Engineering Standard

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Weld Overlays and Welding of Clad Materials

Welding Standards Committee Members

Al-Awwami, Adnan N., Chairman
Rao, Sanyasi X., Vice Chairman
Al-Juraifani, Hatim H.
Al-Nasir, Ghalib T.
Al-Nasri, Nadhir I.
Carrera, Rene L.
Carswell, Raymond J.
Keen, Peter D.
Moyer, Robert E.
Niemeyer, Dennis C.
Stark, Greg D.

Saudi Aramco DeskTop Standards

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Primary contact: Adnan N. Al-Awwami on 874-6126

1 Scope

1.1 This standard specifies the requirements for welding and testing of:

a) Corrosion-resistant and hardfacing weld overlays

b) The overlay portion of weld joints in materials with corrosion-resistant cladding, either integral or weld overlay.

c) Cladding restoration of clad materials.

The principle application of this standard is for pressure vessels, including heat exchangers. This standard is to be considered as a supplement to SAES-W-010. Other applications (e.g., piping, valves, or pumps) may also be subject to this standard if the application standard or job specification makes reference to this standard. These requirements are in addition to the requirements of ASME SEC VIII and ASME SEC IX.

This entire standard may be attached to and made part of purchase orders.

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.

1.4 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

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-A-301	*Materials Resistant to Sulfide Stress Corrosion Cracking*
SAES-W-010	*Welding Requirements for Pressure Vessels*

Saudi Aramco Standard Drawings

AB-036386	*Hardness Testing for Welding Procedure Qualifications*
AB-036367	*Joint Preparation and Welding Details - Alloy and Clad Pressure Vessels and Heat Exchangers*

3.2 Industry Codes and Standards

American Society of Mechanical Engineers

ASME SEC VIII D1	*Pressure Vessels*
ASME SEC VIII D2	*Pressure Vessels, Alternative Rules*
ASME SEC IX	*Welding and Brazing Qualifications*
ASME/ASTM A751	*Specification for Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products*

American Society for Testing and Materials

ASTM G146	*Standard Practice for Evaluation of Disbonding of Bimetallic Stainless Alloy/Steel Plate for Use in High Pressure, High Temperature Refinery Hydrogen Service*

American Welding Society

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

International Standard

ISO 10309	*Metallic Coatings - Porosity Tests - Ferroxyl Test*

4 General

4.1 All corrosion-resistant weld overlays, including clad restoration, shall conform with ASME SEC VIII requirements (Div. 1 or Div. 2, as appropriate) and the requirements of this standard.

Commentary Note:

Refer to ASME SEC VIII D1, Part UCL and ASME SEC VIII D2, Article F-5 for specific requirements.

4.2 The minimum deposit thickness shall be specified in the engineering design but shall not be less than 3 mm for corrosion-resistant overlays.

4.3 The direction of overlay deposition shall be circumferential unless otherwise approved by CSD.

Commentary Note:

Some components and geometries, such as small diameter nozzles, or special applications may not permit welding in a circumferential direction.

4.4 The weld deposit chemistry shall be specified in the engineering design. Where a nominal alloy designation for the overlay or cladding is listed (e.g., 316L), then the overlay deposit shall meet the equivalent filler metal composition requirements unless otherwise specified or exempted in this standard.

4.5 The cladding restoration portion of weld joints between clad materials or attaching clad materials to other materials shall meet the requirements for weld overlays.

4.6 Joint preparation and details for weld joints in clad vessels (including weld overlays) shall be in accordance with Standard Drawing AB-036367.

4.7 Repairs to integrally clad material shall not be done without the specific approval of CSD. Any weld repairs to the cladding shall meet the requirements for weld overlays.

4.8 Ferrite measurements shall be performed in accordance with AWS A4.2.

Commentary Note:

Calculation of the ferrite content using the Schaeffler or DeLong diagrams based on the chemical composition is not sufficient for critical applications (to be determined by CSD). Actual measurements using methods specified in AWS A4.2 are required.

