FOREWORD

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CHANGES – CURRENT

This is a new document.
The rules enter into force 1 January 2016.
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SECTION 1 DESIGN OF WELD JOINTS

Symbols

For symbols not defined in this section, refer to Ch.1 Sec.4.

\( A_{\text{weld}} \) = effective fillet weld area, in cm\(^2\).
\( f \) = root face, in mm.
\( f_{\text{weld}} \) = weld factor.
\( f_{\text{yd}} \) = coefficient dependent on the material strength of the weld deposit:

\[
 f_{\text{yd}} = \max \left[ \left( \frac{1}{k} \right)^{0.5} \left( \frac{235}{R_{\text{elH,weld}}} \right)^{0.75} ; 0.71 \right]
\]

\( f_c \) = coefficient depending on the environment:

\[
 f_c = \begin{cases} 
 1.2 & \text{for liquid cargo tank, water ballast tank, hold for dry bulk cargo and bilge well} \\
 1.0 & \text{elsewhere}
\end{cases}
\]

\( L_{\text{dep}} \) = total length of deposit of weld metal, in mm.
\( L \) = leg length of continuous, lapped or intermittent fillet weld, in mm.
\( L_{\text{weld}} \) = length of the welded connection in mm.
\( R_{\text{elH,weld}} \) = specified minimum yield stress for the weld deposit in N/mm\(^2\), not to be less than:

\[
 R_{\text{elH,weld}} = \begin{cases} 
 355 & \text{for welding of normal strength steel with } R_{\text{elH}} = 235. \\
 375 & \text{for welding of high strength steels with } R_{\text{elH}} \text{ from } 265 \text{ to } 355. \\
 400 & \text{for welding of high strength steel with } R_{\text{elH}} = 390.
\end{cases}
\]

\( \tau_{\text{elH,weld}} \) = specified shear yield stress of weld deposit, in N/mm\(^2\).

\[
 \tau_{\text{elH,weld}} = \frac{R_{\text{elH,weld}}}{\sqrt{3}}
\]

\( t_{\text{as-built}} \) = as-built thickness of the abutting plate, in mm.
\( t_{\text{gap}} \) = allowance for fillet weld gap is not to be taken less than 2.0 mm. Lower value may be accepted based on a case-by-case consideration.
\( t_{\text{throat}} \) = throat thickness of fillet weld in mm, as defined in [2.5.3].
\( k \) = material factor of the abutting member.

1 General

1.1 Application

The requirements of this section apply to all ships, and cover the design of welded connections in hull structures and are based on the requirements laid down in Pt.2.

1.2 Alternatives

1.2.1 The requirements given in this section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details will be specially considered for approval.
1.2.2 The minimum leg length limits given in Table 1 are to be complied with in all cases.

1.3 Documents to be submitted

1.3.1 The documents to be submitted are specified in Ch.1 Sec.3.

1.3.2 If welding consumables with deposit of the lower or higher yield strength than specified in Symbols are used, the $R_{eq,\text{weld}}$ value shall be stated on the drawings submitted for approval. The yield strength of the weld deposit is in no case to be less than required in Pt.2 Ch.4.

2 Tee or cross joint

2.1 Application

2.1.1 The connection of primary supporting members, stiffener webs to plating as well as the plating abutting on another plating, are to be made by fillet or penetration welding, as shown on Figure 1.

![Tee or cross joint diagram](image)

Figure 1 Tee or cross joints

$\theta$ = connecting angle, in deg.

2.2 Continuous fillet welds

2.2.1 Continuous welding is to be used in the following locations:

a) Connection of the web to the face plate for all members.
b) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
c) Boundaries of tanks and watertight compartments.
d) All structures inside tanks and cargo holds.
e) Stiffeners and primary supporting members at tank boundaries.
f) All structures in the aft peak and stiffeners and primary supporting members of the aft peak bulkhead.
g) All structures in the fore peak.
Part 3 Chapter 13 Section 1


Welding

h) Welding in way of all end connections of stiffeners and primary supporting members, including end brackets, lugs, scallops, and at perpendicular connections with other members.
i) All lap welds in the main hull.
j) Primary supporting members and stiffener members to bottom shell in the 0.3 \( L \) forward region.
k) End connections of pillars.
l) Hatch coaming stay webs to deck plating, see [2.4.4].

