2	Local static loads	
Sec 7/5	Accidental loads	
Tab 8.2.7	Design load sets for plating and local support members	
Tab 8.2.8	Specification of design load combination, acceptance criteria and other load parameters for each design load set	
Tab 8.2.9	Design load sets for primary support members	

d) Load combination:
Design load combinations combine local and hull girder load components to represent design load scenarios. The effects of combining the dynamic (D) and the static (S) loads are also included in the combined design loads. The design scenarios are selected to encompass all scenarios that can reasonably occur during operation.

The loading scenarios include the assessment of tank boundaries, e.g. bulkheads, based on the most severe combination of loading hence conditions are assessed with a full tank content on one side and an empty tank on the other side. The situation with the tank contents reverse are also considered. Similarly the shell envelope is assessed for conditions at the deepest draught without internal filing and at the lowest draught with maximum internal filling.

The loads are combined for evaluation of the hull girder and structural members in order to consider the most unfavourable combination of load effects. A variety of different load cases are applied in order to provide maximum loads applied to individual areas of the structure rather than one load case which attempts to envelope all maximum loads simultaneously, since maximum loads acting simultaneously do not actually occur in operation.

These combined load effects are used to develop the longitudinal hull girder strength and the strength evaluation of structural members. The following table, which is Table 2.5.1 from the CSR, illustrates the combination of loads.

<table>
<tr><th colspan="7">Load Scenarios and Corresponding Rule Requirements</th></tr>
<tr><th colspan="2">Load Scenarios</th><th colspan="5">Rule Requirements</th></tr>
<tr><th rowspan="2">Operation</th><th rowspan="2">Loads
(that the vessel is exposed to and is to withstand)</th><th colspan="2">Design Load Combination (specified in Section 7/6)</th><th rowspan="2">Design Format
(specified in Sections 8 and 9)
see Note 1</th><th rowspan="2">Acceptance Criteria Set
(specified in Sections 8 and 9)</th></tr>
<tr><th>Ref. no</th><th>Notation</th></tr>
<tr><td colspan="6">Seagoing operations</td></tr>
<tr><td rowspan="5">Transit</td><td rowspan="2">Static and dynamic loads in heavy weather</td><td rowspan="2">1</td><td rowspan="2">S + D</td><td>1. $S_G + S_L + D_G + D_L \leq \eta_2 R_1$</td><td>AC2</td></tr>
<tr><td>2. $\gamma_S S_G + \gamma_D D_G \leq R_2/\gamma_{R2}$</td><td>AC2</td></tr>
<tr><td>Impact loads in heavy weather</td><td>2</td><td>Impact</td><td>$S_L + D_{imp} \leq \eta_3 R_p$</td><td>AC3</td></tr>
<tr><td>Internal sloshing loads</td><td>3</td><td>Sloshing</td><td>$S_G + D_{slh} \leq \eta_1 R_1$</td><td>AC1</td></tr>
<tr><td>Cyclic wave loads</td><td>4</td><td>Fatigue</td><td>$DM \leq \Sigma\eta_i / N_i$</td><td>-</td></tr>
<tr><td>BWE by flow through or sequential methods</td><td>Static and dynamic loads in heavy weather</td><td>5</td><td>S + D</td><td>$S_G + S_L + D_G + D_L \leq \eta_2 R_1$</td><td>AC2</td></tr>
<tr><td colspan="6">Harbour and sheltered operations</td></tr>
<tr><td>Loading, unloading and ballasting</td><td>Typical maximum loads during loading, unloading and ballasting operations</td><td>6</td><td>S</td><td>$S_G + S_L \leq \eta_1 R_1$</td><td>AC1</td></tr>
<tr><td>Tank testing</td><td>Typical maximum loads during tank testing operations</td><td>7</td><td>S</td><td>$S_G + S_{L1} \leq \eta_1 R_1$</td><td>AC1</td></tr>
<tr><td>Special conditions in harbour</td><td>Typical maximum loads during special operations in harbour, e.g. propeller inspection afloat or dry-docking loading conditions</td><td>8</td><td>S</td><td>$S_G + S_L \leq \eta_1 R_1$</td><td>AC1</td></tr>
<tr><td colspan="6">Accidental condition</td></tr>
<tr><td rowspan="2">Accidental flooding</td><td rowspan="2">Typically maximum loads on internal watertight subdivision structure due to accidental flooding</td><td rowspan="2">9</td><td rowspan="2">A</td><td>for water tight boundaries
1. $S_L \leq \eta_2 R_1$</td><td>AC2</td></tr>
<tr><td>for collision bulkhead
2. $S_L \leq \eta_1 R_1$</td><td>AC1</td></tr>
<tr><td colspan="6"><u>Note</u>
1. The symbols defined in this column are defined in the text of 5.4</td></tr>
<tr><td colspan="6">Where:
D_G dynamic global load
D_L dynamic local load
DM cumulative fatigue damage ratio
S_G static global load
S_L static local load
R_i structural capacity</td></tr>
</table>

CSR references:

CSR-reference	content	comment
Sec 2/4.2.2	Design load combinations	
Sec 2/5.4.1.1 to 5	Load-capacity based requirements	
Tab 2.5.1	Load scenarios and corresponding rule requirements	
Sec 2/5.4.2	Design loads for scantling requirements and strength assessment (FEM)	
Sec 7/6	Combination of loads	
Tab 7.6.1	Design load combinations	
Tab 8.2.7	Design load sets for plating and local support members	
Tab 8.2.8	Specification of design load combination, acceptance criteria and other load parameters for each design load set	
Tab 8.2.9	Design load sets for primary support members	
Tab B.2.3	FE load cases	
Tab B.2.4	FE load cases	

e) Structural modelling:
There are two general forms for structural modelling included in the Rules. The first applies beam and plate theory and prescriptive buckling formulations. The second involves application of finite element modelling.

The first form of structural modelling consists of using engineering principles to calculate section cross area, inertia, section modulus, web area and plate or shell membrane properties, and is associated with the prescriptive rules covering such items as bending, shear and buckling. This type of modelling is used to assess the structural properties of the vessel during the initial stages typically employing a working stress design (WSD) format. The working stress level is determined by applying the design loads using beam and plate theory and buckling formulae. This working stress level is then compared against an allowable stress. In many cases the formula is rearranged mathematically to include the allowable stress and the result is the required structural property such as thickness, section modulus, etc.

The Rules contain details on the section properties to be used with the Rule requirements.

The second form of structural modelling using a finite element (FE) model also employs a working stress design (WSD) format. The Rules include detail specification of the FE model such as; model extent, structure to be modelled, openings to be modelled, properties, element size, element type, aspect ratio, and boundary conditions. The FE analysis employs a series of models using a global model to represent the overall hull girder structure and then using local fine mesh models to review high stress gradient areas and stress concentrations. Finally, very fine mesh FE models are used to zoom in and assess the hopper knuckle connection between the inner-bottom and the hopper plate. The Rules include detail specifications for the fine mesh models similar in content to the global model mentioned above.

It should be noted that all structural models employ the net thickness concept in which the actual as-built thickness is reduced to represent in service diminution due to corrosion. The net thickness concept is described in section 5.II.3.5 of this report.

CSR references:

CSR-reference	content	comment
Sec 2/4.3	Structural capacity assessment	
Sec 2/5.4.4.1	Structural response analysis	
Sec 3/5	Calculation and evaluation of scantling requirements	
Sec 4/2	Structural idealization	
Sec 9/1.3	Hull girder bending moment capacity	Hull girder ultimate strength
Sec 9/2.2.2	Structural modelling	Global FEM
Sec 9/2.3.2	Structural modelling	Fine mesh FEM
App A/2.2.2	Assumptions and modelling of the hull girder cross-section	Hull girder ultimate strength
App B/2.2	Structural modelling	Global FEM
App B/3.2	Structural modelling	Fine mesh FEM
App B/3.4	Application of loads and boundary conditions	Fine mesh FEM
App B/4.2	Structural modelling	Fatigue
App B4.4	Boundary conditions	Fatigue

f) Fatigue:
For fatigue considerations, please refer to section 5.II.4 of this report.

g) Corrosion:
For corrosion considerations, please refer to section 5.II.6.2 of this report.

h) Material imperfections:
The CSR include the IACS requirements for materials covering strength properties, material grades and required application. The remainder of the detail requirements for materials such as the chemical makeup, through thickness properties, testing, etc. are referenced to be in accordance with the individual Classification Society rules.

While the minimum strength properties of yield and ultimate tensile strength are specified in the CSR, the actual physical properties of materials fitted in the ships are usually greater. However these margins are not accounted for and no safety margin is attributed to this.

The strength requirements in the CSR are based on the assumption that the material is manufactured in accordance with minimum strength properties and the allowable under thickness rolling tolerances specified in IACS UR W13. Please also refer to section 5.II.11 of this report.

CSR references:

CSR-reference	content	comment
Sec 2/4.4.1	Materials	
Sec 2/5.5	Materials	
Sec 6/1	Steel grades	

i) Construction workmanship errors:

For construction and workmanship considerations, please refer to section 5.II.11 of this report.

j) Buckling:
The buckling criteria in the CSR include various levels of complexity that build upon one another.

The simplest buckling check is in the form of stiffness and proportion ratios that relate simplified buckling and deflections to the most basic structural property such as panel spacing, unsupported flange breadth or pillar length. Using the spacing, flange length or pillar lengths, ratios are used to determine related permissible thicknesses. The next level of buckling check is performed using prescriptive buckling based on classic Euler buckling of plates, shells, columns and torsional buckling modes. Finally an advanced buckling analysis un-stiffened and stiffened plate panels is based on nonlinear analysis techniques. The most advanced buckling analysis includes an allowance for redistribution of loads such that the ultimate capacity of the panel is calculated.

CSR references:

CSR-reference	content	comment
Sec 2/5.4.5.2	Structural capacity assessment	
Sec 8/1.4	Hull girder buckling strength	
Sec 8/2.6.1.6	Primary support members	Web buckling, ref. to 10/2.3
Sec 9/2.2.5.3	Acceptance criteria	FEM
Sec 10	Buckling and ultimate strength	
App D	Buckling strength assessment	

k) Residual strength:
For residual strength considerations, please refer to section 5.II.5 of this report.

.2 Strength Assessments

The GBS lists various items which should be assessed in the rules. The items mentioned are each discusses as follows:

a) Members to be evaluated:
The CSR include requirements for the structural evaluation of all strength components of the vessel. The evaluations of the cargo block region of the vessel is based on both prescriptive and a finite element analysis. Prescriptive requirements are included for the forward and aft regions and the deckhouse structure . See the following figure, which is Figure 1.1.1 from CSR, for a map of references to the applicable CSR section.

Schematic Layout of the Rules

Topic	Sections
Introduction	1
Rule Principles	2
Rule Application	3
Basic Information	4
Structural Arrangement	5
Materials and Welding	6
Loads	7

Aft end
& Machinery Room

Cargo Area

Fore end

Topic	Sections
Machinery general structure	8/4.1
Machinery bottom structure	8/4.2
Machinery side structure	8/4.3
Machinery deck structure	8/4.4
Machinery internal structure	8/4.5-4.8
Aft end general structure	8/5.1
Aft end bottom structure	8/5.2
Aft end shell structure	8/5.3
Aft end deck structure	8/5.4
Aft end internal structure	8/5.5-5.7

Topic	Sections
Hull girder strength	8/1
Hull envelope plating	8/2.2
Hull envelope framing	8/2.3
Inner bottom	8/2.4
Bulkheads	8/2.5
Primary support members	8/2.6
Sloshing	8/6.2
Hull girder ultimate strength	9/1
Strength assessment (FEM)	9/2
Fatigue strength	9/3

Topic	Sections
General structure	8/3.1
Bottom structure	8/3.2
Side structure	8/3.3
Deck structure	8/3.4
Internal structure	8/3.5-3.9
Bottom slamming	8/6.3
Bow impact	8/6.4

Topic	Sections
Hull openings and closing arrangements	11/1
Crew protection	11/2
Support structure and structural appendages	11/3
Equipment	11/4
Testing procedures	11/5
Ship in operation renewal criteria	12

b) Failure modes:
The criteria for the assessment of scantlings are based on a working stress design (WSD) method. The failure modes include yielding, buckling and fatigue. Deflection criteria is also included and covered in the next section of this report.

The acceptance criteria included in the CSR have been related to the loading scenario as shown in Table 2.5.1 as copied in this report Section 5.II.3.1.d. The failure modes associated with the scenario are indicated in the following tables, which are Tables 2.5.2 and2.5.3 from the CSR.

Principal Acceptance Criteria - Rule Requirements						
	Plate panels and Local Support Members		**Primary Support Members**		**Hull girder members**	
Acceptance criteria set	**Yield**	**Buckling**	**Yield**	**Buckling**	**Yield**	**Buckling**
AC1:	70-80% of yield stress	Control of stiffness and proportions. Usage factor typically 0.8	70-75% of yield stress	Control of stiffness and proportions. Pillar buckling	75% of yield stress	NA
AC2:	90-100% of yield stress	Control of stiffness and proportions. Usage factor typically 1.0	85% of yield stress	Control of stiffness and proportions. Pillar buckling	90-100% of yield stress	Usage factor typically 0.9
AC3:	Plastic criteria	Control of stiffness and proportions	Plastic criteria	Control of stiffness and proportions	NA	NA

Principal Acceptance Criteria - Design Verification - FE Analysis			
	Global cargo tank analysis		**Local fine mesh analysis**
Acceptance criteria set	**Yield**	**Buckling**	**Yield**
AC1:	60-80% of yield stress	Control of stiffness and proportions. Usage factor typically 0.8	local mesh as 136% of yield stress averaged stresses as global analysis
AC2:	80-100% of yield stress	Control of stiffness and proportions. Usage factor typically 1.0	local mesh as 170% of yield stress averaged stresses as global analysis

CSR references: Sections 2/4.5, 2/5.4.1.5 to 10, Table 2.5.1 to 3, 2/5.4.5 and 2/5.4.6.

Yielding: the yielding allowable stresses for bending and shear modes specified for hull girder, primary support members and local members are generally shown in the above tables. More detailed information on the allowable stresses for each individual component is included in the CSR references listed below.

CSR references: Table 2.5.2, Table 2.5.3, Sections 8/1.2, Table 8.1.3, 8/1.3, Table 8.1.4, Table 8.2.4, Table 8.2.5, Table 8.2.10, 9/2.2.5 and Table 9.2.1.

Buckling: the buckling allowable limits specified for hull girder, primary support members and local members are generally shown in the above tables. More detailed information on buckling criteria for each individual component is included in the CSR references listed below.

CSR references: Table 2.5.2, Table 2.5.3, 8/1.4.2.6 to 8/1.4.2.8, Table 9.2.2, 10/2.3, 10/3.2.1.3, 10/3.3.2.1, 10/3.3.3.1 and D/4.

Fatigue: the fatigue criteria is associated with the design life of 25 years and exposure to the North Atlantic environment. See Section 5.II.4 of this report and the CSR references below for additional details.

CSR references: Sections 2/4.3.3, Tab 2.5.1, 2/5.4.3, 2/5.6.5, 8/1.5, 9/3, B/4, C/

c) Deflection:

Hull girder deflection requirement is covered by a minimum vertical hull girder moment of inertia. Local structural deflection is generally covered in the CSR by inclusion of minimum thicknesses, minimum depth-to-thickness ratios and buckling control measures. The establishment of the deflection criteria was based on the existing satisfactory service associated with the existing class rules.

CSR references: Sections 2/5.3.1.1(b), 2/5.4.5.1, 3/5.3.3.4, 8/1.2.2, 8/2.6.1.7 plus individual requirements, and 10/2.

.3 Ultimate Strength

The ultimate strength evaluations cover hull girder properties as well as individual stiffened plate panels.

a) Ultimate strength of the hull girder

The evaluation of the hull girder is the most important component of the strength assessment. The CSR include hull girder longitudinal strength evaluations controlling yielding and buckling based on working stress design (WSD) levels associated with the static and dynamic load components. The in-service operational limits are also closely controlled in order to remain within the WSD limits.

In addition, to provide an additional check for the hull girder, an ultimate limit evaluation is performed to check the condition of the vessel in extreme at-sea conditions using the following general expression.

$$\gamma_S M_{sw} + \gamma_W M_{wv-sag} \leq \frac{M_U}{\gamma_R}$$

Where:

M_{sw} sagging still water bending moment.

$M_{wv\text{-}sag}$ sagging vertical wave bending moment.

M_U sagging vertical hull girder ultimate bending capacity.

γ_S, γ_W, γ_R are the partial safety factors for the design load combinations.

Partial Safety Factors				
Design load combination	Definition of Still Water Bending Moment, M_{sw}	γ_S	γ_W	γ_R
a)	Permissible sagging still water bending moment	1.0	1.2	1.1
b)	Maximum sagging still water bending moment for homogenous full load condition	1.0	1.3	1.1
Where: γ_S partial safety factor for the sagging still water bending moment γ_W partial safety factor for the sagging vertical wave bending moment covering environmental and wave load prediction uncertainties γ_R partial safety factor for the sagging vertical hull girder bending capacity covering material, geometric and strength prediction uncertainties				

Partial safety factors increasing the magnitude of the wave-induced bending moment by 20 and 30 percent are applied in conjunction with the permissible and most probable still water bending moment respectively.

The calculation procedure for the determination of the hull girder bending capacity, is included in Appendix A of the CSR.

CSR references:

CSR-reference	content	comment
Sec 2/5.6.3	Design verification - hull girder ultimate strength	
Sec 9/1	Hull girder ultimate strength	Requirements
App A	Hull girder ultimate strength	Procedure

b) Ultimate strength of plates and stiffeners

In general the CSR includes local plate criteria that employs working stress design (WSD) format, however, some conditions and locations are permitted to approach the ultimate strength of a plate panel. The modes are defined in the advanced buckling section 10/4 and Appendix D of the CSR as follows:

Method 1 – buckling capacity with allowance for redistribution of load. This defines the upper bound value of the buckling capacity and represents the maximum load the panel can carry without suffering major permanent set and is effectively the ultimate load carrying capacity of a panel. The buckling capacity is taken as the load that results in the first occurrence of membrane yield stress anywhere in the stiffened panel. In calculating this, load redistribution within the structure is taken into account. This redistribution of load is a result of elastic buckling of component plates, such as the plating between the stiffeners.

Method 2 - buckling capacity with no allowance for redistribution of load. This defines the lower bound value of the buckling capacity. In calculating the buckling strength, no internal redistribution of load is to be taken into account. Hence this is more conservative than the upper bound value given by Method 1 and checks that the panel does not suffer large elastic deflections with consequent reduced in-plane stiffness.

CSR references:

CSR-reference	content	comment
Sec 10/4	Advanced buckling analysis	Requirements
App D	Buckling strength assessment	Procedure

.3 Structure compatibility

a) purpose of the space

The structural requirements of the CSR include consideration of the purpose and associated environment of the space to which the structure is exposed. This can be either the external environment such as temperature exposure, marine corrosive environment. or the internal environments of cargo, ballast and dry spaces such as liquid density, temperature and corrosive nature. These environments which relate to the purpose of the space influence the material grade requirements, corrosion additions.

CSR references: Sections 2/3.1.7 and 2/3.1.8.

b) structural continuity

Structural continuity, termination of members and alignment with backup structure is covered in the CSR. The objective of the structural continuity requirements is to effectively avoid hard spots, notches and stress concentrations. The CSR has requirements for large hull girder longitudinal members as well as for the end termination of primary and local members. Another important reason for including this in the rules is to clarify the end connection continuity associated with the rule formulations. For instance the continuity of the ends dictate the end connection of a beam which in-turn dictate the bending moment, e.g. fixed-fixed or pinned-pinned, and then influence the associated structural requirement. Therefore the rules contain quite extensive coverage of this subject as listed below.

CSR references:

CSR-reference	content	comment
Sec 4/3.2 to 4	Structure design details	Local and primary support member end connections

Sec 8/1.6	Tapering and structural continuity of longitudinal hull girder elements	
Sec 8/1.6.5 and 6	Structural continuity	Longitudinal bulkheads and longitudinal stiffeners
Sec 8/2.1.4.7	General scanting requirements	End connections
Sec 8/2.3.1.3	Hull envelope framing	End connections
Sec 8/3.1.3	Structural continuity	Forward of the forward cargo tank
Sec 8/4.1.3	Structural continuity	Machinery space
Sec 8/5.1.3	Structural continuity	Aft end

.4 Facilitate loading/unloading

In addition to the operating loads that most designers consider, the CSR also include loading and unloading conditions in the matrix of design loads to be considered. See CSR Table 2.5.1 as copied in this report Section 5.II.3.1.d. Loading conditions upon which the vessel is approved, which include loading and unloading operations are required to be included in the vessel Loading Manual as indicated in Section 8/1.1.2.2(b) of the CSR.

CSR references:

CSR-reference	content	comment
Sec 2/4.2.1	Load scenarios	
Tab 2.5.1	Load scenarios and corresponding rule requirements	
Sec 8/1.1.2.2(b)	Loading manual	Harbour/sheltered water conditions

.5 Net scantlings

The net scantling approach is used to perform the ship design and verification calculations using scantlings in an assumed future corroded condition. Therefore the design is assessed for the critical load cases for the different assessment criteria such as strength (e.g. yielding, ultimate strength and buckling) and fatigue, while in an expected corroded condition. This expected corroded condition is typically defined in association with the assessment criteria type and the structural arrangement of the vessel being investigated.

While the expected corrosion additions which are to be used in design calculations can be accurately defined in a design code or classification society rule, the actual corrosion experienced in-service can vary depending on maintenance performed, coatings provided, coating maintenance, cargo carried, ballast carried, operating environments, loading/unloading processes, etc. Therefore the actual corrosion experienced by a particular ship may be larger or smaller depending on the actual operating conditions and maintenance of the ship throughout its life cycle.

Since the actual corrosion in-service depends on a wide variety of factors that can not be fully anticipated and controlled, the Rules use a design net thickness approach that is aligned and compatible with the associated thickness gauging and renewal requirements that are applied to the vessel. Ships are subjected to thickness measurement requirements during their lifetime. When local thicknesses measured do not comply with the requirements, renewals are required to replace the local plating or stiffening members to their original condition, thereby keeping the individual structural elements in a state that is generally thicker than the net scantlings used in the original design calculations.

In-service diminution allowances for hull girder section modulus and the thickness of individual structural elements are generally set by classification society rules. However, it should be noted that resolution A.744(18), as amended, specifies allowable diminution of the hull girder section modulus for oil tankers 130m in length and upwards and over 10 years of age (ref. resolution MSC.105(73)). Additionally, recommended criteria for specific structural members of single side skin bulk carriers are provided in the IACS Unified Requirements which are referenced by resolution MSC.145(77).

The in-service minimum thickness requirements contained in classification society rule requirements (e.g., IACS UR S7) generally indicate stringent measurement criteria to be used for the assessment of members contributing to hull girder strength and less stringent localized measurement criteria to be used for the assessment of individual local members. The following summary may be made:

.1 Hull Girder Longitudinal Strength Members – the global corrosion or average corrosion of the members contributing to the hull girder longitudinal strength are permitted to waste to the degree whereby the hull girder section modulus is reduced by no more than 10 percent. This in effect limits the corrosion of the deck and bottom members to an average of about 10 percent of the original required thickness. This is consistent with resolution MSC.105(73).

.2 Individual Structural Elements – the local thickness diminution allowance for individual plating and stiffening elements is typically in the range of 2.5 to 4.0 mm. These local individual allowances are generally greater than the 10 percent average which are also applicable for the structural members contributing to hull girder section modulus referred to in .1 above.

