

DEP SPECIFICATION

MANUFACTURE, TESTING, AND INSPECTION OF CARBON AND LOW-ALLOY STEEL FORGINGS FOR SPECIAL/CRITICAL STEEL APPLICATIONS IN DEEPWATER OFFSHORE STRUCTURES AND PIPELINES

DEP 37.81.20.37-Gen.

September 2012

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE



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1. INTRODUCTION

1.1 SCOPE

This new DEP specifies minimum requirements and gives recommendations for manufacture, testing, and inspection of carbon and low-alloy steel forgings, including extrusions, bar and heavy-wall seamless tubular product, for use in special/critical steel (Material Quality Level 1) applications in the fabrication of deepwater offshore structures, manufacture of rig and well systems, marine mechanical or mooring system equipment intended for application on deepwater offshore structures or for critical dynamic tendon, well or pipeline riser components, e.g., tendon length adjustment spools, tendon mechanical couplings, stress joints, tension joints, threaded connectors, flanges, J-lay collars, flex element extensions, etc.

Forgings governed by this DEP are identified on AFC drawings and in project documents by the letter "F" followed by the grade (specified minimum yield strength in N/mm²) and the letters "A" or "AA" (indicative of classification as special steel, i.e., Material Quality Level 1 or critical steel, i.e., Material Quality Level 1-PREQUAL, respectively), a "-", and then the letters "SC" followed by "A", "B", "C", "O" or "P" indicating the Service Category, e.g., F345A-SCA. Additionally, the letter "S" will be added as a suffix after the Service Category when suitability for H₂S service is required, e.g., F345A-SCAS. This DEP is based on ASTM A788, ASTM A961 and MSS SP-75.

This new DEP-Gen. incorporates the content of and supersedes the local EPP standard DEP 37.81.20.37-EPP dated July 2006.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised 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 authorised 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 the fabrication of deepwater offshore structures, manufacture of rig and well systems, marine mechanical, or mooring system equipment intended for application on deepwater offshore structures or for critical dynamic tendon, well or pipeline riser components, e.g., tendon length adjustment spools, tendon mechanical couplings, stress joints, tension joints, threaded connectors, flanges, J-lay collars, flex element extensions, etc. 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 regard 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 **forging Manufacturer/Supplier** is the party that manufactures or supplies forgings for 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 authorised 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
A	Steel designation suffix indicating Material Quality Level 1 "Special" steel.
AA	Steel designation suffix indicating Material Quality Level 1-PREQUAL "Critical" steel.
F	Steel designation prefix indicating the component is a forging, extrusion, shackle, bar or heavy-wall seamless tubular.
S	Steel designation suffix indicating suitability for H ₂ S service is required and forgings shall comply with NACE MR0175/ISO 15156-2.
SCA	Steel designation suffix indicating Service Category A. SCA forgings are those forgings, other than shackles and bar-shaped forgings, not intended to contain, or form part of, structural fabrication weldments.
SCB	Steel designation suffix indicating Service Category B. SCB forgings are those forgings, other than shackles and bar-shaped forgings, intended to contain, or form part of, structural fabrication weldments.
SCC	Steel designation suffix indicating Service Category C. SCC forgings are shackles, pins and bar-shaped forgings.
SCO	Steel designation suffix indicating Service Category O. SCO forgings are forgings in the special or "other" Service Category.
SCP	Steel designation suffix indicating Service Category P. SCP forgings are those forgings which will become part of weldments used in the construction of deepwater pipelines and flowlines.
AFC	Approved for Construction drawings.
AOD	Argon-oxygen decarburization.
Ar3	The temperature at which austenite begins to transform to ferrite during cooling.
CEV	Carbon equivalent value. $CEV = C + (Mn/6) + (Cr+Mo+V)/5 + (Ni+Cu)/15$, all elements in wt %.
CTOD	Crack-tip opening displacement test.
DWT	Drop-weight (a.k.a. Pellini) test.
EAF	Electric Arc Furnace
Grade	Minimum yield strength in N/mm ² .
ID/OD	Inside Diameter/Outside Diameter
LAST	Lowest anticipated service temperature.

