

# W1 Material and welding for gas tankers

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## W1.1 Scope General

W1.1.1 This document gives the requirements for plates, sections, pipes, forgings, castings and weldments used in the construction of cargo tanks, cargo process pressure vessels, cargo and process piping and secondary barriers. This document also gives the requirement for plates and sections of hull structural steels which are subject to reduced temperature due to the cargo and which are not forming part of secondary barrier. (See G1.9.1 and G1.9.4 of UR G1).

The requirements for rolled products, forgings and castings are given in Table 1 through Table 5. The requirements for welding procedure tests are given in W1.4.

W1.1.2 The manufacture, testing, inspection and documentation shall be in accordance with the general practice of the Classification Society and the specific requirement given in this document.

~~W1.1.1 The present texts give the general principles which are applied by Classification Societies for approval and survey of the relevant items of liquefied gas tankers for classification purposes. They do not intend to cover full details of such approval and survey procedures which are to be found in the individual Rules of Classification Societies.~~

~~W1.1.2 Where appropriate, these Rules refer to the basic tank types which are defined under G1 & 2 differing from these definitions will be the subject of special consideration.~~

~~W1.1.3 Consideration of future technical advances may warrant modifications to the principles and details set forth in the text. IACS will accordingly review continuously these requirements.~~

~~W1.1.4 When reference is made in these Rules to "Classification Society," only members or associates of IACS are considered.~~

## W1.2 General Scope

~~W1.2.1 This document gives the requirements for plates, sections, pipes, forgings, castings and weldments used in the construction of cargo tanks, cargo process pressure vessels, cargo and process piping and secondary barriers. This document also gives the requirement for plates and sections of hull structural steels which are subject to reduced temperature due to the cargo and which are not forming part of secondary barrier. (See G1 para. G1.9.1 and G1.9.4).~~

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### Note:

1. Rev.3 of this UR is to be uniformly implemented by IACS Societies to ships contracted for construction on or after 1 January 2017.
2. 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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The requirements for rolled products, forgings and castings are given in Tables 1-5. The requirements for weldments are given in W1.4.

~~W1.2.2 The manufacture, testing, inspection and documentation are to be in accordance with the general practice of the Classification Society and the specific requirement given in this document.~~

W1.2.1 Tensile test

The test specimens and procedures shall be in accordance with UR W2. Tensile strength, yield stress and elongation shall be approved by the Classification Society.

For carbon-manganese steel and other materials with definitive yield points, consideration shall be given to the limitation of the yield to tensile ratio.

W1.2.23 Charpy V-notch impact test

Acceptance tests ~~are to~~ shall include Charpy V-notch ~~toughness~~ impact tests unless otherwise approved. The specified Charpy V-notch impact test requirements are minimum average energy values for three full size (10mm x 10mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch impact test specimens ~~are to~~ shall be in accordance with the requirements of UR W2. The testing of sub-size specimens ~~is to~~ shall be in accordance with UR W2.

~~In all cases~~ For base metal, the largest size Charpy V-notch impact test specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface, as shown in Figure 1. (See Fig. 1 for weld test specimens). In the case where the material thickness is 40mm or below, the Charpy V-notch impact test specimens shall be cut with their edge within 2mm from the "as rolled" surface with their longitudinal axes either parallel or transverse to the final direction of rolling of the material.

~~The re-testing of Charpy specimens is to be in accordance with UR W2.~~

~~At the discretion of the Classification society, other types of toughness tests, e.g., drop weight test, may be used. These may be either in addition to or in lieu of the Charpy V-notch test.~~

For a weld specimen, the largest size Charpy V-notch impact test specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to appoint midway between the surface and the centre of the thickness. In all cases, the distance from the surface of material to the edge of the specimen shall be approximately 1mm or greater. In addition, for double-V butt welds, specimens shall be machined closer to the surface of the second welded side. The specimens shall be taken generally at each of the following locations, as shown in Figure 2, on the centreline of the welds, the fusion line and 1mm, 3mm and 5mm from the fusion line.

The re-testing of Charpy V-notch impact test specimens shall be in accordance with UR W2.

If the average value of the three initial Charpy V-notch impact test specimens fails to meet the stated requirements, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results be combined with those previously obtained to form a new average. If this new average complies with the requirements and if no more than two individual results are lower, than the

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required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted.

~~W1.2.4 Tensile strength, yield stress and elongation are to be approved by the Classification Society.~~

~~For carbon-manganese steel and other materials with definitive yield points, consideration is to be given to the limitation of the yield to tensile ratio.~~

W1.2.35 Bend test

The bend test may be omitted as a material acceptance test, but is required for weld tests. The test specimens and procedures shall be in accordance with UR W2. The bend tests shall be transverse bend tests, which may be face, root or side bends at the discretion of the Classification Society. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

W1.2.4 Section observation and other testing

Macrosection, microsection observations and hardness tests may also be required by the Classification Society, and they shall be carried out in accordance with the Rules of the Classification Society, where required.

~~W1.2.6 Materials with alternative chemical composition or mechanical properties may be accepted by special agreement with the Classification Society.~~

~~W1.2.7 Where postweld heat treatment is specified or required the properties of the base materials are to be determined in the heat treated condition in accordance with the applicable table and the weld properties are to be determined in the heat treated condition in accordance with W1.4. In cases where a postweld heat treatment is applied the test requirements may be modified at the discretion of the Classification Society.~~

~~W1.2.8 Where reference is made to hull structural steels, the requirements of W11 for appropriate grades apply.~~

W1.2.5 Definitions

- (a) Where reference is made in this UR to A, B, D, E, AH, DH, EH and FH hull structural steels, these steel grades are hull structural steels according to UR W11.
- (b) The definitions of "Piece" and "Batch" are given in 11.1 of UR W11.
- (c) The definitions of "controlled rolling (CR)", "Thermo-mechanical controlled processing (TMCP)" and "Accelerated cooling (AcC)" are given in 3.3 of UR W11.

**W1.3 Material requirements**

W1.3.1 The requirements for materials of construction are shown in the tables as follows:

Table 1: Plates, pipes (seamless and welded), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C.

