



# Engineering Standard

SAES-W-011

12 September 2013

Welding Requirements for On-Plot Piping

Document Responsibility: Welding Standards Committee

## Saudi Aramco DeskTop Standards

### Table of Contents

1	Scope.....	<u>2</u>
2	Conflicts and Deviations.....	<u>2</u>
3	References.....	<u>2</u>
4	General.....	<u>4</u>
5	Approved Welding Processes.....	<u>5</u>
6	Welding Consumables.....	<u>6</u>
7	Welding Procedures.....	<u>9</u>
8	Welder and Welding Operator Qualification..	<u>16</u>
9	Joint Details.....	<u>17</u>
10	Corrosion Resistant Materials.....	<u>17</u>
11	Technique and Workmanship.....	<u>18</u>
12	Preheat.....	<u>23</u>
13	Post Weld Heat Treatment.....	<u>24</u>
14	Production Weld Hardness Testing.....	<u>28</u>
15	Inspection Access.....	<u>29</u>
16	Weld Identification.....	<u>29</u>
17	Inspection.....	<u>30</u>
18	Repairs.....	<u>34</u>
19	Miscellaneous Requirements.....	<u>35</u>
	Attachment 1 – Conditioning, Storage, and Exposure of SMAW Electrodes (Notes 1, 2, 3, 4).....	<u>36</u>
	Attachment 2 – Conditioning, Storage and Exposure of Wires and Fluxes.....	<u>39</u>

## 1 Scope

- 1.1 This standard specifies the welding, heat treatment, Nondestructive Testing (NDT), and hardness testing requirements for shop and field fabrication and installation, repair, or modification of piping to ASME B31.3. These requirements are in addition to the requirements of ASME B31.3 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 Systems 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](#)

*Instructions for Obtaining a Waiver of a Mandatory*

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	<i>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

<a href="#"><u>SAES-A-206</u></a>	<i>Positive Material Identification</i>
<a href="#"><u>SAES-W-014</u></a>	<i>Weld Overlays and Welding of Clad Materials</i>
<a href="#"><u>SAES-W-016</u></a>	<i>Welding of Special Corrosion-Resistant Materials</i>

#### Saudi Aramco Standard Drawings

<a href="#"><u>AB-036386</u></a>	<i>Hardness Testing for Welding Procedure Qualifications</i>
<a href="#"><u>AE-036451</u></a>	<i>Preheat Levels for Welding Carbon Steels</i>

### 3.2 Industry Codes and Standards

#### American Petroleum Institute

<i>API RP 582</i>	<i>Welding Guidelines for the Chemical, Oil and Gas Industries</i>
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#### American Society of Mechanical Engineers

<i>ASME B31.3</i>	<i>Process Piping</i>
<i>ASME SEC IIC</i>	<i>Welding Rods, Electrodes and Filler Metals</i>
<i>ASME SEC V</i>	<i>Nondestructive Examination</i>
<i>ASME SEC VIII</i>	<i>Rules for Construction of Pressure Vessels</i>

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*ASME SEC IX Welding and Brazing Qualifications*

American Society for Testing and Materials

<i>ASTM E92</i>	<i>Vickers Hardness of Metallic Materials</i>
<a href="#"><i>ASTM A707</i></a>	<i>Forged Carbon and Alloy Steel Flanges for Low-Temperature Service</i>
<i>ASTM A833</i>	<i>Indentation Hardness of Metallic Materials by Comparison Hardness Testers</i>

American Welding Society, Inc.

<i>AWS A2.4</i>	<i>Standard Welding Symbols</i>
<i>AWS A3.0</i>	<i>Standard Terms and Definitions</i>
<i>AWS A4.3</i>	<i>Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Weld Metal Produced by Arc Welding</i>
<i>AWS A5.32</i>	<i>Specification for Welding Shielding Gases</i>
<i>AWS D1.1</i>	<i>Structural Welding Code</i>

British Standard Institution

<i>BS 7570</i>	<i>Code of Practice for Validation of Arc Welding Equipment</i>
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National Association of Corrosion Engineers

<i>NACE RP0472</i>	<i>Methods and Controls to Prevent In-Service Cracking of Carbon Steel Welds in P-1 Material in Corrosive Petroleum Refining Environments</i>
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National Association of Corrosion Engineers/International Standardization Organization

<a href="#"><i>NACE MR0175/ISO 15156</i></a>	<i>Petroleum and Natural Gas Industries-Materials for use in H<sub>2</sub>S-Containing Environments in Oil and Gas Production</i>
<i>ISO 17025</i>	<i>General Requirements for the Competence of Testing and Calibration Laboratories</i>

