SECTION 12
WELDING AND WELD CONNECTIONS

Contents

A. General

A 100 Introduction

101 In this section requirements related to welding and various connection details are given.

A 200 Definitions

201 Symbols:

t_k = corrosion addition in mm as specified in Sec.2 D400.

A 300 Welding particulars

301 Welding of important hull parts is to be carried out by approved welders only.

302 Welding at ambient air temperature of —5°C or below, is only to take place after special agreement.

303 The welding sequence is to be such that the parts may as far as possible contract freely in order to avoid cracks in already deposited runs of weld. Where a butt meets a seam, the welding of the seam should be interrupted well clear of the junction and not be continued until the butt is completed. Welding of butt should continue past the open seam and the weld be chipped out for the seam to be welded straight through.

304 Welding procedures and welding consumables approved for the type of connection and parent material in question, are to be used. See «Register of Type Approved Products No.2, Welding Consumables».

A 400 Radiographic examination

401 The welds are normally to comply with the requirement to mark 3 (green) of the IIW's Collection of Reference Radiographs of Welds.

402 The welds are to be examined by X-ray or by other approved method in positions indicated by the surveyor.
At least all weld crossings in the bottom and deck plating within 0,4 L amidships are to be examined.

B. Types of Welded Joints

B 100 Butt joints

101 For panels with plates of equal thickness, the joints are normally to be butt welded with edges prepared as indicated in Fig.1.

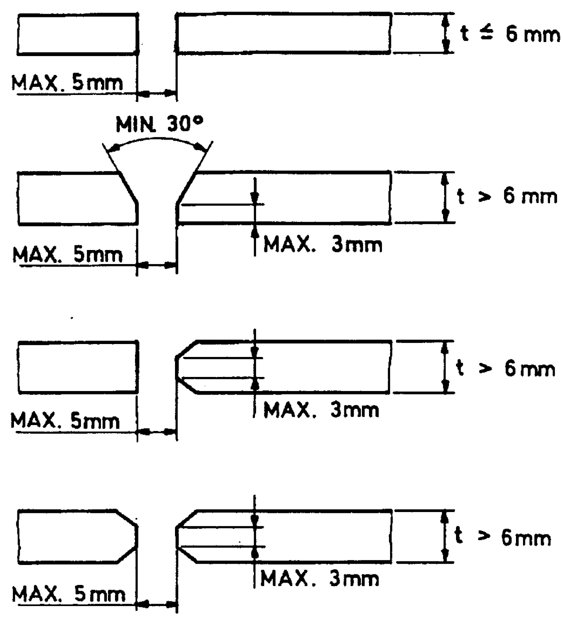

Fig. 1
Manually welded butt joint edges

102 For butt welded joints of plates with thickness difference exceeding 4 mm, the thicker plate is normally to be tapered. The taper is generally not to exceed 1 : 3. After tapering, the end preparation may be as indicated in 101 for plates of equal thickness.

103 All types of butt joints are normally to be welded from both sides. Before welding is carried out from the second side, unsound weld metal is to be removed at the root by a suitable method.

104 Butt welding from one side only will be permitted after special consideration where a backing run is not practicable or in certain structures when the stress level is low.

B 200 Lap joints and slot welds

201 Various types of overlapped joints are indicated in Fig.2.
Type «a» (lap joint) is frequently used in end connection of stiffeners. Unless the stresses are moderate, such overlaps will normally not be accepted for connection of plates to panels. Type «b» (slot weld) may be used for connection of plating to internal webs, where access for welding is not practicable.
For size of slot welds, see C600.

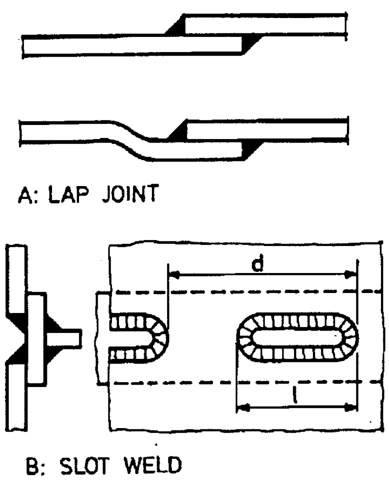

Fig. 2
Lap joints and slot welds

B 300 Tee or cross joints

301 The connection of girder and stiffener webs to plate panel as well as plating abutting on another plate panel, is normally to be made by fillet welds as indicated in Fig.3.

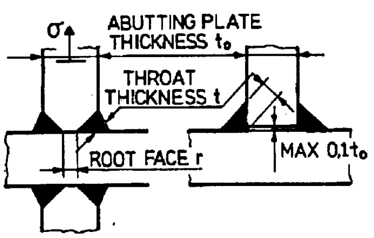

Fig. 3
Tee or cross joints

Where the connection is highly stressed or otherwise considered critical, the edge of the abutting plate may have to be bevelled to give deep or full penetration welding, see also C203. Where the connection is moderately stressed, intermittent welds may be used. With reference to Fig.4, the various types of intermittent welds are as follows:

- chain weld
- staggered weld
- scallop weld (closed).

