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RD T Standard

WELDING OF REACTOR CORE COMPONENTS AND TEST ASSEMBLIES

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WELDING OF REACTOR CORE COMPONENTS AND TEST ASSEMBLIES

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WELDING OF REACTOR CORE COMPONENTS AND TEST ASSEMBLIES

1. SCOPE

This standard establishes the requirements for welding and for the evaluation of welds for replaceable reactor core components and test assemblies. The core components consist of the driver fuel, control rod and radial reflector assemblies and their subcomponents. Test assemblies consist of components requiring special closure welds and which are fabricated in small lots for specially designed in-reactor and out-of-reactor fuels and materials assemblies that may require sophisticated instrumentation.

1.1 Application. This standard defines requirements for the following:

1. Welding procedure qualification and performance qualification of welders, welding operators, welding equipment and special fixturing for fuel pin, absorber pin, test assemblies, wire wrap welding and for all other welds used in the replaceable core component assembly.

2. Application of qualified procedures to production welding of core components.

3. Destructive testing and nondestructive examination for qualification and for production welding.

1.2 Definitions.

1.2.1 Heat. A single homogeneous melt of metal or alloy.

1.2.2 Repair. The process of restoring a nonconforming item characteristic to an acceptable condition, although it does not conform to a specified requirement.

1.2.3 Rework. The process by which a nonconforming item is made to conform to specified requirements.

1.2.4 Welding and Associated Terms. See Appendix A to this standard.

2. APPLICABLE DOCUMENTS

The following documents are a part of this standard to the extent specified herein. The issue of a document in effect on the date of the invitation to bid, including any amendments also in effect on that date, shall apply unless otherwise specified. Where this standard appears to conflict with the requirements of a reference document, such conflict shall be brought to the attention of the purchaser for resolution.

2.1 RDT Standards.

RDT E 15-2T, Requirements for Nuclear Components (Supplement to ASME Boiler and Pressure Vessel Code, Section III)

RDT F 3-6T, Nondestructive Examination

RDT F 5-1T, Cleaning and Cleanliness Requirements for Nuclear Components

RDT F 6-14T, Brazing Fabrication Requirements

2.2 Federal Specifications.

BB-H-1168a, Helium, Technical

2.3 American Society for Testing and Materials (ASTM) Standards.

ASTM E 2, Preparation of Micrographs of Metals and Alloys

ASTM E 3, Preparation of Metallographic Specimens

2.4 American Society of Mechanical Engineers (ASME) Codes.

ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components

ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

2.5 American Welding Society (AWS) Standards.

AWS A2.2, Nondestructive Testing Symbols

AWS A3.0, Terms and Definitions

3. GENERAL REQUIREMENTS

3.1 Welding Procedures and Qualification. Before any welding is performed on components or subcomponents covered by this standard, each supplier shall qualify each proposed welding procedure by:

1. Recording all essential elements of the welding procedure in a welding procedure specification.
2. Verifying the welding procedure specification by welding test assemblies representing each joint to be welded in production and performing nondestructive examination and destructive tests in accordance with the requirements of this standard.

3. Submitting to the purchaser the welding procedure specification and a certified copy of the detailed results obtained from the tests performed on the test welds. When radiography and metallographic examination of the test assembly are required by this standard, the radiographs and metallographic sections shall also be submitted to the purchaser.

3.2 Welding Procedure Specification. The welding procedure specification shall include all essential elements and details, as required by each section of this standard, to cover each joint to be welded by the supplier. Each joint shall be identified in the welding procedure specification. The specification shall include a joint design sketch for each joint welding procedure even if the specification references drawing numbers.

3.3 Base Materials and Filler Materials.

3.3.1 Base materials and filler materials shall comply with the requirements of the drawings and referenced material standards as specified in Tables NNB-2120-1 and NNB-2120-2 of RDT E 15-2 unless otherwise specified in the Ordering Data.

3.3.2 Unless otherwise specified in the Ordering Data, the component supplier shall perform a check analysis of welding materials as specified in NNB-2433 of RDT E 15-2.