**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 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 for butt welds in piping and set-in fittings less than 25.4 mm nominal pipe size (NPS).
    - 5.2.3 The GTAW process shall be used for the root pass of butt welds without backing in piping and set-in fittings of 50.8 mm nominal pipe size or less, except for vent and drain piping open to the atmosphere or Category D piping.
    - 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 the root pass of single-sided groove welds of P-No. 8 or higher materials 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 GMAW short-circuiting (dip) mode shall not be used except for:
      - a) Structural attachments to the outside surface of the pipe, including seal welds.
      - b) Tacking (including continuous tacks) that will be completely removed by backgouging and backwelding.
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- c) The root pass and hot pass only for butt welds in P-No. 1 carbon steels.
  - d) The modified short circuit mode of GMAW may only be used for root pass welding.
- 5.4.2 GMAW and FCAW shall not be used for single-sided tee or corner joints (i.e., branch or nozzle welds).
- 5.4.3 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 and weld irregular profile is rectified).
  - 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. 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 other (unlisted in 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 All consumables shall be stored and dried in accordance with the requirements of Attachment 1 for SMAW electrodes and Attachment 2 for other consumables.
  - 6.3 GTAW filler metal shall have either the AWS/ASME identification or the
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manufacturer's identification marked on each individual rod by the manufacturer with tags ("flags"), stencil, or stamping.

6.4 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.

6.4.1 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. The root pass of single-sided groove welds without backing in P-No. 1 carbon steels may be made with an Exx10 electrode.

6.4.2 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., pipe supports).
    - ii) Non-sour, non-hydrocarbon (e.g., water) services.
  - d) Nickel-based consumables may not be suitable for direct exposure to sulfur or hydrogen-sulfur reducing
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environments at temperature exceeding 400°C due to possible sulfidation attack.

6.4.3 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.

6.4.4 For welding P-No. 1 carbon steels, the weld deposit shall meet the A-No. 1 analysis classification for normal applications or A-No. 10 for low temperature applications, unless approved by CSD.

6.4.5 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.

## 6.5 Submerged Arc Welding Fluxes

6.5.1 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.

6.5.2 Flux fused during welding shall not be reused (i.e., fluxes that use recrushed slag are not acceptable).

6.5.3 SAW fluxes that the flux manufacturer recommends for single pass welding shall not be used for multiple pass welding.

## 6.6 SMAW electrodes shall be limited as follows:

6.6.1 F-Nos. 1 and 2 electrodes shall not be used on materials requiring impact tests either by Code or job specification.

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



## 6.7 Shielding Gases

Shielding gases shall conform to the following requirements:

6.7.1 AWS A5.32 Specification for Welding Shielding Gases

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

6.8 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 shall include the Welding Procedure Request Form (Attachment A), Welding Procedure Specifications (WPS), Qualification Test Records (PQR), and Weld Maps/Tables (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 structural supports 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 support to the pressure-containing component.

#### *Commentary Notes:*

- 1) *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 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 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.

*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.*

7.1.3 WPS and PQR submitted for approval shall include a Weld and Line Description Table (“Weld Table”). The Weld Table (Attachment B) provides a listing of the materials, thickness, and weld joint types for individual line designations. A welding procedure shall be listed for each different weld type and line designation. All base materials (by specification and grade) and wall thicknesses to be used shall be included in the Weld Table. The Weld Table shall not be reviewed without WPSs and PQRs and vice-versa.

With the approval of CSD, standardized Weld Maps and Weld Descriptions and sets of welding procedures may be submitted by the fabricator for general approval. All of the documentation requirements shall be met except specific line designations are not required (but service descriptions must be included).

7.1.4 Each Weld Table must be complete and show all of the line designations, materials, joints, and welding procedures to be used for the complete job or contract.

7.1.5 Welding shall not commence until the welding package has been approved for application by Saudi Aramco Inspector and returned to the fabricator. Any welding prior to the approval of the welding package is subject to rejection at the sole option of Saudi Aramco Inspector. Any rework required as a result of this rejection shall be at the fabricator's expense.

7.1.6 After approval by Saudi Aramco Inspector, the fabricator shall issue copies of the approved Welding Procedures and Weld Table to the

Saudi Aramco Inspection and PMT 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, and Weld Table 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 The PQRs shall include certified copies/facsimiles 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 and the additional requirements of this standard (see [7.4](#)). 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 For all qualifications:
  - a) The welding of all qualification test coupons shall be monitored by either an independent third party 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 ISO 17025 certified test laboratory

**Note:** *For all PQR testing, the ISO 17025 document shall be submitted along with welding submittal as a mandatory requirement prior review and approval.*

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

- 7.3 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 Procedures for API SPEC 5L Grade B through X52 pipes may be qualified on any grade in this range and shall be considered as P-No. 1 Gr. 1 material. Procedures for API SPEC 5L Grade X60 or higher shall be qualified for each specific material grade. Qualification on API SPEC 5L grade X60 shall also qualify all lower grades.

