



Guidelines for Classification and Construction

Part 9 Naval Ship Technology

Volume 5

Guidelines for Naval Ship Materials

2020

Biro Klasifikasi Indonesia



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The following Guidelines come into force on 1st July 2020.

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Foreword

With accumulation of experience and know-how practical application in shipbuilding, BKI have been developed this Guidelines for Naval Ship Materials (Pt.9, Vol.5) 2020 Edition intended for Naval Ship Technology.

These Guidelines accommodate technology, safety standards as basis for classification which consist of 9 Sections namely:

- Section 1 – General
- Section 2 – Steel Plates, Strips, Sections and Bars
- Section 3 – Steel Pipes
- Section 4 – Forgings
- Section 5 – Steel Castings
- Section 6 – Forgings of Wrought Copper Alloys
- Section 7 – Titanium and Titanium Alloys
- Section 8 – Non-Magnetizable Anchor Chain Cables and Accessories
- Section 9 – Non-Magnetizable Anchors

The whole processes of naval class business are pictured clearly on those sections.

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Further queries or comments concerning these Guidelines are welcomed through communication to BKI Head Office.

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Section 1 General

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A. Scope

These Guidelines represent a supplement to the [Rules for Materials \(Pt.1, Vol.V\)](#). The requirements mentioned therein shall be observed. This applies especially for the “Principles and Testing Procedures” mentioned in [Section 1 to 3](#) and the “General Rules” regarding the various materials and product shapes, as listed in [Section 4 to 8](#).

These Guidelines contain requirements for materials and their products which are primarily used for naval shipbuilding. However, they can also be applied to the utilization of such products in the civilian sector.

B. Abbreviations

The following abbreviations are used in this Guidelines :

AOD	Argon Oxygen Decarburization process
ASTM	American Society for Testing and Materials
MIL-S	Military Specification, Department of Defence, USA
SEW	Stahl–Eisen–Werkstoffblatt (Iron and Steel Material Specifications) Verlag Stahleisen GmbH, Postfach 105164, D-40042 Düsseldorf
VG	Verteidigungsgeräte Norm (German Standard for Military Technology Systems)
VOD	Vacuum Oxygen Decarburization process
VODC	Vacuum Oxygen Decarburization (converter) process
WL	Werkstoff Leistungsblatt (Material Performance Sheet of VG Standard)

C. Principles and Test Procedures

The requirements set out in [Section 1 to 2](#) of [Rules for Materials \(Pt.1, Vol.V\)](#) apply.

The following supplementary provision is also applicable :

1. Test of the Permeability

The relative permeability μ_r in both the delivery condition and in the cold-formed state of the steel shall be determined using a volumetric measurement method (e.g. ASTM A 342) in accordance with VG 95578.

To determine the influence of cold-forming on the relative permeability, the samples shall be finished in the intended delivery condition of the steel by stretching.

In the case of non-magnetizable materials, the relative permeability μ_r shall not exceed the value of 1,01.

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Section 2 Steel Plates, Strips, Sections and Bars

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A. Liquid Quenched and Tempered Structural Steels

1. Scope

These Guidelines are applicable to hot-rolled pressure hull and special plates up to a thickness of 150 mm, and to hot-formed or cold-formed bars and sections made of liquid quenched and tempered steels which are used for the construction of naval vessels and floating equipment. Rolled round bars intended for the manufacture of shafts, tie rods and bolts are subject to [Section 4, A](#). The application of these Guidelines to products with larger thicknesses shall be specially agreed with BKI.

Liquid quenched and tempered structural steels within the scope of these Guidelines include the grades KI-M550 (15NiCrMo10-6, WL 1.6780, HY-80), KI-M700 (16NiCrMo12-6, WL 1.6782, HY-100) and KI-M900 (HY-130) as well as equivalent liquid quenched and tempered structural steels. Pressure hull plates (DK) are flat products for the construction of ships' hulls and hull components that are subjected to diving pressure, and special plates (S) are flat products with limited excess weight.

Steels which diverge from these Guidelines, e.g. with regard to their nominal yield strength, their mechanical properties and their chemical composition, shall not be used without special approval from BKI.

2. Approval

The steels must be approved by BKI. For this purpose, the steel manufacturer shall send BKI a material specification containing the required information, such as chemical composition, manufacturing process, mechanical properties, condition of supply, as well as recommendations for welding, hot or cold forming, and heat treatment. BKI reserve the right to require initial approval testing.

The material manufacturer shall verify the weldability of each grade of steel by tests.

3. Requirements

3.1 Steelmaking process

The steels shall be manufactured in works approved by BKI using the AOD, VOD or VODC process, or using another process approved by BKI.

3.2 Chemical composition

The chemical composition shall satisfy the requirements stated in the authorized specification and in [Table 2.1](#). The limit values specified there apply to the melt analysis.

Elements used for alloying and fine grain treatment shall be indicated in the manufacturer's specification.

Table 2.1 Chemical composition of liquid quenched and tempered steels (ladle analysis)

Brief name	BKI Grade		C	Si	Mn	P	S	Cr	Mo	Ni	As	Cu	Sb	Sn	Ti	V
15NiCr Mo10-6	KI-M550	Min.	0,12	0,15 ¹⁾	0,1	–	–	1,0	0,20	2,00	–	–	–	–	–	–
		Max	0,18	0,35	0,4	0,015	0,008	1,8	0,60	3,25	0,025	0,25	0,025	0,03	0,02	0,03
16NiCr Mo12-6	KI-M700	Min.	0,12	0,15 ¹⁾	0,1	–	–	1,0	0,20	2,25	–	–	–	–	–	–
		Max	0,20	0,35	0,4	0,015	0,008	1,8	0,60	3,50	0,025	0,25	0,025	0,03	0,02	0,03
	KI-M900	Min.	–	0,15 ¹⁾	0,6	–	–	0,4	0,30	4,75	–	–	–	–	–	0,05
		Max	0,12	0,35	0,9	0,010	0,008	0,7	0,65	5,25	0,025	0,25	0,025	0,03	0,02	0,10

¹⁾ For vacuum-carbon deoxidization, Si_{min} = 0,05% shall apply.

To assess weldability, sensitivity to cold cracking (P_{cm}) may be calculated from the ladle analysis according to the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B \quad [\%]$$

The maximum permitted value shall be agreed with BKI and must be indicated in the authorized specification.

3.3 Heat treatment

The steels shall be supplied in the quenched and tempered condition. The minimum tempering temperature is 650 °C for thicknesses up to 60 mm and 635 °C for greater thicknesses for KI-M550. For KI-M700 it is 580 °C and for KI-M900 the minimum tempering temperature shall be in accordance with the manufacturers specification.

3.4 Mechanical Properties

The requirements applicable to the mechanical properties and the impact energy shall conform to the data in [Table 2.2](#).

3.5 General characteristics of products

[Rules for Materials \(Pt. I, Vol. V\), Sec. 4.A.5](#) applies in this regard. In addition, it should be noted that:

- procedures for repair welding and reporting thereon must be approved by BKI
- if defects are removed by grinding, the thickness remaining underneath the ground area shall be within the thickness tolerance

3.6 Dimensions; dimensional and geometrical tolerances

[Rules for Materials \(Pt. I, Vol. V\), Sec. 4.A.6](#) applies with the following addition:

For the minus tolerance applicable to the nominal thickness of pressure hull plates, the data according to class C, and for special plates according to class A in [Table 4.1](#) shall apply. In the case of special plates, the average thickness increase is additionally restricted by a limited maximum weight as per [Table 6](#) of EN10029.

Table 2.2 Mechanical and technological properties

Grade	Product shape	0,2% proof stress $R_{p0,2}$ [N/mm ²]	Yield strength ratio $R_{p0,2}/R_m$	Tensile strength R_m [N/mm ²]	Reduction in area Z [%]	Elongation A_5 [%]	Notched-bar impact test		
							Test temp. [°C]	KV [J]	
								long. min.	trans. min.
KI-M550	Plate	550 - 690	$\leq 0,90$	≥ 650	–	≥ 19	– 85	–	50
	Steel bar		$\leq 0,92$		≥ 55 (l) ≥ 50 (q)	≥ 20 (l) ≥ 18 (q)		68	40
	Section				≥ 60			–	95
KI-M700	Plate	685 - 835	$\leq 0,90$	≥ 760	–	≥ 17	– 85	70	70
	Steel bar		$\leq 0,92$		≥ 50 (l) ≥ 45 (q)	≥ 18 (l) ≥ 16 (q)		68	40
	Section				≥ 55			–	95
KI-M900	Plate	900-1035	–	–	–	≥ 11	– 20	–	55

(l) : longitudinal direction
 (q): transverse direction

4. Testing

4.1 Testing of chemical composition

The manufacturer shall determine the composition of every heat and shall issue the relevant certificate.

4.2 Tensile testing

From every piece heat-treated in a unit, at least one tensile test specimen shall be taken and tested. If plates are heat-treated by continuous processes, special arrangements may be made with regard to the number of tests required and the making of the test specimens.

In the case of pressure hull plates, a tensile test specimen shall be taken for each rolled length.

Test specimens shall be cut with their longitudinal axes transverse to the final direction of rolling, except in the case of sections and wide flats < 600 mm in width, where longitudinal test specimens shall be taken. For other product forms, the tensile test specimens may be taken in either the longitudinal or the transverse direction as agreed with BKI. Normally, flat tensile test specimens shall be used. The tensile-test specimens may be taken from the full or the half product thickness; however, one surface side of the product must be maintained. For thicknesses above 30 mm, round tensile test specimens may be used, the axis of which must lie at a distance of 1/4 of the product thickness from the surface.

4.3 Notched-bar impact test

From every piece heat-treated in a unit, or from each rolling length in the case of pressure hull plates, at least one set of three Charpy V-notch impact test specimens in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 2.E.2](#) shall be taken and tested. For continuous heat-treated plates, special consideration may be given to the number and location of test specimens required.

Unless otherwise accepted by BKI, the V-notch impact test specimens for plates and wide flats ≥ 600 mm shall be taken with their axes transverse to the main rolling direction. For other product forms, the impact tests shall be in the longitudinal direction. The specimens' axes must be positioned at a distance of 1/4 of the product thickness from the surface, or as near as possible to this position.

4.4 Through thickness tensile test

If required by BKI, through thickness tensile tests shall be performed by using test specimens taken at right angles to the surface of the product in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 4.I](#), "Steels with Through Thickness Properties".

4.5 Inspection of surface and dimensions

The manufacturer shall inspect the condition of the surface and the dimensions of the product and shall then present the products to BKI Surveyor for inspection.

4.6. Ultrasonic examination

If necessary for the envisaged use of the material, the manufacturer shall perform ultrasonic examinations in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 4.A.8.6](#).

4.7. Retests

If one of the tensile tests fails to meet the requirements, two additional test specimens shall be taken from the same position of the piece and subjected to the test. The piece will be accepted if both additional tests are satisfactory.

When the average value of the impact test fails to meet the requirements or more than one value is below the required average value or when one value is below 70 % of the specified average value, the procedure described in [Rules for Materials \(Pt. I, Vol. V\), Sec. 2.H](#). shall be followed.