3.4 Welding Processes. Except when specifically stated in other sections of this standard, welding processes which satisfy the specified requirements and produce the quality required by this standard are permissible. Welding processes which utilize fluxes and coatings shall not be used. Brazing processes shall be restricted to test assemblies to effect joints around special instrumentation components.

3.5 Cleanliness. The cleanliness requirements of RDT F 5-1 shall apply through all phases of fabrication. A detailed cleaning procedure shall be prepared in accordance with RDT F 5-1 and shall be referenced in the welding procedure specification.

3.6 Backing Strips and Backing Rings. Backing strips and backing rings shall not be used without prior approval by the purchaser.

3.7 Fixtures. The capability of fixtures for aligning parts shall be demonstrated before welding of production parts is initiated. If chill bars or blocks are used, the types of material and their location with respect to the joint shall be included in the procedure specification.

3.8 Position of Qualification Welds. All procedure and performance qualification test welds shall be made in the same positions (see Appendix A) as for production welds.

3.9 Special Conditions for Qualification Welds. All procedure and performance qualification test welds shall be made under conditions which simulate the actual production welding conditions. These conditions shall include space limitations, joint accessibility, degree of discomfort due to heat, position and other handicaps or environmental factors which the welder or welding operator will endure during actual production welding.

3.10 Heat Treatment. Weld preheat and postheat treatments shall not be used without prior approval by the purchaser.

3.11 Interpass Temperature. Weld interpass temperature shall not be less than 60°F or greater than 350°F without prior approval by the purchaser.

3.12 General Visual Inspection Requirements.

3.12.1 Visual examination shall be made under direct daylight-type fluorescent lighting of at least 100 footcandles at the work examination area.

3.12.2 Visual examination shall be performed without the aid of magnifying devices unless otherwise specified.

3.12.3 The inspections required by this standard shall not be performed by the welder or the welding operator who made the welds. However, if the welder or welding operator is qualified in accordance with this standard, he may visually inspect his own welds prior to the inspections required by this standard.

3.12.4 Personnel performing visual inspection shall have 20-20 vision, natural or corrected, stereo acuity, and shall not be color-blind.

3.13 Nondestructive Examination. Nondestructive examination shall meet the requirements of this standard, RDT F 3-6, and the Ordering Data.

3.14 Destructive Testing. Destructive testing shall be performed as specified in each section of this standard.

3.15 Restriction on Halogen and Sulfur Content. The liquid penetrant, ultrasonic coupling, and nondestructive cleaning materials shall be analyzed for chloride, fluoride and sulfur content and shall not exceed the limits specified in the Ordering Data.

3.16 Disposition of Nonconforming Welds. Nonconforming welds shall be disposed of as specified in the Ordering Data.

3.17 Records. Records of welding, associated processing and inspection shall be maintained for all welds. In addition to the requirements listed in each section of this standard, welding records shall include at least the following:

1. Base material (Type, material specification, heat or lot number).
2. Filler material (Type, material specification, heat or lot number).
3. Cleaning procedures.
4. Joint identification and weld maps when applicable.
5. Welding machine type and identification.
6. Welding procedure specification.
7. Welder or welding operator identification.

-
8. Procedure and performance qualifications.
 9. Current-voltage data for machine or automatic welding.
 10. Date welds are made.
 11. Vacuum welding chamber pressure prior to welding or gas back filling.
 12. Inert gas analysis, when applicable.
 13. Heat treatments (preheat, interpass temperature, and post-weld heat treatment), where applicable.
 14. Nondestructive examination procedure.
 15. Nondestructive examination personnel identification.
 16. Examinations and tests (nondestructive and destructive) and the results.
 17. Radiographs, photomacrographs, and photomicrographs.
 18. Metallographic specimens.
 19. Rework and repair of welds.
 20. Disposition of welds.

4. FUEL PIN AND ABSORBER PIN CLOSURE WELDING

This section defines the qualification and welding requirements of fuel pin and absorber pin end closure welding.

4.1 General Qualification Requirements. Fuel pin and absorber pin closure welding shall be in accordance with applicable general requirements of Section 3 and the requirements listed below.

