



Engineering Standard

SAES-W-017

13 December 2011

Welding Requirements for API Tanks

Document Responsibility: Welding Standards Committee

Saudi Aramco DeskTop Standards

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Previous Issue: 4 October 2009 Next Planned Update: 13 December 2016

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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 tanks designed and built to API STD 650 and API STD 620 and repaired to API STD 653. These requirements are in addition to the requirements of the API Codes and ASME SEC IX.

Commentary Note:

For materials other than P-No. 1 or P-No. 8 and for API STD 620 App. Q tanks, the application shall be reviewed by Consulting Services Department to determine if additional requirements need to be specified.

- 1.2 Additional requirements may be contained in Scopes of Work, Drawings, or other Instructions or Specifications pertaining to specific items of work.
- 1.3 Any reference to Consulting Services Department (CSD) shall be interpreted as the CSD Welding Specialist or a representative designated by CSD. Any reference to “approval” shall be interpreted as written approval.
- 1.4 This entire standard may be attached to and made a part of purchase orders.
- 1.5 This standard is generally not applied retroactively to the maintenance and repair of existing facilities unless there are safety, environmental protection, health or security concerns.

2 Conflicts and Deviations

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

3 References

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

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedures

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

Saudi Aramco Standard Drawings

<u>AB-036386</u>	<i>Hardness Testing for Welding Procedure Qualifications</i>
<u>AE-036451</u>	<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>
<i>API STD 620</i>	<i>Design and Construction of Large, Welded, Low-Pressure Storage Tanks</i>
<i>API STD 650</i>	<i>Welded Steel Tanks for Oil Storage</i>
<i>API STD 653</i>	<i>Tank Inspection, Repair, Alteration, and Reconstruction</i>

American Society of Mechanical Engineers

<i>ASME SEC IIC</i>	<i>Welding Rods, Electrodes and Filler Metals</i>
<i>ASME SEC V</i>	<i>Nondestructive Examination</i>

ASME SEC VIII D1 Rules for Construction of Pressure Vessels

ASME SEC IX Welding and Brazing Qualifications

American Society for Testing and Materials

*ASTM A 833 Practice For Indentation Hardness of Metallic
Materials By Comparison Hardness Testers*

*ASTM E 384 Test Method for Knoop and Vickers Hardness of
Materials*

*ASTM E 140 Hardness Conversion Tables For Metals
Relationship among Brinell Hardness, Vickers
Hardness, Rockwell Hardness, Superficial
Hardness, Knoop Hardness, and Scleroscope
Hardness*

American Welding Society, Inc.

*AWS A2.4 Standard Symbols for Welding, Brazing, and
Nondestructive Examination*

*AWS A3.0M/A3.0 Standard Welding Terms and Definitions
Including Terms for Adhesive Bonding,
Brazing, Soldering, Thermal Cutting, and
Thermal Spraying*

*AWS A4.2M/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 Determination of the Diffusible Hydrogen Content
of Martensitic, Bainitic, and Ferritic Steel Weld
Metal Produced by Arc Welding*

*AWS A5.01M/A5.01 Procurement Guidelines for Consumables -
Welding and Allied Processes - Flux and Gas
Shielded Electrical Welding Processes*

*AWS A5.32/A5.32M Welding Consumables - Gases and Gas Mixtures
for Fusion Welding and Allied Processes*

AWS D1.1/D1.1M Structural Welding Code-Steel

National Association of Corrosion Engineers

*NACE SP0472 Methods and Controls to Prevent In-Service
Environmental Cracking of Carbon Steel*

*Weldments in Corrosive Petroleum Refining
Environments*

British Standards Institution

BS 7570

*Code of Practice for Validation of Arc Welding
Equipment*

National Association of Corrosion Engineers/International Standardization
Organization

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

4 General

- 4.1 AWS A2.4 “Standard Symbols for Welding, Brazing, and Nondestructive Examination” shall be used for all welding details on all drawings. Alternatively, pictorials of joints indicating all relevant dimensions may be used if approved by CSD.
- 4.2 AWS A3.0M/A3.0 “Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying” 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 Autogenous GTAW is not accepted (filler metal shall be added).
 - 5.2.2 For tanks with shells, bottoms, and/or shell nozzles or manways made of P-No. 8 material, all manual GTAW shall use a high frequency or Lift-Arc start and post-purge gas flow for the torch.

Commentary Note:

This does not apply for P-No. 8 materials used for internal piping or

heater coils on tanks made from P-No. 1 materials.

- 5.2.3 The GTAW process shall be used for all passes for butt welds in nozzles less than 25.4 mm nominal diameter.
 - 5.2.4 The GTAW process shall be used for the root pass of butt welds without backing in nozzles of size NPS 50.8 mm or less.
 - 5.2.5 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.
 - 5.3 Submerged Arc Welding (SAW)
 - 5.4 Gas Metal Arc Welding (GMAW)
 - 5.4.1 The short-circuiting (dip) mode shall not be used except for:
 - a) Structural attachments to the outside surface of the tank shell, including seal welds.
 - b) Tacking (including continuous tacks) that will be completely removed.
 - 5.4.2 The modified short circuit mode of GMAW may only be used for root pass welding.
 - 5.5 Flux-Cored Arc Welding (FCAW)
 - 5.5.1 The FCAW process shall not be used for the root pass on full penetration, groove joints without backing (or back welding) that are welded from one side only (backing may be used if it is removed after welding).
 - 5.5.2 Self-shielded FCAW is only permitted if approved by CSD. Supplementary testing may be required by CSD.
 - 5.6 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 directly on the tank shell. Thermit welding shall not be used on stainless steel materials.
 - 5.6 Stud Welding is permitted for attaching insulation fasteners.
 - 5.7 Electrogas (EG, but formally listed by AWS as GMAW-EG or FCAW-EG) and Electroslag (ESW) may be used only with the approval of CSD and, depending upon the application, may require testing in addition to that specified by the Code.
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6 Welding Consumables