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.
MT	Magnetic particle testing.
MTR	Material Test Report, a.k.a. mill certificate. Includes results of chemical analyses, mechanical properties tests, visual and non-destructive 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 %.
PMI	Positive material identification
wPQT	Weld procedure qualification test.
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. Shall include inspection and test requirements and provide columns or spaces for the Principal, 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. A QP is also known as an Inspection and Test Plan (ITP).
QTS	Qualification Test Sample.
T	The thickness upon which the dimensions of the QTS are based. 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.
T_f	The finish machined wall thickness across the designated critical section for mechanical properties.
UT	Ultrasonic testing.
VD	Vacuum degassing.
VT	Visual inspection.

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 (10).

1.5 SUMMARY OF MAIN CHANGES

This new DEP-Gen. incorporates the content of and supersedes the local EPP standard DEP 37.81.20.37-EPP dated July 2006. This revision has been a major re-write of the standard and the changes are too numerous to list here.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using the DEP Feedback Form by:

- Entering comments directly in the DEP Feedback System on the Technical Standards Portal <http://swwww.shell.com/standards> (mandatory for users with access to Shell Wide Web);
- Clicking on the DEP Feedback Form button on the DEPs DVD-ROM main page (for users without access to Shell Wide Web);
- Requesting a copy of the DEP Feedback Form from the Administrator at standards@shell.com (for users without access to Shell Wide Web).

For the last two options, the completed DEP Feedback Form can be attached to an email and submitted to the Administrator at standards@shell.com. Only feedback that is entered into the Feedback Form will be considered.

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 forging Manufacturer/Supplier shall implement an ISO 9001 Quality Management System, or equivalent, as approved by the Principal. A QP/ITP and an MPS shall be specifically developed by the forging Manufacturer/Supplier for each order and shall be approved by the Principal prior to commencement of manufacturing operations. Table 1 provides a minimal list of manufacturing steps and process-control variables that shall be defined, including acceptable ranges and aim values where applicable, in the MPS.

2.2 CONTRACTOR PROCUREMENT SPECIFICATION AND APPROVAL OF THE FORGING 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 forging Manufacturer/Supplier and manufacturing facilities, as identified in the MPS, shall require approval by the Principal. Any subcontracted chemical analysis or mechanical testing laboratories shall be approved by the Principal. Chemical analysis and mechanical testing laboratories shall hold a current accreditation by an independent third-party organization to ISO 17025.

2.3 LOWEST ANTICIPATED SERVICE TEMPERATURE (LAST)

Unless otherwise specified in project documents or on AFC drawings, the default LAST shall be as follows:

- 0 °C (+32 °F) for components exposed above the waterline
- +4 °C (+40 °F) for permanently submerged structural components
- +2 °C (+36 °F) for permanently submerged pipeline and flowline components

2.4 SERVICE CATEGORY

The required forging Service Category, i.e., SCA, SCB, SCC, SCO or SCP will be specified in project documents or on AFC drawings as indicated in (1.1). Chemical and mechanical properties requirements for SCA, SCB, SCC and SCP 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 forgings 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 AND STRUCTURAL WELD THICKNESSES

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

2.6 UNDERLYING INDUSTRY STANDARD SPECIFICATION (ASTM A788, ASTM A961 AND MSS SP-75)

All forgings shall be manufactured and tested in accordance with the general requirements of ASTM A788 except that repair welding by the forging Manufacturer/Supplier is not permitted. Additionally, unless otherwise stated in project documents or on AFC drawings, compliance with ASTM A961 and MSS SP-75 shall be required for pressure containing pipeline components, e.g., flex element extensions, J-lay collars, etc. Modifications to ASTM A788, ASTM A961 and MSS SP-75, and specific deletions or identifications of non-applicable parts, are given herein. Unless specifically deleted/waived by this DEP, all provisions of ASTM A788 and for pressure containing pipeline components, ASTM A961 and MSS SP-75, shall apply. Some statements and/or required values in ASTM A788, ASTM A961 and MSS SP-75 are repeated in this DEP for clarity or special emphasis. For pressure containing pipeline components, in case of conflict between ASTM A788, ASTM A961 and MSS SP-75, generally the more stringent shall apply; however, the forging Manufacturer/Supplier shall seek clarification from the Principal in such cases.