4.1.1 Welding Processes. Welding shall be limited to the gas tungsten arc welding process (GTAW) unless approved by the purchaser.

4.1.2 Welding Equipment. Welding shall be done with automatic or machine welding equipment.

4.1.3 Welding Filler Metals. Filler metals shall not be used unless approved by the purchaser.

4.1.4 Welding Atmosphere.

4.1.4.1 First Closure Welds. The first end cap to tube closure welds shall be made using an inert gas such as argon, helium or a mixture of these gases for the shielding and backing gas. The shielding and backing gases shall have a purity of 99.995 percent.

4.1.4.2 Final Closure Welds. The final closure welds shall be made under conditions which will provide an atmosphere of helium both inside and outside the cladding tube. Helium gas shall be used to provide an inert atmosphere for welding and to provide a closed fuel or absorber pin tube containing helium for leak test purposes (see 4.2.2).

4.1.5 Material Preparation. The parts for qualification welds shall be machined and prepared for welding from the same material and in the same manner as those used for fuel pin and absorber pin fabrication.

4.1.6 Types of Qualification Tests. Welds produced for qualification of joint welding procedures, welding operators and equipment shall be subjected to the following destructive tests and nondestructive examinations:

a. Destructive Tests.

1. Pneumatic test for strength.
2. Metallographic examination of weld cross sections for soundness and acceptable weld bead profiles.

b. Nondestructive Examinations.

1. Radiographic examination for general soundness.
2. Liquid penetrant examination for surface discontinuities.
3. Dimensional measurement for weld reinforcement and distortion determination.
4. Visual examination for surface discontinuities or other abnormal conditions.

4.2 Welding Procedure Qualification.

4.2.1 Essential Variables. The welding procedure specification shall include the essential variables listed below and, where appropriate, it shall include tolerances. If changes are made in the essential variables which exceed the limits specified in the welding procedure specification after the procedure has been qualified, a new procedure specification shall be prepared and completely requalified.

1. Joint design: a detailed sketch shall be included which describes the joint design (the joint geometry, fit-up and other required dimensions of the welded joint), tolerances, and material thickness.
2. Material type, product form and specification.
3. Welding position.
4. Electrode type or grade.
5. Electrode size (diameter).

6. Vertex angle of electrode tip at arc end.
7. Distance of electrode extension beyond gas cup.
8. Gas cup size and type.
9. Method of arc initiation.
10. Type of current (ac, dc, polarity, continuous or pulsing).
11. Method of location and alignment of welding equipment with weld joint.
12. Electrode tip-to-work distance and electrode-to-joint off-set distance.
13. Current program including initial current, welding current, final current, and the current-time relationship. If pulsed current is used, the current program shall include pulse frequency, maximum and minimum currents, pulse and interpulse widths.
14. Voltage and the points where voltage is measured.
15. Method of establishing arc length (fixed distance or automatic arc length control).
16. Welding speed or welding speed program, if variable speed is used during weld cycle.
17. Torch angle (axial and lead) and offset.
18. Gas type and flow rate for shielding and backup gas.
19. Fixtures, heat sinks, and welding chills used for assembly of joint for welding. The location of heat sinks or chills from the joint shall be specified.
20. Procedure for evacuating, determining leak rate and backfilling the welding chamber for making closure welds including all requirements of 4.2.2.
21. Type of welding chamber gloves (material).

4.2.2 Welding Chamber Requirements. Final closure welds shall be made in a controlled atmosphere welding chamber (drybox). Before welding commences, the drybox containing the parts to be welded shall be evacuated to 1×10^{-4} Torr, or less, and backfilled with Grade A Helium (99.995 percent purity) meeting the requirements of Federal Specification BB-H-1168a. Unless otherwise specified by the purchaser, no gas other than helium shall be admitted to the drybox during the welding cycle. The welding procedure specification shall include a gas sampling procedure for sampling and monitoring the chamber atmosphere after back-filling and during the complete drybox welding cycle (defined in 4.4.1.2). The welding procedure specification shall include an analytical method for verifying the gas purity of the chamber atmosphere. Unless otherwise speci-

fied in the Ordering Data, the purity of helium shall not be less than 99.9 percent during the drybox welding cycle. If gas tagging (addition of small quantities of unique isotopic gases to fuel pins for identification in the event of in-reactor fuel pin rupture or leak) of fuel pins is required, the welding procedure qualification shall include a tagging procedure including use of the inert welding gas and tag gas mixture if the tag gas is to be introduced into the drybox along with the inert gas. The gas tagging operation is not required for procedure qualification unless the shielding gas is different than Grade A Helium.