- 6.1 Electrodes, filler wires, and fluxes shall conform to ASME SEC IIC or any other International equivalent specifications (e.g., BSI, JIS, DIN, etc.) accepted by the Committee Chairman. Approval to use consumables unlisted in ASME SEC IIC or equivalent specifications 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 I](#) for SMAW electrodes, [Attachment II](#) for SAW fluxes and [Attachment III](#) for wires. Alternative storage and exposure conditions may be approved by CSD with the following conditions:
- a) The fabricator shall have a written procedure for storage and control of welding consumables.
 - b) Any deviations from Attachments [I](#), [II](#) or [III](#) shall be established by tests for each consumable brand, type, and designation.
 - c) The tests shall consist of coating moisture determination and absorbed moisture tests in accordance with the electrode specification and weld metal diffusible hydrogen tests in accordance with AWS A4.3. The tests must be conducted for (but not necessarily by) the fabricator using representative samples. Generic tests by the electrode manufacturer are not sufficient.
- 6.3 GTAW filler metal shall be clearly identified for each individual length. This shall be either the AWS/ASME identification or the manufacturer's identification marked on each individual rod by the manufacturer with tags ("flags"), stencil, or stamping.
- 6.4 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 **AWS A5.01M/A5.01** 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:

6.4.2.1 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

6.4.2.2 Use of stainless steel or nickel-based filler metals on ferritic steels.

DMW 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 and non-hydrocarbon services (e.g., potable water, steam, air, etc.).
- d) Nickel-based consumables may not be suitable for direct exposure to sulfur or hydrogen-sulphur reducing environments at temperature exceeding 400°C due to possible sulfidation attack.

6.4.3 Other than the DMWs listed in paragraph 6.4.1, 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.
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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-No. 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, except for 2-pass lap fillet welds of bottom plates.

6.6 SMAW electrodes shall be limited as follows:

6.6.1 F-Nos. 2 and 3 electrodes shall not be used on base materials requiring impact tests either by Code or job specification.

6.6.2 F-Nos. 1 and 2 electrodes shall not be used for shell welds (excluding the shell-to-bottom weld) or nozzle-to-shell welds.

Commentary Note:

Structural attachments to the shell, such as wind girders or reinforcing pads, are exempt from this requirement.

6.7 Shielding Gases

Shielding gases shall conform to the following requirements:

6.7.1 AWS A5.32/A5.32M Specification for Welding Shielding Gases.

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

7 Welding Procedures Qualifications

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 Maps ([Attachment IV](#)) and Weld description sheets ([Attachment V](#)).

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 structures 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 tank shell, bottom or roof.

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 21 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 in the form of a Company Stamp with Printed Name, Signature of Approver, date, etc.*

- 7.1.2 A Weld Map (with WPS summary table indicated on the weld map or in separate sheet) shall be submitted along with the Welding Procedure Specification (WPS) and Procedure Qualification Record (PQR) documents for each piece of equipment (identical equipment can use

one combined submittal). The Weld Map shall be used to provide a simple single-line sketch of the tank. All weld joints shall be identified on the Weld Map and described in the summary table. All base materials (by specification and grade) and wall thicknesses to be used shall be listed in the summary table. The typical joint design details to be used for all production welding shall be shown on each WPS or on other referenced drawings or Weld Description forms ([Attachment V](#)), which shall be included with the WPS submissions. The Weld Map shall be submitted along with WPSs and PQRs. The Weld Map alone shall not be reviewed without WPSs and PQRs or vice-versa.

With the approval of CSD, a “standardized” set of Weld Maps and welding procedures may be submitted by the fabricator for general approval. All of the documentation requirements, except identification of specific tank numbers, shall be met.

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

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 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.
- 7.1.6 After approval by Saudi Aramco, the fabricator shall make available copies of the approved Weld Maps and WPSs to the Saudi Aramco Inspector at the fabrication site 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.

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- 7.1.8 All Welding Procedure Specifications and Welding Procedure Qualification Records shall be written in English.
- 7.1.9 The PQRs shall include the originals, colored copy of the originals or certified xerox copies (stamped by the testing laboratory) 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.
- 7.1.10 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 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 unless otherwise approved by CSD. Approval for use of welding procedures qualified Out-of-Kingdom shall be obtained prior to the qualification (see [SAEP-352](#)).
- 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
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Aramco Inspection. The monitoring shall include verification of the accuracy of the recorded parameters.

Commentary Note:

CSD welding engineer must be consulted if the contractor is using any proprietary welding system or some special welding process not listed in Section 5.

- 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.

7.2.7 Special requirements may be stated in the job specifications or purchase order, contract specifications, etc., that may specify special qualification tests, such as stress corrosion cracking or embrittlement tests for low alloy steels. Some of those services that may require the special tests are severe corrosion services (e.g., chlorinated seawater) or high temperature service. The committee chairman must be consulted to specify the required tests.

7.3 Procedure Variables

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

7.3.1 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.

7.3.2 A change in filler metal or deposit chemistry from A-No. 1 (based on ASME SEC IX) to A-No. 2 and vice-versa is not permitted without approval. The approval shall be obtained through the welding procedure review process. A change from A-No. 1 to A-No. 2 is not permitted for sour service applications without requalification.

7.3.3 For ASME P-no. 1 materials, all Group 3 or 4 materials shall be qualified separately for each specific material, unless it is being used in

combination with a Group 1 or 2 material and the Group 1 or 2 material strength requirements govern.

7.3.4 Weldable primers may be used only after evaluation and approval by CSD welding engineer. This requires the qualification to be conducted with the primer applied (additional procedure qualification and/or weldability tests may be required). The welding procedure specification shall indicate the use of the primer type and brand. The maximum primer thickness shall also be specified.

7.3.5 Position

7.3.5.1 The direction of welding for the vertical position shall be an essential variable (i.e., a change from vertical-up to vertical-down or vice-versa shall be considered an essential variable) except for the following cases:

Exceptions:

- a) *Root passes that are subsequently backgouged.*
- b) *Root and cover passes if there are no hardness limits specified.*

7.3.5.2 For automatic, semi-automatic, or mechanized welding, any change in position according to ASME SEC IX, QW-461.9 shall be considered an essential variable.

7.3.6 Procedures using any consumable with a “G” or “P1” 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.

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

7.3.8 For single-sided groove welds without backing, the process and electrode type used for the root pass shall be considered an essential variable. The PQR shall be performed as a single-sided groove weld without backing.

