2 Guidelines for the Fabrication and Inspection of Welded Pipelines of Copper-Nickel-Alloys
The following Guidelines come into force on May 1st, 2007

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General Principles and Requirements

A. Scope

1. These Guidelines give technical principles regarding the production and inspection of welded pipes made of copper-nickel alloys designed for the use on ships. Concerning other components made of this material these Guidelines could be correspondingly adopted.

2. These Guidelines are meant to be a supplement of the Rules for Classification and Construction I – Ship Technology Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations, Section 11, which have to be definitely observed for the vessel’s construction under class of Germanischer Lloyd (GL).

3. Germanischer Lloyd reserves the right to modify or to complement these Guidelines according to the technical development and – as the case may be – to the coming into force of new Rules for Classification and Construction.

B. Other Relevant Standards

1. These Guidelines refer to the standard series DIN 85004 „Pipelines of Copper-Nickel-Alloys“ respectively adopt them accordingly.

2. If there are differences concerning the requirements between these Guidelines and the standards which also apply, the requirements of these Guidelines shall take precedence unless otherwise stipulated.

C. Requirements for the Manufacturer

1. The production works must provide qualified equipments in order to carry out the welding appropriate to these Guidelines.

2. Equipments and installations in external places, e.g. concerning the non-destructive testing, can be taken into account for the evaluation of the shop if the conditions for an appropriate testing are given at that place.

3. The manufacturer has to notify welding supervisors, who verify the welding work with responsibility. Only welders and welding procedures, both approved according to Section 2, D. and E. respectively, are allowed to be used for the work.

D. Materials

1. The materials have to be appropriate to the intended use.

1.1 For pipe manufacturing, pipes made of copper-nickel-alloy 90/10 acc. to the GL Rules II – Materials and Welding, Part 1 – Metallic Materials, Chapter 3 – Non-Ferrous Metals, Section 2 (CuNi10Fe1Mn acc. EN 12449) are to be used or similar material (CuNi10Fe1,6Mn acc. to WL 2.1972).

1.2 For the use of other alloys, requirements for the properties of welded joints have to be defined separately. Possible restrictions of analysis for pipe material suitable for welding acc. to the standards are to be observed.

E. Welding Consumables and Auxiliary Materials

1. The welding consumables have to be chosen that way, that the requirements established for the material are also fulfilled by the weld metal and the joint. This is the case if e.g. welding consumables of the type CuNi30 to EN14640 (SG-CuNi30Fe to DIN 1733-1) are used for welding of CuNi10Fe1Mn.

1.1 If possible, welding consumables and auxiliary materials already tested and approved by GL shall be used, see also the GL Rules II – Materials and Welding, Part 3 – Welding, Chapter 1 – General Requirements, Proof of Qualifications, Approvals, Section 2 and DIN 2303 (military equipment) respectively are to be observed.

1.2 The evidence can also be provided through a welding procedure test acc. to Section 2, E. at the user. This kind of recognition is restricted to the user’s work and only valid for max. one year, if an annual repeat test is not carried out.
A. General

1. The working place of copper-nickel-materials has to be separated from the working of steel components.

2. Pipes and pipe fittings have to be handled in a proper condition, that means that dirt of each kind, rests of oil and grease as well as sand, cuttings and other are to be removed.

3. Until installation on board, the openings of the pipes and fittings are to be protected against the penetration of dirt.

B. Forming

1. The procedures of forming (T-Drill process), flanging and reducing of pipes at the manufacturer have to be approved by GL.

2. Cold bending of pipes can be carried out, if the bending diameter is larger than 2 times the external diameter. Occurred bending ripples are to be removed.

3. Pipe branching can be performed by fittings, welded connections or forming (T-Drill process). In the case of forming, the calculated wall thickness has to be observed. If relevant cold works have to be carried out, annealing is required at a temperature of approx. 750 °C.

C. Welding Joints

1. The welding has to be preferably carried out with the tungsten inert gas arc welding process (141) under argon shielding gas, also for root side.

2. In case of multilayer welding of pipes with wall thickness more than 6 mm, manual arc welding (111) with basic covered rod electrodes can be used for the fill and final pass. The root pass must be welded by TIG-process.

3. Other procedures can also be approved on request, if sufficient quality properties are proved by a welding procedure test.

4. The pipelines are to be constructed in that way that as most as possible welding seams can be produced in the shop. Welding shall be executed - as far as possible – in a flat position (PA).