- 7.4.2 The following materials shall be considered as P-No. 1 and do not require separate qualifications as “unlisted” materials:

A707 L3

A707 L5

A350 LF6

A350 LF787

**Note:** *ASTM A707 L5 flanges require a higher preheat refer to the notes in Tables 3A/B and 4A/B.*

- 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.
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- 7.4.4 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.
- 7.4.5 A change in filler metal or deposit chemistry from A-number 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.
- 7.4.6 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 (0.002 inches). 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.
- 7.4.7 Position
- 7.4.7.1 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 is not qualified in the vertical position, then the direction of welding shall be vertical-up.
- 7.4.7.2 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.
- 7.4.8 Procedures using any consumable with a “G” 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.
- 7.4.9 Deletion of a backing strip in a single-sided groove weld shall be considered an essential variable and shall require requalification.
- 7.4.10 For single-sided groove welds without backing, the process and electrode type used for the root pass shall be considered an essential
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variable. The PQR shall be performed as a single-sided groove weld without backing.

7.4.11 For full penetration, double-sided joints, the WPS shall require backgouging (see [11.3.4](#)) for all processes except for the following:

- a) For automatic or mechanized 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 UT or RT, as appropriate for the joint geometry, and shall be sectioned for examination in at least 3 locations. The NDT 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 weld will be radiographed. The applications shall be approved by CSD.

7.4.12 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.

7.4.13 Special requirements for procedures requiring impact testing:

7.4.13.1 Charpy impact testing shall be required on the PQR if it is required or specified by the design code or the company specifications. The minimum absorbed energy of P-No. 1 Gr.1 materials (including API grades through X52) shall be 34/27 J and for Gr. 2 shall be 40/32 J for full size (10 x 10 mm) specimens for both the weld and heat-affected zone at the minimum design temperature. For other Group Numbers, P-Numbers, and materials, the impact test criteria shall be established by CSD.

*Commentary Note:*

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

7.4.13.2 The heat input shall 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 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.

- 7.4.13.3 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).

## 7.5 Welding Procedure Qualification Hardness Testing

- 7.5.1 For applications where hardness testing is specified (see 7.5.2), the hardness testing shall be in accordance with Standard Drawing [AB-036386](#). 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 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.

- 7.5.2 Hardness testing of the welding procedure qualification is required for hydrogen service, sour service applications (except as listed below), and all services requiring PWHT (see [13.3](#)). The maximum allowable hardness is VHN 250.

For welding procedure qualification of the following materials in sour service hardness testing is only required as specified by [NACE MR0175](#) / [ISO 15156](#):

- a) Austenitic stainless steels
  - b) Nickel-based alloys
  - c) For sour service applications, piping that is completely internally clad with austenitic stainless steel or nickel-based alloys
  - d) Welding procedure to be used on external structural attachments where the pipe wall thickness at the attachment point is at least 25 mm.
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Note the additional PQR requirements listed in 13.8 for PWHT for applications requiring hardness testing.

## 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 tests shall be made using butt-welded pipe samples in either the 5G or 6G position or the position to be used in production.
- 7.6.2 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 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.
- 7.6.3 For groove weld qualifications, the test coupons shall be radiographed and shall meet the acceptance criteria of ASME B31.3 Normal Service.

## 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-321](#), [SAEP-322](#), [SAEP-323](#), and [SAEP-324](#), as applicable, for all welding, including tack, temporary, and repair welds.
- 8.2 The test records of all welders and welding operators shall be available at all times at the work location for review by Saudi Aramco Inspection.  
  
Performance qualification tests shall not be performed on production joints on Saudi Aramco work.
- 8.4 Current production repair 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%:

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



where:

% RR = percent repair rate.

$L_T$  = 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 All nozzles, branch, and tee connections shall be made with full penetration groove welds only.
- 9.3 Internal misalignment of butt joints shall not exceed 1.5 mm. Internal tapering in accordance with ASME B31.3 by machining, backwelding, or a combination may be used to correct the misalignment.
- 9.4 Permanent backing rings or strips shall not be used.
- 9.5 Temporary backup strips in weld joints may be used if 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.
- 9.6 Consumable inserts may be used for all applications providing the composition matches the weld metal composition.
- 9.7 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 review process and the minimum included angle shall be an essential variable.
- 9.8 For nozzles with reinforcing pads, the nozzle attachment weld shall be completed and inspected (see [17.6](#)) prior to installing the reinforcing pad.

## 10 Corrosion Resistant Materials

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 Welding of special corrosion-resistant piping materials shall conform to [SAES-W-016](#).
-

## 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
  - 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 windshields 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 (1 in) 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. All holes cut for set-on nozzles, bosses, or branch connections shall be ground smooth and the diameter of the hole shall be  $\pm 1.6$  mm of the inside diameter of the set-on member.

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 Fittings that are re-cut or re-beveled shall have the cut surface examined for laminations before welding. The NDT method to be used shall be determined by Saudi Aramco Inspection.

11.3.4 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 [7.4.11](#). 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 will be mandatory for joint geometries other than butt welds and either backgouging or 100% radiography will be required for butt welds.