.3 Local Pitting, Grooving and Edge Corrosion – for completeness of the rules the thickness diminution allowance for pitting, grooving and edge corrosion of plating and stiffening elements, typically in the range of 25 to 30 percent of required gross thickness, is included in the CSR. These localized items are checked in service and renewed when necessary, but specific accounting is not included in the strength criteria other than via calibration with actual vessel service.

In the CSR, the overall average corrosion for hull girder cross-section and primary support members is given by simultaneously deducting half the local corrosion addition from all structural members comprising the respective cross-sections. This replicates a 10 percent reduction of global strength which will later be monitored in-service. The assessment of local scantlings is performed based on the superposition of stresses associated with the reduced hull girder properties and the local stresses associated with the local full deduction of the corrosion additions. In other words, the CSR assumes that the structure is corroded locally to the maximum allowed and the hull girder is reduced to the maximum allowed overall hull girder corrosion.

Since fatigue is a time-dependant phenomenon that takes place over long periods of the ship’s life, stress calculations associated with fatigue should reflect variations in thicknesses due to corrosion through the design life (e.g. consider full “as-built” scantlings for the vessel in the initial stage of its operational life and expected design net scantlings at the end of the assumed design life). However the CSR contains a simplification which uses the average scantling properties between the initial as-built stage and the expected corroded state at the end of the assumed design life.

CSR references:

CSR-reference	content	comment
Sec 2/4.3.4	Net thickness approach	
Sec 4/2.4	Geometrical properties of local support members	
Sec 6/3	Corrosion additions	

II.4 Fatigue life

Rating: The functional requirement is **covered** by CSR.

Comment:
In the goal based standards, the design fatigue life should be not less than the design life and should be based on North Atlantic Environmental conditions.

The fatigue life calculation procedures of CSR are based on three common major hypotheses:

.1 The long term distribution of stresses in the structure of the ship sailing in North-Atlantic environment may be represented by a two-parameter Weibull law. The best fit of the Weibull distribution to the North-Atlantic scatter diagram is obtained by selecting a probability of occurrence (10^{-4}) for the scale parameter of the Weibull law.
.2 The linear damage accumulation rule of Miner's sum is valid and a unit value of the damage ratio D corresponds to fatigue cracking.
.3 The expected fatigue life is to be greater or equal to the design life (i.e. 25 years).

The Weibull law is defined as follows:

$$\Pr obability(StressRange < x) \quad = F(x) = 1 - \exp[-(\frac{x}{w})^{\xi}]$$

With ξ the shape parameter and $w = Sr/\ln(Nr)^{1/\xi}$ the scale parameter .
In the expression of the scale parameter, Sr is the stress range computed at 1/Nr probability level. The best fit with the scatter diagram is obtained by taking Nr = 10^4 cycles. The value of ξ is obtained by a fitting procedure and lead to a value around 1.0: 0.85 to 1.05 according to the rule set and the length of the ship.

The fatigue cracking appears when the damage ratio is greater than 1, therefore the damage ratio $D = \sum_{i=1}^{i=ntot} \frac{n_i}{N_i}$ is to be less than 1 where the number of cycles is summed on the whole fatigue life of the vessel of 25 years. In the damage ratio expression, n_i is the number of cycles of stress range S_i and N_i the number of cycles leading to failure according to the S-N curve, at the stress range S_i.

CSR references:

CSR-reference	content	comment
Sec 9/3	Fatigue strength	Requirement, not less than 25 years
App C	Fatigue strength assessment	Procedure

II.5 Residual strength

Rating: The functional requirement is **partially covered** by CSR.

Comment:
The rules explicitly states that only intact structure is considered:

2/4.3.5.1 All strength calculations are based on the assumption that the structure is intact. The residual strength of the ship in a structurally damaged condition is not assessed.

Hence, requirements to residual strength as formulated in Tier II.5 are not explicitly covered by the rules. However, it is stated as a general principle in the rules that the ship's structure is designed such that it has adequate structural redundancy to survive in the event that the structure is accidentally damaged:

2/4.1.2.2(d) it has adequate structural redundancy to survive in the event that the structure is accidentally damaged; for example, minor impact leading to flooding of any compartment.

This statement indicates that the rule development implicitly covered residual strength. This was based on typical inherent residual strength exhibited by existing vessels upon which the rules were calibrated.

Flooding is included in the rules as an accidental load:

4.2.7.1 The accidental load scenarios cover loads acting on local structure as a consequence of flooding in accordance with the assumptions made in IMO regulations. This relates to the assessment of the watertight subdivision boundaries.

Only the local scantlings due to flooding pressure is checked. The effect of the flooding pressure on the hull girder loads is not accounted for in the hull girder strength assessment.

The effect of structural damage on the hull girder capacity resulting from collision or grounding is not assessed in CSR.

The effect of collision damage in the upper part of the side was assessed using probabilistic methods in the SAFEDOR project. The conclusion from this study was that the intact condition is dimensioning for the hull girder strength, and that requirements for the damaged case therefore could be omitted. This study is documented in the following reference:

Hørte, T. et al., Probabilistic methods applied to structural design and rule development, RINA Conference, January 2007

Post-buckling behavior is included in the hull girder ultimate strength calculations, but the calculations are only carried out for intact structure.

CSR references:

CSR-reference	content	comment
Sec 2/4.3.5.1	Intact structure	
Sec 2/4.1.2.2	Design principles	
Sec 2/4.2.7.1	Accidental loads	
Sec 7/2.2.3.4	Flooding pressure	
Sec 7/5	Accidental loads	
App A/2.3	Hull girder ultimate strength	

II.6 Protection against corrosion

Rating: The functional requirement is **covered** by CSR.

Comment:
The following two sub-sections pertain to providing protection against corrosion or anticipating corrosion in the strength calculations. The overall goal being that the required scantlings meet the intended strength provisions thoughout the specified design life.

II.6.1 Coating life

With regard to the mandatory use of coatings, the CSR includes it in Section 6/2 Corrosion.

The purpose and intention of this section is to ensure that the Rules are inline with the SOLAS requirement with respect to corrosion prevention of ballast tanks.

The text provides reference to the requirements of SOLAS Reg. II-1/3-2, IMO Resolution A.798(19) and IACS UI SC 122. The requirements are open with respect to application date, which at the time of publishing the rules was yet to be finalized by IMO. It has now been determined that the application date for vessels to which the CSR apply is 8 December 2006, which is based on the building contract date.

As described in the section 6/1.1.1.2, for ships contracted for construction on or after 8 December 2006 which is the date of IMO adoption of the amended SOLAS Regulation II-1/3-2, the coatings of internal spaces subject to the amended SOLAS regulation are to satisfy the requirements of the IMO performance standard.

The IMO performance standard means IMO Resolution MSC.215(82) – "Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers".

The referenced requirements cover the following items related to information and documentation for II.6.

.1 Locations and/or spaces where coatings are required to be used

.2 Types of coating to be used for the various spaces
.3 Reference coating performance standards

Regarding allowances when other corrosion prevention systems are used, the sections "6/2.1.2 Internal cathodic protection systems" and "6/2.1.3 Paint containing aluminium" cover allowances when other corrosion prevention systems are used.

CSR references:

CSR-reference	content	comment
Sec 6/2	Corrosion Protection Including Coatings	

II.6.2 Corrosion addition

The CSR corrosion additions are located in Section 6/3.

Firstly, it should be noted that CSR for tankers does not employ a corrosion rate approach but a more advanced approach using a stochastic corrosion propagation model.

The CSR complies with the functional requirements of Tier II.6.2 Corrosion addition by following the latter approach.

Local corrosion additions for typical structural elements within the cargo tank region are shown in Table 6.3.1 and Fig. 6.3.1. In addition, the relation between corrosion addition and wastage allowance is described in "Section 6/3.2".

The local corrosion additions are derived by adding 0.5mm to wastage allowances for the particular local structural element. The background on the relationship of corrosion additions and wastage allowances is explained in Section 2/4.3.4 (Net thickness approach) and the details on local wastage allowances, are explained in Section 12/1.4 (Renewal criteria of local structure for general corrosion) of the CSR.

Structures considered and the appropriate wastage allowance values for each side of structural elements are as given in Table 12.1.2 of the CSR.

The 0.5mm is added in reserve for the wastage occurring between the inspection intervals of approximately 2.5 years. The verification of the local strength of the vessel is performed on the local net thickness (gross minus corrosion addition t_{corr}) and the global strength of the vessel is performed at global net thickness (gross minus 50 percent of the corrosion addition t_{corr}). As the wastage allowance is assessed based on thickness measurements performed in connection with the renewal survey some margin is needed on the wastage allowance as the vessel will operate for approximately another 2.5 years before being re-assessed. During this 2.5 year interval the thicknesses should not reduce below the net thickness.

In this context, as corrosion additions are completely consistent with wastage allowances.

The total "corrosion addition" or "wastage allowance" values used in the CSR were based on the stochastic corrosion propagation model and information that were being used by IACS ex-WP/S (Working Party/Strength) to arrive at wastage allowance values based on historical data on record of gaugings. In some areas of the structure a extra margin was added to account for the variability of corrosion based on service experience.

The general philosophy for establishing "corrosion additions" or "wastage allowances" was that they are to be:

(a) based, in general, on the premise that today's practice is a reference point, and departures from today's practice will need to be backed-up with technical justification;
(b) established based on the basic assumption of coatings provided (where required) at time of newbuilding, however, there should not be provisions to reduce wastage allowance values based on "superior" coating systems or extra-ordinary maintenance of coating systems or another type of corrosion protection system;
(c) appropriate for a 25-year service life;
(d) based on absolute numbers, i.e., 4.0mm (not 25%);
(e) independent of type of local failure mode employed, i.e., yielding, buckling, or fatigue;
(f) based on published data and recent experience of IACS member societies;

The following basic assumptions were made:

(a) with respect to stiffener and web members, wastage should be based on thickness loss, not section modulus loss;
(b) wastage values, though linked to net thickness deductions, should first be developed independently of the net thickness deductions, and based on the philosophy outlined above;
(c) the wastage values should be based on typical wastage values experienced in service for crude oil carriers;
(d) dependencies on cargo type and vessel size should be considered, but should not be variables used for determining the actual value of the permitted wastage on a ship-by-ship basis;
(e) structural elements within the same area, environment and orientation should as far as possible have the same wastage allowance; and
(f) safety margins should not be included in wastage allowances (i.e., criticality issues should be dealt with in "net" requirements, and not with an increase in the wastage allowance).

Based on the above and following IMO discussion regarding GBS, IACS carried out statistical analysis of collected corrosion data and evaluated "corrosion addition" or "wastage allowance" values by using the 95 percent probability level corrosion measurement values for a 25-year life.

Furthermore, each of the individual societies took into consideration data that they had on hand regarding their own in-house reports and studies in addition to published corrosion data when finally determining "corrosion addition" or "wastage allowance" values appropriate for a 25-year service life.

CSR references:

CSR-reference	content	comment
Sec 6/3	Corrosion additions	
Sec 12/1/4	Renewal criteria of local structure for general corrosion	

References and Background Documents

[1] IMO Resolution A.798(19), Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tanks
[2] IACS UI SC 122, Corrosion Prevention in Seawater Ballast Tanks
[3] IMO Resolution MSC.215(82) – Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers
[4] IMO Resolution MSC.216(82) – Adoption of amendments to the international convention for the safety of life at sea, 1974, as amended
[5] Sone, H. et al., Evaluation of Thickness Diminution in Steel Plates for the Assessment of Structural Condition of Ships in Service、ClassNK Technical Bulletin Vol.21, 2003.

II.7 Structural redundancy

Rating: The functional requirement is **partially covered** by CSR.

Comment:
Requirements to structural redundancy are not covered explicitly by the rules. However, it is stated as a general principle in the rules that the ship's structure is designed such that it has inherent redundancy See CSR 2/4.1.2.2(a):

The ship's structure works in a hierarchical manner and, as such, failure of structural elements lower down in the hierarchy should not result in immediate consequential failure of elements higher up in the hierarchy.

This statement indicates that the rule development implicitly covered structural redundancy. This was based on typical inherent redundancy exhibited by existing vessels upon which the rules were calibrated. It is worth noting that a double hull by its very nature is a very redundant structure. It offers structural redundancies against collisions and groundings, including damages or failures of structural members in either the inner hull or outer hull. The risk of a major structural failure or casualty is much less in a double hull tanker than a single hull tanker because of its structural redundancy.

The use of "criticality class" during the rule development can be considered as contributing to the redundancy of the structure. During the rule development, each structural component was classified according to the criticality with respect to the consequences of failure. At the top level of the hierarchy is the hull girder, while the local plate element is at the bottom. This hierarchical structure was used for setting the acceptance criteria and selecting the capacity models. As a consequence, stricter requirements are applied to the elements high up in the hierarchy. This means that less critical local elements will collapse first, without leading to collapse of higher-level elements.

The use of advanced buckling methods for buckling assessment ensures redundancy of stiffened panels, by allowing local plates to buckle and require that the stiffeners are able to carry the redistributed forces. This principle gives strong stiffeners and weaker plates, and thereby redundant panels.

In contrast to stiffened panels, corrugated bulkheads are generally not redundant, since collapse of the plate flange leads to collapse of the entire bulkhead. The CSR does not have special requirements for redundancy related to corrugated bulkheads however, additional and more complex acceptance criteria are provided and the buckling criteria is lowered to account for this. Especially longitudinal horizontally corrugated bulkheads are critical, due to their contribution to the longitudinal strength.

CSR references:

CSR-reference	content	comment
Sec 2/4.1.2.2	Design principles	
App D/1	Advanced buckling analusis	

CSR External background documentation, available on IACS Web Site:
Section 2/4.5.1 Criticality class of structural elements

II.8 Watertight and weathertight integrity

Rating: the functional requirement is **covered** by CSR.

Comment: The main principles of watertight and weathertight integrity with respect to the subdivision of the ship hull (Sec 5/2 of CSR) are given by the SOLAS Convention of IMO, referenced by Sec3/3.3 and Sec2/2.1.1 of CSR. The position of bulkheads in the cargo area and therefore the number of bulkheads is, in case of the type of ship considered, determined by the limits of cargo tank size with respect to the possible oil outflow and the damage stability (Sec5/2.1.2). These limits are given in the current MARPOL and SOLAS requirements, which are referenced by Sec5/2.1.2, Sec2/2.1.1 and Sec3/3.3. Particular requirements with respect to bulkhead construction and scantlings of watertight boundaries in different areas of the ship are given in Sec8/2.5, Sec8/3.6, Sec8/4.7 and Sec8/5.6.

General requirements related to the securing devices for hull openings are prescribed by requirements of the International Load Line convention and the SOLAS convention of IMO. Particular, ship type specific items are sufficiently described in Sec11/1 of CSR. In particular requirements regarding shell and deck openings are covered by Sec11/1.1, requirements related to air and sounding pipes are covered by Sec11/1.3, requirements for openings in superstructures and deck house sides are included in Sec11/1.4 and requirements to overflows and vents etc. are included in Sec11/1.5.

CSR-reference	content	comment
Sec2/2.1.1	Reference is made to IMO regulations	
Sec3/3.1.1.2	Reference is made to regulations of international, national, canal and other authorities	
Sec3/3	Reference is made to requirements of national and international regulations	Statement that compliance with national and international regulations is not necessary scope of class approval but scope of review by flag state administration
Sec5/2	Watertight subdivision	
Sec5/2.1.2.3	Reference is made to requirements of national regulations	
Sec8/2.5	Scantlings of Bulkheads	

Sec8/3.6	Watertight boundaries in fore-ship area	
Sec8/4.7	Watertight boundaries in machinery space	
Sec8/5.6	Watertight boundaries at aft end of the ship	
Sec11/1	Hull openings and closing arrangements	
Sec11/1.1	Shell and deck openings	
Sec11/1.2	Ventilators	
Sec11/1.3	Air and sounding pipes	
Sec11/1.4	Deck houses, companionways	
Sec11/1.5	Scuppers, inlets, discharges	

II.9 Human element considerations

Rating: The functional requirement is **partially covered** by CSR.

Comment:
Human element considerations with respect to the ship's structure are mainly related to sufficient opening-space for inspection, maintenance, repair and rescue operations, guard rails, ladders, flush decks, covers etc. They are only in scope of classification rules with respect to class surveys (sufficient opening spaces, breadth of access ways etc.). In general this functional requirement is subject of national requirements of flag state authorities and accidental prevention regulations of employer's liability insurance associations and similar organisations. Furthermore there does exist regulations of Tier V like ISO and other industry-standards e.g. ISO 799 "pilot ladders" and DIN 81705 "removable guard rails for seagoing ships".
The requirements are included relative to a number of different sections of the CSR. Special requirements to the protection of the crew members by means of bulwarks and guard rails are given in Sec 11/2.1.
Sizes of openings and details of portable plates are included in Sec 11/1.1
Sizes of access openings are described in Sec 5/5.1

Only the ship-type special requirements are introduced in detail in the CSR. For more general requirements cross-reference is made to effective rules and regulations of the flag state authorities such as SOLAS with respect to accidental prevention and ergonomics.

CSR-reference	content	Comment
Sec3/3.1.1.2	Reference is made to regulations of international, national, canal and other authorities	
Sec5/5.1.1.4	Size of access openings	
Sec11/1.1.11	Portable plates	
Sec11/2	Crew protection	
Sec11/2.1	Bulwarks and Guardrails	
Sec11/2.2	Tank Access	see also table 11.2.2
Sec11/2.3	Bow Access	see also table 11.2.2

II.10 Design transparency

Rating: The functional requirement is **partially covered** by CSR.

Comment:
The functional requirement as written is partially covered by CSR. The "design process" itself is not addressed by classification rules. Elements of the functional requirements of section II.10 are addressed in the sections of CSR as far as the compliance with the classification requirement is to be assured; these are provided below. Neither of the documents, nor any of the classification requirements, address the matter of intellectual property rights. This issue is considered to be outside of classification matters and a contractual matter between the owner, the builder and the manufacturer, as appropriate.

Section 3 contains requirements pertaining to documentation, plans and data that are required to be submitted to the classification society. These documents cover the loading information, calculation data. The plans and supporting calculations which need to be submitted and/or supplied on board are listed.

Section 2/ 2.1.3 Responsibilities of Classification Societies, builders and owners;

2.1.3.1 These Rules address the hull structural aspects of classification and do not include requirements related to the verification of compliance with the Rules during construction and operation. The verification of compliance with these Rules is the responsibility of all parties and requires that proper care and conduct is shown by all parties involved in its implementation. These responsibilities include:

(a) general aspects:
- relevant information and documentation involved in the design, construction and operation is to be communicated between all parties in a clear and efficient manner. The builder is responsible for providing design documentation according to requirements specified in the Rules. Other requirements for information and documentation are specified by the requirements and approval procedures of the individual Classification Societies
- quality systems are applied to the design, construction, operation and maintenance activities to assist compliance with the requirements of the Rules.

(b) design aspects:
- it is the responsibility of the owner to specify the intended use of the ship, and the responsibility of the builder to ensure that the operational capability of the design fulfils the owner's requirements as well as the structural requirements given in the Rules
- the builder shall identify and document the operational limits for the ship so that the ship can be safely and efficiently operated within these limits
- verification of the design is performed by the builder to check compliance with provisions contained in the Rules in addition to national and international regulations
- the design is performed by appropriately qualified, competent and experienced personnel
- the classification society is responsible for a technical review and audit of the design plans and related documents for a ship to verify compliance with the appropriate classification rules.

Section 2/3.1.1.3 The design basis used for the design of each ship is to be documented and submitted to the Classification Society as part of the design review and approval. All deviations from the design basis are to be formally advised to the Classification Society.

Section 4/3.1.1.1: A booklet of standard construction details is to be submitted for review.

Section 9/2.1.2.1 A detailed report of the structural analysis is to be submitted to demonstrate compliance with the specified structural design criteria. This report shall include the following information:

(a) list of plans used including dates and versions
(b) detailed description of structural modelling including all modelling assumptions and any deviations in geometry and arrangement of structure compared with plans
(c) plots to demonstrate correct structural modelling and assigned properties
(d) details of material properties, plate thickness, beam properties used in the model
(e) details of boundary conditions
(f) details of all loading conditions reviewed with calculated hull girder shear force and bending moment distributions
(g) details of applied loads and confirmation that individual and total applied loads are correct
(h) plots and results that demonstrate the correct behaviour of the structural model under the applied loads
(i) summaries and plots of global and local deflections
(j) summaries and sufficient plots of stresses to demonstrate that the design criteria are not exceeded in any member
(k) plate and stiffened panel buckling analysis and results
(l) tabulated results showing compliance, or otherwise, with the design criteria
(m) proposed amendments to structure where necessary, including revised assessment of stresses, buckling and fatigue properties showing compliance with design criteria.

Section 9/2.1.3.3 A computer program that has been demonstrated to produce reliable results to the satisfaction of the Classification Society is regarded as a recognised program.

Section 9/2.2.3.2 The standard load cases to be used in the structural analysis are given in Appendix B/2.3.1. These load cases cover seagoing conditions (design load combination S + D) and harbour/tank testing conditions (design load combination S).

Section 9/2.2.3.3 Where the loading conditions specified by the designer are not covered by the standard load cases then these additional loading conditions are to be examined, see also Appendix B/2.3.1.

Section 9/2.2.5.1 – Cargo tank structural strength analysis. Verification of results against the acceptance criteria is to be carried out in accordance with Appendix B/2.7.

Section 9/2.3.5.1 – Local fine mesh structural strength analysis. Verification of stress results against the acceptance criteria is to be carried out in accordance with Appendix B/3.5.

Section 9/3.1.1.3 The fatigue analysis is to be carried out using either a 'nominal stress approach' or a 'hot spot stress approach' depending on the structural details, as specified in 3.4. The procedure is illustrated in Figure 9.3.1.

Section 2/3.1.5 Operating conditions
3.1.5.1 The ship is to be capable of carrying the intended cargo with the necessary flexibility in operation to fulfil its design role. Specification of cargo loading conditions as required by the Rules and any additional cargo loading conditions required by the owner are the responsibility of the designer.

3.1.5.2 The Rules assume the following:
(a) a minimum set of specified loading conditions as defined in the Rules are examined. These are to include both seagoing and harbour loading conditions
(b) in addition to the minimum set of specified loading conditions, all relevant additional loading conditions covering the intended ship's service which result in increased still water shear force, bending moments or increased local static loadings are to be submitted for review
(c) the Trim and Stability Booklet, Loading Manual and loading computer systems specify the operational limitations to the ship and these comply with the appropriate statutory and classification requirements
(d) all cargo tanks are from a local strength point of view including sloshing designed for unrestricted filling for a cargo density as specified in 3.1.8. Limitations to loading patterns resulting in full or empty adjacent tanks as specified in the Rules and the Loading Manual do however apply for primary support members and hull girder shear force and bending moments.

The Rules refer to the loading conditions and design loading and ballast conditions upon which the approval of the hull scantlings is based are. The conditions which, as a minimum, should be included in the Loading Manual are listed (section 8, 1.1). The Loading Manual is to include the design basis and operational limitations upon which the approval of the hull scantlings are based. The information listed in *Table 8.1.1- Design Parameters* is to be included in the Loading Manual.

