Annex D

Excerpt from the Rules for Welding

A. General Rules

1. General

This Annex by way of excerpts contains the most important requirements and data to ensure a high quality of welding work on metallic materials from the Rules for Classification and Construction, II – Materials and Welding, Part 3 – Welding, called "Rules for Welding" hereinafter - of GL. As far as necessary, the Rules were adapted to the special requirements of yacht construction. If requirements, other than those stated, have to be fulfilled, the GL Rules mentioned above shall be applied as appropriate.

2. Scope

These Rules apply to all welding work on the structure of the hull and on parts of the equipment, including masts and booms/spars with their associated fittings, plus on parts of the machinery, insofar as these components are covered by the abovementioned rules for construction and dimensioning (e.g. tanks, pipelines, etc.). GL may stipulate the application of these Rules also beyond that to other components, or logically to other joining procedures such as for example soldering/brazing.

3. Other rules and standards applicable at the same time

The rules, standards or other technical regulations quoted hereinafter count as part of these Rules. The application of further standards, etc., requires GL approval. Where there are differences in the requirements of standards etc. and rules, those in the GL Rules take precedence.

4. Data in the design documentation

4.1 The drawings and documentation to be submitted for approval in accordance with Form F 146 shall contain data concerning the materials, configuration of seams and dimensions plus any post treatment of the seams (e.g. grinding out notches) that might be needed. If non destructive testing of the weld seam is envisaged or required (see D.6.3), type and scope of the tests is to be indicated, plus some specific quality of seam (e.g. to DIN 8563, Part 3 or DIN-EN 25817) required on strength reasons, if relevant.

4.2 Symbols or letter symbols identifying materials or welded connections are to be explained if the definitions or symbols used are other than those in the standards. Insofar as seam preparation (in conjunction with approved welding procedures) complies with standard shipbuilding practice and these Rules or accepted standards, special depiction is not required.

4.3 In special cases (e.g. use of special materials) additionally data are to be provided about the envisaged welding procedure, the fillers and auxiliary materials, if applicable preheating and heat control during welding, seam preparation, build up of the seam and the root preparation, plus any other details affecting the quality of the welded joint.

5. Quality control, responsibility of the company

5.1 The company shall ensure by their own regular quality control during the course of fabrication, and on completion, that all welding work is carried out in accordance with these Rules and the approved design documentation as well as any instructions given in the course of approval and in accordance with sound engineering practice and shipbuilding. The responsibility for effecting the above mentioned quality control rests with the company.

5.2 When issuing subcontracts to suppliers, the company issuing the contract shall assure that the supplier undertakes to comply with these Rules (see also under B.1.1). The issuing is to be reported to GL; the suppliers are to be named to GL. Depending on the components to be supplied by the subcontractor, i.e. their significance (for safety) and stressing, GL may require certain tests and corresponding verification.

5.3 The checks carried out by the GL surveyor do not relieve the company of the responsibilities set out in 5.1 and 5.2. GL does not guarantee that the components or welded joints tested generally on a random sampling basis have been fabricated entirely in accordance with the requirements and in all parts meet the specification. Components or welded joints which subsequently turn out to be defective may be rejected, or their dressing required, in spite of preceding tests.

B. Manufacturing Prerequisites, Proof of Qualification

1. Approval of welding works

1.1 Shipyards and manufacturers, including branches and suppliers, intending to carry out welding work within the scope of these Rules must have GL approval for this in accordance with the Rules for Welding. Approval from GL is to be applied for, with the necessary data and documentation (description of works, proof of qualification for welders and welding supervisors), by the yards and manufacturer in good time before welding work is executed.

1.2 The company shall have at their disposal suitable equipment and facilities for the faultless execution of the welding work. Installations outside the works (e.g. testing installations) may be taken into account. The suitability of the company's installations will be checked as part of a manufacturing premises' inspection. GL may state requirements in this connection or restrict the scope of the approval in line with the manufacturer's facilities.

2. Welders, welding supervision

2.1 Work with manually controlled welding equipment, where the quality of the welded joint depends overwhelmingly on the manual skill of the welder, may only be carried out by tested GL-approved welders with valid test certificates. The welding tests are to be carried out in accordance with the GL Rules for Welding or accepted standards (e.g. DIN-EN 287 Part 1 "Steel" or Part 2 "Aluminium"). The operating personnel for fully mechanised or automatic welding procedures is tested on the equipment.