### 11.3.5 Buttering or Weld Build-up on Joints

11.3.5.1 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.
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- b) The buttering shall be inspected by RT, and PT or MT after completion of the build-up but before final welding of the joint.

11.3.5.2 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. The recommended tack thickness is 3.2-4.8 mm and length is 12.5–25.4 mm. The minimum number of tack welds are:
  - a) Pipe diameter of 101.6mm or less: three equally spaced tacks.
  - b) Pipe diameter above 101.6mm: minimum of four equally spaced tacks. The designated inspector should determine if more tacks are needed.
- 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.
  - 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.
  - 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 the 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.
- 11.14.3 The use of nitrogen as a backing gas for austenitic stainless steels is prohibited.
- 11.14.4 The back purge for low alloy steel shall reduce the oxygen level below 1%. The method of back purge and the flow rate shall be specified on the WPS.
- 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 inside the pipe during purging. If more than 20 joints are to be welded at the same time then minimum of 10% of the total joints shall be analyzed. The below formula is used to achieve the required purging time:

$$PT = (V/PGFR) \times 4$$

where:

PT = purging time, hr

V = volume of pipe section to be purged, ft<sup>3</sup>

PGFR = purging gas flow rate, ft<sup>3</sup>/hr

#### 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 Weld Encroachment and Minimum Distance between Welds

The requirements for minimum separation between adjacent welds are listed in 11.16.1 and 11.16.2. The distances shall be measured between the edges of the adjacent cap passes. These restrictions do not apply if one of the welds has been

post weld heat treated prior to making the second weld or both welds have been post weld heat treated and inspected.

11.16.1 The minimum distance between parallel butt welds shall be 20 mm or three times the wall thickness of the joint, whichever is greater.

11.16.2 Pressure containing welds (e.g., nozzles and other attachments) shall be separated from other pressure containing welds by no less than 20 mm or three times the joint thickness, whichever is greater. Radiography of the butt welds is required for situations in which the minimum separation is not achieved. For joints other than butt welds, other appropriate inspection methods shall be used, depending on the geometry and material. The following are exemptions:

11.16.2.1 Structural components and reinforcing pads

11.16.2.2 Hot tap split tee end welds which cross the pipe longitudinal seam.

11.17 Back welding may be used for any joint. Proper cleaning and, if necessary, grinding of the root shall be done prior to backwelding. Unless specified otherwise in the welding procedure, the backwelding shall be done using the same process, consumables, and preheat as used for the fill passes.

11.18 Forced or accelerated cooling of welds is prohibited without the specific approval of CSD.

11.19 Socket Welds

11.19.1 All socket welds shall be at least two pass weld.

11.19.2 If SMAW welding is being utilized the largest size of electrode that is permitted is 3.2 mm diameter.

## 12 Preheat

12.1 Preheat shall be in accordance with the ASME B31.3 and this Standard. For materials not covered by the Code or 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 B31.3.

c) The preheat listed in Standard Drawing W-[AE-036451](#) for carbon steel

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materials (all ASME P-No. 1 materials, including API grades up to and including X60). For normal applications, simplified requirements are listed in Tables 3A and 3B for the SMAW process.

- d) For steels with specified minimum yield strengths above 60 ksi, (including API grades X65 or greater) or for materials not listed as an ASME P-number, the preheat shall be determined by Consulting Services Department and shall be as specified in the approved welding procedure. Special applications may require special weldability tests to evaluate the preheat temperature.

*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 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.
- 12.4 Temperature-indicating crayons, thermocouples, or calibrated contact pyrometers shall be used to measure preheat and interpass temperatures. Temperature-indicating crayons shall not be used for any weld joint that is to be coated or that will have a heat-shrink sleeve installed on it.
- 12.5 The preheat temperature shall be established over a minimum distance of 75 mm on each side of the weld.
- 12.6 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.
- 12.7 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-1, P3, P-4 and P-5 steels.

## 13 Post Weld Heat Treatment

- 13.1 Post weld heat treatments (PWHT) shall be in accordance with ASME B31.3. 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 ([Section 7.1](#)).



- 13.2 Prior to the start of work the contractor or fabricator shall prepare a table listing each joint or component requiring heat treatment, which shall be submitted to Saudi Aramco Inspection for review. The table shall include the following information for each joint or component: location, drawing number, diameter, wall thickness, material, heating rate, cooling rate, soak temperature, and soak time.
- 13.3 For carbon and low alloy steels, the following process conditions require PWHT:
- 13.3.1 All caustic soda (NaOH) solutions, including conditions where caustic carryover may occur (e.g., downstream of caustic injection points).
  - 13.3.2 All monoethanolamine (MEA) solutions (all temperatures).
  - 13.3.3 All diglycol amine (DGA) solutions above 176°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 PWHT heating and cooling rates above 316°C shall not exceed 222°C/hr divided by the weld thickness in inches, but in no case shall it be more than 222°C/hr.
- 13.5 The specified PWHT shall be applied over an area extending at least 3 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.
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13.6 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 ends of open lines shall be closed off in order to eliminate drafts or air circulation that could lower the temperature on the inside surface of the joint unless the internal surface is also insulated.

