Section 1

General Design Principles

A. General

1. Scope

These Rules contain universal principles applicable to the designing and dimensioning of welded joints, and to the information contained in the manufacturing documents.

2. Supplementary Rules

The designing and dimensioning of welded joints in the various ranges of application is additionally governed by the component-specific requirements stated in the various sections of Chapter 3 and in the respective Rules for Construction of Germanischer Lloyd.

B. Information Contained in Manufacturing Documents

1. Joint/weld shapes, symbols

1.1 The depiction of welded joints and also the shapes of joints and welds shall conform to the standards (e.g. EN 12345/ISO ….., EN 22553/ISO 2553 or EN 29692/ISO 9692). They shall be identified in the manufacturing documents (drawings, etc.) in an unambiguous manner, e.g. by means of the standard symbols.

1.2 Non-standard weld shapes or symbols shall be illustrated and, where applicable, explained in detail in the manufacturing documents (drawings, welding schedules or specifications). They must be approved by the Society (e.g. in conjunction with the inspection of drawings or a welding procedure test).

1.3 A weld shape appropriate to, and adequately dimensioned or well designed for the nature (static or dynamic) and magnitude of the forces to be transmitted shall be chosen. Where necessary, documentary proof of the design calculations shall be submitted (cf. the supplementary Rules mentioned in A.2.).

2. Information on fabrication

2.1 The manufacturing documents to be submitted for approval shall contain information on fabrication insofar as is relevant to the quality of the welded joints and necessary for inspection by the Society. Besides the materials and weld shapes, this comprises the following information:

- Method of weld preparation (mechanical, thermal, etc.)
- Welding process, welding positions
- Welding consumables and auxiliary materials
- Preheating and, where applicable, heat input during welding
- Weld build-up and number of passes
- Welding sequence (in special cases)
- Grooving of root (method)
- Post-weld (heat) treatments, if any
- Number and location of any production specimens to be welded at the same time (where stipulated).

With regard to the information on the requirements applicable to the welded joints and their inspection, see 3.

2.2 If the preparation and execution of the welds (in conjunction with approved welding procedures, welding consumables and auxiliary materials) conform to normal welding and shipbuilding practice as well as to these Rules and the recognized standards, the Society may waive the requirement that they be specially illustrated or indicated in the manufacturing documents.

3. Requirements for welded joints, inspections

3.1 The manufacturing documents (e.g. drawings, welding or inspection schedules) to be submitted for approval shall also indicate the quality requirements for the welded joints. Depending on the range of application, this may be done by means of the weld factor (cf. Chapter 3, Section 2 and 3), or by means of the weld quality grade (cf. Chapter 3, Section 1, I., Table 1.9) or the evaluation category according to EN 25817/ISO 5817 or EN 30042/ISO 10042 (cf. Annexes A and B). The tests (testing methods and scope of testing) to be used to verify the stipulated weld quality shall also be indicated.

3.2 The requirements to be stated also include the leak-tightness to gases and liquids or the corrosion resistance to particular media.

3.3 With regard to the welding procedure and production tests, cf. Chapter 1, Section 4 and the application-specific Section 1 – 5 of Chapter 3, with regard to non-destructive testing, cf. Section 4 and the application-specific sections of Chapter 3.

C. Materials, Weldability

1. Weldability, processing

Only materials of proven weldability may be used for welded structures. Any conditions linked to the approval of the materials or to the welding procedure tests which impose restrictions on processing and the material manufacturer's recommendations shall be allowed for when designing the welded joint. With regard to the processing and use of TM steels, see the special GL Guidelines.

2. Material-related characteristics

Material-related characteristics, such as the (inferior) strength of rolled products in the thickness direction (cf. D.7.2), the softening of hardened aluminium alloys when welded, or the different degrees of thermal expansion of the various materials, shall be allowed for when designing and dimensioning the components and welded joints.

3. Clad plates

Clad plates where the efficiency of the bond between the supporting and cladding material has been proved by materials testing (cf. Part 1, Chapter 2, Section 1) may generally be treated as solid plates (up to medium plate thicknesses with mostly fillet welds).