7.3.9 For full penetration, double-sided joints, the WPS shall require backgouging (see 10.3.3), except for the EG or automatic SAW processes within the following limitations:

- a) For production joint geometries substantially different from the original PQR, supplementary test coupons shall be prepared using the same type of production equipment and joint geometry.
- b) 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.

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

7.3.11 Special requirements for procedures requiring impact testing.

7.3.11.1 The heat input to be recorded on the PQR and used as the limiting value for the WPS shall be based on the 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.

7.3.11.2 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).

7.4 Welding Procedure Qualification Hardness Testing

7.4.1 For applications where hardness testing is specified (see 7.4.2), the hardness testing shall be in accordance with Standard Drawing [AB-036386 \(Attachment VI\)](#). 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.

7.4.2 Hardness testing is required for all PQRs for:

- a) Sour service tanks of any wall thickness.
- b) For tanks requiring PWHT due to service (see 12.5).

Hardness testing is not required for sour service applications (item a above) if the weld procedure is to be used on external structural attachments only, and the tank wall at the attachment point is at least 25 mm thick.

7.5 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:

- 7.5.1 The qualification test shall include all of the required tests on the same coupon unless size limitations restrict the number and type of specimens that can be reasonably removed from a single coupon. If multiple coupons are required and approved by CSD, each of the coupons shall be of the same material and size and shall be welded with identical parameters. Use of supplementary test coupons for additional 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.
- 7.5.2 For groove welds, the test coupons shall be radiographed and shall meet the acceptance criteria of ASME SEC VIII, UW-51.
- 7.5.3 The procedure qualification test weld shall meet all the requirements imposed on production welds.

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-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 for manual and semi-automatic welding processes.
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For mechanized and automatic welding systems that cannot be run on test specimens, performance qualification tests may be done on production joints with the approval of Inspection Department.

- 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%:

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

Where:

% RR = percent repair rate

L_r = welder's total length of repairs in one week, mm

L_w = welder's total length of weld radiographed in one week, mm

9 Joint Details

- 9.1 All shell, shell-to-bottom, and shell-to-nozzle welds shall be made with multiple passes except for the EG or ES processes when the component thickness is less than 37 mm.
- 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 Inspector for approval.
- 9.3 Permanent backing rings or strips shall not be used, except for butt welds in annular rings or bottom plates.
- 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 set-on nozzles with reinforcing pads (when permitted), the set-on nozzle attachment weld shall be completed and inspected, as required, prior to installing the reinforcing pad.
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10 Technique and Workmanship

10.1 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)
 - 6.5 mm for 1F/2F lap fillet welds.
 - 5 mm for all other 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.

10.2 Welding Environment

10.2.1 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 Inspector. The wind velocity in the weld area shall not exceed 8 kph (2.2 m/s). The wind velocity must be measured at the project site by wind speed meter.

10.2.2 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.

10.2.3 Contamination from the environment, such as wind-blown sand, shall be prevented by the use of adequate shielding.

10.3 Joint Preparation

10.3.1 Oil, moisture, rust, scale, sand, paint (except weldable primers for approved applications - refer to paragraph 7.3.4 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.

10.3.2 Flame cutting and arc-air gouging

10.3.2.1 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 specified otherwise in API, the actual diameter of the hole shall be ± 1.6 mm of the nominal specified diameter.

10.3.2.2 Thermally cut or gouged surfaces for all materials, including carbon steels, shall be power brushed or ground prior to welding.

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

10.3.3 All full penetration joints requiring double sided welding shall be ground or gouged to sound metal and inspected by PT or MT prior to welding the reverse side. The EG, ES, and automatic SAW process are exempt from this requirement if procedure qualification (see 7.3.9) and production results demonstrate that acceptable penetration can be reliably achieved.

10.3.4 Buttering or weld build-up on joints

10.3.4.1 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 penetrant testing (PT) or magnetic particle testing (MT) after completion of the build-up but before final welding of the joint.

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

10.4 Cleaning

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

- 10.4.2 All slag, flux, and spatter shall be removed from the completed weld and surrounding areas.
 - 10.4.3 Stainless steel and nonferrous materials shall be cleaned with grinding wheels or stainless steel brushes not previously used on other materials.
 - 10.5 Tack welds
 - 10.5.1 All tack welds shall be made by qualified welders.
 - 10.5.2 All tacks or temporary welds shall be performed with the same care, materials, electrodes, minimum preheat, and procedures that are used for permanent welds.
 - 10.5.3 Tack welds shall be of sufficient size to maintain joint alignment. The recommended tack thickness is 3.2-4.8mm and length is 12.-25.4 mm. The minimum number of tack welds are:
 - a) diameter equal to or less than of 101.6 mm: three equally spaced tacks
 - b) diameter above 101.6 mm: minimum of four equally spaced tacks. The designated inspector should determine if more tacks are needed.
 - 10.5.4 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.
 - 10.5.5 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.
 - 10.5.6 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.
 - 10.6 Arc strikes, gouges, and other indications of careless workmanship (such as surface porosity, uneven weld profiles, and undercut) shall be removed by grinding.
 - 10.7 Temporary welded attachments or temporary tack welds shall be removed by a method that will not cause tearing or bending of the base metal.
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- 10.8 If any grinding reduces the base metal thickness 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.
- 10.9 If the component thickness exceeds 20 mm or the specified material yield strength exceeds 290 MPa, inspection by magnetic particle or liquid penetrant methods of areas shall be performed where temporary welds have been removed (see 10.7) or weld repairs to ground areas of the base material have been made (see 10.8) or arc strikes after repair by grinding (see 10.6).
- 10.10 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.
- 10.11 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.
- 10.12 Peening
- 10.12.1 Peening shall not be permitted unless approved by CSD and specified in the approved welding procedure. Cleaning of slag is not considered peening.
- 10.12.2 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.
- 10.13 Adjacent beads of a weld shall be staggered and not started in the same location.
- 10.14 Back Purging
- 10.14.1 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.
- 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.*
- 10.14.2 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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10.14.3 The back purge for stainless steel and nickel alloys shall reduce the oxygen level below 0.05%. An oxygen analyzer must be used to determine the oxygen content in the back side pipe during purging. It is the inspector responsibility to determine the analyses frequency.