5. With regard to pipes with a wall thickness up to 2.5 mm, the preparation of square butt weld is to be considered; regarding bigger wall thickness, a preparation of single-V butt joint with an included angle up to 90° is necessary.

6. The joint area has to be metallic clean before welding. Root gap and misalignment have to be minimised as most possible.

7. Tack welds, that are not to be removed, have to be made in the same quality than the welded roots. It is not allowed to over weld broken tack welds. They have to be machined out before fabrication welding.

8. The arc shall only be stroked off in the welding gap. The heat input is to be restricted.

9. Welding spatters, excessive weld and root reinforcement have to be removed, but the wall thickness shall not fall below the minimum.

D. Welder’s Qualification Tests

1. Welder’s qualification tests acc. to EN ISO 9606-3 are required for all welders executing welding by hand guided welding apparatus (e.g. TIG, manual arc welding).

2. The qualification of the operating staff for automatic welding machine (e.g. orbital welding) is to be proved by welded test pieces acc. to EN 1481/ISO 14732, e.g. as part of the procedure test.

3. The welder or operator having successfully passed the welding procedure test in accordance with E. is qualified for the corresponding scope acc. to EN ISO 9606-3 and EN 1418 / ISO 14732 respectively, provided that the decisive test requirements are fulfilled.

4. Apart from the specifications and requirements of the a.m. standards, the requirements of the GL Rules II – Materials and Welding, Part 3 – Welding, Chapter 1 – General Requirements, Proof of Qualifications, Approvals, Section 3 are to be observed.
E. Welding Procedure Tests

1. Before starting the fabrication, it must be proved by means of a welding procedure test that pipe joints acc. to the required quality properties can be manufactured in the workshop.

2. The welding supervisor has to indicate all details in a manufacturer’s welding procedure specification (WPS) how to carry out the welding works. The welding of test pieces is made upon this preliminary welding procedure specification.

3. Concerning the TIG-welding with preparation of the square butt joint, a welder must weld a piece each with a diameter $d_1 = 150$ up to 200 mm and a wall thickness $s = 2.5$ up to 3 mm in a horizontal pipe axis (pos. PA, PF, PE) and in a vertical pipe axis (pos. PC), see Fig. 2.1.

4. If multilayer welding is applied, another set of test pieces with corresponding wall thickness has to be welded. If the welding is restricted to the flat position (PA), e.g. welding on rotating device, the welder can only weld the test pieces in that position.

5. In the case that the measurements of the pipes used during the fabrication are differing too much from the a.m. dimensions of the test piece, an adjusted test program has to be agreed with GL.

6. Prior to sectioning, the welded test pieces are to be examined over the entire length of the seam by non-destructive testing in order to find external or internal welding failures by visual, penetrant and radiographic examination (VT, PT, RT). The evaluation of the imperfections will be assessed according Section 3, Table 3.1, 3.2 and 3.4.

7. The sectioning of the test pieces and the dimensions of the specimens concerning the mechanical-technological testing are described in Figure 2.2 and Fig. 2.3. One test set shall be made up of the following specimens – if not agreed otherwise:
   - 2 transverse tensile test specimens (Z) per welding position
   - 2 transverse bend test specimens per welding position, one is to be bent with the final pass ($F_{BB}$) and one with the root pass ($R_{BB}$) in tension
   - 1 macrographic (M) per welding position

---

**Fig. 2.1 Test pieces for welding procedure tests**

**Fig. 2.2 Positions and preparation of specimens for welding procedure tests**
Table 2.1 Requirements for the welded joints

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile test transversal to weld (Z)</td>
<td>Tensile strength $R_m$ as stipulated for the base material at least 290 N/mm$^2$.</td>
</tr>
</tbody>
</table>
|                                           | The minimum elongation $A \geq 15\%$ shall be checked with an initial gauge length of $L_0 = 5.56 \sqrt{S_0}$.
| Transverse bend test ($F_{BB}, R_{BB}$)   | Bending angle 180° with a mandrel diameter of 3 times the wall thickness. |
|                                           | Minor open defects up to a maximum length of 3 mm may be tolerated.         |
| Macrographic specimen (M)                 | Imperfections are to be within the specified limits of Table 3.1, 3.2 and 3.4. |

8. In welding procedure and production tests on copper-nickel-alloy 90/10, the butt weld specimens must meet the minimum requirements shown in Table 2.1.