4. Pairs of materials, corrosion

Where pairs of different materials are exposed to seawater or other electrolytes, e.g. welded joints between unalloyed (hull) structural steels and stainless steels, attention shall be paid to the increased tendency towards corrosion due to the differences in electrochemical potential. Where possible, these welded joints should be located at points where there is less danger of corrosion, or special corrosion protection should be provided (e.g. coating or cathodic protection).

D. Design Details

1. Accessibility, workmanship and fitness for inspection

1.1 Welded joints shall be planned at the design stage to ensure that they are readily accessible during fabrication and can be executed in the optimum welding position and welding sequence.

1.2 Welded joints and welding sequences shall be designed to minimize residual weld stresses and avoid excessive deformation. Welded joints should therefore not be over-dimensioned.

1.3 Welded joints shall be designed to ensure that the proposed weld type and quality (e.g. complete root fusion in the case of single- and double-bevel butt welds) can be satisfactorily achieved under the given fabricating conditions. Failing this, provision shall be made for welds which are easy to execute and their (possibly inferior) load-bearing capacity shall be allowed for when dimensioning the welds.

1.4 Severely stressed welded joints, which are therefore normally subject to compulsory inspection, shall be designed to facilitate application of the most appropriate inspection technique (radiography, ultrasonic or surface crack inspection, possibly in combination) so that tests offering reliable results can be carried out.

2. Location and configuration of welded joints

2.1 In areas of high stress concentrations resulting from the design - and especially in cases of dynamic loading -, welded joints should be avoided as far as possible or designed in such a way as to provide a generally smooth stress profile without a significant additional notch effect originating from the welding operation. Cf. GL Rules I, "Ship Technology", Part 1, Chaper 1, Section 20 "Fatigue Strength".

2.2 Intersecting butt welds in load-bearing walls of steam boilers and pressure vessels shall be avoided. The longitudinal seams of pipes shall be offset relative to one another at the pipe joints by at least 50 mm. Intersecting butt welds in hull structures are allowed; if possible, however, the first (e.g. longitudinal) welded joint shall be completed and cleanly finished at the ends before the second (e.g. transverse) joint is made.

3. Local clustering of welds, minimum spacing

3.1 The local clustering of welds and insufficient distances between welded joints are to be avoided (cf. also Chapter 3, Section 1, G.4). Welds shall not be

over-dimensioned. The thickness of fillet welds shall not exceed 0,7 times the thickness of the thinner of the two parts to be joined.

3.2 Adjacent butt welds should be separated from each other by a distance of at least 50 mm + 4 × plate thickness. Fillet welds should be separated from each other and from butt welds by a distance of at least 30 mm + 3 × plate thickness. The width of interchangeable sections (strips) of plate should, however, be at least 300 mm or ten times the plate thickness, whichever is the greater. Cf. also Chapter 3, Section 1, G.4.1.

4. Cut-outs, welding apertures

4.1 Adequately sized cut-outs (welding apertures) shall be provided when, for instance, stiffeners are applied to platings before the butt joints in the plating are welded. Cf. also Chapter 3, Section 1, G.5. The welding apertures shall be rounded with a minimum radius of 25 mm or 2 × plate thickness, whichever is the greater.

4.2 In special cases, e.g. when welding components subject to severe dynamic stresses, instead of providing welding apertures in the area of the butt welds it may be advisable to make a double-bevel weld preparation on the component to be attached to the plating, to weld up to this from both sides and to machine out the resulting root defect in the butt weld from the opposite side (of the plating).

5. Local reinforcements, plate doubling

5.1 Where platings (including girder plates and tube or vessel walls) are subjected locally to increased stresses, thicker plates should be used wherever possible in preference to plate doublings. Bearing bushes, hubs, etc. shall invariably take the form of thicker plates, forgings or the like welded into the plating.

5.2 Where doubling plates cannot be avoided, their thickness should not exceed twice the plating thickness and their width should not exceed 30 times the doubling plate thickness. With regard to welding of doubling plates and especially the ends of such plates, cf. Chapter 3, Section 1, G.6. With regard to the design and welding of doubling plates as cut-out reinforcements in pressure vessels, see the Rules for Construction.

