Contents

RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part K MATERIALS

Chapter 1 GENERAL

1.1 General

1.1.1 Application*

1 The requirements in this Part apply to the materials intended to be used for the members or components specified in each Part of hull construction, equipment and machinery unless specified in other parts.

2 The ships carrying liquefied gases in bulk and the ships using low-flashpoint fuels are to comply with the requirements in **Part N** and **Part GF** respectively in addition to this Part. Where, however, items specified in this Part overlap items specified in **Part N** or **Part GF**, the requirements in **Part N** or **Part GF** are applied regardless of the requirements in **Part K**.

3 Materials having characteristics differing from those specified in this Part may be used when the detailed design data, manufacturing procedure and their use are specially approved by the Society. In this case, detailed data relating to the manufacturing process, performance, etc. of the materials are to be submitted for approval to the Society.

1.2 Manufacture and Approval of Materials

1.2.1 Manufacture of Materials*

1 The materials specified in this Part, unless otherwise specially provided or deemed appropriate by the Society, are to be manufactured at the works approved by the Society with regard to the manufacturing process of the materials. The steel material is to be manufactured by basic oxygen convertor, electric furnace or other processes specially approved by the Society.

2 Primary materials such as ingot, slab or billet supplied to other works are to be in accordance with the requirement of preceding **-1** as appropriate.

3 Materials differing from those specified in this Part are to be in accordance with the requirements of preceding **-1** when deemed necessary by the Society.

1.2.2 Approval of Manufacturing Process

1 Approval of manufacturing process specified in **1.2.1** is to be in accordance with the requirements of "**Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**".

2 Where controlled rolling (*CR*) and thermo-mechanical rolling (*TM*) with/without accelerated cooling (*AcC*) are specially applied, the programmed rolling schedules are to be verified by the Society.

1.3 Manufacturing Control of Materials

1.3.1 Operation of Manufacturing Control

1 It is the manufacturer's responsibility to assure that effective process and production controls in operation are adhered to. The manufacturer is especially to adhere to the following requirements;

(1) Where deviation from the controls occurs and/or inferior quality of products exists, the manufacturer is to identify the cause and establish a countermeasure to prevent its recurrence. Also, the complete investigation report is to be submitted to the Surveyor. In this case, each affected piece is to be tested and inspected according to the Surveyor's direction.

(2) Where *CR* and *TM* with/without *AcC* are applied, the manufacturer is adequately to control these programmed rolling schedules

in accordance with the approval condition and is to verify the validity of the control by means of the investigation of the actual rolling records.

2 The manufacturer is to take a suitable measure for identification of ingots, slabs, castings, forgings and finished pieces, etc. which will enable the material to be traced to the processing details as melting, rolling, forging, heat treatments, etc. at all phases of manufacturing process.

1.3.2 Verification of Controls

1 Where the Surveyor deems necessary or the matter specified in **1.3.1-1(1)** was reported, it is to be verified that the approved process is adhered to and the manufacturing control is effective. In this case, the manufacturer is to afford the Surveyor all necessary facilities and access to all relevant parts of the works.

2 Where deviation from the controls is discovered by the verification specified in **-1**, the Society's Surveyor may require a report of investigation on the substantial cause and the increasing of the frequency of subsequent testing and inspection.

1.4 Testing and Inspection for Materials

1.4.1 Execution of Testing and Inspection*

1 Testing and inspection for materials specified in this Part are to be carried out in the presence of the Society's Surveyor at the steelworks prior to delivery except where otherwise specially provided, and are to comply with the requirements of **Chapter 3** to **8** in this Part.

2 The manufacturer is to show the following data to the Surveyor prior to testing and inspection for materials.

(1) material specifications (including special requirements, etc.)

(2) a certificate which states the name of manufacturer who supplied primary materials, melting, casting and the other manufacturing processes, the number of the cast and chemical composition (ladle analysis) (only if primary materials such as ingot, slab or billet are not produced at the works at which it is rolled, piped or forged)

3 The chemical composition is to be analyzed at an adequately equipped and completely staffed laboratory. The testing machines used for the mechanical testing of material are to be those which have the effective certificates issued by the Society or other organization recognized by the Society in accordance with the "**Rules for Testing Machines**" or other standards deemed appropriate by the Society.

4 The Society may dispense with the tests and inspections for materials having the appropriate certificates.

5 The Society may modify the requirement of presence of testing and inspection by the Surveyor where the quality of materials and the quality control system of manufacturer are deemed appropriate by the Society.

1.4.2 Standard for Testing and Inspection*

1 The materials are to comply with the requirements of **Chapter 3** to **8** in this Part.

2 The chemical composition is to be analyzed on samples generally taken from each melt. A check analysis may be required by the Society where deemed necessary.

3 Materials differing from those specified in this Part are to be tested and inspected according to the approved specifications or standards for the testing.

4 The Society may request additional test items, tests under different conditions or different kind of tests specified in this Part in consideration of the intended service condition of the materials.

1.4.3 Quality and Repair

1 All materials are to be free from harmful defects. Repairing of defects is not permitted unless the extent and method of repair (including welding procedure and heat treatment) are approved by the Surveyor.

2 In the event of any material proving unsatisfactory in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing and inspection where the Surveyor considers necessary.

1.4.4 Additional Tests before Rejection

1 Where part of the results of any mechanical test except impact test does not conform to the requirements, but the remainders are satisfactory, additional test specimens twice in number may be taken from the same material and re-tests for the failed test may be carried out. In such a case, all of the test specimens are to conform to the Rule requirements.

2 Where the results of impact test do not conform to the requirements, additional tests are to be carried out in accordance with

the requirements in each Chapter.

3 If a heat treated material fails to meet the requirements in any test, re-tests may be allowed after being heat treated again. In this case, however, the material is not to be considered as having complied with the requirements unless all tests fully comply with the test requirements.

4 If the percentage of elongation of any tensile test specimen is less than that specified and any part of fracture is outside the one-fourth of the gauge length from the centre of gauge length, the test is to be considered as invalid, and an additional test for the material from which the first test specimen has been taken may be allowed.

1.5 Marking and Test Certificate

1.5.1 Marking

1 Every materials complying with the requirements is to be clearly stamped with the Society's brand NK including the marks deemed appropriate by the Society and marked with the following particulars in at least one position by the maker.

(1) Material grade

(2) Name or mark to identify the maker.

(3) Number or mark to identify the piece.

(4) Condition of heat treatment (if **Chapter 3** of this Part applies, except for "as rolled" steel)

(5) Name, order number or other identification marks (if required by the purchaser)

2 Materials which are unsuitable for stamping may be marked with brands, seals or by other suitable means.

3 Materials which can not be stamped and marked in accordance with the requirements in **-1** and **-2** due to small size may be properly marked in the lump.

1.5.2 Test Certificate*

1 The manufacturer is to submit test certificate on the rolled steel materials which have passed the specified test and inspection requirements for each material mark for the Surveyor's signature. However, another method may be used instead of Surveyor's signature, provided that it is deemed appropriate by the Society.

2 The test certificate specified in **-1** are to contain, in addition to the dimensions, mass, etc., of the steel material, at least items **(1)** through **(11)** of the following particulars:

(1) Purchaser's order number and if known the ship number which the material is intended;

(2) Identification number or symbol;

(3) Identification of manufacturer;

(4) Identification of grade of material (including the brand name in the case of the corrosion resistant steel for cargo oil tanks specified in **3.13**);

(5) Chemical Composition (ladle analysis on elements specified in the requirement and added when necessary) (including additive elements for improving corrosion resistance in the case of the corrosion resistant steel for cargo oil tanks specified in **3.13**);

(6) Carbon equivalent (C_{eq}) or cold cracking susceptibility (P_{cm}) calculated from the following formula using ladle analysis except where otherwise specified (only in such a case as specified in this Part.);

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (\%)$$

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

(7) Mechanical test results (including any standards, in cases where standards differing from those specified in this Part are used);

(8) Condition of heat treatment (if **Chapter 3** of this Part applies, except for "as rolled" steel); and

(9) Deoxidation practice is to be stated (rimed steel only).

(10) Results of surface inspections (if **Chapters 3**, **5**, and **6** of this Part apply, specify results only)

(11) Results of ultrasonic tests (if **Chapters 3**, **5**, and **6** of this Part apply, specify results only)

3 The manufacturer is to enter the following statement on the certificate to show that the steel material has been made by an approved process, and the declaration is to be signed by the personnel of the manufacturing shop in charge of product quality control or inspection. However, another method may be used instead of the signature of the person in charge, provided that it is deemed appropriate by the Society.

(Example)

We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of Nippon Kaiji Kyokai.

4 The requirements in **-1** to **-3** are to be applied to the materials which are specified in this Part but which are other than rolled steel materials.

Chapter 2 TEST SPECIMENS AND MECHANICAL TESTING PROCEDURES

2.1 General

2.1.1 Application*

1 Test specimens and mechanical testing procedures for materials are to comply with the requirements in this Chapter, unless otherwise specially provided in and after the next Chapter.

2 Where specimens and mechanical testing procedures differing from those prescribed in this Part are used, they are to be approved by the Society.

3 Test samples are to be cut and test specimens are to be collected, according to each requirement specified in and after the next Chapter.

2.2 Test Specimens

2.2.1 Preparation of Test Specimens*

1 Except where otherwise specified or agreed with the Surveyor, test samples are not to be detached from the material until being stamped by the Surveyor.

2 If test samples are cut from material by flame cutting or shearing, a reasonable margin is required to enable sufficient material to be removed from the cut edges during final machining.

3 The preparation of test specimens is to be done in such a manner that test specimens are not subjected to any significant cold straining or heating.

4 If any test specimen shows defective machining or defects having no relation to the substantial nature, it may be discarded and substituted by another test specimen.

2.2.2 Tensile Test Specimens*

1 Tensile test specimens are to be of size and dimensions given in **Table K2.1**, and the both ends of the test specimen may be machined to such a shape as to fit the holder of the testing machine.

2 The manufacturers may use the test specimens approved by the Society, besides those specified in **Table K2.1**. In this case, the required elongation is to be calculated from the following formula:

$$n = a \cdot E \cdot \left(\frac{\sqrt{A}}{L}\right)^{b}$$

n : Required elongation of test specimen

E : Required elongation for the proportional specimens specified in **Table K2.1**

A : Actual sectional area of test specimen

L : Actual gauge length of test specimen

a, b : Constants given in **Table K2.2** in accordance with the kind of materials.

3 The permissible variation (difference between the maximum and minimum values) at the machine-finished parallel part of test specimens is to be as specified in **Table K2.3**.

2.2.3 Bend Test Specimens

Bend test specimens are to be of size and dimensions given in **Table K2.4** according to the kind of materials.

2.2.4 Impact Test Specimens

1 Impact test specimens are to be provided in a set of three pieces.

2 Impact test specimens are to be of size and dimensions given in **Fig. K2.1** and **Table K2.5**. The notch is to be cut in a face of the specimen which was originally perpendicular to the rolled surface.

3 The position of the notch is not to be nearer than 25 *mm* to a flame-cut or sheared edge.

4 Where *U*4 impact test specimen having the size specified in above **-2** can not be taken because of the thickness of material, the width *W* of the test specimen may be reduced to the dimensions given in **(1)** or **(2)** below, according to the thickness of material.

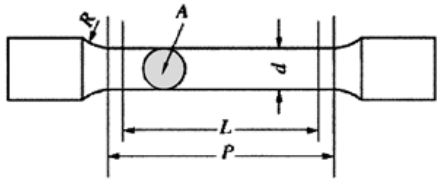
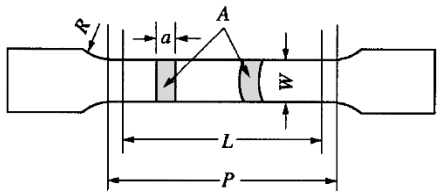
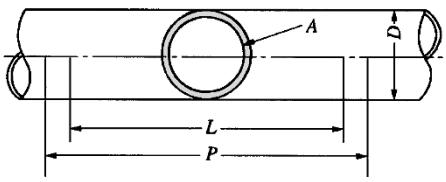
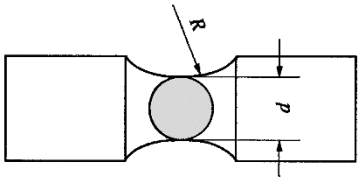
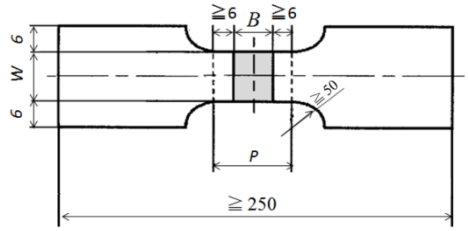
(1) Refer to **Table K2.6** for rolled steel materials.

(2) Refer to **Table K2.7** for steel pipes.

2.2.5 Confirmation for Test Specimens

The size and dimensions of test specimens are to be carefully inspected and verified by suitable means before testing.

Table K2.1 Size and Dimensions of Tensile Test Specimens (Unit: *mm*)

kind	Size of specimens	Dimensions[(1)(2)]	Material to be applied
*U*14*A*		$L = 70$, $d = 14$, $P \cong 80$, $R \geq 10$ (For spheroidal or nodular graphite iron castings, $R \geq 20$). The above-mentioned specimen is generally used, however, a specimen having the following dimensions may also be used: $L = 5d$, $P \cong L + 0.5d$, $R \geq 10$ (For spheroidal or nodular graphite iron castings, $R \geq 20$).	Rolled steels (Chapter 3) Steel pipes (Chapter 4) Steel castings (Chapter 5) Spheroidal or nodular graphite iron castings (Chapter 5) Steel forgings (Chapter 6) Copper alloys (Chapter 7) Aluminium alloys[(3)] (Chapter 8)
*U*14*B*		$L = 5.65\sqrt{A}$, $a = t$, $W \geq 12$ $P \cong L + 2W$, $R \geq 25$	Steel pipes (Chapter 4) Copper pipes (Chapter 7)
		$L = 5.65\sqrt{A}$, $a = t$, $W = 25$ $P \cong L + 2\sqrt{A}$, $R \geq 25$	Rolled steels 3 *mm* and over in thickness (Chapter 3) Aluminium alloys (Chapter8)
*U*1		$L = 200$, $a = t$, $W = 25$ $P \cong 220$, $R \geq 25$	
*U*13*B*		$L = 50$, $a = t$, $W = 12.5$ $P \cong 75$, $R \geq 25$	Rolled steels under 3 *mm* in thickness (Chapter 3)
*U*14*C*		$L = 5.65\sqrt{A}$, $P \cong L + 0.5D$, where P is the distance between the end grips	Steel pipes (Chapter 4) Copper pipes (Chapter 7)
11		$L = 50$, $P \cong L + 0.5D$, where P is the distance between the end grips	Aluminium alloy seamless pipes (Chapter 8)
*U*8		$d = 20$, $R = 25$ The specimen is to be prepared from test assembly, 30 *mm* in diameter, separately casted.	Grey iron casting （Chapter 5）
1		(1)$W = 40$ $(a < 20)$ (2)$W = 25$ $(a \geq 20)$	Aluminium alloy longitudinally welded pipes (Chapter 8)

Notes:

(1) The following designations are used;
d: diameter, *a*: thickness, *W*: width, *L*: gauge length (Recommended to be 20 *mm* and over), *P*: parallel part length, *A*: cross-section, *R*: transition radius, *D*: extermal tube-diameter, *t*: thickness of material, *B*: width of welds

(2) When $L = 5d$ or $5.65\sqrt{A}$, the specimen is called a proportional test specimen. The gauge length may be rounded off the nearest 5 *mm* provided that the difference between this length and *L* is less than 10% of *L*.

(3) Except Aluminium alloys of thickness 12.5 *mm* and less.

Table K2.2 Values of *a* and *b*

Material	Constant	
	a	b
Material I	2.0	0.40
Material II	2.6	0.55
Material III	1.25	0.127

Notes:

(1) Material I: For carbon and low alloy steels with a specified tensile strength not exceeding 600 N/mm^2 in the hot rolled, annealed, normalized, or normalized and tempered conditions.

(2) Material II: For carbon and low alloy steels in the quenched and tempered condition.

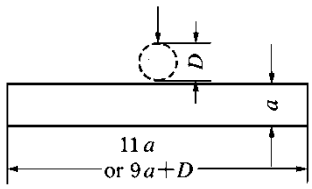
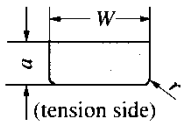
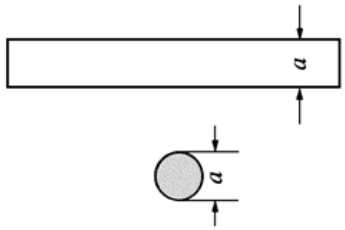
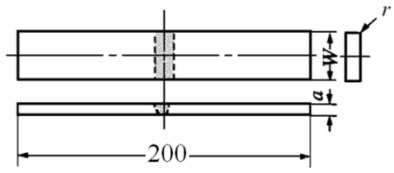
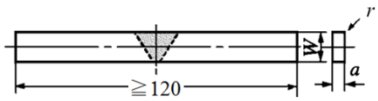
(3) Material III: For austenitic stainless steels with tensile strengths from 450 N/mm^2 to 750 N/mm^2 in the solid solution treatment.

(4) The values of *a* and *b* for materials other than Material I, Material II and Material III are to be as deemed appropriate by the Society.

Table K2.3 Permissible Variation

Diameter of test specimens where they are machined to a circular section, or thickness and width where they are machined to a rectangular section (*mm*)	Permissible variation (*mm*)	
	Circular cross section	Rectangular cross section
Over 3 up to 6	Max. 0.03	Max. 0.06
Over 6 up to 18	Max. 0.04	Max. 0.08
Over 18 up to 30	Max. 0.05	Max. 0.10

Table K2.4 Size and Dimensions of Bend Test Specimens (Unit:*mm*)

Kind	Size of specimens	Dimensions(1)	Material to be applied
*U*1*A*		$a = t$ $W = 30$ $r = 1\sim2$	——(2)
*U*1*B*		$a = 20$ $W = 25$ $r = 1\sim2$	Headers (Chapter 4)
2		$a = d$ Where the diameter or the width across flat of materials exceeds 35 *mm*, they may be machined finished to a circular section of diameter not less than 35 *mm*.	——(2)
B-1	Face and root bend specimen 	$a = t$ $W = 40$ $r < 0.2a$ (however, r is not to exceed 3 *mm*.)	Aluminium alloy longitudinally welded pipes (Chapter 8)
B-2	Side bend specimen 	$a = 8$ $W = t$ $r < 1.6$	

Notes:

The following designations are used;

(1) *a*: Thickness, diameter or width of test specimen, *W*: Width of test specimen
d: Diameter or width across flats, *r*: Edge radius of test specimen
D: Diameter of mandrel, *t*: Material thickness

(2) Materials deemed necessary by the Society.

Fig. K2.1 Impact Test Specimen

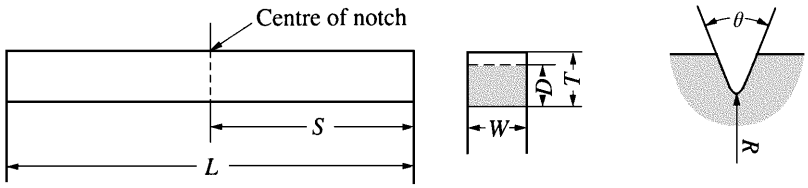


Table K2.5 Dimensions of Impact Test Specimens

Dimensions of test specimen		Kind of test specimen *U*4 Charpy 2 *mm* V-notch test specimen
Length (*mm*)	*L*	55±0.6
Width (*mm*)	*W*	10±0.11
Thickness (*mm*)	*T*	10±0.06
Angle of notch (*deg*)	θ	45±2
Depth below notch (*mm*)	*D*	8±0.06
Root radius of notch (*mm*)	*R*	0.25±0.025
Distance of notch from end of test specimen (*mm*)	*S*	27.5±0.42
Angle between plane of symmetry of notch and longitudinal axis of test specimen (*deg*)	—	90±2
Materials to be applied	—	All materials

Table K2.6 Width of Subsize Test Specimen (For Rolled Steel Plates)

Thickness of plate *t* (*mm*)	Width of impact test specimens *W* (*mm*)
t<6	—(1)
$6 \leq t < 8.5$	5±0.06
$8.5 \leq t < 11$	7.5±0.11

Note:

(1) The impact test may be omitted.

Table K2.7 Width of Subsize Test Specimens (For Steel Tubes)

Thickness of plate *c* (*mm*)(1)	Width of impact test specimens *W* (*mm*)
c<5(2)	—
$5 \leq c < 7.5$	5±0.06
$7.5 \leq c < 10$	7.5±0.11

Notes:

(1) c is to be calculated by the following formula

$$c = at - 1 - \frac{d - \sqrt{d^2 - b}}{2}$$

a and b : Constants determined according to the kind of steel pipe and the point of collection of test specimen. Refer to **Table K2.8.**

t : Nominal thickness (*mm*) of steel pipe

d : Outside diameter (*mm*) of steel pipe

(2) Refer to **note (5)** of **Table K4.27** in cases where thickness of plate is less than 5*mm*.

Table K2.8 Values of a and b

Kind and position for selection		Constant	
		a	b
Hot-working seamless steel pipe		0.875	100
Cold-working seamless steel pipe		0.9	100
Electric-resistance	base metal	0.9	100
welded steel pipe	welded part	0.9	3025

2.3 Mechanical Testing Procedures

2.3.1 Tensile Test

1 The value of yield point is to be measured at the first peak obtained during yielding.

2 When no well-defined yield phenomena exist, the proof stress is to be the strength of the 0.2% permanent elongation except where otherwise specified.

3 Where the value of yield point or proof stress is measured at tensile test, the test is to be carried out with an elastic stress rate, 2~20N/mm^2 *per sec*, for a material of which modulus of longitudinal elasticity is less than 150000N/mm^2 and, 6~60N/mm^2 *per sec*, for a material of which modulus of longitudinal elasticity is not less than 150000N/mm^2.

4 For ductile material, the machine speed during the tensile test is not to exceed that corresponding to a strain-rate at maximum load of 0.8%/*sec*. For brittle materials such as cast iron, the elastic stress-rate is not to exceed 10 N/mm^2 per sec.

2.3.2 Impact Test

1 The impact test is to be conducted on a Charpy impact testing machine having a capacity not less than 150 *J* with the test specimens at the temperature controlled with in ±2°C of the specified temperature.

2 The minimum average absorbed energy of the sub-sized test specimen is to be the value (by counting fractions of 0.5 and over as 1.0 and disregarding the rest) obtained from multiplying the value for the *U*4 impact test specimen by a coefficient given in **Table K2.9** according to the width of the test specimen.

Table K2.9 Multiplier to Absorbed Energy for *U*4 Specimen

Width of impact test specimens W (mm)	Constant
7.5	5/6
5	2/3

Chapter 3 ROLLED STEELS

3.1 Rolled Steels for Hull

3.1.1 Application*

1 The requirements of this chapter are to apply to hull structural rolled steels (including those manufactured as steel coils and those manufactured from steel coils, hereinafter referred to as "steels" in **3.1**) not exceeding 50 *mm* in thickness.

2 Steels having thickness over 50 *mm* up to 100 *mm* are to comply with the requirements of **3.10**. The requirements for steels having thickness exceeding 100 *mm* are to the discretion of the society.

3 In cases where steel coils are uncoiled and cut to manufacture steel plates by a manufacturer different from the one which manufactured the steel coils, the steel coils and the steel plates from steel coils are to be as deemed appropriate by the Society in addition to satisfying the requirements given in this Chapter.

4 Steels having characteristics differing from those specified in **3.1** are to comply with the requirements in **1.1.1-3**.

3.1.2 Kinds

The steels are classified into 16 *grades* as given in **Table K3.1**.

3.1.3 Deoxidation Practice and Chemical Composition*

1 The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table K3.1**. When thermo-mechanical controlled processing (a heat treatment based on controlled rolling approved by the Society ; hereinafter referred to as "*TMCP*") is used as heat treatment, the requirement on the chemical composition of steel may be modified subject to the approval by the Society.

2 The cold cracking susceptibility of steels may be required to be submitted when specially required by the Society.

3.1.4 Heat Treatment*

The heat treatment of each grade is to comply with the requirements given in **Table K3.3**.

3.1.5 Mechanical Properties

The mechanical properties of steels are to comply with the requirements given in **Table K3.4**.

3.1.6 Selection of Test Samples*

1 For the samples of steel from which tensile test specimens are cut, except where specially approved by the Society, steels not greater in weight than 50 *ton* (where the amount of scatter is to be less than 10 *mm* in thickness or diameter even when they belong to the same charge in the same manufacturing process) are to be treated as one lot, and the largest one in thickness or diameter is to be selected from each lot.

2 One set of test samples largest in thickness are to be selected from each lot specified in **Table K3.6**, according to the substance of deoxidation practices, the type of products, and the kind of heat treatments.

3 The samples of steel are to be treated together with and in the same way as the steel presented and are not to be cut from the material until heat treatment has been completed.

4 The test samples are to be taken from the following portions according to the requirements **(1)** to **(3)** below and **Fig. K3.1**, unless otherwise specified:

(1) Plates and flat bars wider than 600 *mm*:

One end at a portion approximately 1/4 of the width from the flange end of the plates or flat bars.

(2) Shapes and flat bars not exceeding 600 *mm* in width:

One end at a portion approximately 1/3 (1/6 for H-sections) of the width from the flange end. In case of channels, unequal angles, and H-sections, the test samples may be taken from the portion approximately 1/4 (1/6 for bulb flats) of the depth from the centre line of the web.

(3) Bars:

The test samples are to be taken so the axis of each test specimen may lie as near as possible to the portion specified in **(a)** and **(b)** below. This rule, however, does not apply when, because dimensions of cross section are insufficient for standard test specimens, a piece cut in a proper length from the product having the largest diameter of a certain lot is used as it is for a tensile

test.

(a) For non-circular sections, at approximately 1/6 of the largest distance from the outside.

(b) For circular section, at approximately 1/3 of the radius from the outside.

Table K3.1 Grades, Deoxidation Practice and Chemical Composition of Steels

Kind	Grade	Deoxidation practice	Chemical composition(%)(1)														Carbon equivalent (%)
			C	*Si*	*Mn*	*P*	*S*(14)	*Cu*	*Cr*	*Ni*	*Mo*	*Al*(8)	*Nb*	*V*	*Ti*	*N*	
Mild Steels	*KA*	Any method except rimmed	0.21 max. (4)(5)	0.50 max.	2.5×C min.(4)	0.035 max.	0.035 max.	—	—	—	—	—	—	—	—	—	—
	KB		0.21 max. (4)	0.35 max.	0.80 min. (4)(6)												
	KD	Killed(2) or Killed and fine grain treated			0.60 min.(4)							0.015 min. (2)(3)(11)					
	KE	Killed and fine grain treated	0.18 max. (4)		0.70 min.(4)							0.015 min. (11)					
High Tensile Steels	*KA*32 *KD*32 *KE*32 *KA*36 *KD*36 *KE*36 *KA*40 *KD*40 *KE*40	Killed and fine grain treated	0.18 max.	0.50 max.	0.90~1.60 (7)	0.035 max.	0.035 max.	0.35 max.	0.20 max.	0.40 max.	0.08 max.	0.015 min. (9)	0.02~0.05 (9)(10)	0.05~0.10 (9)(10)	0.02 max. (10)	—	(13)
	*KF*32 *KF*36 *KF*40		0.16 max.			0.025 max.	0.025 max.			0.80 max.						0.009 max. (12)	

Notes:

(1) Where additions of any other element have been made as part of the steel making practice, the content is to be indicated on the test certificate.

(2) For steels up to 25 *mm* in thickness, killed steel may be accepted and the specified minimum content of aluminium is not needed to be applied.

(3) For steels over 25 *mm* in thickness, aluminium treatment is to be used as a killed and fine grain treatment.

(4) The value of $C + Mn/6$ is not to exceed 0.40%.

(5) For steels sections, maximum carbon content may be increased to 0.23%.

(6) When an impact test is conducted or when steels contain *Si* not less than 0.10%, the minimum manganese content may be reduced to 0.60%.

(7) For steels up to 12.5 *mm* in thickness, the minimum manganese content may be reduced to 0.70%.

(8) Aluminium content is to be represented by the acid soluble aluminium content, but may be determined the total aluminium content. In such a case, the total aluminium content is not to be less than 0.020%.

(9) The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each grain refining element is not applicable.

(10) The total niobium, vanadium and titanium content is not to exceed 0.12%.

(11) Upon the approval by the Society, grain refining elements other than aluminium may be used.

(12) The maximum content of nitrogen may be increased to 0.012% if aluminium is present.

(13) Carbon equivalent is to be recorded on test certificate. When any grade of higher strength steel is supplied in *TMCP* condition, the carbon equivalent is to comply with the requirements of **Table K3.2**.

(14) For steels complying with the requirements specified in **3.11** the maximum content of sulphur is to be 0.008% determined by the ladle analysis.

Table K3.2 Carbon Equivalent for Steels Produced by *TMCP*

Grade	Carbon equivalent(%)(1)
*KA*32, *KD*32, *KE*32, *KF*32	0.36 max.
*KA*36, *KD*36, *KE*36, *KF*36	0.38 max.
*KA*40, *KD*40, *KE*40, *KF*40	0.40 max.

Note:

(1) It is a matter for the manufacturer and shipbuilder to mutually agree in individual cases as to whether they wish to specify a more stringent carbon equivalent.

Table K3.3 Heat Treatment(1)

Grade	Deoxidation Practice	Thickness *t* (*mm*)	Heat treatment(3)
KA	Any method except rimmed	$t \leq 50$	*AR*(4)
KB	Any method except rimmed	$t \leq 50$	
KD	Killed	$t \leq 25$	
	Killed and fine grain treated	$t \leq 35$	*AR*(4)
		$35 < t \leq 50$	*TMCP,N,CR*(5)
KE	Killed and fine grain treated	$t \leq 50$	*TMCP,N*(6)
*KA*32	Killed and fine grain treated	$t \leq 12.5$	*AR*(4)
	(With *Nb* and/or *V*)(2)	$12.5 < t \leq 50$	*TMCP,N,CR*(5)
*KA*36	Killed and fine grain treated	$t \leq 20$	*AR*(4)
	(Without *Nb* and/or *V*)(2)	$20 < t \leq 35$	*TMCP,N,CR*(7)
		$35 < t \leq 50$	*TMCP,N,CR*(5)
*KD*32	Killed and fine grain treated	$t \leq 12.5$	*AR*(4)
	(With *Nb* and/or *V*)(2)	$12.5 < t \leq 50$	*TMCP,N,CR*(5)
*KD*36	Killed and fine grain treated	$t \leq 20$	*AR*(4)
	(Without *Nb* and/or *V*)(2)	$20 < t \leq 25$	*TMCP,N,CR*(7)
		$25 < t \leq 50$	*TMCP,N,CR*(5)
*KE*32, *KE*36	Killed and fine grain treated	$t \leq 50$	*TMCP,N*(6)
*KA*40	Killed and fine grain treated	$t \leq 12.5$	*AR*(4)
		$12.5 < t \leq 50$	*TMCP,N,CR*
*KD*40	Killed and fine grain treated	$t \leq 50$	
*KE*40	Killed and fine grain treated	$t \leq 50$	*TMCP,N,QT*
*KF*32, *KF*36, *KF*40	Killed and fine grain treated	$t \leq 50$	*TMCP,N,QT*

Notes:

(1) These conditions of heat treatment and size of lot for impact test are summarised in **Table K3.6**.

(2) "*Nb* and/or *V*"stands for the addition of *Nb* and/or *V* either singly or in any combination, regardless of the specified minimum content, for grain refining, (ref., **Table K3.1 Note(9)**)

(3) Indication symbols used in heat treatment are as follows (the same holds henceforth in this Chapter):

AR: As Rolled

CR: Controlled rolling

N : Normalising

TMCP : Thermo-Mechanical Controlled Processing

QT: Quenching and Tempering

(4) *CR*, *N* or *TMCP* may be accepted.

(5) Steel materials except steel plates (including steel flats not less than 600*mm* in width) may be left as rolled, subject to the approval by the Society. (hereinafter in **3.1** referred to as *ARS*)

(6) Steel materials except steel plates (including steel flats not less than 600*mm* in width) may be treated according either

to *ARS* or to controlled rolling, subject to the approval by the Society. (hereinafter in **3.1** referred to as *CRS*)

(7) *ARS* may be accepted.

Table K3.4 Mechanical Properties

Grade	Tensile test			Impact test(1)		
	Yield point or proof stress	Tensile strength	Elongation(5) ($L = 5.65\sqrt{A}$)	Testing temperature	Minimum mean absorbed Energy (J)(3)	
	(N/mm^2)	(N/mm^2)	(%)	(℃)	*L*	*T*
KA	235 min.	400~520	22 min.	—	—	—
KB				0(4)	27	20
KD				-20		
KE				-40		
*KA*32	315 min.	440~590	22 min.	0(2)	31	22
*KD*32				-20		
*KE*32				-40		
*KF*32				-60		
*KA*36	355 min.	490~620	21 min.	0(2)	34	24
*KD*36				-20		
*KE*36				-40		
*KF*36				-60		
*KA*40	390 min.	510~650	20 min.	0	39	26
*KD*40				-20		
*KE*40				-40		
*KF*40				-60		

Notes:

(1) *L* (or *T*) denotes that the longitudinal axis of the test specimen is arranged parallel (or transverse) to the final direction of rolling (Refer to **3.1.7-3(2)**).

(2) Refer to **Note (1)** in **Table K3.6**.

(3) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimens is less in value than 70% of the specified minimum mean absorbed energy, the test is considered to be failed.

(4) For steels up to 25 *mm* in thickness, generally no impact testing is required.

(5) The minimum elongation for *U*1 test specimen is to be in compliance with the requirements given in **Table K3.5**.

Table K3.5 Minimum Elongation for *U*1 Specimen (%)

Grade	Thickness *t* (*mm*)							
	$t \leq 5$	$5 < t \leq 10$	$10 < t \leq 15$	$15 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 30$	$30 < t \leq 40$	$40 < t \leq 50$
KA,*KB*,*KD*,*KE*,*KA*32, *KD*32,*KE*32,*KF*32	14	16	17	18	19	20	21	22
*KA*36,*KD*36,*KE*36,*KF*36	13	15	16	17	18	19	20	21
*KA*40,*KD*40,*KE*40,*KF*40	12	14	15	16	17	18	19	20

Table K3.6 Size of Lot for Impact Test

Grade	Deoxidation practice	Products[3]	Heat treatment and size of lot impact test for[4][6] plate thickness (*mm*)
KA	Any method except rimmed	All	*AR* 〈–〉
KB		All	*AR* 〈50〉[5]
KD	Killed	All	*AR* 〈50〉
	Killed and fine grain treated	Plates	*AR* 〈50〉 / *TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉
		Others	*AR* 〈50〉 / *TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉, *ARS* 〈25〉
KE	Killed and fine grain treated	Plates	*TMCP* 〈P〉, *N* 〈P〉
		Others	*TMCP* 〈25〉, *N* 〈25〉, *CRS* 〈15〉
*KA*32 *KA*36[1]	Killed and fine grain treated (With *Nb* and/or *V*)[2]	Plates	*AR* 〈50〉 / *TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉
		Others	*AR* 〈50〉 / *TMCP* 〈50〉, *CR* 〈50〉, *N* 〈50〉, *ARS* 〈25〉
	Killed and fine grain treated (Without *Nb* and/or *V*)[2]	Plates	*AR* 〈50〉 / *ARS* 〈25〉 / *TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉
		Others	*AR* 〈50〉 / *TMCP* 〈50〉, *CR* 〈50〉, *N* 〈50〉, *ARS* 〈25〉
*KD*32 *KD*36	Killed and fine grain treated (With *Nb* and/or *V*)[2]	Plates	*AR* 〈50〉 / *TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉
		Others	*AR* 〈50〉 / *TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉, *ARS* 〈25〉
	Killed and fine grain treated (Without *Nb* and/or *V*)[2]	Plates	*AR* 〈50〉 / *ARS* 〈25〉 / *TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉
		Others	*AR* 〈50〉 / *TMCP* 〈50〉, *CR* 〈50〉, *N* 〈50〉, *ARS* 〈25〉
*KE*32 *KE*36	Killed and fine grain treated	Plates	*TMCP* 〈P〉, *N* 〈P〉
		Others	*TMCP* 〈25〉, *N* 〈25〉, *CRS* 〈15〉
*KA*40	Killed and fine grain treated	All	*AR* 〈50〉 / *TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉
*KD*40	Killed and fine grain treated	All	*TMCP* 〈50〉, *N* 〈50〉, *CR* 〈50〉
*KE*40	Killed and fine grain treated	Plates	*TMCP* 〈P〉, *N* 〈P〉, *QT* 〈PH〉
		Others	*TMCP* 〈25〉, *N* 〈25〉, *QT* 〈25〉
*KF*32 *KF*36 *KF*40	Killed and fine grain treated	Plates	*TMCP* 〈P〉, *N* 〈P〉, *QT* 〈PH〉
		Others	*TMCP* 〈25〉, *N* 〈25〉, *QT* 〈25〉

Notes:

(1) For grades *KA*32 and *KA*36 steels a relaxation in the size of lot may be permitted subject to the special approval of the Society.

(2) Refer to **Note (2)** in **Table K3.3**.

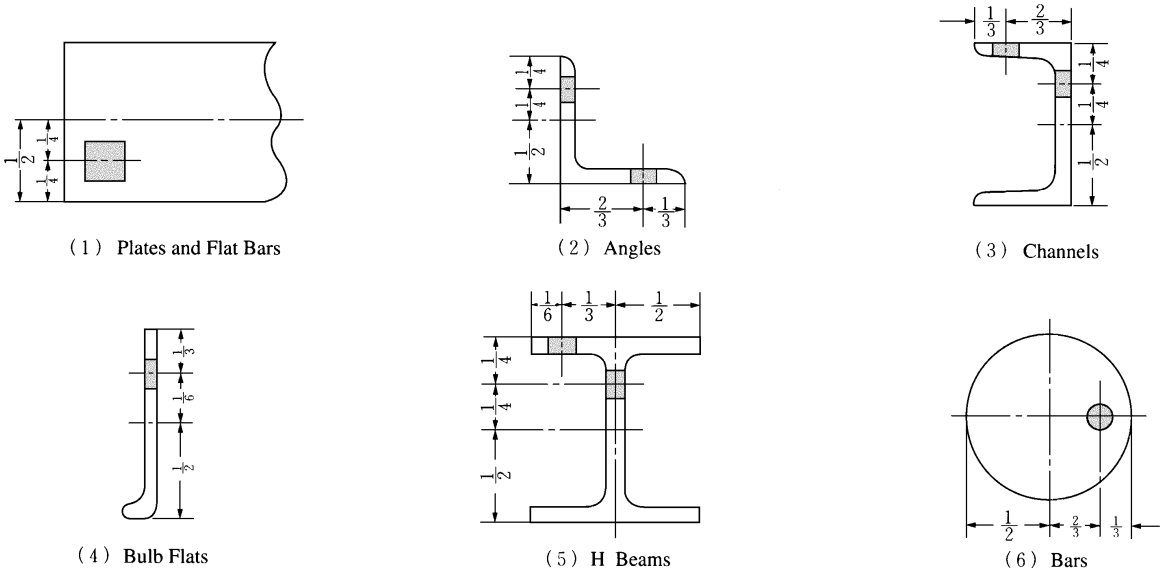
(3) Steel plates include steel flats not less than 600 *mm* in width.

(4) In the Table, "marks" put at the end of each "symbol" for heat treatment (*See* **Notes (3), (5)** and **(6)** of **Table K3.3**) stand for the volume of each lot. For examples, <50>, <25> and <15> each indicate that steels not greater in mass than 50, 25 and 15 *ton* (belonging to the same charge in the same manufacturing process) are to be taken as one lot; <*P*> indicates that steel plate rolled directly from one slab or steel ingot (belonging to the same heat treatment condition) is to be taken as one lot; <*PH*> indicates that steel plate rolled directly from one slab or steel ingot and heat treated simultaneously in the same furnace including continuous furnace is to be taken as one lot; and <-> indicates that no impact test is required.

(5) Refer to **Note (4)** in **Table K3.4**.

(6) Steels, which have been subjected to *TMCP*, *N*, or *CR* instead of being left in a state of *AR* (refer to **Note (4)** in **Table K3.3**) are to be treated equivalent to those left in a state of *AR* with regard to the fundamental unit of "lot".

Fig. K3.1 Selection of Test Samples



3.1.7 Selection of Test Specimens

1 In no case test specimens are to be heat treated separately from the product.

2 Tensile test specimens are to be taken according to **(1)** to **(3)** below.

(1) One test specimen is to be taken from one test sample.

(2) The test specimens are to be taken with their longitudinal axis normal to the final direction of rolling. For shapes, bars, and flat bars not exceeding 600 *mm* in width or when specially approved by the Society, however, they are to be taken with their longitudinal axis parallel to the final direction of rolling.

(3) Flat test specimens of full product thickness are, generally, to be used. Round test specimens, may be used when the product (except bars) thickness exceeds 40 *mm* or for bars. When round test specimens are taken from any steel except bars, they are to be taken at a portion approximately 1/4 of the thickness from the surface.

3 Impact test specimens are to be taken according to **(1)** to **(3)** below.

(1) A set of test specimens are to be taken from one test sample.

(2) The test specimens are to be taken with their longitudinal axis parallel (*L* direction) to the final direction of rolling. When deemed necessary by the Society, however, they are to be taken with their longitudinal axis normal (*T* direction) to the final direction of rolling.

(3) When the product thickness does not exceed 40 *mm*, the text specimens are to be cut with their edge within 2 *mm* from the "as rolled" surface. When the product thickness exceeds 40 *mm*, the test specimens are to be taken at a portion where the axis of the test specimen corresponds to approximately 1/4 of the thickness (1/6 of the diameter for bars) from the surface.

3.1.8 Verification of Dimensions*

1 Verification of dimensions are the responsibility of the steel manufacturer.

2 The minus tolerance in the nominal thickness of steels is to be in compliance with the requirements specified in **Table K3.7**. However, the average thickness of plates and the average thickness of flat bars with widths of 600 *mm* or greater is not to be less than the nominal thickness.

3 The procedure and the records of measurements are to be made available to the Surveyor and copies provided on request.

4 Any requirements regarding the minus tolerance except for the minus tolerance in the nominal thickness is left to the discretion of the Society.

5 The above **-2** and **-3** may not need to be applied, when deemed appropriate by the Society.

6 In accordance with the requirements in **1.3.4-1, Rules for Cargo Handling Appliances**, where extremely thick steel plates are used and where it is deemed by Society to be impracticable to comply with the requirements in **-1** to **-5** above, a treatment different from that specified in said requirements may be accepted.

Table K3.7 Verification of Dimensions

Products	Minus tolerance (*mm*)
Steel plates flat bars with widths of 150 *mm* or greater	0.3 and under
Others	At the discretion of the Society

3.1.9 Quality and Repair of Defects*

1 The finished material is to have a surface quality in accordance with the following **(1)** to **(6)**:

(1) The steel is to be free from surface defects prejudicial to the use of the material for the intended application.

(2) The responsibility for meeting the surface finish requirements rests with the manufacturer of the material, who is to take the necessary manufacturing precautions and is to inspect the products prior to delivery. At that stage, however, rolling or heat treatment scale may conceal surface discontinuities and defects. If, during the subsequent descaling or working operations, the material is found to be defective, the Society may require materials to be repaired or rejected.

(3) The finished material is to have a surface quality in accordance with standards deemed appropriate by the Society for cases other than those specified in this **3.1.9**. Rolled steel bars may comply with manufacturer standards.

(4) The surface quality inspection method is to be in accordance with recognized national or international standards agreed between purchaser and manufacturer, accepted by the Society.

(5) Imperfections of a harmless nature, regarded as being inherent of the manufacturing process, are permissible irrespective of their number, provided the maximum permissible limits of Class A of *EN* 10163 Part 2 or limits specified in a recognized equivalent standard accepted by the Society, are not exceeded and the remaining steel thickness remains in accordance with the requirements in **3.1.8**. Total affected area with imperfection not exceeding the specified limits are not to exceed 15% of the total surface in question.

(6) Defects given in the following **(a)** or **(b)** are to be rejected or repaired irrespective of their size and number.

(a) Affected areas with imperfections with a depth exceeding the limits of Class A of *EN* 10163 Part 2 or the maximum permissible limits specified in a recognized equivalent standard accepted by the Society

(b) Cracks, injurious surface flaws, shells (overlapping material with non-metallic inclusions), sand patches, laminations and sharp edged seams (elongated defects) visually evident on surface and/or edge of plate

2 The repair of defects is in accordance with the following **(1)** and **(2)**:

(1) The defects specified in **-1(6)** may be removed by local grinding provided that the following **(a)** to **(e)** are satisfied. The grounded areas are to have a smooth transition to the surrounding surface of the product. Complete elimination of the defect is to be verified by magnetic particle or liquid penetrant testing. The remaining steel thickness is to remain in accordance with the requirements in **3.1.8**. Such local grindings are to be carried out in the presence of a surveyor unless otherwise approved by the Society.

(a) The nominal product thickness does not be reduced by more than 7% or 3 *mm*, whichever is the less.

(b) Each single grounded area does not exceed 0.25 m^2.

(c) All grounded areas do not exceed 2% of the total surface in question.

(d) Grounded areas lying in a distance less than their average breadth to each other are to be regarded as one single area.

(e) Grounded areas lying opposite each other on both surfaces do not decrease the product thickness by values exceeding the limits as stated under **(a)**.

(2) Defects which cannot be dealt with as **(1)** above may be repaired by chipping or grinding followed by welding, subject to the approval by the Society, provided that the following **(a)** to **(e)** are satisfied. Repair of defects is to be followed by magnetic particle or liquid penetrant testing. Such welding repair is to be carried out in the presence of a surveyor unless otherwise approved by the Society. Subsequent to the finish grinding, the piece may be required to be normalized or otherwise heat treated at the surveyor's discretion.

(a) The weld preparation is not to reduce the thickness of the product below 80% of nominal thickness. For occasional defects with depths exceeding the 80% limit, special consideration may be given at the surveyor's discretion.

(b) Any single welded area is not to exceed 0.125 m^2 and the sum of all areas is not to exceed 2% of the surface side in question.

(c) If weld repair depth exceeds 3 *mm*, ultrasonic testing may be requested by the Society.

(d) The distance between two welded areas is not to be less than their average width.

(e) The repair is to be carried out by qualified welders using a procedure for the appropriate steel grade approved by the Society. The electrodes are to be of low hydrogen type and are to be dried in accordance with the manufacturer's requirements and protected against rehumidification before and during welding.

3 Internal soundness is to be in accordance with the following **(1)** and **(2)**:

(1) Verification of internal soundness is the responsibility of the manufacturer.

(2) If steels are ordered with ultrasonic tests, this is to be made in accordance with an accepted standard at the discretion of the Society.

3.1.10 Additional Tests before Rejection

1 Where the tensile test from the first piece selected fails to meet the requirements, two further tensile tests may be made from the same piece. If both of these additional tests meet all of the requirements, the piece and the remaining pieces from the same lot may be accepted.

2 If one or both of the additional tests referred to above are unsatisfactory, the piece from which the above-mentioned test specimens have been taken is to be rejected. However, the remaining pieces from the same lot may be accepted, provided that two of the remaining pieces in the lot, selected in the same way, are tested with satisfactory results.

3 Where the result of the impact test is unsatisfactory, additional tests may be carried out, with the exception of the following cases specified in **(1)** and **(2)** below, by taking a set of test specimens out of the same piece from which the above-mentioned test specimens have been taken. In this case, all pieces of the same lot from which the test specimens have been taken may be accepted, provided that the average absorbed energy of the six test specimens in all, including those which have been rejected as unsatisfactory, is not less than the required minimum mean absorbed energy, and that among the above six test specimens, whose absorbed energy is under the required minimum average absorbed energy, are not more than two in number or test specimen, whose absorbed energy is under 70% of the required value, is not more than one.

(1) The absorbed energy of all test specimens is under the required minimum average absorbed energy.

(2) The absorbed energy of two of the test specimens is under 70% the required minimum mean absorbed energy.

4 In case of **-3(1)** or **-3(2)** or where the first piece selected specified in **-3** is rejected, additional impact tests may be carried out on additional test specimens from each of two pieces largest in thickness selected further from the same lot. Where, in this case, each set of test specimens is in compliance with the requirements respectively, these pieces and remaining pieces in the same lot may be accepted. If one or both of these additional sets of tests do not give satisfactory results, the pieces in the same lot are to be rejected.

5 Where the test specimens fail in the retests specified above, the piece from which the test specimens have been taken is to be rejected. However, at the manufacturer's option, the remaining pieces in the same lot may be resubmitted individually for test and those pieces which give satisfactory results may be accepted.

6 At the manufacturer's option, the rejected piece may be resubmitted after heat treatment or re-heat treatment, or may be resubmitted as any other grade of steel and then, may be accepted provided that the required tests are satisfactory.

3.1.11 Marking

Steels which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **1.5.1**.

3.2 Rolled Steel Plates for Boilers

3.2.1 Application

1 The requirements are to apply to the steel plates for boilers and pressure vessels to be used at high temperature (hereinafter referred to as "steel plates" in **3.2**).

2 Steel plates having characteristics differing from those specified in **3.2** are to comply with the requirements in **1.1.1-3**.

3.2.2 Kinds

The steel plates are classified into 5 grades as given in **Table K3.8**.

Table K3.8 Grades of Steel Plates

Grade	Application
*KP*42	Not more than 200 *mm* in thickness
*KP*46	Not more than 200 *mm* in thickness
*KP*49	Not more than 200 *mm* in thickness
*KPA*46	Not more than 150 *mm* in thickness
*KPA*49	Not more than 150 *mm* in thickness

3.2.3 Chemical Composition

The chemical composition of the steel plates is to comply with the requirements given in **Table K3.9**.

3.2.4 Heat Treatment*

1 For steel plates of the "*KP*" grade with 50 *mm* or less and of the "*KPA*" grade with 38 *mm* or less in thickness, they are to be as rolled. They, however, may be heat treated as case requires.

2 For steel plates of the "*KP*" grade more than 50 *mm* and of the "*KPA*" grade more than 38 *mm* in thickness, they are to be either normalized to obtain the normal grain size or heated uniformly to such a temperature at the time of hot forming that an effect equivalent to normalizing can be achieved. In case of normalizing, it is, in principle, to be performed by the manufacturer.

3 For steel plates to which stress relieving is required after welding or stress relieving is applied by the purchaser once or several times repeatedly during their working process, instructions regarding both heat treatment conditions and frequency are to be given by the purchaser when the order is placed.

3.2.5 Mechanical Properties

The steel plates are to have the mechanical properties given in **Table K3.10**.

3.2.6 Selection of Test Samples*

1 For the steel plates which are not to be heat treated, one test sample is to be taken from each plate as rolled directly from one slab or ingot ; for the plates which are to be heat treated, one test sample is to be taken from every similarly heat treated plate as rolled directly from one slab or ingot.

2 Where the plates specified in **-1** are to be stress-relieved as specified in **3.2.4-3**, the conditions and frequency of the heat treatment for the stress-relieving of any test samples are to be in accordance with purchaser instructions.

3 The test samples are to be taken from the portion approximately 1/4 of the width from the side end of the piece.

Table K3.9 Chemical Composition

Grade	Thickness t (*mm*)	Chemical composition (%)												
		C	*Si*	*Mn*	*P*	*S*	*Mo*	*Cu*	*Ni*	*Cr*	*Nb*	*V*	*Ti*	*B*
*KP*42	$t \leq 25$	0.24 max.	0.15 ~ 0.40	0.90 max.	0.020 max.	0.020 max.	0.12 max.	0.40 max.	0.40 max.	0.30 max.	0.020 max.	0.030 max.	0.030 max.	0.0010 max.
	$25 < t \leq 50$	0.27 max.												
	$50 < t \leq 100$	0.29 max.												
	$100 < t \leq 200$	0.30 max.												
*KP*46	$t \leq 25$	0.28 max.												
	$25 < t \leq 50$	0.31 max.												
	$50 < t \leq 200$	0.33 max.												
*KP*49	$t \leq 25$	0.31 max.		1.20 max.										
	$25 < t \leq 50$	0.33 max.												
	$50 < t \leq 200$	0.35 max.												
*KPA*46	$t \leq 25$	0.18 max.		0.90 max.			0.45 ~ 0.60							
	$25 < t \leq 50$	0.21 max.												
	$50 < t \leq 100$	0.23 max.												
	$100 < t \leq 150$	0.25 max.												
*KPA*49	$t \leq 25$	0.20 max.												
	$25 < t \leq 50$	0.23 max.												
	$50 < t \leq 100$	0.25 max.												
	$100 < t \leq 150$	0.27 max.												

Notes:

(1) For *KP*42, *KP*46 and *KP* 49, manganese content may be increased by 0.06% for each 0.01% decrease in carbon content. However, the upper limit of manganese content is to be 1.50%

(2) For *KP*42, *KP*46 and *KP* 49, the combined total content of copper, nickel, chromium and molybdenum is not to exceed 1.00%; In addition, the combined total content of chromium and molybdenum is not to exceed 0.32%.

Table K3.10 Mechanical Properties

Grade	Yield point (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%) ($L = 5.65\sqrt{A}$)
*KP*42	225 min.	410~550	24 min.
*KP*46	245 min.	450~590	22 min.
*KP*49	265 min.	480~620	20 min.
*KPA*46	255 min.	450~590	23 min.
*KPA*49	275 min.	480~620	21 min.

Note:

For the plates over 90 *mm* in thickness, the elongation may be reduced from that mentioned in the above Table by 0.5% for each increment of 12.5 *mm* or fraction there of exceeding 90 *mm* in thickness. Such reduction, however, is limited to 3%.

3.2.7 Selection of Test Specimens

Tensile test specimens are to be taken according to **(1)** to **(3)** below.

(1) One test specimen is to be taken from one test sample.

(2) The test specimens are to be taken with their longitudinal axis normal to the final direction of rolling.

(3) The test specimen of bar type are to be taken from the portion approximately 1/4 of the thickness of the surface.

3.2.8 Tolerance for Thickness*

The minus tolerance for the nominal thickness of plates is to be 0.25 *mm* and under.

3.2.9 Quality and Repair of Defects

Surface defects may be removed by local grinding, provided that the thickness is not reduced from nominal thickness to a degree that exceeds the minus tolerance specified in **3.2.8** under any circumstances.

3.2.10 Additional Tests before Rejection

Where the tensile tests from the first test specimens selected fail to meet the requirements, additional tests may be conducted according to the requirements given in **1.4.4**.

3.2.11 Marking for Accepted Steels*

1 Steel plates which have satisfactorily complied with the required tests are to be stamped or marked by some other appropriate method with the identification mark relating to heat treatment in addition to the requirements in **1.5.1**.

2 The marks relating to heat treatment in **-1** are to be as specified in the following;

Where the plates are normalized: *N*

Where the test specimens are heat treated corresponding to the stress relieving to be applied: *SR*

3.3 Rolled Steel Plates for Pressure Vessels

3.3.1 Application

1 The requirements are mainly to apply to the steel plates for pressure vessels to be used at atmospheric temperature (hereinafter referred to as “steel plates” in **3.3**).

2 Steel plates having characteristic differing from those specified in **3.3** are to comply with the requirements in **1.1.1-3**.

3.3.2 Kinds

The steel plates are classified into 6 grades as given in **Table K3.11**.

Table K3.11 Grades of Steel Plates

Grade	Application
*KPV*24	Not more than 200 *mm* in thickness
*KPV*32	Not more than 150 *mm* in thickness
*KPV*36	Not more than 150 *mm* in thickness
*KPV*42	Not more than 150 *mm* in thickness
*KPV*46	Not more than 75 *mm* in thickness
*KPV*50	Not more than 75 *mm* in thickness

3.3.3 Chemical Composition

1 The chemical composition of the steel plates is to comply with the requirements given in **Table K3.12**. When deemed necessary, chemical elements other than those given in the Table may be added.

2 Notwithstanding the requirement given in **-1**, when heat treatment has been conducted according to *TMCP*, the chemical composition of steel plates specified in **Table K3.12** may be modified subject to the approval by the Society.

3.3.4 Heat Treatment*

1 *KPV*24, *KPV*32 and *KPV*36 plates are to be as rolled. They, however, may be controlled-rolled, *TMCP* or properly heat treated as case requires.

2 *KPV*42 plate is to be *TMCP*. But, they may be normalized or quenched and tempered subject to the approval by the Society. *TMCP* plate, however, may be manufactured up to 100*mm* in thickness.

3 *KPV*46 and *KPV*50 plates are to be quenched and tempered. But, they may be normalized or *TMCP* subject to the approval by

the Society.

4 In case of being normalized and quenched and tempered, they are, in principle, to be conducted by the manufacturer.

5 For steel plates to which stress relieving is required after welding or stress relieving is applied by the purchaser once or several times repeatedly during their working process, the requirements in **3.2.4-3** are to be applied.

Table K3.12 Chemical Composition

Grade	Chemical composition (%)						Carbon equivalent $C_{eq}(JIS)$ (%)(1)(2)				
							Quenched and tempered		*TMCP*		
	C		*Si*	*Mn*	*P*	*S*	50 *mm* and under in thickness	Over 50 *mm* and up to 75 *mm* in thickness	50 *mm* and under in thickness	Over 50 *mm* and up to 100 *mm* in thickness	Over 100 *mm* and up to 150 *mm* in thickness
*KPV*24	100 *mm* and under in thickness	0.18 max	0.35 max.	1.40 max.	0.020 max.	0.020 max.	—	—	—	—	—
	Over 100 *mm* in thickness	0.20 max									
*KPV*32	0.18 max.		0.55 max.	1.60 max.			—	—	0.39 max.	0.41 max.	0.43 max.
*KPV*36	0.20 max.		0.55 max.				—	—	0.40 max.	0.42 max.	0.44 max.
*KPV*42	0.18 max.		0.75 max.				—	—	0.43 max.	0.45 max.	—
*KPV*46	0.18 max.		0.75 max.				0.44 max.	0.46 max.	—	—	—
*KPV*50	0.18 max.		0.75 max.				0.45 max.	0.47 max.	—	—	—

Notes:

(1) The carbon equivalent $C_{eq}(JIS)$ is to be obtained using ladle analysis from the following formula, regardless of the requirements in **1.5.2-2(6)**.

$$C_{eq}(JIS) = C + \frac{Mn}{6} + \frac{Si}{24} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{V}{14} \quad (\%)$$

(2) Carbon equivalent $C_{eq}(JIS)$ is not specified where plates are as-rolled, controlled-rolled or normalized.

3.3.5 Mechanical Properties

The steel plates are to have the mechanical properties given in **Table K3.13**.

Table K3.13 Mechanical Properties

Grade	Tensile test					Impact test		
	Yield point or proof stress (N/mm^2)			Tensile strength (N/mm^2)	Elongation ($L = 5.65\sqrt{A}$)	Testing temperature (°C)	Minimum mean absorbed energy (J)	Minimum absorbed energy of individual test specimen (J)
	Thickness (mm)							
	$t \leq 50$	$50 < t \leq 100$	$100 < t \leq 200$		(%)			
*KPV*24	235 min.	215 min.	195 min.	400~510	23 min.	0	47	27
*KPV*32	315 min.	295 min.	275 min.(1)	490~610	22 min.			
*KPV*36	355 min.	335min.	315 min.(1)	520~640	20 min.			
*KPV*42	410 min.	390 min.	370 min.(1)	550~670	18 min.	-10		
*KPV*46	450 min.	430 min.(2)	—	570~700	17 min.			
*KPV*50	490 min.	470 min.(2)		610~740	16 min.			

Notes:

(1) For plate not more than 150 *mm* in thickness, this requirement is applied.

(2) For plate not more than 75 *mm* in thickness, this requirement is applied.

3.3.6 Selection of Test Samples*

1 For the steel plates which are not to be heat treated, one test sample is to be taken from each plate as rolled directly from one slab or ingot; for the steel plates which are to be heat treated, one test sample is to be taken from every similar heat treated plates as rolled directly from one slab or ingot.

2 Where the plates specified in **-1** are to be stress-relieved as specified in **3.3.4-5**, the conditions and frequency of the heat treatment for the stress-relieving of any test samples are to be in accordance with purchaser instructions.

3 The test samples are to be taken from the portion approximately 1/4 of the width from the side end of the piece.

3.3.7 Selection of Test Specimens*

1 Tensile test specimens are to be taken according to **(1)** to **(3)** below.

(1) One test specimen is to be taken from one test sample.

(2) The test specimens are to be taken with their longitudinal axis normal to the final direction of rolling.

(3) When tensile test specimens of bar type are taken from any steel except bars, they are to be taken at portion approximately 1/4 of the thickness from the surface.

2 Impact test specimens are to be taken according to **(1)** to **(3)** below.

(1) A set of test specimens are to be taken from one test sample.

(2) The test specimens are to be taken with their longitudinal axis parallel (*L* direction) to the final direction of rolling. When deemed necessary by the Society, however, they are to be taken with their longitudinal axis normal (*T* direction) to the final direction of rolling.

(3) The test specimen is to be taken at a portion where the axis of the test specimen corresponds to approximately 1/4 of the thickness from the surface.

3.3.8 Surface Inspection and Verification of Dimensions*

1 Surface inspection and verification of dimensions are the responsibility of the steel manufacturer.

2 The minus tolerance in the nominal thickness of plates is to be 0.25 *mm* and under.

3.3.9 Quality and Repair of Defects

Surface defects may be removed by local grinding, provided that the thickness is not reduced from nominal thickness to a degree that exceeds the minus tolerance specified in **3.3.8-2** under any circumstances.

3.3.10 Additional Tests before Rejection

1 Where the tensile test from the first test specimen selected fail to meet the requirements, additional tests may be conducted according to the requirements given in **1.4.4**.

2 In case where the mean value of absorbed energies in impact tests of 3 test specimens shows 85% or more of the specified value and each value of 2 or more test specimens meets the required value, although the mean value fails to meet the requirements, three additional test specimens may be put to retest taking such specimens from the position in the vicinity where the former test specimens were taken. In this case, if the mean value of 6 test specimens and each value of 3 test specimens in the retest meet the requirements, they may be accepted.

3.3.11 Marking*

1 Steel plates which have satisfactorily complied with the required tests are to be stamped or marked by some other appropriate method with the identification mark relating to heat treatment in addition to the requirements in **1.5.1**.

2 The marks relating to heat treatment in **-1** are to be as specified in the following:

Where the plates are controlled-rolled : *CR*

Where the plates are heat treated by *TMCP* : *TMC*

Where the plates are normalized : *N*

Where the plates are quenched and tempered : *Q*

Where the test specimens are heat treated corresponding to the stress relieving to be applied: *SR*

3.3.12 Steel Plates Equivalent to Standard

1 The mild steel plates of Grade *KD* and Grade *KE*, the high tensile steels of rolled steels for hull specified in **3.1** are taken as equivalent to the plates specified in **3.3**, in case where the test specimens are taken as required in **3.3.6** and **3.3.7** and test results are in compliance with the requirements in **3.1**. In this case, "*PV*" is to be suffixed to the markings to indicate the kind of plates specified in **3.1**.

2 Any requirements regarding heat treatment of steel plates specified in **-1** is left to the discretion of the Society.

3.4 Rolled Steels for Low Temperature Service

3.4.1 Application

1 The requirements are to apply to the rolled steels not exceeding 50 *mm* in thickness intended for tanks and ship's hull structures adjacent to tanks of liquefied gas carriers or ships using low-flashpoint fuels, and other parts such as hull structures of refrigerated cargo carrier which are exposed to low temperature (hereinafter referred to as "steels" in **3.4**).

2 Any requirement regarding the steels over 50 *mm* in thickness is left to the discretion of the Society.

3 Steels having characteristics differing from those specified in **3.4** are to comply with requirements in **1.1.1-3**.

4 The requirements provided in **3.1** are applicable except where specified in **3.4**.

3.4.2 Kinds

The steels are classified into 10 grades as given in **Table K3.14**.

3.4.3 Deoxidation Practice and Chemical Composition

1 The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table K3.14**. When deemed necessary, chemical elements other than those given in the table may be added to the option of the manufacturer.

2 Notwithstanding the requirement given in **-1**, when heat treatment has been conducted according to *TMCP*, the chemical composition of steels specified in **Table K3.14** may be modified subject to the approval by the Society.

Table K3.14 Grades and Chemical Composition

Grade	Deoxidation	Chemical composition (%)						Carbon equivalent (%)
		C	*Si*	*Mn*	*P*	*S*	*Ni*	
KL24A	Fully killed	0.16 max.	0.10~0.50	0.70~1.60	0.030 max.	0.025 max.	—	0.41 max.
KL24B	Aluminum	0.14 max.						
KL27	treated							
KL33	fine grain							
KL37								
KL2N30			0.30 max.	0.70 max.	0.025 max.	0.025 max.	2.10~2.50	—
KL3N32							3.25~3.75	
KL5N43		0.12 max.		1.50 max.			4.75~6.00	
KL9N53		0.10 max.		0.90 max.			8.50~9.50	
KL9N60								

3.4.4 Heat Treatment

The heat treatment of each grade is to comply with the requirements given in **Table K3.15**.

3.4.5 Mechanical Properties

1 The mechanical properties of steels are to comply with the requirements given in **Table K3.15**.

2 Where deemed necessary by the Society, other tests on notch toughness may be required.

3 For steels to which the requirement in **17.12, Part N** is applicable, the specified value of the maximum yield point or proof stress may be set after obtaining verification by the Society.

Table K3.15 Heat Treatment and Mechanical Properties

Grade	Heat treatment	Tensile test			Impact test(4)(5)		
		Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation(3) ($L = 5.65 \times \sqrt{A}$) (%)	Testing temperature (℃)	Minimum mean absorbed energy(J)	
						L	*T*
KL24A	Normalized, quenched and tempered or *TMCP*(1)	235 min.	400~510	20 min.	-40	41 min.	27 min.
KL24B					-50		
KL27		265 min.	420~540		-60		
KL33		325 min.	440~560				
KL37		360 min.	490~610	19 min.			
KL2N30	Normalized, normalized and tempered, quenched and tempered or *TMCP*(2)	295 min.	420~570		-70		
KL3N32		315 min.	440~590		-95		
KL5N43		420 min.	540~690		-110		
KL9N53	Double normalized and tempered, quenched and tempered or *TMCP*(2)	520 min.	690~830	18 min.	-196		
KL9N60		590 min.			-196		

Notes:

(1) Controlled rolling may be used as the heat treatment procedure in cases where deemed appropriate by the Society.

(2) If it is deemed appropriate by the Society, the intermediate heat treatment (the intermediate heat treatment is an operation of cooling from a dual phase composed of austenite and ferrite intended for improving toughness which is carried out prior to tempering) may be applied.

(3) The specified value for *U*1 test specimen other than those of proportional-size type is to be in compliance with the requirements given in **Table K3.16**.

(4) *L* (or *T*) indicates that the longitudinal axis of the test specimen is arranged parallel (or transverse) to the final direction of rolling.

(5) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value than 70% of the specified minimum average absorbed energy, the test is considered to be failed.

Table K3.16 Minimum Elongation for *U*1 Specimen (%)

Grade	Thickness t (mm)									
	$t \leq 5$	$5 < t \leq 10$	$10 < t \leq 15$	$15 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 30$	$30 < t \leq 35$	$35 < t \leq 40$	$40 < t \leq 45$	$45 < t \leq 50$
KL24A, *KL24B*, *KL27*	13	14	15	16	17	18	18	19	19	20
KL33	12	13	14	15	16	17	18	19	19	20
KL37	11	12	13	14	15	16	17	18	18	19
KL2N30, *KL3N32*, *KL5N43*	12	13	14	15	16	17	17	18	18	19
KL9N53, *KL9N60*	10	11	12	13	14	15	16	17	17	18

Table K3.17 (Deleted)

3.4.6 Selection of Test Samples

1 For steel plates, one test sample is to be taken from each plate which is rolled directly from one slab or ingot and is simultaneously heat treated in the same furnace including continuous furnace. When *TMCP* is used as heat treatment, one test sample is to be taken from each plate which is rolled directly from one slab or ingot.

2 For test samples used in other steels than steel plates, steels not greater in weight than 10 *tonnes* (having the same cross-sectional dimensions and being from the same cast manufactured by the same process) are to be treated as one lot, and one test sample is to be taken from each lot.

3 The requirements specified in **3.1.6-4** are to be applied to the selection of the test samples.

3.4.7 Selection of Test Specimens

1 Tensile test specimens are to be taken according to the requirements specified in **3.1.7**.

2 Impact test specimens are to be taken according to the following **(1)** and **(2)**:

(1) The requirement specified in **3.1.7-3(1)** and **(3)** are to apply.

(2) For steel plates, the test specimens are to be taken with their longitudinal axis normal (*T* direction) to the final direction of rolling; for other steels than steel plates, they are to be taken with their longitudinal axis parallel (*L* direction) to the final direction of rolling.

3.4.8 Surface Inspection and Verification of Dimensions*

1 Surface inspection and verification of dimensions are the responsibility of the steel manufacturer.

2 The minus tolerance in the nominal thickness of plates is to be 0.25 *mm* and under.

3 For steels other than plates, any requirement regarding the minus tolerance is left to the discretion of the Society.

3.4.9 Quality and Repair of Defects

Surface defects may be removed by local grinding, provided that the thickness is not reduced from nominal thickness to a degree that exceeds the minus tolerance specified in **3.4.8-2** under any circumstances.

3.4.10 Additional Tests before Rejection

1 Where the tensile test from the first piece selected fails to meet the requirements, additional test may be conducted according to the requirements given in **1.4.4**.

2 Regarding the impact test, additional tests may be conducted according to the requirements given in **3.1.10-3**.

3.4.11 Marking

1 Steels which have satisfactorily complied with the required test are to be marked with identification mark in accordance with the requirements in **1.5.1**.

2 For steels to which the requirement in **3.4.5-3** is applicable, the specified value of the maximum yield point or proof stress and "*U*" are to be suffixied to the grade mark.

(*e.g. KL*33-440*U*)

3.5 Rolled Stainless Steels

3.5.1 Application*

1 The requirements are to apply to the rolled stainless steels for tanks of liquefied gas carriers or ships using low-flashpoint fuels, or corrosion-resisting service (hereinafter referred to as "steels" in **3.5**).

2 Notwithstanding **-1** above, such steels may be used for other equipment in cases where deemed appropriate by the Society.

3 Steels having characteristics differing from those specified in **3.5** are to comply with the requirements in **1.1.1-3**.

4 The requirements provided in **3.1** are applicable except where otherwise specified in **3.5**.

3.5.2 Kinds

The steels are classified into 16 grades as given in **Table K3.18**.

3.5.3 Chemical Composition

The chemical composition of the steels is to comply with the requirements given in **Table K3.18**.

Table K3.18 Grades and Chemical Composition of Stainless Steels

Grade	Chemical composition (%)									
	C	*Si*	*Mn*	*P*	*S*	*Ni*	*Cr*	*Mo*	*N*	Others
*KSUS*304	0.08 max.	1.00 max.	2.00 max.	0.045 max.	0.030 max.	8.00~10.50	18.00~20.00	—	—	—
*KSUS*304*L*	0.030 max.					9.00~13.00				
*KSUS*304*N*1	0.08 max.		2.50 max.			7.00~10.50			0.10~0.25	
*KSUS*304*N*2						7.50~10.50			0.15~0.30	*Nb*≤0.15
*KSUS*304*LN*	0.030 max.					8.50~11.50	17.00~19.00		0.12~0.22	—
*KSUS*309*S*	0.08 max.		2.00 max.			12.00~15.00	22.00~24.00		—	
*KSUS*310*S*		1.50 max.				19.00~22.00	24.00~26.00			
*KSUS*316		1.00 max.				10.00~14.00	16.00~18.00	2.00~3.00		
*KSUS*316*L*	0.030 max.					10.00~14.00				
*KSUS*316*N*	0.08 max.					10.00~14.00			0.10~0.22	
*KSUS*316*LN*	0.030 max.					10.50~14.50	16.50~18.50		0.12~0.22	
*KSUS*317	0.08 max.					11.00~15.00	18.00~20.00	3.00~4.00	—	
*KSUS*317*L*	0.030 max.									
*KSUS*317*LN*									0.10~0.22	
*KSUS*321	0.08 max.					9.00~13.00	17.00~19.00	—	—	*Ti*≥5×*C*
*KSUS*323*L*	0.030 max.	1.00 max.	2.50 max.	0.040 max.	0.030 max.	3.00~5.50	21.50~24.50	0.05~0.60	0.05~0.20	0.05≤*Cu*≤0.60
*KSUS*329*J*1	0.08 max.	1.00 max.	1.50 max.	0.040 max.	0.030 max.	3.00~6.00	23.00~28.00	1.00~3.00	—	—
*KSUS*329*J*3*L*	0.030 max.	1.00 max.	2.00 max.	0.040 max.	0.030 max.	4.50~6.50	21.00~24.00	2.50~3.50	0.08~0.20	—
*KSUS*329*J*4*L*	0.030 max.	1.00 max.	1.50 max.	0.040 max.	0.030 max.	5.50~7.50	24.00~26.00	2.50~3.50	0.08~0.30	—
*KSUS*347	0.08 max.	1.00 max.	2.00 max.	0.045 max.	0.030 max.	9.00~13.00	17.00~19.00	—	—	*Nb*≥10×*C*
*KSUS*821*L*1	0.030 max.	0.75 max.	2.00 ~4.00	0.040 max.	0.020 max.	1.50~2.50	20.50~21.50	0.60 max.	0.15~0.20	0.50≤*Cu*≤1.50

3.5.4 Heat Treatment

The steels are generally to a solid solution treatment.

3.5.5 Mechanical Properties*

1 The mechanical properties of steels are to comply with the requirements given in **Table K3.19**. However, the specified value of the minimum proof stress may be altered to other values subject to the approval of the Society.

2 The hardness in hardness tests, according to the test methods, is to comply with the requirements given in **Table K3.19**.

3 Where deemed necessary by the Society, impact tests may be required.

Table K3.19 Mechanical Properties of Stainless Steels

Grade	Tensile test			Hardness test		
	Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation ($L = 5.65\sqrt{A}$)(%)	Brinell hardness *HBW*	Rockwell hardness *HRB*	Vickers hardness *HV*
*KSUS*304	205 min.	520 min.	40 min.	187 max.	90 max.	200 max.
*KSUS*304*L*	175 min.	480 min.				
*KSUS*304*N*1	275 min.	550 min.	35 min.	217 max.	95 max.	220 max.
*KSUS*304*N*2	345 min.	690 min.		248 max.	100 max.	260 max.
*KSUS*304*LN*	245 min.	550 min.	40 min.	217 max.	95 max.	220 max.
*KSUS*309*S*	205 min.	520 min.		187 max.	90 max.	200 max.
*KSUS*310*S*						
*KSUS*316						
*KSUS*316*L*	175 min.	480 min.				
*KSUS*316*N*	275 min.	550 min.	35 min.	217 max.	95 max.	220 max.
*KSUS*316*LN*	245 min.		40 min.			
*KSUS*317	205 min.	520 min.		187 max.	90 max.	200 max.
*KSUS*317*L*	175 min.	480 min.				
*KSUS*317*LN*	245 min.	550 min.		217 max.	95 max.	220 max.
*KSUS*321	205 min.	520 min.		187 max.	90 max.	200 max.
*KSUS*323*L*	400 min.	600 min.	25 max. (2)	290 max.	32 max. (1)	310 max.
*KSUS*329*J*1	390 min.	590 min.	18 min.	277 max.	29 max. (1)	292 max.
*KSUS*329*J*3*L*	450 min.	620 min.	18 min.	302 max.	32 max. (1)	320 max.
*KSUS*329*J*4*L*	450 min.	620 min.	18 min.	302 max.	32 max. (1)	320 max.
*KSUS*347	205 min.	520 min.	40 min.	187 max.	90 max.	200 max.
*KSUS*821*L*1	400 min.	600 min.	25 max. (2)	290 max.	32 max. (1)	310 max.

Notes:

(1) Rockwell hardness of *KSUS*323*L*, *KSUS*329*J*1, *KSUS*329*J*3*L*, *KSUS*329*J*4*L* and *KSUS*821*L*1 is to *C* scale value (*HRC*).

(2) For steels 2.0 *mm* or less in thickness, elongation is not to be less than 20%.

3.5.6 Other Properties

Where deemed necessary by the Society according to the use of steels, tests on corrosion resistance may be required.

3.5.7 Selection of Test Samples

1 One test sample is to be taken from each steel as rolled directly from one slab or ingot.

2 The requirements provided in **3.1.6-4.** are to be applied to the selection of the test samples.

3.5.8 Selection of Test Specimens

1 Tensile test specimens are to be taken according to the requirements specified in **3.1.7-2**.

2 The hardness test specimen may be a portion of tensile test specimen.

3.5.9 Surface Inspection and Verification of Dimensions*

1 Surface inspection and verification of dimensions are the responsibility of the steel manufacturer.

2 The minus tolerance in the nominal thickness of plates is to be 0.25 *mm* and under.

3 For steels other than plates, any requirement regarding the minus tolerance is left to the discretion of the Society.

3.5.10 Quality and Repair of Defects

Surface defects may be removed by local grinding, provided that the thickness is not reduced from nominal thickness to a degree that exceeds the minus tolerance specified in **3.5.9-2** under any circumstances.

