

DEP SPECIFICATION

MANUFACTURE, TESTING, AND INSPECTION OF CARBON AND LOW-ALLOY STEEL CASTINGS GRADES 345-586 N/MM2 (50-85 KSI) FOR PRIMARY STEEL APPLICATIONS IN DEEPWATER OFFSHORE STRUCTURES AND PIPELINES

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TABLE OF CONTENTS

1.	INTRODUCTION	5
1.1	SCOPE.....	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	5
1.4	CROSS-REFERENCES	7
1.5	SUMMARY OF MAIN CHANGES	7
1.6	COMMENTS ON THIS DEP	8
1.7	DUAL UNITS.....	8
2.	GENERAL.....	9
2.1	QUALITY REQUIREMENTS, QP AND MPS	9
2.2	CONTRACTOR PROCUREMENT SPECIFICATION AND APPROVAL OF THE CASTING MANUFACTURER/SUPPLIER AND MANUFACTURING FACILITIES AND SUBCONTRACTED CHEMICAL ANALYSIS OR MECHANICAL TESTING LABORATORIES.....	9
2.3	LAST	9
2.4	SERVICE CATEGORIES.....	9
2.5	CRITICAL SECTIONS FOR MECHANICAL PROPERTIES, CRITICAL REGIONS FOR NDT AND STRUCTURAL WELD THICKNESSES	9
2.6	UNDERLYING INDUSTRY STANDARD SPECIFICATION (ASTM A703)	9
2.7	TRACEABILITY	10
2.8	INFORMATION TO BE CONVEYED TO CASTING MANUFACTURER/SUPPLIER.....	10
2.9	SUMMARY OF DOCUMENT SUBMITTALS REQUIRING APPROVAL BY THE PRINCIPAL AND CONTRACTOR, IF APPLICABLE.....	10
2.10	PREPRODUCTION MEETING	10
2.11	POST-JOB PRODUCTION HISTOGRAMS	10
2.12	INSPECTION CERTIFICATES	10
2.13	PQT PLATES/SPOOLS	10
3.	PROCESS OF MANUFACTURE AND CHEMICAL COMPOSITION.....	11
3.1	STEELMAKING AND REFINING PRACTICE	11
3.2	REQUIREMENT FOR FULLY KILLED STEEL.....	11
3.3	CHEMICAL COMPOSITION.....	11
4.	HEAT TREATMENT	12
4.1	HEAT TREATMENT PROCESS CONTROL REQUIREMENTS.....	12
4.2	QUENCHING	12
4.3	HEAT-TREATMENT FURNACE RECORDS OR CHARTS, TEMPERATURES AND CYCLE TIMES	12
5.	QUALIFICATION TEST SAMPLE (QTS).....	13
5.1	CASTINGS REPRESENTED BY QTS	13
5.2	QTS DIMENSIONAL REQUIREMENTS.....	13
5.3	HEAT TREATMENT OF QTSs	13
5.4	PARTIAL SEVERING OF QTSs	14
6.	MECHANICAL PROPERTIES AND TESTS	14
6.1	TENSILE TESTS	14
6.2	HARDNESS TESTS	14
6.3	CVN TESTS	15
6.4	DWT TESTS	15
7.	REPAIR WELDING OF CASTINGS.....	16
7.1	APPROVAL OF REPAIR WELDING WPSs AND PQRs AND CODE COMPLIANCE	16
7.2	ALLOWABLE WELDING PROCESSES	16
7.3	PWHT OF MAJOR WELD REPAIRS	16
7.4	IDENTIFICATION	16
7.5	RECORDS OF WELDER AND WELDING OPERATOR QUALIFICATION TEST RESULTS	16

7.6	WELDING CONSUMABLES.....	16
7.7	WELDING PROCEDURE SPECIFICATION (WPS).....	17
7.8	REPAIR WELD PROCEDURE QUALIFICATION REQUIREMENTS	19
7.9	REPAIR WELD WORKMANSHIP AND TECHNIQUE	22
7.10	NDT OF REPAIR WELDS	23
7.11	REPAIR WELD CHARTS AND MAXIMUM ALLOWABLE REPAIR WELD VOLUME AND SURFACE AREA	24
8.	NONDESTRUCTIVE EXAMINATION (NDT) OF CASTINGS.....	25
8.1	VT OF CASTINGS	25
8.2	NDT OF CASTINGS FOR SURFACE DEFECTS	25
8.3	NDT OF CASTINGS FOR SUBSURFACE DEFECTS	26
8.4	REQUIREMENT FOR WRITTEN AND APPROVED NDT PROCEDURES.....	27
8.5	DOCUMENTATION OF NDT RESULTS	27
9.	DIMENSIONAL INSPECTION	28
10.	MTR	28
11.	REFERENCES	29

