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Volume 2, WELDING FABRICATION PROCEDURE

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RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	8/16/04	Initial issue.	Kelly Bingham, <i>FWO-DECS</i>	Gurinder Grewal, <i>FWO-DO</i>
1	10/27/06	Administrative changes only. ISD number changes based on new Conduct of Engineering IMP 341. Other administrative changes.	Kelly Bingham, <i>FM&E-DES</i>	Kirk Christensen, <i>CENG</i>

Contact the Welding Standards POC for upkeep, interpretation, and variance issues

WFP 2-16	<u>Welding POC/Committee</u>
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WFP 2-15 ASME SECTION III NUCLEAR COMPONENTS

1.0 PURPOSE AND SCOPE

- A. This Welding Fabrication Procedure shall govern the welding of components to requirements of ASME Section III, Division 1 (Reference 1) and ASME Section III, Division 3 (Reference 2). The Code edition and addenda for this procedure shall be the latest in effect or as otherwise specified by the applicable specification.
- B. This procedure is not applicable for code certification of components under the requirements of References 1 or 2, unless implemented in conjunction with the corresponding ASME Section III Certificate(s) of Authorization.

2.0 REFERENCES

- 1. ASME Section III, Division 1, “Rules for Construction of Nuclear Facility Components”
- 2. ASME Section III, Division 3, “Containment Systems for Storage and Transport Packaging of Spent Nuclear Fuel and High Level Radioactive Material and Waste”
- 3. ASME Section IX, “Welding and Brazing Qualifications”

3.0 WELDER QUALIFICATION

- A. Welder/welding operators shall be currently certified, having performed qualification tests in accordance with GWS 1-05, *Welder Performance Qualification & Certification* and Reference 3.
- B. The additional procedure and performance qualification requirements of References 1 and 2 shall be met for welding of Tube-to-Tubesheet welds and Specially Designed Seal Welds.

4.0 WELDING PREREQUISITES

- A. All welding shall comply with the requirements specified in the Welding Procedure Specification (WPS) or Welding Technique Sheet (WTS).
- B. Welding shall not be performed when the ambient temperature in the immediate vicinity of the weld is lower than 0 °F (-18 °) or when surfaces are wet or exposed to rain, snow, dust, or high wind. The welder and weld joint shall be sufficiently protected from inclement conditions. Care shall be taken to assure that moisture has not been trapped between members that are to be welded and that moisture has not been introduced into previously fit-up joints prior to final welding. Preheating above the minimum specified temperature in the WPS or WTS may be necessary to remove any entrapped moisture. The additional preheat should be applied if there is suspicion of moisture being present.
- C. Welding shall not be started on components that are to be post weld heat treated (PWHT) until it has been established that the total qualified PWHT time at temperature indicated in the WPS or WTS is sufficient to cover the total PWHT time at temperature to be applied to the component. This shall include time that may be needed for subsequent repair.

5.0 MATERIALS

A. Base Materials

1. Only the materials specified in the WPS or WTS may be welded using this procedure.

B. Filler Materials

1. Welding filler materials to be used with this procedure are specified in the WPS or WTS. A listing of applicable welding filler materials is provided in GWS 1-07, Material Specifications.
2. Welding filler material shall be purchased and controlled at the site in accordance with GWS 1-03, Welding and Brazing Material Procurement and Control.
3. Welding filler materials (electrodes, bare filler wire, or consumable inserts) shall be utilized by welders making weldments with this procedure. Welders shall not perform welds autogenously.

6.0 BASE MATERIAL JOINT PREPARATION

- A. Members to be joined may be cut to shape and size by machining, shearing, chipping, grinding, thermal cutting, or air carbon arc gouging. After thermal cutting or air carbon arc gouging, all slag and detrimental discoloration of material that has been molten shall be removed by grinding or other mechanical means prior to welding or further fabrication. Base material joint bevels prepared using thermal cutting or air carbon arc gouging may require additional grinding prior to welding. Kerf or gouge marks on the joint bevel deeper than 1/8" (0.125) shall be repaired prior to fit-up and tack welding.
- B. Prior to thermal cutting or air carbon arc gouging, the preheat temperature specified in GWS 1-03, *Weld Material Control* shall be applied to the material, except that preheat is not required for P1 Group 1, P8, or nonferrous materials.

