IACS Common Structural Rules for Double Hull Oil Tankers, January 2006

Background Document

SECTION 8/1 – SCANTLING REQUIREMENTS
LONGITUDINAL STRENGTH

NOTE:

- This TB is published to improve the transparency of CSRs and increase the understanding of CSRs in the industry.

- The content of the TB is not to be considered as requirements.

- This TB cannot be used to avoid any requirements in CSRs, and in cases where this TB deviates from the Rules, the Rules have precedence.

- This TB provides the background for the first version (January 2006) of the CSRs, and is not subject to maintenance.

IACS
INTERNATIONAL ASSOCIATION OF CLASSIFICATION SOCIETIES LTD.

© IACS - the International Association of Classification Societies and the International Association of Classification Societies Limited

All rights reserved.

Except as permitted under current English legislation no part of this work may be photocopied, stored in a retrieval system, published, performed in public, adapted, broadcast, transmitted, recorded or reproduced in any form or by means, without prior permission of the copyright owner.

Where IACS has granted written permission for any part of this publication to be quoted such quotation must include acknowledgement to IACS.

Enquiries should be addressed to the Permanent Secretary,
International Association of Classification Societies Ltd,
36 Broadway
London, SW1H 0BH
Telephone: +44 (0)20 7976 0660
Fax: +44 (0)20 7808 1100
Email: PERMSEC@IACS.ORG.UK

Terms and Conditions

The International Association of Classification Societies (IACS), its Member Societies and IACS Ltd. and their directors, officers, members, employees and agents (on behalf of whom this notice is issued) shall be under no liability or responsibility in contract or negligence or otherwise howsoever to any person in respect of any information or advice expressly or impliedly given in this document, or in respect of any inaccuracy herein or omission herefrom or in respect of any act or omission which has caused or contributed to this document being issued with the information or advice it contains (if any).

Without derogating from the generality of the foregoing, neither the International Association of Classification Societies (IACS) nor IACS Ltd. nor its Member Societies nor their directors, officers, members, employees or agents shall be liable in contract or negligence or otherwise howsoever for any direct, indirect or consequential loss to any person caused by or arising from any information, advice, inaccuracy or omission given or contained herein or any act or omission causing or contributing to any such information, advice, inaccuracy or omission given or contained herein.

Any dispute concerning the provision of material herein is subject to the exclusive jurisdiction of the English courts and will be governed by English Law.

TABLE OF CONTENTS:

1 LONGITUDINAL STRENGTH

1.1 Loading Guidance

1.1.1 General

1.1.1.a The longitudinal strength requirements define the operational envelope for the ship in terms of limits to the hull girder still water shear and bending. The following items are covered:

(a) hull girder section modulus and bending stiffness;
(b) hull girder bending strength;
(c) hull girder shear strength;
(d) hull girder buckling strength;
(e) hull girder fatigue strength.

1.1.1.b This section complies with the following IACS Unified Requirement for Strength:

S1	Requirements for Loading Conditions, Loading Manual and Loading instrument
S4	Criteria for the use of high tensile steel with yield points of 315N/mm^2 and 355N/mm^2 (with respect to longitudinal strength)
S5	Calculation of midship section moduli for conventional ship for ship's scantlings
S7	Minimum longitudinal strength standard
S11	Longitudinal strength standard$^{1)}$
Note 1: URS11 buckling code replaced by the CSR Bulk carrier buckling code	

1.1.1.c Background to the IACS unified requirements are not repeated in this section.

1.1.1.d Hull girder stresses (bending and shear) derived in this Section are used as a basis for the assessment of criteria for local support members and primary support members (FEM).

1.1.1.e This section is in general based on UR S1. The periodical surveys requirements in S1 are not included as the Rules do not include any survey requirements, these being covered by the individual Classification Society.

1.1.1.f The minimum draughts forward are required to be included in the loading guidance information in order to ensure the crew are aware of this operational limitation in poor weather and hence reduce the probability of incurring slamming damage.

1.1.2 Loading manual

1.1.2.a The assumptions used during the structural design process are to be clearly defined as operational limitations in the loading manual and the Loading Computer System (LCS). The intention is to give the operators and other interested parties easy access to and full information about the operational limitations of the ship.

1.1.2.b The minimum set of loading conditions for seagoing and harbour operation to be included in the Loading Manual are taken from UR S11. Additional conditions related to ballast water exchange and ballast conditions are added.