3.5.11 Marking

1 Steels which have satisfactorily complied with the required tests are to be marked with identification mark in accordance with the requirements in **1.5.1**.

2 For steels complying with the requirement in **3.5.1-2**, "-*SU*" is to be suffixed to the grade mark of the steel bars. (*ex*. *KSUS*304-*SU*)

3 For steels to which the provisory requirement in **3.5.5-1** is applicable, the specified value of proof stress and "*M*" are to be suffixed to the grade mark. (*e.g. KSUS*304-235*M*)

3.6 Round Bars for Chains

3.6.1 Application

1 The requirements are to apply to the rolled steel round bars for chains specified in **Part L** (hereinafter referred to as "chain bars" in **3.6**).

2 Chain bars having characteristic differing from those specified in **3.6** are to comply with the requirements in **1.1.1-3.**

3 The requirements provided in **3.1** are applicable except where specified in **3.6**.

3.6.2 Kinds

The chain bars are classified into 6 grades as given in **Table K3.20**.

Table K3.20 Grades of Chain Bars

Grade		Application
Grade 1 chain bar	*KSBC*31	Studless chain, Grade 1 chain
Grade 2 chain bar	*KSBC*50	Grade 2 chain
Grade 3 chain bar	*KSBC*70	Grade 3 chain
Grade *R*3 chain bar	*KSBCR*3	Grade *R*3 chain
Grade *R*3*S* chain bar	*KSBCR*3*S*	Grade *R*3*S* chain
Grade *R*4 chain bar	*KSBCR*4	Grade *R*4 chain
Grade *R*4*S* chain bar	*KSBCR*4*S*	Grade *R*4*S* chain
Grade *R*5 chain bar	*KSBCR*5	Grade *R*5 chain

3.6.3 Deoxidation Practice and Chemical Composition

1 The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table K3.21**. Elements other than specified in **Table K3.21** may be added subject to a special approval by the Society.

2 Grades *KSBCR*4*S* and *KSBCR*5 are to be vacuum degassed.

3.6.4 Rolled Reduction Ratio

The rolled reduction ratio of grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5 is to be at least the approved value.

3.6.5 Grain Size

1 The austenitic grain size of grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5 is to be 6 or finer in accordance with *ASTM E*112 or an equivalent grain size index in accordance with *ISO* 643 or to be deemed as equivalent by the Society.

2 Measurements of grain size are to be taken at a depth of 1/3 radius from the surface.

3.6.6 Mechanical Properties*

The mechanical properties of steel bars are to comply with the requirements given in **Table K3.22**.

Table K3.21 Deoxidation Practice and Chemical Composition (%)

Grade	Deoxidation	*C*	*Si*	*Mn*	*P*	*S*	$Al_{(1)}$
*KSBC*31	Killed	0.20 max.	0.15~0.35	0.40 min.	0.040 max.	0.040 max.	—
*KSBC*50	Fine grained killed	0.24 max.	0.15~0.55	1.60 max.	0.035 max.	0.035 max.	0.020 min.
*KSBC*70		0.36 max.	0.15~0.55	1.00~1.90	0.035 max.	0.035 max.	0.020 min.
*KSBCR*3 *KSBCR*3*S* *KSBCR*4 *KSBCR*4*S* *KSBCR*5	Fine grained killed	Detailed chemical composition is to be approved by the Society. For Grade *KSBCR*4, *KSBCR*4*S* and *KSBCR*5 the steel should a minimum of 0.2% molybdenum.					

Note:

(1) *Al* content is to be represented by the total *Al* content and may be replaced partly other fine graining elements.

Table K3.22 Mechanical Properties

Grade	Tensile test				Impact test(1),(2)	
	Yield point or proof stress(3) (N/mm^2)	Tensile strength(3) (N/mm^2)	Elongation (L=5d) (%)	Reduction of area (%)	Testing temperature (℃)	Minimum mean absorbed energy(J)
*KSBC*31	-	370～490(4)	25 min.	-	-	-
*KSBC*50	295 min.	490～690	22 min.	-	0	27
*KSBC*70	410 min.	690 min.	17 min.	40 min.	0	60
*KSBCR*3	410 min.	690 min.	17 min.	50 min.	-20(5)	40(5)
*KSBCR*3*S*	490 min.	770 min.	15 min.	50 min.	-20(5)	45(5)
*KSBCR*4	580 min.	860 min.	12 min.	50 min.	-20	50
*KSBCR*4*S*	700 min.	960 min.	12 min.	50 min.	-20	56
*KSBCR*5	760 min.	1000 min.	12 min.	50 min.	-20	58

Notes:

(1) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value than 70% of the specified minimum mean absorbed energy, the test is considered to have failed.

(2) For *KSBC*50 intended for Grade 2 chain which will be heat-treated according to the provision **3.1.5 of Part L**, no impact testing is required.

(3) Aim value of yield to tensile ratio for grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5 is to be maximum 0.92.

(4) Lower limit of tensile strength of grade *KSBC*31 may be 300 N/mm^2 with the approval of the Society.

(5) Impact test of grade *KSBCR*3 and *KSBCR*3*S* may be carried out at the temperature 0℃ where approved by the Society. In this case, minimum mean absorbed energy is to be not less than 60 *J* for grade *KSBCR*3 and 65 *J* for grade *KSBCR*3*S*.

3.6.7 Selection of Test Samples

1 Steel bars not greater in weight than 50 *tonnes* (from the same cast manufactured by the same process) are to be treated as one lot, and one test sample largest in diameter is to be taken from each lot.

2 The heat treatment of the test samples is to comply with the requirements given in **Table K3.23** for each grade. In this case, the same heat treatment applied to chain bars after welding is to be carried out on the test sample.

Table K3.23 Heat Treatment of Test Sample

Grade	Heat treatment
*KSBC*31	As rolled or Normalized(1)
*KSBC*50	As rolled or Normalized(1)
*KSBC*70, *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S*, *KSBCR*5	Normalized, Normalized and tempered, or Quenched and tempered

Note:

(1) The round bars for chains which will not be heat treated according to the provision **3.1.5 of Part L** are to be treated as rolled.

3.6.8 Selection of Test Specimens*

1 Test specimens are to be taken in accordance with **Table K3.24** from test samples specified in **3.6.7**.

2 For grades *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5 in addition to the test specimen required by **-1**, two tensile test specimens having diameter of 20 *mm* in principle are to be taken the hydrogen embrittlement test. In this case, test specimen is to be taken from the central region of bar materials which have been simulated heat treated shown as **(1)** or **(2)**.

(1) In case of continuous casting, test samples representing both the beginning and the end of the charge are to be taken.

(2) In case of ingot casting, test samples representing two different ingots are to be taken.

3 The test specimens are to be taken with their longitudinal axis parallel to the final direction of rolling.

4 The tensile and impact test specimens are to be taken from the test sample in the longitudinal direction at a depth of 1/3 radius *r* from the surface or as close as possible to this position (See **Fig. K3.2**).

5 The longitudinal axis of the notch is to correspond approximately to the radial direction of each test specimen.

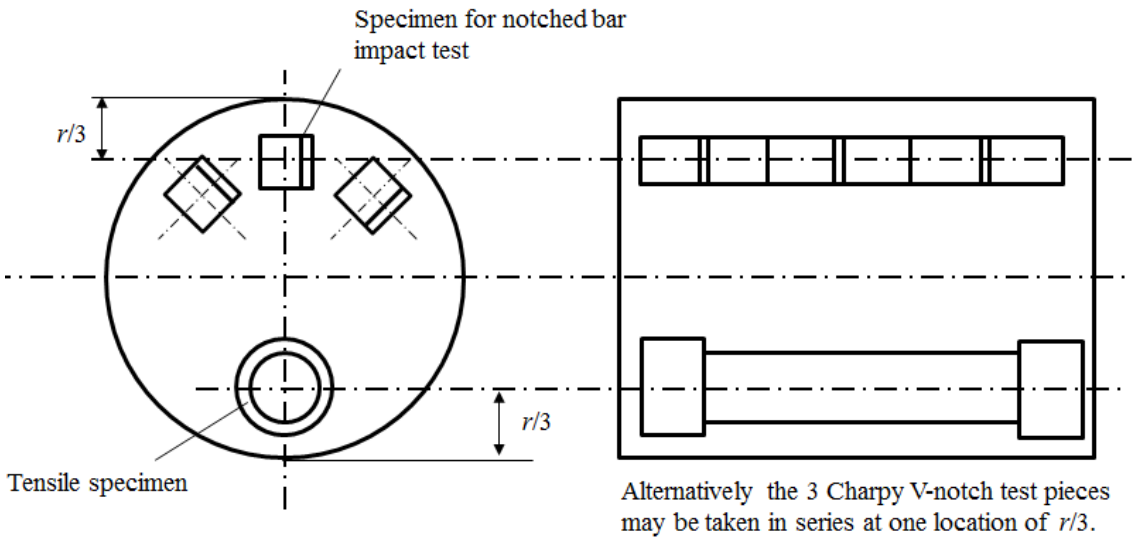
Table K3.24 Number of Test Specimens

Grade	Number of tensile test specimens	Number of impact test specimens
*KSBC*31	1 piece	—
*KSBC*50	1 piece	1 set (3 pieces)(1)
*KSBC*70, *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S*, *KSBCR*5	1 piece	1 set (3 pieces)

Note:

(1) In case where **Note (2)** of **Table K3.22** is applied, no impact test specimen need to be taken.

Fig. K3.2 Selection of Test Specimens



3.6.9 Hydrogen Embrittlement Test*

1 Hydrogen embrittlement test is to be carried out in accordance with the following procedure.

(1) One specimen is to be tested within max. 3 *hours* after machining or the specimen may be cooled to -60℃ immediately after machining and kept at that temperature for a period of max. 5 *days*.

(2) The other specimen is to be tested after baking at 250℃ for 4 *hours*.

(3) A slow strain rate as far as practicable (strain rate less than 0.0003 s^{-1}) is used during the entire test, and tensile strength, elongation and reduction of area are to be measured.

2 The test result is to be complied with the following formula.

$Z_{(1)}/Z_{(2)} \geq 0.85$

$Z_{(1)}$ is the reduction of area measured by the test specified in **-1(1)**

$Z_{(2)}$ is the reduction of area measured by the test specified in **-1(2)**

3.6.10 Surface Inspection, Non-destructive Test, Verification of Dimensions and Repair of Defects*

1 Surface inspection for all grades is to be carried out it is to be confirmed that there is no harmful defect.

2 For grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5, the entire bar material is to be examined by a magnetic particle test, an eddy current test or a magnetic leakage flux test in accordance with standards deemed appropriate by the Society and it is to be confirmed that there are no harmful defects.

3 For grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5, the entire bar material supplied in a machined (peeled) condition is to be visually inspected and it is to be confirmed that there are no harmful defects. In cases where deemed necessary, the Society may require 10% of the material be inspected by the non-destructive tests specified in **-2** to confirm there are no longitudinal imperfections. The maximum depth of peeling is to be agreed upon with the offshore chain manufacturer.

4 For grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5, the entire bar material is to be subjected to an ultrasonic test at an appropriate stage of manufacturing and it is to be confirmed that there are no harmful defects.

5 In the case specified in **-4** above, the area to be removed is to be agreed upon with the offshore chain manufacturer in cases where the end lengths of bar materials which are not subjected to ultrasonic tests are to be removed from the ends.

6 Notwithstanding the requirements of **-2** to **-4** above, the frequency of non-destructive test may be reduced where approved by the Society considering quality control of bar manufacturer is consistently achieved. However, non-destructive test to the test samples required by **3.6.7** is to be carried out in any case.

7 With respect to **-2** to **-4** above, non-destructive test procedures, together with rejection/acceptance criteria are to be submitted to the Society.

8 With respect to **-2** to **-4** above, non-destructive test operators are to be appropriately qualified in performing non -destructive test.

9 Dimensional tolerance of round bars refers to **Table K3.25**.

10 For grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5, repair of bars by welding is not permitted.

Table K3.25 Dimensional Tolerance

Nominal diameter (*mm*) (1)	Tolerance on diameter (*mm*)	Tolerance on roundness ($d_{max.}$ - $d_{min.}$) (*mm*)(2)
$d < 25$	-0 ～ +1.0	0.60 max.
$25 \leq d \leq 35$	-0 ～ +1.2	0.80 max.
$36 \leq d \leq 50$	-0 ～ +1.6	1.10 max.
$51 \leq d \leq 80$	-0 ～ +2.0	1.50 max.
$81 \leq d \leq 100$	-0 ～ +2.6	1.95 max.
$101 \leq d \leq 120$	-0 ～ +3.0	2.25 max.
$121 \leq d \leq 160$	-0 ～ +4.0	3.00 max.
$161 \leq d \leq 222$	-0 ～ +5.0	4.00 max.

Notes:

(1) For bar materials of nominal diameter which exceeds 222 *mm*, dimensional tolerance is to be as deemed appropriate by the Society.

(2) $d_{max.}$ and $d_{min.}$ are the maximum and minimum diameter of a single bar material.

3.6.11 Additional Tests before Rejection

1 Where the tensile test or impact test on the selected first test specimens have failed to meet the requirements, additional tests may be carried out according to the requirements given in **3.1.10-1** or **-3**.

2 Where the test of heat treated samples has failed, additional tests may be carried out according to the requirements given in **1.4.4-3**.

3 Where the hydrogen embrittlement test selected for the first test specimen has failed to meet the requirements specified in **3.6.9-2**, the bar materials may be subjected to a hydrogen degassing treatment after approved by the Society, and additional test can be performed after degassing.

3.6.12 Marking*

1 Chain bars which have proved satisfactory compliance with the required tests are to be marked with identification marks in accordance with the requirements in **1.5.1**.

2 In the case of chain bars of grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5, the material grade is, in principle, to be stamped onto the bar. However, the material grade may be marked by some other appropriate method in cases where approved by the Society.

3.6.13 Submission of Data*

1 For grades *KSBCR*4*S* and *KSBCR*5, the following information for each heat is to be submitted by the bar manufacturer to the offshore chain manufacturer.

(1) The results of the microscopic examinations for non-metallic inclusions.

(2) The results of macro etched examinations in order to confirm that there is no injurious segregation or porosity.

(3) The results of hardenability tests.

2 For grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5, the maximum depth of peeling specified in **3.6.10-3**.

3 For grades *KSBCR*3, *KSBCR*3*S*, *KSBCR*4, *KSBCR*4*S* and *KSBCR*5, the end lengths of the bar materials which are not subjected to the ultrasonic tests specified in **3.6.10-5**.

3.7 Rolled Steel Bars for Structures

3.7.1 Application

1 The requirements are to apply to the rolled steel bars used for machine structures such as shafts or bolts (hereinafter referred to as “steel bars” in **3.7**) and rolled steel bars used for hull structures such as stern frames.

2 Steel bars having characteristics differing from those specified in **3.7** are to comply with the requirements in **1.1.1-3**.

3.7.2 Kinds

The steel bars are classified into 2 grades as given in **Table K3.26**.

Table K3.26 Grades of Steel Bars

Kind	Grade
Rolled carbon steel bars	The grade of steel bars is to be indicated by suffixing a letter "*R*" to the grade "*KSF*" specified in **Table K6.3(a)** and **Table K6.3(b)** (e.g. *KSFR*440-*M* and *KSFR*440-*H*)
Rolled alloy steel bars	The grade of steel bars is to be indicated by suffixing a letter "*R*" to the grade "*KSFA*" specified in **Table K6.3(a)** and **Table K6.3(b)** (e.g. *KSFAR*600-*M* and *KSFAR*600-*H*)

3.7.3 Deoxidation Practice and Chemical Composition

1 Deoxidation practice for steel bars is to be killed.

2 Chemical composition of steel bars is to comply with the requirements given in **6.1.4**. In application, the terms "steel forgings" are to be read as "steel bars".

3.7.4 Reduction Ratio and Heat Treatment

1 The reduction ratio of steel bars is to be not less than 6 unless specially approved by the Society.

2 The heat treatment of steel bars is to be as deemed appropriate by the Society.

3.7.5 Mechanical Properties

Mechanical properties of steel bars are to comply with the requirements given in **6.1.6-1** and **-2**. In application, the term "steel forgings" is to be read as "steel bars".

3.7.6 Selection of Test Samples

For the test samples, steel bars not greater in mass than 5 *tons* (belonging to the same diameter from the same manufacturing process in the same charge) are to be treated as one lot, and one sample is to be selected each lot.

3.7.7 Selection of Test Specimens

Test specimens are to be taken according to **(1)** to **(3)** below:

(1) One tensile test specimen is to be taken from one test sample.

(2) A set of test specimens are to be taken from one test sample.

(3) The requirements specified in **3.6.8-3**, **-4** and **-5** are to apply.

3.7.8 Surface Inspection and Verification of Dimensions

1 Surface inspection and verification of dimensions are the responsibility of the steel bars manufacturer.

2 For steel bars, the verification of dimensions is left to the discretion of the Society.

3.7.9 Non-destructive Test

Non-destructive test of steel bars is to comply with the requirements given in **6.1.10.** In application, the terms "steel forgings" are to be read as "steel bars".

3.7.10 Repair of Defects

Repair of defects is to comply with the requirements given in **6.1.11**. In application, the term "steel forgings" is to be read as "steel bars".

3.7.11 Additional Tests before Rejection

Where the tensile test or the hardness test from the first test specimen selected fails to meet the requirements, additional tests may be conducted according to the requirements given in **1.4.4**.

3.7.12 Markings

Steel bars which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **1.5.1**. For steel bars to which the requirements given in **6.1.6-2** have been applied, the value corresponding to the required tensile strength employed is to be suffixed to their respective grade markings (e.g. where the required tensile strength employed is 440 N/mm^2, "*KSFR*440-*M*" or "*KSFR*440-*H*" is to be indicated)

3.8 High Strength Rolled Steels for Offshore Structures

3.8.1 Application

1 The requirements given in **3.8** are to apply to the high strength rolled steels for marine or offshore structures intended for mobile offshore units, tanks of liquefied gas carriers or ships using low-flashpoint fuels, and process pressure vessels, etc. (hereinafter referred to as "steels" in **3.8**).

2 Steel plates having characteristics differing from those specified in **3.8** are to comply with the requirements in **1.1.1-3**.

3.8.2 Kinds*

1 The steels are classified into the grade of steels as given in **Table K3.27**.

2 Maximum thickness according to type of products and heat treatment is to comply with the requirements given in **Table K3.28.**

3 The requirements for steels whose thicknesses exceed values given in **Table K3.28** are at the discretion of the Society.

Table K3.27 Grade of Steel, Heat Treatment and Chemical Composition

Deoxidation practice	Killed and fine grain treatment					
Heat treatment(1)	*N* /*NR*		*TMCP*(2)		*QT*	
Grade of steel / Chemical composition (3)	*KA*420 *KD*420 *KA*460 *KD*460	*KE*420 *KE*460	*KA*420 *KD*420 *KA*460 *KD*460 *KA*500 *KD*500 *KA*550 *KD*550 *KA*620 *KD*620 *KA*690 *KD*690 *KA*890	*KE*420 *KF*420 *KE*460 *KF*460 *KE*500 *KF*500 *KE*550 *KF*550 *KE*620 *KF*620 *KE*690 *KF*690 *KD*890 *KE*890	*KA*420 *KD*420 *KA*460 *KD*460 *KA*500 *KD*500 *KA*550 *KD*550 *KA*620 *KD*620 *KA*690 *KD*690 *KA*890 *KA*960	*KE*420 *KF*420 *KE*460 *KF*460 *KE*500 *KF*500 *KE*550 *KF*550 *KE*620 *KF*620 *KE*690 *KF*690 *KD*890 *KE*890 *KD*960 *KE*960
C (%)	0.20 max.	0.18 max.	0.16 max.	0.14 max.	0.18 max.	
Mn (%)	1.0~1.70		1.0~1.70		1.70 max.	
Si (%)	0.60 max.		0.60 max.		0.80 max.	
P (%)(4)	0.030 max.	0.025 max.	0.025 max.	0.020 max.	0.025 max.	0.020 max.
S (%)(4) (5)	0.025 max.	0.020 max.	0.015 max.	0.010 max.	0.015 max.	0.010 max.
Al (%)(6)	0.02 min.		0.02 min.		0.018 min.	
Nb (%)(7)	0.05 max.		0.05 max.		0.06 max.	
V (%)(7)	0.20 max.		0.12 max.		0.12 max.	
Ti (%)(7)	0.05 max.		0.05 max.		0.05 max.	
Ni (%)	0.80 max.		2.00 max.(8)		2.00 max.(8)	
Cu (%)	0.55 max.		0.55 max.		0.50 max.	
Cr (%)(7)	0.30 max.		0.50 max.		1.50 max.	
Mo (%)(7)	0.10 max.		0.50 max.		0.70 max.	
N (%)	0.025 max.		0.025 max.		0.015 max.	
O (*ppm*)(9)	–		–	50 max.	–	30 max.

Notes:

(1) Symbols used to indicate heat treatment are as follows. The kinds and definitions of heat treatment are to be as deemed appropriate by Society.

N : Normalizing (*N*)

NR : Controlled Rolling (*CR* / *NR*)

TMCP : Thermo-Mechanical Controlled Processing (*TMCP*)

QT : Quenching and Tempering (*QT*)

(2) Direct quenching thermos-mechanical rolling (*TMR*) followed by tempering may be considered equivalent to *TMCP* only when the requirements in this section are applied.

(3) In cases where adding *B*, the maximum of the *B* content is not to be higher than 0.005%, and the analysis result is to be reported.

(4) For sections, the *P* and *S* content may be 0.005% higher than the value specified in the table.

(5) For steels complying with the requirements specified in **3.11**, the maximum of *S* content is to be 0.008%.

(6) The total *Al* to *Ni* ratio is to be a minimum of 2:1. When other nitrogen binding elements are used, the minimum *Al* value and *Al*/*N* ratio do not apply

(7) Total *Nb*, *V*, *Ti* content is not to exceed 0.26% and total *Mo*, *Cr* content is not to exceed 0.65%. This does not apply to *QT* steels.

(8) The maximum of the *Ni* content may exceed 2.00% in cases where approved by the Society.

(9) The requirement for maximum *O* content is only applicable to *KD*890, *KE*890, *KD*960 and *KE*960.

3.8.3 Steel Making Processes, Deoxidation Practice and Chemical Composition*

1 Steel making processes are to comply with the requirements given in **1.2.1-1**. However, the steels listed in the following **(1)** and **(2)** are to be vacuum degassed.

(1) Steels subject to the requirements given in **3.11** related to the improvement of thickness properties.

(2) Steels whose strength level is *K*690, *K*890 or *K*960.

2 The deoxidation practice and chemical composition of steels are to comply with the requirements given in **Table K3.27**. Where subjected to the approval of the Society, other elements than specified in the Table may be added at the option of the manufacturer.

3 The steel is to be fine grain treated using an appropriate process.

4 The carbon equivalent value is to comply with the requirements given in **Table K3.29**. The value is to be calculated using ladle analysis with the formula specified in **1.5.2**.

5 Notwithstanding the requirements given in **-4**, for *TMCP* or *QT* heat-treated steels whose carbon contents does not exceed 0.12%, cold cracking susceptibility (P_{cm}) for evaluating weldability may be used instead of the carbon equivalent. The cold cracking susceptibility (P_{cm}) is to be calculated using ladle analysis with the formula specified in **1.5.2** and is to comply with the requirements given in **Table K3.29.**

3.8.4 Heat Treatment

1 The heat treatment of each grade is to comply with the requirements given in **Table K3.27**.

2 The reduction ratio of the steel is to be not less than three except in cases where approved by the Society.

3.8.5 Mechanical Properties

The steels are to conform to the requirements given in **Table K3.30** as to mechanical properties.

3.8.6 Selection of Test Samples

1 For the test samples from which tensile test specimens are selected, steels (belonging to the same charge, with the same heat treatment, and of the same thickness) not greater in weight than 25 *tonnes* are to be treated as one lot, and one test sample is to be selected from each lot.

2 For the test samples from which impact test specimens are selected, the following **(1)** to **(3)** are to be complied with according to condition of heat treatment and type of product.

(1) For *N*/*NR* or *TMCP* heat-treated steels (including flat bars not less than 600 *mm* in width), steels rolled directly from a single slab, ingot, etc. are to be treated as one lot, and one test sample is to be selected from each lot.

(2) For *QT* heat-treated steels (including flat bars not less than 600 *mm* in width), steels rolled directly from a single slab, ingot,

etc. and simultaneously heat treated in the same furnace are to be treated as one lot, and one test sample is to be selected from each lot.

(3) For steels (including flat bars less than 600 *mm* in width, sections, bars and tubulars) regardless of condition of heat treatment, steels (belonging to the same cast, with the heat treatment and of the same thickness) not greater in weight than 25 *tonnes* are to be treated as one lot, and one test sample is to be selected from each lot.

3 Notwithstanding the requirements given in **-1** and **-2**, where simultaneous heat treated is applied, a frequency of selection of test sampling differing from those given above may be allowed in cases where approved by the Society.

4 The requirements specified in **3.1.6-4** are to be applied to the selection of the test samples. However, the selection of the test samples for tubers is to be as deemed appropriate by the Society.

3.8.7 Selection of Test Specimens

1 Under no circumstances are test specimens to be heat treated separately from the product.

2 Tensile test specimens are to be taken according to the following requirements.

(1) One test specimen is to be taken from a test sample.

(2) Test specimens are to be taken with their longitudinal axis transverse to the final direction of rolling. For sections, bars, and flat bars not exceeding 600 *mm* in width, tubulars or in cases approved by the Society, however, test specimens may be taken with their longitudinal axis parallel to the final direction of rolling.

(3) Flat test specimens of full product thickness are generally to be used. However, round test specimens may be used for bars as alternatives to flat test specimens.

(4) When the flat test specimens are used, the specimens are to be prepared in such a manner as to maintain the rolling scale at least on one side.

(5) When round test specimens are taken from any steel except bars, they are to be taken at a portion where the axis of the test specimen corresponds to approximately 1/4 of the thickness (1/6 of the diameter for bars) from the surface. An additional 1/2 of the thickness is to be taken when product thickness exceeds 100 *mm*.

3 Impact test specimens are to be taken according to the following requirements.

(1) A set of test specimens is to be taken from one test sample.

(2) Test specimens are to be taken with their longitudinal axis transverse (the *T* direction) to the final direction of rolling. For sections, bars, and flat bars not exceeding 600 *mm* in width and tubulars, however, test specimens are to be taken with their longitudinal axis parallel (the *L* direction) to the final direction of rolling.

(3) When product thickness does not exceed 50 *mm*, test specimens are to be cut with their edges within 2 *mm* from the "as rolled" surface. When product thickness exceeds 50 *mm*, test specimens are to be taken at a portion where the axis of the test specimen corresponds to approximately 1/4 and 1/2 of the thickness (1/6 of the diameter for bars) from the surface.

3.8.8 Verification of Dimensions

The requirements specified in **3.1.8** are to apply to verification of dimensions are to be specified in **3.1.8**.

3.8.9 Quality and Repair of Defects

Quality and repair of defects are to comply with the requirements of **3.1.9**.

3.8.10 Additional Tests before Rejection

1 Where the tensile test from the first test specimen selected fails to meet the requirements, additional tests may be conducted according to the requirements given in **3.1.10-1**.

2 Regarding the impact tests, additional tests are to be carried out according to the requirements given in **3.1.10-3**.

3.8.11 Marking

Steels which have satisfactorily complied with the required tests are to be marked with identification mark in accordance with the requirements in **1.5.1**. In addition, for steels to which the requirements given in the provisions to **Notes (5)** and **(6)** in **Table K3.30** have been applied, "-*YP* [new yield point or proof stress value] *M* " is to be suffixed to the marking in cases where the yield point or proof stress value is changed, and "-*TS* [new tensile point value] *M* " is to be suffixed to the marking in cases where the tensile point value is changed. (Example: *KA*620-*YP*620*M*-*TS*700*M*)

Table K3.28 Maximum Thickness According to Type of Product and Heat Treatment

Heat treatment \ Type of product	Maximum thickness (*mm*) (1)			
	Plate/Flat bar	Section	Bar	Tubular
N	250	50	250	65
NR	150	(2)		
TMCP	150	50	—	—
QT	150	50	—	50

Notes:

(1) For bars, "thickness" is to be read as either "radius" or "length of one side"

(2) As deemed appropriate by the Society. However, maximum thickness is not to exceed that of *N* products.

Table K3.29 Maximum Carbon Equivalent and Cold Cracking Susceptibility Values

Grade of steel and heat treatment		Carbon equivalent (%)(1)							Cold cracking Susceptibility (%)
		C_{eq}						*CET*	P_{cm}
		Thickness (*mm*)(2)							
		Plate/Flat bar			Section	Bar	Tubular		
		$t \leq 50$	$50 < t \leq 100$	$100 < t \leq 250$	$t \leq 50$	$t \leq 250$ or $d \leq 250$	$t \leq 65$		
*KA*420 *KD*420 *KE*420 *KF*420	*N*/*NR*	0.46	0.48	0.52	0.47	0.53	0.47	—	—
	TMCP	0.43	0.45	0.47	0.44	—	—	—	—
	QT	0.45	0.47	0.49	—	—	0.46	—	—
*KA*460 *KD*460 *KE*460 *KF*460	*N*/*NR*	0.50	0.52	0.54	0.51	0.55	0.51	0.25	—
	TMCP	0.45	0.47	0.48	0.46	—	—	0.30	0.23
	QT	0.47	0.48	0.50	—	—	0.48	0.32	0.24
*KA*500 *KD*500 *KE*500 *KF*500	*TMCP*	0.46	0.48	0.50	—	—	—	0.32	0.24
	QT	0.48	0.50	0.54	—	—	0.50	0.34	0.25
*KA*550 *KD*550 *KE*550 *KF*550	*TMCP*	0.48	0.50	0.54	—	—	—	0.34	0.25
	QT	0.56	0.60	0.64	—	—	0.56	0.36	0.28
*KA*620 *KD*620 *KE*620 *KF*620	*TMCP*	0.50	0.52	—	—	—	—	0.34	0.26
	QT	0.56	0.60	0.64	—	—	0.58	0.38	0.30
*KA*690 *KD*690 *KE*690 *KF*690	*TMCP*	0.56	—	—	—	—	—	0.36	0.30
	QT	0.64	0.66	0.70	—	—	0.68	0.40	0.33
*KA*890 *KD*890 *KE*890	*TMCP*	0.60	—	—	—	—	—	0.38	0.28
	QT	0.68	0.75	—	—	—	—	0.40	—
*KA*960 *KD*960 *KE*960	*QT*	0.75	—	—	—	—	—	0.40	—

Notes:

(1) For steel grades *K*460 and higher, *CET* may be used instead of C_{eq}. In such cases, *CET* is to be calculated according to the following formula.

$$CET = C + \frac{(Mn + Mo)}{10} + \frac{(Cr + Cu)}{20} + \frac{Ni}{40}$$

(2) For bars, "thickness" is to be read as either "radius" or "length of one side"

Table K3.30 Mechanical Properties

Grade of steel and heat treatment		Yield point or Proof stress (N/mm^2)			Tensile strength (N/mm^2) [3]		Elongation $L_0=5.65\sqrt{S_0}$ (%) [1] [2]		Impact test [7] [8]		
		Thickness (mm) [4]			Thickness (mm) [4]				Testing temperature	Minimum mean absorbed energy (J) [2]	
		$3< t \leq 50$	$50< t \leq 100$ [5]	$100< t \leq 250$ [5]	$3< t \leq 100$	$100< t \leq 250$ [6]	T	L	(°C)	T	L
*KA*420	*N*/*NR* *TMCP* *QT*	420 min.	390 min.	365 min.	520~680	470~650	19	21	0	28	42
*KD*420									-20		
*KE*420									-40		
*KF*420									-60		
*KA*460	*N*/*NR* *TMCP* *QT*	460 min.	430 min.	390 min.	540~720	500~710	17	19	0	31	46
*KD*460									-20		
*KE*460									-40		
*KF*460									-60		
*KA*500	*TMCP* *QT*	500 min.	480 min.	440 min.	590~770	540~720	17	19	0	33	50
*KD*500									-20		
*KE*500									-40		
*KF*500									-60		
*KA*550	*TMCP* *QT*	550 min.	530 min.	490 min.	640~820	590~770	16	18	0	37	55
*KD*550									-20		
*KE*550									-40		
*KF*550									-60		
*KA*620	*TMCP* *QT*	620 min.	580 min.	560 min.	700~890	650~830	15	17	0	41	62
*KD*620									-20		
*KE*620									-40		
*KF*620									-60		
*KA*690	*TMCP* *QT*	690 min.	650 min.	630 min.	770~940	710~900	14	16	0	46	69
*KD*690									-20		
*KE*690									-40		
*KF*690									-60		
*KA*890	*TMCP* *QT*	890 min.	830 min.	—	940~1100	—	11	13	0	46	69
*KD*890									-20		
*KE*890									-40		
*KA*960	*QT*	960 min.	—	—	980~1150	—	10	12	0	46	69
*KD*960									-20		
*KE*960									-40		

Notes:

(1) For steels whose strength levels are *K*420 to *K*960, *U*1 test specimens may be used. In such cases, the minimum elongation for the *U*1 test specimen is to comply with the requirements given in **Table K3.29**.

(2) The direction of the longitudinal axis of the test specimen to the direction of final rolling is denoted by *L* for parallel or *T* for transverse.

(3) For steels complying with the requirements specified in **3.11**, the results of tensile tests in the through thickness direction are not to be less than 80% of specified minimum tensile strength.

(4) For bars, “thickness” is to be read as “radius” or “length of one side”

(5) For plates, flat bars and sections, the values in the thickness range of $3< t \leq 50$ are to applied regardless of thickness in cases where the design requires that tensile properties are maintained throughout the thickness.

(6) For plates, flat bars and sections for applications, values in the thickness range of $3< t \leq 100$ are to applied regardless of thickness in cases where the design requires that tensile properties are maintained throughout the thickness.

(7) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value than 70% of the specified minimum mean absorbed energy, the test is considered to be failed.

(8) Impact tests for nominal thicknesses of less than 6 *mm* may be omitted.

Table K3.31 Minimum Elongation for *U*1 Specimen (%)

Grade of steel	Thickness *t* (*mm*)						
	$t \leq 10$	$10 < t \leq 15$	$15 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 40$	$40 < t \leq 50$	$50 < t \leq 70$
*KA*420, *KD*420, *KE*420, *KF*420	11	13	14	15	16	17	18
*KA*460, *KD*460, *KE*460, *KF*460	11	12	13	14	15	16	17
*KA*500, *KD*500, *KE*500, *KF*500	10	11	12	13	14	15	16
*KA*550, *KD*550, *KE*550, *KF*550	10	11	12	13	14	15	16
*KA*620, *KD*620, *KE*620, *KF*620	9	11	12	12	13	14	15
*KA*690, *KD*690, *KE*690, *KF*690	9	10	11	11	12	13	14

Note:

(1) *U*1 test specimens are to be taken with their longitudinal axis transverse to the final direction rolling.

3.9 Stainless Clad Steel Plates

3.9.1 Application

1 The requirements in Section **3.9** are to apply to the stainless clad steels not exceeding 50 *mm* in thickness intended for tanks of ships carrying dangerous chemicals in bulk, tank circumference hull construction units, and corrosion-resisting tanks (hereinafter referred to as "steel plates" in **3.9**).

2 The requirements other than those specified in Section **3.9** are to apply to **3.1**.

3 Any requirements regarding the steel plates over 50 *mm* in thickness are to comply with the requirements in **1.1.1-3**.

4 Steel plates having characteristics differing from those specified in **3.9** are to comply with the requirements in **1.1.1-3**.

3.9.2 Process of Manufacture

1 Manufacture of steel plates is to comply with the processes shown in **(1)** to **(5)** below:

(1) Rolling

(2) Cast rolling

(3) Explosive pressing

(4) Explosive rolling

(5) Overlay rolling

2 Application of any other process of manufacture than those specified in **-1** is left to the discretion of the Society.

3.9.3 Structural Metals

1 Base and cladding metals for steel plates are to be steel plates of rolled steels for hull specified in **3.1** and steel plates of rolled stainless steels specified in **3.5** respectively. However, the standard thickness of cladding metals is not less than 1.5 *mm*.

2 The symbol of the plate is to be of combination of that of the base plates and the cladding metals.

3.9.4 Heat Treatment

The steel plates are to comply with the requirements for heat treatment of the base metal.

3.9.5 Mechanical Properties

The steel plates are to conform to the requirements given in **Table K3.32** as to mechanical properties.

Table K3.32 Mechanical Properties

Kind of base metal	Grade of base metal	Tensile test(1)			Shearing strength test(3)	Impact test
		Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Shearing strength (N/mm^2)	
Mild steel	*KA*, *KB*, *KD*, *KE*	235 min.	σ_B min.(2)	To be complied with the requirement for base metal	200 min.	To be complied with the requirement for base metal
High tensile steel	*KA*32, *KA*36, *KD*32, *KD*36, *KE*32, *KE*36, *KF*32, *KF*36	σ_y min.(2)				

Notes:

(1) The tensile test specimen is to be U1 test specimen.

(2) σ_y and σ_B are to be obtained from the following formulae:

$$\sigma_y = \frac{t_1\sigma_{y1}+t_2\sigma_{y2}}{t_1+t_2} \ (N/mm^2)$$

$$\sigma_B = \frac{t_1\sigma_{B1}+t_2\sigma_{B2}}{t_1+t_2} \ (N/mm^2)$$

t_1 : Thickness of base metal (*mm*)
t_2 : Thickness of cladding metal (*mm*)
σ_{y1} : Specified minimum yield point or proof stress of base metal (N/mm^2)
σ_{y2} : Specified minimum yield point or proof stress of cladding metal (N/mm^2)
σ_y : Yield point or proof stress of steel plate (N/mm^2)
σ_{B1} : Specified minimum tensile strength of base metal (N/mm^2)
σ_{B2} : Specified minimum tensile strength of cladding metal (N/mm^2)
σ_B : Tensile strength of steel plate (N/mm^2)

(3) Shear strength test is applied for the case that the thickness of cladding metals is not less than 1.5 *mm*. Any requirement for the procedure of the test is left to the discretion of the Society.

3.9.6 Other Properties

Where deemed necessary by the Society according to the use of steel plates, tests on corrosion resistance may be required.

3.9.7 Selection of Test Samples

1 One test sample is to be taken from each steel plate, being from the same manufacturing process, which belong to the plate as rolled from a slab or ingot of a certain base metal.

2 The requirements specified in **3.1.6-4** are to be applied to the selection of the test samples.

3.9.8 Selection of Test Specimens

1 Tensile test specimens are to be taken according to the requirements specified in **3.1.7-2**.

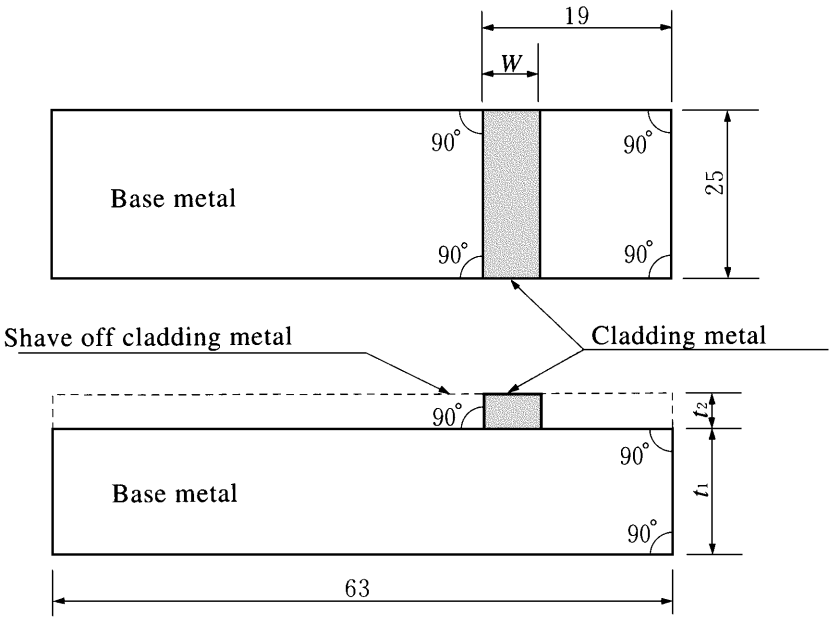
2 Impact test specimens are to be taken according to the requirements specified in **3.1.7-3**. In this case, the thickness of the test specimens is to agree with that of the base metal from which the cladding metal has been removed.

3 Shearing strength test specimens are to be taken according to the requirements specified in the following **(1)** to **(2)**:

(1) One test specimen is to be taken from one test sample.

(2) The size and dimensions of the test specimens are to be determined according to **Fig. K3.3**.

Fig. K3.3 Size and Dimensions of Shearing Test Specimens (Unit: *mm*)



Length of cladding metal : $W = 1.5t_2$

3.9.9 Surface Inspection and Verification of Dimensions*

1 Surface inspection and verification of dimensions are the responsibility of the manufacturer.

2 The minus tolerance in the nominal thickness of plates is left to the discretion of the Society.

3.9.10 Quality and Repair of Defects

1 Each steel plate is to be subjected to ultrasonic testing. Any requirement for the test procedure is left to the discretion of the Society.

2 Any defects on the surface or joints of material found by the ultrasonic testing, etc. may be repaired by welding, subject to the special approval by the Society.

3.9.11 Marking

1 The test certificates are to comply with the requirements given in **1.5.2** and are to contain the particulars as to the process of manufacture of steel plates and the thickness of the cladding metal.

2 Steel plates which have satisfactorily complied with the required tests are to be suffixed with the following marks relating to the process of manufacture of the steel plates, in addition to the marks showing the kinds of the base and cladding metals.

(Example: *KA* + *KSUS*316*L*-*R*).

Rolling	: "-*R*"
Cast rolling	: "-*ER*"
Explosive pressing	: "-*B*"
Explosive rolling	: "-*BR*"
Overlay rolling	: "-*WR*"

3.10 Additional Requirements for Rolled Steel Plates for Hull with Thickness above 50 mm up to 100 mm

3.10.1 Application

1 This provision is to apply to hull structural rolled steel plates (including steel flats not less than 600 *mm* in width, hereinafter referred to as "steel plates" in **3.10**) with thickness above 50 *mm* up to 100 *mm*.

2 The requirements other than those specified in **3.10** are to apply to **3.1**.

3.10.2 Kinds

The steel plates are classified into the grades as given in **Table K3.33**.

3.10.3 Deoxidation Practice and Chemical Composition

1 The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table K3.33**. The requirements on the chemical composition of steel plates may be modified subject to the approval by the Society.

2 The carbon equivalent of steels may be required to be submitted when specially required by the Society.

Table K3.33 Kinds, Deoxidation Practice and Chemical Composition Steel Plates (%)

Kind	Grade	Deoxidation practice	Chemical Composition (%)(1)														Carbon Equivalent C_{eq} (%)(8)	Cold cracking Susceptibility P_{cm}(%)
			C	*Si*	*Mn*	*P*	*S* (9)	*Cu*	*Cr*	*Ni*	*Mo*	*Al*(3)	*Nb*	*V*	*Ti*	*N*		
Mild Steels	*KA*	Killed	0.21 max. (2)	0.50 max.	2.5×C min. (2)	0.035 max.	0.035 max.	—	—	—	—	—	—	—	—	—	—	—
	KB			0.35 max.	0.60 min. (2)													
	KD	Killed and fine grain treated										0.015 min. (6)						
	KE		0.18 max. (2)		0.70 min. (2)													
High Tensile Steels	*KA*32	Killed and fine grain treated	0.18 max.	0.50 max.	0.90 ~ 1.60	0.035 max.	0.035 max.	0.35 max.	0.20 max.	0.40 max.	0.08 max.	0.015 min. (4)	0.02 ~ 0.05 (4) (5)	0.05 ~ 0.10 (4) (5)	0.02 max. (5)	—	0.38 max. (10)	—
	*KD*32																	
	*KE*32																	
	*KA*36																0.40 max. (10)	
	*KD*36																	
	*KE*36																	
	*KA*40																0.42 max. (10)	
	*KD*40																	
	*KE*40																	
	*KF*32		0.16 max.			0.025 max.	0.025 max.			0.80 max.						0.009 max. (7)	0.38 max. (10)	
	*KF*36																0.40 max. (10)	
	*KF*40																0.42 max. (10)	
	*KE*47		0.18 max.	0.55 max.	0.90~ 2.00	0.020 max.	0.020 max.		0.25 max.	1.0 max.						—	0.49 max.	0.22 max.

Notes:

(1) Where additions of any other element have been made as part of the steel making practice, the content is to be indicated on the test certificate.

(2) The value of $C+Mn/6$ is not to exceed 0.40%.

(3) Aluminium content is to be represented by the acid soluble aluminium content, but may be determined by the total

aluminium content. In such case, the total aluminium content is not to be less than 0.020%.

(4) The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each grain refining element is not applicable.

(5) The total niobium, vanadium and titanium content is not to exceed 0.12%.

(6) Upon the approval by the Society, grain refining elements other than aluminium may be used.

(7) The maximum content of nitrogen may be increased to 0.012% if aluminium is contained.

(8) Carbon equivalent is to be recorded on test certificate.

(9) For steels complying with the requirements specified in **3.11** the maximum content of sulphur is to be 0.008% determined by the ladle analysis.

(10) Only in cases where *TMCP* is applied for heat treatment.

3.10.4 Heat Treatment

The heat treatment of each grade is to comply with the requirements given in **Table K3.34.**

3.10.5 Mechanical Properties

The mechanical properties of steel plates are to comply with requirements given in **Table K3.34**.

Table K3.34 Heat Treatment and Mechanical Properties

Grade	Heat treatment[1]	Tensile test			Impact test[4]						
		Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation ($L = 5.65\sqrt{A}$) (%)	Testing temperature (°C)	Minimum mean absorbed energy (J)[5] Thickness t (mm)					
						50<t≤70		70<t≤85		85<t≤100	
						L	*T*	*L*	*T*	*L*	*T*
KA	*TMCP*, *N*[2]	235 min.	400~520	22 min.	+20[6]	34[6]	24[6]	41[6]	27[6]	41[6]	27[6]
KB					0	34	24	41	27	41	27
KD	*TMCP*, *N*[3]				-20						
KE	*TMCP*, *N*				-40						
*KA*32	*TMCP*, *N*	315 min.	440~590	22 min.	0	38	26	46	31	46	31
*KD*32					-20						
*KE*32					-40						
*KF*32	*TMCP*, *N*, *QT*				-60						
*KA*36	*TMCP*, *N*	355 min.	490~620	21 min.	0	41	27	50	34	50	34
*KD*36					-20						
*KE*36					-40						
*KF*36	*TMCP*, *N*, *QT*				-60						
*KA*40	*TMCP*, *N*, *QT*	390 min.	510~650	20 min.	0	46	31	55	37	55	37
*KD*40					-20						
*KE*40					-40						
*KF*40					-60						
*KE*47	*TMCP*[7]	460 min.	570~720	17 min.	-40	53	[8]	64	[8]	75	[8]

Notes:

(1) *See* **Note (3)** of **Table K3.3.**

(2) *AR* or *CR* (hereinafter referred to as "*ARS*" or "*CRS*" in **3.10**) may be accepted, subject to the approval by the Society.

(3) *CRS* may be accepted.

(4) *L* (or *T*) denotes that the longitudinal axis of the test specimen is arranged parallel (or transverse) to the final direction of rolling.

(5) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value than 70% of the specified minimum mean absorbed energy, the test is considered to be failed.

(6) It may be applied in case where the heat treatment is *ARS* or *CRS*. (*See*, **Note (2)**)

(7) Other heat treatments may be permitted subject to the approval of the Society.

(8) Standards deemed appropriate by Society.

3.10.6 Selection of Test Samples

The test samples are to be taken according to the following **(1)** and **(2)**.

(1) In the case of ingot casting the test samples are to be taken from a position representing the top of the ingot.

(2) The lot for the impact test is given in **Table K3.35**.

Table K3.35 Size of Lot for Impact Test

Grade	Heat treatment and size of lot
KA	*TMCP*< –>, *N*< –>, *CRS*<50>, *ARS*<50>
KB	*TMCP*<50>, *N*<50>, *CRS*<25>, *ARS*<25>
KD	*TMCP*<50>, *N*<50>, *CRS*<25>
KE	*TMCP*<*P*>, *N*<*P*>
*KA*32, *KA*36	*TMCP*<50>, *N*<50>
*KD*32, *KD*36	
*KE*32, *KE*36	*TMCP*<*P*>, *N*<*P*>
*KA*40, *KD*40	*TMCP*<50>, *N*<50>, *QT*<*PH*>
*KE*40, *KF*32, *KF*36, *KF*40	*TMCP*<*P*>, *N*<*P*>, *QT*<*PH*>
*KE*47	*TMCP*<*P*>

Note:

In the Table, “mark” put at the end of each “symbol” for heat treatment (*See* **Notes (1)** and **(2)** of **Table K3.34**) stand for the volume of each lot. For examples, <50> and <25> each indicate that steel plates not greater in mass than 50 and 25 *tonnes* (belonging to the same manufacturing process in the same charge) are to be taken as one lot; <*P*> indicates that steel plate rolled directly from one slab or steel ingot (belonging to the same heat treatment condition) is to be taken as one lot; <*PH*> indicates that steel plate rolled directly from one slab or steel ingot and heat treated simultaneously in the same furnace including continuous furnace is to be taken as one lot; and <->indicates that no impact test is required.

3.11 Additional Requirements for Through Thickness Properties

3.11.1 Application

1 The provisions given in **3.11** are to apply to the steels which are required to be improved through thickness properties relating to the structural design.

2 The requirements are to apply to hull structural rolled steels and high strength rolled steels for offshore structures for plates and wide flats with thickness of 15 *mm* and over.

3 The requirements are applicable to the other steels than the material specified in **-2** above, where deemed appropriate by the Society.

3.11.2 Through Thickness Properties

1 The through thickness properties of steels are to conform to the requirements in **Table K3.36** as the result of tensile tests whose specimens are taken in the through thickness direction of the product.

Table K3.36 Through Thickness Properties

Kinds of Steel	Suffix	Tensile test in the through thickness direction	
		Reduction of area (%)	
		Average value of three specimens	One individual value (1)
Rolled steels for hulls	Z25	25 min.	15 min.
High strength rolled steels for offshore structures	Z35	35 min.	25 min.

Note:

(1) If two or more individual results are less than the specified average value, the test is considered to be failed.

3.11.3 Selection of Test Samples

1 For steel, of same thickness, belonging to the same charge and same heat treatment condition, one test sample is to be taken from each lot specified in **Table K3.37**.

2 The test samples are to be taken from one end (top of ingot when applicable) of the portion corresponding to the middle of the plates or flat bars as shown in **Fig. K3.4**.

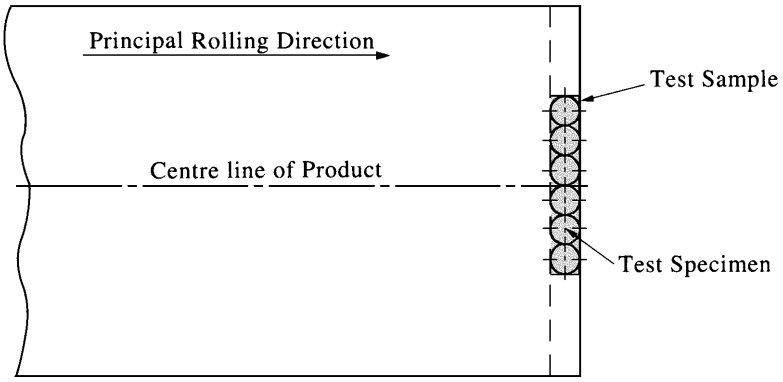
Table K3.37 Lot for Tensile Test in the Through Thickness Direction

Product	Content of S	
	$S \leq 0.005\%$	$0.005\% < S$
Plates		<P>
Wide flats of nominal thickness ≤ 25 *mm*	<50>	<10>
Wide flats of nominal thickness > 25 *mm*		<20>

Note:

In the Table, <50>, <20> and <10> each indicate that steels not greater in mass than 50, 20 and 10 *tonnes* are to be taken as one lot; <*P*> indicates that steel rolled directly from one slab or steel ingot is to be taken as one lot.

Fig. K3.4 Selection of Test Samples



3.11.4 Selection of Test Specimens

1 Three tensile test specimens are to be taken from one test sample in the through thickness direction.

2 The test specimens are to be taken according to the requirements for dimensions provided in **Table K3.38**.

3 Where the product thickness dose not allow to prepare specimens of sufficient length suitable for the gripping jaws of the testing machine, the ends of the specimens may be built up by suitable welding methods. The welding is not to impair the portion of the specimen within the parallel length.

Table K3.38 Dimensions of Specimen

Product thickness t (*mm*)	Diameter of test specimen d (*mm*)	Parallel length L (*mm*)
$15 \leq t \leq 25$	$d = 6$	$9 \leq L$
$25 < t$	$d = 10$	$15 \leq L$

3.11.5 Non-destructive Testing*

1 Each steel, complying with the requirements specified in **3.11**, which rolled directly from one slab, ingot, etc. (belonging to the same heat treatment condition) is to be subjected to ultrasonic testing. Any requirement for the test procedure and judgment are left to the discretion of the Society.

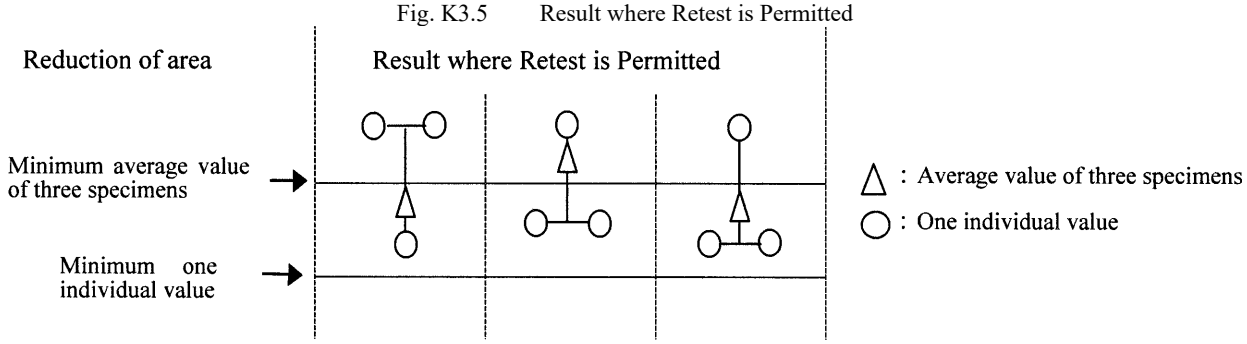
3.11.6 Additional Tests before Rejection

1 Where the tensile test in the through thickness direction fails to meet the requirements and where a retest is permitted according to **Fig. K3.5**, three more tests are to be carried out on the remaining test pieces.

2 As the results of the retest according to the above **-1**, the average of the results of all six tests is to be greater than the required minimum average with no greater than two results below the minimum average.

3 In the case of failure after retest, either the batch represented by the piece is rejected or each piece within the batch is required to be tested.

Fig. K3.5 Result where Retest is Permitted



3.11.7 Marking

For the products complying with the requirements specified in **3.11**, "*Z*25" or "*Z*35" given in **Table K3.36** is to be suffixed to the markings. (Example: *KD*36-*Z*25 for *KD*36.)

3.12 Additional Requirements for Brittle Crack Arrest Properties

3.12.1 Application

1 The provisions given in **3.12** are to apply to the steels which are considered so as to have brittle crack arrest properties relating to the brittle crack arrest design for the container carriers specified in **10.5, Part 2-1, Part C**.

2 The requirements are to apply to hull structural rolled steels for plates with thickness exceeding 50 *mm* but not exceeding 100 *mm* (*KE*36, *KE*40 and *KE*47).

3 The requirements are applicable to steels other than those specified in **-2** above, where deemed appropriate by the Society.

3.12.2 Deoxidation Practice and Chemical Composition

The deoxidaition practices and chemical compositions of *KE*36, *KE*40, *KE*47 are to comply with the requirements given in **Table K3.39** regardless of the requirements given in **Table K3.33**. However, the chemical compositions of *KE*36, *KE*40, and *KE*47 may be different from the requirements in **Table K3.39** with the approval of the Society.

3.12.3 Brittle Crack Arrest Properties etc.*

1 The brittle crack arrest properties of steel plates are to conform to the requirements in **Table K3.40** as the result of temperature gradient *ESSO* tests or double tension tests in addition to the mechanical properties given in **Table K3.34**. Any requirements for the test procedure are left to the discretion of the Society.

2 When Crack Arrest Temperature (*CAT*) evaluation tests are substituted for temperature gradient *ESSO* tests or double tension tests specified in **-1** above, the results are to conform to the requirements in **Table K3.41** in addition to the mechanical properties given in **Table K3.34**. Any requirements for test procedures are left to the discretion of the Society.

3 A brittle fracture test deemed appropriate by the Society may be substituted for temperature gradient *ESSO* tests, double tension tests or *CAT* evaluation tests specified in **-1** and **-2** above.

Table K3.39 Deoxidation Practices and Chemical Compositions of Steels Considered to have with Brittle Crack Arrest Properties

Grade	Deoxidation practice	Chemical composition (%)(1)													Carbon Equivalent C_{eq}(5) (%)	Cold cracking Susceptibility P_{cm} (%)
		C	*Si*	*Mn*	*P*	*S*	*Cu*	*Cr*	*Ni*	*Mo*	*Al*(2)	*Nb*	*V*	*Ti*		
*KE*36	Killed and fine grain treated	0.18 max	0.50 max	0.90 ~ 2.0	0.020 max	0.020 max	0.50 max	0.25 max	2.0 max	0.08 max	0.015 max (3)	0.02 ~ 0.05 (3)(4)	0.05 ~ 0.10 (3)(4)	0.02 max (4)	0.47 max	—
*KE*40															0.49 max	
*KE*47			0.55 max					0.50 max							0.55 max	0.24 max

Notes:

(1) Where additions of any other element have been made as part of the steel making practice, the content is to be indicated on the test certificate.

(2) Aluminium content is to be represented by the acid soluble aluminium content, but may be determined by the total aluminium content. In such a case, the total aluminium content is not to be less than 0.020%.

(3) The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each grain refining element is not applicable.

(4) The total niobium, vanadium and titanium content is not to exceed 0.12%.

(5) Carbon equivalent is to be recorded on test certificate.

Table K3.40 Brittle Crack Arrest Properties

Kinds of Steels		Classification	Temperature gradient *ESSO* tests or double tension tests	
			Evaluation Temperature (℃)	Arrest Toughness Value K_{ca} ($N/mm^{3/2}$)
Rolled Steels for Hull	*KE*36 *KE*40 *KE*47	*BCA*6000	-10	min. 6000
		*BCA*8000	-10	min. 8000

Note:

In cases where deemed appropriate by the Society, a new classification division for those properties different from *BCA*6000 and *BCA*8000 may be permitted.

Table K3.41 Brittle Crack Arrest Properties Resulting from *CAT* Evaluation Tests

Kinds of Steels		Classification	Required *CAT* (℃)
Rolled Steels for Hull	*KE*36 *KE*40 *KE*47	*BCA*6000	-10 max.
		*BCA*8000	(1)

Note:

(1) Standards deemed appropriate by the Society.

3.12.4 Selection of Test Samples

1 The test samples are to be taken from each steel plate rolled directly from a single slab or ingot unless otherwise deemed by the Society.

2 The test samples are to be taken from one end (top of ingot when applicable) of the portion corresponding to the middle of the plate width.

3.12.5 Selection of Test Specimens

1 Two test specimens are to be taken from one test sample.

2 The test specimens are to be taken with their longitudinal axis parallel to the final direction of rolling.

3 Thickness of the test specimens is to be same thickness of the steel plates.

4 The dimensions and types of the test specimens, except the requirement specified in **-3**, are left to the discretion of the Society.

3.12.6 Additional Tests before Rejection

1 Where the result of temperature gradient *ESSO* tests or double tension tests fails to meet the requirements, those tests may be carried out additionally on two more test specimens taken from the first test sample. In this case, the judgment of acceptance is to be made on the Arrest Toughness Value K_{ca} of all four test specimens.

2 For *CAT* evaluation tests, where the result of one test specimen fails to meet the requirements, additional tests may be carried out on one more test specimen taken from the first test sample. When the additional test is accepted, the test is accepted.

3.12.7 Marking

For the products complying with the requirements specified in **3.12**, "*BCA*6000" or "*BCA*8000" given in **Table K3.40** or **Table K3.41** is to be suffixed to the markings. (Example: *KE*40-*BCA*6000 for *KE*40.)

3.13 Additional Requirements for Corrosion Resistant Steel for Cargo Oil Tanks

3.13.1 Application

1 The requirements are to apply to the corrosion resistant steel used in the cargo oil tanks of crude oil tankers required by **3.3.5.4-1(2), Part 1, Part C** or **22.4.3(2), Part CS**.

2 The requirements are to apply to corrosion resistant steel not exceeding 50 *mm* in thickness.

3 The requirements other than those specified in **3.13** are to apply to **3.1** and **3.11**.

3.13.2 Kinds

The steels are classified into kinds and grades as given in **Table K3.42**.

Table K3.42 Kinds of Corrosion Resistant Steel for Cargo Oil Tanks

Kind	Grade
For upper decks	The grade is to be indicated by adding the suffix "*RCU*" to the grade specified in **Table K3.1** (*ex. KA*36-*RCU*)
For inner bottom plating	The grade is to be indicated by adding the suffix "*RCB*" to the grade specified in **Table K3.1** (*ex. KA*36-*RCB*)
For both upper decks and inner bottom plating	The grade is to be indicated by adding the suffix "*RCW*" to the grade specified in **Table K3.1** (*ex. KA*36-*RCW*)

3.13.3 Chemical Composition

1 The chemical composition of corrosion resistant steel for cargo oil tanks is to be within the range specified for rolled steels for hull. In addition, elements to be added for improving the corrosion resistance are to be generally within 1% in total.

2 The chemical composition range of elements to be added for improving corrosion resistance is to be approved by the Society during approval of manufacturing process.

Chapter 4 STEEL PIPES

4.1 Steel Tubes for Boilers and Heat Exchangers

4.1.1 Application*

1 The requirements mainly apply to steel tubes intended for heat transfer at inside or outside of the tubes ; for example, smoke tubes, water tubes, stay tubes, super-heater tubes of boilers, other tubes for high temperature heat exchangers, etc. (hereinafter referred to as "steel tubes" in **4.1**).

2 Pipes which comply with standard deemed equivalent by the Society may be treated as pipes that comply with this section. Such pipes are, in principle, to satisfy the following conditions.

(1) Their manufacturers are subjected to manufacturing process approval in accordance with the **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

(2) Their material tests and inspections are carried out in the presence of the Society's surveyor.

3 Except where specified in **2** above, steel tubes having characteristics differing from those specified in **4.1** are to comply with the requirements in **1.1.1-3**.

4.1.2 Kinds

The steel tubes are classified into 7 grades as specified in **Table K4.1**.

4.1.3 Heat Treatment*

The steel tubes are to be heat treated in accordance with the requirements in **Table K4.2**.

4.1.4 Chemical Composition

The steel tubes are to have the chemical composition given in **Table K4.3**.

Table K4.1 Grades of Tubes

Grade	Symbol	Material Category	Description
Grade 2	*KSTB*33	Carbon Steels	Low carbon seamless steel tubes and electric-resistance welded steel tubes
Grade 3	*KSTB*35		Low carbon killed seamless steel tubes and electric-resistance welded steel tubes
Grade 4	*KSTB*42		Medium carbon killed seamless steel tubes and electric-resistance welded steel tubes
Grade 12	*KSTB*12	Molybdenum Steels	$\frac{1}{2}Mo$ alloy seamless steel tubes and electric-resistance welded steel tubes
Grade 22	*KSTB*22	Chromium Molybdenum Steels	$1Cr-\frac{1}{2}Mo$ alloy seamless steel tubes and electric-resistance welded steel tubes
Grade 23	*KSTB*23		$1\frac{1}{4}Cr-\frac{1}{2}Mo-\frac{3}{4}Si$ alloy seamless steel tubes
Grade 24	*KSTB*24		$2\frac{1}{4}Cr-1Mo$ alloy seamless steel tubes and electric-resistance welded steel tubes

Note:

The symbols indicating the method of manufacture are to be fitted at the end of the above symbols, as follows:

Hot finished seamless steel tube : *-S-H*

Cold finished seamless steel tube : *-S-C*

Electric-resistance welded steel tube of other than hot and cold working : *-E-G*

Electric-resistance welded steel tube of hot working : *-E-H*

Electric-resistance welded steel tube of cold working : *-E-C*

Table K4.2 Heat Treatment for Tube

Grade	Seamless steel tube		Electric-resistance welded steel tube		
	Hot finished	Cold finished	As welded	Hot finished	Cold finished
Grade 2	As manufactured (1)	Low temperature annealing, normalizing or full annealing	Normalizing	As manufactured (1)	Normalizing (2)
Grade 3					
Grade 4			Normalizing	Low temperature annealing	Normalizing (2)
Grade 12	Low temperature annealing, isothermal annealing, full annealing, normalizing or normalizing followed by tempering		Isothermal annealing, full annealing, normalizing or normalizing followed by tempering		
Grade 22	Low temperature annealing, isothermal annealing, full annealing or normalizing followed by tempering		Isothermal annealing, full annealing or normalizing followed by tempering		
Grade 23	Isothermal annealing, full annealing or normalizing followed by tempering at 650℃ and over		—		
Grade 24			Isothermal annealing, full annealing or normalizing followed by tempering at 650℃ and over		

Notes:

(1) Low temperature annealing or normalizing may be applied if necessary.

(2) The cold finished electric resistance welded steel tubes which are normalized prior to cold finishing may be finished by annealing.

Table K4.3 Chemical Composition

Grade	Chemical composition(%)						
	C	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*
Grade 2	0.18 max.	0.35 max.	0.25~ 0.60	0.035 max.	0.035 max.	—	—
Grade 3	0.18 max.	0.10~ 0.35	0.30~ 0.60	0.035 max.	0.035 max.	—	—
Grade 4	0.32 max.	0.10~ 0.35	0.30~ 0.80	0.035 max.	0.035 max.	—	—
Grade 12	0.10 to 0.20	0.10~ 0.50	0.30~ 0.80	0.035 max.	0.035 max.	—	0.45~ 0.65
Grade 22	0.15 max.	0.50 max.	0.30~ 0.60	0.030 max.	0.035 max.	0.80~ 1.25	0.45~ 0.65
Grade 23	0.15 max.	0.50~ 1.00	0.30~ 0.60	0.030 max.	0.030 max.	1.00~ 1.50	0.45~ 0.65
Grade 24	0.15 max.	0.50 max.	0.30~ 0.60	0.030 max.	0.030 max.	1.90~ 2.60	0.87~ 1.13

Note:

In case where approved by the Society, Grades 3 and 4 may be killed steel with below 0.10% *Si*.

4.1.5 Mechanical Properties*

The steel tubes are to conform to be following requirements as to mechanical properties:

(1) Tensile test

The steel tubes are to conform to the requirements in **Table K4.4**.

(2) Flattening test

A tubular section which is taken from the end of the tube is to stand being flattened cold between parallel plates, without

cracking or showing flaw, until the distance between the plates becomes less than the value of H calculated by the following formula. In this case, Length L is to be not less than 50 *mm*, however, not more than 100 *mm*. For tubes, however, of 15% of outside diameter and over in thickness, *C*-type test specimen may be used, having a part of its circumference discarded as shown in **Fig. K4.2**.

$$H = \frac{(1+e)t}{e+\frac{t}{D}}$$

Where:

H : Distance between flattening plate (*mm*)

t : Thickness of tube (*mm*)

D : Outside diameter of tube (*mm*)

e : Constant given in **Table K4.5** which varies according to the grade of tubes

For electric-resistance welded tubes, however, the welded line is to be placed at right angle to the direction of the applied force as shown in **Fig. K4.1**. Where *C*-type test specimen is used, it is to be placed as in **Fig. K4.2**.

(3) Flanging test

A section of tube which is taken from its end is to be turned over cold so as to have a flange, the outside diameter of which is not less than specified in **Table K4.6** at right angle to the axis without cracking or showing flaw. In this case, the flanging test specimen is to be of length L such that after testing the remaining cylindrical portion is not less than $0.5D$. But, this test is to be made only for Grade 2 tube having wall thickness not more than 1/10 of its outside diameter and not more than 5 *mm*.

(4) Flaring test

A section of tube which is taken from its end is to stand being flared cold with a tool having an included angle of 60 degrees, until the tube at the mouth of the flare is expanded without cracking or showing flaw to the diameter shown in **Table K4.7**. In this case, the length of test specimen is to be $1.5D$, however, not less than 50 *mm*. For Grade 2 tubes which require the flanging test, this test need not be carried out.

(5) Crushing test

For Grade 2 tubes, where required by the Surveyor, a crushing test is to be made on a section of tube of 65 *mm* in length which is to stand crushing longitudinally without cracking or splitting to the height specified in **Table K4.8**.

(6) Reverse flattening test

A section of tube of 100 *mm* in length which is taken from the tube is to be slotted longitudinally on the opposite side of the welded line, opened and flattened without cracking or showing flaw on the inside of the welded line. There is also to be no misalignment, lack of penetration, and overlap. But, this test is applied to electric-resistance welded tubes only.

(7) Hydraulic test

(a) Tubes are to be hydraulically tested to a satisfactory result by 2 times and over the maximum working pressure at the mill. But the minimum test pressure is to be 7.0*MPa*.

(b) The test pressure prescribed in **(a)** need not exceed the pressure calculated by the following formula :

$$P = 2St/D$$

where:

P : Hydraulic test pressure (*MPa*)

t : Thickness of tube (*mm*)

D : Outside diameter of tube (*mm*)

S : 60% of the prescribed minimum yield point or proof stress (N/mm^2)

(c) Where each tube is hydraulically tested as a regular procedure during the process of manufacturing at the mill, which makes a number of tubes continually, and the results are forwarded to the Surveyor, the test in the presence of the Surveyor may be dispensed with.

(d) A non-destructive test deemed appropriate by the Society may be substituted for the hydraulic test specified **(a)**.

Table K4.4 Tensile Test

Grade	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L = 5.65\sqrt{A}$)
Grade 2	175 min.	325 min.	26(22) min.
Grade 3	175 min.	340 min.	26(22) min.
Grade 4	255 min.	410 min.	21(17) min.
Grade 12	205 min.	380 min.	21(17) min.
Grades 22, 23&24	205 min.	410 min.	21(17) min.

Notes:

(1) The values of elongation in parentheses are applicable to the test specimens taken transversely.
In this case, the sampling material is to be heated 600℃ to 650℃ after flattened and annealed in order to make it free from strain.

(2) In case where a test specimen of non-tubular section is taken from an electric-resistance welded tube, the test specimen is to be taken from the part that does not include the welded line.

Table K4.5 Value of e

Grades 2&3	0.09
Others	0.08

Fig. K4.1 Flattening Test

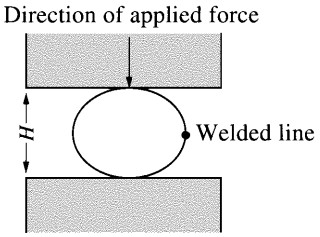


Fig. K4.2 Flattening Test for *C*-type Test Specimen

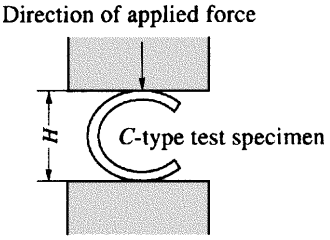


Table K4.6 Outside Diameter or Flange after Flanging

Outside diameter of tube D (mm)	Outside diameter of flange (mm)
$D < 63$	1.3D
$D \geq 63$	D+20

Table K4.7 Outside Diameter or Tube End after Flaring

Grade	Outside diameter of tube end (mm)
Grades 2,3&4	1.2D
Grades 12, 22, 23&24	1.14D

Table K4.8 Height of Section after Crushing

Thickness of tube t (*mm*)	Height of section after crushing
$t \leq 3.4$	19 *mm* or until outside folds are in contact
$t > 3.4$	32 *mm*

4.1.6 Selection of Test Specimen

The test specimens are to be taken in accordance with the requirements in **(1)** and **(2)**, from each grade and each size which has been heat treated at the same time in the same heating furnace for heat-treated tubes and from each grade and each size for non-heat-treated tubes respectively.

(1) Seamless steel tubes

(a) Grade 2

One sampling tube is to be selected from each lot of 100 tubes or fraction thereof, and one tension, one flattening and one flanging or flaring test specimens are to be taken from each of the sampling tubes.

(b) Other than Grade 2

One sampling tube is to be selected from each lot of 50 tubes or fraction thereof and each one specimen for tensile test, flattening test and flaring test is to be taken from the sampling tubes.

(2) Electric-resistance welded steel tubes

For electric-resistance welded steel tubes, in addition to the requirements in **(1)**, one sampling tube is to be selected from each lot of 100 tubes or fraction thereof, and one reverse flattening test specimen is to be taken from each of the sampling tubes.

(3) Tensile test specimen is to comply with the requirements specified in **Table K2.1**.

4.1.7 Tolerances for Dimensions of Tubes

The tolerances for the outside diameter and thickness are to be in accordance with the requirements in **Table K4.9**.

Table K4.9(a) Tolerance for Outside Diameter of Tubes (*mm*)

Kind	Outside diameter of tube			
	D<100	100≤D<160	160≤D<200	200≤D
Hot finished seamless steel tube	+0.4 -0.8	+0.4 -1.2	+0.4 -1.8	+0.4 -2.4

Kind	Outside diameter of tube									
	D<25	25 ≤ D <40	40 ≤ D <50	50 ≤ D <60	60 ≤ D <80	80 ≤ D <100	100 ≤ D<120	120 ≤ D<160	160 ≤ D<200	200 ≤ D
Cold finished seamless steel tube and electric-resistance welded steel tube of cold working	±0.10	±0.15	±0.20	±0.25	±0.30	±0.40	+0.40 -0.60	+0.40 -0.80	+0.40 -1.20	+0.40 -1.60
Electric-resistance welded steel tube other than of cold working	±0.15	±0.20	±0.25	±0.30	±0.40	+0.40 -0.60	+0.40 -0.80	+0.40 -1.00	+0.40 -1.20	+0.40 -1.60

Table K4.9(b) Tolerances for Thickness of Tube (% except where specially noted)

Kind	Outside diameter D (*mm*)	Thickness t (*mm*)				
		$t<2$	$2\leq t<2.4$	$2.4\leq t<3.8$	$3.8\leq t<4.6$	$4.6\leq t$
Hot finished seamless steel tube	$D<100$	—	+40 0	+35 0	+33 0	+28 0
	$D\geq 100$	—	—	+35 0	+33 0	+28 0
Cold finished seamless steel tube and electric-resistance welded steel tube of cold working	$D<40$	+0.4 *mm* 0	+20 0			
	$D\geq 40$	+22 0				
Electric-resistance welded steel tube other than of cold working	$D<40$	+0.3 *mm* 0	+18 0			
	$D\geq 40$	+18 0				

Note:

For hot finished seamless steel tubes, the tolerance for deviation in wall thickness is to be 22.8% and under of the thickness of the tube. But, for tubes less than 5.6 *mm* in thickness, this note in not applied.

4.1.8 Quality

The steel tubes are to be of uniform quality and free from harmful defects. For electric-resistance welded tubes, deposit metal projected on outside of tubes is to be removed and finished smooth and that projected on inside of tubes is to be removed to have a height not more than 0.25 *mm*.

4.1.9 Marking

The name or brand of the manufacturer, grade of tubes, symbol of the method of the manufacture and size are to be legibly stamped or stenciled before shipment on each length tube in case of 30 *mm* and above in outside diameter and on each bundle or container of tubes in case of less than 30 *mm* in outside diameter. The Society's brand indicating compliance with the requirements is to be stamped in the vicinity of the foregoing marks.

4.2 Steel Pipes for Pressure Piping

4.2.1 Application*

1 The requirements are mainly to apply to steel pipes intended for use in pipings classified as Group 1 and Group 2 specified in **Part D** (hereinafter referred to as "steel pipes" in **4.2**).

2 Pipes which comply with standard deemed equivalent by the Society may be treated as pipes that comply with this section. Such pipes are, in principle, to satisfy the following conditions.

(1) Their manufacturers are subjected to manufacturing process approval in accordance with the **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

(2) Their material tests and inspections are carried out in the presence of the Society's surveyor.

3 Carbon steel pipes for ordinary piping (steel gas pipes) specified in **12.1.5-1, Part D** are to be in accordance with the followings, regardless of the requirements in **1.2**, **1.4** and **4.2.2** to **4.2.9**.