Table 2: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to –55°C.

Table 3: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below –55°C and down to –165°C.

Table 4: Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0°C and down to –165°C.

Table 5: Plates and sections for hull structures required by G1.9.1 and G1.9.4 of UR G1.

The requirements for castings and forgings intended for cargo and process piping for design temperature above 0°C are at the discretion of the Classification Society.

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**Table 1 Plates, pipes (seamless and welded), <sup>(1),(2)</sup> sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C.**

| CHEMICAL COMPOSITION AND HEAT TREATMENT   |   |                       |
|---|---|-----------------------|
| CARBON-MANGANESE STEEL (Fully killed fine grain steel)  |   |                       |
| Small additions of alloying elements by agreement with the Classification Society.  |   |                       |
| Composition limits to be approved by the Classification Society.  |   |                       |
| Normalized, or quenched and tempered. <sup>(4)</sup>  |   |                       |
| TENSILE AND CHARPY V-NOTCH IMPACT TEST REQUIREMENTS   |   |                       |
| SAMPLING FREQUENCY  |   |                       |
| PLATES  | Each "piece" to be tested.  |                       |
| SECTIONS AND FORGINGS   | Each "batch" to be tested.  |                       |
| MECHANICAL PROPERTIES   |   |                       |
| TENSILE PROPERTIES  | Specified minimum yield stress not to exceed 410 N/mm <sup>2</sup> <sup>(5)</sup> |                       |
| CHARPY V-NOTCH IMPACT TEST  |   |                       |
| PLATES  | Transverse test pieces. Minimum average energy value (KV) 27J                     |                       |
| SECTIONS AND FORGINGS   | Longitudinal test pieces. Minimum average energy value (KV) 41J                   |                       |
| TEST TEMPERATURE  | Thickness t (mm)  | Test temperature (°C) |
|   | t ≤ 20  | 0                     |
|   | 20 < t ≤ 40 <sup>(3)</sup>  | -20                   |
| NOTES:  |   |                       |
| (1) For seamless pipes and fittings, normal practice of the Classification Society applies. The use of longitudinally or spirally welded pipes shall be specially approved by the Classification Society.   |   |                       |
| (2) Charpy V-notch impact tests are not required for pipes.   |   |                       |
| (3) This table is generally applicable for material thicknesses up to 40mm. Proposals for greater thicknesses shall be approved by the Classification Society.  |   |                       |
| (4) A controlled rolling procedure or TMCP may be used as an alternative.   |   |                       |
| (5) Materials with specified minimum yield stress exceeding 410 N/mm <sup>2</sup> may be specially approved by the Classification Society. For these materials, particular attention shall be given to the hardness of the weld and heat affected zone. |   |                       |

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|--|---|-----------------------|
| CHEMICAL COMPOSITION AND HEAT TREATMENT  |   |                       |
| CARBON-MANGANESE STEEL   | Fully killed  |                       |
| Fine grain steel where thickness exceeds 20 mm.  |   |                       |
| Small additions of alloying elements by agreement with the Classification Society. Composition limits to be approved by the Classification Society.  |   |                       |
| Normalized, or quenched and tempered. <sup>(2)</sup>   |   |                       |
| TENSILE AND (IMPACT) TEST REQUIREMENTS   |   |                       |
| PLATES   | Each "piece" to be tested.  |                       |
| SECTIONS AND FORGINGS  | Batch test.   |                       |
| TENSILE PROPERTIES   | Specified minimum yield stress not to exceed 410 N/mm <sup>2</sup> . <sup>(3)</sup> |                       |
| CHARPY V-NOTCH TEST  | Transverse test pieces. Minimum average energy value E, 27J                         |                       |
| PLATES   | Longitudinal test pieces. Minimum average energy value E, 41J                       |                       |
| SECTIONS AND FORGINGS  |   |                       |
| TEST TEMPERATURE   | Thickness t (mm)  | Test temperature (°C) |
|  | t ≤ 20  | 0                     |
|  | 20 < t ≤ 40   | -20                   |
| NOTES  |   |                       |
| 1. For seamless pipes and fittings normal Classification Society practice applies. The use of longitudinally or spirally welded pipes should be specially approved by the Classification Society.  |   |                       |
| 2. A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval by the Classification Society.  |   |                       |
| 3. Materials with specified minimum yield stress exceeding 410 N/mm <sup>2</sup> may be specially approved by the Classification Society. For these materials, particular attention is to be given to the hardness of the weld and heat affected zone. |   |                       |

**Table 2 Plates, sections and forgings <sup>(1)</sup> for cargo tanks, secondary barriers <sup>(5)</sup> and process pressure vessels for design temperatures below 0°C and down to -55°C. Maximum thickness 25mm. <sup>(2)</sup>**