APPENDICES

APPENDIX A	TABLES.....	31
APPENDIX B	SPECIFIC REQUIREMENTS FOR CARBON AND LOW-ALLOY STEEL CASTINGS FOR USE IN PRIMARY STEEL IN NON-DEEPWATER APPLICATIONS	37



1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for manufacture, testing and inspection of carbon and low-alloy steel castings Grades 345-586 N/mm² (50-85 ksi) for use in primary steel (Material Quality Level 2). It is applicable to the fabrication of offshore structures, manufacture of rig and well systems, marine mechanical or mooring system equipment intended for application on offshore structures or for components, e.g., piggable "WYE" castings, used in the construction of deepwater offshore pipelines.

Castings governed by this DEP are identified on AFC drawings and in project documents by the letters "C" followed by the Grade (minimum yield strength in N/mm²), the letter "B" (indicative of classification as primary steel, i.e., Material Quality Level 2), a "-", and then the letters "SC" followed by "A", "B", "C" or "O" indicating the Service Category e.g., C345B-SCA. Additionally, the letter "S" will be added as a suffix after the Service Category when suitability for H₂S service is required, e.g., C345B-SCAS.

Specific requirements for carbon and low-alloy steel castings for use in primary steel in non-deepwater applications are given in (Appendix B).

This DEP was created from and supersedes the EPP of the same number dated February 2006.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorized by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorized access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to offshore oil and gas production. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorized to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
“B”	Steel designation suffix indicating Material Quality Level 2 “Primary” steel.
“C”	Steel designation prefix indicating the component is a casting.
“SCA”	Steel designation suffix indicating Service Category A. SCA castings are those castings, other than shackles and bar-shaped castings, not intended to contain, or form part of, structural fabrication weldments, other than repair welds to the casting itself.
“SCB”	Steel designation suffix indicating Service Category B. SCB castings are those castings, other than shackles and bar-shaped castings, intended to contain, or form part of, structural fabrication weldments. Components, e.g., piggable “WYE” castings, used in the construction of deepwater offshore pipelines are in this Service Category.
“SCC”	Steel designation suffix indicating Service Category C. SCC castings are shackles and bar-shaped castings.
“SCO”	Steel designation suffix indicating Service Category O. SCO castings are castings in the special or "other" service category.
AFC Drawings	Approved for Construction drawings
AOD	Argon oxygen decarburization
Ar3	The temperature at which austenite begins to transform to ferrite during cooling.
ASME BPVC-IX	ASME Boiler and Pressure Vessel Code Section IX - Welding and Brazing Qualifications
ASME BPVC-V	ASME Boiler and Pressure Vessel Code Section V - Nondestructive Examination
ASME BPVC-VIII	ASME Boiler and Pressure Vessel Code Section VIII Division 1, 2 or 3 - Rules for Construction of Pressure Vessels
BOP	Bead on plate
CEV	Carbon equivalent value. $CEV = C + (Mn/6) + (Cr+Mo+V)/5 + (Ni+Cu)/15$, all elements in wt %.
CVN	Charpy V-notch impact test.
DWT	Drop-weight (a.k.a. Pellini) test.
FCAW	Flux cored arc welding process.
Grade	Minimum yield strength in N/mm^2 .
GTAW	Gas Tungsten Arc Welding process
HAZ	Weld heat-affected zone
LAST	Lowest Anticipated Service Temperature
Major Weld Repair	Repair weld whose depth of the cavity required for welding exceeds 20 % of the actual wall thickness or 25 mm (1 in), whichever is smaller; or weld repairs for which the area of the cavity required for welding exceeds approximately 65 mm^2 (10 in^2).

