



Engineering Standard

SAES-W-010

30 June 2013

Welding Requirements for Pressure Vessels

Document Responsibility: Welding Standards Committee

Saudi Aramco DeskTop Standards

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Revised paragraphs are indicated in the right margin

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1 Scope

- 1.1 This standard specifies the welding, heat treatment, and hardness testing requirements for shop and field fabrication, repair, or modification of pressure vessels and heat exchangers to ASME SEC VIII. These requirements are in addition to the requirements of ASME SEC VIII and ASME SEC IX.
- 1.2 Additional requirements may be contained in Scopes of Work, Drawings, or other Instructions or Specifications pertaining to specific items of work.
- 1.3 Any reference to Consulting Services Department (CSD) shall be interpreted as the CSD Welding Specialist or a representative designated by CSD. Any reference to “approval” shall be interpreted as written approval.
- 1.4 This entire standard may be attached to and made a part of purchase orders.
- 1.5 This standard is generally not applied retroactively to the maintenance and repair of existing facilities unless there are safety, environmental protection, health or security concerns.

2 Conflicts and Deviations

- 2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.
- 2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure [SAEP-302](#) and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

Unless stated otherwise, all Codes, Standards, and Drawings referenced in this Standard shall be of the latest issue (including revisions, addenda, and supplements) and are considered a part of this Standard.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

[SAEP-302](#)

*Instruction for Obtaining a Waiver of a Mandatory
Saudi Aramco Engineering Requirement*

<u>SAEP-321</u>	<i>Performance Qualification Testing and Certification https://standards.aramco.com.sa:10009/docs/Sae/p/PDF/SAEP-322.PDF of Saudi Aramco Welders</i>
<u>SAEP-322</u>	<i>Performance Qualification Testing and Certification of Saudi Aramco Brazers</i>
<u>SAEP-323</u>	<i>Performance Qualification Testing of Contract Welders and Brazers</i>
<u>SAEP-324</u>	<i>Certification Review and Registration of Project Welders and Brazers</i>
<u>SAEP-325</u>	<i>Inspection Requirements for Pressurized Equipment</i>
<u>SAEP-352</u>	<i>Welding Procedures Review and Approval</i>
<u>SAEP-1140</u>	<i>Qualification of Saudi Aramco NDT Personnel</i>
<u>SAEP-1142</u>	<i>Qualification of Non-Saudi Aramco NDT Personnel</i>
<u>SAEP-1150</u>	<i>Inspection Coverage on Projects</i>

Saudi Aramco Engineering Standards

<u>SAES-W-014</u>	<i>Weld Overlays and Welding of Clad Materials</i>
<u>SAES-W-015</u>	<i>Strip Lining Application</i>

Saudi Aramco Materials System Specifications

<u>32-SAMSS-004</u>	<i>Manufacture of Pressure Vessels</i>
<u>32-SAMSS-011</u>	<i>Manufacture of Air-Cooled Heat Exchangers</i>

Saudi Aramco Standard Drawings

<u>AE-036451</u>	<i>Preheat Levels for Welding Carbon Steels</i>
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3.2 Industry Codes and Standards

American Society of Mechanical Engineers

<i>ASME SEC IIC</i>	<i>Welding Rods, Electrodes and Filler Metals</i>
<i>ASME SEC VIII</i>	<i>Rules for Construction of Pressure Vessels</i>
<i>ASME SEC IX</i>	<i>Welding and Brazing Qualifications</i>

American Petroleum Institute

<i>API RP 510</i>	<i>Pressure Vessel Inspection Code "Maintenance, Inspection, Rating, Repair, and Maintenance"</i>
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API RP 582 *Welding Guidelines for the Chemical, Oil and Gas Industries*

American Society for Testing and Materials

ASTM E92 *Vickers Hardness of Metallic Materials*

ASTM E140 *Hardness Conversion Tables for Metals*

American Welding Society

AWS A2.4 *Standard Welding Symbols*

AWS A3.0 *Standard Terms and Definitions*

AWS A4.2 *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal*

AWS A4.3 *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Weld Metal Produced by Arc Welding*

AWS A5.32 *Specification for Welding Shielding Gases*

AWS D1.1 *Structural Welding Code*

National Association of Corrosion Engineers

NACE RP0472 *Methods and Controls to Prevent In-Service Cracking of Carbon Steel Welds in P-1 Material in Corrosive Petroleum Refining Environments*

British Standards Institution

[BS EN50504](#) *Validation of Arc Welding Equipment*

National Association of Corrosion Engineers/International Standardization Organization

[NACE MR0175/ISO 15156](#) *Petroleum and Natural Gas Industries-Materials for use in H₂S-Containing Environments in Oil and Gas Production*

4 General

- 4.1 AWS A2.4 “Standard Welding Symbols” shall be used for all welding details on all drawings.
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- 4.2 AWS A3.0 “Standard Terms and Definitions” shall be used for all specifications and documents.
- 4.3 These requirements apply to all sub-contractors or sub-vendors for items within the scope of this standard.

5 Approved Welding Processes

The following processes are approved for use with the restrictions and requirements as listed below:

- 5.1 Shielded Metal Arc Welding (SMAW).
 - 5.2 Gas Tungsten Arc Welding (GTAW).
 - 5.2.1 Except for ASME P-No. 1 through P-No. 5A/5B/5C base materials, all manual GTAW shall use a high frequency start and post-purge gas flow for the torch. Filler metal shall always be added, autogenous welding is not permitted unless specifically approved by CSD.
 - 5.2.2 The GTAW process shall be used for all passes of piping butt welds and set-in/on nozzles less than 25.4 mm nominal pipe size (NPS).
 - 5.2.3 The GTAW process shall be used for the root pass of piping butt welds and set-in nozzles (where the back side is not visually inspected) of 50.8 mm nominal pipe size or less.
 - 5.2.4 The GTAW process shall be used for the root pass of single-sided groove welds without backing made with stainless steel or nickel-based consumables.
 - 5.2.5 The use of flux-cored GTAW wires for root pass of single-sided groove welds for base materials of P-No. 8 or higher with or without backing gas is not permitted unless specifically approved by CSD.
 - 5.3 Submerged Arc Welding (SAW).
 - 5.4 Gas Metal Arc Welding (GMAW) including Flux Cored Arc Welding (FCAW).
 - 5.4.1 The short-circuiting (dip) mode shall not be used except for:
 - a) Structural attachments to the outside surface of the vessel shell, including seal welds.
 - b) Tacking (including continuous tacks) that shall be completely removed by backgouging and backwelding.
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- c) The modified short circuit mode of GMAW may only be used for root pass welding.

5.4.2 Flux-Cored Arc Welding (FCAW).

- a) The FCAW Gas Shielded process shall not be used for the root pass on full penetration, groove joints that are welded from one side only without backing (backing may be used if it is removed after welding).
- b) Self-shielded FCAW shall not be used without the specific approval of CSD.

- 5.5 Thermit Welding using a copper alloy is permitted for attaching electrical grounding or cathodic protection cables to structural members. Thermit welding shall not be used on stainless steel materials.
- 5.6 Stud Welding is permitted for attaching insulation fasteners and heat conductors.
- 5.7 Other processes (such as brazing, Electro-Gas, Electro-slag, Plasma, etc.) may be used only with the approval of CSD. Depending upon the process and application proposed, CSD may require testing in addition to that specified by the Code. Approval to use other processes shall be obtained through the welding procedure review process.

