RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

RULES

Part K Materials

2020 AMENDMENT NO.2

Rule No.112 24 December 2020

Resolved by Technical Committee on 5 August 2020

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

Rule No.112 24 December 2020
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 3 ROLLED STEELS

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

3.10.2 Kinds

Table K3.33 has been amended as follows.

Table K3.33 Kind, Deoxidation Practice and Chemical Composition of 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*		
(Omitted)																		
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. (~~11~~10)	—
	*KD*32																	
	*KE*32																	
	*KA*36																0.40 max. (~~11~~10)	
	*KD*36																	
	*KE*36																	
	*KA*40																0.42 max. (~~11~~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. (~~11~~10)	
	*KF*36																0.40 max. (~~11~~10)	
	*KF*40																0.42 max. (~~11~~10)	
	~~*KE*47~~		~~(10)~~														~~0.49 max.~~	~~0.22 max.~~
	*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) to (9) are omitted.)

~~(10) The chemical composition of *KE*47 is to be as deemed appropriate by the Society.~~

(~~11~~10) Only in cases where *TMCP* is applied for heat treatment.

3.10.4 Heat Treatment

Table K3.34 has been amended as follows.

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	(~~7~~8)	64	(~~7~~8)	75	(~~7~~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.

(~~7~~8) Standards deemed appropriate by Society.

Section 3.12 has been amended as follows.

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 ~~specially~~ considered so as to have brittle crack arrest properties relating to the ~~structural~~brittle crack arrest design for the

container carriers specified in **32.13**, **Part C of the Rules**.

2 The requirements are to apply to hull structural rolled steels for plates with thickness exceeding 50 *mm* but not exceeding 100 *mm* (~~*KE, KE32,* *KE*36, *KE*40~~, and *KE*47~~, *KF32, KF36 and KF*40~~).

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.~~2~~3 Brittle Crack Arrest Properties etc.*

1 The brittle crack arrest properties of steel plates are to conform to the requirements in **Table K3.~~39~~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.

~~2~~3 A brittle fracture test deemed appropriate by the Society may be substituted for temperature gradient *ESSO* tests ~~or,~~ 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.~~39~~40 Brittle Crack Arrest Properties

Kinds of Steels		~~e~~Classification	Temperature gradient *ESSO* tests or double tension tests	
			Evaluation Temperature (°C)	Arrest Toughness Value K_{ca} ($N/mm^{3/2}$)
Rolled Steels for Hull	~~*KE*, *KE*32, *KF*32,~~ *KE*36~~, *KF*36,~~ *KE*40~~, *KF*40,~~ *KE*47	~~*A*400~~	~~-10~~	~~min. 4000~~
		~~*A*500~~	~~-10~~	~~min. 5000~~
		~~*A*600~~ *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 ~~exceeding *A*600~~ 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* (°C)
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.~~3~~4 Selection of Test Samples

1 ~~For the samples, steel plates (of same thickness, belonging to the same charge and same heat treatment condition), which are not greater in weight than 50 *ton*, are to be treated as one lot, and one test sample is to be taken from each lot~~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.~~4~~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 ~~assembly~~test specimens, except the requirement specified in **-3**, are left to the discretion of the Society.

3.12.~~5~~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.~~6~~7 Marking

For the products complying with the requirements specified in **3.12**, "~~*A400*~~*BCA*6000" or "~~*A600*~~*BCA*8000" given in **Table K3.~~39~~40 or Table K3.41** is to be suffixed to the markings. (Example: *KE*40-~~*A400*~~*BCA*6000 for *KE*40.)

3.13 Additional Requirements for Corrosion Resistant Steel for Cargo Oil Tanks

Paragraph 3.13.2 has been amended as follows.

3.13.2 Kinds

The steels are classified into kinds and grades as given in **Table K3.4~~0~~2**.

Table K3.40 has been amended as follows.

Table K3.4~~0~~2 Kinds of Corrosion Resistant Steel for Cargo Oil Tanks
(Table is omitted.)

EFFECTIVE DATE AND APPLICATION

1. The effective date of the amendments is 1 January 2021.

2. Notwithstanding the amendments to the Rules, the current requirements apply to steels being used on ships for which the date of contract for construction* is before the effective date.

* "contract for construction" is defined in the latest version of IACS Procedural Requirement (PR) No.29.

IACS PR No.29 (Rev.0, July 2009)

1. The date of "contract for construction" of a vessel is the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. This date and the construction numbers (i.e. hull numbers) of all the vessels included in the contract are to be declared to the classification society by the party applying for the assignment of class to a newbuilding.

