RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part K Materials

RULES

2023 AMENDMENT NO.2

Rule No.67 22 December 2023
Resolved by Technical Committee on 27 July 2023

An asterisk (*) after the title of a requirement indicates that there is also relevant information in the corresponding Guidance.

Rule No.67 22 December 2023
AMENDMENT TO THE RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

"Rules for the survey and construction of steel ships" has been partly amended as follows:

Part K MATERIALS

Chapter 4 STEEL PIPES

4.1 Steel Tubes for Boilers and Heat Exchangers

Paragraph 4.1.1 has been amended as follows.

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.

~~2~~3 Except where specified in **2** above, ~~S~~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**.

Table K4.1 has been amended as follows.

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*

4.2 Steel Pipes for Pressure Piping

Paragraph 4.2.1 has been amended as follows.

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.

~~2~~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.

~~3~~4 Except where specified in **2** and **3** above, ~~S~~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**.

Table K4.10 has been amended as follows.

Table K4.10 Grades of ~~p~~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*

4.3 Stainless Steel Pipes

4.3.1 Application*

Sub-paragraph -2 has been renumbered to Sub-paragraph -3, and Sub-paragraph -2 has been added as follows.

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.
~~2~~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**.

Table K4.19 has been amended as follows.

Table K4.19 Grades and Chemical Composition

<table>
<tr><th rowspan="2">Grade
(Symbol)</th><th rowspan="2">Material Category</th><th colspan="9">Chemical composition (%)</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Ni</th><th>Cr</th><th>Mo</th><th>Others</th></tr>
<tr><td>$K304TP$</td><td rowspan="9">Austenitic stainless steels</td><td>0.08 max.</td><td rowspan="3">1.00 max.</td><td rowspan="9">2.00 max.</td><td rowspan="9">0.040 max.</td><td rowspan="9">0.030 max.</td><td>8.00~11.00</td><td rowspan="2">18.00~20.00</td><td rowspan="4">-</td><td rowspan="8">-</td></tr>
<tr><td>$K304LTP$</td><td>0.030 max.</td><td>9.00~13.00</td></tr>
<tr><td>$K309STP$</td><td rowspan="3">0.08 max.</td><td>12.00~15.00</td><td>22.00~24.00</td></tr>
<tr><td>$K310STP$</td><td>1.50 max.</td><td>19.00~22.00</td><td>24.00~26.00</td></tr>
<tr><td>$K316TP$</td><td rowspan="5">1.00 max.</td><td>10.00~14.00</td><td rowspan="2">16.00~18.00</td><td rowspan="2">2.00~3.00</td></tr>
<tr><td>$K316LTP$</td><td>0.030 max.</td><td>12.00~16.00</td></tr>
<tr><td>$K317TP$</td><td>0.08 max.</td><td rowspan="2">11.00~15.00</td><td rowspan="2">18.00~20.00</td><td rowspan="2">3.00~4.00</td></tr>
<tr><td>$K317LTP$</td><td>0.030 max.</td></tr>
<tr><td>$K321TP$</td><td>0.08 max.</td><td>9.00~13.00</td><td>17.00~19.00</td><td>-</td><td>$Ti \geq 5 \times C$</td></tr>
<tr><td>$K329J1TP$</td><td rowspan="3">Austenitic Ferritic stainless steels</td><td>0.08 max.</td><td>1.00 max.</td><td>1.50 max.</td><td>0.040 max.</td><td>0.030 max.</td><td>3.00~6.00</td><td>23.00~28.00</td><td>1.00~3.00</td><td>-</td></tr>
<tr><td>$K329J3LTP$</td><td>0.030 max.</td><td>1.00 max.</td><td>1.50 max.</td><td>0.040 max.</td><td>0.030 max.</td><td>4.50~6.50</td><td>21.00~24.00</td><td>2.50~3.50</td><td>N: 0.08~0.20</td></tr>
<tr><td>$K329J4LTP$</td><td>0.030 max.</td><td>1.00 max.</td><td>1.50 max.</td><td>0.040 max.</td><td>0.030 max.</td><td>5.50~7.50</td><td>24.00~26.00</td><td>2.50~3.50</td><td>N: 0.08~0.30</td></tr>
<tr><td>$K347TP$</td><td>Austenitic stainless steels</td><td>0.08 max.</td><td>1.00 max.</td><td>2.00 max.</td><td>0.040 max.</td><td>0.030 max.</td><td>9.00~13.00</td><td>17.00~19.00</td><td>-</td><td>$Nb \geq 10 \times C$</td></tr>
</table>

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*

4.4 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**.

Table K4.23 has been deleted as follows.

~~Table K4.23 Grades of Headers~~

~~Grade~~	~~Grade 1~~	~~Grade 2~~	~~Grade 3~~	~~Grade 4~~	~~Grade 5~~	~~Grade 6~~
~~Symbol~~	~~*KBH-1*~~	~~*KBH-2*~~	~~*KBH-3*~~	~~*KBH-4*~~	~~*KBH-5*~~	~~*KBH-6*~~

4.4.3 Heat Treatment

Headers are to be heat treated by annealing or normalizing.

Paragraph 4.4.4 has been amended as follows.

4.4.4 Chemical Composition

Headers are to have the chemical composition given in **Table K4.2~~4~~3**.

4.4.5 Mechanical Properties

Sub-paragraph (1) has been amended as follows.

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 4.2~~5~~4**.

(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 K4.24 has been renumbered to Table K4.23, Table K4.23 has been amended as follows.

Table K4.2~~4~~3 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 K4.25 has been renumbered to Table K4.24.

Table K4.2~~5~~4 Tensile Test
(Table is omitted.)

4.4.6 Selection of Test Specimen

Sub-paragraph -2 has been amended as follows.

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 K4.2~~6~~5**.
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°C to 650°C 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 K4.26 has been renumbered to Table K4.25.

Table K4.2~~6~~5 Number of Test Specimens
(Table is omitted.)

4.5 Steel Pipes for Low Temperature Service

4.5.1 Application

Sub-paragraphs -2 and -3 have been renumbered to Sub-paragraphs -3 and -4, and Sub-paragraph -2 has been added as follows.

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°C 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.

~~2~~3 Any requirement regarding the steel pipes over 25 *mm* in thickness is left to the discretion of the Society.

~~3~~4 Steel pipes having characteristics differing from these specified in **4.5** are to comply with the requirements in **1.1.1-3**.

Paragraph 4.5.2 has been amended as follows.

4.5.2 Kinds

The steel pipes are classified into 6 grades as given in **Table K4.2~~7~~6**.

Paragraph 4.5.3 has been amended as follows.

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 K4.2~~7~~6**.

Table K4.27 has been renumbered to Table K4.26, Table K4.26 has been amended as follows.

Table K4.2~~7~~6 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.

Paragraph 4.5.4 has been amended as follows.

4.5.4 Heat Treatment

The steel pipes are to be heat treated in accordance with the requirements in **Table K4.2~~8~~7**.

4.5.5 Mechanical Properties

Sub-paragraphs -1(1) to (3) has been amended as follows.

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 K4.2~~8~~7**.

(2) Impact test
The steel pipes are to be subjected to impact test and to comply with the requirements in **Table K4.2~~8~~7**.

(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 K4.2~~8~~7**, 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 K4.28 has been renumbered to Table K4.27.

Table K4.2~~8~~7 Heat Treatment and Mechanical Properties
(Table and Notes are omitted.)

Paragraph 4.5.7 has been amended as follows.

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 K4.2~~9~~8**.