2.3 Intermittent fillet welds

2.3.1 Where continuous welding is not required, intermittent welding may be applied.

2.3.2 With reference to Figure 2, the various types of intermittent welds are as follows:
   — chain weld
   — staggered weld
   — scallop weld (closed).

   For size of welds, see [2.5].

Figure 2 Recommended arrangement of intermittent welds

2.3.3 When chain and staggered welds are used on continuous members penetrating oil- and watertight boundaries, the weld termination towards the tank boundary shall be closed by a scallop, see Figure 3.

Where intermittent welds are accepted, scallop welds shall be used in tanks for water ballast, cargo oil or fresh water.

Chain, staggered and one side continuous fillet welds may be used in dry spaces and tanks arranged for fuel oil only.

Figure 3 Weld termination towards tank boundary

2.3.4 Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of every intersection. In addition, the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

Where intermittent welding or one side continuous welding is permitted, double continuous welds are to be applied for one-tenth of their shear span, in accordance with [2.5.2] and [2.5.3].
2.3.5 Size for one side continuous weld

The size for one side continuous weld is to be as required by [2.5.2] for intermittent welding, where \( f_2 \) factor as defined in [2.5.2] is to be taken as 2.0.

2.4 Partial and full penetration welds

2.4.1 Partial or full penetration welding

In areas with high tensile stresses or areas considered critical, full or partial penetration welds are to be used.

In case of full penetration welding, the root face is to be removed, e.g. by gouging before welding of the back side.

For partial penetration welds the root face, \( f \), is generally to be taken between 3 mm and \( t_{as-built} / 3 \).

The groove angle made to ensure welding bead penetrating up to the root of the groove, \( \alpha \), is usually from 40° to 60°, and is to be in accordance with recognised fabrication standard.

The welding bead of the full/partial penetration welds is to cover the root of the groove.
Examples of partial penetration welds are given in Figure 4.

![Figure 4 Partial penetration welds](image)

2.4.2 One side partial penetration weld

For partial penetration welds with one side bevelling the fillet weld at the opposite side of the bevel shall satisfy the requirements given in [2.5.2].

2.4.3 Extent of full or partial penetration welding

The minimum extent of full or partial penetration welding is to be evaluated based on stress distribution in way of the reference point, i.e. intersection point of structural members, end of bracket toe, etc. In general, an extent of 300 mm from the reference point is acceptable.

2.4.4 Locations required for full penetration welding

Full penetration welds shall be used in the following locations:

a) Radiused hatch coaming plates in way of deck opening corners welded to the deck plate as shown in Figure 5.

b) Connection of vertical corrugated bulkhead to the lower hopper plate and to the inner bottom plate within the cargo area, when the vertical corrugated bulkhead is arranged without a lower stool.

c) Connection of vertical corrugated bulkhead to top plating of lower stool.

d) Edge reinforcement or pipe penetration both to strength deck, sheer strake and bottom plating within 0.6 \( L \) amidships, when the dimensions of the opening exceeds 300 mm, see Figure 5.

e) Abutting plate panels with as-built thickness less than or equal to 12 mm, forming outer shell boundaries below the scantling draught, including but not limited to: sea chests, rudder trunks, and portions of transom. For as-built thickness greater than 12 mm, partial penetration in accordance with [2.4.1].

f) Crane pedestals and associated bracketing in way of end support, Ch.11 Sec.2 [4.4.2].
g) Rudder horns and shaft brackets to shell structure.
h) Rudder side plating to rudder stock connection areas.
i) Upper connection of main vertical webs in spade rudders.

Figure 5 Deck and bottom penetrations
Full penetration welds may be required for other connections considered critical.