6 Welding Consumables

- 6.1 Electrodes, filler wires, and fluxes shall conform to ASME SEC IIC. Other consumables may be used only with the approval of CSD and, depending upon the process and application proposed, may require testing in addition to that specified by ASME SEC IX. Approval to use consumables not listed in ASME SEC IIC shall be obtained through the welding procedure review process. For unlisted consumables, vendor literature, which shall include intended use and approximate chemistry and mechanical properties, shall be submitted with the procedure.
- 6.2 Electrodes shall be properly stored and segregated in the store, shop, or ovens to avoid mix-up. Separate ovens are required for different welding consumable types. The Fabricator shall ensure that adequate inventory control is established to account for all consumables checked-out.
- 6.3 All consumables shall be stored and dried in accordance with the requirements of [Attachment 1](#) for SMAW electrodes and [Attachment 2](#) for other consumables.

- 6.4 GTAW filler metal shall have either the AWS/ASME identification or the manufacturer's identification marked on each individual rod by the manufacturer with tags ("flags"), stencil, or stamping on both ends.
- 6.5 Welding consumables shall be selected based on their mechanical properties, compatibility with the materials to be joined, their suitability for the intended service, and consideration of polarity, position, and direction of welding. Welding consumables not meeting standard industry practice using the above criteria may be rejected by CSD. Welding consumables which are being used outside of their rated tensile or impact ranges listed in the manufacturing specs shall be batch tested or have CSD approval. Batch testing shall be in accordance with SFA 5.01 to verify that they shall meet the requirements of the base material.
- 6.5.1 Low hydrogen consumables (defined as less than or equal to 8 ml of hydrogen per 100 g of deposited weld metal, measured in accordance with AWS A4.3) shall be used except for:
- i) The root pass of closure seams on P-No. 1 (carbon steel) vessels in non-hydrocarbon service with less than 12.7 mm wall thickness where the inside is not accessible.
 - ii) If approved by CSD, the root pass for field repairs of joints accessible from one side only.
- 6.5.2 Dissimilar Metal Welds (DMW) are defined as:
- i) Any weld joint (excluding weld overlays or strip lining) between ferritic steel and either austenitic stainless steel, duplex stainless steel, or nickel-based alloys, or
 - ii) Use of stainless steel or nickel-based filler metals on ferritic steels.
- They shall be restricted as follows:
- a) Are not permitted for pressure-containing or load bearing welds in sour service (welds in clad systems are acceptable if the DMW interface with the ferritic steel is not in contact with the sour fluid). Minor attachments may be made with the approval of the Welding Standards committee.
 - b) Are permitted for non-sour hydrocarbon service if made with a nickel-based consumable.
 - c) Austenitic stainless steel consumables may be used only for the following applications and if the maximum design temperature is below 300°C:
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- i) External structural attachments (e.g., name plates).
 - ii) Non-sour, non-hydrocarbon (e.g., water) services.
 - d) Nickel-based consumables may not be suitable for direct exposure to sulphur or hydrogen-sulphur reducing environments at temperature exceeding 400°C due to possible sulfidation attack.
 - 6.5.3 Other than the DMWs listed in paragraph 6.4.2, the selection of filler metal compositions for joining base materials of different P-Numbers or compositions shall be as follows:
 - a) For attaching non-pressure parts to pressure parts, the nominal composition of the filler metal shall match the nominal composition of the pressure part.
 - b) For other applications, the filler metal shall conform to either base metal composition or to an intermediate composition, whichever is the most appropriate for the application.
 - 6.5.4 For welding P-No. 1 carbon steels, the weld deposit shall meet the A-No. 1 analysis classification unless approved by CSD.
 - 6.5.5 Filler metal or deposit chemistries conforming to A-number 2 (ASME SEC IX), i.e., carbon-0.5% Mo, shall not be used for sour service applications without post weld heat treatment unless specifically approved by CSD.
 - 6.6 Submerged Arc Welding fluxes
 - 6.6.1 Active type Submerged Arc Welding fluxes shall not be used without approval. The approval shall be obtained prior to the welding procedure qualification. The fabricator shall clearly identify the proposed use of active fluxes in their welding procedure submissions.
 - 6.6.2 Flux fused during welding shall not be reused (i.e., fluxes that use recrushed slag are not acceptable).
 - 6.6.3 SAW fluxes that the flux manufacturer recommends for single pass welding shall not be used for multiple pass welding.
 - 6.7 SMAW electrodes shall be limited as follows:
 - 6.7.1 F-Nos. 1, 2, and 3 electrodes shall not be used on materials requiring impact tests either by Code or job specification.
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6.7.2 F-Nos. 1 and 2 electrodes shall not be used for pressure-retaining welds.

6.8 Shielding Gases

Shielding gases shall conform to the following requirements:

6.8.1 AWS A5.32 Specification for Welding Shielding Gases.

6.8.2 The requirements for other gases and gas mixtures shall be submitted to CSD for approval.

6.9 For sour service application, all welding related requirements of ISO 15156 shall be followed. Note that for sour service, carbon steel welding consumables containing more than 1.1 % mass fraction nickel are not acceptable.

7 Welding Procedures

7.1 Documentation

7.1.1 All welding procedures to be used shall be submitted as a complete package to Saudi Aramco for the technical approval prior to the start of work (refer to [SAEP-352](#) for details). The welding procedure submittal shall include the Welding Procedure Specifications (WPS), Qualification Test Records (PQR), and a Weld Map ([Attachment A](#)).

Welding procedures approved by CSD or Saudi Aramco Welding Representatives may be used for additional jobs if approved by a Saudi Aramco assigned PID or VID inspector. The welding procedure shall meet all of the requirements of the new job as a minimum the following shall be checked:

- Material of new job shall be covered by WPS
- Diameter of new job shall be covered by WPS
- Thickness of new job shall be covered by WPS
- PWHT condition of new job shall be covered by WPS
- If new job is for Sour service then the review sheet shall indicate “for sour service” or the hardness values in the PQR shall be checked.
- If the new job has “impact requirements” then the review sheet shall be checked for impact approval and the MDMT.

And the ranges of variables on the new project fall within the ranges of the approved procedures. A weld map for the new work shall be submitted to the assigned inspector.

Welding procedures for external structurals such as platforms, walkways and stairways do not require CSD approval and they may be qualified to AWS D1.1. This does not apply to the welding procedures to attach the supports to the vessel's wall.

Commentary Note:

The contractor is permitted to use any welding procedure previously approved by Saudi Aramco without CSD re-review. However, the assigned inspector and the contractor welding engineer/representative shall verify that the welding procedure is within the welding parameters qualification range (e.g., diameter, thickness, material grade, etc.) for the new job.

If the welding procedure was approved to a previous revision of the Welding Standards the contractor shall also write a formal letter to PMT indicating that the subject welding procedure still complies with the latest revision of Saudi Aramco Welding Standards.

It shall generally take a minimum of 10 working days to complete welding procedures review. Urgent review shall not be accepted unless supported in writing by the proponent Project Manager or Superintendent. The letter should include details for the reasons (safety, cost impact, etc.) to justify the urgent review.

CSD approval shall be indicated in all pages of the WPS. Weld maps are not approved; they provide a “check” that the procedures are being applied properly. Weld maps frequently change during the course of the work.