Term	Definition
MPS	Manufacturing Procedure Specification. Reference ISO 9000 Paragraphs 2.7.2.c, 2.7.2.e, 3.4.5 and 3.7.3. The MPS shall clearly define the sequence of operations and process controls to be implemented at each manufacturing step as well as specifically annotate any procedures, processing parameters, or requirements that deviate from this DEP. It is required that the MPS be approved by the Principal and Contractor, if applicable.
MT	Magnetic particle examination
MTR	Material Test Report, a.k.a. mill certificate. Includes results of chemical analyses, mechanical properties tests, visual and nondestructive tests and dimensional inspections
NDT	Non-destructive testing
Pcm	Composition parameter. $P_{cm} = C + (Si/30) + (Mn+Cu+Cr)/20 + (Ni/60) + (Mo/15) + (V/10) + (5B)$, all elements in wt %.
PQR	Welding procedure qualification record
PQT	Weld procedure qualification test
PT	Liquid dye penetrant examination
PWHT	Post-weld heat treatment
QHT	Quality heat treatment. Defined as the collective sequence of heat-treatments performed to achieve final properties, including the final austenitization, quench from final austenitization (if applicable), tempering or ageing and quenching (if applicable) from tempering or ageing.
QP	Quality Plan. Reference ISO 9000 Paragraphs 2.7.2.b and 3.7.5. It shall include inspection and test requirements and provide columns or spaces for the Principal and Contractor, if applicable, to indicate 3rd party inspector inspection activities, e.g., monitor, witness, hold points, etc. for the operations to be undertaken. It is required that the QP be approved by the Principal and Contractor, if applicable.
QTS	Qualification Test Sample
RT	Radiographic examination
SAW	Submerged Arc Welding process
SMAW	Shielded Metal Arc Welding process
UT	Ultrasonic examination
VD	Vacuum degassing
VT	Visual examination
WPS	Welding Procedure Specification

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (11).

1.5 SUMMARY OF MAIN CHANGES

This DEP supersedes the EPP of the same number dated February 2006.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. GENERAL

2.1 QUALITY REQUIREMENTS, QP AND MPS

The casting Manufacturer/Supplier shall implement an ISO 9001 or equivalent as approved by the Principal and Contractor, if applicable. A QP and an MPS shall be specifically developed for each order and shall be approved by the Principal and Contractor, if applicable, prior to commencement of manufacturing operations.

2.2 CONTRACTOR PROCUREMENT SPECIFICATION AND APPROVAL OF THE CASTING MANUFACTURER/SUPPLIER AND MANUFACTURING FACILITIES AND SUBCONTRACTED CHEMICAL ANALYSIS OR MECHANICAL TESTING LABORATORIES

This DEP may be used directly for procurement or, at the Contractor's option; the Contractor may prepare a detailed Procurement Specification which is compatible with the Contractor's document format and quality system. As a minimum, the Contractor's Procurement Specification shall incorporate all requirements contained herein and shall require approval by the Principal. The casting Manufacturer/Supplier and manufacturing facilities, as identified in the MPS, shall require approval by the Principal and Contractor, if applicable. Any subcontracted chemical analysis or mechanical testing laboratories shall be approved by the Principal and Contractor, if applicable.

2.3 LAST

The default LAST is -10 °C (14 °F) unless otherwise specified in project documents or on AFC drawings, except that for permanently-submerged deepwater pipeline components and other components permanently submerged in service, the default LAST is 4 °C (40 °F).

2.4 SERVICE CATEGORIES

Casting Service Category, i.e., SCA, SCB, SCC or SCO will be specified in project documents or on AFC drawings. Chemical and mechanical properties requirements for SCA, SCB and SCC are provided in this DEP. Any special chemical and mechanical properties for Service Category O shall be provided in project documents or on AFC drawings. When the letter "S" is added to the end of the Service Category suffix, suitability for H₂S service is required and castings shall comply with NACE MR0175/ISO 15156-2. Any steels qualified for Service Category suffix "S" under NACE MR0175/ISO 15156-2 Para. 7.2 Option 2 or by testing in accordance with NACE MR0175/ISO 15156-2 Annex B shall require specific approval by the Principal on a case-by-case basis.

2.5 CRITICAL SECTIONS FOR MECHANICAL PROPERTIES, CRITICAL REGIONS FOR NDT AND STRUCTURAL WELD THICKNESSES

Critical sections for mechanical properties, critical regions for NDT and structural weld thicknesses for casting edges which will be fabricated (welded) by entities other than the casting Manufacturer/Supplier will be specified in project documents or on AFC drawings.