Section 2/4.6 Principle of Safety Equivalence
4.6.1 General
4.6.1.1 Novel designs deviating from the design basis or structural arrangements covered by the Rules will be subject to special consideration. The principle of equivalence is to be applied to the novel design, hence it must be demonstrated that the structural safety of the novel design is at least equivalent to that intended by the Rules.
4.6.1.2 The principle of equivalence may be applied to alternative calculation methods.
4.6.1.3 A systematic review process was undertaken in developing these Rules. This identified and evaluated the likely consequences of hazards due to operational and environmental influences on tanker structural configurations and arrangements covered by these Rules. For novel designs, dependent on the nature of the deviation, it may be necessary to conduct an independent systematic review to document equivalence with the Rules.

The equivalence procedure is also addressed in section 3.4.

The information to be required for inclusion in the Ship Construction File is currently defined in UR Z23, section 10.

CONSTRUCTION

II.11 Construction quality procedures

Rating: The functional requirement is **covered** by CSR.

Comment:
The functional requirements of section II.11 are addressed in the sections of CSR and in IACS Unified Requirement Z23 as provided below. Neither of the documents, nor any of the classification requirements, address the matter of intellectual property rights. This issue is considered to be the contractual matter between the owner, the builder and the manufacturer, as appropriate.

References:

CSR Tanker: Section 2/2.1.3 Responsibilities of Classification Societies, builders and owners

Section 2/2.1.3.1(c)
(c) construction aspects:
- the builder is responsible for ensuring that adequate supervision and quality control is provided during the construction
- construction is to be carried out by qualified and experienced personnel
- workmanship, including alignment and tolerances, is to be in accordance with acceptable shipbuilding standards
- the Classification Society is responsible for auditing to verify that the construction and quality control are in accordance with the plans and procedures.

The Rules address design and dimensions of welds as well as requirements for welding sequence, qualification of welders, welding procedures and welding consumables (section 6/4.4 and 5).

In addition to below reference in UR Z23, CSR section 6 requires that the structural fabrication is to be carried out, in accordance with '*IACS Recommendation 47, Shipbuilding and Repair Quality Standard for New Construction*' or a recognised fabrication standard which has been accepted by the Classification Society prior to the commencement of fabrication/construction, and lists what is required in the fabrication standard.

Section 2/3.1.9
The structural requirements included in the Rules were developed with the assumption that construction and repair will follow acceptable shipbuilding and repair standards and tolerances. The Rules may require that additional attention is paid during construction and repair of critical areas of the structure.

The Rules define the renewal criteria for the individual structural items. The structural requirements included are developed on the assumption that the structure will be subject to periodical survey in accordance with individual Classification Society Rules and Regulations.

UR Z23 will be implemented into individual IACS Member's Rules and Regulations.

UR Z23, 7.4

Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. Structural fabrication is to be carried out in accordance with IACS Recommendation 47, "Shipbuilding and Repair Quality Standard for New Construction", or a recognized fabrication standard which has been accepted by the Classification Society prior to the commencement of fabrication/construction. The work is to be carried out in accordance with the Rules and under survey of the classification society.

Table 1 provides a list of surveyable items for the hull structure covered by this UR and address welding consumables, welder qualification, welding – mechanical properties (welding procedures), welding equipment, welding environment, welding supervision, welding- surface discontinuities, welding – embedded discontinuities, steel preparation and fit up, surface preparation, marking and cutting, straightening, forming, conformity with alignment/fit up/gap criteria, conformity for critical areas with alignment/fit up or weld configuration, steelwork process, e.g. sub-assembly, block, grand and mega block assembly, pre-erection and erection, closing plates, remedial work and alteration, tightness testing, including leak and hose testing, hydropneumatic testing, structural testing, corrosion protection systems, e.g. coatings, cathodic protection, installation, welding and testing of: hatch covers, doors and ramps integral with the shell and bulkheads, rudders, forgings and castings, appendages, equipment forming the watertight and weathertight integrity of the ship, e.g. overboard discharges, air pipes, ventilators, freeboard marks and draft marks, principal dimensions.

II.12 Survey

Rating: The functional requirement is **covered** by CSR.

Comment:
This functional requirement is addressed in IACS Unified Requirement Z23, in particular paragraphs 7.1, 7.2 and 7.3 and Table 1 focusing on the specific activities that need to be planned for and addressed.

Prior to commencing any newbuilding project, the society is to discuss with the shipbuilder at a kick off meeting the items listed in Table 1. The purpose of the meeting is to agree how the list of specific activities shown in Table 1 is to be addressed. The meeting is to take into account the shipbuilders construction facilities and ship type and deal with sub-contractors if it is known that the builder proposes to use them. The shipyard is to be informed of likely intervals for sampling and patrol activities. A record of the meeting is to be made, based upon the contents of the Table – the Table can be used as the record with comments made into the appropriate column. If the society has nominated a surveyor for a specific newbuilding project then the surveyor is to attend the kick off meeting. The builder is to be asked to agree to undertake ad hoc for the builder to agree to keep the classification society advised of the progress of any investigation. Whenever an investigation is undertaken, the builder is to be requested, in principle, to agree to suspend relevant construction activities if warranted by the severity of the problem.

The records are to take note of specific published Administration requirements and interpretations of statutory requirements.

The record of the meeting is to be updated as the construction process progresses in the light of changing circumstances, e.g. if the shipbuilder chooses to use or change sub-contractors, or to incorporate any modifications necessitated by changes in production or inspection methods, rules and regulations, structural modifications, or in the event where increased inspection requirements are deemed necessary as a result of a substantial non-conformance or otherwise.

IN-SERVICE CONSIDERATIONS

II.13 Survey and Maintenance

Rating: The functional requirement is **partially covered** by CSR.

Comment:
The functional requirement is fulfilled with respect to design and construction requirements to allow adequate survey of the structure. This includes the avoidance of closed spaces and the size of access openings (Sec 5/5 and Sec11/2.2, 2.3 and table 11.2.2).

Criteria for planning survey and maintenance are not explicitly included in the CSR. A reference is made to the Unified Requirement Z 10.4 of IACS with respect to the assessment and the related inspections and surveys for thickness measurements in section 12/1.2.1. The hull survey for new constructions is regulated by the Unified Requirement Z 23.

It is stated, that the CSR do not include requirements related to the verification of compliance with the rules during construction and operation in section 2/2.1.3. The owner and the individual Classification Society are responsible for maintaining the ship and verify the compliance with the class requirements in accordance with the Classification Society survey scheme as stated in Sec 2/2.1.3.1(d).

CSR-reference	content	comment
Sec2/2.1.3	Responsibilities of Classification Societies, builders and owners	
Sec5/5	Access Arrangements	
Sec5/5.1.1.4	Size of access openings	
Sec11/2.2	Tank Access	see also table 11.2.2
Sec11/2.3	Bow Access	see also table 11.2.2
Sec12/1.2	Assessment of thickness measurements	Reference to UR Z 10.4 and requirements of individual Classification Society

II.14 Structural accessibility

Rating: The functional requirement is **not covered** by CSR.

Comment:
In the goal based standards, means of access to the ship's structure for inspection and thickness measurements are required according to Tier II.14.

The CSR refers to SOLAS Ch II-1, Part A-1, regulation 3-6, see CSR Section 5/5.

Both sets of rules add requirements for access to specific areas: duct keel and pipe tunnel in CSR for oil tankers, shaft tunnels and steering gear compartment in CSR for bulk carriers.

Reference documents

Reference documents are the SOLAS requirements Ch II-1 regulation 3-6, resolution MSC 158(78) and IACS UI SC 191.

RECYCLING CONSIDERATIONS

II.15 Recycling

Rating: The functional requirement is **not covered** by CSR.

Comment: Recycling matters are not scope of today's classification rules. Therefore requirements regarding recycling of the ship structure are not explicitly included in CSR. Reference is made, that other national or international rules and regulations may exist, which are relevant for the particular ship. It is noted that the MEPC plans to address this topic in a future IMO mandatory instrument on Recycling of Ships.

6. Conclusions

This report was prepared by IACS to provide a working example of how IACS in the future may provide background documentation illustrating how classification rules meet the GBS. This was done to assist IMO conduct a pilot trial application of Tier III of the *GBS for oil tankers and bulk carriers*. The intention of the pilot is to validate the Tier III verification framework, identifying shortcomings and making proposals for improvement. The pilot project will test the IMO GBS Tier III Verification Framework and not actually be the verification of the IACS CSR at this time.

Appendix A
IMO Goal-based New Ship Construction Standards

To assist the Pilot Project members, the following is a copy of the GBS Tier I and II.

TIER I [1]

Ships are to be designed and constructed for a specified design life to be safe and environmentally friendly, when properly operated and maintained under the specified operating and environmental conditions, in intact and specified damage conditions, throughout their life.

.1 Safe and environmentally friendly means the ship shall have adequate strength, integrity and stability to minimize the risk of loss of the ship or pollution to the marine environment due to structural failure, including collapse, resulting in flooding or loss of watertight integrity.
.2 Environmentally friendly also includes the ship being constructed of materials for environmentally acceptable dismantling and recycling.
.3 Safety also includes the ship's structure being arranged to provide for safe access, escape, inspection and proper maintenance.
.4 Specified operating and environmental conditions are defined by the operating area for the ship throughout its life and cover the conditions, including intermediate conditions, arising from cargo and ballast operations in port, waterways and at sea.
.5 Specified design life is the nominal period that the ship is assumed to be exposed to operating and/or environmental conditions and/or the corrosive environment and is used for selecting appropriate ship design parameters. However, the ship's actual service life may be longer or shorter depending on the actual operating conditions and maintenance of the ship throughout its life cycle.

[1] Report of MSC 80, MSC 80/24, paragraph 6.39

TIER II FUNCTIONAL REQUIREMENTS [2]

(Applicable to new oil tankers and bulk carriers in unrestricted navigation[*])

DESIGN

II.1 Design life

The specified design life is not to be less than 25 years.

II.2 Environmental conditions

Ships should be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams.

II.3 Structural strength

Ships should be designed with suitable safety margins:

.1 to withstand, at net scantlings[**], in the intact condition, the environmental conditions anticipated for the ship's design life and the loading conditions appropriate for them, which should include full homogeneous and alternate loads, partial loads, multi-port and ballast voyage, and ballast management condition loads and occasional overruns/overloads during loading/unloading operations, as applicable to the class designation; and

.2 appropriate for all design parameters whose calculation involves a degree of uncertainty, including loads, structural modelling, fatigue, corrosion, material imperfections, construction workmanship errors, buckling and residual strength.

The structural strength should be assessed against excessive deflection and failure modes, including but not limited to buckling, yielding and fatigue. Ultimate strength calculations should include ultimate hull girder capacity and ultimate strength of plates and stiffeners. The ship's structural members should be of a design that is compatible with the purpose of the space and ensures a degree of structural continuity. The structural members of ships should be designed to facilitate load/discharge for all contemplated cargoes to avoid damage by loading/discharging equipment which may compromise the safety of the structure.

II.4 Fatigue life

The design fatigue life should not be less than the ship's design life and should be based on the environmental conditions in II.2.

II.5 Residual strength

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[2] Report of MSC 82, MSC 82/WP.5, ANNEX I

[*] Unrestricted navigation means that the ship is not subject to any geographical restrictions (i.e. any oceans, any seasons) except as limited by the ship's capability for operation in ice.

[**] The net scantlings should provide the structural strength required to sustain the design loads, assuming the structure in intact condition and excluding any addition for corrosion.

Ships should be designed to have sufficient strength to withstand the wave and internal loads in specified damaged conditions such as collision, grounding or flooding. Residual strength calculations should take into account the ultimate reserve capacity of the hull girder, including permanent deformation and post-buckling behaviour. Actual foreseeable scenarios should be investigated in this regard as far as is reasonably practicable.

II.6 Protection against corrosion

Measures are to be applied to ensure that net scantlings required to meet structural strength provisions are maintained throughout the specified design life. Measures include, but are not limited to, coatings, corrosion additions, cathodic protection, impressed current systems, etc.

II.6.1 Coating life

Coatings should be applied and maintained in accordance with manufacturers' specifications concerning surface preparation, coating selection, application and maintenance. Where coating is required to be applied, the design coating life is to be specified. The actual coating life may be longer or shorter than the design coating life, depending on the actual conditions and maintenance of the ship. Coatings should be selected as a function of the intended use of the compartment, materials and application of other corrosion prevention systems, e.g. cathodic protection or other alternatives.

II.6.2 Corrosion addition

The corrosion addition should be added to the net scantling and should be adequate for the specified design life. The corrosion addition should be determined on the basis of exposure to corrosive agents such as water, cargo or corrosive atmosphere, or mechanical wear, and whether the structure is protected by corrosion prevention systems, e.g. coating, cathodic protection or by alternative means. The design corrosion rates (mm/year) should be evaluated in accordance with statistical information established from service experience and/or accelerated model tests. The actual corrosion rate may be greater or smaller than the design corrosion rate, depending on the actual conditions and maintenance of the ship.

II.7 Structural redundancy

Ships should be of redundant design and construction so that localized damage of any one structural member will not lead to immediate consequential failure of other structural elements leading to loss of structural and watertight integrity of the ship.

II.8 Watertight and weathertight integrity

Ships should be designed to have adequate watertight and weathertight integrity for the intended service of the ship and adequate strength and redundancy of the associated securing devices of hull openings.

II.9 Human element considerations

Ships should be designed and built using ergonomic design principles to ensure safety during operations, inspection and maintenance of ship's structures. These considerations should include stairs, vertical ladders, ramps, walkways and standing platforms used for permanent means of access, the work environment and inspection and maintenance considerations.

II.10 Design transparency

Ships should be designed under a reliable, controlled and transparent process made accessible to the extent necessary to confirm the safety of the new as-built ship, with due consideration to intellectual property rights. Readily available documentation should include the main goal-based parameters and all relevant design parameters that may limit the operation of the ship.

CONSTRUCTION

II.11 Construction quality procedures

Ships should be built in accordance with controlled and transparent quality production standards with due regard to intellectual property rights. The ship construction quality procedures should include, but not be limited to, specifications for material, manufacturing, alignment, assembling, joining and welding procedures, surface preparation and coating.

II.12 Survey

A survey plan should be developed for the construction phase of the ship, taking into account the ship type and design. The survey plan should contain a set of requirements, including specifying the extent and scope of the construction survey(s) and identifying areas that need special attention during the survey(s), to ensure compliance of construction with mandatory ship construction standards.

IN-SERVICE CONSIDERATIONS

II.13 Survey and Maintenance

Ships should be designed and constructed to facilitate ease of survey and maintenance, in particular avoiding the creation of spaces too confined to allow for adequate survey and maintenance activities. The survey plan in II.12 should also identify areas that need special attention during surveys throughout the ship’s life and in particular all necessary in-service survey and maintenance that was assumed when selecting ship design parameters.

II.14 Structural accessibility

The ship should be designed, constructed and equipped to provide adequate means of access to all internal structures to facilitate overall and close-up inspections and thickness measurements.

RECYCLING CONSIDERATIONS

II.15 Recycling

Ships should be designed and constructed of materials for environmentally acceptable recycling without compromising the safety and operational efficiency of the ship.

Appendix B
IACS Common Structural for Double Hull Oil Tankers

This report was prepared in association with the IACS 2006 "*Common Structural Rules for Double Hull Oil Tankers*"(referred to as CSR or Rules in this report), which entered into force on 1 April 2006. A copy of these Rules is available from any IACS member or may be downloaded from the IACS web site free of charge at the following:

www.iacs.org.uk

The CSR and this report refer to IACS Unified Requirements, which may also be obtained from the above web site.

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Appendix C
Background Documents for the IACS Common Structural for Double Hull Oil Tankers

This report was prepared to assist IMO conduct a pilot trial application of Tier III of the GBS for oil tankers and bulk carriers is not intended to actually be the verification of the IACS CSR themselves. The Section 5 commentary of this report was generally prepared in order to summarize and illustrate how the CSR relates to the GBS. It is noted that some members of the Pilot Project may wish to delve deeper into the background of the IACS CSR.

At the time of writing this report, IACS is in the process of placing a copy of the background documents for the CSR for Tankers on the IACS web site. Once posted, a copy of the background documents may be downloaded from the IACS web site free of charge at the following:

www.iacs.org.uk

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IACS Documentation Package for the IMO GBS Pilot Project

[2nd Trial Application]

31 March 2008

Submitted to:

**INTERNATIONAL MARITIME ORGANIZATION
Maritime Safety Committee**

IMO Pilot Project
(MSC 82/24, Paragraph 5.29 and Annex 15)

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Produced in March 2008 for the International Association of Classification Societies.

Contents:

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1. General

At the 81st session of the IMO Maritime Safety Committee held in May 2006, IACS agreed to use the recently developed common structural rules as basis for a pilot to conduct a trial application of the IMO *Goal-based New Ship Construction Standards* (GBS). While IACS has published common structural rules for both tankers and bulk carriers, in order to limit the scope for the pilot, only the common rules for tankers will be used. Therefore, the IACS 2006 "*Common Structural Rules for Double Hull Oil Tankers*"(referred to as CSR or Rules in this report), which entered into force on 1 April 2006 have been used.

- The first trial application was conducted by IACS and submitted (Ref: MSC 83/INF.5).
- MSC 83 agreed that a second trial application based on the new "Guidelines for the verification of the compliance with GBS" (the Guidelines) dated 3rd july 2007 using the IACS CSR for Double Hull Oil Tankers would be necessary in order to finalise the draft Guidelines.

2. Objective

2.1 Objective of the Pilot Project

The objective of the pilot project is to conduct a trial application of Tier III of the *GBS for oil tankers and bulk carriers* with the intention of validating the Tier III verification framework, identifying shortcomings and making proposals for improvement.
[Note, the pilot project will test the IMO GBS Tier III Verification Framework and not actually carry out the verification of the IACS CSR at this time.]

2.2 Objective of the submission from IACS

The objective of the second submission from IACS is to provide to the pilot panel a working example of how IACS in the future may provide the background documentation illustrating how classification rules meet the GBS.
The intention has been to provide this to the pilot panel in accordance with the instructions from the Pilot Panel chairman as follows –

<u>IACS Task Statement – GBS Trial Application</u>

Demonstrate, using the Common Structural Rules (CSR) for oil tankers, how a recognized organization's rule set could be verified as meeting Tiers I and II, considering the draft Guidelines for the verification of compliance with GBS (the Guidelines). IACS is requested to do the following:

1. Submit a documentation package to the Pilot Panel (PP) by March 31, 2008. The documentation package should include -
    - all the elements listed in paragraph 3 of Part A of the Guidelines[1].
    - Additionally, in order to allow the consideration of alternatives to improve the efficiency of the verification process,
        - IACS should include a self-assessment of CSR using the evaluation criteria listed in Part B of the Guidelines.
        - The self-assessment should include the analysis made by IACS to conclude whether a functional requirement is satisfied or not.

[1] The "Rules", as referred in Part A and Part B of the Guidelines, include the published rule set, guidelines, interpretations, internal procedures, etc., that are included in the quality certification process of a Recognized Organization.

3. Structure of this report

The content of this, 2nd trial application, "IACS Documentation Package for the IMO GBS Pilot Project" is composed as follows.

In Section 4, the following tables are provided.

- In sub-section 4.1, a summary table is provided linking the functional requirements to the CSR Rules.

- In sub-section 4.2, a summary table of the IACS self-assessment is provided, indicating whether the functional requirement is covered or not covered. If the functional requirement is not covered then an explanation is also provided.

- In sub-section 4.3, a detailed table of the IACS self-assessment is provided. The detailed summary provides the response to each of the specific evaluation criteria of the functional requirements listed in Part B of the guidelines

- In sub-section 4.4, a summary table of the information and documentation submitted to comply with GBS Tier III Guidelines – Chapter 2, is provided.

  [Note: For the preparation of the above tables the submission templates, included as appendix 1 in Part A of the Guidelines, has been used.]

In Section 5, detailed further commentary for each of the GBS functional requirements is provided.

Finally, Section 6 contains conclusions and recommendations.

4. Cross reference tables

This section contains the following tables as mentioned in the Guidelines:

- Table c.: Rule linkage
- Table d-1.: Self-assessment – Summary table
- Table d-2.: Self-assessment – Detailed table
- Table e.: Information and documentation

4.1 Table c. Rule Linkage

The following table includes a cross reference to the CSR for each of the GBS Tier II functional requirements.