- 7.1.2 A Weld Map shall be submitted along with the WPS and PQR documents for each piece of equipment (identical equipment can use one combined submittal). The Weld Map ([Attachment A](#)) provides a simple single-line sketch of an equipment item. All welds including non-pressure attachments shall be identified by a separate letter or number. All base materials (by specification and grade) and wall thicknesses to be used shall be listed in the Weld. WPSs and PQRs shall not be reviewed without applicable Weld Maps.

With the approval of CSD, standardized Weld Maps and Weld Descriptions and sets of welding procedures for common types of vessels may be submitted by the fabricator for general approval. All of the documentation requirements shall be met except specific

vessel identification is not required and generic weld identifications may be used.

- 7.1.3 For shop fabrication In-Kingdom and all field fabrication and installation, the Welding Procedure Specifications (WPSs) and Procedure Qualification Records (PQRs) shall be prepared as per the suggested format of ASME SEC IX.

Standardized PQR forms from an approved independent test laboratory are acceptable. Equivalent WPS forms from a contractor may be acceptable if approved by CSD.

- 7.1.4 Each Weld Map shall be complete and show the Saudi Aramco equipment tag number and the purchase order number. Identical equipment items may be combined on one set of forms.
- 7.1.5 Welding shall not commence until the WPSs have been approved by Saudi Aramco and returned to the fabricator. Any welding prior to the approval of these welding documents is subject to rejection at the sole option of Saudi Aramco. Any rework required as a result of this rejection shall be at the fabricator's expense.
- 7.1.6 After approval by Saudi Aramco, the fabricator shall issue copies of the approved Weld Maps to the Saudi Aramco Inspector prior to the start of fabrication.
- 7.1.7 Approval of welding procedures shall not be construed as authority for deviation from listed specifications or requirements of the relevant codes and standards and shall not relieve the contractor, fabricator, or vendor from correcting any deviations.
- 7.1.8 All WPSs, PQRs, Weld Maps shall be available at the work site for verification at any time by the authorized Saudi Aramco inspector.
- 7.1.9 All Welding Procedure Specifications and Welding Procedure Qualification Records shall be written in English.
- 7.1.10 WPSes and PQRs shall be submitted as legible, paper copies. Digital copies are not acceptable. The WPS shall have the signature of the responsible person from the contractor or manufacturer. Once the WPS is approved and stamped it becomes the approved original for Saudi Aramco work. The PQR shall have the signature of the contractor or manufacturer, the testing agency and a witnessing third party.
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7.1.11 Originals of all test records, mill certificates, etc., including records from the independent test laboratory shall be made available for review by Saudi Aramco upon request.

7.2 General Requirements

7.2.1 All WPSs and PQRs shall conform to the latest edition of the ASME SEC IX. Procedures that comply with a previous edition but not the current edition of the relevant Code are not acceptable. Procedures no longer conforming to the latest Code edition shall be revised, requalified and resubmitted for CSD approval. All pressure containing welds, attachments to pressure containing welds and load bearing welds shall be qualified by full procedure testing including, as a minimum, tensile and bend tests.

7.2.2 For any new or additional qualification tests that are required, Saudi Aramco reserves the right to monitor any and all phases of the procedure qualification, including welding of the coupons and mechanical testing. Saudi Aramco may assign the monitoring to an inspection agency.

7.2.3 All information shown on the PQR, such as amperage, voltage, travel speed, post weld heat treatment time and temperature, as applicable, shall be actual data as recorded using calibrated instruments. The actual interpass temperature shall be recorded prior to starting every pass.

7.2.4 Qualification of welding procedures for all shop fabrication in Saudi Arabia and field erection work shall be performed In-Kingdom. Approval for use of welding procedures qualified Out-of-Kingdom shall be obtained through the welding procedure review process (see [SAEP-352](#)).

7.2.5 For In-Kingdom qualifications:

- a) The welding of all qualification test coupons shall be monitored by either an approved independent test laboratory, an independent third party approved by Saudi Aramco, or Saudi Aramco Inspection. The monitoring shall include verification of the accuracy of the recorded parameters.
- b) All procedure qualification mechanical tests and examinations shall be performed by an approved independent test laboratory unless the fabricator is specifically approved by Saudi Aramco Inspection to perform their own tests.

- 7.2.6 For all automatic welding and any process with pulsing, the welding procedure shall include all applicable equipment and controller parameter settings.

7.3 Special Qualification Requirements

- 7.3.1 Tube-to-tubesheet welding procedures and welders, including seal welds, shall be qualified in accordance with ASME IX, QW-202.6(b) (i.e., mockup test per QW-193.1).. In addition to the qualification essential variables specified in QW-288 and the Procedure Qualification Specimen requirements listed in QW-193.1, it is also required that the mockup assembly tubesheet be at least as thick as the production tubesheet thickness (but it is not required to be thicker than 50 mm). For seal welds, the required weld throat thickness shall be as specified by the designer.

- 7.3.2 For special applications as determined by CSD, such as but not limited to severe corrosion service (e.g., chlorinated seawater) or high temperature service, special qualification tests, such as stress corrosion cracking or embrittlement tests for low alloy steels, may be specified by CSD. These special requirements may be stated in the job specifications or purchase order, contract specifications, etc.

7.4 Procedure Variables

The following additional restrictions shall be considered essential variables for procedure qualification:

- 7.4.1 Any SAW flux or FCAW electrode shall be restricted to the specific brand, type, and maximum size as used for the PQR. If so restricted, the brand name and type of flux or electrode shall be specified on both the WPS and PQR.
- 7.4.2 A change in filler metal or deposit chemistry from A-No 1 (based on ASME SEC IX) to A-No 2 and vice-versa is not permitted without approval. The approval shall be obtained through the welding procedure review process. A change from A-No. 1 to A-No. 2 is not permitted for sour service applications without requalification.
- 7.4.3 For ASME P-No. 1 materials, all Group 3 or 4 materials shall be qualified separately for each specific material, unless it is being used in combination with a Group 1 or 2 material and the Group 1 or 2 material strength requirements govern.

- 7.4.4 Aluminum flake weldable primers (e.g., “Bloxide”, “Deoxaluminite”, or other brand approved by CSD) may be used without requalification of the procedure. The welding procedure specification shall indicate the use of the type and brand of weldable primer. The maximum coating thickness shall not exceed 0.050 mm. The use of other weldable primers or coatings is not permitted unless specifically approved by CSD. Additional procedure qualification and/or weldability tests may be required by CSD.
- 7.4.5 Position
- 7.4.5.1 The direction of welding for the vertical position shall be an essential variable (i.e., a change from vertical-up to vertical-down or vice-versa shall be considered an essential variable). If the procedure was not qualified in the vertical position, then the direction of welding shall be vertical-up.
- 7.4.5.2 For automatic, or mechanized welding, the position limitations listed in ASME SEC IX, QW-461.9 shall be considered as an essential variable for procedure qualification.
- 7.4.6 Procedures using any consumable with a “G” or unlisted designation (ASME SEC IIC) shall be restricted to the brand and type of electrode used for the PQR. The nominal chemistry of the specific brand and type of electrode shall be identified on the WPS. Substitution of the “G” consumables with the “P1” requires technical evaluation by CSD.
- 7.4.7 Deletion of a backing strip in a single-sided groove weld shall be considered an essential variable and shall require requalification.
- 7.4.8 For single-sided groove welds without backing, the process and electrode type used for the root pass shall be considered an essential variable. The PQR shall be performed as a single-sided groove weld without backing.
- 7.4.9 For full penetration, double-sided joints, the WPS shall require backgouging (see 11.3.3) for all processes except for the following:
- a) For automatic or mechanized welding processes if additional PQR testing is conducted. The PQR shall include supplementary coupons using the production equipment and joint geometry. The supplementary coupons shall be examined by ultrasonic testing (UT) or radiographic testing (RT), as appropriate for the joint geometry, and shall be sectioned for examination in at least
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3 locations. The NDE results and cross-sections shall show complete fusion, complete penetration, and freedom from cracks.

