W31 Application of YP47 Steel Plates

(Jan 2013) (Rev.1 Sept 2015)

1. Application

1.1 General

1.1.1 ~~This UR is to be complied with for container carriers incorporating extremely thick steel plates in accordance with 1.2.1.~~ Steel plates designated as YP47, refer to steel plates with a specified minimum yield point of 460 N/mm^2. The scope of application is defined in 1.1.2 and 1.2.

1.1.2 ~~This document gives the basic concepts for application of YP47 steel plates to longitudinal structural members~~ The YP47 steel can be applied to longitudinal structural members in the upper deck region of container carriers (such as hatch side coaming, hatch coaming top and the attached longitudinals). Special consideration is to be given to the application of YP47 steel plate for other hull structures.

This document defines grade YP47, its approval requirements, its certification requirements, welding consumables requirements and requirements for weld procedure qualification.

1.1.3 In the case where YP47 steel is applied as brittle crack arrest steel required by UR S33, the brittle crack arrest properties shall be in accordance with 2.1.2 of this UR.

1.1.4 Brittle fracture toughness of welded joints is to comply with IACS UR W11, UR W28 and this UR.

1.1.~~3~~5 Unless otherwise specified in this document, UR W11 is to be followed.

~~1.1.4 YP47 steel plates mean the steel plates of specified minimum yield point of 460 N/mm^2. The scope of application is defined under 1.2 and 1.3.~~

1.2 Thickness

1.2.1 This document gives the requirements for steel plates ~~with~~ in thickness ~~of over~~ greater than 50mm and not greater than 100mm intended for hatch coamings and upper decks of container ships.

1.2.2 For steel plates outside of this thickness range, special consideration is to be given by each Classification Society.

Notes:

1. This UR is to be applied by IACS Societies to ships contracted for construction on or after 1 January 2014.

2. Revision 1 of this UR is to be applied by IACS Societies to ships contracted for construction on or after 1 January 2017.

~~2~~3. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

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~~**1.3 Use of steel grade**~~

~~1.3.1 In the case that YP47 steel plates are used for longitudinal structural members in the upper deck region such as hatch side coaming and hatch coaming top and their attached longitudinals, the grade of YP47 steel plates is to be EH47 specified hereinafter.~~

2. General

~~**2.1 Hull structures (design)**~~

~~2.1.1 HT factor (Material factor of high tensile steel, K)~~

~~HT factor for the assessment of hull girder strength is to be taken as 0.62.~~

~~2.1.2 Fatigue assessment~~

~~Fatigue assessment on the longitudinal structural members is to be performed in accordance with each Classification Society's procedures.~~

~~2.1.3 Details of construction design~~

~~Special consideration is to be paid to the details of constructions of structural members where YP47 steel plates are applied such as connections between outfitting and hull structures. Connections are to be in accordance with each Classification Society's procedures.~~

2.~~2~~1 Material specifications

2.~~2~~1.1 Material specifications for YP47 steel plates are defined in Table 1 and Table 2.

Table 1 Conditions of supply, grade and mechanical properties for YP47 steel plates

Supply condition	Grade	Mechanical Properties			Impact test			
		Yield Strength (N/mm^2) min.	Tensile Strength (N/mm^2)	Elongation (%) min	Test Temp. (^oC)	Average Impact Energy (J) min.		
						50 < t ≤ 70	70 < t ≤ 85	85 < t ≤ 100
TMCP*	EH47	460	570/720	17	-40^{o}C	53	64	75

Note

t: thickness (mm)

* Other conditions of supply are to be in accordance with each Classification Society's procedures.

Table 2 Chemical compositions for YP47 steel plates

Chemical composition	C_{eq}*1	P_{cm}*2
As approved by each Classification Society	≤ 0.49%	≤ 0.22%

Note

*1 The carbon equivalent C_{eq} value is to be calculated from the ladle analysis using the following formula.

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

*2 Cold cracking susceptibility is to be calculated using the following formula.

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

The extent of testing is to be one set of three specimens taken from each piece defined in UR W11 11.1.

2.1.2 For the purpose of this UR, brittle crack arrest steel is defined as steel plate with measured crack arrest properties at manufacturing approval stage, K_{ca} at -10 degree C ≥ 6,000 N/mm$^{3/2}$ or other methods based on the determination of Crack Arrest Temperature (CAT).