c. Rule Linkage	
Tier II − Functional Requirement	**Rule section link to Functional Requirement**
II.1 Design life The specified design life is not to be less than 25 years.	*Design Life* - 2/3.1.3 *Design Fatigue Life* - 9/3.2.3.1 *Design Life* - B/2.4.7.2 *Fatigue Life* - C/1.4.1.3 *Fatigue Life* - C/1.4.1.4
II.2 Environmental conditions Ships should be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams.	2/3 – *Design basis* 2/3.1.7.1 - *External environment* 2/4.2.6.2(d) – *Environmental loads* 2/4.6 – *Principle of Safety Equivalence* 2/5.4.2 – *Design loads for strength* 2/5.4.3 – *Design loads for fatigue* 7/3 – *Dynamic load components* 7/4 – *Sloshing and impact loads* 7/6 – *Combination of loads* 9/3.2.2.1 – *Fatigue loads*
II-3 Structural strength ***II.3.1 Safety margins*** Ships should be designed with suitable safety margins: .1 to withstand, at net scantlings, in the intact condition, the environmental conditions anticipated for the ship's design life and the loading conditions appropriate for them, which should include full homogeneous and alternate loads, partial loads, multi-port and ballast voyage, and ballast management condition loads and occasional overruns/overloads during loading/unloading	**II.3.1 Safety Margins** *Net scantlings*: 2/4.3.4, 4/2.4, 6/3 *Intact structure*: 2/4.3.5 *Environmental loads*: 2/3.1.7, 2/4.2, 7/3 *Loading conditions:* 2/3.1.5 thru 6, 2/3.1.8, 2/Tab 2.4.1, 2/4.2.5, 2/5.4.1.1 thru 5, 2/5.4.2(FEA)

c. Rule Linkage	
Tier II − Functional Requirement	**Rule section link to Functional Requirement**
operations, as applicable to the class designation; and .2 appropriate for all design parameters whose calculation involves a degree of uncertainty, including loads, structural modelling, fatigue, corrosion, material imperfections, construction workmanship errors, buckling and residual strength.	7/2.1, 7/2.2, 8/1.1.2, 8/Tab 8.2.7 thru 9 B/Tab B.2.3 and 4 *Accidental loads:* 2/4.2.7, Tab 2.4.1, 7/2.2.3.4, 7/5, 7/Tab 7.6.1, 8/Tab 8.2.7 thru 9
II.3.2 Deformation and failure modes The structural strength should be assessed against excessive deflection and failure modes, including but not limited to buckling, yielding and fatigue.	**II.3.2 Deformation and failure modes** *Yield acceptance criteria:* 2/4.5, 2/5.4.1.5 thru 10, 2/Tab2.5.1 thru 3 2/5.4.5 and 6, 8/Tab 8.1.3 (BM) 8/Tab 8.1.4 (Shear), 8/Tab 8.2.4 and 5 (Local), 8/Tab 8.2.10 (PSM), 9/2.2.5 (FEM) 9/Tab 9.2.1 (FEM) *Deflection criteria:* 2/5.3.1.1(b), 2/5.4.5.1, 3/5.3.3.4, 8/1.2.2, 8/2.6.1.7 plus individual reqts., 10/2 *Buckling criteria:* 2/4.5, 2/Tab 2.5.2 and 3 8/1.2.1.4, 8/1.4, 9/2.2.5.3, 9/Tab 9.2.2, 10/, D/ *Fatigue criteria:* 2/4.3.3, 2/Tab 2.5.1, 2/5.4.3, 2/5.6.5, 8/1.5, 9/3, B/4, C/
II.3.3 General design The ship's structural members should be of a design that is compatible with the purpose of the space and ensures a degree of structural continuity. The structural members of ships should be designed to facilitate load/discharge for all contemplated cargoes to avoid damage by loading/discharging equipment which may compromise the safety of the structure.	**II.3.3 General Design** *Compatibility:* 2/3.1.7, 2/3.1.8 *Continuity:* 4/3.2 thru 4, 8/1.6, 8/2.1.4.7, 8/2.3.1.3 8/3.1.3, 8/4.1.3 , 8/5.1.3 *Loading / Unloading* 2/4.2.1 , 2/Tab 2.5.1, 8/1.1.2.2(b)
II.3.4 Ultimate strength Ultimate strength calculations should include ultimate hull girder capacity and ultimate strength of plates and stiffeners. ** The net scantlings should provide the structural strength required to sustain the design loads, assuming the structure in intact condition and excluding any addition for corrosion.	**II.3.4 Ultimate strength** *Hull girder* 2/5.6.3, 9/1, A/ *Plates and stiffeners* 10/4, D/
II.4 Fatigue life The design fatigue life should not be less than the ship's design life and should be based on the environmental conditions in II.2.	 9/3.2.3.1 B/4 C/

c. Rule Linkage	
Tier II − Functional Requirement	**Rule section link to Functional Requirement**
II.5 Residual strength Ships should be designed to have sufficient strength to withstand the wave and internal loads in specified damaged conditions such as collision, grounding or flooding. Residual strength calculations should take into account the ultimate reserve capacity of the hull girder, including permanent deformation and post-buckling behaviour. Actual foreseeable scenarios should be investigated in this regard as far as is reasonably practicable.	2/4.1.2.2(a) and (d) – *General principles* 2/4.2.7.1 – *Accidental loads* 2/4.3.5.1 – *General principles* 7/2.2.3.4 – *Flooding pressure* 7/5 – *Accidental loads* App. A – *Hull girder ULS*
II.6 Protection against corrosion Measures are to be applied to ensure that net scantlings required to meet structural strength provisions are maintained throughout the specified design life. Measures include, but are not limited to, coatings, corrosion additions, cathodic protection, impressed current systems, etc. ***II.6.1 Coating life*** Coatings should be applied and maintained in accordance with manufacturers' specifications concerning surface preparation, coating selection, application and maintenance. Where coating is required to be applied, the design coating life is to be specified. The actual coating life may be longer or shorter than the design coating life, depending on the actual conditions and maintenance of the ship. Coatings should be selected as a function of the intended use of the compartment, materials and application of other corrosion prevention systems, e.g. cathodic protection or other alternatives. ***II.6.2 Corrosion addition*** The corrosion addition should be added to the net scantling and should be adequate for the specified design life. The corrosion addition should be determined on the basis of exposure to corrosive agents such as water, cargo or corrosive atmosphere, or mechanical wear, and whether the structure is protected by corrosion prevention systems, e.g. coating, cathodic protection or by alternative means. The design corrosion rates (mm/year) should be evaluated in accordance with statistical information established from service experience and/or accelerated model tests. The actual corrosion rate may be greater or smaller than the design corrosion rate, depending on the actual conditions and maintenance of the ship.	***II.6.1 Coating life*** 6/2 – *Corrosion protection including coatings:* 6/2.1 – *Hull protection* 6/2.1.1 – *General* 6/2.1.2 – *Internal cathodic protection systems* 6/2.1.3 – *Paint containing Aluminium* ***II.6.2 Corrosion addition*** 6/3 – *Corrosion additions* 6/3.1 – *General* 6/3.2 – *Local corrosion additions* 6/3.3 – *Application of corrosion additions* 12/1.1.2 – *Wastage allowance concept* 12/1.2 – *Assessment of thickness measurements* 12/1.3 – *Categories of corrosion* 12/1.4 – *Renewal criteria of local structure for general corrosion* 12/1.5 – *Renewal criteria of hull girder sectional properties for general corrosion* 12/1.6 – *Allowable material*

c. Rule Linkage	
Tier II − Functional Requirement	**Rule section link to Functional Requirement**
	diminution for pitting, grooving and edge corrosion
II.7 Structural redundancy Ships should be of redundant design and construction so that localized damage (such as local permanent deformation, cracking or weld failure) of any stiffening structural member will not lead to immediate consequential collapse of the complete stiffened panel.	2/4.1.2.2(a) and (d) – *General principles* App. D/1 – *Advanced buckling analysis*
II.8 Watertight and weathertight integrity Ships should be designed to have adequate watertight and weathertight integrity for the intended service of the ship and adequate strength and redundancy of the associated securing devices of hull openings.	*References to other rules:* 2/2.1.1, 3/3.1.1.2, 3/3, 5/2.1.2.3 *watertight subdivision*: 5/2 *bulkheads:* 8/2.5 *watertight boundarie*s: 8/3.6, 8/4.7, 8/5.6 *hull openings and closing arrangements*: 11/1
II.9 Human element considerations Ships should be designed and built using ergonomic design principles to ensure safety during operations, inspection and maintenance of ship's structures. These considerations should include stairs, vertical ladders, ramps, walkways and standing platforms used for permanent means of access, the work environment and inspection and maintenance considerations.	*Reference to maritime regulatory framework* 2/2.1.1 *Responsibilities* 2/2.1.3 *Reference to other regulations:* 3/3.1.1.2 *size of access openings:* 5/5.1.1.4 *crew protection:* 11/2
II.10 Design transparency Ships should be designed under a reliable, controlled and transparent process made accessible to the extent necessary to confirm the safety of the new as-built ship, with due consideration to intellectual property rights. Readily available documentation should include the main goal-based parameters and all relevant design parameters that may limit the operation of the ship.	*Design Basis* - 2/3 *Design Principles* - 2/4 *Application of principles* - 2/5 *Documentation, Plans and Data Requirements* - 3/2 *Equivalency Procedure* - 3/4
II.11 Construction quality procedures Ships should be built in accordance with controlled and transparent quality production standards with due regard to intellectual property rights. The ship construction quality procedures should include, but not be limited to, specifications for material, manufacturing, alignment, assembling, joining and welding procedures, surface preparation and coating.	*Materials and Welding* - 2/4.4 *Fabrication* - 6/4.1.2 *Welding and Joint Preparation* - 6/4.4, 6/5

c. Rule Linkage	
Tier II − Functional Requirement	**Rule section link to Functional Requirement**
II.12 Survey A survey plan should be developed for the construction phase of the ship, taking into account the ship type and design. The survey plan should contain a set of requirements, including specifying the extent and scope of the construction survey(s) and identifying areas that need special attention during the survey(s), to ensure compliance of construction with mandatory ship construction standards.	*Responsibility of Classification Society* - 2/2.1.2.1 *Responsibilities of Classification Societies, builders and owners* - 2/2.1.3.1(a) and (c) *Structural Construction and Inspection* - 2/3.1.9 *Plans to be supplied onboard the ship* - 3/2.2.3.1 *Testing Procedures* - 11/5
II.13 Survey and Maintenance Ships should be designed and constructed to facilitate ease of survey and maintenance, in particular avoiding the creation of spaces too confined to allow for adequate survey and maintenance activities. Areas should be identified that need special attention during surveys throughout the ship's life. In particular, this should include all necessary in-service survey and maintenance that was assumed when selecting ship design parameters.	*Assumptions included in the rules with respect to construction and survey scheme* - 2/2.1.3.1(d) 2/3.1.9.1 *Renewal criteria* - 2/3.1.9.3 *Plans to be on board* - 3/2.2.3.1 *Equivalence Procedure* – 3/4 *Access arrangements* – 5/5 *Crew protection* – 11/2 *Thickness measurements* – 12/1.2
II.14 Structural accessibility The ship should be designed, constructed and equipped to provide adequate means of access to all internal structures to facilitate overall and close-up inspections and thickness measurements.	3/2.2.2.1(d) 5/5
RECYCLING CONSIDERATIONS	
II.15 Recycling Ships should be designed and constructed of materials for environmentally acceptable recycling without compromising the safety and operational efficiency of the ship.	2/2.1.1 3/3.3

4.2 Table d-1. Self-assessment – Summary Table

To assist the pilot panel members, a self assessment has been prepared by the IACS team summarising the extent to which IACS CSR meet each of the GBS Tier II functional requirements.
A summary table of the self assessment can be found on the next page. A more detailed self-assessment table is provided in the subsequent pages, providing a detailed response to each of the evaluation criteria listed in Part B of the Guidelines.

The self assessment indicates where the GBS are covered and where the GBS are not covered in the CSR. Possible reasons why the CSR do not fully cover the GBS include;

- the subject area is not normally covered in class newbuilding construction rules,
- the subject area is implicitly covered and not explicitly covered,
- the subject area is covered by other rules or regulations,
- the subject area is only partially covered,
- etc.

Wherever an item is indicated as not being fully covered in the CSR an accompanying comment is given.

Self Assessment – Summary Table

The following table includes a quick cross reference to the CSR for each of the GBS Tier II functional requirements.

Item	Fully covered in Rules	Not Fully covered in Rules	Comment
DESIGN			
II.1 Design life	✓		
II.2 Environmental conditions	✓		
II.3 Structural strength	✓		
II.4 Fatigue life	✓		
II.5 Residual strength		✓	2 out of 3 evaluation criteria are not covered in Rules. See detailed table.
II.6 Protection against corrosion	✓		
II.6.1 Coating life	✓		
II.6.2 Corrosion addition	✓		
II.7 Structural redundancy		✓	2 out of 3 evaluation criteria are not covered in Rules. See detailed table.
II.8 Watertight and weathertight integrity	✓		
II.9 Human element considerations		✓	2 out of 6 evaluation criteria are not covered in Rules. See detailed table.
II.10 Design transparency		✓	3 out of 3 evaluation criteria are not covered in Rules. See detailed table.
CONSTRUCTION			
II.11 Construction quality procedures	✓		
II.12 Survey	✓		
IN-SERVICE CONSIDERATIONS			
II.13 Survey and Maintenance		✓	2 out of 4 evaluation criteria are not covered in Rules. See detailed table.
II.14 Structural accessibility	✓		
RECYCLING CONSIDERATIONS			
II.15 Recycling		✓	3 out of 3 evaluation criteria are not covered in Rules. See detailed table.

4.3 Table d-2. Self-assessment – Detailed Table

Self-assessment of CSR using evaluation criteria listed in Part B of the *Guidelines*.
[Note : Where no comment is provided for a 'Yes' finding for each of the specific evaluation criteria more detailed comments to support the findings can be found in the list of Information and documentation provided in sub-section 4.4 Table e and the references therein.]

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
III.1 Design life			
1 Are structural strength, fatigue and corrosions additions, and any other design parameters used in the Rules based upon the specified design life?	Yes		
2 Has the design life been properly applied in sections of the Rules where specified	Yes		
III.2 Environmental conditions			
1 Do the Rules specify the wave spectrum and the short/long term method used to obtain the design extreme value, including its probability of exceedance?	Yes		
2 Does the wave data properly represent North Atlantic conditions and include the regions where the most severe conditions are expected[2]?	Yes		
3 Are the most probable extreme loads based on not less than 10^8 cycles of wave encounters (assumed to correspond to a 25-year design life)?	Yes		
4 Are the methodologies used to develop ship motions and loads validated by the experimental or service history data?	Yes		
5 Are the ship speeds used for assessment of ship motions and loads based upon speeds that can be	Yes		

2 In no case should the data yield most probable significant wave height (extreme values) less than those obtained from IACS Recommendation No. 34.

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
expected in the sea states under consideration and taking into account the methods used for the analyses? Equal distribution of heading may be assumed unless the expected distribution is more severe.			
6 Do the Rules properly specify the range of applicability of ship motions and loads, and when further analysis, such as direct sea-keeping analysis or model testing, is required? Do the Rules clearly state the assumptions used in III.2.b.4?	Yes		
III.3 Structural Strength			
1 Do the Rules specify the probability level for which global and local dynamic loads are calculated? Has justification been provided?	Yes		
2 Are the limits of yielding, buckling and ultimate strength set at levels that will maintain the structural integrity?	Yes		
3 Do the Rules satisfactorily consider deformations that may compromise the integrity of the ship's structure?	Yes		
4 Do the Rules specify the required extent of finite element models and how ship structures should be modeled, including how boundary conditions and loads are to be applied, and elements and mesh size selected? Are primary, secondary and tertiary stresses properly accounted for?	Yes		
5 Are the following loading conditions included at a minimum: homogeneous, partial, alternate loads, multi-port, ballast conditions including ballast management, and loading and	Yes		

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
offloading sequences and intermediate conditions? Are these, and any other conditions identified in the loading or stability manuals, considered without exceeding allowable bending moments, shear forces and stresses?			
6 Is the methodology for developing the lightship and deadweight loads and distributions clearly defined, in a way that it will be consistently applied?	Yes	Rule definition and use of the Lightship weight and distribution are considered only in the Direct Strength Assessment procedure of CSR but not the prescriptive portion of the rules	The rule requirements do not develop the loads, but they specify a procedure or expressions to derive the loads. The evaluation criteria should be reformulated to better reflect this.
7 Do the Rules include methodology for the development of local loads, including specifying the minimum density for cargo and ballast to be applied?	Yes		See above comment.
8 With regard to local strength:			
.1 Do the Rules require the structure in way of cargo and ballast spaces to be suitable for any level of filling, from empty to maximum capacity (where maximum capacity is either 100% full or the clearly defined operational limit on filling height)	Yes		
.2 Do the Rules define loading patterns for evaluation, including full and empty adjacent tanks, full and empty athwartships rows of tanks, full and empty asymmetric loading, and the drafts to be considered for each loading pattern?	Yes		
.3 Do the Rules consider any reasonable combination of cargo or ballast spaces in any one athwartships row across to be empty at or near the scantling draft?	Yes	In the condition with one athwartship row across empty, a draft of 0.55Tsc is used which is considered “reasonable”. The 0.55Tsc value was determined based on review of loading manuals of existing ships.	

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
.4 Do the assumed draft limits and assumed cargo densities cover the expected operational range? .5 Do the local strength evaluations consider the effects of maximum allowable still water and wave bending and shear loads on the structure? .6 Are sloshing effects adequately covered by the Rules?	Yes Yes Yes	The Rules state that if an actual draft deeper than 0.55Tsc is to be used with one athwartship row across empty, than that actual deeper draft is to be analyzed.	
9 Do the Rules satisfactorily consider workmanship standards and construction tolerances?	Yes		
10 Do weld designs and procedures provide a level of strength of welds in their net condition to withstand the expected loads on the joints?	Yes		
11 Are the requirements for tapering primary structures, including transitions fore and aft of the cargo block, defined in sufficient detail in the Rules? .1 Where prescriptive measures are specified, do these measures provide for adequate continuity and termination of primary structure and primary supporting members? .2 Where analytical methods are allowed for evaluating structural continuity, is the methodology sufficiently defined to enable adequate assessment of the proposed arrangements for the termination of primary structure and primary supporting members? Do these analytical methods include	Yes Yes No	General requirements are provided for the transition areas, but the transition requirements do not contain very detailed prescriptive requirements on order to be able to handle the many variations proposed by various shipyards worldwide. Designers may substantiate or analyze transition areas using analytical methods, but the rules do not require an analysis for all vessels. Therefore analytical criteria is not defined, however the same criteria as specified for the midship region may be used.	

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
both the local stress evaluation and the effect of the relative stiffness of the members at the termination?			
12 Do the Rules specify procedures for direct calculation of local stresses in structural details or if direct calculation is not required, do the Rules include definition and application of stress concentration factors? If stress concentration factors are utilized, a justification of the definition and application of these factors should be included.	Yes		
13 Do the Rules satisfactorily consider deformations or vibration levels that may damage or impair the ship structure, equipment or machinery?	Yes	CSR include prescriptive scantling requirements based on experience of existing ships, including historic vibration issues. However the CSR does not require a distinct vibration analysis to be carried out for each vessel.	
14 Do the Rules include adequate safety factors?	Yes		
15 Have the results from the strength and ultimate strength assessments been benchmarked? Do they compare favourably with service history and other standards?	Yes		
III.4 Fatigue life			
1 Do the Rules describe how structural details should be modeled? Do the Rules take into account stress concentrations, as may be applicable to the detail analyzed?	Yes		
2 Is the methodology used to develop cyclic loads, such as inertial loads and internal/external hydrodynamic loads, based on the North Atlantic environment?	Yes		

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
3 Do the Rules identify structural elements and typical critical design details prone to fatigue throughout the entire ship that are required to be included in the evaluation of ship's fatigue life?	Yes		
4 Do the Rules specify a representative ship's operating profile to be used in long term fatigue response analysis?	Yes		
5 Are the assumed loading conditions (e.g. loaded and ballast) used in fatigue life analysis representative of the critical (maximum stress range) fatigue stress conditions for North Atlantic service?	Yes		
6 Do the Rules specify the required extent of finite element models and how ship structures should be modeled, including how boundary conditions and loads are to be applied, and elements and mesh size selected? Are primary, secondary and tertiary stresses properly accounted for?	Yes		
7 Do the Rules specify procedures for the calculation of cyclic stresses in structural details?	Yes		
8 Do the Rules satisfactorily consider construction tolerances and procedures, material imperfections and surface treatment, such as grinding and peening?	Yes		
9 Do the fatigue life calculations consider degradation of coating performance under seawater environment?	Yes		
10 If the Rules take slamming (e.g. whipping) and vibratory-induced fatigue effects (e.g. springing or propeller induced vibrations) into consideration,	Indeterminate	The Rules don't consider explicitly the possible effects of shocks and vibrations on fatigue behaviour. Observed variations in fatigue life of structural details may be	Delete this criterion as the underlying hypothesis is presently not established. In addition, the answer to the question is indeterminate if the premise is false, which is

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
do the fatigue life calculations properly take this into account?		reproduced without taking these factors into consideration.	quite unfortunate for a criteria.
11 Do the Rules satisfactorily account for uncertainties or assumptions on fatigue life?	Yes		
12 Have the results from the fatigue life assessment methodology been benchmarked? Do the results compare favourably with service history and other standards?	Yes		
III.5 Residual strength			
1 Can a ship designed to the Rules sustain flooding as defined in relevant IMO instruments and survive in North Atlantic conditions with intact structure at net scantlings?	Yes		
2 Does a ship designed to the Rules have sufficient residual strength to survive a more significant casualty event (e.g. flooding with structural damage due to collision or grounding) under environmental conditions consistent with the likelihood of occurrence? Are the assumed damage scenarios representative of the intent of damage in relevant IMO instruments?	No	Service history and calculations have shown that ships designed to the rules are able to survive a significant casualty event, but no damage scenarios are included in the rule requirements.	A more detailed definition of structural damage extent due to collision and/or grounding needs to be established by IMO. A procedure for evaluating residual strength will have to be established by IMO so that ships designed to the Rules may be assessed. The current evaluation criteria statement is too open-ended.
3 Has the residual strength assessment procedure been validated with experimental and/or casualty data?	No	There is no residual strength assessment procedure included in the rules	See above comment
III.6 Protection against corrosion			
III.6.1 Coating life			
1 Do the Rules include appropriate requirements to achieve stated target useful life of the coating and fulfill SOLAS requirements as a minimum?	Yes	Relevant IMO instruments such as SOLAS Reg. II-1/3-2 are referred to in the Rules. In addition, as stated in Section 2/2.1.1 of the Rules, the Rules assume that all applicable statutory requirements are complied with.	
2 Do alternative or additional	Yes	Relevant IMO instruments such as SOLAS	

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
requirements allowed by the Rules provide protection levels at least equivalent to those required by SOLAS?		Reg. II-1/3-2 are referred to in the Rules. In addition, as stated in Section 2/2.1.1 of the Rules, the Rules assume that all applicable statutory requirements are complied with. Furthermore, in case of cathodic protection and paint containing aluminium, the Rules require additional detailed requirements.	
3 Are the procedures indicated in b.3 and b.4 adequately documented in the Rules?	Yes	Section 2/2.1.1.4 and Section 2/2.1.1.6 satisfy b.3 and b.4 respectively. The two descriptions in the Rules, however, are different from each other, i.e. the former is a requirement to shipbuilders and the latter is an action to be taken by Class.	The square bracket in b.3 should be deleted. Otherwise the question about b.3 in the left end column may not be appropriate to verify the Rules.
4 Is adequate justification provided to support the use of alternatives?	Yes	Relevant IMO instruments such as SOLAS Reg. II-1/3-2 are referred to in the Rules. In addition, as stated in Section 2/2.1.1 of the Rules, the Rules assume that all applicable statutory requirements are complied with. Especially it should be noted that the Rules refer to IMO “Performance standard for protective coatings for ballast tanks and void spaces” which contains such procedures to comply with b.5.	
III.6.2 Corrosion addition			
1 Does the methodology and supporting statistical data justify the corrosion additions?	Yes		
2 Confirm that reductions in the Rule design corrosion additions are prohibited.	Yes		
3 Is consideration given to the corrosion of welds and heat-affected zones?	Yes	In general, corrosion addition to net thickness of steel structure is a measure to keep the net thickness against general corrosion. Concerning corrosion of welds, corrosion addition is implicitly considered in the Rules because weld design and dimensions are based on gross scantlings as stated in	

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
		Section 6/5. In case where corrosion of heat-affected zones results in non-general corrosion such as grooving, it should be subject to steel renewal according to allowable material diminution specified in Section 12/1.6 of the Rules.	
4 Do the Rules clearly establish the steel/structure renewal criteria? For ships in service, do the renewal criteria provide for scantlings that are not less than the required net scantlings and that produce a hull girder section modulus within SOLAS requirements?	Yes		
5 Has the methodology used to determine corrosion addition and establish steel/structure renewal criteria been benchmarked? Does it compare favourably with experimental and service history data?	Yes		
III.7 Structural redundancy			
1 Does a ship designed to the Rules have sufficient structural redundancy to survive local damage to a stiffening member?	Yes		
2 Are the analytical methods for assessing the consequences of localized damage satisfactorily described?	No	There are no analytical methods included in the rules for assessing the consequence of localized damage.	A more detailed definition of damage extent should be established by IMO before consideration can be given to this requirement being included in class rules
3 Has the methodology used to assess structural redundancy been benchmarked? Does it compare favourably with experimental or casualty history data?	No	There is no methodology included in the rules to assess structural redundancy.	See above comment
III.8 Watertight and weathertight integrity			
1 Do the Rules satisfy all relevant IMO watertight and weathertight integrity	Yes		

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
requirements?			
2 Do the Rules require sufficient strength for closing arrangements and securing devices to meet environmental conditions, design loads and specified design life? Do the securing devices have adequate redundancy?	Yes Yes	The last question is a repetition of the functional requirement but no evaluation criteria. It is furthermore focused to the device – not to the rule.	Reformulation of the last question.
III.9 Human element considerations			
1 Are human element and ergonomic considerations accounted for in the design of stairs, vertical ladders, ramps, walkways and work platforms?	Yes	Only by reference to other relevant regulations. CSR includes no requirements for stairs, ladders etc. This criterion is in scope of Tier V regulations such as accidental prevention regulations of employer's liability insurance associations, ISO etc.	
2 Do the Rules require structural or other arrangements to facilitate adequate lighting and ventilation in spaces normally manned or occupied by the crew?	No	Lightning and ventilation of spaces in general not in scope of structural rules. Rules for ventilation and lightning may affect the structural arrangement.	
3 Do the Rules require structural or other measures to reduce the generation and transmission of noise and vibration to a level at or below the acceptable ergonomic standards for spaces normally manned or occupied by the crew?	No	This is not in scope of todays shipbuilding rules because not related to the safety of the ship. However there exist rules, which are focused on that, but not part of the structural rules for the ship hull. It can be considered as an owners extra Sec2/3.1.10(a)	
4 Do the Rules require structural or other arrangements to facilitate adequate lighting and ventilation for the purposes of inspection, survey and maintenance?	Yes	Lightning not in scope of structural rules	
5 Do the Rules require structural arrangements to facilitate emergency egress from tanks or closed spaces?	Yes	By reference to IMO regulations	
6 Are relevant IMO requirements included	Yes	Referred to	

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
or referred to in the Rules (i.e. bow access, etc.)?			
III.10 Design transparency			
1 Do the Rules establish clear and auditable requirements for including and updating design specific and critical information, including limitations, in the Ship Construction File?	No	The information to be required for inclusion in the Ship Construction File is currently defined in IACS UR Z23, section 10.	This requirement is not clear. It should be amended to clarify and exactly list what kind of information is to be included in the Ship Construction File, e.g. cross reference to SOLAS regulation. (Further clarification should be sought in consultation with the Pilot Panel at our meeting on 5th/6th May)
2 Do the Rules establish clear criteria and techniques for assessing alternate methods used in the design? Are all equivalencies documented in the Ship Construction File and made available to the owner and flag State?	No	The Rules describe the Process to be followed in assessing alternative designs and/or methods. Alternatives are generally assessed on a case by case basis.	This requirement is not clear. It should be amended to clarify and exactly list what kind of information is to be included in the Ship Construction File. (Further clarification should be sought in consultation with the Pilot Panel at our meeting on 5th/6th May)
3 Are there clear and auditable procedures to provide for ship's structural related design and technical correspondence and data pertaining to the ship to be made available to the owner, class and flag State upon request?	Yes/No	The contract for marine services is generally signed between yard/class and there is no contractual obligation for technical correspondence on design and survey to be shared with owner unless the owner has made this a requirement of the specification between yard and owner and agreed by the Yard. On the other hand requests for correspondence between class and yard to be made available to the flag administration if so requested by them would be agreed as per SOLAS requirements.	This requirement should be reformulated and if kept should only relate to ship related structural related design data and included in the Ship Construction File.
III.11 Construction quality procedures			
1 Have the Rules' quality construction requirements been benchmarked? Do they compare favourably with recognized international shipbuilding and repair quality standards?	Yes	The standards are based on years of experience and good practice. IACS recommendation 47 " Shipbuilding and Repair Standards for New Construction" has been developed concurrently with well established recognised international Shipbuilding quality standards.	