4.9 Single layer overlays require prior approval by CSD. Additional qualification and production tests may be required, as determined by CSD.

4.10 All welders and welding operators for weld overlays shall be qualified in accordance with ASME SEC IX.

Commentary Note:

Special overlay qualifications are required by ASME SEC IX (see QW-380). Standard groove weld qualifications, even with the specified electrodes, are not acceptable.

4.11 All chemical analysis methods shall conform to ASME/ASTM A751.

5 Weld Overlay Procedure Qualification

5.1 All weld overlays shall be qualified in accordance with ASME SEC IX. The Welding Procedure Specification (WPS) shall include a listing of the specified range for the deposit chemical composition, including all of the elements specified in paragraph 5.6.

5.2 The WPS shall indicate the minimum deposit thickness qualified and the minimum number of layers required. The number of layers used for the Procedure Qualification Record (PQR) shall be recorded and shall be the minimum number of layers specified on the WPS and used in production.

5.3 For all processes and all layers, the heat input specified on the WPS shall not exceed the heat input recorded on the PQR by more than 10%.

5.4 For the SAW and Electro-slag processes, any change in the flux brand, trade name, or designation shall be considered an essential variable.

5.5 For single layer weld overlays, any increase in spacing between adjacent beads (i.e., any decrease in overlap) shall be requalified. The overlap or spacing must be measured and recorded on the PQR and specified on the WPS.

5.6 The following elements shall be analyzed and specified for the deposit chemistry for all stainless steel and nickel-based alloy weld metal overlays:

C, Ni, Cr, Cu, Mo, Mn, Fe, plus any other significant elements that are intentionally added to either the base metal or filler metal (e.g., Nb or Ti for stabilized stainless steel grades).

Commentary Note:

For overlay materials other than those listed above, the elements to be analyzed shall be specified by CSD.

5.7 For Monel overlays, a minimum of two layers are required and the deposit chemistry shall comply with the following analysis:

Fe 7% maximum

Ni 57% minimum

Cu 23% minimum.

5.8 For austenitic stainless steel weld overlays, the ferrite content shall be checked in the as-welded condition. The Ferrite Number shall be between 3 and 10 FN.

5.9 Welding Procedure Qualification Hardness Testing

5.9.1 PQR hardness testing is required for weld overlays in:

a) Hydrogen service components of any wall thickness.

b) Sour service components of any wall thickness.

c) For pressure vessels in any service if the base metal wall thickness is greater than 38 mm.

5.9.2 Hardness testing shall be in accordance with Standard Drawing AB-036386. The maximum allowable hardness is VHN 250 for the base metal and HAZ of all overlays and for the weld metal deposit of austenitic stainless steel corrosion-resistant overlays.

Commentary Note:

The hardnesses for the weld deposit of hardfacing overlays and nickel-based corrosion-resistant overlays are not specified since this will depend on the overlay material and the application. For sour service applications, SAES-A-301 requirements for the weld metal overlay must be met.

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 method 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.

6 Production Welding and Inspection

6.1 Production welding shall conform to the WPS, including all supplementary essential variables and restrictions specified in this standard, such as heat input restrictions (see 5.3), flux brand (see 5.4), and overlap (see 5.5).

6.2 The base metal shall be cleaned and this requires removal of the mill scales and any adherent corrosion products.

6.3 The actual overlay thickness achieved, after any machining, shall be measured by ultrasonic methods or by physical measurement. At least one thickness measurement shall be made for each head, shell course, or other component. Additional measurement locations shall be made at any changes in geometry or cross-section (e.g., for a flange, the flange face and the bore would require separate measurements). The method of measurement shall be submitted to Inspection for review and approval. The minimum final thickness shall not be less than the thickness specified in the engineering design.

6.4 The final weld overlay surface shall have the chemical composition checked prior to final Post Weld Heat Treatment (PWHT) or hydrotest. The chemistry shall be tested using either:

a) A physical sample (e.g., drillings) shall be removed for quantitative analysis.

b) A portable spectrograph. With the specific approval of Saudi Aramco Inspection, a portable X-ray fluorescence machine may be used instead of a spectrograph.