Table K4.29 has been renumbered to Table K4.28.

Table K4.2~~9~~8 Tolerances for Outside Diameter and Wall Thickness(1)
(Table and Notes are omitted.)

Chapter 8 ALUMINIUM ALLOYS

Title of Section 8.2 has been amended as follows.

8.2 Aluminium Alloy pPipes

8.2.1 Application*

Sub-paragraph -3 has been renumbered to Sub-paragraph -4, and Sub-paragraph -3 has been added as follows.

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.

34 Aluminium alloy pipes having characteristics differing from those specified in **8.2** are to comply with the requirements in **1.1.1-3**.

EFFECTIVE DATE AND APPLICATION

1. The effective date of the amendments is 1 January 2024.

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part K **Materials**

GUIDANCE

2023 AMENDMENT NO.2

Notice No.63 22 December 2023
Resolved by Technical Committee on 27 July 2023

Notice No.63 22 December 2023
AMENDMENT TO THE GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

"Guidance for the survey and construction of steel ships" has been partly amended as follows:

Part K MATERIALS

Amendment 2-1

K4 STEEL PIPES

K4.1 Steel Tubes for Boilers and Heat Exchangers

Paragraph K4.1.1 has been added as follows.

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.

K4.2 Steel Pipes for Pressure Piping

Paragraph K4.2.1 has been added as follows.

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.

K4.3 Stainless Steel Pipes

Paragraph K4.3.1 has been added as follows.

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.

Section K4.5 has been added as follows.

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.

K8 ALUMINIUM ALLOYS

K8.2 Aluminium Alloy Pipes

Paragraph K8.2.1 has been added as follows.

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.

EFFECTIVE DATE AND APPLICATION (Amendment 2-1)

1. The effective date of the amendments is 1 January 2024.

Amendment 2-2

K3 ROLLED STEELS

K3.12 Additional Requirements for Brittle Crack Arrest Properties

K3.12.3 has been amended as follows.

K3.12.3 Brittle Crack Arrest Properties etc.

1 In **3.12.3-1, Part K of the Rules**, "the discretion of the Society" can be regarded as means that carrying out the test in accordance with **Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS 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 the requirements in **3.12.5-1, Part K of the Rules**, notwithstanding the requirements in **1.2.11, Annex K3.12.3-1**.

2 In **3.12.3-2, Part K of the Rules**, "the discretion of the Society" may be regarded as means that carrying out the test in accordance with **Annex K3.12.3-2** "GUIDANCE FOR CAT EVALUATION TESTS 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 of the Society.

(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**.

Annex K3.12.3-1 has been amended as follows.

Annex K3.12.3-1 GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS

1.1 ~~General~~ Application

~~1.1.1 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 ~~The requirements in this Guidance~~ This annex apply to rolled steel plates with thicknesses ~~of~~ exceeding 50 *mm* but 100 *mm* or less. Rolled steel plates having thicknesses exceeding 100 *mm* are ~~to~~ at the discretion of the ~~s~~Society.

~~1.1.2 Definition~~

~~Unless specified otherwise, the definition of the symbols used in this Guidance are as specified in **Table 1**.~~

~~Table 1 Definition of the Symbols Used in this Guidance~~

~~Symbol~~	~~Unit~~	~~Significance~~
~~a~~	~~*mm*~~	~~Crack length or arrest crack length~~
~~E~~	~~N/mm^2~~	~~Modulus of longitudinal elasticity~~
~~E_i~~	~~*J*~~	~~Impact energy~~
~~E_s~~	~~*J*~~	~~Strain energy stored in test specimen~~
~~E_t~~	~~*J*~~	~~Total strain energy stored in tab plates and pin chucks~~
~~F~~	~~*MN*~~	~~Applied load~~
~~K~~	~~$N/mm^{3/2}$~~	~~Stress intensity factor~~
~~K_{ca}~~	~~$N/mm^{3/2}$~~	~~Arrest toughness value~~
~~L~~	~~*mm*~~	~~Test specimen length~~
~~L_p~~	~~*mm*~~	~~Distance between loading pins~~
~~L_{pc}~~	~~*mm*~~	~~Pin chuck length~~
~~L_{tb}~~	~~*mm*~~	~~Tab plate length~~
~~T~~	~~°C~~	~~Temperature or arrest temperature~~
~~T_D~~	~~*K*~~	~~Specific temperature~~
~~T_K~~	~~*K*~~	~~Arrest temperature of arrest toughness value obtained from requirement **1.2.9**~~
~~t~~	~~*mm*~~	~~Test specimen thickness~~
~~t_{tb}~~	~~*mm*~~	~~Tab plate thickness~~
~~t_{pc}~~	~~*mm*~~	~~Pin chuck thickness~~
~~W~~	~~*mm*~~	~~Test specimen width~~
~~W_{tb}~~	~~*mm*~~	~~Tab plate width~~
~~W_{pc}~~	~~*mm*~~	~~Pin chuck width~~

~~x_a~~	~~*mm*~~	~~Coordinate of main crack tip in width direction~~
~~x_{br}~~	~~*mm*~~	~~Coordinate of longest branch crack tip in width direction~~
~~y_a~~	~~*mm*~~	~~Coordinate of main crack tip in stress loading direction~~
~~y_{br}~~	~~*mm*~~	~~Coordinate of longest branch crack tip in stress loading direction~~
~~σ~~	~~N/mm^2~~	~~Applied stress~~
~~σ_{Y0}~~	~~N/mm^2~~	~~Yield stress at room temperature~~

1.2 ~~Temperature Gradient *ESSO* Tests~~ Test Procedures

~~1.2.1 General~~

1 ~~The requirements in this section are related to the evaluation of brittle crack arrest toughness through the use of temperature gradient *ESSO* tests.~~ 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 ~~Items not specified in this Guidance are to be in accordance with *WES2815* (Test method for brittle crack arrest toughness, K_{ca}) of the Japan Welding Engineering Society.~~ 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".

~~1.2.2 Test Equipment~~

~~**1** Test equipment is to be hydraulic test equipment of a pin load type which is capable of tensile tests.~~

~~**2** The method of applying loads is to be such that the stress distribution in the plate width direction is made uniform by aligning the centers of the loading pins of both sides and neutral axis of the integrated specimen.~~

~~**3** The direction of loading is to be either vertical or horizontal. In the case of the horizontal direction, test specimen surfaces are to be placed perpendicular to the ground.~~

~~**4** The distance between the loading pins, L_p, is to be standardized as 3.4 *W* or more.~~

~~1.2.3 Impact Equipment~~

~~**1** Impact equipment for initiating brittle crack in integrated specimen is to be of either a drop weight type or an air gun type. Impact load is to be applied to integrated specimen by wedge.~~

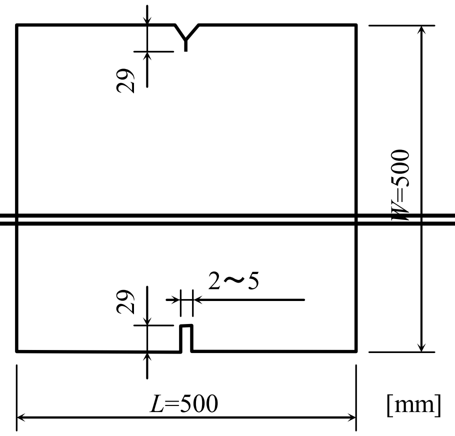
~~**2** Wedge is to be hard enough to prevent significant plastic deformation caused by impact.~~

~~**3** The thickness of a wedge thickness is to be equal to or greater than that of the test specimen. In addition, the angle of the wedge is to be greater than the angle of the notch formed in the test specimen and have a shape capable of opening up the notch of the test specimen.~~

~~1.2.4 Test Specimen Shapes~~

~~**1** The standard test specimen shape is shown in **Fig. 1**. In principle, test specimen length, *L*, is to be equal to or greater than test specimen width, *W*.~~

Fig. 1 Standard Test Specimen Shape



2 **Table 2** shows the ranges of test specimen thicknesses, *t*, and widths, *W*.