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
2 Are the construction tolerances used in Rule formulations and calculations incorporated in the construction plan and verified during construction?	Yes		
3 Do the quality requirements include continuous design improvement based on experience?	Yes		
III.12 Survey during construction			
1 Do the Rules require the development of a Survey Plan that is reviewed during the initial kick off meeting? Does the survey plan address activities during ship construction sufficient to verify the ship is built in accordance with the appropriate rules or standards and address all elements in III.12.b.1?	Yes	This is addressed by the individual Class requirements in accordance with URZ23	
2 Do the Rules contain provisions that areas of high stress or fatigue risk identified during design approval are surveyed with adequate detail and extent during construction?	Yes		
3 Does the classification society have procedures to provide for an adequate number of qualified surveyors to carry out proposed surveys in accordance with the size of the project?	Yes		
4 Do the Rules include acceptance criteria for all tests required? Are the test criteria based on Rule formulation parameters?	Yes		
5 Is survey related correspondence between yard and class relating to vessel design and construction made available to the owner and flag Administration?	Yes/No	This issue is considered to be outside of classification matters and a contractual matter between the owner, the builder and the manufacturer, as appropriate. The CSR Rules does not have a procedure to make available design related/technical correspondence.	

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
		This is not traditionally covered by classification rule. See comments in III.10.3 re Flag Admin.	
6 Have the Rules' construction survey requirements been benchmarked? Do they compare favourably with recognized international shipbuilding and repair quality standards?	Yes	See Comments in III.11.1	General observation : Consideration should be given to combining Sections III.11 and III.12 into one combined section under 'Construction'
III.13 Survey and Maintenance			
1 Do the Rules include design requirements to provide for spaces of adequate size for ship survey and maintenance?	Yes	By reference to SOLAS II-1 regulation 3-6	
2 Do the Rules contain provisions for the identification of areas of high stress or fatigue risk that require monitoring while in-service?	Yes	By reference to SOLAS II-1 regulation 3-6 (Ship Structure Access Manual)	
3 Do the Rules include provisions for the identification of design parameters or features selected on the basis of special in-service survey or maintenance requirements?	No	In General design parameters and features required by the rules are based on the assumption, that a survey scheme is in place and the ship structure will be maintained acc. to this scheme. Design parameters or features deviating from the rules have to be handled acc. to Sec 3/4 Equivalence Procedure in agreement with the individual class society.	
4 Do the Rules include provisions for the identification of other parameters needing special attention during the ship's life?	No	The meaning of this criterion is not clear. Which other parameters are meant? What is the intention behind this criterion?	Delete this criterion or include a clear unmistakable description of the criterion.
III.14 Structural accessibility			
1 Are relevant IMO requirements included or referred to in the Rules (i.e. permanent means of access, etc.)?	Yes	Referred to.	
2 Are there provisions to provide for safe access to critical areas defined in II.13?	No		
III.15 Recycling		The whole item Recycling is not in scope of	This item will be regulated by the new IMO

Item Evaluation Criteria	Findings (Yes/No)	Comments	Recommendations
		class rules	convention "INTERNATIONAL CONVENTION FOR THE SAFE AND ENVIRONMENTALLY SOUND RECYCLING OF SHIPS" which is currently under development of MEPC
1 Do the Rules include provisions that ships be designed and constructed of materials that are environmentally acceptable at recycling?	No	Will be regulated by new IMO-convention	No need to regulate this item by Class Rules, reference to the new convention should be sufficient
2 Do the Rules include determination of whether or not materials are acceptable, including: .1 List of environmentally acceptable and unacceptable materials. .2 Criteria for evaluating new materials for acceptability/unacceptability. .3 Criteria for determining safety and operational efficiency. .4 Provisions for documenting materials in Ship Construction File.	No	Will be regulated by new IMO-convention	No need to regulate this item by Class Rules, reference to the new convention should be sufficient
3 Do the Rules include provisions for documenting changes to any of the above during the vessel's service life?]	No	Will be regulated by new IMO-convention	No need to regulate this item by Class Rules, reference to the new convention should be sufficient

4.4 Table e. Information and documentation

e. Information and documentation submitted to comply with GBS Tier III Guidelines, chapter 2, as approved by MSC	
Tier III item	**List of information and documentation**
Design	
III-1 Design life	See Commentary, Section 5/II.1 Background document Section 2/3.1.3 Design life Background document Section 7/3 Dynamic Loads Background document Section 8/1.5.1b Hull girder fatigue Background document Section 12/1.4 Renewal criteria
III-2 Environmental conditions	See Commentary, Section 5/II.2 Background document Section 2/3 Design Basis Background document Section 7/3 Dynamic Loads Background document Section 7/4 Impact Load Background document Section 7/6 Load combination
III-3 Structural strength	See Commentary, Section 5/II.3 Background document Section 2/3, 2/4 Background document Section 4/3 Background document Section 6/1, 6/4 Background document Section 7 Background document Section 8/1, 8/2, 8/4 Background document Section 9/1, 9/2 Background document Section 10 Background document Appendix-A Background document Appendix-B Background document Appendix-D
III-4 Fatigue life	See Commentary, Section 5/II.4 Background document Section 2/4.3.3 Criteria for fatigue Background document Section 8/1 Hull girder fatigue Background document Section 9/3 Verification of Fatigue Background document Appendix C - Fatigue assessment
III-5 Residual strength	See Commentary, Section 5/II.5 Background document Section 2 Rule Principles
III-6 Protection against corrosion	See Commentary, Section 5/II.6 Background document Section 6 Material and Welding Background document Section 12 Ship in Operation Renewal Criteria
III-7 Structural redundancy	See Commentary, Section 5/II.7 Background document Section 2/4.5.1 Design Methods
III-8 Watertight and weathertight integrity	See Commentary, Section 5/II.8 Background document Section 8/2- SCANTLING REQUIREMENTS CARGO TANK REGION - 2.5 (Bulkheads), Background document Section 11 – General Requirements – 1.1 – 1.5

e. Information and documentation submitted to comply with GBS Tier III Guidelines, chapter 2, as approved by MSC	
Tier III item	**List of information and documentation**
III-9 Human element considerations	See Commentary, Section 5/II.9 Background document Section 11 Background document Section 5/5 – Access Arrangements Background document Section 2
III-10 Design transparency	See Commentary, Section 5/II-10 Background document: Section 2 – Rule Principles Section 3 – Rule Application
Construction	
III-11 Construction quality procedures	See Commentary, Section 5/II-11 Background document: Section 6 – Materials and Welding Other Documents: IACS PR32 IACS UR Z23 IACS Recommendation 47, Shipbuilding and Repair Quality Standard for New Construction
III-12 Survey	See Commentary, Section 5/II-12 Background document: Section 12 – Ship in Operation Renewal Criteria
In-service consideration	
III-13 Survey and maintenance	See Commentary, Section 5/II.13 Background document Section 2 Background document Section 5/5 – Access Arrangements Background document Section 11 – Crew Protection Background document Section 12
III-14 Structural accessibility	See Commentary, Section 5/II.14 Background document Section 5/5 Access arrangements Background document Section 11/2 Crew protection
Recycling consideration	
III-15 Recycling	See Commentary, Section 5/II.15

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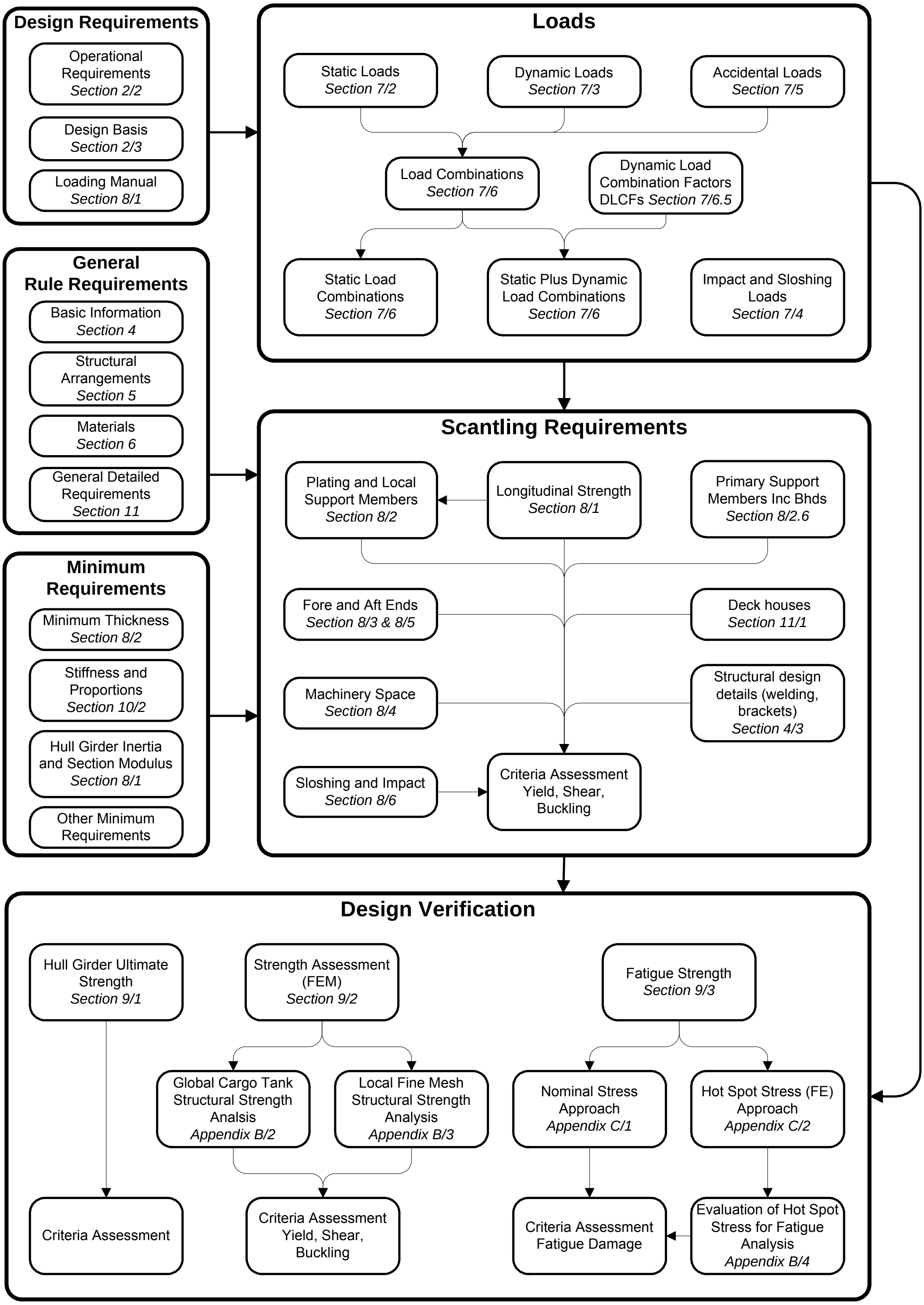
5. Commentary

Tier II Functional Requirements

To demonstrate how the CSR/Tankers address the IMO GBS Tier II Functional Requirements, each of the functional requirements is listed followed by a description of how the CSR/Tanker relates.

This report has been organized by sections according to the GBS functional requirements; however the Rules themselves are organized similar to a typical design flow as illustrated in the figure below, which is Figure 2.5.1 from the CSR.

Overview of Structural Design Process



DESIGN

II.1 Design life

Statement of intent: The intent of the functional requirement is **covered** by CSR.

Comment:
In Tier II.1 of the Goal based standards the design life, defined in Goal 5 of Tier I, is to be 25 years.

CSR definitions of design life are given in Section 2/3.1.3. These definitions are essentially the same as the one provided in Tier I.

The design life of 25 years is an input parameter for the determination of the values of the scantling loads, fatigue loads, expected fatigue life and corrosion wastage allowances:

.1 In CSR, the characteristic value of loads used in ultimate strength analysis is the expected maximum load likely to be encountered during the design life, i.e. 25 years. With a mean wave period of about 9 seconds, 25 years corresponds to 10^8 cycles. Influence of design life variations on characteristic loads is negligible: about 1% variation for a life increase of five years from 20 to 25 years as compared to typical pre-CSR requirements.

.2 The increase of design fatigue life from the past practice of 20 years to 25 years has an important influence on the fatigue checking of the structure, see section II.4 Fatigue of this report.

.3 To take into account general uniform corrosion of the structure of the ships, values of wastage allowances are given in CSR Rules. The wastage allowances were determined such that 95% of the measured thicknesses present in the IACS statistics are larger than the renewal thickness given in the rules at the end of the design life (25 years of service).

CSR Reference:

CSR-reference	content	comment
Sec 2/3.1.3	Design life	
Sec 2/5.4.2.4	Description regarding the 10^8 cycles	

II.2 Environmental conditions

Statement of intent: The intent of the functional requirement is **covered** by CSR.

Comment:

.1 Sea state data

The rule text explicitly specifies that the rule requirements are based on a ship trading in the North Atlantic wave environment for its entire design life.

It is specified in the rule text that wave loads are derived using the sea state data given in IACS Recommendation No. 34. This recommendation gives the wave data using a scatter diagram where the probability of sea-states is described as occurrences per

100000 observations. The area covered by the scatter diagram is also specified. The scatter diagram given in Rec. 34 is developed based on wave data obtained from British Marine Technology.

The sea-state data that the rule requirements are based on, and background documentation of the scatter diagram used, can be found in the following publications:

- IACS Recommendation No. 34, "Standard Wave Data"
- British Marine Technology (Primary contributors Hogben N., Da Cunha, L.F. and Oliver, H.N.). "Global Wave Statistics", Unwin Brothers Limited, London 1986.
- Bitner-Gregersen, E.M., Cramer, E.H., Korbijin, F., "Environmental Description for Long-term Load Response of Ship Structures", ISOPE June 1995, The Hague, The Netherlands.

CSR reference:

CSR-reference	content	comment
Sec 2/3.1.7.1	External environment	

.2 Derivation of ship motions and loads

The basis for the development of load formulations using the specified wave environment is explained in the following.

The Rule formulations for the wave loads are based on envelope values calculated by numerical wave load analysis and regression analysis, and calibrated with feedback from service experience and model tests. The envelope value is the long term value, at a given probability level, taking into consideration the effect of all wave headings.

The general principles for the derivation of the wave load values are:

(a) the application of load values is consistent for all similar load scenarios
(b) the characteristic load value is selected to suit the purpose of the application of the load and the selected structural assessment method, e.g. for strength assessment the expected lifetime maximum load is applied while for fatigue assessment an average value representing the expected load history is applied
(c) load calculations are performed using 3-D linear hydrodynamic computational tools. The effects of speed are considered
(d) the derivation of characteristic wave loads is based on a long term statistical approach which includes representation of the wave environment (North Atlantic scatter diagram), probability of ship/wave heading and probability of load value exceedance based on IACS Rec. 34. All of which result in envelope values
(e) non-linear effects are considered for the expected lifetime maximum loads.

The hydrodynamic calculations are based on:

(a) the Pierson-Moskowitz wave spectrum
(b) a wave energy-spreading of $\cos^2$
(c) an equal probability on all wave headings
(d) a 30 degree step of ship/wave heading

The speed and loading condition are chosen based on the corresponding application of load and the structural assessment method. Thus, for:

(a) strength evaluation; a heavy ballast condition and a full load condition at scantling draught have been used for the assessment, applying no forward speed, as tankers are

full-form ships with negligible manoeuvring speed in extreme heavy weather due to voluntary and involuntary reasons;
(b) fatigue assessment; normal ballast and full load condition at design draught have been evaluated as the two most common sailing conditions. A speed of 75% of service speed has been taken as the average speed over the lifetime, taking into account effects of slamming, bow submergence, added wave resistance and voluntary speed reduction.

The considered wave-induced loads include:
(a) hull girder loads (i.e., vertical and horizontal bending moments)
(b) dynamic wave pressures
(c) dynamic tank pressures.

The probability of occurrence is selected based on the purpose of application of the load and the selected structural assessment method to be as follows:
(a) the loads for fatigue assessment are based on a probability of exceedance of 10^{-4}, which means loads which occur frequently. The 10^{-4} is the reference probability level that together with a Weibull shape parameter and average zero-crossing period define the expected load history.
(b) the loads for strength evaluation are based on a probability of exceedance of 10^{-8}. The probability level represents the expected maximum load during the design life. The exception is the sloshing loads, where a probability level of 10^{-4} is used, which is a load that occurs frequently.

General formulae for linear wave induced ship motion, acceleration, hull girder loads and wave pressures are given at both 10^{-8} and 10^{-4} probability levels.

The design load combinations corresponding to the identified load scenarios produce realistic design load sets suitable for the design and verification of the structural capability. Design load sets apply all the applicable simultaneously acting static and dynamic local load components and static and dynamic global load components for the design of a particular or group of structural members.

The combination of dynamic loads considers all simultaneously occurring dynamic load components. In deriving the simultaneously occurring loads, one particular load component is maximised or minimised and the relative magnitude of all simultaneously occurring dynamic load components is specified by the application of dynamic load combination factors (DLCF) based on the envelope load value. These dynamic load combination factors are based on the application of the equivalent design wave approach and are given as tabulated values.

For scantling requirements and strength assessments, correction factors to account for non-linear wave effects and operational considerations in heavy weather are applied to the linear loads. In beam sea condition a heading correction factor of 0.8 to account for operational considerations are applied to the linear loads. This is done because the assumption of equal probability of all wave headings is not considered to be correct for extreme conditions, since the ship in such weather will be steered up against the waves.

For the fatigue requirements given, the load assessment is based on the expected load history and an average approach is applied. The expected load history for the design life is characterised by the 10^{-4} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding stresses.

The fatigue analysis is calculated for two representative loading conditions covering the ship's intended operation. These two conditions are:
(a) full load homogeneous conditions at design draught
(b) normal ballast condition.

The ships life is divided into three operational phases with 42.5% in full load at sea, 42.5% in ballast at sea and the remaining 15% in harbour or sheltered waters.

Correction factors to account for speed effects are applied to the linear loads for fatigue assessment. Also factors to calculate the loads at probability levels 10^{-8} and 10^{-4} are applied.

Limits of applicability are stated under Design Basis in the Rule Principles section. Main limitations are:
- Vessel length: Min 150m
- Arrangement: Double side, and min. one longitudinal bulkhead

Limitations of the hull form with respect to environmental loading are stated as follows:
(a) full form ship with block coefficient (*Cb*) greater than 0.7
(b) the ship length breadth ratio (*L/B*) greater than 5
(c) ship breadth depth ratio (*B/D*) less than 2.5
(d) the metacentric height (*GM*) not greater than 0.12*B* for homogeneously full load conditions, and 0.33*B* for ballast conditions.

The rules state that novel designs deviating from the design basis or structural arrangements covered by the Rules will be subject to special consideration. In this case, the principle of equivalence is to be applied to the novel design, which means it must be demonstrated that the structural safety of the novel design is at least equivalent to that intended by the Rules. This may need to incude a systematic review process, in order to identify and evaluate the likely consequences of hazards due to operational and environmental influences.

CSR references:

CSR-reference	content	comment
Sec 2/3	Design Basis	
Sec 2/4.2.6	Environmental loads	
Sec 2/4.6	Principle of Safety Equivalence	
Sec 2/5.4.2	Design loads for scantling requirements and strength assessment	
Sec 2/5.4.3	Design loads for fatigue assessment	

The environmental conditions are used for development of the environmental loads, but only the load formulations themselves are included in the rule text. Since North Atlantic environmental conditions are assumed for all vessels covered by the rules, the environmental conditions does not enter into the rule formulations.

The environmental conditions are used for development of the load formulations given in the rule sections as listed below:

CSR references:

CSR-reference	content	comment
Sec 7/3	Dynamic load components	
Sec 7/4	Sloshing and impact loads	
Sec 7/6	Combination of loads	

The main tool used for development of ship motion and load formulations is the hydrodynamic seakeeping software. Such software is usually benchmarked using small-scale model tests, as well as reckognized benchmark data available. Full scale measurements are also used to some extent. In addition, some model tests were carried out for direct calibration of the rule formulations.

In the end, the scantlings resulting from the rule requirements are compared with service history data. This is an implicit check of the load formulations, since the scantlings are a result of both the loads and the strength formulations.

II.3 Structural Strength

Statement of intent: The intent of the functional requirement is **covered** by CSR.

Comment:
The GBS Tier II.3 criteria calls for the documentation of the structural requirements included in the class rules.

.1 Safety Margins

The GBS lists various items which should be taken into account when establishing suitable safety margins in the rules. The items mentioned are each discussed as follows:

a) Environmental conditions:
The environmental loads included in the CSR, which are used during the assessment of structural strength, have been based on a 25 year exposure to the North Atlantic environment. The probability of exceedance levels for the various individual design environmental loads are included in Section 5.II.2 of this report.