Note 1: The Crack Arrest Fracture Toughness K_{ca} is to be determined by the ESSO Test shown in this UR or other alternative method. Crack Arrest Temperature (CAT) may also be determined by the Double Tension Wide Plate Test or equivalent. The use of small scale test parameters such as the Nil Ductility Test Temperature (NDTT) may be considered provided that mathematical relationships of NDTT to K_{ca} or CAT can be shown to be valid.

Note 2: Where the thickness of the steel exceeds 80 mm the required K_{ca} value or alternative crack arrest parameter for the brittle crack arrest steel plate is to be specifically agreed with each Classification Society.

2.~~3~~2 Manufacturing approval test

2.~~3~~2.1 General

Approval test items, test methods and acceptance criteria not specified in this document are to be in accordance with each Classification Society's procedures.

2.~~3~~2.2 Approval range

One test product with the maximum thickness to be approved is to be selected provided the approved target chemical composition range remains unchanged.

2.~~3~~2.3 Base Metal test

(a) Charpy V-notch Impact Tests

Generally Charpy V-notch impact testing is to be carried out in accordance with IACS UR W11.

Test samples are to be taken from the plate corresponding to the top of the ingot, unless otherwise agreed.

In the case of continuous castings, test samples are to be taken from a randomly selected plate.

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The location of the test sample is to be at the square cut end of the plate, approximately one-quarter width from an edge, as shown Fig.1.

Samples are to be taken with respect to the principal rolling direction of the plate at locations representing the top and bottom of the plate as follows:

Longitudinal Charpy V-notch impact tests - Top and bottom,
Transverse Charpy V-notch impact tests - Top only,
Strain aged longitudinal Charpy V-notch impact test - Top only.

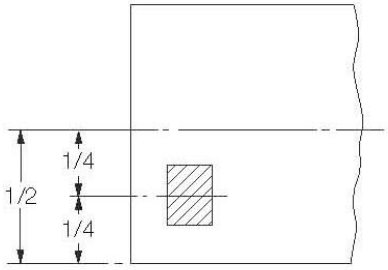

Fig.1 Plates and flats

Charpy V-notch impact tests are required from both the quarter and mid thickness locations of the test samples.

One set of 3 Charpy V-notch impact specimens is required for each impact test.

The Charpy V-notch impact test temperature is to be -40°C.

In addition to the determination of the energy value, the lateral expansion and the percentage crystallinity are also to be reported.

The strain aged samples are to be strained to 5% followed by heating to 250°C for 1 hour prior to testing.

Additionally at each location, Charpy V-notch impact tests are to be carried out with appropriate temperature intervals to properly define the full transition range.

(b) Brittle fracture initiation test

Deep notch test or Crack Tip Opening Displacement (CTOD) test is to be carried out and the result is to be reported.

Test method is to be in accordance with each Classification Society's practice.

(c) Naval Research Laboratory (NRL) drop weight test

The test method is to comply with ASTM E208 or equivalent method.

Nil Ductility Test Temperature (NDTT) is to be reported for reference and may be used in the qualification of production test methods.

(d) Brittle crack arrest test

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~~Standard~~ ESSO test described in Annex ~~2~~1 ~~of UR S33 (Safety Measures of Extremely Thick Steel Plates)~~ or other alternative test (e.g. double tension test etc.) is to be carried out in order to obtain the brittle crack arrest toughness for reference.

2.~~3~~2.4 Weldability test

(a) Charpy V-notch Impact Test

Charpy V-notch impact tests are to be taken at a position of 1/4 thickness from the plate surface on the face side of the weld with the notch perpendicular to the plate surface.

One set of the specimens transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line.

The fusion boundary is to be identified by etching the specimens with a suitable reagent.

One additional set of the specimens is to be taken from the root side of the weld with the notch located at the same position and at the same depth as for the face side.

The impact test temperature is -40°C.

Additionally at each location, impact tests are to be carried out with appropriate temperature intervals to properly define the full transition range.

(b) Y- shape weld crack test (Hydrogen crack test)

The test method is to be in accordance with recognized national standards such as KS B 0870, JIS Z 3158 or GB 4675.1.

Acceptance criteria are to be in accordance with each society's practice.

(c) Brittle fracture initiation test

Deep notch test or CTOD test is to be carried out.

Test method and results are to be considered appropriate by each Classification Society.

2.~~4~~3 Welding works

2.~~4~~3.1 Welder

Welders engaged in YP47 welding work are to possess welder's qualifications specified in each Classification Society's procedures.