1.1.2.c The requirement of not having any dry or clean ballast for the seagoing homogeneous loading condition at scantling draft only applies to the departure condition. Ballast may be used in mid-voyage and arrival conditions to correct the trim due to reduction of fuel oil.

1.1.2.d The terminology of clean and dry ballast is taken from IACS URS11. Clean ballast means segregated ballast tanks and dry ballast is a collective term for other types of ballast that may be used, e.g. sand etc.

1.1.2.e A "normal ballast" condition is included in order to define the typical operational ballast condition for the vessel to which the fatigue calculations are based upon. A "heavy ballast" condition is included in order to ensure that the master can fill the fore peak tank in heavy weather without exceeding any still water bending moment or shear force limits during the process. The requirement of having a condition in which the fore peak ballast tank is full only applies if the ship is arranged with a fore peak ballast tank.

1.1.2.f The text related to mid-voyage conditions is taken directly from IACS URS11. As the conditions in IACS URS11 are design loading conditions their purpose is to ensure that the ship has adequate operational flexibility in terms of still water bending and shear force limits. Consequently the mid-voyage conditions relate to any "special" condition in which the ship is intended to operate and where the hull girder bending moment may be greater than that of the ballast condition.

1.1.2.g The requirement of inclusion of typical complete loading and unloading operations applies for conditions where the hull girder bending moments and /or shear forces are greater than those given by the other conditions in the manual. The purpose is to ensure that the assigned limits to the vessel for harbour / sheltered water conditions encompass also the loading unloading sequence.

1.1.2.h The additional design ballast condition given in Section 8/1.1.2.2 c) is included to ensure that the minimum design ballast draught, T_{bal} defined in *Section 4/1.1.5.2 of the Rules*, used for the structural design process is not unrealistically high. The latter may be the case if the "normal" ballast condition includes filling of the peak tanks. The minimum design ballast draught is important as it is used for calculation of counter pressure on the side and bottom shell structure.

1.1.2.i The definition of departure and arrival conditions is in accordance with the definition given in IACS URS 25.

1.1.2.j Restriction on loading conditions with partly filled ballast tanks as described in *Section 8/1.1.2.5 and 1.1.2.6 of the Rules* is included in accordance with UR S11.

1.1.2.k *Section 8/1.1.2.9 of the Rules* lists design limits used as the basis for the standard Rule requirements and that may have an impact on operational flexibility. If there is a wish/need to exceed these limits during operation of the vessel the extended limits are to be specified and included in the design assessment and are therefore required to be included in the loading manual. If the limits are exceeded some additional scantlings in some areas will be expected.

1.1.3 Loading computer system

1.1.3.a The old loading instruments are now replaced with Loading Computer Systems, LCS, and the term loading instrument is not used in the rule text. Also, single point instrument acceptable according to UR S1 are banned as these Rules require that the

LCS is capable of showing many read out positions for bending moments and shear forces.

1.1.3.b The approval of the LCS is not included in the Rules, this being covered by the individual Classification Society.

1.1.3.c The 2% accuracy required for acceptance of LCS reflects the improvement in accuracy of modern day computer programs. Traditionally this value has been between 2 and 5% depending on Classification Society.

1.2 Hull Girder Bending Strength

1.2.1 General

1.2.1.a The requirement to continuity of longitudinal members specified in *Section 8/1.2.1.2 of the Rules* is taken from IACS URS 7.

1.2.2 Minimum requirements

1.2.2.a The minimum hull girder moment of inertia is based on the IACS UR S4 "as built" requirement, which states:

$$I_{\min-URS4} = 3Z_{\min-URS7}L$$

Where:

$Z_{min\text{-}URS7}$ required end of life or "net" section modulus for mild steel given in UR S7

$$= C_{wv}L^2B(C_b + 0.7)$$

Note IACS UR S7 allows a 10% reduction in hull girder section modulus for ships in service as compared to new ships.

1.2.2.b The Rule required minimum moment of inertia is based on net hull girder properties and hence the IACS UR S4 requirement is reduced by 10% to be consistent with UR S7, giving the following formulation for Rule required net hull girder moment of inertia:

$$I_{v-\min} = 2.7C_{wv}L^3B(C_b + 0.7)$$

1.2.2.c The hull girder moment of inertia requirement is an implicit means to reduce the probability of excessive whipping and springing.

1.2.2.d The minimum section modulus, $Z_{v\text{-}min}$, is based on IACS UR S7 using the coefficient c_s, see IACS UR S7, for ships in service.