2.4.5 Fillet welds and penetration welds subject to high tensile stresses
In case any penetration welding subject to high tensile stresses is used, the double continuous welding sizes shall not be less than:

\[
t_{p1} + t_{p2} = 2\left(f_{yd} \cdot f_c \cdot f_{ten} \cdot t_w + t_{gap}\right)
\]

\[
f_{ten} = 0.85\left[0.25 + \left(\eta - 0.2\right)\frac{f}{t_w}\right]
\]

where:
- \(t_{p1}, t_{p2}\) = weld connection in mm as defined in Figure 4.
- \(f_{ten}\) = welding factor subject to high tensile stresses.
- \(t_w\) = effective thickness of abutting plate in mm as defined in [2.5.2].
- \(\eta\) = yield usage factor for the connection:
  - \(= \sigma / \sigma_{perm}\)
- \(\sigma\) = calculated maximum tensile stress in abutting plate, in N/mm\(^2\).
- \(\sigma_{perm}\) = permissible stress of abutting plate according to the design load sets, in N/mm\(^2\).
- \(f\) = root face in mm, see Figure 4.

2.5 Weld size criteria

2.5.1 The required weld sizes are to be rounded to the nearest half millimetre.

2.5.2 The leg length, in mm, of continuous, lapped or intermittent fillet welds is not to be taken less than the greater of the following values:

\[
t_{leg} = f_c f_1 f_2 t_w
\]
\[ t_{\text{leg}} = f_y d f_c f_{\text{weld}} f_2 f_3 t_w + t_{\text{gap}} \]

t_{\text{leg}} as given in Table 1.

where:

\[ t_w = \text{effective thickness of abutting plate in mm} \]
\[ t_w = t_{\text{as-built}} \text{ for } t_{\text{as-built}} \leq 25 \text{ mm} \]
\[ t_w = 0.5 (25 + t_{\text{as-built}}) \text{ for } t_{\text{as-built}} > 25 \text{ mm} \]
\[ t_w = 25 + 0.25 (t_{\text{as-built}} - 25) \text{ for longitudinals of flat-bar type with } t_{\text{as-built}} > 25 \text{ mm} \]
\[ f_1 = \text{coefficient depending on welding type:} \]
\[ f_1 = 0.30 \text{ for double continuous welding.} \]
\[ f_1 = 0.38 \text{ for intermittent welding.} \]
\[ f_2 = \text{coefficient depending on the edge preparation: for partial penetration welds with one side bevelling,} \]
\[ f_2 = \text{Min}(f/t_{\text{as-built}} + 0.35 ; 1.0) \]
\[ f_{\text{weld}} = \text{weld factor dependent on the type of the structural member, see Table 1 and Table 2.} \]
\[ f_3 = \text{correction factor for the type of weld:} \]
\[ f_3 = f_0 \text{ for double continuous weld.} \]
\[ f_3 = s_{\text{ctr}}/t_{\text{weld}} \text{ for intermittent or chain welding.} \]
\[ s_{\text{ctr}} = \text{distance between successive fillet welds, in mm, see Figure 6.} \]
\[ f_0 = \text{factor defined in [2.5.7].} \]

2.5.3 The throat size \( t_{\text{throat}} \), in mm, as shown in Figure 6, is not to be less than:

\[ t_{\text{throat}} = \frac{t_{\text{leg}}}{\sqrt{2}} \]

**Figure 6 Weld scantlings definitions**
### Table 1 Minimum leg length

<table>
<thead>
<tr>
<th>Plate thickness (web thickness), (t_w) in mm</th>
<th>Minimum leg length, in mm</th>
<th>Tanks, hold for dry bulk cargo and bilge well</th>
<th>Elsewhere</th>
</tr>
</thead>
<tbody>
<tr>
<td>(t_w \leq 4.0)</td>
<td>4.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>(4.0 &lt; t_w \leq 6.5)</td>
<td>4.5</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>(6.5 &lt; t_w \leq 9.0)</td>
<td>5.0</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>(t_w &gt; 9.0)</td>
<td>5.5</td>
<td>4.5</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 Weld factors, \(f_{\text{weld}}\) for different structural members

<table>
<thead>
<tr>
<th>No</th>
<th>Structural members</th>
<th>70% of span</th>
<th>At ends</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stiffeners in general</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Stiffeners on boundary of watertight compartments and tanks</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stiffeners attached to decks, except in accommodation</td>
<td>0.15</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>Stiffeners in after peak below waterline</td>
<td>0.25</td>
<td>0.4</td>
</tr>
</tbody>
</table>