While the design loads of the North Atlantic have been used to formulate the design loads, most vessels do not typically trade exclusively in the North Atlantic. Therefore there is a safety factor associated with relating the actual environment under which the vessel trades versus the North Atlantic environment, as the CSR have not included reductions to the design loads to account for actual benign environments. The safety margin varies based on the future trading patterns of the vessels.

These environmental conditions are used to develop the dynamic wave-induced components of the design loads for longitudinal hull girder strength and the strength evaluation of local structural members.

CSR references:

CSR-reference	content	comment
Sec 2/3.1.7	External environment	
Sec 7/3	Dynamic loads	

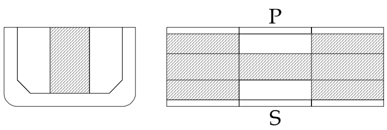
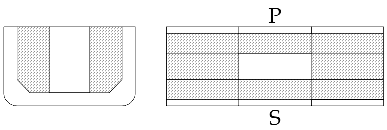
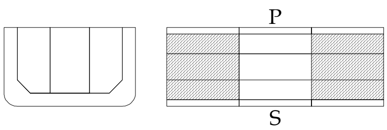
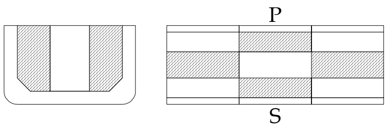
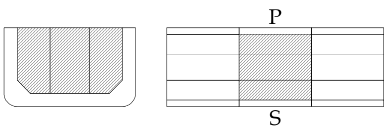
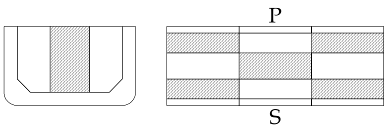
b) Loading conditions:
Representative design cargo and ballasting loading conditions are specified to envelope the actual vessel loading conditions. The design loading conditions include various combinations of full and empty tanks to represent homogeneous, alternate, partial, multi-port, ballast, and ballast management conditions. If actual vessel loading conditions include non-typical conditions such as asymmetric loading or simultaneously emptying all cargo tanks across a section, the Rules state that they also have to be used in the structural evaluation.

While the Rule specified loading conditions which include checkerboard or alternate tank loading have been used to formulate the design loads, most vessels typically trade in homogeneous full load or ballast load conditions. Therefore there is a safety factor associated with relating the actual loading conditions under which the vessel trades versus the Rule conditions. As this depends on the unknown future loading patterns of the vessels, there is no way of actually quantifying the safety margin attributed to this.

These vessel loading conditions are used to develop the static components of the design loads for longitudinal hull girder strength and the strength evaluation of structural members. Additional information on the loading conditions is included in Section 5.II.2 of this report.

The Rules relate the design loading conditions to the actual operation of the vessel by specifying that loading conditions and operation instructions be included in the vessel Loading Manual and/or Loading Instrument which will be used by the vessels' operating personnel. The Rules require that the Loading Manual include design parameters and operational limitations upon which approval of the hull scantlings have been based. Limitations on permissible still water bending moment and shear forces, scantling draft, minimum draft, minimum forward draft, allowable cargo density, ballast water exchange operations, and the design speed are to be included.

The following table, which is a partial copy of Table B.2.3 from the CSR, illustrates representative loading conditions to be evaluated in the FEM analysis which are included in the Rules.

<table>
<tr><th colspan="9">FE Load Cases for Tankers with Two Oil-tight Longitudinal Bulkheads</th></tr>
<tr><th rowspan="3">Loading Pattern</th><th rowspan="3">Figure</th><th colspan="3">Still Water Loads</th><th colspan="3">Dynamic load cases</th></tr>
<tr><th rowspan="2">Draught</th><th rowspan="2">% of Perm. SWBM(2)</th><th rowspan="2">% of Perm. SWSF(2)</th><th>Strength assessment (1a)</th><th colspan="2">Strength assessment against hull girder shear loads (1b)</th></tr>
<tr><th>Midship region</th><th>Forward region</th><th>Midship and aft regions</th></tr>
<tr><td colspan="9">Design load combination S + D (Sea-going load cases)</td></tr>
<tr><td rowspan="2">A1</td><td rowspan="2"></td><td rowspan="2">0.9 T_{sc}</td><td>100% (sag)</td><td>See note 3</td><td>1</td><td>\</td><td>\</td></tr>
<tr><td>100% (hog)</td><td>100% (-ve fwd) See note 4</td><td>2, 5a</td><td>\</td><td>\</td></tr>
<tr><td rowspan="2">A2</td><td rowspan="2"></td><td rowspan="2">0.9 T_{sc}</td><td>100% (sag)</td><td>See note 3</td><td>1</td><td>\</td><td>\</td></tr>
<tr><td>100% (hog)</td><td>100% (-ve fwd) See note 4</td><td>2, 5a</td><td>\</td><td>\</td></tr>
<tr><td rowspan="2">A3(6)</td><td rowspan="2"></td><td rowspan="2">0.55 T_{sc} see note 5</td><td rowspan="2">100% (hog)</td><td>100% (-ve fwd) See note 5</td><td>2</td><td>4</td><td>2</td></tr>
<tr><td>100% (-ve fwd) See note 5</td><td>5a</td><td>\</td><td>\</td></tr>
<tr><td>A4</td><td></td><td>0.6 T_{sc}</td><td>100% (sag)</td><td>100% (+ve fwd) See note 4</td><td>1, 5a</td><td>\</td><td>\</td></tr>
<tr><td rowspan="2">A5(7)</td><td rowspan="2"></td><td rowspan="2">0.8 T_{sc} See note 6</td><td rowspan="2">100% (sag)</td><td>100% (+ve fwd) See note 5</td><td>1</td><td>3</td><td>1</td></tr>
<tr><td>100% (+ve fwd) See note 4</td><td>5a</td><td>\</td><td>\</td></tr>
<tr><td>A6</td><td></td><td>0.6 T_{sc}</td><td>100% (hog)</td><td>100% (-ve fwd) See note 4</td><td>5a</td><td>\</td><td>\</td></tr>
</table>

CSR references:

CSR-reference	content	comment
Sec 2/3.1.5	Operating conditions	
Sec 2/3.1.6	Operating draughts	
Sec 7/2.1	Static hull girder loads	
Sec 8/1.1	Loading guidance	
Sec 8/1.1.2	Loading manual	
Sec 8/1.1.3	Loading computer program	

c) Local loads:

The above mentioned wave-induced dynamic (D) and loading condition static (S) load components are combined in order to calculate the maximum local loads (S + D) used to evaluate structural members. Design loads included in the Rules also contain margins to cover accidental (A) loads such as occasional overruns or overloads during loading or unloading operations. This includes the height of air pipes and pressure relief vale settings. Details of the determination of the local loads are included in Section 5.II.2 of this report.

The following table, which is a copy of Table 2.4.1 from the CSR, indicates load categories included in the Rules.

Load Categorisations		
Operational Loads	Lightship weight	Steel weight and outfit Machinery and permanent equipment
	Buoyancy loads	Buoyancy of the ship
	Variable loads	Cargo Ballast water Stores and consumables Personnel Temporary equipment
	Other loads	Tug and berthing loads Towing loads Anchor and mooring loads Lifting appliance loads
Environmental loads	Cyclic loading due to wave action including inertia loads	Dynamic wave pressures
		Dynamic loads and dynamic tank pressures due to ship accelerations
	Impact loads or resonant loads	Wave impacts Bottom slamming Liquid sloshing in tanks Green sea loads
Accidental loads		Flooding of compartments
Deformation loads		Thermal loads Deformations due to construction

CSR references:

CSR-reference	content	comment
Sec 2/3.1.8	Internal environment (cargo and water ballast tanks)	
Sec 2/4.2.3	Load categorisation	
Tab 2.4.1	Load categorisation	
Sec 2/4.2.5	Operational loads	
Sec 2/4.2.7	Accidental loads	
Sec 7/2.2	Local static loads	
Sec 7/5	Accidental loads	
Tab 8.2.7	Design load sets for plating and local support members	
Tab 8.2.8	Specification of design load combination, acceptance criteria and other load parameters for each design load set	
Tab 8.2.9	Design load sets for primary support members	

d) Load combination:

Design load combinations combine local and hull girder load components to represent design load scenarios. The effects of combining the dynamic (D) and the static (S) loads are also included in the combined design loads. The design scenarios are selected to encompass all scenarios that can reasonably occur during operation.

The loading scenarios include the assessment of tank boundaries, e.g. bulkheads, based on the most severe combination of loading hence conditions are assessed with a full tank content on one side and an empty tank on the other side. The situation with the tank contents reverse are also considered. Similarly the shell envelope is assessed for conditions at the deepest draught without internal filing and at the lowest draught with maximum internal filling.

The loads are combined for evaluation of the hull girder and structural members in order to consider the most unfavourable combination of load effects. A variety of different load cases are applied in order to provide maximum loads applied to individual areas of the structure rather than one load case which attempts to envelope all maximum loads simultaneously, since maximum loads acting simultaneously do not actually occur in operation.

These combined load effects are used to develop the longitudinal hull girder strength and the strength evaluation of structural members. The following table, which is Table 2.5.1 from the CSR, illustrates the combination of loads.

Load Scenarios and Corresponding Rule Requirements

Load Scenarios		Rule Requirements			
Operation	**Loads** (that the vessel is exposed to and is to withstand)	**Design Load Combination** (specified in *Section 7/6*) **Ref. no**	**Notation**	**Design Format** (specified in *Sections 8* and *9*) see Note 1	**Acceptance Criteria Set** (specified in *Sections 8* and *9*)
Seagoing operations					
Transit	Static and dynamic loads in heavy weather	1	S + D	1. $S_G + S_L + D_G + D_L \leq \eta_2 R_1$	AC2
				2. $\gamma_S S_G + \gamma_D D_G \leq R_2/\gamma_{R2}$	AC2
	Impact loads in heavy weather	2	Impact	$S_L + D_{imp} \leq \eta_3 R_p$	AC3
	Internal sloshing loads	3	Sloshing	$S_G + D_{slh} \leq \eta_1 R_1$	AC1
	Cyclic wave loads	4	Fatigue	$DM \leq \Sigma\eta_i / N_i$	-
BWE by flow through or sequential methods	Static and dynamic loads in heavy weather	5	S + D	$S_G + S_L + D_G + D_L \leq \eta_2 R_1$	AC2
Harbour and sheltered operations					
Loading, unloading and ballasting	Typical maximum loads during loading, unloading and ballasting operations	6	S	$S_G + S_L \leq \eta_1 R_1$	AC1
Tank testing	Typical maximum loads during tank testing operations	7	S	$S_G + S_{L1} \leq \eta_1 R_1$	AC1
Special conditions in harbour	Typical maximum loads during special operations in harbour, e.g. propeller inspection afloat or dry-docking loading conditions	8	S	$S_G + S_L \leq \eta_1 R_1$	AC1
Accidental condition					
Accidental flooding	Typically maximum loads on internal watertight subdivision structure due to accidental flooding	9	A	for water tight boundaries 1. $S_L \leq \eta_2 R_1$	AC2
				for collision bulkhead 2. $S_L \leq \eta_1 R_1$	AC1

<u>Note</u>

1. The symbols defined in this column are defined in the text of *5.4*

Where:

D_G	dynamic global load
D_L	dynamic local load
DM	cumulative fatigue damage ratio
S_G	static global load
S_L	static local load
R_i	structural capacity

CSR references:

CSR-reference	content	comment
Sec 2/4.2.2	Design load combinations	
Sec 2/5.4.1.1 to 5	Load-capacity based requirements	
Tab 2.5.1	Load scenarios and corresponding rule requirements	
Sec 2/5.4.2	Design loads for scantling requirements and strength assessment (FEM)	
Sec 7/6	Combination of loads	
Tab 7.6.1	Design load combinations	
Tab 8.2.7	Design load sets for plating and local support members	
Tab 8.2.8	Specification of design load combination, acceptance criteria and other load parameters for each design load set	
Tab 8.2.9	Design load sets for primary support members	
Tab B.2.3	FE load cases	
Tab B.2.4	FE load cases	

e) Structural modelling:
There are two general forms for structural modelling included in the Rules. The first applies beam and plate theory and prescriptive buckling formulations. The second involves application of finite element modelling.

The first form of structural modelling consists of using engineering principles to calculate section cross area, inertia, section modulus, web area and plate or shell membrane properties, and is associated with the prescriptive rules covering such items as bending, shear and buckling. This type of modelling is used to assess the structural properties of the vessel during the initial stages typically employing a working stress design (WSD) format. The working stress level is determined by applying the design loads using beam and plate theory and buckling formulae. This working stress level is then compared against an allowable stress. In many cases the formula is rearranged mathematically to include the allowable stress and the result is the required structural property such as thickness, section modulus, etc.

The Rules contain details on the section properties to be used with the Rule requirements.

The second form of structural modelling using a finite element (FE) model also employs a working stress design (WSD) format. The Rules include detail specification of the FE model such as; model extent, structure to be modelled, openings to be modelled, properties, element size, element type, aspect ratio, and boundary conditions. The FE analysis employs a series of models using a global model to represent the overall hull girder structure and then using local fine mesh models to review high stress gradient areas and stress concentrations. Finally, very fine mesh FE models are used to zoom in and assess the hopper knuckle connection between the inner-bottom and the hopper plate. The Rules include detail specifications for the fine mesh models similar in content to the global model mentioned above.

It should be noted that all structural models employ the net thickness concept in which the actual as-built thickness is reduced to represent in service diminution due to corrosion. The net thickness concept is described in section 5.II.3.5 of this report.

CSR references:

CSR-reference	content	comment
Sec 2/4.3	Structural capacity assessment	
Sec 2/5.4.4.1	Structural response analysis	
Sec 3/5	Calculation and evaluation of scantling requirements	
Sec 4/2	Structural idealization	
Sec 9/1.3	Hull girder bending moment capacity	Hull girder ultimate strength
Sec 9/2.2.2	Structural modelling	Global FEM
Sec 9/2.3.2	Structural modelling	Fine mesh FEM
App A/2.2.2	Assumptions and modelling of the hull girder cross-section	Hull girder ultimate strength
App B/2.2	Structural modelling	Global FEM
App B/3.2	Structural modelling	Fine mesh FEM
App B/3.4	Application of loads and boundary conditions	Fine mesh FEM
App B/4.2	Structural modelling	Fatigue
App B4.4	Boundary conditions	Fatigue

f) Fatigue:
For fatigue considerations, please refer to section 5.II.4 of this report.

g) Corrosion:
For corrosion considerations, please refer to section 5.II.6.2 of this report.

h) Material imperfections:
The CSR include the IACS requirements for materials covering strength properties, material grades and required application. The remainder of the detail requirements for materials such as the chemical makeup, through thickness properties, testing, etc. are referenced to be in accordance with the individual Classification Society rules.

While the minimum strength properties of yield and ultimate tensile strength are specified in the CSR, the actual physical properties of materials fitted in the ships are usually greater. However these margins are not accounted for and no safety margin is attributed to this.

The strength requirements in the CSR are based on the assumption that the material is manufactured in accordance with minimum strength properties and the allowable under thickness rolling tolerances specified in IACS UR W13. Please also refer to section 5.II.11 of this report.

CSR references:

CSR-reference	content	comment
Sec 2/4.4.1	Materials	
Sec 2/5.5	Materials	
Sec 6/1	Steel grades	

i) Construction workmanship errors:

For construction and workmanship considerations, please refer to section 5.II.11 of this report.

j) Buckling:
The buckling criteria in the CSR include various levels of complexity that build upon one another.

The simplest buckling check is in the form of stiffness and proportion ratios that relate simplified buckling and deflections to the most basic structural property such as panel spacing, unsupported flange breadth or pillar length. Using the spacing, flange length or pillar lengths, ratios are used to determine related permissible thicknesses. The next level of buckling check is performed using prescriptive buckling based on classic Euler buckling of plates, shells, columns and torsional buckling modes. Finally an advanced buckling analysis un-stiffened and stiffened plate panels is based on nonlinear analysis techniques. The most advanced buckling analysis includes an allowance for redistribution of loads such that the ultimate capacity of the panel is calculated.

CSR references:

CSR-reference	content	comment
Sec 2/5.4.5.2	Structural capacity assessment	
Sec 8/1.4	Hull girder buckling strength	
Sec 8/2.6.1.6	Primary support members	Web buckling, ref. to 10/2.3
Sec 9/2.2.5.3	Acceptance criteria	FEM
Sec 10	Buckling and ultimate strength	
App D	Buckling strength assessment	

k) Residual strength:
For residual strength considerations, please refer to section 5.II.5 of this report.

.2 Strength Assessments

The GBS lists various items which should be assessed in the rules. The items mentioned are each discusses as follows:

a) Members to be evaluated:
The CSR include requirements for the structural evaluation of all strength components of the vessel. The evaluations of the cargo block region of the vessel is based on both prescriptive and a finite element analysis. Prescriptive requirements are included for the forward and aft regions and the deckhouse structure . See the following figure, which is Figure 1.1.1 from CSR, for a map of references to the applicable CSR section.

Schematic Layout of the Rules

Topic	Sections
Introduction	1
Rule Principles	2
Rule Application	3
Basic Information	4
Structural Arrangement	5
Materials and Welding	6
Loads	7

Aft end & Machinery Room

Topic	Sections
Machinery general structure	8/4.1
Machinery bottom structure	8/4.2
Machinery side structure	8/4.3
Machinery deck structure	8/4.4
Machinery internal structure	8/4.5-4.8
Aft end general structure	8/5.1
Aft end bottom structure	8/5.2
Aft end shell structure	8/5.3
Aft end deck structure	8/5.4
Aft end internal structure	8/5.5-5.7

Cargo Area

Topic	Sections
Hull girder strength	8/1
Hull envelope plating	8/2.2
Hull envelope framing	8/2.3
Inner bottom	8/2.4
Bulkheads	8/2.5
Primary support members	8/2.6
Sloshing	8/6.2
Hull girder ultimate strength	9/1
Strength assessment (FEM)	9/2
Fatigue strength	9/3

Fore end

Topic	Sections
General structure	8/3.1
Bottom structure	8/3.2
Side structure	8/3.3
Deck structure	8/3.4
Internal structure	8/3.5-3.9
Bottom slamming	8/6.3
Bow impact	8/6.4

Topic	Sections
Hull openings and closing arrangements	11/1
Crew protection	11/2
Support structure and structural appendages	11/3
Equipment	11/4
Testing procedures	11/5
Ship in operation renewal criteria	12

b) Failure modes:
The criteria for the assessment of scantlings are based on a working stress design (WSD) method. The failure modes include yielding, buckling and fatigue. Deflection criteria is also included and covered in the next section of this report.

The acceptance criteria included in the CSR have been related to the loading scenario as shown in Table 2.5.1 as copied in this report Section 5.II.3.1.d. The failure modes associated with the scenario are indicated in the following tables, which are Tables 2.5.2 and2.5.3 from the CSR.

Principal Acceptance Criteria - Rule Requirements						
	Plate panels and Local Support Members		**Primary Support Members**		**Hull girder members**	
Acceptance criteria set	**Yield**	**Buckling**	**Yield**	**Buckling**	**Yield**	**Buckling**
AC1:	70-80% of yield stress	Control of stiffness and proportions. Usage factor typically 0.8	70-75% of yield stress	Control of stiffness and proportions. Pillar buckling	75% of yield stress	NA
AC2:	90-100% of yield stress	Control of stiffness and proportions. Usage factor typically 1.0	85% of yield stress	Control of stiffness and proportions. Pillar buckling	90-100% of yield stress	Usage factor typically 0.9
AC3:	Plastic criteria	Control of stiffness and proportions	Plastic criteria	Control of stiffness and proportions	NA	NA

Principal Acceptance Criteria - Design Verification - FE Analysis			
	Global cargo tank analysis		**Local fine mesh analysis**
Acceptance criteria set	**Yield**	**Buckling**	**Yield**
AC1:	60-80% of yield stress	Control of stiffness and proportions. Usage factor typically 0.8	local mesh as 136% of yield stress averaged stresses as global analysis
AC2:	80-100% of yield stress	Control of stiffness and proportions. Usage factor typically 1.0	local mesh as 170% of yield stress averaged stresses as global analysis

CSR references: Sections 2/4.5, 2/5.4.1.5 to 10, Table 2.5.1 to 3, 2/5.4.5 and 2/5.4.6.

Yielding: the yielding allowable stresses for bending and shear modes specified for hull girder, primary support members and local members are generally shown in the above tables. More detailed information on the allowable stresses for each individual component is included in the CSR references listed below.

CSR references: Table 2.5.2, Table 2.5.3, Sections 8/1.2, Table 8.1.3, 8/1.3, Table 8.1.4, Table 8.2.4, Table 8.2.5, Table 8.2.10, 9/2.2.5 and Table 9.2.1.

Buckling: the buckling allowable limits specified for hull girder, primary support members and local members are generally shown in the above tables. More detailed information on buckling criteria for each individual component is included in the CSR references listed below.

CSR references: Table 2.5.2, Table 2.5.3, 8/1.4.2.6 to 8/1.4.2.8, Table 9.2.2, 10/2.3, 10/3.2.1.3, 10/3.3.2.1, 10/3.3.3.1 and D/4.

Fatigue: the fatigue criteria is associated with the design life of 25 years and exposure to the North Atlantic environment. See Section 5.II.4 of this report and the CSR references below for additional details.

CSR references: Sections 2/4.3.3, Tab 2.5.1, 2/5.4.3, 2/5.6.5, 8/1.5, 9/3, B/4, C/

c) Deflection:

Hull girder deflection requirement is covered by a minimum vertical hull girder moment of inertia. Local structural deflection is generally covered in the CSR by inclusion of minimum thicknesses, minimum depth-to-thickness ratios and buckling control measures. The establishment of the deflection criteria was based on the existing satisfactory service associated with the existing class rules.

CSR references: Sections 2/5.3.1.1(b), 2/5.4.5.1, 3/5.3.3.4, 8/1.2.2, 8/2.6.1.7 plus individual requirements, and 10/2.

.3 Ultimate Strength

The ultimate strength evaluations cover hull girder properties as well as individual stiffened plate panels.

a) Ultimate strength of the hull girder

The evaluation of the hull girder is the most important component of the strength assessment. The CSR include hull girder longitudinal strength evaluations controlling yielding and buckling based on working stress design (WSD) levels associated with the static and dynamic load components. The in-service operational limits are also closely controlled in order to remain within the WSD limits.

In addition, to provide an additional check for the hull girder, an ultimate limit evaluation is performed to check the condition of the vessel in extreme at-sea conditions using the following general expression.

$$\gamma_S M_{sw} + \gamma_W M_{wv-sag} \le \frac{M_U}{\gamma_R}$$

Where:

M_{sw} sagging still water bending moment.

M_{wv-sag} sagging vertical wave bending moment.

M_U sagging vertical hull girder ultimate bending capacity.

γ_S, γ_W, γ_R are the partial safety factors for the design load combinations.

Partial Safety Factors				
Design load combination	Definition of Still Water Bending Moment, M_{sw}	γ_S	γ_W	γ_R
a)	Permissible sagging still water bending moment	1.0	1.2	1.1
b)	Maximum sagging still water bending moment for homogenous full load condition	1.0	1.3	1.1
Where: γ_S partial safety factor for the sagging still water bending moment γ_W partial safety factor for the sagging vertical wave bending moment covering environmental and wave load prediction uncertainties γ_R partial safety factor for the sagging vertical hull girder bending capacity covering material, geometric and strength prediction uncertainties				

Partial safety factors increasing the magnitude of the wave-induced bending moment by 20 and 30 percent are applied in conjunction with the permissible and most probable still water bending moment respectively.