All elements specified for the deposit chemistry shall be analyzed and reported, except for carbon when using the X-ray fluorescence method. The analysis method and accuracy limits for each element shall be submitted to Inspection for review and approval. The repair method for areas where samples have been removed shall be submitted to Inspection for review and approval.

6.5 The frequency of chemical composition analyses shall be as follows:

a) Automatic welding - One analysis for each overlay area or clad joint. Separate analyses shall be made for each heat/batch of filler metal or electrode.

b) Manual welding - One analysis for each 1 m sq. of area or one analysis at intervals of 2 m or less for overlay restoration of clad joints.

6.6 Ferrite measurements shall be made for austenitic stainless steel welds when the design temperature exceeds 427°C. The ferrite content shall be checked in the as-welded condition. The Ferrite Number shall be between 3 and 10 FN. The ferrite number checks shall be performed at the same frequency as specified above (see 6.5) for chemical composition analyses.

For service temperatures below 427°C, the chemical analysis results shall be used to calculate the ferrite content using the DeLong diagram. If the calculated ferrite content is not between 3 and 10 FN, then actual ferrite measurements shall be taken on the production piece. The measured Ferrite Number shall be between 3 and 10 FN.

6.7 Liquid Penetrant Testing

6.7.1 The first layer of multi-layer overlays shall be examined by liquid penetrant in accordance with ASME SEC VIII D1, Appendix 8 (equivalent to ASME SEC VIII D2, Article 9-2). The area examined shall be a 10 percent random coverage. If rejectable indications are found, then the entire area shall be 100% examined.

6.7.2 The final layer, including single layer overlays, shall be examined by liquid penetrant over the entire area (100%) in accordance with ASME SEC VIII D1, Appendix 8 (equivalent to ASME SEC VIII D2, Article 9-2). The examination shall be conducted on the surface in its final condition, i.e., as-welded or machined. The examination shall be conducted after the final PWHT, if PWHT is specified.

Commentary Notes:

The fabricator will normally perform an additional examination prior to PWHT in order to find and repair any defects prior to PWHT.

If determined by the Inspector that extensive cracking or fissuring has occurred, then additional testing, such as a ferroxyl test, shall be performed to determine the extent and nature of the cracking.

Commentary Notes:

A ferroxyl or ferricyanide test is an iron contamination test to determine if the cracking extends to the base metal. If iron contamination is found,

then the overlay shall be repaired by complete removal of the overlay to base metal in the area of fissuring prior to rewelding. If iron contamination is not found, then only localized repairs are required (i.e., the excavations only need to be large enough to completely remove the defect indications).

6.8 Repairs to overlays shall be performed by removing the defect by machining or grinding (thermal methods are not permitted). Removal of the overlay defect shall not reduce the base metal thickness below the minimum design thickness. The repair area shall be welded using an approved overlay procedure with a nominal composition that shall match the original overlay composition.

6.9 The finished overlay surface shall be free of overlaps, undercutting, and notches and shall be relatively smooth. All flux and slag shall be completely removed.

Only stainless steel brushes, ceramic (glass) beads, iron-free grit, or stainless steel grit shall be used to mechanically clean the overlay surfaces.

6.10 Weld overlay to clad/overlay weld joints (see Standard Drawing AB-036367)

The base metal cladding or overlay shall be stripped back 10 mm from each side of the weld joint prior to welding the base metal portion of the weld. Complete removal of the cladding/overlay shall be verified by a suitable etching test or chemical analysis of the stripped back surface.

Commentary Note:

Suitable etchants include nitric acid or nital.

After welding the base metal portion of the joint, the side of the weld to be overlaid shall be ground flush using mechanical methods.

The overlay of the weld joint area shall be performed using a qualified overlay procedure and shall comply with all of the other overlay requirements in this standard.