2. The date of "contract for construction" of a series of vessels, including specified optional vessels for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective owner and the shipbuilder.

For the purpose of this Procedural Requirement, vessels built under a single contract for construction are considered a "series of vessels" if they are built to the same approved plans for classification purposes. However, vessels within a series may have design alterations from the original design provided:

(1) such alterations do not affect matters related to classification, or

(2) If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to the Society for approval.

The optional vessels will be considered part of the same series of vessels if the option is exercised not later than 1 year after the contract to build the series was signed.

3. If a contract for construction is later amended to include additional vessels or additional options, the date of "contract for construction" for such vessels is the date on which the amendment to the contract, is signed between the prospective owner and the shipbuilder. The amendment to the contract is to be considered as a "new contract" to which **1.** and **2.** above apply.

4. If a contract for construction is amended to change the ship type, the date of "contract for construction" of this modified vessel, or vessels, is the date on which revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder.

Note:
This Procedural Requirement applies from 1 July 2009.

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

GUIDANCE

Part K Materials

2020 AMENDMENT NO.2

Notice No.61 24 December 2020

Resolved by Technical Committee on 5 August 2020

Notice No.61 24 December 2020
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

K3 ROLLED STEELS

K3.12 Additional Requirements for Brittle Crack Arrest Properties

Paragraph K3.12.2 has been amended as follows.

K3.12.~~2~~3 Brittle Crack Arrest Properties, etc.

1 In **3.12.~~2~~3-1, Part K of the Rules**, "the discretion of the Society" can be regarded as **Annex K3.12.~~2~~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 the requirements in **3.12.~~4~~5-1, Part K of the Rules**, notwithstanding the requirements in **1.2.11, Annex K3.12.~~2~~3-1**.

2 In **3.12.3-2**, **Part K of the Rules**, "the discretion of the Society" may be regarded as **Annex K3.12.3-2** "GUIDANCE FOR CAT EVALUATION TESTS" in the case of Crack Arrest Temperature (*CAT*) evaluation tests.

~~2~~3 For **3.12.~~2~~3-1, 3.12.3-2** and **3.12.~~4~~5-4**, **Part K of the Rules**, test plan, containing information on the items mentioned below, are to be submitted 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)

Annex K3.12.2-1 has been amended as follows.

Annex K3.12.~~2~~3-1 GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS

1.1 General

Paragraph 1.1.1 has been amended as follows.

1.1.1 Application

The requirements in this Guidance apply to rolled steel plates ~~for hulls of~~ with thicknesses of exceeding 50 *mm* but 100 *mm* or less. Rolled steel plates having thickness exceeding 100 *mm* are to the discretion of the society.

1.2 Temperature Gradient *ESSO* Tests

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.

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

Table 2 has been amended as follows.

Table 2 Dimensions of Test Specimens

Test specimen thickness, t	~~6~~50 *mm* ~~<~~≤ $t \leq 100$ *mm*
Test specimen width, W	350 *mm* $\leq W \leq 1000$ *mm*
Test specimen width/test specimen thickness, W / t	$W / t \geq 5$

Note:
Test specimen width is standardized as 500 *mm*.

Paragraph 1.2.8 has been amended as follows.

1.2.8 Test Procedures

(-1 is omitted.)

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. ~~If no crack is initiated,~~ 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 is omitted.)

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, ~~I~~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 $y = 0$.

(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

Sub-paragraph -4 has been amended as follows.

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.

$$K_{ca} = \sigma\sqrt{\pi a}\sqrt{\left(\frac{2W_{\text{~~s~~}}}{\pi a}\right)\tan\left(\frac{\pi a}{2W_{\text{~~s~~}}}\right)}$$

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

Paragraph 1.2.11 has been amended as follows.

1.2.11 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.