(1) They are to conform to the requirements in *JIS G* 3452 (Carbon Steel Pipes for Ordinary Piping) or equivalent there to.

(2) The manufacturing approval tests by the Society is not required.

4 Except where specified in **2** and **3** above, steel pipes having characteristics differing from those specified in **4.2** are to comply with the requirements in **1.1.1-3**.

4.2.2 Kinds

The steel pipes are classified into 12 grades as specified in **Table K4.10**.

4.2.3 Heat Treatment

The steel pipes are to be heat treated in accordance with the requirements in **Table K4.11**.

4.2.4 Chemical Composition

The steel pipes are to have the chemical composition given in **Table K4.12**.

4.2.5 Mechanical Properties*

1 The steel pipes are to conform to the following requirements as to mechanical properties:

(1) Tensile test

The steel pipes are to be subjected to tensile test and to conform to the requirements in **Table K4.13**.

(2) Flattening test

A tubular section of pipe which is taken from the end of the pipe, is to stand being flattened cold between parallel plates, without cracking or showing flaw, until the distance between the plates becomes less than the value of H calculated by the following formula. In this case, the length of test specimen is to comply with the requirements specified in **4.1.5(2)**. For pipes, however, of 15% of outside diameter and above in thickness, C-type test specimen may be used, having a part of its circumference discarded as shown in **Fig. K4.3**.

(a) Pipes other than Grade 1 of electric-resistance welded pipe

$$H = \frac{(1+e)t}{e + t/D}$$

where:

H : Distance between flattening plates (mm)

t : Thickness of pipe (mm)

D : Outside diameter of pipe (mm)

e : Constant given in **Table K4.14**

(b) Electric-resistance welded pipes Grade 1

$H = 2D/3$ for welded line,

$H = D/3$ for elsewhere

In case of electric-resistance welded pipes, the welded line is to be placed at right angle to the direction of the applied force, as in **Fig. K4.1**. Where C-type test specimen is used, it is to be placed as in **Fig. K4.2**.

For steel pipes of 50 mm and smaller in outside diameter (except for Grade 4 pipes), the bend test specified in below may be substituted for a flattening test.

Bend test:

Test specimen of tubular section which is taken from the end of the pipe and has sufficient length is to stand being bent cold, up to the specified value given in **Table K4.15**.

(3) Hydraulic test

(a) Pipes are to be hydraulically tested with the pressure specified in **Table K4.16**.

(b) In case where the test pressure higher than prescribed in **(a)** is specified by the purchaser, the test is to be carried out with the specified pressure.

In this case, test pressure need not exceed the pressure calculated by the following formula:

$$P = 2St/D$$

where:

P : Hydraulic test pressure (MPa)

D : Outside diameter of pipe (mm)

t : Thickness of pipe (mm)

S : 60% of the prescribed minimum yield point or proof stress (N/mm^2)

(c) When each pipe is hydraulically tested as a regular procedure during the process of manufacturing at the mill which marks a number of pipes continually, and the results are forwarded to the Surveyor, the test in the presence of the Surveyor may be dispensed with.

(d) A non-destructive test deemed appropriate by the Society may be substituted for the hydraulic test specified in **(a)**.

2 For steel pipes to which the requirement in **17.12, Part N** is applicable, the specified value of the maximum yield point or proof stress may be set after obtaining verification by the Society.

Table K4.10 Grades of Pipes

Grade		Symbol	Material Category	Description
Grade 1	No.2	*KSTPG*38	Carbon steels	Low carbon seamless steel pipe and electric-resistance welded steel pipe
	No.3	*KSTPG*42		Medium carbon seamless steel pipe and electric-resistance welded steel pipe
Grade 2	No.2	*KSTS*38		Low carbon killed seamless steel pipe
	No.3	*KSTS*42		Medium carbon killed seamless steel pipe
	No.4	*KSTS*49		
Grade 3	No.2	*KSTPT*38		Low carbon coarse grain killed seamless steel pipe and electric-resistance welded steel pipe
	No.3	*KSTPT*42		Medium carbon coarse grain killed seamless steel pipe and electric-resistance welded steel pipe
	No.4	*KSTPT*49		Medium carbon coarse grain killed seamless steel pipe
Grade 4	No.12	*KSTPA*12	Molybdenum steels	$\frac{1}{2}Mo$ alloy seamless steel pipe
	No.22	*KSTPA*22	Chromium Molybdenum steels	$1Cr-\frac{1}{2}Mo$ alloy seamless steel pipe
	No.23	*KSTPA*23		$1\frac{1}{4}Cr-\frac{1}{2}Mo-\frac{3}{4}Si$ alloy seamless steel pipe
	No.24	*KSTPA*24		$2\frac{1}{4}Cr-1Mo$ alloy seamless steel pipe

Notes:

The symbols indicating the method of manufacture are to be fitted at the end of the above symbols, as follows:

Hot finished seamless steel pipe : *-S-H*

Cold finished seamless steel pipe : *-S-C*

Electric-resistance welded steel pipe of other than hot & cold working : *-E-G*

Electric-resistance welded steel pipe of hot working : *-E-H*

Electric-resistance welded steel pipe of cold working : *-E-C*

Table K4.11 Heat Treatment

Grade		Seamless steel pipe		Electric-resistance welded steel pipe		
		Hot finished	Cold finished	As weld	Hot finished	Cold finished
Grade 1	No.2	As manufactured	Annealing	As weld	As manufactured	Annealing
	No.3					
Grade 2	No.2	As manufactured (1)	Low temperature annealing or normalizing	—		
	No.3	As manufactured (1)	Low temperature annealing or normalizing	—		
	No.4					
Grade 3	No.2	As manufactured (1)	Low temperature annealing or normalizing	Low temperature annealing or normalizing	As manufactured (1)	Low temperature annealing or normalizing
	No.3					
	No.4			—		
Grade 4	No.12	Low temperature annealing, isothermal annealing, full annealing, normalizing or normalizing followed by tempering		—		
	No.22	Low temperature annealing, isothermal annealing, full annealing or normalizing followed by tempering				
	No.23	Isothermal annealing, full annealing or normalizing followed by tempering at 650℃ and over		—		
	No.24					

Note:

(1) Low temperature annealing or normalizing may be applied if necessary.

Table K4.12 Chemical Composition

Grade		Chemical composition (%)						
		C	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*
Grade1	No.2	0.25 max.	0.35 max.	0.30~0.90	0.040 max.	0.040 max.	—	—
	No.3	0.30 max.	0.35 max.	0.30~1.00	0.040 max.	0.040 max.	—	—
Grade2	No.2	0.25 max.	0.10~0.35	0.30~1.10	0.035 max.	0.035 max.	—	—
	No.3	0.30 max.	0.10~0.35	0.30~1.40	0.035 max.	0.035 max.	—	—
	No.4	0.33 max.	0.10~0.35	0.30~1.50	0.035 max.	0.035 max.	—	—
Grade3	No.2	0.25 max.	0.10~0.35	030~0.90	0.035 max.	0.035 max.	—	—
	No.3	0.30 max.	0.10~0.35	0.30~1.00	0.035 max.	0.035 max.	—	—
	No.4	0.33 max.	0.10~0.35	0.30~1.00	0.035 max.	0.035 max.	—	—
Grade4	No.12	0.10~0.20	0.10~0.50	0.30~0.80	0.035 max.	0.035 max.	—	0.45~0.65
	No.22	0.15 max.	0.50 max.	0.30~0.60	0.035 max.	0.035 max.	0.80~1.25	0.45~0.65
	No.23	0.15 max.	0.50~1.00	0.30~0.60	0.030 max.	0.030 max.	1.00~1.50	0.45~0.65
	No.24	0.15 max.	0.50 max.	0.30~0.60	0.030 max.	0.030 max.	1.90~2.60	0.87~1.13

Table K4.13 Tensile Test

Grade	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L = 5.65\sqrt{A}$)
Grade 1 No.2 Grade 2 No.2 Grade 3 No.2	215 min.	370 min.	24 (20) min.
Grade 1 No.3 Grade 2 No.3 Grade 3 No.3	245 min.	410 min.	21 (17) min.
Grade 2 No.4 Grade 3 No.4	275 min.	480 min.	19 (15) min.
Grade 4 No.12	205 min.	380 min.	21 (17) min.
Grade 4 No.22 Grade 4 No.23 Grade 4 No.24	205 min.	410 min.	21 (17) min.

Notes:

(1) The requirements for elongation given in parentheses in the Table are applied for the case where test specimens are taken transversely. In this case, the test coupon is to be stress relieved at the temperature of 600℃ to 650℃ after flattened.

(2) In case where test specimen of non-tubular section is taken from electric-resistance welded pipes, the test specimen is to be taken from the part that does not include the welded line.

Fig. K4.3 The position of selection for impact test specimen taken from the seamless steel pipes and other portions than seam of electric resistance welded steel pipes

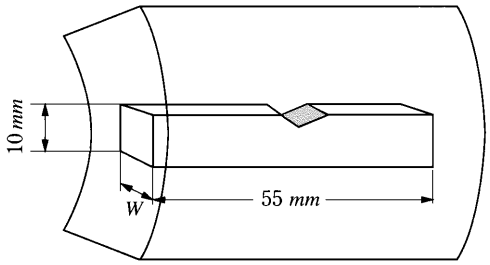


Table K4.14 Value of e

Grade	Grade 1 No.3, Grade 2 No.3, Grade 3 No.3, Grade 2 No.4, Grade 3 No.4,	Grade 1 No.2, Grade 2 No.2, Grade 3 No.2, Grade 4 all Nos.
e	0.07	0.08

Table K4.15 Bend Test

Grade	Degree of bending	Inside bend radius
1,2 and 3	90°	6 times the outside diameter of pipe

Note:

Electric-resistance welded pipes are to be so bent as the welded line is placed widest.

Table K4.16 Schedule and Hydraulic Test Pressure

Nominal diameter (*A*)	Outside diameter (*mm*)	Nominal thickness(*mm*)									
		Schedule 10(10*S*)	Schedule 20(20*S*)	Schedule 30	Schedule 40	Schedule 60	Schedule 80	Schedule 100	Schedule 120	Schedule 140	Schedule 160
6	10.5	(1.2)	(1.5)	—	1.7	2.2	2.4	—	—	—	—
8	13.8	(1.65)	(2.0)	—	2.2	2.4	3.0	—	—	—	—
10	17.3	(1.65)	(2.0)	—	2.3	2.8	3.2	—	—	—	—
15	21.7	(2.1)	(2.5)	—	2.8	3.2	3.7	—	—	—	4.7
20	27.2	(2.1)	(2.5)	—	2.9	3.4	3.9	—	—	—	5.5
25	34.0	(2.8)	(3.0)	—	3.4	3.9	4.5	—	—	—	6.4
32	42.7	(2.8)	(3.0)	—	3.6	4.5	4.9	—	—	—	6.4
40	48.6	(2.8)	(3.0)	—	3.7	4.5	5.1	—	—	—	7.1
50	60.5	(2.8)	3.2(3.5)	—	3.9	4.9	5.5	—	—	—	8.7
65	76.3	(3.0)	4.5(4.0)	—	5.2	6.0	7.0	—	—	—	9.5
80	89.1	(3.0)	4.5(4.0)	—	5.5	6.6	7.6	—	—	—	11.1
90	101.6	(3.0)	4.5(4.0)	—	5.7	7.0	8.1	—	—	—	12.7
100	114.3	(3.0)	4.9(4.0)	—	6.0	7.1	8.6	—	11.1	—	13.5
125	139.8	(3.4)	5.1(5.0)	—	6.6	8.1	9.5	—	12.7	—	15.9
150	165.2	(3.4)	5.5(5.0)	—	7.1	9.3	11.0	—	14.3	—	18.2
200	216.3	(4.0)	6.4(6.5)	7.0	8.2	10.3	12.7	15.1	18.2	20.6	23.0
250	267.4	(4.0)	6.4(6.5)	7.8	9.3	12.7	15.1	18.1	21.4	25.4	28.6
300	318.5	(4.5)	6.4(6.5)	8.4	10.3	14.3	17.4	21.4	25.4	28.6	33.3
350	355.6	6.4	7.9	9.5	11.1	15.1	19.0	23.8	27.8	31.8	35.7
400	406.4	6.4	7.9	9.5	12.7	16.7	21.4	26.2	30.9	36.5	40.5
450	457.2	6.4	7.9	11.1	14.3	19.0	23.8	29.4	34.9	39.7	45.2
500	508.0	6.4	9.5	12.7	15.1	20.6	26.2	32.5	38.1	44.4	50.0
550	558.8	6.4	9.5	12.7	15.9	22.2	28.6	34.9	41.3	47.6	54.0
600	609.4	6.4	9.5	14.3	17.5	24.6	31.0	38.9	46.0	52.4	59.5
650	660.4	7.9	12.7	—	18.9	26.4	34.0	41.6	49.1	56.6	64.2
Hydraulic test pressure (*MPa*)		2.0	3.5	5.0	6.0	9.0	12	15	18	20	20

Note:

The values of nominal thickness in parentheses are applicable to stainless steel pipes.

4.2.6 Selection of Test Specimen

The test specimens are to be taken in accordance with the following requirements, from each grade and each size which was heat treated at the same time for heat treated pipes, and from each grade and each size for non-heat-treated pipes, respectively.

(1) Grade 1

One sampling pipe is to be selected from each lot given in **Table K4.17**, and each one specimen for tensile test and flattening test is to be taken from each sampling pipe. As for pipes of 50 *mm* and under in outside diameter, the specimen for flattening test may be substituted for that for bend test.

(2) Grades 2 and 3

One sampling pipe is to be selected from each lot of 50 pipes or fraction thereof, and each one specimen for tensile test and flattening test is to be taken from each sampling pipe. As for pipes of 50 *mm* and under in outside diameter, the specimen for flattening test may be substituted for that for bend test.

(3) Grade 4

One sampling pipe is to be selected from each lot of 50 pipes of fraction thereof, and each one specimen for tensile test and

flattening test is to be taken from each sampling pipe.

(4) Tensile test specimen is to comply with the requirements specified in **Table K2.1**.

Table K4.17 Number of Sampling Pipe

Outside diameter D (*mm*)	Number of sampling pipe
$D < 70$	One pipe for each lot of 1000 pipes or fraction thereof
$70 \leq D < 160$	One pipe for each lot of 500 pipes or fraction thereof
$160 \leq D < 350$	One pipe for each lot of 250 pipes or fraction thereof
$D \geq 350$	One pipe for each lot of 150 pipes or fraction thereof

4.2.7 Tolerances for Dimensions of Pipes

The tolerances for the outside diameter and the thickness are to be in accordance with the requirements in **Table K4.18**.

Table K4.18 Tolerances for Dimensions(1)

Kind	Outside diameter D (*mm*)	Tolerance for outside diameter	Tolerance for wall thickness			
			Grade 1		Grade 2, 3 and 4	
Hot finished seamless steel pipe	$D<50$	±0.5 *mm*	Thickness of pipe : t (*mm*) $t<4$	+0.6 *mm* -0.5 *mm*	Thickness of pipe : t (*mm*) $t<4$	±0.5 *mm*
	$50 \leq D<160$	±1%	Thickness of pipe : t (*mm*) $t \geq 4$	+15% -12.5%	Thickness of pipe : t (*mm*) $t \geq 4$	±12.5%
	$160 \leq D<200$	±1.6 *mm*				
	$D \geq 200$	±0.8% (2)				
Cold finished seamless steel pipe and electric-resistance welded steel pipe	$D<40$	±0.3 *mm*	Thickness of pipe : t (*mm*) $t<3$	±0.3 *mm*	Thickness of pipe : t (*mm*) $t<2$	±0.2 *mm*
	$D \geq 40$	±0.8% (2)	Thickness of pipe : t (*mm*) $t \geq 3$	±10%	Thickness of pipe : t (*mm*) $t \geq 2$	±10%

Notes:

(1) For hot finished seamless steel pipes Grades 2, 3 and 4, the tolerance for deviation in wall thickness is to be 20% of the thickness of the pipes and under. However, for pipes less than 5.6 *mm* in wall thickness, this note is not applied.

(2) For pipes of 350 *mm* and over in outside diameter, length of circumstances may substitute as a basis for tolerance for outside diameter. In this case, the tolerance is to be ±0.5%.

4.2.8 Quality

The steel pipes are to be of uniform quality and free from harmful defects.

4.2.9 Marking

1 The name or brand of the manufacturer, symbol of grade, symbol of the method of manufacture and size are to be legibly stamped or stenciled before shipping on each length pipe of 60 *mm* or over in outside diameter and on each bundle of pipes less than 60 *mm* in outside diameter. The Society's brand indicating compliance with the requirements is to be stamped in the vicinity of the foregoing marks.

2 For steel pipes to which the requirement in **4.2.5-2** is applicable, the specified value of the maximum yield point or proof stress and "*U*" are to be suffixied to the grade mark. (*e.g. KSTPG*38-440*U*)

4.3 Stainless Steel Pipes

4.3.1 Application*

1 The requirements apply to the stainless steel pipes for low temperature service or corrosion-resistance service (hereinafter referred to as "stainless steel pipes" in **4.3**).

2 Pipes which comply with standard deemed equivalent by the Society may be treated as pipes that comply with this section. Such pipes are, in principle, to satisfy the following conditions.

(1) Their manufacturers are subjected to manufacturing process approval in accordance with the **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

(2) Their material tests and inspections are carried out in the presence of the Society's surveyor.

3 Stainless steel pipes having characteristics differing from those specified in **4.3** are to comply with the requirements in **1.1.1-3**.

4.3.2 Kinds

The stainless steel pipes are classified as specified in **Table K4.19**.

4.3.3 Heat Treatment

The stainless steel pipes are generally to receive a solid solution treatment.

4.3.4 Chemical Composition

The chemical composition of stainless steel pipes is to comply with the requirements given in **Table K4.19**.

Table K4.19 Grades and Chemical Composition

Grade (Symbol)	Material Category	Chemical composition (%)								
		C	*Si*	*Mn*	*P*	*S*	*Ni*	*Cr*	*Mo*	Others
*K*304*TP*	Austenitic stainless steels	0.08 max.	1.00 max.	2.00 max.	0.040 max.	0.030 max.	8.00~11.00	18.00~20.00	-	-
*K*304*LTP*		0.030 max.					9.00~13.00			
*K*309*STP*		0.08 max.	1.50 max.				12.00~15.00	22.00~24.00		
*K*310*STP*							19.00~22.00	24.00~26.00		
*K*316*TP*			1.00 max.				10.00~14.00	16.00~18.00	2.00~3.00	
*K*316*LTP*		0.030 max.					12.00~16.00			
*K*317*TP*		0.08 max.					11.00~15.00	18.00~20.00	3.00~4.00	
*K*317*LTP*		0.030 max.								
*K*321*TP*		0.08 max.					9.00~13.00	17.00~19.00	-	$Ti \geq 5 \times C$
*K*329*J*1*TP*	Austenitic Ferritic stainless steels	0.08 max.	1.00 max.	1.50 max.	0.040 max.	0.030 max.	3.00~6.00	23.00~28.00	1.00~3.00	-
*K*329*J*3*LTP*		0.030 max.	1.00 max.	1.50 max.	0.040 max.	0.030 max.	4.50~6.50	21.00~24.00	2.50~3.50	*N*: 0.08~0.20
*K*329*J*4*LTP*		0.030 max.	1.00 max.	1.50 max.	0.040 max.	0.030 max.	5.50~7.50	24.00~26.00	2.50~3.50	*N*: 0.08~0.30
*K*347*TP*	Austenitic stainless steels	0.08 max.	1.00 max.	2.00 max.	0.040 max.	0.030 max.	9.00~13.00	17.00~19.00	-	$Nb \geq 10 \times C$

Notes:

Symbols indicating the method of manufacture are to be added to the ends of the above-mentioned symbols as follows:

Hot finished seamless steel tube : *-S-H*

Cold finished seamless steel tube : *-S-C*

Automatic arc welded steel tube : *-A*

Cold finished automatic arc welded steel tube : *-A-C*

Bead conditioned automatic arc welded steel tube : *-A-B*

Laser welded steel tube : *-L*

Cold finished laser welded steel tube : *-L-C*

Bead conditioned laser welded steel tube : *-L-B*

Electric-resistance welded steel tube (other than hot and cold finished) : *-E-G*

Cold finished electric-resistance welded steel tube : *-E-C*

4.3.5 Mechanical Properties*

1 The mechanical properties of stainless steel pipes are to comply with the following requirements:

(1) Tensile test:

The tensile tests of stainless steel pipes are to comply with the requirements given in **Table K 4.20**.

(2) Flattening test:

Flattening tests are to be carried out in accordance with the requirements in **4.2.5(2)**. Where the requirement is applied, the value of e is to be taken as 0.09. For automatic arc welded steel pipes, laser beam welded steel pipes and electric-resistance welded steel pipes of 200 *mm* and over in outside diameter, The guide bend test for welded zone deemed appropriate by the Society may be carried out, instead of flattening test.

(3) Hydraulic test:

(a) Pipes are to be hydraulically tested with the pressure specified in **Table K4.21**.

(b) In case where the test pressure higher than prescribed in **(a)** is specified by the purchaser, the test is to be carried out with the specified pressure. In this case, the test pressure need not exceed the pressure calculated by the following formula:

$$P = 2St/D$$

where:

P : Hydraulic test pressure (MPa)

D : Outside diameter of pipe (mm)

t : Thickness of pipe (mm)

S : 60% of the prescribed minimum yield point or proof stress (N/mm^2)

(c) When each pipe is hydraulically tested as a regular during the process of manufacturing at the mill which makes a number of pipes continually, and the results are forwarded to the Surveyor, the test in the presence of the Surveyor may be dispensed with.

(d) A non-destructive test deemed appropriate by the Society may be substituted for the hydraulic test specified in **(a)**.

2 Where deemed necessary by the Society, corrosion-resistance test or impact test may be required in addition to the tests specified in **4.3**.

4.3.6 Selection of Test Specimens

One sampling pipe is to be selected from each lot of 50 pipes which are of the same charge, size and kind and are simultaneously heat treated or fraction thereof, and each one specimen for tensile test and flattening test is to be taken from each sampling pipe. Where, however, guided bend test for welded zone is carried out, each one specimen is to be taken from each 120 *m* of pipe which are of the same charge, size and kind and are simultaneously heat treated or fraction thereof.

Table K4.20 Tensile Test(2)(3)

Grade	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L = 5.65\sqrt{A}$)	
			L(1)	T(1)
*K*304*TP*	205 min.	520 min.	26 min.	22 min.
*K*304*LTP*	175 min.	480 min.		
*K*309*STP*	205 min.	520 min.		
*K*310*STP*				
*K*316*TP*				
*K*316*LTP*	175 min.	480 min.		
*K*317*TP*	205 min.	520 min.		
*K*317*LTP*	175 min.	480 min.		
*K*321*TP*	205 min.	520 min.		
*K*329*J*1*TP*	390 min.	590 min.	14 min.	10 min.
*K*329*J*3*LTP*	450 min.	620 min.	14 min.	10 min.
*K*329*J*4*LTP*	450 min.	620 min.	14 min.	10 min.
*K*347*TP*	205 min.	520 min.	26 min.	22 min.

Notes:

(1) *L* (or *T*) denotes that the longitudinal axis of the test specimen is arranged parallel (or normal) to the final direction of rolling.

(2) Where the nominal diameter of stainless steel pipes is 200 *mm* and over, tension test specimens may be taken transversely.

(3) Where test specimens of non-tubular section are taken from automatic arc welded steel pipes, laser beam welded steel pipes and electric-resistance welded steel pipes, the test specimens are to be taken from the part that does not include the welded line.

Table K4.21 Hydraulic Test Pressure

Schedule No.	10*S*	20*S*	40	80	120	160
Test pressure (*MPa*)	2.0	3.5	6.0	12	18	20

4.3.7 Tolerances for Dimensions Pipes

The tolerances for outside diameter and wall thickness of pipes are to be in accordance with the requirements given in **Table K 4.22**.

Table K4.22 Tolerances for Outside Diameter and Wall Thickness

Division	Outside diameter D (*mm*)	Tolerance for outside diameter	Thickness of pipe t (*mm*)	Tolerance for wall thickness
Hot finished seamless steel pipe	$D < 50$	$\pm 0.5mm$	$t < 4$	± 0.5 *mm*
	$D \geq 50$	$\pm 1\%$	$t \geq 4$	$\pm 12.5\%$
Cold finished seamless steel pipe, automatic arc welded steel pipe, laser beam welded steel pipe and electric-resistance welded steel pipe	$D < 30$	$\pm 0.3mm$	$t < 2$	± 0.2 *mm*
	$D \geq 30$	$\pm 1\%$	$t \geq 2$	$\pm 10\%$

Note:

For hot finished seamless steel pipes, the tolerance for deviation in wall thickness is to be 20% of the thickness and under. However, it shall not be applied to the pipes less than 5.6 *mm* in wall thickness.

4.3.8 Quality

The stainless steel pipes are to be of uniform quality and free from harmful defects.

4.3.9 Marking

Marking for stainless steel pipes is to comply with the requirements given in **4.2.9**.

4.4 Headers

4.4.1 Application

1 The requirements are to apply to the headers to be used for boilers.

2 Headers having characteristics differing from those specified in **4.4** are to comply with the requirements in **1.1.1-3**.

4.4.2 Kinds

The headers are classified into 6 grades as specified in **Table K 4.23**.

4.4.3 Heat Treatment

Headers are to be heat treated by annealing or normalizing.

4.4.4 Chemical Composition

Headers are to have the chemical composition given in **Table K4.23**.

4.4.5 Mechanical Properties

Headers are to conform to the following requirements as to mechanical properties:

(1) Tensile test:

Headers are to be subjected to tensile test and to conform to the requirements given in **Table K 4.24**.

(2) Bend test:

The test specimen is to stand being bent cold through 180 degrees without flaw and cracking on the outside of bent portion to an inside radius of 12 *mm*. Where the test specimen of 20 *mm* in thickness can not be taken, the test specimen may be as original in thickness, in which case, however, the width of test specimen is not to be less than 1.5 times the thickness and the inside radius of bend is to be equal to the thickness.

Table K4.23 Grades and Chemical Composition

Grade	Symbol	Material Category	Chemical composition(%)						
			C	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*
Grade 1	*KBH*-1	Carbon steels	0.25 max.	0.10 ~0.35	0.30 ~0.80	0.040 max.	0.040 max.	—	—
Grade 2	*KBH*-2		0.30 max.	0.10 ~0.35	0.30 ~0.80	0.040 max.	0.040 max.	—	—
Grade 3	*KBH*-3	Molybdenum steels	0.10 ~0.20	0.10 ~0.50	0.30 ~0.80	0.030 max.	0.040 max.	—	0.45 ~0.65
Grade 4	*KBH*-4	Chromium Molybdenum steels	0.10 ~0.20	0.10 ~0.50	0.30 ~0.60	0.030 max.	0.030 max.	0.80 ~1.20	0.20 ~0.45
Grade 5	*KBH*-5		0.15 max.	0.10 ~0.50	0.30 ~0.60	0.030 max.	0.030 max.	0.80 ~1.20	0.45 ~0.65
Grade 6	*KBH*-6		0.15 max.	0.10 ~0.50	0.30 ~0.50	0.030 max.	0.030 max.	2.00 ~2.50	0.90 ~1.10

Table K4.24 Tensile Test

Grade	Symbol	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L = 5.65\sqrt{A}$)	Reduction of area(%)
Grade 1	*KBH*-1	205 min.	410 min.	24 min.	38 min.
Grade 2	*KBH*-2	225 min.	450 min.	23 min.	40 min.
Grade 3	*KBH*-3	205 min.	380 min.	22 min.	40 min.
Grade 4	*KBH*-4	205 min.	410 min.	21 min.	40 min.
Grade 5	*KBH*-5	205 min.	410 min.	21 min.	40 min.
Grade 6	*KBH*-6	205 min.	410 min.	21 min.	40 min.

Note:

When test specimens are taken at right angle to the direction of rolling, the values of yield point or proof stress, and the values of tensile strength are to be as given in the above Table and the elongation is to take the value reduced by 5% from the percentage given in the above Table. The value of reduction of area may be only remained on records for reference.

4.4.6 Selection of Test Specimen

1 Tensile test specimens are to be taken lengthwise or crosswise to the direction of rolling and bend test specimens to be taken at right angle to the direction of rolling from the open ends of headers respectively.

2 For the headers of the same size made from the same melt and subjected to the heat treatment simultaneously in the same furnace, tensile and bend test specimens are to be selected in accordance with the requirements given in **Table K4.25**.

3 Where the both ends of header are closed by reforging, the test coupons of proper size may be cut from the open ends before reforging. In this case, the test coupons are to be heat treated simultaneously with the body in the same furnace.

4 Where test coupons cut from circular headers, etc. are necessary to be flattened, the test coupons are to be taken from the body before being subjected to the heat treatment and after flattening the test coupons are to be heat treated simultaneously with the body in the same furnace, or the test coupons are to be cut from the structures after being subjected to the heat treatment and after flattened cold, they are to be heated to the temperature of 600℃ to 650℃ for the purpose of removing the distortion due to the flattening, and the required test specimens are to be cut from the coupons.

5 Tensile and bend test specimens are to comply with the requirements specified in **Tables K2.1** and **K2.4** respectively.

Table K4.25 Number of Test Specimens

Grade	Number of test specimens
Grade 1 & Grade 2	1 set for each one length : 3,000 *mm* and over in length 1 set for each three lengths : 2,000 *mm* and over up to 3,000 *mm* in length 1 set for each five lengths : Less than 2,000 *mm* in length
Grade 3 to Grade 6	1 set from each end for each one length : 3,000 *mm* and over in length 1 set for each one length : Less than 3,000 *mm* in length

4.4.7 Tolerance for Thickness

The tolerance for thickness is to be ±12.5%. The tolerance, however, may not apply to the closed portions of headers on circular or square section, the side corners of square headers and the corrugated headers.

4.4.8 Quality

The headers are to be of uniform quality and free from harmful defects.

4.4.9 Marking

Marking for headers is generally to comply with the requirements given in **4.1.9**.

4.5 Steel Pipes for Low Temperature Service

4.5.1 Application*

1 The requirements are to apply to the seamless steel pipes and electric resistance welded steel pipes not exceeding 25 *mm* in thickness, intended to be used at the design temperature lower than 0℃ in liquefied gas carriers or ships using low-flashpoint fuels (hereinafter referred to as "steel pipes" in **4.5**).

2 Pipes which comply with standard deemed equivalent by the Society may be treated as pipes that comply with this section. Such pipes are, in principle, to satisfy the following conditions.

(1) Their manufacturers are subjected to manufacturing process approval in accordance with the **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

(2) Their material tests and inspections are carried out in the presence of the Society's surveyor.

3 Any requirement regarding the steel pipes over 25 *mm* in thickness is left to the discretion of the Society.

4 Steel pipes having characteristics differing from these specified in **4.5** are to comply with the requirements in **1.1.1-3**.

4.5.2 Kinds

The steel pipes are classified into 6 grades as given in **Table K4.26**.

4.5.3 Deoxidation Practice and Chemical Composition

The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table K4.26**.

Table K4.26 Grades and Chemical Compositions (%)

Grade	Material Category	Deoxidation	*C*	*Si*	*Mn*	*P*	*S*	*Ni*
KLPA	Carbon steels	Fully killed fine grain	0.25 max.	0.35 max.	1.35 max.	0.035 max.	0.035 max.	-
KLPB			0.18 max.	0.35 max.	1.60 max.	0.035 max.	0.035 max.	-
KLPC			0.18 max.	0.35 max.	1.60 max.	0.035 max.	0.035 max.	-
*KLP*2	Nickel steels		0.19 max.	0.10~0.35	0.90 max.	0.035 max.	0.035 max.	2.00~2.60
*KLP*3			0.18 max.	0.10~0.35	0.30~0.60	0.030 max.	0.030 max.	3.20~3.80
*KLP*9			0.13 max.	0.10~0.35	0.90 max.	0.030 max.	0.030 max.	8.50~9.50

Note:

Other alloying elements than those given in the above table may be added if necessary.

4.5.4 Heat Treatment

The steel pipes are to be heat treated in accordance with the requirements in **Table K4.27**.

4.5.5 Mechanical Properties

1 The steel pipes are to comply with the following requirements as to mechanical properties:

(1) Tensile test

The steel pipes are to be subjected to tensile test and to comply with the requirements in **Table K4.27**.

(2) Impact test

The steel pipes are to be subjected to impact test and to comply with the requirements in **Table K4.27**.

(3) Flattening test

Flattening test is to be carried out in accordance with the requirement given in **4.2.5(2)**. Where this requirement is applied, the value of e is to be taken as 0.08.

For steel pipes of 50 *mm* and under in outside diameter, bend test specified in below may be substituted for flattening test.

Bend test: Test specimen of tubular section which is taken from the end of the pipe and has sufficient length is to stand being bent cold, up to the specified value in **Table K4.27**, without flaw and cracking on the wall.

Moreover, electric resistance welded pipes are to be bent in such a way that the welded line is placed on the outside of bent portion.

(4) Hydraulic test

All steel pipes are to be subjected to hydraulic test in accordance with the requirements given in **4.2.5(3)**.

2 Where deemed necessary by the Society, other tests may be required in addition to the tests specified in **-1**.

3 For steel pipes to which the requirement in **17.12, Part N** is applicable, the specified value of the maximum yield point or proof stress may be set after obtaining the verification by the Society.

Table K4.27 Heat Treatment and Mechanical Properties

Grade	Heat treatment	Tensile test (1)(2)(3)				Bend test		Impact test	
		Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation ($L = 5.65\sqrt{A}$) (%)		Inside radius of bend	Angle of bend (°)	Testing temperature (°C)	Mean absorbed energy (J)(4)
				L	T				
KLPA	Normalized, normalized followed by tempering or quenched and tempered	205 min.	380 min.	26 min.	19 min.	6 times the outside diameter of pipe	90	-40	27
KLPB								-50	
KLPC								-60	
*KLP*2		245 min.	450 min.	20 min.	14 min.			-70	34
*KLP*3								-95	
*KLP*9	Double normalized followed by tempering or quenched and tempered	520 min.	690 min.	15 min.	11 min.			-196	41

Notes:

(1) L (or T) denotes that the longitudinal axis of the test specimen is arranged parallel (or normal) to the final direction of rolling.

(2) Where the nominal diameter of steel pipes is 200 *mm* and over, the tensile test specimen may be taken transversely.

(3) Where test specimen of non-tubular section is taken from electric resistance welded pipes, the test specimen is to be taken from the part that does not include the welded line.

(4) Where absorbed energy of more than one of a set of test specimens is under the required minimum mean absorbed energy, or where the absorbed energy of one test specimen is under 70% of the required value, the test is considered to be failed.

(5) In case where the width of test specimens required by **Tables K2.5** and **K2.7** cannot be taken, impact tests may be omitted subject to satisfying the following **(a)** and **(b)**:

(a) Chemical composition contains not less than 0.010% of acid soluble aluminium or not less than 0.015% total aluminium.

(b) In cases where the actual impact test records of material which is manufactured on a like-for-like basis regarding manufacturing process and chemical composition are found to be satisfactory.

4.5.6 Selection of Test Specimens

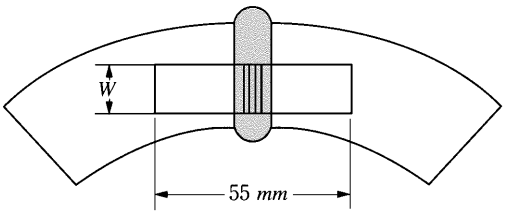
(1) One sampling pipe is to be selected from each lot of 50 pipes or fraction thereof which are of the same charge, size and kind and are simultaneously heat treated.

(2) Each one specimen for tensile test and flattening test (or bend test) is to be taken from each sample pipe. Tensile test specimens are to comply with the requirements specified in **Table K2.1**.

(3) One set of three specimens for impact test is to be taken from each sample pipe in accordance with **Fig. K4.3**. Moreover, for electric resistance welded pipes, another set of three specimens is to be taken from the welded zone in accordance with **Fig.**

K4.4. Impact test specimens are to comply with the requirements specified in Table K2.5.

Fig. K4.4 The Position of Selection for Impact Test Specimen Taken from the Weld Zone of Electric Resistance Welded Steel Pipes



4.5.7 Dimensional Tolerance

The tolerances for outside diameter and wall thickness of steel pipes are to be in accordance with the requirements given in Table K4.28.

Table K4.28 Tolerances for Outside Diameter and Wall Thickness(1)

Division	Outside diameter D (*mm*)	Tolerance for outside diameter	Tolerance for wall thickness
Hot finished seamless steel pipe	D<50	±0.5 *mm*	t < 4 *mm* : ±0.5 *mm* t≥4 *mm* : ±12.5%
	50≤D<160	±1%	
	160≤D<200	±1.6 *mm*	
	D≥200	±0.8%(2)	
Cold finished seamless steel pipe and electric-resistance welded steel pipe	D<40	±0.3 *mm*	t < 2 *mm* : ±0.2 *mm* t≥2 *mm* : ±10%
	D≥40	±0.8%(2)	

Notes:

(1) For hot finished seamless steel pipes, the tolerance for deviation in wall thickness is to be 20% of the thickness and under. However, it shall not be applied to the pipes less than 5.6 *mm* in wall thickness.

(2) For pipes of 350 *mm* and over in outside diameter, length of circumstances may substitute as a basis for tolerance for outside diameter. In this case, the tolerance is to be ±0.5%.

4.5.8 Quality

The steel pipes are to be of uniform quality and free from harmful defects.

4.5.9 Additional Tests before Rejection

1 Where other mechanical tests than impact tests from the first test specimens selected fail to meet the requirements, additional tests may be carried out according to the requirements given in 1.4.4.

2 Regarding the impact tests, additional tests are to be carried out according to the requirements given in 3.1.10-3.

4.5.10 Marking

1 Marking for steel pipes is generally to comply with the requirements given in 4.2.9.

2 For steel pipes to which the requirement in 4.5.5-3 is applicable, the specified value of the maximum yield point or proof stress and "*U*" are to be suffixied to the grade mark.

(*e.g. KLPB*38-440*U*)

Chapter 5 CASTINGS

5.1 Steel Castings

5.1.1 Application

1 The requirements of **5.1** are to apply to the steel castings intended to be used for the components specified in Parts of hull construction, equipment, and machinery, except that of defined in **5.2**, **5.3** and **5.5**.

2 Steel castings having characteristics differing from those specified in **5.1** are to comply with the requirements in **1.1.1-3.**

5.1.2 Manufacturing Process

1 Flame cutting or scarfing to remove risers and surplus metals is to be completed before final heat treatment of the steel castings. Preheating is to be carried out when judged necessary in consideration of the chemical composition and size of the steel castings.

2 Where steel castings are built up by welding, the welding procedure is to be submitted to the Society before the work. In this case, the Society may request to carry out the welding procedure qualification test.

3 Steel castings may be repaired by welding in accordance with the requirements specified in **5.1.11** after obtaining approval of the Surveyor.

4 Where the surface of steel castings is subjected to hardening process by induction hardening, nitrising, cold rolling or other methods, an approval from the Society is to be obtained.

5 Steel castings are to be manufactured from killed steel.

5.1.3 Kinds

The steel castings are classified as specified in **Table K5.2**.

5.1.4 Chemical Composition

1 Steel castings are to have the chemical composition given in **Table K5.1**.

2 For steel castings intended for welded construction, "*W*" is to be suffixed to their respective grade markings (e.g. *KSC440W* and *KSCA440W*).

3 Suitable grain refining elements such as aluminium may be added at the discretion of the manufacturer.

4 The manufacturer is to make an analysis of each melt in ladles (When multiple heats are tapped into a common ladle, the ladle analysis is to apply.) and the results are to be reported to the Surveyor.

Table K5.1 Chemical Composition

Kind		Chemical composition (%)										
		C	*Si*	*Mn*	*S*	*P*	*Cu*	*Cr*	*Ni*	*Mo*	*V*	Total residual elements
Steel castings not intended for welding	Carbon steel castings	0.40 max.	0.60 max.	0.50-1.60	0.035 max.	0.035 max.	0.30 max.(1)	0.30 max.(1)	0.40 max.(1)	0.15 max.(1)	—	0.80 max.
	Alloy steel castings	0.45 max.	0.60 max.	0.50-1.60	0.030 max.	0.035 max.	0.30 min. (2)	0.40 min. (2)	0.40 min. (2)	0.15 min. (2)	—	—
Steel castings intended for welding	Carbon steel castings	0.23 max.	0.60 max.	0.50-1.60	0.035 max.	0.035 max.	0.30 max. (1)	0.30 max. (1)	0.40 max. (1)	0.15 max.(1)	—	0.80 max.
	Alloy steel castings (3)	0.25 max.	0.60 max.	0.50-1.70	0.030 max.	0.035 max.	0.30 max. (1)	0.40 min. (2)	0.40 min. (2)	0.15 min. (2)	0.12 max. (1)	—

Notes:

(1) Elements considered to be as residual elements. Residual elements are not to be intentionally added to the steel.

(2) One or more of the elements is to comply with the minimum content.

(3) The chemical composition of this table are to be applied unless otherwise deemed appropriate by the Society.

5.1.5 Heat Treatment

1 For ensuring greater grain refining of the metal crystal, better removal of residual stresses and required mechanical properties, steel castings are to be annealed, normalized, normalized and tempered, or quenched and tempered at proper stages of the manufacturing process; however, alloy steel castings are not to be delivered immediately after annealing. Tempering temperature is to exceed 550 °C, and manufacturers are responsible for selecting heat treatment methods that are appropriate for obtaining the required mechanical properties.

2 Steel castings, which were locally heated or subjected to any cold work after heat treatment, are to be stress-relieved by approved methods. Castings for components such as crankshafts and engine bedplates, where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be carried out at a temperature of not less than 550 °C followed by furnace cooling to 300 °C or lower. Manufacturers are to strictly control this temperature in order to avoid any detrimental effects to the final heat treatment and resultant microstructure and mechanical properties of the castings.

3 The furnace intended to be used for heat treatment is to have sufficient size for uniform heating of the steel castings to the required temperature. The furnace is to be equipped with a device capable of regulating and recording the furnace temperature.

4 Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

5 The foundry is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature.

5.1.6 Mechanical Properties

1 The mechanical properties of the steel castings are to conform to the requirements given in **Table K5.2** using the test blocks specified in **5.1.8-2**.

2 Intermediate values of those tabulated in **Table K5.2** may be applicable where approval of the Society is obtained. In this case, the values are to be obtained by interpolation and counting fractions over 0.5 as one and disregarding the rest.

Table K5.2 Mechanical Properties of Steel Casting

Kind		Grade [4]	Tensile strength [1] (N/mm^2)	Yield point or proof stress (N/mm^2)	Elongation ($L = 5.65\sqrt{A}$) (%)	Reduction of area (%)	Charpy V-notch impact test [2]	
							Test temperature (°C)	Minimum average energy (J)
Steel castings not intended for welding	Carbon steel castings	*KSC*400	400 min.	200 min.	25 min.	40 min.	*AT*[3]	27
		*KSC*440	440 min.	220 min.	22 min.	30 min.		
		*KSC*480	480 min.	240 min.	20 min.	27 min.		
		*KSC*520	520 min.	260 min.	18 min.	25 min.		
		*KSC*560	560 min.	300 min.	15 min.	20 min.		
		*KSC*600	600 min.	320 min.	13 min.	20 min.		
	Alloy steel castings	*KSCA*550	550 min.	340 min.	16 min.	35 min.		
		*KSCA*600	600 min.	400 min.	16 min.	35 min.		
		*KSCA*650	650 min.	450 min.	14 min.	32 min.		
		*KSCA*700	700 min.	540 min.	12 min.	28 min.		
Steel castings intended for welding	Carbon steel castings	*KSC*400*W*	400 min.	200 min.	25 min.	40 min.	0	
		*KSC*440*W*	440 min.	220 min.	22 min.	30 min.		
		*KSC*480*W*	480 min.	240 min.	20 min.	27 min.		
		*KSC*520*W*	520 min.	260 min.	18 min.	25 min.		
		*KSC*560*W*	560 min.	300 min.	15 min.	20 min.		
		*KSC*600*W*	600 min.	320 min.	13 min.	20 min.		
	Alloy steel castings	*KSCA*550*W*	550 min.	355 min.	18 min.	30 min.		
		*KSCA*600*W*	600 min.	400 min.	16 min.	30 min.		
		*KSCA*650*W*	650 min.	450 min.	14 min.	30 min.		
		*KSCA*700*W*	700 min.	540 min.	12 min.	28 min.		

Notes:

(1) A tensile strength range of 150 N/mm^2 may additionally be specified.

(2) Special consideration may be given to alternative requirements for Charpy V-notch impact tests, depending on design and application, and subject to Society approval.

(3) *AT* refers to the ambient temperature specified in *ISO* 148-1:2016 (i.e. 23 °C±5 °C).

(4) For steel castings intended for welded construction, "*W*" is to be suffixed to their respective grade markings in accordance with **5.1.4-2.**

5.1.7 Mechanical Tests

1 Mechanical tests for the steel castings are to be carried out in accordance with the requirements specified in **Chapter 2**.

2 Where the tensile tests from the first test specimens selected fail to meet the requirements, additional tests may be conducted according to the requirements given in **1.4.4**.

3 Where the results of impact tests do not conform to the requirements, additional impact tests are to be carried out in accordance with **3.1.10-3**.

5.1.8 Selection of Test Specimens

1 Test specimens for steel castings are, after final heat treatment, to be taken from the test block either attached to the castings, cast integrally onto the castings or cast separately. However, test blocks may be separated from the body of the casting before final heat treatment in cases where deemed appropriate by the Society. At least one test block is to be provided for each casting or batch of castings, and one set of test specimens is to be taken from each test block. The "one set of test specimens" referred to above includes one tensile test specimen and three shock test specimens.

2 Test block is to be in accordance with the following **(1)** or **(2)**:

(1) The preferred test block arrangement, where practical, is for the manufacturer to provide at least one 30 *mm* test block by either attached to the castings or cast integrally on the castings.[1]

Note 1:

The test results represent the material from which the castings have been poured and the subsequent heat treatment process and may not necessarily represent the properties of the castings. These properties can be affected by solidification conditions and the rate of cooling during heat treatment, which are in turn influenced by casting thickness, size, complexity and shape. The purpose of the test bock is to provide a qualitative check to demonstrate the effective control of existing heat treatment processes and procedures.

(2) For castings where it is required that the mechanical properties need to be demonstrated for specific section thicknesses and when agreed upon between the manufacturer and the purchaser, then proposals[2] for alternative test block arrangements instead of **(1)** above (in terms of size and type) are to be submitted to the Society for approval.

Note 2:

The size of the "alternative test block instead of **(1)** above" for mechanical testing may be determined by the ruling section of the casting that they are representative of the casting's heat treatment and microstructure. Also see *ISO 4885:2018*; *ISO683-1:2016* and *ISO 683-2: 2016*.

Alternatively, determination of "alternative test block arrangements instead of **(1)** above (in terms of size and type)" may be supported by historical and statistical test data, production of a representative test block or a component, simulation software, or a combination of all these items.

3 The number of test blocks is to be as given in the following **(1)** through **(4)**:

(1) Except where specified otherwise by the Society, one test block is to be taken from each steel casting. In cases where the mass of one steel casting (as heat treated, hereinafter referred to as the "mass") is more than ten tons, two test blocks are to be taken from each steel casting, located as far as practicable from each other.

(2) In cases where the mass of one casting is one ton and under one test block is to be taken from every one group of steel castings cast from the same charge and heat treated simultaneously in the same furnace. In cases where the total mass of one group of steel casting exceeds two tons, two test blocks are to be taken.

(3) In cases where a number of steel castings of similar form and size are cast from the same charge and the mass for each casting is less than 500 *kg*, test blocks may be separately cast under Surveyor approval regardless of the requirements in **-1** and **(2)** above. In this case, the test blocks are to be heat treated simultaneously with the body of the steel casting in the same furnace.

(4) In cases where one steel casting is made from two or more casts, which are not mixed in a ladle prior to pouring, one test block is to be taken from each charge regardless of the requirements in **(1)** or **(2)** above. These are to be attached to the casting or cast integrally on the castings at locations as widely separated as possible.

5.1.9 Surface Inspection and Dimension Inspection*

1 When heat treatment and machining are finished and, if necessary, at a proper stage during machining, surface inspection is to be carried out.

2 The steel castings are not to be subjected to any treatment such as painting, which is harmful for inspection before the surface inspection.

3 The dimension inspection of the steel castings is to be conducted under the responsibility of the manufacturer.

4 Notwithstanding the requirements in **-1** to **-3** above, surface inspections or dimension inspections may be omitted for steel castings when not required according to **2.2.1-1**, **Part D of the Rules**.

5.1.10 Non-destructive Testing*

1 The steel castings are to be subjected to non-destructive testing in accordance with **(1)** and **(2)** of the following requirements:

(1) Ultrasonic test

(a) The steel castings intended for stern frame, rudder frame and other important hull structural members and required for ultrasonic test as specified in **2.2.1-1, Part D** are to be subjected to ultrasonic tests at an appropriate stage of the manufacturing process and the test reports are to be showed or submitted to the Surveyor.

(b) Performance of ultrasonic testing apparatus is to be of good efficiency for testing of large steel castings.

(c) Operator engage in the ultrasonic tests is to have a sufficient technique and experience for the testing of steel castings.

(2) Magnetic particle test

The important parts of the following steel castings are to be subjected to magnetic particle tests at an appropriate stage of the manufacturing process. But, machining surfaces may be subjected to liquid penetrant tests.

(a) Steel castings intended for stern frame, rudder frame and other important hull structural members

(b) Steel castings required for magnetic particle test or liquid penetrant test specified in **2.2.1-1**, **Part D**

(c) Propellers

(d) Turbine casings

2 In place of the test methods given in **-1**, the Society may accept the application of other non-destructive testing considered adequate by the Society.

3 The Society may require non-destructive inspections by radiographic test, ultrasonic test, magnetic particle test or liquid penetrant test not only for the steel castings specified in **-1** but also for the steel castings deemed necessary by the Society.

4 The welding parts of steel castings used for welded construction are to be subjected to non-destructive inspections considered adequate by the Society.

5.1.11 Repair of Defects*

1 Where castings are to be repaired, manufacturers are to exercise robust control over all repair operations with respect to dimensions, heat treatment, inspection and quality control.

2 In the event of finding defects and unacceptable indications considered harmful for the intended use of the steel casting, the defects are to be removed by a grinder or other means. Thermal methods of metal removal of defects and weld repair are to be allowed only before the final heat treatment. All grooves are to have a bottom radius of approximately three times the groove depth and are to be smoothly blended to the surface area with a finish equal to that of the adjacent surface. After removing the defects, magnetic particle tests or liquid penetrant tests are to be carried out to ensure that all defects have been completely removed.

3 Where steel castings from which defects were removed are used in that condition, an approval of the Surveyor is to be obtained for confirming casting adequacy. Steel castings from which defects were removed may be permitted to be used without weld repairs provided that the depth of the defect removal is not over 15 *mm* or 10 % of wall thickness, whichever is less, and will cause no appreciable reduction in the strength of the casting or affect its intended use. Portions of castings from which defects were removed are to be finished smoothly to avoid stress concentration.

4 Where steel castings from which defects were removed are repaired by welding, the welding consumables used are to be of an appropriate composition, giving weld deposits with mechanical properties similar and in no way inferior to those of the parent castings. In addition, surveyor approval is to be obtained in advance as to the scope of repairs, welding and heat treatment, and welding procedure tests are to be carried out to demonstrate that satisfactory mechanical properties can be obtained after the heat treatment of the portion of welded repair.

5 On completion of heat treatment, the portions repaired by welding and adjacent material are to be ground smooth and confirmed that they are free from harmful defects by magnetic particle or liquid penetrant testing.

6 The manufacturer is to present full records detailing the extent and location of repairs made to each casting and details of weld procedures and heat treatments applied for repairs, to the Surveyor on request.

7 In addition to **-1** to **-6** above, weld repairs for carbon steel castings are to be in accordance with the following **(1)** through **(3)**. Furthermore, weld repairs for carbon alloy steel castings are to be approved by the Society.

(1) Major weld repairs are to be in accordance with the following **(a)** and **(b)**. The term "major weld repairs" refers to those where the depth is greater than 25 % of the wall thickness or 25 *mm,* whichever is less, or the total weld area on a casting exceeds 0.125 m^2 of the casting surface; however, in cases where the distance between two welds is less than their average width, they are to be considered the same weld.

(a) They are to be carried out before the final delivery heat treatment condition.

(b) They are to be in accordance with **1.4.3-1**.

(2) Minor weld repairs are to be in accordance with the following **(a)** and **(b)**. The term "minor weld repairs" refers to those other than the major weld repairs described in **(1)** above, except in cases where the Society determines minor repairs for critical areas are to be treated as major repairs.

(a) They are to be carried out before the final delivery heat treatment condition.

(b) They may be carried out without prior approval by the Society, except for alloy steels or minor weld repairs that are to be treated as major repairs.

(3) Both major and minor weld repairs are to be in accordance with the following **(a)** through **(d)**.

(a) All alloy steel castings and all castings for crankshafts are to be suitably pre-heated prior to welding. Carbon steel castings may also require pre-heating depending on their chemical composition as well as the dimensions and positions of the weld repairs.

(b) Welding procedures are to be approved and match the delivery condition of the casting. Approval for welding procedures is to be in accordance with rules and standards deemed appropriate by the Society.

(c) Welding is to be done at well ventilated positions free from adverse weather conditions by qualified welders under adequate supervision. As far as possible, all welding is to be carried out in the downhand position.

(d) After welding has been completed, castings are to be given either a suitable heat treatment in accordance with **5.1.5** or a stress relieving heat treatment at a temperature of not less than 550 °C for carbon steel castings. For alloy steel castings, the heat treatment is to be agreed with the Society. The type of heat treatment employed is to be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs, and is not to affect the properties of the casting. However, where deemed appropriate by the Society, special consideration may be given to the omission of post weld heat treatment or to the acceptance of local stress-relieving heat treatment, where the repaired area is small and machining of the casting has reached an advanced stage.

5.1.12 Marking*

1 Steel castings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **1.5.1**. For steel castings to which the requirements given in **5.1.6-2** have been applied, the value corresponding to the required tensile strength employed is to be used to the grade mark. (ex. Where the required tensile strength employed is 430 N/mm^2, "*KSC*44" is to be indicated)

2 The grade of material and the manufacturer's name or trade mark are to be cast stamped or marked by some other appropriate method on all cast steels. In addition, cast number and test number are to be stamped or marked by some other appropriate method on all cast steels greater than 250 *kg* in weight. The Society's brand indicating satisfactory compliance with the Rule requirements is to be stamped on all cast steels in the neighbourhood of the above mentioned marks.

5.1.13 Additional Requirements for Crank Throws*

1 In case where semi-built-up crank throws for reciprocating internal combustion engines are made of steel castings, the manufacturing procedure is to be approved by the Society.

2 Where the manufacturing processes using the surface treatments are adopted to reduce the size of crank throw according to the requirements in **2.3.1-4**, **Part D**, the preliminary tests instructed by the Society are to be carried out.

5.2 Steel Castings for Chains

5.2.1 Application

1 The Requirements are to apply to the steel castings intended to be used for link of Grades 2 and 3 chains and shackle, swivel,

etc. of all grades chains except Grade 1 chains specified in **Part L** (hereinafter referred to as "steel castings" in **5.2**).

2 Steel castings having characteristics differing from those specified in **5.2** are to comply with the requirements in **1.1.1-3**.

5.2.2 Kinds

The steel castings are classified into 5 grades as specified in **Table K5.3**

Table K5.3 Grades of Steel Castings

Grades		Application
Grade 2 steel casting	*KSCC*50	Grade 2 chain
Grade 3 steel casting	*KSCC*70	Grade 3 chain
Grade *R*3 steel casting	*KSCCR*3	Grade *R*3 chain
Grade *R*3*S* steel casting	*KSCCR*3*S*	Grade *R*3*S* chain
Grade *R*4 steel casting	*KSCCR*4	Grade *R*4 chain
Grade *R*4*S* steel casting	*KSCCR*4*S*	Grade *R*4*S* chain
Grade *R*5 steel casting	*KSCCR*5	Grade *R*5 chain

5.2.3 Heat Treatment

1 Steel castings are to be normalized, normalized and tempered, quenched and tempered or heat treated by the process approved by the Society.

2 Steel castings which are locally heated or subjected to any cold work after heat treatment, are to be stress-relieved by the approved methods.

3 Flame cutting or scarfing to remove risers and surplus metals is to be completed before final heat treatment of the steel castings.

5.2.4 Grain Size

1 The austenitic grain size of grades *KSCCR*3, *KSCCR*3*S*, *KSCCR*4, *KSCCR*4*S* and *KSCCR*5 is to be 6 or finer in accordance with *ASTM E*112 or an equivalent grain size index in accordance with *ISO* 643 or to be deemed as equivalent by the Society.

2 Measurements of grain size for circular sections are to be taken at a depth of 1/3 radius from the surface. Measurements of grain size for non-circular sections are to be taken at a depth of 1/4 thickness from the surface.

5.2.5 Chemical Composition, Deoxidation Practice and Vacuum Degasification Process

1 The chemical composition of steel castings is to be subjected to the special approval by the Society. Grades *KSCCR*4, *KSCCR*4*S* and *KSCCR*5 are to contain a minimum of 0.2% molybdenum.

2 Grades *KSCCR*4*S* and *KSCCR*5 are to be vacuum degassed.

3 For grades *KSCCR*3, *KSCCR*3*S*, *KSCCR*4, *KSCCR*4*S* and *KSCCR*5, all steel castings are to be killed and fine grain treated.

5.2.6 Mechanical Properties

1 The mechanical properties of steel castings are to comply with the requirements specified in **Table K 5.4**.

Table K5.4 Mechanical Properties

Grade	Tensile test				Impact test(1)	
	Yield point or proof stress(2) (N/mm^2)	Tensile strength(2) (N/mm^2)	Elongation (%) ($L=5d$)	Reduction of area (%)	Testing temperature (℃)	Minimum mean absorbed energy (J)
*KSCC*50	295 min.	490~690	22 min.	—	0(3)	27(3)
*KSCC*70	410 min.	690 min.	17 min.	40 min.	0	60
*KSCCR*3	410 min.	690 min.	17 min.	40 min.	-20(4)	40(4)
*KSCCR*3*S*	490 min.	770 min.	15 min.	40 min.	-20(4)	45(4)
*KSCCR*4	580 min.	860 min.	12 min.	35 min.	-20	50
*KSCCR*4*S*	700 min.	960 min.	12 min.	35 min.	-20	56
*KSCCR*5	760 min.	1000 min.	12 min.	35 min.	-20	58

Notes:

(1) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value than 70% of the specified minimum mean absorbed energy, the test is considered to have failed.

(2) Aim value of yield to tensile ratio for grades *KSCCR*3, *KSCCR*3*S*, *KSCCR*4, *KSCCR*4*S* and *KSCCR*5 is to be maximum 0.92.

(3) Impact test is only required for accessories, enlarged links and end links made by casting excluding enlarged links and end links which are connected to chains made by casting and are made therewith.

(4) Impact test of grade *KSCCR*3 and *KSCCR*3*S* may be carried out at the temperature of 0℃ where approved by the Society. In this case, minimum mean absorbed energy is to be not less than 60 *J* for grade *KSCCR*3 and 65 *J* for grade *KSCCR*3*S*.

5.2.7 Selection of Test Specimen

1 One test sample is to be taken from castings of similar dimensions originating from the same heat treatment charge and the same cast of steel. In this case, the test sample may be the test assembly cast with the body of casting and similar area.

2 One tensile test specimen and one set (3 pieces) of impact test specimens are to be taken from the test sample specified in **-1** above. However, for Grade 2 steel castings to be not required carrying out impact test according to **Note (4)** of **Table K5.4**, impact test specimens need not to be taken.

3 The tensile and impact test specimens are to be taken from the test sample in the longitudinal direction at a depth of 1/6 diameter from the surface or as close as possible to this position (*See* **Fig. K3.2**).

4 The tensile and the impact test specimens are to comply with the requirements specified in **Tables K2.1** and **K2.5** respectively.

5.2.8 Quality

Steel castings are to be of uniform quality and free from harmful defects.

5.2.9 Surface Inspection and Non-destructive Test*

1 For grades *KSCC*50 and *KSCC*70, surface inspections are to be carried out and it is to be confirmed that there are no harmful defects after the heat treatment of the steel castings is finished.

2 For grades *KSCCR*3, *KSCCR*3S, *KSCCR*4, *KSCCR*4*S* and *KSCCR*5, steel castings are to be examined by magnetic particle tests in accordance with standards deemed appropriate by the Society and it is to be confirmed that there are no harmful defects after the heat treatment of the castings is finished.

3 For grades *KSCCR*3, *KSCCR*3S, *KSCCR*4, *KSCCR*4*S* and *KSCCR*5, the entire steel casting is to be subjected to an ultrasonic test at an appropriate stage of manufacture in accordance with standards deemed appropriate by the Society and it is to be confirmed that there are no harmful defects.

4 For grades *KSCC*50 and *KSCC*70, a suitable non-destructive test such as an ultrasonic test may be required where deemed necessary by the Society.

5 With respect to **-2** and **-3** above, non-destructive test procedures, together with rejection/acceptance criteria are to be submitted to the Society.

6 With respect to **-2** and **-3** above, non-destructive test operators are to be appropriately qualified in performing non-destructive tests.

5.2.10 Repair of Defects*

1 The surface defects on non-machined surfaces may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0.8 *mm* in order to repair any spurious indications.

2 In cases where the repair entails removal of more than 5% of the diameter or thickness, the defective area is to be repaired by welding. The excavations are to be suitably shaped to allow good access for welding and the resulting grooves are to be subsequently ground smooth.

3 In addition to **-2** above, complete elimination of defects is to be verified by non-destructive test prior to any repairs by welding.

4 The repairing procedures (extent and location of the repair by welding (including photographs or sketches)) are to be submitted and approved by the Society in cases where the groove depth prepared for welding exceeds 25% of the diameter/thickness or 25 *mm*,

whichever is smaller.

5 In cases where repairs by welding are carried out in accordance with **-4** above, a post weld heat treatment or a repeat of the heat treatment of castings specified in **5.2.3** are to be carried out.

6 Repairs by welding are to be recorded in sketches or photographs to show the extent and positions of the repairs.

7 All repairs by welding are to be carried out by qualified welders using **Chapter 5, Part M of the Rules** or standards deemed appropriate by the Society.

8 All repairs by welding are to be carried out in accordance with the welding procedure specification approved in accordance with **Chapter 4, Part M of the Rules** or standards deemed appropriate by the Society. For welding procedure qualification tests, impact tests whose notch locations are in central region of weld metal, fusion line and 2 *mm* and 5 *mm* from the fusion line are to be carried out.

5.2.11 Additional Tests before Rejection

Where the tensile test or impact test on the selected first test specimens fails to meet the requirements, additional tests may be conducted according to the requirements given in **3.6.11**.

5.2.12 Marking

Steel castings which have satisfactorily complied with the required tests are to be marked with identification mark in accordance with the requirements in **5.1.12**.

5.2.13 Submission of Data*

For grades *KSCCR*4*S* and *KSCCR*5, the following information for each heat is to be submitted by the bar manufacturer to the offshore chain manufacturer.

(1) The results of the microscopic examinations for non-metallic inclusions.

(2) The results of macro etched examinations in order to confirm that there is no injurious segregation or porosity.

(3) The results of hardenability tests.

5.3 Stainless Steel Castings

5.3.1 Application

1 The requirements are to apply to the stainless steel castings for valves and pipe fittings in piping systems used at low temperature (-165℃ and over in design temperature) service or corrosion-resisting service (hereinafter referred to as “steel castings” in **5.3**).

2 Steel castings having characteristics differing from those specified in **5.3** are to comply with the requirements in **1.1.1-3**.

3 In addition to the requirements given in **5.3**, general requirements may be considered by the Society.

5.3.2 Kinds

The steel castings are classified into 7 grades as specified in **Table K5.5**.

5.3.3 Heat Treatment

The steel castings are generally to receive a solid solution treatment.

5.3.4 Chemical Composition

The chemical composition of stainless steel castings is to comply with the requirements given in **Table K5.5**.

5.3.5 Mechanical Properties

1 The mechanical properties in tensile tests and hardness tests are to comply with the requirements given in **Table K5.6**.

2 Where deemed necessary by the Society, other tests on notch toughness or corrosion-resistance may be required in addition to the specified tests.

Table K5.5 Grades and Chemical Composition of Stainless Steel Castings

Grade	Chemical composition (%)								
	C	*Si*	*Mn*	*P*	*S*	*Ni*	*Cr*	*Mo*	Others
*KSCS*13	0.08 max.	2.00 max.	2.00 max.	0.040 max.	0.030 max.	8.00~ 11.00	18.00~ 21.00	—	—
*KSCS*14	0.08 max.	1.50 max.	2.00 max.	0.040 max.	0.030 max.	10.00~ 14.00	17.00~ 20.00	2.00~ 3.00	—
*KSCS*16	0.030 max.	1.50 max.	2.00 max.	0.040 max.	0.030 max.	12.00~ 16.00	17.00~ 20.00	2.00~ 3.00	—
*KSCS*17	0.08 max.	2.00 max.	2.00 max.	0.040 max.	0.030 max.	12.00~ 15.00	22.00~ 26.00	—	—
*KSCS*18	0.08 max.	2.00 max.	2.00 max.	0.040 max.	0.030 max.	19.00~ 22.00	23.00~ 27.00	—	—
*KSCS*19	0.030 max.	2.00 max.	2.00 max.	0.040 max.	0.030 max.	8.00~ 12.00	17.00~ 21.00	—	—
*KSCS*21	0.08 max.	2.00 max.	2.00 max.	0.040 max.	0.030 max.	9.00~ 12.00	18.00~ 21.00	$1.35 \geq Nb + Ta \geq 10 \times C$	

Table K5.6 Mechanical Properties of Stainless Steel Castings

Grade	Tensile test			Brinell hardness *HBW*
	Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L = 5.65\sqrt{A}$)	
*KSCS*13	185 min.	440 min.	26 min.	183 max.
*KSCS*14	185 min.	440 min.	26 min.	
*KSCS*16	175 min.	390 min.	31 min.	
*KSCS*17	205 min.	440 min.	26 min.	
*KSCS*18	185 min.	440 min.	26 min.	
*KSCS*19	185 min.	390 min.	31 min.	
*KSCS*21	205 min.	440 min.	26 min.	

5.3.6 Selection of Test Specimens

1 Where a stainless steel casting is 500 *kg* and over in mass, one tensile test specimen and one hardness test specimen are to be taken from each casting.

2 Where a number of stainless steel castings of similar form and size, each of which mass less than 500 *kg*, are cast from the same charge, two tensile test specimens and two hardness test specimens are to be taken from each group of castings simultaneously heat treated in the same furnace.

3 Hardness test specimen may be a portion of tensile test specimen.

4 Tensile test specimen is to comply with the requirements given in **Table K2.1**.

5.4 Steel Castings for Low Temperature Service

5.4.1 Application

1 The requirements are to apply to the steel castings for valves and pipe fittings in piping systems intended to used for low temperature service (hereinafter referred to as “steel castings”).

2 Steel castings other than specified in **5.4** or those used in other parts than specified in **-1** are to comply with the requirements given in **1.1.1-3**.

3 In addition to the requirements given in **5.4**, general requirements may be considered by the Society.

5.4.2 Kinds

The steel castings are classified into 4 grades as given in **Table K5.7**.

Table K5.7 Grades and Chemical Composition (%)

Grade	Deoxidation	*C*	*Si*	*Mn*	*P*	*S*	*Ni*	*Mo*
KLCA	Fully killed fine grain	0.30 max.	0.60 max.	1.00 max.	0.035 max.	0.035 max.	—	—
KLCB		0.25 max.	0.60 max.	0.50 ~0.80	0.035 max.	0.035 max.	—	0.45 ~0.65
*KLC*2		0.25 max.	0.60 max.	0.50 ~0.80	0.030 max.	0.030 max.	2.00 ~3.00	—
*KLC*3		0.15 max.	0.60 max.	0.50 ~0.80	0.030 max.	0.030 max.	3.00 ~4.00	—

5.4.3 Heat Treatment

Steel castings are to be normalized or normalized and tempered.

5.4.4 Deoxidation Practice and Chemical Composition

The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table K5.7**.

5.4.5 Mechanical Properties

1 The mechanical properties of steel castings are to comply with the requirements given in **Table K5.8**.

2 Where deemed necessary by the Society, other tests may be required in addition to the tests specified in **-1**.

Table K5.8 Mechanical Properties

	Tensile test				Impact test(1)	
Grade	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L=5d$)	Reduction of area (%)	Testing temperature (℃)	Mean absorbed energy (J)
KLCA	245 min.	450 min.	21 min.	35 min.	-45	27 min.
KLCB					-60	
*KLC*2	275 min.				-70	34 min.
*KLC*3					-95	

Note:

(1) There the absorbed energy of more than one of a set of test specimens is under the required minimum mean absorbed energy, or where the absorbed energy of one test specimens is under 70% of required value, the test is considered to be failed.

5.4.6 Selection of Test Specimens

1 Where a steel casting is 500 *kg* and over in mass, one tensile test specimen and one set of three impact test specimens are to be taken from each casting.

2 Where a number of steel castings of similar form and size, each of which mass less than 500 *kg*, are cast from the same charge, two tensile test specimens and two sets of three impact test specimens are to be taken from each group of castings simultaneously heat treated in the same furnace.

3 The size and dimensions of tensile and impact test specimens are to comply with the requirements specified in **Table K2.1** and **Table K2.5** respectively.

5.4.7 Additional Tests before Rejection

1 Where the tensile tests from the first test specimens selected fail to meet the requirements, additional tests may be carried out according to the requirements given in **1.4.4**.

2 Regarding the impact tests, additional tests are to be carried out according to the requirements given in **3.1.10-3**.

5.4.8 Marking

Marking of the steel casting is to comply with the requirements given in **5.1.12**.

5.5 Gray Iron Castings

5.5.1 Application

1 The requirements in this section are to apply to the gray iron castings (hereinafter referred to as "iron castings").

2 Iron castings other than specified in **5.5** are to comply with the requirements given in **1.1.1-3.**

5.5.2 Manufacturing Process

Suitable mechanical methods such as grinding are to be employed for the removal of surplus material from iron castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

5.5.3 Kinds

The iron castings are classified as specified in **Table K5.9.**

Table K5.9 Kinds and Mechanical Properties of Iron Castings

Material grade	Tensile strength(1)(N/mm^2)
*KFC*20	200 min.
*KFC*25	240 min.
*KFC*30	290 min.
*KFC*35	340 min.

Note:

(1) The standards given in this Table are for the test sample taken from iron casting separately cast. Where the test sample cast integral with the casting is used, the standards applied are left to the discretion of the Society.

5.5.4 Chemical Composition

The chemical composition of iron castings is to be suitable to obtain the specified mechanical properties. Where deemed necessary by the Society, the Society may require the manufacturer to be carried out an analysis of each melt in ladle.

5.5.5 Heat Treatment

The iron castings may be carried out by appropriate heat treatments if necessary.

5.5.6 Mechanical Properties*

1 Mechanical properties of iron castings are to comply with the requirements given in **Table K5.9**.

2 Intermediate value of those tabulated in **Table K5.9** may be applicable where approval of the Society is obtained. In this case, the values are to be obtained by interpolation and counting fractions over 0.5 as one and disregarding the rest.

5.5.7 Mechanical Test

1 Mechanical test for iron castings is tensile test, and is to be carried out in accordance with the requirements given in **Chapter 2**.

2 Where tensile test fails to meet the requirements, retest may be carried out in accordance with the requirements in **1.4.4**. In this case, however, test specimens are to be taken out of other test samples.

5.5.8 Selection of Test Specimens

1 Separately cast test samples of iron casting are to be used.

2 Test samples are to be cast from the same ladle as the one for castings in the moulds of the same type of material as the one for the moulds of the castings and are not to be stripped from the moulds until the metal temperature is below 500 °C. Test samples are to be in the form of bars 30 *mm* in diameter and of a suitable length. When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 *mm* apart from each other (*See* **Fig. K5.2**).

3 One tensile test specimen of iron castings is to be taken from the test samples required by the followings.

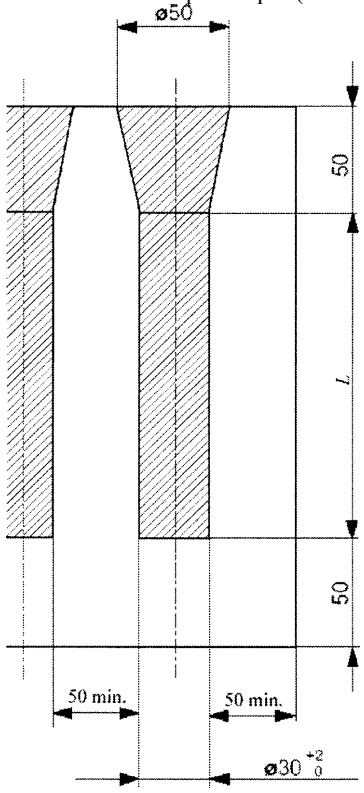
(1) Except where otherwise specially specified by the Society, one lot is iron castings whose weight is less than 2 *tons* and consist

of the castings poured from a single ladle of metal provided that they are all of similar type and dimensions, and one test sample is to be taken from each one lot. If weight of single iron casting is not less than 2 *tons*, one lot is it, and one test sample is to be taken from each one lot.

(2) Notwithstanding the requirement in **(1)** above, for continuous melting of the same grade of casting steels, one lot is the mass of a batch which may be increased to the output of 2 *hours* of pouring. One test sample is to be taken from each one lot.

(3) Notwithstanding the requirements in **(1)** and **(2)** above, one lot may be taken at longer intervals or from large quantities where approved by the Society.

Fig. K5.2 Test Sample Shapes (Units: *mm*)



Note:

L : Parallel part length

5.5.9 Surface Inspection and Dimension Inspection

Surface inspection and dimension inspection are to be carried out in accordance with the requirements in 5.1.9.

5.5.10 Non-destructive Testing

The Society may require non-destructive test for the iron castings if deemed necessary by the Society.

5.5.11 Quality

1 The iron castings are to be free from harmful defects to use.

2 Small surface blemishes are to be removed by local grinding. Subject to the prior approval of the Surveyor, the steel castings containing small porosity may be rectified by a suitable repair process.

3 Repairs by welding are generally not permitted.

5.5.12 Marking

Marking of the iron castings is to follow the requirements in 5.1.12.

5.6 Spheroidal or Nodular Graphite Iron Castings

5.6.1 Application

1 The requirements are to apply to the spherical or nodular graphite iron castings (hereinafter referred to as “iron castings”).

2 Iron castings other than specified in 5.6 are to comply with the requirements given in 1.1.1-3.

5.6.2 Manufacturing Process

1 Suitable mechanical methods such as grinding are to be employed for the removal of surplus material from iron castings. Thermal cutting process is not acceptable, except as a preliminary operation to mechanical methods.

2 Where the iron castings are subjected to surface hardening process, an approval from the Society is to be obtained.

5.6.3 Kinds

The iron castings are classified as specified in **Table K5.10**.

Table K5.10 Kinds and Mechanical Properties of Iron castings

Material grade	Tensile test			Impact test	
	Tensile strength (N/mm^2)	Proof stress(2) (N/mm^2)	Elongation (%) ($L = 5.65\sqrt{A}$)	Testing temperature (℃)	Minimum mean absorbed energy (J)
*KFCD*37	360	235	17	—	—
*KFCD*40	390	255	12	—	—
*KFCD*45	440	285	10	—	—
*KFCD*50	490	325	7	—	—
*KFCD*60	590	370	3	—	—
*KFCD*70	680	420	2	—	—
*KFCD*80	780	480	2	—	—
*KFCD*36*S*	350	220	22	20	17(14)(3)
*KFCD*41*S*	400	250	18	20	14 (11)(3)

Notes:

(1) The standards given in this Table are for the test sample taken from iron casting separately cast. Where the test sample cast integral with the casting is used, the standards applied are left to the discretion of the Society.

(2) The proof stress required in the Table is shown for reference.

(3) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value than shown in brackets in the Table, the test is considered to be failed.

5.6.4 Chemical Composition

1 The chemical composition of iron castings is to be suitable to obtain the specified mechanical properties. Where deemed necessary by the Society, the Society may require the manufacturer to carry out an analysis of each melt in ladle.

2 A dispersed spheroidal or nodular form of graphite is generally to be at least 90 %. The Society may require the confirmation of a dispersed spheroidal or nodular form of graphite if deemed necessary by the Society.

5.6.5 Heat Treatment

Iron castings may be supplied in a suitable heat treatment if necessary. For *KFCD*36*S* and *KFCD*41*S*, fertilizing heat treatment is to undergo.