For size of welds, see C500.

302 Double continuous welds are required in the following connections irrespective of the stress level:

- weathertight, watertight and oiltight connections
- connections in foundations and supporting structures for machinery
- all connections in after peak
- connections in rudders, except where access difficulties necessitate slot welds
- connections at supports and ends of stiffeners, pillars, cross ties and girders
- centre line girder to keel plate.

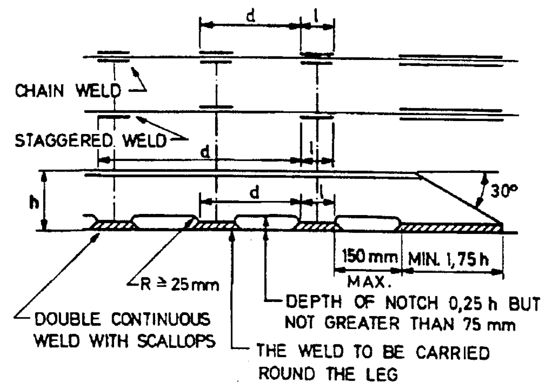

Fig. 4
Intermittent welds

303 Where intermittent welds are accepted, scallop welds are to be used in tanks for water ballast, cargo oil or fresh water. Chain and staggered welds may be used in dry spaces and tanks arranged for fuel oil only.

C. Size of Weld Connections

C 100 Continuous fillet welds, general

101 Unless otherwise stated, it is assumed that the welding consumables used will give weld deposit with yield strength σ_{fw} as follows:

σ_{fw} = 355 N/mm² for welding of normal strength steel
= 375 N/mm² for welding of the high strength steels NV-27, NV-32 and NV-36
= 390 N/mm² for welding of high strength steel NV-40.

If welding consumables with deposits of lower yield strength than specified above are used, the σ_{fw}-value is to 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.3.
For welding of the high strength steels NV-32, NV-36 and NV-40, welding consumables with deposits of higher yield strength than specified above may be used. The weld dimensions for these steels are, however, in no case to be based on σ_{fw}-values higher than 1,5 times the yield strength of the material to be welded.

102 When deep penetrating welding processes are applied, the required throat thicknesses may be reduced by 15% provided sufficient weld penetration is demonstrated.

103 The throat thickness of double continuous fillet welds is not to be less than:

$$t = \frac{C\sqrt{f_{pm}}\; t_0}{f_w} + 0{,}5t_k \quad \text{(mm)}$$

C = weld factor given in Table C1
t_0 = net thickness in mm of abutting plate, corrosion addition not included.
For net plate thicknesses (t_n) above 22 mm, t_0 may be substituted by 0,5 (22 + t_n)
f_{pm} = material factor f_1 as defined in Sec.2 B100 for plates to be joined
f_w = material factor for weld deposit

$$= \left(\frac{\sigma_{fw}}{235}\right)^{0,75}$$

σ_{fw} = yield strength in N/mm² of weld deposit

When welding consumables with deposits as assumed in 101 are used, f_w may be taken as follows dependent on parent material:

f_w = 1,36 for NV-NS
= 1,42 for NV-27, NV-32 and NV-36
= 1,46 for NV-40.

Table C1 Weld factor C

Item	*60% of span*	*At ends*
Local buckling stiffeners	0,14	0,14
Stiffeners, frames, beams or longitudinals to shell, deck, o.t. or w.t. girders or bulkhead plating, except in after peaks	0,16	0,26
Web plates of non-watertight girders except in after peaks	0,20	0,32
Girder webs and floors in double bottom Stiffeners and girders in after peaks	0,26	0,43
Watertight centre line girder to bottom and inner bottom plating Boundary connection of ballast and liquid cargo bulkhead: — longitudinal bulkheads — transverse bulkheads Hatch coamings at corners and transverse hatch end brackets to deck. Top horizontal profile to coaming Strength deck plating to shell Scuppers and discharges to deck	0,52	
Fillet welds subject to compressive stresses only	0,25	
All other welds not specified above or in 200 to 400	0,43	

104 The throat thickness of fillet welds is in no case to be taken less than given in the following table:

Plate thickness (web thickness) t_0 (mm)	*Minimum throat thickness (mm)* 1)
$t_0 \leq 4$	2,0
$4 < t_0 \leq 6,5$	2,5
$6,5 < t_0 \leq 8$	3,0
$t_0 > 8$	0,21 t_0, minimum 3,5 2)

1) Corrosion addition 0,5 t_k to be added where relevant, see Sec.2 D.
2) 0,18 t_0, minimum 3,0 when automatic deep penetration welding is applied.