10.14.4 The use of nitrogen as a backing gas for austenitic stainless steels is prohibited.

10.14.5 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, ft³

PGFR = purging gas flow rate, ft³/hr

10.15 Seal welding

10.15.1 All threaded joints and faying surfaces, except those specifically designed and designated as removable bolted connections and the exceptions listed below, shall be seal welded by a continuous fillet weld (required external weep holes shall be left unwelded). The following exceptions do not require seal welding unless specifically required by other standards or specifications:

Exceptions:

- a) *The underside of lap-welded roof plates.*
- b) *The underside of lap-welded bottom plates.*
- c) *The underside of backing strips used for butt-welded bottom and annular plates.*

10.15.2 Sealing compounds or tapes shall not be used on joints that are to be seal welded.

10.15.3 Seal welding of threaded connections shall cover all exposed threads and shall have a smooth contour between the two surfaces.

10.16 Details regarding the method and sequence for erecting the shell plates and the sequence for welding the bottom plates shall be submitted to the assigned inspector for review.

11 Preheat

- 11.1 Preheat shall be in accordance with API and this Standard. For materials not covered in this Standard, the preheat and post weld heat treatment shall be as specified in the approved welding procedure.
- 11.2 The minimum preheat shall not be less than the greater of the following:
- 10°C.
 - The required or recommended preheat listed in the applicable API standard.
 - For field repair of P-No. 1 carbon steel materials, the preheat listed in Standard Drawing [AE-036451](#) ([Attachment VII](#)).
- 11.3 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.

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.

- 11.4 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.
- 11.5 Temperature-indicating crayons, thermocouples, or calibrated contact pyrometers shall be used to measure preheat and interpass temperatures.
- 11.6 The preheat temperature shall be established over a minimum distance of 75 mm on each side of the weld.
- 11.7 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.
- 11.8 Unless specified otherwise, the maximum interpass temperature shall be 177°C for P-Numbers 8, 3X and 4X materials and 315°C for P-Numbers 1, 3, 4 and 5 steels.

12 Post Weld Heat Treatment

- 12.1 Post weld heat treatments (PWHT) shall be in accordance with ASME SEC VIII Division 1. A written procedure describing the general PWHT requirements shall be submitted for review and approval. The PWHT procedure shall include
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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).

12.2 Prior to the start of work the contractor or fabricator shall prepare a data sheet for each tank (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 and nozzles), material, heating rate, cooling rate, soak temperature, and soak time.

12.3 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 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.

12.4 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.

- 12.5 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.

- 12.6 For applications where PWHT is required by the service fluid (as defined by 12.3, engineering requirements or as specified in the relevant SAMSS) 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.

- 12.7 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.

- 12.8 Welding or heating after the final PWHT is not permitted if the tank is PWHTed for service.

- 12.9 PWHT shall be carried out using one or more of the following types of heat sources:

- a) Permanent or semi-permanent furnaces using gas or oil or electric heaters (a tank itself may be considered a furnace if heated internally and externally insulated).
- b) Electrical resistance heaters.
- c) Induction heaters.

- 12.10 For tanks completely PWHTed in a furnace, the thermocouple locations shall be attached to the inside of the tank, if possible. For tanks PWHTed from the inside, the thermocouple locations shall be attached to the outside of the tank. If thermocouples are placed on the same side as the heating source, the thermocouples shall be covered with an insulation patch. The locations of the thermocouples shall include:

- a) The thinnest major component.

- b) The thickest member.
- c) The top of the tank (as oriented during PWHT).
- d) The bottom of the tank (as oriented during PWHT).

12.11 Localized PWHT

- 12.11.1 Localized post weld heat treatment of weld joints is not permitted except butt welds in nozzles and associated piping or, when approved by CSD, for maintenance repairs.

Commentary Note:

This restriction on localized PWHT is not intended to prohibit the PWHT of nozzle assemblies prior to their installation into the tank.

- 12.11.2 If localized PWHT of the tank 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 tank 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.

- 12.11.3 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.

- 12.12 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 tank (or joint/component for localized PWHT) being heat treated.

- 12.13 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.

12.14 Thermocouples

- 12.14.1 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 of the junction between the compensating cable and the thermocouple lead is from 0 to + 80°C.

12.14.2 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.

12.14.3 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.

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

12.16 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.

12.17 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.

12.18 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. Openings shall be restricted 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.

- 12.19 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 Production Weld Hardness Testing

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

- a) For all materials in sour service.
- b) For tanks PWHTed for service.

The testing shall be in accordance with NACE RP0472 and the requirements listed below. All welds, for all welding processes and consumables, 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 [NACE MR 0175 ISO 15156](#) Petroleum and Natural Gas Industries-Materials for use in H₂S-Containing Environments in Oil and Gas Production (equivalent hardness conversions shall be in accordance with ASTM E140). Welds for external attachments on tank shells are exempt from hardness testing.

Commentary Note:

NACE RP 0472 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.

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

Commentary Note:

Equotip is not accepted for production weld hardness test.

- 13.3 The weld reinforcement shall be ground to provide a smooth flat surface for testing.
- 13.4 Hardness indentations shall be made at or near the middle of the deposited weld bead.

- 13.5 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 Inspection Access

- 14.1 Saudi Aramco representatives shall have free access to the work at all times.
- 14.2 Saudi Aramco shall have the right to inspect the fabrication at any state and to reject material or workmanship which does not conform to the specified requirements.
- 14.3 Saudi Aramco reserves the right to inspect 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. Saudi Aramco reserves the right to photograph and/or videotape all materials and fabricated components that will be delivered to Saudi Aramco.
- 14.4 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.
- 14.5 The fabricator shall provide the authorized Saudi Aramco inspector all reasonable facilities to satisfy him that the work is being performed as specified.
- 14.6 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.

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 member and weld joint. The identification system shall be used to identify all examinations, surveys, inspections, etc.
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- 15.3 Fabricator shall provide NDT weld map to represent all weld joints in their respective position or location. The weld map shall be as-built to show exact location of welds that were NDE Tested. This shall include fabricated sub-assemblies that will be welded on site. The Weld map shall be presented to Projects Inspection for tracking purposes during fabrication/construction and will form a mandatory QA/QC document that will be submitted upon completion.