7 Hydrogen Disbonding Test Supplement

7.1 General

7.1.1 Hydrogen disbonding tests are required to qualify weld overlay procedures in high temperature, high pressure hydrogen service. These requirements are in addition to all of the other requirements listed in this standard. This test procedure shall be used when both the design temperature exceeds 350°C and the hydrogen partial pressure exceeds 5 MPa.

7.1.2 The general principles of ASTM G146 shall be followed, with the following modifications and requirements as specified below. Alternative test procedures may be submitted to CSD for consideration. CSD has the sole approval authority to accept any alternative test procedures or methods. Submission of any such proposals shall include details of the test procedure and representative data from previous test results.

7.1.3 Testing shall be performed specifically for each vessel (or set of vessels if manufactured at the same time using the same materials and welding procedures) as part of the welding procedure qualification testing or, if existing procedure qualifications are to be used, as a supplementary qualification test. Evidence of previous disbonding tests on similar material using identical welding procedures may be submitted for consideration. CSD has the sole approval authority to accept previous test results.

7.1.4 All welding of the test specimens must be performed by the fabricator using production equipment. The disbonding tests shall be conducted by an organization experienced with such tests. The fabricator shall nominate the testing organization to be used for approval by CSD.

7.2 Specimen Preparation

7.2.1 A test coupon shall be prepared using the production overlay procedure. A separate test coupon is required for each overlay procedure. The size of the test coupon is not specified but shall be large enough to obtain all of the required specimens from one coupon. The test coupon shall also be sufficiently large so that the welding conditions are fully representative of production welding. The test coupon shall be prepared on the same base materials and using the same welding consumables as will be used for actual production. The coupon shall be welded and heat treated in accordance to the procedures to be used for production (including the maximum time and same temperature that will be used for production).

7.2.2 At least six (6) test specimens shall be removed from the coupon, with the size and shape as appropriate for the testing apparatus, however, the minimum sizes shall be 50 mm diameter for round specimens and 50 mm for length and width for rectangular specimens. Half the number of specimens shall include the overlap region between adjacent passes of the weld overlay across the nominal center of the specimen surface. The results of all specimens prepared or used shall be considered and shall be included in the test report.

7.3 Test Apparatus and Exposure

7.3.1 Autoclaves using either single-sided or complete exposure are permitted. If single-sided exposure is used, the test specimen must have a stainless steel overlay around all sides (excluding the "bottom" side), in addition to the test overlay on the top (test) surface. The use of cathodic charging is not permitted as an alternative to autoclave exposure.

7.3.2 The specimens shall be hydrogen charged in an autoclave using hydrogen gas on the clad side of the specimen at 500°C and 150 kg/cm² for 48 hours minimum. If the design temperature or pressure of the particular vessel are higher than these values, then the test values shall be increased to the design values.

7.3.3 After the charging period, the specimen shall be cooled to room temperature at a minimum cooling rate of 200°C/hr for conventional materials and 300°C/hr for V-modified steels.

7.4 Test Evaluation

7.4.1 The specimen shall be held at room temperature for 10 days.

7.4.2 The specimen shall be examined by UT. If the interface reflection is more than 20% of the initial backwall reflection, disbonding is considered to have occurred. The UT test procedure is subject to approval by Saudi Aramco.

7.4.3 After UT examination, the specimens shall be cross-sectioned perpendicular to the direction of welding. A minimum of 5 parallel cross-sections shall be made with no more than 8 mm between each section. The locations of the cross-sections shall be adjusted to include any potential areas of disbonding detected by the UT examination. Each section shall be polished and examined by microscope at 20x magnification minimum.

7.4.4 For acceptance, none of the specimens shall show any disbonding by either UT or cross-section methods.

7.4.5 Retests are not permitted unless specifically authorized by CSD and, if authorized, may include additional restrictions or requirements as determined by CSD.

7.4.6 The results of the UT examination and cross-sections shall be submitted as part of the PQR.

Revision Summary

29 June 2005	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor changes.