

# Engineering Standard

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SAES-W-010

14 November 2005

Welding Requirements for Pressure Vessels

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## Saudi Aramco DeskTop Standards

### Table of Contents

|   |                                 |   |
|---|---------------------------------|---|
| 1 | Scope.....                      | 2 |
| 2 | Conflicts and Deviations.....   | 2 |
| 3 | References.....                 | 3 |
| 4 | General.....                    | 5 |
| 5 | Approved Welding Processes..... | 5 |
| 6 | Welding Consumables.....        | 6 |

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Revised paragraphs are indicated in the right margin

Page 1 of 49

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|    |  |    |
|----|--|----|
| 7  | Welding Procedures.....                                    | 17 |
| 8  | Welder and Welding Operator Qualification.                 | 17 |
| 9  | Joint Details.....   | 18 |
| 10 | Corrosion Resistant Cladding,<br>Overlays and Linings..... | 18 |
| 11 | Technique and Workmanship.....                             | 18 |
| 12 | Preheat.....   | 23 |
| 13 | Post Weld Heat Treatment.....                              | 24 |
| 14 | Production Weld Hardness Testing.....                      | 29 |
| 15 | Weld Identification.....                                   | 30 |
| 16 | Repairs.....   | 30 |
| 17 | Miscellaneous Requirements.....                            | 31 |

**Table of Contents**

|   |    |
|---|----|
| Attachment 1 – Conditioning, Storage and<br>Exposure of SMAW Electrodes.....  | 32 |
| Attachment 2 – Conditioning, Storage and<br>Exposure of Wires and Fluxes..... | 35 |
| Attachment A.....   | 36 |

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## Attachment B..... 37

**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.
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### 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

|                                  |   |
|----------------------------------|---|
| <a href="#"><u>SAEP-302</u></a>  | <i>Instruction for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement</i> |
| <a href="#"><u>SAEP-321</u></a>  | <i>Performance Qualification Testing and Certification of Saudi Aramco Welders</i>            |
| <a href="#"><u>SAEP-322</u></a>  | <i>Performance Qualification Testing and Certification of Saudi Aramco Brazers</i>            |
| <a href="#"><u>SAEP-323</u></a>  | <i>Performance Qualification Testing of Contract Welders and Brazers</i>                      |
| <a href="#"><u>SAEP-324</u></a>  | <i>Certification Review and Registration of Project Welders and Brazers</i>                   |
| <a href="#"><u>SAEP-325</u></a>  | <i>Inspection Requirements for Pressurized Equipment</i>                                      |
| <a href="#"><u>SAEP-352</u></a>  | <i>Welding Procedures Review and Approval</i>   |
| <a href="#"><u>SAEP-1140</u></a> | <i>Qualification of Saudi Aramco NDT Personnel</i>  |
| <a href="#"><u>SAEP-1142</u></a> | <i>Qualification of Non-Saudi Aramco NDT Personnel</i>  |
| <a href="#"><u>SAEP-1150</u></a> | <i>Inspection Coverage on Projects</i>  |

##### Saudi Aramco Engineering Standards

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[SAES-A-301](#) *Materials Resistant to Sulfide Stress Corrosion Cracking*

[SAES-W-014](#) *Weld Overlays and Welding of Clad Materials*

[SAES-W-015](#) *Strip Lining Application*

#### Saudi Aramco Standard Drawings

[AB-036386](#) *Hardness Testing for Welding Procedure Qualifications*

*AE-036451* *Preheat Levels for Welding Carbon Steels*

### 3.2 Industry Codes and Standards

#### American Society of Mechanical Engineers

*ASME SEC IIC* *Welding Rods, Electrodes and Filler Metals*

*ASME SEC VIII* *Rules for Construction of Pressure Vessels*

*ASME SEC IX* *Welding and Brazing Qualifications*

#### American Petroleum Institute

*API RP 510* *Pressure Vessel Inspection Code "Maintenance, Inspection, Rating, Repair, and Maintenance"*

*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, Inc.

*AWS A2.4* *Standard Welding Symbols*

*AWS A3.0* *Standard Terms and Definitions*

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*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*

*NACE MR0175-2002 Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*

British Standards Institution

*BS 7570 Code of Practice for Validation of Arc Welding Equipment*

#### **4 General**

- 4.1 AWS A2.4 "Standard Welding Symbols" shall be used for all welding details on all drawings.
  - 4.2 AWS A3.0 "Standard Terms and Definitions" shall be used for all specifications and documents.
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- 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 must 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).
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- 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 will be completely removed by backgouging and backwelding

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.