The calculation procedure for the determination of the hull girder bending capacity, is included in Appendix A of the CSR.

CSR references:

CSR-reference	content	comment
Sec 2/5.6.3	Design verification - hull girder ultimate strength	
Sec 9/1	Hull girder ultimate strength	Requirements
App A	Hull girder ultimate strength	Procedure

b) Ultimate strength of plates and stiffeners

In general the CSR includes local plate criteria that employs working stress design (WSD) format, however, some conditions and locations are permitted to approach the ultimate strength of a plate panel. The modes are defined in the advanced buckling section 10/4 and Appendix D of the CSR as follows:

Method 1 – buckling capacity with allowance for redistribution of load. This defines the upper bound value of the buckling capacity and represents the maximum load the panel can carry without suffering major permanent set and is effectively the ultimate load carrying capacity of a panel. The buckling capacity is taken as the load that results in the first occurrence of membrane yield stress anywhere in the stiffened panel. In calculating this, load redistribution within the structure is taken into account. This redistribution of load is a result of elastic buckling of component plates, such as the plating between the stiffeners.

Method 2 - buckling capacity with no allowance for redistribution of load. This defines the lower bound value of the buckling capacity. In calculating the buckling strength, no internal redistribution of load is to be taken into account. Hence this is more conservative than the upper bound value given by Method 1 and checks that the panel does not suffer large elastic deflections with consequent reduced in-plane stiffness.

CSR references:

CSR-reference	content	comment
Sec 10/4	Advanced buckling analysis	Requirements
App D	Buckling strength assessment	Procedure

.3 Structure compatibility

a) purpose of the space

The structural requirements of the CSR include consideration of the purpose and associated environment of the space to which the structure is exposed. This can be either the external environment such as temperature exposure, marine corrosive environment. or the internal environments of cargo, ballast and dry spaces such as liquid density, temperature and corrosive nature. These environments which relate to the purpose of the space influence the material grade requirements, corrosion additions.

CSR references: Sections 2/3.1.7 and 2/3.1.8.

b) structural continuity

Structural continuity, termination of members and alignment with backup structure is covered in the CSR. The objective of the structural continuity requirements is to effectively avoid hard spots, notches and stress concentrations. The CSR has requirements for large hull girder longitudinal members as well as for the end termination of primary and local members. Another important reason for including this in the rules is to clarify the end connection continuity associated with the rule formulations. For instance the continuity of the ends dictate the end connection of a beam which in-turn dictate the bending moment, e.g. fixed-fixed or pinned-pinned, and then influence the associated structural requirement. Therefore the rules contain quite extensive coverage of this subject as listed below.

CSR references:

CSR-reference	content	comment
Sec 4/3.2 to 4	Structure design details	Local and primary support member end connections

Sec 8/1.6	Tapering and structural continuity of longitudinal hull girder elements	
Sec 8/1.6.5 and 6	Structural continuity	Longitudinal bulkheads and longitudinal stiffeners
Sec 8/2.1.4.7	General scanting requirements	End connections
Sec 8/2.3.1.3	Hull envelope framing	End connections
Sec 8/3.1.3	Structural continuity	Forward of the forward cargo tank
Sec 8/4.1.3	Structural continuity	Machinery space
Sec 8/5.1.3	Structural continuity	Aft end

.4 Facilitate loading/unloading

In addition to the operating loads that most designers consider, the CSR also include loading and unloading conditions in the matrix of design loads to be considered. See CSR Table 2.5.1 as copied in this report Section 5.II.3.1.d. Loading conditions upon which the vessel is approved, which include loading and unloading operations are required to be included in the vessel Loading Manual as indicated in Section 8/1.1.2.2(b) of the CSR.

CSR references:

CSR-reference	content	comment
Sec 2/4.2.1	Load scenarios	
Tab 2.5.1	Load scenarios and corresponding rule requirements	
Sec 8/1.1.2.2(b)	Loading manual	Harbour/sheltered water conditions

.5 Net scantlings

The net scantling approach is used to perform the ship design and verification calculations using scantlings in an assumed future corroded condition. Therefore the design is assessed for the critical load cases for the different assessment criteria such as strength (e.g. yielding, ultimate strength and buckling) and fatigue, while in an expected corroded condition. This expected corroded condition is typically defined in association with the assessment criteria type and the structural arrangement of the vessel being investigated.

While the expected corrosion additions which are to be used in design calculations can be accurately defined in a design code or classification society rule, the actual corrosion experienced in-service can vary depending on maintenance performed, coatings provided, coating maintenance, cargo carried, ballast carried, operating environments, loading/unloading processes, etc. Therefore the actual corrosion experienced by a particular ship may be larger or smaller depending on the actual operating conditions and maintenance of the ship throughout its life cycle.

Since the actual corrosion in-service depends on a wide variety of factors that can not be fully anticipated and controlled, the Rules use a design net thickness approach that is aligned and compatible with the associated thickness gauging and renewal requirements that are applied to the vessel. Ships are subjected to thickness measurement requirements during their lifetime. When local thicknesses measured do not comply with the requirements, renewals are required to replace the local plating or stiffening members to their original condition, thereby keeping the individual structural elements in a state that is generally thicker than the net scantlings used in the original design calculations.

In-service diminution allowances for hull girder section modulus and the thickness of individual structural elements are generally set by classification society rules. However, it should be noted that resolution A.744(18), as amended, specifies allowable diminution of the hull girder section modulus for oil tankers 130m in length and upwards and over 10 years of age (ref. resolution MSC.105(73)). Additionally, recommended criteria for specific structural members of single side skin bulk carriers are provided in the IACS Unified Requirements which are referenced by resolution MSC.145(77).

The in-service minimum thickness requirements contained in classification society rule requirements (e.g., IACS UR S7) generally indicate stringent measurement criteria to be used for the assessment of members contributing to hull girder strength and less stringent localized measurement criteria to be used for the assessment of individual local members. The following summary may be made:

.1 Hull Girder Longitudinal Strength Members – the global corrosion or average corrosion of the members contributing to the hull girder longitudinal strength are permitted to waste to the degree whereby the hull girder section modulus is reduced by no more than 10 percent. This in effect limits the corrosion of the deck and bottom members to an average of about 10 percent of the original required thickness. This is consistent with resolution MSC.105(73).

.2 Individual Structural Elements – the local thickness diminution allowance for individual plating and stiffening elements is typically in the range of 2.5 to 4.0 mm. These local individual allowances are generally greater than the 10 percent average which are also applicable for the structural members contributing to hull girder section modulus referred to in .1 above.

.3 Local Pitting, Grooving and Edge Corrosion – for completeness of the rules the thickness diminution allowance for pitting, grooving and edge corrosion of plating and stiffening elements, typically in the range of 25 to 30 percent of required gross thickness, is included in the CSR. These localized items are checked in service and renewed when necessary, but specific accounting is not included in the strength criteria other than via calibration with actual vessel service.

In the CSR, the overall average corrosion for hull girder cross-section and primary support members is given by simultaneously deducting half the local corrosion addition from all structural members comprising the respective cross-sections. This replicates a 10 percent reduction of global strength which will later be monitored in-service. The assessment of local scantlings is performed based on the superposition of stresses associated with the reduced hull girder properties and the local stresses associated with the local full deduction of the corrosion additions. In other words, the CSR assumes that the structure is corroded locally to the maximum allowed and the hull girder is reduced to the maximum allowed overall hull girder corrosion.

Since fatigue is a time-dependant phenomenon that takes place over long periods of the ship's life, stress calculations associated with fatigue should reflect variations in thicknesses due to corrosion through the design life (e.g. consider full "as-built" scantlings for the vessel in the initial stage of its operational life and expected design net scantlings at the end of the assumed design life). However the CSR contains a simplification which uses the average scantling properties between the initial as-built stage and the expected corroded state at the end of the assumed design life.

CSR references:

CSR-reference	content	comment
Sec 2/4.3.4	Net thickness approach	
Sec 4/2.4	Geometrical properties of local support members	
Sec 6/3	Corrosion additions	

II.4 Fatigue life

Statement of intent: The intent of the functional requirement is **covered** by CSR.

Comment:
In the goal based standards, the design fatigue life should be not less than the design life and should be based on North Atlantic Environmental conditions.

The fatigue life calculation procedures of CSR are based on three common major hypotheses:

.1 The long term distribution of stresses in the structure of the ship sailing in North-Atlantic environment may be represented by a two-parameter Weibull law. The best fit of the Weibull distribution to the North-Atlantic scatter diagram is obtained by selecting a probability of occurrence (10^{-4}) for the scale parameter of the Weibull law.
.2 The linear damage accumulation rule of Miner's sum is valid and a unit value of the damage ratio D corresponds to fatigue cracking.
.3 The expected fatigue life is to be greater or equal to the design life (i.e. 25 years).

The Weibull law is defined as follows:

$$\Pr obability(StressRange < x) \quad = F(x) = 1 - \exp[-(\frac{x}{w})^{\xi}]$$

With ξ the shape parameter and w = Sr/ln(Nr)$^{1/\xi}$ the scale parameter .
In the expression of the scale parameter, Sr is the stress range computed at 1/Nr probability level. The best fit with the scatter diagram is obtained by taking Nr = 10^4 cycles. The value of ξ is obtained by a fitting procedure and lead to a value around 1.0: 0.85 to 1.1 according to the area considered and the length of the ship.

The fatigue cracking appears when the damage ratio is greater than 1, therefore the damage ratio $D = \sum_{i=1}^{i=ntot} \frac{n_i}{N_i}$ is to be less than 1 where the number of cycles is summed on the whole fatigue life of the vessel of 25 years. In the damage ratio expression, n_i is the number of cycles of stress range S_i and N_i the number of cycles leading to failure according to the S-N curve, at the stress range S_i.

The S-N curves selected in the rules are two standard deviations below the mean line.

The Rules consider two approaches depending of the structural detail to be analyzed:

1. A nominal stress approach where a specific S-N curve is associated to a particular detail of longitudinal stiffener end connection to primary member

2. A FEM based hot spot stress approach used for connections of primary members.

A minimum set of locations where the analysis is required in given in Section 9/3.3 of the Rules.

A typical operational profile of navigation in North Atlantic is considered with 50% full load condition, 50% normal ballast condition, with a ship spending 85% of her life at sea.

For the nominal stress approach using simple beam models, the stress components to be considered (primary, secondary, tertiary) are defined and formulas are given for each of them.

For the hot spot stress approach, a detailed description of the structural model to be used is provided in appendix B/4. The hot spot stress location and calculation procedure is defined in appendix C/2.4.2 and appendix B/4.

The rules take into account the progressive degradation of the coating through a coefficient f_{SN}. Benefits of weld toe grinding are taken into account in some cases.

CSR references:

CSR-reference	content	comment
Sec 9/3	Fatigue strength	Requirement, not less than 25 years
App C	Fatigue strength assessment	Procedure
App B/4	Hot spot stress approach	

II.5 Residual strength

Statement of intent: The intent of the functional requirement is **not covered** by CSR.

Comment:

.1 Flooding

Flooding is included in the rules as an accidental load:

4.2.7.1 The accidental load scenarios cover loads acting on local structure as a consequence of flooding in accordance with the assumptions made in IMO regulations. This relates to the assessment of the watertight subdivision boundaries.

Only the local scantlings due to flooding pressure is checked. The effect of the flooding pressure on the hull girder loads is not accounted for in the hull girder strength assessment.

CSR references:

CSR-reference	content	comment
Sec 2/4.2.7.1	Accidental loads	
Sec 7/2.2.3.4	Flooding pressure	

Sec 7/5	Accidental loads	

.2 Residual strength

The rules explicitly states that only intact structure is considered:

2/4.3.5.1 All strength calculations are based on the assumption that the structure is intact. The residual strength of the ship in a structurally damaged condition is not assessed.

Hence, requirements to residual strength as formulated in Tier II.5 are not explicitly covered by the rules. However, it is stated as a general principle in the rules that the ship's structure is designed such that it has adequate structural redundancy to survive in the event that the structure is accidentally damaged:

2/4.1.2.2(d) it has adequate structural redundancy to survive in the event that the structure is accidentally damaged; for example, minor impact leading to flooding of any compartment.

This statement indicates that the rule development implicitly covered residual strength. This was based on typical inherent residual strength exhibited by existing vessels upon which the rules were calibrated.

The effect of structural damage on the hull girder capacity resulting from collision or grounding is not assessed in CSR.

The effect of collision damage in the upper part of the side was assessed using probabilistic methods in the SAFEDOR project. The conclusion from this study was that the intact condition is dimensioning for the hull girder strength, and that requirements for the damaged case therefore could be omitted. This study is documented in the following reference:

Hørte, T. et al., Probabilistic methods applied to structural design and rule development, RINA Conference, January 2007

Post-buckling behavior is included in the hull girder ultimate strength calculations, but the calculations are only carried out for intact structure.

CSR references:

CSR-reference	content	comment
Sec 2/4.1.2.2	Design principles	
Sec 2/4.3.5.1	Intact structure	
App A/2.3	Hull girder ultimate strength	

II.6 Protection against corrosion

Statement of intent: The intent of the functional requirement is **covered** by CSR.

Comment:
The following two sub-sections pertain to providing protection against corrosion or anticipating corrosion in the strength calculations. The overall goal being that the required scantlings meet the intended strength provisions throughout the specified design life.

II.6.1 Coating life

With regard to the mandatory use of coatings, the CSR includes it in Section 6/2 Corrosion.

The purpose and intention of this section is to ensure that the Rules are inline with the SOLAS requirement with respect to corrosion prevention of ballast tanks.

The text provides reference to the requirements of SOLAS Reg. II-1/3-2, IMO Resolution A.798(19) and IACS UI SC 122. The requirements are open with respect to application date, which at the time of publishing the rules was yet to be finalized by IMO. It has now been determined that the application date for vessels to which the CSR apply is 8 December 2006, which is based on the building contract date.

As described in the section 6/1.1.1.2, for ships contracted for construction on or after 8 December 2006 which is the date of IMO adoption of the amended SOLAS Regulation II-1/3-2, the coatings of internal spaces subject to the amended SOLAS regulation are to satisfy the requirements of the IMO performance standard.

The IMO performance standard means IMO Resolution MSC.215(82) – "Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers".

The referenced requirements cover the following items related to information and documentation for II.6.

.1 Locations and/or spaces where coatings are required to be used
.2 Types of coating to be used for the various spaces
.3 Reference coating performance standards

Regarding allowances when other corrosion prevention systems are used, the sections "6/2.1.2 Internal cathodic protection systems" and "6/2.1.3 Paint containing aluminium" cover allowances when other corrosion prevention systems are used.

CSR references:

CSR-reference	Content	comment
Sec 6/2	Corrosion Protection Including Coatings	

II.6.2 Corrosion addition

The CSR corrosion additions are located in Section 6/3.

Firstly, it should be noted that CSR for tankers does not employ a corrosion rate approach but a more advanced approach using a stochastic corrosion propagation model.

The CSR complies with the functional requirements of Tier II.6.2 Corrosion addition by following the latter approach.

Local corrosion additions for typical structural elements within the cargo tank region are shown in Table 6.3.1 and Fig. 6.3.1. In addition, the relation between corrosion addition and wastage allowance is described in "Section 6/3.2".

The local corrosion additions are derived by adding 0.5mm to wastage allowances for the particular local structural element. The background on the relationship of corrosion additions and wastage allowances is explained in Section 2/4.3.4 (Net thickness approach) and the details on local wastage allowances, are explained in Section 12/1.4 (Renewal criteria of local structure for general corrosion) of the CSR.

Structures considered and the appropriate wastage allowance values for each side of structural elements are as given in Table 12.1.2 of the CSR.

The 0.5mm is added in reserve for the wastage occurring between the inspection intervals of approximately 2.5 years. The verification of the local strength of the vessel is performed on the local net thickness (gross minus corrosion addition t_{corr}) and the global strength of the vessel is performed at global net thickness (gross minus 50 percent of the corrosion addition t_{corr}). As the wastage allowance is assessed based on thickness measurements performed in connection with the renewal survey some margin is needed on the wastage allowance as the vessel will operate for approximately another 2.5 years before being re-assessed. During this 2.5 year interval the thicknesses should not reduce below the net thickness.

In this context, as corrosion additions are completely consistent with wastage allowances.

The total "corrosion addition" or "wastage allowance" values used in the CSR were based on the stochastic corrosion propagation model and information that were being used by IACS ex-WP/S (Working Party/Strength) to arrive at wastage allowance values based on historical data on record of gaugings. In some areas of the structure a extra margin was added to account for the variability of corrosion based on service experience.

The general philosophy for establishing "corrosion additions" or "wastage allowances" was that they are to be:

(a) based, in general, on the premise that today's practice is a reference point, and departures from today's practice will need to be backed-up with technical justification;
(b) established based on the basic assumption of coatings provided (where required) at time of newbuilding, however, there should not be provisions to reduce wastage

allowance values based on “superior” coating systems or extra-ordinary maintenance of coating systems or another type of corrosion protection system;
(c) appropriate for a 25-year service life;
(d) based on absolute numbers, i.e., 4.0mm (not 25%);
(e) independent of type of local failure mode employed, i.e., yielding, buckling, or fatigue;
(f) based on published data and recent experience of IACS member societies;

The following basic assumptions were made:
(a) with respect to stiffener and web members, wastage should be based on thickness loss, not section modulus loss;
(b) wastage values, though linked to net thickness deductions, should first be developed independently of the net thickness deductions, and based on the philosophy outlined above;
(c) the wastage values should be based on typical wastage values experienced in service for crude oil carriers;
(d) dependencies on cargo type and vessel size should be considered, but should not be variables used for determining the actual value of the permitted wastage on a ship-by-ship basis;
(e) structural elements within the same area, environment and orientation should as far as possible have the same wastage allowance; and
(f) safety margins should not be included in wastage allowances (i.e., criticality issues should be dealt with in “net” requirements, and not with an increase in the wastage allowance).

Based on the above and following IMO discussion regarding GBS, IACS carried out statistical analysis of collected corrosion data and evaluated “corrosion addition” or ”wastage allowance” values by using the 95 percent probability level corrosion measurement values for a 25-year life.

Furthermore, each of the individual societies took into consideration data that they had on hand regarding their own in-house reports and studies in addition to published corrosion data when finally determining “corrosion addition” or ”wastage allowance” values appropriate for a 25-year service life.

CSR references:

CSR-reference	Content	comment
Sec 6/3	Corrosion additions	
Sec 12/1/4	Renewal criteria of local structure for general corrosion	

References and Background Documents

[1] Background document Section 6 Material and Welding
[2] Background document Section 12 Ship in Operation Renewal Criteria
[3] IMO Resolution A.798(19), Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tanks
[4] IACS UI SC 122, Corrosion Prevention in Seawater Ballast Tanks
[5] IMO Resolution MSC.215(82) – Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers
[6] IMO Resolution MSC.216(82) – Adoption of amendments to the international convention for the safety of life at sea, 1974, as amended

[7] Sone, H. et al., Evaluation of Thickness Diminution in Steel Plates for the Assessment of Structural Condition of Ships in Service、ClassNK Technical Bulletin Vol.21, 2003.

II.7 Structural redundancy

Statement of intent: The intent of the functional requirement is **not covered** by CSR.

Comment:
Requirements to structural redundancy are not covered explicitly by the rules. However, it is stated as a general principle in the rules that the ship's structure is designed such that it has inherent redundancy See CSR 2/4.1.2.2(a):

The ship's structure works in a hierarchical manner and, as such, failure of structural elements lower down in the hierarchy should not result in immediate consequential failure of elements higher up in the hierarchy.

This statement indicates that the rule development implicitly covered structural redundancy. This was based on typical inherent redundancy exhibited by existing vessels upon which the rules were calibrated. It is worth noting that a double hull by its very nature is a very redundant structure. It offers structural redundancies against collisions and groundings, including damages or failures of structural members in either the inner hull or outer hull. The risk of a major structural failure or casualty is much less in a double hull tanker than a single hull tanker because of its structural redundancy.

The use of "criticality class" during the rule development can be considered as contributing to the redundancy of the structure. During the rule development, each structural component was classified according to the criticality with respect to the consequences of failure. At the top level of the hierarchy is the hull girder, while the local plate element is at the bottom. This hierarchical structure was used for setting the acceptance criteria and selecting the capacity models. As a consequence, stricter requirements are applied to the elements high up in the hierarchy. This means that less critical local elements will collapse first, without leading to collapse of higher-level elements.

The use of advanced buckling methods for buckling assessment ensures redundancy of stiffened panels, by allowing local plates to buckle and require that the stiffeners are able to carry the redistributed forces. This principle gives strong stiffeners and weaker plates, and thereby redundant panels.

Further, the capacity of the stiffened panels are calculated using linear elastic material models, and not utilizing the capacity reserve beyond initial yielding. This means that the panel will have reserve capacity even if some capacity is lost due to local damage. Analyses have also been carried to evaluate the effect of local damage to plate and stiffeners, indicating a moderate effect of localized damages on the panel capacity.

In contrast to stiffened panels, corrugated bulkheads are generally not redundant, since collapse of the plate flange leads to collapse of the entire bulkhead. The CSR does not have special requirements for redundancy related to corrugated bulkheads however, additional and more complex acceptance criteria are provided and the buckling criteria is lowered to account for this. Especially longitudinal horizontally corrugated bulkheads are critical, due to their contribution to the longitudinal strength.

CSR references:

CSR-reference	content	comment
Sec 2/4.1.2.2	Design principles	
App D/1	Advanced buckling analysis	

CSR External background documentation, available on IACS Web Site:
Section 2/4.5.1 Criticality class of structural elements

II.8 Watertight and weathertight integrity

Statement of intent: The intent of the functional requirement is **covered** by CSR .

Comment: The relevant requirements can be subdivided in requirements related to the watertight subdivision of the ship and to requirements related to the weathertight and watertight integrity of the hull, which can be further subdivided to requirements for the watertight boundaries of the structure and requirements for hull openings.
The requirements related to the subdivision are given in Sec 5/2 of the Rules. These Requirements are based on SOLAS II-1 Part B Regulation 11. The position of bulkheads in the cargo area and therefore the number of bulkheads is, in case of the type of ship considered, determined by the limits of cargo tank size with respect to the possible oil outflow and the damage stability (Sec5/2.1.2). These limits are given in the current MARPOL and SOLAS requirements, which are referenced by Sec5/2.1.2, Sec2/2.1.1 and Sec3/3.3.
The requirements with respect to bulkhead construction and scantlings of watertight boundaries in different areas of the ship are given in Sec8/2.5, Sec8/3.6, Sec8/4.7 and Sec8/5.6.
General requirements related to the securing devices for hull openings are prescribed by requirements of the International Load Line convention and the SOLAS convention of IMO. Particular, ship type specific items are sufficiently described in Sec11/1 of CSR. In particular requirements regarding shell and deck openings are covered by Sec11/1.1 including requirements related to the redundancy of the closing devices (Sec11/1.1.4.2, 1.1.4.3, 1.1.6.14), requirements related to air and sounding pipes are covered by Sec11/1.3, requirements for openings in superstructures and deck house sides are included in Sec11/1.4 and requirements to overflows and vents etc. are included in Sec11/1.5.
The rules follow the requirements given in ICLL (International Convention on Load Lines) (regulation 13) and SOLAS with respect to the definition which opening in which position of the ship has to be water- or weather tight.
The requirements for the determination of the strength and redundancy of closing arrangements are based on the formulations and requirements given in the ICLL regulation 16 (hatch covers), regulation 17 (machinery space openings), regulation 19 (ventilators), regulation 20 (airpipes) etc. and IACS Unified Requirements S26 and S27 as well as P3 for Air pipes.