Table 2 Dimensions of Test Specimens

Test specimen thickness, *t*	50 *mm* < *t* ≤ 100 *mm*
Test specimen width, *W*	350 *mm* ≤ *W* ≤ 1000 *mm*
Test specimen width/test specimen thickness, *W* / *t*	*W* / *t* ≥ 5

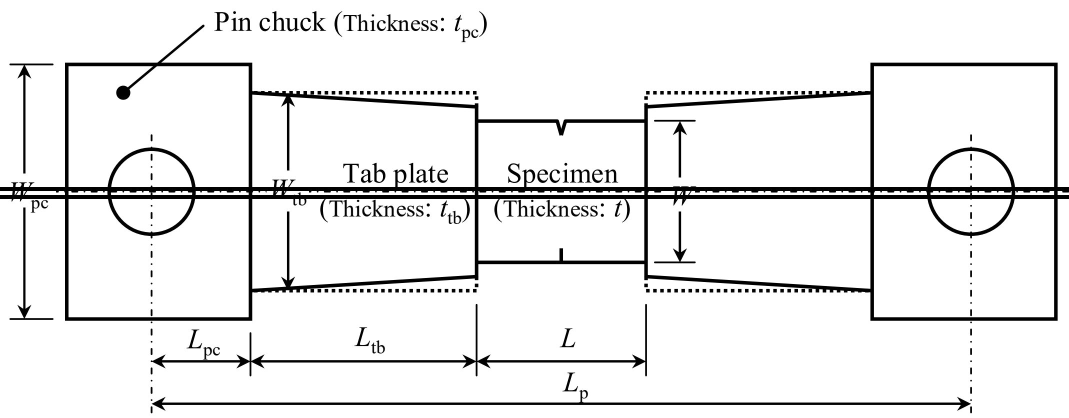
Note:

Test specimen width is standardized as 500 *mm*.

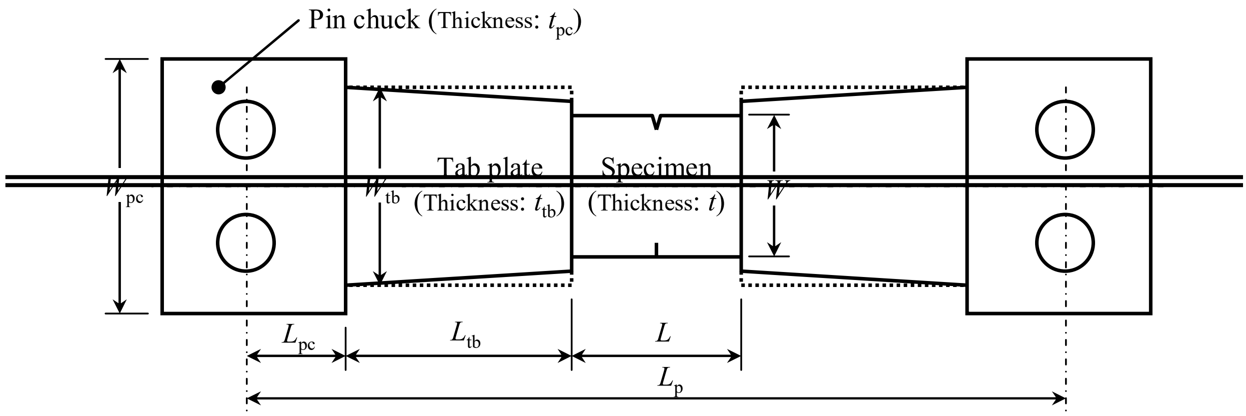
1.2.5 Shapes of Tab Plates and Pin Chucks