2.7 TRACEABILITY

The forging Manufacturer/Supplier, and any other Manufacturer/Supplier involved in processing the forgings, shall prepare and submit for approval by the Principal, a written materials traceability plan. As a minimum, full traceability of forgings and QTSS relative to heat, position within ingot or bloom and heat-treat sequence or lot shall be maintained. Each forging shall be given a unique serial number. The serial number shall be traceable to the heat number, ingot or bloom 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 FORGING MANUFACTURER/SUPPLIER

Table 2 provides a summary of information to be conveyed to the forging Manufacturer/Supplier in the forging procurement documents in order for the forging 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

Various documents are identified by this DEP as requiring submittal to the Principal for approval. Documents shall be submitted to the Principal in a timely manner as specified in project documents, or otherwise by the Principal, in order to allow for the formal review and approval process. Table 3 provides a summary of required document submittals.

2.10 PREPRODUCTION MEETING

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

2.11 POST-JOB PRODUCTION HISTOGRAMS

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

2.12 INSPECTION CERTIFICATES

Inspection certificates (a.k.a. MTRs or mill certificates) shall conform to ASTM A788 Section 16 and ISO 10474 Test Report Type 3.2. Unless, otherwise stated in project documents, MTRs shall be provided in electronic digital form. Pages of the MTR with stamps or signatures shall be scanned.

2.13 WPQT PLATES/SPOOLS AND OTHER TEST SPOOLS

Unless specified otherwise in project documents or on AFC Drawings, a minimum of six WPQT plates or four WPQT spools shall be supplied along with all SCB or SCP forgings for usage by organizations other than the forging Manufacturer/Supplier for qualification of fabrication/field welding procedures. Unless specified otherwise in project documents or on AFC Drawings, WPQT plates are required for all SCB forgings and WPQT spools are required for SCP forgings.

WPQT plates/spools and other test spools shall be tested for full compliance with this DEP. The entire volume of WPQT plates/spools and other test spools shall be considered critical for NDT and mechanical properties. Unless specified otherwise in project documents or on AFC Drawings, WPQT plate size shall be W 305 mm x L 610 mm x T 38 mm (12 in x 24 in x 1.5 in). Unless specified otherwise in project documents or on AFC Drawings, WPQT spool size shall be L 500 mm (20 in). Unless specified otherwise in project documents or on AFC Drawings, WPQT spools shall be of the largest diameter and wall thickness of the weld ends of the forgings that they represent.

WPQT plates/spools shall have Pcm and CEV no lower than 0.025 wt % below the maximum of the forgings they represent. The Pcm and CEV requirement specified above does not apply to other test spools, e.g., fatigue test spools, UT calibration standards, etc., unless specifically stated in project documents or on AFC Drawings. The forging process for WPQT plates/spools and other test spools shall be the same as that for the weld ends of the forgings they represent and overall forging reduction for WPQT plates/spools and other test spools shall not exceed that for the weld ends of the forgings they represent. Heat treat cycles, temperatures and times for WPQT plates/spools and other test spools shall be the same as those for the weld ends of the forgings they represent. WPQT and other test spools shall have section dimensions at QHT which are the same as the weld ends of the forgings they are to represent. Acoustic properties of WPQT spools and other test spools shall be determined in accordance with (Appendix A) and shall meet the tolerances of (Appendix A) relative to the weld ends of the forgings they are to represent.

2.14 DESIGN OF SCP COMPONENTS

If design of SCP components has been included in the forging Manufacturer/Supplier's scope of work, as indicated in project documents or on AFC Drawings, then the SCP components shall be designed to withstand, without any permanent distortion, a hydrostatic test pressure that would cause a hoop stress of 95 % of the specified minimum yield strength in pipe of the same nominal size, wall thickness and grade as the SCP component.

Design of SCP components may be established by mathematical analyses in accordance with the design principles of ASME B31.8 (gas export and flowline service) or ASME B31.4 (oil export service), as applicable; or by the proof testing of a prototype component in accordance with MSS SP-75 Section 4, provided that the prototype is not, in the Principal's judgment, significantly different in dimensions or grade from the component in question.

2.15 HYDROSTATIC TESTING OF SCP COMPONENTS

Hydrostatic testing shall be performed on each finished SCP component when specified in project documents or on AFC Drawings. When performed, hydrostatic testing shall be accomplished with clean fresh water at the pressure specified in project documents or on AFC Drawings for a minimum of 30 minutes. Any hydrostatic testing shall be witnessed by the Principal's representative or a 3rd-party inspector approved by the Principal. Documentation including pressure recorder chart and calibration certificates for instrumentation shall be provided in the MTR for each finished SCP component.