**Primary supporting structures**

| 4   | PSM's in general\(^1\)                                | 0.2          | 0.3     |
| 5   | PSM's below scantling draught\(^1\)                    | 0.25         | 0.4     |
|     | PSM's of decks, except in accommodation, pontoon decks and hatch covers\(^1\) |             |         |
|     | PSM's in bow impact and stern slamming zone            | 0.25         | 0.4     |
|     | PSM's in after peak tanks                              | 0.25         | 0.4     |

**Non-tight decks/bulkheads**

| 6   | Non-tight bulkheads                                    | 0.3          |         |
|     | Perforated decks                                       |             |         |

**Watertight boundaries**

| 7   | Boundary connection of watertight compartments and tanks in general | 0.4         |         |
| 8   | Boundary connection of liquid cargo tanks               |             |         |
|     | Boundary connection of water ballast tanks              | 0.5         |         |
|     | Boundary connection of weather deck                     |             |         |
|     | Collision bulkhead                                     |             |         |
|     | Cargo hatch coamings or deck coamings at corners of hatchway for 15% of the hatch length for large openings and end bracket to deck plating | 0.5         |         |

**Other structure**
Welding

**2.5.4 Simplified calculation of weld factors for connection between stiffeners and primary support members (PSM) for vessels with length \( L < 90 \text{ m} \)**

The size of fillet is to be calculated according to [2.5.2] based on the weld factors given in Table 3, which may be applied for ships with length less than 90 meters.

**Table 3 Weld factors, \( f_{\text{weld}} \), for connection between stiffeners and PSM’s**

<table>
<thead>
<tr>
<th>Item</th>
<th>Weld factor ( f_{\text{weld}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary supporting member web stiffener connection to intersecting stiffener</td>
<td>At tank boundary 0.4</td>
</tr>
<tr>
<td>Shear connection inclusive lug or collar plate</td>
<td>Without web stiffener on top of the intersecting stiffener 0.3</td>
</tr>
</tbody>
</table>

**2.5.5 Welding size of connection between stiffeners and primary support members (PSM)**

The minimum leg length of welding for the connection between stiffener and primary supporting member is not to be less than \( t_{\text{leg}} \) given in Table 1 and [2.5.2] with weld factors \( f_{\text{weld}} = 0.25 \).

The required welding size at stiffener connection to primary supporting members are not to be less than the values obtained from the following formula:

a) **Shear connection inclusive of lug or collar plate:**

\[
 t_{\text{leg} - s} = \sqrt{2} \cdot f_{\text{yd}} \cdot f_{c} \cdot \frac{1000W_{1}}{2f_{s} \cdot \tau_{\text{perm}} + t_{\text{gap}}}
\]

b) **PSM stiffener to intersecting stiffener:**

\[
 t_{\text{leg} - w} = \sqrt{2} \cdot f_{\text{yd}} \cdot f_{c} \cdot \frac{1000W_{2}}{2d_{\text{wc}} \cdot \sigma_{\text{perm}} + t_{\text{gap}}}
\]

where:

- \( W_{1} \) = the load, in kN, transmitted through the shear connection as defined in Ch.6 Sec.7 [1.2.3].
- \( W_{2} \) = the load, in kN, transmitted through the PSM stiffener as defined in Ch.6 Sec.7 [1.2.4].
- \( \tau_{\text{perm}} \) = permissible shear stress, in N/mm\(^2\), as defined in Ch.6 Sec.7 [1.2.4].
- \( \sigma_{\text{perm}} \) = permissible nominal stress, in N/mm\(^2\), as defined in Ch.6 Sec.7 [1.2.4].
- \( \ell_{s} \) = total length of shear connection, see Ch.6 Sec.7 Figure 2.
- \( \ell_{d} + \ell_{c} \)
\[ d_{wc} = \text{total length of connection between the primary supporting member web stiffener/backing bracket and the stiffener in mm, see Ch.6 Sec.7 Figure 3.} \]
\[ = d_{wc1} + d_{wc2} \]

For the welding in way of the shear connection the size is not to be less than that required for the PSM web plate for the location under consideration.