7.0 BASE MATERIAL JOINT CLEANING

- A. Prior to welding, surfaces for welding shall be clean and free from paint, oil, rust, scale, slag, grease, and other foreign materials which are detrimental to welding for a distance of at least 2 in. from the welding joint preparation. Weld-through primers, i.e., Deoxaluminite, Spatter Weld, and Carboweld 11, need not be removed.
- B. Solvents approved for use on the base material and weld materials are methyl alcohol, ethyl alcohol, isopropyl alcohol, acetone, methyl ethyl ketone, toluene, Varson 4, Dowanol EB, and Stoddard solvents.

8.0 JOINT FIT-UP AND ALIGNMENT

- A. Root opening and fit-up tolerances shall be as specified in the GWS 1-06, Weld Joint Design section of this program and Attachment 1. If the tolerances cannot be achieved, the end preparations may be built up by welding or prepared by machining or grinding.
- B. Alignment of sections at edges to be butt welded shall be such that the maximum offset is not greater than the applicable amount listed in Attachment 1.

- C. Parts to be joined by a tee or fillet weld shall be brought into as close contact as is practicable. The maximum gap between these parts shall not exceed $\frac{3}{16}$ in. If the separation is greater than $\frac{1}{16}$ in. the leg of the fillet weld shall be increased by the amount of separation.
- D. In assembly of the socket weld joints, the pipe or tube shall be withdrawn a distance of approximately $\frac{1}{16}$ in. (1.5 mm) away from contact between the end of the pipe and the face of the shoulder of the socket. In sleeve-type joints without an internal shoulder, there shall be a distance of approximately $\frac{1}{8}$ in. (3 mm) between the butting ends of the pipe or tube. The butting ends shall be centered in the sleeve. The depth of insertion of pipe or tube within the socket or sleeve shall not be less than $\frac{1}{4}$ in. (6 mm). Note: Gap inserts (Gapalets or equivalent) and approved shims may be used with prior approval from the design engineer or the LANL WPA.

9.0 PREHEAT

- A. When the base material temperature is below the minimum preheat temperature specified in the Weld Material Control Section, the base material shall be heated such that the surfaces to be welded are at or above the minimum preheat temperature prior to welding.
- B. The minimum preheat temperature shall be maintained for a distance of at least 3 in. (75 mm) on each side of the weld joint and in advance of the welding.
- C. Preheat temperatures above 125 °F (52 °C) shall be checked by using a surface pyrometer, “Tempilstik,” or nonmercury-type thermometer, or other approved devices Temperature indicating crayons shall not be used directly in the weld zone.

10.0 TACK WELDS

- A. Tack welds shall be made by qualified welders in accordance with an approved WPS or WTS.
- B. Acceptable tack welds may be incorporated into the final weld.
- C. Defective tack welds shall be removed or repaired prior to welding.
- D. For GTAW tack welds on consumable inserts, the insert at the point of the tack weld (button), shall not be totally consumed, no purge is required, and cracks in tack welds on consumable inserts shall be re-fused prior to making the root weld.

11.0 PURGE GAS

- A. The WPS or WTS shall specify the required purge gas and any special requirements. For argon, the inlet shall be at the bottom and the outlet vent at the top.
- B. When purge gas is specified on the WTS, the oxygen content of the gas exiting from the purge vent shall be less than 2 % prior to welding. This shall be measured using one of the following types of oxygen analyzers or an equivalent:
 - Mine Safety Appliance MSA Type E
 - Johnson & Williams Model K
 - Honeywell Corporation Model K-4015.

Note: Flame type (matches, [wood or paper]) devices are not an equivalent method of analyzing the oxygen content and shall not be used.