5.4.3 The STT mode of GMAW may only be used for root pass welding.

- 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
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specified by ASME SEC IX. Approval to use other (unlisted to ASME SEC IIC) consumables 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.
  - 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 must be batch tested or have CSD approval. Batch testing must be in accordance with SFA 5.01 to verify that they will 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.
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- 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 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).
- 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:
  - 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:

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- 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.
  - 6.7.2 F-Nos. 1 and 2 electrodes shall not be used for pressure-retaining welds.
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## 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.

## 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 shall include the Welding Procedure Specifications (WPS), Qualification Test Records (PQR), Weld Map (Attachment A) and Weld Description Sheet (Attachment B).

Welding procedures approved by CSD or Saudi Aramco Welding Representative may be used for additional jobs if approved by a Saudi Aramco assigned inspector. The welding documents and data for the new job must be identical to the approved copies and the range of variables on the new project fall within the ranges of the approved procedures.

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. However, this does not apply to the welding procedures to attach the supports to the vessel's wall.

#### *Commentary Notes:*

- 1) *The contractor is permitted to use any welding procedure previously approved by Saudi Aramco without CSD re-review. However, the*
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*assigned inspector and the contractor welding engineer/representative must 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 must also write a formal letter to PMT indicating that the subject welding procedure still complies with the latest revision of Saudi Aramco Welding Standards.*

- 2) It will generally take a minimum of 10 working days to complete welding procedures review. Urgent review will 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.*
- 3) CSD approval shall be indicated in all pages of the WPS.*

7.1.2 A Weld Map with Weld Description 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 except minor nonpressure attachments shall be identified by a separate letter or number. Each different weld, including minor non-pressure attachment welds, shall be described on a Weld Description form (Attachment B). All base materials (by specification and grade) and wall thicknesses to be used shall be listed in the Weld Map or Weld Descriptions. Weld Map or Weld Description shall not be reviewed without applicable WPSs and PQRs or vice-versa.

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.

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- 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 Section IX.

*Commentary Note:*

*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 must 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 Weld Maps, Weld Descriptions, and 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 and Weld Descriptions 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, and Weld Descriptions shall be available at the work site for verification at any time by the authorized Saudi Aramco inspector.
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- 7.1.9 All Welding Procedure Specifications and Welding Procedure Qualification Records shall be written in English.
  - 7.1.10 The PQRs shall include certified copies of all test records (for In-Kingdom qualification, the independent testing agency that issued the test record shall certify the copies), which may be permanently retained by Saudi Aramco.
  - 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.
  - 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.
  - 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](#)).
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*Commentary Note:*

*The variables of the WPS and PQR should use consistent measurement units system, either metric or customary.*

## 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, including seal welds, shall be qualified in accordance with ASME SEC VIII D2, Article F-3. 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

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

- 7.4.1 For field repair and modification, the following materials shall be considered as P-No. 1 and do not require separate qualifications as "unlisted" materials:
- API 5L Gr. B
  - API 5L Gr. X52
  - A707 L3
  - A707 L5
  - A350 LF6
  - A350 LF787
- 7.4.2 Any GMAW electrode to be used for procedures with impact toughness requirements and 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.
- 7.4.3 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.
- 7.4.4 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.
- 7.4.5 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
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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.

#### 7.4.6 Position

7.4.6.1 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.

7.4.6.2 For automatic, semi-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.

7.4.7 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.

7.4.8 Deletion of a backing strip in a single-sided groove weld shall be considered an essential variable and shall require requalification.

7.4.9 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.

7.4.10 For full penetration, double-sided joints, the WPS shall require backgouging (see 11.3.3) for all processes except for the following:

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- 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 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 will be radiographed. The applications shall be approved by CSD.
- 7.4.11 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.
- 7.4.12 Special requirements for procedures requiring impact testing
- 7.4.12.1 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).
  - 7.4.12.2 The heat input to be recorded on the PQR and used as the limiting value for the WPS shall be based on the average value of welding parameters used at the location where the impact specimens are removed. If the PQR heat input varies by pass or layer, then additional impact specimens, in addition to those locations specified by the relevant Code, may be required in order to utilize the full range of heat inputs used in the PQR.
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- 7.4.12.3 If the PQR thickness exceeds 12 mm and multiple processes or consumables are used, then 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).

*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.