2.2 The work is to be monitored responsibly by a welding supervisor belonging to the company. Regarding the requirements stated for welding supervisors and their duties, see also GL Rules for Welding. The welding supervisor shall be named to GL; GL is to be provided with proof of his/her professional qualification. Changes in welding supervision are to be reported to GL without being asked for.

3. Welding procedures, procedure tests

3.1 The only welding procedures which may be used are those whose suitability for the field of application in question (base materials, plate/component thickness, welding position, etc.) is either established by general experience or has been proved in a procedure test in accordance with the GL Rules for Welding. The procedures shall have been approved by GL for the manufacturer in question.

3.2 As a rule procedure tests are required for:

- materials other than the normal strength Grade A to D ship steel in accordance with GL Rules for Materials or as comparable structural steels in accordance with the standards
- welding procedures other than manual arc welding with rod electrodes and partially mechanised shielded arc welding
- vertical down welding
- single fillet welding on ceramic or other weld pool support

Before starting work for the conventional submerged arc welding of normal strength A to D ship steel, it is sufficient to proof for reliable operation by test welds and non destructive tests (e.g. radiographic inspections) as required by the surveyor.

C. Design and Dimensioning of the Welded Joints

1. Materials and suitability for welding

1.1 Only base materials whose suitability for welding is established may be used for welded structures. The materials shall meet the conditions of Annex C of these Rules and shall be authorised by the test certificates stipulated in Annex C and F. Other materials comparable to ship steels according to recognised standards (e.g. general structural steels Fe 360B or C (St 37-2 or -3U) or Fe 510C (St 52-3U) in accordance with EN 10025, regarding this see also Annex C, Table C.1) require GL approval in each individual case. This applies logically to stainless steels, aluminium alloys and other non-ferrous metals.

Note:

For the ship steels described in the GL Rules for Materials and comparable general structural steels, plus for rolled products for welded structures of the boiler, storage tank, pipeline and machinery construction industry, suitability for welding is assumed proven. The suitability for welding of stainless steels, aluminium alloys and other non-ferrous metals (e.g. Cu-Ni alloys) habitually used in shipbuilding is also generally accepted. The notes and recommendations of the manufacturers of materials, fillers and supplementary materials are to be observed.

1.2 Materials shall be so chosen that materials and welded joints are able to stand up to the demands (stresses from loads, operating temperatures, corrosion, etc.) they are subject to. The materials are to be identified completely and clearly in the design documentation (drawings, etc.). Insofar as materials and/or welded joints require special treatment (e.g. preheating for welding or surface treatment to achieve ade-

quate corrosion resistance) during or after processing, this shall be stated, too.

2. General design principles

2.1 Welded joints shall be planned from the beginning of the design process to be accessible and to be made in as favourable a position and sequence as possible. It shall be assured that the proposed type of seam (e.g. full penetration butt seam) can be faultlessly made and if necessary non destructively tested under the fabrication conditions prevailing.

2.2 Welded joints in load carrying components shall be configured to achieve as undisturbed a flow of forces as possible, without major internal or external notches or sudden changes in rigidity, and without impeding expansion. In zones of high stress concentration necessitated by design - especially if those stresses are dynamic - welded joints shall be avoided if possible or configured to allow for a substantially undisturbed flow of forces without any significant additional notch effect originating from the weld. Thicker components and larger cross sections shall be matched to thinner/smaller ones by gradual transitions (e.g. with a ratio of 1 : 3)

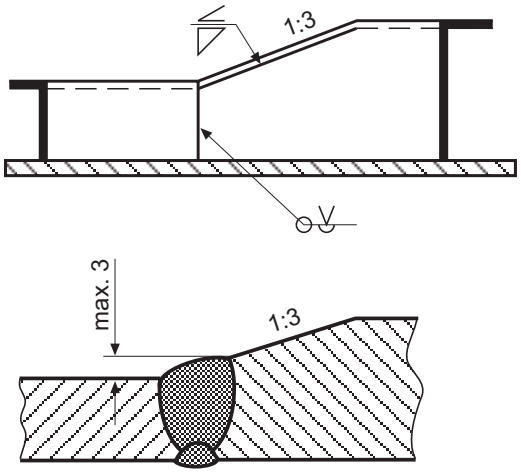

Fig. D.1 Transitions between differing plate thicknesses or section heights

2.3 For locally increased stresses in plating, thicker plates are to be provided if possible (rather than doubling plates). If doubling plates cannot be avoided, they are not to be more than twice as thick as the component to which they are to be welded. Bearing bushes, hubs, reinforcements for holes in eye plates, etc., are on principle to take the form of thicker plates or lengths of round material welded in or on.