- b) For other special processes on butt joints where the production welds shall be radiographed. The applications shall be approved by CSD.

7.4.10 Deletion of a backing gas purge or a change in the backing gas composition for a joint welded or brazed from one side without backing material shall require requalification.

7.4.11 Special requirements for procedures requiring impact testing:

Charpy impact testing shall be required on the PQR if it is required or specified by the design code or the company specifications. The impact test acceptance criteria shall be as specified by the SAMSS of the vessel or heat exchanger (e.g., [32-SAMSS-004](#) or [32-SAMSS-011](#)).

7.4.12 Heat Input Measurement

For applications requiring heat input restrictions (e.g., applications with Charpy impact testing, weld overlays), the heat input to be recorded on the PQR and used as the limiting value for the WPS and it shall be based on the average value of welding parameters used.

If the PQR thickness exceeds 12 mm and multiple processes or consumables are used, separate impact test specimens shall be conducted for each process or consumable. If the impact test specimen size is larger than the deposit thickness of a specific process or consumable, then the impact test specimen shall contain the maximum possible amount of the deposit for that process or consumable (a separate set of specimens is still required for the other process or consumable). Only full size specimens (10 mm X 10 mm) are required unless the PQR wall thickness requires sub-sized specimens.

Commentary Note:

The notch of the HAZ impact samples should be centered on the HAZ region.

7.5 Welding Procedure Qualification Hardness Testing

7.5.1 Hardness testing is required for all PQRs for:

- a) Hydrogen service vessels of any wall thickness.
 - b) Sour service vessels of any wall thickness.
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- c) For vessels in any service if the shell or head wall thickness is greater than 38 mm.
- d) For vessels requiring PWHT due to service.

Refer to the vessel data sheet to determine if the above services or conditions apply.

Note the additional PQR requirements listed in 13.8 for PWHT for applications requiring hardness testing.

- 7.5.2 Hardness testing shall comply with NACE MR0175/ISO 15156. Only the Vickers test method (in accordance with ASTM E92) is acceptable, with a maximum test load of 10 kg. The maximum allowable hardness is VHN 250.

Welding procedures for wet sour service shall be qualified on the material with the highest carbon equivalent to be used in production. The test coupon shall be allowed to cool to the minimum preheat temperature or lower prior to starting each pass. The actual preheat/interpass temperature of the test coupon shall be recorded prior to welding each pass. The preheat/interpass temperature and heat inputs shall be essentially the same as used for all similar passes in the test coupon. It is not permitted to weld one pass at a low preheat or low heat input to increase the range of these parameters. Note that PWHT is required for wet sour service. The following essential variables shall be implemented:

- a) The nominal preheat/interpass temperature used for the testing shall be the minimum preheat/interpass temperature in the production welding.
- b) The carbon equivalent of the material used for the PQR test shall be the maximum carbon equivalent to be used in production.
- c) The minimum heat input used in production shall be no less than the minimum used in the qualification.

For procedures that have been qualified previously a validation test may be conducted with only hardness testing performed. The essential variables noted above shall still be monitored and the welding procedure shall be revised to incorporate these variables

7.6 Preparation of Test Coupons

For new procedures or procedures that are to be re-qualified (i.e., existing PQRs that are acceptable without any supplementary tests are exempt), the following

additional requirements shall apply:

- 7.6.1 The qualification test shall include all of the required tests on the same coupon unless size limitations restrict the number and type of specimens that can be reasonably removed from a single coupon. If multiple coupons are required and approved by CSD, each of the coupons shall be of the same material and size and shall be welded with identical parameters. Use of supplementary test coupons for additional Charpy impact to be combined with existing PQRs shall be approved by CSD. The supplementary qualification test shall comply with all of the essential and, where applicable, supplementary essential variables of the original PQR.
- 7.6.2 For groove welds, the test coupons shall be radiographed and shall meet the acceptance criteria of ASME SEC VIII D1, UW-51.

8 Welder and Welding Operator Qualification

- 8.1 All welders, welding operators, brazers, and brazing operators shall be qualified in accordance with the ASME SEC IX and [SAEP-1150](#), [SAEP-321](#), [SAEP-322](#), [SAEP-323](#), and [SAEP-324](#), as applicable, for all welding, including tack, temporary, and repair welds.
- 8.2 Performance qualification tests shall not be performed on production joints on Saudi Aramco work.
- 8.3 Current production rates of each welder shall be made available to Saudi Aramco Inspection upon request. The repair rates shall be calculated on a linear basis. The maximum weekly repair rate for each welder should not exceed 2%, or as determined by Saudi Aramco Inspection:

$$\% \text{ RR} = (L_r/L_w) \times 100 \quad (1)$$

Where:

- % RR = percent repair rate
 L_r = welder's total length of repairs in one week, mm
 L_w = welder's total length of weld radiographed in one week, mm

9 Joint Details

- 9.1 All pressure-containing welds shall be made with multiple passes.
- 9.2 For any closure welds without internal access after welding, the welding and inspection details necessary to ensure proper joint quality shall be submitted to
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Saudi Aramco for approval.

- 9.3 Permanent backing rings or strips shall not be used.
- 9.4 Temporary backup strips in weld joints may be used providing the backing material is of a composition similar to the base metal or weld metal. Under no circumstances shall rebar or galvanized steel be used. Temporary backup shoes made of non-metallic, non-fusing material may be used.
- 9.5 Consumable inserts may be used for all applications providing the composition matches the weld metal composition.
- 9.6 Full penetration groove joint included angles less than 30 degrees (except for portions of compound bevels) shall not be used without approval. The approval shall be obtained through the welding procedure review process and the minimum included angle shall be an essential variable.
- 9.7 For nozzles with reinforcing pads (when permitted), the nozzle attachment weld shall be completed and inspected, as required, prior to installing the reinforcing pad.

10 Corrosion Resistant Cladding, Overlays and Linings

The following standards shall apply in addition to the requirements of this standard:

- 10.1 Weld overlays and welding of integral cladding shall conform to [SAES-W-014](#).
- 10.2 Strip linings shall conform to [SAES-W-015](#).

11 Production Welding

11.1 The maximum allowable SMAW electrode sizes that can be used are given below. The ability of each welder to use the maximum sizes listed in the table shall be checked by the Inspector as early as possible during fabrication.

- a) Low hydrogen electrodes
 - 5 mm for the 1G/1F position.
 - 4 mm for all other positions.
- b) Non-low hydrogen electrodes (not normally used)
 - 5 mm for all positions.