5. Marking

Every finished piece shall be clearly marked by the maker in at least one place with BKI's stamp and the following particulars:

- manufacturer's mark
- unified identification mark for the grade of steel (e.g. KI-M550) or manufacturer's trade name
- heat number, plate number or equivalent identification mark

The entire set of markings shall be encircled with paint or otherwise highlighted so as to be easily recognized.

B. Non-Magnetizable Steels

1. Scope

These Guidelines are applicable to flat products, including pressure hull plates and special plates as well as sections and bars, made of non-magnetizable steels that are used for the construction of naval ships or floating equipment. Rolled round bars intended for the manufacture of shafts, arbors, pins and similar parts are subject to [Section 4, B](#). Pressure hull plates (DK) are flat products for the construction of ships' hulls and hull components that are subjected to diving pressure, and special plates (S) are flat products with limited excess weight.

2. Materials

Non-magnetizable steels are steels according to SEW 390 or comparable grades with relative permeability $\mu_r < 1,01$.

In addition plates, strips, bars and sections as per VG 81224 and VG 81237 can be utilized in accordance with the following material performance sheets (WL); see [Tables 2.3](#) and [2.4](#).

Table 2.3 Plates, strips and hollow sections

WL	Part	Steel
1.3914	1	X2CrNiMnMoNNb21-15-7-3
1.3951	1	X2CrNiMoN22-15
1.3952	1	X2CrNiMoN18-14-3
1.3964	1	X2CrNiMnMoNNb21-16-5-3
1.3974	1	X2CrNiMnMoNNb23-17-6-3

Table 2.4 Bars and sections

WL	Part	Steel
1.3914	2	X2CrNiMnMoNNb21-15-7-3
1.3951	2	X2CrNiMoN22-15
1.3952	3	X2CrNiMoN18-14-3
1.3964	2	X2CrNiMnMoNNb21-16-5-3
1.3974	2	X2CrNiMnMoNNb23-17-6-3

Steels which are intended for carrying liquefied gases, or for which a special chemical stability in relation to the cargo or operating fluids is required, must additionally comply with the requirements set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 4.F and 4.G](#).

BKI reserve the right to demand an approval test for the grade of steel in question.

3. Condition of supply and heat treatment

All products shall be presented in the heat-treated condition appropriate to the material, i.e. the steels must be solution-annealed and quenched. The steel grade X5NiCrTiMoV26-15 (1.3980) must be additionally artificially aged at 710 – 750 °C.

4. Dimensional tolerances

Unless stipulated otherwise in the order specification, plates shall be supplied in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 4.A.6.](#), Class B - [Table 4.1](#) (permitted thickness tolerance – 0,3 mm). For the minus tolerance applicable to the nominal thickness of pressure hull plates, the data according to class C and for special plates according to class A shall apply. In the case of special plates, the average thickness increase is additionally restricted by a limited maximum weight as per Table 6 of EN 10029. For all other products, the values stated in the relevant standards shall apply.

5. General condition of products

The provisions of [Rules for Materials \(Pt. I, Vol. V\), Sec. 4.A.5](#) shall apply. Surface defects may generally only be repaired by grinding.

In doing so, the relevant minus tolerance must not be exceeded at any point.

The rectification of surface defects by welding is not permissible.

The edges of the cut plates and strips shall be free of cracks.

For pressure hull plates, the permissible depth of rolled-in scale, depressions or other types of surface damage shall be limited to 0,20 mm, whereby the thickness at these points must not fall below the

nominal thickness. Isolated depressions of up to 0,40 mm are permissible, provided that the thickness at these points does not fall below the nominal thickness and the sum of these flawed areas is not larger than 15 % of the total area of one side of the plate. The defects exceeding 0,20 mm in depth must be remedied by grinding, whereby it must be ensured that the nominal thickness is maintained and the transitions are smooth.

For the surface condition of cold-rolled products, the provisions set out in Iron and Steel Material Specification SEW 390 shall apply.

6. Requirements applicable to material properties

6.1 Chemical composition

The limit values for the chemical composition stated in the standards or in the specifications approved by BKI shall apply.

For welded structures which cannot be heat treated after welding and for which resistance to intercrystalline corrosion is required, only stabilized austenitic steels or steels with carbon contents of $C \leq 0,03$ % shall be used.

6.2 Mechanical properties

The requirements applicable to the mechanical properties which are stated in the recognized standard or the approved material specification shall be verified during testing. If not defined in a different way the minimum value of the 0,2 % compression yield point shall be equivalent to the value of the 0,2 % proof stress.

6.3 Notch impact energy

The requirements applicable to the impact energy which are stated in the recognized standard or the approved material specification shall be satisfied.

7. Testing and scope of tests

The following tests shall be performed.

7.1 Testing of chemical composition

The manufacturer shall determine the chemical composition of each heat and issue the relevant certificate.

7.2 Testing of resistance to intercrystalline corrosion

All products shall be tested for resistance to intercrystalline corrosion. For this purpose, at least 2 specimens shall be taken from each heat. The test shall be performed in accordance with ISO 3651-2 on specimens in the following condition:

- stabilized steels and steels with a carbon content $\leq 0,03\%$: sensitized (annealed at 700 °C for 30 minutes and quenched in water)
- all other steels: in the condition in which they are supplied

Because of the alloy content, no demands can be made on the steel grades 1.3805, 1.3817, 1.3818, 1.3949 and 1.3962 with regard to their resistance against intercrystalline corrosion; the test shall be omitted for these steels.

7.3 Tensile testing

At least one tensile test specimen shall be taken from each test batch and tested. A test batch comprises for:

- plates > 20 mm thick: the rolled length
- plates ≤ 20 mm thick: max. 40 rolled plates of approximately the same thickness (deviation max. 20 %) originating from the same heat and the same heat treatment batch with a total weight not exceeding 30 t
- strip and plates taken therefrom: one specimen each from the beginning of the coil
- all other product shapes: 5000 kg for products of the same shape originating from the same heat and the same heat treatment batch
- in the case of pressure hull plates, a tensile test specimen shall be taken for each rolled length

In the case of plates and wide flats with a width of ≥ 300 mm, the specimens shall lie in the transverse direction. For all other product shapes, they may lie in the longitudinal or transverse directions.

7.4 Compression test

For pressure hull plates with a fabrication thickness ≥ 10 mm a compression test specimen shall be taken for each rolled length. The specimens shall be detached in longitudinal direction at a position with half distance between front face and middle axis. The detaching of specimens may also be in accordance with VG 81224. For the compression test DIN 50106 shall be used as guidance. Specimens with 10 mm diameter and 30 mm length have to be used. The front face of the specimens have to be lubricated with molybdenum sulfite.

7.5 Notched-bar impact test

Unless otherwise required by BKI or stipulated in the purchase order, a notched bar impact test with Charpy V-notch specimens is required for:

- flat products with a thickness > 20 mm
- rods and bars with diameters or thicknesses > 50 mm

If the products are used for operating temperatures below – 10 °C, the impact test temperature shall be agreed with BKI.

7.6 Testing of surface finish and dimensions

The surface finish and dimensions of all products shall be tested and checked by the manufacturer. The products shall also be presented to the BKI Surveyor for final testing. In the case of flat products, the underside shall also be inspected as far as possible.

7.7 Testing for use of correct material

The manufacturer shall test his products before delivery by appropriate methods as to whether the correct material has been used, and shall confirm this in the acceptance test certificate.

7.8 Testing the permeability

For each item or for each plate or strip of non-magnetizable steel, the relative permeability μ_r shall be determined on a metallic clean surface for both the delivery condition and the cold-formed state.

The relative permeability μ_r must not exceed the value of 1,01.

7.9 Other tests

If there are special requirements regarding resistance to pitting or crevice corrosion, appropriate corrosion tests shall be performed, e.g. according to ASTM-G48. The scope of these tests will be determined by BKI from case to case.

Section 3 Steel Pipes

A.	Pipes of Liquid Quenched and Tempered Structural Steels	3-1
B.	Pipes of Non-Magnetizable Steels.....	3-4

A. Pipes of Liquid Quenched and Tempered Structural Steels

1. Scope

These Guidelines apply to seamless and welded pipes made of liquid quenched and tempered structural steels that are intended for use in the construction of submarines, for example.

For this purpose, suitable pipes made of steel grades KI-M550, KI-M700 or comparable qualities shall be used, insofar as they fulfil the requirements mentioned in these Guidelines.

In the case of pipes intended for use in steam boilers, pressure vessels, equipment and pipelines at normal environmental temperatures as well as at elevated temperatures, the requirements set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.C](#). "High-Temperature Steel Pipes" shall apply in addition.

In the case of pipes intended for cargo-handling and processing equipment with design temperatures below 0 °C, the requirements set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.D](#). "Pipes Tough at Sub-Zero Temperatures" shall apply in addition.

2. Heat treatment

The pipes shall be supplied in quenched and tempered condition. The minimum tempering temperature is 580 °C. A subsequent heat treatment for stress relief is only permissible if expressly approved by BKI.

3. Dimensions, length-related dimensions (weights) and limit deviations

3.1 Dimensions

The outer diameters and wall thicknesses of the pipes shall be agreed when the order is placed; for hot-finished pipes preferably according to ISO 4200, and for cold-finished pipes preferably according to EN 10305-1 or EN 10305-3.

For the length types of the pipes, [Table 3.1](#) shall apply:

Table 3.1 Length types and tolerances of the pipes

Length type		Tolerances [mm]
Random length ¹⁾		1
Fixed length		± 500
Exact lengths	≤ 6m	- 0 to +10
	> 6m, but ≤ 12m	- 0 to +15
	> 12m	By arrangement
¹⁾ The pipes are delivered in the lengths occurring during manufacture. These lengths vary according to diameter, wall thickness and manufacturing works, and must be stated by the manufacturer.		

3.2 Tolerances

The tolerances for the outer diameter d_a of the hot-finished pipes are as follows:

- $d_a \leq 50$ $\pm 0,5$ mm
- $50 < d_a \leq 160$ ± 1 %
- $160 < d_a \leq 200$ $\pm 1,6$ mm
- $d_a > 200$ $\pm 0,8$ %

At points where the surface of the pipes was remedied through mechanical processing, e.g. grinding, it is permissible to exceed the limit value of the diameter to a minor extent, provided the remaining wall thicknesses still complies with requirements.

The limit deviations for the wall thicknesses of the hot-finished pipes are $-12,5\%$, whereby the upper limit is given by the permissible weight deviation for a single pipe, see 3.5.

By agreement when the order is placed, the tolerance for the diameter of hot-finished pipes with $d_a > 200$ mm can also be referred to the inner diameter.

When the order is placed for cold-finished pipes, the tolerances according to EN 10305-1 or EN 10305-3 apply for the outer and inner diameters as well as for the wall thicknesses.

By agreement when the order is placed, the hot-finished and cold-finished pipes can also be delivered with closer tolerance for the outer diameter and wall thickness.

3.3 Shape

3.3.1 Roundness tolerance

The pipes should be as cylindrical as possible. The roundness tolerance shall lie within the tolerances for the outer diameter.