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 1.5% nominal chromium content.

13.9 For applications where PWHT is required by the service fluid (see [paragraph 13.3](#)) or where hardness limits are specified:

- a) Any reductions in the PWHT temperature or alternative temperatures below the normal holding temperatures listed in ASME B31.3 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:

- a) Permanent or semi-permanent furnaces using gas or oil or electric heaters.
  - b) Electrical resistance heaters.
  - c) Induction heaters.
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13.13 If localized PWHT is used, the following minimum number of equally spaced recording thermocouples (T/C) shall be used:

- a) Pipe diameter of 305 mm or less: 1 T/C.
- b) Pipe diameter above 305 mm up to and including 610 mm: 2 T/C.
- c) Pipe diameter above 610 mm: 4 T/C.

Additional thermocouples are required if multiple heat control zones are used, in which a control zone is not monitored by any of the primary T/Cs.

13.14 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 joint/component being heat treated. Multipoint chart recorders shall clearly differentiate/identify each channel/point by use of different colored inks or automatic number stamping.

13.15 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.

13.16 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-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.

13.16.2 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.

- 13.16.3 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.
- 13.17 Prior to the start of the PWHT, components shall be checked to ensure that all restraints are removed and 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).
- 13.18 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.
- 13.19 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.
- 13.20 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.

## **14 Production Weld Hardness Testing**

- 14.1 Testing shall be in accordance with NACE RP0472 and the requirements listed below. Exemptions with respect to welding process and consumables are not allowed. The testing guidelines in Appendix A of NACE RP0472 shall be mandatory. Readings in the heat-affected zone shall be conducted if specified by the applicable Code or Standard.
- 14.2 Production hardness testing of welds shall be performed as required by ASME B31.3.
- 14.3 Production hardness testing for welds in P-No 1 material in sour or PWHTed service shall also be performed. 10% of the welds shall be sampled. The maximum allowed hardness is 200 BHN.
- 14.4 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.

- 14.5 If any welds are found to be unacceptable, then two additional welds from the same lot shall be tested. If more than one weld in a lot is found to be unacceptable, then all welds in that lot shall be tested.

*Commentary Note:*

*If telebrinell hardness tester can not be applied due to the weld geometry then alternative hardness tester may be used after approval by CSD welding engineer.*

## 15 Inspection Access

- 15.1 Saudi Aramco representatives shall have free access to the work at all times.
- 15.2 Saudi Aramco shall have the right to inspect the fabrication at any state or stage and to reject material or workmanship which does not conform to the specified requirements.
- 15.3 Saudi Aramco reserves the right to inspect, photograph, and/or videotape all material, fabrication, coating, and workmanship and any materials, equipment, or tools used or to be used for any part of the work to be performed. Saudi Aramco may reject the use of any materials, equipment, or tools that do not conform to the specification requirements, jeopardize safety of personnel, or impose hazard of damage to Saudi Aramco property.
- 15.4 All of the rights of Saudi Aramco and their designated representatives for access, documentation, inspection, and rejection shall include any work done by sub-contractors or sub-vendors.
- 15.5 The fabricator shall provide the authorized Saudi Aramco inspector all reasonable facilities to satisfy him that the work is being performed as specified.
- 15.6 The fabricator shall furnish, install, and maintain in a safe operating condition all necessary shoring, scaffolding, ladders, walkways, and lighting for a safe and thorough inspection which is satisfactory to Saudi Aramco Inspection.

## 16 Weld Identification

- 16.1 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.
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- 16.2 The fabricator shall establish and submit for approval an identification system that shall uniquely identify each member and weld joint. The identification system shall be used to identify all examinations, surveys, inspections, etc.

## 17 Inspection

### 17.1 General

- 17.1.1 Nondestructive Examination (NDT) inspection procedures shall be established in accordance with ASME SEC V. A written procedure for each inspection method and technique, including acceptance criteria, to be used shall be submitted to Inspection Department for approval. Qualification of the procedure by the contractor may be required, as determined by Saudi Aramco Inspection. Inspection procedures in conformance with other standards are acceptable only with the approval of Inspection Department.