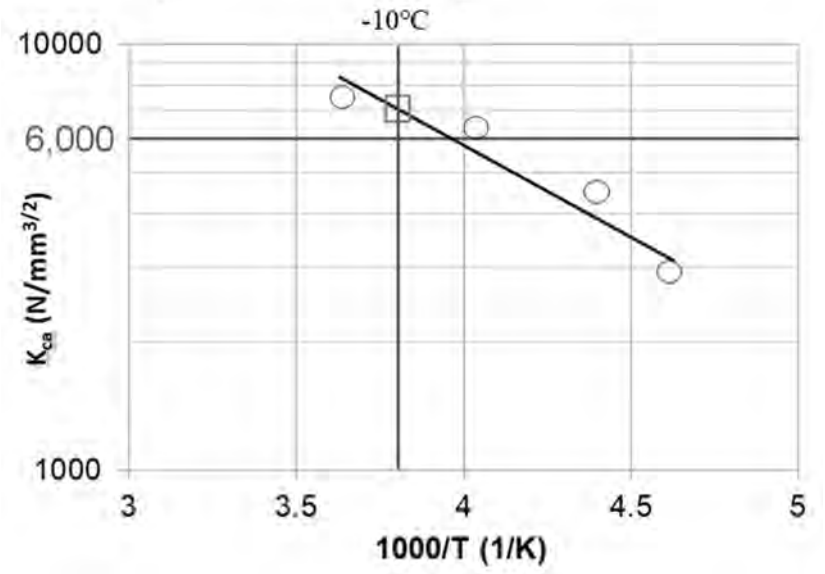
$$K_{ca} = K_0 \exp\left(\frac{C}{T_K}\right)$$

((1) to (4) are omitted.)

2 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 to comply with either the following **(1)** or **(2)**.

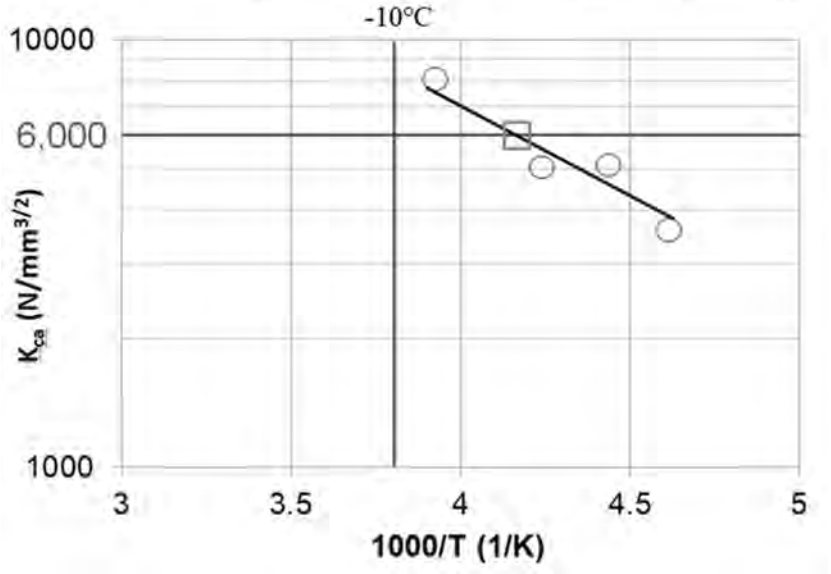
(1) The evaluation temperature of K_{ca} (i.e. -10°C) is to be located between the upper and lower limits of the arrest temperature, with the K_{ca} corresponding to the evaluation temperature not lower than the required K_{ca} (e.g. 6,000 $N/mm^{3/2}$ or 8,000 $N/mm^{3/2}$), as shown in **Fig. 8**.

Fig. 8 Evaluation Example of K_{ca} at -10°C



(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. 9**.

Fig. 9 Evaluation Example of Temperature Corresponding to Required K_{ca}



Annex K3.12.3-2 has been added as follows.

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 **1.1.2**, **Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS".

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 specified in **Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS".

1.2.3 Test Specimens

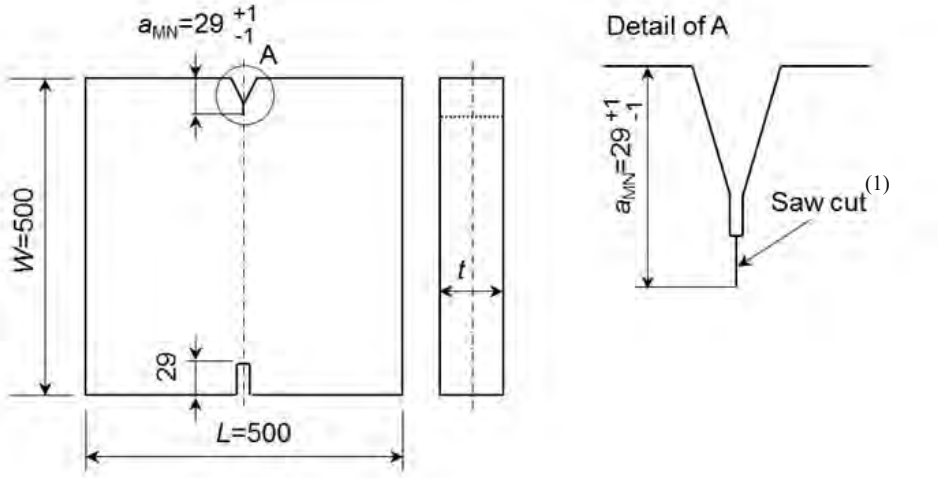
1 Test specimens are to be in accordance with **Annex K3.12.3-1** "GUIDANCE FOR TEMPERATURE GRADIENT ESSO TESTS AND DOUBLE TENSION TESTS", unless otherwise specified in this Guidance.