2.~~4~~3.2 Short bead

Short bead length for tack and repairs of welds by welding are not to be less than 50mm.

In the case where P_{cm} is less than or equal to 0.19, 25mm of short bead length may be adopted with approval of each Classification Society.

2.~~4~~3.3 Preheating

Preheating is to be 50°C or over when air temperature is 5°C or below.

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In the case where P_{cm} is less than or equal to 0.19, air temperature of 0°C or below may be adopted with approval of each Classification Society.

2.4~~3~~.4 Welding consumable

Specifications of welding consumables for YP47 steel plates are to be in accordance with Table 3.

Table 3 Mechanical properties for deposited metal tests for welding consumables

Mechanical Properties			Impact test	
Yield Strength (N/mm^2) min.	Tensile Strength (N/mm^2)	Elongation (%) min	Test Temp. (°C)	Average Impact Energy (J) min.
460	570/720	19	-20	53

Consumable tests for butt weld assemblies are to be in accordance with Table 4.

Table 4 Mechanical properties for butt weld tests for welding consumables

Tensile strength (N/mm^2)	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests		
		Test temperature (°C)	Average energy (J) min.	
			Downhand, horizontal-vertical, overhead	Vertical (upward and downward)
570 - 720	4	- 20	53	53

2.4~~3~~.5 Others

Special care is to be paid to the final welding so that harmful defects do not remain.

Jig mountings are to be completely removed with no defects in general, otherwise the treatment of the mounting is to be accepted by each Classification Society.

2.5~~4~~ Welding Procedure Qualification Test

2.5~~4~~.1 General

Approval test items, test methods and acceptance criteria not specified in this document are to be in accordance with each Classification Society's procedures.

2.5~~4~~.2 Approval range

UR W28 is to be followed for approval range.

2.5~~4~~.3 Impact test

UR W28 is to be followed for impact test. 64J at -20°C is to be satisfied.

2.5~~4~~.4 Hardness

HV10, as defined in UR W28, is to be not more than 380. Measurement points are to include mid-thickness position in addition to the points required by UR W28.

2.5~~4~~.5 Tensile test

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Tensile strength in transverse tensile test is to be not less than 570N/mm^2.

2.~~5~~4.6 Brittle fracture initiation test

Deep notch test or CTOD test may be required.

Test method and acceptance criteria are to be considered appropriate by each Classification Society.

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Annex 1
ESSO Test

1 Scope

1.1 The ESSO test method is used to estimate the brittle crack arrest toughness value K_{ca} of rolled steel plates for hull of thickness 100 mm or less.

2 Symbols

Table 1 Nomenclature

Symbol	Unit	Meaning
t_S	mm	Thickness of test specimen
W_S	mm	Width of test specimen
L_S	mm	Length of test specimen
t_r	mm	Thickness of tab plate
W_r	mm	Width of tab plate
L_r	mm	Length of tab plate
L_P	mm	Distance between pins
a	mm	Length of crack projected on surface normal to the line of load
a_a	mm	Maximum crack length at brittle crack arrest position
T	^oC	Temperature of test specimen
dT/da	^oC/mm	Temperature gradient of test specimen
σ	N/mm^2	Gross stress in tested part ($load / W_S.t_S$)
K_{ca}	N/mm$^{3/2}$	Brittle crack arrest toughness value

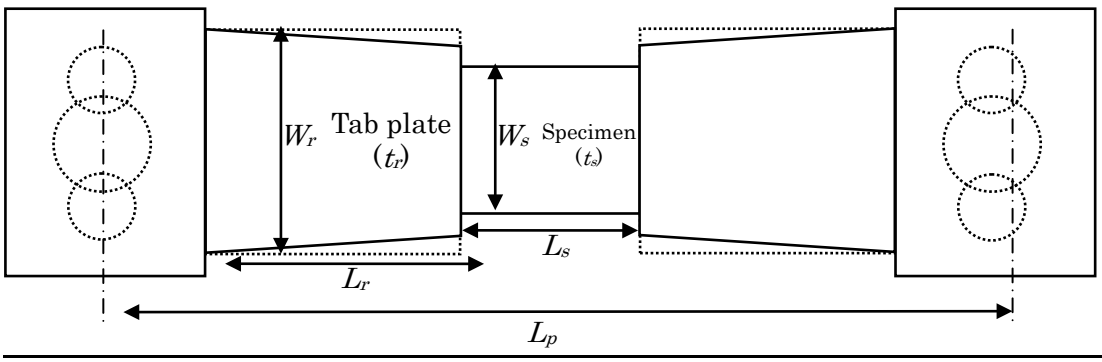

Fig.1 Conceptual view of test specimen, tab and load jig

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3 Purpose

3.1 The purpose of this test is to encourage the performance of a standard test for assessment of brittle crack arrest toughness with temperature gradient and to obtain the corresponding brittle crack arrest toughness value K_{ca}.