*Commentary Note:*

*The ASNT term Nondestructive Testing (NDT) has been used in this standard and shall be considered synonymous with the ASME term Nondestructive Examination (NDE).*

- 17.1.2 Written reports and evaluations of all inspections performed by vendors, contractors, and fabricators shall be made and submitted to Saudi Aramco Inspection, at a frequency to be determined by Saudi Aramco Inspection.
- 17.1.3 Additional inspection of any weld joint at any stage of the fabrication may be requested by Saudi Aramco Inspection, including re-inspection of previously inspected joints. Saudi Aramco Inspection also has the right to request or conduct independent NDT of any joint. If such testing should disclose gross non-conformance to the Code requirements, all repair and NDT costs shall be done at the contractor's expense.
- 17.1.4 Inspection at the mill, shop, or fabrication yard shall not release the manufacturer or fabricator from responsibility for repairing or replacing any defective material or workmanship that may be subsequently discovered in the field.
- 17.1.5 All appropriate safety precautions shall be taken for each inspection method.
- 17.1.6 All NDT personnel shall be qualified in accordance with [SAEP-1140](#) or [SAEP-1142](#), as applicable.
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- 17.1.7 Surface irregularities, including weld reinforcement, inhibiting accurate interpretation of the specified method of NDT shall be ground smooth.
- 17.1.8 Inspection of all welds shall include a band of base metal at least 25 mm wide on each side of the weld.
- 17.1.9 For progressive examination requirements, a lot shall be defined as all of the same kind of welds made since the last acceptable weld, excluding “penalty” examinations, for a given welder from any previous production on a specific line classification. The progressive examination shall be limited to the specific welder with the defective welds. The last acceptable weld is defined as a weld that has been examined and accepted by both RT (or UT) and all other specified NDT methods (visual, PT, MT).

The “same kind” of weld is defined as: the same process or combination of processes, same type of joint (groove vs. fillet), and same P-Number. Different diameters and wall thicknesses may be classified within the “same kind” of weld.

Any inspection performed due to progressive examination requirements shall not count toward the required overall examination frequency (percentage).

## 17.2 Radiography

- 17.2.1 ASME SEC V, Article 2 shall be used to determine the minimum number and required locations of radiographs for circumferential joints.
- 17.2.2 Fluorescent intensifying screens shall not be used. Fluoro-metallic screens shall be approved by Saudi Aramco Inspection prior to use.
- 17.2.3 All field radiographic exposures (vendor, shop, and yard radiography are exempt) shall be performed using at least two people: a [SAEP-1140](#) or [SAEP-1142](#) qualified Level II radiographer and an assistant who is qualified to operate all of the equipment.
- 17.2.4 If the joint is required to be radiographed and radiography is not feasible, then UT and MT may be used in lieu of RT. This requires the approval of Saudi Aramco Inspection. This does not apply if radiography is required by ASME B31.3.

## 17.3 Magnetic Particle

- 17.3.1 Permanent magnet yokes are not permitted.
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17.3.2 Prods are not permitted for use on air hardenable materials or on materials with impact testing requirements or on the fluid side surface of components in sour service.

17.3.3 The acceptance criteria for magnetic particle examination shall be ASME SEC VIII, Appendix 6.

#### 17.4 Liquid Penetrant

The acceptance criteria for liquid penetrant examination shall be ASME SEC VIII, Appendix 8.

#### 17.5 NDT Coverage

All welds will be inspected in accordance with ASME B31.3 and with the additions listed below. The listed extent of NDT shall be applied using the following methods:

##### 17.5.1 Visual Examination

17.5.1.1 All welds shall be visually examined. Visual examination shall be performed prior to other NDT.

17.5.1.2 Where accessible, welds shall be visually examined from the root side to ensure that proper penetration and fusion have been achieved.

##### 17.5.2 Radiography

Butt welds in piping shall be radiographed as required in the following subparagraphs. If a weld falls under multiple classifications then the most stringent requirement is applicable. The minimum percent coverage of the specified NDT method may be increased (at any level up to 100%) if, in the opinion of the authorized Saudi Aramco inspector, the welds are of questionable workmanship or if NDT indicates an excessive number of defects. Additional or alternative NDT methods may be used at the discretion of the authorized Saudi Aramco inspector in order to assist in determining the type or extent of defects. Note that for Saudi Aramco projects where less than 100% radiographic coverage is required, random selection of welds shall be based on the weekly weld production.



### 17.5.2.1 Onshore Piping Radiographic Requirements

Service per B31.1	Coverage	Notes
Normal above -18C MDT	10%	1, 2, 3, 4, 5
Normal equal to or below -18C MDT	10% for shop welds 100% for field welds	1, 2, 3, 4, 5
Category D above -18C MDT	None	1, 2, 3, 4, 5
Category D equal to or below -18C MDT	10% for shop welds 100% for field welds	1, 2, 3, 4, 5
Category M	100%	

**Notes:**

1. All stainless steels (except type 304 and 316) and nickel alloys require 100% radiography. Interpretation shall be to "normal" service except there shall be no lack of root penetration or root fusion.
2. All P4, P5 and P6 welds require 100% Radiography
3. Above-ground and below-ground gravity sewers require no radiography
4. Hydrocarbon lines at road crossings (carrier pipe only) requires 100% radiography
5. Piping with severe cyclic service (per ASME B31.3) requires 100% radiography