2.4 Local accumulation of welds and welded joints spaced too close together shall be avoided. Adjoining butt seams shall be at least 50 mm + 4 t (t = plate thickness) apart; butt seams and fillet welds and fillet welds from one another, at least 30 mm + 3 t.

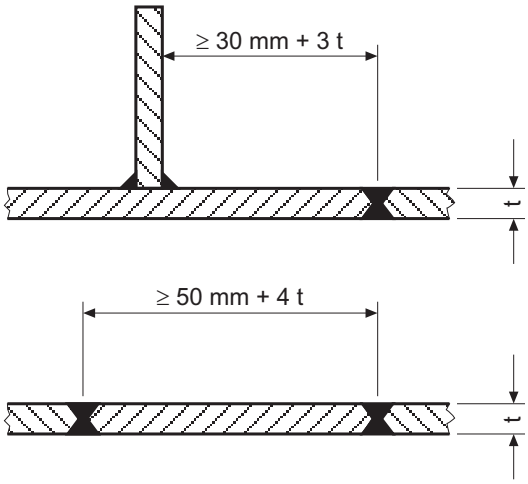

Fig. D.2 Minimum distances between butt seams and fillet seams

The width of strips of plate to be inserted or exchanged shall however be at least 10 t or 150 mm, whichever is the larger.

2.5 Through-welding holes for the (subsequent) welding of butt or fillet seams following the addition of crossing components (e.g. of stiffeners on sheet panels) are to be rounded, the minimum radius being 25 mm. Where welding of seams is completed before crossing components are added, through-welding holes are not needed. Any seam protrusions shall be removed or the component to be added shall be notched.

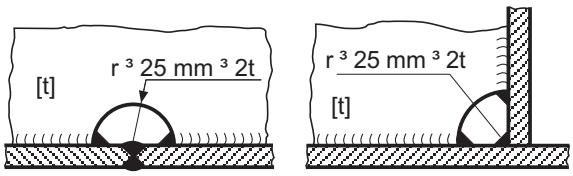

Fig. D.3 Through-welding holes

2.6 For welds in cold formed areas (e.g. at bends), the minimum bend radius for plate thicknesses up to 4 mm is to be 1 · t; for up to 8 mm, 1,5 · t; for up to 12 mm, 2 · t; for up to 24 mm, 3 · t. Edge bending operations may necessitate a larger bend radius.

2.7 Material dependent peculiarities, such as for example the softening of work hardened or precipitation hardened aluminium alloys by welding, are to be taken into account in the design and dimensioning of welded joints. Where joints between different materials, such as for example welds joining mild and stainless steel, are exposed to sea water or other electrolyte, the increased tendency to corrode due to potential differences, particularly near welded seams, is to be taken into consideration. If applicable, the welded joints shall be located in less endangered zones, or special corrosion protection measures taken.

3. Weld geometry and dimensions

3.1 Butt-welded seams (e.g. square, V- or X-seams) and corner or cross welds (e.g. with single-bevel or double-bevel seams (K-seams)) shall be planned for full penetration of the plate- or section cross section in principle. The root shall be grooved out and welded from the reverse side, in principle. In the case of single- or double-bevel (K-)seams, grooving out of the root may be dispensed with and a root defect of up to 0,2 t (t = thickness of the abutting component), max. 3 mm, may be accepted if the missing weld cross section is replaced by additional fillet welds.

3.2 Depending on plate thickness, welding procedure, welding position, etc., seam forms shall be planned to be in accordance with the standards (e.g. DIN 1912, DIN 8551, DIN 8552), with adequate angular opening, sufficient shoulder (air)gap and minimum shoulder height. Other (different) forms of seams shall have the compliance of GL, e.g. as part of the plan approval; if necessary, the seam forms are determined in conjunction with a procedure test.