16 Inspection

16.1 General

- 16.1.1 Nondestructive Testing (NDT) procedures shall be established. A written NDT procedure for each NDT method and technique to be employed, including acceptance criteria, shall be submitted for approval by the Saudi Aramco Inspection Department or its designated representative. Qualification of the NDT procedure, by the contractor, may be required as determined by the Saudi Aramco 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).

- 16.1.2 Written reports and evaluations of all inspections or examinations 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.
- 16.1.3 Additional inspection or examination of any weld joint at any stage of the fabrication may be requested by Saudi Aramco Inspection, including re-inspection or re-examination of previously inspected joints. Saudi Aramco Inspection reserves the right to request or conduct independent NDT of any joint. If non-conformances to Code requirements are disclosed, all repair and NDT costs shall be at the contractor's expense. Subsequent NDT to a previously accepted joint or part does not relieve the fabricator/contractor of the responsibility for unacceptable workmanship in accordance with the applicable code.
- 16.1.4 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.

- 16.1.5 All appropriate safety precautions shall be taken for each inspection method.
- 16.1.6 All NDT personnel shall be qualified in accordance with [SAEP-1140](#) or [SAEP-1142](#), as applicable.
- 16.1.7 Surface irregularities, including weld reinforcement, inhibiting accurate interpretation of the specified method of NDT shall be ground smooth.
- 16.1.8 Inspection of all welds shall include a band of base metal at least 25 mm wide on each side of the weld.

16.2 Radiography

- 16.2.1 Fluorescent intensifying screens shall not be used. Fluoro-metallic screens shall be approved by Saudi Aramco Inspection prior to use.
- 16.2.2 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.

16.3 Ultrasonic Testing

Ultrasonic testing may be substituted for radiography if approved by Saudi Aramco Inspection. The procedure, equipment, technique, personnel, and acceptance criteria shall be proposed by the fabricator and shall be approved by Saudi Aramco Inspection.

16.4 Magnetic Particle Testing

- 16.4.1 Permanent magnet yokes are not permitted.
- 16.4.2 Magnetic particle testing shall be conducted on any structural attachment welds on primary components made of ferromagnetic material that are not hydrotested after making the attachment weld.
- 16.4.3 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. For other applications where prods are permitted, any arc strikes shall be removed by grinding.

16.5 Liquid Penetrant Testing

Liquid penetrant testing shall be conducted on any structural attachment welds

on primary components made of non-ferromagnetic material that are not hydrotested after making the attachment weld.

16.6 NDT coverage

16.6.1 The minimum percent coverage of the specified NDT method shall be as defined in the applicable API standard. It 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. NDT shall be applied using the following methods:

- Butt welds – advance ultrasound or radiography
- Other welds (including branch connections such as weldolets, sockolets, and welding bosses) - advance ultrasound or radiography
- Magnetic particle (MT) for ferromagnetic materials
- Liquid penetrant (PT) for non-ferromagnetic and ferromagnetic materials.

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.

Commentary Note:

The amount of NDT is specified in API STD 620 / API STD 650 / API STD 653 as appropriate.

16.6.2 General (all applications)

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

16.6.2.2 All branch connection welds made with single-sided groove welds shall be visually examined from the root side to ensure that proper penetration and fusion have been achieved.

17 Repairs

17.1 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.

- 17.2 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.

- 17.3 Repair welding shall be performed using a properly qualified and approved procedure. In-process repairs (i.e., repairs performed prior to completion of the joint using the same welding procedure as for the original fabrication) do not require a separate repair procedure except for cracks (see 17.2).
- 17.4 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.
- 17.5 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.
- 17.6 Damage or deformation to the base metal or welds, including dimensional changes, caused by external forces (intentional or accidental) requires special repair and inspection procedures be submitted to Saudi Aramco Inspection and if necessary forwarded to CSD for review and approval prior to undertaking the repairs.
- 17.7 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.

18 Miscellaneous Requirements

- 18.1 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 tank).
- 18.2 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.
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Validation or calibration records shall be available to Saudi Aramco Inspection upon request.

- 18.3 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:

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

Revision Summary

13 December 2011 Revised the "Next Planned Update." Reaffirmed the content of the document, and reissued with minor revisions.

Attachment I – 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.

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.

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 II – Conditioning, Storage, and Exposure of Fluxes

SAW fluxes

Fluxes for material with a minimum specified tensile strength less than or equal to 70Ksi

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 manufacturer's recommendations in order to achieve a dissolved hydrogen content of less than 8 ml H₂/100 g metal. A written procedure giving the handling requirements will be submitted to inspection.

Attachment III – Storage of Wires

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.

Attachment IV – Weld Map

WELD MAP

Vendor Name:
Saudi Aramco Purchase Order No.:
Equipment Tag No.:
Vendor Order No.:

Design Code	Repairs/Modifications	Service Requirements (Check if "yes")	
<input type="checkbox"/> API STD 650	<input type="checkbox"/> API STD 653	<input type="checkbox"/> Charpy Impact	<input type="checkbox"/> Hardness (sour Service)
<input type="checkbox"/> API STD 620		<input type="checkbox"/> PWHT for service	

1. Draw a single -line sketch of the equipment.
2. Locate all welds, except minor non-pressure attachment welds.
3. Identify each weld by a separate letter or number (identical weld joints may use a single identification).
4. Complete a Weld Description Form for each weld.,

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

Attachment V – Weld Description

WELD DESCRIPTION

Vendor Name:
 Saudi Aramco Purchase Order No.:
 Equipment Tag No.:

Weld Identification:
 Shell - longitudinal Shell to roof Pipe to fitting
 Shell - circumferential Nozzle attachment (*) Pipe to pipe
 Shell to bottom Annular plate Other (describe)
 * Nozzle attachment detail
 API 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
 Welded from both sides Fillet
 Welded from one side Overlay
 With backing
 Without backing