- C. When purge gas is required, it shall be maintained for a minimum of $\frac{3}{16}$ in. or three layers of weld.
- D. For socket welds, purge gas is not required unless the WPS or WTS identifies a purge gas type and the thickness of the pipe is less than 0.109 in.
- E. For weld joints using a consumable insert, the purge gas flow shall be approximately static and the use of an inclined manometer is recommended with pressure maintained at 0.5 inches maximum until the insert has been completely fused for the entire root circumference.

12.0 INTERPASS TEMPERATURE

- A. Interpass temperature shall not exceed the maximum value specified in the WPS or WTS and shall be checked on the surface of the component using a surface pyrometer, “Tempilstik,” or nonmercury-type thermometer. Temperature indicating crayons shall not be used directly in the weld zone.
- B. If the temperature of the weld is above the maximum inter-pass temperature specified in the WPS or WTS, the weld shall be allowed to cool down to below the maximum inter-pass temperature, but not below the minimum preheat temperature, prior to resumption of welding.

13.0 WELDING TECHNIQUE

- A. Welding voltage and amperage shall be in accordance with the limits specified in the WPS or WTS. Voltage ranges are not mandatory for ASME IX purposes. Voltage and amperage range gages located on the welding power supply are for reference only and are not mandatory check or hold points. Voltage and amp range checks for documentation purposes shall be performed by a qualified (CWI or equivalent) inspector using calibrated voltage and amp meters or approved welding parameter recording equipment.
- B. Cracks or blowholes that appear on the surface of a weld bead shall be removed by filing, grinding, chipping, or air carbon arc gouging before depositing the next bead. Oxygen gouging shall not be used on quenched and tempered steel.
- C. Before welding over previously deposited weld material, all slag and flux shall be removed, and the weld and adjacent base material 1” on either side of the weld shall be brushed clean.
- D. For double-welded butt joints before applying weld material on the second side to be welded, the root shall be prepared by suitable methods such as chipping, grinding, or air carbon arc gouging to ensure sound material. The weld must be visually examined to ensure that no cracks have occurred before welding is resumed.
- E. Recommended bead thickness shall be $\frac{1}{16}$ in. to $\frac{3}{16}$ in. All passes shall be less than $\frac{1}{2}$ in. thick unless otherwise specified in the WPS or WTS.
- F. Unless specifically stated in the WPS or WTS, consumable inserts, root retainers, trailing shielding gas, and pulsing current shall not be used.
- G. Peening of P1 materials may be used to control distortion or to relieve residual stresses. Peening shall not be performed until at least $\frac{3}{8}$ in. depth of bevel has been deposited. Peening shall not be applied to cover passes, base material, or weld layers requiring nondestructive examination. Peening shall not be used to mask a defect. Use of manual or pneumatic chipping hammers to remove slag is not considered peening.

- H. All welding processes may be single pass or multiple passes per side unless specifically stated in the WPS or WTS. Socket welds shall have a minimum of two weld passes, with the exception that two weld passes are not required for socket welds on pipe NPS 1 or smaller.
- I. Welding shall be performed single arc unless otherwise specified in the WPS or WTS.