4 Standard test specimen

4.1 Fig.2 shows the shape and size of the standard test specimen.

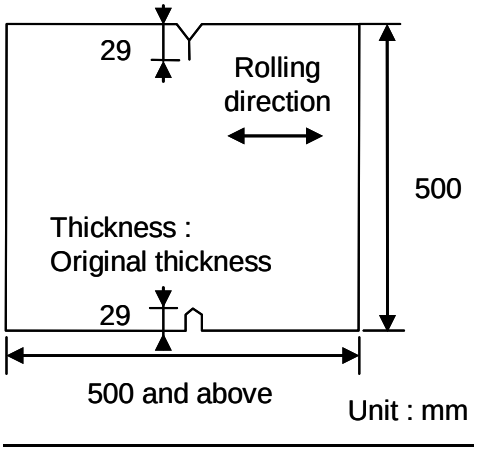

Fig.2 Shape and size of specimen

4.2 The thickness and width of the test specimen are to be in accordance with Table 2.

Table 2 Thickness and width of test specimen

Thickness, t_s	100 mm and below
Width of test specimen, W_s	500 mm

Note: If the width of the test specimen cannot be made at 500 mm, it may be taken as 600 mm.

4.3 The test specimens are to be taken from the same steel plate.

4.4 Test specimens are to be taken in such a way that the axial direction of the load is parallel to the rolling direction of the steel plate.

4.5 The thickness of the test specimen is to be the same as the thickness of the steel plate to be used in the vessel structure.

5 Test equipment

5.1 The test equipment to be used is to consist of pin load type hydraulic test equipment capable of tensile tests.

5.2 The distance between the pins is to be not less than 2,000 mm. The distance between pins refers to the distance between the centres of the pin diameters.

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5.3 Drop weight type or air gun type impact equipment may be used for the impact energy required for generating brittle cracks.

5.4 The wedge is to have an angle greater than the upper notch of the test specimen, and an opening force is to be applied on the notch.

6 Test preparations

6.1 The test piece is to be fixed directly to the pin load jig or by means of weld joint through the tab plate. The overall length of the test specimen and tab plate is to be not less than 3Ws. The thickness and width of the tab plate are to be in accordance with Table 3.

Table 3 Allowable dimensions of tab plate

	Thickness: t_r	Width: W_r
Dimensions of tab plate	0.8ts(Notes 1 and 2) ≤ t_r ≤ 1.5t_s	$W_s \le W_r \le 2W_s$

Note 1: t_s: Thickness of test specimen

Note 2: If the tab plate has a thickness smaller than the test specimen, the reflection of stress wave will be on the safer side for the assessment; therefore, considering the actual circumstances for conducting the test, the lower limit of thickness is taken as $0.8t_s$.

6.2 Thermocouples are to be fitted at 50 mm pitch on the notch extension line of the test specimen.

6.3 If the brittle crack is estimated to deviate from its presumed course, thermocouples are to be fitted at two points separated by 100 mm on the line of load from the notch extension line at the centre of width of the test specimen.

6.4 If dynamic measurements are necessary, strain gauges and crack gauges are to be fitted at specific locations.

6.5 The test specimen is to be fixed to the testing machine together with the tab plate after welding and the pin load jig.

6.6 The impact equipment is to be mounted. The construction of the impact equipment is to be such that the impact energy is correctly transmitted. An appropriate jig is to be arranged to minimize the effect of bending load due to the impact equipment.

7 Test method

7.1 To eliminate the effect of residual stress or correct the angular deformation of tab welding, a preload less than the test load may be applied before cooling.

7.2 Cooling and heating may be implemented from one side on the side opposite the side on which the thermocouple is fitted, or from both sides.

7.3 The temperature gradient is to be controlled in the range of 0.25°C/mm to 0.35°C/mm in the range of width from $0.3W_s$ to $0.7W_s$ at the central part of the test specimen.

7.4 When the specific temperature gradient is reached, the temperature is to be maintained for more than 10 minutes, after which the specified test load may then be applied.