Joint sketch

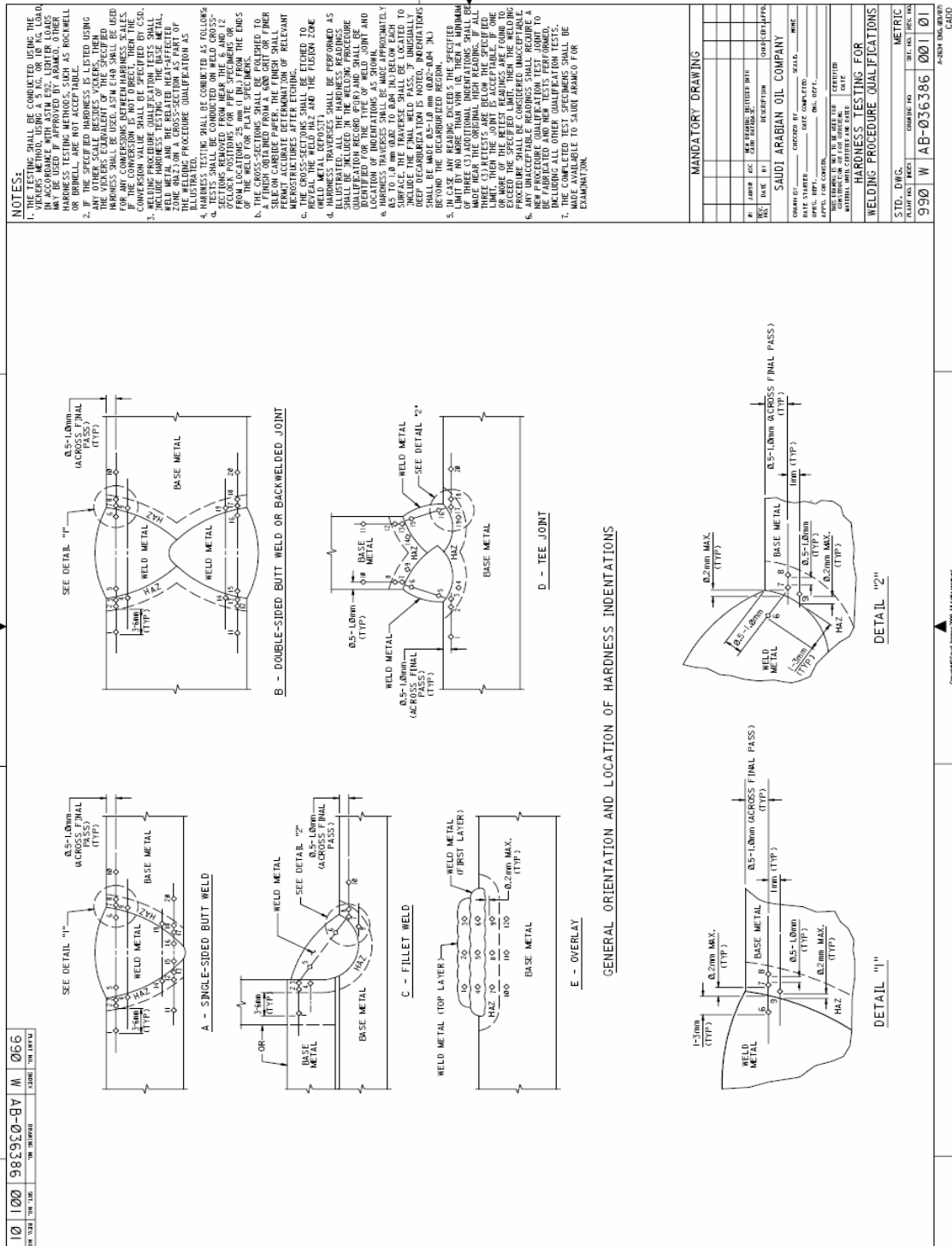
(show bevel angles, land, gas, sequence, and backing)

Process and Filler Metal

Pass	Process						Filler Metal	
	S	S	G	G	F	O	<u>AWS Classification</u>	<u>Trade name(s)</u>
	M	A	T	M	C	t		
	A	W	A	A	A	h		
	W		W	W	W	e		
						r		
Root	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Fill 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Fill 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
Backweld	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		

Backgouging: Yes No
 Shielding gas: Back purge gas:
 Post Weld Heat Treatment: Yes No
 Preheat temperature:

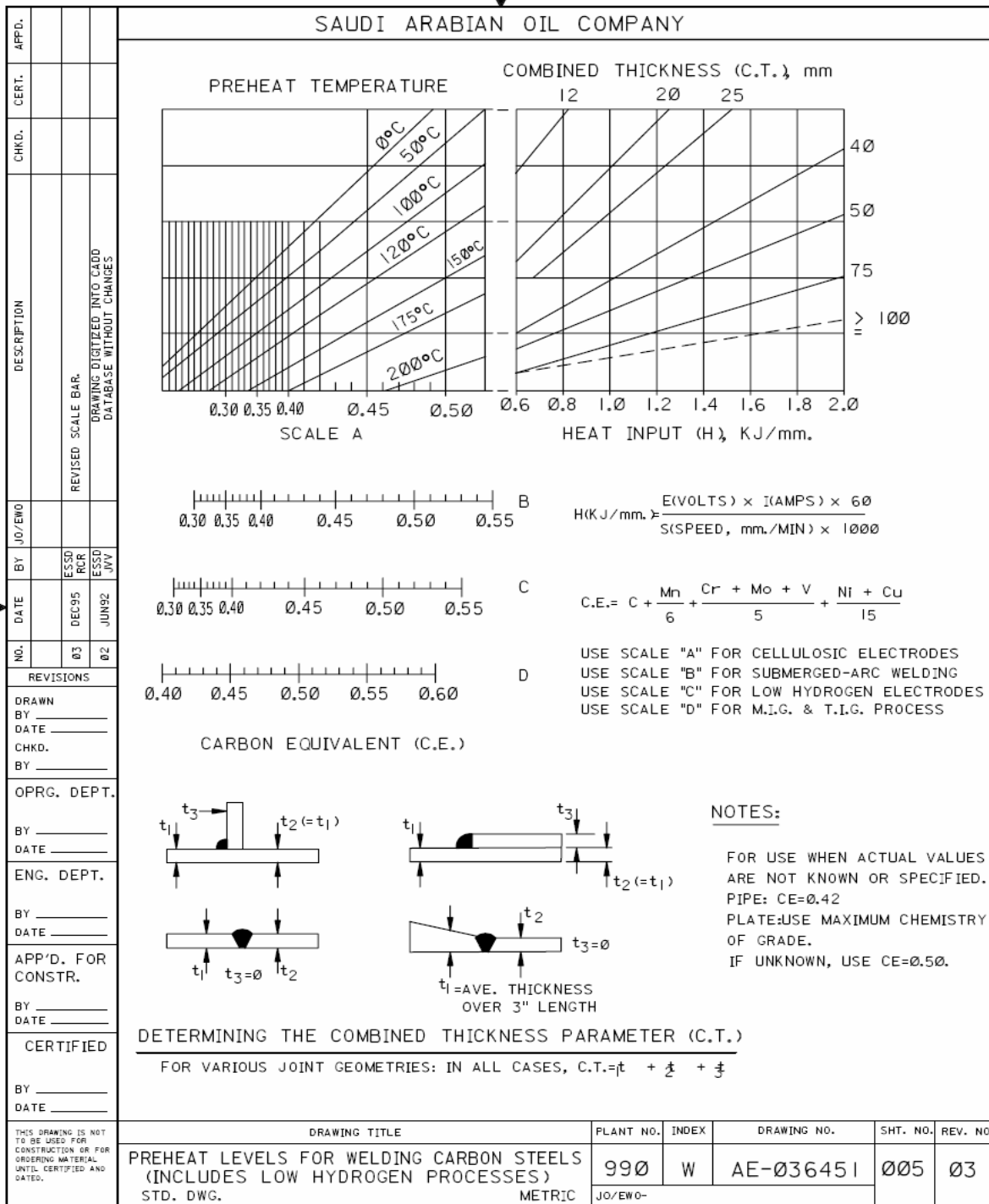
Attachment VI – Hardness Testing Drawing