1.2.2.e The net thickness philosophy combined with the values for corrosion additions meets the UR S7 requirement for new ships.

1.2.2.f The effective deck height requirement is based on IACS UR S5 which adjusts the vertical distance from the neutral axis to the deck as a consequence of any fitted continuous trunks or longitudinal hatch coamings.

1.2.3 Hull girder requirement on total design bending moment

1.2.3.a The requirement is based on UR S11, but reformulated to the net scantling approach adopted in these Rules.

1.2.3.b UR S11.3.1.1 states the allowable hull girder stress for gross scantlings to be $\sigma = 175/k$ (N/mm^2) for seagoing operations, seagoing operations being synonymous with the S+D design combination, see *Section 2/5.4 of the Rules*. By including the factor 0.9 from UR S7 (i.e. the factor to convert the section modulus requirement for "new ships" to be applicable to "ships in service") the allowable stress level for seagoing operation (S+D) will be: $175/0.9\ k = 194/k$ N/mm^2. This has been rounded down to $190/k$ N/mm^2 to ensure that the CSR Rules in the "net" format are on the conservative side and ensure compliance with the corresponding IACS URS 11 gross requirement.

1.2.3.c The acceptance stress criteria within $0.1L$ of the A.P and F.P, $\sigma = 140/k$ N/mm^2, is derived from gross scantling requirement in DNV Rules Pt.3 Ch.1 Sec.5 C303 of $125/k$ N/mm^2 for seagoing operations and a similar requirement in LR Rules of $122/k$ N/mm^2. The $140/k$ value being derived from $125/0.9k = 139/k$ N/mm^2 and rounded.

1.2.3.d Harbour/tank testing operations are synonymous with the S design load combination. In harbour/tank testing operations the Rules consider that only still water bending moments are acting and the acceptance criteria is based on an allowable hull girder bending stress taken as 75% of the allowable for seagoing operations (S+D). The reduction in allowable stress gives some margin for dynamic wave loads that might occur in harbour/sheltered water loading environments which are not required to be explicitly evaluated and also for accidental overloading during harbour operations without leading to structural failure or permanent deformations.

1.3 Hull Girder Shear Strength

1.3.1 General

1.3.1.a The method for hull girder shear strength assessment as specified in *Section 8/1.3 of the Rules* is based on the existing Rules and procedures of ABS, LR and DNV.

1.3.1.b The capacity model for shear strength is based on linear beam theory and takes into account change in material properties/thickness within the depth of the hull girder web.

1.3.1.c In accordance with the intent of UR S11, the capacity model for shear strength for the longitudinal bulkhead takes account of "local load" distribution effects which result in the actual distribution of shear force in the hull girder departing from the classical beam shear flow predictions, especially towards the ends of the cargo holds. "Local load" distribution to inner hull and side shell is ignored, since in the loading conditions critical for shear strength, this effect normally results in these items carrying less shear force than according to shear flow theory.

1.3.1.d The approach to "local load" distribution is based on an "envelope approach" in order to simplify the rule application. Consequently the rule requirement assumes the worst case of high complimentary shear force in way of transverse bulkhead stringer end attachments for the "cargo tank empty with adjacent tanks full abreast" loading condition.

1.3.2 Assessment of hull girder shear strength

1.3.2.a The equation is a development of LR Rules Pt 3, Ch 4 and re-written to accommodate the Rule net thickness approach.

1.3.2.b At the ends of the ship and at the centre of each cargo tank, the actual shear force carried by each structural member will conform well, with the closed cell shear flow theory. The hull girder net plating thickness used in the shear formulations is as follows:

$t_{ij\text{-}net50}$ = Equivalent thickness for the plate considered. Generally

$$t_{ij} = t_{grs} - 0{,}5 \cdot t_{corr}$$

where

index *i* refers to structural the member, e.g. side shell, longitudinal bulkhead, inner hull, etc

j is index for the plate element

1.3.2.c The shear flow factors in *Figure 8.1.2 of the Rules* are taken from LR Rules Pt 3, Ch 4, Table 4.6.1. For ships that are not of standard design the shear force distribution factors should be used with care and checked against values obtained by shear flow analysis.

1.3.2.d Towards the ends of the cargo tanks, the actual shear force carried by each structural member departs from closed cell shear flow theory due to local load effects.