6. Stress flow, transitions

6.1 All welded joints on supporting members shall be designed to provide as smooth a stress profile as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to expansion.

6.2 To this end, components with different dimensions shall be adjusted to one another by means of gradual transitions (e.g. by bevelling the edges of the thicker component). Steel castings and forgings must therefore be provided with integrally cast or forged welding flanges. Cf. Chapter 3, Section 1, G.3. and the Rules for Construction.

7. Double-T (cruciform) joints, stress in the thickness direction

7.1 Where, in the case of double-T (cruciform) joints, rolled products are stressed in the thickness direction due to the residual weld stresses or the applied loads, suitable measures shall be taken in the design of the structures to prevent lamellar tearing (stratified fractures). Such measures include the use of suitable weld shapes with a minimum weld volume and a welding sequence designed to reduce the shrinkage stresses in the thickness direction.

7.2 Where there are very severe stresses in the thickness direction (e.g. due to bulky single- or double-bevel butt welds), materials with enhanced characteristics in the direction at right angles to the surface of the product are to be used (cf. Part 1, Chapter 2, Section 1).

8. Welding of cold-formed sections

Welding of cold-formed sections of (hull) structural steels is permissible provided that the conditions stated in Chapter 3, Section 1, G.8. are complied with. In special cases, post-weld heat treatment may be necessary or documentary proof of adequate toughness after welding may be demanded.

9. Other design measures

9.1 Welds should not be located in channels of sections owing to the danger of the presence of segregations and the residual stresses in these areas arising from the rolling process.

9.2 Welded joints (fillet weld joints) in areas where the risk of corrosion cannot be excluded shall be continuously executed around components, cut-outs, etc. to provide a seal.

9.3 If heat treatment is carried out on components with sealed-off hollow spaces necessitated by the design, such as occur in the case of cut-out reinforcements (doublings), mounted loose flanges or suspender rings, a means of venting, e.g. a drilled hole, shall be provided.

E. Dimensioning of Welded Joints

1. Dimensioning, design calculations

1.1 Dimensioning shall be carried out in accordance with the Rules for Construction with reference to the shape and quality of the weld in question and the type (static or dynamic) and level of stress. The dimensions of the weld (if required) must be apparent from the manufacturing documents to be submitted for approval. In the case of fillet welds, an indication shall also be given as to whether the dimensional data refer to the throat thickness of the weld "a" or to the leg length "z".

1.2 Where required by the Society (e.g. in the Rules for Construction or as part of the examination of the drawings), mathematical proof (a general stress analysis and/or proof of fatigue strength) shall be furnished that the weld is adequately dimensioned.

2. Minimum thicknesses of fillet welds

Fillet weld throat thicknesses shall conform to the GL Rules or the results of design calculations. Throat thicknesses not established according to the Rules or design calculations shall be executed, as a minimum requirement, with a throat thickness of

$$a = 0{,}5 \times \text{plate thickness},$$

the smaller plate thickness being the ruling dimension. Unless otherwise agreed (e.g. for the fully-mechanised welding of smaller plate thicknesses in appropriate clamping jigs), the minimum fillet weld throat thickness shall be

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \ [\text{mm}], \text{ but not less than 3 mm}$$

t_1 = smaller (e.g. the web) plate thickness in [mm]

t_2 = larger (e.g. the flange) plate thickness in [mm]

A smaller minimum fillet weld throat thickness (e.g. 2,5 mm) may be agreed to if its faultless execution is demonstrated by means of a welding procedure test.

3. Machining allowance

Adequate machining allowances (thicker welds) shall be provided for the subsequent machining of welds to ensure that the prescribed minimum weld thicknesses are achieved on completion of the work. This particularly applies to welds with only partial penetration, as occasionally occur for instance in machinery components, in which case provision shall be made for machining correspondingly deeper joints from the outset. In the case of the notch-free grinding of the welds, which is employed in the case of particular weld quality requirements, correspondingly thicker welds shall be deposited.