3.3.2 Straightness tolerance

The hot-finished pipes shall appear straight to the eye. For cold-finished pipes, EN10305-1 or EN10305-3 shall apply. Special requirements can be agreed for the straightness tolerance.

3.4 Finish of the pipe ends

The pipe ends should be cut off at right angles to the pipe axis.

Deburring can be agreed when the order is placed.

3.5 Length-related dimensions (weights) and limit deviations

For calculating the weights of the steels to which this section is applicable, a density of $7,85$ kg/dm³ is assumed.

The values for the length-related dimensions (weights) are given in ISO 4200.

The following limit deviations are permissible:

- 8 to +12 % for a single pipe
- 5 to +10 % for a consignment of at least 10 t.

4. Requirements applicable to the material

4.1 Chemical composition

The chemical composition of the pipe steels must conform to the approved standards or specifications. The chemical composition of the BKI grades is given in [Section 2, Table 2.1](#).

4.2 Mechanical properties

The required values of tensile strength, 0,2 % proof stress, elongation and impact energy must be satisfied in tests performed in accordance with the standard or the recognized specification, see [Table 3.2](#).

Table 3.2 Mechanical properties of the pipes according to BKI grades

Grade	0,2% proof stress $R_{p0,2}$ [N/mm ²]	Yield strength ratio $R_{p0,2}/R_m$	Tensile strength R_m [N/mm ²]	Elongation A_5 [%]	Notched-bar impact test KV at -20°C [J] min.
KI-M550	550-690	≤ 0,92	≥ 650	≥ 19	95
KI-M700	685-835	≤ 0,95	≥ 760	≥ 15	

4.3 Technological properties

When subjected to the ring tests, the pipes must display a capacity for deformation which meets the requirements specified in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.5](#).

5. Testing and scope of tests

The following tests shall be performed:

5.1 Testing of chemical composition

The chemical composition of each heat shall be determined by the pipe manufacturer, or, where appropriate in the case of welded pipes, by the manufacturer of the starting material in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.1](#).

5.2 Tensile testing

Specimens of the sample pipes selected in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.2](#) shall be subjected to the tensile test.

5.3 Notched-bar impact test

For the pipes selected in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.2](#), the notched bar impact test shall be performed on Charpy V-notch specimens. Where the wall thickness is > 30 mm, the specimens shall be so located that their longitudinal axis lies ¼ of the pipe wall thickness from the outer surface, or as close as possible to this point.

The samples shall be so taken and tested that the notch axis lies at right angles to the pipe surface.

5.4 Technological test

Unless more extensive testing is prescribed in the standards, one of the ring tests specified in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A, Table 5.1](#) shall be performed on one end of 2 % of the pipes. To

calculate the distance between the platens to be used in the ring flattening test, a value of 0,06 for KI-M550 and 0,05 for KI-M700 shall be assigned to the constant C in the formula given in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.5.2](#).

5.5 High-temperature tensile test

Where called for in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.3](#) or stipulated in the purchase order, the 0,2 % or 1 % proof stress shall be determined by the high-temperature tensile test.

5.6 Testing of surface finish and dimensions

The tests shall be performed according to [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.6](#).

5.7 Non-destructive testing

The welds of all welded pipes shall be subjected by the manufacturer to non-destructive testing over their entire length, cf. [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.7](#)

For radiographic inspections, see [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.D.4.7.2](#).

5.8 Tightness test

All pipes shall be tightness tested by the manufacturer in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.8](#).

B. Pipes of Non-Magnetizable Steels

1. Scope

These Guidelines are applicable to seamless and welded pipes of non-magnetizable steels intended for pipeline construction as well as for tanks and equipment for which non-magnetizability is required. Suitable pipe grades as per SEW 390, and conforming to the material performance sheets WL 1.3964-6 or other examined and approved specifications, are appropriate for these applications.

Pipes which are intended for cargo-handling and processing equipment with design temperatures below 0 °C, or for which a special chemical stability in relation to the cargo or operating fluids is required, must additionally comply with the requirements set out in [Rules for Materials \(Pt. I, Vol. V\), Section 5.D and 5.E](#).

2. Heat treatment

The pipes shall be supplied in the solution-annealed and quenched condition. The requirement for proper heat treatment is deemed to have been met for hot-pressed pipes if they were quenched in water after removal from the solution-annealing temperature zone.

Pipes made of X5NiCrTiMoV26-15 (1.3980) shall be artificially aged at 710 to 750 °C after the quenching.

3. Requirements applicable to the material

3.1 Chemical composition

The chemical composition of the pipe steels must conform to recognized standards or specifications.

Where pipes are to be resistant to intercrystalline corrosion in the delivery state and where the welding is not to be followed by heat treatment (solution annealing), only those pipe grades may be used which are corrosion-resistant in the welded condition, e.g. steels stabilized with Ti or Nb or steels with carbon contents of $C \leq 0,03$ %.

3.2 Mechanical properties

The required values of tensile strength, 0,2 % proof stress and elongation must be satisfied in tests at room temperature in accordance with the standard or the recognized specification.

3.3 Technological properties

When subjected to the ring tests, the pipes must display a capacity for deformation which meets the requirements specified in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.5.](#)

3.4 High-temperature characteristics

Where pipes are used at elevated temperatures, the required values for the 0,2 % or 1 % proof stress prescribed in the relevant standards or recognized specifications must be met at the corresponding temperature level, unless otherwise stipulated by BKI.

3.5 Testing the permeability

The pipes must be tested for their relative permeability.

3.6 Notch impact energy

The required impact energy values must be satisfied in tests at room temperature in accordance with the relevant standard or the recognized specification.

4. Testing and scope of tests

The following tests shall be performed:

4.1 Testing of chemical composition

The chemical composition of each heat shall be determined by the pipe manufacturer.

4.2 Testing of resistance to intercrystalline corrosion

Depending on the application and grade of the pipes, a test of resistance to intercrystalline corrosion shall be performed on the following pipes:

- pipes for use on submarines irrespective of the type of material
- pipes which do not meet the requirements in respect of stabilization or limited carbon content specified in [3.1](#)
- pipes made of stabilized steels or steels with limited carbon contents intended not for application on submarines, where such testing is specially prescribed in view of the anticipated corrosive attack.

The test conditions shall be as prescribed in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.D.4.2.2.](#)

4.3 Tensile testing

Specimens of the sample pipes selected in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.3](#) shall be subjected to the tensile test.

4.4 Technological test

Unless more extensive testing is prescribed in the standards, one of the ring tests specified in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A, Table 5.1](#) shall be performed on one end of 2 % of the pipes. To calculate the distance between the plates to be used in the ring flattening test, a value of 0,10 shall be assigned to the constant C in the formula given in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.5.2](#).

4.5 High-temperature tensile test

Where called for in [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.3](#) or stipulated in the purchase order, the 0,2 % or 1 % proof stress shall be determined by a high-temperature tensile test.

4.6 Testing of surface finish and dimensions

The tests shall be performed according to [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.6](#).

4.7 Tightness test

All pipes shall be tightness tested by the manufacturer in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 5.A.8.8](#).

4.8 Testing the permeability

For each pipe of non-magnetizable steel, the relative permeability μ_r shall be determined on a metallic clean surface for both the delivery condition and the cold-formed state.

The relative permeability μ_r must not exceed the value of 1,01.

Section 4 Forgings

A.	Forgings of Liquid Quenched and Tempered Structural Steels.....	4-1
B.	Forgings of Non-Magnetizable Steels	4-4

A. Forgings of Liquid Quenched and Tempered Structural Steels

1. Scope

These Guidelines are applicable to forgings made of liquid quenched and tempered structural steels of the grades KI-M550S (1.6780, HY-80), KI-M700S (HY-100) and KI-M900S (HY-130) as well as of equivalent liquid quenched and tempered structural steels with a heat-treated wall thickness up to 400 mm that are used for the construction of naval vessels and floating equipment.

These Guidelines are also applicable to rolled steel bars, where they are to be used in place of forgings for the manufacture by machining of shafts, arbours, pins and similar parts.

2. Manufacturing process

The steels shall be manufactured in works approved by BKI using the AOD, VOD or VODC process, or using another process approved by BKI.

In deviation to the stipulations set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 6.A.4.5](#), forgings made of liquid quenched and tempered structural steels shall exhibit a minimum degree of deformation of 2:1.

3. Delivery condition

The steels shall be supplied in the quenched and tempered condition. The tempering temperature must lie above 635 °C (KI-M550S), above 610 °C (KI- M700S) or above 540 °C (KI-M900S).

4. Surface finish

Depending on the purchase order, the forgings shall be delivered as unmachined, rough machined or final machined.

Workpieces to be delivered as unmachined should exhibit a smooth surface corresponding to the manufacturing process.

Manufacture-related surface imperfections at unmachined points are permitted if their depth lies within the machining allowance.

For rough machined surface areas, the permissible depth of the imperfections must be agreed upon.

Imperfections within the permissible depth can be removed by grinding.

The surfaces of finish-machined forgings shall not exhibit any cracks.

5. Dimensions, shape, weight

The dimension standards stipulated in the purchase orders or appended drawings shall be applicable for the dimensions and the shape.

For the determination of weight, a density of 7,85 g/cm³ shall apply.

6. General requirements applicable to the material

The chemical composition, the mechanical properties and the hardness shall conform to the data contained in these Guidelines, the relevant standards or the approved specifications.

7. Testing

To provide proof of compliance with the technical requirements, the tests specified below shall be carried out on the completed forging (delivery condition). The results shall be documented.

7.1 Chemical composition

The chemical composition is characterized by means of the ladle analysis. The manufacturer shall determine the proportions of all the elements specified in Table 4.1 by applying the usual methods.

Table 4.1 Chemical composition of liquid quenched and tempered forging steels

Brief name	KI grade		C	Si	Mn	P	S	Cr	Mo	Ni	As	Cu	Sb	Sn	Ti	V
15NiCr Mo10-6	KI - M550S	Min.	0,12	0,15 ¹⁾	0,10	-	-	1,0	0,20	2,00	-	-	-	-	-	-
		Max.	0,18	0,35	0,40	0,015	0,008	1,80	0,60	3,25	0,02	0,25	0,02	0,03	0,02	0,05
16NiCr Mo12-6	KI - M700S	Min.	0,12	0,15 ¹⁾	0,10	-	-	1,35	0,30	2,75	-	-	-	-	-	-
		Max.	0,20	0,35	0,40	0,015	0,008	1,80	0,60	3,50	0,02	0,25	0,02	0,03	0,02	0,03
-	KI - M900S	Min.	-	0,20 ¹⁾	0,60	-	-	0,40	0,30	4,75	-	-	-	-	-	0,05
		Max.	0,12	0,35	0,90	0,010	0,008	0,70	0,65	5,25	-	0,25	-	-	0,02	0,10

¹⁾ For vacuum-carbon deoxidization, Si_{min} = 0,05% shall apply.

7.2 Mechanical properties

The requirements for the mechanical properties are given in Table 4.2.