5.6.6 Mechanical Properties*

1 Mechanical properties of iron castings are to comply with the requirements given in **Table K5.10**.

2 Intermediate value of those tabulated in **Table K5.9** may be applicable where approval of the Society is obtained. In this case, the values are to be obtained by interpolation and counting fractions over 0.5 as 1.0 or disregarding the rest.

5.6.7 Mechanical Tests

1 Mechanical tests of iron castings are the tensile test and the impact test according to the grade of iron castings, and are to be carried out in accordance with the requirements in **Chapter 2**.

2 Where the result of the tensile test is failed, retest may be carried out in accordance with the requirements in **1.4.4**. In this case, test specimens are to be taken from other test samples.

3 Where the result of the impact test is failed, retest may be carried out in accordance with the requirements in **3.1.10-3**. In this case, test specimens are to be taken from other test samples.

5.6.8 Selection of Test Specimens*

1 Test specimens of iron castings are to be taken from test samples separately cast.

2 The test samples are to be cast from the same ladle as the one for the castings in the moulds of the same type of material as the one for the moulds for the castings and are not to be stripped from the moulds until the metal temperature is below 500℃. Type and dimensions of test samples are to be deemed appropriate by the Society.

3 One piece of tensile test specimen and one set of impact test specimens of iron castings are to be taken from the following test samples respectively.

(1) Except where otherwise specially specified by the Society, one lot is iron castings whose weight is less than 1 *ton* and consist of the castings poured from a single ladle of metal, provided that they are all of similar type and dimensions, one test sample is to be taken from each one lot. If weight of single iron casting is not less than 2 *tons*, one lot is it, and one test sample is to be taken from each one lot.

(2) Notwithstanding the requirements in **(1)** above, for large castings where more than one ladle of treated metal is used, one test sample is to be taken from each ladle.

5.6.9 Surface Inspection and Dimension Inspection

Surface inspection and dimension inspection are to be carried out in accordance with the requirements in **5.1.9**.

5.6.10 Non-destructive Testing

The Society may require non-destructive testing for the iron castings if deemed necessary by the Society.

5.6.11 Quality

1 The iron castings are to be free from harmful defects to use.

2 Small surface blemishes are to be removed by local grinding. Subject to the prior approval of the Surveyor, the steel castings containing small porosity may be rectified by a suitable repair process.

3 Repairs by welding are generally not permitted.

5.6.12 Marking

Marking of the iron castings is to follow the requirements in **5.1.12**.

5.7 Stainless Steel Propeller Castings

5.7.1 Application

1 The requirements specified in **5.7** apply to the stainless steel castings intended to be used for propellers and propeller blades (hereinafter referred to as “steel propeller castings” in **5.7**).

2 Steel propeller castings with characteristics differing from those specified in **5.7** are to comply with the requirements in **1.1.1-3**.

3 Manufacturers are responsible for ensure that effective quality, process and production controls within the manufacturing specifications are adhered during manufacturing.

5.7.2 Kinds

The steel propeller castings are classified as specified in **Table K5.11**.

Table K5.11 Kinds and Grades

Kind	Grade
Martensitic stainless steel propeller casting, Grade 1 (12*Cr*-1*Ni*)	*KSCSP*1
Martensitic stainless steel propeller casting, Grade 2 (13*Cr*-4*Ni*)	*KSCSP*2
Martensitic stainless steel propeller casting, Grade 3 (16*Cr*-5*Ni*)	*KSCSP*3
Austenitic stainless steel propeller casting, Grade 4 (19*Cr*-11*Ni*)	*KSCSP*4

5.7.3 Chemical Composition

1 The chemical composition of steel propeller castings is to comply with the requirements specified in **Table K5.12**.

2 Manufacturers are to maintain records of the chemical analyses of the production casts, and these records are to be made available to Surveyor.

5.7.4 Heat Treatment

Martensitic stainless steel propeller castings are to be quenched and tempered. Austenitic stainless steel castings are to be solution treated.

5.7.5 Mechanical Properties

The mechanical properties are to comply with the requirements given in **Table K5.13**.

Table K5.12 Chemical Composition

Grade	Chemical composition (%)							
	C	*Si*	*Mn*	*P*	*S*	*Ni*	*Cr*	*Mo*
*KSCSP*1	0.15 max.	1.0 max.	2.0 max.	0.040 max.	0.030 max.	2.0 max.	11.5～17.0	0.5 max.
*KSCSP*2	0.06 max.	1.0 max.	2.0 max.	0.040 max.	0.030 max.	3.5～5.0	11.5～17.0	1.0 max.
*KSCSP*3	0.06 max.	1.0 max.	2.0 max.	0.040 max.	0.030 max.	3.5～6.0	15.0～17.5	1.5 max.
*KSCSP*4	0.12 max.	2.0 max.	1.6 max.	0.040 max.	0.030 max.	8.0～13.0	16.0～21.0	4.0 max.

Table K5.13 Mechanical Properties

Grade	Tensile test				Impact test(3)
	Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation ($L=5d$) (%)	Reduction of area (%)	Minimum mean absorbed energy(J)
*KSCSP*1	440 min.	590 min.	15 min.(4)	30 min.	20
*KSCSP*2	550 min.	750 min.	15 min.(4)	35 min.	30
*KSCSP*3	540 min.	760 min.	15 min.(4)	35 min.	30
*KSCSP*4	180 min.(2)	440 min.	30 min.	40 min.	20

Notes:

(1) The requirements specified in this Table apply to specimens cut from propeller casting itself. Where specimens cut from separately-cast samples, the requirements are to be deemed appropriate by the Society.

(2) The strength of the 1.0% permanent elongation may be considered as the proof stress of *KSCSP*4. In this case, the require proof stress is 205 N/mm^2 min.

(3) This test is required only for propellers of ships with an ice class notation. The test temperature is to be -10℃. For the judgement of the test, **Note (1)** of **Table K5.4** is to be referred to.

(4) For propellers of ships with an ice class notation, the elongation is not to be less than 19%.

5.7.6 Mechanical Tests

1 Tensile test and impact test are to be carried out in compliance with the requirements specified in **Chapter 2** to verify the mechanical properties of steel propeller castings.

2 Where any test results from the first test specimen selected fail to meet the requirements, additional tests may be conducted according to the requirements given in **5.4.7**. The test specimens for the additional tests are to be taken from the same sample from which the first test specimen is taken or from other test samples representative of the steel propeller castings.

5.7.7 Selection of Test Specimens

1 The test specimens for steel propeller castings are to be taken from the integrally cast test samples attached to the propeller castings. The test samples separately cast from the steel propeller castings are subject to the prior approval.

2 The dimensions of test samples attached to blades are to be deemed appropriate by the Society.

3 The test samples attached to blades are to be located in an area between 0.5R to 0.6R, where R is the radius of the propeller, and not to be detached from the castings until the final heat treatment has been carried out. Removal is to be by non-thermal procedures.

4 At least one test sample is to be made on material representing each steel propeller casting. Where a number of small propellers of about the same size, and less than 1 *m* in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. In this case, at least one test sample is to be made for each multiple of five castings in the batch.

5 Mechanical tests are to be carried out with one test specimen and one set of test specimens for tensile test and impact test respectively.

5.7.8 Surface and Dimensional Inspection*

1 A general visual examination is to be carried out by the Surveyor. All finished castings are to be 100 % visually inspected by the manufacturer.

2 All castings are to be free from imperfections which would be prejudicial to their proper application in service.

3 The dimensional inspections of steel propeller castings are to be performed by the manufacturer. Where straightening of a bent blade is carried out, the approval by the Society is to be obtained in advance. The procedure for the straightening is to be deemed appropriate by the Society.

4 Dimensional inspection reports are to be submitted to Surveyor, and surveyors may require checks be made in their presence when deemed necessary.

5.7.9 Non-destructive Inspection*

1 The steel propeller castings are to be subjected to the penetrant test according to **7.2.10**. Magnetic particle tests in accordance with *ISO* 9934-1 or an equivalent standard deemed appropriate by the Society may be used in lieu of liquid penetrant tests for examinations of *KSCP*1, *KSCP*2 and *KSCP*3. In such cases, the magnetic particle test procedure is to be submitted to the Society. The aforementioned standards, in principle, refer to the most recent version published.

2 The ultrasonic or radiographic test is to be required, if deemed necessary by the Society. The ultrasonic test procedure is to be approved by the Society. The acceptance criteria or applied quality levels for ultrasonic or radiographic tests are to be agreed upon between the manufacturer and the Society in accordance with a recognised standard.

3 Qualification of non-destructive inspection operators is to comply with **7.3.2** to **7.3.4**, **Part M of the Rules**.

5.7.10 Repair of Defects*

1 The defects which would be prejudicial to the proper application of steel propeller castings in service, are to be removed by grinding, etc., and the contour of the ground depressions are to be as smooth as possible. Liquid penetrant tests or magnetic particle tests in accordance with **5.7.9-1** are to be carried out on the repaired areas to ensure that all defects have been completely removed to the Surveyor's satisfaction. Notwithstanding the zones, welds having area less than 5 cm^2 are to be avoided.

2 Weld repairs for the parts where defects were removed are to comply with the following requirements according to the zones for the non-destructive inspection shown in **Fig. K7.3**:

(1) The zones where weld repairs are allowed are to be as follows:

Zone A : Weld repairs are not allowed. (Except when otherwise specially approved by the Society)

Zone B : Weld repairs are subject to the approval. (If the thickness of the part where the defect occurred is "t", then defects not deeper than t/40 *mm* or 2 *mm* (whichever is the greatest) are to be removed by grinding.)

Zone C : Weld repairs are allowed.

(2) Prior to the weld repair on Zone B or C mentioned in **(1)** above, the extent of the repair, a repair plan including welding procedures, welding consumables, edge preparations for weld repair after removing defects and heat treatment is to be submitted and approved by the Society.

(3) Liquid penetrant tests on welded areas are to be carried out in the presence of a Surveyor to ensure that no defect exists.

3 The welding procedures are to be in accordance with **(1)** and **(7)**. The welding procedures and related specifications approved by the Society are valid for welding work in all shops and sites belonging to the yard under the same facility and control system.

(1) Welding grooves are to be prepared in a manner that allows good fusion of the groove bottom.

(2) The position of welding is, in principle, to be flat.

(3) Welders are to be qualified as deemed appropriate by the Society.

(4) The recommended temperature of the preheating and stress relieving heat treatment after welding is to be as deemed appropriate by the Society. The martensitic steel propeller castings are to be furnace re-tempered after welding repairs except for the case of local stress relieving for minor repairs subject to the prior approval. And on completion of heat treatment of martensitic steels

the weld repairs and adjacent material are to be ground smooth.

(5) The welding procedure qualification tests are to be carried out in the presence of a Surveyor as follows:

(a) Tests for butt welding

i) Test sample

The minimum dimensions of the test sample are to be as shown in **Fig. K5.3**.

ii) Non-destructive inspection

Test assemblies are to be examined by visual and liquid penetrant tests prior to the cutting of test specimens. Magnetic particle tests may be used in lieu of liquid penetrant tests for examinations of *KSCP*1, *KSCP*2 and *KSCP*3. The welded surface is to be regular and uniform, and free from prejudicial defects such as cracks and undercuts. In cases where post-weld heat treatment is carried out, non-destructive inspections are to be performed after the heat treatment. Imperfections detected by liquid penetrant tests and magnetic particle tests are to be assessed in accordance with **7.2.10-1**.

iii) Macro-etching test

Three test specimens are to be prepared and etched on one side of each specimen at the centre of the test sample and at the welding end parts to clearly reveal the weld metal, the fusion line and the *HAZ*. No pores greater than 3 *mm* and cracks in welded sections are permitted.

iv) Tensile test

The shapes and dimensions of tensile test specimens are to be of kind *U*2*A* or *U*2*B* given in **Table M3.1, Part M**, the number of tensile test specimens is to be two. The tensile strength is to meet the required values of the base metal. The location of fracture (i.e. the weld metal, *HAZ* or base material) is to be reported.

v) Bend test

The shapes and dimensions of the bend test specimens are to be of kind *UB*-1 given in **Table M3.2, Part M**. Two root and two face bend specimens are to be tested. For thicknesses of 12 *mm* and over, four side bend specimens may alternatively be tested. In such cases, the shapes and dimensions of the side bend test specimens are to be of kind *UB*-2 given in **Table M3.2, Part M**. There is to be no cracks or other defects greater than 3 *mm* in length in any direction on the surface of bent specimen. The diameter of the former is to be 4 *times* the thickness for martensitic stainless steel propeller castings and 3 *times* the thickness for austenitic stainless steel propeller castings. The bending angle is to be 180 *degrees*.

vi) Impact test

Impact test is required, where the base metal is impact tested. The shapes and dimensions of the impact test specimens are to be of kind *U*4 given in **Table K2.5**. Two sets (i.e. a total of six specimens) are to be tested. One set (i.e. three specimens) is to have the notch positioned in the centre of the weld and the other set is to have the notch positioned in the *HAZ*(FL+1 *mm*), respectively. The test temperature and impact energy are to comply with the requirements specified for the base material.

vii) Hardness test

The macro-sections of welding start parts are to be used for hardness test. The hardness of the weld metal, the heat-affected zones (both sides) and the base material (both sides) are to be reported for information. Test force is to be 98.07 *N*.

(b) Test of mold cavity welding

i) Test piece

The dimensions of the test piece are to be as shown in **Fig. K7.11**.

ii) Macrostructure test

The cross section of the welded part is to be free from defects such as cracks.

iii) Microstructure test

The microstructures of the welded metal, base metal and heat-affected zones are to be in satisfactory condition.

iv) Hardness test

The deviation among the hardness of the welded metal, base metal and heat-affected zones is not to be significant.

(6) Where the tests specified in the preceding **(5)** are failed, retests are to be in accordance with **4.2.12, Part M**.

(7) The scopes of approval of the welding procedures and related specifications of steel propeller castings are to be in accordance with the following **(a)** through **(h)**, on the condition that the other welding conditions are same.

(a) Base metal

Range of approval for steel cast propeller is limited to steel grade tested.

(b) Thickness

Range of thickness is to be in accordance with **Table K5.16**.

(c) Welding position

Approval for a test made in any position is restricted to that position.

(d) Welding process

Approval is only valid for the welding process used in the welding procedure test. Single run is not qualified by a multi-run butt weld test.

(e) Filler metal

Approval is only valid for the filler metal used in the welding procedure test.

(f) Heat input

The upper limit of heat input approved is 15 % greater than that used in welding the test piece. The lower limit of heat input approved is 15 % lower than that used in welding the test piece.

(g) Preheating and interpass temperature

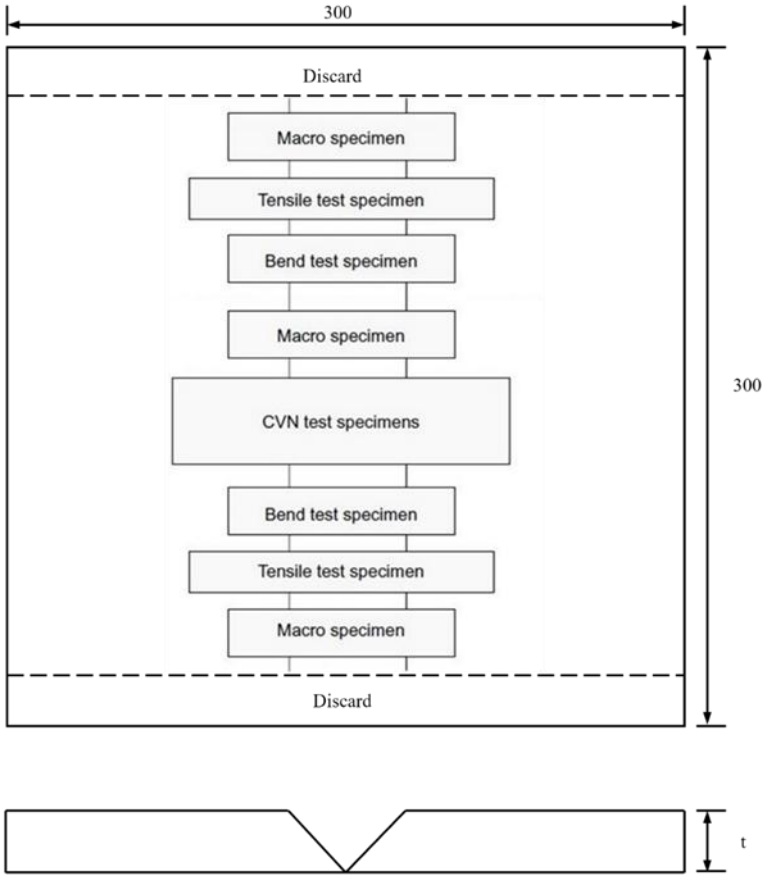
The minimum preheating temperature is not to be less than that used in the qualification test. The maximum interpass temperature is not to be higher than that used in the qualification test.

(h) Post-weld heat treatment

Heat treatment used in the qualification test is to be maintained during actual work. Holding time may be adjusted as a function of thickness.

4 Foundries are to maintain records of inspections, welding, and any subsequent heat treatments, traceable to each casting.

Fig. K5.3 Test Sample for Butt Welding Test (*mm*)



Note: Joint preparation and fit-up as detailed in the preliminary welding procedure specification

Table K5.16 Approval range of thickness

Thickness of the test sample, t (*mm*)	Approval range
$15 < t \leq 30$	3 *mm* to 2 t
$30 < t$	0.5 t to 2 t or 200 *mm*, whichever is the greater

5.7.11 Marking and Test Certificate

1 Marking for steel propeller castings is to comply with the requirements specified in **7.2.12-1**.

2 Test certificate for steel propeller castings is to comply with the requirements specified in **7.2.12-2**.

Chapter 6 STEEL FORGINGS

6.1 Steel Forgings

6.1.1 Application

1 The requirements of 6.1 are to apply to the steel forgings intended to be used for the components of hull construction, equipment, and machinery specified in each Part (hereinafter referred to as the "steel forgings" in 6.1). (steel forgings defined in 6.2, 6.3 and 6.4 are excluded)

2 Steel forgings having characteristics differing from those specified in 6.1 are to comply with the requirements in 1.1.1-3.

6.1.2 Manufacturing Process*

1 Steel forgings are to be manufactured from killed steel.

2 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregation in the finished forgings.

3 Primary materials such as ingot supplied to other works are to be manufactured at the works approved by the Society with regard to the manufacturing process of the materials.

4 Steel forgings are to be forged in accordance with the following **(1)** to **(6)**.

(1) The plastic deformation by forging is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after the heat treatment specified in 6.1.5.

(2) The forging ratio is to be calculated with reference to the average cross-sectional area of the cast material.

(3) In cases where the cast material is initially upset, the reference area in **(2)** above may be taken as the average cross-sectional area after this operation.

(4) The total forging ratio is to be not less than those in Table K6.1 unless otherwise deemed appropriate by the Society.

(5) Steel forgings are to be gradually and uniformly forged as far as practicable and are to be brought as near as possible to the finished shape and size so as to cause metal flow in the most favourable direction having regard to the mode of stressing in service.

(6) When upsetting, ingots are to be compressed in the axial direction using anvils whose cross-sections are larger than that of the ingot in order to have sufficient internal forging effects (e.g. uniform deformation of internal portions) on the ingot. Forging ratios are to be described on mill sheets.

5 Where steel forgings are subjected to surface hardening process such as induction hardening, nitriding or rolling press, data relative to the hardening process is to be submitted for approval to the Society in advance.

6 Steel forgings shaped by flame cutting or scarfing are to have a sufficient machining allowance for removing the heat-affected zone, and the operation is to be carried out before the final heat treatment. Preheating is to be carried out according to the chemical composition, dimensions and form of the steel forgings.

7 When upsetting, ingots are to be compressed in the axial direction using anvils whose cross-sections are larger than that of the ingot in order to have sufficient internal forging effects (e.g. uniform deformation of internal portions) on the ingot. Forging ratios are to be described on mill sheets.

Table K6.1 Forging Ratio

Type	Dimension(1)	Forging ratio(2)
Forgings made from ingots or from forged blooms or billets	$L > D$	S =3
	$L \leq D$	S =1.5
Forgings made from rolled products	$L \leq D$	S =4
	$L > D$	S =2
Forgings made by upsetting (3)	—	U =1/3
Rolled bars	—	S =3

Notes:

(1) L and D are respectively the length and the diameter of the forged products.

(2) Forging ratio is to be calculated by the following equation:

$$S = \frac{A}{a}, \quad U = \frac{1}{L_i / L_f}$$

where:

A : Mean sectional area of original ingot (m^2)

a : Sectional area of the portion after forging (m^2)

L_i : Length before upsetting (m)

L_f : Length after upsetting (m)

(3) In the case of an initial forging ratio of at least S =1.5, the forging ratio may be not more than U =1/2 of the length before upsetting.

6.1.3 Kinds

Steel forgings are classified as specified in **Table K6.3(a)** and **Table K6.3(b)**.

6.1.4 Chemical Composition

1 Steel forgings are to have the chemical composition given in **Table K6.2(a)** and **Table K6.3(b)**.

2 For steel forgings intended for welded constructions, "*W*" is to be suffixed to their respective grade markings (e.g. *KSF*440*W* and *KSFA*600*W-H*).

3 For steel forgings for rudder stocks and pintles, chemical composition is to be of a weldable quality. In cases where high strength carbon steel forgings are used, **-2** above may be relaxed subject to approval by the Society. In this case, "(*W*)" is to be suffixed to the markings.

4 Steel forgings may be added with *Al*, *Nb* or *V* element for greater grain refining of the metal crystal.

5 The manufacturer is to make an analysis of each melt in ladles (multiple heats tapped into a common ladle are considered as one heat.) and the results are to be reported to the surveyor.

Table K6.2(a) Chemical Composition of Machinery Steel Forgings

Kind		Chemical Composition (%) (1)									
		C	*Si*	*Mn*	*P*	*S*	*Cr* (2)	*Mo* (2)	*Ni* (2)	*Cu* (2)	Total residual elements
Steel forgings not intended for welding	Carbon steel forgings	0.65 max. (4)	0.45 max.	0.30～1.50	0.035 max.	0.035 max.	0.30 max.	0.15 max.	0.40 max.	0.30 max.	0.85 max.
	Alloy steel forgings	0.45 max.	0.45 max.	0.30～1.00	0.035 max.	0.035 max.	0.40 min. (3)	0.15 min. (3)	0.40 min. (3)	0.30 max.	—
Steel forgings intended for welding	Carbon steel forgings	0.23 max. (4)	0.45 max.	0.30～1.50	0.035 max.	0.035 max.	0.30 max.	0.15 max.	0.40 max.	0.30 max.	0.85 max.
	Alloy steel forgings (5)	0.25 max.	0.45 max.	0.30～1.00	0.035 max.	0.035 max.	0.40 min. (3)	0.15 min. (3)	0.40 min. (3)	0.30 max.	—

Notes:

(1) Where other elements approved by the Society are added, their contents are to be described in the test results.

(2) Elements considered to be residual elements except in cases where a minimum value is indicated. Residual elements are not to be intentionally added to the steel. The contents of residual elements are to be described in the test results.

(3) One or more of the elements is to comply with the minimum content.

(4) Carbon content may be increased in cases where the carbon equivalent (C_{eq}) specified in **1.5.2-2(6)** is less than 0.41 %.

(5) The chemical composition in this table is to be applied unless otherwise deemed appropriate by the Society.

Table K6.2(b) Chemical Composition of Hull Steel Forgings

Kind		Chemical Composition (%) (1)									
		C	*Si*	*Mn*	*P*	*S*	*Cr* (2)	*Mo* (2)	*Ni* (2)	*Cu* (2)	Total residual elements
Steel forgings not intended for welding	Carbon steel forgings	0.65 max. (4)	0.45 max.	0.30～1.50	0.035 max.	0.035 max.	0.30 max.	0.15 max.	0.40 max.	0.30 max.	0.85 max.
	Alloy steel forgings (5)	0.45 max. (6)	0.45 max.	0.30～1.00 (6)	0.030 max.	0.030 max.	0.40～3.50 (3)(6)	0.15～0.70 (3)(6)	0.40～3.50 (3)(6)	0.30 max.	—
Steel forgings intended for welding	Carbon steel forgings	0.23 max. (4)	0.45 max.	0.30～1.50	0.035 max.	0.035 max.	0.30 max.	0.15 max.	0.40 max.	0.30 max.	0.85 max.
	Alloy steel forgings (5)	0.25 max. (6)	0.45 max.	0.30～1.00 (6)	0.035 max.	0.035 max.	0.40 min. (3)(6)	0.15 min. (3)(6)	0.40 min. (3)(6)	0.30 max.	—

Notes:

(1) Where other elements approved by the Society are added, their contents are to be described in the test results.

(2) Elements considered to be residual elements except in cases where a minimum value is indicated. Residual elements are not to be intentionally added to the steel. The contents of residual elements are to be described in the test results.

(3) One or more of the elements is to comply with the minimum content.

(4) Carbon content may be increased in cases where the carbon equivalent (C_{eq}) specified in **1.5.2-2(6)** is less than 0.41 %.

(5) The chemical composition in this table is to be applied unless otherwise deemed appropriate by the Society.

(6) Specification is to be submitted for approval regardless of the values in the table.

6.1.5 Heat Treatment*

1 Steel forgings are to be annealed, normalized and tempered, or quenched and tempered at a proper stage of manufacturing process for the purpose of grain refining of the metal crystal, removal of residual stress and of obtaining necessary mechanical properties; however, alloy steel forgings are not to be delivered immediately after annealing. Tempering temperatures of steel forgings are not to be less than 550 °C, and manufacturers are responsible for selecting heat treatment methods appropriate for obtaining the required mechanical properties. However, where forgings for gearing are not intended for surface hardening, lower tempering temperatures may be allowed.

2 Steel forgings which are subjected to any hot work likely to cause change in the crystal structure of metal or to generate residual stress after heat treatment are to be heat treated again.

3 Steel forgings which are locally reheated or subjected to cold work involving an excessive degree of straightening are to be stress relieved accordingly. Manufacturers are to strictly control this temperature in order to avoid any detrimental effects to the final heat treatment and resultant microstructure and mechanical properties of the forgings.

4 Where steel forgings are subjected to surface hardening process such as carburizing, heat treatment suitable for surface hardening is to be carried out at a proper stage of the manufacturing process.

5 The furnace intended to be used for heat treatment is to have sufficient size for uniformly heating the steel forgings to the required temperature. The furnace is to be equipped with a device capable of regulating and recording the furnace temperature.

6 Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

7 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature.

6.1.6 Mechanical Properties*

1 Regardless of welding, the mechanical properties of steel forgings are to be in accordance with **Tables K6.3(a)** and **K6.3(b)**. However, mechanical properties of alloy steel forgings with yield point or proof stress values different from the values in **Tables K6.3(a)** and **K6.3(b)** are to be as deemed appropriate by the Society.

2 Intermediate values of those tabulated in **Tables K6.3(a)** and **K6.3(b)** may be applicable where approval of the Society is obtained. In this case, the values are to be obtained by interpolation and counting fractions over 0.5 as one and disregarding the rest.

3 The difference in tensile strength between the maximum and minimum values in case where two or more tension test specimens were taken from one steel forgings is not to exceed 70 N/mm^2 for steel forgings less than 600 N/mm^2 in the specified tensile strength and not to exceed 100 N/mm^2 for steel forgings not less than 600 N/mm^2 in the specified tensile strength.

4 Where batch material tests are carried out, the Surveyor may request hardness test on each product material. In this case, the difference in measured hardness between the maximum and minimum values of the steel forgings of the same lot is not to exceed 20 (*HBW*) for steel forgings less than 600 N/mm^2 in the specified tensile strength and is not to exceed 30 (*HBW*) for steel forgings not less than 600 N/mm^2 in the specified tensile strength.

5 Gears and rims are to conform to the requirements in **6.1.15-4** for hardness test.

Table K6.3(a) Mechanical Properties of Machinery Steel Forgings

Kind		Grade (7)	Tensile strength (1) (N/mm^2)	Yield point or proof stress (N/mm^2)	Elongation ($L = 5.65\sqrt{A}$) (%)		Reduction of area (%)		Brinell hardness(2) *HBW*	Charpy V-notch impact test (6)		
					L	*T*	*L*	*T*		*Test temperature (°C)*	*Minimum average energy (J)*(3)	
											L	*T*
For machinery (8)	Carbon steel forgings	*KSF*400-*M*	400 min.	200 min.	26 min.	19 min.	50 min.	35 min.	110～150	*AT*(9)	27	18
		*KSF*440-*M*	440 min.	220 min.	24 min.	18 min.	50 min.	35 min.	125～160			
		*KSF*480-*M*	480 min.	240 min.	22 min.	16 min.	45 min.	30 min.	135～175			
		*KSF*520-*M*	520 min.	260 min.	21 min.	15 min.	45 min.	30 min.	150～185			
		*KSF*560-*M*	560 min.	280 min.	20 min.	14 min.	40 min.	27 min.	160～200			
		*KSF*600-*M*	600 min.	300 min.	18 min.	13 min.	40 min.	27 min.	175～215			
		*KSF*640-*M*	640 min.	320 min.	17 min.	12 min.	40 min.	27 min.	185～230			
		*KSF*680-*M*	680 min.	340 min.	16 min.	12 min.	35 min.	24 min.	200～240			
		*KSF*720-*M*	720 min.	360 min.	15 min.	11 min.	35 min.	24 min.	210～250			
		*KSF*760-*M*	760 min.	380 min.	14 min.	10 min.	35 min.	24 min.	225～265			
	Alloy steel forgings	*KSFA*600-*M*	600 min.	360 min.	18 min.	14 min.	50 min.	35 min.	175～215			
		*KSFA*700-*M*	700 min.	420 min.	16 min.	12 min.	45 min.	30 min.	205～245			
		*KSFA*800-*M*	800 min.	480 min.	14 min.	10 min.	40 min.	27 min.	235～275			
		*KSFA*900-*M*	900 min.	630 min.	13 min.	9 min.	40 min.	27 min.	260～320			
		*KSFA*1000-*M*	1000 min.	700 min.	12 min.	8 min.	35 min.	24 min.	290～365			
		*KSFA*1100-*M*	1100 min.	770 min.	11 min.	7 min.	35 min.	24 min.	320～385			

Notes:

(1) For steel forgings whose specified minimum tensile strength is less than 900 N/mm^2, a tensile strength range of 150 N/mm^2 may additionally be specified. For steel forgings whose specified minimum tensile strength is 900 N/mm^2 or more, a tensile strength range of 200 N/mm^2 may additionally be specified.

(2) Hardness values are standard and are given for information purposes only.

(3) The letters *"L"* and *"T"* refer to longitudinal and tangential respectively and indicate the direction in which the specimen is to be taken with respect to the product.

(4) The requirement for carbon steel forgings is applicable to those annealed, normalized, normalized and tempered, or quench and tempered.

(5) The requirement for low alloy steel forgings is applicable to those quenched and tempered. In cases where they are normalized and tempered, their mechanical properties are subject to Society approval.

(6) Special consideration may be given to alternative requirements for Charpy V-notch impact test, depending on design and application, and subject to Society approval.

(7) For steel forgings complying with **6.1.4-2**, "*W*" is to be suffixed to their respective grade markings.

(8) For steel forgings complying with the table, "-*M*" is to be suffixed to their respective grade markings (e.g.: *KSF*400-*M* and *KSFA*600*W*-*M*)

(9) *AT* refers to the ambient temperature specified in *ISO* 148-1:2016 (i.e. 23 °C±5 °C).

Table K6.3(b) Mechanical Properties of Hull Steel Forgings

Kind		Grade [6]	Tensile strength [1] (N/mm^2)	Yield point or proof stress (N/mm^2)	Elongation ($L = 5.65\sqrt{A}$) (%)		Reduction of area (%)		Charpy V-notch impact test [5]		
					L	*T*	*L*	*T*	*Test temperature (°C)*	*Minimum average energy (J)* [2]	
										L	*T*
For hull [7]	Carbon steel forgings	*KSF*400-*H*	400 min.	200 min.	26 min.	19 min.	50 min.	35 min.	0	27	18
		*KSF*440-*H*	440 min.	220 min.	24 min.	18 min.	50 min.	35 min.			
		*KSF*480-*H*	480 min.	240 min.	22 min.	16 min.	45 min.	30 min.			
		*KSF*520-*H*	520 min.	260 min.	21 min.	15 min.	45 min.	30 min.			
		*KSF*560-*H*	560 min.	280 min.	20 min.	14 min.	40 min.	27 min.			
		*KSF*600-*H*	600 min.	300 min.	18 min.	13 min.	40 min.	27 min.			
	Alloy steel forgings	*KSFA*550-*H*	550 min.	350 min.	20 min.	14 min.	50 min.	35 min.			
		*KSFA*600-*H*	600 min.	400 min.	18 min.	13 min.	50 min.	35 min.			
		*KSFA*650-*H*	650 min.	450 min.	17 min.	12 min.	50 min.	35 min.			

Notes:

(1) For steel forgings whose specified minimum tensile strength is less than 600 N/mm^2, a tensile strength range of 120 N/mm^2 may additionally be specified. For steel forgings whose specified minimum tensile strength is 600 N/mm^2 or more, a tensile strength range of 150 N/mm^2 may additionally be specified.

(2) The letters *"L"* and *"T"* refer to longitudinal and tangential respectively and indicate the direction in which the specimen is taken with respect to the product.

(3) The requirement for carbon steel forgings is applicable to those annealed, normalized, normalized and tempered, or quench and tempered.

(4) The requirement for low alloy steel forgings is applicable to those quenched and tempered. In cases where they are normalized and tempered, their mechanical properties are subject to Society approval.

(5) Special consideration may be given to alternative requirements for Charpy V-notch impact test, depending on design and application, and subject to Society approval.

(6) For steel forgings complying with **6.1.4-2**, "*W*" is to be suffixed to their respective grade markings.

(7) For steel forgings complying with the table, "*-H*" is to be suffixed to their respective grade markings (e.g. *KSF*400-*H* and *KSFA*600*W*-*H*)

6.1.7 Mechanical Test

1 Mechanical tests for steel forgings are to be carried out in accordance with the requirements given in **Chapter 2**.

2 Where the tensile test or hardness test fails to meet the requirements, retest may be carried out in accordance with the requirements of **1.4.4**.

3 For propeller shafts used for ships with ice class notation (except *ID* class ships), Charpy V-notch impact testing is to be carried out for all steel types at −10 *°C* and the average energy value is to be minimum 20 *J* (using a set of three *U*4 test specimen for longitudinal test). Where the energy values of two or more specimens among a set of specimens are less than 20 *J* or where one individual value is less than 70 % of 20 *J*, the test is considered to have been failed.

4 Where the results of impact tests do not conform to the requirements, additional impact tests are to be carried out in accordance with **3.1.10-3**.

6.1.8 Selection of Test Specimens

1 Unless otherwise specially specified, the test specimens for steel forgings are, after final heat treatment, to be taken longitudinal from a part having a sectional area not less than that of the body of forging. But they are to be taken tangential where deemed necessary according to the form of the forgings.

2 The test specimens are not to be separated from the body before the final heat treatment has been completed. In the case of stamp forging or other case of forging requiring the surface hardening process, the test specimens may be separated at a proper stage before the final heat treatment providing that such is approved by the Surveyor.

3 Unless otherwise agreed, the longitudinal axis of test specimens is to be positioned as follows:

(1) For thicknesses (*t*) or diameters (*D*) of 50 *mm* or less, the axis is to be at a distance of *t*/2 or *D*/2 below the heat treated surface.

(2) For thicknesses (*t*) or diameters (*D*) of greater than 50 *mm*, the axis is to be at *t*/4 or *D*/4 (mid-radius) or 80 *mm*, whichever is less, below any heat treated surface as shown in **Fig. K6.1**.

(3) For ring and disc forgings for which the thickness is 25 *mm* or less, tangential test specimens are to be taken at a distance of *t*/2 below the heat treated surface in both the vertical and horizontal directions.

(4) For ring and disc forgings for which the thickness is greater than 25 *mm*, tangential test specimens are to be taken at a distance of 12.5 *mm* below the heat treated surface in both the vertical and horizontal direction. No part of the test specimen is to be closer than 12.5 *mm* to any heat treated surface, as shown in **Fig. K6.1**.

4 Notwithstanding **-3** above, where manufacturers demonstrate that a proposed testing location or orientation is more representative of the required mechanical properties of a component, this location or orientation may allowed by the Society. In such cases, the heat treatment process, the proposed testing location or orientation, and technical justification are to be submitted to the Society for approval.

5 The number of test specimens is to be in accordance with the following **(1)** through **(4)**. In such cases, “one set of specimens” means one tensile test specimen and one set of three impact test specimens:

(1) For steel forgings more than 4 *tons* in mass and 3 *m* in length as heat treated (hereinafter referred to as “mass” and “length”), one set of test specimens is to be taken from both ends of the steel forging.

(2) For steel forgings more than 4 *tons* in mass and 3 *m* or less in length or for steel forgings 500 *kg* or greater but 4 *tons* or less in mass, one set of test specimens is to be taken from one end of the forging in a longitudinal direction; however, the alternative directions or positions shown in **Fig. K6.2** thorough **Fig. K6.4** may be used at manufacturer discretion.

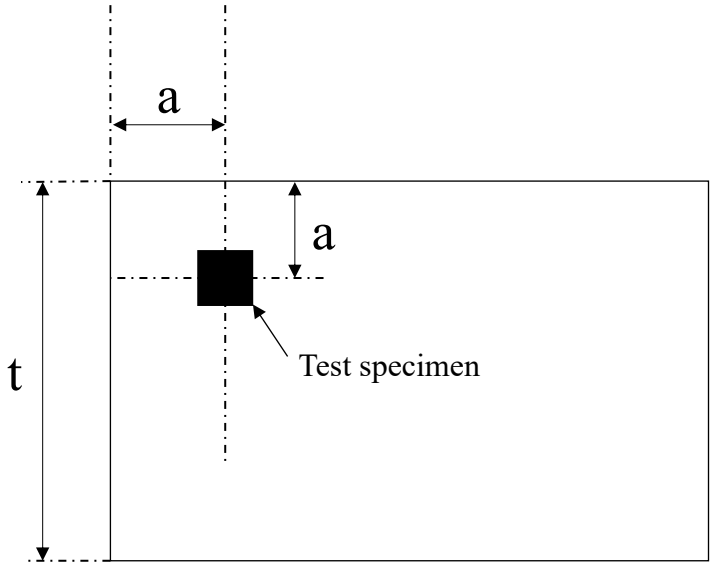
(3) Where a number of steel forgings of similar form and size, each of which is 250 *kg* up to 500 *kg* (exclusive) in mass, are made from the same ingot (or bloom) and heat treated simultaneously, one set of test specimens is to be taken from each three forgings or a fraction thereof.

(4) Where a number of steel forgings of similar form and size, each of which is less than 250 *kg* in mass, are made from same ingot (or bloom) and heat treated simultaneously in the same furnace, one set of test specimens is to be taken from a total mass not exceeding 6 tons in case that the forgings are annealed, normalized, normalized and tempered and is to be taken from a total mass not exceeding 3 tons in case that the forgings are quench and tempered. Where approved by the Society, test specimens may be taken from the test samples which forged from same ingot and same condition, and heat treated by same furnace on same time.

6 The steel forgings heat treated with continuous heat treatment furnace, without changing the heat treatment conditions are to be

considered that they have been simultaneously heat treated.

Fig. K6.1 Test Specimen Position



Note:

"*t*" is the thickness of the steel forging, and "*a*" is the distance from the test specimen to heat treated surface based on 6.1.8-3(2) and **(4)**.

Fig. K6.2 Alternative Directions or Position of the Test Specimen for Plain Shaft

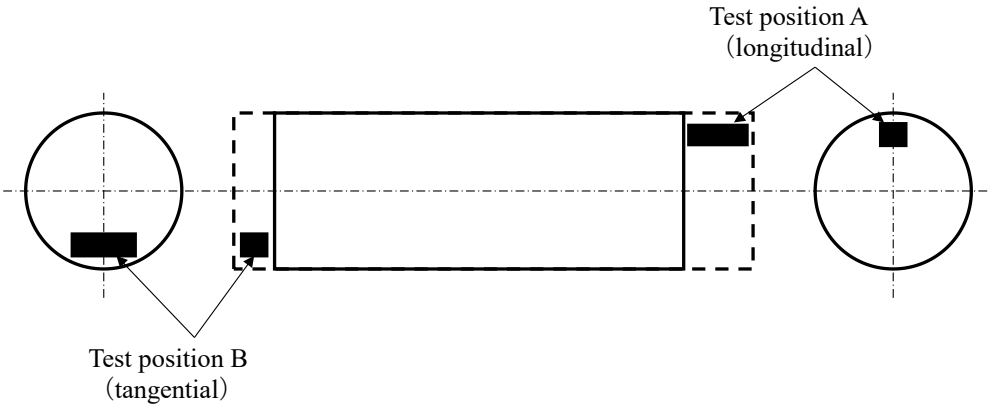


Fig. K6.3 Alternative Directions or Positions for the Test Specimens for Flanged Shafts

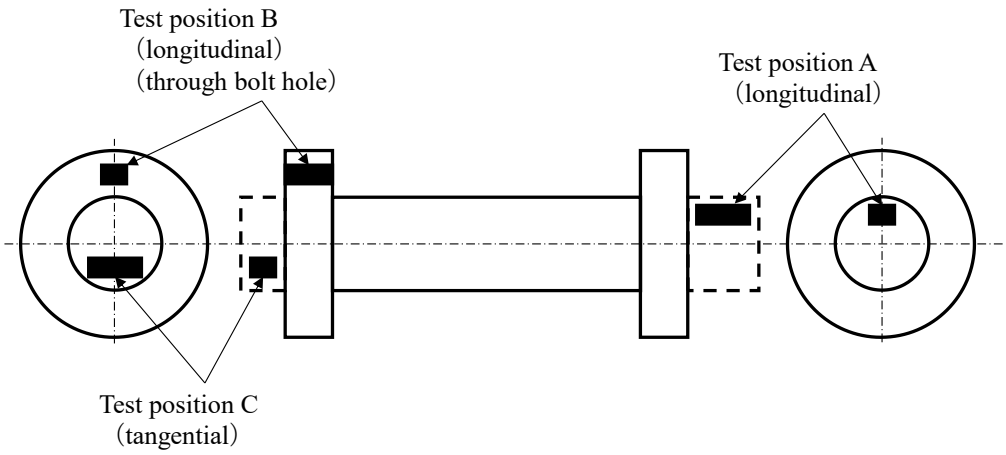
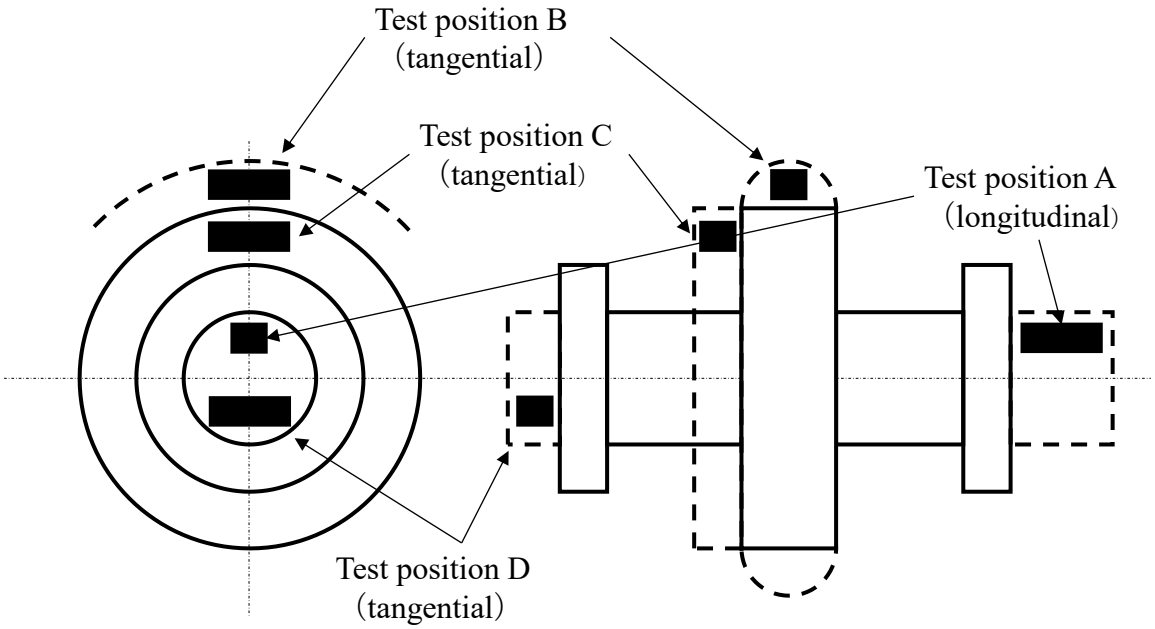


Fig. K6.4 Alternative Directions or Positions for the Test Specimen for Flanged Shafts with Collars



6.1.9 Surface Inspection and Dimension Inspection*

1 When heat treatment and final machining are completed and, if necessary, at a proper stage during machining, surface inspection is to be carried out.

2 Dimension inspection of the steel forgings is to be conducted under the responsibility of the manufacturer.

3 Notwithstanding the requirements in **-1** and **-2** above, surface inspections or dimension inspections may be omitted for steel forgings when not required according to **2.2.1-1**, **Part D of the Rules**.

6.1.10 Non-destructive Testing*

1 Steel forgings are to be subjected to non-destructive testing in accordance with **(1)** and **(2)** of the following requirements:

(1) Ultrasonic test

(a) The following steel forgings are to be subjected to ultrasonic test at an appropriate stage of the manufacturing process and the test reports are to be showed or submitted to the Surveyor.

i) Rudder stocks and pintles
ii) Steel forgings which are to be subjected to ultrasonic test according to the requirement specified in **2.2.1-1, Part D**
iii) Thrust shafts, intermediate shafts and propeller shafts
iv) Reduction gears and reduction gear shafts
v) Turbine rotors, turbine discs and turbine blades

(b) Performances of ultrasonic testing apparatus are to be of good efficiency for testing of these forgings.

(c) Operator engaged in the ultrasonic test is to have sufficient technique and experience for the testing of the forgings.

(2) Magnetic Particle or liquid penetrant testing

The important parts of the following steel forgings are to be subjected to magnetic particle or liquid penetrant test at an appropriate stage of the manufacturing process:

(a) Steel forgings which are to be subjected to magnetic particle test or liquid penetrant test according to the requirement specified in **2.2.1-1, Part D**.

(b) Propeller shafts.

(c) Reduction gears.

(d) Turbine rotors, turbine discs and turbine blades.

2 The Society may require sulphur print test for the portion of gears where teeth will be cut.

3 In place of the test methods given in, **-1** and **-2**, the Society may accept the application of other non-destructive tests considered adequate by the Society.

4 The Society may require non-destructive test for the steel forgings other than those specified in **-1** when such is deemed necessary by the Society.

5 The welded parts of steel forgings used for welded construction are to be subjected to the non-destructive tests considered adequate by the Society.

6 Where advanced ultrasonic testing methods are applied (e.g. *PAUT* or *TOFD*), they are to be in accordance with requirements specified otherwise by the Society.

7 Where forgings are supplied in the "as forged" condition for machining at separate works and it is physically or technically difficult to conduct ultrasonic examinations (e.g. probes cannot be fitted onto forgings during machining), manufacturers are to conduct suitable ultrasonic examinations in accordance with procedures deemed appropriate by the Society.

6.1.11 Repair of Defects*

1 In the event of finding defects considered harmful for the intended use in the steel forgings, the defects are to be removed by grinder, etc.

2 After removing the defects, magnetic particle test or liquid penetrant test is to be carried out to ensure that all defects have been removed completely.

3 The steel forgings from which defects are removed are to be approved by the Surveyor. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours and stress concentration.

4 Repair welding of forgings except those subjected to torsional fatigue, such as crankshaft forgings and propeller shaft forgings, may be permitted subject to Society approval. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted to the Society for approval.

5 The forging manufacturer is to present records of repairs and subsequent inspections traceable to each forging repaired, to the surveyor on request.

6.1.12 Marking

Steel forgings which have satisfactorily complied with the required tests are to be marked with the identification mark in accordance with the requirements in **1.5.1**. For steel forgings to which the requirements given in **6.1.6-2** have been applied, the value corresponding to the required tensile strength employed is to be used to the grade mark. (*ex*. Where the required tensile strength employed is 460 N/mm^2, "*KSF*47" is to be indicated)

6.1.13 Additional Requirements for Crankshafts*

1 Where solid crank shafts of 250 *mm* and over in finished diameter are manufactured by free forging, the heat treatment is

normally to be carried out after crank parts are machined as nearly as possible to the finished shape. In this case, one set of test specimens is to be taken from each end of the shaft.

2 For solid crankshafts manufactured adopting the special forging processes, semi-built-up crank throws and full-built-up crank webs, the preliminary tests instructed by the Society are to be carried out, in connection with the manufacturing processes and the selection of test specimens.

3 Where the special forging processes are adopted to reduce the size of crank shaft according to the requirements in **2.3.1-4, Part D**, the preliminary tests instructed by the Society are to be carried out.

6.1.14 Additional Requirements for Turbine Rotors

1 Test specimens for turbine rotors are to be taken in accordance with the following **(1)** and **(2)**:

(1) Where turbine rotors are greater than 3 *tons* in mass, one set of longitudinal test specimens is to be taken from each end of the shaft portion and one set of tangential test specimens is to be taken in the tangential direction from the body portion (*See* **Fig. K6.5**).

(2) Where the turbine rotor is not exceeding 3 *tons* in mass, one set of longitudinal test specimens is to be taken from one end of the shaft portion and one set of tangential test specimens in the tangential direction from the body portion respectively.

2 For each turbine disc, one set of tangential test specimens in the tangential direction is to be taken from the boss portion (*See* **Fig. K6.6**).

3 Solid forged turbine rotors intended for main propulsion service where the inlet steam temperature exceeds 400℃ are to be subjected to stability tests at least once at a suitable time after rough machining or heat treatment. This requirement is also applicable to rotors fabricated by welding. The method of stability test is to be approved by the Society prior to the test.

6.1.15 Additional Requirements for Reduction Gears*

1 Pinions intended for reduction gears are to conform to the following **(1)** through **(4)**:

(1) Where the finished diameter over the portion where teeth will be cut does not exceed 200 *mm*, one set of longitudinal test specimens is to be taken from one end of the journal (*See* **Fig. K6.7**).

(2)

(a) Where the finished diameter is greater than 200 *mm* and the length of one piece is greater than 1.25 *m*, one set of tangential test specimens is to be taken from each end of the adjacent portion where the teeth will be cut (*See* **(A)** in **Fig. K6.8**). In the case of pinions where the diameter of journal precludes the preparation of test specimens from this portion, tangential test specimens may be taken from the ends of the journal (*See* **(B)** in **Fig. K6.8**). Where the finished journal diameter does not exceed 200 *mm*, one set of longitudinal test specimens may be taken from each end of the journals (*See* **(C)** in **Fig. K6.8**).

(b) Where the finished diameter is greater than 200 *mm* and the length of one piece is greater than 1.25 *m*, one set of test specimens is to be taken from one end of the pinion in accordance with **(a)**.

(3) Where the pinions are so designed that the tooth body is inserted in the shaft, one set of tangential test specimens in the tangential direction is to be taken from the ends of the tooth body. Where the finished length is greater than 1.25 *m*, one set of test specimens is to be taken from each end.

(4) Where a number of pinions, each of which mass less than 250 *kg*, are made from the same ingot and heat treated simultaneously, one set of test specimens is to be taken from every two pinions at least.

2 Rims intended for reduction gears are to conform to the following **(1)** through **(3)**:

(1) Where the finished diameter of a rim exceeds 2.5 *m* or the mass exceeds 3 *tons*, one set of tangential test specimens is to be taken from each end of the rim at diametrically opposite positions (*See* **Fig. K6.10**). In cases where the finished width of the rim does not exceed 1 *m*, one set each test specimens may be taken from either end of the rim at diametrically opposite positions. The mechanical properties are to conform to the requirements applicable to cases where test specimens are taken in the direction parallel to the forging direction.

(2) Where the mass and finished diameter are different from those given in **(1)** above, one set of test specimens may be taken from one end of the rim.

(3) Where a number of separate forgings, each of which is not exceeding 250 *kg* in mass, are made from the same ingot (or bloom) and heat treated simultaneously, one set of test specimens is to be taken from every two rims at least, in accordance with **(2)** above.

3 For gear wheels, one set of tests is to be taken from each forging in a tangential direction (*See* **Fig. K6.11**).

4 Where gears are to be subjected to the surface hardening, the detailed information relating to manufacturing is to be submitted and the test procedure is to be approved by the Society before the work is commenced. In this case, a preliminary test is to be carried out where deemed necessary by the Society.

5 The gears specified in **-1** thorough **-4** are to be subjected to the following hardness tests:

(1) Non-surface-hardened gears

Four hardness tests are to be made at equal distances round the circumference prior to machining the gear teeth. Where the width of the toothed portion exceeds 500 *mm*, hardness tests are to be made at each end of the toothed portion.

(2) Surface-hardened gears

Hardness tests are to be made on the surface of gear teeth when surface hardening has been completed.

(3) The measured hardness value is to be approved by the Society.

6.1.16 Forged Rings (such as slewing rings)

Test specimens for forged rings (such as slewing rings) are to be taken in accordance with the following **(1)** and **(2)** (*See* **Fig. K6.12**):

(1) Where the finished diameter is 2.5 *m* or less, one set of test specimens is to be taken from each forging in a tangential direction.

(2) Where the finished diameter is greater than 2.5 *m* or the mass is greater than 3 *tons*, two sets of test specimens are to be taken at diametrically opposite positions.

Fig. K6.5 Selection of Test Specimens for Turbine Rotors

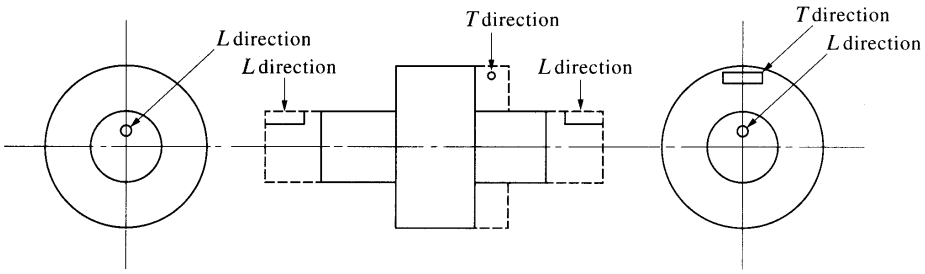
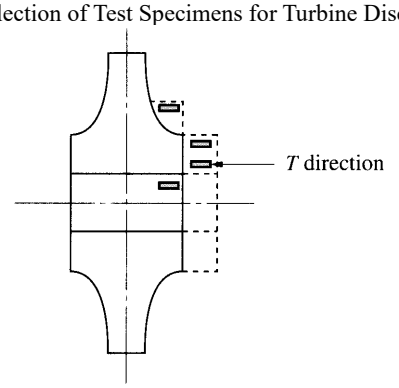


Fig. K6.6 Selection of Test Specimens for Turbine Discs



Note : One set of test specimens may be taken from one location given in the Figure.

Fig. K6.7 Selection of Test Specimens for Pinion Not Exceeding 200 *mm* in Finished Diameter

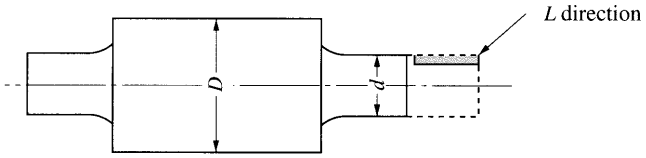


Fig. K6.8 Selection of Test Specimens for Pinion Greater Than 200 *mm* in Finished Diameter

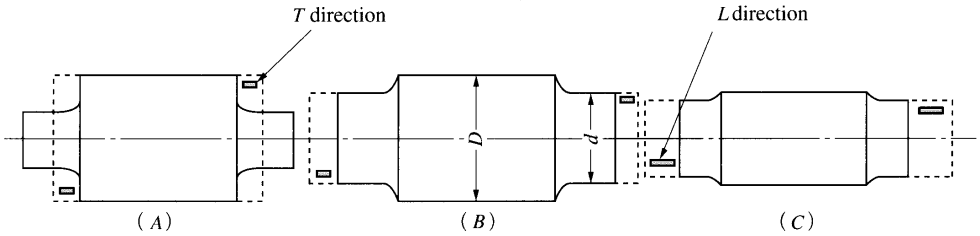


Fig. K6.9 Selection of Test Specimens for Pinion Sleeves

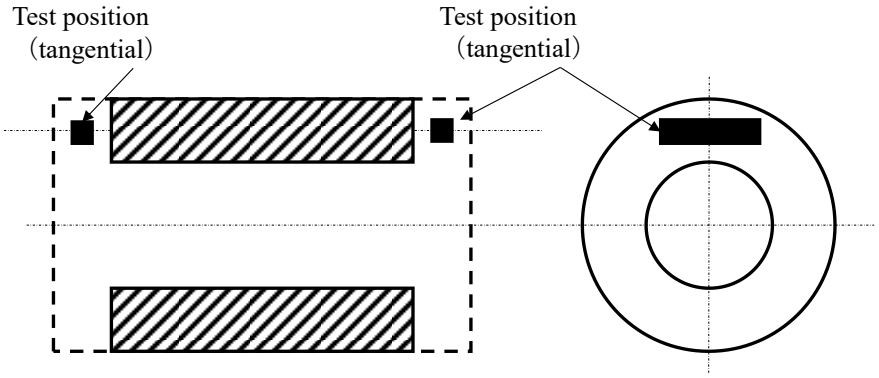


Fig. K6.10 Selection of Test Specimens for Rim

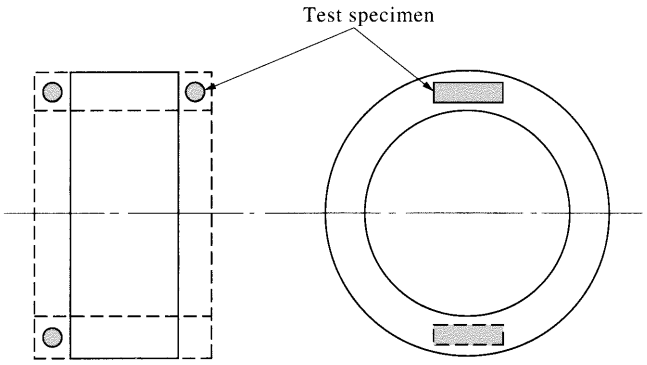


Fig. K6.11 Selection of Test Specimens for Gear Wheel

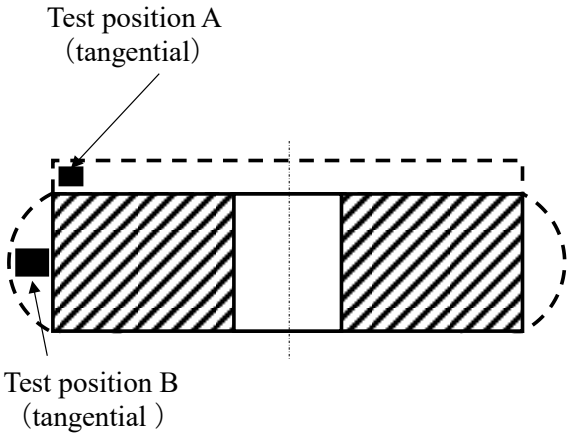
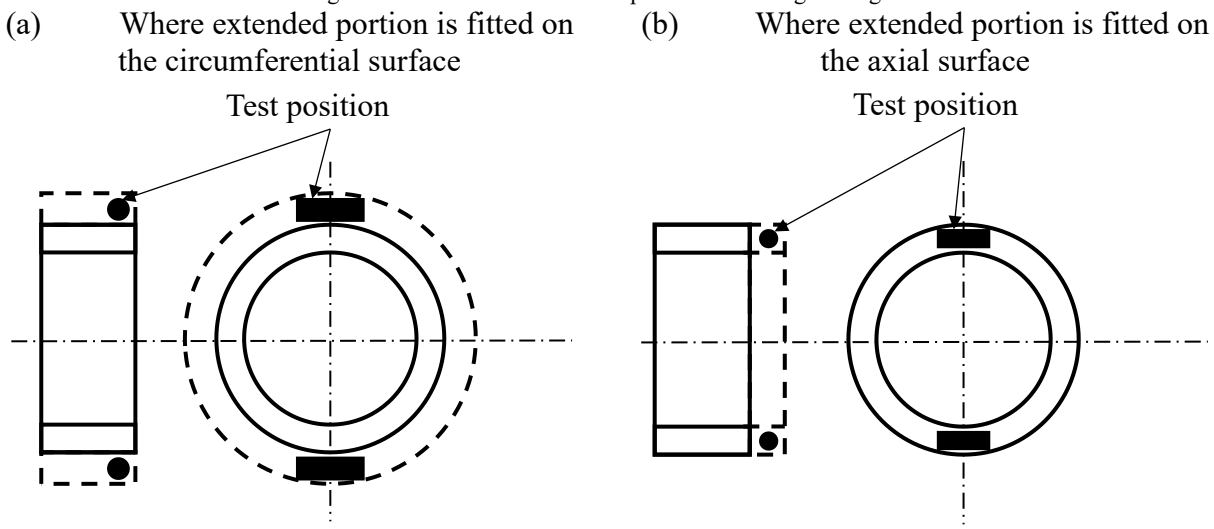


Fig. K6.12 Selection of Test Specimens for Forged Rings



6.2 Stainless Steel Forgings

6.2.1 Application

1 The requirements are to apply to the stainless steel forgings for propeller shafts and valves and pipe fittings in piping systems used at low temperature service (-165℃ and over in design temperature) or corrosion-resisting service (hereinafter referred to as “stainless steel forgings” in **6.2**).

2 Stainless steel forgings having characteristics differing from those specified in **6.2** are to comply with the requirements in **1.1.1-3**.

3 In addition to the requirements given in **6.2** general requirements may be considered by the Society.

6.2.2 Manufacturing Process

Manufacturing process of stainless steel forgings is to be as **6.1.2**.

6.2.3 Kinds

The steel forgings are classified into 9 grades as specified in **Table K6.4**.

6.2.4 Chemical Composition

Stainless steel forgings are to have the chemical composition given in **Table K6.4**.

6.2.5 Heat Treatment*

1 The stainless steel forgings are generally to receive a solid solution treatment.

2 Stainless steel forgings which are subjected to any hot work likely to cause change in the crystal structure of metal or to generate residual stress after heat treatment are to be heat treated again.

3 Stainless steel forgings which are subjected to any cold work involving an excessive degree of straightening are to be stress relieved accordingly.

4 The furnace intended to be used for heat treatment is to have sufficient size for uniformly heating the stainless steel forgings to the required temperature. The furnace is to be equipped with a device capable of regulating and recording the furnace temperature.

6.2.6 Mechanical Properties

1 The mechanical properties of stainless steel forgings are to conform to the requirements given in **Table K6.5**. For the application of the Table, the stainless steel forgings receive a solid solution treatment.

2 Notwithstanding in **-1**, for stainless steel forgings for valves and pipe fittings in piping systems used at low temperature, hardness tests may be omitted.

3 Where deemed necessary by the Society, other tests on notch toughness or corrosion-resistance may be required in addition to the specified test.

Table K6.4 Grades and Chemical Composition

Grade	Chemical composition (%)							
	C	*Mn*	*P*	*S*	*Si*	*Cr*	*Ni*	Others
*KSUSF*304	0.08 max.	2.00 max.	0.040 max.	0.030 max.	1.00 max.	18.00~20.00	8.00~12.00	
*KSUSF*304*L*	0.030 max.					18.00~20.00	8.00~12.00	
*KSUSF*309*S*	0.08 max.					22.00~24.00	12.00~15.00	
*KSUSF*310*S*	0.08 max.					24.00~26.00	19.00~22.00	
*KSUSF*316	0.08 max.					16.00~18.00	10.00~14.00	*Mo* 2.00~3.00
*KSUSF*316*L*	0.030 max.					16.00~18.00	10.00~14.00	*Mo* 2.00~3.00
*KSUSF*317	0.08 max.					18.00~20.00	10.00~15.00	*Mo* 3.00~4.00
*KSUSF*321	0.08 max.					17.00~19.00	9.00~12.00	$Ti \geq 5 \times C$
*KSUSF*347	0.08 max.					17.00~19.00	9.00~13.00	$Nb + Ta \geq 10 \times C$

Table K6.5 Mechanical Properties

Grade	Tensile test				Hardness test		
	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) ($L = 5.65\sqrt{A}$)	Reduction of area (%)	Brinell hardness *HBW*	Rockwell hardness *HRB*	Vickers hardness *HV*
*KSUSF*304*L* *KSUSF*316*L*	175 min.	450 min.	37 min.	50 min.	187 max.	90 max.	200 max.
Others	205 min.	520 min.	37 min.	50 min.			

6.2.7 Mechanical Tests

1 Mechanical tests for stainless steel forgings are to be carried out in accordance with the requirements given in **Chapter 2**.

2 Where the tensile test or hardness test fails to meet the requirements, retest may be carried out in accordance with the requirements of **1.4.4**.

3 The difference in tensile strength between the maximum and minimum values in case where two or more tensile test specimens were taken from one stainless steel forgings is not to exceed 70 N/mm^2.

4 The difference in measured hardness between the maximum and minimum values of the stainless steel forgings of the same lot is not to exceed 20 (*HBW*).

6.2.8 Selection of Test Specimens

1 The number of tension test specimens is to comply with the requirements given in **6.1.8**.

2 The tensile test specimens are to be cut with their longitudinal axes parallel to the direction of forging, unless otherwise specially provided.

3 Where tests are carried out in accordance with **6.1.8-4(3)** or **(4)**, the Surveyor may require a hardness test for each steel forging.

4 Tensile test specimen is to comply with the requirements given in **Table K2.1**.

6.2.9 Surface Inspection and Dimension Inspection*

1 When heat treatment and final machining are completed and, if necessary, at a proper stage during machining, surface inspection is to be carried out.

2 Dimension inspection of the stainless steel forgings is to be conducted under the responsibility of the manufacture.

6.2.10 Non-destructive Testing*

1 Stainless steel forgings used for propeller shafts and so on are to be subjected to non-destructive testing in accordance with **(1)** and **(2)** of the following requirements:

(1) Ultrasonic test

(a) The stainless steel forgings are to be subjected to ultrasonic test at an appropriate stage of the manufacturing process and the test reports are to be shown or submitted to the Surveyor.

(b) Performances of ultrasonic testing apparatus are to be of good efficiency for testing of these forgings.

(c) Operator engaged in the ultrasonic test is to have sufficient technique and experience for the testing of the stainless steel forgings.

(2) The important parts of the stainless steel forgings are to be subjected to liquid penetrant test at an appropriate stage of the manufacturing process.

2 In place of the test methods given in, **-1**, the Society may accept the application of other non-destructive test considered adequate by the Society.

6.2.11 Repair of Defects

The repair of defects of the stainless steel forgings are to be in accordance with the requirements given in **6.1.11**.

6.2.12 Marking

The markings of the stainless steel forgings are to be in accordance with the requirements given in **1.5.1**.

6.3 Steel Forgings for Chains

6.3.1 Application

1 The requirements are to apply to the steel forgings intended to be used for chain accessories such as shackle, swivel, etc. of chains specified in **Part L** (hereinafter referred to as “steel forgings” in **6.3**).

2 Steel forgings having characteristics differing from those specified in **6.3** are to comply with the requirements in **1.1.1-3**.

3 In addition to the requirements given in **6.3**, general requirements may be considered by the Society.

6.3.2 Kinds

The steel forgings are classified into 5 grades as specified in **Table K6.6**.

Table K6.6 Grades of Steel Forgings

Grade		Application
Steel forging for Grade 2 chain	*KSFC*50	Grade 2 chain
Steel forging for Grade 3 chain	*KSFC*70	Grade 3 chain
Grade *R*3 steel forgings	*KSFCR*3	Grade *R*3 chain
Grade *R*3*S* steel forgings	*KSFCR*3*S*	Grade *R*3*S* chain
Grade *R*4 steel forgings	*KSFCR*4	Grade *R*4 chain
Grade *R*4*S* steel forgings	*KSFCR*4*S*	Grade *R*4*S* chain
Grade *R*5 steel forgings	*KSFCR*5	Grade *R*5 chain

6.3.3 Heat Treatment and Forging Ratio

1 The steel forgings are to be normalized, normalized and tempered, quenched and tempered or heat treated by the process approved by the Society.

2 The forging ratio of grades *KSFCR*3, *KSFCR*3*S*, *KSFCR*4, *KSFCR*4*S* and *KSFCR*5 is to be at least the approved value.

6.3.4 Grain Size

1 The austenitic grain size of grades *KSFCR*3, *KSFCR*3*S*, *KSFCR*4, *KSFCR*4*S* and *KSFCR*5 is to be 6 or finer in accordance with *ASTM E*112 or equivalent grain size index in accordance with *ISO* 643 or to be deemed as equivalent by the Society.

2 Measurements of grain size for circular sections are to be taken at a depth of 1/3 radius from the surface. Measurements of grain size for non-circular sections are to be taken at a depth of 1/4 thickness from the surface.

6.3.5 Deoxidation Practice and Chemical Composition

1 The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table K6.7**. Elements other than specified in **Table K6.7** may be added subject to a special approval by the Society.

2 Grades *KSFCR*4*S* and *KSFCR*5 are to be vacuum degassed.

6.3.6 Mechanical Properties

The mechanical properties of each grade are to comply with the requirements specified in **Table K6.8**.

Table K6.7 Deoxidation Practice and Chemical Composition (%)

Grade	Deoxidation	*C*	*Si*	*Mn*	*P*	*S*	*Al*(1)
*KSFC*50	Fine grained	0.24 max.	0.15~0.55	1.60 max.	0.035 max.	0.035 max.	0.020 min.
*KSFC*70	Killed	0.36 max.	0.15~0.55	1.00~1.90	0.035 max.	0.035 max.	0.020 min.
*KSFCR*3		Detailed chemical composition is to be approved by the Society. For Grade *KSFCR*4, *KSFCR*4*S* and *KSFCR*5, the steel should contain a minimum of 0.2% molybdenum.					
*KSFCR*3*S*							
*KSFCR*4							
*KSFCR*4*S*							
*KSFCR*5							

Note:

(1) *Al* content is to be represented by the total *Al* content and may be replaced partly by other fine graining elements.

Table K6.8 Mechanical Properties

Grade	Tensile test				Impact test(1)	
	Yield point or proof stress(2) (N/mm^2)	Tensile strength(2) (N/mm^2)	Elongation ($L=5d$) (N/mm^2)	Reduction of area (%)	Testing temperature (℃)	Minimum mean absorbed energy (J)
*KSFC*50	295 min.	490~690	22 min.	—	0	27
*KSFC*70	410 min.	690 min.	17 min.	40 min.	0	60
*KSFCR*3	410 min.	690 min.	17 min.	50 min.	-20(3)	40(3)
*KSFCR*3*S*	490 min.	770 min.	15 min.	50 min.	-20(3)	45(3)
*KSFCR*4	580 min.	860 min.	12 min.	50 min.	-20	50
*KSFCR*4*S*	700 min.	960 min.	12 min.	50 min.	-20	56
*KSFCR*5	760 min.	1000 min.	12 min.	50 min.	-20	58

Notes:

(1) When the absorbed energy of two or more test specimens among a set of test specimens is less in value than the specified minimum mean absorbed energy or when the absorbed energy of a single test specimen is less in value than 70% of the specified minimum mean absorbed energy, the test is considered to have failed.

(2) Aim value of yield to tensile ratio for grades *KSFCR*3, *KSFCR*3*S*, *KSFCR*4, *KSFCR*4*S* and *KSFCR*5 is to be maximum 0.92.

(3) Impact test of grade *KSFCR*3 and *KSFCR*3*S* may be carried out at the temperature 0℃ where approved by the Society. In this case, minimum mean absorbed energy is to be not less than 60 *J* for grade *KSFCR*3 and 65 *J* for grade *KSFCR*3*S*.

6.3.7 Selection of Test Specimens*

1 One sample steel forging is to be selected from every number of steel forgings for Grade 2 and 3 steel forgings specified in **Table K6.9** or a fraction thereof and for Grade *R*3, *R*3*S*, *R*4, *R*4*S* and *R*5 steel forgings specified in **Table K6.10** or a fraction thereof, which belong to the same heat, according to the nominal diameter of the common links to which the steel forgings are intended to link. Where specially approved by the Society, the test sample may be taken from representative part of the steel forgings at a proper time during manufacturing, or separate sample forged to the forge ratio equivalent to that of the steel forgings. In this case, the test sample is to be heat-treated simultaneously with the steel forgings.

2 The test specimens from one test sample prepared according to **-1** are to be cut with their longitudinal axis parallel to the direction of steel forging and to consist of one tensile test specimen at one set (3 pieces) of impact test specimens.

3 The tensile and impact test specimens are to be taken from the test sample in the longitudinal direction at a depth of 1/6 diameter from the surface or as close as possible to this position (*See* **Fig. K3.2**).

4 Tensile and impact test specimens are to comply with the requirements specified in **Table K2.1** and **Table K2.5** respectively.

5 For grades *KSFCR*3*S*, *KSFCR*4, *KSFCR*4*S* and *KSFCR*5, two tensile test specimens having a diameter of 20 *mm* are, in principle, to be subject to hydrogen embrittlement tests. In such cases, the test specimens are to be taken from the central regions of steel forgings which are heat treated according to the following **(1)** or **(2)**.

(1) In the case of continuous casting, test samples representing both the beginning and the end of the charge are to be taken.

(2) In the case of ingot casting, test samples representing two different ingots from the same charge are to be taken.

Table K6.9 Number of Steel Forgings for Selection of One Sample of Grade 2 and 3 Chain

Normal diameter *d* (*mm*) of common links to which steel forgings are linked	Number of steel forgings belonging to the same heat
12.5≤*d*≤28	250
30≤*d*≤48	100
50≤*d*≤68	75
70≤*d*≤98	50
100≤*d*≤162	25

Table K6.10 Number of Steel Forgings for Selection of One Sample of Grade *R*3, *R*3*S*, *R*4, *R*4*S* and *R*5 Chain

Normal diameter *d* (*mm*) of common links to which steel forgings are linked	Number of steel forgings belonging to the same heat
50≤*d*<75	75
75≤*d*<100	50
100≤*d*<125	25
125≤*d*<150	20
150≤*d*	15

6.3.8 Hydrogen Embrittlement Test*

1 Hydrogen embrittlement tests are to be carried out in accordance with the following procedure:

(1) One specimen is to be tested either within a maximum of 3 *hours* after machining, or within a period not exceeding 5 *days* after it has been cooled to -60°C immediately after machining and then maintain at that temperature until tested.

(2) The other specimen is to be tested after baking at 250°C for 4 *hours*.

(3) A slow strain rate (i.e., a strain rate less than 0.0003 s^{-1}) is to be used during the entire test, as far as practicable, and tensile strength, elongation and reduction of area are to be measured.

2 The test result is to comply with the following formula.

$Z_{(1)}/Z_{(2)} \geq 0.85$

$Z_{(1)}$ is the reduction of area measured by the test specified in **-1(1)**

$Z_{(2)}$ is the reduction of area measured by the test specified in **-1(2)**

6.3.9 Surface Inspection and Non-destructive Test*

1 For grades *KSFC*50 and *KSFC*70, surface inspections are to be carried out and it is to be confirmed that there are no harmful defects after the heat treatment of the steel forgings is finished.

2 For grades *KSFCR*3, *KSFCR*3*S*, *KSFCR*4, *KSFCR*4*S* and *KSFCR*5, the steel forgings are to be examined by magnetic particle tests in accordance with standards deemed appropriate by the Society and it is to be confirmed that there are no harmful defects after the heat treatment of the forgings is finished.

3 For grades *KSFCR*3, *KSFCR*3*S*, *KSFCR*4, *KSFCR*4*S* and *KSFCR*5, the entire steel forging is to be subjected to an ultrasonic test at an appropriate stage of manufacturing in accordance with standards deemed appropriate by the Society and it is to be confirmed that there are no harmful defects.

4 With respect to **-2** and **-3** above, non-destructive test procedures, together with rejection/acceptance criteria are to be submitted to the Society.

5 With respect to **-2** and **-3** above, non-destructive test operators are to be appropriately qualified in performing non-destructive tests.

6.3.10 Repair of Defects

1 For grades *KSFCR*3, *KSFCR*3*S*, *KSFCR*4, *KSFCR*4*S* and *KSFCR*5, repairs by welding are not permitted.

2 The surface defects on non-machined surfaces may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0.8 *mm* in order to repair any spurious indications.

6.3.11 Additional Tests before Rejection

Where the tensile test or impact test on the selected first test specimens fails to meet the requirements, additional tests may be carried out according to the requirements given in **3.6.11**.

6.3.12 Marking

Steel forgings which have proved satisfactory compliance with the required tests are to be marked with identification marks in accordance with the requirements in **1.5.1**.

6.3.13 Submission of Data*

For grades *KSFCR*4*S* and *KSFCR*5, the following information for each heat is to be submitted by the bar manufacturer to the offshore chain manufacturer.