9. A successfully passed welding procedure test is valid for the examined welding process, for the used copper-nickel-alloy, for the used welding consumable type and for the tested welding position(s).

The scope of the wall thickness and the diameter is determined according to the welder’s qualification test acc. to EN ISO 9606-3.

10. Depending upon the pipe class, the validity of a welding procedure is determined in Chapter 1 – General Requirements, Proof of Qualifications, Approvals, Section 3 and Chapter 3 – Welding in the Various Fields of Application, Section 4 of the GL Rules II – Materials and Welding, Part 3 – Welding.
A. Visual Inspection

1. The external condition of all weld seams are to be inspected, even the root sides of the seams, as far as accessible.

2. Unevenness of the weld seams inside the pipelines, e.g. welding beads or sagging drops of weld, has to be removed, but the minimum wall thickness has to be respected.

3. The root reinforcement shall not exceed the values given in Table 3.1. The misalignment of the inside does not exceed the half of the wall thickness or 2 mm max. The sum of root reinforcement and the inside misalignment has not to be more than the values described in Table 3.1. The evaluation of other imperfections has to be made according to Table 3.2.

### Table 3.1 Limits of internal excess

<table>
<thead>
<tr>
<th>Pipe-nominal width</th>
<th>Maximum permissible inside advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN</td>
<td>mm</td>
</tr>
<tr>
<td>≤ 40</td>
<td>1,5</td>
</tr>
<tr>
<td>50 to 150</td>
<td>2</td>
</tr>
<tr>
<td>175 to 250</td>
<td>2,5</td>
</tr>
<tr>
<td>≥ 300</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 3.2 Imperfection of welded joints

<table>
<thead>
<tr>
<th>Designation</th>
<th>Classification number</th>
<th>Symbol</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas pore</td>
<td>2011</td>
<td>Aa</td>
<td>see Table 3.4</td>
</tr>
<tr>
<td>Clustered porosity</td>
<td>2013</td>
<td>–</td>
<td>not permissible 1,2</td>
</tr>
<tr>
<td>Linear porosity</td>
<td>2014</td>
<td>–</td>
<td>not permissible 2</td>
</tr>
<tr>
<td>Worm-hole</td>
<td>2016</td>
<td>Ab</td>
<td>not permissible</td>
</tr>
<tr>
<td>Tungsten inclusion</td>
<td>3041</td>
<td>H</td>
<td>not permissible 3</td>
</tr>
<tr>
<td>Lack of fusion</td>
<td>401</td>
<td>C</td>
<td>not permissible</td>
</tr>
<tr>
<td>Lack of penetration</td>
<td>402</td>
<td>D</td>
<td>not permissible</td>
</tr>
<tr>
<td>Undercut, continuous</td>
<td>5011</td>
<td>F</td>
<td>not permissible</td>
</tr>
<tr>
<td>Undercut, intermittent</td>
<td>5012</td>
<td>F</td>
<td>conditionally permissible</td>
</tr>
<tr>
<td>Shrinkage groove</td>
<td>5013</td>
<td>–</td>
<td>not permissible</td>
</tr>
<tr>
<td>Crack</td>
<td>100</td>
<td>E</td>
<td>not permissible</td>
</tr>
<tr>
<td>Irregular bead appearance</td>
<td>514</td>
<td>–</td>
<td>permissible</td>
</tr>
<tr>
<td>Poor restart</td>
<td>517</td>
<td>–</td>
<td>not permissible</td>
</tr>
</tbody>
</table>

1. Pores up to 0,5 mm are ignored for wall thickness of 2 mm and above.
2. Pores up to 0,3 mm are not evaluated.
3. Tungsten inclusions up to 0,5 mm are ignored for wall thickness of 2 mm and above; tungsten inclusions up to 0,3 mm are not evaluated.
B. Penetrant Inspection

1. A penetrant testing of weld seams of the pipelines of pipe class I and II are to be carried out in a spot check way.


3. The evaluation of the imperfections has to be executed according to Table 3.2.

C. Radiographic Inspection

1. Radiographic sources and test classes

1.1 The radiographic examination upon welded pipe lines of copper-nickel-alloys has to be carried out according DIN 85004-9. X-rays is the preferable source for the radiographic examination upon the a.m. pipe lines. Test class B according to EN 444 is the basis. The maximum of the tube voltage can be increased by 50 kV, see Fig. 3.1.