### 17.5.2.2 Offshore Piping Radiographic Requirements (includes all lines over water, over tidal flats, or within 30 m of the shoreline)

Service per B31.1	Coverage	Notes
Hydrocarbon	100%	
Normal Fluid	100%	
Category D above -18C MDT	10%	1, 2, 3
Category D Equal to or below -18C MDT	100%	
Category M	100%	

**Notes:**

1. All stainless steels (except type 304 and 316) and nickel alloys require 100% radiography. Interpretation shall be to "normal" service except there shall be no lack of root penetration or root fusion.
2. All P4, P5 and P6 welds require 100% Radiography
3. Piping with severe cyclic service (per ASME B31.3) requires 100% radiography

### 17.5.3 Magnetic Particle Testing and Liquid Penetrant Testing

Magnetic particle testing (MT) for ferromagnetic materials.

Liquid penetrant testing (PT) for non-ferromagnetic materials.

- 17.5.3.1 All pressure containing welds, other than butt welds, (including branch connections such as weldolets, sockolets, and welding bosses) shall be 100% examined.
- 17.5.3.2 All attachment welds on pressurized components that are not hydrotested after making the attachment weld shall be 100% examined.

#### 17.6 Positive Material Identification (PMI)

PMI shall be conducted for the materials listed in Table 1 of [SAES-A-206](#).

## 18 Repairs

18.1 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.

18.2 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.*

18.3 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 18.2).

18.4 The repair procedure may utilize a welding procedure previously approved by CSD in conjunction with a separate method statement or it may be a separate detailed welding procedure.

18.5 All repaired welds shall be inspected using the original testing method. Additional test methods may also be required, if deemed necessary by the authorized Saudi Aramco inspector. Replacement weld (cut-out) shall be examined as a repair.

- 18.6 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 to be submitted to Saudi Aramco Inspection and if necessary forwarded to CSD for review and approval prior to undertaking the repairs.
- 18.7 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.

## 19 Miscellaneous Requirements

- 19.1 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., on an elevated pipe rack).
- 19.2 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.
- 19.3 Welding on offshore platform piping from workboats requires proper grounding to prevent stray current corrosion during welding. The welding ground connections shall comply with API RP2A-WSD, paragraph 12.7.
- 19.4 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:

$$HI (J/cm) = Voltage \times Amperage \times 60 / \text{Travel Speed (cm/min)} \quad (1)$$

### Revision Summary

30 March 2005	Major revision.
4 October 2009	Revised the “Next Planned Update.” Editorial revision to add paragraph 5.4.1(d). Deleted paragraph 5.4.4. Replaced cancelled SAES-A-301 with <a href="#">NACE MR0175/ISO 15156</a> .
12 September 2013	Editorial revision clarifying paragraph 6.8 pertaining to nickel requirements and to be aligned with SAES-W-012 new requirements.

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## **Attachment 1 – Conditioning, Storage and Exposure of SMAW Electrodes (Notes 1, 2, 3, 4)**

### **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.

### **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.

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### **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. 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.

## **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.

#### **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 70 Ksi

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 70 Ksi

Fluxes will be dried, stored and handled in accordance with the manufacturers' 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.

Table 3A - Preheat Temperatures for Vertical-Up SMAW Butt Welds  
 (Notes 1, 2)  
 (SI Units)

Carbon Equivalent (Note 3)

Wall Thickness Range (4)	0.40	0.42	0.46	0.48	0.50	Pipe	Wall Thickness Range (4)
< 9.5 mm	10°C	10°C	10°C	10°C	10°C	10°C	< 9.5 mm
9.6 - 12.7	10°C	10°C	10°C	38°C	66°C	10°C	9.6 - 12.7
12.8 - 15.9	10°C	10°C	52°C	79°C	93°C	10°C	12.8 - 15.9
16.0 - 19.0	10°C	24°C	93°C	107°C	121°C	10°C	16.0 - 19.0
19.1 - 22.2	24°C	66°C	107°C	121°C	135°C	10°C	19.1 - 22.2
22.3 - 25.4	66°C	93°C	135°C	149°C	163°C	10°C	22.3 - 25.4
25.5 - 31.8	93°C	121°C	149°C	163°C	177°C	79°C	25.5 - 31.8
31.9 - 38.1	121°C	135°C	163°C	177°C	191°C	93°C	31.9 - 38.1
38.2 - 44.5	135°C	149°C	177°C	191°C	191°C	93°C	38.2 - 44.5
44.6 - 50.8	149°C	163°C	191°C	204°C	204°C	135°C	44.6 - 50.8

Table 3B - Preheat Temperatures for Vertical-Up SMAW Butt Welds  
 (Notes 1, 2)  
 (Conventional Units)

Carbon Equivalent (Note 3)