| CHEMICAL COMPOSITION AND HEAT TREATMENT  |   |                         |   |                         |                        |
|--|---|-------------------------|---|-------------------------|------------------------|
| CARBON-MANGANESE STEEL (Fully killed aluminium treated fine grain steel)   |   |                         |   |                         |                        |
| Chemical composition (ladle analysis)  |   |                         |   |                         |                        |
| <u>C</u><br>0.16% max. <sup>(3)</sup>  | <u>Mn</u><br>0.70-1.60%   | <u>Si</u><br>0.10-0.50% | <u>S</u><br>0.025% max.   | <u>P</u><br>0.025% max. |                        |
| Optional additions:  | Alloys and grain refining elements may be generally in accordance with the following: |                         |   |                         |                        |
| <u>Ni</u><br>0.80% max.  | <u>Cr</u><br>0.25% max.   | <u>Mo</u><br>0.08% max. | <u>Cu</u><br>0.35% max.   | <u>Nb</u><br>0.05% max. | <u>V</u><br>0.10% max. |
| Al content total 0.02% min (Acid soluble 0.015% min)   |   |                         |   |                         |                        |
| Normalized or quenched and tempered <sup>(4)</sup>   |   |                         |   |                         |                        |
| TENSILE AND CHARPY V-NOTCH IMPACT TEST REQUIREMENTS  |   |                         |   |                         |                        |
| SAMPLING FREQUENCY   |   |                         |   |                         |                        |
| PLATES   |   |                         | Each "piece" to be tested.  |                         |                        |
| SECTIONS AND FORGINGS  |   |                         | Each "batch" to be tested.  |                         |                        |
| MECHANICAL PROPERTIES  |   |                         |   |                         |                        |
| TENSILE PROPERTIES   |   |                         | Specified minimum yield stress not to exceed 410 N/mm <sup>2</sup> <sup>(5)</sup> |                         |                        |
| CHARPY V-NOTCH IMPACT TEST   |   |                         |   |                         |                        |
| PLATES   |   |                         | Transverse test pieces. Minimum average energy value (KV) 27J                     |                         |                        |
| SECTIONS AND FORGINGS <sup>(1)</sup>   |   |                         | Longitudinal test pieces. Minimum average energy value (KV) 41J                   |                         |                        |
| TEST TEMPERATURE   |   |                         | 5°C below the design temperature or -20°C, whichever is lower                     |                         |                        |
| NOTES:   |   |                         |   |                         |                        |
| (1) The requirements of Charpy V-notch impact test and chemical composition for forgings may be specially considered.  |   |                         |   |                         |                        |
| (2) For material thickness more than 25mm, Charpy V-notch impact tests shall be conducted as follows:  |   |                         |   |                         |                        |
| Material Thickness   |   |                         | Test Temp.  |                         |                        |
| 25 < t ≤ 30 mm   |   |                         | 10°C below design temperature or -20 whichever is lower                           |                         |                        |
| 30 < t ≤ 35 mm   |   |                         | 15°C below design temperature or -20 whichever is lower                           |                         |                        |
| 35 < t ≤ 40 mm   |   |                         | 20°C below design temperature   |                         |                        |
| 40 mm < t  |   |                         | Temperature approved by the Classification Society                                |                         |                        |
| The Charpy V-notch impact energy value shall be in accordance with the table for applicable type of test specimen.   |   |                         |   |                         |                        |
| Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or -20°C, whichever is lower.  |   |                         |   |                         |                        |
| For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank-shell thickness.  |   |                         |   |                         |                        |
| (3) By special agreement with the Classification Society the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than -40°C.   |   |                         |   |                         |                        |
| (4) A controlled rolling procedure or TMCP may be used as an alternative.  |   |                         |   |                         |                        |
| (5) Materials with specified minimum yield stress exceeding 410 N/mm <sup>2</sup> may be approved by the Classification Society. For these materials, particular attention shall be given to the hardness of the weld and heat affected zones. |   |                         |   |                         |                        |

## Guidance:

For materials exceeding 25mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steel or steels in accordance with Table 3 may be necessary.

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| CHEMICAL COMPOSITION AND HEAT TREATMENT  |            | Aluminium treated fine grain steel                  |   |             |            |
|--|------------|---|---|-------------|------------|
| CARBON-MANGANESE STEEL— Fully killed   |            |   |   |             |            |
| Chemical composition (ladle analysis)  |            |   |   |             |            |
| C  | Mn         | Si  | S   | P           |            |
| 0.16% max. <sup>(3)</sup>  | 0.70-1.60% | 0.10-0.50%  | 0.035% max.   | 0.035% max. |            |
| Optional additions: Alloys and grain refining elements may be generally in accordance with the following:  |            |   |   |             |            |
| Ni   | Cr         | Mo  | Cu  | Nb          | V          |
| 0.80% max.   | 0.25% max. | 0.08% max.  | 0.35% max.  | 0.05% max.  | 0.10% max. |
| Normalized or quenched and tempered <sup>(4)</sup>   |            |   |   |             |            |
| <b>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</b>  |            |   |   |             |            |
| PLATES   |            |   | Each "piece" to be tested.  |             |            |
| SECTIONS   |            |   | Batch test.   |             |            |
| CHARPY V NOTCH TEST  |            |   | Test temperatures 5°C below the design temperature or -20°C whichever is lower. |             |            |
| PLATES   |            |   | Transverse test pieces. Minimum average energy value E, 27J                     |             |            |
| SECTIONS AND FORGINGS <sup>(4)</sup>   |            |   | Longitudinal test pieces. Minimum average energy value E, 41J                   |             |            |
| <b>NOTES</b>   |            |   |   |             |            |
| 1. The Charpy V-notch and chemistry requirements for forgings may be specially considered.   |            |   |   |             |            |
| 2. For material more than 25mm thick, Charpy V-notch tests are to be conducted as follows:   |            |   |   |             |            |
| Material Thickness   |            | Test Temp.  |   |             |            |
| 25 < t ≤ 30 mm   |            | 10°C below design temp. or -20°C whichever is lower |   |             |            |
| 30 < t ≤ 35 mm   |            | 15°C below design temp. or -20°C whichever is lower |   |             |            |
| 35 < t ≤ 40 mm   |            | 20°C below design temp.                             |   |             |            |
| The impact energy value shall be in accordance with the table for applicable type of test specimen. For material more than 40mm thick, the Charpy V-notch values should be specially considered.                             |            |   |   |             |            |
| Material for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or -20°C whichever is lower.                                  |            |   |   |             |            |
| 3. By special agreement with the Classification Society the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than -40°C.  |            |   |   |             |            |
| 4. A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval by the Classification Society.  |            |   |   |             |            |
| 5. Where the secondary barrier is formed by the deck or shell side platings, the material grade required by Table 2 should be carried into the adjacent deck or side shell platings, where applicable, to a suitable extent. |            |   |   |             |            |