*Exemptions:*

*Hardness testing need only comply with all [SAES-A-301](#) requirements for the following:*

- i) The vessel is made using austenitic stainless steel or nickel-based alloys for all wetted pressure boundary materials.*
  - ii) If all internal surfaces of the vessel are clad or weld overlaid with austenitic stainless steel or nickel-based alloys. Strip lining (partial or complete) or partial cladding or partial overlay are not exempt from hardness testing requirements.*
- c) For vessels in any service if the shell or head wall thickness is greater than 38 mm.
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*Exemptions:*

*Hardness testing is not required if the weld procedure is to be used on external structural attachments only, and the vessel wall at the attachment point is at least 25 mm thick. This exemption applies only if no other hardness testing requirement applies.*

- 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 The hardness testing shall be in accordance with Standard Drawing W-[AB-036386](#). The maximum allowable hardness is VHN 250. Prior hardness test results may be accepted as equivalent to the Standard Drawing only with the approval of CSD and with the following conditions:

- a) Only the Vickers test method (in accordance with ASTM E92) is acceptable, with a maximum test load of 10 kg.
- b) The location of the HAZ indents nearest the fusion line can be demonstrated (by specification or actual measurement) to be within 0.2 mm of the fusion line.

## 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

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coupons shall be of the same material and size and shall be welded with identical parameters. Use of supplementary test coupons for additional tests (e.g., Charpy impact or hardness) to be combined with existing PQRs must 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

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## 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 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](#).
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## 11 Technique and Workmanship

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

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- 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 VIII, the actual diameter of the hole shall be  $\pm 1.6$  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 air-hardenable materials (e.g., Chrome-Moly steels). Additional nondestructive examination may be required on 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,
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production results shall demonstrate that acceptable penetration can be reliably achieved. If periodic lack-of-penetration defects are found, then backgouging will be mandatory for joint geometries other than butt welds and either backgouging or 100% radiography will 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.

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## 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 must 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.
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- 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.
- 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 will 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 For P-No. 5 and higher materials, any back purging shall be maintained until at least 10 mm of the weld deposit thickness has been completed.
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- 11.14.3 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 The back purge for stainless steel and nickel alloys 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). 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.

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## 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:
- 10°C.
  - The required or recommended preheat listed in ASME SEC VIII.
  - For field fabrication or repair of P-No. 1 carbon steel materials, the preheat listed in Standard Drawing W-AE-036451.

*Commentary Note:*

*The listed preheats are minimum requirements. The actual preheat temperature selected and used by the fabricator must 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.
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- 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. 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 For carbon and low alloy steels, the following process conditions require PWHT. Other process conditions may also require PWHT, as determined during the project design. Code exemptions for PWHT are not permitted if PWHT is specified for process conditions.
- 13.3.1 All caustic soda (NaOH) solutions, including conditions where caustic carryover may occur.
- 13.3.2 All monoethanolamine (MEA) solutions (all temperatures).
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- 13.3.3 All diglycol amine (DGA) solutions above 138°C design temperature.
- 13.3.4 All rich amino diisopropanol (ADIP) solutions above 90°C design temperature.
- 13.3.5 All lean ADIP solutions above 60°C design temperature.
- 13.3.6 Boiler deaerator service (i.e., ambient temperature vacuum deaerators are exempt).
- 13.3.7 Hydrogen service for P-No. 3, 4, and 5A/B/C base materials.
- 13.3.8 All diethanolamine (DEA) solutions.

The applicable industry specs must be followed for PWHT requirement for any service not listed above. Other process conditions may also require PWHT, as determined during the project design. Code exemptions for PWHT are not permitted if PWHT is specified for process conditions.

These requirements apply to external welds to attach non-pressure containing component to the piping (e.g., reinforcement pad or sleeve attached to the pipe) and to seal welds. Seal welds on threaded valves may be exempt from the PWHT requirements if the PWHT will damage the valve internals, if they cannot be removed.

- 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 must also be insulated to avoid lowering the temperature on the inside surface of the joint.
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- 13.6 Code exemptions for post weld heat treatment are not permitted for vessels requiring PWHT for service conditions.
- 13.7 Code exemptions for post weld heat treatment of ferritic materials based on the use of austenitic or nickel-based electrodes are not permitted.

*Commentary Note:*

*Austenitic or nickel-based electrodes shall not be used for ferritic materials except dissimilar metal welds listed in 6.4.2 and overlays.*

- 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.
  - c) If hardness limits are specified, the soak time for production welds shall not be less than 80% of the PQR soak time unless approved by CSD.
- 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:
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- 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. 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).