1.3.2.e Permissible shear stress for seagoing operations (S+D condition) is increased from $110/k$ N/mm^2 for gross scantlings (UR S11) to $120/k$ N/mm^2 to reflect the net thickness approach. The acceptance criteria for harbour/tank testing operations is 87.5% of that for the seagoing conditions. The corresponding ratio for the allowable bending stress is 75%. The reason for the difference is that the ratio between dynamic and the static component is different for the two responses. Where as the wave bending moment is typically 1.5-2 times the static bending moment the situation is opposite for shear where the design static shear force is about 2 times the wave shear. The 87.5% for the harbour is set such that 100% is achieved by adding half the dynamic component which is the hull girder wave shear force.

1.3.3 Shear force correction for longitudinal bulkheads between cargo tanks

1.3.3.a Towards each end of the cargo tanks, the shear force carried by longitudinal bulkheads, inner hull and side shell departs from closed cell shear flow theory, due to "local shear force distribution" effects.

1.3.3.b "Local shear force distribution" is due to the shear load being transferred into the longitudinal structure via the transverse structure such as floors to the longitudinal bulkheads and girders into the transverse bulkheads.

1.3.3.c In LR Rules, the local shear force distribution effect is dealt with by a factor "m_i", in DNV Rules Pt.3 Ch.1 Sec.5 D this effect is dealt with by the factor ΔQs. In ABS, DNV and LR Tanker Rules the effect is also taken into account explicitly within the required FEM analyses.

1.3.3.d The “local shear force distribution” is accounted for in the CSR Rule formulation by applying a thickness deduction, t_{Δ}, to the longitudinal bulkhead thickness used in the calculation of shear capacity. This thickness deduction represents the proportion of the longitudinal bulkhead shear capacity that is required to resist the local shear force distribution effects and hence can not be utilised as part of the longitudinal shear capacity.

$$t_{sfc-net50} = t_{grs} - 0.5t_{corr} - t_{\Delta}$$

$$t_{\Delta} = \frac{\delta Q_3}{h_{blk}\tau_{ij-perm}}\left(1 - \frac{x_{blk}}{0.5l_{tk}}\right)\left(2 - \frac{2(z_p - h_{db})}{h_{blk}}\right)$$

Note

The parameters in the above expressions are explained below

1.3.3.e The additional shear stress caused by the local shear force distribution is assumed to be a triangularly distributed with the maximum value at the inner bottom level decreasing to zero at upper deck, hence the vertical distribution of the thickness deduction also linearly decreases. This distribution is consistent with that seen in 3D FEM analysis results.

1.3.3.f It is assumed that the maximum thickness reduction, $t_{\Delta-max}$, due to the shear force correction is found close to the transverse bulkhead just above the inner bottom, hence where x_{blk} = 0 and $z = h_{db}$, see *Figure 8.1.a,* and that the reduction is linearly tapered from this maximum value to zero at the middle of the tank ($x_{blk} = 0.5l_{tk}$).

$$t_{\Delta-\max} = \frac{2 \cdot \delta Q_3}{h_{blk} \cdot \tau_{ij-perm}}$$

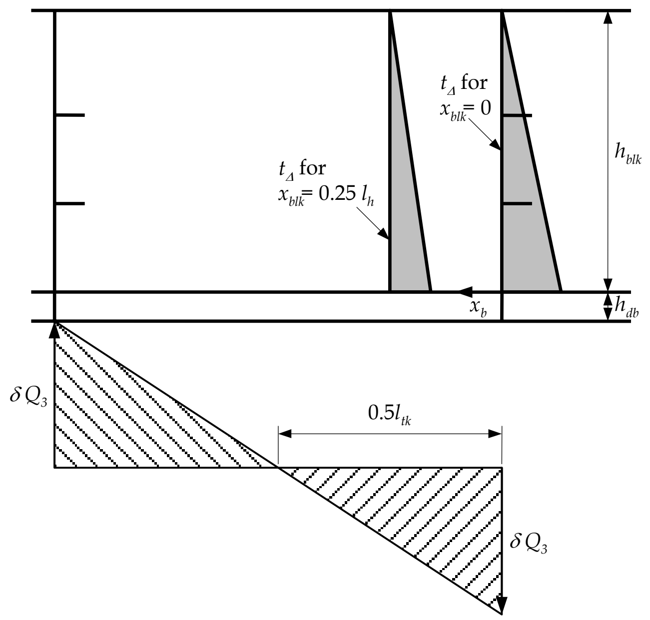
1.3.3.g The term δQ_3 represents the mean value of local shear force that is transferred to the longitudinal bulkhead via the floors. This value is dependent on the cargo tank configuration as well as the bottom structure arrangement and stiffness. In all cases, the magnitude of δQ_3 is based on the worst case differential net load on the double bottom structure.

$$\delta Q_3 = 0.5K_3\, F_{db}$$

1.3.3.h For tankers with a centre line bulkhead the local load distribution factor, K_3, is calculated depending on the structural arrangement and is taken from DNV existing rule formulations of Pt 3 Ch 1 Section 5 D400. The formulation for K_3 assumes there are no partial girders fitted to the design. Based on previous studies within DNV and LR, it is known that maximum δQ_3 occurs in the loading condition with the greatest downwards net load in the cargo tanks.