1 The definitions of the dimensions of tab plates and pin chucks are shown in **Fig. 2**.

Fig. 2 Definitions of Dimensions of Tab Plates and Pin Chucks



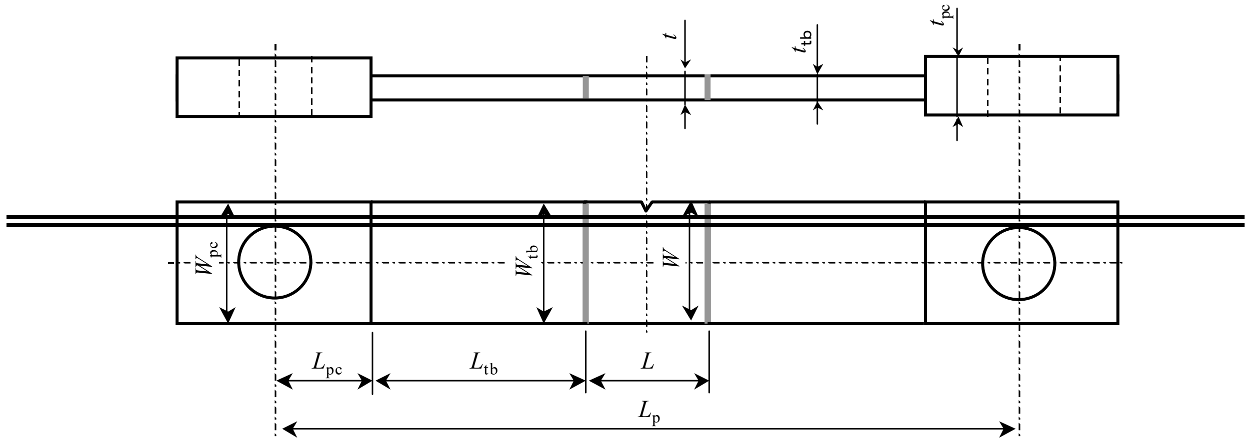
(a) Single-pin type



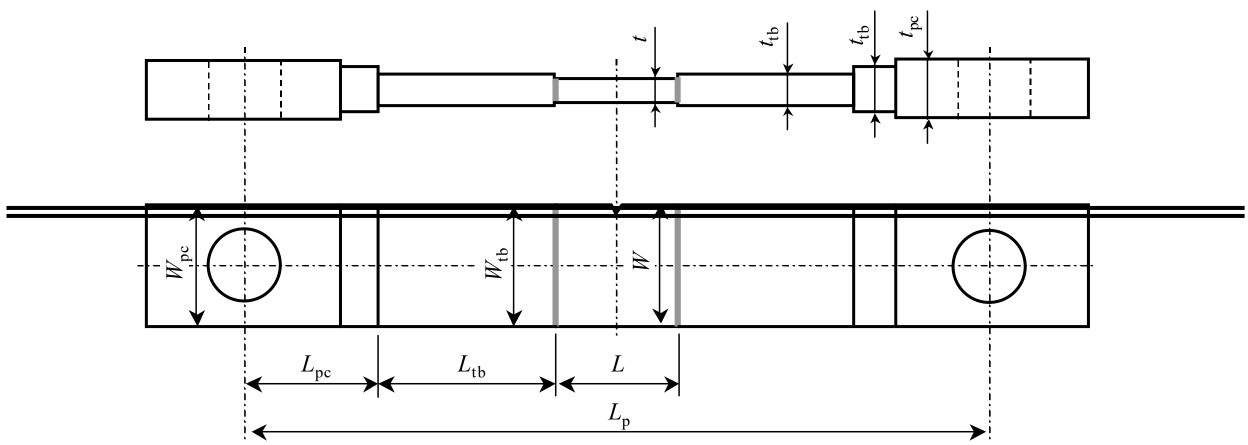
(b) Double-pin type

2 The standard dimensions of tab plates and pin chucks are shown in **Fig. 3**.

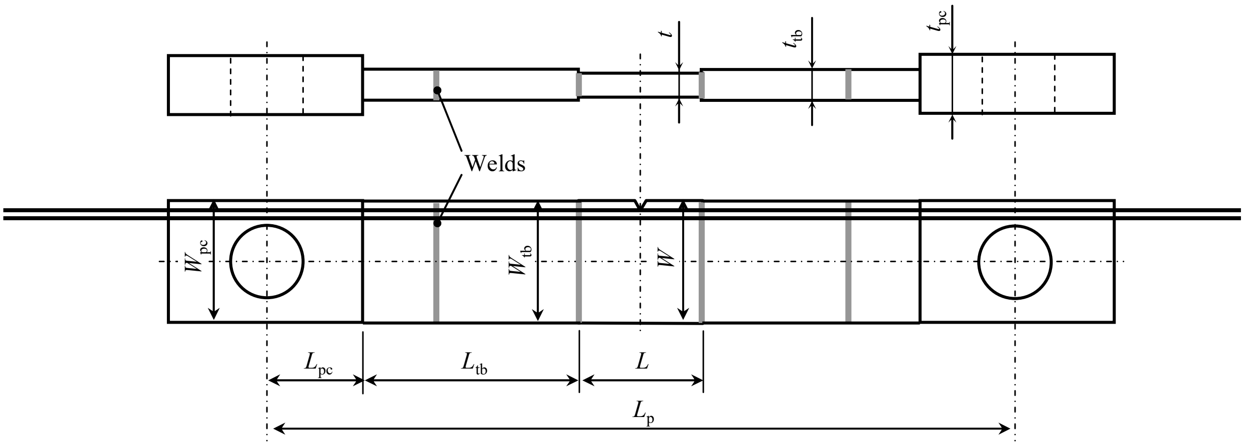
Fig. 3 Standard dimensions of tab plates and pin chucks



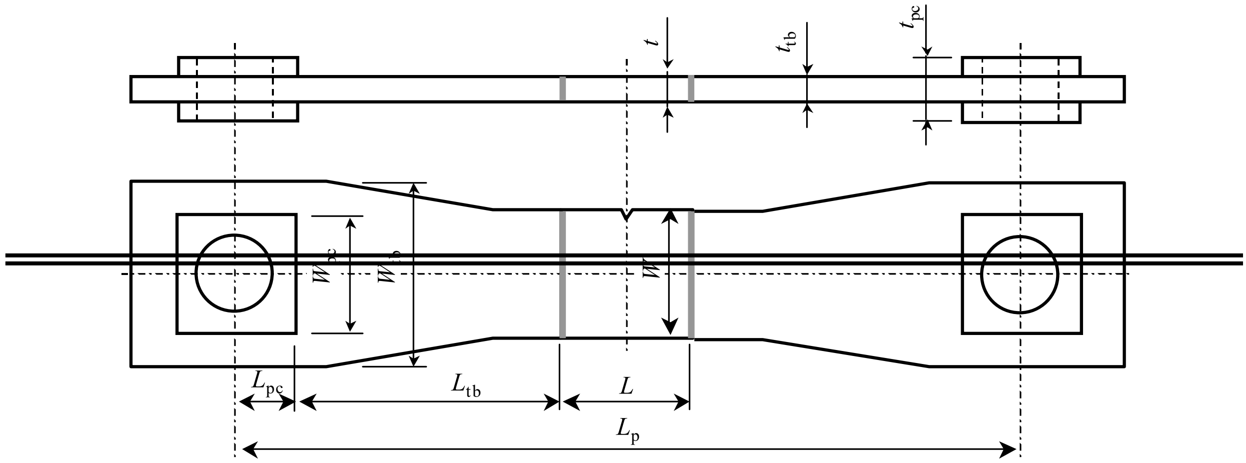
(a) Example 1



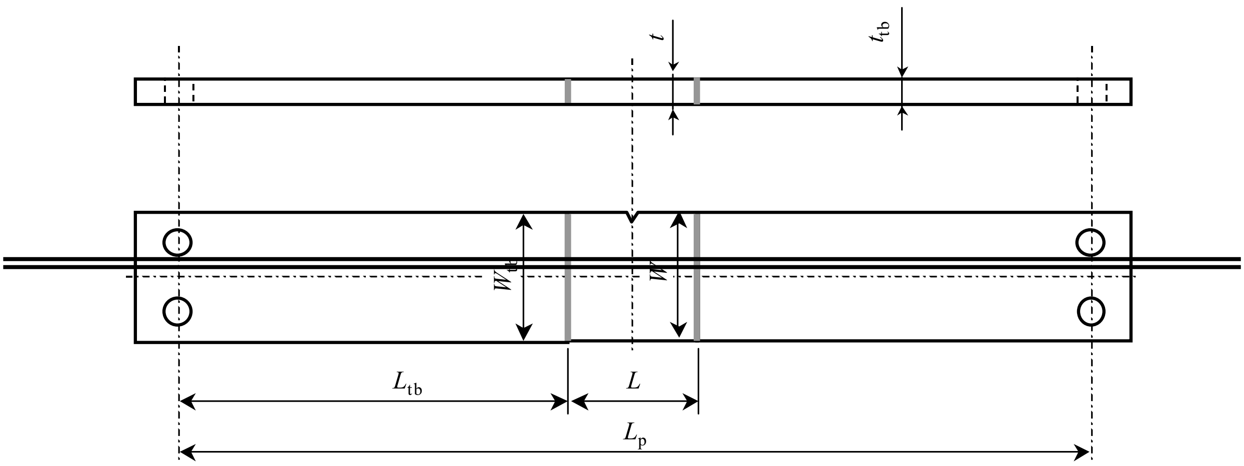
(b) Example 2



~~(c) Example 3~~



~~(d) Example 4~~



~~(e) Example 5~~

~~**3** The tolerances of tab plate dimensions are shown in **Table 3**. When the lengths of tab plates attached to both ends of a test specimen are different, the shorter length is to be used as the tab length, L_{tb}.~~

Table 3 Tolerances of Tab Plate Dimensions

Tab plate thickness, t_{tb}	$0.8t \leq t_{tb} \leq 1.5t$
Tab plate width, W_{tb}	$W \leq W_{tb} \leq 2.0W$
Total length of test specimen and tab plates, $L + 2L_{tb}$ (Total length of test specimen and a single tab plate $L + L_{tb}$)	$L + 2L_{tb} \geq 3.0W$ ($L + L_{tb} \geq 2.0W$)
Tab plate length (L_t) / Tab plate width, (W)	$L_{tb} / W \geq 1.0$

4 In principle, pin chuck width, W_{pc}, is to be equal to or greater than tab plate width, W_{tb}. Pin chucks are to be designed to have sufficient load bearing strength. When pin chucks attached to both ends of an integrated specimen are asymmetric, the length of the shorter one is to be used as the pin chuck length, L_{pc}.

5 The distance between pins, L_p, is to be obtained from the following formula. In the case shown in **Fig. 3 (e), Example 5**, it is obtained by setting $L_{pc} = 0$.