3.3 Fillet welds in areas of high local stresses (e.g. load transfer zones) shall be planned to be continuous on both sides, if possible. In corrosion endangered zones (e.g. bilges, water tanks, around the bottom of fuel tanks, or in spaces where condensation, spray or leakage water can accumulate), components of non corrosion resistant materials shall be planned only to have fillet or cut-out welds continuous on both sides. The fillet welds shall be continued around the ends of the stiffeners or cut-outs to seal them. The same applies logically to lap welded joints.

3.4 The required fillet weld throat "a" (the height of the inscribed isosceles triangle) depends on component thickness and the relevant stress and is to be determined by calculation if necessary. Regarding this see Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 1 – Hull Structures, Section 19 and 20. Generally - for continuous welds on both sides - the fillet weld throats can be inserted in accordance with the following Table:

Plate thickness "t" of the thinner of the components to be joined (mm)	generally required fillet weld throat "a" for continuous welds on both sides (mm)
up to 5	2,5
over 5 up to 10	3,0
over 10 up to 15	3,5
over 20	4,0

3.5 The values according to 3.4 apply to normal and higher strength ship steels and comparable structural steels. For other steels and aluminium alloys it may be necessary to increase the a-dimension; similarly for discontinuous welds in accordance with 3.7, regarding this see also the Rules for Welding. The minimum fillet weld throat is:

$$a_{min} = \sqrt{\frac{(t_1 + t_2)}{3}} \quad [mm]$$

where t_1 and t_2 are the thicknesses of the two components to be joined. The maximum throat thickness is not to exceed 0,7 times the thickness of the thinner plate.

3.6 Reinforced fillet welds shall be planned for areas of locally increased and/or dynamic stress. These are, amongst others, force transfer points such as chain plates, the area around the rudder stock and shaft bracket, the engine seating or the structure supporting the mast. Except where something else is specifically laid down (e.g. under 4. or as part of the plan approval), a throat a = 0,5 t (t = the thickness of the thinner component) is to be planned there. Where stresses are particularly high, single or double V- (K-) welds shall be used.

3.7 Discontinuous, instead of continuous on both sides, fillet welding can be carried out as chain welding (with or without cut-outs) or as zig-zag welding. The subdivision of discontinuous fillet seams is to be so chosen that the shortest length of weld is not less than 10 times, and the longest unwelded length (longest distance between two fillet welds on the same or on opposite sides) is not more than 25 times the lesser thickness of the parts to be joined by welding. The length of cut-outs shall however not exceed 20 times the lesser thickness.

3.8 The thickness "a_u" of discontinuous fillet seams shall be calculated in accordance with the following formula, depending on the subdivision-ratio b/ℓ chosen and the thickness "t" on which the fillet thickness "a" depends,:

$$a_u = 0{,}15\, t \frac{b}{\ell} 1{,}1 \quad [mm]$$

but not less than the minimum throat size.

Where:

b = subdivision = e + ℓ [mm]

e = distance between the welds

ℓ = length of individual fillet welds [mm]

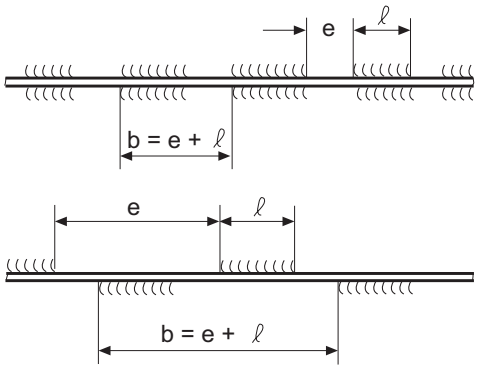

Fig. D.4 Discontinuous welding

3.9 For relatively low stressed components, (e.g. shell longitudinal seams) lap welded joints may be planned instead of butt joints. As far as possible these shall only be arranged parallel to the direction of principal stress (in the example, parallel to the longitudinal bending stress of the hull). In locally high stressed force transfer areas (e.g in way of ballast keel connection, chain plates or rudder stock) lap welded joints shall be avoided, if possible. The width of overlap shall be about 1,5 t + 15 mm, where "t" is the thickness of the thinner plate. The above applies as appropriate to throats.