Wall Thickness Range (4)	0.40	0.42	0.46	0.48	0.50	Pipe	Wall Thickness Range (4)
< 0.375 inch	50°F	50°F	50°F	50°F	50°F	50°F	< 0.375 inch
0.376 - 0.500	50°F	50°F	50°F	100°F	150°F	50°F	0.376 - 0.500
0.501 - 0.625	50°F	50°F	125°F	175°F	200°F	50°F	0.501 - 0.625
0.626 - 0.750	50°F	75°F	200°F	225°F	250°F	50°F	0.626 - 0.750
0.751 - 0.875	75°F	150°F	225°F	250°F	275°F	50°F	0.751 - 0.875
0.876 - 1.000	150°F	200°F	275°F	300°F	325°F	50°F	0.876 - 1.000
1.001 - 1.250	200°F	250°F	300°F	325°F	350°F	175°F	1.001 - 1.250
1.251 - 1.500	250°F	275°F	325°F	350°F	375°F	200°F	1.251 - 1.500
1.501 - 1.750	275°F	300°F	350°F	375°F	375°F	200°F	1.501 - 1.750
1.756 - 2.000	300°F	325°F	375°F	400°F	400°F	275°F	1.756 - 2.000




**Notes to Tables 3A and 3B:**

- 1) This table assumes a minimum heat input of 1.2 kJ/mm (30 kJ/inch) and is valid only for:
  - a) All positions except vertical-down.
  - b) E6010 or E7010 root pass and E7018 or E8018-C3/C3 fill and cap electrodes, 3.2 mm minimum diameter.
  - c) Carbon steel materials up through Grade X60.
- 2) Except for split tee longitudinal welds, other hot-taps installation welds are exempt from these requirements.
- 3)  $CE = C + (Mn/6) + (Cr+Mo+V)/5 + (Ni+Cu)/15$ 

General instructions for selecting the CE value if the actual value (by Mill Test Report or if the CE value is marked on the fitting) is not known:

  - a) For pipe to 01-SAMSS-035/332/333, use the column labeled "PIPE" (valid only for pipe-to-pipe joints; for pipe-to-fitting joints, use the fitting CE).
  - b) For pipe to 01-SAMSS-038, use CE = 0.42.
  - c) For flanges, assume CE = 0.46.
  - d) For fittings (other than flanges):
    - i) If unknown vintage, assume CE = 0.50
    - ii) If prior to 02-SAMSS-005 (August, 1988), assume CE = 0.46
    - iii) If to 02-SAMSS-005 (August, 1988), assume CE = 0.50
    - iv) If to 02-SAMSS-005 (May, 1993), assume CE = 0.42
- 4) General instruction for selecting the Wall Thickness value:
  - a) For pipe-to-pipe joints, use the actual wall thickness.
  - b) For pipe-to-fitting or fitting-to-fitting:
    - i) For fittings (other than flanges), use the next higher wall thickness range greater than the nominal wall thickness.
    - ii) For flanges, use the thickness corresponding to two higher wall thickness ranges greater than the nominal wall thickness.
    - iii) For fitting to fitting joints (including flanges), use the sum of the number of increased ranges for each member (i.e., 1 range for fittings, 2 ranges for flanges). Example, a flange to elbow fitting would use three ranges higher than the nominal wall thickness.

**SAES-W-011/012**  
**Attachment A**

<b>REQUEST FOR WELDING PROCEDURE APPROVAL</b>		 <b>أرامكو السعودية</b> <b>Saudi Aramco</b>
<b>It is requested that the following Welding Procedure Specification (WPS) be reviewed and approved. The listed WPS has been qualification tested in accordance with SAES-W-010/SAES-W-012. It has been edited for clerical completeness and technical content.</b>		
Company	Project	J.O./BI/PO/CONTRACT #
WELDING PROCEDURE SPEC. NO.		PROCEDURE QUALIFICATION RECORD (PQR) #
CODE / SPEC B31.3 B31.4 B31.8	DESIGN CONDITIONS: MAX. TEMP. _____ SERVICE FLUID _____ MIN. TEMP. _____ SOUR SERVICE ? YES NO CVN IMPACTS REQUIRED? YES NO HARDNESS TESTS? YES NO	
QUALIFICATION ASME SEC IX API STD 1104 AWS D1.1 OTHER: _____	SAMSS (Where Applicable)	LINE CLASS(es)
<b>Submitting Saudi Aramco Organization</b>		
		Date _____
Name: _____		Department: _____
Signature: _____		Address: _____
Telephone: _____		_____
FAX: _____		_____
<b>Inspection Department Approval</b>		
Name _____		Unit/Div/Dept: _____
Signature _____		Date: _____

**SAUDI ARAMCO  
WELD AND LINE DESCRIPTION TABLE**

SAES-W-011/012 ATTACHMENT B	Piping Class or Designation or Service Description		Weld joint type			Material (P-No. or Grade)	Pipe Size Range	Wall Thickness Range	Service Requirements (check if yes)			Welding Procedure	Remarks
			Butt Weld	Branch connection	Filler				Hardness	Charpy Impact	PWHT		
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
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