CSR-reference	content	comment
Sec2/2.1.1	Reference is made to IMO regulations	
Sec3/3.1.1.2	Reference is made to regulations of international, national, canal and other authorities	
Sec3/3	Reference is made to requirements	Statement that compliance

	of national and international regulations	with national and international regulations is not necessary scope of class approval but scope of review by flag state administration
Sec5/2	Watertight subdivision	
Sec5/2.1.2.3	Reference is made to requirements of national regulations	
Sec8/2.5	Scantlings of Bulkheads	
Sec8/3.6	Watertight boundaries in fore-ship area	
Sec8/4.7	Watertight boundaries in machinery space	
Sec8/5.6	Watertight boundaries at aft end of the ship	
Sec11/1	Hull openings and closing arrangements	
Sec11/1.1	Shell and deck openings	
Sec11/1.2	Ventilators	
Sec11/1.3	Air and sounding pipes	
Sec11/1.4	Deck houses, companionways	
Sec11/1.5	Scuppers, inlets, discharges	

II.9 Human element considerations

Statement of intent: The intent of the functional requirement is **not covered** by CSR.

Comment: Human element considerations with respect to the ship's structure are mainly related to sufficient opening-space for inspection, maintenance, repair and rescue operations, guard rails, ladders, flush decks, covers etc. They are only in scope of classification rules with respect to class surveys (sufficient opening spaces, breadth of access ways etc.).
In general this functional requirement is subject of national requirements of flag state authorities and accidental prevention regulations of employer's liability insurance associations and similar organisations. Furthermore there does exist regulations of Tier V like ISO and other industry-standards e.g. ISO 799 "pilot ladders" and DIN 81705 "removable guard rails for seagoing ships".
Requirements for stairs, vertical ladders etc. used for permanent access for inspection and maintenance are given by SOLAS II-1 regulation 3-6 and the related Resolutions A.864(20) " Recommendations for entering enclosed spaces aboard ships" and MSC.133(76) "Technical provisions for means of access for inspections". SOLAS requirements are referenced in the CSR. Design and arrangement of walkways are described in International Convention of Load Lines (ICLL) regulation 25-1 and other means for crew protection by regulation 25 of ICLL.
It is assumed, that the IMO requirements (SOLAS and related resolutions) consider also the needs for emergency egress of inspection personnel. Additional requirements are given in Sec 5/5 of the CSR.
Requirements related to sufficient lightning and the minimization of noise and vibration are not in scope of classification rules for the ship hull structure, because these items are not directly related to the structural safety and integrity of the ship hull. However this item can be covered as an owners extra as stated in Sec2/3.1.10.1(a) of CSR in acc. to regulations and recommendations of the individual classification society. SOLAS II-1

regulation 35 and regulation 36 includes requirements with respect to sufficient ventilation and protection against noise but are related to machinery installations. Furthermore IMO resolution A.468(XII) regulates permissible noise levels on board ships.
Special requirements to the protection of the crew members by means of bulwarks and guard rails are given in Sec 11/2.1. Sizes of openings and details of portable plates are included in Sec 11/1.1. Sizes of access openings are described in Sec 5/5.
In general ergonomic design principles are not in scope of classification rules for the ship hull. There exist a number of rules and regulations within the maritime regulatory framework that the designer has to be considering in designing a ship like rules and requirements of national or canal authorities and employer's liability insurance associations as well as other tier V rules. The relations between CSR and other rules of the regulatory framework as well as responsibilities of the parties involved in ship design and construction are given in Sec 2/2 "General Assumptions" of CSR. References to requirements of other rules and regulations are given in Sec 3/3 of CSR.

CSR-reference	content	Comment
Sec2/2.1.1	Reference to the regulatory framework	
Sec2/2.1.3	Responsibilities of Classification Societies, Builders and Owners	
Sec3/3.1.1.2	Reference is made to regulations of international, national, canal and other authorities	
Sec5/5.1.1.4	Size of access openings	
Sec11/1.1.11	Portable plates	
Sec11/2	Crew protection	
Sec11/2.1	Bulwarks and Guardrails	
Sec11/2.2	Tank Access	see also table 11.2.2
Sec11/2.3	Bow Access	see also table 11.2.2

II.10 Design transparency

Statement of intent: The intent of the functional requirement is **not covered** by CSR.

Comment: The functional requirement is partially covered by CSR. The "design process" itself is not addressed by classification rules. Elements of the functional requirements of section II.10 are addressed in the sections of CSR as far as the compliance with the classification requirement is to be assured; these are provided in the table below. The CSR Rules require certain plans and documents to be submitted to the classification society in aid of the design appraisal. These documents cover the loading information, calculation data. The plans and supporting calculations which need to be submitted and/or supplied on board are listed.

The Rules refer to the loading conditions and design loading and ballast conditions upon which the approval of the hull scantlings is based. The conditions which, as a minimum, should be included in the Loading Manual are listed (section 8, 1.1). The Loading Manual is to include the design basis and operational limitations upon which the approval of the hull scantlings is based. The information listed in Table 8.1.1- Design Parameters is to be included in the Loading Manual.

The information to be required for inclusion in the Ship Construction File is currently defined in IACS UR Z23, section 10.

In certain cases the CSR Rules allows alternative methods to be used in lieu of the rule requirements. The equivalency procedure is sub-divided into three types:

- General CSR Rule application; CSR is applicable to ships of normal form, proportions, speed and structural arrangements. Anything which is outside the assumption in the Rules is to be specially considered (3/4.1.1).
- Novel designs; ships of novel design is also specially considered (3/4.1.2).
- Alternative calculation methods; where the Rules allow alternative methods are permitted to be used in lieu of the specific Rule requirement (3/4.1.3). The Rules require the user to demonstrate equivalent strength.

Relevant CSR References:

Ref.	Content	Comment
2.1.3.1	Lists the responsibilities of Classification Societies, builders and owners for the different phases of the ship building process.	
2/3.1.1.3 (a) & (b)	Requires the design basis to be submitted in support of the design appraisal.	
4/3.1.1.1	standard construction details	
9/2.1.2.1	Requires the submission of a detailed report of the structural analysis to demonstrate compliance with the specified structural design criteria and the content of the reports is listed.	
9/2.1.3.3	Computer program used	
9/2.2.3.2	Standard load cases to be used	
9/2.2.3.3	Non-standard load cases	
9/2.2.5.1	Verification of results	
9/2.3.5.1	Fine mesh results verification	
9/3.1.1.3	Fatigue analysis options	
2/3.1.5	Operating conditions. Rule assumed loading conditions.	
2/4.6.1 3/4	Novel designs and equivalency procedure	

Neither of the documents, nor any of the classification requirements, addresses the matter of intellectual property rights. This issue is considered to be outside of classification matters and a contractual matter between the owner, the builder and the manufacturer, as appropriate.

The CSR Rules does not have a procedure to make available design related/technical correspondence. This is not traditionally covered by classification rules.

CONSTRUCTION

II.11 Construction quality procedures

Statement of intent: The intent of the functional requirement is **covered** by CSR.

Comment: The functional requirements of section II.11 are addressed in the sections of CSR and in IACS Unified Requirement Z23 as provided below. Surveys, in general, are covered by the individual class society requirements. Neither of the documents, nor any of the classification requirements, address the matter of intellectual property rights. This issue is considered to be the contractual matter between the owner, the builder and the manufacturer, as appropriate.

Relevant CSR References:

Ref.	Content	Comment
2.1.3.1	Lists the responsibilities of Classification Societies, builders and owners for the different phases of the ship building process.	
2/3.1.1.3 (c)	Construction aspects.	
2/3.1.9	Structural construction and inspection	
6/4.4 6/5	Fabrication Weld design and dimensions	

The Rules address design and dimensions of welds as well as requirements for welding sequence, qualification of welders, welding procedures and welding consumables.

In addition to below reference in UR Z23, CSR section 6 requires that the structural fabrication is to be carried out, in accordance with '*IACS Recommendation 47, Shipbuilding and Repair Quality Standard for New Construction*' or a recognised fabrication standard which has been accepted by the Classification Society prior to the commencement of fabrication/construction, and lists what is required in the fabrication standard.

The structural requirements included in the Rules were developed with the assumption that construction and repair will follow acceptable shipbuilding and repair standards and tolerances. The Rules may require that additional attention is paid during construction and repair of critical areas of the structure.

The Rules define the renewal criteria for the individual structural items. The structural requirements included are developed on the assumption that the structure will be subject to periodical survey in accordance with individual Classification Society Rules and Regulations.

Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during a kick-off meeting (prior to commencing any newbuilding project). Structural fabrication is to be carried out in accordance with IACS Recommendation 47, "Shipbuilding and Repair Quality Standard for New Construction", or a recognized fabrication standard which has been accepted by the Classification Society prior to the commencement of fabrication/construction. The work is to be carried out in accordance with the Rules and under survey of the classification society.

Table 1 (of UR Z23) provides a list of surveyable items for the hull structure covered by the UR and address welding consumables, welder qualification, welding – mechanical properties (welding procedures), welding equipment, welding environment, welding supervision, welding- surface discontinuities, welding – embedded discontinuities, steel preparation and fit up, surface preparation, marking and cutting, straightening, forming, conformity with alignment/fit up/gap criteria, conformity for critical areas with alignment/fit up or weld configuration, steelwork process, e.g. sub-assembly, block, grand and mega block assembly, pre-erection and erection, closing plates, remedial work and alteration, tightness testing, including leak and hose testing, hydropneumatic testing, structural testing, corrosion protection systems, e.g. coatings, cathodic protection, installation, welding and testing of: hatch covers, doors and ramps integral with the shell and bulkheads, rudders, forgings and castings, appendages, equipment forming the watertight and weathertight integrity of the ship, e.g. overboard discharges, air pipes, ventilators, freeboard marks and draft marks, principal dimensions.

Any items found not to be in accordance with the Rules or the approved plans or any material, workmanship or arrangements found to be unsatisfactory, are required to be rectified.

The individual Classification society has Quality Assurance Scheme requirements for hull construction of ships to ensure the ship yard has the capability to meet the quality requirements. This scheme addresses situations where the "as-built" is different than the approved "design" plans.

The maintenance of the CSR Rules is described in IACS PR32 "Maintenance, Harmonization and Further Development of IACS CSR for Double Hull Oil Tankers and Bulk Carriers".

II.12 Survey

Statement of intent: The intent of the functional requirement is **covered** by CSR.

Comment: This functional requirement is addressed in IACS Unified Requirement Z23, in particular paragraphs 7.1, 7.2 and 7.3 and Table 1 focusing on the specific activities that need to be planned for and addressed.

Prior to commencing any newbuilding project, the society is to discuss with the shipbuilder at a kick off meeting the items listed in Table 1. The purpose of the meeting is to agree how the list of specific activities shown in Table 1 is to be addressed. The meeting is to take into account the shipbuilders construction facilities and ship type and deal with sub-contractors if it is known that the builder proposes to use them. The shipyard is to be informed of likely intervals for sampling and patrol activities. A record of the meeting is to be made, based upon the contents of the Table – the Table can be used as the record with comments made into the appropriate column. If the society has nominated a surveyor for a specific newbuilding project then the surveyor is to attend the kick off meeting. The builder is to be asked to agree to undertake ad hoc for the builder to agree to keep the classification society advised of the progress of any investigation. Whenever an investigation is undertaken, the builder is to be requested, in principle, to agree to suspend relevant construction activities if warranted by the severity of the problem.

The records are to take note of specific published Administration requirements and interpretations of statutory requirements.

The record of the meeting is to be updated as the construction process progresses in the light of changing circumstances, e.g. if the shipbuilder chooses to use or change sub-contractors, or to incorporate any modifications necessitated by changes in production or inspection methods, rules and regulations, structural modifications, or in the event where increased inspection requirements are deemed necessary as a result of a substantial non-conformance or otherwise.

IN-SERVICE CONSIDERATIONS

II.13 Survey and Maintenance

Statement of intent: The intent of the functional requirement is **not covered** by CSR.

Comment: The provision of adequate space for survey and maintenance is given by reference to SOLAS II-1 regulation 3-6. This regulation includes furthermore a requirement for the indication and documentation of critical areas of the structure in the Ship Structure Access Manual (regulation 3-6 subparagraph 4).
CSR rules include explicitly requirements to the access to closed spaces and the size of access openings (Sec 5/5 and Sec11/2.2, 2.3 and table 11.2.2).

Criteria for planning survey and maintenance are not explicitly included in the CSR. A reference is made to the Unified Requirement Z 10.4 of IACS with respect to the assessment and the related inspections and surveys for thickness measurements in section 12/1.2.1. Scope and extent of surveys are furthermore regulated by IMO resolution A.948(23). The hull survey for new constructions is regulated by the IACS Unified Requirement Z 23.

It is stated, that the CSR do not include requirements related to the verification of compliance with the rules during construction and operation in section 2/2.1.3. The owner and the individual Classification Society are responsible for maintaining the ship and verify the compliance with the class requirements in accordance with the Classification Society survey scheme as stated in Sec 2/2.1.3.1(d). The structural rule requirements of CSR are developed under the assumption that such a survey scheme is in place and the structure is built acc. to shipbuilding standards and tolerances as stated in Sec2/3.1.9. Therefore no indication of special areas due to the selection of special design parameters or features is needed. The use of parameters ore features deviating from CSR can be handled as described in Sec3/4 - Equivalence Procedure. In such cases special in-service survey or maintenance can be required in agreement with the individual classification society.

CSR-reference	content	comment
Sec2/2.1.3	Responsibilities of Classification Societies, builders and owners	
Sec2/3.1.9	Structural construction and inspection	
Sec3/4	Equivalence Procedure	
Sec5/5	Access Arrangements	
Sec5/5.1.1.4	Size of access openings	
Sec11/2.2	Tank Access	see also table 11.2.2
Sec11/2.3	Bow Access	see also table 11.2.2
Sec12/1.2	Assessment of thickness	Reference to UR Z 10.4 and

	measurements	requirements of individual Classification Society

II.14 Structural accessibility

Statement of intent: The intent of the functional requirement is **not covered** by CSR.

Comment:
In the goal based standards, means of access to the ship's structure for inspection and thickness measurements are required according to Tier II.14.
Means of access are covered in SOLAS and corresponding IACS interpretations.

The CSR refers to SOLAS Ch II-1, Part A-1, regulation 3-6, see CSR Section 5/5.

CSR for Oil tankers add requirements for access to specific areas: duct keel and pipe tunnel.
Reference documents:
Reference documents are the SOLAS requirements Ch II-1 regulation 3-6, resolution MSC 158(78) and IACS UI SC 191.

RECYCLING CONSIDERATIONS

II.15 Recycling

Statement of intent: The intent of the functional requirement is **not covered** by CSR.

Comment: Recycling matters are not scope of today's classification rules. Therefore requirements regarding recycling of the ship structure are not explicitly included in CSR. Reference is made, that other national or international rules and regulations may exist, which are relevant for the particular ship. It is noted that the MEPC plans to address this topic in a future IMO mandatory instrument on Recycling of Ships (see draft of "International Convention for the Safe and Environmentally Sound Recycling of Ships" document MEPC56.WP5).

6. Conclusions

This report was prepared by IACS to provide a working example of how IACS in the future may provide background documentation illustrating how classification rules meet the GBS. This was done to assist IMO conduct a pilot trial application of Tier III of the *GBS for oil tankers and bulk carriers*. The intention of the pilot is to validate the Tier III verification framework, identifying shortcomings and making proposals for improvement.
[Note : The pilot project will test the IMO GBS Tier III Verification Framework and not actually be the verification of the IACS CSR at this time.]

Appendix A
IMO Goal-based New Ship Construction Standards

To assist the Pilot Project members, the following is a copy of the GBS Tier I and II.

TIER I [3]

Ships are to be designed and constructed for a specified design life to be safe and environmentally friendly, when properly operated and maintained under the specified operating and environmental conditions, in intact and specified damage conditions, throughout their life.

.1 Safe and environmentally friendly means the ship shall have adequate strength, integrity and stability to minimize the risk of loss of the ship or pollution to the marine environment due to structural failure, including collapse, resulting in flooding or loss of watertight integrity.
.2 Environmentally friendly also includes the ship being constructed of materials for environmentally acceptable dismantling and recycling.
.3 Safety also includes the ship's structure being arranged to provide for safe access, escape, inspection and proper maintenance.
.4 Specified operating and environmental conditions are defined by the operating area for the ship throughout its life and cover the conditions, including intermediate conditions, arising from cargo and ballast operations in port, waterways and at sea.
.5 Specified design life is the nominal period that the ship is assumed to be exposed to operating and/or environmental conditions and/or the corrosive environment and is used for selecting appropriate ship design parameters. However, the ship's actual service life may be longer or shorter depending on the actual operating conditions and maintenance of the ship throughout its life cycle.

[3] Report of MSC 80, MSC 80/24, paragraph 6.39

TIER II FUNCTIONAL REQUIREMENTS [2]

(Applicable to new oil tankers and bulk carriers in unrestricted navigation[*])

DESIGN

II.1 Design life

The specified design life is not to be less than 25 years.

II.2 Environmental conditions

Ships should be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams.

II.3 Structural strength

II.3.1 Safety margins

Ships should be designed with suitable safety margins:

.1 to withstand, at net scantlings, in the intact condition, the environmental conditions anticipated for the ship's design life and the loading conditions appropriate for them, which should include full homogeneous and alternate loads, partial loads, multi-port and ballast voyage, and ballast management condition loads and occasional overruns/overloads during loading/unloading operations, as applicable to the class designation; and

.2 appropriate for all design parameters whose calculation involves a degree of uncertainty, including loads, structural modelling, fatigue, corrosion, material imperfections, construction workmanship errors, buckling and residual strength.

II.3.2 Deformation and failure modes

The structural strength should be assessed against excessive deflection and failure modes, including but not limited to buckling, yielding and fatigue.

II.3.3 General design

The ship's structural members should be of a design that is compatible with the purpose of the space and ensures a degree of structural continuity.

The structural members of ships should be designed to facilitate load/discharge for all contemplated cargoes to avoid damage by loading/discharging equipment which may compromise the safety of the structure.

II.3.4 Ultimate strength

Ultimate strength calculations should include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

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[2] Report of MSC 82, MSC 82/WP.5, ANNEX I

[*] Unrestricted navigation means that the ship is not subject to any geographical restrictions (i.e. any oceans, any seasons) except as limited by the ship's capability for operation in ice.

[**] The net scantlings should provide the structural strength required to sustain the design loads, assuming the structure in intact condition and excluding any addition for corrosion.

II.4 Fatigue life

The design fatigue life should not be less than the ship's design life and should be based on the environmental conditions in II.2.

II.5 Residual strength

Ships should be designed to have sufficient strength to withstand the wave and internal loads in specified damaged conditions such as collision, grounding or flooding. Residual strength calculations should take into account the ultimate reserve capacity of the hull girder, including permanent deformation and post-buckling behaviour. Actual foreseeable scenarios should be investigated in this regard as far as is reasonably practicable.

II.6 Protection against corrosion

Measures are to be applied to ensure that net scantlings required to meet structural strength provisions are maintained throughout the specified design life. Measures include, but are not limited to, coatings, corrosion additions, cathodic protection, impressed current systems, etc.

II.6.1 Coating life

Coatings should be applied and maintained in accordance with manufacturers' specifications concerning surface preparation, coating selection, application and maintenance. Where coating is required to be applied, the design coating life is to be specified. The actual coating life may be longer or shorter than the design coating life, depending on the actual conditions and maintenance of the ship. Coatings should be selected as a function of the intended use of the compartment, materials and application of other corrosion prevention systems, e.g. cathodic protection or other alternatives.

II.6.2 Corrosion addition

The corrosion addition should be added to the net scantling and should be adequate for the specified design life. The corrosion addition should be determined on the basis of exposure to corrosive agents such as water, cargo or corrosive atmosphere, or mechanical wear, and whether the structure is protected by corrosion prevention systems, e.g. coating, cathodic protection or by alternative means. The design corrosion rates (mm/year) should be evaluated in accordance with statistical information established from service experience and/or accelerated model tests. The actual corrosion rate may be greater or smaller than the design corrosion rate, depending on the actual conditions and maintenance of the ship.

II.7 Structural redundancy

Ships should be of redundant design and construction so that localized damage (such as local permanent deformation, cracking or weld failure) of any stiffening structural member will not lead to immediate consequential collapse of the complete stiffened panel.

II.8 Watertight and weathertight integrity

Ships should be designed to have adequate watertight and weathertight integrity for the intended service of the ship and adequate strength and redundancy of the associated securing devices of hull openings.

II.9 Human element considerations

Ships should be designed and built using ergonomic design principles to ensure safety during operations, inspection and maintenance of ship's structures. These considerations should include stairs, vertical ladders, ramps, walkways and standing platforms used for permanent means of access, the work environment and inspection and maintenance considerations.

II.10 Design transparency

Ships should be designed under a reliable, controlled and transparent process made accessible to the extent necessary to confirm the safety of the new as-built ship, with due consideration to intellectual property rights. Readily available documentation should include the main goal-based parameters and all relevant design parameters that may limit the operation of the ship.

CONSTRUCTION

II.11 Construction quality procedures

Ships should be built in accordance with controlled and transparent quality production standards with due regard to intellectual property rights. The ship construction quality procedures should include, but not be limited to, specifications for material, manufacturing, alignment, assembling, joining and welding procedures, surface preparation and coating.

II.12 Survey

A survey plan should be developed for the construction phase of the ship, taking into account the ship type and design. The survey plan should contain a set of requirements, including specifying the extent and scope of the construction survey(s) and identifying areas that need special attention during the survey(s), to ensure compliance of construction with mandatory ship construction standards.

IN-SERVICE CONSIDERATIONS

II.13 Survey and Maintenance

Ships should be designed and constructed to facilitate ease of survey and maintenance, in particular avoiding the creation of spaces too confined to allow for adequate survey and maintenance activities. Areas should be identified that need special attention during surveys throughout the ship's life. In particular, this should include all necessary in-service survey and maintenance that was assumed when selecting ship design parameters.

II.14 Structural accessibility

The ship should be designed, constructed and equipped to provide adequate means of access to all internal structures to facilitate overall and close-up inspections and thickness measurements.

RECYCLING CONSIDERATIONS

II.15 Recycling

Ships should be designed and constructed of materials for environmentally acceptable recycling without compromising the safety and operational efficiency of the ship.

Appendix B
IACS Common Structural for Double Hull Oil Tankers

This report was prepared in association with the IACS 2006 "*Common Structural Rules for Double Hull Oil Tankers*"(referred to as CSR or Rules in this report), which entered into force on 1 April 2006. A copy of these Rules is available from any IACS member or may be downloaded from the IACS web site free of charge at the following:

www.iacs.org.uk

The CSR and this report refer to IACS Unified Requirements, which may also be obtained from the above web site.

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Appendix C
Background Documents for the IACS Common Structural for Double Hull Oil Tankers

This report was prepared to assist IMO conduct a pilot trial application of Tier III of the GBS for oil tankers and bulk carriers is not intended to actually be the verification of the IACS CSR themselves. The Section 5 commentary of this report was generally prepared in order to summarize and illustrate how the CSR relates to the GBS.

The Technical Background Documents for IACS CSR for Double Hull Oil Tankers may be downloaded from the IACS web site free of charge at the following:

www.iacs.org.uk

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