1.3.3.i For tankers with two longitudinal bulkheads the local load distribution factor, K_3, is calculated depending on the structural arrangement and is taken from DNV existing rule formulations of Pt 3 Ch 1 Section 5 D302. Based on previous studies within DNV and LR, it is known maximum δQ_3 occurs in the loading condition with the greatest downwards net load in the centre cargo tank.

Figure 8.1.a
Shear Force Correction for Longitudinal Bulkheads



1.3.3.j For consistency of Calculation of Maximum Resulting (or net load) Force (or net load) on the double bottom, F_{db}, the loading patterns used in the design verification by finite element analysis, see *Appendix B/2.3.1 of the Rules,* are also used to derive the maximum net load on the double bottom. For standard tankers and simplicity F_{db} can be expressed as a function of the principal dimensions of the cargo tank and the ship's draught.

1.3.3.k The load cases for determining the thickness deduction for shear force correction encompass the Rule minimum conditions specified in *Table 8.1.6 of the Rules* which correspond to the Rule FE load cases, and any loading condition included in the Loading manual. The maximum value of F_{db} calculated for any of the specified conditions is to be used.

1.3.4 Shear force correction due to loads from transverse bulkhead stringers

1.3.4.a It is known from the results of 3D FEM analysis that loading conditions which feature wing and centre tanks abreast filled with adjacent cargo tanks fore/aft empty result in very high shear stress at the longitudinal bulkhead in the vicinity of transverse bulkhead below the horizontal stringers. This is due to the local shear force transferred from the transverse bulkhead stringers into the longitudinal bulkheads.

1.3.4.b This phenomenon is addressed explicitly in existing DNV Rules Pt.3 Ch.1 Sec.5 D500 and is also featured in LR Rules Pt 4, Ch 9,8.3.1(e). LR's existing Plan Approval procedure normally requires re-enforcement of these areas following finite element analysis. Existing ABS rules address this using finite element analysis.

1.3.4.c In the Rules it was therefore decided that the assigned shear forces should account for this additional local shear stress in an explicit and transparent way.

1.3.4.d Accordingly the rule formulation for permissible hull girder shear force accounts for the additional shear stress components acting in this loading condition by reducing the effective longitudinal bulkhead thickness used in the hull girder shear capacity calculation.

1.3.4.e The main area affected is the longitudinal bulkhead plating in way of the ends of the transverse bulkhead stringers. The maximum local shear stresses are experienced when the transverse bulkhead is only loaded from one side. For example, with a combination of all cargo tanks across being empty on one side of the bulkhead and all full on the other side, see *Figure 8.1.b,* this induces the maximum net load across the bulkhead and hence the maximum reaction/support forces in the ends of the bulkhead stringers.

1.3.4.f The total stringer supporting force (F_{str-k}) in way of a longitudinal bulkhead may be divided into three parts:

(a) below the stringer, complimentary shear acting downwards (Q_{str-k}) which adds to the hull girder longitudinal shear stress