Table 4.2 Mechanical properties

Grade	0,2% proof stress R _{p0,2} [N/mm ²]	Yield strength ratio R _{p0,2} /R _m	Reduction in area [%]	Elongation A5 [%]	Notched-bar impact test (transv. or tangential) KV [J] ¹⁾
KI-M550S	550-680	≤ 0,95	≥ 55 (l) ≥ 50 (q)	≥ 20 (l) ≥ 18 (q)	≥ 85 (at -20°C) ≥ 70 (at -85°C) ²⁾
KI-M700S	690-795		≥ 50 (l) ≥ 45 (q)	≥ 18 (l) ≥ 16 (q)	≥ 85 (at -20°C) ≥ 70 (at -85°C) ³⁾
KI-M900S	900-1000		≥ 50	≥ 15	≥ 75 (at -20°C)

¹⁾ Average value of 3 samples; the smallest single value must be at least 90 % of the minimum average value.
²⁾ 40 J for wall thicknesses > 150 mm
³⁾ 40 J for wall thicknesses > 100 mm
 (l) : longitudinal direction
 (q) : transverse direction

7.2.1 Tensile testing

The mechanical properties shall be verified by tensile testing. For preparing the test specimens, forgings with similar dimensions and nominal weights up to 500 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 6.A.10.2, Table 6.1](#).

Two samples shall be taken from each test batch. One specimen is sufficient for:

- quantities of forgings ≤ 10
- quantities of forgings ≤ 30 if the weight of the forgings does not exceed 15 kg.

For batchwise testing, the hardest and softest forgings in each batch shall be selected for testing ([see 7.2.3](#)).

In the case of forgings with unit weights of more than 500 kg, a test specimen shall be taken from every forging. When the length of such forgings, excluding test metal, exceeds 2 m, a test specimen shall be taken from each end of the forging.

7.2.2 Notched-bar impact test

The forgings shall be subjected to the notched bar impact test using Charpy V-notch specimens. The number of sets of test specimens (3 specimens per set) shall be determined in the same way as the number of tensile test specimens. Unless agreed otherwise, the notched bar impact test shall be carried out at $-20\text{ }^{\circ}\text{C}$.

The notch shall be made perpendicularly to the surface of the forging.

7.2.3 Hardness test

Each forging in the quenched and tempered condition shall be subjected to a hardness test.

7.3 Dimensions, shape and weight examination

The dimensions and shapes shall be examined according to the relevant drawings and/or standards.

The weight shall be determined by weighing.

7.4 Test of surface finish

An examination must be carried out to ascertain whether the surface finish stipulated in the purchase order has been attained and whether the requirements set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 6.A.6](#) have been observed. The determination of the crack depth is performed as chosen by the manufacturer.

7.5 Testing of the internal condition

The test shall be carried out in compliance with the requirements set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 6.H.6](#).

For the test, the surface of the forgings shall be descaled and the surface finish shall be adapted to meet the required accuracy of indication.

7.6 Identification

The forgings shall be tested to ascertain whether the correct material has been used.

7.7 Marking test

The markings shall be examined for correctness.

B. Forgings of Non-Magnetizable Steels

1. Scope

These Guidelines are applicable to bars, open-die forgings and drop forgings as well as to seamless rolled rings of non-magnetizable steels intended for the construction of naval vessels and floating equipment.

They are also applicable to rolled steel bars, where it is to be used in place of forgings for the manufacture by machining of shafts, arbors, pins and similar parts.

2. Permissible materials and delivery conditions

The following materials may be used:

- forging steels as per SEW 390
- materials listed in the Material Handbook of Military Technology¹ in accordance with the material performance sheets (WL) listed in [Table 4.3](#)
- other materials approved by BKI according to other standards or specifications

The required delivery condition shall be stipulated by the customer in the purchase order.

In the case of forgings intended for the manufacture of flanges, nozzles, valve housings, socket welding and welding neck components for boilers, pressure vessels, equipment and pipelines or for design temperatures below 0 °C, the requirements set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 6.E and 6.F](#) shall be observed in addition.

Table 4.3 Materials of forgings of non-magnetizable steels

WL	Part	Material
1.3914	2, 3	X2CrNiMnMoNNb21-15-7-3
1.3951	2, 3	X2CrNiMoN22-15
1.3952	3, 4	X2CrNiMoN18-14-3
1.3964	2, 3, 6	X2CrNiMnMoNNb21-16-5-3
1.3974	2, 3, 6	X2CrNiMnMoNNb23-17-6-3

3. Surface finish

The surface of the forgings shall comply with the agreements made on placing the order and the requirements set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 6.A.6](#).

4. External and internal defects

All products shall be delivered without defects, which could impair the useability.

Surface defects on unmachined products shall be removed by mechanical processing within the tolerances.

¹ Material Handbook of Military Technology, DIN – Deutsches Institut für Normung e.V., Berlin

During the removal of local defects the transitions must be smooth. The radius of the transition shall be at least three times the depth.

Cracks at rough-machined and final-machined forgings are not permissible.

For the non-destructive tests, the prerequisites relating to the relevant testing method and those applying to the external condition of the products must be fulfilled. In addition a subdivision into testing zones shall be undertaken and statements on the acceptance level (quality class according to EN 10228) shall be made when the order is placed; the corresponding agreements on the basis of [Rules for Materials \(Pt. I, Vol. V\)](#), [Sec. 6.H](#) shall be concluded.

If necessary, agreements can be concluded regarding the remedial work on surface flaws on the basis of EN 10163-3 and ISO 9443.

5. Dimensions and shape

The dimension standards stipulated in the purchase order or the appended drawings shall be applicable for the dimensions and the shape.

6. Requirements applicable to the material

6.1 General requirements

The chemical composition, the mechanical properties and the hardness shall conform to the data contained in the relevant standards or approved specifications.

6.2 Resistance to intercrystalline corrosion

All steel grades shall be resistant to intercrystalline corrosion in the condition in which they are supplied.

If forgings for welded assemblies are to be used without post-weld heat treatment, steel grades which are corrosion-resistant in this condition shall be chosen, e.g. steels stabilized with Ti or Nb or steels with carbon contents of $C \leq 0,03$ %.

Because of the alloy content, no demands can be made on the steel grades 1.3805, 1.3817, 1.3818, 1.3949 and 1.3962 with regard to their resistance against intercrystalline corrosion; the test shall be omitted for these steels.

7. Acceptance test

To verify compliance with the technical requirements, the tests listed below shall be performed. The results shall be documented.

7.1 Chemical composition

The chemical composition is characterized by means of the ladle analysis. The manufacturer shall determine the proportions of all the elements specified in the approved standard or specification by applying the usual methods. For the permissible deviations of the chemical composition according to the product analysis from limit values according to the ladle analysis, SEW 390 shall apply.

7.2 Testing of resistance to intercrystalline corrosion

The manufacturer shall check the resistance to intercrystalline corrosion of steel forgings intended for welded assemblies and – where stipulated in the purchase order – of other austenitic steels as well. Testing shall be carried out in the following conditions:

- steels containing $C \leq 0,03 \%$ and stabilized steels: after sensitizing heat treatment (700 °C, 30 min., quenching in water)
- all other steels: in the condition in which they are supplied. At least two specimens from each heat shall be tested in accordance with ISO 3651-2

7.3 Tensile testing

The mechanical properties shall be verified by tensile testing. For preparing the test specimens, forgings with similar dimensions and nominal weights up to 500 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 6.A.10.2, Table 6.1.](#)

Two samples shall be taken from each test batch. For quantities of ≤ 10 - and ≤ 30 in the case of nominal weights not exceeding 15 kg - one specimen is sufficient.

In the case of forgings with unit weights of more than 500 kg, a test specimen shall be taken from every forging. When the length of such forgings, excluding test metal, exceeds 2 m, a test specimen shall be taken from each end of the forging.

7.4 Permeability test

The permeability shall be tested according to VG 95578 on a metallic clean surface.

7.5 Identification

The products shall be tested for correct material by spectroscopy or an equivalent method.

7.6 Dimension and shape examination

The dimensions and shapes shall be examined according to the relevant standards and/or drawings.

7.7 Test of surface finish

A test shall be performed to ascertain whether the surface finish stipulated in the material specification or in the purchase order has been attained.

The surface crack test shall be carried out by applying non-destructive testing methods in a surface condition that is suitable for the method. Depending on the product, the following can be applied:

- visual inspection
- dye penetrant method

7.8 Testing of the internal condition (ultrasonic test)

Products with a nominal weight of over 300 kg shall be examined by ultrasonic test on the basis of [Rules for Materials \(Pt. I, Vol. V\), Sec. 6.A.10.4.](#) for the internal condition under the testing conditions specified in the purchase order.

Section 5 Steel Castings

A.	Liquid Quenched and Tempered Steel Castings.....	5-1
B.	Non-Magnetizable Steel Castings	5-4

A. Liquid Quenched and Tempered Steel Castings

1. Scope

These Guidelines are applicable to statical and centrifugal castings made of liquid quenched and tempered cast steel grades intended for the construction of naval ships and floating equipment.

2. Grades of liquid quenched and tempered steel castings

Liquid quenched and tempered steel casting grades are quenched and tempered steels alloyed with nickel, chromium and molybdenum, the carbon content of which is so adjusted that, on the one hand, a martensitic-bainitic structure is produced on hardening in water or oil, ensuring high strength at the same time as very high toughness and, on the other hand, impairment of the component quality during hardening is reliably prevented. Liquid quenched and tempered steel casting grades in the sense of these Guidelines include, for example:

- the BKI quality grades KI-M550G, KI-M650G and KI-M700G
- G14NiCrMo10-6 (1.6779) and G17NiCrMo13-6 (1.6781) as per SEW 520
- G15NiCrMo10-6 as per WL 1.6786
- G16NiCrMo12-6 as per WL 1.6787
- G12NiMoCr17-4 as per WL 1.6788
- HY80 and HY100 as per MIL-S-23008
- G17NiCrMo13-6 as per EN 10213-3

In each case, these grades or others approved by BKI must meet the requirements set out in 3.

3. Technical requirements

3.1 Steel-making process

The steels shall be manufactured in works approved by BKI using the AOD, VOD or VODC process, or using another process approved by BKI.

3.2 Chemical composition

The chemical composition shall satisfy the requirements stated in the approved specification and in [Table 5.1](#).

In addition, the maximum content of other elements must not exceed the values given in [Table 5.2](#).

3.3 Heat treatment

The castings shall be subjected to annealing with a transformation of the primary structure and to quenching and tempering, in accordance with the data given in the approved specifications or as per [Table 5.3](#). The details of the heat treatment shall be determined by the manufacturer. All individual steps of the heat treatment process must be documented.