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

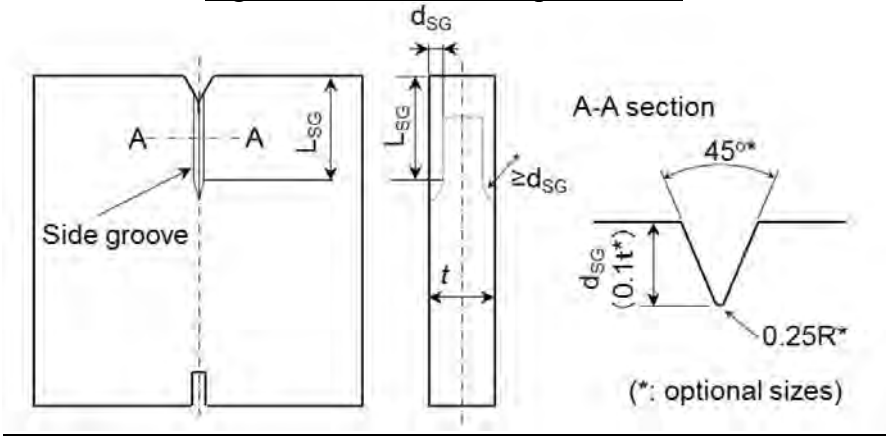
3 In *LTG* embrittlement, side grooves are mandatory. Side grooves with the same shape and size are to be machined on both side surfaces.

4 The length of side groove (L_{SG}) is to be no shorter than the sum of the required embrittled zone length 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.

Fig. 2 Side Groove Shape and Size



1.2.7 Nominal Length of Embrittled Zone

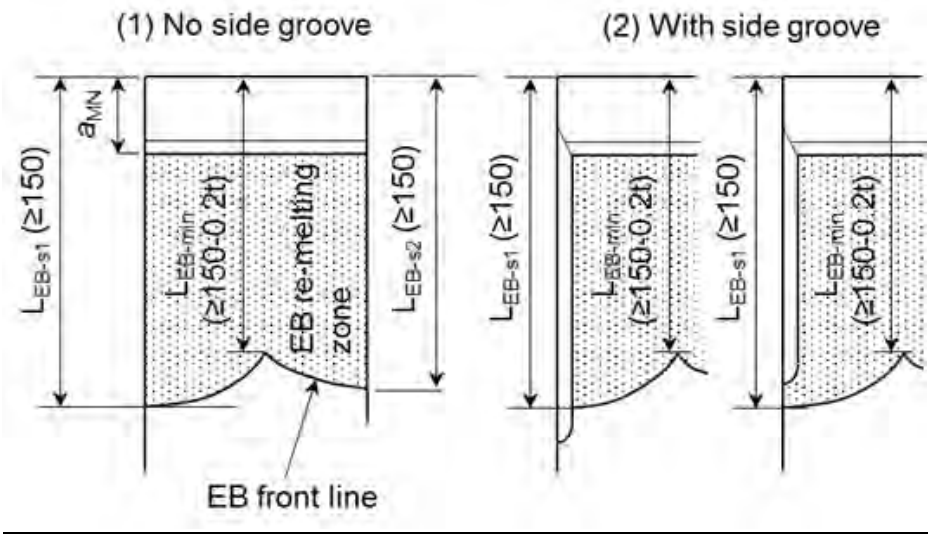
1 *EBW* zone length is regulated by three measurements on the fracture surface after tests, as shown in **Fig. 3**, $L_{EB\text{-}min}$ between specimen edges and the *EBW* front line, and $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$.

2 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)**.

3 $L_{EB\text{-}s1}$ 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*.