14.0 INTERRUPTION OF WELDING

- A. Definition - Interruption of welding means dropping from minimum preheat or inter-pass temperature to ambient temperature prior to completion of welding or performing PWHT.
- B. Welding on P3, P4, P5A, and P5C material with chromium content of 3.0 % or less may be interrupted and the weld may be allowed to cool prior to post weld heat treatment, provided all of the following conditions are satisfied:
 - 1. A minimum of $\frac{3}{8}$ in. (10 mm) thickness of weld is deposited or 25 % of the welding groove is filled, whichever is greater
 - 2. The weld is allowed to cool slowly to room temperature. Use of insulated blankets may be required to allow slow cooling.
 - 3. The weld has been visually examined to ensure that no cracks have occurred before welding is resumed
 - 4. The required preheat has been applied before any welding is resumed.
- C. Field welding of P5B and P6 material requires special care to assure the desired weld properties are achieved and maintained throughout the welding process. Interruption of in-process welding on P5B and P6 materials should be controlled and limited as a non-routine practice. When necessary, welding on P5B and P6 materials may be interrupted before completion and the weld may be allowed to cool prior to post weld heat treatment, provided the following conditions are satisfied:
 - 1. A minimum of $\frac{1}{2}$ in. thickness of weld is deposited or $\frac{2}{3}$ of the welding groove is filled, whichever is greater.
 - 2. A temperature of $450\text{ }^{\circ}\text{F} \pm 50\text{ }^{\circ}\text{F}$ is maintained for 1 hour after welding and the weld joint is then allowed to cool slowly to ambient temperature.
 - 3. The weld has been visually examined to ensure that no cracks have occurred before welding is resumed.
 - 4. The required preheat has been applied before any welding is resumed.
- D. Welding on other materials may be interrupted without restriction, unless otherwise specified in the WPS or WTS.

15.0 INSPECTOR QUALIFICATION

- A. The Inspector who performs welding inspection for acceptance to this procedure shall be an AWS-CWI, and authorized by the LANL WPA.

16.0 ACCEPTANCE CRITERIA FOR COMPLETED WELDS

- A. Butt Welds (Subsections NB, NC, ND, and NE)
 - 1. As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys.

2. The surface condition of the finished welds shall be suitable for the proper interpretation of radiographic and other nondestructive examinations when nondestructive examinations are required. In those cases where there is a question regarding the surface condition on the interpretation of a radiographic film, the film shall be compared to the actual weld surface for interpretation and determination of acceptability.
 3. Undercuts shall not exceed $\frac{1}{32}$ in. or 10% of the wall thickness, whichever is less, and shall not encroach on the minimum required section thickness.
 4. A reduction in thickness due to welding is acceptable provided the reduction does not exceed $\frac{1}{32}$ in. or 10 % of the wall thickness of the adjoining surface and the reduction does not exceed the minimum required thickness at any point.
 5. For single-welded joints (butt joints welded from one side), concavity of the root surface is permitted. The contour of the concavity shall be smooth and the resulting thickness of the weld, including reinforcement, shall be at least equal to the required thickness of the thinner section (applies only when inside surface of the weld is readily accessible or the weld has been radiographed).
 6. Weld reinforcement greater than the amounts specified in Attachment 1 shall be considered unacceptable.
 7. Weld grooves shall be completely filled so that the surface of the weld at any point does not fall below the surface of the adjoining base materials; weld material may be added as reinforcement on each face of the weld. The thickness of the weld reinforcement on each face shall not exceed the amounts specified in Attachment 1.
- B. Socket and Fillet Welds (Subsections NB, NC, ND, and NE)
1. As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys.
 2. The surface condition of the finished welds shall be suitable for the proper interpretation of nondestructive examinations.
 3. The reduction of the thickness of the base material due to welding shall meet the requirements of paragraphs 16.A.3 and 16.A.4.
 4. Socket and fillet welds may vary from convex to concave. The size of a fillet weld is determined as shown in Attachment 2. Typical weld details for socket-welding components are also contained in Attachment 2.
- C. Butt Welds (Subsection NF)
1. As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys for the proper interpretation of radiographic and other nondestructive examinations when nondestructive examinations are required. In those cases where there is a question regarding the surface condition on the interpretation of a radiographic film, the film shall be compared to the actual weld surface for interpretation and determination of acceptability.
 2. For single-welded joints (butt joints welded from one side), concavity of the root surface is permitted. The contour of the concavity shall be smooth and the resulting thickness of the weld, including reinforcement, shall be at least equal to the required thickness of the thinner section (applies only when inside surface of the weld is readily accessible or the weld has been radiographed).