(1) The results of the microscopic examinations for non-metallic inclusions.

(2) The results of macro etched examinations in order to confirm that there is no injurious segregation or porosity.

(3) The results of hardenability tests.

6.4 Steel Forgings for Low Temperature Service

6.4.1 Application

1 The requirements are to apply to the steel forgings for valves and pipe fittings in piping systems intended to be used for low temperature service (hereinafter referred to as “steel forgings”).

2 Steel forgings other than specified in **6.4** or those used in other parts than specified in **-1** are to comply with the requirements given **1.1.1-3**.

3 In addition to the requirements given in **6.4**, general requirements may be considered by the Society.

6.4.2 Kinds

The steel forgings are classified into 5 grades as given in **Table K6.11**.

6.4.3 Heat Treatment

The steel forgings are to be normalized and tempered, quenched and tempered or double-normalized and tempered.

6.4.4 Deoxidation Practice and Chemical Composition

The deoxidation practice and chemical composition of each grade are to comply with the requirements given in **Table K6.11**.

Table K6.11 Grades and Chemical Composition (%)

Grade	Deoxidation	*C*	*Si*	*Mn*	*P*	*S*	*Ni*	*Cr*	*Cu*	*Al*
KLFA	Fully killed fine grain	0.23 max.	0.15 ~0.35	1.10 max.	0.030 max.	0.030 max.	—	—	—	—
KLFB		0.20 max.	0.15 ~0.35	1.60 max.			—	—	—	—
KLFC		0.12 max.	0.10 ~0.35	0.55 ~1.00			0.50 ~0.95	0.50 ~0.95	0.40 ~0.75	0.04 ~0.30
*KLF*3		0.20 max.	0.15 ~0.35	0.90 max.			3.25 ~3.75	—	—	—
*KLF*9		0.10 max.	0.10 ~0.35	0.90 max.			8.50 ~9.60	—	—	—

6.4.5 Mechanical Properties

1 The mechanical properties of steel forgings are to comply with the requirements given in **Table K 6.12**.

2 Where deemed necessary by the Society, other tests may be required in addition to the tests specified in **-1**.

6.4.6 Selection of Test Specimens

1 The number of test specimens is to be in accordance with the requirements specified in **6.1.8**.

2 The test specimens for tensile and impact tests are to be cut with their longitudinal axes parallel to the direction of forging, except where otherwise specially specified.

3 Where tests are made in accordance with the requirements in **6.1.8-3(3)** and **(4)**, the Surveyor may require a hardness test for each forging.

4 The size and dimensions of tensile and impact test specimens are to comply with the requirements specified in **Table K2.1** and **Table K2.5** respectively.

6.4.7 Additional Tests before Rejection

1 Where the tensile tests from the first test specimens selected fail to meet the requirements, additional tests may be carried out according to the requirements given in **1.4.4**.

2 Regarding the impact tests, additional tests are to be carried out according to the requirements given in **3.1.10-3**.

6.4.8 Marking

Marking of the steel castings is to comply with the requirements given in **6.1.12**.

Table K6.12 Mechanical Properties

	Tensile test				Impact test(1)	
Grade	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation ($L = 5.65\sqrt{A}$) (N/mm^2)	Reduction of area (%)	Testing temperature (℃)	Mean absorbed energy (J)
KLFA	205 min.	410 min.	23 min.	40 min.	-40	27 min.
KLFB	275 min.	490 min.	20 min.		-50	
KLFC	205 min.	410 min.	23 min.		-60	
*KLF*3	275 min.	490 min.	23 min.	50 min.	-95	34 min.
*KLF*9	520 min.	680 min.	19 min.	45 min.	-196	41 min.

Note:

(1) Where the absorbed energy of more than one of a set of test specimens is under the required minimum mean absorbed energy, or where the absorbed energy of one test specimen is under 70% of the required value, the test is considered to be failed.

Chapter 7 COPPER AND COPPER ALLOYS

7.1 Copper and Copper Alloy Pipes and Tubes

7.1.1 Application

1 The requirements are to apply to the copper and copper alloy pipes and tubes.

2 Copper and copper alloy pipes and tubes are to conform to the requirements in *JIS H* 3300 or equivalent thereto. However, the manufacturing approval test by the Society is not required.

3 Copper and copper alloy pipes and tubes having characteristics differing from those specified in **7.1** are to comply with the requirements in **1.1.1-3**.

7.1.2 Kinds

Copper and copper alloy pipes and tubes are classified as specified in **Table K7.1**.

7.1.3 Mechanical Properties

The mechanical properties of copper and copper alloy pipes and tubes are to comply with the requirements given in **Table K7.2**.

Table K7.1 Kind and Grade

Kind		Grade
Copper seamless pipes and tubes	Phosphorus deoxidized copper	*C*1201, *C*1220
Copper alloy seamless pipes and tubes	Brass	*C*2600, *C*2700, *C*2800
	Brass for condenser tube	*C*4430, *C*6870, *C*6871, *C*6872
	Cupro-nickel for condenser	*C*7060, *C*7100, *C*7150

Table K7.2 Mechanical Properties

Kind	Grade	Tensile test	
		Tensile strength (N/mm^2)	Elongation (%)
Phosphorus deoxidized copper seamless pipes and tubes	*C*1201 *C*1220	205 min.	40 min.
Brass seamless pipes and tubes	*C*2600	275 min.	45 min.
	*C*2700	295 min.	40 min.
	*C*2800	315 min.	35 min.
Brass seamless pipes and tubes for condenser	*C*4430	315 min.	30 min.
	*C*6870 *C*6871	370(1) min.	40 min.
	*C*6872	350(2) min.	40 min.
Cupro-nickel seamless pipes and tubes for condenser	*C*7060	275 min	30 min.
	*C*7100	315 min.	30 min.
	*C*7150	360 min.	30 min.

Notes:

(1) It is applicable to those having 5 *mm* and up to 50 *mm* in outside diameter.

(2) It is applicable to those having over 50 *mm* up to 200 *mm* in outside diameter.

7.1.4 Testing and Inspection

Testing and inspection of pipes and tubes are to comply with the requirements specified in *JIS H* 3300. Those subjected to the maximum working pressure not exceeding 1 *MPa* may not require the presence of the Society's Surveyor.

7.2 Copper Alloy Castings

7.2.1 Application

1 The requirements specified in 7.2 are to apply to the copper alloy casting to be used for propellers and propeller blades (hereinafter referred to as "propeller castings" in 7.2).

2 Propeller castings having characteristics differing from those specified in 7.2 are to comply with the requirements in 1.1.1-3.

3 Manufacturers are responsible for ensuring that effective quality, process and production controls within the manufacturing specifications are adhered to during manufacturing.

4 Copper alloy castings to be used for important parts other than propeller castings are to conform to the requirements given in *JIS* or equivalent thereto. In this case, testing and inspection may not require the presence of the Society's Surveyor except where special requirements are given in connection with the design.

7.2.2 Kinds

The propeller castings are classified as specified in Table K7.3.

Table K7.3 Kinds and Grades

Kind	Grades
Manganese bronze casting, Grade 1	*KHBsC*1
Ni-Manganese bronze casting, Grade 2	*KHBsC*2
Ni-Aluminium bronze casting, Grade 3	*KAℓBC*3
Mn-Aluminium bronze casting, Grade 4	*KAℓBC*4

7.2.3 Chemical Composition

1 The chemical composition of propeller castings is to comply with the requirements specified in Table K7.4. Moreover, for *KHBsC*1 and *KHBsC*2, they are also to comply with the following **(1)** or **(2).**

(1) The zinc equivalent as specified below does not exceed 45 %.

$$\text{Zinc equivalent (\%)} = 100 - \frac{100 \times Cu(\%)}{100 + A}$$

where

$$A = Sn + 5Al - 0.5Mn - 0.1Fe - 2.3Ni \ \ (\%)$$

(2) Each tensile test specimen is examined metallographically, and the proportion of alpha-phase determined from an average of five counts is not less than 25 %.

2 Manufacturers are to maintain records of the chemical analyses of the production casts, and these records are to be made available to the Surveyor.

Table K7.4 Chemical Composition (%)

Grade	Cu	Al	Mn	Zn	Fe	Ni	Sn	Pb
*KHBsC*1	52～62	0.5～ 3.0	0.5～ 4.0	35～40	0.5～2.5	1.0 max.	1.5 max.	0.5 max.
*KHBsC*2	50～57	0.5～ 2.0	1.0～ 4.0	33～38	0.5～2.5	2.5～8.0	1.5 max.	0.5 max.
*KAℓBC*3	77～82	7.0～11.0	0.5～ 4.0	1.0 max.	2.0～6.0	3.0～6.0	0.1 max.	0.03 max.
*KAℓBC*4	70～80	6.5～ 9.0	8.0～20.0	6.0 max.	2.0～5.0	1.5～3.0	1.0 max.	0.05 max.

7.2.4 Manufacturing Process

1 Pouring is to be carried out into dried moulds using degassed liquid metal.

2 Pouring is to be controlled to avoid turbulences of flow.

3 Special devices or procedures are to be employed to prevent slag from flowing into moulds.

7.2.5 Heat Treatment

Where propeller castings are heat treated, detailed procedure for the heat treatment is to be submitted for approval before the heat treatment is started.

7.2.6 Mechanical Properties

The mechanical properties of propeller castings are to comply with the requirements specified in **Table K7.5**.

Table K7.5 Mechanical Properties

Grade	Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%) (L=5d)
*KHBsC*1	175 min.	440 min.	20 min.
*KHBsC*2	175 min.	440 min.	20 min.
*KAℓBC*3	245 min.	590 min.	16 min.
*KAℓBC*4	275 min.	630 min.	18 min.

Notes:

(1) The requirements specified in this Table apply to specimens cut from separately-cast samples, where specimens cut from propeller casting itself, the requirements are to be deemed appropriate by the Society.

(2) The requirements concerning proof stress apply to cases where proof stress is required by the Society in relation with design.

7.2.7 Mechanical Tests

1 Mechanical tests on propeller castings are to be tensile test, and to be carried out in compliance with the requirements specified in **Chapter 2**.

2 Where any test result from the first test specimen selected fails to meet the requirements, additional tests may be conducted according to the requirements given in **1.4.4**. The test specimens for the additional tests are to be taken from the same sample from which the first test specimen is taken or from other test samples representative of the propeller castings.

7.2.8 Selection of Test Specimens*

1 The test samples for propeller castings are to be separately cast from the propeller castings. In addition to complying with **5.7.7-3,** test specimens to be taken from integrally cast test samples are to as deemed appropriate by the Society.

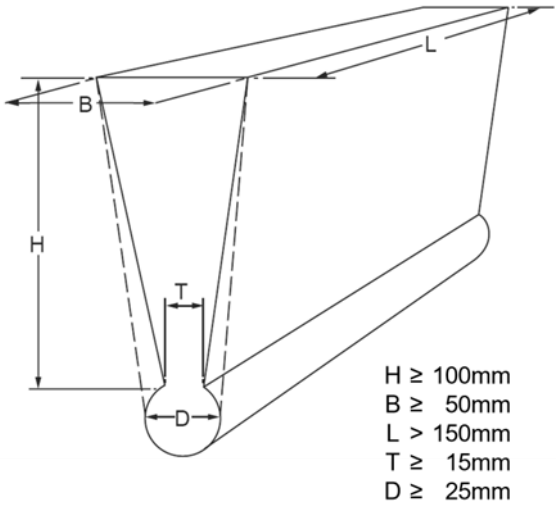
2 The test samples are to be cast in moulds made of the same material as the mould for the propeller castings and they are to be cast under the same condition as the propeller castings. The shapes and dimensions of the test samples are to comply with **Fig. K7.1**. The shape given by the dotted lines shown in the figure, however, may be acceptable.

3 The test samples are to be cast from the same ladle of metal used for the propeller castings except the cases where special requirements are given by the Society. Where more than one ladles of metal are used for propeller castings without mixing before pouring, one test sample is to be provided for each ladle.

4 When propellers are to be subjected to heat treatment, their test samples are to be heat treated together with them.

5 One test specimen is to be taken from each test sample.

Fig. K7.1 Shapes and Dimensions of the Test Samples



7.2.9 Surface and Dimensional Inspection*

1 All finished castings are to be 100 % visually inspected by the manufacturer. A general visual examination is to be carried out by the Surveyor.

2 Castings are to be free from cracks, hot tears, or other imperfections which (due to their nature, degree or extent) will interfere with the use of the castings.

3 The dimensional inspections of propeller castings are to be conducted by the manufacturer. Where straightening of a bent blade is carried out, the procedure for the straightening is to comply with the following requirements.

(1) Loading used for straightening purposes is to be static.

(2) In the case of hot straightening, uniform heating is to be conducted to a sufficient area, and the temperature is to be measured by a suitable instrument. The temperature is to be maintained within the range given in **Table K7.6** during the straightening operation. Weld repaired areas may be subject to hot straightening, provided it can be demonstrated that the weld properties are not impaired by the hot straightening operations, and it is approved by the Society.

(3) Cold straightening is to be restricted to the case of minor repairs of tips and edges. Cold straightening is to be followed by a stress relieving heat treatment other than *KAlBC*3. The heat treatment is to be conducted in accordance with **7.2.11-3(4)**.

4 Dimension inspection reports are to be submitted to Surveyor, and Surveyor may require checks to be made in their presence when deemed necessary.

Table K7.6 Temperature for Hot Straightening

Grade	Temperature(℃)
*KHBsC*1	500–800
*KHBsC*2	500–800
*KAlBC*3	700–900
*KAlBC*4	700–850

7.2.10 Non-destructive Inspection*

1 The propeller castings are to be subjected to the penetrant test according to **(1)** to **(4)** below.

(1) The methods of the testing are to conform to *ISO* 3452-1 or an equivalent standard thereto. The aforementioned standards, in principle, refer to the most recent version published. Where indications of defects appear, the type of the defects and the size of the indications are to be recorded in detail. These records are to be presented to the Surveyor. For reference, the true sizes of the defects are also to be confirmed.

(2) Test areas are classified as Zones A, B and C as specified in **Fig. K7.3**. Tests on Zone A are to be carried out in the presence of Surveyor, while tests on Zones B and C are to be performed by the manufacturer and may be witnessed by the Surveyor upon his request.

(3) Defects detected by penetrant tests are divided into the following **(a)** to **(d)** types (see **Fig. K7.2**).

(a) Cracks: defects regarded as a crack.

(b) Circular defects: defects other than cracks in which the length (l) is equal to or less than 3 *times* the width (w)

(c) Linear defects: defects other than cracks in which the length (l) is greater than 3 *times* the width (w).

(d) Aligned defects: defects consisting of three or more circular defects which are almost aligned and for which the spacing (d) in between does not exceed 2 *mm*. In addition, defects consisting of two or more linear defects which are almost aligned and for which the spacing (d) in between does not exceed the longest indications of the defects. The length of an aligned defect is to be as the sum of the lengths of all individual defects and all spacing in between.

(4) The defects to be evaluated are to be indications of defects for which the length exceeds 1.5 *mm*. Where cracks or other defects which do not meet the acceptance criteria given in **Table K7.7** are detected by penetrant tests, they are to be repaired in accordance with **7.2.11**. Areas which are prepared for welding are always to be assessed according to Zone A regardless of their location.

2 The ultrasonic or radiographic test is to be required if deemed necessary by the Society. The ultrasonic test procedure is to be approved by the Society. The acceptance criteria or applied quality levels are to be agreed upon between the manufacturer and the Society in accordance with a recognised standard.

3 Qualification of non-destructive inspection operators is to comply with **7.3.2** to **7.3.4**, **Part M of the Rules**.

Fig. K7.2 Shapes of Indications of Defects

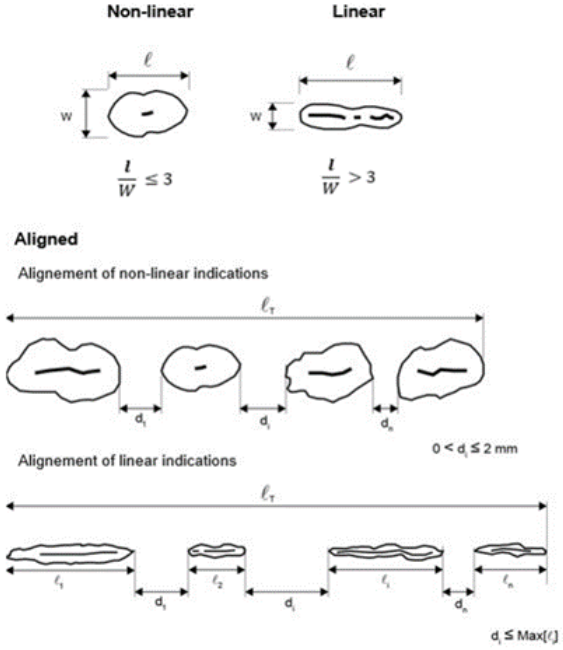


Table K7.7 Acceptance Criteria

Area of Test	Type of Defect (excluding cracks)	Acceptance Criteria		
		Max. total number of defects (I)	Defects of same type	
			Number of each type (II)	Max. size for each indication (III)(*mm*)
Zone A	Circular	7	5	4
	Linear		2	3
	Aligned		2	3
Zone B	Circular	14	10	6
	Linear		4	6
	Aligned		4	6
Zone C	Circular	20	14	8
	Linear		6	6
	Aligned		6	6

Notes:

(1) Defects are to be repaired when they do not meet the one or more criteria of (I) through (III) in this table.

(2) The counting of the number of defects is to be conducted to the most unfavourable location relative to the indication being evaluated. The area of a reference zone is to be 100 cm^2. Each reference area may be square or rectangular with the major dimension not exceeding 250 *mm*.

(3) Singular circular indications less than 2 *mm* for Zone A and less than 3 *mm* for other zones may be disregarded.

(4) The total number of non-linear indications may be increased to the max. total number, or part thereof, represented by the absence of linear or aligned indications.

7.2.11 Repair of Defects*

1 In event of finding defects which would be prejudicial to the proper application of propeller castings in service, the defects are to be removed by grinding, etc., and the surfaces of the ground depressions are to be as smooth as possible. Liquid penetrant tests are to be carried out to the repaired areas to ensure that all defects have been completely removed, and the repaired propeller casting is to

be approved by the Society's surveyor upon the use in service.

2 Repair weldings for the parts where defects were removed are to comply with the following requirements according to the zones for non-destructive inspection shown in **Fig. K7.3**. Notwithstanding the zones, welds having areas less than 5 cm^2 are to be avoided.

(1) The areas according to **Fig. K7.3** where repair weldings are acceptable are to be as follows:

Zone A : Repair weldings are not allowed (Except when otherwise specially approved by the Society)

Zone B : Repair weldings are allowed provided that prior approval was given by the Society. (If the thickness of the part where the defect occurred is "t", then defects not deeper than t/40 *mm* or 2 *mm* (whichever is the greatest) are to be removed by grinding.)

Zone C : Repair weldings are allowed

(2) Prior to the weld repair on Zone B or C mentioned in **(1)** above, the extent of the repair, a repair plan including welding procedures, welding consumables, edge preparations for weld repair after removing defects and heat treatment is to be submitted and approved by the Society.

(3) Liquid penetrant tests on welded areas are to be carried out in the presence of a Surveyor to ensure that no defect exists.

3 The welding procedures are to be as in accordance with **(1)** and **(7)**. The welding procedures and related specifications approved by the Society are valid for welding work in all shops and sites belonging to the yard under the same facility and control system.

(1) Welding grooves are to be prepared in a manner that allows good fusion of the groove bottom.

(2) The kind of welding is to be either *MIG* or *TIG* welding, and the position of welding is, in principle, to be flat. In addition, welding consumables are, in principle, to be aluminium bronze or common metals.

(3) Welders are to have qualifications deemed appropriate by the Society.

(4) The preheating and stress relieving heat treatment following the repair weldings are to be in accordance with **Tables K7.8** and **K7.9**, and the area to be heat treated is to be as large as possible.

(5) Welding procedure qualification tests are to be carried out in the presence of a Surveyor as follows:

(a) Tests for butt welding

i) Test sample

The minimum dimensions of the test sample are to be as shown in **Fig. K7.4**.

ii) Non-destructive inspection

Test assemblies are to be examined by visual and liquid penetrant tests prior to the cutting of test specimens. The welded surface is to be regular and uniform and free from prejudicial defects such as cracks and undercuts. In cases where post-weld heat treatment is carried out, non-destructive inspections are to be performed after the heat treatment. Imperfections detected by liquid penetrant tests are to be assessed in accordance with **7.2.10-1**.

iii) Macro-etching test

Three test specimens are to be prepared and etched on one side to clearly reveal the weld metal, the fusion line and the *HAZ*. No pores greater than 3 *mm* and cracks in welded sections are permitted.

iv) Tensile test

The shapes and dimensions of the tensile test specimens are to be of kind *U2A* or *U2B* given in **Table M3.1, Part M**, the number of tensile test specimens is to be two, and tensile strength is to be in compliance with **Table K7.10**.

(b) Test of mold cavity welding

i) Test piece

The dimensions of the test piece are to be as shown in **Fig. K7.5**.

ii) Macrostructure test

The cross section of the welded part is to be free from defects such as cracks.

iii) Microstructure test

The microstructures of the deposit metal, base metal and heat-affected zones are to be in satisfactory condition.

iv) Hardness test

The deviation among the hardness of the deposit metal, base metal and heat-affected zones is not to be unacceptable.

(6) Where the tests specified in the preceding **(5)** are failed, retests are to be in accordance with **4.2.12, Part M**.

(7) The scopes of approval of the welding procedures and related specifications of propeller castings are to be in accordance with the following **(a)** through **(h)**, on the condition that the other welding conditions are same.

(a) Base metal

Range of approval for propeller castings is limited to be in accordance with **Table K7.11**.

(b) Thickness

Range of thickness is to be in accordance with **Table K7.12**.

(c) Welding position

Approval for a test made in any position is restricted to that position.

(d) Welding process

Approval is only valid for the welding process used in the welding procedure test. Single run is not qualified by a multi-run butt weld test.

(e) Filler metal

Approval is only valid for the filler metal used in the welding procedure test.

(f) Heat input

The upper limit of heat input approved is 25 % greater than that used in welding the test piece. The lower limit of heat input approved is 25 % lower than that used in welding the test piece.

(g) Preheating and interpass temperature

The minimum preheating temperature is not to be less than that used in the qualification test. The maximum interpass temperature is not to be higher than that used in the qualification test.

(h) Post-weld heat treatment

Heat treatment used in the qualification test is to be maintained during actual work. Holding time may be adjusted as a function of thickness.

4 Foundries are to maintain records of inspections, welding, and any subsequent heat treatments, traceable to each casting.

7.2.12 Marking and Test Certificate

1 In addition to **5.1.12**, propeller castings are to be marked with the following **(1)** through **(3)** particulars:

(1) Date of final inspection

(2) Ice class symbol, where applicable

(3) Skew angle for high skew propellers.

2 In addition to **1.5.2**, test certificate for propeller castings is to contain the following **(1)** through **(11)** particulars:

(1) Purchaser, order number and shipbuilding project number, if known

(2) Description of the casting with drawing number

(3) Diameter, number of blades, pitch, direction of turning

(4) Grade of alloy and chemical composition of each heat

(5) Heat or casting number

(6) Final weight

(7) Results of non-destructive tests and details of test procedure where applicable

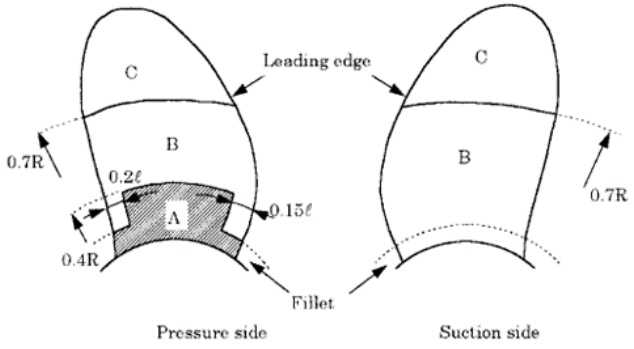
(8) Portion of alpha-phase for *KHBsC*1 and *KHBsC*2 alloys

(9) Results of the mechanical tests

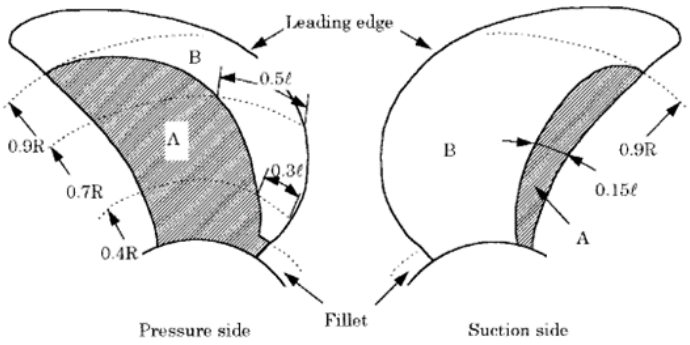
(10) Casting identification number

(11) Skew angle for high skew propellers

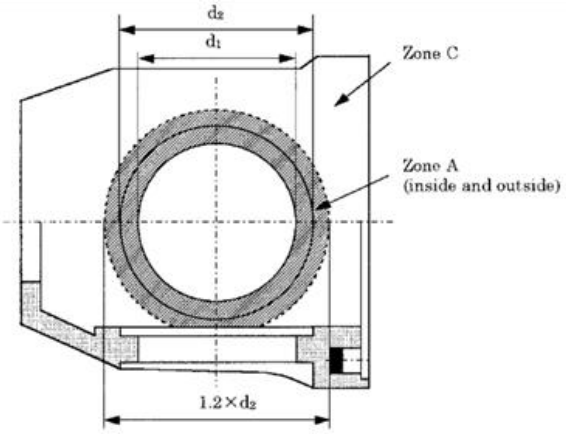
Fig. K7.3 Zones for Non-destructive Inspection



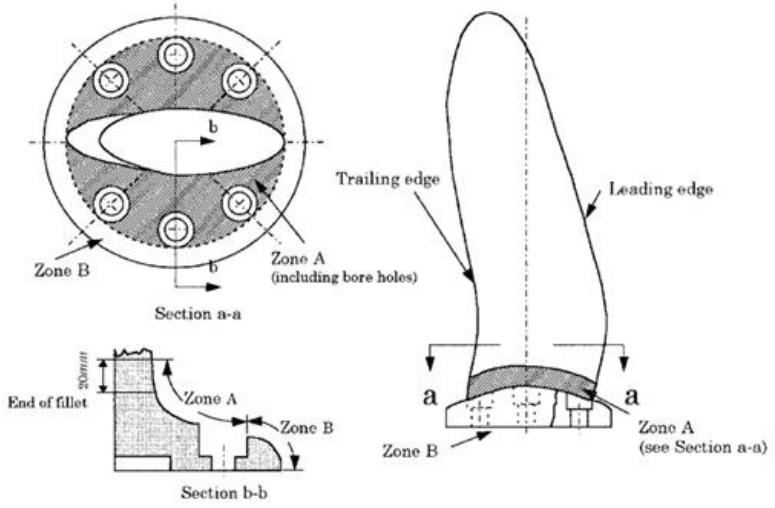
(a) Propeller other than highly skewed propeller



(b) Highly skewed propeller



(a) Zones for Non-destructive Inspection for Controllable Pitch Propeller Boss



(b) The zones for non-destructive inspection on the root areas of the of controllable pitch or build up propeller blades (for remaining surface of the propeller blades, see **Fig. K7.1, Part K**)

Notes:

(1) R is the radius of the propeller, l is the chord length at any radius.

(2) Highly skewed propeller is a propeller with a skew angle exceeding 25°.

(3) The boss area of a integrally cast propeller is regarded as Zone C.

Table K7.8 Temperature for Heat Treatment

Grade	Preheat temperature (℃)	Interpass temperature (℃)	Stress relief temperature (℃)
*KHBsC*1	150 min.	300 max.	350–500
*KHBsC*2	150 min.	300 max.	350–550
*KAlBC*3	50 min.	250 max.	450–550
*KAlBC*4	100 min.	300 max.	450–600

Notes:

(1) The cooling rate after any stress relieving heat treatment is , in principle, not to exceed 50 ℃/*h* until the temperature reaches 200 ℃.

(2) Stress relieving for *KAlBC*3 may be dispensed with.

Table K7.9 Soaking Times for Stress Relief Heat Treatment

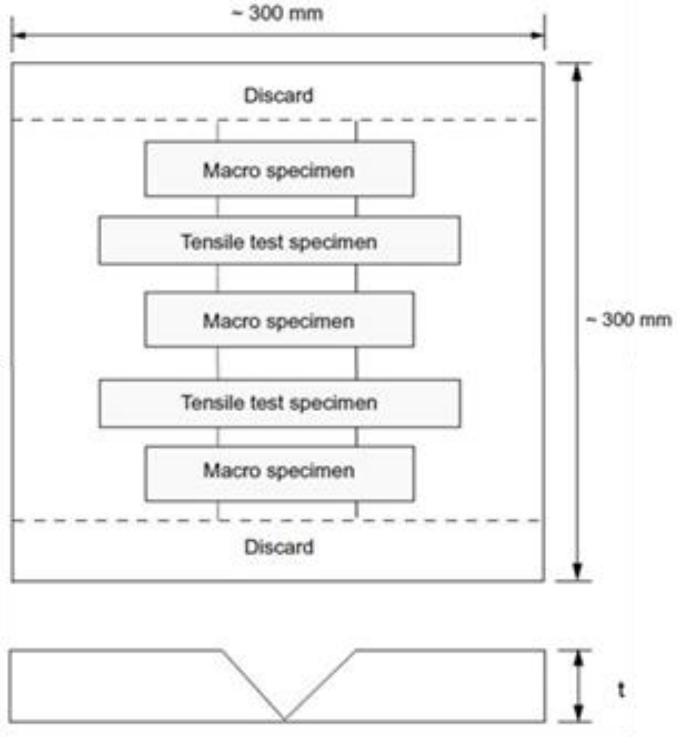
Stress relief temperature (℃)	*KHBsC*1 and *KHBsC*2		*KAlBC*3 and *KAlBC*4	
	Hours per 25 mm thickness	Maximum soaking times (*h*)	Hours per 25 mm thickness	Maximum soaking times (*h*)
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4(1)	1/2(1)	1/2(2)	2(2)
600	—	—	1/4(2)	1(2)

Note:

(1) 550 ℃ only applicable for *KHBsC*2.

(2) 550 ℃ and 600 ℃ only applicable for *KAlBC*4.

Fig. K7.4 Test Sample for Butt Welding Test (*mm*)



Note: Joint preparation and fit-up as detailed in the preliminary welding procedure specification

Table K7.10 Tensile Strength for Butt Welding Test

Grade	Tensile strength (N/mm^2)
*KHBsC*1	370 min.
*KHBsC*2	410 min.
*KAlBC*3	500 min.
*KAlBC*4	550 min.

Fig. K7.5 Test Piece for Mold Cavity Welding (*mm*)

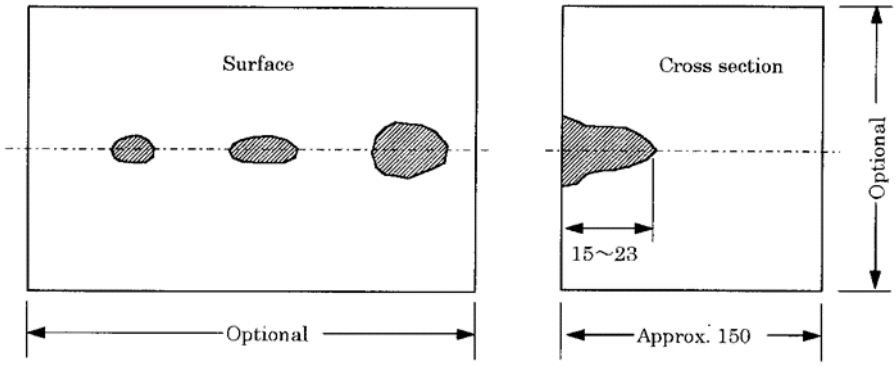


Table K7.11 Approval Range of Base Metal

Grade of the test sample	Approval range
*KHBsC*1	*KHBsC*1
*KHBsC*2	*KHBsC*1, *KHBsC*2
*KAlBC*3	*KAlBC*3
*KAlBC*4	*KAlBC*4

Table K7.12 Approval Range of Thickness

Thickness of the test sample, t (*mm*)	Approval range
$30 \leq t$	≥ 3 *mm*

Chapter 8 ALUMINIUM ALLOYS

8.1 Aluminium Alloy Plates and Extruded Shapes

8.1.1 Application

1 The requirements in this section are to apply to the plates and extruded shapes made of aluminium alloys (hereinafter referred to as "aluminium alloys" in this section.) intended to be used for tanks of liquefied gas carriers or ships using low-flashpoint fuels, and for hull structures.

2 Aluminium alloys having characteristics differing from those specified in **8.1** are to comply with the requirements in **1.1.1-3**.

8.1.2 Kinds

The aluminium alloys are classified as specified in **Table K8.1**.

Table K8.1 Kind of Aluminium Alloys

Products	Material grade
Rolled Products	5083*P*
	5086*P*
	5383*P*
	5059*P*
	5754*P*
	5456*P*
	6061*P*
Extruded Shapes	5083*S*
	5383*S*
	5059*S*
	5086*S*
	6005*AS*
	6061*S*
	6082*S*

8.1.3 Chemical Composition

The chemical composition of aluminium alloys is to comply with the requirements given in **Table K8.2**.

8.1.4 Heat Treatment

The heat treatment (hereinafter referred to as "temper condition") of aluminium alloys is subject to in **Table K8.3**.

8.1.5 Mechanical Properties*

1 The mechanical properties of aluminium alloys are to comply with the requirements given in **Table K8.3**.

2 Where deemed necessary by the Society, other tests may be required in addition to the specified tests according to their application.

8.1.6 Selection of Test Samples

1 For test sample for rolled products, one test specimen is to be taken out of each one lot, except where specially approved by the Society. One lot is made up of rolled products:

(1) of which weight is not exceeding 2,000 *kg*;

(2) of the same alloy and from the same cast;

(3) of the same thickness;

(4) manufactured by the same process; and

(5) having been submitted simultaneously to the same temper condition.

For single plates or coils weighting more than 2,000 *kg* each, one lot is made up of a single plate or coil.

2 For test samples for extruded shapes, except where specially approved by the Society, one test specimen is to be taken out of each one lot that is made up of extruded shape:

(1) not exceeding 1 *ton* where its nominal weight per one *metre* is less than 1 *kg/m*;

(2) not exceeding 2 *tons* where its nominal weight per one *metre* is not less than 1 *kg/m* and not more than 5 *kg/m*; or

(3) not exceeding 3 *tons* where its nominal weight per one *metre* is more than 5*kg/m*

(4) of the same product form and the same dimensions;

(5) manufactured by the same process; and

(6) having been submitted simultaneously to the same temper condition.

3 Test samples are to be taken out of the place at one third of the width from a longitudinal edge of rolled products, or in the range 1/ 3 to 1/2 of the distance from the edge to the centre of the thickest part of extruded products.

Table K8.2 Chemical Composition

	Chemical composition(%)										
Material grade	*Si*	*Fe*	*Cu*	*Mn*	*Mg*	*Cr*	*Zn*	*Ti*	Others(1)		*Al*
									Each	Total	
5083*P* 5083*S*	≤0.40	≤0.40	≤0.10	0.40～1.0	4.0～4.9	0.05～0.25	≤0.25	≤0.15	≤0.05	≤0.15	
5383*P* 5383*S*	≤0.25	≤0.25	≤0.20	0.7～1.0	4.0～5.2	≤0.25	≤0.40		≤0.05 (4)	≤0.15 (6)	
5059*P* 5059*S*	≤0.45	≤0.50	≤0.25	0.6～1.2	5.0～6.0	≤0.25	0.40～0.90	≤0.20	≤0.05 (5)	≤0.15 (6)	
5086*P* 5086*S*	≤0.40	≤0.50	≤0.10	0.20～0.7	3.5～4.5	0.05～0.25	≤0.25	≤0.15			Remainder
5754*P* (2)		≤0.40		≤0.50	2.6～3.6	≤0.30	≤0.20				
5456*P*	≤0.25			0.50～1.0	4.7～5.5	0.05～0.20	≤0.25	≤0.20	≤0.05	≤0.15	
6005*AS*	0.50～0.9	≤0.35	≤0.30	≤0.50	0.40～0.7	≤0.30	≤0.20	≤0.10			
6061*P* (3) 6061*S* (3)	0.40～0.8	≤0.7	0.15～0.40	≤0.15	0.8～1.2	0.04～0.35	≤0.25	≤0.15			
6082*S*	0.7～1.3	≤0.50	≤0.10	0.40～1.0	0.6～1.2	≤0.25	≤0.20	≤0.10			

Notes:

(1) When the existence of the other elements is presumed in the course of routine analysis, further analysis thereof is to be conducted.

(2) $0.10 \leq Mn + Cr \leq 0.60$

(3) $0.12 \leq Mn + Cr \leq 0.50$

(4) $Zr \leq 0.20$

(5) $0.05 \leq Zr \leq 0.25$

(6) The total for other elements does not include Zirconium.

Table K8.3(a) Temper Conditions and Mechanical Properties[1] (Rolled Products)

Material grade	Temper condition[2]	Thickness t (mm)	Tensile test		
			Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%)[3] ($L = 5.65\sqrt{A}$)
5083*P*	*O*	$t \leq 50$	125 min.	275～350	14 min.
		$50 < t \leq 80$	120～195	275～345	14 min.
		$80 < t \leq 100$	110 min.	265 min.	
		$100 < t \leq 120$		260 min.	12 min.
		$120 < t \leq 160$	105 min.	255 min.	
		$160 < t \leq 200$	100 min.	250 min.	10 min.
	*H*111	$t \leq 50$	125 min	275～350	14 min.
	*H*112			275 min.	10 min.
	*H*116		215 min.	305 min.	
	*H*321	$t \leq 50$	215～295	305～385	10 min.
		$50 < t \leq 80$	200～295	285～380	9 min.
5383*P*	*O*	$t \leq 50$	145 min.	290 min.	17 min.
	*H*111				
	*H*116		220 min.	305 min.	10 min.
	*H*321				
5059*P*	*O*	$t \leq 50$	160 min.	330 min.	24 min.
	*H*111				
	*H*116	$t \leq 20$	270 min.	370 min.	10 min.
		$20 < t \leq 50$	260 min.	360 min.	
	*H*321	$t \leq 20$	270 min.	370 min.	
		$20 < t \leq 50$	260 min.	360 min.	
5086*P*	*O*	$t \leq 50$	95 min.	240～305	14 min.
	*H*111				
	*H*112	$t \leq 12.5$	125 min.	250 min.	—
		$12.5 < t \leq 50$	105 min.	240 min.	9 min.
	*H*116	$t \leq 50$	195 min.	275 min.	
5754*P*	*O*	$t \leq 50$	80 min.	190～240	17 min.
	*H*111				
5456*P*	*O*	$t \leq 6.3$	130～205	290～365	—
	*H*116	$t \leq 30$	230 min.	315 min.	10 min.
		$30 < t \leq 40$	215 min.	305 min.	
		$40 < t \leq 50$	200 min.	285 min.	
	*H*321	$t \leq 12.5$	230～315	315～405	—
		$12.5 < t \leq 40$	215～305	305～385	10 min.
		$40 < t \leq 50$	200～295	285～370	
6061*P*	*T*6	$t \leq 6.5$	245 min.	295 min.	—

Table K8.3(b) Temper Conditions and Mechanical Properties[1] (Extruded Shapes)

Material grade	Temper condition[2]	Thickness t (mm)	Tensile test		
			Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%)[3] ($L = 5.65\sqrt{A}$)
5083*S*	*O*	$t \leq 50$	110 min.	270～350	12 min.
		$50 < t \leq 130$	110 min.	275～355	10 min.
	*H*111	$t \leq 50$	165 min.	275 min.	
	*H*112		110 min.	270 min.	
5383*S*	*O*	$t \leq 50$	145 min.	290 min.	17 min.
	*H*111				
	*H*112		190 min.	310 min.	13 min.
5059*S*	*H*112	$t \leq 50$	200 min.	330 min.	10 min.
5086*S*	*O*	$t \leq 50$	95 min.	240～315	12 min.
	*H*111		145 min.	250 min.	10 min.
	*H*112		95 min.	240 min.	
6005*AS*	*T*5	$t \leq 50$	215 min.	260 min.	8 min.
	*T*6	$3 < t \leq 10$			—
		$10 < t \leq 50$	200 min.	250 min.	6 min.
6061*S*	*T*6	$t \leq 50$	240 min.	260 min.	8 min.
6082*S*	*T*5	$t \leq 50$	230 min.	270 min.	6 min.
	*T*6	$3 < t \leq 5$	250 min.	290 min.	—
		$5 < t \leq 50$	260 min.	310 min.	8 min.

Notes:

(1) Aluminium alloy may be subject to any other standards in lieu of the requirements given in this Table where they are approved by the Society.

(2) Indication symbols used in temper condition are as follows. Furthermore, although the mechanical properties of *O* and *H*111 of rolled products are the same, a separate notation is used to indicate that their qualities are different.

O : Annealing

*H*111 : Work hardened

*H*112 : As manufacturing process

*H*116 : Work hardened

*H*321 : Stabilizing treatment after work hardened

*T*5 : Artificial age hardening treatment after elevated temperature working and succeeding cooling

*T*6 : Artificial age hardening treatment after solution treatment

(3) The standards for elongation given in this Table applies to the tensile test using the proportional specimen for aluminium alloys whose thickness is more than 12.5 *mm*. Where test specimens other than the proportional specimens are applied to the tensile test or thickness of aluminium alloys is not more than 12.5 *mm*, the standards for elongation is subject to the discretion of the Society.

8.1.7 Selection of Test Specimens

Tensile test specimens are to be taken according to **(1)** to **(4)** below.

(1) One test specimen is to be taken out of each test sample.

(2) For rolled products, the longitudinal axis of the test specimen is to be taken transversely to the rolling direction. If the width is insufficient to obtain transverse test specimen or in the case of strain hardening alloys, however, the longitudinal direction may be taken parallel to the rolling direction.

(3) For extruded shapes, the longitudinal axis of test specimen is to be taken parallel to the extruded direction.

(4) For thickness up to and including 40 *mm*, the longitudinal axis of the test specimen is to be located at a distance from the surface equal to half of the thickness. For thickness over 40 *mm*, the longitudinal axis of the test specimen is to be located at a distance from one of the surfaces equal to one quarter of the thickness.

8.1.8 Corrosion Resistance Test*

1 For aluminium alloys specified in **Table K8.3(a)** in the *H*116 and *H*321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected, corrosion resistance test is to be carried out.

2 For corrosion resistance test sample, one test specimen is to be taken out of each one lot specified in **8.1.6-1**. In this case, the weight of one lot may exceed 2 *tons*. Test samples are to be taken out of the place at mid part of the plate width.

3 Corrosion resistance test means that metallographic examination or corrosion tests for exfoliation corrosion resistance and intergranular corrosion resistance. Testing method and judging criteria are left to discretion of the Society.

8.1.9 Surface Inspection and Dimensional Tolerance*

1 Surface inspection and verification of dimensions are left to the responsibility of the manufacturer.

2 The underthickness tolerances of rolled products are to comply with the requirements given in **Table K8.4**.

3 Dimensional tolerance except those specified in **-2** above is left to the discretion of the Society.

Table K8.4 Minus Tolerance for a Nominal Thickness (Rolled Products)

Nominal thickness t (*mm*)	Nominal width W (*mm*)		
	$W < 1500$	$1500 \leq W < 2000$	$2000 \leq W \leq 3500$
	Minus tolerance (*mm*)		
$3 \leq t < 4$	0.10	0.15	0.15
$4 \leq t < 8$	0.20	0.20	0.25
$8 \leq t < 12$	0.25	0.25	0.25
$12 \leq t < 20$	0.35	0.40	0.50
$20 \leq t \leq 50$	0.45	0.50	0.65

8.1.10 Quality

1 Aluminium alloys are to be of uniform quality and free from internal and surface harmful defects prejudicial to the use of the concerned material for the intended application.

2 Slight surface imperfections may be removed by smooth grinding or machining as long as the thickness of the materials remains within the tolerances specified in **8.1.9-2**.

8.1.11 Additional Tests before Rejection

1 When the tensile test from the first piece selected fails to meet the requirements, two further tensile tests may be made from the same piece. If both of these additional tests meet all of the requirements, the piece and the remaining pieces from the same lot may be accepted.

2 If one or both of the additional tests referred to above are unsatisfactory, the piece is to be rejected. However, the remaining materials from the same batch may be accepted provided that two of the remaining pieces in the batch selected in the same way, are tested with satisfactory results.

8.1.12 Marking

1 Aluminium alloys, which have satisfied with the required tests, are to be marked with the identification mark in accordance with the requirements in **1.5.1**. In this case, the mark of temper conditions is to be put subsequent to the mark of material grade. For aluminium alloys, which have satisfied with the corrosion resistance tests specified in **8.1.8**, the mark of "-*M*" is to be put subsequent to the mark of the temper condition, for example, "6005*AS-T5-M*".

2 In case of aluminum alloys applied to other standards in accordance with the provision of **Note (1)** of **Table K8.3**, "-*YP*", altered value and "*M*" where proof stress is altered or "-*TS*", altered value and "*M*" where tensile strength is to be put subsequent to the mark specified in **-1**, for example, "6005*AS-T5-M-YP200M*".

8.2 Aluminium Alloy Pipes

8.2.1 Application*

1 The requirements in this section apply to aluminium alloy seamless pipes and aluminium alloy longitudinally welded pipes (hereinafter referred as "aluminium alloy pipes") intended to be used for the cargo and process piping of ships carrying liquefied gases in bulk and for the fuel and process piping of ships using low-flashpoint fuels.

2 Aluminium alloy longitudinally welded pipes are not required to be subjected to approval of manufacturing process. Such pipes are, however, to comply with the following requirements:

(1) Aluminium alloy plates approved in accordance with the requirement of **8.1** are to be used.

(2) Welding procedure tests for aluminium alloy longitudinally welded pipes are to be carried out according to the requirements of **6.5.4**, **Part N of the Rules** in cases where the pipes are used for the cargo and process piping of liquefied gas carriers, or the requirements of **16.3.4**, **Part GF of the Rules** in cases where the pipes are used for the fuel and process piping of ships using low-flashpoint fuels.

(3) Welding work for pipe welds is to be performed by welders who have passed the welder qualification tests related to aluminium alloys specified in **Chapter 5** of **Part M of the Rules**.

(4) Welding consumables approved in accordance with the requirements in **Chapter 6** of **Part M of the Rules** are to be used.

3 Aluminium alloy seamless pipes which comply with standard deemed equivalent by the Society may be treated as pipes that comply with this section. Such pipes are, in principle, to satisfy the following conditions.

(1) Their manufacturers are subjected to manufacturing process approval in accordance with the **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

(2) Their material tests and inspections are carried out in the presence of the Society's surveyor.

4 Aluminium alloy pipes having characteristics differing from those specified in **8.2** are to comply with the requirements in **1.1.1-3**.

8.2.2 Kinds

The aluminium alloy pipes are classified as specified in **Table K8.5**.

Table K8.5 Kind of Aluminium Alloy Pipes

Products	Material grade
Seamless Pipes	5083*TE*/*TD*
Longitudinally Welded Pipes	5083*TWA*

Notes:

(1) *TE* : Extruded pipes

(2) *TD* : Drawn pipes

(3) *TWA* : Longitudinally welded pipes

8.2.3 Chemical Composition

The chemical composition of aluminium alloy pipes is to comply with the requirements given in **Table K8.6**.

8.2.4 Heat Treatment

The heat treatment (hereinafter referred to as "temper condition") of aluminium alloy pipes is subject to in **Table K8.7**.

8.2.5 Mechanical Properties*

1 Aluminium alloy pipes are to comply with the following requirements with respect to their mechanical properties.

(1) Tensile tests

Aluminium alloy seamless pipes are to be subjected to tensile tests and are to comply with the requirements in **Table K8.7(a)** and **Table K8.7(b)**.

Welds of aluminium alloy longitudinally welded pipes are to be subjected to tensile tests and are to comply with the requirements in **Table K8.7(c)**.

(2) Bend tests

Aluminium alloy longitudinally welded pipes are to be subjected to bend tests carried out in accordance with standards deemed appropriate by the Society. There are to be no cracks greater than or equal to 3 *mm* in length on the outer surface of welds of

bended specimens. The radius of the plunger is to be $\frac{10}{3}$ times test specimen thickness.

(3) Hydraulic tests

(a) Aluminium alloy longitudinally welded pipes are to be subjected to hydraulic tests at their place of manufacture at pressures of at least 1.5 times maximum working pressure specified by the manufacturer for at least 10 minutes with satisfactory results.

(b) In cases where each aluminium alloy longitudinally welded pipes is hydraulically tested as a regular procedure during the process of manufacturing at their place, which makes a number of the pipes continually, and the results are forwarded to the Surveyor, the test in the presence of the Surveyor may be dispensed with.

(c) A non-destructive test deemed appropriate by the Society may be substituted for the hydraulic test specified in **(a)**.

2 Where deemed necessary by the Society, other tests may be required in addition to the specified tests according to their application.

8.2.6 Non-destructive Test*

1 Welds of aluminium alloy longitudinally welded pipes are to be subjected to radiographic tests.

2 The criteria of the test specified in **-1** above is to be as deemed appropriate by the Society.

Table K8.6 Chemical Composition

	Chemical composition (%)										
Material grade	*Si*	*Fe*	*Cu*	*Mn*	*Mg*	*Cr*	*Zn*	*Ti*	Others(1)		*Al*
									Each	Total	
5083*TE*/*TD*/*TWA*	≤0.40	≤0.40	≤0.10	0.40～1.0	4.0～4.9	0.05～0.25	≤0.25	≤0.15	≤0.05	≤0.15	Remainder

Note:

(1) When the existence of the other elements is presumed in the course of routine analysis, further analysis thereof is to be conducted.

Table K8.7(a) Temper Conditions and Mechanical Properties(1) (Extruded pipes)

Material grade	Temper condition(2)	Thickness *t* (*mm*)	Tensile test			
			Sectional area (cm^2)	Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%) ($L = 50$)
5083*TE*	*O*	*t*≤25	200 max.	110 min.	275～355	14 min.

Notes:

(1) Aluminium alloy seamless pipes may be subject to any other standards in lieu of the requirements given in this Table where they are approved by the Society.

(2) Indication symbols used in temper condition are as follows.

O : Annealing

Table K8.7(b) Temper Conditions and Mechanical Properties[1] (Drawn pipes)

Material grade	Temper condition[2]	Thickness t (mm)	Tensile test		
			Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation(%) ($L = 50$)
5083*TD*	*O*	$0.6 \leq t \leq 12$	110 min.	275～355	14 min.

Notes:

(1) Aluminium alloy seamless pipes may be subject to any other standards in lieu of the requirements given in this Table where they are approved by the Society.

(2) Indication symbols used in temper condition are as follows.
O : Annealing

Table K8.7(c) Temper Conditions and Mechanical Properties[1] (Longitudinally welded pipes)

Material grade	Temper condition[2]	Thickness t (mm)	Tensile test
			Tensile strength (N/mm^2)
5083*TWA*	*O*	$t \leq 25$	275～350

Notes:

(1) Aluminium alloy longitudinally welded pipes may be subject to any other standards in lieu of the requirements given in this Table where they are approved by the Society.

(2) Indication symbols used in temper condition are as follows.
O : Annealing

8.2.7 Selection of Test Specimen

1 For aluminium alloy seamless pipes, one sampling pipe is to be selected from each grade and each size which has been heat treated at the same time in the same heating furnace. The selection is to be conducted for each lot of 1,000 *kg* or fraction thereof in cases where the weight per one meter is not more than 1 *kg*, each lot of 2,000 *kg* or fraction thereof in cases where the weight per one meter is more than 1 *kg* and not more than 5 *kg*, or each lot of 3,000 *kg* or fraction thereof in cases where the weight per one meter is more than 5 *kg*. One tensile test specimen is to be taken from each of the sampling pipes and the specimen is to comply with the requirements specified in **Table K2.1**.

2 For aluminium alloy longitudinally welded pipes, specimens for tensile, face bend, root bend and side bend tests are to be selected from one test sample made for each 60 *m* or fraction thereof of the weld length.

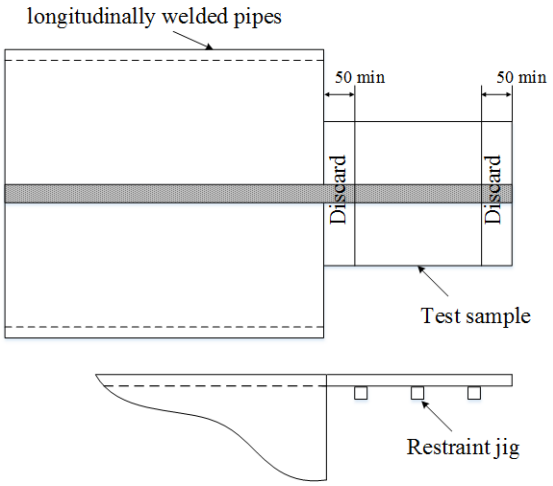
(1) Test sample
Plates having the same material and same thickness as pipes are to be fitted on a pipe end and are to be welded at the same time as the welding of the pipe seam with the plate welded line located on the same line as the pipe seam. At least 50 *mm* of both ends of the plate are to be discarded after the welding. (See **Fig. K8.1**)

(2) Tensile test specimen
One tensile test specimen is to be taken from a test sample and to be of the size and dimensions given in **Table K2.1**.

(3) Bend test specimen
One face bend and root bend test specimen each is to be taken from a test sample and to be of the size and dimensions given in B-1, **Table K2.4**. In cases where pipe thickness is not less than 20 *mm*, two side bend test specimens are to be taken from a test sample and to be of the size and dimensions given in B-2, **Table K2.4**.

3 Radiographic tests for welds of aluminium alloy longitudinally welded pipes are to be carried out per 50 pipes.

Fig. K8.1 Aluminium alloy longitudinally welded pipe test sample



8.2.8 Dimension*

1 Verification of dimension is left to the responsibility of the manufacturer.

2 Dimensional tolerance is left to the discretion of the Society.

8.2.9 Quality

1 Aluminium alloy pipes are to be of uniform quality and free from harmful defects. For aluminium alloy longitudinally welded pipes, the height of reinforcement of the weld is to be not more than that given in **Table K8.15**. In cases where the height of reinforcement of the weld may make the pipe difficult to use, it is to be reduced to an appropriate height.

2 Surface defects may be removed by local grinding. The thickness of the portions where defects have been removed, however, is to remain within the tolerances specified in **8.2.8-2**.

Table K8.15 Allowable height of reinforcement

Thickness (t)	Height
up to 6	2
over 6 up to 15	$\frac{1}{3}t$
over 15 up to 25	5

8.2.10 Additional Tests before Rejection

1 Where the mechanical tests from the first test specimens selected fail to meet the requirements, additional tests may be conducted according to the requirements given in **1.4.4**.

8.2.11 Marking

The name of the manufacturer, material grade, temper condition and size are to be legibly stamped or stenciled onto each pipe prior to shipment. The Society's brand indicating compliance with the requirements is to be stamped in the vicinity of the aforementioned markings. Pipes which cannot be individually stamped or stenciled in accordance with this requirement due to their small size may be bundled together and each bundle is to be properly stamped and marked.

Contents

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part K MATERIALS

K1 GENERAL

K1.1 General

K1.1.1 Application

1 Stiffeners for boiler used the rolled steel bar are to comply with the **Annex K1.1.1-1** "GUIDANCE RELATING TO ROLLED STEEL BAR FOR BOILERS".

2 Seamless shells of boilers made of steel forgings are to comply with the **Annex K1.1.1-2** "GUIDANCE FOR SEAMLESS FORGED STEEL DRUMS" of this Part.

3 High manganese austenitic steels used for tanks and hull structures adjacent to tanks of liquefied gas carriers or ships using low-flashpoint fuels are to comply with **Annex K1.1.1-3 "Guidance relating to High Manganese Austenitic Steels"** of this part.

4 In the application of **1.1.1-3**, **Part K of the Rules for the Survey and Construction of Steel Ships**, those pipes made from metallic materials other than steels (for example titanium pipes, including primary material of pipes) are to be accordance with **Chapter 2**, **Part 1 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

K1.2 Manufacture and Approval of Materials

K1.2.1 Manufacture of Materials

For primary materials of steel pipes specified in **Chapter 4**, **Part K of the Rules**, primary materials manufactured by the works specified in **(1)** to **(3)** can be used, in addition to the works specified in **1.2.1-1** and **-2**, **Part K of the Rules**:

(1) For primary materials of steel tubes for boilers and heat exchangers specified in **4.1**, **Part K of the Rules**, steel pipes for pressure piping in **4.2**, **Part K of the Rules** and headers specified in **4.4**, **Part K of the Rules**, the works having the approved manufacturing process of rolled steels for hull, rolled steel plates for boilers and rolled steel plates for pressure vessels specified in **Chapter 3**, **Part K of the Rules**.

(2) For primary materials of stainless steel pipes specified in **4.3**, **Part K of the Rules**, the works having the approved manufacturing process of rolled stainless steels specified in **3.5**, **Part K of the Rules**.

(3) For primary materials of steel pipes for low temperature service specified in **4.5**, **Part K of the Rules**, the works having the approved manufacturing process of rolled steels for low temperature service specified in **3.4**, **Part K of the Rules**.

K1.4 Testing and Inspection for Materials

K1.4.1 Execution of Testing and Inspection

1 To implement the surveys specified in **1.4.1-1, Part K of the Rules**, in lieu of traditional ordinary surveys where the Surveyor is in attendance, the Society may approve survey methods which it considers to be able to obtain information equivalent to that obtained through traditional ordinary surveys.

2 The wording "Where the quality of materials and the quality control system of manufacturer are deemed appropriate by the Society" in **1.4.1-5, Part K of the Rules**, means that the quality of materials and the quality control system of manufacturer are approved by the Society according to **Rules for Approval of Manufacturers and Service Suppliers** or deemed equivalent thereto.

K1.4.2 Standard for Testing and Inspection

Samples for the check analyses required by **1.4.2-2**, **Part K of the Rules** are to be taken from specimens for mechanical tests or from the portion of the body adjacent to the part where such specimens had been taken.

K1.5 Marking and Test Certificate

K1.5.2 Test Certificate

1 "It is deemed appropriate by the Society" specified in **1.5.2-1** and **1.5.2-3, Part K of the Rules**, means that the quality of materials and the quality control system of manufacturer are approved by the Society according to **Rules for Approval of Manufacturers and Service Suppliers** or deemed equivalent thereto.

2 Where the quality of materials and the quality control system of manufacturer are approved by the Society according to **Rules for Approval of Manufacturers and Service Suppliers**, the manufacturer is to enter the following statement to show that effect on the test certificate specified in **1.5.2-1, Part K of the Rules**.

(Example)

This Certificate is issued by the manufacturer under the arrangement authorized by Nippon kaiji Kyokai in the approved quality system (Approval Number ..CLQA. ..) in accordance with Rules for Approval of Manufacturers.

3 In principle, chemical composition and mechanical test results for materials are to be measured until the next digit of the least significant digit of required significant figures. Then, such measurements are to be rounded off in accordance with Rule A of *ISO* 31-0 Annex B or Rule A of *JIS Z* 8401, and to be indicated in the same number of significant figures as the specified value. In cases where other methods are used, they are subject to preliminary Society approval.

K2 TEST SPECIMENS AND MECHANICAL TESTING PROCEDURES

K2.1 General

K2.1.1 Application

In case where test specimens or test procedures specified in the requirements of *ISO* are adopted, the approvals by the Society may be dispensed with, notwithstanding the requirement in **2.1.1-2, Part K of the Rules**.

K2.2 Test Specimens

K2.2.1 Preparation of Test Specimens

1 "Where otherwise specified or agreed with the Surveyor" referred in **2.2.1-1, Part K of the Rules** means only where manufacturing process of the material has been already approved according to the requirements of **Part 1 of Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use** by the Society.

2 In case specified in above **-1**, if test samples are detached from the materials before being stamped by the Surveyor, adequate means e.g. stamping any identifiable marks are to be taken in order to collate test samples with the materials.

K2.2.2 Tensile Test Specimens

1 The gauge length of the *U*14*B* tensile test specimens specified in **Table K2.1, Part K of the Rules** may be round off as given in **Table K2.2.2-1** in accordance with **Note (2)** in **Table K2.1, Part K of the Rules**:

Table K2.2.2-1 Rounding of Gauge Length

Thickness of test specimen t (*mm*)	Width of test specimen W (*mm*)	Gauge length L (*mm*)
$3 \leq t \leq 4$	25	50
$4 < t \leq 5$		60
$5 < t \leq 7$		70
$7 < t \leq 10$		80
$10 < t \leq 15$		100
$15 < t \leq 20$		120
$20 < t \leq 30$		140
$30 < t \leq 40$		160

2 In **2.2.2-2, Part K of the Rules**, corrections for elongation are to be in accordance with the following:

(1) Aluminium alloy specified in **Part K of the Rules** are to be considered as Material I in **Table K2.2, Part K of the Rules**.

(2) Corrections for elongation may not be required in the case of copper alloy.

(3) Where test specimens differing from those specified in **Table K2.1, Part K of the Rules** are used, the standard value of elongation are to be corrected according to the following formula :

$n = E/F$

E : Elongation equivalent corresponding to standard to where the proportion specimens (L =5.65$\sqrt{A}$) specified in **Table K2.1, Part K of the Rules** are used

n : Elongation where optional test specimens are used

F : Coefficient of correction for elongation are shown in **Table K2.2.2-2** below according to the gauge length

(4) In case **(3)** above, the elongation (n) is to be recorded in the certificates of the material test.

(5) Diagrams for conversion of elongation between the test specimens having gauge length L=200 *mm* or L=50 *mm* and the proportional specimens are as shown in **Fig. K2.2.2-1** and **Fig. K2.2.2-2**. However, in case the of Material III, the diagram for

conversion of elongation is to be according to *ISO* 2566-2:1984.

Table K2.2.2-2 Values of F

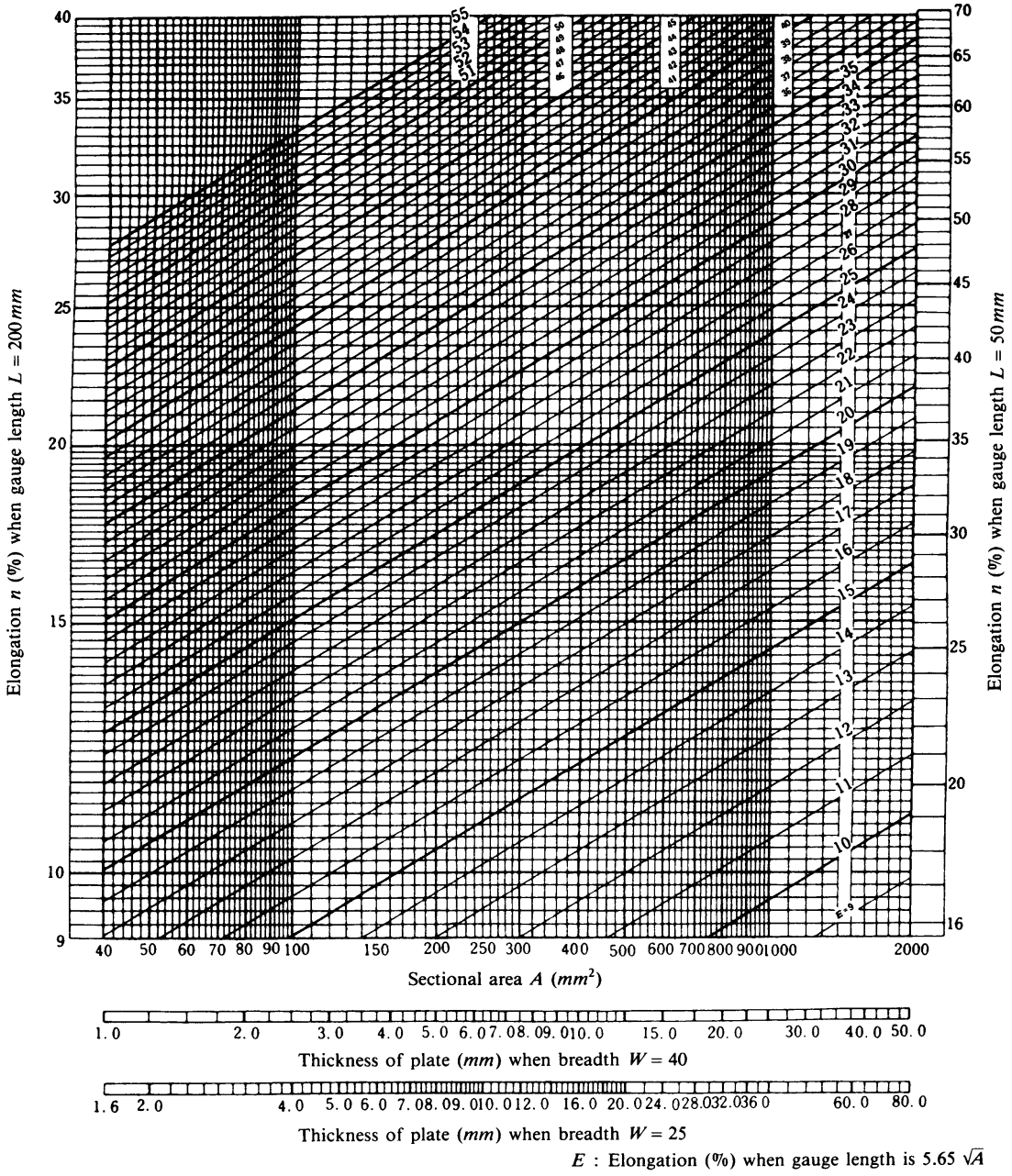
Gauge length	Material I	Material II	Material III
$L = 8D$	1.21	1.29	1.06
$L = 8\sqrt{A}$	1.15	1.21	1.04
$L = 4D$	0.91	0.88	0.97
$L = 4\sqrt{A}$	0.87	0.82	0.95

Notes:

D : Diameter of the test specimen

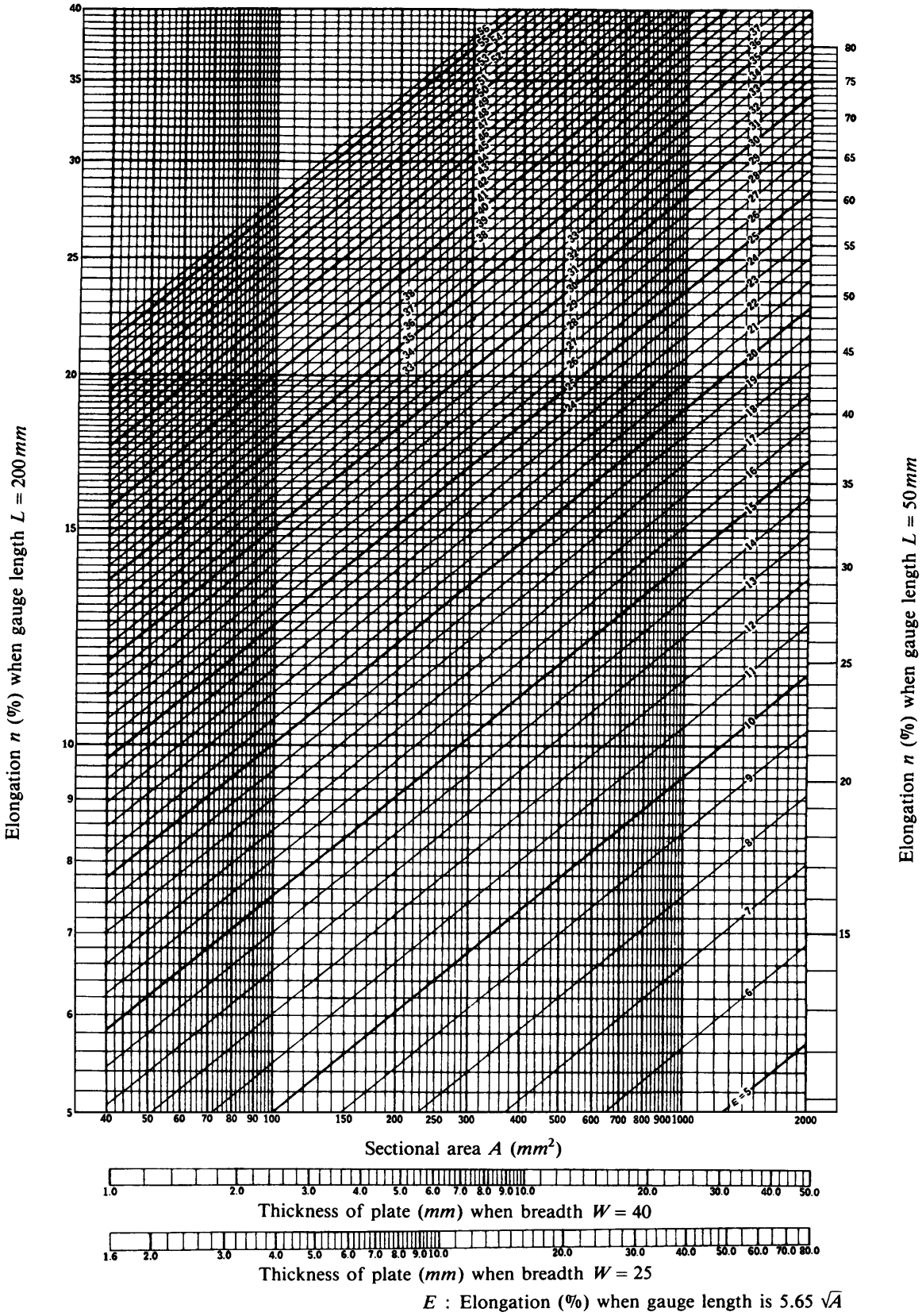
A : Sectional area of the test specimen

Fig. K2.2.2-1. Diagram for Conversion of Elongation between Gauge Lengths $L = 5.65\sqrt{A}$ and $L = 200$ *mm* or 50 *mm*



(1) In the case of Material I

Fig. K2.2.2-2 Diagram for Conversion of Elongation between Gauge Lengths $L = 5.65\sqrt{A}$ and $L = 200\ mm$ or $50\ mm$



(2) In the case of Material II

K3 ROLLED STEELS

K3.1 Rolled Steels for Hull

K3.1.1 Application

1 The wording "to be as deemed appropriate by the Society" in **3.1.1-3, Part K of the Rules** means to comply with the following with respect to the provisions of **3.1, Part K of the Rules**.

(1) Approval of Manufacturing Process

Manufacturers of steel coils and manufacturers of steel plates from steel coils are to obtain the approval of the Society in advance with regard to the manufacturing process of such materials. However, manufacturers of steel plates from steel coils which are subject to the quality control management of the manufacturer of steel coils are to be according to the discretion of the Society.

(2) Testing and Inspection

(a) Manufacturers of steel coils are to have their steel coils inspected in the presence of Society Surveyors and are to issue a test certificate certifying the results of such inspections.

(b) Manufacturers of steel plates from steel coils are to carry out tensile tests for each coil except *KA* and *KB*. On such occasions, in cases where one coiled material is not greater in weight than 50 *tons*, one test sample is to be cut from the coiled material; however, in cases where one coiled material is greater in weight than 50 *tons* then one test sample each is to be cut from beginning and end of the coiled material.

(3) Test Certificates

Test certificates are to comply with the following in addition to requirements given in **1.5.2, Part K of the Rules**:

(a) Manufacturers of steel coils are to indicate on test certificates that the steel coils need to be uncoiled and cut by a manufacturer approved by the Society.

(b) Manufacturers of steel plates from steel coils are to indicate on test certificates that the steel plates are cut and made from steel coils prepared by a manufacturer approved by the Society. In addition, test certificates of the steel coils are to be attached to the test certificates of the steel plates made from such steel coils.

K3.1.3 Deoxidation Practice and Chemical Composition

The term of "thermo-mechanical controlled processing" is defined in **K3.1.4**.

K3.1.4 Heat Treatment

The kind and definition of heat treatment referred to in Remarks **(3)** in **Table K3.3, Part K of the Rules** are as follows: (Refer to **Figs. K3.1.4-1** and **K3.1.4-2**)

(1) As Rolled (*AR*) involves steel being air cooled as it is rolled with no further heat treatment. The rolling and finishing temperature are typically in the austenite recrystallization region and above the normalizing temperature.

(2) Normalizing (*N*) involves heating rolled steel above the critical temperature, *Ac*3, and in the lower end of the austenite recrystallization region for a specific period of time, followed by air cooling.

(3) Quenching and Tempering (*QT*) involves heating rolled steel in the austenite recrystallization region for a specific period of time, followed by rapid cooling, and shortly thereafter involves heating rolled steel under the critical temperature, *Ac*1, followed by air cooling. The wording "direct quenching after rolling" in **Fig. K3.1.4-1** means that the quenching is rapidly carried out.

(4) Controlled Rolling (*CR*) (Normalizing Rolling (*NR*)) is one of heat treatment methods in which heating temperature, rolling temperature and rolling reduction are controlled to fine steel structure and improve mechanical properties. The rollings are generally finished in low austenite temperature range between normalizing temperature and *Ar*3 transition temperature followed by air cooling.

(5) Thermo-Mechanical Controlled Processing (*TMCP*) is a kind of heat treatment being based on the strict control of both the steel temperature and rolling reduction and is divided into the following two categories.

(a) Thermo-Mechanical Rolling: *TMR*

A kind of controlled rolling, generally a high proportion of rolling reduction is carried out close to or below the *Ar*3

transition temperature. The rolling towards the lower end of the austenite-ferrite intercritical duplex phase region may be included into *TMR*.

(b) Accelerated Cooling Processing: *AcC*

After completion of thermo-mechanical rolling, homogeneous cooling was made with adequate cooling speed faster than air cooling in the range of *Ar*3 transition temperature or below.

Fig. K3.1.4-1 Kind of Heat Treatment

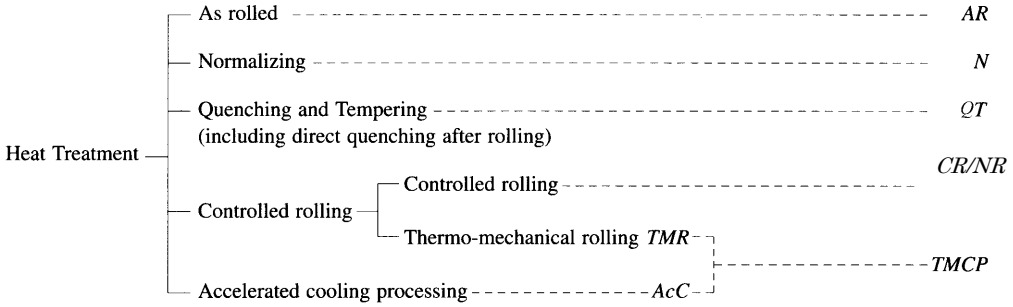
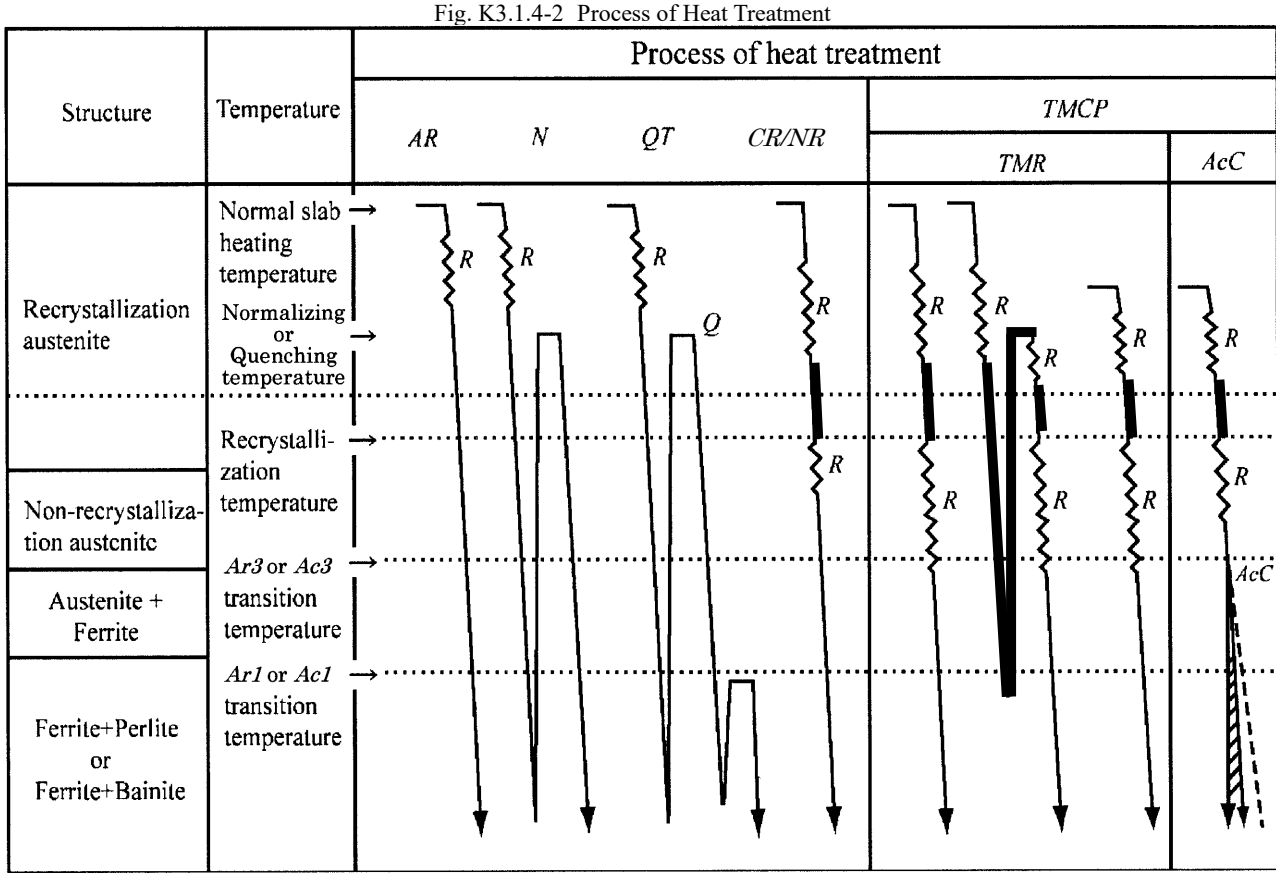


Fig. K3.1.4-2 Process of Heat Treatment



Note:

▬: Delays to allow cooling before finishing rolling process

R : Reduction

Q : Quenching

K3.1.6 Selection of Test Samples

1 The terms of "may be permitted subject to the special approval of the Society" specified in **Table K3.6 Note (1)**, **Part K of the Rules** is to be dealt with as follows:

(1) Impact tests for *KA*32 and *KA*36 may be dispensed with as far as periodical examinations are carried out in the presence of the Society's Surveyor, except otherwise specially specified on the approval of the manufacturing process.