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

(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

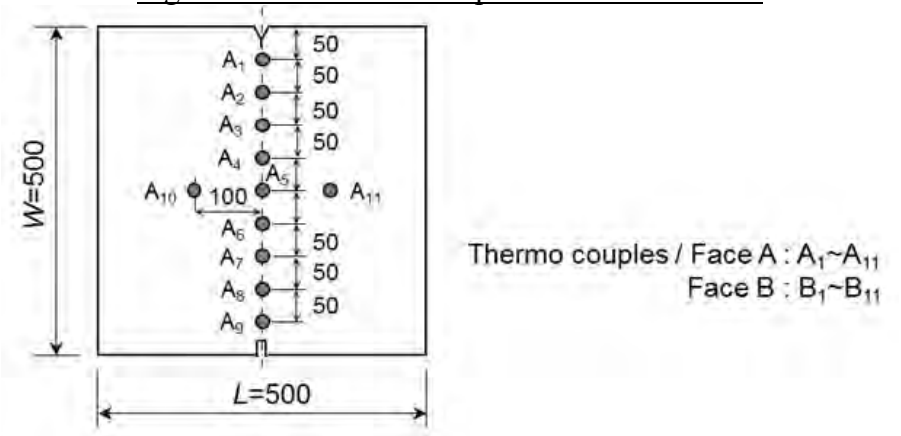
1 Preloading at room temperature may be applied to avoid brittle crack initiation at tests. The applied preloading is to be according to **(1)** and **(2)** below.

(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℃ of the target test temperature (T_{target}).

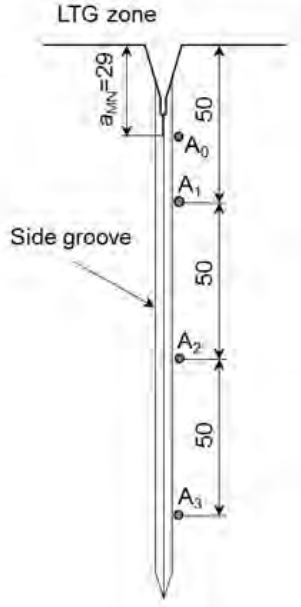
(2) When all measured temperatures across the range of 0.3*W*~0.7*W* have reached T_{target}, steady temperature control is to be keep at least for 10+0.1×*t* (*mm*) minutes to ensure a uniform temperature distribution into mid-thickness prior to applying test load.

(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**.

Fig. 5 Detail of *LTG* Zone and Additional Thermocouple A_0

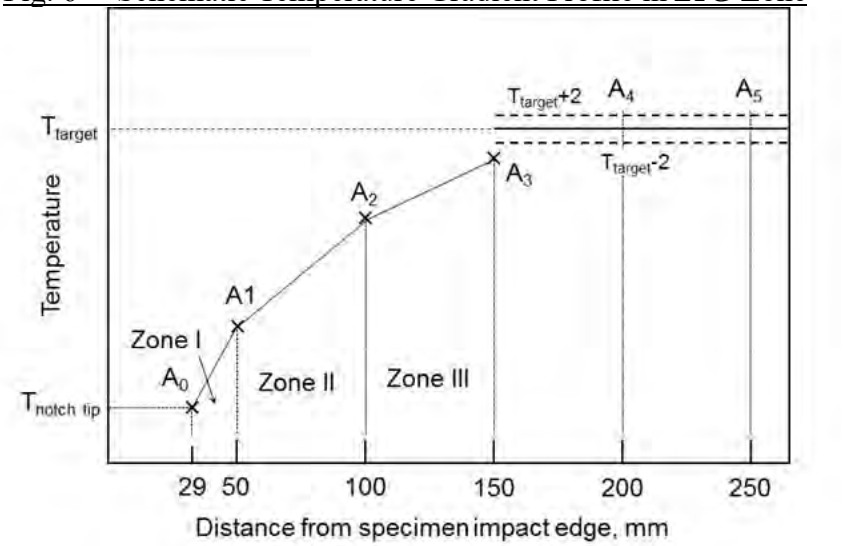


(2) The temperatures of the thermocouples across the range of 0.3*W*~0.7*W* in both width and longitudinal directions are to be controlled within ±2℃ of the target test temperature (T_{target}). However, the temperature measurement at 0.3*W* (location of A_3 and B_3) is to be in accordance with **(6)** 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**.

Fig. 6 Schematic Temperature Gradient Profile in *LTG* Zone



(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**.

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.

(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.

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

1.2.11 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.