Table 5.1 Chemical composition of liquid quenched and tempered cast steel grades [%]

Brief name	KI grade		C	Si	Mn	Cr	Mo	Ni
G15NiCrMo10-6	KI-M550G	Min.	0,12	-	0,55	1,20	0,45	2,70
		Max.	0,18	0,35	0,70	1,80	0,55	3,20
G12NiMoCr17-4	KI-M650G	Min.	0,09	-	0,30	0,20	0,20	4,00
		Max.	0,14	0,35	0,60	0,50	0,40	4,50
G16NiCrMo12-6	KI-M700G	Min.	0,15	-	0,55	1,30	0,45	3,00
		Max.	0,19	0,35	0,70	1,80	0,55	3,50

Table 5.2 Maximum content of other elements in steel castings

Element	P	S	Al	As	Cu	N	Sb	Sn	Ti	V
Max. content [%]	0,010	0,008	0,04	0,015	0,20	0,01	0,010	0,020	0,020	0,030

Table 5.3 Data for heat treatment

Grade	Annealing		Quenching and tempering ¹⁾		
	Heating Temp.	Cooling	1st hardening	2nd hardening	Tempering ²⁾
KI-M550G	900-950 °C	Furnace until 700°C/ furnace	850-900°C/ water ³⁾	-	640-680 °C/ water
KI-M650G	930 °C	Air	850°C/water	850 °C/ water	550-570 °C/ water
KI-M700G	930-960 °C	Air	850-900°C/water	850-900 °C/ water	600-630 °C/ water

¹⁾ Repeated quenching and tempering is permissible
²⁾ Minimum duration 5 hours
³⁾ For wall thicknesses ≤ 30 mm, oil hardening is recommended

3.4 Mechanical properties

The requirements applicable to the mechanical properties and the impact energy shall conform to the data given in [Table 5.4](#) or to the recognized standards or approved specifications.

Table 5.4 Mechanical and technological properties

Grade	0,2% proof stress R _{p0,2} [N/mm ²]	Yield strength ratio R _{p0,2} /R _m	Tensile strength R _m [N/mm ²]	Hardness [HB]	Reduction in area [%]	Elongation A5 [%]	Notched bar impact test at -85 °C KV[J] min.
KI-M550G	550-690	≤ 0,90	650-800	200-255	≥ 50	≥ 18	50
KI-M650G	≥ 650		≥ 770	225-280	≥ 60	≥ 16	130
KI-M700G	≥ 690		770-900	240-310	≥ 40	≥ 16	75

3.5 External and internal condition

Depending on the quality requirements, the external and internal condition shall conform to the severity levels as per [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.G.](#)

For the test, the castings can be subdivided into testing zones with different requirements regarding their quality levels. The subdivision is based on one or more of the following principles:

- operating loads to be expected
- effect of defects on the component safety
- possible risk of damage on failure of the component
- required welding reliability at the intersections
- necessary freedom from defects after machining

If the evaluation is carried out according to other standards, the requirements shall be equivalent to those specified in the BKI Rules.

3.5.1 Severity levels

For the admissibility of external and internal imperfections in castings, the provisions set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.G.3.](#) apply.

3.5.2 Surface finish

The surface finish of the castings must permit the execution and evaluation of the prescribed non-destructive tests.

In the areas that are not machined, the castings must be freed from their casting skin completely – as far as is technically possible - by grinding. The surface quality to be achieved thereby should comply with reference sample 4 S 2 of Technical Recommendation No. 359-01¹. In the area of the welding edges, the surface quality must comply with reference sample 2 S 2. The welding edges shall be stated in the casting drawing.

The width of the welding edges shall be $1,5 \times$ the wall thickness.

4. Testing

The castings shall be presented for testing in the finished condition (delivery condition) and shall undergo the following tests. In the case of castings intended for steam boilers, [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.D.6.](#) Casting of safety class I shall be tested individually.

4.1 Tensile testing

The mechanical properties shall be verified by tensile testing. The tests shall be performed on a heat-by-heat basis, parts undergoing the same heat treatment being grouped into test batches in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.A.10.2.2.](#) A tensile test specimen shall be taken from each test batch and tested. Castings with unit weights > 1000 kg shall be tested individually.

4.2 Notched-bar impact bending test

The castings shall be subjected to the notched bar impact test. The number of sets of test specimens (3 Charpy V-notch specimens per set) shall be determined in the same way as the number of tensile test specimens.

¹ Bureau de Normalisation des Industries de la Fonderie, France

4.3 Hardness test

All quenched and tempered steel castings which are tested on a heat-by-heat basis shall be subjected to a comparative hardness test. The result of the hardness test shall show that quenching and tempering has been carried out homogeneously (the difference in hardness between the hardest and the softest tested component in the test batch shall not exceed 30 HB).

4.4 Non-destructive testing

The manufacturer shall ensure by non-destructive tests on his products that the requirements pertaining to the external and internal condition according to 3.5 are met. Furthermore, the rules set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.A.10.4](#) shall be observed.

B. Non-Magnetizable Steel Castings

1. Scope

These Guidelines are applicable to steel castings made of non-magnetizable steels which are used for the construction of naval vessels and floating equipment.

2. Suitable grades of casting

The following, or comparable, grades of casting with a relative permeability $\mu_r < 1,01$ may be used, provided that they meet the requirements of 6.:

- non-magnetizable casting steel as per SEW 395
- other non-magnetizable casting steels conforming to other standards or specifications, after their suitability has been established by BKI. An initial test of product suitability on the manufacturer's premises may be required for this purpose.
- the non-magnetizable cast steel grades according to [Table 5.5](#).

Table 5.5 Materials for non-magnetizable steel castings in accordance with WL

WL	Part	Steel
1.3940		G-X2CrNiN18-13
1.3952	2	G-X2CrNiMoN18-14-3
1.3955		G-X12CrNi18-11
1.3964 ¹⁾	4	G-X2CrNiMnMoNNb21-16-5-3

¹⁾ The material no. for cast steel grade WL 1.3964-4 is 1.3967

3. Selection of the grades of cast steel

Non-magnetizable casting steels which are intended for cargo-handling and processing equipment with design temperatures below 0 °C, or for which a special chemical stability in relation to the cargo or operating fluids is required, must additionally comply with the requirements for castings set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.E. "Steel Castings for Use at Low Temperatures"](#) and [F. "Stainless Steel Castings"](#).

4. Heat treatment and delivery condition

All steel castings shall be supplied in a heat-treated condition appropriate to the grade of cast steel, i.e. they must be solution-annealed and quenched in water.

5. External and internal condition

5.1 Basic requirements

Depending on the quality requirements, the external and internal condition shall conform to the quality levels as per [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.G](#).

For testing of internal condition there should be used the radiographic inspection. In view to ultrasonic inspection special agreements have to be met.

For the test, the castings can be subdivided into testing zones with different requirements regarding their quality levels. The subdivision is based on one or more of the following principles:

- operating loads to be expected
- effect of defects on the component safety
- possible risk of damage on failure of the component
- required welding reliability at the intersections
- necessary freedom from defects after machining

If the evaluation is carried out according to other standards, the requirements shall be equivalent to those specified in [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.G](#).

5.2 Severity levels

For the admissibility of external and internal imperfections in castings, the provisions set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.G.3](#) apply.

5.3 Surface finish

The surface finish of the castings must permit the execution and evaluation of the prescribed non-destructive tests.

In the areas that are not machined, the castings must be freed of their casting skin completely - as far as is technically possible - by grinding.

6. Requirements applicable to the material

6.1 Chemical composition

The limits stated in the standards and/or the specifications approved by BKI are applicable.

6.2 Resistance to intercrystalline corrosion

All grades of cast steel shall be resistant to intercrystalline corrosion in the condition in which they are supplied. If it is intended to weld castings without post-weld heat treatment, only grades of cast steel that are corrosion-resistant in this condition shall be used, e.g. cast steels stabilized with Nb or containing not more than 0,03 % C.

Because of the alloy content, no demands can be made on the steel grades 1.3802 and 1.3966 with regard to their resistance against intercrystalline corrosion; the test shall be omitted for these steels.

6.3 Mechanical properties and impact energy

The requirements specified in the standards or in the approved specifications are applicable.

7. Testing

The castings shall be presented for testing in the finished condition (delivery condition) and shall undergo the following tests:

7.1 Tensile testing

The mechanical properties shall be verified by tensile testing. The tests shall be performed on a heat-by-heat basis, parts undergoing the same heat treatment being grouped into test batches in accordance with [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.A.10.2.2](#). A tensile test specimen shall be taken from each test batch and tested. Castings with unit weights > 1000 kg shall be tested individually.

7.2 Notched-bar impact test

The castings shall be subjected to the notched bar impact test. The number of sets of test specimens (3 Charpy V-notch specimens per set) shall be determined in the same way as the number of tensile test specimens.

7.3 Test of resistance to intercrystalline corrosion

The manufacturer shall check the resistance to intercrystalline corrosion of austenitic steel castings intended for welded assemblies and – where stipulated in the order – of other austenitic steels as well. Testing shall be carried out in the following conditions:

- steels containing $C \leq 0,03 \%$ and stabilized steels: after sensitizing heat treatment (700 °C, 30 minutes, quenching in water)
- all other steels: in the condition in which they are supplied. At least two specimens from each heat shall be tested in accordance with ISO 3651-2. The test shall be confirmed by the manufacturer by means of a certificate.

7.4 Non-destructive testing

The manufacturer shall ensure by non-destructive tests on his products that the requirements pertaining to the external and internal condition according to [A.3.5](#) are met. Furthermore, the rules set out in [Rules for Materials \(Pt. I, Vol. V\), Sec. 7.A.10](#) shall be observed.

7.5 Testing the permeability

For castings of non-magnetizable steel, the relative permeability μ_r shall be determined by random tests on a metallic clean surface for the delivery condition. For the number of necessary random samples see [Table 5.6](#).

The relative permeability μ_r must not exceed the value of 1,01.

Table 5.6 Number of random samples

Batch size	Number of random samples
2 - 15	2
16 - 25	3
26 - 90	5
91 - 150	8
151 - 500	13
501 - 1200	20

Section 6 Forgings of Wrought Copper Alloys

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A. Scope

These Guidelines are applicable to bars and forgings intended for the manufacture of engineering parts, connecting elements and other components, e.g. hydraulics and high-pressure fittings.

B. Suitable Wrought Copper Alloys

Depending on their suitability for seawater service, the alloys according to [Tables 6.1](#) and [6.2](#) can be considered for the scope to which these Guidelines are applicable:

Table 6.1 Alloys suitable for seawater service

Alloy	Standard
CuNi2Si	EN 12420
CuNi10Fe1Mn	
CuNi30Mn1Fe	
CuNi14Al3	WL 2.1504
CuNi17Mn5Al2Fe	WL 2.0880
CuAl9Ni3Fe2	EN 12420
CuAl10Fe3Mn2	
CuAl10Ni5Fe4	
CuAl11Fe6Ni6	
CuAl8Mn	WL 2.0958
CuAl9Ni7	WL 2.0967

Table 6.2 Alloys without seawater impingement

Alloy	Standard
CuZn40	EN 12420
CuZn39Pb3	
CuZn40Pb2	

Materials according to other standards or material specifications may be used, provided that their suitability is confirmed by BKI.

C. Requirements to be met by Manufacturers

Manufacturers wishing to supply products in accordance with these Guidelines must be approved by BKI for the corresponding alloys and product shapes. This is conditional upon their fulfilling the

manufacturing and quality control requirements stated in [Section 1, C.](#) and furnishing proof of this to BKI prior to the commencement of deliveries. BKI reserve the right to carry out suitability tests on products selected for the purpose.