Sizes larger than those listed are acceptable only if approved by CSD and only if the PQR was performed using the electrode size and positions to be

used in production. The approval shall be obtained through the welding procedure review process.

11.2 Welding Environment

- 11.2.1 Wind shields or tents shall be required when the wind is strong enough to affect arc stability or shielding gas coverage or when deemed necessary by Saudi Aramco Inspection. GTAW, GMAW, and gas-shielded FCAW shall not be used for field or yard fabrication unless adequate wind shields are used. The wind velocity in the weld area for GTAW, GMAW, or gas shielded FCAW shall not exceed 8 kph (2.2 m/s).
- 11.2.2 Welding shall not be done when surfaces are wet or damp or exposed to rain or snow or when the welders are exposed to inclement conditions.
- 11.2.3 Contamination from the environment, such as wind-blown sand, shall be prevented by the use of adequate shielding.

11.3 Joint Preparation

- 11.3.1 Oil, moisture, rust, scale, sand, paint (except weldable primers for approved applications - refer to paragraph 7.4.4 for restrictions), metallic coatings (e.g., zinc), or other foreign matter shall be removed from the weld surface and at least 25 mm of adjacent base metal prior to welding, including any such coatings on temporary attachments or supports.
 - 11.3.2 Flame cutting and arc-air gouging
 - 11.3.2.1 Ragged and irregular edges shall be ground or machined to bright metal. Holes cut for nozzles or bosses attachment shall be ground smooth and as accurate as possible. Unless otherwise specified by ASME SEC VIII, the actual diameter of the hole shall be ± 1.6 mm of the nominal specified diameter.
 - 11.3.2.2 Thermally cut or gouged surfaces for all materials, including carbon steels, shall be power brushed or ground prior to welding.
 - 11.3.2.3 A minimum of 1.5 mm depth shall be removed by grinding or machining from thermally cut or gouged surfaces of a ir-hardenable materials (e.g., Chrome-Moly steels). Additional nondestructive examination may be required on
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the cut surface, at the option of the authorized Saudi Aramco inspector.

11.3.2.4 Thermal cut surfaces of stainless steel and non-ferrous materials shall be ground to bright (unoxidized) material prior to welding.

11.3.3 All full penetration joints requiring double sided welding shall be ground or gouged to sound metal and inspected by penetrant testing (PT) or magnetic particle testing (MT) prior to welding the reverse side, unless exempted by 7.4.10. For the exempt applications, production results shall demonstrate that acceptable penetration can be reliably achieved. If periodic lack-of-penetration defects are found, then backgouging shall be mandatory for joint geometries other than butt welds and either backgouging or 100% radiography shall be required for butt welds.

11.3.4 Buttering or Weld Build-Up on Joints

11.3.4.1 Buttering or weld build-up on the prepared surfaces shall not exceed the lesser of $\frac{1}{3}$ of the base metal thickness or 10 mm without the approval of CSD. If the buttering or build-up exceeds this, then the following requirements shall apply:

- a) The buttering operation shall be witnessed by Saudi Aramco Inspection.
- b) The buttering shall be inspected by radiographic testing (RT) and PT or MT after completion of the build-up but before final welding of the joint.

11.3.4.2 Buttering of joints between dissimilar metal joints requires prior approval by CSD. The approval shall be obtained through the welding procedure review process.

11.4 Cleaning

11.4.1 Each weld pass shall be thoroughly cleaned and all slag or other foreign matter removed before the next pass is deposited.

11.4.2 All slag, flux, and spatter shall be removed from the completed weld and surrounding areas.

11.4.3 Stainless steel and nonferrous materials shall be cleaned with grinding wheels or stainless steel brushes not previously used on other materials.

11.5 Tack Welds

- 11.5.1 All tack welds shall be made by qualified welders.
 - 11.5.2 All tacks or temporary welds shall be performed with the same care, materials, electrodes, minimum preheat, and procedures that are used for permanent welds.
 - 11.5.3 Tack welds shall be of sufficient size to maintain joint alignment.
 - 11.5.4 Tack welds that are to be incorporated into the final weld shall be thoroughly cleaned, prepared at each end, and inspected for cracks. Any cracked tacks shall be removed before welding the joint.
 - 11.5.5 If the tack welds are to be incorporated into the final root pass weld and are made with a different process or electrode than the root pass, then the tack weld process and electrode shall have been used as the root pass for an appropriate procedure qualification.
 - 11.5.6 Bridge tacks (located above the root area) are acceptable but such tacks shall be made completely within the weld groove and shall be completely removed prior to completion of the weld.
- 11.6 Arc strikes, gouges, and other indications of careless workmanship (such as surface porosity, uneven weld profiles, and undercut) shall be removed by grinding and then examined by Magnetic Particle Inspection.
 - 11.7 Any temporary welded attachments or temporary tack welds shall be ground off. Attachments may be cut off no closer than 3 mm to the base metal surface, prior to the required grinding.
 - 11.8 If any grinding reduces the base metal thickness to less than the design minimum, the ground area shall be rewelded and ground flush with the original base metal surface or the component shall be replaced. Rewelding shall be done only with the prior approval of Saudi Aramco Inspection.
 - 11.9 For all materials, inspection by magnetic particle or liquid penetrant methods of areas shall be performed where temporary welds have been removed (see 11.7) or weld repairs to ground areas of the base material have been made (see 11.8) or arc strikes after repair by grinding (see 11.6).
 - 11.10 Temporary attachments, grounding lugs, or supports welded to any component shall be made with a compatible material. Under no circumstances shall rebar or galvanized steel be used.
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- 11.11 Coated and clad or overlaid surfaces shall be protected from the welding arc, associated weld spatter, and damage from ground clamps or other associated equipment.
- 11.12 Peening
 - 11.12.1 Peening shall not be permitted unless approved by CSD and specified in the approved welding procedure. Cleaning of slag is not considered peening.
 - 11.12.2 When peening is specified, the welding procedure specification shall include details of how it shall be performed. If peening is specified or performed, the welding procedure shall be qualified using peening.
- 11.13 Adjacent beads of a weld shall be staggered and not started in the same location.
- 11.14 Back Purging
 - 11.14.1 An inert backing gas shall be used for GTAW or GMAW root passes on single-sided groove welds for materials of ASME P-No. 5 and higher.
 - 11.14.2 Any back purging shall be maintained until completion of root, hot and 1st fill passes.
 - 11.14.3 For ASME P-No. 5, the back purge shall be sufficient to reduce the oxygen level below 1%. The method of back purge and the flow rate shall be specified on the WPS.
 - 11.14.4 The use of nitrogen as a backing gas for austenitic stainless steels is prohibited.
 - 11.14.5 For stainless steel and nickel alloys, the back purge shall reduce the oxygen level below 0.05%. An oxygen analyzer should be used to determine the oxygen content in the back side pipe during purging. It is the inspector responsibility to determine the analyses frequency.

Commentary Note:

If it is not possible to use gas purging then we may accept using cleaning compound/tool to remove the oxide discoloration on the back side of the weld. The inspector should be consulted to evaluate/accept the cleaning method.

- 11.15 Seal Welding
 - 11.15.1 All threaded joints and faying surfaces shall be seal welded by a continuous fillet weld (required weep holes shall be left unwelded).
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Connections or attachments designed for periodic removal may be exempted from seal welding.