2.5.6 Welding factor for connection between stiffeners and primary supporting members (PSM) against bow impact and slamming pressure

The size of the fillet welds is to be calculated according to [2.5.2] with respect to bow impact and slamming pressure as given in Ch.10 Sec.1, Ch.10 Sec.2 and Ch.10 Sec.3 with the weld factor given below:

\[ f_{weld} = 0.6 \frac{10W}{A_1 \tau_{eH} + A_w R_{eH}} \]

where:

\[ W = \text{load, in kN, as defined in Ch.10 Sec.1 [3.2.3].} \]
\[ A_1 = \text{effective net shear area, in cm}^2, \text{as defined in Ch.6 Sec.7 [1.2.3].} \]
\[ A_w = \text{effective net cross sectional area, in cm}^2, \text{as defined in Ch.6 Sec.7 [1.2.3].} \]

2.5.7 Where the minimum weld size is determined by the requirements of second formula given in [2.5.2], the weld connections to shell, decks or bulkheads are to take account of the cut out, where stiffeners pass through the member. In cases where the width of the cut-out exceeds 20 % of the stiffener spacing, the size of weld leg length is to be adjusted by a factor equal:

\[ f_0 = \max \left(1.0, \frac{0.8s}{\ell_w}\right) \]

where:

\[ s = \text{stiffener spacing in mm, as shown in Figure 7.} \]
\[ \ell_w = \text{length of web plating between notches, in mm, as shown in Figure 7.} \]

**Figure 7 Effective material in web cut-outs for stiffeners**

2.5.8 End connection of primary supporting members

The weld connection area of bracket to adjoining girders or other structural parts shall be based on the calculated normal and shear stresses. Double continuous welding shall be used.
The section modulus of the weld area at the end connection of simple girders shall satisfy the requirement for section modulus given for the girder in question.

Welding of the end connections, inclusive 10% of shear span, of primary supporting members is to be such that the weld area is to be equivalent to the gross cross sectional area of the member. The weld leg length, in mm, \( \ell \) is to be taken as:

\[
\ell_{\text{weld}} = \eta_{\text{act}} \cdot t_w
\]

where:
- \( h_w \) = web height of primary supporting members, in mm.
- \( t_{gr,\text{req}} \) = required gross thickness of the web in way of the end connection, including 10% of shear span, in mm, taken as:
  \[
  t_{gr,\text{req}} = \eta_{\text{act}} \cdot t_w
  \]
- \( \eta_{\text{act}} \) = highest average usage factor for yield in case of FE analysis, Ch.7, or maximum usage factor with respect to shear area requirement, Ch.6 Sec.6.
- \( \ell_{\text{weld}} \) = length of the welded connection in mm, as shown in Figure 8.
- \( \ell_{\text{dep}} \) = total length of deposit of weld metal, in mm, taken as:
  \[
  \ell_{\text{dep}} = 2 \ell_{\text{weld}}
  \]

The size of weld is not to be less than the value calculated in accordance with \[2.5.2\].

Where high shear stresses occur in web plates at end connection (inclusive 10% of shear span), double continuous fillet welds shall have weld leg length, in mm, not less than:

\[
\ell_{\text{weld}} = \frac{\sqrt{2} \cdot t_w \cdot \tau}{2 C_t \tau_{eH,weld}}
\]

\( \tau \) = calculated average shear stress in web plate in way of the weld, in N/mm²
\( C_t \) = permissible shear stress coefficient for the design load set being considered, as given in Ch.6 Sec.6 Table 2.
2.5.9 Longitudinal continuity provided by brackets
Where a longitudinal strength member is cut at a primary supporting structure and the continuity of strength is provided by brackets, $t_{\text{leg}}$ is not to be less than the requirement given in [2.4.5], [2.5.2] and [2.5.10]

2.5.10 Reduced weld size
Where an approved automatic deep penetration procedure is used and quality control facilitates are working to a gap between members of 1 mm and less, the weld factors given in Table 3 may be reduced by 15% but not more than fillet weld leg size of 1.5 mm. Reductions of up to 20%, but not more than the fillet weld leg size of 1.5 mm, will be accepted provided that the Shipyard is able to consistently meet the following requirements:

a) The welding is performed to a suitable process selection confirmed by welding procedure tests covering both minimum and maximum root gaps.

b) The penetration at the root is at least the same amount as the reduction into the members being attached.