3. Weld reinforcement greater than the amounts specified in Attachment 1 shall be considered unacceptable.
 4. Weld grooves shall be completely filled so that the surface of the weld material at any point does not fall below the surface of the adjoining base materials; weld material may be added as reinforcement on each face of the weld. The thickness of the weld reinforcement on each face shall not exceed the amounts specified in Attachment 1.
 5. Cracks and incomplete fusion shall not be permitted. Rounded end conditions that occur in welding (starts and stops) shall not be considered as incomplete fusion and shall be considered irrelevant.
 6. Craters shall be considered acceptable when the minimum weld size criteria are met. Craters that occur outside of the specified weld length shall be considered irrelevant provided there are no cracks.
 7. The requirements for undercut shall be as follows:
 - a. For materials $\frac{3}{8}$ in. thickness and less, undercuts shall not exceed $\frac{1}{32}$ in. or 10% of the wall thickness, whichever is less, and shall not encroach on the minimum required section thickness. For members welded on both sides where undercut exists in the same plane of a member, the cumulative lengths of undercut for both sides shall not exceed the above requirements.
 - b. For material greater than $\frac{3}{8}$ in. thickness, undercuts shall not exceed $\frac{1}{32}$ in. or 10% of the wall thickness, whichever is less, and shall not encroach on the minimum required section thickness. When either welds or undercut exist only on one side of the member or are not in the same plane the allowable undercut may be increased to $\frac{1}{16}$ in. for the full length of the weld.
 8. Only surface porosity whose major surface dimension exceeds $\frac{1}{16}$ in. shall be considered relevant. Surface porosity that exceeds $\frac{3}{8}$ in. in any linear inch of weld or $\frac{3}{4}$ in. in any 12 in. of weld shall be considered unacceptable. Also, surface porosity shall be unacceptable when four or more pores are aligned and the pores are separated by $\frac{1}{16}$ in. or less, edge to edge.
 9. Only slag whose major surface dimension exceeds $\frac{1}{8}$ in. shall be considered relevant. Isolated slag that remains after weld cleaning and exceeds $\frac{1}{4}$ in. in its major surface dimension shall be considered unacceptable. (Slag shall be considered to be isolated when it does not occur more frequently than once per weld or more than once in a 3 in. weld segment.)
 10. Arc strikes and associated blemishes on the weld surface or base material shall be considered acceptable provided there are no cracks.
- D. Fillets Welds (Subsection NF)
1. As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys for the proper interpretation of nondestructive examinations.
 2. Fillet welds may vary from convex to concave. The size of a fillet weld is determined as shown in Attachment 2.
 3. Cracks shall not be permitted. Incomplete fusion exceeding $\frac{3}{8}$ in. in any 4 in. weld segment, and $\frac{1}{4}$ in. in welds less than 4 in. long shall be considered unacceptable. Rounded end conditions that occur in welding (starts and stops) shall not be considered as incomplete fusion and shall be considered irrelevant.