(2) "Periodical" in **(1)** above means once a month. In this case, impact tests specified are carried out for a set (3 pieces) of specimens and the results of which are to be confirmed in compliance with the specifications.

(3) In case where the result does not comply with the specifications, retests for the lot of steel material to which the failed specimens are belonging may be carried out in accordance with the requirements in **3.1.10, Part K of the Rules**.

(4) Where the result of the retest does not comply with the requirements, impact tests provided in **Table K3.6, Part K of the Rules** are to be carried out for all the steels manufactured thereafter. Where the test results during 6 months are confirmed as being satisfactory, the procedure specified in **(2)** above may be applied again.

(5) Every manufacturer is to submit the annual report compiling the results of the impact tests to the Society.

K3.1.7 Selection of Test Specimens

When the capacity of the available testing machine is insufficient to allow the use of flat test specimens taken from samples, testing may be carried out using specimens of reduced thickness in the thickness direction of the product in cases where approved by the Society.

K3.1.8 Verification of Dimensions

The treatment of the requirements in **3.1.8, Part K of the Rules** is to be as follows:

(1) In the application of **3.1.8-2, Part K of the Rules**, thickness measuring locations are to be as follows:

(a) Flat bars with widths of 600 *mm* or greater and plates

i) At least two lines among Line 1, Line 2 or Line 3, as shown in **Fig. K3.1.8-1**, are to be selected for the thickness measurements and at least three points on each selected line, as shown in **Fig. K3.1.8-1,** are to be selected for thickness measurement. If more than three points are taken on each line the number of points is to be equal on each line.

ii) For automated methods, the measuring points at sides are to be located not less than 10 *mm* but not greater than 300 *mm* from the transverse or longitudinal edges of the product.

iii) For manual methods, the measuring points at sides are to be located not less than 10 *mm* but not greater than 100 *mm* from the transverse or longitudinal edges of the product.

iv) The above **i)** to **iii)** may be applied to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Examples of the original measurements relative to later cut products are shown in **Fig. K3.1.8-2**.

(b) Flat bars with widths of greater than 150 *mm* and less than 600 *mm*

i) Random locations whose distance from a longitudinal edge is to be at least 10 *mm*. However, local surface depressions resulting from imperfections (such as an affected part of shearing) and ground areas resulting from the elimination of defects may be disregarded.

(c) Other

i) As deemed appropriate by the Society.

(2) The average thickness of plates specified in **3.1.8-2, Part K of the Rules** is defined as the arithmetic mean of the measurements made in accordance with the requirements of **(1)(a)** above.

(3) "When deemed appropriate by the Society" specified in **3.1.8-5**, **Part K of the Rules**, means that plates comply with requirements for Class C of *ISO* 7452:2013, as amended, or national/international standards as deemed appropriate by the Society. In such cases, it is required that the steel mill demonstrate to the satisfaction of the Society that the number of measurements and measurement distribution is appropriate to establish that the mother plates produced are at or above the specified nominal thickness.

Fig. K3.1.8-1 Locations of Thickness Measuring Points

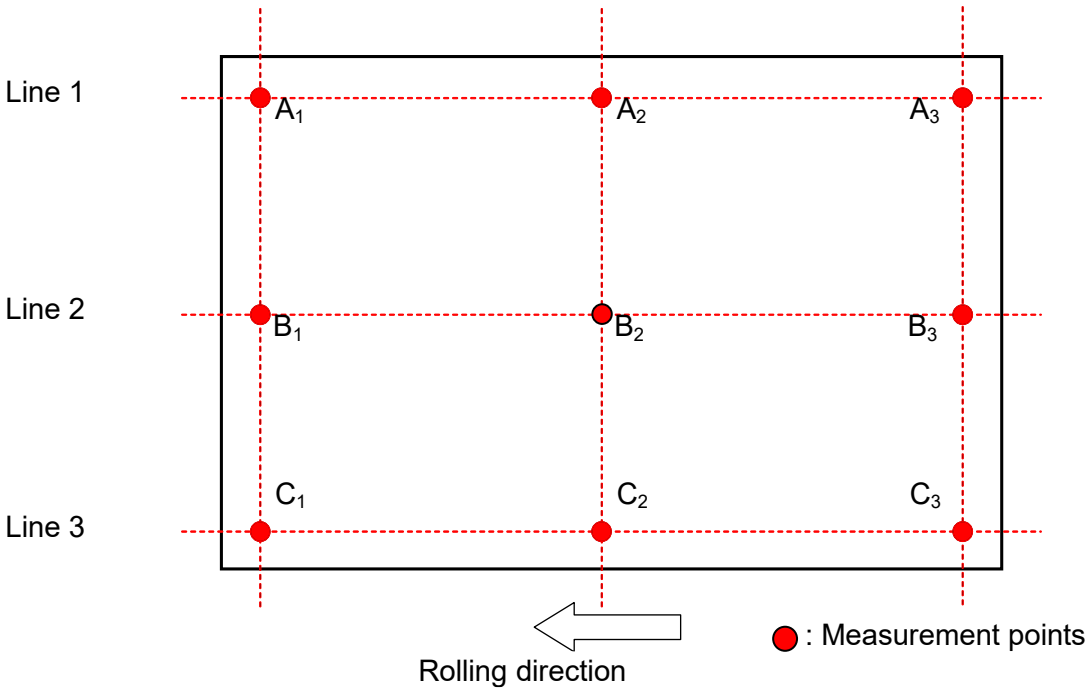
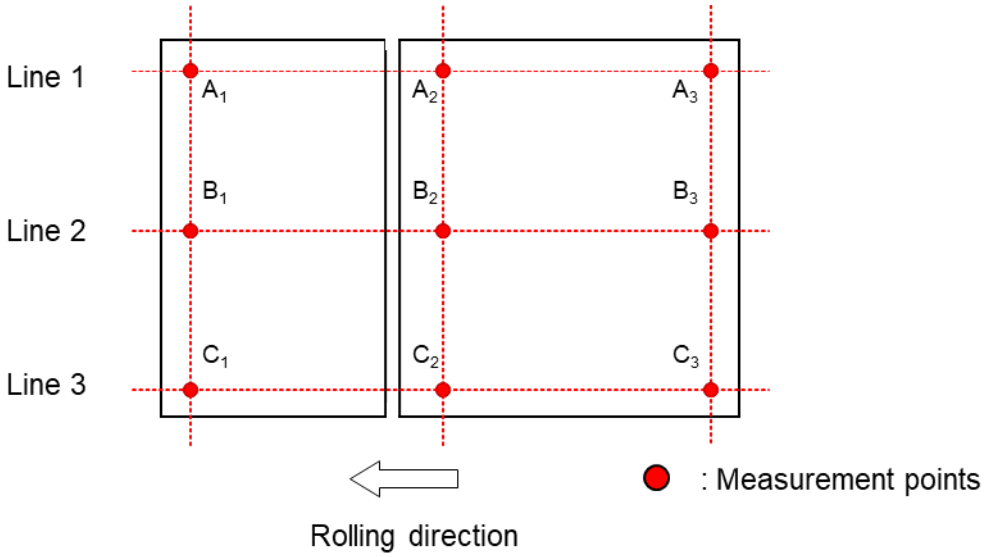
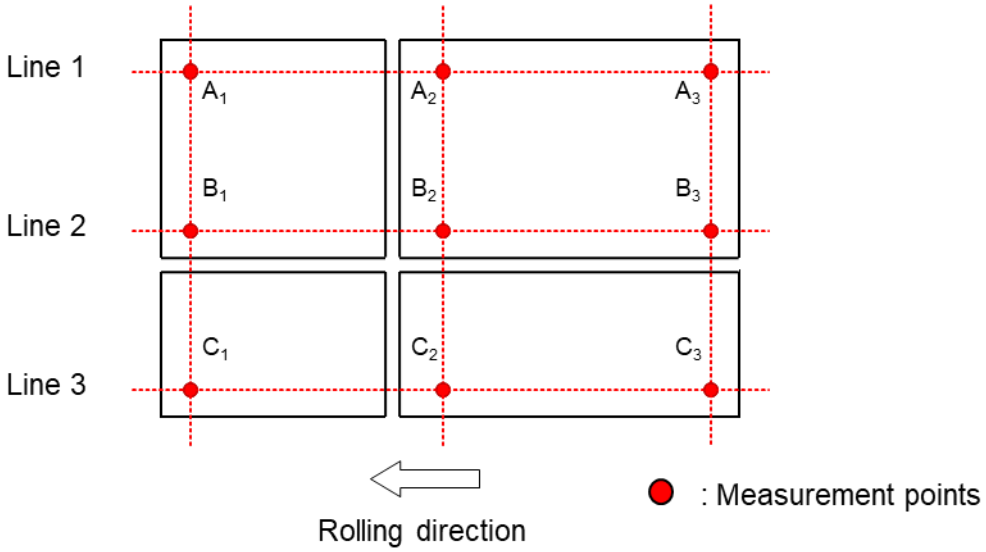
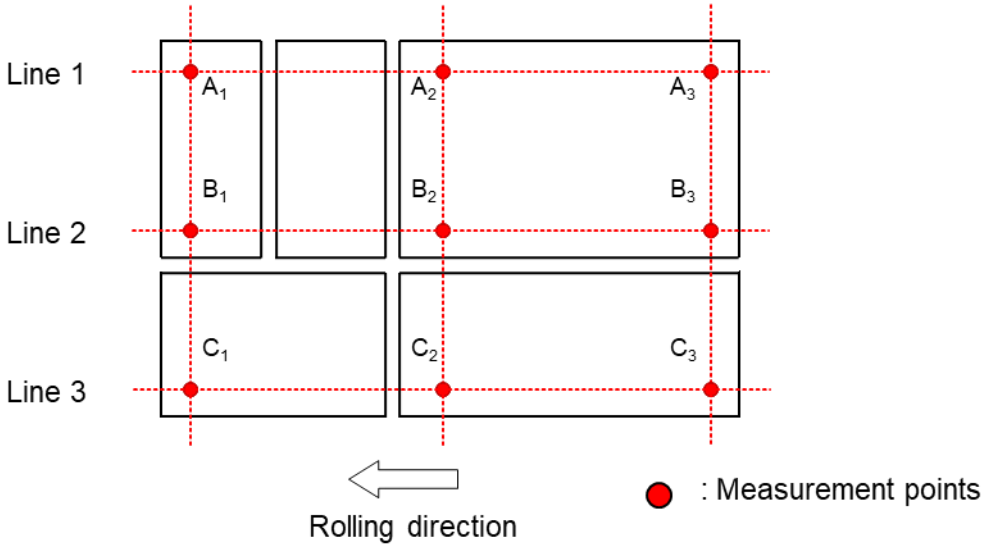


Fig. K3.1.8-2 Locations of Thickness Measuring Points for the Cut Steel Products







K3.1.9 Quality and Repair of Defects

1 The wording "standards deemed appropriate by the Society" specified in **3.1.9-1(3), Part K of the Rules** means the standards specified in *EN* 10163 Part 1, Part 2, Part 3 or the equivalent thereto.

2 Surface inspection standards for pitting and scab in imperfections are, in principle, to be in accordance with Japan Shipbuilding Quality Standards (*JSQS*).

3 Affected areas specified in **3.1.9-1(5), Part K of the Rules** are to conform to standards applied by the manufacturer.

4 In the case specified in **3.1.9-2(2), Part K of the Rules**, the manufacturer is to present records of repairs and subsequent inspections which are traceable to each repair to the surveyor upon request.

5 Before repair works prescribed in **3.1.9-2(2), Part K of the Rules**, the following documents are to be submitted to the Society for approval.

(1) Specifications of repairing procedure which state about kind of surface defects, the way of chipping, grinding and welding, etc.

(2) Reports on results of tensile test, bend test, impact test, macro-structure inspection and hardness test on test samples repaired according to the procedure specified in above **(1)**

K3.2 Rolled Steel Plates for Boilers

K3.2.4 Heat Treatment

Normalizing of steel plates specified in **3.2.4-2, Part K of the Rules** may be carried out by the purchasers at their own factories. In this case, test specimen are to be taken in accordance with the requirements of **K3.2.6**.

K3.2.6 Selection of Test Samples

1 Where the purchasers carry out normalizing specified in **3.2.4-2, Part K of the Rules** at their factories, test samples are to comply with the following requirements:

(1) The manufacturer is to carry out normalizing of the test sample in accordance with purchaser instructions regarding heat treatment conditions and frequency. Where no instructions have been given by the purchaser, the manufacturer may carry out normalizing as considered preferable. In this case, the manufacturer is to inform the purchaser the conditions of normalizing which had been carried out.

(2) The mechanical properties obtained by the test specimens specified in **(1)** above are to comply with the provisions in **Table K3.10, Part K of the Rules**.

2 The marking related to the heat treatment of the steel plates specified in **-1** is to be "*TN*" in cases where normalizing is carried out for test specimens only.

K3.2.7 Selection of Test Specimens

When the capacity of the available testing machine is insufficient to allow the use of flat test specimens taken from samples, testing may be carried out using specimens of reduced thickness in the thickness direction of the product in cases where approved by the Society.

K3.2.8 Tolerance for Thickness

Thickness is to be measured at random locations whose distance from a longitudinal edge is to be at least 10 *mm*. However, local surface depressions resulting from imperfections (such as an affected part of shearing) and ground areas resulting from the elimination of defects may be disregarded.

K3.2.11 Marking for Accepted Steels

The wording "some other appropriate method" in **3.2.11-1, Part K of the Rules** means stenciling, etc.

K3.3 Rolled Steel Plates for Pressure Vessels

K3.3.4 Heat Treatment

Normalizing or quenching and tempering of the steel plates specified in **3.3.4-4, Part K of the Rules** may be carried out by the purchasers at their own factories. In this case, test samples are to be taken in accordance with the requirements of **K3.3.6**.

K3.3.6 Selection of Test Samples

1 Where the purchasers carry out normalizing or quenching and tempering specified in **3.3.4-4, Part K of the Rules** at their

factories, test samples are to comply with the following requirements:

(1) The manufacturer is to carry out normalizing or quenching and tempering of the test sample in accordance with purchaser instructions regarding heat treatment conditions and frequency. Where no instructions have been given by the purchaser, the manufacturer may carry out normalizing or quenching and tempering as considered preferable. In this case, the manufacturer is to inform the purchaser the conditions of normalizing or quenching and tempering which had been carried out.

(2) The mechanical properties obtained by the test specimens specified in **(1)** above are to comply with the requirements specified in **Table K3.13, Part K of the Rules**.

2 The marking related to the heat treatments of the steel plates specified in **-1** is to either be "*TN*" in cases where normalizing is carried out for test samples only or "*TQ*" in cases where quenching and tempering are carried out for test samples only.

K3.3.7 Selection of Test Specimens

1 In **3.3.7-2(2), Part K of the Rules**, "deemed necessary by the Society" means the case where the steel plates are used for spherical tanks or end plates, etc. of cylindrical tanks to contain cold liquefied gas at normal temperature. In such a case, the specified values of the impact tests are to be in accordance with **Table K3.13, Part K of the Rules**.

2 When the capacity of the available testing machine is insufficient to allow the use of flat test specimens taken from samples, testing may be carried out using specimens of reduced thickness in the thickness direction of the product in cases where approved by the Society.

K3.3.8 Surface Inspection and Verification of Dimensions

Thickness is to be measured at random locations whose distance from a longitudinal edge is to be at least 10 *mm*. However, local surface depressions resulting from imperfections (such as an affected part of shearing) and ground areas resulting from the elimination of defects may be disregarded.

K3.3.11 Marking

The wording "some other appropriate method" in **3.3.11-1, Part K of the Rules** means stenciling, etc.

K3.4 Rolled Steels for Low Temperature Service

K3.4.8 Surface Inspection and Verification of Dimensions

Thickness is to be measured at random locations whose distance from a longitudinal edge is to be at least 10 *mm*. However, local surface depressions resulting from imperfections (such as an affected part of shearing) and ground areas resulting from the elimination of defects may be disregarded.

K3.5 Rolled Stainless Steels

K3.5.1 Application

In **3.5.1-2, Part K of the Rules**, "deemed necessary by the Society" refers to the following **(1)** and **(2)** cases.

(1) When steel bars complying with following **(a)** to **(e)** are used for propeller shafts and so on.

(a) Forging ratio is not to be less than 6.

(b) Heat treatment is to comply with **6.2.5, Part K of the Rules**.

(c) Selection of test specimens is to comply with **6.2.8, Part K of the Rules** in addition to the regulations **3.5.7** and **3.5.8, Part K of the Rules**. Mechanical tests are to comply with **6.2.7**, **Part K of the Rules**.

(d) Surface inspection and dimension inspection are to be subjected in accordance with **6.2.9** and **6.2.10, Part K of the Rules**.

(e) Repair of defects is to comply with **6.1.11**, **Part K of the Rules**.

(2) When used in equipment with specifications equivalent to or exceeding those originally required when using steel in consideration of the conditions of use.

K3.5.5 Mechanical Properties

Application of provisory requirement specified in **3.5.5-1, Part K of the Rules** is to be limited to the case where minimum proof stress of the stainless steel plates of which the specified minimum proof stress is 315 N/mm^2 or less is specified at a greater value. In this case, the specified minimum proof stress is to be accordance with **Table K3.5.5-1** as a standard.

Table K3.5.5-1 Specified Minimum Proof Stress

Grade	Proof stress (N/mm^2)
-235M	235 min.
-275M	275 min.
-315M	315 min.

K3.5.9 Surface Inspection and Verification of Dimensions

Thickness is to be measured at random locations whose distance from a longitudinal edge is to be at least 10 *mm*. However, local surface depressions resulting from imperfections (such as an affected part of shearing) and ground areas resulting from the elimination of defects may be disregarded.

K3.6 Round Bars for Chains

K3.6.6 Mechanical Properties

1 Where applying the **Notes (5)** of **Table K3.22, Part K of the Rules**, manufacturer is to submit the documents indicating that manufacturer and purchaser agreed to conduct impact test in accordance with **Notes (5)** of **Table K3.22, Part K of the Rules**, to the Society for approval.

2 Where applying the **Notes (3)** of **Table K5.4, Part K of the Rules** and **Table K6.8, Part K of the Rules**, manufacturer is to submit the documents in accordance with the requirement of **-1** above.

K3.6.8 Selection of Test Specimens

1 The tensile test specimen whose diameter has 20 *mm* specified in **3.6.8-2, Part K of the Rules**, means the proportional test specimen of *U*14*A* tensile test specimen specified in **Chapter 2, Part K of the Rules**.

2 If the loading capacity of the testing machine is not sufficient, the tensile test specimen may be the *U*14*A* tensile specimen instead of 20 *mm* tensile test specimen specified in **-1** above.

K3.6.9 Hydrogen Embrittlement Test

Where hydrogen embrittlement test specimens are *U*14*A* tensile test specimens instead of 20 *mm* tensile specimens in accordance with **K3.6.8-2**, hydrogen embrittlement test is to be carried out in accordance with the following procedure and the test result is to be complied with the requirement of **3.6.9-2, Part K of the Rules**.

(1) One specimen is to be tested within max. 1.5 *hours* after machining or the specimen may be cooled to -60℃ immediately after machining and kept at that temperature for a period of max. 5 *days*.

(2) The other specimen is to be tested after baking at 250℃ for 2 *hours*.

(3) A slow strain rate as far as practicable (strain rate less than 0.0003 s^{-1}) is used during the entire test, and tensile strength, elongation and reduction of area are to be measured.

K3.6.10 Surface Inspection, Non-destructive Test, Verification of Dimensions and Repair of Defects

1 The wording "harmful defects" specified in **3.6.10-1** to **-3, Part K of the Rules** means the depth of the defect in the surface exceeds 1% of the nominal diameter of the bar material. In cases where the depth of the defect in the surface does not exceed 1% of the nominal diameter of the bar material, the defect may be removed by the grinding or another suitable method. In such cases, the bar material is to be repaired smoothly in the longitudinal direction and the dimension tolerance for the bar material is also to comply with the requirements in **3.6.10-7, Part K of the Rules** after completion of the repair work.

2 The wording "standards deemed appropriate by the Society" specified in **3.6.10-2, Part K of the Rules** means the following standards or the equivalent thereto.

(1) Magnetic particle test: *ASTM E*1444 or *ISO* 9934

(2) Magnetic leakage flux test: *JIS Z*2319

(3) Eddy current test: *ISO* 15549

3 In applying the requirements in **3.6.10-4, Part K of the Rules**, phased array ultrasonic tests may be accepted in cases where approved by the Society.

4 The wording **"**to be appropriately qualified in performing non-destructive tests" specified in **3.6.10-8, Part K of the Rules**, means those qualified *Level* II or higher in accordance with *ISO* 9712, *ACCP* or an equivalent qualification deemed appropriate by the

Society.

5 Non-destructive test operator qualification according to an employer or responsible agency qualification scheme based on SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level III is *ASNT Level* III, *ISO* 9712 *Level* III or *ACCP* Professional *Level* III and certified in the applicable method. In such cases, notwithstanding the requirements in **-4** above, the wording "to be appropriately qualified in performing non-destructive tests" specified in **3.6.10-8, Part K of the Rules** means those qualified Level II or higher.

K3.6.12 Marking

The wording "some other appropriate method" in **3.6.12-2, Part K of the Rules** means stenciling, etc.

K3.6.13 Submission of Data

1 The results of the microscopic examinations for non-metallic inclusions specified in **3.6.13-1(1), Part K of the Rules** are to conform to national/international standards.

2 The macro etched examination specified in **3.6.13-1(2), Part K of the Rules** is to conform to *ASTM E*381 or other standard as deemed appropriate by the Society.

3 The hardenability test specified in **3.6.13-1(3), Part K of the Rules** is to conform to *ASTM A*255 or other standard as deemed appropriate by the Society.

K3.8 High Strength Rolled Steels for Offshore Structures

K3.8.2 Kind

The wording "to be as deemed appropriate by Society" in **Note (1) for Table K3.27, Part K of the Rules** means to comply with the provisions of **K3.1.4**.

K3.8.3 Steel Making Processes, Deoxidation Practice and Chemical Composition

A fine grain structure is to have an index of 6 or finer as standard which is to be determined by micrographic examination in accordance with *ISO* 643 or an equivalent test standard deemed appropriate by the Society.

K3.8.7 Selection of Test Specimens

When the capacity of the available testing machine is insufficient to allow the use of flat test specimens taken from samples, testing may be carried out using specimens of reduced thickness in the thickness direction of the product in cases where approved by the Society.

K3.9 Stainless Clad Steel Plates

K3.9.9 Surface Inspection and Verification of Dimension

1 The wording "to the discretion of the Society" specified in **3.9.9-2, Part K of the Rules** means the following **(1)** to **(3)**.

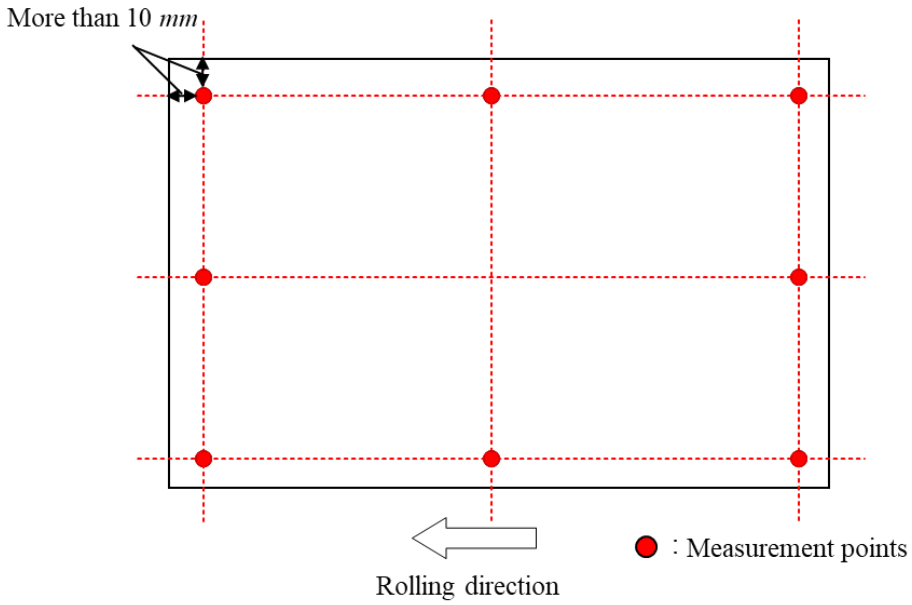
(1) The minus tolerance for the nominal thickness of the plate is to be 0.3 *mm* or less.

(2) The minus tolerance for the nominal thickness of the cladding metal is to be 10% or less of this thickness, but is not to exceed 0.25 *mm*.

(3) The minus tolerance for the nominal thickness of the base metal is to be 0.3 *mm* or less. However, minus tolerances need not be considered in cases where the minimum proof stress and tensile strength of the cladding metal are respectively higher than both the minimum yield point or proof stress, and the minimum tensile strength of the base metal.

2 Thickness measuring locations, as shown in **Fig. K3.9.9-1**, are all corners of the plate and the central regions of each side whose distance from an edge is at least 10 *mm*. However, local surface depressions resulting from imperfections (such as parts affected by shearing) and ground areas resulting from the elimination of defects may be disregarded.

Fig. K3.9.9-1 Locations of Thickness Measuring Points



K3.11 Additional Requirements for Through Thickness Properties

K3.11.5 Non-destructive Testing

Ultrasonic testing is to be performed, with a probe frequency of 4 *MHz*, in accordance with either *EN* 10160 Level S1/E1:1999 or *ASTM* A578 Level C:2017 or with other standards which is left to the discretion of the Society.

K3.12 Additional Requirements for Brittle Crack Arrest Properties

K3.12.3 Brittle Crack Arrest Properties etc.

1 In **3.12.3-1, Part K of the Rules**, "the discretion of the Society" means that carrying out the test in accordance with **Annex K3.12.3-1** "Guidance for Temperature Gradient ESSO Tests and Double Tension Tests" in the case of temperature gradient *ESSO* tests and double tension tests. The number of test specimens selected from a single test sample may be in accordance with **3.12.5-1, Part K of the Rules**, notwithstanding **1.2.11, Annex K3.12.3-1**.

2 In **3.12.3-2, Part K of the Rules**, "the discretion of the Society" means that carrying out the test in accordance with **Annex K3.12.3-2** "Guidance for CAT Evaluation Tests" in the case of Crack Arrest Temperature (*CAT*) evaluation tests.

3 For **3.12.3-1**, **3.12.3-2** and **3.12.5-4, Part K of the Rules**, test plans, containing information on the items mentioned below, are to be submitted to the Society for approval.

(1) Testing machine specifications (including testing machine capacity and distance between pins)

(2) Details of test specimen (including types and dimensions of test specimen and method of joint with tab plate)

(3) Types, dimensions and mechanical properties of tab plate and load jig

(4) Measurement specifications (including whether dynamic measurements are necessary and positions on which the thermocouples, strain gauges and crack gauges are fitted)

(5) Test conditions (including how to generate a brittle crack, impact energy, temperature of test specimen, temperature gradient, preload stress and test stress)

4 In **3.12.3-3, Part K of the Rules**, "A brittle fracture test deemed appropriate by the Society" means a test with an evaluation procedure approved by the Society in accordance with **Annex 1.1** "Approval Scheme of Small-scale Test Methods for Brittle Crack Arrest Steels", **Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

K4 STEEL PIPES

K4.1 Steel Tubes for Boilers and Heat Exchangers

K4.1.1 Application

The wording "standard deemed equivalent to the Society" in **4.1.1-2, Part K of the Rules** means *JIS G* 3461, *JIS G* 3462 or an equivalent standard thereto.

K4.1.3 Heat Treatment

The definition of low temperature annealing, isothermal annealing and full annealing specified in **Table K4.2, Part K of the Rules** is to be in accordance with the follows:

(1) Low temperature annealing

Low temperature annealing is the annealing carried out at or under the transformation temperature for the purpose of lowering the residual stress or softening. This is sometimes carried out at or under recrystallization temperature.

(2) Isothermal annealing

Isothermal annealing is the annealing involving austenitizing, followed by cooling which is interrupted by soaking for a period at temperature at which the transformation from austenite into ferrite and pearlite or cementite and pearlite is completed.

(3) Full annealing

Full annealing is the annealing carried out above the temperature of *Ac*3.

K4.1.5 Mechanical Properties

The non-destructive tests to be substituted for the hydraulic tests specified in **4.1.5(7), Part K of the Rules** are to be either ultrasonic tests or eddy current tests.

K4.2 Steel Pipes for Pressure Piping

K4.2.1 Application

The wording "standard deemed equivalent to the Society" in **4.2.1-2, Part K of the Rules** means *JIS G* 3454, *JIS G* 3455, *JIS G* 3456, *JIS G* 3458 or an equivalent standard thereto.

K4.2.5 Mechanical Properties

The non-destructive tests substituted for the hydraulic tests specified in **4.2.5(3), Part K of the Rules** are dealt with according to the provisions in **K4.1.5**.

K4.3 Stainless Steel Pipes

K4.3.1 Application

The wording "standard deemed equivalent to the Society" in **4.3.1-2, Part K of the Rules** means *JIS G* 3459 or an equivalent standard thereto.

K4.3.5 Mechanical Properties

The guide bend test for welded zone specified in **4.3.5-1(2), Part K of the Rules** is to be in accordance with the requirements of *JIS G* 3459 (Stainless Steel Pipes).

K4.5 Steel Pipes for Low Temperature Service

K4.5.1 Application

The wording "standard deemed equivalent to the Society" in **4.5.1-2, Part K of the Rules** means *JIS G* 3460 or an equivalent standard thereto.

K5 CASTINGS

K5.1 Steel Castings

K5.1.8 Selection of Test Specimens

The wording "when deemed appropriate by the Society" specified in **5.1.8-1, Part K of the Rules** means the cases for which the Society approves test blocks separated from the body of casting be heat treated simultaneously with the body of the steel casting in the same furnace, and the test specimens taken from such test blocks represent the microstructure and mechanical properties of the steel casting.

K5.1.9 Surface Inspection and Dimension Inspection

The surface inspection of steel castings specified in **5.1.9, Part K of the Rules** are to be dealt with as follows :

(1) Stern frames and rudder frames

The surface inspections of stern frame and rudder frame are to comply with the **Annex K5.1.9(1)** "GUIDANCE FOR ULTRASONIC TESTS AND SURFACE INSPECTION OF HULL STEEL CASTINGS" of this Part.

(2) Crankshafts

The surface inspections of crankshafts made of steel castings are to comply with the **Annex K5.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF CRANKSHAFTS" of this Part.

K5.1.10 Non-destructive Testing

The non-destructive tests for steel castings specified in **5.1.10-1** and **-2, Part K of the Rules** are to be dealt with as follows.

(1) Stern frame and rudder frame

The non-destructive tests of stern frame and rudder frame are to comply with the **Annex K5.1.9(1)** "GUIDANCE FOR ULTRASONIC TESTS AND SURFACE INSPECTION OF HULL STEEL CASTINGS" of this Part.

(2) Crankshafts

The non-destructive tests of crankshafts made of steel castings are to comply with the **Annex K5.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF CRANKSHAFTS" and **Annex K5.1.10(2)** "GUIDANCE FOR ULTRASONIC TESTS OF CAST STEEL CRANKTHROWS" of this part.

K5.1.11 Repair of Defects

1 Repairs by welding of crankshafts made of steel castings are to comply with the **Annex K5.1.11(1)** "GUIDANCE FOR REPAIRS BY WELDING FOR CAST STEEL CRANK THROWS" of this Part.

2 Repairs by welding of steel alloy castings are to comply with the preliminary tests in **1.7** of the Guidance referred to in **-1** above.

3 Repairs of steel castings such as stern frame, rudder frame and others intended for important parts of hull structure are to comply with the **Annex K5.1.11(3)** "GUIDANCE FOR REPAIRING OF HULL STEEL CASTINGS" of this Part.

4 The wording "the rules and standards deemed appropriate by the Society" specified in **5.1.11-7(3)(b), Part K of the Rules** means **Chapter 4, Part M of the Rules** or *ISO* 11970:2016.

5 For steels with carbon contents of 0.23 % or more, or for which the carbon equivalent (C_{eq}) specified in **1.5.2-2(6), Part K of the Rules** is 0.45 % or more, welding procedure qualification tests (*WPQT*) on which welding procedure tests (*WPS*) are based are recommended to be carried out using base materials having a C_{eq} as follows:

The C_{eq} of the base material is not to fall below more than 0.02 % of the material to be welded; for example, the WPQT for a material with an actual C_{eq} = 0.50 % may be tested using a material with $C_{eq} \geq 0.48$ %.

K5.1.12 Marking

The wording "some other appropriate method" in **5.1.12-2, Part K of the Rules** means stenciling, etc.

K5.1.13 Additional Requirements for Crank Throws

The wording "the preliminary tests instructed by the Society" in **5.1.13-2, Part K of the Rules** means the tests in accordance with **Chapter 4, Part 1 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

K5.2 Steel Castings for Chains

K5.2.9 Surface Inspection and Non-destructive Test

1 The wording "standards deemed appropriate by the Society" specified in **5.2.9-2** and **-3, Part K of the Rules** means the following standards or the equivalent thereto.

(1) Magnetic particle test: wet continuous magnetization technique specified in *ASTM E*709

(2) Ultrasonic test: *ASTM A*609 or *ISO* 13588

2 The wording "to be appropriately qualified in performing non-destructive tests" specified in **5.2.9-6, Part K of the Rules**, means those qualified *Level* II or higher in accordance with *ISO* 9712, *ACCP* or an equivalent qualification deemed appropriate by the Society.

3 Non-destructive test operator qualification according to an employer or responsible agency qualification scheme based on SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level III is *ASNT Level* III, *ISO* 9712 *Level* III or *ACCP* Professional *Level* III and certified in the applicable method. In such cases, notwithstanding the requirements in **-2** above, the wording "to be appropriately qualified in performing non-destructive tests" specified in **5.2.9-6, Part K of the Rules**, means those qualified Level II or higher.

K5.2.10 Repair of Defects

1 The wording "standards deemed appropriate by the Society" specified in **5.2.10-7, Part K of the Rules** is conform to *ISO* 9606, *ASME* IX, *ASTM A*488 or the equivalent thereto.

2 The wording "standards deemed appropriate by the Society" specified in **5.2.10-8, Part K of the Rules** is conform to *ISO* 15614, *ASME* IX, *ASTM A*488 or the equivalent thereto.

K5.2.13 Submission of Data

1 The results of the microscopic examinations for non-metallic inclusions specified in **5.2.13 (1), Part K of the Rules** are to conform to national/international standards.

2 The macro etched examination specified in **5.2.13(2), Part K of the Rules** is to conform to *ASTM E*381 or other standard as deemed appropriate by the Society.

3 The hardenability test specified in **5.2.13(3), Part K of the Rules** is to conform to *ASTM A*255 or other standard as deemed appropriate by the Society.

K5.5 Grey Iron Castings

K5.5.6 Mechanical Properties

Where test samples cast integral with the casting are used in accordance with the requirements in **Note (1)** of **Table K5.9, Part K of the Rules**, the mechanical properties are given in the **Table K5.5.6**.

Table K5.5.6 Mechanical Properties of Iron Castings

Material Grade	Thickness of iron castings t (mm)	Tensile Strength(1) (N/mm^2)
*KFC*20	$20 \leq t < 40$	170 min.
	$40 \leq t < 80$	150 min.
	$80 \leq t < 150$	140 min.
	$150 \leq t < 300$	130 min.
*KFC*25	$20 \leq t < 40$	210 min.
	$40 \leq t < 80$	190 min.
	$80 \leq t < 150$	170 min.
	$150 \leq t < 300$	160 min.
*KFC*30	$20 \leq t < 40$	250 min.
	$40 \leq t < 80$	220 min.
	$80 \leq t < 150$	210 min.
	$150 \leq t < 300$	190 min.
*KFC*35	$20 \leq t < 40$	290 min.
	$40 \leq t < 80$	260 min.
	$80 \leq t < 150$	230 min.
	$150 \leq t < 300$	210 min.

K5.6 Spheroidal or Nodular Graphite Iron Castings

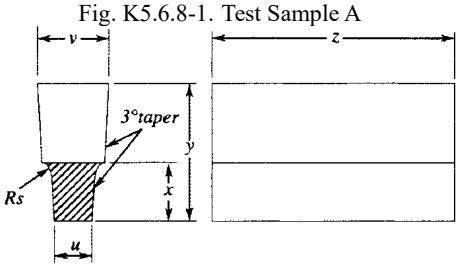
K5.6.6 Mechanical Properties

Where test samples cast integral with the casting are used in accordance with the requirements in **Note (1)** of **Table K5.9, Part K of the Rules**, the mechanical properties are to comply with the recognized standard such as *ISO*, *JIS*, *ASTM*, *DIN*, etc.

K5.6.8 Selection of Test Specimens

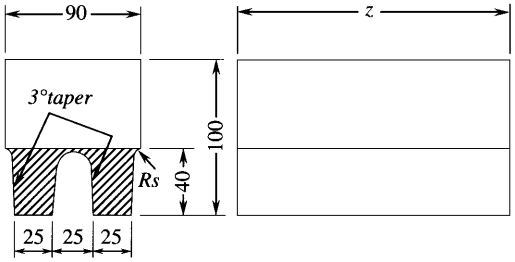
The shapes and dimensions deemed appropriate by the Society specified in **5.6.8-2, Part K of the Rules** means those shown in **Fig. K5.6.8-1.** to **-3.** The thickness u at the portion from where test specimens are to be taken (shown by hatching in the figures) is to be 25 *mm* in general. Where the thickness is other than 25 *mm*, either the size specified in **Fig. K5.6.8-1.** or **Fig. K5.6.8-3.** is to be selected.

Fig. K5.6.8-1. Test Sample A



	Standard size	Sizes other than standard		
		(1)	(2)	(3)
u (*mm*)	25	12	50	75
v (*mm*)	55	40	90	125
x (*mm*)	40	30	60	65
y (*mm*)	100	80	150	165
z	Length adjusted to testing machine			
Rs	Approx. 5*mm*			

Fig. K5.6.8-2 Test Sample B (Unit: *mm*)

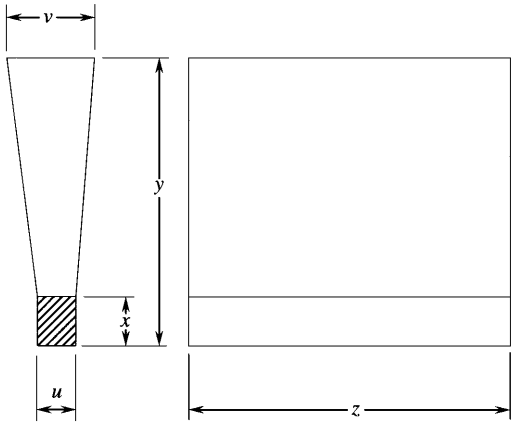


Notes:

Z : Length adjusted to testing machine

Rs : Approximately 5 *mm*

Fig. K5.6.8-3 Test Sample C



	Standard size	Sizes other than standard		
		(1)	(2)	(3)
u (*mm*)	25	12	50	75
v (*mm*)	55	40	100	125
x (*mm*)	40	25	50	65
y (*mm*)	140	135	150	175
z	Length adjusted to testing machine			

K5.7 Stainless Steel Propeller Castings

K5.7.7 Selection of Test Specimens

The wording "to be deemed appropriate by the Society" in **5.7.7-2, Part K of the Rules** means to be in accordance with either *JIS G* 0307 or an equivalent standard approved by the Society. The aforementioned standards, in principle, refer to the most recent version published.

K5.7.8 Surface and Dimensional Inspection

The wording "to be deemed appropriate by the Society" in **5.7.8-3, Part K of the Rules** means the followings :

(1) The straightening load is to be static.

(2) In case of hot straightening, the uniform heating is to be conducted to a sufficient area, and the temperature is to be measured by a suitable instrument. The recommended temperature range during the straightening operation is given in **Table K5.7.8-1**.

(3) Cold straightening is to be restricted to the case of minor repairs of tips and edges. Cold straightening is to be followed by a stress relieving heat treatment. The heat treatment is to be conducted in accordance with the requirement of **K5.7.10(3)**.

K5.7.9 Non-destructive Inspection

1 The wording "an equivalent standard deemed appropriate by the Society" means, for example, *JIS Z* 2320-1.

2 Due to the attenuating effect of ultrasound within austenitic steel castings, ultrasonic testing may not be practical in some cases, depending on the shape/type/thickness, and grain-growth direction of the casting.

Table K5.7.8-1 Temperature of Hot Straightening

Grade	Temperature (℃)
*KSCSP*1	～700(1)
*KSCSP*2	590～620(1)
*KSCSP*3	
*KSCSP*4	Ambient Temperature(2)

Notes:

(1) Stress relieving may be omitted if the temperature of hot straightening is maintained for an hour after the straightening is completed.

(2) In case where work hardening is excessive, solution treatment is to be carried out.

K5.7.10 Repair of Defects

The wording “to be as deemed appropriate by the Society” in **5.7.10-3(4), Part K of the Rules** means as given in **Table K5.7.10-1**.

Table K5.7.10-1 Temperature for Heat Treatment

Grade	Preheat temperature (℃)	Interpass Temperature (℃)	Stress relief Temperature (℃)
*KSCSP*1	100～200	350	680～730
*KSCSP*2	100～200	300	590～620
*KSCSP*3	20～100	200	590～620
*KSCSP*4	Not applicable	Not applicable	Not applicable

K6 STEEL FORGINGS

K6.1 Steel Forgings

K6.1.2 Manufacturing Process

1 The wording "unless otherwise deemed appropriate by the Society" in **6.1.2-4(4), Part K of the Rules** means the requirements may be suitably modified at the discretion of the surveyor according to the size or form, or the use for which they are intended, except for compression deformations of steel ingots or forging materials in the longitudinal direction (i.e. upsetting).

2 In relation to **6.1.2-7, Part K of the Rules**, where gas workings are being carried out on the parts subjected to high stress such as mass removal of crankshaft, the data related to the processes (including pre-heating) and change of material due to working are to be submitted approval of the Society.

K6.1.5 Heat Treatment

Where the size of the furnace intended to be used does not conform to the requirement specified in **6.1.5-5, Part K of the Rules** and overall length of the product is not afforded to be heat treated simultaneously, it is requested that an approval of the surveyor is to be obtained beforehand. In this case, one set of test specimens is to be taken from each end of the product. Degree of heterogeneity in micro structure at the boundary zone caused by such a heat treatment is to be examined by sump photograph and ultrasonic test.

K6.1.6 Mechanical Properties

"Deemed appropriate by the Society" specified in **6.1.6-1, Part K of the Rules** is applied as follows:

Where the value of yield point or proof stress of alloy steel forgings in mechanical properties is altered, the value of yield point or proof stress and "*M*" is to be suffixed to the markings. (for example, *KSFA*600-*M*-410*M or KSFA*600-*H*-410*M*)

K6.1.9 Surface Inspection and Dimension Inspection

Surface inspections of the steel forgings specified in **6.1.9, Part K of the Rules** are to be dealt with as follows:

(1) Crankshaft

The surface inspection of forged crankshaft is to comply with the **Annex K5.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF CRANKSHAFTS" of this Part.

(2) Other steel forgings

The surface inspections of propeller shafts and parts of engines, etc., are to comply with the **Annex K6.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF STEEL FORGINGS" of this Part.

K6.1.10 Non-destructive Testing

1 Non-destructive tests of steel forgings specified in **6.1.10-1** and **-2, Part K of the Rules** are to be dealt with as follows:

(1) Crankshaft

The non-destructive tests of forged steel crankshafts are to comply with the **Annex K5.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF CRANKSHAFTS" and the **Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS" of this Part.

(2) Other steel forgings

Non-destructive tests of propeller shafts and parts of engines, etc., are to comply with the **Annex K6.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF STEEL FORGINGS" and **Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS" of this Part.

2 "Operator engage in the ultrasonic test is to have sufficient technique and experience" prescribed in **6.1.10-1(1)(c), Part K of the Rules** means the operators of ultrasonic tests who correspond to either of the following **(1)** or **(2)**.

(1) Those who belong to the manufacturing factory of the steel forgings, occupied in ultrasonic test operation of steel forgings under the system of manufacturing schedule control and quality considered appropriate by the Society and deemed to have sufficient understanding of characteristics and nature of steel forgings.

(2) Those having official qualification considered appropriate by the Society.

3 The wording "other non-destructive tests considered adequate by the Society" specified in **6.1.10-3, Part K of the Rules** means, for example, test procedures in accordance with the IACS Recommendation No. 68.

4 The wording "requirements specified otherwise by the Society" specified in **6.1.10-6, Part K of the Rules** means **Chapter 9, Part M of the Rules.**

K6.1.11 Repair of Defects

In the requirement of **6.1.11-4, Part K of the Rules**, repair by welding in order of correct shapes for the portions not subjected to high stress may be accepted.

K6.1.13 Additional Requirements for Crankshafts

1 In **6.1.13-1, Part K of the Rules**, where the heat treatments of the crankthrows of solid crankshafts are carried out without mass removal, one set of test specimens are to be taken from the removed mass of the central crank throw at the part neighboring the pin, as shown in **Fig. K6.1.13-1** after the heat treatment.

2 In relation to the tests for semi-built-up crank throws specified in **6.1.13-2, Part K of the Rules**, following requirements are to be complied with.

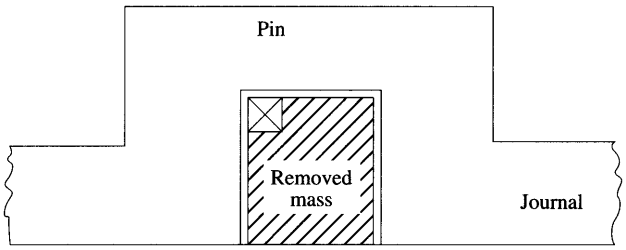
(1) Test specimens are to be taken, in general, one set from each arm in the longitudinal direction.

(2) In case where either the process of manufacturing those approved are intended to be changed or cranks larger than ever approved are intended to be manufactured, the tests instructed by the Society are to be newly carried out.

3 The wording "the special forging processes" in **6.1.13-2** and **-3, Part K of the Rules** means continuous grain flow forging methods (*e.g.* RR forging, TR forging or stamp forging), other than the free forging methods (block forging, upset & twisting forging and upsetting forging) used for the manufacture of solid crankshafts, block forging methods used for the manufacture of semi-built-up crankshafts and bend forging methods.

4 The wording "the preliminary tests instructed by the Society" in **6.1.13-2** and **-3, Part K of the Rules** means the tests in accordance with **Chapter 3** and **Chapter 4, Part 1 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use** respectively.

Fig. K6.1.13-1 Location of Test Specimens



K6.1.15 Additional Requirements for Reduction Gears

1 The test specimens for gears subjected to surface hardening specified in **6.1.15-3, Part K of the Rules** are to be selected as the following.

2 Induction Hardened or Nitrized Gears

(1) Tensile and impact test specimens

The test specimens are to be taken from the product after the final heat treatment and before the surface hardening in accordance with the requirements specified in **6.1.15-1** and **-2, Part K of the Rules**.

(2) Depth of the hardened layer

(a) In case of induction hardening

The depth of the hardened layer of the product is to be measured when the gear is produced for the first time, and tests thereafter may be dispensed with.

(b) In case of nitrization

i) Selection of test samples

Test samples are to be made of the same material as the product having been processed under the same conditions.

ii) Size of test samples

The size of the test samples may be optional.

iii) Heat treatments of test samples

The test samples are to be heat treated and nitrized simultaneously together with the product.

iv) Measurements of depth of hardened layer

The depth of hardened layer is to be measured every lot of same nitrization.

3 Carburized Gears

(1) Tensile and impact test specimens

(a) Selection of test sample

The samples are to be taken from the extended portion of the product before carburizing and after shaped by forging. In the cases specified in **6.1.15-1(4)** and **6.1.15-2(3), Part K of the Rules**, one each test samples are to be taken at least from 2 bodies of the products respectively.

(b) Size of test samples

The diameter of the test samples is to be as specified in **Table K6.1.15-1**, corresponding to the diameter of the toothed portion.

Table K6.1.15-1 Diameter of Test Samples

Diameter of toothed portion D (mm)	Diameter of test sample (mm)
$D \leq 240$	$D/4$
$D > 240$	60

Note:

Test samples having square sections is acceptable.

(c) Heat treatment of test samples

The test samples are to be given the same conditions of heat hysteresis as of the product, but carburizing is not required.

(d) Selection of test specimens

The test specimens are to be taken from the surface layer of the test samples.

(2) Depth of the hardened layer

(a) Selection of the test samples

The test samples are to be made of the same materials as the product and processed under the same conditions.

(b) Size of test samples

The sizes of the test samples may be optional.

(c) Heat treatment of test samples

The test samples are to be carburized and heat treated simultaneously with the product.

(d) Measurement of depth of hardened layer

The depth of the hardened layer is to be measured every lot of same carturization.

4 In cases where measuring the depth of the hardened layer specified in **-2(2)(a)**, **(b) iv)** and **-3(2)(d)** for bevel gears, it is to be confirmed that the measured value of said depth, at Vickers hardness (HV) values of 400 and 550, is not to be less than the value calculated according to the formula specified in **D5.3.1(2), Part D of the Guidance**.

5 The hardness tests of the surface hardened gears are to be dealt with as follows:

(1) The requirements for the measurement of hardness after surface hardening processes specified in **6.1.15-4(2), Part K of the Rules** have been required related to the "Power Transmission Systems" in **Chapter 5, Part D of the Rules**, and the measured hardness value is to be approved by the Society in relation to the approval of the manufacturing processes.

(2) In case where the measurements of hardness for every gear of the products are difficult owing to their sizes and shapes, the hardness may be measured at appropriate locations considered to be representative in respect to the value of hardness resulted from the approval tests for the manufacturing processes referred to in **(1)** above.

K6.2 Stainless Steel Forgings

K6.2.5 Heat Treatment

In generally, temperature of solid solution treatment is accordance with **Table K6.2.5-1**.

Table K6.2.5-1 Temperature of Solid Solution Treatment

Grade	Solid solution treatment (℃)	Grade	Solid solution treatment (℃)	Grade	Solid solution treatment (℃)
*KSUSF*304	1010~1150 rapid cooling	*KSUSF*310S	1030~1180 rapid cooling	*KSUSF*317	1010~1150 rapid cooling
*KSUSF*304L	1010~1150 rapid cooling	*KSUSF*316	1010~1150 rapid cooling	*KSUSF*321	920~1150 rapid cooling
*KSUSF*309S	1030~1150 rapid cooling	*KSUSF*316L	1010~1150 rapid cooling	*KSUSF*347	980~1150 rapid cooling

K6.2.9 Surface Inspection and Dimension Inspection

The surface inspection specified in **6.2.9, Part K of the Rules** is to comply with the **Annex K6.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF STEEL FORGINGS" of this Part.

K6.2.10 Non-destructive Testing

1 Non-destructive tests specified in **6.2.10, Part K of the Rules** is to comply with the **Annex K6.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF STEEL FORGINGS" and **Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS" of this Part.

2 "Operator engaged in the ultrasonic test is to have sufficient technique and experience" prescribed in **6.2.10-1(1)(c), Part K of the Rules** means the operators of ultrasonic tests who correspond to either of the following **(1)** or **(2)**.

(1) Those who belong to the manufacturing factory of the steel forgings, occupied in ultrasonic test operation of steel forgings under the system of manufacturing schedule control and quality considered appropriate by the Society and deemed to have sufficient understanding of characteristics and nature of steel forgings.

(2) Those having official qualification considered appropriate by the Society.

K6.3 Steel Forgings for Chains

K6.3.7 Selection of Test Specimens

1 The tensile test specimens whose diameters are 20 *mm* specified in **6.3.7-5, Part K of the Rules**, means a proportional test specimen such as the *U*14*A* tensile test specimen specified in **Chapter 2, Part K of the Rules**.

2 If the loading capacity of the testing machine is not sufficient, the tensile test specimen may be a *U*14*A* tensile specimen instead of the 20 *mm* tensile test specimen specified in **-1** above.

K6.3.8 Hydrogen Embrittlement Test

In cases where hydrogen embrittlement test specimens are *U*14*A* tensile test specimens instead of 20 *mm* tensile specimens in accordance with **K6.3.7-2**, the hydrogen embrittlement test is to be carried out in accordance with the following procedures and the test results are to comply with **6.3.8-2, Part K of the Rules**.

(1) One specimen is to be tested either within a maximum of 3 *hours* after machining, or within a period not exceeding 5 *days* after it has been cooled to -60°C immediately after machining and then maintain at that temperature until tested.

(2) The other specimen is to be tested after baking at 250°C for 4 *hours*.

(3) A slow strain rate (i.e., a strain rate less than 0.0003 s^{-1}) is to be used during the entire test, as far as practicable, and tensile strength, elongation and reduction of area are to be measured.

K6.3.9 Surface Inspection and Non-destructive Test

1 The wording "standards deemed appropriate by the Society" specified in **6.3.9-2** and **-3, Part K of the Rules** means the following standards or the equivalent thereto.

(1) Magnetic particle test: wet continuous magnetization technique specified in *ASTM A*275 or *EN*10228-1

(2) Ultrasonic test: *EN*10228-3, *ASTM A*388 or *ISO* 13588

2 The wording "to be appropriately qualified in performing non-destructive tests" specified in **6.3.9-5, Part K of the Rules**, means those qualified *Level* II or higher in accordance with *ISO* 9712, *ACCP* or an equivalent qualification deemed appropriate by the

Society.

3 Non-destructive test operator qualification according to an employer or responsible agency qualification scheme based on *SNT-TC*-1*A* may be accepted if the employer's written practice is reviewed and found acceptable and the Level III is *ASNT Level* III, *ISO* 9712 *Level* III or *ACCP* Professional *Level* III and certified in the applicable method. In such cases, notwithstanding the requirements in **-2** above, the wording "to be appropriately qualified in performing non-destructive tests" specified in **6.3.9-5, Part K of the Rules**, means those qualified Level II or higher.

K6.3.13 Submission of Data

1 The results of the microscopic examinations for non-metallic inclusions specified in **6.3.13(1), Part K of the Rules** are to conform to national/international standards.

2 The macro etched examination specified in **6.3.13(2), Part K of the Rules** is to conform to *ASTM E*381 or other standard as deemed appropriate by the Society.

3 The hardenability test specified in **6.3.13(3), Part K of the Rules** is to conform to *ASTM A*255 or other standard as deemed appropriate by the Society.

K7 COPPER AND COPPER ALLOYS

K7.2 Copper Alloy Castings

K7.2.9 Surface and Dimensional Inspection

1 The wording "a sufficient area" in **7.2.9-3(2), Part K of the Rules** means the entire area in the thickness direction of the blade at the bent region and approximately 500 *mm* wide zones on either side of it.

2 The wording "a suitable instrument" in **7.2.9-3(2), Part K of the Rules** means, for example, thermocouple instruments or temperature indicating crayons.

3 Due to the attenuating effect of ultrasound within cast copper alloys, ultrasonic testing may not be practical in some cases, depending on the shape/type/thickness, and grain- growth direction of the casting. In such cases, effective ultrasound penetration into the casting should be practically demonstrated on the item. This would normally be determined by way of back-wall reflection, and/or target features within the casting.

K7.2.10 Non-destructive Inspection

1 The wording "equivalent thereto" in **7.2.10-1(1), Part K of the Rules** means, for example, *JIS Z* 2343.

2 The true size of the defects obtained in the tests specified in **7.2.10-1(1), Part K of the Rules** is also to be confirmed for reference.

K7.2.11 Repair of Defects

For the etching specified in **7.2.11-3(5)(a)iii), Part K of the Rules**, a suitable etchant is 5 *g* iron (III) chloride, 30 *ml* hydrochloric acid (cone) and 100 *ml* water.

K8 ALUMINIUM ALLOYS

K8.1 Aluminium Alloy Plates and Extruded Shapes

K8.1.5 Mechanical Properties

Where the requirements given in **Note (3) of Table K8.3** of the Rules are applied, the standards for elongation are according to the followings.

(1) Where the tensile test specimen shown in **Fig. K8.1.5-1** is used, the standard for elongation is shown in **Table K8.1.5-1**.

(2) Where the tensile test specimen shown in **Fig. K8.1.5-2** is used for aluminium alloy with thickness not more than 12.5 *mm*, the standard for elongation is shown in **Table K8.1.5-2**.

Fig. K8.1.5-1 Test Specimen

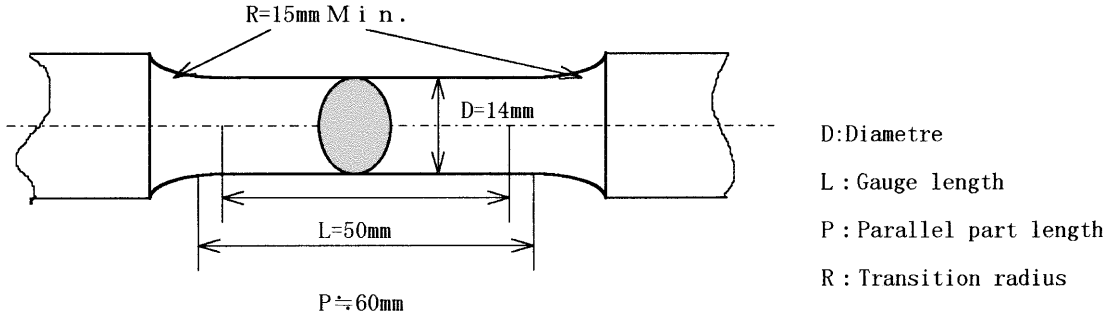
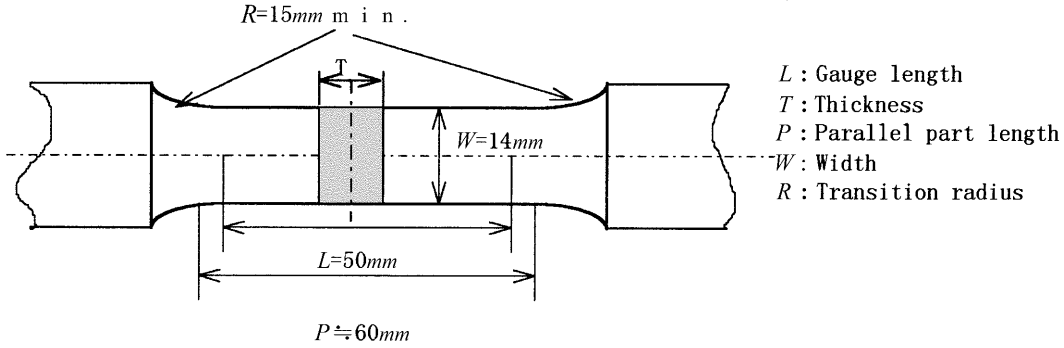


Fig. K8.1.5-2 Test Specimen



K8.1.8 Corrosion Resistance Test

Testing method and judging criteria of corrosion resistance test are to comply with the following requirements.

(1) Metallographic examination

Metallographic examination is to be performed in accordance with *ASTM B* 928:2015 9.6.1 or other standards which is left to the discretion of the Society.

(2) Corrosion test

Corrosion test is to be performed with respect to both exfoliation and intergranular corrosion resistance, and the test requirements are in accordance with the following **(a)** or **(b)**:

(a) *ASTM G* 66:2018 and *ASTM G* 67:2018 carried out under the conditions specified in *ASTM B* 928:2015

The evaluation criteria are as follows:

i) When subjected to the test described in *ASTM G* 66:2018, the samples are to have exhibited no evidence of exfoliation corrosion and a pitting rating of *N*, *PA* or *PB*.

ii) When subjected to the test described in *ASTM G* 67:2018, the samples are to have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2.

(b) Standards deemed appropriate by the Society

K8.1.9 Surface Inspection and Dimensional Tolerance

Any requirements regarding the minus tolerance except for the minus tolerance of rolled products in the nominal thickness is to comply with *JIS H* 4000 and *JIS H* 4100 as a standard.

Table K8.1.5-1 The Standard for Elongation

(a) Rolled Products

Material grade	Temper grade	Thickness t (*mm*)	Elongation (%)
5083*P*	*O*	12.5<t≤50	16 min.
		50< t≤100	16 min.
		100<t≤160	14 min.
		160<t≤200	11 min.
	*H*112	12.5<t≤50	11 min.
	*H*116		
	*H*321	12.5<t≤80	11 min.
5383*P*	*O*	12.5<t≤50	19 min.
	*H*116		11 min.
	*H*321		
5059*P*	*O*	12.5<t≤50	27 min.
	*H*116		11 min.
	*H*321		
5086*P*	*O*	12.5<t≤50	16 min.
	*H*112		10 min.
	*H*116		
5456*P*	*O*	12.5<t≤50	16 min.
	*H*116		11 min.
	*H*321		
5754*P*	*O*	12.5<t≤50	19 min.

(b) Extruded Shapes

Material grade	Temper grade	Thickness t (*mm*)	Elongation (%)
5083*S*	*O*	12.5<t≤50	14 min.
		50<t≤130	11 min.
	*H*111	12.5<t≤50	
	*H*112		
5383*S*	*O*	12.5<t≤50	19 min.
	*H*111		
	*H*112		15 min.
5059*S*	*H*112	12.5<t≤50	11 min.
5086*S*	*O*	12.5<t≤50	14 min.
	*H*111		11 min.
	*H*112		
6005*AS*	*T*5	12.5<t≤50	9 min.
	*T*6		7 min.
6061*S*	*T*6	12.5<t≤50	9 min.
6082*S*	*T*5	12.5<t≤50	7 min.
	*T*6		9 min.

Table K8.1.5-2 The Standard for Elongation

(a) Rolled Products

Material grade	Temper grade	Thickness *t* (*mm*)	Elongation (%)
5083*P*	*O*	*t*≤12.5	16 min.
	*H*112		12 min.
	*H*116		10 min.
	*H*321		12 min.
5383*P*	*H*116	*t*≤12.5	10 min.
	*H*321		
5059*P*	*H*116	*t*≤12.5	10 min.
	*H*321		
5086*P*	*O*	*t*≤12.5	16 min.
	*H*112		8 min.
	*H*116	*t*≤6.3	8 min.
		6.3< *t*≤12.5	10 min.
5754*P*	*O*	*t*≤12.5	18 min.
5456*P*	*O*	*t*≤12.5	16 min.
	*H*116		10 min.
	*H*321		12 min.
6061*P*	*T*6	*t*≤6.5	10 min.

(b) Extruded Shapes

Material grade	Temper grade	Thickness *t* (*mm*)	Elongation (%)
5083*S*	*O*	*t*≤12.5	14 min.
	*H*111		12 min.
	*H*112		
5383*S*	*O*	*t*≤12.5	17 min.
	*H*111		
5086*S*	*O*	*t*≤12.5	14 min.
	*H*111		12 min.
	*H*112		
6005*AS*	*T*5	*t*≤12.5	9 min.
	*T*6		8 min.
6061*S*	*T*6	*t*≤12.5	10 min.
6082*S*	*T*5	*t*≤12.5	8 min.
	*T*6	3< *t*≤5	6 min.
		5< *t*≤12.5	10 min.

K8.2 Aluminium Alloy Pipes

K8.2.1 Application

The wording “standard deemed equivalent to the Society” in **8.2.1-3**, **Part K of the Rules** means *JIS H* 4080 or an equivalent standard thereto.

K8.2.5 Mechanical Properties

1 The wording "standards deemed appropriate by the Society" given in **8.2.5-1(2), Part K of the Rules** means *JIS* Z3122 or *ISO* 5173.

2 The non-destructive tests to be substituted for the hydraulic tests specified in **8.2.5-1(3), Part K of the Rules** are to be tightness tests. In such cases, aluminium alloy longitudinally welded pipes are, in principle, to be subjected to the tests at their place of manufacture at pressures of at least 1.1 times maximum working pressure for at least 10 minutes with satisfactory results.

K8.2.6 Non-destructive Test

1 The wording "the discretion of the Society" given in **8.2.6, Part K of the Rules** means at least class 2 specified in the appendix 4, *JIS* Z3105.

K8.2.8 Dimension

Dimensional tolerance is, as a standard, to comply with *JIS* H4080 and *JIS* H4090.

Annex K1.1.1-1 GUIDANCE RELATING TO ROLLED STEEL BAR FOR BOILERS

1.1 Application

(1) The requirements apply to the hot rolled steel bars used for the stays for boiler.

(2) The requirements other than those in this guidance are to be in accordance with **Chapter 1** and **Chapter 2, Part K of the Rules**.

1.2 Kind

The steel bars are classified into 2 grades as given in **Table 1**.

Table 1 Kind

Grade
KPS42B
KPS46B

1.3 Chemical Composition

Chemical Composition of steel bars is to comply with the requirements given in **Table 2**.

Table 2 Chemical Compositions

Grade	Chemical Composition (%)		
	C	*S*	*P*
KPS42B	0.30 max.	0.04 max.	0.05 max.
KPS46B	0.33 max.	0.04 max.	0.05 max.

1.4 Heat Treatment

The heat Treatment of steel bars is to be as deemed appropriate by the Society.

1.5 Mechanical Properties

Mechanical Properties of the steel bars are to the conform with following requirements.

(1) Tensile test: The steel bars are to be subjected to tensile tests and to conform to the requirements in **Table 3**.

(2) Bend test: The bent test specimen is to stand being bent cold through 180 degrees without cracking on the outside of the bent portion to an inside radius given in **Table 4**.

Table 3 Mechanical Properties

Grade	Yield point (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)($L = 5.65\sqrt{A}$)
*KPS*42*B*	225 min.	410～490	24 min.
*KPS*46*B*	245 min.	450～540	22 min.

Note:

The required value of yield point for the steel bars exceeding 100 *mm* in diameter may be taken as 205 N/mm^2 for *KPS*42 and 225 N/mm^2 for *KPS*46*B* regardless of the above requirements.

Table 4 Bend Test

Diameter of steel bar (*mm*)	Ratio of inside of bend to diameter of test specimen	
	*KPS*42*B*	*KPS*46*B*
up to 25	$\frac{3}{4}$	1
over 25 up to 50	1	$1\frac{1}{4}$
over 50 up to 75	$1\frac{1}{4}$	$1\frac{1}{4}$
over 75	$1\frac{1}{4}$	$1\frac{1}{2}$

1.6 Selection of Test Samples

For the test samples of steel bars, steel bars which belong to the same cast manufactured by same process and where the amount of scatter is to be less than 10 *mm* in diameter, are to be treated as one lot, and test samples are to be taken from each lot according to the mass of the lot and to the requirements provided in **Table 5**.

Table 5 Number of Test Samples

Mass of Group (*t*)	Number of Test Samples
25 and under	1
Over 25 up 30	2
Over 30	2 plus 1 for each 10 *tons* of excess or fraction thereof

1.7 Selection of Test Samples

(1) Each one piece of tensile and bend test specimen in **Table K2.4 of the Rules** is to be taken from one test sample.

(2) Test specimens are to be taken with their longitudinal axis parallel to the final direction of rolling.

(3) Tensile test specimens are to be taken from the centre part or the position of approximately 1/6 of diameter from the surface. (*See* **Fig K3.2 of the Rules**)

1.8 Tolerance for Diameter

The tolerance for diameter of the steel bars is to be in accordance with the requirements in **Table 6**.

Table 6 Tolerance for Diameter

Diameter of steel bar (*mm*)	Tolerance
Less than 16	±0.4 *mm*
Over 16 less than 28	±0.5 *mm*
28 and over	±1.8%

1.9 Marking

The steel bars, prior to their shipment, are to be properly separated in bundles or containers which are to be marked with the name or brand of the manufacture, the letter indicating grade of steel and the charge number for identification. The Society's brand indicating compliance with the requirements are to be stamped on each bundle or container in the vicinity of the foregoing marks.

Annex K1.1.1-2 GUIDANCE FOR SEAMLESS FORGED STEEL DRUMS

1.1 Application

1 The requirements in this Guidance apply to seamless forged steel drums intended for boiler construction (hereinafter referred to as "forged drums").

2 Items differing from those specified in this Guidance are to comply with the requirements in **Chapter 1** and **Chapter 2, Part K of the Rules**.

1.2 Kind

The forged drums are classified into grades as given in **Table 1**.

Table 1 Kind

Grade
KSFB 42
KSFB 53

1.3 Mechanical Properties

The forged drums are to comply with the following requirements.

(1) Tensile test

The forged drums are to conform to the requirements given by **Table 2** in the tensile test.

(2) Bend test

The test specimen is to stand being bent cold through 180 *degrees* without cracking outside to the inside radius given in **Table 3**.

Table 2 Tensile Tests

Grade	Yield point or proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) (L =5D)	Reduction of area (%)
KSFB 42	205 min.	410 min.	24 min.	38 min.
KSFB 53	255 min.	520 min.	22 min.	40 min.

Table 3 Bend inside Radius

Grade	*KSFB* 42		*KSFB* 53	
	$\sigma_B \leq 490$ (N/mm^2)	$\sigma_B > 490$ (N/mm^2)	$\sigma_B \leq 560$ (N/mm^2)	$\sigma_B > 560$ (N/mm^2)
Bend inside radius (mm)	6	9.5	9.5	16

1.4 Selection of Test Specimens

1 One set specimens each for tensile test and bend test are to be taken from each end of the forged drum, perpendicular to the

centreline of the forged drum as well as opposite side each other with the centreline.

2 Only in the case where ends of the forged drums are closed by reforging after machining, the test coupon may be cut from the forged drum before the reforging and heat treated simultaneously with the forged drum. In such a case, the forged drum is to be heat treated again after reforging. The latter heat treatment is to be annealing at a temperature above the critical temperature but not above the temperature of the first annealing when the former heat treatment is annealing, and to be same treatment as the former when the former heat treatment is normalizing and tempering.

Annex K1.1.1-3 GUIDANCE RELATING TO HIGH MANGANESE AUSTENITIC STEELS

1.1 High Manganese Austenitic Steels

1.1.1 Application

1 This annex specifies batch release testing of high manganese austenitic steels for cryogenic service.

2 This annex applies to steel plates with thicknesses between 6 *mm* to 40 *mm or less*. The requirements for steels plates having thicknesses exceeding 40 *mm* are at the discretion of the Society.

3 High manganese austenitic steels differing in chemical composition, deoxidation practice, condition of supply and mechanical properties may be considered, subject to special approval by the Society.

1.1.2 Definitions

1 "High manganese austenitic steel" means steel with a high amount of manganese in order to retain austenite as its primary phase at atmospheric and service temperatures.

2 "Piece" means the rolled product from a single slab, billet or ingot when rolled directly into plates.

1.1.3 Approval

1 High manganese austenitic steel plates, unless otherwise specially provided or deemed appropriate by the Society, are to be manufactured at steel works which have been approved by the Society. The suitability of steel plates for forming and welding are to be demonstrated during the initial approval test at the steelworks. Approval of the steelworks is to follow a scheme given in **Chapter 1, Part 1 of the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

2 Manufacturers are responsible for assuring that effective quality, process and production controls during manufacturing adhered to manufacturing specifications. Manufacturing specifications are to be submitted to the Society at the time of initial approval.

3 Where non-conformities arise, manufacturers are to identify the cause and establish countermeasures to prevent recurrence. In addition, such non-conformities and countermeasures are to be documented and reported to the Society.

1.1.4 Deoxidation Practice and Chemical Composition

1 The deoxidation practice is to be fully killed for steel plates.

2 Steel plates are to be fine grain treated and have fine grain structures. The fine grain practice is to be as detailed in the manufacturing specification.

3 The chemical composition of samples taken from each ladle of each cast is to be determined by manufacturers in an adequately equipped and competently staffed laboratory and is to comply with the standards listed in **Table 1**.

4 Aim analysis is to be in accordance with manufacturing specifications, and all the elements listed in **Table 1** are to be reported.

Table 1 Chemical Composition for High Manganese Austenitic Steel Plates

Grade	Chemical composition (%)								
	C	*Si*	*Mn*	*P*	*S*	*Cr*	*B*	*N*	*Cu*
*KHMA*400	0.35–0.55	0.10–0.50	22.50–25.50	≤ 0.030	≤ 0.010	3.00–4.00	≤ 0.005	≤ 0.050	0.30–0.70

Notes:

(1) The content of other elements used for alloying and fine grain treatment may be specified by manufacturers, as appropriate.

(2) Silicon (*Si*) may be less than 0.1 %, provided total aluminium is 0.03 % or higher, or provided acid soluble aluminium is 0.025 % or higher.

1.1.5 Heat Treatment and Reduction Ratio

1 The heat treatment for all material is to be hot rolled with subsequent controlled cooling if necessary. Other heat treatment are to be as deemed appropriate by the Society.

2 The reduction ratio of slab to finished product thickness is to be not less than 3:1.

1.1.6 Mechanical Properties

Material specifications for high manganese austenitic steel plates are to be as listed in **Table 2**.

Table 2 Conditions of Grade and Mechanical Properties for High Manganese Austenitic Steel Plates

Grade	Tensile test			Impact test		
	Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%) min $L = 5.65\sqrt{A}$	Testing temperature (°C)	Minimum mean absorbed energy (J)	
					T	L
KHMA400	≥ 400	800–970	≥ 22	−196	≥ 27	≥ 41

1.1.7 Test Sample Selection

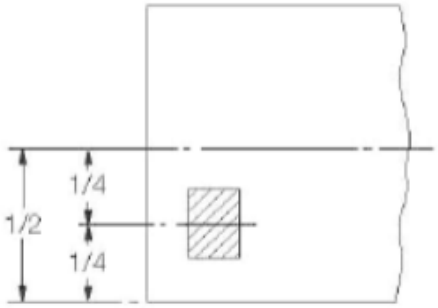
1 One test sample which test specimens are cut is to be taken from each piece.

2 The samples of steel plates are to be treated together with and in the same way as the steel presented, and are not to be cut from the material until heat treatment has been completed.

3 Test specimens are not to be heat treated separately from test samples in any way.

4 Unless otherwise agreed, test samples are to be taken from one end at a position approximately midway between the axis in the direction of the rolling and the edge of the rolled product according to **Fig. 1**.

Fig. 1 Test Sample Location



1.1.8 Test Specimen Selection

1 Test specimens are not to be heat treated separately from test samples in any way.

2 Tensile test specimens are to be taken as follows.

(1) One test specimen is to be taken from one test sample.

(2) Test specimens are to be taken with their longitudinal axes normal to the final direction of rolling (T direction).

(3) Test specimens of full product thickness are to be used.

3 Impact test specimens are to be taken as follows.

(1) A set of test specimens is to be taken from one test sample.

(2) Test specimens are to be taken with their longitudinal axes normal (T direction) to the final direction of rolling. When deemed necessary by the Society, however, they are to be taken with their longitudinal axes parallel (L direction) to the final direction of rolling.

(3) When product thickness does not exceed 40 *mm*, test specimens are to be cut with their edges within 2 *mm* from the "as rolled" surface.

1.1.9 Verification of Dimensions

Unless otherwise specially provided or deemed appropriate by the Society, the thickness tolerances of steel plates are to be in accordance with **3.1.8, Part K of the Rules**.