2.6 UNDERLYING INDUSTRY STANDARD SPECIFICATION (ASTM A703)

Castings shall be manufactured and tested in accordance with the general requirements of ASTM A703 except that hydrostatic testing as required by ASTM A703 Section 11 is not required unless the requirement for such has been stipulated in project documents or on AFC drawings or compliance with the ASME BPVC-VIII has been specified.

Additionally, although the product marking requirements of ASTM A703 Paragraph 17 shall be applied, a raised pad is not required. Modifications to ASTM A703 and specific deletions or identifications of non-applicable parts are given herein. Unless specifically deleted/waived by this DEP, all provisions of ASTM A703 shall apply. Some statements and/or required values in ASTM A703 are repeated in this DEP for clarity or special emphasis. Compliance with the ASME BPVC-VIII may also be specified, in which case, such code requirements shall supersede the requirements stipulated by this DEP, when

more stringent. Unless otherwise stated in project documents or on AFC drawings, compliance with the ASME BPVC-VIII, and the requirement for hydrostatic testing per ASTM A703 Section 11, shall be required for pressure containing pipeline components, e.g., piggable "WYE" castings.

2.7 TRACEABILITY

The casting Manufacturer/Supplier, and any other Manufacturer/Supplier involved in processing the castings, shall prepare and submit for approval by the Principal and Contractor, if applicable, a written materials traceability plan. As a minimum, full traceability of castings and QTS's relative to heat and heat treat lot shall be maintained. Each casting shall be given a unique serial number. The serial number shall be traceable to the heat number and heat treat lot or batch number. Reference to the traceability plan shall be included in the MPS.

2.8 INFORMATION TO BE CONVEYED TO CASTING MANUFACTURER/SUPPLIER

Table 1 provides a summary of information to be conveyed to the casting Manufacturer/Supplier in the casting procurement documents in order for the casting Manufacturer/Supplier to be able to properly supply product in compliance with this DEP.

2.9 SUMMARY OF DOCUMENT SUBMITTALS REQUIRING APPROVAL BY THE PRINCIPAL AND CONTRACTOR, IF APPLICABLE

Various documents are identified by this DEP as requiring submittal to the Principal and Contractor, if applicable, for approval. Documents shall be submitted to the Principal and Contractor, if applicable, in a timely manner as specified in project documents, or otherwise by the Principal or Contractor, as applicable, in order to allow for the formal review and approval process. Table 2 provides a summary of required document submittals.

2.10 PREPRODUCTION MEETING

If required by the Principal or Contractor, as applicable, a preproduction meeting shall be held at the casting Manufacturer/Supplier's manufacturing facility prior to commencement of manufacture in order to discuss and assure common understanding of the QP and MPS in relation to the order. This preproduction meeting, when required, shall be a designated Hold Point in the QP.

2.11 POST-JOB PRODUCTION HISTOGRAMS

If required by the Principal or Contractor, as applicable, a summary report of results containing histograms of chemical, mechanical and dimensional properties measured and recorded, as required in the QP and MPS, shall be supplied by the casting Manufacturer/Supplier at the completion of the order.

2.12 INSPECTION CERTIFICATES

Inspection certificates (a.k.a. MTR's or mill certificates) shall conform to ASTM A703 Section 16 and ISO 10474 Test Report Type 3.2. Unless, otherwise stated in project documents, MTR's shall be provided in electronic digital form. Pages of the MTR with stamps or signatures shall be scanned.

2.13 PQT PLATES/SPOOLS

Unless specified otherwise in project documents or on AFC Drawings, a minimum of six PQT plates or two PQT spools shall be supplied along with all Service Category B castings for usage by organizations other than the casting Manufacturer/Supplier for qualification of fabrication/field welding procedures. Unless specified otherwise in project documents or on AFC Drawings, PQT plates are required for all Service Category B castings not intended for pipeline components and PQT spools are required for Service Category B castings intended for pipeline components. PQT plates or spools shall be tested for full compliance with this DEP. The entire volume of PQT plates or spools shall be considered critical for

NDT and mechanical properties. Unless specified otherwise in project documents or on AFC Drawings, PQT plate size shall be W 305 mm (12 in) x L 610 mm (24 in) x T 38 mm (1.5 in). Unless specified otherwise in project documents or on AFC Drawings, PQT spool size shall be L 305 mm (12 in). In general, PQT spools shall be of the largest diameter and wall thickness of the weld ends of the castings that they represent. PQT plates and spools shall have Pcm and CEV within 0.025 wt % of the upper limit allowed for the chemical composition range of the castings they represent. Additionally, heat treat requirements for PQT plates and spools shall be the same as those for QTS's relative to the castings they represent. PQT spools shall have ends machined in the same manner as the castings of the same wall thickness that they are to represent.