D. Surface Finish

As blanks, forgings shall have a surface corresponding to the manufacturing process.

Surface defects and flaws, such as bulges, depressions, forging wrinkles and impact marks on the forging surface can be removed in a suitable manner, provided that the parts remain within the prescribed tolerances. The intended use of the parts must not be impaired.

E. Dimensions; Dimensional and Geometrical Tolerances

The dimensions and the dimensional and geometrical tolerances are governed by the values specified in the drawings relating to the purchase order or in the relevant standards, as applicable. Instructions on this point shall be given in the order documents and shall be made known to BKI Surveyor.

F. Requirements Applicable to the Material

1. Material condition

All products shall be delivered in the material conditions intended for the relevant alloy.

2. Chemical composition

The composition must comply with the requirements for the corresponding material in the applicable standards, material performance sheets or other material specifications.

With regard to composition, the alloys mentioned in [B.](#) must meet the requirements according to [Table 6.3.](#)

3. Mechanical properties

For the mechanical properties, the data given in the material performance sheets and in the approved standards or material specifications shall apply.

For the materials mentioned in [B.](#), the minimum requirements defined in [Table 6.4](#) must be observed.

4. Magnitude of residual stresses

Forgings ordered for delivery in the unstressed state shall not exhibit any cracks on being tested. The test must be carried out according to [G.4.](#)

5. Relative permeability

If requirements have been prescribed for the relative permeability, the maximum values listed in [Table 6.4](#) must be observed.

Table 6.3 Chemical composition

Alloy	Chemical composition [%]								
	Cu	Al	Fe	Mn	Ni	Pb	Si	Zn	Total other
CuNi2Si	rest	-	≤ 0,2	≤ 0,1	1,6 – 2,5	≤ 0,02	0,4 – 0,8	-	≤ 0,3
CuNi10Fe1Mn	rest	-	1,0 – 2,0	0,5 – 1,0	9,0 – 11,0	≤ 0,02	-	≤ 0,5	≤ 0,2 S + C ≤ 0,05 P ≤ 0,02
CuNi30Mn1Fe	rest	-	0,4 – 1,0	0,5 – 1,5	30,0 – 32,0	≤ 0,02	-	≤ 0,5	≤ 0,2 S + C ≤ 0,05 P ≤ 0,02
CuNi17Mn5Al2Fe	73,7 – 76,4	1,7 – 2,7	0,8 – 1,4	3,0 – 5,4	15,0 – 17,5	-	-	-	-
CuAl9Ni3Fe2	rest	8,0 – 9,5	1,0 – 3,0	≤ 2,5	2,0 – 4,0	≤ 0,05	≤ 0,1	≤ 0,2	≤ 0,3 Sn ≤ 0,1
CuAl10Fe3Mn2	rest	9,0 – 11,0	2,0 – 4,0	1,5 – 3,5	≤ 1,0	≤ 0,05	≤ 0,2	≤ 0,5	≤ 0,2 Sn ≤ 0,1
CuAl10Ni5Fe4	rest	8,5 – 11,0	3,0 – 5,0	≤ 1,0	4,0 – 6,0	≤ 0,05	≤ 0,2	≤ 0,4	≤ 0,2 Sn ≤ 0,1
CuAl11Fe6Ni6	rest	10,5 – 12,5	5,0 – 7,0	≤ 1,5	5,0 – 7,0	≤ 0,05	≤ 0,2	≤ 0,5	≤ 0,2 Sn ≤ 0,1
CuAl8Mn	82,0 – 85,0	7,0 – 9,0	≤ 1,5	5,0 – 6,5	1,0 – 2,0	≤ 0,1	≤ 0,1	≤ 0,3	-
CuAl9Ni7	80,0 – 82,6	9,0 – 9,5	0,9 – 1,3	0,8 – 1,2	6,7 – 7,3	-	≤ 0,1	≤ 0,3	-
CuZn40	59,5 – 61,5	≤ 0,05	≤ 0,2	-	≤ 0,3	≤ 0,3	-	rest	≤ 0,1 Sn ≤ 0,2
CuZn39Pb3	57,0 – 59,0	≤ 0,05	≤ 0,3	-	≤ 0,3	2,5 – 3,5	-	rest	≤ 0,2 Sn ≤ 0,3
CuZn40Pb2	57,0 – 59,0	≤ 0,1	≤ 0,4	-	≤ 0,3	1,6 – 2,5	-	rest	≤ 0,2 Sn ≤ 0,3

F

Table 6.4 Mechanical and technological properties

Alloy	Dimension Group ¹⁾	Hardness		Tensile strength R_m [N/mm ²] Min.	0,2% proof stress $R_{p0,2}$ [N/mm ²] Min.	Elongation A_5 [%] Min.	Relative permeability μ_r Max.
		HB Min.	HV Min.				
CuNi2Si	I	160	-	490	390	15	1,01
	II	155	-	490	340	14	
	III	150	160	490	340	12	
	IV	140	150	470	320	12	
CuNi10Fe1Mn	I, II, III, IV	70	75	280	100	25	1,5
CuNi30Mn1Fe	I, II, III, IV	90	95	340	120	25	1,1
CuNi17Mn5Al2Fe	I, II	210	-	750	490	15	1,03
CuAl9Ni3Fe2	I, II	135	-	620	290	22	1,08
	III, IV	130	-	600	270	20	
CuAl10Fe3Mn2	I	180	-	690	340	7	1,5
	II	160	-	650	300	10	
	III	125	130	590	250	10	
	IV	120	125	560	200	12	
CuAl10Ni5Fe4	I	195	-	740	390	10	1,9
	II	185	-	730	370	10	
	III	175	190	720	360	12	
	IV	170	185	700	330	15	
CuAl11Fe6Ni6	I, II	210	-	760	440	6	1,9
	III	205	-	740	420	5	
	IV	200	210	740	410	4	
CuAl8Mn	I	140	-	590	290	20	1,03
	II, III	135	-	540	240	22	
	IV	130	-	540	220	23	
CuAl9Ni7	I, II	150	-	620	300	12	1,03
	III	150	-	600	300	12	
	IV	140	-	570	270	14	
CuZn40	I, II, III, IV	75	80	340	100	25	1,03
CuZn39Pb3	I, II, III	80	85	360	120	20	
CuZn40Pb2	IV	75	80	340	110	20	1,05
¹⁾ Dimension groups: I. 10 – 25 mm \emptyset II. 25 – 50 mm \emptyset III. 50 – 80 mm \emptyset as well as drop forgings and open-die forgings up to a wall thickness or part thickness of 80 mm IV. > 80 mm \emptyset as well as open-die forgings with a wall thickness or part thickness exceeding 80 mm, and washers/discs, bushes and rings							

G. Testing

1. Sampling

For the test, the forgings shall be grouped into test batches according to [Table 6.5](#).

Note

A maximum of 5 samples can be taken per forging.

The samples must be taken from the completely manufactured product. The test sections must be removed from the samples. The test sections and the specimens produced from them must not be subjected to any further treatment, except the metal-cutting machining needed to make the specimens.

Table 6.5 Test batches for forgings

Weight of a single forging [kg]		Size of the unit testing quantity for a test piece [kg]
over	up to	up to
–	0,5	500
0,5	2,0	1000
2,0	10	1500
10	–	2000

2. Testing of chemical composition

The manufacturer must determine the chemical composition of each test batch, and must inform the BKI Surveyor.

3. Tensile testing

The forgings shall be subjected to tensile testing. In this test, the tensile strength, the 0,2 % proof stress and the elongation must be determined.

4. Hardness test

With the hardness test according to Brinell and as per ISO 6506-1, the load factor $0,102 F/D^2 = 10$ must be applied.

For the hardness test according to Vickers and as per ISO 6507-1, a proof force of 49,03 N or 294,21 N must be applied.

5. Testing the resistance to stress corrosion cracking

The resistance to stress corrosion cracking (SCC) must be tested according to either DIN 50916 or ISO 196.

6. Relative permeability

The permeability shall be tested according to VG 95578 on a metallic clean surface.

H. Retesting

If the requirements for the mechanical/technological tests are not met, the retesting procedure described in [Rules for Materials \(Pt.1, Vol.V\), Sec. 2, H.](#) may be applied before the test batch is rejected.

If a specimen does not pass the test for stress cracking resistance, it must be allowed that the unit testing quantity from which the specimen originates be subjected to further treatment to reduce the residual stresses. Then a new test section must be taken. If the test is now passed satisfactorily, the product must again be subjected to all the other tests, except for the chemical analysis. If a specimen does not pass a test, the unstressed product shall be deemed not to have met the requirements.

I. Marking

The forgings shall be marked at the point prescribed in the order documents.

The marking must give the minimum data as follows:

- name or abbreviation of the manufacturer
- material
- heat no.
- specimen no.
- code number (e.g. component no.)

If there is not enough space for the application of this minimum set of data, abbreviated marking can be made by means of a code, the interpretation of which must be given in the accompanying documents so that an unambiguous identification is possible at any time.

J. Certificates

For each consignment, the manufacturer must supply to the Surveyor a certificate containing at least the following details:

- purchaser and order number
- nature of forging and grade of material
- method of forging
- item number and number of units
- heat number and chemical analysis
- results of the mechanical tests
- details of the heat treatment
- results of any special tests applied

If the alloys are not cast in the works in which they are processed to semifinished products, BKI Surveyor shall be furnished with a certificate of the melting works indicating the batch number and the chemical composition. The manufacturer of the starting products must be approved by BKI.

Section 7 Titanium and Titanium Alloys

A. Wrought Titanium Alloys 7-1

A. Wrought Titanium Alloys

1. Scope

These Guidelines are applicable to the wrought titanium alloys, as described in the following, which are intended for the manufacture of ship's hulls, superstructures and other hull components as well as for pipelines.

2. Requirements to be met by manufacturers

Manufacturers wishing to supply products in accordance with these Guidelines must be approved by BKI for the corresponding alloys and product shapes. This is conditional upon their fulfilling the manufacturing and quality control requirements stated in [Section 1, C.](#) and furnishing proof of this is to BKI prior to the commencement of deliveries. BKI reserve the right to carry out suitability tests on products selected for the purpose.

3. Manufacture and material condition

The starting material for all products is melted in an arc vacuum furnace. Plates and strips are produced by hot- or cold-rolling or a combination of the two methods. Open-die forgings and drop forgings are produced by forging; bars also by hot-rolling or by a combination of the two methods.

All products shall be delivered in the material conditions intended for the relevant alloy.

4. Suitable alloys and material conditions

Materials according to DIN 17860 to DIN 17864 can be considered.

For the chemical composition, the standards DIN 17850 and DIN 17851 shall apply.

Alloys and material conditions which comply with other standards or material specifications of the manufacturer may be used, provided that BKI has tested their properties and serviceability and approved their use.

5. General condition of products

The products must have a smooth surface consistent with the method of manufacture and must be free of defects liable to have an adverse effect on their workability and intended use, e.g. cracks, laminations, large inclusions of foreign matter, or major mechanical damage.