2.16 PREQUALIFICATION OF FORGING FACILITIES AND PROCESS FOR "AA" DESIGNATION STEELS

The forging Manufacturers/Suppliers that have not successfully supplied forgings of the same alloy/grade, melt source and method, similar forging method and sequence and similar forging configuration and size to the Principal in accordance with this DEP, or its

predecessors, shall, unless otherwise agreed by the Principal, produce for the purposes of prequalification a prototype forging of a grade, configuration and size specified by the Principal. The prequalification forging shall be fully tested and inspected for compliance with all requirements of this DEP. Additional testing requirements may also be specified by the Principal. Manufacture and testing of the prototype shall be witnessed by the Principal's representative or a 3rd-party inspector approved by the Principal. Previous documented experience on similarly shaped and sized parts by the forging Manufacturer/Supplier with the particular alloy system specified and utilizing essentially the same manufacturing process may be considered by the Principal in order to fulfil some, or all, of the prequalification requirements.

3. PROCESS OF MANUFACTURE AND CHEMICAL COMPOSITION

3.1 STEELMAKING AND REFINING PRACTICE

Steel shall be made by a practice which is followed by VD as per ASTM A788 Supplementary Requirement S8. Steelmaking followed by AOD shall also be acceptable. If the hydrogen content exceeds 1.5 ppm, then a hydrogen flake control practice approved by the Principal shall be implemented. In order to obtain relief from the steelmaking requirements stated above, the forging Manufacturer/Supplier shall produce a prototype forging, prior to full production, using the proposed steelmaking method and process of manufacture. The configuration of the prototype forging shall be approved by the Principal. The prototype forging shall be tested for full compliance with all aspects of this DEP. Such testing shall include sectioning of the forging in critical regions for confirmation of specified mechanical properties. Manufacture and testing of the prototype shall be witnessed by the Principal's representative or a 3rd party inspector approved by the Principal. If results are approved by the Principal, 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 forgings.

3.2 REQUIREMENT FOR FULLY KILLED FINE GRAIN STEEL

Steel shall be fully killed prior to teeming, or prior to casting for continuous-cast product. The molten stream during teeming or casting shall be protected by vacuum or argon/inert gas shrouding. Additionally, forgings shall have a fine (ASTM 7 or finer) prior austenitic grain size for all forgings as determined in accordance with ASTM E112 Plate I Para. 10.2.1, A3.2.1.1, A3.3.1.5 and A3.4.1 on one forging or QTS per heat per heat-treat batch or uninterrupted continuous heat treating sequence. Evaluation shall be on specimens whose polished and etched face is parallel to the primary grain flow direction.

SCP component forgings shall have ASTM 8 or finer prior austenitic grain size in accordance with the above.

3.3 STEEL CLEANLINESS

The top and bottom of each ingot or continuous cast bloom shall be tested for cleanliness (inclusion content) in compliance with the requirements of ASTM E45 Method A prior to shipment from the forging Manufacturer/Supplier unless otherwise approved by the Principal. As an alternative, the heat sampling plan detailed in SAE AMS2301 Section 4.3.1 may be utilized, provided all non-tested ingots/strands are cropped (top and bottom) at least as much as the successfully tested ingots/strands. At least three specimens shall be obtained at each test location, i.e., top or bottom, subsequent to primary ingot or continuous-cast bloom breakdown and after the material has been cropped and discards made. For ingot or continuous-cast bloom that will be manufactured into hollow product, sampling location within the cross-section shall be such that material is as close as practical to the eventual internal, i.e., ID, surface is sampled. Average inclusion rating numbers from the three specimens at each test location, i.e., top or bottom, shall be less than or equal to those given in Table 4 for the applicable inclusion type. Additional cropping and discard, followed by successful re-testing as above, may be utilized to bring a particular non-conforming location, i.e., top or bottom, into conformance. Average inclusion

rating numbers for each test location per ingot or continuous cast bloom shall be included in the MTR.

3.4 CHEMICAL COMPOSITION

3.4.1 General

Unless specific chemical composition specifications are specified in project documents or on AFC drawings, the forging Manufacturer/Supplier shall propose for approval by the Principal a chemical composition for the forgings, including the allowable elemental ranges and aim (target) values, which will result in forgings meeting all requirements of this DEP. Chemical compositions listed in Table 5a, Table 5b, Table 5c, and Table 7 or Table 8, as applicable for the specified Service Category and their applicable Grades, are pre-approved by the Principal.