- 11.15.2 Sealing compounds or tapes shall not be used on joints that are to be seal welded.
- 11.15.3 Seal welding of threaded connections shall cover all exposed threads and shall have a smooth contour between the two surfaces.
- 11.16 Forced or accelerated cooling of welds is prohibited without the specific approval of CSD.
- 11.17 For field welding, remote current controls shall be used if the welding is more than 30 m from the welding power source or when the welders are working in “remote” locations (e.g., inside a vessel).
- 11.18 Welding power supplies shall be validated in accordance with BS EN50504 or an approved equivalent if impact toughness test is required by the applicable company or industry specifications or codes. The fabricator shall also use calibrated amps/volt meter to measure the welding current and voltage and compare the readings against the welding machine indicators. Discrepancies in the readings shall be rectified before commencing/continuing welding. The validation practice may be monitored by Saudi Aramco assigned inspector. Validation or calibration records shall be available to Saudi Aramco Inspection upon request.
- 11.19 The heat input (HI) of each production weld shall be calculated, if notch-toughness tests are specified, and then confirmed not to exceed the heat input limits listed in the welding procedure specifications.

12 Preheat

- 12.1 Preheat shall be in accordance with the applicable division of ASME SEC VIII and this Standard. For materials not covered in this Standard, the preheat shall be as specified in the approved welding procedure.
- 12.2 The minimum preheat shall not be less than the greater of the following:
 - a) 10°C.
 - b) The required or recommended preheat listed in ASME SEC VIII.
 - c) For field fabrication or repair of P-No. 1 carbon steel materials, the preheat listed in Standard Drawing [AE-036451](#).

Commentary Note:

The listed preheats are minimum requirements. The actual preheat temperature selected and used by the fabricator shall be sufficient to prevent cracking and to achieve the required hardness, if specified.

- 12.3 For steels with specified minimum yield strengths above 414 MPa, the preheat shall be as specified in the approved welding procedure. Special applications may require special weldability tests to evaluate the preheat temperature.
- 12.4 If a weld joint is wet or has surface moisture or condensation, it shall be dried by heating for a distance of 100 mm from the weld joint and shall be warm to the hand before welding unless a greater preheat temperature is required.
- 12.5 Temperature-indicating crayons, thermocouples, or calibrated contact pyrometers shall be used to measure preheat and interpass temperatures.
- 12.6 The preheat temperature shall be established over a minimum distance of 75 mm on each side of the weld.
- 12.7 If the wall thickness exceeds 25 mm and preheating is to be done from the same side as the welding, then the heat source shall be removed for 1 minute to allow for temperature equalization prior to measuring the temperature.
- 12.8 Unless specified otherwise, the maximum interpass temperature shall be 177°C for P-No. 8, P No. 3X and P-No. 4x materials and 315°C for P-No. 1, P3, P-4 and P-5 steels.
- 12.9 For specified preheat temperatures of 120°C or higher, the preheat shall be maintained without interruption until the start of PWHT. This PWHT may be either the full PWHT, an Intermediate Stress Relief (600°C for 1 hour), or a Dehydrogenation Heat Treatment (350°C for 4 hours).

13 Post Weld Heat Treatment

- 13.1 Post weld heat treatments (PWHT) shall be in accordance with ASME SEC VIII. A written procedure describing the general PWHT requirements shall be submitted for review and approval. The PWHT procedure shall include descriptions of the equipment, method of heating, location and type of heating elements, temperature measurement, and thermocouple locations. The review and approval process shall be the same as described for welding procedures ([paragraph 7.1](#)).
 - 13.2 Prior to the start of work the contractor or fabricator shall prepare a data sheet for each vessel (or joint for localized PWHT) requiring heat treatment, which shall be submitted to Saudi Aramco Inspection for review and approval.
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The data sheet shall include the following information: wall thicknesses (for shell, heads, and nozzles), material, heating rate, cooling rate, soak temperature, and soak time.

- 13.3 Apart from Code requirements of PWHT for carbon and low alloy steels, the following process services require PWHT. Other process conditions may also require PWHT, as determined during the project design or as specified by the Saudi Aramco Engineer as defined in this standard. Code exemptions for PWHT are not permitted if PWHT is specified for process conditions.
- 1) All caustic soda (NaOH) solutions, including conditions where caustic carryover may occur (all temperatures).
 - 2) All amine solutions, at all temperatures excepting the following:
 - a. Diglycol amine (DGA) solutions below 176°C design temperature
 - b. Rich amino di-isopropanol (ADIP) solutions below 90°C design temperature
 - c. Lean ADIP solutions below 60°C design temperature.
 - 3) Boiler deaerators above 80°C design temperature
Note: Vacuum deaerators operating at ambient temperature are exempt.
 - 4) Vessels in hydrogen service at all temperatures manufactured from P-No.3, 4, and 5A/B/C base materials
 - 5) Vessels in carbonate cracking environments.
 - 6) Vessels in sour service
- 13.4 The specified PWHT shall be applied over an area extending at least 6 times the thickness of the material being welded from each edge of the weld but not less than 25 mm from each edge of the weld, whichever is greater.
- 13.5 For PWHTs that are not performed in a furnace, insulation shall be applied a minimum of 300 mm on either side of the weld that is to be PWHTed. The insulation shall not be removed before the temperature has cooled to below 150°C. The internal surface shall also be insulated to avoid lowering the temperature on the inside surface of the joint.
- 13.6 Code exemptions for post weld heat treatment are not permitted for vessels requiring PWHT for service conditions.
- 13.7 Austenitic or nickel-based electrodes shall not be used for ferritic materials except dissimilar metal welds listed in 6.4.2 and overlays or single sided welds in clad materials.
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- 13.8 Code exemptions for post weld heat treatment of P-No. 4 and P-No. 5 materials are not permitted for applications involving either sour service or materials exceeding 2.5% nominal chromium content.
- 13.9 For applications where PWHT is required by the service fluid or where hardness limits are specified:
- a) Any reductions in the PWHT temperature or alternative temperatures below the normal holding temperatures listed in the applicable Code are not permitted.
 - b) The minimum PWHT soak time shall be 1 hour.
- 13.10 All temperatures within the heated zone for furnace or localized PWHT shall exceed the specified minimum holding temperature. The actual temperature range for the soak period, as recorded by thermocouples, shall not have a spread of more than 40°C.
- 13.11 Welding or heating to joints that have been PWHTed requires re-PWHT. Post weld heat treatment shall follow all welding and repairs but shall be performed prior to any hydrotest.
- 13.12 PWHT shall be carried out using one or more of the following types of heat sources:
- a) Permanent or semi-permanent furnaces using gas or oil or electric heaters (a vessel itself may be considered a furnace if heated internally and externally insulated).
 - b) Electrical resistance heaters.
 - c) Induction heaters.
- 13.13 Thermocouple locations shall include both the inside and outside surfaces of the vessel for weld thicknesses in excess of 75 mm.
- 13.14 For all vessels PWHTed in a furnace, the thermocouple locations shall include:
- a) The thinnest major component.
 - b) The thickest member.
 - c) The top of the vessel (as oriented during PWHT).
 - d) The bottom of the vessel (as oriented during PWHT).
- 13.15 Localized PWHT
- 13.14.1 Localized post weld heat treatment of weld joints is not permitted except for:
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- a) Nozzles - Cat. B and C welds.
 - b) Closure seams.
 - c) Repairs, alterations, or modifications.
- 13.14.2 If localized PWHT of the vessel shell is used, it shall be monitored using at least four sets of thermocouples, with each set consisting of one thermocouple each on the inside and outside surfaces. Each set shall be placed at 90 degree intervals around the vessel circumference. Additional thermocouple sets are required if multiple heat control zones are used when a control zone is not monitored by one of the four primary sets.
- 13.14.3 Localized PWHT of nozzle welds shall have the following minimum number of thermocouples. Nozzles with a diameter of 305 mm or less shall have at least one thermocouple. At least two equally spaced thermocouples shall be used for circumferential welds on nozzle diameters above 305 mm through 610 mm. Nozzles larger than 610 mm diameter shall have at least four thermocouples equally spaced around the circumference.
- 13.14.4 Localized PWHT shall conform to the requirements of ASME SEC VIII (e.g., full circumferential band around vessel) except for field repairs and modifications to in-service vessels that were not originally PWHTed. For these cases, the requirements shall be established by CSD.
- 13.15 Thermocouples and a calibrated temperature chart recorder shall be used to provide an accurate and legible record of all PWHTs. All charts shall be marked with the date and sufficient information to uniquely identify the vessel (or joint/component for localized PWHT) being heat treated. Multipoint chart recorders shall clearly differentiate/identify each channel/point by use of different colored inks or automatic number stamping.
- 13.16 Temperature recorders shall be calibrated every three months and a current calibration sticker shall be maintained on the recorder. The calibration frequency may be extended to 12 months with the approval of Saudi Aramco Inspection if the documented calibration checks for that particular recorder demonstrate acceptable accuracy for a suitable period.
- 13.17 Thermocouples
- 13.16.1 Only Type K (Chromel-Alumel) or Type J (iron-Constantan) thermocouples are permitted. All extension cables, compensating cables, and jumper cables in the measurement or control circuits shall be the specified thermocouple wire or the matching extension wire
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(i.e., KX or JX, as appropriate). For Type K thermocouples, copper-Constantan (Type T) compensating cables may be used with the following conditions:

- a) The junction between the copper-Constantan compensating cable and the Type K thermocouple lead shall be a minimum of 0.5 m outside the insulated area.
- b) The acceptable temperature range of the junction between the compensating cable and the thermocouple lead is from 0 to +80°C.

13.17.2 The national standard that the thermocouple conforms to shall be indicated in the PWHT procedure. The procedure shall also include a listing of the insulation coloring of each core wire and the overall sheath for both the compensating cable and thermocouple. This information is required for site inspectors to verify that the proper wires have been used and are connected in the proper polarity.

13.17.3 Thermocouples shall be attached to the component by capacitive discharge welding only. Other methods of attachment are not permitted. The thermocouples shall not be in direct contact with electrical heating elements or subjected to flame impingement by gas or oil burners.

13.18 Prior to the start of the PWHT, components shall be checked to ensure that all restraints are removed, the component is free to expand and contract, and suitable and sufficient supports are used. In addition, the PWHT chart should be marked, prior to PWHT, with identification number of the weld(s).

13.19 All machined surfaces, such as flange faces, threaded bolt holes, threads, etc., shall be protected from oxidation during the heat treatment by coating with deoxaluminite or other suitable material.

13.20 All PWHT chart records shall be submitted to Saudi Aramco Inspection for review and approval. All records shall be submitted as part of the equipment file for permanent record.

13.21 After completion of the PWHT all thermocouples shall be removed and the attachment areas ground smooth to clean and sound metal. If specified by the Inspector, the areas shall be examined by MT or PT after grinding.

13.22 PWHT shall be performed before NDE is conducted.

14 Production Weld Hardness Testing

14.1 Hardness testing is required on production welds for the following applications:

- a) For all materials in sour service.
- b) For vessels PWHTed for service (see 13.3).
- c) Vessels of P-No. 4 or 5 material.

The testing shall be in accordance with NACE RP0472 and the requirements listed below. The testing location and frequency shall be in accordance with NACE RP0472. No exemptions, as allowed in NACE RP0472, are permitted. The maximum allowable hardness for P-No. 1 materials is BHN 200. For all other materials, it shall be the equivalent hardness as specified in NACE MR0175/ISO 15156 (equivalent hardness conversions shall be in accordance with ASTM E140). Welds for external attachments on vessel shells are exempt from hardness testing.

14.2 The testing guidelines listed in Appendix A of NACE RP0472 shall be mandatory.

14.3 Testing shall be conducted with portable hardness testers (TeleBrineller or approved equivalent) that comply with ASTM A833. The Brinell scale shall be used unless another scale is specifically approved by CSD. The hardness of the reference bar shall be within $\pm 10\%$ of the maximum specified hardness.

14.3.1 Leeb type (rebound) hardness testers (i.e., Equotip) are not permitted.

14.3.2 UCI (ultrasonic contact impedance) hardness testers are permitted if the procedure is approved by CSD.

14.4 The weld reinforcement shall be ground to provide a smooth flat surface for testing.

14.5 Hardness indentations shall be made at or near the middle of the deposited weld bead.

14.6 If any reading exceeds the specified limit by no more than 10 BHN, then a minimum of three (3) additional indentations shall be made near the original high reading. If all three (3) retests are below the specified limits, then the joint is acceptable. If any of the retest readings are found to exceed the specified limits, then the weld shall be considered unacceptable.

15 Weld Identification

- 15.1 All weld joints shall be marked for identification by a weld number and a welder symbol. These identifications shall be made with a suitable weather-proof marking material. The markings shall be placed in a location such that they shall be easily observed and remain visible for a time suitable to the authorized Saudi Aramco inspector.
- 15.2 The fabricator shall establish and submit for approval by inspection an identification system that shall uniquely identify each component and weld joint. The identification system shall be used to identify all examinations, surveys, inspections, etc. This system shall also be used to identify the final position of each piece of pressure-retaining material (including each heat number) in the completed vessel.

16 Repairs

- 16.1 Welds may be repaired twice at any defect location. If a weld is still not acceptable after the second repair, then Saudi Aramco Inspection has the sole authority for the decision to permit additional repair attempts or to require that the entire weld be cut out. The limitation on the number of repairs does not include adjacent sequential repairs where the length of the area to be repaired is limited by structural strength or other considerations.
 - 16.2 Repair of cracks, that are fabrication related, shall require the approval of Saudi Aramco assigned inspector. The repair procedure including inspection, excavation, approved welding procedures shall be reviewed and approved by the inspector. Cracks that are related to the base metal or welding consumable shall be evaluated by CSD before any repair attempts. Crater cracks may be repaired without Saudi Aramco approval.
 - 16.3 In-process repairs (i.e., repairs performed prior to completion of the joint using the same welding procedure as for the original fabrication) during production do not require a separate repair procedure except for cracks (see 16.2).
 - 16.4 The repair procedure may utilize a welding procedure previously approved by CSD in conjunction a separate method statement or it may be a separate detailed welding procedure.
 - 16.5 All repaired welds shall, as a minimum, be inspected using the original testing method. Additional test methods may also be required, if deemed necessary by the authorized Saudi Aramco inspector. Replacement welds (cut-outs) shall be examined as a repair.
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- 16.6 Damage or deformation to the base metal or welds, including dimensional changes, caused by external forces (intentional or accidental) requires special repair and inspection procedures be submitted to Saudi Aramco Inspection and if necessary forwarded to CSD for review and approval prior to undertaking the repairs.
- 16.7 Any weld not meeting the acceptance criteria of the applicable code or standard shall be cut out or repaired. Other methods, such as sleeving, shall not be permitted.