C 200 Fillet welds and penetration welds subject to high tensile stresses

201 In structural parts where high tensile stresses act through an intermediate plate (see Fig.3) increased fillet welds or penetration welds are to be used. Examples of such structures are:

— transverse bulkhead connection to the double bottom
— vertical corrugated bulkhead connection to the top of stooltank or directly to the inner bottom
— stooltanks to inner bottom and hopper tank
— structural elements in double bottoms below bulkhead and stooltanks
— transverse girders in centre tanks to longitudinal bulkheads.

202 The throat thickness of double continuous welds is not to be less than:

$$t = C_1\, t_o + 0,5\, t_k \quad \text{(mm)}$$

$$C_1 = \frac{1,36}{f_w}\left[0,2 + \left(\frac{\sigma}{270} - 0,25\right)\frac{r}{t_0}\right]$$

σ = calculated maximum tensile stress in abutting plate in N/mm²
r = root face in mm
t_o = net thickness in mm of abutting plate, corrosion addition not included
f_w = as given in 103.

Typical design values for C_1 are given below:

Plate material	*σ*	C_1 *Fillet weld: $r=t_o$*	*Root face: $r=t_o/3$*	*Full penetration: r=0*
NS	160	0,54	0,31	0,20
NV-32	205	0,68	0,35	0,19
NV-36	222	0,74	0,37	0,18

203 Full penetration welds are in any case to be used in the following connections:

— rudder horns and shaft brackets to shell structure
— rudder side plating to rudder stock connection areas
— end brackets of hatch side coamings to deck and coaming
— edge reinforcements or pipe penetrations to strength deck (including sheer strake) and bottom plating within 0,6 L amidships, when transverse dimension of opening exceeds 300 mm, see Fig.5.

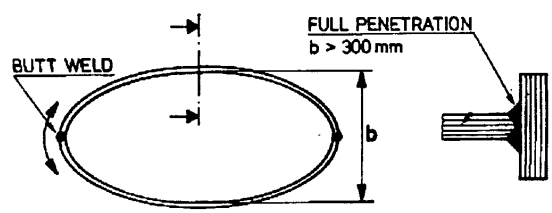

Fig. 5
Deck and bottom penetrations

C 300 End connections of girders, pillars and cross ties

301 The weld connection area of bracket to adjoining girders or other structural parts is to be based on the calculated normal and shear stresses. Double continuous welding is to be used. Where large tensile stresses are expected, welding according to 200 is to be applied.

302 The end connections of simple girders are to satisfy the requirements for section modulus given for the girder in question.
Where high shear stresses in web plates, double continuous boundary fillet welds are to have throat thickness not less than:

$$t = \frac{\tau\, t_0}{200\, f_w} + 0,5\, t_k \quad \text{(mm)}$$

τ = calculated shear stress in N/mm²
t_o = net thickness of abutting plate, corrosion addition not included

f_w = as given in 103.

303 End connection of pillars and cross ties are to have a weld area not less than:

$$a = \frac{k A p}{f_w} + a_k \quad (cm^2)$$

A = load area in m^2 for pillar or cross tie
p = design pressure in kN/m^2 as given for the structure in question
a_k = corrosion addition corresponding to t_k
f_w = as given in 103
k = 0,05 when pillar in compression only
= 0,14 when pillar in tension.

C 400 End connections of stiffeners

401 Stiffeners may be connected to the web plate of girders in the following ways:

- welded directly to the web plate on one or both sides of the frame
- connected by single- or double-sided lugs
- with stiffener or bracket welded on top of frame
- a combination of the above.

In locations with great shear stresses in the web plate, a double-sided connection or a stiffening of the unconnected web plate edge is normally required. A double-sided connection may be taken into account when calculating the effective web area.

402 The connection area at supports of stiffeners is normally not to be less than:

$$a_0 = c\, k\, (l - 0,5\, s)\, s\, p \quad (cm^2)$$

c = factor as given in Table C2
k = $r_1 r_2$
r_1 = 0,125 when pressure acting on stiffener side
= 0,1 when pressure acting on opposite side
r_2 = $1,0/f_{pm}$ for stiffeners with mainly loading from one side (pressure ratio less than 0,3 or greater than 3,3)
= 1,0 for stiffeners with loading from two sides
f_{pm} = material factor f_1 as defined is Sec.2 B100 for plate
l = span of stiffener in m
s = spacing between stiffeners in m
p = design pressure in kN/m^2.

Corrosion addition as specified in Sec.2 D400 is not included in the formulae for a_0, and is to be added where relevant.
Weld area is not to be less than:

$$a = \frac{1,15\, a_0 \sqrt{f_{pm}}}{f_w} + a_k \quad (cm^2)$$

a_k = corrosion addition corresponding to t_k
f_w = as given in 103.