1.1.10 Surface Quality and Internal Soundness

1 Steel plates are to be reasonably free from segregations and non-metallic inclusions.

2 The finished material is to have a workmanlike finish and is to be free from internal and surface defects prejudicial to the use of the material for its intended application.

3 The surface finishes of steel plates are to be in accordance with **3.1.9-1, Part K of the Rules**.

4 Manufacturers are responsible for verifying internal soundness, acceptance by a Society surveyor does not absolve manufacturers of this responsibility.

1.1.11 Retest Procedures

1 Where the tensile test fails to meet the requirements, retest procedures for tensile tests are to be in accordance with **1.4.4, Part K of the Rules**.

2 For the impact test, retest may be conducted in accordance with **3.1.10-3, Part K of the Rules**.

1.1.12 Marking

1 Steel plates which have passed required tests are to be marked with identification marks in accordance with **1.5.1, Part K of the Rules**.

2 In the case of high manganese austenitic steels that have been corrosion tested for ammonia compatibility during manufacturing process approval testing and confirmed to be suitable for ammonia environments, "*A*" is added to the marking. (Example: *KHMA*400-*A*)

Annex K3.12.3-1 GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS

1.1 Application

1 *ISO* 20064:2019 specifies a test method for the determination of brittle crack arrest toughness of steel by using wide plates with a temperature gradient. This annex specifies the test procedures for brittle crack arrest toughness (i.e. K_{ca}) of steel using a fracture mechanics parameter and determination method for K_{ca} at the specific temperatures specified in *ISO* 20064:2019. Additionally, this annex specifies the evaluation method for K_{ca} of test plate.

2 This annex apply to rolled steel plates with thicknesses exceeding 50 *mm* but 100 *mm* or less. Rolled steel plates having thicknesses exceeding 100 *mm* are at the discretion of the Society.

1.2 Test Procedures

1 Test procedures (including testing equipment, test specimens, test methods, determination of arrest toughness, reporting of test results, etc.) are to be in accordance with *ISO* 20064:2019.

2 As a method for initiating a brittle crack, a secondary loading mechanism can be used in accordance with Annex D of *ISO* 20064:2019, except that the first sentence in Annex B.2.4 of *ISO* 20064:2019 is to be read as "Obtain the value {Kca /[K0 *exp(−c/TcaK)]} for each data point".

1.3 Method for Obtaining Arrest Toughness Value at a Specific Temperature

1 Method

The arrest toughness value K_{ca} at a specific temperature is calculated by using test results which are obtained by conducting two or more of the tests in accordance with Annex B of *ISO* 20064:2019.

2 Evaluation

The straight-line approximation obtained from the test data of the valid K_{ca} data is to comply with either the following **(1)** or **(2)**.

(1) The evaluation temperature of K_{ca} (i.e. −10 °C) is to be located between the upper and lower limits of the arrest temperature, with the K_{ca} corresponding to an evaluation temperature not lower than the required K_{ca} (e.g. 6,000 $N/mm^{3/2}$ or 8,000 $N/mm^{3/2}$), as shown in **Fig. 1**.

(2) The temperature corresponding to the required K_{ca} (e.g. 6,000 $N/mm^{3/2}$ or 8,000 $N/mm^{3/2}$) is to be located between the upper and lower limits of the arrest temperature, with the temperature corresponding to the required K_{ca} not higher than the evaluation temperature (i.e. −10 °C), as shown in **Fig. 2**.

3 If both of **(1)** and **(2)** of **-2** above are not satisfied, additional tests may be conducted to satisfy this condition.

Fig. 1 Evaluation Example of K_{ca} at -10℃

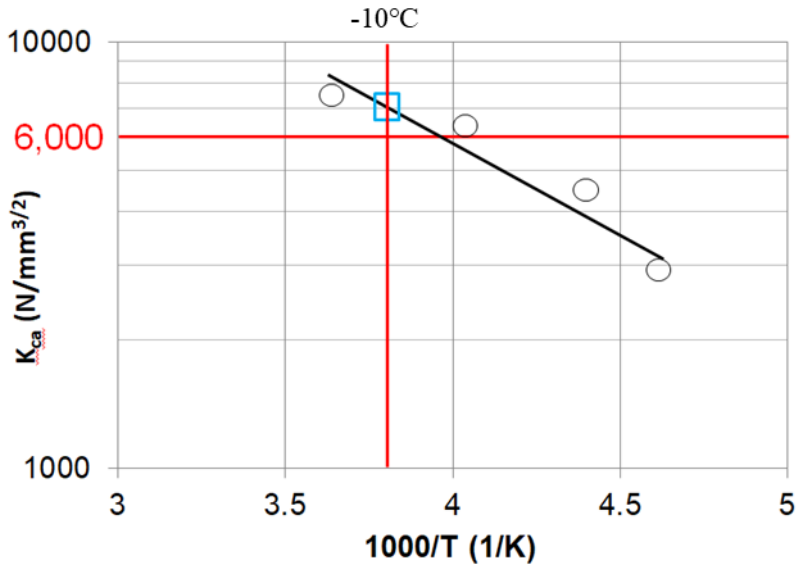
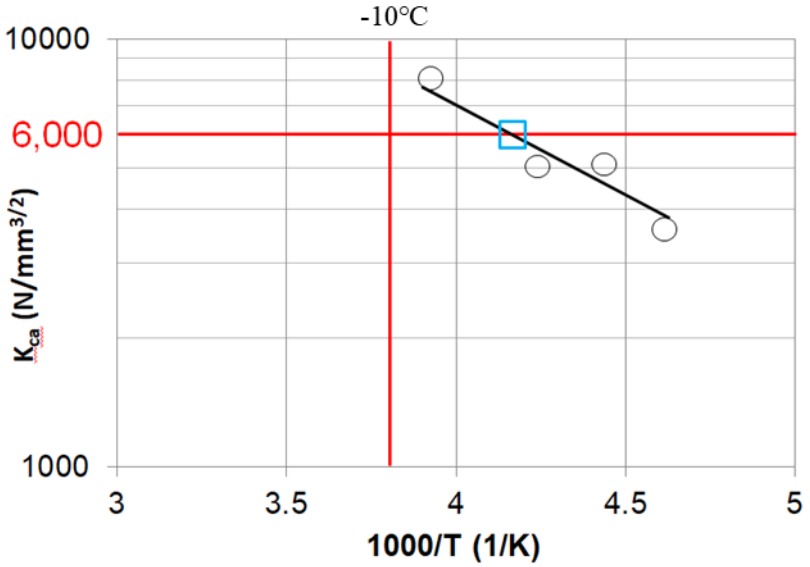


Fig. 2 Evaluation Example of Temperature Corresponding to Required K_{ca}



Annex K3.12.3-2 GUIDANCE FOR CAT EVALUATION TESTS

1.1 General

1.1.1 Application

The requirements in this Guidance apply to rolled steel plates for hulls of thicknesses exceeding 50 *mm* but 100 *mm* or less. Requirements for other rolled steel plates are at the discretion of the Society.

1.1.2 Definition

The definition of the symbols used in this Guidance is as specified in **Table 1** as well as Table 1 of *ISO* 20064:2019.

Table 1 Definition of the Symbols Used in this Guidance

Symbol	Unit	Significance
a_{MN}	*mm*	Machined notch length on specimen edge
L_{SG}	*mm*	Side groove length on side surface from the specimen edge (L_{SG} is defined as a groove length with constant depth except a curved section in depth at side groove end.)
d_{SG}	*mm*	Side groove depth in section with constant depth
$L_{EB\text{-}min}$	*mm*	Minimum length between specimen edge and electron beam re-melting zone front
$L_{EB\text{-}s1,\ -s2}$	*mm*	Length between specimen edge and electron beam re-melting zone front appeared on both specimen side surfaces
L_{LTG}	*mm*	Local temperature gradient zone length for brittle crack runway
a_{arrest}	*mm*	Arrest crack length
T_{target}	*℃*	Target test temperature
T_{test}	*℃*	Defined test temperature
T_{arrest}	*℃*	Target test temperature at which valid brittle crack arrest behaviour is observed
SMYS	N/mm^2	Specified minimum yield strength of the tested steel grade to be approved
CAT	*℃*	Brittle crack arrest temperature obtained in **1.2.14**

1.2 *CAT* Evaluation tests

1.2.1 General

The requirements in this section are related to the evaluation of brittle crack arrest toughness through the use of *CAT* evaluation tests.

1.2.2 Test Equipment and Impact Equipment

1 The test equipment to be used is to be of a hydraulic type of sufficient capacity to provide a tensile load equivalent to 2/3 of *SMYS* of the steel grade to be approved.

2 The temperature control system is to be equipped to maintain the temperature in the specified region of the specimen within ±2℃ from T_{target}.

3 Methods for initiating the brittle crack may be of a drop weight type, air gun type or double tension tab plate type.

4 Detailed requirements for testing equipment are to be in accordance with Table 1 of *ISO* 20064:2019.

1.2.3 Test Specimens

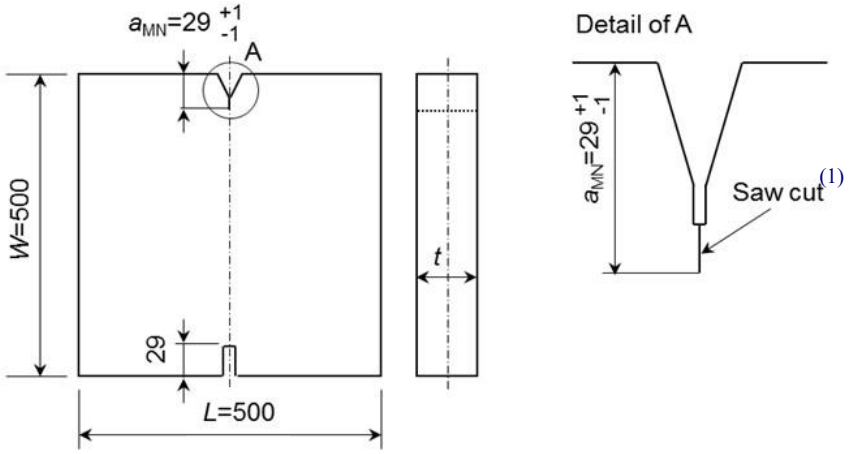
1 Test specimens are to be in accordance with *ISO* 20064:2019, unless otherwise specified in this Guidance.

2 Test specimen shape is as shown in **Fig. 1**. Test specimen width (*W*) is to be 500 *mm*, while test specimen length (*L*) is to be equal to or greater than 500 *mm*.

3 *V*-shape notch for brittle crack initiations is to be machined on the specimen edge of the impact side. The whole machined notch length is to be equal to 29 *mm* with a tolerance range of ±1 *mm*.

4 The requirements for side grooves are specified in **1.2.6**.

Fig. 1 Test Specimen Shape



Note:

(1) Saw cut notch radius may be machined in the range 0.1 *mmR* and 1 *mmR* in order to control brittle crack initiation at the test.

1.2.4 Double Tension Type Crack Initiation

1 Reference is to be made to Annex D of *ISO* 20064:2019 for the shape and size of the secondary loading tab and secondary loading method for brittle crack initiation.

2 The secondary loading tab plate may be subject to further cooling to enhance an easy brittle crack initiation.

1.2.5 Embrittled Zone Setting

1 An embrittled zone is to be applied to ensure the initiation of a running brittle crack.

2 Either Electron Beam Welding (*EBW*) or Local Temperature Gradient (*LTG*) may be adopted to facilitate the embrittled zone.

3 In *EBW* embrittlement, electron beam welding is to be applied along the expected initial crack propagation path, which is the centreline of the specimen in front of the machined *V*-notch.

4 Complete penetration through the specimen thickness is to be required along the embrittled zone. One side *EBW* penetration is preferable, but dual side *EBW* penetration may be also adopted when *EBW* power is not enough to achieve complete penetration by one side *EBW*.

5 *EBW* embrittlement is recommended to be prepared before specimen contour machining.

6 The *EBW* embrittlement zone is to be of an appropriate quality.

7 In *LTG* systems, the specified local temperature gradient between machined notch tip and isothermal test region is to be regulated after isothermal temperature control.

8 In *LTG* systems, a steady temperature gradient through the thickness is to be ensured just before brittle crack initiation.

1.2.6 Side Grooves

1 Side grooves on side surface may be machined along the embrittled zone to keep brittle crack propagation straight. Side grooves are to be machined in the cases specified in this Guidance.

2 In *EBW* embrittlement, side grooves are not necessarily mandatory since use of *EBW* avoids shear lips. However, when shear lips are evident on the fractured specimen (e.g. shear lips over 1 *mm* in thickness on either side), the side grooves are to be machined to suppress the shear lips.

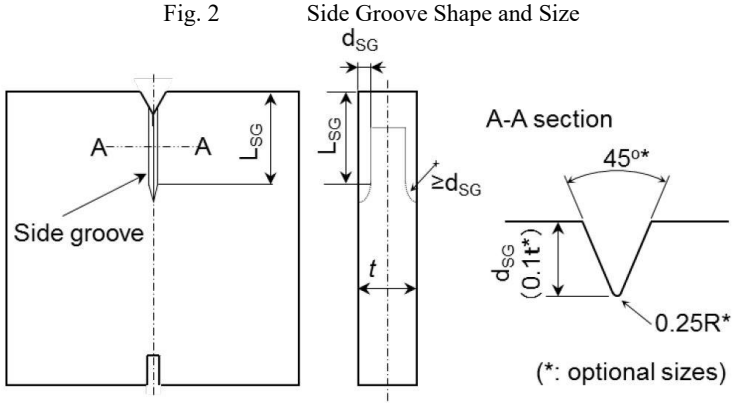
3 In *LTG* embrittlement, side grooves are mandatory. Side grooves with the same shape and size are to be machined on both side surfaces.

4 The length of side groove (L_{SG}) is to be no shorter than the sum of the required embrittled zone length.

5 When side grooves are introduced, side groove depth, the tip radius and the open angle are not regulated, but are to be adequately selected in order to avoid any shear lips over 1 *mm* thickness on either side. An example of side groove shape is shown in **Fig.2**.

6 Side groove ends are to be machined to make groove depth gradually shallow with curvatures larger than or equal to groove depth (d_{SG}). Side groove length (L_{SG}) is defined as a groove length with constant depth except for a curved section in depth at the side groove end.

Fig. 2 Side Groove Shape and Size



1.2.7 Nominal Length of Embrittled Zone

1 The length of embrittled zone is to be at least 150 *mm*.

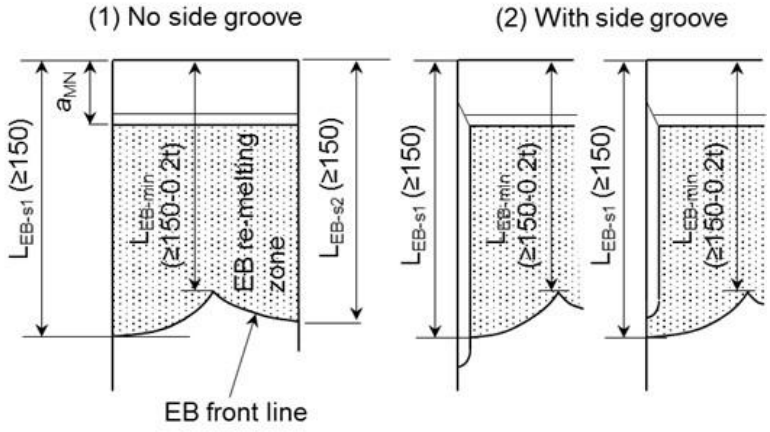
2 *EBW* zone length is regulated by three measurements on the fracture surface after tests, as shown in **Fig. 3**, $L_{EB\text{-}min}$ between specimen edges and the *EBW* front line, and $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$.

3 The minimum length between specimen edges and the *EBW* front line ($L_{EB\text{-}min}$) is to be no smaller than 150 *mm*. When $L_{EB\text{-}min}$ is smaller than 150 *mm* and no smaller than 150 *mm* - 0.2*t*, T_{test} is described in **1.2.13-1(2)**.

4 $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$ are the lengths between specimen edges and the *EBW* front for both side surfaces. Both $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$ are to be no smaller than 150 *mm*.

5 In *LTG* systems, L_{LTG} is set as 150 *mm*.

Fig. 3 Definition of *EBW* Length



1.2.8 Tab Plate and Pin Chuck Details

The following **(1)** and **(2)** are to be as specified in *ISO* 20064:2019.

(1) The shape and size of tab plates and pin chucks.

(2) The plane accuracy and the accuracy of in-plate loading axes in the integrated specimen, which is welded with specimen, tab plates and pin chucks.

1.2.9 Test Method

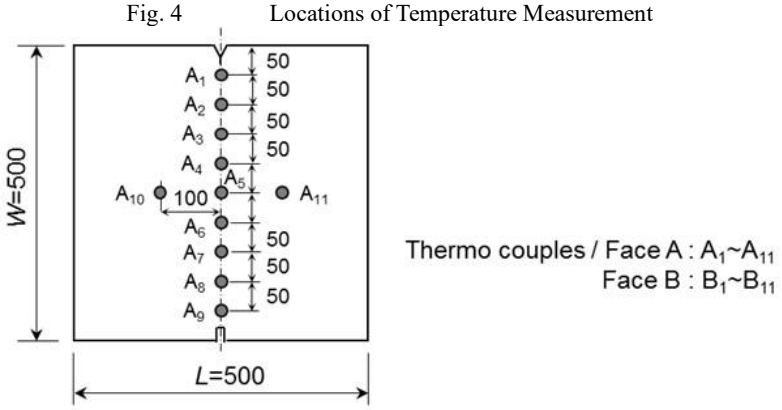
1 Preloading at room temperature may be applied to avoid brittle crack initiation at tests. The applied preloading is to be according to **(1)** and **(2)** below.

(1) Preloading is to be no greater than the test stress.

(2) Preloading may be applied at higher temperature than ambient temperature when brittle crack initiation is expected at preloading process. However, the specimen is not to be subjected to temperature higher than 100°C.

2 Thermocouples are to be attached to both sides of the test specimen at a maximum interval of 50 *mm* in the whole width and in the longitudinal direction at the test specimen centre position (0.5 *W*) within the range of ±100 *mm* from the centreline in the longitudinal direction, as shown in **Fig. 4**.

Fig. 4 Locations of Temperature Measurement



3 *EBW* temperature control is to be according to **(1)** to **(3)** below.

(1) The temperatures of the thermocouples across the range of 0.3*W*~0.7*W* in both width and longitudinal directions are to be controlled within ±2°C of the target test temperature (T_{target}).

(2) When all measured temperatures across the range of 0.3*W*~0.7*W* have reached T_{target}, steady temperature control is to be keep at least for 10+0.1×*t* (*mm*) minutes to ensure a uniform temperature distribution into mid-thickness prior to applying test load.

(3) The machined notch tip may be locally cooled to easily initiate brittle crack. Nevertheless, the local cooling is not disturb the steady temperature control across the range of 0.3*W*~0.7*W*.

4 *LTG* temperature control is to be according to **(1)** to **(10)** below.

(1) In addition to the temperature measurements shown in **Fig. 4**, an additional temperature measurement at the machine notch tips (A_0 and B_0) is required. Thermocouple positions within *LTG* zone are shown in **Fig. 5**.

(2) The temperatures of the thermocouples across the range of 0.3*W*~0.7*W* in both width and longitudinal directions are to be controlled within ±2°C of the target test temperature (T_{target}). However, the temperature measurement at 0.3*W* (location of A_3 and B_3) is to be in accordance with **(6)** below.

(3) Once the all measured temperatures across the range of 0.3*W*~0.7*W* have reached T_{target}, steady temperature control is to be kept at least for 10+0.1×*t* (*mm*) minutes to ensure a uniform temperature distribution into mid-thickness, then the test load is applied.

(4) *LTG* is controlled by local cooling around the machined notch tip. *LTG* profile is to be recorded by the temperature measurements from A_0 to $A_{3,as}$ shown in **Fig. 6**.

(5) *LTG* zones are to be established by temperature gradients in three zones, Zone I, Zone II and Zone III. The acceptable range for each temperature gradient is listed **Table 2**.

(6) Two temperature measurements at (A_2, B_2) and (A_3, B_3) are to satisfy the following requirements:

T at A_3, T at $B_3 < T_{target}$ - 2°C

T at $A_2 < T$ at A_3 - 5°C

T at $B_2 < T$ at B_3 - 5°C

(7) No temperatures for T at A_0 and T at A_1 temperatures when T at A_3 and T at A_2 satisfy the requirements above. Face *B* is the same.

(8) The temperatures from (A_0, B_0) to (A_3, B_3) are to be decided at test planning stage refer to **Table 2** which gives the recommended

temperature gradients in three zones, Zone I, Zone II and Zone III in *LTG* zone.

(9) The temperature profile in *LTG* zone mentioned above is to be ensured after holding time at least for 10+0.1×*t* (*mm*) minutes to ensure a uniform temperature distribution into mid-thickness before brittle crack initiation.

(10) The acceptance of *LTG* in the test is to be decided from **Table 2** based on the measured temperatures from A_0 to A_3.

Fig. 5 Detail of *LTG* Zone and Additional Thermocouple A_0

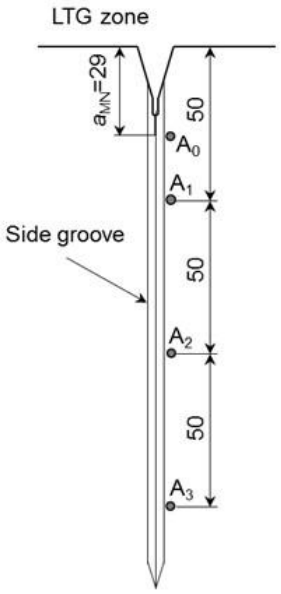


Fig. 6 Schematic Temperature Gradient Profile in *LTG* Zone

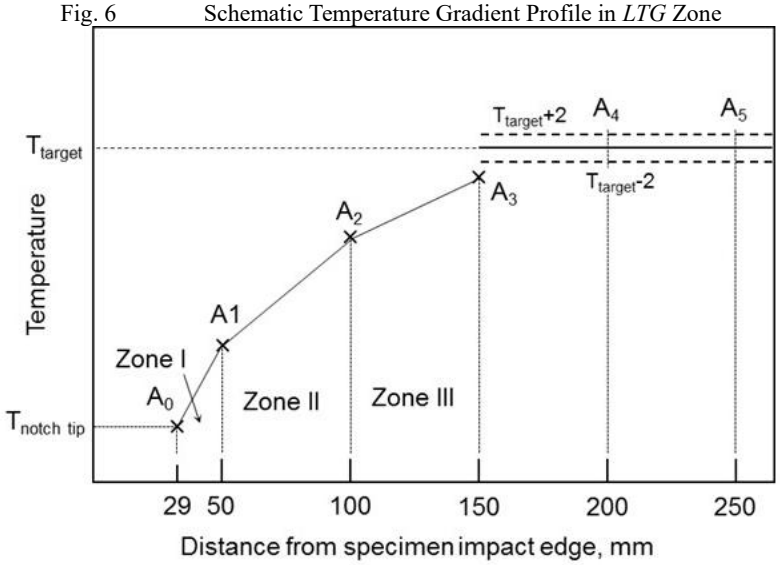


Table 2 Acceptable *LTG* Range

Zone	Location from edge (*mm*)	Acceptable range of temperature gradient (°C/*mm*)
Zone I	29～50	2.00～2.30
Zone II	50～100	0.25～0.60
Zone III(1)	100～150	0.10～0.20

Note:

(1) The Zone III arrangement is mandatory.

5 For double tension type crack initiation specimens, temperature control and holding time at steady state are to be the same as the case of *EBW* embrittlement or the case of *LTG* embrittlement.

1.2.10 Loading and Brittle Crack Initiation

1 Prior to testing, a target test temperature (T_{target}) is to be selected.

2 Test procedures are to be in accordance with *ISO* 20064:2019 except that the applied stress is to be 2/3 of *SMYS* of the steel grade tested.

3 The test load is to be held at the test target load or higher for a minimum of 30 seconds prior to crack initiation.

4 Brittle crack is to be initiated by impact or secondary tab plate tension after all temperature measurements and the applied force are recorded.

1.2.11 Measurements after Test and Test Validation Judgment

1 The validation of brittle crack initiation is to be in accordance with **(1)** and **(2)** below.

(1) If brittle crack spontaneously initiates before the test force is achieve or the specified hold time at the test force is not achieved, the test is considered invalid.

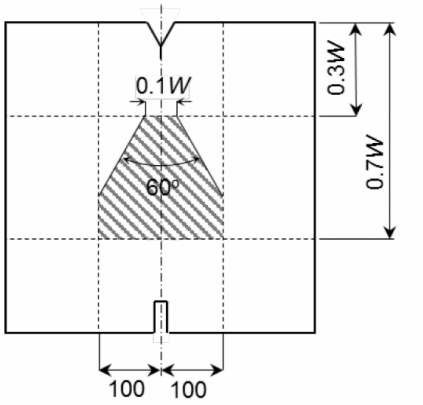
(2) If brittle crack spontaneously initiates without impact or secondary tab tension but after the specified time at the test force is achieved, the test is considered to be a valid initiation. The following validation judgments of crack path and fracture appearance are to be examined.

2 The validation of crack path examination is to be in accordance with **(1)** and **(2)** below.

(1) When brittle crack path in embrittled zone deviates from *EBW* line or side groove in *LTG* system due to crack deflection and/or crack branching, the test is considered invalid.

(2) All of the crack path from embrittled zone end is to be within the range shown in **Fig. 7**. If not, the test is considered invalid.

Fig. 7 Allowable Range of Main Crack Propagation Path



3 Fracture surface examination, crack length measurement and their validation are to be in accordance with **(1)** to **(7)** below.

(1) Fracture surface is to be observed and examined. The crack initiation and propagation are to be checked for validity and judgments recorded. The crack arrest positions are to be measured and recorded.

(2) When crack initiation trigger point is clearly detected at side groove root, other than the *V*-notch tip, the test is considered invalid.

(3) In *EBW* embrittlement setting, *EBW* zone length is quantified by three measurements of $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ and $L_{EB\text{-}min}$, which are defined in **1.2.7**. When either or both of $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$ are smaller than 150 *mm*, the test is considered to be invalid. When $L_{EB\text{-}min}$ is smaller than 150 *mm* - 0.2*t*, the test is considered invalid.

(4) When the shear lip with thickness over 1 *mm* in either side near side surfaces of embrittled zone are visibly observed independent of the specimens with or without side grooves, the test is considered invalid.

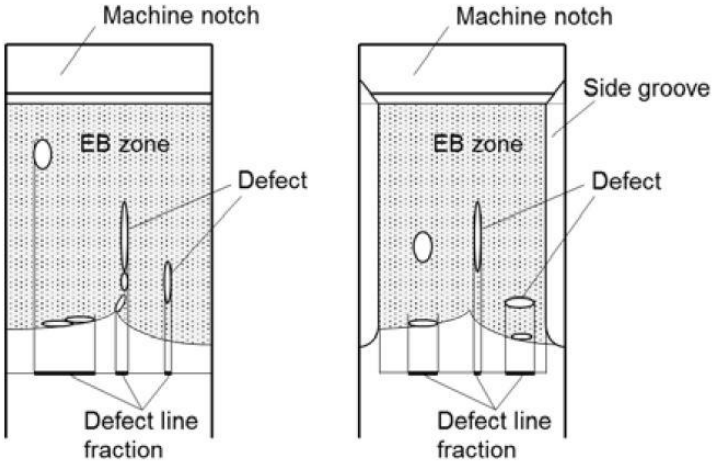
(5) In *EBW* embrittlement setting, the penetration of brittle crack beyond the *EBW* front line is to be visually examined. When any brittle fracture appearance area continued from the *EB* front line is not detected, the test is considered invalid.

(6) The weld defects in *EBW* embrittled zone are to be visually examined. If detected, it is to be quantified. A projecting length of defect on the thickness line through *EB* weld region along brittle crack path is to be measured, and the total occupation ration of the projected defect part to the total thickness is defined as defect line fraction (See **Fig. 8**). When the defects line fraction is larger than 10%, the test is considered invalid.

(7) In *EBW* embrittlement by dual sides' penetration, a gap on embrittled zone fracture surface which is induced by miss meeting

of dual fusion lines is visibly detected at an overlapped line of dual side penetration, the test is considered invalid.

Fig. 8 Counting Procedure of Defect Line Fraction



1.2.12 Judgment of "Arrest" or "Propagate"

1 If the initiated brittle crack is arrested and the tested specimen is not broken into two pieces, the fractured surfaces are to be exposed with the procedures specified in *ISO* 20064:2019.

2 When the specimen is not broken into two pieces during testing, the arrested crack length, a_{arrest} is to be measured on the fractured surfaces. The length from the specimen edge of impact side to the arrested crack tip (the longest position) is defined as a_{arrest}.

3 For *LTG* and *EBW*, a_{arrest} is to be greater than L_{LTG} and $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ or $L_{EB\text{-}min}$. If not, the test is considered invalid.

4 Even when the specimen was broken into two pieces during testing, it may be considered as "arrest" when brittle crack re-initiation is clearly evident. Even when the fractured surface consists almost entirely of the brittle fracture, when a part of brittle crack surface from embrittled zone is continuously surrounded by thin ductile tear line, the test may be judged as re-initiation behaviour. If so, the maximum crack length of the part surrounded tear line may be measured as a_{arrest}. If not, the test is judged as "propagate".

5 The test is judged as "arrest" when the value of a_{arrest} is no greater than $0.7W$. If not, the test is judged as "propagate".

1.2.13 T_{test} and T_{arrest} Determination

1 T_{test} determination is to be in accordance with **(1)** to **(4)** below.

(1) It is to be ensured on the thermocouple measured record that all temperature measurements across the range of $0.3W$~$0.7W$ in both width and longitudinal direction are in the range of T_{target} ±2℃ at brittle crack initiation. If not, the test is considered invalid. However, the temperature measurement at $0.3W$ (location of A_3 and B_3) in *LTG* systems is to be exempted from this requirement.

(2) If $L_{EB\text{-}min}$ in *EBW* embrittlement is no smaller than $150mm$, T_{test} may be defined to equal with T_{target}. If not, T_{test} is equal to T_{target} +5℃.

(3) In *LTG* embrittlement, T_{test} may be equal to T_{target}.

(4) The final arrest judgment at T_{test} is concluded by at least two tests at the same test condition which are judged as "arrest".

2 T_{arrest} determination is to be in accordance with **(1)** and **(2)** below.

(1) When at least repeated two "arrest" tests appear at the same T_{target}, brittle crack arrest behavior at T_{target} is to be judged as (T_{arrest} = T_{target}).

(2) When a "propagate" test result is included in the multiple test results at the same T_{target}, the T_{target} is not to be judged as T_{arrest}.

1.2.14 *CAT* Determination

1 When *CAT* is determined, one "propagate" test is needed in addition to two "arrest" tests. The target test temperature (T_{target}) for "propagate" test is recommended to select 5℃ lower than T_{arrest}. The minimum temperature of T_{arrest} is judged as *CAT*.

2 With only the "arrest" tests, without "propagation" test, it is judged only that *CAT* is lower than T_{test} in the two "arrest" tests, i.e. not deterministic *CAT*.

1.2.15 Reporting

The following items are to be reported as the test results:

(1) Test material: grade and thickness

(2) Test machine capacity

(3) Test specimen dimensions: thickness t; width W and length L; notch details and length a_{MN}; side groove details if machined;

(4) Embrittled zone type: *EBW* or *LTG* embrittlement

(5) Integrated specimen dimensions: tab plate thickness, tab plate width, integrated specimen unit length including the tab plates, and distance between the loading pins, angular distortion and linear misalignment

(6) Brittle crack trigger information: impact type or double tension. If impact type, drop weight type or air gun type, and applied impact energy.

(7) Test conditions: applied load, preload stress, test stress

- Judgments for preload stress limit, hold time requirement under steady test stress.

(8) Test temperature: complete temperature records with thermocouple positions for measured temperatures (figures and/or tables) and target test temperature.

- Judgments for temperature scatter limit in isothermal region.

- Judgment for local temperature gradient requirements and holding time requirement after steady local temperature gradient before brittle crack trigger, if *LTG* systems are used.

(9) Crack path and fracture surface: tested specimen photos showing fracture surfaces on both sides and crack path side view; make at “embrittled zone tip” and “arrest” positions.

- Judgment for crack path requirement

- Judgment for cleavage trigger location (whether side groove edge or *V*-notch edge)

(10) Embrittled zone information

(a) When *EBW* is used: $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ and $L_{EB\text{-}min}$

- Judgment for shear lip thickness requirement

- Judgment whether brittle fracture appearance area continues from the *EBW* front line

- Judgment for *EBW* defects requirement

- Judgment for *EBW* length, $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ and $L_{EB\text{-}min}$ requirements

(b) When *LTG* is used: L_{LTG}

- Judgment for shear lip thickness requirement

(c) Test results:

When the specimen did not break into two pieces after brittle crack trigger, arrested crack length a_{arrest}

When the specimen broke into two pieces after brittle crack trigger,

- Judgment whether brittle crack re-initiation or not.

If so, arrested crack length a_{arrest}:

- Judgement for a_{arrest} in the valid range ($0.3W < a_{arrest} \leq 0.7W$)

Final judgment either “arrest”, “propagate” or “invalid”

(11) Dynamic measurement results: history of crack propagation velocity, and strain charge at pin chucks, if needed

1.2.16 Use of Test for Material Qualification Testing

Where required, the method may also be used for determining the lowest temperature at which steels may arrest a running brittle crack (the determined *CAT*) as the material property characteristic in accordance with **1.2.14**.

Annex K5.1.9(1) GUIDANCE FOR ULTRASONIC TESTS AND SURFACE INSPECTION OF HULL STEEL CASTINGS

1.1 Application

The requirements in this Guidance apply to ultrasonic tests and surface inspection of steel castings intended to be used for stern frames (including steel castings used as parts of built-up stern frames mainly comprising steel plates) and rudder frames (hereinafter referred to as "castings"). These requirements, however, are not applied to castings being overlaid.

1.2 Ultrasonic Tests

1.2.1 General

The manufacturer is to carry out ultrasonic tests of the castings independently in accordance with the requirements specified herein at appropriate periods after the heat treatments of the castings. The results of ultrasonic test are to be presented to the Society's Surveyor on request.

1.2.2 Flaw Detector

The ultrasonic flaw detector is, in principle, to be of reflection type with a frequency range of 1 ~ 5 *MHz*.

1.2.3 Conditions of Ultrasonic Testing

The conditions of ultrasonic testing are, as a standard, to be those specified in the following Table.

Table 1 Standard Conditions of Ultrasonic Testing

Test frequency	1 *MHz*
Working sensitivity	The echo height against the flaw of the standard test block SII show in **1.2.7** is to be 20%
Couplant	Machine oil

1.2.4 Scanning Zone

The Scanning zone is to be as shown in **Fig. 2** and **Fig. 3**.

1.2.5 Judgement

In case where continuous zone in which only flaw echoes but no bottom echoes appear is observed, information is to be made to the Society's Surveyor, except in cases caused by the configuration of a product. The Surveyor makes decision, judging generally from the results of tests using different frequency or different probe as well as the results of surface inspections specified in **1.3**.

1.2.6 Testing on Internal Surface of Boss

The testing on the inside surface of the boss is to be carried out setting the time base by using a flaw detector with high resolution and, if possible, using a double crystal probe. The method and the flaw detector for the test are to be those capable of detecting flaws existing within a depth of 20 *mm* from the scanning surface.

1.2.7 Standard Test Block

(1) Material

The material is to be of high carbon chromium bearing steel manufactured of killed steel having the chemical composition given in **Table 2** and by rolling with the forging ratio of 10 *S* or more, and being spheroidized. No residual stresses and anisotropy distorting ultrasonic beam of 1 ~ 10 *MHz* are to be existed.

(2) Ultrasonic attenuation of material

The attenuation of the material is to be not more than 5 *dB/m* for 5 *MHz*, and 20 *dB/m* for 10 *MHz*.

(3) Surface treatment

The surface A in **Fig. 1** is to be polished with the roughness of 4～6μm and to be finished with an oil stone.

(4) Size and Dimensions

The size and dimensions of the standard test block are to be as shown in **Fig. 1** and **Table 3**.

(5) Checking of the standard test block

(a) The measured values of the standard flaw are to be within the following limits of deviation from the values of the officially verified standard test block.

at 2 or 2.25 MHz ± 1 dB

at 5 MHz ± 1 dB

at 10 MHz ± 2 dB

(b) Echoes other than those from the standard flaw are to be lower more than 10 dB in the vicinity of the echoes of the standard flaw.

Table 2 Chemical Composition (%)

C	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*Cu*	*Ni*
0.95~ 1.00	0.15~ 0.35	0.50 max.	0.025 max.		1.30~ 1.60	0.08 max.	0.25 max.	

Table 3 Size of Standard Test Block (*mm*)

	l	*d*	*L*	*T*	*r*
SI	150±0.5	1±0.05	180±0.5	50±1.0	<12
SII		5.6±0.28			

1.3 Surface Inspection

1.3.1 Kind of Inspection

The surface inspections are to be composed of visual inspection and magnetic particle test.

1.3.2 Visual Inspection

The visual inspection is to be carried out over the visible surface as cast and all the machined surface.

1.3.3 Magnetic Particle Test

(1) Testing method

The test is to be carried out along two directions so that magnetic field can be directed at an right angle each other by means of the wet prod methods or the yoke method. In making magnitization by the prod method, the distance between prods is to be 200 ~ 300 *mm*. The magnetizing current is to be *DC* 800 ~ 1200 *Amp*. for the prod method and *AC* 1200 *Amp. T.* for the yoke method.

(2) Testing area

The testing area is to be as shown in **Fig. 2** and **Fig. 4**.

1.3.4 Judgement for Acceptance

(1) In cases where blowholes or sand inclusions with sizes smaller than those given in **Table 4** are detected, the product may be used without repairs.

(2) All cracks, and blowholes or sand inclusions with sizes larger than those given in **Table 4** are to be repaired in accordance with the **Annex K5.1.11(3)** “GUIDANCE FOR REPAIRING OF HULL STEEL CASTINGS”.

Fig. 1 Standard Test Block

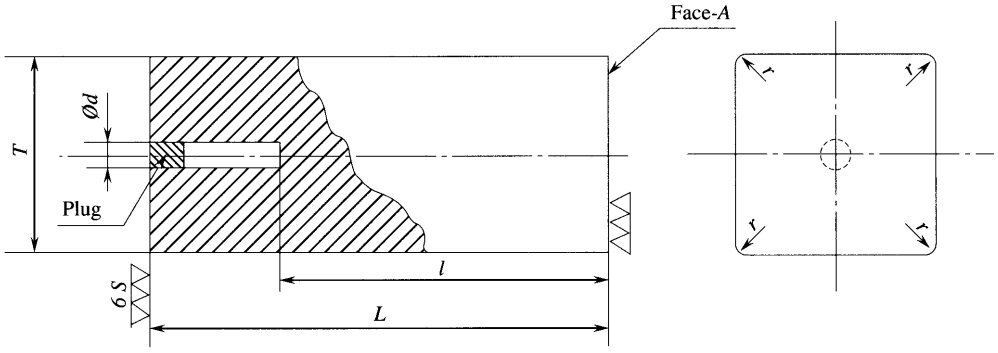
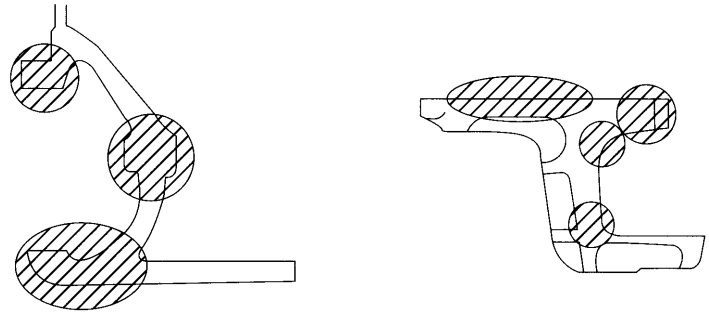
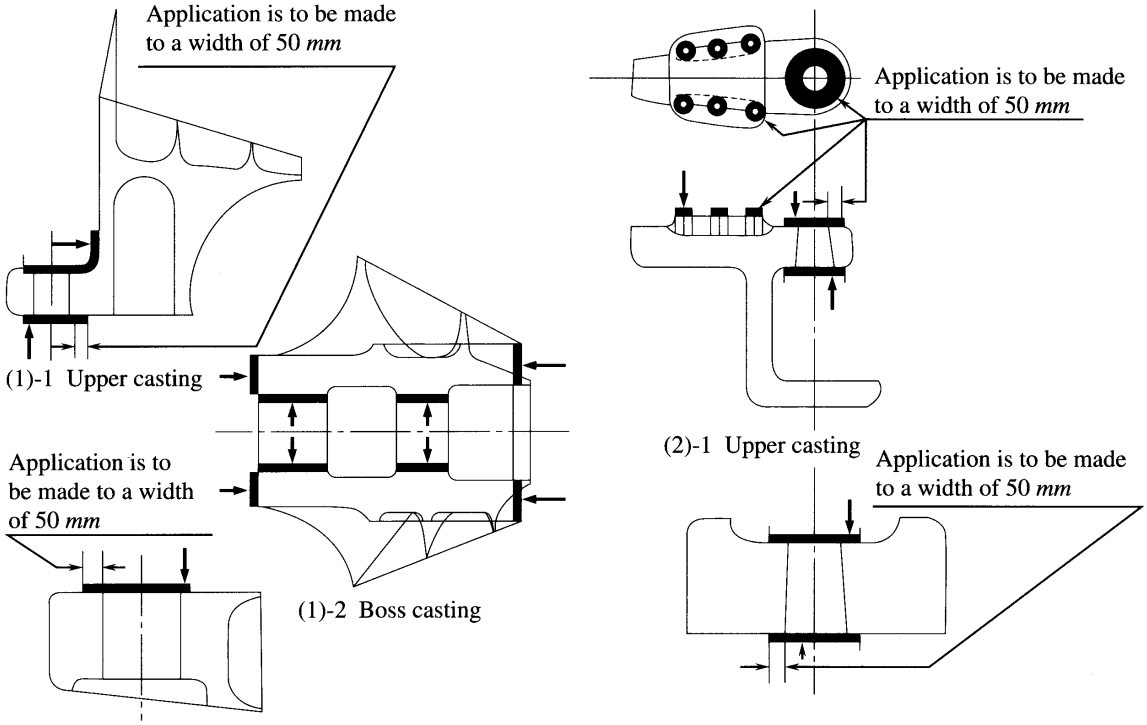


Fig. 2 Detection Area for Non-destructive Test



(1) Stern frame (2) Rudder frame

Fig. 3 Examples of Application of Ultrasonic Tests

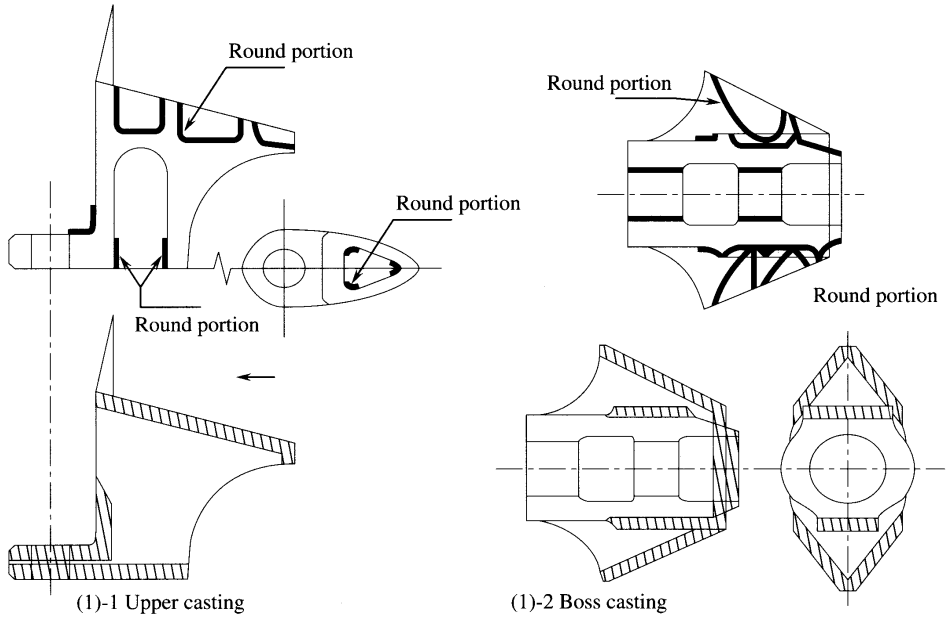


Notes:

(1) The areas shown in thick lines are to be subjected to the flaw detection.

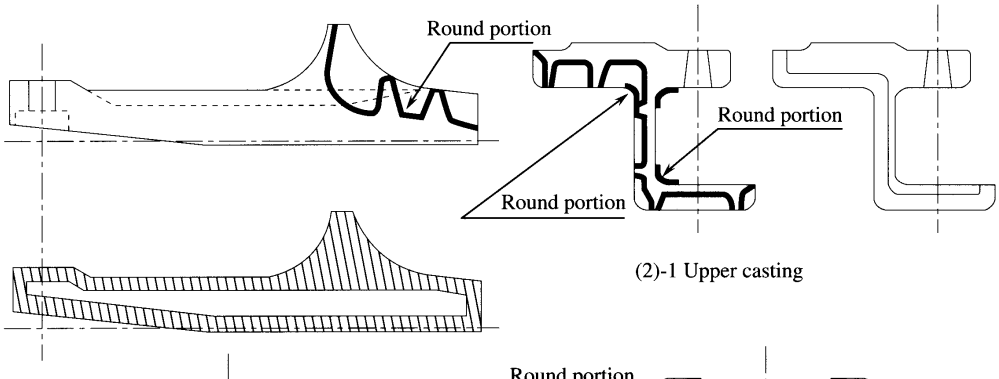
(2) The arrows show the direction of the flaw detection.

Fig. 4 Examples of Application of Magnetic Particle Tests

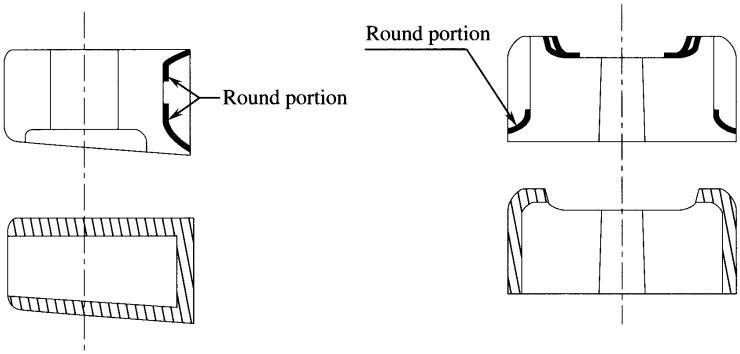


(1)-1 Upper casting

(1)-2 Boss casting



(2)-1 Upper casting



(1)-3 Lower casting

(1) Stern frame

(2)-2 Lower casting

(2) Rudder frame

Notes:

(1) The entire edge preparation shown with the hatched areas and the 100 *mm* width from the areas outside are to be subjected to the tests.

(2) The portions shown in thick lines are also to be subjected to the test.

(3) The portions of feeding heads and gates of the castings are to be subjected to the test.

Table 4 Allowable Sizes of Surface Defects(1)(2)

Detection area	Kind of defect		
	Crack	Blowhole	Sand inclusion (scaf, seizure)
Edge preparation	Not allowable	2 *mm*	Not allowable
The portions specified in **Notes (1)**, **(2)** and **(3)** of **Fig.4** and portions machined	Not allowable	4 *mm*	
Others	Not allowable	10 *mm*	

Notes:

(1) The values of defect sizes in the Table are shown as the actual size.

(2) The degree of concentration of defects is to be as considered appropriate by the Society.

Annex K5.1.9(2) GUIDANCE FOR SURFACE INSPECTION OF CRANKSHAFTS

1.1 Application

(1) This Guidance provides for the surface inspection of the crankshaft to be carried out on completion of machining (for shrunk parts, before shrinkage).

(2) The surface inspection is to be carried out by the methods specified in 1.3. Where defects were found as a result of the inspection, the Surveyor is to decide pass or rejection of the crankshaft by the standards for allowable limit of defects prescribed in 1.6.

(3) The inspection during the intermediate stage under construction is to be carried out actively by the manufacturer. The inspection methods are prescribed in 1.4.

1.2 Divisions for Inspection Surface

The inspection surface of the crankshaft is divided into the following I to IV zones as shown in Fig. 1. The inspection methods and standards are specified depending on the zones respectively.

1.3 Methods of Inspection

1.3.1 General

The surface is to be inspected as under in accordance with "Divisions for Inspection Surface" prescribed in 1.2. But where Grade *C* defects (in case of steel forgings) or *CC* defects (in case of steel castings) have been detected as a result of the inspection, the Surveyor may demand ultrasonic inspection additionally.

(1) Zone I and II: Magnetic particle inspection or dye penetrant inspection

(2) Zone III and IV: Visual inspection

Notes:

1. Regarding the parts used as forged or cast condition, it is to be subjected to magnetic particle inspection notwithstanding the above requirement.
2. Regarding the Zone III of the crankshaft to which quenching and tempering heat treatments are applied, or the same zone of the crankshaft to which surface hardening treatment is applied, it is to be subjected to either magnetic particle inspection or dye penetrant inspection notwithstanding the above requirement.

1.3.2 Magnetic Particle Inspection, Dye Penetrant Inspection and Visual Inspection

The methods of magnetic particle inspection, dye penetrant inspection and visual inspection are to be as deemed appropriate by the Society.

1.4 Inspection during Intermediate Stage

1.4.1 Ultrasonic Inspection

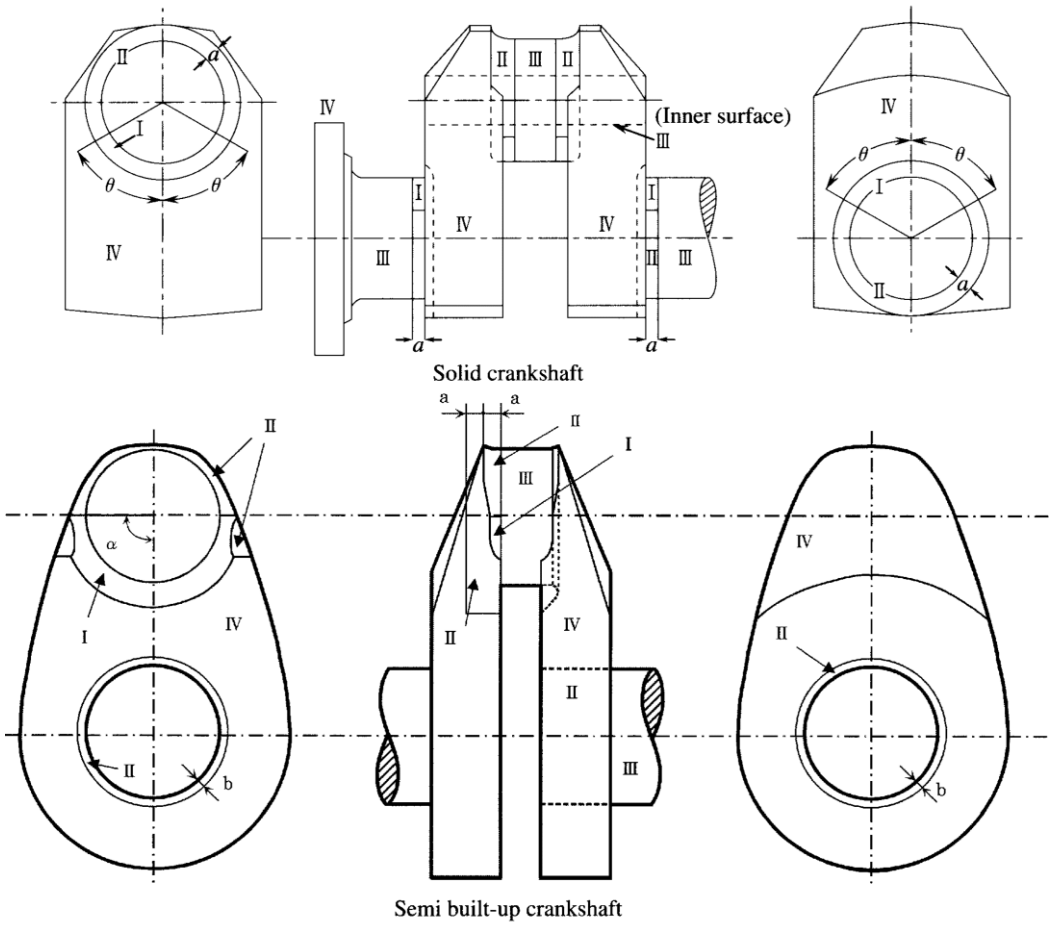
The manufacturer is recommended to carry out actively ultrasonic inspection for the crankshaft at the appropriate stage during the manufacturing process and prove that the crankshaft has no harmful defects internally.

1.4.2 Surface Inspection

The manufacturer should carry out actively the surface inspection at each stage under production. As the results when harmful defects of the material were found, the manufacturer is to inform the Surveyor of the facts and obey his instruction. Regarding cast steel crankshafts, when accepted by the Surveyor, defects can be remedied by welding according to the Annex K5.1.11(1) "GUIDANCE FOR REPAIRS BY WELDING FOR CAST STEEL CRANK THROWS". Regarding the crankshaft which surface hardening treatment is taken, the manufacturer is actively to inspect the surface. The records of surface inspection are to be submitted

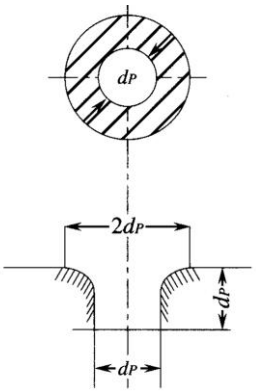
to the Surveyor when he requires.

Fig. 1 Divisions for Inspection Surface



Notes:

(1) Where the crankpin or journal has oil holes, the circumferential surface of the oil holes should be classified into division II (See the right figure).



(2) In the above figures, θ, α, a, and b are as follows:

$\theta = 60°$

$\alpha = 90°$

$a = 0.1d$

$b = 0.05d$ but not less than 25 *mm*

d : Diameter of crankshaft

1.5 Standards for Surface Inspection

1.5.1 General

When defects have been detected as a result of the surface inspection prescribed in 1.3, pass or rejection is to be decided by the following 1.6, considering the results of the inspection of 1.4. But even those which have failed to comply with these limits may be taken as passed, if in consideration with the position, size, direction and nature of the defects as well as the shape and dimension of such crankshafts, and the Surveyor accepted justifiable. Conversely, even those which have complied with these limits would be disqualified if they should contain such numerous defects as to make them unsuitable as crankshaft from the nature, distribution and direction of the defects.

1.5.2 Treatment of Defects

The treatment of defects for surface inspection is to be as the followings:

(1) The lengths of the defects in the Standards are the actual lengths appeared by visual inspection.

(2) The defects can be removed after acceptance of the Surveyor.

(3) Removal of defects is to be carried out by grinding (including scrubbing down with oil stones). However, it is recommended that for the hardened parts, the removal of defects is applied by using a hand file.

(4) Where two defects spaced less than 5 *mm* apart, these are to be removed regarding as one defect.

(5) The grooves caused by removing are to be smoothly rounded off by as large radius as possible toward the shaft surface.

(6) The size of grooves caused by removing means the size before rounding off.

(7) Regarding cast steel crankshafts, when accepted by the Surveyor, defects can be remedied by welding according to the **Annex K5.1.11(1)** "GUIDANCE FOR REPAIRS BY WELDING FOR CAST STEEL CRANK THROWS".

(8) When defects were removed, it is to be confirmed that the defects have been completely removed, by magnetic particle inspection or dye penetrant inspection.

(9) Regarding the crankshaft which defects are left and removed, the manufacturer is to make detailed inspection records and submit the same to the Surveyor. In these inspection records, the position, size, direction and nature of the defects on the inspected surface and the position and size of grooves caused by removing the defects is to be recorded.

1.6 Standards for Allowable Limit of Defects for Surface Inspection

1.6.1 Steel Forged Crankshaft

1 Application

(1) The standards are to be applied to the carbon and low alloy steel forged crankshafts which have a finished diameter not less than 100 *mm*.

(2) In order to decide pass or rejection of the crankthrow with defects, first find the crankthrow's class according to the division prescribed in **-2** and then make a decision by the standard of each class prescribed in **-4**.

(3) Defects specified in **-4** are based on the classification and designation shown in **-3**.

2 Classes of crankthrow

(1) Crankthrows are divided into the following three classes:

Class *AA*

Class *A*

Class *B*

(2) The class of a crank-throw required as a minimum is specified according to the grade of material as follows:

(a) Class *AA*: *KSF*60, *KSF*65, *KSF*70, *KSF*75, *KSF*78 or those considered equivalent thereto (excluding those for built-up crankshafts)

*KSFA*60, *KSFA*65, *KSFA*70, *KSFA*75, *KSFA*80, *KSFA*85, *KSFA*90, *KSFA*95, *KSFA*100, *KSFA*105, *KSFA*110, or those considered equivalent thereto

(b) Class *A*: *KSF*41, *KSF*45, *KSF*50, *KSF*55, or those considered equivalent thereto (excluding those for built-up crankshafts)

(c) Class *B*: *KSF*41, *KSF*45, *KSF*50, *KSF*55, *KSF*60 or those considered equivalent thereto for built-up crankshafts.

3 Classification and designation of material defects

Classification and designation of the surface defects, in the Standards, are shown in the following **Table 1** but Grade *A* defects are excluded from consideration by the standards:

Table 1 Classification of Defects

<table>
<tr><td>Classification</td><td colspan="3">Names of defects</td></tr>
<tr><td rowspan="3">Grade A defects</td><td rowspan="3">Microscopic non-metallic inclusion</td><td colspan="2">Sulfide and silicate</td></tr>
<tr><td colspan="2">Alumina</td></tr>
<tr><td colspan="2">Granular oxide</td></tr>
<tr><td rowspan="4">Grade B defects</td><td rowspan="4">Macroscopic non-metallic inclusion</td><td rowspan="3">Sand mark</td><td>Sulfide and silicate</td></tr>
<tr><td>Alumina</td></tr>
<tr><td>Granular oxide</td></tr>
<tr><td colspan="2">Sand inclusion</td></tr>
<tr><td rowspan="8">Grade C defects</td><td colspan="3">Pipe (Primary pipe and secondary pipe)</td></tr>
<tr><td colspan="3">Porosity</td></tr>
<tr><td colspan="3">Segregation crack</td></tr>
<tr><td rowspan="3">Crack</td><td colspan="2">Lap</td></tr>
<tr><td colspan="2">Network mark</td></tr>
<tr><td colspan="2">Over heating</td></tr>
<tr><td colspan="3">Heat crack</td></tr>
<tr><td colspan="3">Grinding crack</td></tr>
</table>

4 Standards

(1) [Class *AA* crankshaft]

Zone I & II: In case Grade *C* defects are detected, the crankshaft is to be rejected. Grade *B* defects are to be removed. The depth of grooves caused by such removing is to be less than 0.01 *d* (*d*: diameter of crankshaft), in this case, the fillet parts are to be so finished that the original shape is retained. Regarding the other parts, the grooves are to be so rounded off that the bottom radius of the grooves is not less than three times the depth of the grooves.

Zone III: In case that Grade *C* defects are detected, the crankshaft is to be rejected. Grade *B* defects are to be removed except those of length not exceeding 2 *mm*. The depth of grooves caused by such removing is to be less than 0.01*d*, and the grooves are to be so rounded off that the bottom radius of the grooves is not less than twice the depth of the groove.

Zone IV: In case that Grade *C* defects are detected, the crankshaft is to be rejected. Grade *B* defects are to be removed except those of length not exceeding 5 *mm*. The depth of grooves caused by such removing is to be such that it does not affect the strength of the zone, and for the depth, it is necessary to receive the Surveyor's approval.

(2) [Class *A* crankshaft]

(a) For carbon steel

Zone I: All defects detected are to be removed, and the depth of grooves caused by such removing is to be less than 0.01*d*. In this case, the grooves for the fillet part are to be smoothly rounded off so that the original shape is not impaired. Grooves for the parallel and surface parts are to be so rounded off that the bottom radius of the grooves is not less than three times the depth of the grooves.

Zone II: All defects are to be removed except the following:

(i) Dotted indications that have been detected by dye penetrant inspection, which are however several Grade *B* defects that could be discernible with naked eye only with difficulty.

(ii) Grade *B* defects of length not exceeding 2 *mm* with sufficient spacing between each two.

The depth of grooves caused by such removing is to be less than 0.01*d* and the grooves are to be so rounded off that the bottom radius of the grooves is generally not less than three times the depth of the groove, and in no case it shall be less than twice the depth.

Zone III: All defects detected are to be removed except the following:

(i) Grade *B* defects of length not exceeding 6 *mm*.

(ii) Grade *C* defects of length not exceeding 3 *mm*.

The depth of grooves caused by such removing is to be less than 0.01*d* and the grooves are to be so rounded off

that the bottom radius of the grooves is not less than twice the depth of the groove.

Zone IV: All defects detected are to be removed except the following:

(i) Grade *B* defects of length not exceeding 10 *mm*.

(ii) Grade *C* defects of length not exceeding 5 *mm*.

The depth of grooves caused by such removing is to be such that it does not affect the strength of the zone, and for the depth, it is necessary to receive the Surveyor's approval.

(b) For low alloy steel

(i) In case when Grade *C* defects were detected, whatever zones are, the crankshaft is to be rejected.

(ii) Regarding the standards in case when Grade *B* defects were detected, those for the carbon steel are to be applied correspondingly.

(3) [Class *B* Crankshaft]

(a) For carbon steel

Zone I: All defects detected are to be removed except the following:

(i) Dotted indications that have been detected by dye penetrant inspection, which are however several Grade *B* defects that could be discernible with the naked eye only with difficulty.

(ii) Grade *B* defects of length not exceeding 2 *mm* with sufficient spacing between each two.

The depth of grooves caused by such removing is to be less than $0.01d$ and the grooves are to be so rounded off that the bottom radius of the grooves is generally not less than three times the depth of the groove, and in no case it shall be less than twice the depth.

Zone II: All defects detected are to be removed except the following:

(i) Fillet part: Grade *B* defects of length not exceeding 2 *mm* with sufficient spacing between each two.

(ii) Other part: Grade *B* defects of length not exceeding 5 *mm* with sufficient spacing between each two.

The depth of grooves caused by such removing is to be less than $0.01d$ and the grooves are to be so rounded off that the bottom radius of the grooves is not less than twice the depth of the groove.

Zone III: All defects detected are to be removed except the following:

(i) Grade *B* defects of length not exceeding 6 *mm*.

(ii) Grade *C* defects of length not exceeding 3 *mm*.

The depth of grooves caused by such removing is to be less than $0.01d$ and the grooves are to be so rounded off that the bottom radius of the grooves is not less than twice the depth of the groove.

Zone IV: All defects detected are to be removed except the following:

(i) Grade *B* defects of length not exceeding 10 *mm*.

(ii) Grade *C* defects of length not exceeding 5 *mm*.

The depth of grooves caused by such removing is to be such that it does not affect the strength of the zone, and for the depth, it is necessary to receive the Surveyor's approval.

(b) For low alloy steel

(i) In case when Grade *C* defects were detected, whatever zones are, the crankshaft is to be rejected.

(ii) Regarding the standards in case when Grade *B* defects were detected, those for the carbon steel are to be applied correspondingly.

1.6.2 Cast Steel Crankshafts

1 Application

(1) The standards are to be applied to the semi built-up cast steel and full built-up crankshafts. For forged crankjournal and crankpin, the standards of Class *B* prescribed in **1.6.1-2** are to be applied.

(2) Defects specified in this standards are Grade *CC* shown in **-2**.

2 Classification of Material Defects

The surface defects are classified as the following **Table 2**, but Grade *CA* defects are excluded from consideration by the standards.

Table 2 Classification of Material Defects

Classification	Name of defects
Grade *CA* defects	Microscopic non-metal inclusion
Grade *CB* defects	Pin hole and inclusion which do not exceed 0.2 *mm* in length
Grade *CC* defects	Exceed 0.2 *mm* in length Pin-hole, blow hole sand-inclusion, slag inclusion Shrinkage cavity, Hot tear, cold crack

3 Standards

Zone I: All defects which are detected are to be removed. The depth of grooves caused by such removing is to be less than 0.01*d*. In this case, the fillet parts are to be so finished that the original shape is retained. For parallel and plane parts, the grooves are to be so rounded off that the bottom radius of the grooves is not less than three times the depth of the groove.

Zone II: All defects which are detected are to be removed, except the following defects:

(i) Defects not exceeding 1 *mm* which are not crowed.

(ii) Defects not exceeding 3 *mm* with sufficient spacing between each two.

The depth of grooves caused by such removing is to be less than 0.01d, and the grooves are to be so rounded off that the bottom radius of the grooves is not less than three times the depth of the groove, and in no case it shall be less than twice the depth.

Zone III: All defects which are detected are to be removed, except the following defects:

(i) Defects not exceeding 3 *mm* which are not crowded.

(ii) Defects not exceeding 5 *mm* with sufficient spacing between each two.

The depth of grooves caused by such removing is to be less than 0.01*d*, and the grooves are to be so rounded off that the bottom radius of the grooves is not less than twice the depth of the groove.

Zone IV: All defects which are detected are to be removed, except those not exceeding 8 *mm*. The depth of grooves caused by such removing is to be such that it does not affect the strength of the zone, and for the depth, it is necessary to receive the Surveyor's approval.

Annex K5.1.10(2) GUIDANCE FOR ULTRASONIC TESTS OF CAST STEEL CRANKTHROWS

1.1 Application

1 This Guidance applies to the ultrasonic testing of cast steel crankthrows specified in **5.1.10-1, Part K of the Rules**.

2 The ultrasonic testing in accordance with practices other than those specified in this guidance may be accepted upon special consideration by the Society.

1.2 General

1 In principle, the tests are to be carried out by the contact method with straight beam technique. Scanning depth is to be at least 0.2*d* (*d* is the crankpin diameter.).

2 Procedures of testing and performance of flaw detector other than those specified in this guidance are to be in accordance with an international or a national standard deemed appropriate by the Society.

1.3 Submission of Documents

The document of testing procedures is to be submitted in triplicate for approval. This document is to contain various information about manufacturing process of casting (the location of riser, etc.) in addition to testing procedures.

1.4 Timing of Ultrasonic Tests

The ultrasonic tests are to be carried out when the whole area of cast steel crankthrow is ready for testing after the final heat treatment to obtain the specified mechanical properties.

1.5 Performance of Flaw Detector

1 The reserving gain defined as the difference of the attenuation on the gain controller or the attenuator in the following states **(1)** and **(2)** is to be 30 *dB* or more under the measuring conditions that the pulse width is minimized at a frequency of 2 or 2.25 *MHz* with rejection being set to "0" or "OFF".

(1) A state where the sensitivity is at its maximum under condition that the electrical noise assumes 10% or less.

(2) A state where the flaw echo height of the standard test block SII specified in **1.2.7 of the Annex K5.1.9(1)** "GUIDANCE FOR ULTRASONIC TESTS AND SURFACE INSPECTION OF HULL STEEL CASTINGS" is calibrated to 50% on the graticule.

2 A length of the dead zone is to be 20 *mm* or less as a estimated distance in steel at a total sensitivity calibrated to 50% or more for the flaw echo height of the standard test block SI specified in **1.2.7 of the Annex K5.1.9(1)** "GUIDANCE FOR ULTRASONIC TESTS AND SURFACE INSPECTION OF HULL STEEL CASTINGS" at a frequency of 2 or 2.25 *MHz*. In this case, the measurement of length of the dead zone is to be taken at a position of 20% on the graticule.

3 The noise level is to be 5% or less on the graticule at a total sensitivity calibrated to 80% or more for the flaw echo height of the standard test block SI at a frequency of 2 or 2.25 *MHz*.

4 The linearity of the amplifier and of the output on CRT against input is to satisfy the following **(1)** and **(2)** when the echo from an reflection source is set near the centre on the graticule at sensitivity calibrated to 100% for the echo height with rejection being set at "0" or "OFF" at a frequency of 2 or 2.25 *MHz*.

(1) Measuring the echo height at every step of 2 *dB* by increasing attenuation up to 26 *dB*, the deviation between the reference value (%) specified in the **Table 1 of Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS" and measured value (%) for each echo height is to comply with the following formula :

$d(+), d(-) \leq 3$

where

$d(+)$ = Absolute value (%) of the positive maximum deviation between the reference value (%) and measured value (%) within 2～26 *dB* (See **Table 1 of Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS") of attenuation

$d(-)$ = Absolute value (%) of the negative maximum deviation between the reference value (%) and measured value (%) within 2～26 *dB* (See **Table 1 of Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS") of attenuation

(2) Further, it is to be verified that the echo still exists at the attenuation of 30 *dB*.

5 The linearity of the time base is to be verified by the method specified in **(1)** through **(4)**.

(1) The first 6th base echoes (excluding transmission pulse) are to be displayed on the time base, putting a probe on surface A of the standard test block given in the following **(3)** with rejection being set at "0" or "OFF" at a frequency of 5 *MHz*. These base echoes are to be denoted as B_1 to B_6.

(2) The graticule is to be divided into five equal parts on the width used for ultrasonic detection and put graduations 0 and 50, and each of the five equal parts is to be further divided into ten equal parts. The time base is to be adjusted so that the left sides of B_1 and B_6 are located to the graduations of 0 and 50 respectively. The sensitivity is to be so calibrated that the height of B_6 echo is above 50% on the graticule.

(3) Tests are to be carried out for four kinds of the standard test blocks LI, LII, LIII and LIV specified in **Fig. 1 of the Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS", respectively. The material, surface treatment, etc. of the standard test blocks are to be equal to the standard test blocks specified in **1.2.7 of the Annex K5.1.9(1)** "GUIDANCE FOR ULTRASONIC TESTS AND SURFACE INSPECTION OF HULL STEEL CASTINGS".

(4) The maximum value of a_2～a_5, which are the deviations between the left sides of the echoes of B_2～B_5 and the graduations of 10～40 respectively (See **Fig.2 of Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS"), is to be a half graduation or less.

6 The long distance resolution defined as the value of h_2/h_1 obtained from the following procedures specified in **(1)** and **(2)** is to be 30 *dB* or more.

(1) Putting a probe on the standard test block A1 specified in **Fig. 3 of Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS" at the position shown in **Fig. 4 of Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS", to display the three echoes, A, B and C on the CRT at a frequency of 2～2.25 *MHz*.

(2) Then, moving the prove back and forth to adjust the echoes form B and C in a uniform height, and measuring the value of h_2/h_1 shown in **Fig. 5 of Annex K6.1.10(1)** "GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS" by attenuator.

1.6 Reference Test Block

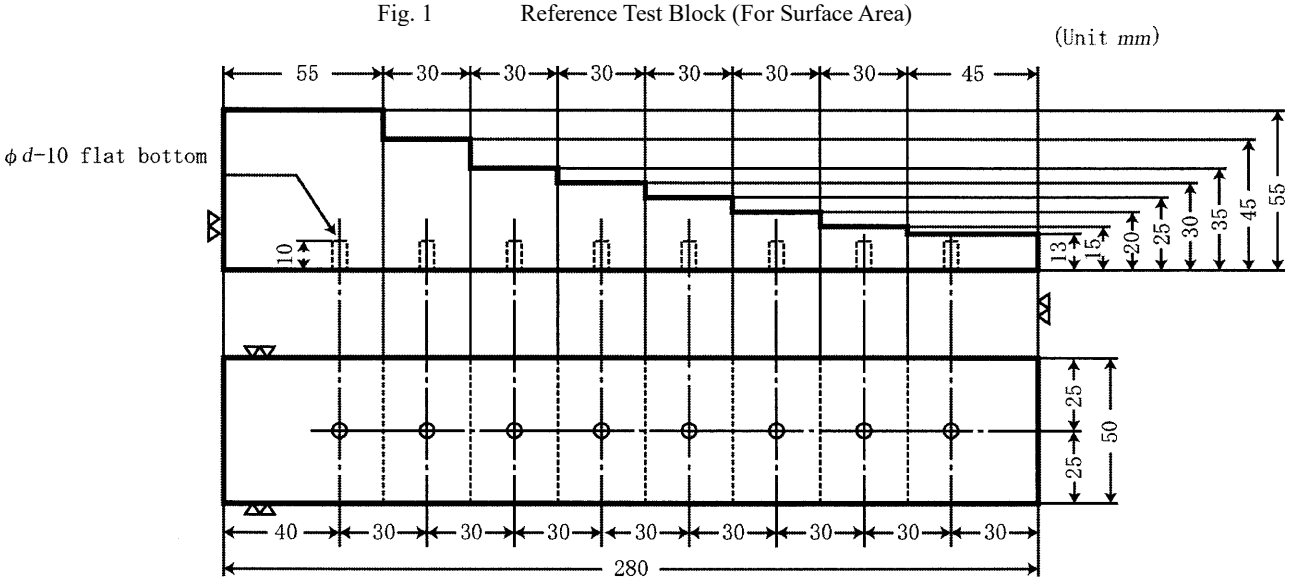
The reference test blocks are to be manufactured by the same casting process of the inspected crankthrows. The chemical composition of the reference test blocks is to be satisfied with the same standard which the inspected crankthrows are to conform to.

The size and dimension of the reference test blocks are to be as shown in **Fig. 1**, **Fig. 2** and **Table 1**.

Table 1 Size of Reference Block (For other than Surface Area)

Kind	Metal Distance B (*mm*)	Overall Length C (*mm*)	Diameter D (*mm*)
SIII-25	25	45	50 or more
SIII-50	50	70	50 or more
SIII-75	75	95	50 or more
SIII-150	150	170	75 or more
SIII-250	250	270	100 or more
SIII-B	B	B+20	125 or more

Fig. 1 Reference Test Block (For Surface Area)

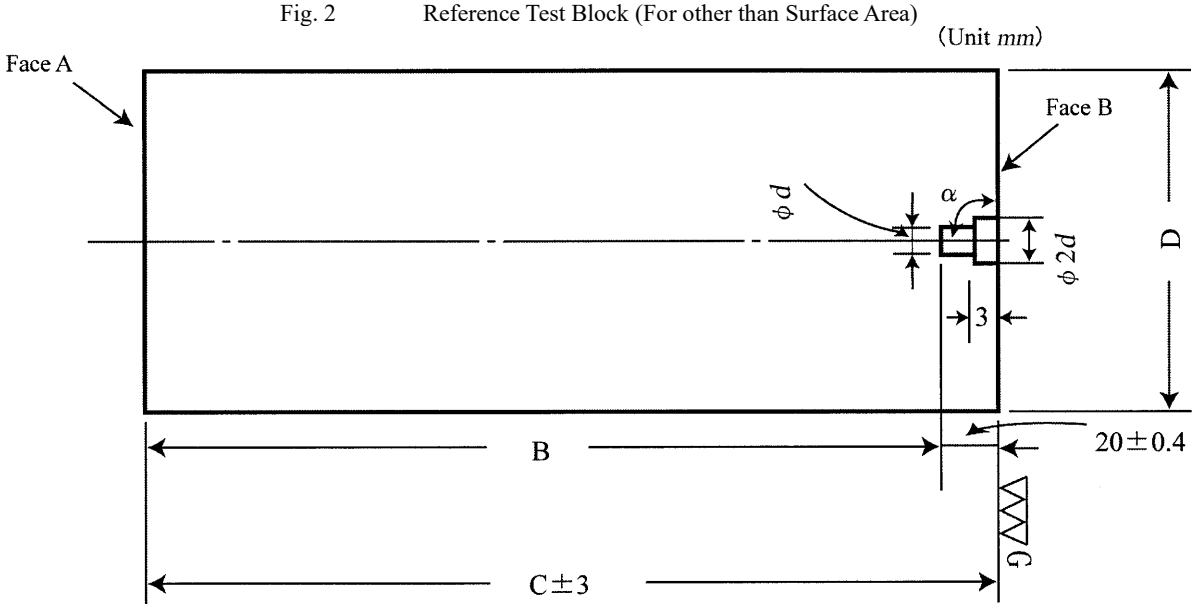


Notes:

(1) Diameter of flat bottom hole $d = \phi 2.0 \pm 0.1$ *mm* (Flatness : 0.02 *mm*)
Hole is to be straight and perpendicular to entry surface within $\pm 0.5^\circ$.

(2) Surface roughness of the reference test block is to be the same of inspected surface.

Fig. 2 Reference Test Block (For other than Surface Area)



Notes:

(1) Diameter of flat bottom hole $d = \phi 3.0 \pm 0.1$ *mm*.

(2) For flat bottom hole, perpendicularity : $\alpha = 90^\circ \pm 30'$,
eccentricity to longitudinal axis : within 0.3 *mm*, flatness : 0.02 *mm*

(3) Parallelism between Face A and Face B : within 0.03 *mm*,
perpendicularity between Face A and longitudinal axis : within 0.2°

(4) Surface roughness of Face A is to be the same of the inspected surface.