**Table 3 Plates, sections and forgings <sup>(1)</sup> for cargo tanks, secondary barriers and process pressure vessels for design temperatures below - 55°C and down to - 165°C.  
<sup>(2)</sup> Maximum thickness 25mm. <sup>(3),(4)</sup>**

| <u>Minimum design temperature (°C)</u>  | <u>Chemical composition <sup>(5)</sup> and heat treatment</u>  | <u>Charpy V-notch impact test temperature (°C)</u> |
|---|--|--|
| <u>-60</u>  | <u>1.5% nickel steel</u><br><u>– normalized or normalized and tempered or quenched and tempered or TMCP <sup>(6)</sup></u>       | <u>-65</u>   |
| <u>-65</u>  | <u>2.25% nickel steel</u><br><u>– normalized or normalized and tempered or quenched and tempered or TMCP <sup>(6),(7)</sup></u>  | <u>-70</u>   |
| <u>-90</u>  | <u>3.5% nickel steel</u><br><u>– normalized or normalized and tempered or quenched and tempered or TMCP <sup>(6),(7)</sup></u>   | <u>-95</u>   |
| <u>-105</u>   | <u>5% nickel steel</u><br><u>– normalized or normalized and tempered or quenched and tempered <sup>(6),(7),(8)</sup></u>         | <u>-110</u>  |
| <u>-165</u>   | <u>9% nickel steel</u><br><u>– double normalized and tempered or quenched and tempered <sup>(6)</sup></u>                        | <u>-196</u>  |
| <u>-165</u>   | <u>Austenitic steels such as stainless steels (e.g. types 304, 304L, 316, 316L, 321, and 347 Solution treated <sup>(9)</sup></u> | <u>-196</u>  |
| <u>-165</u>   | <u>Aluminium alloys</u><br><u>(e.g. type 5083 Annealed)</u>  | <u>Not required</u>                                |
| <u>-165</u>   | <u>Austenitic Fe-Ni alloy (36% nickel)</u><br><u>– Heat treatment as agreed</u>  | <u>Not required</u>                                |
| <b>TENSILE AND CHARPY V-NOTCH IMPACT TEST REQUIREMENTS</b>  |  |  |
| <b>SAMPLING FREQUENCY</b>   |  |  |
| <u>PLATES</u>   | <u>Each “piece” to be tested.</u>  |  |
| <u>SECTIONS AND FORGINGS</u>  | <u>Each “batch” to be tested.</u>  |  |
| <b>CHARPY V-NOTCH IMPACT TEST</b>   |  |  |
| <u>PLATES</u>   | <u>Transverse test pieces. Minimum average energy value (KV) 27J</u>   |  |
| <u>SECTIONS AND FORGINGS</u>  | <u>Longitudinal test pieces. Minimum average energy value (KV) 41J</u>   |  |
| <b>NOTES:</b>   |  |  |
| <u>(1) The Charpy V-notch impact test required for forgings used in critical applications shall be subject to special consideration.</u>  |  |  |
| <u>(2) The requirements for design temperatures below -165°C shall be specially agreed.</u>   |  |  |
| <u>(3) For materials 1.5% Ni, 2.25% Ni, 3.5% Ni, and 5% Ni, with thickness greater than 25 mm, the Charpy V-notch impact tests shall be conducted as follows:</u>   |  |  |
|   | <u>Material Thickness</u>  | <u>Test Temperature</u>                            |
|   | <u>25 &lt; t ≤ 30 mm</u>   | <u>10°C below design temperature</u>               |
|   | <u>30 &lt; t ≤ 35 mm</u>   | <u>15°C below design temperature</u>               |
|   | <u>35 &lt; t ≤ 40 mm</u>   | <u>20°C below design temperature</u>               |
| <u>The Charpy V-notch impact energy value shall be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40mm, the Charpy V-notch impact energy values shall be specially considered.</u>                    |  |  |
| <u>(4) For 9% Ni steels, austenitic steels and aluminium alloys, thickness greater than 25 mm may be used.</u>  |  |  |
| <u>(5) The chemical composition limits shall be approved by the Classification Society.</u>   |  |  |
| <u>(6) TMCP nickel steels will be subject to acceptance by the Classification Society.</u>  |  |  |
| <u>(7) A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Classification Society.</u>   |  |  |
| <u>(8) A specially heat treated, 5% nickel steel, for example triple heat treated 5% nickel steel may be used down to -165°C upon special agreement with the Classification Society, provided that the Charpy V-notch impact tests are carried out at -196°C.</u> |  |  |
| <u>(9) The Charpy V-notch impact test may be omitted subject to agreement with the Classification Society.</u>  |  |  |

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| Minimum design temperature (°C)  | Chemical composition <sup>(4)</sup> and heat treatment  | Impact test temperature (°C)  |
|--|---|---|
| -60  | 1.5% nickel steel — normalized  | -65   |
| -65  | 2.25% nickel steel — normalized or normalized and tempered <sup>(5)</sup>                         | -70   |
| -90  | 3.5% nickel steel — normalized or normalized and tempered <sup>(5)</sup>                          | -95   |
| -105   | 5% nickel steel — normalized or normalized and tempered <sup>(6)</sup> , <sup>(6)</sup>           | -110  |
| -165   | 9% nickel steel — double normalized and tempered or quenched and tempered                         | -196  |
| -165   | Austenitic steels (e.g. types 304, 304L, 316, 316L, 321, and 347) Solution treated <sup>(7)</sup> | -196  |
| -165   | Aluminium alloys; e.g. type 5083 annealed   | Not required  |
| -165   | Austenitic Fe-Ni alloy. (36% nickel) Heat treatment as agreed                                     | Not required  |
| <b>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</b>  |   |   |
| <b>PLATES</b>  |   | Each "piece" to be tested.  |
| <b>SECTIONS</b>  |   | Batch test.   |
| <b>CHARPY V-NOTCH TEST</b>   |   |   |
| <b>PLATES</b>  |   | Transverse test pieces. Minimum average energy value E,27J Longitudinal test pieces. Minimum average energy value E,41J |
| <b>SECTIONS AND FORGINGS</b>   |   |   |
| <b>NOTES:</b>  |   |   |
| 1. The impact test required for forgings used in critical applications should be subject to special consideration.                         |   |   |
| 2. The requirements for design temperatures below -165°C are to be specially agreed.   |   |   |
| 3. For materials 1.5% Ni, 2.25% Ni, 3.5% Ni, and 5% Ni, with thickness greater than 25 mm, the impact tests shall be conducted as follows: |   |   |
| <b>Material Thickness</b>  |   | <b>Test Temp.*</b>  |
| 25 < t ≤ 30 mm   |   | 10°C below design temp.   |
| 30 < t ≤ 35 mm   |   | 15°C below design temp.   |
| 35 < t ≤ 40 mm   |   | 20°C below design temp.   |
| * In no case shall the test temperature be above that indicated in the table.  |   |   |

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The energy value shall be in accordance with the table for the applicable type of test specimen. For material more than 40mm thick, the Charpy V-notch values should be specially considered.