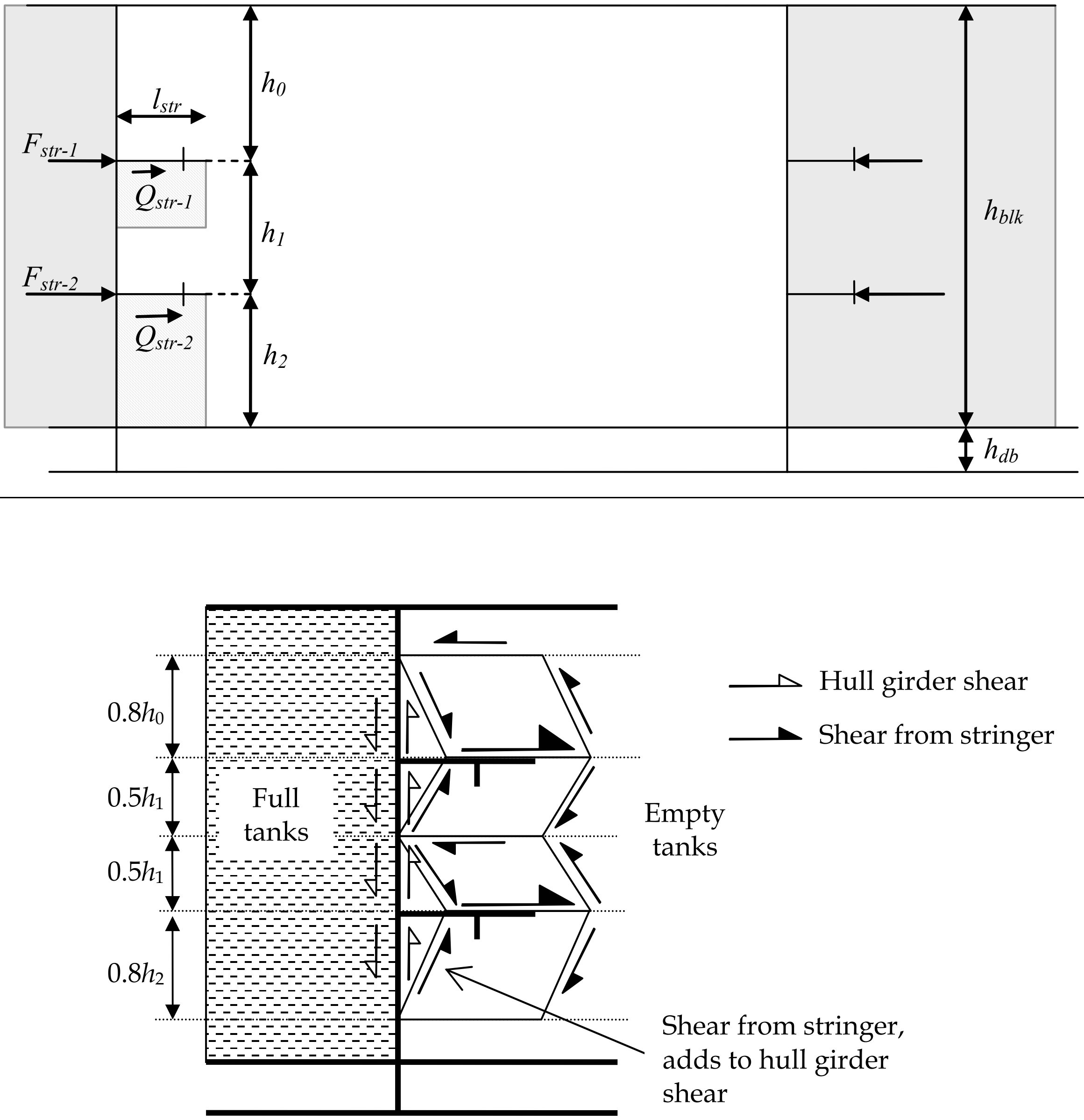
(b) above the stringer, complimentary shear acting upwards (Q_{u-k}) which will subtract from the hull girder shear stress

Direct stresses in way of toe and heel of stringer connection to longitudinal bulkhead (axial stress in longitudinal or platform in way of termination of stinger)
Note

k denotes the *k*-th bulkhead stringer from the deck

© IACS 2006

Figure 8.1.b
Region for Stringer Correction for a Tanker with Two Stringers



1.3.4.g The additional shear stress, τ_{str-k}, caused by the complimentary acting shear force will have the same sign as the local still water hull girder shear stress and may be expressed as:

$$\tau_{str-k} = \frac{Q_{str-k}}{l_{str} \cdot t_{sfc-net50}}$$

Where

l_{str}	connection length of stringer, in m
$t_{sfc\text{-}net50}$	actual thickness adjusted for corrosion addition and shear correction for longitudinal bulkheads in way of the *k*-th stringer $= t_{grs} - 0.5t_{corr} - t_{\Delta}$

1.3.4.h Correspondingly, the shear force above the stringer ($Q_{u\text{-}k}$) will produce a shear stress ($\tau_{u\text{-}k}$) with opposite sign to the hull girder shear stress.