Revision Summary

8 September 2012
30 June 2013

Major revision.
Editorial revision clarifying paragraph 6.9 pertaining to nickel requirements and to be aligned with SAES-W-012 new requirements.

Attachment 1 – Conditioning, Storage and Exposure of SMAW Electrodes (Notes 1, 2, 3)

Low Hydrogen Electrodes to A5.1

Drying and Re-drying

Prior to use all electrodes shall be dried at 260-430°C for 2 hours minimum. The drying step may be deleted if the electrodes are supplied in the dried condition in a hermetically sealed metal can with a positive indication of seal integrity or vacuum sealed package. Electrodes may be re-dried only once.

Storage

After drying, the electrodes shall be stored continuously in ovens at 120°C minimum.

Exposure

Upon removal from the drying or storage oven or hermetically sealed containers, the electrodes may not be exposed to the atmosphere for more than 4 hours. The exposure may be extended to 8 hours if the electrodes are continuously stored in a portable electrode oven heated to 65°C minimum. Electrodes exposed to the atmosphere for less than the permitted time period may be re-conditioned. Electrodes exposed in excess of the permitted time period shall be re-dried. Electrodes that have become wet or moist shall not be used and shall be discarded.

Re-conditioning

Electrodes exposed to the atmosphere for less than the permitted time period may be returned to a holding oven maintained at 120°C minimum; after a minimum holding period of four hours at 120°C minimum the electrodes may be reissued.

Low Hydrogen Electrodes to A5.5

Drying and Re-drying

Prior to use all electrodes shall be dried at 370-430°C for 2 hours minimum. For E70xx and E80xx electrodes, the drying step may be deleted if the electrodes are supplied in the dried condition in a hermetically sealed metal can with a positive indication of seal integrity or vacuum sealed package. Electrodes may be re-dried only once.

Storage

After drying, the electrodes shall be stored continuously in ovens at 120°C minimum.

Exposure

Upon removal from the drying or storage oven or hermetically sealed containers, the electrodes may not be exposed to the atmosphere for more than 2 hours for E70xx or E80xx electrodes and 30 minutes for any higher strength electrodes. The exposure times may be doubled (to 4 hours and 1 hour, respectively) if the electrodes are continuously stored in a portable electrode oven heated to 65°C minimum. E70xx and E80xx electrodes exposed to the atmosphere for less than the permitted time period may be re-conditioned. E70xx and E80xx electrodes exposed in excess of the permitted time period shall be re-dried. Higher strength electrodes (above E80xx) shall be re-dried after any atmospheric exposure. Electrodes that have become wet or moist shall not be used and shall be discarded.

Re-conditioning

E70xx and E80xx electrodes exposed to the atmosphere for less than the permitted time period may be returned to a holding oven maintained at 120°C minimum; after a minimum holding period of four hours at 120°C minimum the electrodes may be reissued.

Stainless Steel and Non-Ferrous Electrodes

Drying and Re-drying

Prior to use all electrodes shall be dried at 120-250°C for 2 hours minimum. The drying step may be deleted if the electrodes are supplied in the dried condition in a hermetically sealed metal can with a positive indication of seal integrity or vacuum sealed package. Electrodes may be re-dried only once.

Storage

After drying, the electrodes shall be stored continuously in ovens at 120-200°C minimum.

Exposure

Upon removal from the drying or storage oven or hermetically sealed containers, the electrodes may not be exposed to the atmosphere for more than 4 hours. The exposure may be extended to 8 hours if the electrodes are continuously stored in a portable electrode oven heated to 65°C minimum. Electrodes

exposed to the atmosphere for less than the permitted time period may be re-conditioned. Electrodes exposed in excess of the permitted time period shall be re-dried. Electrodes that have become wet or moist shall not be used and shall be discarded.

Re-conditioning

Electrodes exposed to the atmosphere for less than the permitted time period may be returned to a holding oven maintained at 120°C minimum; after a minimum holding period of four hours at 120°C minimum the electrodes may be reissued.

Non-Low Hydrogen Electrodes to A5.1 or A5.5

The electrodes shall be stored in a dry environment. Any electrodes that have become moist or wet shall not be used and shall be discarded.

Notes:

- 1) Storage and rebake ovens shall have a calibrated temperature gauge to continuously monitor the temperature.
- 2) Portable electrode storage ovens with a minimum temperature of 120°C are considered equivalent to storage ovens. Proper use of the oven (e.g., closed lid, continuously on while in use) and periodic checks of the temperature achieved with each portable oven are required.
- 4) Electrode types are listed in accordance with ASME SEC IIC.

Attachment 2 – Conditioning, Storage and Exposure of Wires and Fluxes

SAW Fluxes

Fluxes for material with a minimum specified tensile strength less than or equal to 482 MPa:

All fluxes shall be stored in sealed containers in a dry environment. Opened SAW flux containers shall be stored continuously in ovens at 65°C minimum or the manufacturer's recommendation, whichever is greater. Any flux that has become moist or wet shall not be used and shall be discarded.

Fluxes for material with a minimum specified tensile strength exceeding 482 MPa:

Fluxes shall be dried, stored and handled in accordance with the manufacturer's recommendations in order to achieve a dissolved hydrogen content of less than 8 ml H₂/100 g metal. A written procedure giving the handling requirements shall be submitted to inspection.

SAW, GTAW, GMAW and FCAW electrodes and wires

All electrodes and wires shall be stored in sealed containers in a dry environment. Any wires that have visible rusting or contamination shall not be used and shall be discarded.

FCAW electrodes are susceptible to moisture pickup. The electrode manufacturer may require special testing, baking and packaging in order to guarantee the low hydrogen (8 ml H₂/100 g metal) characteristic of his consumable. Special storage and handling procedures may be required.

Attachment 3

**WELD MAP
SAUDI ARAMCO
PRESSURE VESSEL AND HEAT EXCHANGER**

Vendor Name:
Saudi Aramco Purchase Order No.:
Equipment Tag No.:
SAMSS(s) (list all relevant specs):

ASME SEC VIII	Service Requirements (Check if "yes")
Design Code	<input type="checkbox"/> Charpy Impact List MDMT: _____ °C
<input type="checkbox"/> Pressure Vessel: <input type="checkbox"/> Division 1 <input type="checkbox"/> Division 2	<input type="checkbox"/> Hardness (sour Service)
<input type="checkbox"/> Heat Exchanger	<input type="checkbox"/> PWHT for service
1. Draw a single -line sketch of the equipment.	
2. Locate all welds, except minor non-pressure attachment welds.	
3. Identify each weld by a separate letter or number (identical weld joints may use a single identification).	
4. The materials and thickness, shall be indicated on the Weld Map	

Vendor Contact
Name:
Tel:
Fax:

Review Status
<input type="checkbox"/> 1 - Approved as submitted
<input type="checkbox"/> 2 - Approval with commented
<input type="checkbox"/> 3 - Proceed but revise and resubmit
<input type="checkbox"/> 4 - Revise and resubmit
<input type="checkbox"/> 5 - Rejected