For 9% Ni, austenitic stainless steels, and aluminium alloys, thicknesses greater than 25mm may be used at the discretion of the Classification Society.

4. The chemical composition limits should be approved by the Classification Society.
5. A lower minimum design temperature for quenched and tempered steels may be specially agreed.
6. A specially heat treated, e.g, triple heat treated 5% nickel steel may be used down to -165°C upon special agreement with the Classification Society, provided that the impact tests are carried out at -196°C.
7. The impact test may be omitted subject to agreement with the Classification Society.

**Table 4 Pipes (seamless and welded), <sup>(1)</sup> forgings <sup>(2)</sup> and castings <sup>(2)</sup> for cargo and process piping for design temperatures below 0°C and down to -165°C. <sup>(3)</sup> Maximum thickness 25mm.**

| <u>Minimum design temperature (°C)</u>   | <u>Chemical composition <sup>(5)</sup> and heat treatment</u>   | <u>Charpy V-notch impact test temperature (°C)</u> | <u>Minimum average energy (KV) (J)</u> |
|--|---|--|--|
| -55  | <u>Carbon-manganese steel</u><br>– Fully killed fine grain.<br><u>Normalized or as agreed <sup>(6)</sup></u>                      | <u>See Note 4</u>                                  | <u>27</u>                              |
| -65  | <u>2.25% nickel steel</u><br>– Normalized or normalized and tempered or quenched and tempered <sup>(6)</sup>                      | <u>-70</u>   | <u>34</u>                              |
| -90  | <u>3.5% nickel steel</u><br>– Normalized or normalized and tempered or quenched and tempered <sup>(6)</sup>                       | <u>-95</u>   | <u>34</u>                              |
| -165   | <u>9% nickel steel <sup>(7)</sup></u><br>– Double normalized and tempered or quenched and tempered                                | <u>-196</u>  | <u>41</u>                              |
|  | <u>Austenitic steels such as stainless steels (e.g. types 304, 304L, 316, 316L, 321, and 347 Solution treated <sup>(8)</sup>)</u> | <u>-196</u>  | <u>41</u>                              |
|  | <u>Aluminium alloys (e.g. type 5083 Annealed)</u>   |  | <u>Not required</u>                    |
| <b>TENSILE AND CHARPY V-NOTCH IMPACT TEST REQUIREMENTS</b>   |   |  |  |
| <b>SAMPLING FREQUENCY</b>  |   |  |  |
| <u>Each “batch” to be tested</u>   |   |  |  |
| <b>CHARPY V-NOTCH IMPACT TEST</b>  |   |  |  |
| <u>CHARPY V-NOTCH IMPACT TEST: Longitudinal test pieces</u>  |   |  |  |
| <b>NOTES:</b>  |   |  |  |
| (1) <u>The use of longitudinally or spirally welded pipes shall be specially approved by the Classification Society.</u> |   |  |  |
| (2) <u>The requirements for forgings and castings may be subject to special consideration.</u>                           |   |  |  |
| (3) <u>The requirements for design temperatures below -165°C shall be specially agreed.</u>                              |   |  |  |
| (4) <u>The test temperature shall be 5°C below the design temperature or -20°C whichever is lower.</u>                   |   |  |  |
| (5) <u>The chemical composition limits shall be approved by the Classification Society.</u>                              |   |  |  |
| (6) <u>A lower design temperature may be specially agreed for quenched and tempered materials.</u>                       |   |  |  |
| (7) <u>The chemical composition is not suitable for castings.</u>  |   |  |  |
| (8) <u>Charpy V-notch impact tests may be omitted subject to agreement with the Classification Society.</u>              |   |  |  |

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| Minimum design temperature (°C)  | Chemical composition <sup>(5)</sup> and heat treatment  | Impact test Test temperature (°C) | Minimum average energy E (J) |
|--|---|-----------------------------------|------------------------------|
| -55  | Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed <sup>(6)</sup>   | See Note 4                        | 27                           |
| -65  | 2.25% nickel steel. Normalized or normalized and tempered <sup>(6)</sup>  | -70                               | 34                           |
| -90  | 3.5% nickel steel. Normalized or normalized and tempered <sup>(6)</sup>   | -95                               | 34                           |
| -165   | 9% nickel steel. <sup>(7)</sup> Double normalized and tempered or quenched and tempered   | -196                              | 41                           |
|  | Austenitic steels, e.g. types 304, 304L, 316, 316L, 321, and 347. Solution treated. <sup>(8)</sup><br>Aluminium alloys, e.g. type 5083 annealed | -196                              | 41                           |
|  |   |                                   | Not required                 |
| <p><b>TENSILE AND TOUGHNESS (IMPACT) TEST REQUIREMENTS</b><br/> Each batch tested<br/> IMPACT TEST - Longitudinal test pieces</p>  |   |                                   |                              |
| <p>NOTES:</p> <ol style="list-style-type: none"> <li>1. The use of longitudinally or spirally welded pipes should be specially approved by the Classification Society</li> <li>2. The requirements for forgings and castings may be subject to special consideration.</li> <li>3. The requirements for design temperatures below -165°C should be specially agreed.</li> <li>4. The test temperature should be 5°C below the design temperature or -20°C whichever is lower.</li> <li>5. The composition limits should be approved by the Classification Society.</li> <li>6. A lower minimum design temperature may be specially agreed for quenched and tempered materials.</li> <li>7. This chemical composition is not suitable for castings.</li> <li>8. Impact tests may be omitted subject to agreement with the Classification Society.</li> </ol> |   |                                   |                              |

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Table 5 Plates and sections for hull structures required by G1.9.1 and G1.9.4 of UR G1.