4.2.3 Charts. Current-voltage trace charts shall be recorded for each weld as a part of the procedure qualification.

4.2.4 Weld Lap-Over. Each weld shall be a single-pass weld with a minimum lap-over of 60 (circumferential) degrees at welding current. The current shall then be gradually reduced until the arc is extinguished.

4.2.5 Test Specimens for Closure Welds.

4.2.5.1 Number and Description of Test Specimen. Each welding procedure specification shall be qualified by making forty welds which pass the tests and examinations described in subsequent paragraphs. The allowable tolerances for major parameters in each welding procedure shall be established by making the welds in three "test sets" as described in 4.2.5.2. The welds within each of the test sets shall be made consecutively. Test specimens shall consist of end caps and cladding tubes which duplicate production assemblies in joint design, diameter, configuration and specified material. The cladding tubes shall not be less than three inches long. The welds shall be made with the same equipment and conditions which will be used in production welding.

4.2.5.2 Description of Test Sets.

a. Twelve of the welds shall be made using settings from the ranges and tolerances permitted by the procedure specification which should produce the least depth of fusion (lowest current, fastest speed, shortest weld time, maximum arc length, and the minimum distance between the weld and the welding chill).

b. Twelve welds shall be made using values within specification limits most likely to produce the greatest depth of fusion (highest weld current, slowest speed, longest weld time, minimum arc length, and the maximum distance between the weld and the welding chill).

c. Sixteen welds shall be made using mid-range settings.

4.2.6 Requirements to Pass Qualification Tests. Each weld in each test set shall meet all of the prescribed nondestructive and destructive examinations and test requirements. The failure of one or more welds in any test set shall disqualify that test set. If more than one test set is disqualified, the entire procedure qualification test (40 welds) shall be requalified. If one test set is disqualified, it shall be requalified after corrective action has been taken and the welding procedure specification has been modified to show the changes made. If corrective action and modification involves changes in essential variables (4.2.1) other than those listed in 4.2.5.2, the entire procedure qualification

test (40 welds) shall be requalified. If requalification of the test set fails, the entire procedure qualification test (40 welds) shall be requalified.

4.2.7 Qualification Examinations and Tests.

4.2.7.1 Visual Examination.

a. All closure welds shall be visually examined using optical magnification of not less than 7X.

b. All weld surface and adjacent base metal shall be free of cracks, incomplete fusion, craters, inclusions, porosity, arc strikes, undercut, concavity, spatter or oxidation which results in black or gray flaking or spalling particles. Iridescent temper films and the normal dark metallic vapor deposits which may occur adjacent to the weld are acceptable. These films and deposits shall be removed by approved cleaning procedures.

4.2.7.2 Helium Leak Test. Each closure weld shall be helium leak tested prior to contact with any liquid or grease. Leakage shall not exceed 1×10^{-8} std cc/sec of helium unless otherwise specified by the purchaser.

4.2.7.3 Penetrant Examination. The entire surface of each weld, including the heat-affected zone, shall be examined using a color contrast method for indications in accordance with RDT F 3-6. All indications shall be visually inspected and evaluated. If the cause of the penetrant indication is not visible, the weld shall be reprocessed through penetrant examination. Reappearance of any penetrant indication shall be cause for rejection.