Surface defects shall only be remedied by grinding if this is done with smooth transitions to the product surface and the permissible dimensional tolerances are not exceeded. Rectification of defects by welding is only permissible if expressly approved by BKI.

6. Dimensional and geometrical tolerances

Unless otherwise arranged with BKI, the dimensional and geometrical tolerances given in the relevant standards shall apply.

The manufacturer takes responsibility for compliance with the tolerances and requirements for the general condition. Testing of the products by BKI Surveyor does not release the manufacturer from this responsibility.

If non-destructive testing is necessary, the procedures and judgement scales shall be agreed with BKI.

7. Chemical composition

The chemical composition of the alloys mentioned in these Guidelines must conform to the data given in the relevant standards.

The manufacturer must determine the chemical composition by using specimens from each batch, and the hydrogen content for each heat treatment batch. Minor deviations from the prescribed composition may be permissible with the consent of BKI, provided that the serviceability of the corresponding product is not impaired thereby.

The analysis certificate of the manufacturer is normally recognized, whereby BKI Surveyor reserves the right to perform check analyses from time to time.

8. Mechanical properties

The requirements stated in the standards and also in the purchase order must be fulfilled. For the performance of the tests [Rules for Materials \(Pt.I, Vol. V\), Sec. 2](#) shall apply.

8.1 Testing and scope of tests

8.1.1 Strips and plates

.1 Strips and plates from large strips

For the undivided strip or for the plates of a divided strip, the following test scope shall apply, unless specified otherwise in the order:

- 1 tensile test at room temperature at both the beginning and the end of the strip
- 1 notched-bar impact test (strip thickness > 5 mm) at room temperature or 1 bend test (strip thickness < 5 mm) at both the beginning and the end of the strip

The test scope for the mechanical/technological tests is also applicable to plates cut off from one strip which belong to the same heat treatment batch and which were submitted for the acceptance test at the same time.

.2 Sheet-rolled plates

For sheet-rolled plates, the following test scope shall apply, unless specified otherwise in the order:

- 1 tensile test at room temperature
- 1 notched-bar impact test (strip thickness > 5 mm) or 1 bend test (strip thickness < 5 mm) at both ends for lengths over 5 m, and at one end for lengths up to 5 m, for each rolled plate.

For thicknesses up to 15 mm, the test scope for the mechanical-technological tests can be reduced to 25% of the number of rolled plates per heat, heat treatment batch and thickness.

If these plates are rolled as one batch from a mill bar, the test scope for the mechanical-technological tests can be reduced to 2 specimen sets per batch in the case of thicknesses up to 3 mm.

.3 Sampling

The samples for the mechanical-technological tests are taken from strips and plates in the delivery condition.

The samples for the tensile test specimens are taken from strips and plates from large strips in the rolling direction, for the notched-bar impact test and bend test specimens transverse to the rolling direction in 1/3 of the strip width at the beginning and end of the strip.

The samples are taken from sheet-rolled plates transverse to the rolling direction in 1/3 of the width, namely for lengths up to 5 m at one end, and for lengths over 5 m at both ends.

For strips and plates with thicknesses over 10 mm, the samples shall lie 1/4 of the thickness under the surface.

8.1.2 Forgings and bars

For each heat treatment batch

- 1 tensile test at room temperature
- 1 notched-bar impact test at parts with a thickness from 20 mm in the longitudinal direction (from 70 mm thickness, optionally also transverse samples)

shall be performed.

.1 Sampling

The samples for the mechanical-technological tests are taken in the delivery condition.

The samples for the tensile test specimens are each taken at one end of the bars in the longitudinal or transverse direction, at least in ¼ of the thickness under the surface, as far as is possible.

In the case of bars over 80 mm in diameter or 5000 mm² in cross-section for forging, the sample can be taken from a separately forged piece.

For forgings, the position must be agreed upon.

.2 Additional tests

If additional tests were specified in the purchase order, e.g. notched-bar impact test, tensile test at elevated temperatures, hardness test, determination of the structural condition, then the test scope, the test method (including the test conditions) and the required values shall be complied with as stipulated.

.3 Non-destructive testing

For forgings, a surface crack test shall be carried out.

8.2 Retests

If a sample does not meet the requirements during the test, two more specimens shall be taken from the same sample and tested. If both substitute specimens meet the test conditions, the piece from which the substitute specimens originate and the other pieces of the test batch can be accepted.

If one or both substitute specimens do not meet the conditions, the piece from which the specimens originate shall be rejected. The other pieces of the test batch can be accepted if specimens from two

further pieces are tested with satisfactory results. If these specimens also do not fulfil the conditions, the entire test batch shall be rejected.

In the case of products which do not fulfil the test conditions but already bear BKI's stamp, the brand symbol must be removed unmistakably.

9. Marking of products

The manufacturer must mark each product at one point at least in the following manner:

- manufacturer's mark
- abbreviation for the alloy
- abbreviation for the material condition
- number of the production batch, enabling the manufacturing process to be traced back

The products must also be marked with the "batch stamp" of BKI.

If sections, bars or pipes are bundled together or packed in crates, the marking can be applied to a tag durably attached to the products.

10. Certificate of the delivering works

For each accepted consignment, the manufacturer must furnish BKI Surveyor with an acceptance certificate or a delivery certificate containing the following details:

- purchaser and order no.
- project or hull no., if known
- quantity, dimensions and weight of the products
- alloy designation and material condition
- manufacturing process
- chemical composition
- number of the production batch or identification code
- results of the mechanical test, if the test was performed by the manufacturer
- details of the heat treatment, if applicable

If the alloys are not produced in the works in which they are processed to semifinished products, Surveyor shall be furnished with a certificate of the melting works indicating the batch number and the chemical composition. The manufacturer of the starting materials must be approved by BKI.

Section 8 Non-Magnetizable Anchor Chain Cables and Accessories

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C.	Construction and Manufacture.....	8-2
D.	Testing of Finished Chain Cables.....	8-3
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F.	Testing of Accessories.....	8-5

A. General

1. Scope

These Guidelines are applicable to all non-magnetizable anchor chain cables and chain accessories which are used on naval ships. This includes:

- anchor chain cables as per VG 84511
- chain cable lengths and chain cable links as per VG 84517
- kenter-type joining shackle as per VG 84518
- forerunners as per VG 84522
- swivel shackle as per VG 84523
- anchor lashings as per VG 84535
- other anchor chain cables and accessories according to recognized specifications approved by BKI

Note

Non-magnetizable anchor chain cables should be always studless to avoid the danger of confusion.

For connecting parts permanently joined to the anchor, see [Section 9](#).

2. Approval of chain manufacturers

Anchor chains and accessories shall only be manufactured in works approved by BKI for this purpose. The conditions prescribed in [Rules for Materials \(Pt.1, Vol.V\), Sec.13.A.3](#). shall apply.

B. Chain Materials

1. Scope

These Guidelines are applicable to rolled steels, forgings and steel castings made of non-magnetizable austenitic steel of the grade X2CrNiMnMoNb21-16-5-3 (1.3964). The suitability of other steel grades for the corresponding application must be examined and approved by BKI.

2. Requirements applicable to material manufacturers

All materials for the manufacture of anchor chain cables and accessories shall only be delivered by manufacturers approved by BKI for this purpose. For this, approval tests must be carried out.

Rolled products, forgings and castings intended for the manufacture of anchor chain cables and accessories shall meet the requirements set out in the [Sections 2, 4 and 5](#) as well as in [Rules for Materials \(Pt.1, Vol.V\) Sec. 4, 6 and 7](#).

3. Testing

Anchor chain cables and their individual components shall be manufactured from the materials defined in the standards mentioned in [A.1](#). From a material delivery of up to 5 t per batch, one set of specimens shall be taken from the thickest piece of the unit testing quantity. A set consists of one tensile test specimen and three impact test specimens.

In general the mechanical test of the bars will be carried out at the rolling mill, whereby the test sections must be in the final heat treatment condition of the finished chain.

In case that the final heat treatment will be performed at the chain cable manufacturer's works specimen material shall be supplied in a heat treatment condition appropriate to the finished chain cable or the finished accessory components. Then the rolled bars shall be supplied together with the manufacturer's certificate on the chemical composition of each heat, whereas the mechanical tests shall be performed at the chain manufacturer's works.

4. Marking

The steels shall be marked with at least the manufacturer's mark, the steel grade and an abbreviation for the heat. In the case of bars up to 40 mm in diameter which are bundled together, the marking can be applied by means of a durably attached tag.

5. Works acceptance certificate

For each consignment, the manufacturer must furnish BKI-Surveyor with a certificate containing at least the following information:

- project number or purchase order number
- quantity, dimensions and weight of the products in the consignment
- steel grade
- heat no.
- steelmaking process
- chemical analysis
- details on the heat treatment of the test section (where applicable)
- results of the mechanical test (where applicable)
- specimen numbers (where applicable)

C. Construction and Manufacture

1. Method of manufacture

The material shall be processed and heat treated according to the processing rules of the delivering works and the applicable material specifications. The anchor chain cables shall be produced by the flash-butt welding method. Rewelding of chain links is inadmissible. Shallow slivers and other surface defects may be removed by grinding. However, the tolerances according to the dimension standards must be observed. Before the test, the anchor chains and the chain accessories shall be subjected to final heat treatment and loading with the production proof load (chain cables only).

All parts which were subjected to a breaking test shall not be used for the chain equipment of ships. They must be rendered unserviceable by the chain manufacturer.

Accessory components, such as shackles, swivels and swivel shackles, shall be made out of forging steel or casting steel in accordance with [Section 4, B.](#) or [Section 5, B.](#)

2. Construction

Anchor chains shall be produced according to a standard recognized by BKI. The chain length must have an odd number of chain links.

If the execution does not comply with these provisions or if accessories are to be produced by welding, drawings shall be submitted to BKI for approval, with all details of the manufacturing process and the heat treatment.

3. Mechanical properties

The mechanical properties of the finished chain and the accessories, i.e. tensile stress, elongation, reduction in area and the impact energy must fulfil the requirements of the approved specification.

4. Requirements for proof load and breaking load

The chains and the accessories shall be so manufactured that they withstand the proof loads and breaking loads stipulated for non-magnetizable austenitic steels according to BKI Rules or BKI approved specification. The tested parts shall not fracture or exhibit cracking.

5. Freedom from defects

All individual parts must have a satisfactory surface in consideration of the manufacturing process and must be free from cracks, notches, inclusions and other defects liable to have an adverse effect on their serviceability. Flash and forging seam must be removed properly from the products; cf. also [Rules for Materials \(Pt.1, Vol.V\), Sec 13, A.3.7.2.](#)

Minor surface defects can be levelled off by grinding, with smooth transitions to the surrounding product surface. Outside of the curves of the chain links, local grinding is permitted to a depth of 5 % of the nominal diameter.

6. Dimensions and dimensional tolerances

The dimensions of chain links must comply with a recognized standard or approved specification.

7. Magnetic properties

If not otherwise required by the Naval Administration the relative permeability μ_r shall not exceed the value 1,10.

D. Testing of Finished Chain Cables

1. Proof load and breaking load tests

All chain cables and accessory components shall be subjected to the tests mentioned in the following in the presence of BKI Surveyor. For this, the chains must be free of coatings or corrosion protection.