2.5.11 Reduced weld size documentation
Where any of the methods for reduction of the weld size are used, the specific conditions for the reduction are to be specified on the drawings. The drawings are to document the weld design and dimensioning requirements for the reduced weld length and the required weld leg length given by [2.5.2] without the leg length reduction. The drawings shall also describe the difference in the two leg lengths and their application.
3 Butt joint

3.1 General

3.1.1 Joints in the plate components of stiffened panel structures are generally to be joined by butt welds, see Figure 9.

Figure 9 Typical butt welds

3.1.2 Butt welding from one side against permanent backing or without backing will only be permitted after special consideration, and for locations where the stress level is considered low. Such welding shall not be used inside tanks.

3.2 Thickness difference

3.2.1 Taper
In the case of welding of plates with difference in as-built thickness equal to or greater than 4 mm, the thicker plate is normally to be tapered. The taper has to have a length of not less than 3 times the difference in as-built thickness. If the width of groove is greater than 3 times the difference in as-built thickness the transition taper may be omitted.

4 Other types of joints

4.1 Lapped joints

4.1.1 Areas
Lap joint welds may be adopted in very specific cases, such as for the following connections:
— Peripheral connections of doublers.
— Internal structural elements subject to very low stresses.

4.1.2 Lap joint welds, see Figure 10, may be used for connections dominated by shear- or in plane stresses acting parallel to the weld. Such a overlap will normally not be accepted for connection of main hull structures contributing to hull girder longitudinal strength and connection of primary supporting structures, with high in-plane stresses transverse to the weld.

4.1.3 Overlap width
Where overlaps are adopted, the width of the overlap is not to be less than 50mm, but does not need to be greater than 100mm, in general, see Figure 10. Otherwise, the overlap width is specially considered on case-by-case basis.

![Figure 10 Fillet weld in lapped joint](image)

4.1.4 Overlaps for lugs
The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the thickness of the lug but need not to be greater than 50 mm.

4.1.5 Lapped end connections
Lapped end connections are to have continuous welds on each edge with leg length, \( t_{\text{leg}} \) in mm, as shown in Figure 10 such that the sum of the two leg lengths is not to be less than 1.5 times the as-built average thickness of both plates.

4.1.6 Overlapped seams
Overlapped seams are to have continuous welds on both edges, of the sizes required by [2.5.2] for the boundaries of tank/hold or watertight bulkheads. Seams for plates with as-built thickness of 12.5 mm or less, which are clear of tanks/holds, may have one edge with intermittent welds in accordance with [2.5.2] for watertight bulkhead boundaries.

4.2 Slot welds

4.2.1 Slot welds may be adopted in very specific cases. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0.6 \( L \) amidships.

4.2.2 Slot weld may be used for connection of plating to internal webs, where access for welding is not practicable.
Continuous slot weld as shown in Figure 11 shall not be used in case of pressure from abutting plate side or in tank boundaries.

![Figure 11 Continuous slot weld](image)
4.2.3 Slot weld is not acceptable in areas with high in-plane stresses transversely to the slots.

4.2.4 Slots are to be well-rounded and have a minimum slot length, $\ell_{\text{slot}}$ of 75 mm and width, $w_{\text{slot}}$ of twice the as-built plate thickness. Where used for doublers, such welds are in general to be spaced a distance, $s_{\text{slot}}$ of 2 $\ell_{\text{slot}}$ to 3 $\ell_{\text{slot}}$ but not greater than 250 mm, see Figure 12. The size of the fillet welds is to be determined from second formula given in [2.5.2] using $t_{\text{as-built}}$ and a weld factor $f_{\text{weld}}= 0.40$.