3. PROCESS OF MANUFACTURE AND CHEMICAL COMPOSITION

3.1 STEELMAKING AND REFINING PRACTICE

Steel shall be made by a practice which is followed by either VD or AOD, unless a production deviation permit is granted by the Principal and Contractor, if applicable. In order to obtain relief from the VD or AOD requirement, the Manufacturer/Supplier shall produce a prototype casting, prior to full production, using the proposed steelmaking method and process of manufacture. The configuration of the prototype casting shall be approved by the Principal and Contractor, if applicable. The prototype casting shall be tested for full compliance with all aspects of this DEP. Such testing shall include sectioning of the casting in critical regions for confirmation of specified mechanical properties. If results are approved by the Principal and Contractor, if applicable, then relief from the VD or AOD requirement shall be indicated in the MPS. In either case, the steelmaking and refining practice shall be described in the MPS and on the MTR for each heat of castings.

3.2 REQUIREMENT FOR FULLY KILLED STEEL

Steel shall be fully killed prior to casting.

3.3 CHEMICAL COMPOSITION

Unless specific chemical composition specifications are specified in project documents or on AFC drawings, the casting Manufacturer/Supplier shall propose for approval by the Principal and Contractor, if applicable, a chemical composition for the castings, including the allowable elemental ranges and aim (target) values, which will result in castings meeting all requirements of this DEP. Chemical compositions listed in Table 3a or Table 3b, as applicable for the specified Service Category and their applicable Grades, are pre-approved by the Principal.

The chemical compositions listed in Table 3a or Table 3b, as applicable, are not necessarily equivalent and selection of a specific composition shall take into consideration the specific application as well as the ability of the composition to meet specified requirements in the Grade and critical section thickness combinations required. Specifically, when the letter "S" is added to the end of the Service Category suffix, suitability for H₂S service is required and castings shall comply with NACE MR0175/ISO 15156-2. Any steel compositions qualified for Service Category suffix "S" under NACE MR0175/ISO 15156-2 Para. 7.2 Option 2 or by testing in accordance with NACE MR0175/ISO 15156-2 Annex B shall require specific approval by the Principal on a case-by-case basis. The specific chemical composition specification and allowable elemental ranges and their aim (target) values selected shall be stated in the MPS.

Any element specifically limited by the chemical composition specification or intentionally added, as stated in the MPS, shall be reported in the MTR. For Service Category B, nitrogen, aluminum, niobium and titanium shall be reported in addition to those elements included in the Pcm equation.

Unless different or more restrictive ranges are required by the chemical composition specification specified in the MPS, as approved by the Principal and Contractor, if applicable, the elemental limits given in Table 4 shall apply to the heat analysis.

3.3.1 Pcm and CEV limits

The Pcm, based on final heat analysis, shall be ≤ 0.23 wt % for Grade C345B-SCB, ≤ 0.25 wt % for Grade C414B-SCB, and ≤ 0.27 wt % for Grade C483B-SCB unless otherwise approved by the Principal and Contractor, if applicable. Pcm limits for Grades C552B-SCB and C586B-SCB shall be proposed by the casting Manufacturer/Supplier for approval by the Principal and Contractor, if applicable, or as otherwise specified in project documents or on AFC drawings. For pipeline component castings only, CEV shall be ≤ 0.45 wt % for C345B-SCB and ≤ 0.48 wt % for C414B-SCB and C483B-SCB, or as otherwise specified in project documents or on AFC drawings.

3.3.2 Chemical properties and tests

The final heat analysis and a product analysis taken from one QTS for each heat of steel, in accordance with ASTM A703 Para. 5. and Supplementary Requirement S1, shall be included in the MTR. Pcm (and CEV for pipeline components) shall be calculated for the final heat analysis of steels for use in Service Category B and Service Category O, if Pcm (and CEV for pipeline components) has been specified for Service Category O, and shall be reported in the MTR for each heat.