Each chain cable length (25 m) and each accessory component shall be subjected to a proof load test on an approved testing machine with the proof load stipulated for the corresponding chain or accessory component, see Table 8.1.

1.1 Surface crack test

After the loading tests, the surface crack test shall be performed, using a penetration method according to EN 571-1. For the chain accessories, each item of the consignment must be tested. Of the chain lengths, only the specimens put aside for the breaking test shall be subjected to the surface crack test before the breaking test is performed.

1.2 Breaking test

For four chain cable lengths in each case, one specimen consisting of three connected common links (cut off from either end of a chain cable length which is longer by four links) shall be subjected to the breaking load according to Table 8.1. The corresponding links must have been produced in one working process together with the chain, and must have been welded and heat-treated together with the chain. Only after this shall the links be separated from the chain, in the presence of BKI-Surveyor. In the case of accessory components, the breaking test shall be performed on one piece for each batch (up to 50 kenter shackles or up to 25 other individual parts of the same dimensions belonging to the forerunner).

Table 8.1 Proof and breaking loads for chain cables and accessories

Nominal Thickness [mm]	14	16	18	20	22	24	26
Proof load [kN]	60	80	105	130	155	185	215
Breaking load [kN]	145	190	240	295	355	425	495

2. Retests

If a breaking load test does not meet the requirements, another specimen can be cut off from the same chain length and tested. The test is deemed to have been passed if all requirements are then fulfilled.

If the retest is not successful, the corresponding chain length must be rejected. On request by the manufacturer, the other 3 lengths belonging to the test batch may be individually subjected to the breaking load test. If any one test does not meet the requirements, the entire test batch will not be accepted.

If a proof load test does not meet the requirements, the defective links shall be replaced; then a local heat treatment must be applied to the new links and the proof load test must be repeated. In addition, the causes for the failure must be determined.

3. Testing the mechanical properties of nonmagnetizable chain cables

Testing of the mechanical properties shall be performed, if the final heat treatment will be performed by the chain cable manufacturer.

A tensile test specimen and a set of 3 Charpy V-notch specimens shall be taken from every 4th chain length and tested. The specimen must be taken from the base material at the side of the link opposite to the weld. In addition, a set of Charpy V-notch specimens shall be taken with the notch positioned in the weld and tested.

To produce the specimens, an additional link (for small chain sizes, several additional links) shall be provided at a chain length which is not used to provide specimens for the breaking load test. The sample must be manufactured and heat-treated together with the chain length.

The mechanical properties and impact energy must meet the requirements for the base material.

4. Testing of the magnetic properties

If not otherwise required by the Naval Administration one shot of chain cable with the corresponding connection pieces of each finished unit shall be presented for determination of permeability.

Finished unit within the terms of this Guidelines means chain of same diameter, the same material, finished to the same production procedure.

E. Marking

Chain cables which have fulfilled the requirements shall be stamped with at least the following data at both end links of each chain length, see Fig. 8.1 :

- steel grade "NM"
- test certificate number
- BKI's stamp
- month and year of the test
- nominal diameter
- proof load

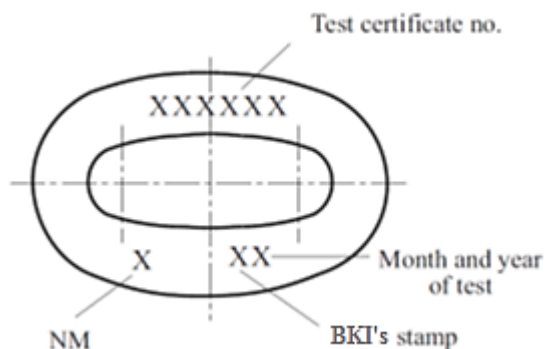


Fig. 8.1 Stamping of chain cables

F. Testing of Accessories

1. Proof load test

All accessories are to be subjected to the proof load test at the proof load specified for the corresponding chain in Table 8.1.

2. Breaking load test

2.1 If not otherwise specified in the appropriate standard, from each manufacturing batch (same heat, size and heat treatment) of 25 units or less of shackles, swivels, swivel shackles, large links and end links, and from each manufacturing batch of 50 units or less of kenter shackles, one unit is to be subjected to the breaking load test. Parts tested in this way may not be put to further use.

2.2 In the case of swivels and swivel and anchor shackles, BKI may waive the breaking load test if:

- the breaking load has been demonstrated on the occasion of the approval testing of parts of the same design
- the parts are subjected to suitable non-destructive testing

3. **Material tests**

The parts shall be subjected to material tests in accordance with [Section 4, B.](#) or [Section 5, B.](#) respectively in BKI Surveyor's presence, depending on the nature and grade of the material.

4. **Marking**

Accessories which meet the requirements shall be stamped as follows:

- steel grade "NM"
- test certificate number
- Surveyor's stamp
- month and year of test

Section 9 Non-Magnetizable Anchors

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A. Scope

1. These Guidelines apply to non-magnetizable anchors made of forged or cast steel as well as to anchors made of welded components. They are also applicable to the repair of damaged anchors.

The term “anchor” also covers the connecting components which are fixed thereto, such as the anchor shanks, the swivel shackle and also the bolts.

2. Anchors conforming to these Guidelines are divided into three categories according to their holding power:

Category 1: Anchors with normal holding power

Category 2: Anchors with high holding power (HHP anchors)

Category 3: Anchors with very high holding power (VHHP)

B. Design and Tests

1. The design of the anchors must be approved by BKI. To this end, the anchor manufacturer shall submit to BKI for approval drawings and/or data sheets containing all the details necessary for carrying out an evaluation of the anchor and its associated components (anchor shackles and swivel shackles).

2. Connecting components, such as shackles and swivel shackles must be designed to withstand at least the test loads of the appropriate anchors.

3. HHP anchors and VHHP anchors and also swivel shackles which are regarded as part of the anchor shall be subjected to a type test in the presence of the BKI-Surveyor. In the case of swivel shackles, the proof and breaking loads shall also be demonstrated in accordance with [Section 8, Table 8.1](#).

The scope of the tests performed, including the tests on the HHP and VHHP anchors shall be agreed on a case by case basis between the manufacturers and BKI.

C. Materials for Anchors and Anchor Components

1. Forged anchor components such as shanks and crowns must be made of weldable nonmagnetizable steels and must meet the requirements set out in [Section 4, B](#).

2. Cast anchor components such as shanks and crowns must be made of weldable non-magnetizable cast steel and must meet the requirements set out in [Section 5, B](#).

3. Rolled steels for the manufacture of anchors of welded construction must be made of weldable non-magnetizable steel and must meet the requirements specified in [Section 2, B](#).

4. The choice of non-magnetizable steel for shackles, swivel shackles, bolts and other connecting components is left to the manufacturer. In this case, the components shall be cast or hot-formed into a form approaching the final dimensions, with a small machining allowance. Excessive machining, such as turning a swivel body made of round steel to a smaller pin diameter is not permitted. All parts must be produced with the maximum fillet radii possible. Threads must be produced in such a way that they cannot cause notch effects at their runout.

D. Testing

1. Testing of materials

1.1 For all anchor components, the anchor manufacturer must provide the Surveyor with certificates, issued by the manufacturer of the material or fittings, indicating the, the heat treatment condition or the condition chemical composition on delivery, the heat number and the results of the mechanical tests performed on the components.

1.2 All cast steel parts must be subjected, in the presence of the Surveyor, to a material test as set out in [Section 5, B](#).

2. Characteristics of the anchors

2.1 All anchors must be free from defects liable to impair their function, e.g. cracks, major casting and forging defects and improperly executed welds.

2.2 After testing at the test load specified in [3](#), anchors may not reveal any permanent deformations. In addition, in the case of anchors of composite construction, the freedom of movement of the arms over the whole angle of deflection must be preserved following the test, and no excessive changes may be caused by deformation of the bearings.

3. Testing of anchors

3.1 Condition in which tested

Anchors are to be submitted for testing in the fully assembled condition and may not be coated with paint or preservatives.

3.2 Load test

3.2.1 Anchors with a total weight (including the stock) of 75 kg and over are to be subjected in the presence of a BKI Surveyor to a load test at the appropriate loads shown in [Table 9.1](#) using a calibrated testing machine approved by BKI.

3.2.2 In the case of large anchors weighing 15000 kg and over, other tests may be substituted for the load tests, if the available testing machine is incapable of producing the specified test load. The nature of these tests is to be agreed with BKI.

3.2.3 The test load shall be applied at a point on the arm or palm which, measured from the point of the palm, is located at one third of the distance from the point of the palm to the centre of the anchor crown. With stockless anchors, both arms are to be tested simultaneously in both end positions. In the case of stocked anchors, the test load is to be applied alternately to each arm.

3.2.4 The following anchor weights are to be applied in establishing the test loads in accordance with [Table 9.1](#):

- a) stockless anchors: the total weight

- b) stocked anchors: the weight without the stock
- c) anchors with high holding power (HHP):
a weight equal to 1.33 times the actual weight
- d) anchors with very high holding power (VHHP):
a weight equal to 2,0 times the actual weight of the anchor
- e) mooring anchors: a weight equal to 1.33 times the actual weight, unless specified otherwise

4. Inspection

4.1 Before the load test, anchors are to be inspected by the manufacturer for unacceptable faults in accordance with 2.1. Any defects are to be removed.

4.2 After the load test, anchors are to be submitted to BKI-Surveyor for verification of their delivery condition. With composite anchors, this shall include verification that the arms are able to move freely.

E. Marking

1. Anchors which have fulfilled the test conditions are to be marked by the manufacturer as follows:

- manufacturer's symbol
- number of the BKI test certificate
- month and year of test
- total weight
- weight of stock (in the case of stocked anchors)
- the letters HHP in the case of anchors with high holding power
- the letters VHHP in the case of anchors with very high holding power
- steel grade "NM"

2. The marks are to be impressed with punches on the shank and on one arm of the crown of stockless anchors, and on the shank only of stocked anchors.

Table 9.1 Test loads for anchors ¹⁾

Weight ²⁾ [kg]	Test load [kN]	Weight ²⁾ [kg]	Test load [kN]	Weight ²⁾ [kg]	Test load [kN]
50	23	375	93	1250	239
55	25	400	98	1300	247
60	27	425	103	1350	255
65	29	450	107	1400	262
70	31	475	112	1450	270
75	32	500	116	1500	278
80	34	550	125	1600	292
90	36	600	132	1700	307
100	39	650	140	1800	321
120	44	700	149	1900	335
140	49	750	158	2000	349
160	53	800	166	2100	362
180	57	850	175	2200	376
200	61	900	182	2300	388
225	66	950	191	2400	401
250	70	1000	199	2500	414
275	75	1050	208	2600	427
300	80	1100	216	2700	438
325	84	1150	224	2800	450
350	89	1200	231	2900	462

¹⁾ Intermediate values can be determined by linear interpolation.

²⁾ In order to establish the test load of HHP anchors, VHP anchors and mooring anchors, the weight stated in the table is to be multiplied by the factors given in D. 3.2.4, c), d) and e).