5 Connection details

5.1 Bilge keels

5.1.1 The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a continuous fillet weld in accordance with Table 4. The leg length shall not be less than the minimum leg length as given in Table 1 and the first formula given in [2.5.2].
Table 4 Connections of bilge keels

<table>
<thead>
<tr>
<th>Structural items being joined</th>
<th>Leg length of weld, in mm</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At ends</td>
<td>Elsewhere</td>
</tr>
<tr>
<td>Ground bar to the shell</td>
<td>0.60 $t_{1\text{as_built}}$</td>
<td>0.45 $t_{1\text{as_built}}$</td>
</tr>
<tr>
<td>Bilge keel web to ground bar</td>
<td>0.50 $t_{2\text{as_built}}$</td>
<td>0.30 $t_{2\text{as_built}}$</td>
</tr>
</tbody>
</table>

$t_{1\text{as\_built}}$ = as-built thickness of ground bar, in mm.  
$t_{2\text{as\_built}}$ = as-built thickness of web of bilge keel, in mm.

5.1.2 Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating is not permitted. This may be obtained by use of removable backing.

5.1.3 At the ends of the ground bar, the leg length thickness is to be increased as given in Table 4, without exceeding the as-built thickness of the ground bar. The welded transition at the ends of the ground bar to the plating connection shall be formed with the weld flank angle of 45 deg or less.

5.1.4 In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width of the butt weld and not less than 25 mm. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

5.2 End connections of pillars and cross-ties

5.2.1 Pillars and cross-ties exposed to tensile stress

When pillars and cross-ties are exposed to tensile stress, an effective fillet weld area in cm², i.e. weld throat multiplied by weld length, shall not be less than:

$$A_{\text{weld}} = \frac{0.14}{C_p} \left( \frac{235}{R_{cH_{\text{weld}}}} \right)^{0.75} F$$

where:

$F$ = maximum tensile design force in kN, to be taken as the maximum of the design tensile force corresponding to AC-I and 80% of the design tensile force corresponding to AC-II and AC-III.

$C_p$ = Coefficient for design tensile force  
= 1.0 for AC-I  
= 1.25 for AC-II and AC-III

6 Welding of rudders, rudder horns and rudder trunks

6.1 General

6.1.1 Welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) shall be made as full penetration welds. In way of highly stressed areas e.g. cut-out in semi-spade rudder and upper part of spade rudder, cast or welded ribs shall be arranged. Two sided full penetration welding shall normally be arranged. Where back welding is impossible welding shall be performed against ceramic backing
Welding

bar or equivalent. Steel backing bars may be used and shall be continuously welded on one side to the heavy piece.

6.1.2 In spade rudders, the weld connection of the main vertical webs to the rudder top plate shall be of full penetration type.

6.1.3 The weld at the connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding.

6.1.4 Vertical webs and horizontal webs in effective area of rudder as defined in Ch.14 Sec.1 [6.3.2], shall be connected to the side plates with continuous fillet weld in accordance with [2.5.2]. Weld factor $f_{\text{weld}}$ to be used is 0.40.

6.1.5 Slot welding shall be limited as far as possible. Slot welding is not acceptable in areas with high in plane stresses transversely to the slots or in way of cut-out areas of semi-spade rudders. Continuous butt welding with backing might be accepted in lieu of slot welds. When continuous butt welding is applied, the root gap is to be between 6-10 mm. The bevel angle is to be at least 15°, see Figure 11. When slot welding is applied, minimum length of slots is 75 mm and minimum breadth is $2 \cdot t_{\text{as-built}}$, where $t_{\text{as-built}}$ is the as built rudder plate thickness in mm. The distance between the slots is not to be greater than 125 mm. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots as shown in Figure 12 shall not be filled with weld.

6.1.6 In way of the rudder horn recess of semi-spade rudders the radii in the rudder plating are not to be less than 5 times the plate thickness, but in no case less than 100 mm. Welding in side plate is to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.

6.1.7 Plate edges at openings in rudder side plating shall be ground smooth. Cover plates shall be arranged with rounded corners and are not to be welded directly to cast parts.

6.1.8 The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is normally to be full penetration. Partial penetration welds against ceramic backing will be accepted, see Figure 13.