The chemical compositions listed in Table 5a, Table 5b and Table 5c, Table 7 and Table 8, 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 forgings 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 SCB and SCP, nitrogen, aluminium, 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), the elemental limits given in Table 6 shall apply to the heat analysis.

Inclusion shape control shall be required. The method of inclusion shape control shall be stated in the MTR.

3.4.2 Pcm and CEV limits

Unless otherwise approved by the Principal, the Pcm, based on final heat (ladle) analysis, shall be as follows for SCB and SCP only:

- $P_{cm} \leq 0.23 \text{ wt } \%$ for F345,
- $P_{cm} \leq 0.24 \text{ wt } \%$ for F414 thru F483,
- $P_{cm} \leq$ as proposed by Manufacturer/Supplier and approved by the Principal for higher than F483.

For SCP only, CEV shall be $\leq 0.45 \text{ wt } \%$, or as otherwise specified in project documents or on AFC drawings. CEV requirements apply to the final heat (ladle) analysis only.

Pcm and CEV limits above for SCB and SCP do not apply to Shell A707 Modified, ASTM A350 LF787, ASTM A707 L5, ASTM A859 or grades that will receive PWHT after fabrication welding. Pcm and/or CEV heat (ladle) analysis limits for these grades shall be proposed by the Manufacturer/Supplier and approved by the Principal and shall be reported so that compliance with (2.13) can be verified.

3.4.3 Chemical properties and tests and PMI

The final heat (ladle) analysis and a product analysis taken from one QTS for each heat of steel, in accordance with ASTM A788 Paragraphs 8.1 and 8.4, respectively, shall be included in the MTR. The heat (ladle) analysis shall include a determination of the

hydrogen content of the last liquid steel subsequent to all alloying treatments, bath reheating, and degassing operations. If the hydrogen content exceeds 1.5 ppm, then a hydrogen flake control practice approved by the Principal shall be implemented. Pcm (and CEV for SCP) shall be calculated for the final heat (ladle) analysis of steels for use in SCB, SCP and SCO (if Pcm and/or CEV has been specified for SCO), and shall be reported in the MTR for each heat.

A Principal-approved Positive Material Identification (PMI) program in accordance with DEP 31.10.00.10-Gen. shall be implemented for all SCP components and any other components specifically identified for this requirement by the Principal. PMI in accordance with ASTM E1916 shall be performed on each forging prior shipment in order to assure there has been no inadvertent grade mix-up. The method for PMI shall be stated in the MPS.

3.5 HOT-WORK RATIO

Forgings may be produced by open or closed die forging, ring rolling, extrusion, or by seamless tubular processes (e.g., pierce and draw, etc.). The overall hot-work ratio shall be sufficient to produce a wrought grain structure throughout all sections of the forging. The overall hot-work ratio from ingot or continuous-cast bloom to product in designated critical sections shall be $\geq 4:1$ unless the original ingot or bloom centreline has been removed, in which case the minimum overall hot-work ratio for designated critical sections shall be $\geq 3:1$. The overall hot-work ratio is defined as the product of the hot-work ratio for each separate hot-working or forging operation, not including initial upsetting or any upsetting not followed by drawing or extrusion. For example, if the overall hot-working or forging process consists of two separate operations, then the overall hot-work ratio is calculated by multiplying the hot-work ratio for first operation by the hot-work ratio for the second operation. If the forging Manufacturer/Supplier cannot achieve the specified hot-work ratio, then a full-scale prototype forging shall be produced prior to full production, using the proposed forging sequence and hot-work ratios. The configuration of the prototype forging shall be approved by the Principal. The prototype forging shall be tested for full compliance with all aspects of this DEP. Such testing shall include sectioning of the forging in critical regions for confirmation of specified mechanical properties. Manufacture and testing of the prototype shall be witnessed by the Principal's representative or a 3rd-party inspector approved by the Principal. Hot-work calculations and sketches showing forging configuration at the different hot-working stages with sufficient dimensional information to verify hot-work ratio calculations and a description of the post-forge cooling/thermal processing practice shall be included in the MPS. A statement of the hot-work ratio shall be included in the MTR.

3.6 REPAIR WELDING NOT ALLOWED

Repair welding by the forging Manufacturer/Supplier is not allowed and a statement that no weld repair was performed shall be included in the MTR.