Table C2 Values of c

Type of connection (see figure)	*Stiffener/bracket on top of stiffener*		
	None	*Single-sided*	*Double-sided*
a	1,00	1,25	1,00
b	0,90	1,15	0,90
c	0,80	1,00	0,80

403 Various standard types of connections are shown in Fig.6.
Other types of connection will be considered in each case.

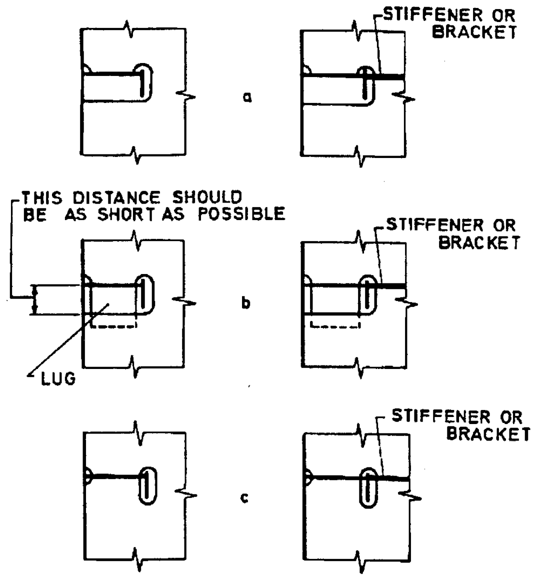

Fig. 6
End connections

Guidance note:

In ballast and cargo tanks the connection types b or c should be used for longitudinals on ship sides, unless double-sided brackets are arranged, see also Sec.7 E500.

---e-n-d---o-f---G-u-i-d-a-n-c-e---n-o-t-e---

404 Connection lugs are to have a thickness not less than 75% of the web plate thickness.

405 Lower ends of peak frames are to be connected to the floors by a weld area not less than:

$$a = 0,105\, l\, s\, p + a_k \quad (cm^2)$$

l, s, p and a_k = as given in 402.

406 For stiffeners which may be sniped at the ends according to the requirements given in Sec.3 C202, the required connection area is satisfied by the plating.

407 Bracketed end connections as mentioned below, are to have a weld area not less than:

$$a = \frac{k Z}{h} + a_k \quad (cm^2)$$

Z = net section modulus of stiffener in cm^3, corrosion addition not included
h = stiffener height in mm
k = 24 for connections between supporting plates in double bottoms and transverse bottom frames or reversed frames
= 25 for connections between the lower end of main frames and brackets (minimum weld area = 10 cm^2)
= 15 for brackets fitted at lower end of 'tween deck frames, and for brackets on stiffeners
= 10 for brackets on 'tween deck frames carried through the deck and overlapping the underlying bracket
a_k = corrosion addition corresponding to t_k.

408 Brackets between transverse deck beams and frames or bulkhead stiffeners are to have a weld area not less than:

$$a = 0,41 \sqrt{Z\, t_b} + a_k \quad (cm^2)$$

t_b = net thickness in mm of bracket
Z = as defined in 407
a_k = as defined in 407.

409 The weld area of brackets to longitudinals is not to be less than the sectional area of the longitudinal. Brackets are to be connected to bulkhead by a double continuous weld.

C 500 Intermittent welds

501 The throat thickness of intermittent fillet welds is not to be less than:

$$t = \frac{C \sqrt{f_{pm}}\; t_0}{f_w} \; \frac{d}{l} + 0,5\, t_k \quad (mm)$$

C, t_0, f_{pm} and f_w are as given in 103. C-values given for 60% of span may be applied.

d = distance, in mm, between successive welds, see Fig.4
l = length, in mm, of weld fillet, not to be less than 75 mm.

502 In addition to the minimum requirements in 501, the following apply:

— for chain intermittent welds and scallop welds the throat thickness is not to exceed 0,6 t_0
— for staggered intermittent welds the throat thickness is not to exceed 0,75 t_0.

C 600 Slot welds

601 Slots are to have a minimum length of 75 mm and, normally, a width of twice the plate thickness. The ends are to be well rounded, see Fig.2. The distance d between slots is not to exceed 3l, maximum 250 mm.

602 Fillets welds in slots are to have a throat thickness as given by the formula in 501 with:

t_0 = net thickness of adjoining web plate
d = distance between slots, see Fig.2
l = length of slots.

603 Slots through plating subject to large in-plane tensile stresses across the slots may be required to be completely filled by weld. More narrow slots with inclined sides (minimum 15° to the vertical) and a minimum opening of 6 mm at bottom should then be used. A continuous slot weld may, however, in such cases be more practical.