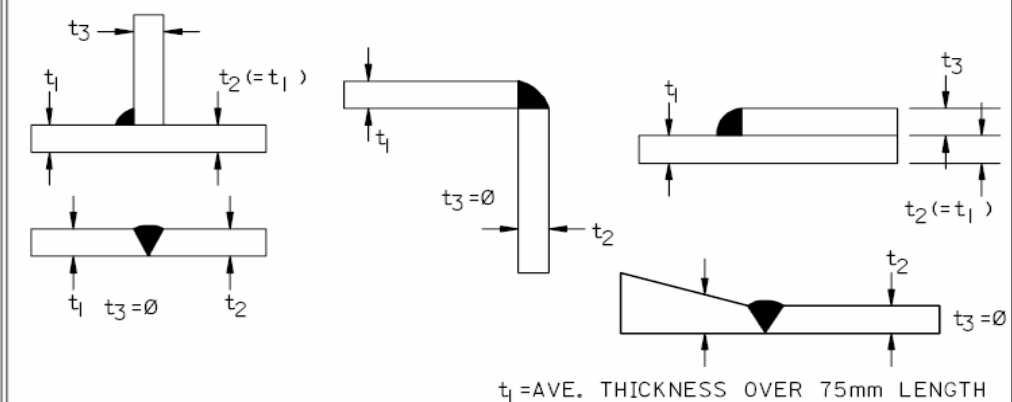
Attachment VII – Preheat Levels for Welding Carbon Steel

APPD.	CERT.	CHKD.	DESCRIPTION	SAUDI ARABIAN OIL COMPANY												
			DRAWING DIGITIZED INTO CADD DATABASE WITHOUT CHANGES	<p>HOW TO USE THE PREHEAT CURVES</p> <p>FIRST : DETERMINE THE FOLLOWING INFORMATION</p> <ol style="list-style-type: none"> (1) <u>WELDING PROCESS</u> TO BE USED. (2) <u>WELDING HEAT INPUT</u> IN KILOJOULES PER CENTIMETER OF WELD FOR THE SELECTED PROCESS. (THIS CAN BE CALCULATED BY USING THE FORMULA ON SH. 005. THE TABLE OF TYPICAL HEAT INPUT VALUES ON SH. 007, OR THE TABLE FOR FIELD DETERMINATION OF HEAT INPUT VALUE FOR WELDING DONE WITH MANUAL ELECTRODES ON SH. 008) (3) <u>THE CARBON EQUIVALENT</u> OF THE STEEL BEING WELDED. (OBTAINED EITHER FROM THE MILL SHEETS SUPPLIED WHEN THE STEEL WAS PURCHASED OR FROM THE TABLE "C.E. VALUES FOR USE WHEN ACTUAL VALUES ARE NOT KNOWN" ON SH. 007) (4) <u>THE COMBINED THICKNESS</u> IN CENTIMETERS OF THE PIECES BEING WELDED. (SEE THE EXPLANATION ON SH. 007) <p>SECOND : USE THIS INFORMATION TO DETERMINE THE REQUIRED PREHEAT TEMPERATURE FROM THE GRAPHS ON SH. 005 AS ILLUSTRATED IN THE EXAMPLE BELOW.</p> <p>EXAMPLE : WHAT IS THE PREHEAT REQUIREMENT TO BUTT WELD 19mm WALL THICKNESS PIPE WITH C.E.=0.41? WELDING WILL BE DONE WITH 4.0mm DIA. E-6010 (CELLULOSIC) ELECTRODES. ON-SITE WELDING CURRENT AND VOLTAGE ARE NOT KNOWN.</p> <p>STEP 1. SINCE ON-SITE WELDING PARAMETERS ARE NOT KNOWN, THE HEAT INPUT VALUE IS OBTAINED FROM THE TABLE OF TYPICAL VALUES ON SH. 007. FOR 4.0mm DIA. CELLULOSIC ELECTRODES, THIS IS 8 KJ/cm.</p> <p>STEP 2. ENTER THE RIGHT-HAND GRAPH ON SH. 005 AT 8 KJ/cm AND DRAW A VERTICAL LINE UPWARDS UNTIL IT INTERSECTS THE CORRECT COMBINED THICKNESS LINE. USING THE GUIDE ON SH. 005, THE COMBINES THICKNESS FOR A 19mm THICK BUTT WELD IS $C.T. = t + b + z = 19 + 19 + 0 = 38$. DRAW A HORIZONTAL LINE FROM THIS POINT OVER TO THE LEFT HAND GRAPH.</p> <p>STEP 3. ENTER THE BOTTOM OF THE LEFT HAND GRAPH AT C.E. = 0.41 USING SCALE "A" BECAUSE CELLULOSIC ELECTRODES WERE SPECIFIED. DRAW A VERTICAL LINE UPWARDS UNTIL IT INTERSECTS THE HORIZONTAL LINE DRAWN IN THE PRECEDING STEP. THIS INTERSECTION FALLS ON THE 95°C PREHEAT LINE. THE CORRECT PREHEAT FOR THIS SITUATION IS, THEREFORE 95°C.</p>												
				<p>NOTE:</p> <p>I. GENERAL REVISION OF AD-036451 & AD-036452 THAT COMBINES THESE TWO, FORMERLY SEPARATE DRAWINGS INTO ONE DRAWING. CHANGED DRAWING SIZE FROM "D" TO "E".</p>												
				<p>REVISIONS</p> <p>NO. 02 DATE JUN92</p>												
				<p>BY _____</p> <p>DATE _____</p> <p>CHKD. BY _____</p> <p>OPRG. DEPT. _____</p> <p>BY _____</p> <p>DATE _____</p> <p>ENG. DEPT. _____</p> <p>BY _____</p> <p>DATE _____</p> <p>APP'D. FOR CONSTR. BY _____</p> <p>DATE _____</p> <p>CERTIFIED BY _____</p> <p>DATE _____</p>												
THIS DRAWING IS NOT TO BE USED FOR CONSTRUCTION OR FOR ORDERING MATERIAL UNTIL CERTIFIED AND DATED.				<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 40%;">DRAWING TITLE</th> <th style="width: 10%;">PLANT NO.</th> <th style="width: 10%;">INDEX</th> <th style="width: 15%;">DRAWING NO.</th> <th style="width: 10%;">SHT. NO.</th> <th style="width: 15%;">REV. NO.</th> </tr> </thead> <tbody> <tr> <td>PREHEAT LEVELS FOR WELDING CARBON STEELS (INCLUDES LOW HYDROGEN PROCESSES) STD. DWG. METRIC</td> <td>990</td> <td>W</td> <td>AE-036451</td> <td>006</td> <td>02</td> </tr> </tbody> </table>	DRAWING TITLE	PLANT NO.	INDEX	DRAWING NO.	SHT. NO.	REV. NO.	PREHEAT LEVELS FOR WELDING CARBON STEELS (INCLUDES LOW HYDROGEN PROCESSES) STD. DWG. METRIC	990	W	AE-036451	006	02
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Attachment VII – Preheat Levels for Welding Carbon Steel (continue)