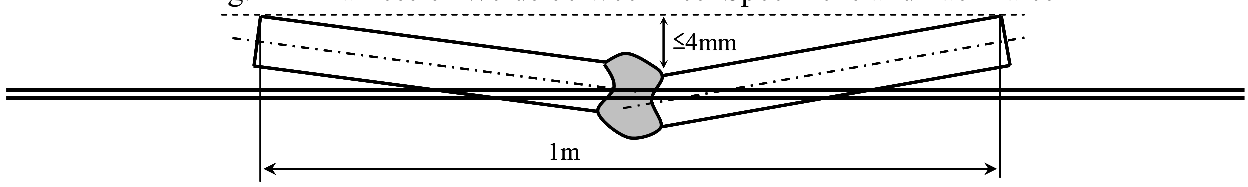
$$L_p = L + 2L_{tb} + 2L_{pc}$$

1.2.6 Welding of Test Specimens and Tab Plates

1 Test specimens, tab plates, and pin chucks are to be connected by welding. The welds are to have sufficient load bearing strength.

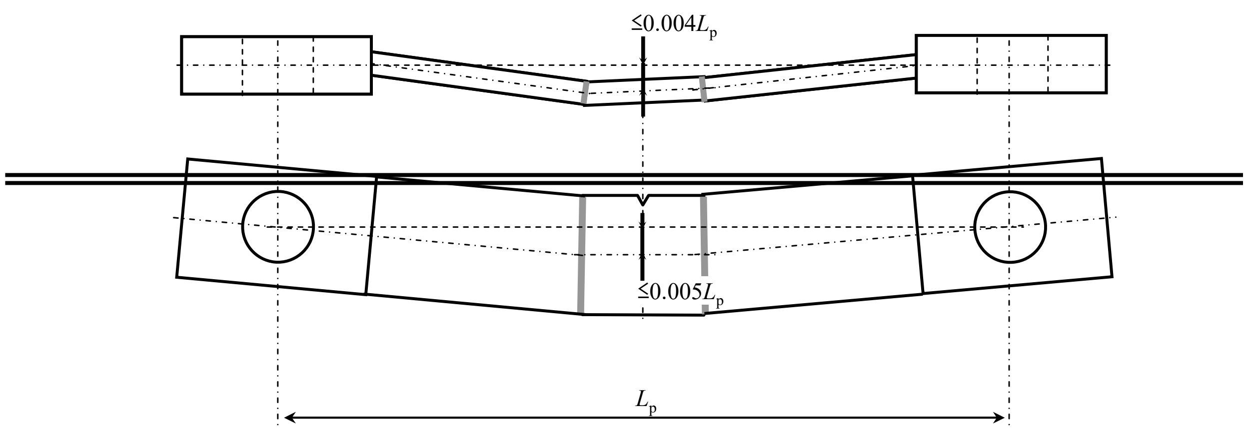
2 As shown in **Fig. 4**, the flatness (angular distortion and linear misalignment) of the welds between test specimens and tab plates are to be 4 *mm* or less *per meter*. In the case of preloading, however, it is acceptable if the value after preloading satisfies this condition.

Fig. 4 Flatness of Welds between Test Specimens and Tab Plates



3 The accuracy of in-plane and out-of-plane loading axes are shown in **Fig. 5**. The accuracy of the in-plane loading axis is to be 0.5% or less of the distance between the pins, and the accuracy of the out-of-plane loading is to be 0.4% or less of the distance between the pins. Stress in a loaded test specimen is to be uniform.

Fig. 5 Accuracy of In-plane and Out-of-plane Loading Axes



1.2.7 Test Methods

1 A predetermined temperature gradient is to be established across a test specimen width by soldering at least nine thermocouples to the test specimen for temperature measurement and control. The temperature gradient is to be established in accordance with the following **(1)** to **(3)** conditions.

(1) A temperature gradient of 0.25 °C/*mm* to 0.35 °C/*mm* is to be established in a test specimen width range of 0.3 *W* to 0.7 *W*. When measuring temperatures at the center positions of the test specimen thickness, it is to be kept within ±2 °C for 10 minutes or more, whereas when measuring temperatures on the front and back surface positions of the test specimen, it is to be kept within ±2°C for (10 + 0.1*t* [*mm*]) minutes or more taking account of the time needed for soaking to the center.

(2) At the test specimen width center position (i.e., 0.5 *W*), and in the range of ±100 *mm* in the test specimen length direction, the deviation from the temperature at the center position in the length direction is to be controlled within ±5 °C. However, when temperature measurement is not performed at the center position in the length direction, the average temperature at the closest position is to be used as the temperature at the center position in the length direction.

(3) At the same position in the width direction, the deviation of the temperature on the front and back surfaces is to be controlled within ±5 °C.

2 It is desirable that impact energy, E_i, to thickness, t, ratios satisfy following formula:

$$\frac{E_i}{t} \leq \min(1.2\sigma - 40,200)$$

where "min" means the minimum of the two values.

1.2.8 Test Procedures

1 Pretest procedures are to be in accordance with following **(1)** to **(8):**

(1) Place integrated specimen in the test machine.

(2) Mount a cooling device on the test specimen. A heating device may also be mounted on the test specimen as needed.

(3) Attach an impact apparatus. An appropriate reaction force receiver maybe arranged as needed.

(4) After checking that all measured values of the thermocouples indicate room temperature, start cooling. The temperature distribution and the holding time are to be as specified in **1.2.7-1**.

(5) Set the impact apparatus so that it can supply the predetermined energy to the test specimen.

(6) Apply a load to the test specimen until it reaches the predetermined test load. Load is, in principle, to be applied after temperature control, but temperature control may, however, be implemented after loading. Loading rate and applied stress are to satisfy the following **(a)** and **(b)**, respectively.

(a) The loading rate is to meet the conditions that the test specimen temperature distribution can be held and loading can be controlled not to become excessively large compared to the predetermined load.

(b) Applied stress is to satisfy the following formula:

$$\sigma \leq \frac{2}{3}\sigma_{Y0}$$

However, applied stress is standardized to a value equal to 1/6 σ_{Y0} or greater.

(7) Immediately prior to impact, the notch may be further cooled on the condition that such cooling does not cause the temperature to be outside the range 0.3 *W* to 0.7 *W*. The test temperature in this case is to be the measured temperature obtained from the temperature record immediately before any further notch cooling.

(8) Record the load value measured by a load recorder.

2 Loading procedures are to be in accordance with following **(1)** to **(4)**:

(1) After holding a predetermined load for 30 seconds or more, apply an impact to the wedge

using the impact apparatus. If a crack initiates autonomously and the exact load value at the time of the crack initiation cannot be obtained, the test is invalid.

(2) After impact, record the load value measured by the load recorder.

(3) When the load after impact is smaller than the test load, it is to be considered that a crack initiation has occurred. An increase in the number of times of impact may cause a change in the shape of the notch of the test specimen. Since the number of impacts has no effect on the value of brittle crack arrest toughness, no limit is specified for the number of impacts. However, because the temperature gradient is often distorted by impact, the test is to be conducted again after temperature control in cases where applying another impact to the wedge.

(4) When a crack initiation, propagation, and arrest are observed, remove the load.

3 Procedures after testing are to be in accordance with following **(1)** to **(3)**:

(1) Remove the cooling device, impact apparatus, thermocouples, and strain gauges.