| Minimum design temperature of hull structure (°C)   | Maximum thickness (mm) for steel grades   |    |    |    |    |    |    |    |
|---|---|----|----|----|----|----|----|----|
|   | A   | B  | D  | E  | AH | DH | EH | FH |
| 0 and above <sup>(1)</sup><br>-5 and above <sup>(2)</sup>   | Normal practice   |    |    |    |    |    |    |    |
| down to -5  | 15  | 25 | 30 | 50 | 25 | 45 | 50 | 50 |
| down to -10   | x   | 20 | 25 | 50 | 20 | 40 | 50 | 50 |
| down to -20   | x   | x  | 20 | 50 | x  | 30 | 50 | 50 |
| down to -30   | x   | x  | x  | 40 | x  | 20 | 40 | 50 |
| Below -30   | In accordance with Table 2 except that the thickness limitation given in Table 2 and in note 2 of Table 2 does not apply. |    |    |    |    |    |    |    |
| NOTES:<br>"x" means steel grade not to be used.<br>(1) For the purpose of G1.9.4 of UR G1.<br>(2) For the purpose of G1.9.1 of UR G1. |   |    |    |    |    |    |    |    |

| Minimum design temperature of hull structure (°C)   | Maximum thickness (mm) for steel grades in accordance with W1.2.8  |    |    |          |    |    |    |  |  |
|---|--|----|----|----------|----|----|----|--|--|
|   | A  | B  | D  | E        | AH | DH | EH |  |  |
| 0 and above <sup>(1)</sup><br>-5 and above <sup>(2)</sup>   | Normal   |    |    | practise |    |    |    |  |  |
| down to -5  | 15   | 25 | 30 | 50       | 25 | 45 | 50 |  |  |
| down to -10   | x  | 20 | 25 | 50       | 20 | 40 | 50 |  |  |
| down to -20   | x  | x  | 20 | 50       | x  | 30 | 50 |  |  |
| down to -30   | x  | x  | x  | 40       | x  | 20 | 40 |  |  |
| Below -30   | In accordance with Table 2 except that the thickness limitation given in Table 2 and the supplementary requirements for thicker material given in footnote 2 of that Table do not apply. |    |    |          |    |    |    |  |  |
| NOTES:<br>"x" means steel grade not to be used.<br>(1) For the purpose of G1.9.4<br>(2) For the purpose of G1.9.1 |  |    |    |          |    |    |    |  |  |

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W1.3.2 Materials with alternative chemical composition or mechanical properties may be accepted by special agreement with the Classification Society.

W1.3.3 Where post-weld heat treatment is specified or required, the properties of the base materials shall be determined in the heat treated condition in accordance with the applicable table and the weld properties shall be determined in the heat treated condition in accordance with W1.4. In cases where a post-weld heat treatment is applied, the test requirements may be modified at the discretion of the Classification Society.

W1.3.4 Where reference is made to hull structural steels, the requirements of UR W11 for appropriate grades apply.

## W1.4 Welding and non-destructive ~~nondestructive~~ testing

### W1.4.1 General

The article W1.4 shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. The requirements listed herein are those generally employed for carbon, carbon-manganese, nickel alloy and austenitic stainless steels, aluminium alloy and may form the basis for acceptance testing of other material. At the discretion of the Classification Society, Charpy V-notch impact testing of austenitic stainless steels and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

### W1.4.2 Welding consumables

Welding consumables intended for welding of liquefied gas cargo tanks ~~are to~~ shall be approved by the Classification Society, ~~unless otherwise agreed.~~

Deposited weld metal tests and butt weld tests ~~are~~ shall be required for all welding consumables, unless specially agreed otherwise. The results obtained from tensile and Charpy V-notch impact tests ~~are to~~ shall be approved by the Classification Society. The chemical composition of the deposited weld metal ~~is to~~ shall be reported for information and approval.

### W1.4.3 Welding procedure tests for cargo tanks and process pressure vessels; ~~and secondary barriers~~

#### (a) Number and orientation of test assemblies

Welding procedure ~~Procedure~~ tests for cargo tanks and process pressure vessels are required for all butt welds. The test assemblies shall ~~and are to~~ be representative of the following:

- (i) Each base material
- (ii) Each type of consumable and welding process
- (iii) Each welding position

For butt welds in plates, the test assemblies ~~are to~~ shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test ~~is to~~ shall be approved by the Classification Society. Radiographic or ultrasonic ~~examination~~ testing may be performed at the option of the fabricator or the Classification Society. ~~Fillet welding procedure tests are to be in accordance with the~~

# W1

(cont)

Classification Society practice. In such cases consumables should be selected which exhibit satisfactory impact properties.

(b) Required tests

The following welding procedure tests for cargo tanks and process pressure vessels shall be carried out in accordance with W1.2, with the specimens made ~~are required~~ from each test assembly:

(i) Cross-weld tensile tests

(ii) Longitudinal all-weld tensile testing, where required by the Classification Society.

~~(ii)~~(iii) Transverse bend tests: ~~they~~ which may be face, root or side bends at the discretion of the Classification Society. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

~~(iii)~~(iv) One set of three Charpy V-notch impacts ~~are to be made~~ test specimens, generally at each of the following indications (see Fig. 42):

- (1) Centre line of the welds
- (2) Fusion line (F.L.)
- (3) 1mm from the F.L.
- (4) 3mm from the F.L.
- (5) 5mm from the F.L.

~~(iv)~~(v) Macrosection, ~~Microsection~~ microsection and hardness survey may also be required at the discretion of the Classification Society.

## W1.4.4 Test requirements

(a) Tensile tests

Generally tensile strength ~~is shall~~ not to be less than the specified minimum tensile strength for the appropriate parent materials. It may also be accepted subject to agreement with the Classification Society that the transverse weld tensile strength is not to be less than the specified minimum tensile strength for the weld deposited metal, where the weld metal has lower tensile strength than that of the parent metal. In ~~any~~ every case, the position of fracture ~~is to~~ shall be reported for information.