4.2.7.4 Radiographic Examination. Closure welds shall be radiographed in accordance with the Ordering Data. Acceptance criteria are listed below:

1. There shall be no cracks in the welds or heat-affected zone.
2. The fusion zone and heat-affected zone shall be free of any evidence of intergranular attack (mottled appearance on radiograph).
3. The welds shall be free of porosity and inclusions.
4. There shall be complete fusion in the welded joint. Fillet welds with grooves in the end cap under the joint shall show evidence of melt-through. Fillet welds without grooves under the joint shall have fusion to the root of the joint.
5. There shall be no undercuts.
6. The actual throat thickness (minimum leak path) for the fuel pin and the control rod absorber pin end closure welds shall meet the requirements specified in the Ordering Data.

4.2.7.5 Dimensional Inspection. Each weld shall meet the fuel and absorber pin specification requirements.

4.2.7.6 Pneumatic Test. After nondestructive examination has been completed, unless otherwise specified by the purchaser, two welds from test set "a" .

(4.2.5.2), two welds from test set "b" and four welds from test set "c" shall be pneumatically tested. The test weld cladding tube shall not be less than three inches long. Each test sample shall be heated uniformly along its length (within plus or minus 5 degrees of the test temperature) to a test temperature of $1200^{\circ}\text{F} \pm 50^{\circ}\text{F}$ and internally pressurized at a rate that will cause failure in less than three minutes. Failure in the weld or heat-affected zone shall be cause for rejection. When there is doubt as to where the failure originated, the burst pressure shall be within two standard deviations of the mean burst pressure of the balance of the samples tested.

4.2.7.7 Metallographic Examination.

a. The test welds not used for pneumatic testing shall be sectioned longitudinally through the sample, thus permitting examination of two cross sections (180 degrees apart) for each weld. Fifty percent of these welds from each group shall be sectioned at the location where the welding was stopped. The remaining welds shall be sectioned at a location 90° degrees circumferentially from where the weld was stopped. The sections shall be prepared for metallographic examination, measurement, and photography as specified in ASTM E 2 and E 3. The prepared section surfaces shall be truly representative of the entire weld cross section and adjacent base metals, be sufficiently flat from edges to center to permit examination at all points and magnifications required, be free of scratches, stains, and other imperfections which tend to mar its appearance, and contain intact all inclusions which might be present. Metallographic examination for cracks, microfissures, and incomplete fusion in the fusion and heat affected zone shall be done at not less than 100X. Three photographs shall be taken of each sample and shall become a part of the record of the qualification tests. One photomacrograph showing both weld sections in each sample shall be taken at 10X to 20X magnification for the fuel pin samples and at 6X to 8X magnification for the absorber pin samples. One photomicrograph (using brightfield illumination) shall be taken of each weld section from each sample at 50X to 75X magnification for the fuel pin samples and at 20X to 30X magnification for the absorber pin samples. The photomicrographs shall include the weld root areas and the cladding and end cap adjacent to the root areas. All photomacrographs and photomicrographs shall be representative of the actual weld cross sections and adjacent base metals.

b. The cross sections shall be free of incomplete fusion, cracks, grain boundary separations, undercuts, heavy metal inclusions, and porosity or slag inclusions in excess of one pore or slag inclusion per sample. The maximum dimension of any pore or slag inclusion shall not exceed 10 percent of the cladding wall thickness or 0.003 inch, which ever is less.

c. The actual throat thickness (minimum leak path) for fuel pin end closures and for control rod absorber pin end closures shall meet the requirements specified in the Ordering Data.

4.2.8 Repairs. Qualification test welds shall not be repaired.

4.3 Performance Qualification.

4.3.1 Welding Operator Qualification. Qualification requirements for

welding operators shall be the same as for procedure qualification in 4.2, except (1) any setting for current, etc., within the range of essential variables qualified may be used, (2) only twenty welds are required, and (3) only four pneumatic tests are required. Welding operators who make acceptable procedure qualification tests or welding power supply and associated fixture performance qualification tests are qualified for that welding procedure.

4.3.2 Welding Power Supply and Associated Fixture Qualification. The capability of the welding power supply and associated major equipment shall be demonstrated by welding in accordance with 4.2 before any production welding is performed on fuel or absorber pin closures with one exception. Only six welds are required at the high and low range conditions and only eight welds are required for the mid-range conditions; only one pneumatic test is required at each of the high and low range conditions, and only two pneumatic tests are required for the mid-range conditions. Any welding power supply and associated equipment or fixtures used to make acceptable procedure qualification test assemblies shall be considered qualified.