3.10 When welding with cut-outs, these shall preferably be holes elongated in the direction of the principal stress. Spacing and length of holes shall be logically as in 3.7 for discontinuous welds; the throat shall be determined in accordance with 3.9. If the throat thickness so determined exceeds 0,7 times the plate thickness, the subdivision ratio is to be altered as necessary. Cut-out width is to be at least twice the plate thickness but not less than 15 mm. Cut-out ends shall be made semicircular. Plates or sections placed underneath shall be at least as thick as the plate with cut-outs.

4. Welded joints between separate components

4.1 Floor-to-frame welded joints shall be made as shown in Fig. D.5. The a dimension necessary shall be determined in accordance with the Table under 3.4. In corrosion endangered areas (cf. 3.3) welding shall be continuous, i.e. the weld taken right around the overlap to act as a seal, see also under 3.3

4.2 Frame-to-bracket-to-deck beam welded joints or frame-to-deck beam ones without any bracket may be made as show in Fig. D.6, depending on the loading. As regards the fillet welds, 4.1 applies logically. In areas of localised higher stresses (e.g in way of the mast of sailing yachts), the design shall have reinforcement (e.g. corners of frames flange reinforced) with correspondingly enlarged welded joints.

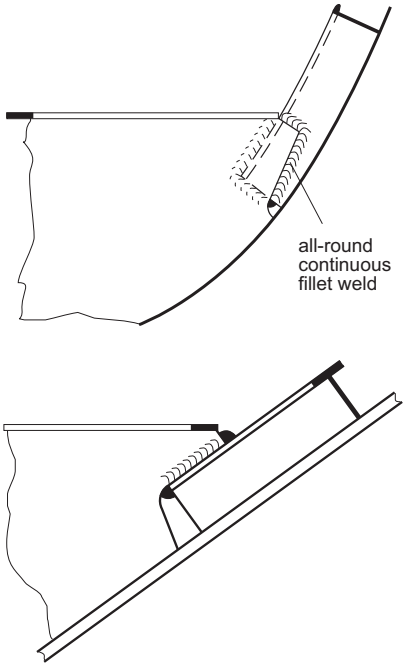

Fig. D.5 Floor-to-frame welded joint

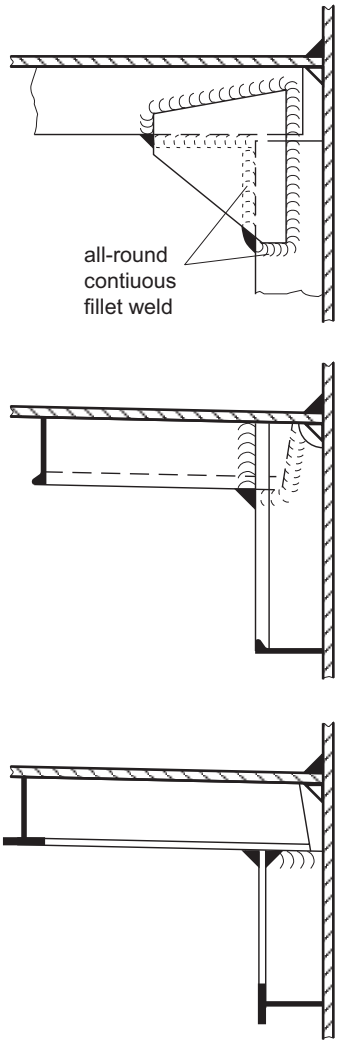

Fig. D.6 Frame-(to-bracket)to-deck beam welded joint

4.3 Examples of welded joints between rudder (coupling plate) and rudder stock are shown in Fig. D.7. Particularly when welding the stock into the coupling plate or the rudder, care shall be taken to achieve a notch free weld with "soft" transitions to the stock; as a rule the surface of the weld and the transitions are given a ground finish. Other solutions, equivalent to the ones shown, may be authorised - subject to the submission of detailed drawings and calculations if necessary (fatigue strength).