#### 13.14 Localized PWHT

13.14.1 Localized post weld heat treatment of weld joints is not permitted except for:

- 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.

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- 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 (i.e., KX or JX, as appropriate). For Type K thermocouples, copper-
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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.

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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. All welding processes and consumables, including SMAW and GTAW, shall be tested. The testing location and frequency shall be in accordance with NACE RP0472. 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 [SAES-A-301](#) (equivalent hardness conversions shall be in accordance with ASTM E140). Welds for external attachments on vessel shells are exempt from hardness testing.

*Commentary Note:*

*NACE RP0472 exempts welds from hardness testing if they are made with specific processes and consumables, unless otherwise specified by the user. This paragraph imposes the hardness testing for all welds (e.g., including E6010, E7018, and ER70S-2), i.e., it does not permit the exemptions to be used.*

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

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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.

*Commentary Note:*

*Equotip is not accepted for production weld hardness test.*

- 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 will 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 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.
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## 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.
- Commentary Note:*
- Crater cracks do not require special repair and shall be ground out only.*
- 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.
- 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
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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.

## 17 Miscellaneous Requirements

- 17.1 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)
- 17.2 Welding power supplies shall be validated in accordance with BS 7570 or an approved equivalent if impact toughness test is required by the applicable company or industry specifications or codes. The fabricator must 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.
- 17.3 The heat input (HI) of each production weld must be calculated, if notch-toughness tests are specified, and then confirmed not to exceed the heat input limits listed in the welding procedure specifications. The HI formula is:

$$\text{HI (J/cm)} = \text{Voltage X Amperage X 60/Travel Speed (cm/min)} \quad (2)$$

## **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 must 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.

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## **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 must be re-dried. Higher strength electrodes (above E80xx) must 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.

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## **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 must 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.

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**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.
- 3) Some applications may require higher drying temperatures and shorter atmospheric exposure times.
- 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 will be dried, stored and handled in accordance with the manufacturer's recommendations in order to achieve a dissolved hydrogen content of less than 8ml H<sub>2</sub>/100g metal. A written procedure giving the handling requirements will 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.

Issue Date: 14 November 2005

Next Planned Update: 1 December 2010

Welding Requirements for Pressure Vessels

**Attachment A**

**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):

Issue Date: 14 November 2005

Next Planned Update: 1 December 2010

Welding Requirements for Pressure Vessels

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| 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                        |

Issue Date: 14 November 2005

Next Planned Update: 1 December 2010

Welding Requirements for Pressure Vessels

**Attachment B**

**WELD DESCRIPTION**

**SAUDI ARAMCO**

**PRESSURE VESSEL AND HEAT EXCHANGER**

Vendor Name: \_\_\_\_\_

Saudi Aramco Purchase Order No.: \_\_\_\_\_

Equipment Tag No.: \_\_\_\_\_

Vendor Order No: \_\_\_\_\_

**Weld Type**

- |  |  |   |
|--|--|---|
| <input type="checkbox"/> Shell - longitudinal    | <input type="checkbox"/> Nozzle attachment (*) | <input type="checkbox"/> Pipe to fitting  |
| <input type="checkbox"/> Shell - circumferential | <input type="checkbox"/> Skirt to head         | <input type="checkbox"/> Pipe to pipe     |
| <input type="checkbox"/> Shell to head           | <input type="checkbox"/> Tube to tubesheet     | <input type="checkbox"/> Overlay          |
| <input type="checkbox"/> Shell to end Flange     | <input type="checkbox"/> Tubesheet to head     | <input type="checkbox"/> Other (describe) |

\* Nozzle attachment detail

ASME SEC VIII Figure No. \_\_\_\_\_

Detail letter: \_\_\_\_\_

**Material**

ASME/ASTM: \_\_\_\_\_ P-No.: \_\_\_\_\_ Thickness: \_\_\_\_\_

ASME/ASTM: \_\_\_\_\_ P-No.: \_\_\_\_\_ Thickness: \_\_\_\_\_

**Vendor Welding Procedure Specification**

WPS No. \_\_\_\_\_ Rev. \_\_\_\_\_ Date: \_\_\_\_\_

**Weld Type**

- |   |                                 |
|---|---------------------------------|
| <input type="checkbox"/> Welded from both sides | <input type="checkbox"/> Fillet |
|---|---------------------------------|