4.3.3 Regualification of Welding Operators, Equipment or Welding Procedures.

4.3.3.1 When four or more of any forty consecutive fuel or absorber pin closure welds made in production by one welding operator to a given welding procedure on the same equipment do not meet the specification requirements due to any of one type defect or when eight or more of the 40 consecutive welds are rejected for any reason, the following action shall be taken:

1. The balance of the 40 welds shall be considered as nonconforming items.
2. It shall be determined whether the cause of the reject welds is due to equipment malfunction, welding operator performance or the welding procedure.
3. If it is determined that the fault is equipment malfunction, corrective action shall be taken and recorded. If more than four of the next group of 40 consecutive welds made on the equipment do not meet specification requirements due to any one type defect, a complete equipment requalification test shall be made.
4. If it is determined that the fault is due to welding operator performance, a complete performance qualification test shall be made.
5. If it is determined that the fault is due to an unsatisfactory welding procedure, a complete procedure qualification test shall be made.

4.3.3.2 When a welding operator has not made welds in accordance with the applicable procedure for a 90-day period, a complete performance qualification test shall be made.

4.4 Fuel Pin and Absorber Pin Production Welding.

4.4.1 Definitions.

4.4.1.1 Weld-Lot. A weld-lot is defined as all welds made in one drybox cycle, or a group of welds, not to exceed 100, made in succession in one out-of-drybox welding cycle by the same welding operator using the same equipment throughout.

4.4.1.2 Drybox Welding Cycle. The completion of drybox welding preparation requirements of 4.2.2 and the start of production welding shall be defined as the beginning of a drybox welding cycle. The cycle shall be considered terminated when:

1. All joints in the drybox at the time welding started have been completed,
2. Any condition requisite to the beginning of welding ceases to exist, or
3. A change is made in the welding operator or associated equipment.

4.4.1.3 Out-of-Drybox Welding Cycle. The out-of-drybox welding cycle shall begin with the start of production welding under specification conditions. The cycle shall be considered terminated when:

1. All joints prepared for welding have been completed,
2. Any condition requisite to the beginning of welding ceases to exist, or
3. A change is made in the welding operator or associated equipment.

4.4.2 General Fuel Pin and Absorber Pin Closure Welding Requirements. Fuel and absorber pin closure welding shall be performed in accordance with qualified and approved welding procedures as defined in 4.1 through 4.3.

4.4.3 Weldability Tests. Not less than six weldability tests shall be made using a duplicate of the production weld joint configuration and applicable welding procedure for each base material heat or combination of base material heats which are intended for production welding. The welds shall be evaluated metallographically in accordance with the requirements 4.2.7.7. If the welds do not meet the specified requirements, the base materials being evaluated shall be considered as nonconforming. The presence of tungsten inclusions shall not be cause for rejection.

4.4.4 First and Last Weld. In addition to all other examinations and tests, representative samples of the first and last welds made by a welding operator at the beginning and end of any shift or every weld-lot, whichever is less, shall be examined visually, dimensionally and metallographically in accordance with the requirements specified in 4.2.7.1, 4.2.7.5, and 4.2.7.7. Test specimens shall be a minimum of three inches long and shall duplicate production assemblies in joint design, diameter, and configuration. The test specimens shall be made from the same heats of material that is used in the production welds.

a. Current-voltage trace charts shall be made for the first and last welds.

b. Welded samples shall be sectioned at the location where welding terminated.

c. Production welds shall not be accepted until results of the test welds are determined. In the event of failure of a test weld, two additional joints shall be examined. Should either of these welds fail, the end closure welds made during the shift shall be considered as nonconforming items.

4.4.5 Closure Welding Acceptance Examination and Testing. All closure welds shall be examined and tested in accordance with procedure qualification tests in 4.2.7 except for penetrant tests, pneumatic tests, and metallographic examination unless otherwise specified in the Ordering Data.