1.2 In the case of repair where already installed pipes cannot be tested by x-rays because of access problems, the examination with gamma rays (e.g. Ir192 or Se75) according to test class B acc. to EN 444 is admissible. If the penetrated wall thickness is smaller than 10 mm, only Se75 is to be used.

1.3 If a further distance reduction is necessary because of access problems or for a central radiograph, one can examine the pipe with Se75 according to test class A, but the minimum of the optical density has to be increased up to $\geq 2.5$.

1.4 When taking radiographs with gamma rays, one has to make specimen radiographs because of the loss of sensitivity with regard to the source-film-distance according to test class B and A respectively.

1.5 Exposure time and film systems are to be chosen that way that the optical density according to 3. is achieved.

2. Film systems and intensifying screens

2.1 Class C3 and C4 films according to EN 584-1 are to be used. With regard to the tube voltage $U_r \leq 150$ kV C3 films and $U_r \geq 150$ kV respectively with Ir192 and Se75 C4 films are to be used.

2.2 Intensifying screens are to be chosen according to EN 444 in case of front intensifying screens (VF) or rear intensifying screen (HF). In case of tube voltage $U_r \leq 150$ kV, 0.02 mm front intensifying screens (VF) and rear intensifying screens (VF) and rear intensifying screens (HF) are preferably to be used.

2.3 One has to make sure that the films are very close to the screens (vacuum packaging).

3. Optical density, image quality and image quality indicator

3.1 Optical density

Following EN 444, an optical density of $\geq 2.0$ and in case of gamma rays of $\geq 2.3$ is required within the scope of radiographic images.

When using gamma ray sources acc. to test class A, the minimum of the optical density is 2.5.

3.2 Image quality indicator

The image quality has to be checked with image quality indicators (copper) acc. to EN 462-1 and be proven acc. to EN 462-3.

3.3 Stepped photometric absorption wedge

For evaluation of the radiographic films with regard to determine the excessive root respectively cover pass reinforcement the stepped photometric absorption wedge according to Fig. 3.2 has to be used.

Depending upon different test arrangements, flat and bend step wedges are to be used. The bend step wedge is to be arranged far from the film; the flat step wedge is to be arranged near the film (Fig. 3.3).

Step wedge (position 1 in Fig. 3.3) can also be arranged parallel to the weld seam, if it is additionally indicated by a lead letter “F” (F = near the film).
4. Test arrangements and film-focus distance (FFD)

The test arrangement has to follow the pictures I – IV (Fig. 3.4). Central radiographs for pipe nominal diameter from DN 100 are admissible. The respective FFDs depending upon the used focus shows Fig. 3.5. The film-focus distance for other test arrangements shall be taken from EN 444.

5. Scope of tests

Prior to sectioning, each butt weld test piece for welder’s and welding procedure qualification tests shall undergo a radiographic inspection over the entire length.

Butt welds at pipelines of the pipe class I are to be examined to 100%, those by pipelines of the pipe class II to 10%. The details are settled on GL Rules II – Materials and Welding, Part 3 – Welding, Chapter 3 – Welding in the Various Fields of Application, Section 4.

The tests of the welding seams on CuNiFe-pipelines for German navy ships are to be carried out according to a spot check inspection plan, see Table 3.3.

6. Evaluation of radiographs

The radiographs are to be evaluated according the following criteria:

Assessment of the radiographic images:
- Image quality acc. to EN 444 and EN 462-3, test class B respectively A
- Optical density (blackness) acc. to DIN 85004-9
- Is the used film in line with the required film system class acc. to EN 584-1 respectively the GL Rules II – Materials and Welding, Part 3, - Welding, Chapter 2 – Design, Fabrication and Inspection of Welded Joints, Annex C.
- Positioning of the step wedges

Evaluation of the imperfections in the welded joints:
- Admissible internal root reinforcement acc. to Table 3.1
- Imperfections of the weld seam acc. to Table 3.2 and Table 3.4

The evaluation of CuNiFe-radiographs regarding the permissible internal root reinforcement and existing weld imperfections may only be performed by trained persons with adequate practical experience. GL may require appropriate documentary proof of such training and experience.
Table 3.3  Spot check inspection plan according to DIN 85004-2

<table>
<thead>
<tr>
<th>N</th>
<th>n</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 8</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>9 to 15</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>16 to 25</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>26 to 50</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>51 to 90</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>91 to 150</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>151 to 280</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>281 to 500</td>
<td>50</td>
<td>5</td>
</tr>
</tbody>
</table>

1 Batch volume (number of the weld seams being presented at the same time)
2 Sample test volume (number of the weld seams being selected for the test).
3 Acceptance number (permissible number of the faulty weld seams).