(2) Return the temperature of the test specimen to room temperature. In order to achieve this, the test specimen may be heated using a gas burner or the like. If it is necessary to prevent fracture surfaces from having a burnt color at approval tests for the manufacturing processes, the direct heating of crack zones is to be avoided.

(3) After gas-cutting an uncracked ligament, use the test machine to cause a ductile fracture, as necessary. Another way is after using the test machine to develop a ductile crack to a sufficient length, gas-cut the uncracked ligament.

4 Observation of fracture surfaces and measurement of crack arrest length, a, are to be in accordance with following **(1)** to **(3)**:

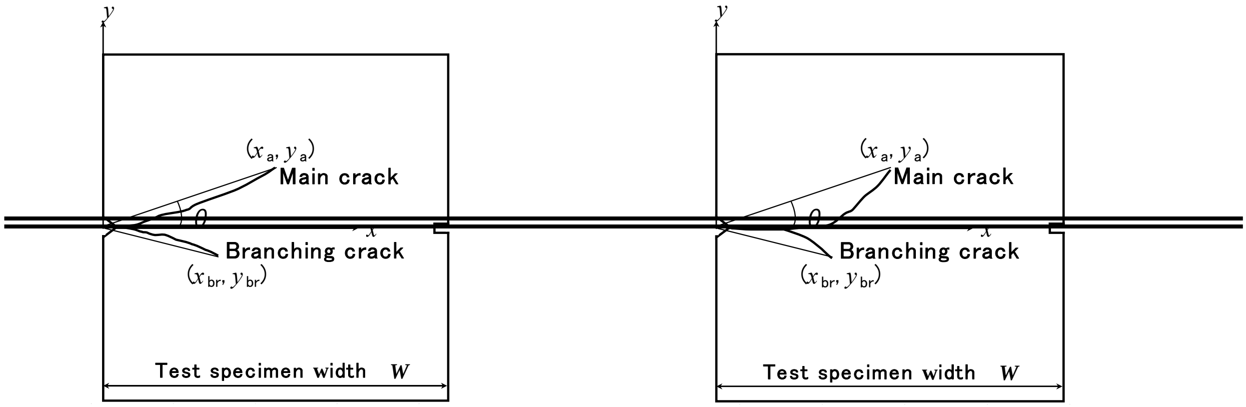
(1) Take photographs of fracture surfaces and propagation path.

(2) Measure the longest length of an arrest crack tip in the plate thickness direction, and record it as the arrest crack length, a. In cases where a crack deviates from the direction vertical to the loading direction, the length projected to the plane vertical to the loading line is defined as the arrest crack length a. In the following cases, however, evaluate the results in accordance with following **(a)** and **(b)**, respectively:

(a) In cases where a brittle crack has re-initiated from an arrested crack, the original arrest position is defined as the arrest crack position. Here re-initiation is defined as the case where a crack and re-initiated cracks are completely separated by a stretched zone and brittle crack initiation from the stretched zone can be clearly observed. In cases where a crack continuously propagates partially in the thickness direction, the position of the longest brittle crack is defined as the arrest position.

(b) In cases where a crack deviates from the direction vertical to the loading direction, the length projected to the plane vertical to the loading line is defined as the arrest crack length. Similarly, in cases where a crack deviates from the direction vertical to the loading direction, the length projected to the plane vertical to the loading line is defined as the arrest crack length. In the case of crack branching, the length of the longest branch crack projected to the plane vertical to the loading line is defined as the branch crack length. To be more specific, from the coordinates (x_a, y_a) of the arrest crack tip position and the coordinates (x_{br}, y_{br}) of the branch crack tip position shown in **Fig. 6**, obtain the angle θ from the x-axis and define x_a as the arrest crack length, a. Here, x is the coordinate in the test specimen width direction, and the side face of the impact side is set as $x = 0$; y is the coordinate in the test specimen length direction, and the notch position is set as $y = 0$.

Fig. 6 Measurement Methods of Main Crack and Branch Crack Lengths



(a) Case of branching from the notch (b) Case of branching during brittle crack propagation

(3) Prepare a temperature distribution curve (line diagram showing the relationship between temperature and the distance from the test specimen top side) from the thermocouple measurement results, and obtain the arrest temperature, T, corresponding to the arrest crack length, a.

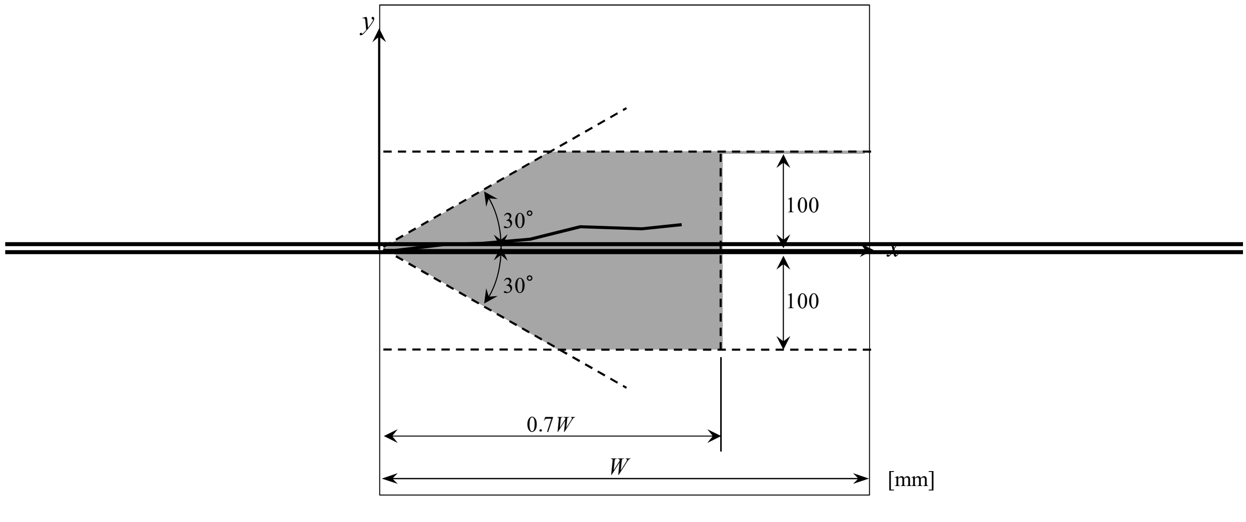
1.2.9 Determination of Arrest Toughness Value

1 When an arrested crack satisfies all of the conditions **(1)** to **(4)** described below, the length of the arrested crack, a, determined by requirement **1.2.8** is valid. If any of the conditions are not met, the arrest toughness value, K_{ca}, calculated from requirement in **4** is a reference value.

(1) All the crack path from crack initiation to arrest is to be within the range shown in **Fig. 7**. In cases where the main crack tip lies within this range but a part of the main crack passes outside the range, however, arrest toughness value, K_{ca}, may be assessed valid if the temperature at the most deviated position of the main crack in the y direction is lower than that at $y = 0$, and also the stress intensity factor, K, for the main crack falls within ± 5% of the K value for a straight crack of the same a. The stress intensity factor, K, is to be obtained from the following formula:

$$K = K_I \cos^3\left(\frac{\phi}{2}\right) + 3K_{II}\cos^2\left(\frac{\phi}{2}\right)\sin\left(\frac{\phi}{2}\right)$$

Fig. 7 Allowable Range of Main Crack Propagation Path



(2) The arrest crack length, a, is to satisfy the following **(a)** to **(c)** formulae. However, if the strain at the pin position and the crack length at the pin position have been dynamically measured and the value of the strain at the time of arrest is 90% or more of the static strain immediately before crack initiation, the application of formula **(c)** is not necessarily needed.