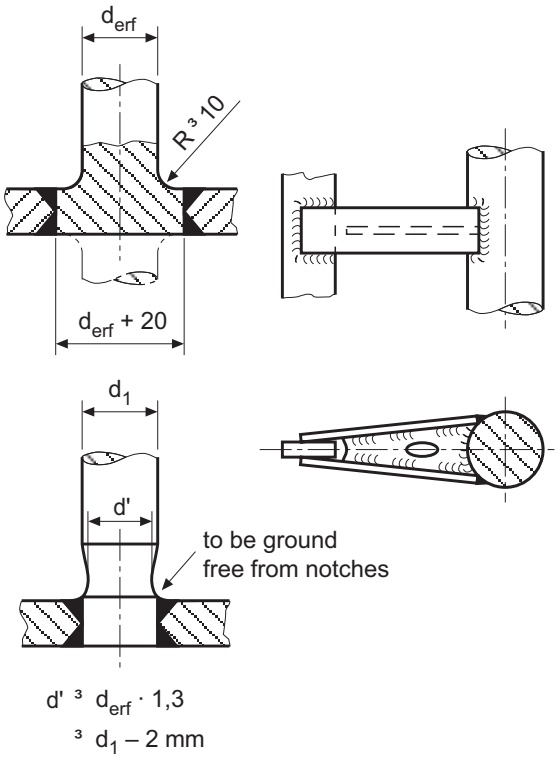

Fig. D.7 Welded joints between rudder (coupling plate) and stock

D. Making and Testing the Welded Joints

1. Seam preparation and part assembly

1.1 When preparing the components and fitting them together, attention is to be paid to the maintenance of the seam forms and shoulder (air)gaps stated in the design documentation and/or the standards. Particularly in the case of single or double V-(K)seams accessible only from one side, care is to be taken to leave an air gap large enough to achieve adequate penetration. Where temporary or permanent pool support is used, the air gap is to be increased appropriately.

1.2 The component butts to be welded shall be aligned as accurately as possible. In the case of sections etc. welded to plating the ends shall left loose to achieve this. If longitudinal girders and frames etc. are interrupted by bulkheads and similar components, or for example web frames (flanges) are interrupted by decks etc., their alignment shall be checked by test drillings through the transverse component, if necessary. These shall later be welded-up again.

Note

Useful guidance concerning acceptable fabrication tolerances is given in the "Fertigungsstandard des Deutschen Schiffbaus" (Manufacturing Standard of the German Shipbuilding Industry) issued by the "Verband für Schiffbau und Meerestechnik" (Shipbuilding and Marine Technology Association) in Hamburg. GL has approved this standard with the proviso that in exceptional cases, for instance important, highly stressed components or where there is an accumulation of deviations from the specified size, it may make a decision deviating from the standard and demand dressing.

2. Tacking, auxiliary materials

2.1 Tack welds shall be made as sparingly as possible and by trained personnel. If the quality of tack welds is not up to that required for the welds to be carried out on the component, they shall be carefully removed before the proper welding. Cracked tacks must never be welded over; they shall all be ground out.

2.2 Clamps, tack ties, fitting pins, etc. shall be of easily weldable steel (e.g. ship steel) or in the case of stainless steel and aluminium alloys of the same material if possible, but at least of one of the same kind, as the components to be joined. They must not to be used more often than necessary; for welding on, the same fillers shall be used as for joining the components.

2.3 Auxiliary materials and welds shall be removed after use in such a way that damage to the component surfaces is avoided as far as possible. Places damaged by inexpert removal of auxiliary material are to be ground out neatly, then welded up and ground notch free. GL may require a surface crack detection test before and/or after the welding up.

3. Weather protection, preheating

3.1 The working environment of the welder is to be protected against wind, wet and cold - especially in the case of outdoor work. Particularly for shielded arc welding, attention shall be paid to effective draught screening. Where work in the open is done under unfavourable weather conditions, heating the seam edges to dry them before welding is recommended.

3.2 In cold weather (below 0 °C) faultless execution of the welds shall be ensured by suitable measures (covering the components, large scale warming, pre-

heating especially when welding thick walled components with relatively little heat input, e.g thin fillet welds). If possible, welding is to be suspended at temperatures below 0 °C.

3.3 Ordinary hull structural steels (e.g. Grade A to D) and comparable structural steels in general do not need preheating, apart from the measures in accordance with 3.1 and 3.2. In the case of components with very thick walls and that sort of forging or steel casting, slight preheating to about 80 to 120 °C before welding is recommended. The preheating temperature necessary for other materials (e.g. higher strength ship steels) shall be determined from the GL Rules for Welding, if applicable.