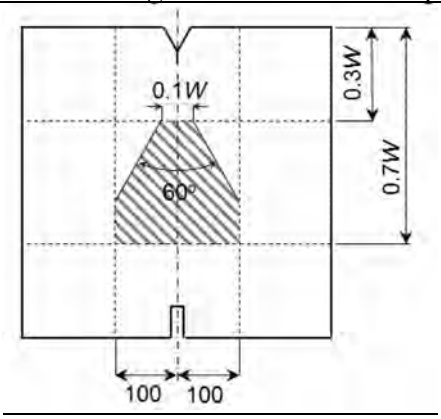
(2) If brittle crack spontaneously initiates without impact or secondary tab tension but after the specified time at the test force is achieved, the test is considered to be a valid initiation. The following validation judgments of crack path and fracture appearance are to be examined.

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.

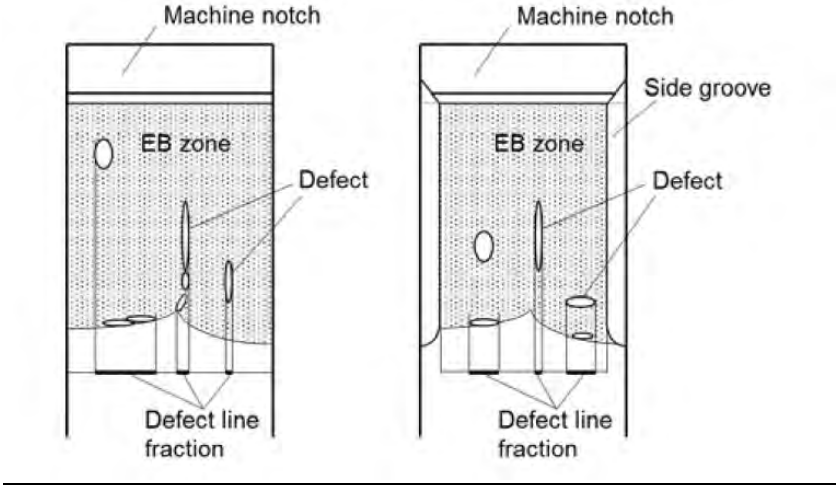
(3) In *EBW* embrittlement setting, *EBW* zone length is quantified by three measurements of $L_{EB\text{-}s1}$, $L_{EB\text{-}s2}$ and $L_{EB\text{-}min}$, which are defined in **1.2.7**. When either or both of $L_{EB\text{-}s1}$ and $L_{EB\text{-}s2}$ are smaller than 150 *mm*, the test is considered 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.

Fig. 8 Counting Procedure of Defect Line Fraction



(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.

1.2.12 Judgment of "Arrest" or "Propagate"

1 If initiated brittle crack is arrested and the tested specimen is not broken into two pieces, the fracture 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".

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 the fracture surface all occupied by 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°C 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 150*mm*, 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**.

EFFECTIVE DATE AND APPLICATION

1. The effective date of the amendments is 1 January 2021.

2. Notwithstanding the amendments to the Guidance, the current requirements apply to steels being used on ships for which the date of contract for construction* is before the effective date.

* "contract for construction" is defined in the latest version of IACS Procedural Requirement (PR) No.29.

IACS PR No.29 (Rev.0, July 2009)

1. The date of "contract for construction" of a vessel is the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. This date and the construction numbers (i.e. hull numbers) of all the vessels included in the contract are to be declared to the classification society by the party applying for the assignment of class to a newbuilding.

2. The date of "contract for construction" of a series of vessels, including specified optional vessels for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective owner and the shipbuilder.

For the purpose of this Procedural Requirement, vessels built under a single contract for construction are considered a "series of vessels" if they are built to the same approved plans for classification purposes. However, vessels within a series may have design alterations from the original design provided:

(1) such alterations do not affect matters related to classification, or

(2) If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to the Society for approval.

The optional vessels will be considered part of the same series of vessels if the option is exercised not later than 1 year after the contract to build the series was signed.

3. If a contract for construction is later amended to include additional vessels or additional options, the date of "contract for construction" for such vessels is the date on which the amendment to the contract, is signed between the prospective owner and the shipbuilder. The amendment to the contract is to be considered as a "new contract" to which **1.** and **2.** above apply.

4. If a contract for construction is amended to change the ship type, the date of "contract for construction" of this modified vessel, or vessels, is the date on which revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder.

Note:
This Procedural Requirement applies from 1 July 2009.