(a) $0.3 \leqq \left(\frac{a}{W}\right) \leqq 0.7$

(b) $\left(\frac{a}{t}\right) \geqq 1.5$

(c) $\left(\frac{a}{L_p}\right) \leqq 0.15$

(3) Satisfying the following formula is the condition for crack straightness:

$|y_a| \leqq 50\ mm$

In cases where $50\ mm < |y_a| \leq 100\ mm$ and $|\theta| \leq 30°$, it is valid only when the temperature at $x = 0.5\ W$, $y = \pm 100\ mm$ falls within $\pm$ 2.5°C at $x = 0.5\ W$, and $y = 0$.

(4) Satisfying the following formula is the condition for crack branching:

$\left(\frac{x_{br}}{x_a}\right) \leq 0.6$

2 Impact energy, E_i, is to satisfy the following formulae. If these formulae are not satisfied, the arrest toughness value, K_{ca}, calculated from the formulae in requirement **4** is to be treated as a reference value.

$$\frac{E_t}{E_s+E_t} \leqq \frac{5a-1050+1.4W}{0.7W-150},\quad \text{where}\quad 0.3 \leqq \left(\frac{a}{W}\right) \leqq 0.7$$

$$E_s = \frac{10^9 F^2}{2E}\frac{L}{W\,t}$$

$$E_t = \frac{10^9 F^2}{E}\left(\frac{L_{tb}}{W_{tb}\,t_{tb}} + \frac{L_{pc}}{W_{pc}\,t_{pc}}\right)$$

3 In cases where tab plates are multistage as shown in **Fig. 3 (b)**, calculate and total the strain energy of each tab plate. In cases where tab plate widths are tapered as shown in **Fig. 3 (d)**, calculate the strain energy based on elastostatics.

4 The arrest toughness value, K_{ca}, at temperature, T, is to be calculated from the following formula using the arrest crack length, a, and the applied stress, σ, judged by requirement **1** above.

$$K_{ca} = \sigma\sqrt{\pi a}\sqrt{\left(\frac{2W}{\pi a}\right)\tan\left(\frac{\pi a}{2W}\right)}$$

$$\sigma = \frac{10^6 F}{W\,t}$$

1.2.10 Reporting

The following items are to be reported. An example of the format to be used for reports is shown in **REPORT-ESSO(E)**.

(1) Test material: Steel type and yield stress at room temperature

(2) Testing machine: Capacity of the test machine

(3) Test specimen dimensions: Thickness, width, length, angular distortion, and linear misalignment

(4) Integrated specimen dimensions: Tab plate thickness, tab plate width, integrated specimen length including tab plates, and distance between loading pins

(5) Test conditions: Applied load, applied stress, temperature gradient, impact energy, and the

ratio of impact energy to the strain energy stored in the integrated specimen (sum of test specimen strain energy and tab plate strain energy)

(6) Test results

(a) Judgment on arrest: Crack length, presence or absence of crack branching, main crack angle, presence or absence of crack re-initiation, and arrest temperature

(b) Arrest toughness value

(7) Temperature distribution at the moment of impact: Thermocouple position, temperature value, and temperature distribution

(8) Test specimen photographs: Crack propagation path (one side), and brittle crack fracture surface (both sides)

(9) Dynamic measurement results (if measurements are carried out): History of crack propagation velocity, and strain change at pin chucks

1.2.111.3 Method for Obtaining Arrest Toughness Value at a Specific Temperature

1 The arrest toughness value, K_{ca}, at a specific temperature, T_D, may be obtained in accordance with following **(1)** to **(4)** by using test results which are obtained by conducting two or more of the tests specified in this section. The formula below shows the dependency of K_{ca} on the arrest temperature T_K.

$$K_{ca} = K_0 \exp\left(\frac{c}{T_K}\right)$$

(1) Obtain at least four valid K_{ca} data. T_D must be located between the upper and lower limits of the arrest temperature. If T_D is not located in this range, conduct additional tests to satisfy this condition.

(2) Approximate log K_{ca} by a linear expression of $1/T_K$, determine the coefficients log K_0 and c for the data described in **(1)** above using the least square method.

$$\log K_{ca} = \log K_0 + c\frac{1}{T_K}$$

(3) Obtain the value of K_{ca} / K_0 exp(c/ T_K) for each data. When the number of data outside the range of 0.85 to 1.15 does not exceed n, the least square method used in the **(2)** above is considered to be valid. Here n is an integer obtained by rounding down the value of (number of all data/6). If this condition is not met, conduct additional tests to add at least two data and apply the **(2)** above to said data.

$$\frac{K_{ca}}{K_0 \exp\left(\frac{c}{T_K}\right)}$$

(4) The value of $K_0 \exp(c/T_D)$ is defined as the estimated value of K_{ca} at T_D. The estimated value for the temperature corresponding to a specific value of K_{ca} can be obtained from $T_K = c/\log(K_{ca}/K_0)$. If the condition specified in the **(3)** above is not met, these estimated values are treated as reference values.

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 and the arrest temperature T_K according to -1 above are 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 the 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. 81**.

(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. 92**.

3 If both of **(1)** and **(2)** of **-2** above are not satisfied, additional tests may be conducted to satisfy this condition.

Fig. 81 Evaluation Example of K_{ca} at −10 °C

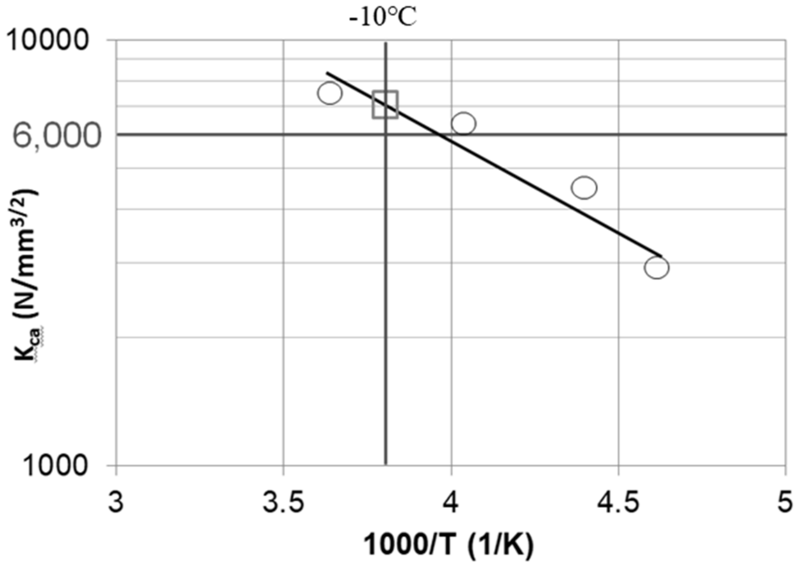
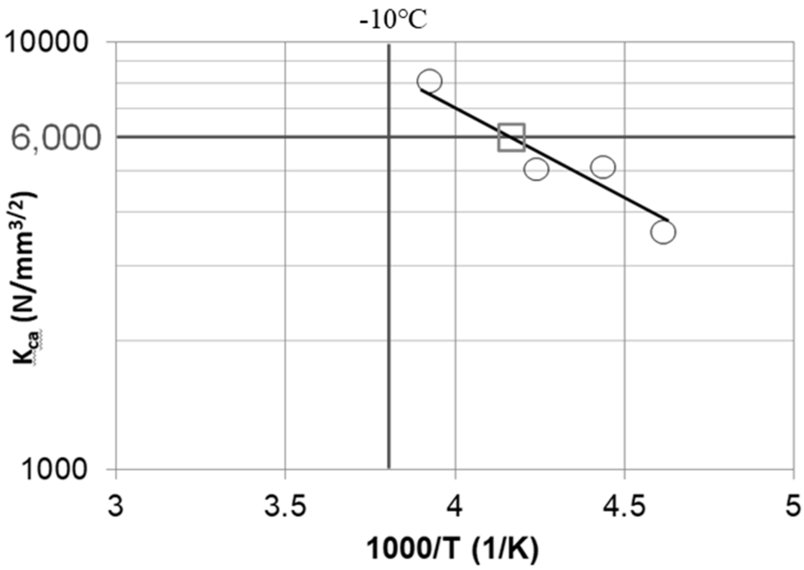