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7.5 After maintaining the test load for at least 30 seconds, a brittle crack is to be generated by impact. The standard impact energy is taken as 20 to 60 J per 1 mm plate thickness. If the brittle crack initiation characteristics of the base metal are high, and it is difficult to generate a brittle crack, the impact energy may be increased to the upper limit of 120 J per 1 mm plate thickness.

7.6 Loading is stopped when the initiation, propagation, and arrest of crack have been confirmed. Normal temperature is restored, and if necessary, the ligament is broken by gas cutting and forcibly the specimen is broken by using the testing machine. Or, after the ductile crack has been propagated to an adequate length with the testing machine, the ligament is broken by gas cutting.

7.7 After forcing the fracture, photos of the fractured surface and the propagation route are to be taken, and the crack length is to be measured.

8 Test results

8.1 The distance from the top of the test specimen including the notch to the maximum length in the plate thickness direction of the arrested crack tip is to be measured. If the crack surface deviates from the surface normal to the line of load of the test specimen, the projected length on the surface normal to the line of load is to be measured. In this case, if the trace of brittle crack arrest is clearly visible on the fractured surface, the first crack arrest position is taken as the arrest crack position.

8.2 From the results of thermocouple measurement, the temperature distribution curve is to be plotted, and the arrest crack temperature is to be measured corresponding to the arrest crack length.

8.3 The brittle crack arrest toughness value (K_{ca} value) of each test is to be determined by using the following formula:

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

9 Report

9.1 The following items are to be reported:

(i) Testing machine specifications; testing machine capacity, distance between pins (L_p)

(ii) Load jig dimensions; tab plate thickness (t_r), tab plate width (W_r), test specimen length including tab plate ($L_s + 2L_r$)

(iii) Test specimen dimensions; plate thickness (t_s); test specimen width (W_s) and length (L_s)

(iv) Test conditions; preload stress, test stress, temperature distribution (figure or table) impact energy

(v) Test results; crack arrest length (a_a), temperature gradient at arrest position, brittle crack arrest toughness (K_{ca})

(vi) Dynamic measurement results (if measurement is carried out); crack growth rate, strain change

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(vii) Test specimen photos; fracture route, fractured surface

9.2 If the conditions below are not satisfied, the test results are to be treated as reference values.

(i) The brittle crack arrest position is to be in the range of the hatched part shown in Fig.3. In this case, if the brittle crack arrest position is more than 50 mm away from the centre of the test specimen in the longitudinal direction of the test specimen, the temperature of the thermocouple at the ±100 mm position is to be within ±3°C of the thermocouple at the centre.

(ii) The brittle crack should not have a distinct crack bifurcation while it propagates.

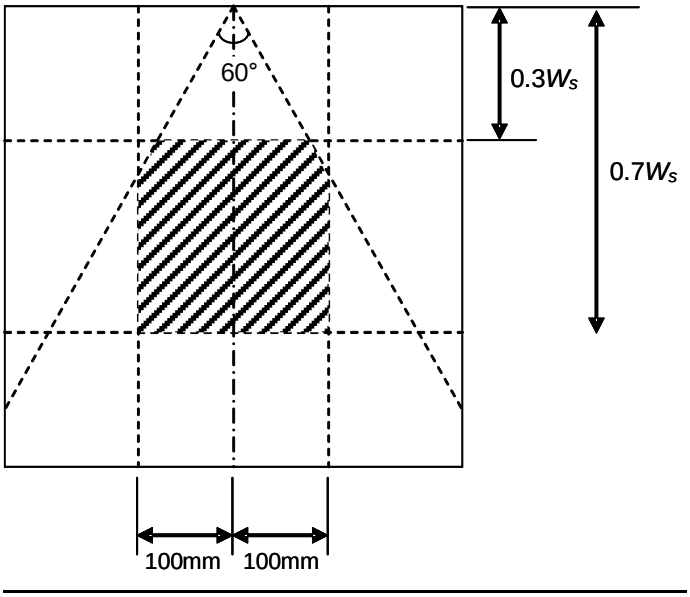

Fig.3 Necessary conditions of arrest crack position

9.3 From effective test results measured at more than 3 points, the linear approximation equation is to be determined on the Arrhenius plot, and K_{ca} at the desired temperature is to be calculated. In this case, data should exist on both sides, that is, the high temperature and low temperature sides around the assessed temperature.

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