4. HEAT TREATMENT

4.1 HEAT TREATMENT PROCESS CONTROL REQUIREMENTS

Heat treatment process control requirements for QHT and PWHT, if applicable, shall be fulfilled by the selection and adherence to this (4.1).

QHT and PWHT of castings and QTS's shall be conducted in qualified working zone of furnaces meeting the requirements of AMS-2750, MIL-STD-1684, or BS 2M 54, or equivalent, as approved by the Principal and Contractor, if applicable, except that furnace uniformity tolerance for austenitizing shall be limited to ± 14 °C (± 25 °F) and furnace uniformity tolerance for tempering, ageing or PWHT shall be limited to ± 8 °C (± 15 °F).

QHT and PWHT of castings and QTS's shall be conducted in furnaces with load thermocouples attached to all castings and QTS's. Locations and method of attachment for load thermocouples shall be clearly described in the MPS. QTS temperature shall be within ± 14 °C (± 25 °F) for austenitizing and within ± 8 °C (± 15 °F) for tempering, ageing and PWHT of all castings to be qualified by the QTS.

4.2 QUENCHING

If quenching is required by the MPS, quenching equipment location and handling facilities shall be sufficient to prevent castings and QTS's from dropping below the Ar3 temperature for the alloy prior to immersion in the quench medium. In addition, quenching facilities shall have sufficient agitation and be of sufficient volume such that the following are ensured:

If water or water-based (i.e., polymer) quenching is required by the MPS, then the temperature of the water or water-based quench medium shall not exceed 38 °C (100 °F) at the start of the quench, nor exceed 49 °C (120 °F) at any time during the quench. Additionally, castings and QTS's shall not be removed from the quench medium until they have cooled to below 204 °C (400 °F), unless otherwise specified in the MPS.

If oil-based quenching is required by the MPS, then the temperature of the oil-based quench medium shall be 16 °C - 71 °C (60 °F - 160 °F) at the start of the quench and shall not exceed 93 °C (200 °F) at any time during the quench. Additionally, castings and QTSs shall not be removed from the quench medium until they have cooled to below 204 °C (400 °F), unless otherwise specified in the MPS.

4.3 HEAT-TREATMENT FURNACE RECORDS OR CHARTS, TEMPERATURES AND CYCLE TIMES

Heat-treatment furnace records or charts shall be maintained showing time and temperature for all heat-treatment operations, including PWHT, per ASTM A703

Supplementary Requirement S21. In addition, a record of heat-treatment temperature and cycle times, as well as a description of the methods of cooling, shall be included in the MTR for each heat and heat treat lot for all heat treatment cycles, including PWHT of castings and simulation PWHT of QTSs, in compliance with ASTM A703 Supplementary Requirement S25.

5. QUALIFICATION TEST SAMPLE (QTS)

5.1 CASTINGS REPRESENTED BY QTS

A QTS shall be utilized to qualify the mechanical properties of all castings on a heat and heat treat lot basis which have been heat treated (and quenched, if applicable) together in the same lot or batch.

5.2 QTS DIMENSIONAL REQUIREMENTS

QTS's shall conform to the test block requirements of ASTM A703 Supplementary Requirement S26 with exceptions and clarifications as follows:

QTS's shall be cast in the same mould and gated to the castings they represent in such a way that molten metal flows through the casting (mould cavity) into the QTS. QTS's shall be of sufficient size to extract all required test specimens, with sufficient additional material to allow for retests should these be required.

The size of QTS's shall not be limited to the 375 mm x 375 mm x 125 mm (15 in x 15 in x 5 in) block as described in ASTM A703 Para. S26.3.3. As an alternative, QTS size may have minimum dimensions of $T \times T \times [2T + 50.8 \text{ mm (2 in)}]$.

The casting thickness, T , as described in ASTM A703 Para. S26.2, upon which the dimensions of the QTS are based, shall be defined as the diameter of the largest circle that can be inscribed within the critical section for mechanical properties or the structural weld thickness, as applicable, at QHT.

If more than one critical section for mechanical properties has been identified then the thickest (largest) critical section for mechanical properties shall be used as the basis for defining QTS size requirements.

If more than one structural weld thickness has been identified, then the thickest structural weld thickness shall be used as the basis for defining QTS size requirements.