4. Overlap that does not exceed the requirements for fusion shall be considered acceptable. When fusion in the overlap length cannot be verified, an overlap length exceeding $\frac{3}{8}$ in. in any 4 in. weld segment, and $\frac{1}{4}$ in. in welds less than 4 in. long shall be considered unacceptable.
 5. Craters shall be considered acceptable when the minimum weld size criterion is met. Craters that occur outside of the specified weld length shall be considered irrelevant provided there are no cracks.
 6. The requirements for undercut shall be as follows:
 - a. For materials $\frac{3}{8}$ in. thickness and less, undercuts shall not exceed $\frac{1}{32}$ in. or 10% of the wall thickness, whichever is less, and shall not encroach on the minimum required section thickness. For members welded on both sides where undercut exists in the same plane of a member, the cumulative lengths of undercut for both sides shall not exceed the above requirements.
 - b. For material greater than $\frac{3}{8}$ in. thickness, undercuts shall not exceed $\frac{1}{32}$ in. or 10% of the wall thickness, whichever is less, and shall not encroach on the minimum required section thickness. When either welds or undercut exist only on one side of the member or are not in the same plane, the allowable undercut may be increased to $\frac{1}{16}$ in. the full length of the weld.
 7. Only surface porosity whose major surface dimension exceeds $\frac{1}{16}$ in. shall be considered relevant. Surface porosity that exceeds $\frac{3}{8}$ in. in any linear inch of weld or $\frac{3}{4}$ in. in any 12 in. of weld shall be considered unacceptable. Also, surface porosity shall be unacceptable when four or more pores are aligned and the pores are separated by $\frac{1}{16}$ in. or less, edge to edge.
 8. Only slag whose major surface dimension exceeds $\frac{1}{8}$ in. shall be considered relevant. Isolated slag that remains after weld cleaning and exceeds $\frac{1}{4}$ in. in its major surface dimension shall be considered unacceptable. (Slag shall be considered to be isolated when it does not occur more frequently than once per weld or more than once in a 3 in. weld segment.)
 9. Arc strikes and associated blemishes on the weld surface or base material shall be considered acceptable provided there are no cracks.
- E. Butt Welds (Subsection WB)
1. As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys for the proper interpretation of nondestructive examinations.
 2. Weld reinforcement shall be in accordance with Attachment 1.
 3. Undercuts shall not exceed $\frac{1}{32}$ in. and shall not encroach the required section thickness.
 4. Concavity of the root side of a single-welded circumferential butt weld is permitted when the resulting thickness of the weld complies with the design/construction specification.
 5. Surface grinding of the weld to achieve the above requirements shall not reduce the weld or base material below the required minimum thickness.
- F. Socket and Fillet Welds (Subsection WB)
1. Fillet welds may vary from convex to concave. The size and shape of fillet welds shall be as shown in Attachment 2.

2. A fillet weld in any single continuous weld may be less than the specified fillet weld dimension by not more than $\frac{1}{16}$ in., provided the total undersize portion of the weld does not exceed 10 % of the length of the weld. Individual undersize weld portions shall not exceed 2 in. in length.
3. For socket welds, a gap of approximately $\frac{1}{16}$ in. shall be provided prior to welding, as shown in Attachment 2. The gap need not be present or verified after welding.

17.0 WELD REPAIRS

- A. Weld repairs shall be performed using the original WPS or WTS or an alternate Repair WTS to restore a weld to an acceptable condition.
- B. Unacceptable defects shall be removed by chipping, grinding, machining, or air carbon arc gouging. Prior to air carbon arc gouging on P1 Group 3, P3, P4, P5A, P5B, P5C, or P6 materials with chromium content greater than 3.0 %, the preheat specified in the WPS or WTS shall be applied to the material.

18.0 POST WELD HEAT TREATMENT

- A. Post weld heat treatment when indicated in the WPS or WTS shall be performed in accordance with the Post Weld Heat Treatment Section of this manual.
- B. The nominal thickness for determining whether PWHT is required shall be the thickness of the weld, the thickness of pressure retaining material, or the thinner of the sections being joined, whichever is least. For fillet welds, the nominal thickness is the throat thickness and for partial penetration and repair welds, the nominal thickness is the depth of groove or preparation.
- C. For welds joining materials of different P numbers, the PWHT requirements of the material with the higher PWHT temperature shall govern, unless exemptions apply. The lower transformation temperature shall not be exceeded for either material.
- D. Above 800 °F (425 °C), the rate of heating and cooling shall not exceed 400 °F (205 °C) divided by the maximum thickness of the material. In no case shall the rate exceed 400 °F (205 °C) per hour and the rate need not be less than 100 °F (38 °C) per hour. The WPS or WTS may further restrict PWHT heating and cooling rates.

19.0 ATTACHMENT WELDS

- A. Attachment welds shall be performed in accordance with a WPS or WTS.
- B. When applying attachments to materials of different thicknesses, observe the preheat requirements of the thicker materials.
- C. When the specification requires that temporary attachments be removed, a method that will not damage the base material shall be utilized, i.e., cut, grind, or air carbon arc gouge the attachment off and grind the area flush.

20.0 ATTACHMENTS

Attachment 1: Weld Reinforcement Table and Alignment Tolerance Table

Attachment 2: Fillet Weld and Socket Weld Profiles