Table 3.4  Permissible porosity

<table>
<thead>
<tr>
<th>Nominal wall thickness s mm</th>
<th>Weld joint thickness mm min.</th>
<th>Acceptable number of pores per 50 mm joint length for pore size 1</th>
<th>Nominal wall thickness s mm</th>
<th>Weld joint thickness mm min.</th>
<th>Acceptable number of pores per 50 mm joint length for pore size 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>over 0,3 up to 0,5</td>
<td></td>
<td></td>
<td>over 0,3 up to 0,5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>over 0,5 up to 1</td>
<td></td>
<td></td>
<td>over 1 up to 1,5</td>
</tr>
<tr>
<td>1,5</td>
<td>1,65</td>
<td>4</td>
<td>8</td>
<td>8,8</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>2,2</td>
<td>2</td>
<td>–</td>
<td>–</td>
<td>7</td>
</tr>
<tr>
<td>2,5</td>
<td>2,75</td>
<td>2</td>
<td>8</td>
<td>8,8</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>3,3</td>
<td>2</td>
<td>–</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td>3,5</td>
<td>3,85</td>
<td>2</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>4,4</td>
<td>3</td>
<td>10</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>5,5</td>
<td>4</td>
<td>–</td>
<td>–</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>6,6</td>
<td>2</td>
<td>–</td>
<td>12</td>
<td>4</td>
</tr>
</tbody>
</table>

1 The pore size is the maximum size of a pore detectable (projected) in the radiographic film.
2 Pore size up to 0,5 mm is ignored for wall thickness of 2 mm and above; pores up to 0,3 mm are not evaluated.

7. Digital radiography
If the weld seams of CuNiFe-pipelines shall be examined via the digital radiography and the use of memory foil or of detector, a GL approval is needed based on specially manufactured test specimens in order to validate the examination system.
Fig. 3.3 Test arrangements of image quality indicator and stepped photometric absorption wedge

1. Even stepped photometric absorption wedge
2. Bend stepped photometric absorption wedge

FFD: film-focus-distance
Test arrangement and film-focus distance (FFD) depending upon pipe's nominal diameters (DN)

Note:
In the application case IV instead of 2 irradiations (elliptic radiation), 4 individual radiographs are to be set up.

Test arrangement for central radiographies

**Fig. 3.4** Test arrangement and film-focus distances (FFD) depending upon the pipe's nominal diameters (DN) and test arrangement for central radiographies
Fig. 3.5 Film-focus distance (FFD) depending upon the pipe’s nominal diameters (DN) and upon the used focus

D. Hydrostatic Test

In presence of the Surveyor, finished pipe sections of pipe class I and II are to be subjected to a hydraulic pressure test according to GL Rules I – Ship Technology, Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations, Section 11. Generally, the test pressure is 1.5-fold of the design pressure. It is to be assured that the 0.2 % proof stress ($R_{p0.2}$) of the material is not exceeded during the test.
Section 4

Documentation of Approval, Assessment Forms and Certificates

1. Forms with regard to the shop approval, welder’s qualification test and procedure test can be found in the GL Rules II – Materials and Welding, Part 3 – Welding, Chapter 1 – General Requirements, Proof of Qualifications, Approvals, Annex A to D. These forms are also available in the internet under www.gl-group.com.

2. With regard to the approval for welding of military structure according to DIN 2303, the application form Annex B of the Standard has to be duly completed by the manufacturer.

3. The completed forms are to be submitted to the GL Head Office together with all necessary documents, e.g. welding procedure specification (WPS), test results, NDT-record, see also GL Rules II – Materials and Welding, Part 3 – Welding, Chapter 1 – General Requirements, Proof of Qualifications, Approvals, Section 2 (Shop approval), Section 3 (Welder’s qualification tests) and Section 4 (Welding procedure test).

4. If the stated requirements are fulfilled, an employee of the department „Materials and Welding“ will issue the according certificates – based upon the submitted documents, verified by the Surveyor.