If both critical sections for mechanical properties and structural weld thicknesses have been identified, then one of the following options shall be adhered to:

Option1

One QTS based on the maximum thickness determined above.

Option 2

Two QTS's, one with a thickness based on the maximum critical section for mechanical properties and one with a thickness based on the maximum structural weld thickness.

Option 3

A stepped QTS containing thicknesses based on both the maximum critical section for mechanical properties and the maximum structural weld thickness.

QTS configuration and dimensions shall be specifically approved by the Principal and Contractor, if applicable, and fully described in the MPS and in the MTR.

5.3 HEAT TREATMENT OF QTSs

QTS's shall be heat treated and quenched with the castings they are to qualify in conformance to ASTM A703 Supplementary Requirement S22.1 except that QTS's are not required to accompany the castings they represent through PWHT or stress relief thermal cycles. If PWHT or stress relief is to be performed on the castings by either the casting

Manufacturer/Supplier or a subsequent fabricator, then a simulation PWHT or stress relief shall be performed on the QTS in accordance with ASTM A703 Supplementary Requirement S22.2 at a temperature within ± 8 °C (± 15 °F) of the actual PWHT or stress relief temperature of the castings to be qualified.

5.4 PARTIAL SEVERING OF QTSs

For QTS's cast integral to castings, partial severing shall be employed as necessary so that final removal subsequent to quality heat treat is by mechanical means only.

6. MECHANICAL PROPERTIES AND TESTS

6.1 TENSILE TESTS

Tensile test requirements shall be as described in ASTM A703 Section 7 and ASTM A703 Supplementary Requirements S14, S22 and S26.

Test results shall comply with the requirements of (Table 5) for the applicable Grade. For Grades not listed in Table 5, but within the ranges given, linear interpolation is acceptable for the determination of minimum and maximum yield strength and minimum ultimate tensile strength requirements. Retests and any reheat treatment shall conform to ASTM A703 Section 13. Retest specimens shall be extracted from material immediately adjacent to the failed specimen, but still fulfilling the specified specimen extraction location requirements.

Results from all tensile tests, including failures, shall be reported in the MTR.

6.2 HARDNESS TESTS

As per ASTM A703 Supplementary Requirement S13, Brinell hardness determinations in accordance with ASTM E10 shall be made as near as practicable to the center of at least three of the original cast surfaces of QTS's and at locations approved by the Principal for the production castings after QHT and PWHT or stress relief, if applicable. If Brinell hardness testing in accordance with ASTM E10 is impracticable, then portable Brinell hardness testing in accordance with ASTM E110 or other portable hardness measurement methods as approved by the Principal and Contractor, if applicable, may be substituted. The specific method and procedure for hardness testing shall be described in the MPS. The average Brinell Hardness of QTSs shall be within 15 Brinell hardness units of the average Brinell Hardness of each casting they are to represent.

Each Brinell hardness determined above on castings shall comply with the range specified in Table 5 for the applicable Grade. For Grades not listed in Table 5 but within the ranges given, linear interpolation is acceptable for the determination of minimum and maximum Brinell hardness requirements. When the letter "S" is added to the end of the Service Category suffix, suitability for H₂S service is required and castings shall comply with NACE MR0175/ISO 15156-2. Specifically, for any steel with Grade suffix "S" accepted under NACE MR0175/ISO 15156-2 Annex A, hardness shall be limited to 22 HRC (237 HBW). Hardness limits for any steel qualified for Service Category suffix "S" under NACE MR0175/ISO 15156-2 Para. 7.2 Option 2 or by testing in accordance with NACE MR0175/ISO 15156-2 Annex B shall require specific approval by the Principal on a case-by-case basis. In the event that a production casting does not exhibit the required minimum hardness level, the casting may be considered to have an acceptable hardness if the measured value equals or exceeds the value given by the following equation:

$$HB_{\text{cast}} = (UTS_{\text{req}} / UTS_{\text{QTS}}) \times HB_{\text{QTS}}$$

NOTE: HB_{cast} = minimum acceptable Brinell hardness for production castings

UTS_{req} = minimum required ultimate tensile strength for the applicable Grade

UTS_{QTS} = average ultimate tensile strength determined by tensile specimens extracted and tested from the QTS

HB_{QTS} = average Brinell hardness determined on the QTS surface as discussed in (6.2)