(b) Bend tests

No fracture ~~is acceptable~~ after 180° bend over a former diameter of 4t where t is the thickness of the test pieces, ~~unless otherwise specially required or agreed.~~

(c) Charpy V-notch impact tests

Charpy V-notch impact tests ~~test are to~~ shall be conducted at the temperature prescribed for the base material being joined. The results of weld metal Charpy V-notch impact tests, minimum average energy  $E(KV)$ , ~~are to~~ shall be no less than 27J. The weld metal requirements for subsized specimens and single energy values ~~are to~~ shall be in accordance with W1.2.23. The results of fusion line and heat affected zone Charpy V-notch impact tests, shall show a minimum average energy  $E(KV)$ , are to be generally in accordance with the transverse or longitudinal requirements of the base



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material whichever is applicable, and requirements for subsize specimens, the minimum average energy  $E(KV)$ , ~~are to be generally~~ in accordance with W1.2.23. ~~When~~ If the material thickness does not permit machining either full size or standard subsize specimens, the testing procedure and acceptance standards ~~are to~~ shall be approved by the Classification Society.

## W1.4.5 Fillet welding procedure tests

Fillet welding procedure tests shall be in accordance with the Rules of the Classification Society. In such cases, welding consumables shall be selected which exhibit satisfactory Charpy V-notch impact properties.

## W1.4.6 Welding procedure tests for secondary barriers

Welding procedure tests for secondary barriers shall be in accordance with the Rules of the Classification Society.

## W1.4.57 Welding procedure tests for piping

Welding procedure tests for piping are required and ~~are to~~ shall be similar to those detailed for cargo tanks provided in W1.4.3. Unless specially agreed otherwise the test requirements ~~are to~~ shall be in accordance with W1.4.4.

## W1.4.68 Production weld tests

For all cargo tanks and process pressure vessels except for integral and membrane tanks, production tests ~~are~~ shall generally ~~to~~ be performed for approximately each 50 m of butt weld joints and ~~are to~~ shall be representative of each welding position. For secondary barriers, the same type production tests as required for ~~each~~ primary tanks ~~are to~~ shall be performed except that the number of tests may be reduced subject to the agreement with the Classification Society. Tests, other than those specified, may be required for cargo tanks or secondary barriers at the discretion of the Classification Society. Test requirements shall be in accordance with W1.4.4.

The quality assurance/quality control programme shall ensure the continued conformity of the production welds as defined in the material manufacturer's quality manual.

### (a) Independent type Type A and type B independent tanks and semi-membrane semimembrane tanks

The production tests for ~~independent tanks type A and type B independent tanks and semimembrane~~ semi-membrane tanks ~~are to~~ shall include the following tests:

Bend tests and, where required for procedure tests, one set of three Charpy V-notch impact tests ~~should~~ shall be made for each 50m of weld.

The Charpy V-notch impact tests ~~are to~~ shall be made with specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic ~~stainless~~ steels, all notches ~~should~~ shall be in the centre of the weld.

~~The test requirements are the same as the applicable test requirements listed in W1.4.4 except that impact tests that do not meet the prescribed energy requirements (see W1.2.3) may still be accepted, upon special consideration by the Classification Society, by passing a drop weight test. In such cases, two drop weight specimens are to be~~

# W1

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~~tested for each set of Charpy specimens that failed and both must show "no break" performance at the temperature at which the Charpy tests were conducted.~~

- (b) ~~Independent type~~ Type C independent tanks and process pressure vessels

In addition to those tests listed in (a), for ~~independent~~ type C independent tanks and process pressure vessels, transverse weld tensile tests are also required.

~~The test requirements are the same as the applicable test requirements listed in W1.4.4 except that impact tests that do not meet the prescribed energy requirements (see W1.2.3) may still be accepted, upon special consideration by the Classification Society, by passing a drop weight test. In such cases, two drop weight specimens are to be tested for each set of Charpy specimens that failed and both must show "no break" performance at the temperature at which the Charpy tests were conducted.~~

- (c) Integral and membrane tanks

~~Production tests~~ The test requirements for integral and membrane tanks are to be in accordance with the requirements of the Classification Society the same as the applicable test requirements listed in W1.4.3.

## W1.4.79 ~~Nondestructive~~ Non-destructive testing

All test procedures and acceptance standards shall be in accordance with the Classification Society, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall be used, in principle, to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but, in addition, supplementary radiographic testing at selected locations shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained. The quality assurance/quality control programme shall ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual.

- (a) ~~Independent type~~ Type A and B independent tanks and ~~semimembrane~~ semi-membrane tanks

- (i) For ~~independent~~ type A independent tanks and ~~semimembrane~~ semi-membrane tanks where the design temperature is equal to or lower than  $-20^{\circ}\text{C}$ , and for ~~independent~~ type B tanks, regardless of temperature, all full penetration butt welds of the shell plating of cargo tanks ~~are to~~ shall be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in the first paragraph of W1.4.9. 100 percent inspected by radiographic testing.
- (ii) For ~~independent~~ type A independent tanks and ~~semimembrane~~ semi-membrane tanks, where the design temperature is higher than  $-20^{\circ}\text{C}$ , all full penetration butt welds in way of intersections and at least 10% of the remaining full penetration butt welds of tank structures ~~are to~~ shall be inspected subjected to by radiographic testing or ultrasonic testing under the same conditions as described in the first paragraph of W1.4.9.
- (iii) In each case, the remaining tank structure, including the welding of stiffeners and other fittings and attachments, ~~is to~~ shall be examined tested by magnetic particle or dye penetrant methods, nondestructive test methods as considered necessary by the Classification Society.

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(iv) ~~All testing procedures and acceptance standards are to be approved by the Classification Society. At the discretion of the Classification Society, an approved ultrasonic testing procedure may be used in lieu or in addition to radiographic testing.~~

(b) ~~Independent type~~ Type C independent tanks and process pressure vessels

Inspection of ~~independent type C independent~~ tanks and ~~process~~ process pressure vessels ~~is to~~ shall be carried out in accordance with G 2.8.2(i) or (ii) of UR G2.