Attachment VII – Preheat Levels for Welding Carbon Steel (continue)

APPD.		SAUDI ARABIAN OIL COMPANY																	
CERT.		DETERMINING THE COMBINED THICKNESS PARAMETER (C.T.) FOR VARIOUS JOINT GEOMETRIES: IN ALL CASES, C.T.=$t_1t + 2t + 3t$																	
CHKD.																			
DESCRIPTION	DRAWING DIGITIZED INTO CADD DATABASE WITHOUT CHANGES																		
BY JO/EWO	ESSD JUV	TYPICAL HEAT INPUT VALUES FOR VARIOUS WELDING PROCESSES. FOR USE WHEN THE ACTUAL ON-SITE VALUES ARE NOT KNOWN. NOTE: WIDE VARIATIONS ARE POSSIBLE AND DEPEND PRIMARILY ON THE INDIVIDUAL WELDERS INVOLVED.																	
DATE	JUN92	<table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th style="width:50%;">WELDING PROCESS</th> <th style="width:50%;">HEAT INPUT, KJ/cm</th> </tr> </thead> <tbody> <tr> <td>CELLULOSIC ELECTRODES (EG. E-6010, E-7010, HYP, ETC.)</td> <td>($\varnothing \leq 3.2\text{mm}$) 6 ($\varnothing \geq 4.0\text{mm}$) 8</td> </tr> <tr> <td>LOW HYDROGEN ELECTRODES (EG. E-7018, E-8016, ETC.)</td> <td>($\varnothing \leq 3.2\text{mm}$) 8 ($\varnothing \geq 4.0\text{mm}$) 10</td> </tr> <tr> <td>M.I.G.</td> <td>8</td> </tr> <tr> <td>T.I.G.</td> <td>6</td> </tr> <tr> <td>SUBMERGED ARC</td> <td>(ROOT PASS) 10 (ALL OTHERS) 20</td> </tr> <tr> <td>FLUX-CORED ARC</td> <td>10</td> </tr> </tbody> </table>				WELDING PROCESS	HEAT INPUT, KJ/cm	CELLULOSIC ELECTRODES (EG. E-6010, E-7010, HYP, ETC.)	($\varnothing \leq 3.2\text{mm}$) 6 ($\varnothing \geq 4.0\text{mm}$) 8	LOW HYDROGEN ELECTRODES (EG. E-7018, E-8016, ETC.)	($\varnothing \leq 3.2\text{mm}$) 8 ($\varnothing \geq 4.0\text{mm}$) 10	M.I.G.	8	T.I.G.	6	SUBMERGED ARC	(ROOT PASS) 10 (ALL OTHERS) 20	FLUX-CORED ARC	10
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NO.	02	REVISIONS DRAWN BY _____ DATE _____ CHKD. BY _____ OPRG. DEPT. _____ BY _____ DATE _____ ENG. DEPT. _____ BY _____ DATE _____ APP'D. FOR CONSTR. _____ BY _____ DATE _____ CERTIFIED _____ BY _____ DATE _____																	
CARBON EQUIVALENT VALUES FOR USE WHEN ACTUAL VALUES ARE NOT KNOWN. PIPE: CE = 0.42 ASTM STEELS: USE MAXIMUM C.E. ALLOWABLE FOR THE GIVEN GRADE. IF UNKNOWN, USE C.E. = 0.50.		NOTES: I. GENERAL REVISION OF AD-036451 AND AD-036452 THAT COMBINES THESE TWO, FORMERLY SEPARATE DRAWING INTO ONE DRAWING. CHANGED DRAWING SIZE FROM "D" TO "E".																	
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		JO/EWO-																	