The fillet shoulder radius, in mm (see Figure 13) is to be as large as practicable and to comply with the following formulae:

$$r = 60 \quad \text{when } \sigma \geq 40 / k \ [\text{N/mm}^2]$$

$$r = 0.1d_c, \text{ without being less than } 30 \quad \text{when } \sigma < 40 / k \ [\text{N/mm}^2]$$

where:

$d_c = \text{rudder stock diameter axis defined in Ch.14 Sec.1 [4.1.2]}$

$\sigma = \text{bending stress in the rudder trunk in N/mm}^2$

$k = \text{material factor as given in Ch.14 Sec.1 [1.6.2] or Ch.14 Sec.1 [1.6.6] respectively.}$

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

Rudder trunks comprising of materials other than steel are to be specially considered by the Society.
6.1.9 The welded joint when the rudder stock is connected to the rudder by horizontal flange coupling is to be made in accordance with Figure 14 or equivalent.

Figure 13 Fillet shoulder radius

Figure 14 Welded joint between rudder stock and coupling flange
7 Welding of propeller nozzles

7.1 General

7.1.1 The inner shell plate shall be welded to the ring webs with double continuous fillet welding.

7.1.2 The outer shell plate is as far as possible to be welded continuously to the ring webs. Slot welding may be accepted on the following conditions:
If the web spacing $s \leq 350$ mm all welds to outer plating may be slot welds. If the web spacing $s > 350$ mm at least two ring webs shall be welded continuously to the outer shell. A continuous weld as shown in Figure 11 may be accepted.

8 Welding of sheer strake

8.1 General

8.1.1 Welding
The sheer strake may be either welded to the stringer plate or rounded.
Longitudinal weld seams of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the as-built thicknesses of the sheer strake.
The upper edge of the welded sheer strake is to be rounded smooth and free of notches.
Welded sheer strake is to be connected to strength deck by partial or full penetration welds according to [2.4]. For plate thickness less than 25 mm, fillet welds are permitted.

Deck fittings
8.1.2 Fixtures such as bulwarks and eye plates are not to be directly welded on the upper edge of sheer strake, except within $0.1L$ from A.E. and F.E., for ship with length $L \geq 90$m. Drainage openings with a smooth transition in the longitudinal direction may be permitted.
The design of the fittings shall be such as to minimise stress concentrations, with a smooth transition towards deck level.
For vessels with low/moderate hull girder stress, such details will be considered on a case-by-case basis.

8.1.3 Rounded sheer strake
Welding of deck fittings to rounded sheer strakes shall be kept to a minimum within $0.6L$ amidships. Subject to special consideration, such welding may be carried out provided:
— when cold formed, the material is of grade D or higher
— the material is hot formed in accordance with Ch.3 Sec.5 [2.5].

9 Welding of outfitting details to hull

9.1 General

9.1.1 Generally connections of outfitting details to the hull shall be such that stress concentrations are minimised and welding to highly stressed parts is avoided as far as possible.
Connections shall be designed with smooth transitions and proper alignment with the hull structure elements. Terminations shall be supported.
9.1.2 Equipment details as clips for piping, support of ladders, valves, anodes etc. shall be kept clear of the toe of brackets, edge of openings and other areas with high stresses. Connections to top flange of girders and stiffeners shall be avoided if not well smoothened. Preferably supporting of out fittings shall be welded to the stiffener web.

9.1.3 All materials welded to the hull shell structure shall be of ship quality steel, or equivalent, preferably with the same strength group as the hull structure the item is welded to.

9.1.4 Gutterway bars on strength deck shall be arranged with expansion joints unless the slenderness requirements given in Ch.8 Sec.2 [2] are fulfilled.

9.1.5 Welds to the deck plating within the hatch corner region are to be avoided as far as possible.

9.1.6 Requirements for welding of outfitting details for container ships are given in Pt.5 Ch.2 Sec.10 [3.2.4].

10 Welding of aluminium alloys

10.1 General

10.1.1 The welding of aluminium alloys are to be in accordance with rules for High Speed, Light Craft and Naval Surface Craft, HSLC Pt.3 Ch.3.
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