1.7 Testing Procedure

1 Scanning direction and division is to be as shown in **Fig. 3** and **Fig. 4**.

2 Probes are to be in accordance with the followings.

(1) Diameter of transducer is within 5～25 *mm* for 2～5 *MHz*.

(2) Soft protective membrane is applied to the probe.

3 Testing procedures are to be in accordance with the followings.

(1) Scanning depth of 0.05*d* or less (hereinafter referred to as the "surface area")

(a) The distance amplitude characteristic curve (hereinafter referred to as the "ARL") which is used for evaluating the size of flaws is to be drawn by the followings.

i) The maximum signal amplitude for the flat bottom hole in the reference test block shown in **Fig. 1** is to be calibrated to 80% on the graticule by use of the attenuator.

ii) Other flat bottom hole indication heights of the reference test block are marked on the graticule with the same sensitivity calibrated in **i)**, then an ARL curve is to be drawn through these marks on the graticule.

iii) If there is a portion where the height of ARL becomes 10% or less, segment ARLs are to be drawn by increased sensitivity 6 *dB* or 12 *dB* from the sensitivity calibrated in **i)** and to be marked with ARL(+6) or ARL(+12) respectively.

(b) Scanning sensitivity is to be set the same sensitivity in **a)** above.

(c) Where the surface roughness of the inspected crankthrow is different from that of the reference test block, the approximate compensation for the attenuation of the surface roughness is to be provided. The approximate compensation for the attenuation of the round surfaces is also to be provided.

(2) Scanning depth of more than 0.05*d* (other than surface area)

(a) An ARL is to be drawn by the same procedure specified in **(1)** with using the reference test blocks shown in **Fig. 2** and **Table 1**.

(b) Scanning sensitivity is to be set the same sensitivity in **a)** above.

(c) Where the surface roughness of the inspected crankthrow is different from that of the reference test block, the approximate compensation for the attenuation of the surface roughness is to be provided. The approximate compensation for the attenuation of the round surfaces is also to be provided.

4 The double transducer probe is to be used for the examination of the surface area of Zone I and II shown in **Fig. 4**.

Fig. 3 Scanning Direction

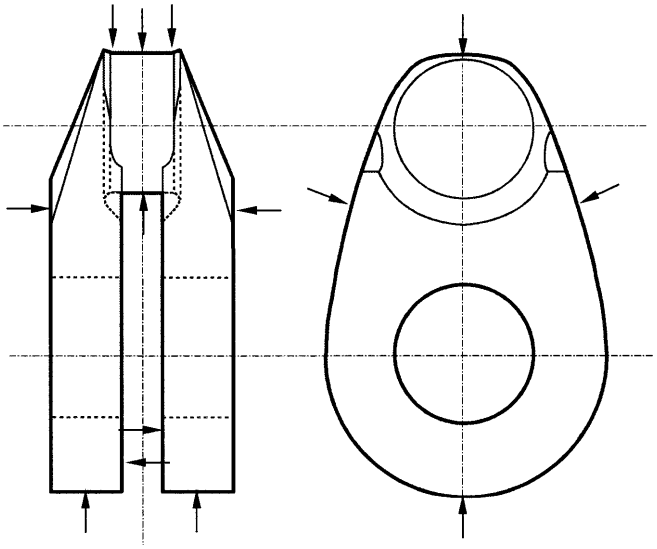
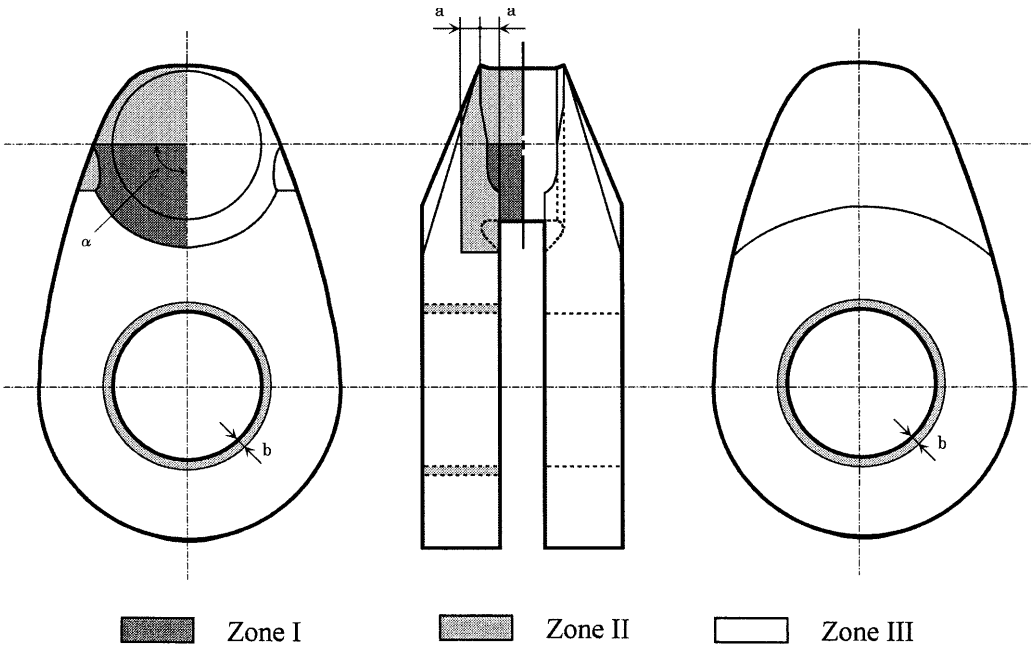


Fig. 4(a) Division of Crankthrow



Notes:

(1) In the above figure,α, a and b are as follows;

$\alpha = 90°$

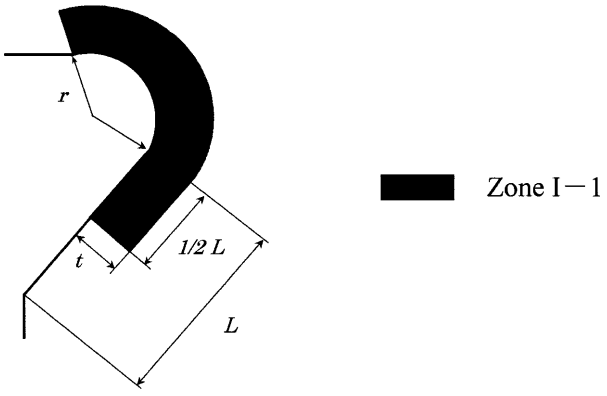
$a = 0.1d$

$b = 0.05d$

d = Diameter of pin or journal (mm)

(2) Divisions for examination may be out of this Guidance, when deemed appropriate by the Society, considering the casting process and figure of crankthrow.

Fig. 4(b) Division of Crankthrow (Pin-fillet details)



Notes:

(1) Zone I-1 is the sub-division of Zone I, and consists of the arc with radius "r" and the straight portion with a half length "1/2L" at the cross-section in the fillet between crankweb and crankpin, with depth of $t = 0.01d$ from the surface.

(2) Zone I-2 is the sub-division of Zone I other than Zone I-1.

1.8 Acceptance Criteria

1 In principle, the following crankthrows are to be rejected.

(1) Those having a flaw whose size does not comply with the acceptance criteria shown in **Table 2**.

(2) Those having an area of more than 5 cm^2 where the reduction of back reflection is 75% or more.

2 A crankthrow which is rejected in accordance with **-1** may be acceptable, provided that a detailed evaluation using other ultrasonic examination technique and/or other non-destructive tests is conducted with a result considered satisfactory by the Society.

1.9 Record

1 The following items are to be recorded as the examination results of crankthrows.

(1) Indication height and location of the flaw, of which indication height exceeds a half the maximum acceptable flaw shown in **Table 2** (It may be omitted in case the size of flaw is less than 2 *mm*.)

(2) Location, extent and other data of the area specified in **1.8-1(2)**

2 The following items are to be included in the examination results.

(1) Hull number, (2) Drawing numbers, (3) Order number, (4) Heat numbers, (5) Manufacturing number, (6) Type of steel, (7) Product name and type, (8) Sketch showing the physical outline of the crankthrow and scanning position (T and B of steel ingot are to be specified), (9) Date of examination, (10) Timing of examination, (11) Name and type of flaw detector, (12) Frequencies, (13) Kind and size of probe, (14) Surface roughness, (15) Scanning sensitivity, (16) Length of the dead zone (equivalent to a distance in steel), (17) Couplant, (18) Results of examination, (19) Name of the operator, (20) Comments and signature of the supervisor

Table 2 Acceptance Criteria

Zone		Scanning Depth t	Acceptance criteria
I	I－1	$0 < t \leqq 0.01\ d$	F.B.H. 2 *mm* or less
	I－2	$0 < t \leqq 0.2\ d$	F.B.H. 3 *mm* or less
II		$0 < t \leqq 0.05\ d$	F.B.H. 3 *mm* or less
		$0.05\ d < t \leqq 0.2\ d$	F.B.H. 5 *mm* or less
III		$0 < t \leqq 0.05\ d$	F.B.H. 5 *mm* or less
		$0.05\ d < t \leqq 0.2\ d$	F.B.H. 7 *mm* or less

Notes:

(1) The division of zone is to be in accordance with **Fig. 4**.

(2) “F.B.H.” means the diameter of flaw equivalent to flat bottom hole.

Annex K5.1.11(1) GUIDANCE FOR REPAIRS BY WELDING FOR CAST STEEL CRANK THROWS

1.1 General

(1) Where defects are discovered in the crank throws of cast steel crankshafts under manufacture (including full built-up crank webs: hereafter called, the crank throws), repairs by welding may be carried out in accordance with the following standards. However, where the depth of the depression from which all defects have been removed is not over 15 *mm* or 10 % of wall thickness, whichever is less, and will cause no appreciable reduction in the strength of the casting or affect its intended use, it is recommended that no repairs by welding be carried out. In this case, the finishing of the base part of the depression is to be such that the rounding is over three times the depth of the depression the angle between it and surface is sufficiently rounded up, and it is equal to smoothness of the adjacent surface.

(2) When the manufacturer desires to carry out repairs by welding, he shall apply in advance to the Surveyor for approval. In the case the Surveyor has found that such repairs by welding are not suitable or has perceived that there are too many places to be welded in such repairs, he will not approve the application, advising scrapping of the crank throw in question.

(3) When the manufacturer desires to carry out repairs by welding, he shall arrange in advance for the crank throw to be subjected to the preliminary tests stipulated in **1.7** below.

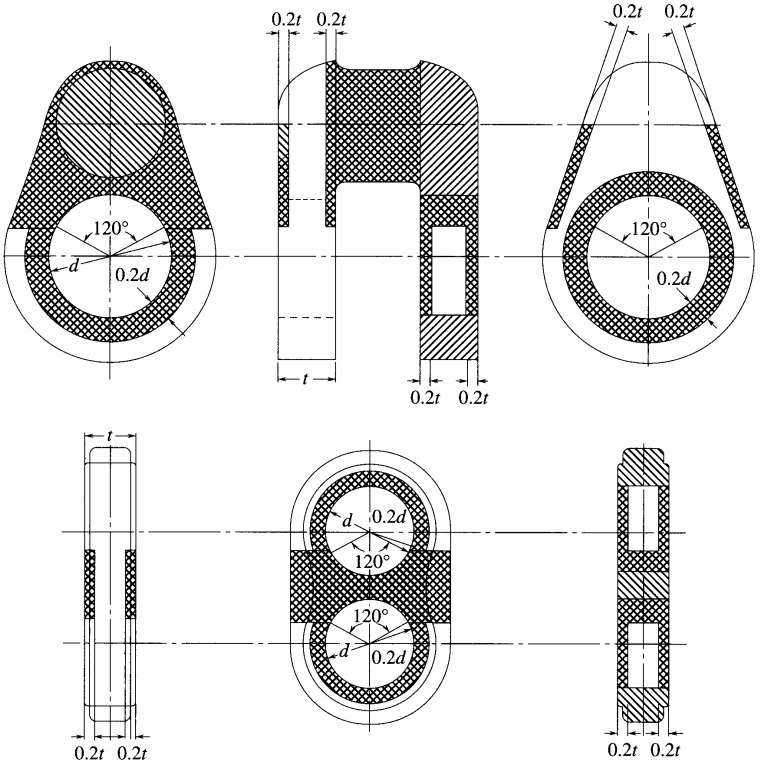
(4) Where castings are to be repaired, manufacturers are to exercise robust control over all repair operations with respect to dimensions, heat treatment, inspection and quality control.

1.2 The Scope and Conditions Permitting Repairs

(1) Repairs by welding are not to be carried out at the base part of the pin and web as well as the cross-hatched zones marked on **Fig. 1**.

(2) The depth of the depression from which all defects have been removed is to be less than 0.1t.

Fig. 1 Zones where Repairs of Welding Should Not be Carried Out



1.3 Timing for Repairs

Repairs by welding are to be carried out before the crank throws being given a formal heat treatment. However, when approved by the Surveyor, the weld repairing of comparatively minor defects may be carried out after the formal heat treatment.

1.4 Methods of Repairs

Repairs by welding are to be carried out in conformity with the requirements of the following items:

(1) Welder

The welder engaging in repairs shall be the one who has passed the qualification tests of this Society and who has further had the experience in the preliminary tests stipulated in **1.7** below.

(2) Removal of defects

After defects have been removed by grinding or gouging, the depression is to be made shapely so as to fit for welding; while it is to be confirmed that the defects have been completely removed by means of the magnetic particle inspection or dye penetrant inspection.

(3) Preheating

The part undergoing the weld repairing and its neighbourhood are to be preheated to temperatures exceeding 200℃.

(4) Welding process

Welding is to be the downhand electric arc welding.

(5) Electrode

The low hydrogen electrode approved by the Society is to be used.

(6) Post heating

On completion of welding the crank throws are to be heat-treated as specified, but those heat-treated formally previous to repairs by welding with the approval of the Surveyor may require the annealing process only used 600～650℃ for stress relief.

(7) Finish after repairs

The repaired part is to be finished smoothly by grinding.

1.5 Inspection after Repairs

It is to be confirmed by means of the magnetic particle inspection that the welded part and its neighbourhood are free from harmful defects.

1.6 Records

The manufacturer is to make a documentation of the records including sketches of the positions and dimensions of the welded repairs, methods of repairs, details of the heat treatment and inspection results for submission to the Surveyor.

1.7 Preliminary Tests

The manufacturer shall arrange for the following preliminary tests to be given before repairs by welding; provided however except the cases where change has been made in the material used, welding conditions or welders or where the Society has recognized the necessity specifically, these tests need not be repeated on every occasion.

(1) Mold cavity weld test

(a) Test piece: Material is to be of same quality as that of the crank throw.

(b) Shape of test piece and procedures of repairs by welding: The dimensions of test piece are to be as shown in **Fig. 2**. The cavities are model as shown in the figure and then padding welding is carried out.

i) Sizes of cavities: Proper sizes permitting free operation of electrode.

ii) Distribution of cavities: Distribution of cavities and distance of each cavity from the edge of test piece is to be such

that these simulate the actual condition in the crank throw to be welded.

iii) Welding process: To be same as in the actual welding.

iv) Electrode: To be the same as in the actual welding.

v) Pre-heating and post-heating: To be similar heat treatments to those applied for the crankthrow.

(c) Tests:

Macrostructure test: After heat treatment, the test piece is to be cut so that the welded part is included, for the purpose of confirmation that the root of welding is well penetrated and there is not any crack.

Hardness test: It is to be confirmed that there are no changes in the hardness of the weld metal, base metal and the boundary part between them.

Microstructure: It is to be confirmed that there are no abnormality in the structure of the weld metal, base metal and boundary part between them.

(2) Butt weld test

(a) Test assembly: Material of same quality with the crank throw.

(b) Shape of test assembly and main point of repairs by welding: Dimensions and shape of test assembly are shown in **Fig. 3**. The welding conditions and heat treatment are same as in **(1)** above.

(c) Test: Each two test pieces are to be prepared for tension test and bending test respectively as shown in **Fig. 4** from the test assembly described in **Fig. 3**.

i) Tensile test: Tensile test is to be carried out with the welded metal positioned at the center of the gauge length. The value obtained is not to be less than the specified minimum value of the base metal.

(Test piece dimension = 14 *mm*ϕ × 70 *mm*ℓ)

ii) Bending test: Bending test is to be carried out with the welded metal positioned at the center of test piece and bent to 180 degrees with the inside radius of 25 *mm*. It is to be confirmed that no defects have appeared in the welded part and heat affecting part.

(Test piece dimension = 25 *mm* × 19 *mm* × any given length)

Fig. 2 Dimensions and Shape of Test Piece

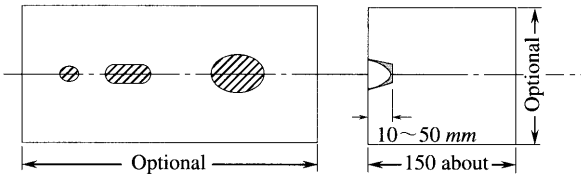


Fig. 3 Dimensions and Shape of Test Assembly

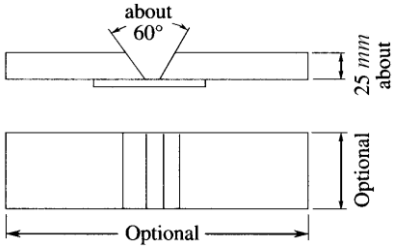


Fig. 4 Test Assembly

		*
		T
		B
		B
		T
		*

Note:

T : Test piece for tensile test

B : Test piece for bending test

* : Discard

Annex K5.1.11(3) GUIDANCE FOR REPAIRING OF HULL STEEL CASTINGS

1.1 Application

1 For stern frame, rudder frame and other carbon steel castings intended to be used for important structural hull members (hereinafter referred to as "steel castings"), repairing of defects is to be in accordance with this Guidance.

2 In cases where, after removing defects, steel castings are either used as they are or repair weldings are made, surveyor approval is to be obtained. In cases where the depth of the recess after removing defects is not larger than 15 *mm* (or 10 % of the thickness of the steel castings, whichever is smaller) and the length is not more than 100 *mm*, the steel castings may be used without repair welding. In such cases, however, there is to be no appreciable reduction in the strength of the casting and its intended use is not to be affected.

1.2 Methods of Repairing

Defects are to be completely removed either by scarfing, gouging, chipping, grinding or machining, and to be repaired by either of the following methods:

(1) In the case of no repair welding being carried out

Portions requiring no repair welding after removing defects are to be finished with a grinder or other means in accordance with the following:

(a) The bottom of the groove is to be rounded with a radius greater than three times the depth.

(b) Grooves and their vicinity are to be finished smoothly avoiding abrupt changes in configuration.

(c) The portions where defects have been removed are to be verified that they are free from harmful defects by liquid penetrant test or magnetic particle test after finishing of the surface configuration.

(2) In case of repair welding being carried out

The portions required to be repaired by welding are to be suitably ground and verified that they are free from harmful defects by nondestructive tests specified in **-1(3)** above. The procedure of repair welding is to be as follows.

(a) Welders

Welders to be engaged in repair work by welding are to pass the qualification tests of the Society.

(b) Welding consumables

The welding consumables are to be either of low-hydrogen type approved by the Society or those deemed equivalent.

(c) Preheating

i) In cases where the carbon equivalent C_{eq} (*JIS*) of the steel castings exceeds 0.44%, the portions of repair welding and their vicinity are to be preheated to a temperature higher than 200℃. In this case, the carbon equivalent C_{eq} (*JIS*) is to be calculated by the following formula

$$C_{eq}(JIS) = C + \frac{Mn}{6} + \frac{Si}{24} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{V}{14}(\%)$$

ii) Even in case where carbon equivalent C_{eq} (*JIS*) is 0.44% or less, preheating may be required taking into account the shape and size of the steel castings.

(d) Position of welding

The positions of welding are to be as given in the following **Table 1** in general.

(e) Post weld heat treatment

i) Post weld heat treatment may be exempted in the following cases, provided that the carbon equivalent C_{eq} (*JIS*) does not exceed 0.44%.

1) In case where the depth of chipping after the removal of defects is not more than 25 *mm* (or 20% of the thickness, whichever is smaller) and the length is not more than 200 *mm*.

2) In cases where the depth of chipping after the removal of defects is not more than 15 *mm* and also the area is not more than 250,000 mm^2.

ii) Post weld heat treatment is to be carried out in furnaces. The holding temperature is to be 550～650℃ and the period is to be not less than one hour per every 25 *mm* of welding depth. In case where annealing in furnace is impossible depending on the final condition of the steel castings to be finished, etc. or where the welding depth is not more than 50 *mm* as well as the length is not more than 300 *mm*, partial post weld heat treatment may be accepted as an alternative. By the partial post weld heat treatment, the welded portions and their vicinity within 100 *mm* therefrom are to be heated to a temperature not lower than 600℃ and kept at the temperature in a period not less than 10 minutes per every 25 *mm* of the welding depth, and then to be cooled gradually.

(f) Finishing after repair welding

The portions repaired by welding are to be finished by grinding, etc. so that inspection can be available.

(g) Inspection after repair welding

The soundness of the portions repaired by welding and their vicinity is to be verified by appropriate non-destructive tests.

Table 1 Position of Welding

Kind	Position of welding			
	Flat	Vertical	Horizontal	Overhead
Manual welding	○	○	○	○
Semi-automatic welding	○		○	

Annex K6.1.9(2) GUIDANCE FOR SURFACE INSPECTION OF STEEL FORGINGS (EXCEPT FOR CRANKSHAFTS)

1.1 Application

(1) This Guidance applies to the surface inspection of carbon steel forgings (excluding crankshafts) specified in **6.1.9** and **6.1.10-1(2) of Part K of the Rules**.

(2) The surface inspection of crankshafts is to be in accordance with the **Annex K5.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF CRANKSHAFTS."

(3) To steel forgings other than those concretely specified in this Guidance, the requirements in this Guidance are to apply correspondingly considering their kinds, shapes and stress conditions being subjected.

1.2 Divisions of Inspection Surfaces

The surfaces to be inspected are divided into some zones as specified in the following **Table 1**, according to the kind of steel forgings.

Table 1 Divisions of Surface Inspection

Kind	Divisions
Propeller shaft	3 Divisions of zone I, III and IV in **Fig. 1 (a)**
Intermediate shaft, thrust shaft	2 Divisions of zone III and IV in **Fig. 1 (b) (c)**
Connecting rod, piston	3 Divisions of zone I, III and IV in **Fig. 1 (d)**
Crosshead	2 Divisions of zone III and IV in **Fig. 1 (e)**
Various bolts (1)	2 Divisions of zone I and III in **Fig. 1 (f)**
Rudder stock	2 Divisions of zone III and IV in **Fig. 1 (g)**

Note:

(1) Those bolts subjected directly to fluctuated loads as cylinder cover bolts, tie rods, crankpin bolts, main bearing bolts, etc.

1.3 Timing of Inspection

The surface inspection is to be carried out after the completion of finishing processes by machining. In case where shrinkage fit of sleeves is applied, the inspection is to be carried out before the fitting.

1.4 Methods of Inspection

(1) The following surface inspections are to be carried out according to "Divisions of Inspection Surfaces" specified in **1.2** above.

Zone I : Magnetic particle test or liquid penetrant test

Zone III and IV : Visual inspection

Note:

The portions where surface hardening treatments have been carried out or where surfaces are as forged in such a case of

connecting rods, etc., are to be subjected to magnetic particle tests or liquid penetrant tests notwithstanding the requirements above.

(2) The methods of magnetic particle test, dye penetrant test and visual inspection are to be as deemed appropriate by the Society.

1.5 Standards for Surface Inspection

(1) In case where defects are detected as the result of the surface inspection specified in **1.4**, pass or rejection is to be decided by the following **1.6**, considering the results of ultrasonic test and other available examinations. Even in cases of failure in meeting the acceptance criteria specified in **1.6**, consideration may be given by taking into account the location, size, direction and nature of the defects, also the shape and dimensions of the steel forgings. Conversely, even in cases of meeting the acceptance criteria, those with a lot of defects considered to be inadequate as a product due to the nature, distribution and direction of defects can be rejected.

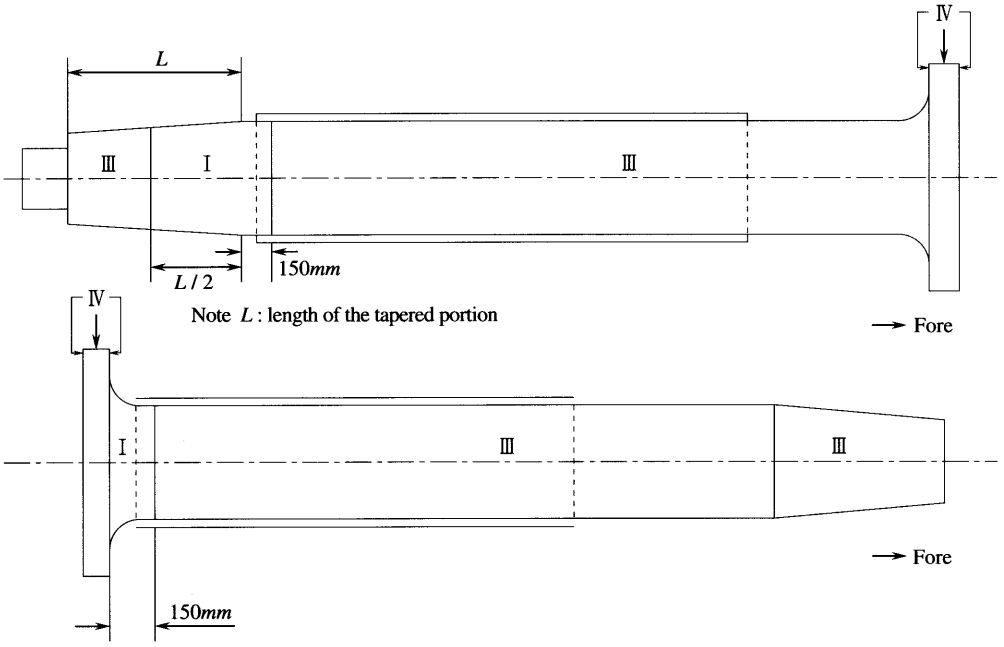
(2) The treatment of defects for surface inspection are to be in compliance with the **Annex K5.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF DIESEL ENGINE CRANKSHAFTS" referred to in **1.5.2**.

(3) The classification of defects for surface inspection are to be in compliance with the **Annex K5.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF DIESEL ENGINE CRANKSHAFTS" referred to in **1.6.1-3**.

1.6 Acceptance Criteria

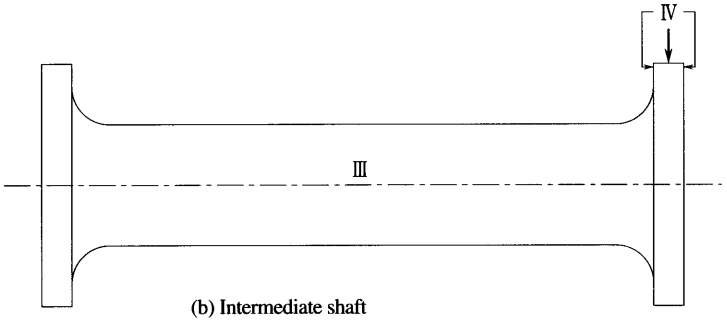
The acceptance criteria for surface inspection are to be in accordance with **Table 2**.

Fig. 1 Divisions of Surfaces Inspection

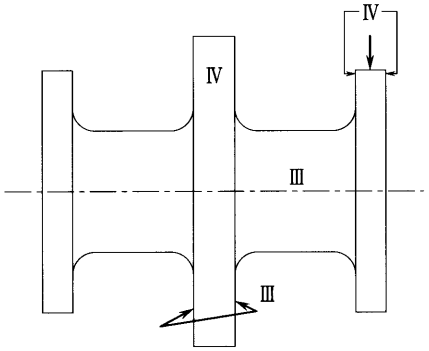


The inside surface of a hollow shaft is to be dealt with as zone Ⅲ

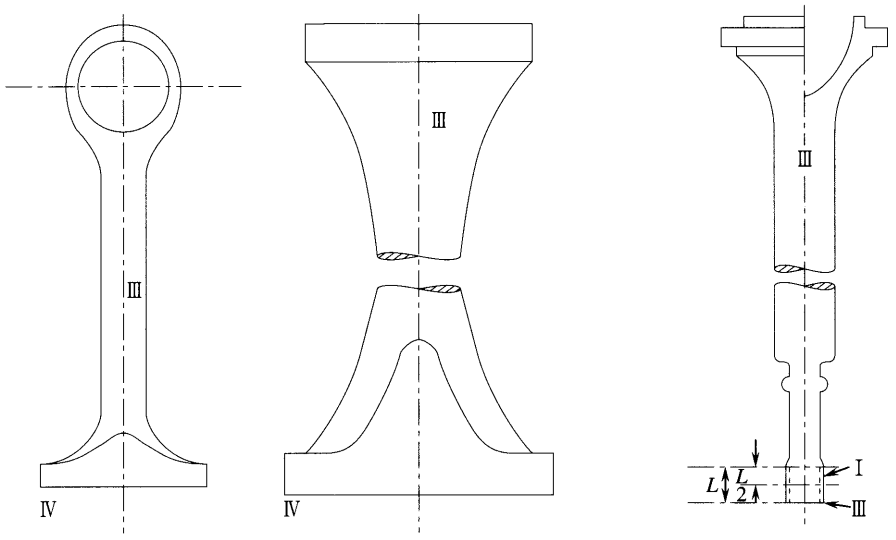
(a) Propeller shaft



(b) Intermediate shaft

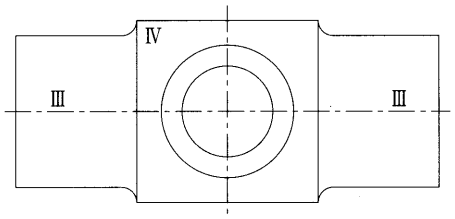


(c) Thrust shaft

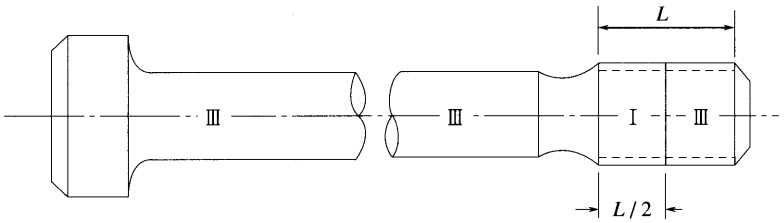


(d) Connecting rod and piston rod

L : length of thread

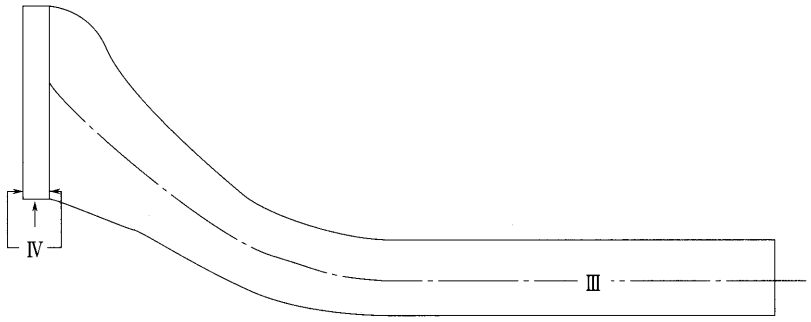


(e) Crosshead



L : length of thread

(f) Bolt



(g) Rudder stock

Table 2 The Acceptance Criteria for Surface Inspection

Item	Scope of Application	Zone I	Zone III	Zone IV
Propeller Shaft	100 *mm* or more in diameter	All defects detected are to be removed. The depth of grooves after the removal of defects is to be not more than 0.01 *d* (1.5 *mm* max.) and to be finished round at the bottom with a radius twice the depth of the groove. (*d*: diameter of the propeller shaft)(1)(2)	All defects detected are to be removed excluding those of Grade *B* not more than 10 *mm* in length. The depth of grooves after the removal of defects is to be not more than 0.01 *d* (3 *mm* max.), and to be finished round at the bottom with a radius twice the depth of the groove. (*d*: diameter of the propeller shaft)(2)(3)	All defects detected are to be removed excluding the followings: (i) Defects of Grade *B* not more than 20 *mm* in length (ii) Defects of Grade *C* not more than 10 *mm* in length: The repairing is to be within the extent permissible in respect of the strength, and the approval of the Surveyor is to be required
Intermediate shaft, Thrust shaft, Rudder stock		—	All the defects detected are to be removed excluding the followings. (i) Defects of Grade *B* not more hen 10 *mm* in length (ii) Defects of Grade *C* not more than 5 *mm* in length The depth of the groove after the removal of the defects is to be not more than 0.01 *d* (3 *mm* max.) finished round at the bottom of grooves with a radius more than twice the depth of the groove. (*d*: diameter of intermediate shaft, thrust shaft or connecting rod, etc.)	
Connecting rod, Piston rod	75 *mm* or more in diameter of rod	To be free from any defects		
Crosshead	All	—	To be free from any defect other than those disappear by slight lapping with oil stone. The slight defects given above can be removed using oil stone under the Surveyor's acceptance.	
Various bolts	50 *mm* or more in diameter	—	All defects detected are to be removed excluding those of Grade *B* have a length not more than 0.1 *d* in the longitudinal direction. The depth of the groove after the removal of the defects is to be not more than 0.01 *d*, and to be finished round with a radius not smaller than twice the depth around the bottom corners. (*d*: diameter of bolt)	

Notes:

(1) In the vicinity of the big end of tapered part of propeller shaft, the reduction in contact area with the propeller boss due to removal of defects is to be such that the arc length of noncontacting is not more than 5% of the circumference length in any cross section of the shaft.

(2) Repairs of the propeller shaft in way of the sleeve end are to be of those accepted by the Surveyor.

(3) The permissible limit of residual defects at the threaded portion and the repairs are to be of those accepted by Surveyor.

Annex K6.1.10(1) GUIDANCE FOR ULTRASONIC TESTS OF STEEL FORGINGS

1.1 Application

(1) This Guidance applies to the ultrasonic testing of steel forgings such as crankshafts, propeller shafts, intermediate shafts, turbine rotor shafts, rudder stocks and pintles specified in **6.1.10-1, Part K of the Rules** (hereinafter referred to as the "steel forgings").

(2) To steel forgings other than those concretely specified in this Guidance, the requirements in this Guidance are to apply correspondingly in consideration of their kind, shapes and stress conditions being subjected.

1.2 Timing of Ultrasonic Tests

The ultrasonic testing is to be carried out at such time when the whole area of steel forgings is ready for testing after the final heat treatment to obtain the specified mechanical properties. For turbine rotor shafts, positions where taper grinding is to be done are, in principal, to be step milled (to a rectangular shape) first and then flaw detected. When the ultrasonic testing is not available after the final heat treatment due to product shape processed by such as machining of grooves between disks, etc. before the final heat treatment, the testing is to be carried out before the process and also after completing the heat treatment on the whole area as far as practicable.

1.3 Flaw Detector Performance

Ultrasonic flaw detectors are to conform to national standards or such standards considered appropriate by the Society (e.g., *JIS Z* 2344("General rule of ultrasonic testing of metals by pulse echo technique")) and, in addition, are to comply with the following requirements:

1.3.1 Gain Controllers or Attenuators

Gain controllers or attenuators are to be built-in or connected to flaw detectors. The amount of adjustment for a single step is to be 2 *dB* or less and the total amount of adjustment is to be 70 *dB* or more.

1.3.2 Margin of Sensitivity

The margin of sensitivity is to be calibrated in accordance with *JIS Z* 2352 ("Method for evaluating performance characteristics of ultrasonic pulse-echo testing systems") at a frequency of 2 or 2.25 *MHz* and to be 30 *dB* or more.

1.3.3 Amplitude Linearity

Amplitude linearity is to be calibrated in accordance with *JIS Z* 2352 ("Method for evaluating performance characteristics of ultrasonic pulse-echo testing systems") at a frequency of 2 or 2.25 MHz and to be within ±3%.

1.3.4 Linearity of Time Base

Linearity of time base is to be calibrated in accordance with *JIS Z* 2352 ("Method for evaluating performance characteristics of ultrasonic pulse-echo testing systems") and to be within ±1%.

1.3.5 Far Surface Resolution

Far surface resolution is to be within 9 *mm* calibrated by a RB-RA type reference block in accordance with *JIS Z* 2352 ("Method for evaluating performance characteristics of ultrasonic pulse-echo testing systems").

1.3.6 Distance Amplitude Characteristics

Flaw detectors are to have distance amplitude characteristics such that the echo heights from standard artificial flaws (drilled hole: diameter 3 *mm*×length 30 *mm*) do not deviate over the allowance shown in **Fig. 1** and **Table 1** at a frequency of 2 or 2.25 *MHz* and at a test distance range from 50 to 500 *mm*. Standard artificial flaws are to be provided in test pieces whose material is to be normalized KSF 45 ~ KSF 55 without macro-segregation with acoustic uniformity. An example of such a test piece is shown in **Fig. 2**. When materials other than those above are used, acoustic characteristics are to be considered. Diagrams of distance amplitude

characteristics are to be prepared in advance and available to be submitted if necessary.

Fig. 1 Distance Characteristic of Echo Height from Standard Artificial Flaw

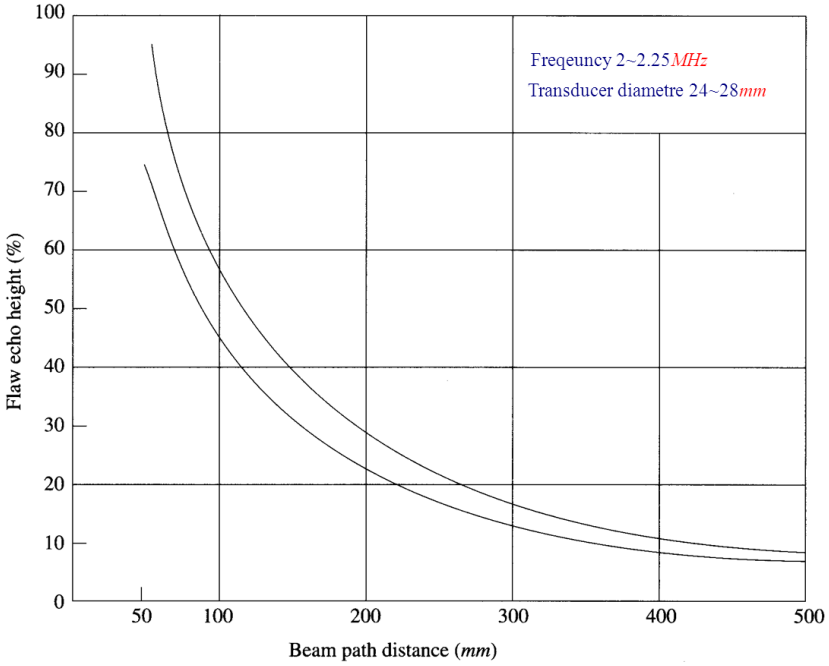
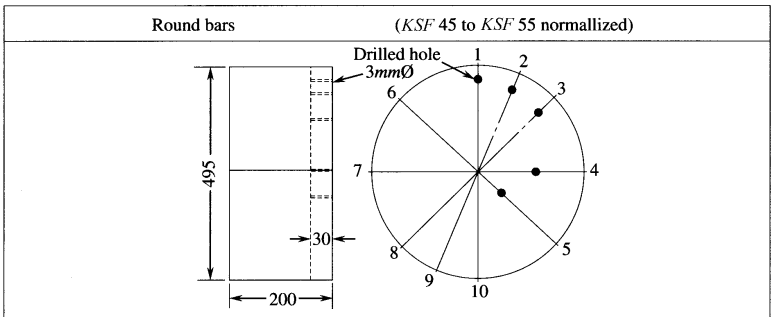


Table 1 Distance Characteristic of Echo Height from Standard Artificial Flaw

Beam path distance (*mm*)	Flaw echo height	
	Allowable range	
	Upper limit (%)	Lower limit (%)
50	95	75
100	55	45
200	28	22
300	17	13
400	11	9
500	8	7

Fig. 2 Test Piece for Measuring Distance Amplitude Characteristic (Including Artificial Flaw)



Flaw No.	1	2	3	4	5	6	7	8	9	10
Beam path distance (*mm*)	25	50	100	150	200	295	345	395	445	470

1.4 Testing Procedure

The testing procedure is to be as given in **Table 2**.

Table 2 Ultrasonic Testing Procedures

<table>
<tr><th>Item</th><th>Scanning zone</th><th>Roughness of scanning surface(1)</th><th>Contact medium</th><th>Probe(2)</th><th>Scanning sensitivity</th><th>Evaluation sensitivity(3)(4)</th><th>Scanning method(5)</th></tr>
<tr><td>Crank shaft</td><td>Whole surface (See Fig. 3)</td><td>Pin and journal parts: approx. 6.3 μmRa or 25 μmRz (finished surface by spring-necked turning tool)
Arm parts: Approx. 8.8 μmRa or 35 μmRz</td><td rowspan="5">Machine oil or oil medium which has the equivalent viscosity.(7)</td><td rowspan="5">Frequency:
2 ~ 2.25 MHz
Transducer diameter:
20~28 mm</td><td rowspan="4">The scanning sensitivity is to be set by increased by 6 dB, after being calibrated the evaluation sensitivity.</td><td rowspan="4">The evaluation sensitivity is to be calibrated on each scanning section so that the first bottom echo height from an sound area is to be adjusted to 80% on the graticule.</td><td>Scanning speed is to be less than or equal to 150 mm/s by hand and scanning is to be over lapped more than or equal to 25% of the transducer diameter</td></tr>
<tr><td>Propeller shaft, intermediate shaft, thrust shaft</td><td>See Fig. 4</td><td rowspan="3">Approx. 12.5 μmRa or 50 μmRz</td><td rowspan="3">Scanning speed is to be less than or equal to150 mm/s</td></tr>
<tr><td>Connecting rod, piston rod, crosshead</td><td>See Fig. 5</td></tr>
<tr><td>Rudder stock, pintle</td><td>See Fig. 6</td></tr>
<tr><td>Turbine rotor shaft</td><td>Whole External Surface(6)</td><td>Approx. 6.3 μmRa or 25 μmRz (finished surface by spring-necked turning tool)</td><td colspan="2">The sensitivity is to be calibrated on each scanning section so that the first bottom echo height from a sound area is to be adjusted to 100% of the graticule, and then increased by the gain controller or attenuator by a multiplier shown in Fig.7 according to the outside diameter and the centre bore diameter of each scanning section.</td><td>Scanning speed is to be less than or equal to 150 mm/s by hand and scanning is to be over lapped more than or equal to 25% of transducer diameter</td></tr>
</table>

Notes:

(1) Scanning surface is not to be covered with anything (gauges, chips, paints, etc.) that hinders proper flaw detection.

(2) Soft-faced probes may be to be used if necessary.

(3) If the bottom echo with required height cannot be obtained due to configuration of the bottom surface, the evaluation sensitivity may be calibrated on a position having the similar dimension.

(4) The pulse width is to be adjusted to the minimum at the required sensitivity, and rejection is to be set to “0” or “OFF”.

(5) The proximity of steel forgings (except turbine rotor shafts) is to be detected again by evaluation sensitivity when abnormal echoes are detected during scanning evaluations by scanning sensitivity. Scanning techniques or conditions may be changed as needed in order to identify the causes of abnormal echoes and obtain information needed for final evaluation.

(6) Axial scanning may be conducted as needed.

(7) Contact mediums are to be equivalent to the *ISO VG* 46~100 specified in *JIS K* 2238.

1.5 Evaluation

1.5.1 Divisions

The scanning zone is divided as given in **Table 3** according to the item of products.

Table 3 Divisions for Each Item

Item	Division
Crankshaft	Three divisions of zone I, II and III shown in **Fig. 3**
Propeller shaft, intermediate shaft, thrust shaft	Two divisions of zone II and III shown in **Fig. 4**
Connecting rod, piston rod, crosshead	Two divisions of zone II and III shown in **Fig. 5**
Rudder stock, pintle	One division of zone III shown in **Fig. 6**
Turbine rotor shaft	One division of I for the whole zone

1.5.2 Acceptance Criteria

(1) Crankshafts or turbine rotor shafts, are to be rejected when indications equal to or exceeding the bottom echo height are detected in the zone I, or when the bottom echo height becomes 10% or less on the graticule due to other than geometric configurations in all zones.

(2) Other products than **(1)** are to be rejected when the bottom echo can not be obtained due to other than geometric configurations.

(3) In addition to the above requirements, when indications are detected, acceptance or rejection is to be decided according to **Table 4**.

(4) When indications which do not comply with the acceptance criteria given in **Table 4** are detected, the evaluation is to be made from overall judgments through the results of detections by using different frequencies and probes, non-destructive testing, etc. and especially, for turbine rotor shafts, the following items:

(a) Estimation of the size of flaws by taking into account the factors as attenuation and direction of flaws, etc.

(b) Investigation on degree of cluster of flaws

(c) Detections by other frequencies

(d) Calculation of critical flaw size in relation to working stresses at the location of flaws and fracture toughness of the material, etc.

Table 4 Acceptance Criteria

Item	Criteria diagram	Zone		Acceptance criteria
Crankshaft	Fig. 8(1)	I	Class *AA* and Class *A*(2)	No indications
			Others(2)	Reference line I-2 or less
		II		Reference line II-2 or less
		III		Reference line III-2 or less
Propeller shaft, intermediate shafts, thrust shaft	Fig. 9(1)	II exterior part(3)		Reference line II-1 or less
		III exterior part(3)		Reference line III-1 or less
Rudder stock, pintle, connecting rod, piston rod, crosshead	Fig. 9(1)	II		Reference line II-1 or less
		III		Reference line III-1 or less
Turbine rotor shaft	Fig. 10	I		An isolated flaw indication(4): Reference line II-2 or less
				Clustered flaw indication(4): Reference line I-2 or less

Notes:

(1) The evaluation of indications detected in a range of not more than 50 *mm* or not less than 500 *mm* of beam path distance is to be made by examining the results of detections using different frequencies and/or probes, non-destructive test of their surface, etc.

(2) Division of the Class is to be in accordance with the **Annex K5.1.9(2)** "GUIDANCE FOR SURFACE INSPECTION OF CRANKSHAFTS".

(3) The exterior part means the part beyond one-third of the shaft radius from the centre of axis.

(4) "Clustered flaw indications" means flaw echoes which are above the dotted-line shown in **Fig. 10** and those consisting of more than five flaw indications within 50 *mm* equivalent to a distance in steel on time base, and indications in number less than the above is termed the "isolated flaw indication".

1.6 Recording

1.6.1 Indication of Examination Results

(1) Examination results on steel forgings except turbine rotor shafts are to be recorded in accordance with the following **Fig. 11 and Fig. 12** for each section being examined. Flaw indications whose height is equal to or below 50% of each reference line do not require recording.

All flaw indications which require remarks, and scanning positions where the bottom echo height is equal to 50% or below at the evaluation sensitivity on the graticule due to geometric configurations, are to have the locations and extents of their defective areas recorded.

Where there are no flaw indications, only scanning sensitivity results, as for the representative shape shown in **Fig. 11,** are need to be recorded.

(2) For turbine rotor shafts, all isolated flaw indications exceeding the Reference line I-2 and clustered flaw indications exceeding the broken line in **Fig. 12** are to be recorded in accordance with the following **Fig. 13** and **Fig. 14**. In such cases, flaw indications which require remarks are to have the location and extent of their defective areas clearly indicated. Any flaw indications exceeding 100% are to be indicated in % by using the gain controller or attenuator.

Note:

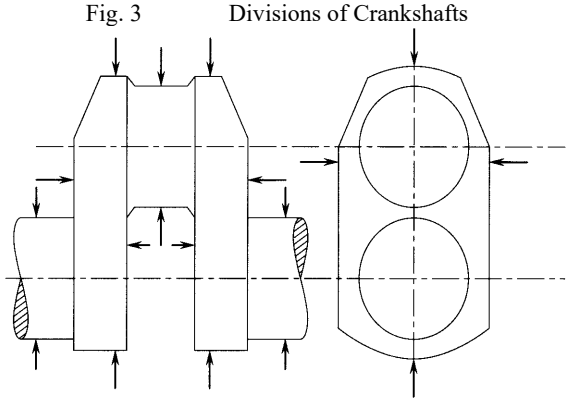
"Flaw indications which require remarks" means those clustered or continued, even when their height is within the allowable range

1.6.2 Report

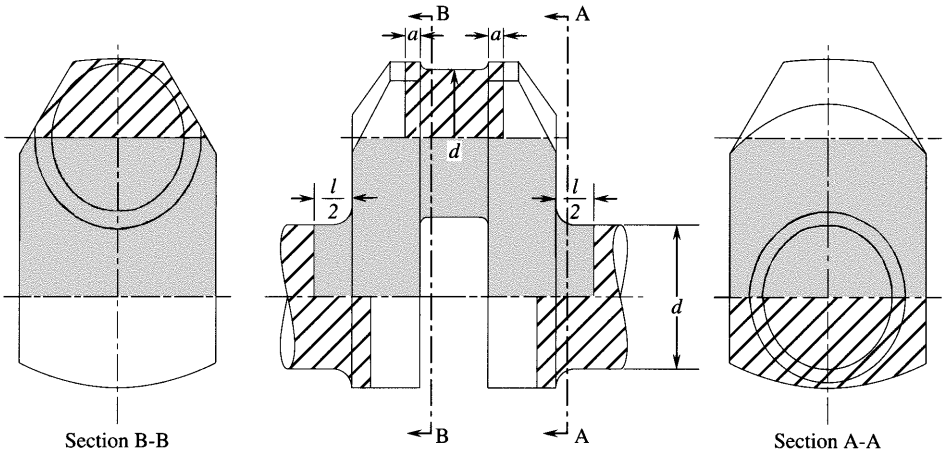
The reports are to include at least the following items.

(1) Hull number
(2) Drawing number
(3) Order number
(4) Heat number
(5) Manufacturing number
(6) Type of steel
(7) Product name and type
(8) Sketch showing the physical outline of the forging and scanning position (*T* and *B* of steel ingot are to be specified)
(9) Date of examination
(10) Timing of examination
(11) Name and type of flaw detector
(12) Frequencies
(13) Kind and size of probe
(14) Surface roughness
(15) Scanning sensitivity
(16) Pulse width (equivalent to a distance in steel)
(17) Couplant
(18) Flaw indication results (echo height, distribution and position)
(19) Name of the operator
(20) Comment and signature of the supervisor

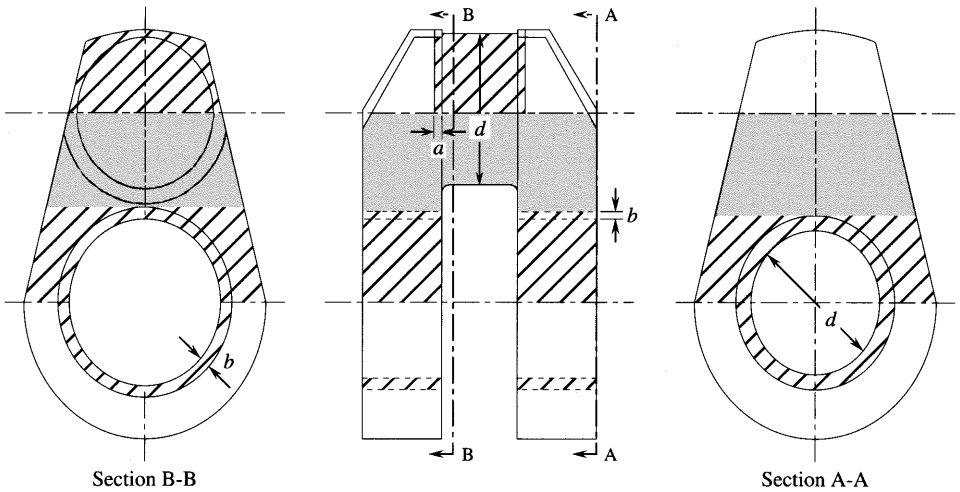
Fig. 3 Divisions of Crankshafts



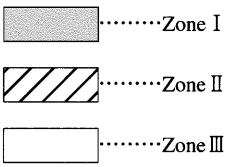
Scanning direction



Solid crankshaft



Semi-built-up crankshaft



a = 0.1 d, however 25 *mm* or more
b = 0.05 d, however 25 *mm* or more
d = pin or journal diameter (*mm*)
l = journal length

Fig. 4 Divisions for Shafts

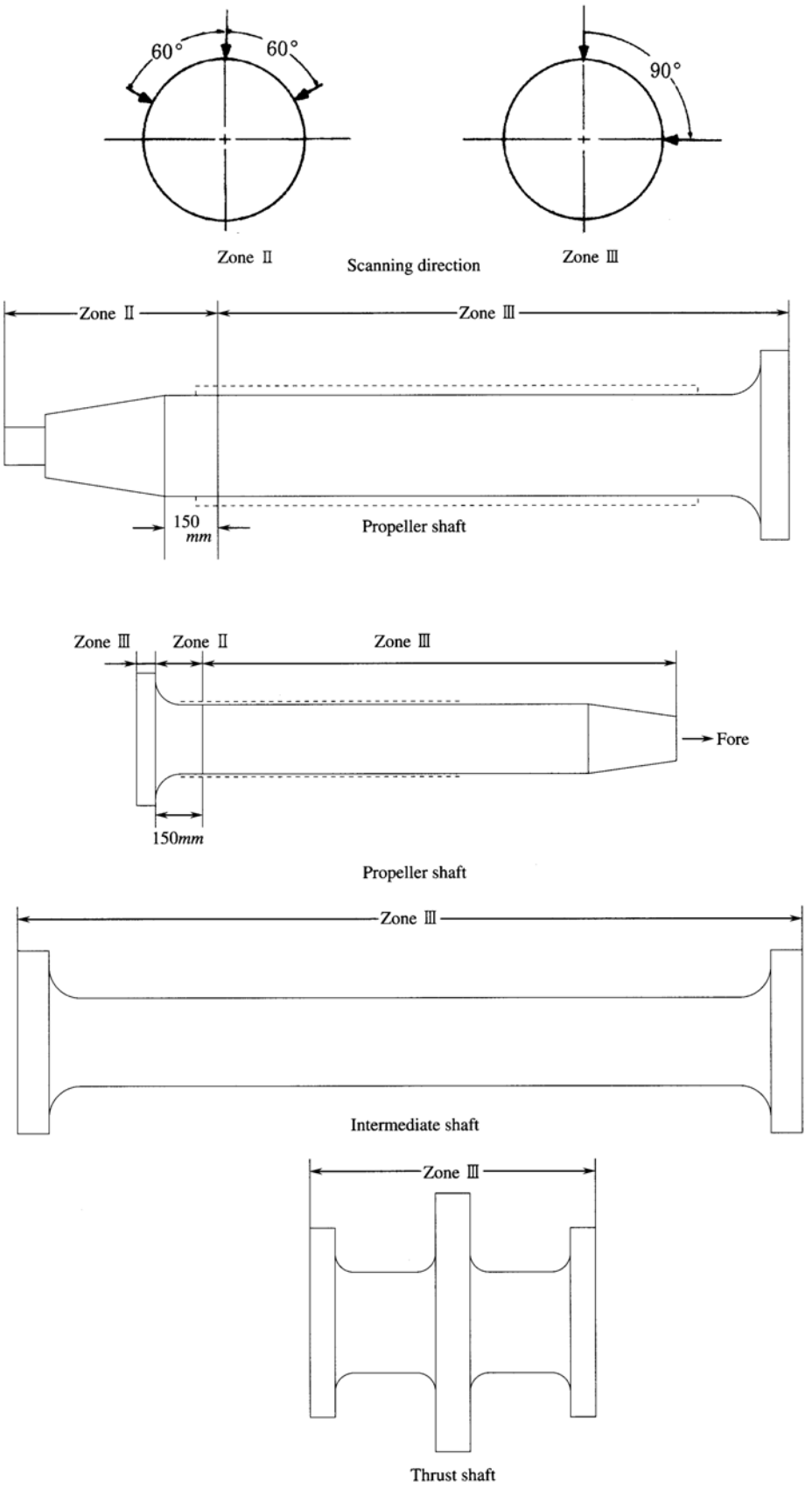


Fig. 5 Divisions for Connecting Rods, Piston Rods and Crossheads

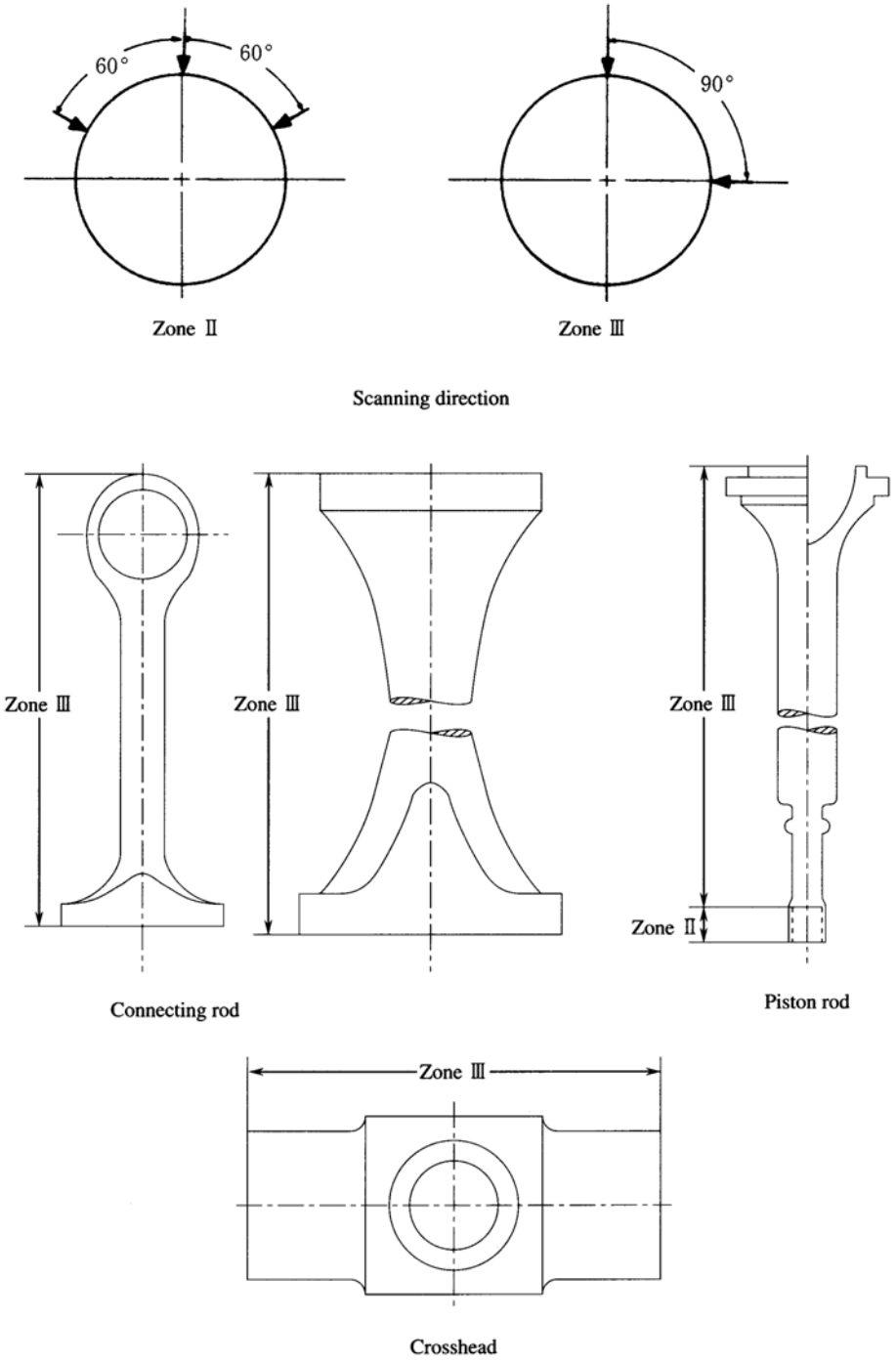
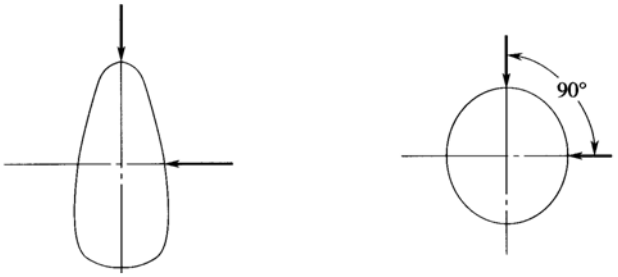
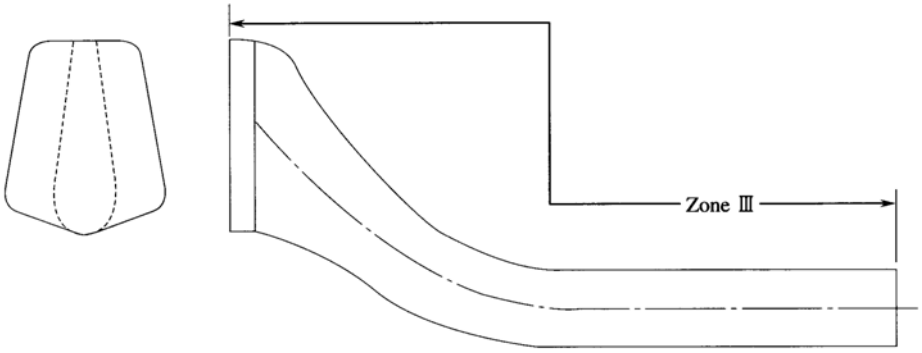
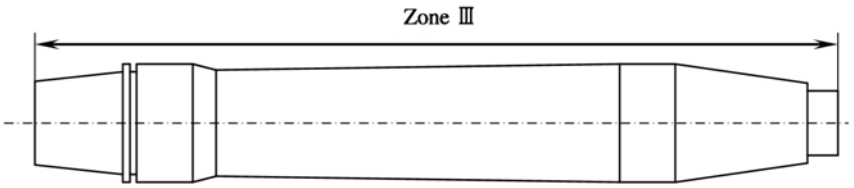


Fig. 6 Divisions for Rudder Stocks and Pintles







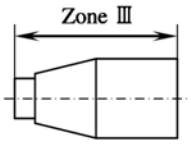


Fig. 7 Relation between Diameter of Rotor Shaft and Sensitivity Multiplier

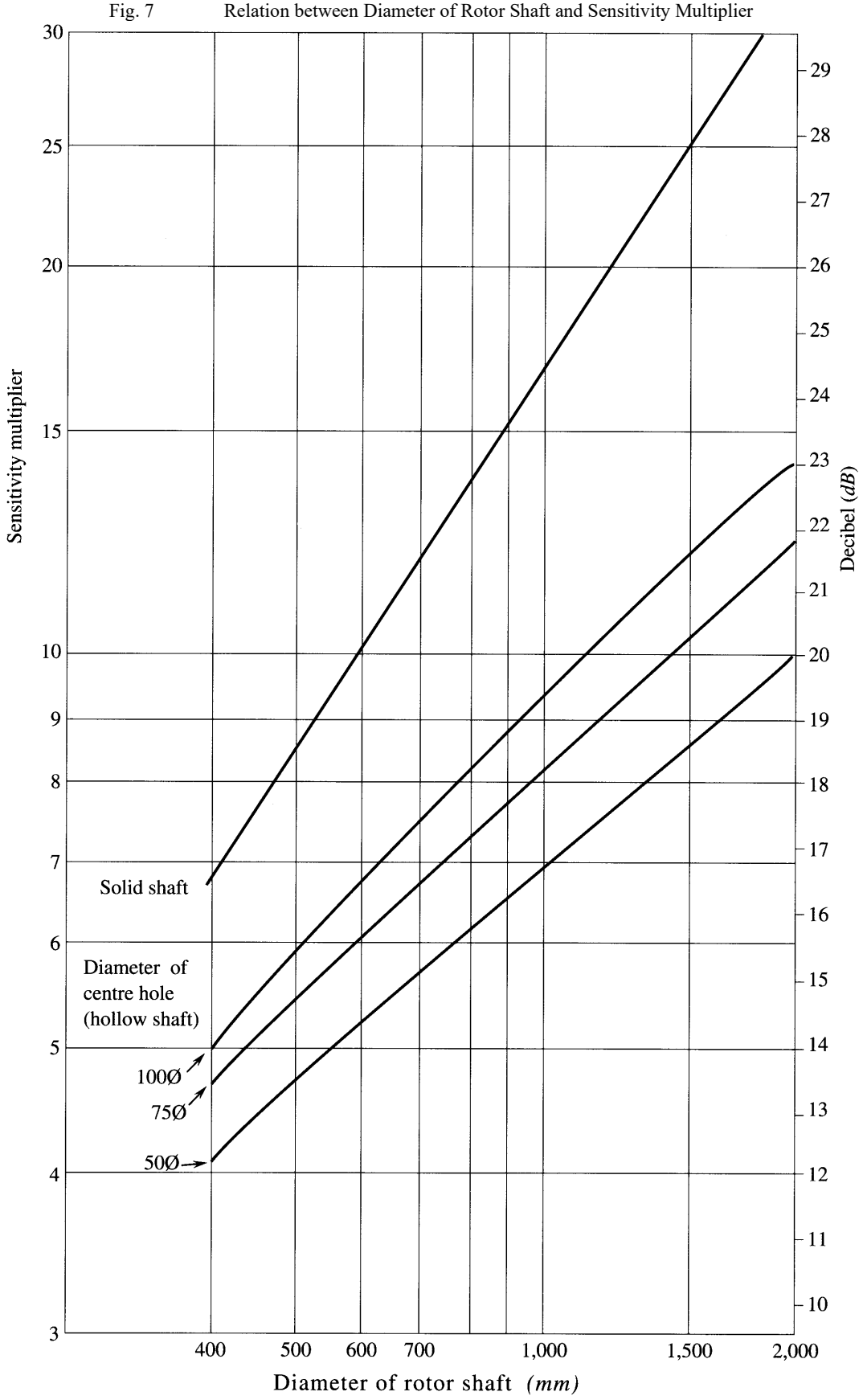


Fig. 8 Acceptance Criteria Diagram for Crankshafts

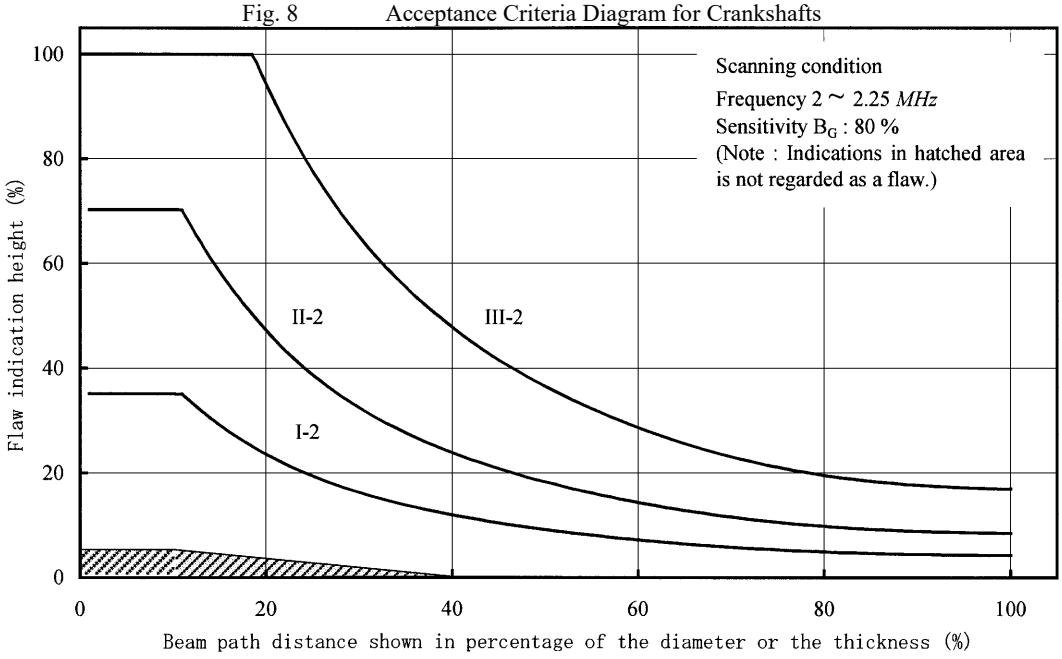


Fig. 9 Acceptance Criteria Diagram for Shafts, Rods, Rudder Stocks, and Pintles

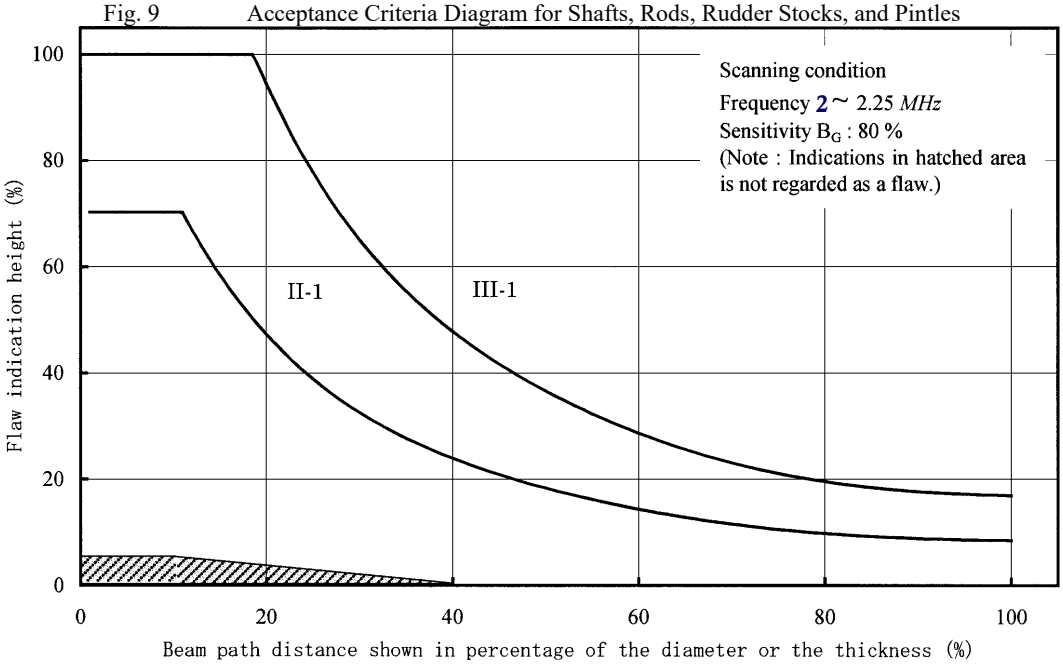
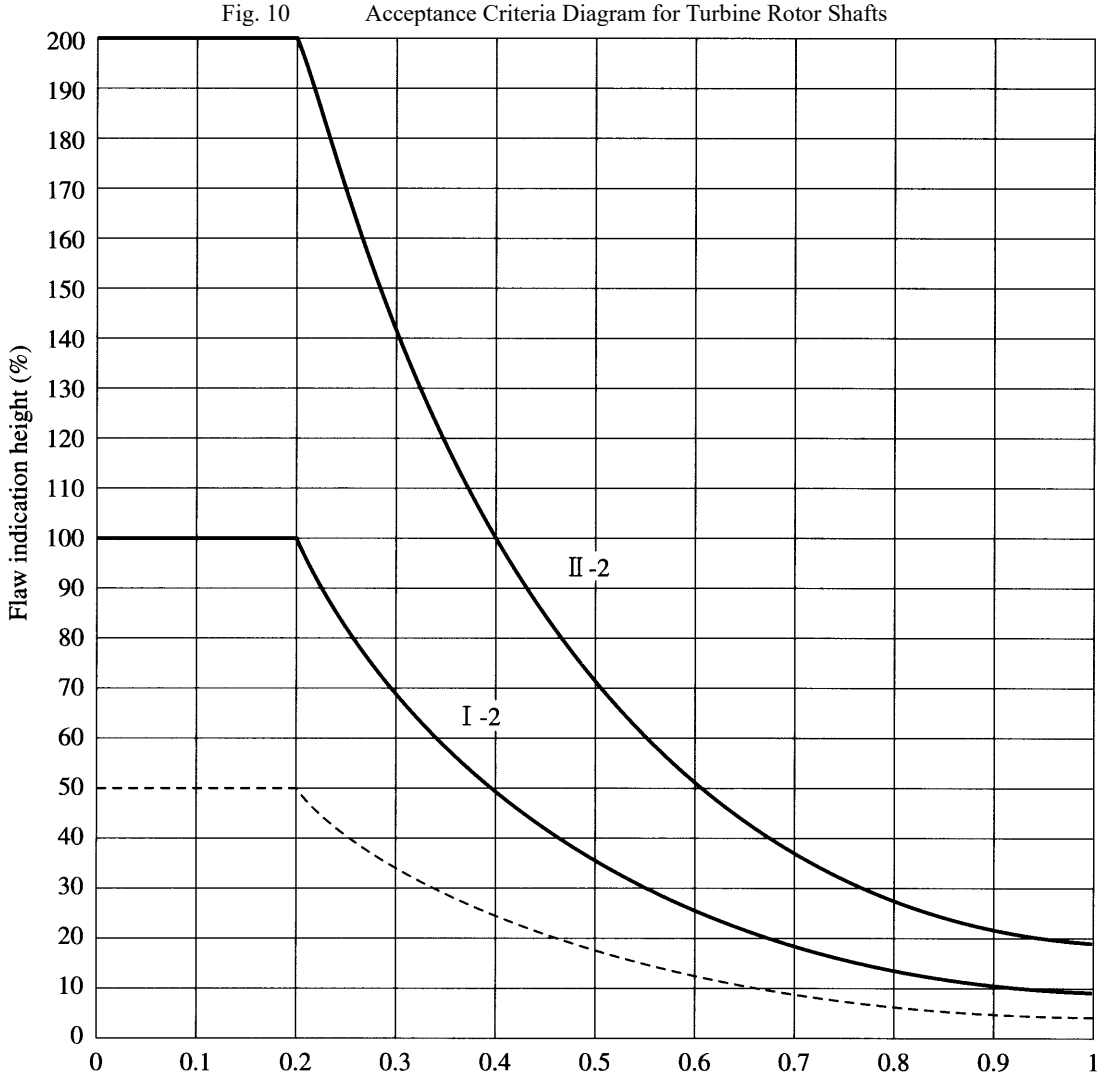


Fig. 10 Acceptance Criteria Diagram for Turbine Rotor Shafts



Note:

Beam path distance shown by assuming the distance between the outer surface of the shaft and the inner surface of the central hole or the center of the shaft as 1.

Fig. 11 Flaw Indication (In the Area Free from Defects)

Bottom echo height (%) of (B_1)~(B_3) = B100, 60, 30

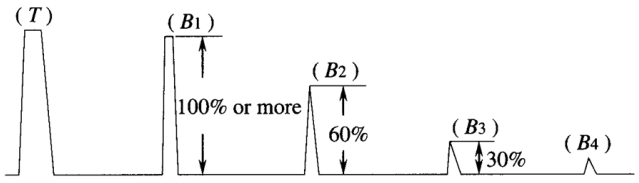
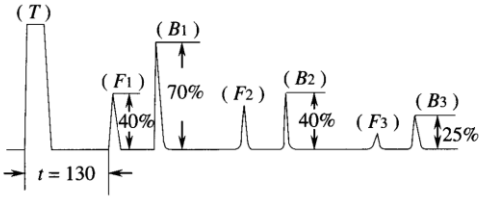


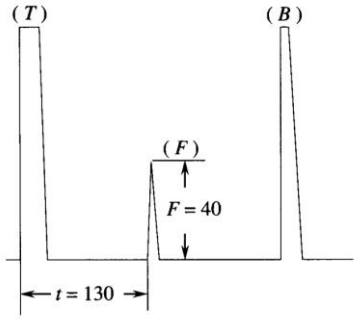
Fig. 12 Flaw Indication (In the Area with Defects)



(F_1) Flaw indication height(%),

$$\frac{(t)\text{ distance from surface }(mm)}{\text{Bottom echo height (\%) of }(B_1)\sim(B_3)\ )} = \frac{40\ (130)}{70,\ 40,\ 25}$$

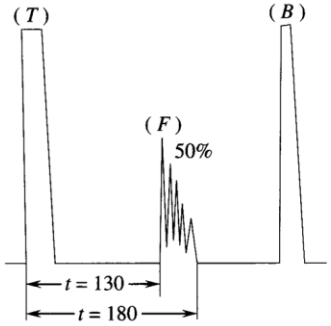
Fig. 13 Flaw Indication (Isolated Echo)



(F) Flaw indication height(%),

$$\frac{((t)\text{ distance from surface }(mm))}{(F/B)\ dB} = \frac{40\ (130)}{26}$$

Fig. 14 Flaw Indication (Clustered Echo)



(F) Flaw indication height(%),

$$\frac{(t)\text{ distance from surface }(mm)}{(F/B)\ dB}$$

$$= \frac{50,\ 45,\ 35,\ 25,\ 20\ (130\sim180)}{16,\ 17,\ 19,\ 22,\ 24}$$