1.3.4.i The total shear stress below a stringer must satisfy the following:

$$\tau_{HG} + \tau_{str-k} \leq C_t \cdot \tau_{yd} = \tau_{ij-perm}$$

The actual hull girder shear stress in way of a stringer is given by:

$$\tau_{HG} = \frac{t_r \cdot \tau_{ij-perm}}{t_{sfc-net50}}$$

hence

$$\frac{t_r \cdot \tau_{ij-perm}}{t_{sfc-net50}} + \frac{Q_{str-k}}{l_{str} \cdot t_{sfc-net50}} \leq \tau_{ij-perm}$$

And consequently

$$t_r = \left(\tau_{ij-perm} - \tau_{str}\right)\frac{t_{sfc-net50}}{\tau_{ij-perm}} = t_{sfc-net50}\left(1 - \frac{\tau_{str}}{\tau_{ij-perm}}\right)$$

Where:

C_t	≈0.90 permissible shear stress coefficient . Actual value of C_t will depend on material strength as the material factor *k* is included in $\tau_{ij\text{-}perm}$
τ_{yd}	specified minimum shear yield stress of the material, in N/mm^2
t_r	the available or equivalent thickness in way of the k th stringer based on the hull girder shear stress assessment taking into account the shear load from stringers
$\tau_{ij\text{-}perm}$	permissible hull girder shear stress
τ_{str}	$= \dfrac{Q_{str-k}}{l_{str} \cdot t_{sfc-net50}}$

1.3.4.j In the Rules, the thickness, t_r, has been redefined as the equivalent net thickness, $t_{str\text{-}k}$. This thickness is the thickness that is available to be used in the hull girder shear capacity assessment after deducting a proportion of that thickness which is used to resist the local shear stresses arising from the bulkhead stringers. Hence $t_{str\text{-}k}$ is given by:

$$t_{str-k} = t_{sfc-net50}\left(1 - \frac{\tau_{str}}{\tau_{ij-perm}}\right)$$

Where:

$t_{sfc-net50}$ Effective net plating thickness after correction for the local shear correction for longitudinal bulkheads between cargo tanks

1.3.4.k This stringer correction is to be carried out in the full length of the stringer connection (buttress) and from the level of the considered stringer to a level $0.5h_k$ below, see *Figure 8.1.a*. For the lowermost stringer the stringer correction to be applied down to the level of the inner bottom, see also *Figure 8.1.b*.

1.3.4.l Based on FEM analyses the total shear force in the longitudinal bulkhead was found to be 75-80% of the total stringer supporting force (F_{str-k}) and with the remaining force carried by direct stresses in way of toe and heel of the stringer connection. The distribution between the stringer shear force above and below the stringer connection was found to be dependent on the relative distance to the inner bottom and upper deck. From this the following expressions for the stringer shear forces Q_{str-k} and Q_{u-k} were developed:

$$Q_{str\text{-}k} = 0.8 \cdot F_{str\text{-}k} \cdot \left(1 - \frac{z_{str} - h_{db}}{h_{blk}}\right) \quad \text{and} \quad Q_{u\text{-}k} = 0.8 \cdot F_{str\text{-}k} \cdot \frac{z_{str} - h_{db}}{h_{blk}}$$

where

$$h_{db} \le z_{str} \le h_{blk} + h_{db}$$

1.4 Hull Girder Buckling Strength

1.4.1 General

1.4.1.a The hull buckling strength considers the uni-axial hull girder compressive stress and the hull girder shear stress separately.

1.4.1.b The hull girder buckling strength assessment is only given based on the static + dynamic condition. This is because the wave bending moment is significantly greater than the difference between harbour and seagoing still water bending moment and hence the total bending moment (still water + wave) will be maximum in the seagoing condition. Consequently the static condition (harbour/tank testing) is not governing and as a simplification omitted from the Rules.

1.4.2 Buckling assessment

1.4.2.a Details of the buckling procedure are included in *Section 10/3.1 of the Rules*. The buckling code used as basis for the longitudinal strength check in *Section 8/1.4 of the Rules* is not based on the buckling code given in *IACS URS 11 Rev 4*.

1.4.2.b Details on the net thickness concept for buckling assessment are given *Section 2/4.3.4.7 and 6/3.3.2 of the Rules*.

1.4.2.c The minimum hull girder stress of 30/k used for hull girder buckling assessment in *Section 8/1.4.2.3 of the Rules* is in accordance with the minimum value specified in *IACS UR S11*. The minimum value of 30/k is an implicit but simplified way of accounting for horizontal hull girder bending.