(c) Integral and membrane tanks

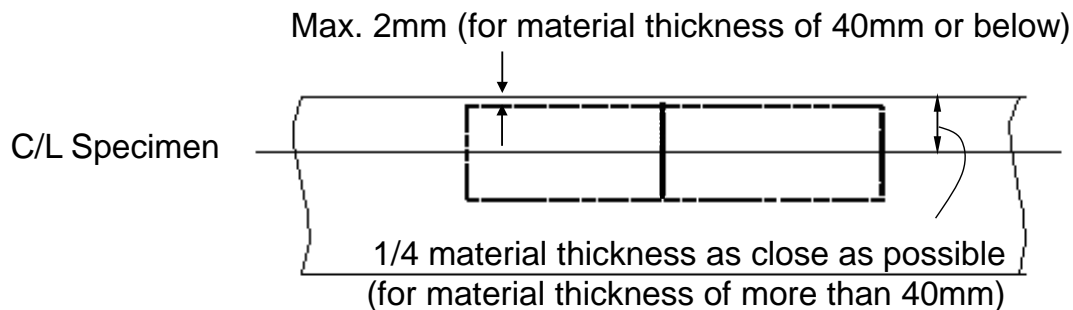
Special weld inspection procedures and acceptable standards ~~are to~~ shall be submitted by the designers of integral and membrane tanks for approval by the Classification Society.

(d) Piping

Inspection of piping ~~is to~~ shall be carried out in accordance with UR G3.

(e) Secondary barriers

The secondary barrier ~~is to~~ shall be ~~radiographed~~ non-destructive tested for internal defects as considered necessary. When the outer shell of the hull is part of the secondary barrier, all sheerstrake butts and the intersections of all butts and seams in the side shell ~~are to~~ shall be ~~examined~~ tested by radiographic testing radiography.



**Figure 1 Sampling position of Charpy V-notch impact test specimens (Base metal)**

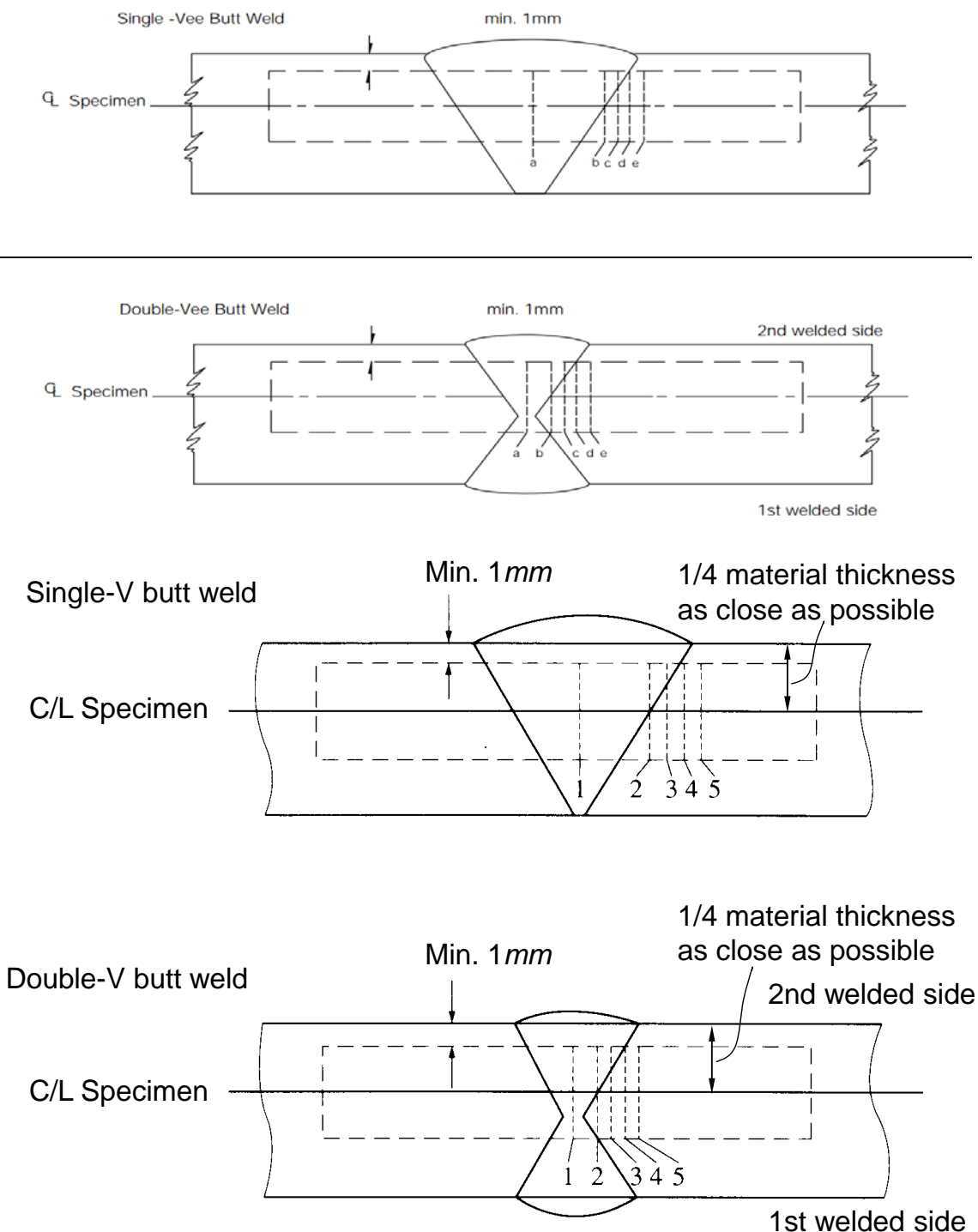
## FIGURE 1

### Location of Weld Test Specimen

~~The largest size Charpy specimens possible for the material thickness are to be machined with the centre of the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. For double-vee butt welds, specimens are to be machined closer to the surface of the second welded side.~~

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**Figure 2 Sampling position of Charpy V-notch impact test specimens (Weld)**

Notch location

- a1 Centreline of the weld
- b2 On fusion line
- c3 In HAZ, 1mm from fusion line
- d4 In HAZ, 3mm from fusion line
- e5 In HAZ, 5mm from fusion line

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