4. Welding position, welding sequence

4.1 Welding work should be done in the most favourable position (e.g. down hand position). Unfavourable welding positions welding shall be used only where absolutely necessary. Welders compelled to perform unfavourable welding positions must have been tested in this, see also under B.2.1. This applies especially to welding vertically downwards.

4.2 Even following a successful procedure test and approval of the procedure (cf. B.3.2), vertical downward welding may not be used for joining components to high local and/or dynamic stresses, as for example described in C.3.6. In case of doubt, the extent of vertical downward welding shall be agreed with GL before work starts (e.g. in the course of plan approval).

4.3 The welding sequence shall be chosen so as to minimise the interference with shrinkage. As far as possible, welding of plating butts shall be completed before stiffeners are set up, but in any case before they are welded to the plating. At T-shaped seam crossings (e.g where individual plates or patches are inserted later), the longitudinal seams shall be opened (or left open) over the transverse butts, and the latter shall be welded before the former.

5. Workmanship, repair of defects

5.1 The components shall be clean and dry around the weld seams. Scale, rust, slag, paint, grease and dirt shall be carefully removed before welding. Fabrication coating (shop primer) permitted by GL which may be welded over may be so treated if the layer is no thicker than the limiting value (usually 0,03 mm) stated in the permission. In cases of doubt, GL may require fillet weld fracture tests to prove that welds are faultless, without excessive porosity (regarding this see also Rules for Welding).

5.2 Regarding welding over tacked places see 2.1. In multi pass welding the slag from the preceding pass shall be removed carefully before welding the next pass. Visible defects such as pores, slag inclusions or cracks must not be welded over but rather machined out and repaired.

5.3 The welded seams shall have adequate penetration and clean, even surfaces with "soft" transitions to the base material. Excessively proud seams and undercuts, and notches at the edges of components or cut-outs, shall be avoided.

5.4 Butt welded joints must be welded right through the cross section of the plate or section. To this end the root is generally to be grooved out and welded from the reverse side. Single side welds (e.g. on ceramic weld pool support) shall be so prepared and carried out that here also full penetration is achieved. Single side welds on permanent, welded in, weld pool supports require GL approval, e.g. as part of the plan approval.

5.5 In the case of fillet welds attention shall be paid to good root cover. The penetration shall at least extend close to the theoretical root point. The fillet weld cross section to be aimed at is an isosceles flat seam without excessive bulge and with notch free transition to the base material. In storage tanks and other corrosion endangered spaces (cf. C.3.3) the fillet weld is to be continued around at web ends, cut-outs, through welding holes, etc. to provide a seal.

5.6 The repair of major workmanship defects or of flaws in the material requires the approval of the surveyor. Minor surface defects shall be eliminated by shallow grinding, if possible; deeper defects ground out cleanly and welded-up, the surfaces to be smoothed, see also 2.3.

6. Visual checks, non destructive testing

6.1 All welds shall be subjected to a visual check by the manufacturer's welding supervisor for completeness and proper execution of the work. Following the check on the part of the works and dressing if necessary, the components shall be presented to the GL surveyor in sensible phases of construction, easily accessible and as a rule unpainted, for the acceptance survey. The surveyor may reject components not adequately checked beforehand and demand presentation again after successful checking by the manufacturer, and if necessary dressing. Regarding this see also A.5.

6.2 If due to inadequate or lacking data in the fabrication documentation (cf. A.4.) the quality of the welded joints or the strength or operability of the components is in doubt, the GL surveyor may demand more extensive tests and/or appropriate improvements. This applies logically to supplementary or additional components (e.g. reinforcements) even if these were not called for at the plan approval or could not be called for because the representation was insufficiently detailed.

6.3 Depending on the importance and stressing of the components or their welded joints, non destructive tests (e.g. radiographic tests) shall be provided on top of the tests listed above. Nature and scope of such tests shall be agreed with the GL surveyor; the surveyor determines the test positions. The results shall be submitted to him for final evaluation. If these tests reveal defects on a major scale, the scope of the tests is to be increased. Repaired defects are to be re-tested. The tests shall be documented by the building yard; the documentation is to be retained there for an appropriate length of time (at least one class period).