Fig. 92 Evaluation Example of Temperature Corresponding to Required K_{ca}



1.3 Temperature Gradient Double Tension Tests

1.3.1 General

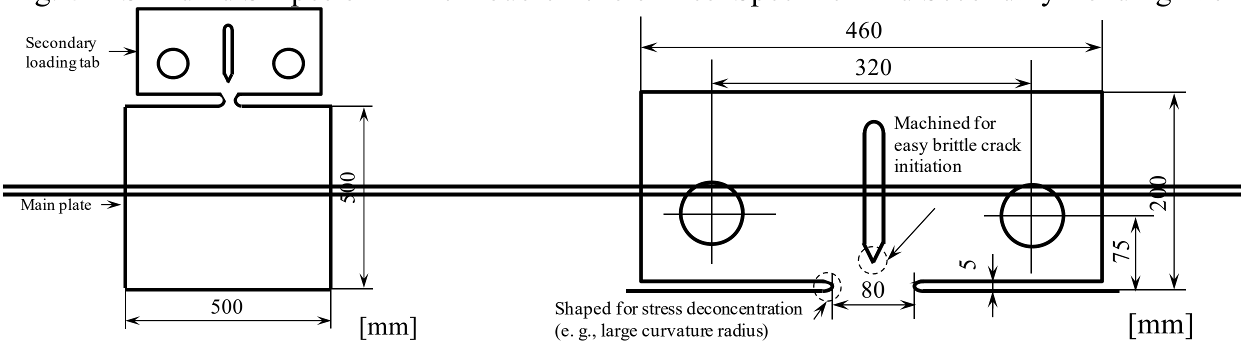
1 The requirements in this section are related to the evaluation of brittle crack arrest toughness through the use of temperature gradient double tension tests.

2 Items not specified in this section are to be accordance mutatis mutandis with the requirements in **1.2**

~~1.3.2 Test Specimen Shapes~~

~~The standard shapes of an entire double tension test specimen and a secondary loading tab are shown in **Fig. 8**.~~

~~Fig. 8 Standard Shapes of Entire Double Tension Test Specimen and Secondary Loading Tab~~



~~(a) The shape of an entire test specimen~~

~~(b) The shape of a secondary loading tab~~

~~1.3.3 Temperature Conditions and Temperature Control Methods~~

~~1 Temperature control methods for secondary loading tabs are to in accordance with the requirements in **1.2.7-1**.~~

~~2 Secondary loading tabs are to be cooled without affecting the temperature gradient of the main plate. The cooling method may use a cooling box and coolant in a similar way as the cooling method for test specimens.~~

~~3 The temperature of the secondary loading tab is to be measured using thermocouples.~~

~~1.3.4 Secondary Loading Method~~

~~Secondary loading devices used to apply loads to secondary loading tabs are to comply with the following **(1)** to **(3)**:~~

~~(1) In order to avoid unnecessary loads affecting the integrated specimen, secondary loading devices need to be held in position using an appropriate method. Suspension type or floor type holding methods can be used.~~

~~(a) Suspension type holding methods~~

~~This method uses a crane or similar device to suspend and hold the secondary loading device in the proper position.~~

~~(b) Floor type holding methods~~

~~This method uses a frame or similar device to lift and hold the secondary loading device it the proper position.~~

~~(2) Loading systems for applying loads to secondary loading tabs are to be of a hydraulic type.~~

~~(3) Loading methods for secondary loading tabs are to be of a pin type. However, other loading methods pin type may be used in cases where deemed appropriate by the Society.~~

Annex K3.12.3-2 GUIDANCE FOR *CAT* EVALUATION TESTS

1.1 General

Paragraphs 1.1.2 has been amended as follows.

1.1.2 Definition

The definition of the symbols used in this Guidance is as specified in **Table 1** as well as ~~**1.1.2**, **Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS"~~ Table 1 of *ISO* 20064:2019.

Title of Section 1.2 has been amended as follows.

1.2 *CAT* ~~e~~Evaluation tests

1.2.2 Test Equipment and Impact Equipment

Sub-paragraph -4 has been amended as follows.

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 °C 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 ~~specified in **Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS"~~ to be in accordance with Table 1 of *ISO* 20064:2019.

1.2.3 Test Specimens

Sub-paragraph -1 has been amended as follows.

1 Test specimens are to be in accordance with ~~**Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS"~~ *ISO* 20064:2019, unless otherwise specified in this Guidance.

Title of Paragraph 1.2.4 has been amended as follows.

1.2.4 Double ~~t~~Tension ~~t~~Type ~~c~~Crack ~~i~~Initiation

Sub-paragraph -1 has been amended as follows.

1 Reference is to be made to ~~**Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS"~~ 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.

1.2.6 Side Grooves

Sub-paragraphs -4 and -6 have been amended as follows.

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 ~~of 150 *mm*~~.
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.

Paragraph 1.2.7 has been amended as follows.

1.2.7 Nominal Length of Embrittled Zone

1 The length of embrittled zone is to be at least 150 *mm*.
~~1~~2 *EBW* zone length is regulated by three measurements on the fracture surface after tests, as shown in **Fig. 3**, L_{EB-min} between specimen edges and the *EBW* front line, and L_{EB-s1} and L_{EB-s2}.
~~2~~3 The minimum length between specimen edges and the *EBW* front line (L_{EB-min}) is to be no smaller than 150 *mm*. When L_{EB-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)**.
~~3~~4 L_{EB-s1} and L_{EB-s2} are the lengths between specimen edges and the *EBW* front for both side surfaces. Both L_{EB-s1} and L_{EB-s2} are to be no smaller than 150 *mm*.
~~4~~5 In *LTG* systems, L_{LTG} is set as 150 *mm*.

Paragraph 1.2.8 has been amended as follows.

1.2.8 Tab Plate and Pin Chuck Details

The following **(1)** and **(2)** are to be as specified in ~~**Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS"~~ *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.

1.2.10 Loading and Brittle Crack Initiation

Sub-paragraphs -2 and -4 have been amended as follows.

1 Prior to testing, a target test temperature (T_{target}) is to be selected.
2 Test procedures are to be in accordance with ~~**Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS"~~ *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 ~~of the~~ temperature measurements and the applied force are recorded.

1.2.12 Judgment of "Arrest" or "Propagate"

Sub-paragraphs -1 and -4 have been amended as follows.

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 ~~**Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS"~~ *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 ~~in~~ when the fractured surface ~~all occupied by~~ 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".

EFFECTIVE DATE AND APPLICATION (Amendment 2-2)

1. The effective date of the amendments is 1 July 2024.
2. Notwithstanding the amendments to the Guidance, the current requirements apply to steels for which the application for approval is submitted to the Society before the effective date.