1.4.2.d The design stress, $\sigma_{hg\text{-}net50}$, is based on the net hull girder scantlings and at the actual position of the member being considered assuming linear beam-theory and without correction for the shear lag effect. The hull girder buckling assessment in Section 8/1.4 of the Rules is an initial simplified assessment. The hull girder buckling strength is also assessed as part of the FE analysis as required in *Section 9/2 of the Rules* in which shear lag effects as well as pressures and biaxial stresses are accounted for.

1.4.2.e Sagging moments are used as basis for evaluation of structure above the neutral axis and hogging moment for structure below the neutral axis, as buckling is assessed for compressive stresses.

1.4.2.f The reduced acceptance criteria (less than 1.0), in *Section 8/1.4.2.6 and 1.4.2.8 of the Rules,* for structure below 0.5D makes allowance for the presence of bi-axial compressive stresses due to bending between primary support members, transverse compressive stresses and lateral pressure, which are more significant in the lower region of the hull girder cross section. These effects are directly covered in the design verification by FEA.

1.5 Hull Girder Fatigue Strength

1.5.1 General

1.5.1.a The fatigue requirement for the hull girder section modulus is based on the same nominal stress approach as given in the *Section 9/3 of the Rules* with the assumption that there are only global stresses acting, i.e. stresses due to local pressure are ignored in this requirement. The purpose of the requirement is to enable the hull girder section modulus to be reasonably dimensioned before the full fatigue assessment is undertaken. Consequently, this requirement is for general guidance during the initial longitudinal strength investigation only, as the detailed fatigue review is required per *Section 9/3 of the Rules*.

1.5.1.b The vertical bending moments are assumed in the calculations to be the same in loaded and ballast condition and therefore it is sufficient to calculate the fatigue damage for one loading condition, i.e. i=1 and a=1 in:

$$DM_i = \frac{\alpha_i N_L}{K_2} \frac{S_{Ri}^m}{(\ln N_R)^{m/\xi}} \mu_i \Gamma(1 + \frac{m}{\xi})$$

Where definition of symbols are given in *Appendix C/1.4.1.4 of the Rules*.

1.5.1.c The following assumptions and simplifications were applied:

- The thickness effect is not included.
- Corrosive environment is modelled by applying a factor of 1.06 on the stress level.
- A mean stress factor is applied using a factor of 0.85.

- Simplified scaling from net scantlings using $0.25t_{corr}$ to scantlings based on $0.50t_{corr}$ can be achieved by decreasing the hull girder stress by 5%.
- The hull girder stress calculation is based on the deck corner assuming that the deck camber and the depth of the deck longitudinals are counteracting each other and ignoring horizontal bending effects.
- The allowable dynamic stress range was developed using curve fitting on data from the test ships.

1.5.1.d Based on the above assumptions, the allowable stress range at moulded deck line at side is calculated as:

$$R_{al} = \frac{0.95 S_{SN}}{1.06 \cdot 0.85}$$

Where:

R_{al} the allowable stress range corresponding to 25 years fatigue life and selected SN-curve

1.6 Tapering and Structural Continuity of Longitudinal Hull Girder Elements

1.6.1 Tapering based on minimum hull girder section property requirements

1.6.1.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

1.6.2 Longitudinal extent of higher strength steel

1.6.2.a The longitudinal extent of material with higher strength steel is to be carried through to a position where the hull girder stress is below the permissible for mild steel or high tensile steel of lower yield stress if this is used.

1.6.3 Vertical extent of higher strength steel

1.6.3.a The vertical extent of higher strength steel considers hull girder bending stresses only and takes into account the actual hull girder bending stress in deck or bottom. Similar to the longitudinal extent of higher strength steel the requirement of vertical extent of higher strength steel is included to ensure that the stress level in the structural members outside the high strength steel area are not above the allowable in relation to the material in this area.

1.6.4 Tapering of plate thickness due to hull girder shear requirement

1.6.4.a Longitudinal tapering of shear reinforcement shall be carried out so that for any longitudinal position member the requirements given in *Section 8/1.3.2 of the Rules* are complied with. Control of shear strength at intermediate positions is to be carried out by linear interpolation of permissible shear limits at bulkheads and at the mid-length of cargo tanks.

1.6.5 Structural continuity of longitudinal bulkheads

1.6.5.a Termination at deck and bottom incorporating brackets with a minimum leg length of $0.05D$ is considered to comply with the requirement of large transition brackets.

© IACS 2006

1.6.6 Structural continuity of longitudinal stiffeners

1.6.6.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.