5. WRAP WIRE WELDING

This section defines the qualification and welding requirements for "end cap to wrap wire" welds, hereafter called wrap wire welds. Wrap wire welds as used in this standard are defined as welds between the ends of small diameter wires and fuel pin and absorber pin end caps.

5.1 General Qualification Requirements. Wrap wire welding shall be in accordance with applicable general requirements of Section 3 and the requirements listed below.

5.1.1 Welding Process. Welding shall be limited to the gas tungsten arc welding process (GTAW) unless approved by the purchaser.

5.1.2 Welding Equipment. Welding may be done with manual, automatic or machine welding equipment. Welding equipment shall include current decay controls.

5.1.3 Material Preparation. The parts for qualification welds shall be machined and prepared for welding from the same material and in the same manner as those used for production welding.

5.1.4 Types of Qualification Tests. Joint welding procedures, welders, welding operators, and equipment shall be qualified by the following destructive and nondestructive tests of sample welds:

1. Tensile tests for strength.
2. Metallographic for soundness and weld bead profiles.
3. Visual examination for surface discontinuities, profile, or other abnormal conditions.
4. Radiographic examination for soundness and weld bead profiles.
5. Dimensional measurement to determine compliance with drawing or standards requirements.

5.2 Welding Procedure Qualification.

5.2.1 Essential Variables. The welding procedure specification shall include the essential variables listed below and, where appropriate, it shall include tolerances. If changes are made in the essential variables which exceed the limits specified in the welding procedure specification after the procedure has been qualified, a new procedure specification shall be prepared and completely requalified.

1. Joint design: a detailed sketch shall be included which describes the joint design (the joint geometry, fit-up and other required dimensions of the welded joint), tolerances and material thickness.
2. Material type, product form and specification.
3. Welding position.
4. Electrode type or grade.
5. Electrode size (diameter).
6. Vertex angle of electrode tip at arc end.
7. Distance of electrode extension beyond gas cup.
8. Gas cup size and type.
9. Method of arc initiation.
10. Method of current decay used for manual welding.
11. Type of current (ac, dc, polarity, continuous or pulsing).
12. Filler metal type and size.
13. Electrode tip-to-work distance (automatic or machine welding only).
14. Current program including initial current, welding current, final current and the current-time relationship (automatic or machine welding only). If pulsed current is used, the current program shall include pulse frequency and pulsed current envelope.
15. Voltage and the points where voltage is measured.
16. Method of establishing arc length (fixed distance or automatic arc length control) (automatic or machine welding only).
17. Torch angle (axial and lead, automatic or machine welding only).
18. Gas type and flow rate.
19. Fixtures, heat sinks, and welding chills used for assembly of joint for welding. The location of heat sinks or chills from the joint shall be specified.

5.2.2 Charts. Current-voltage trace charts shall be recorded for each weld as a part of the procedure qualification for automatic or machine welding. Calibrated current and voltage indicating meters may be substituted for trace chart type equipment for manual welding. The current and voltage ranges shall be recorded for manual welding.

5.2.3 Test Specimens. The test specimens shall duplicate production end cap to wrap wire assemblies in joint design, diameter and specified material. The test specimens shall be long enough to permit the required tension tests to be performed. The use of cladding tubes is not required to be a part of these test weld specimens. The welds shall be made with the same welding equipment to be used in production welding.

5.2.3.1 Number of Test Specimens. Welding procedures for automatic or machine welds shall be qualified by making twenty welds of the types described in the welding procedure specification. Welds within each of the three test sets described in 5.2.3.2.a, b and c, below, shall be made consecutively. Manual welds shall be qualified by making ten consecutive welds described in the procedure specification. Each of the welds shall pass the tests and examinations described in subsequent paragraphs.

5.2.3.2 Description of Test Sets.

a. Six welds shall be made using settings for the ranges and tolerances permitted by the procedure specification which should produce the least depth of fusion (lowest current).

b. Six welds shall be made using values within specification limits most likely to produce the greatest depth of fusion (highest current).

c. Eight welds shall be made using mid-range settings.

5.2.3.3 Requirements to Pass Qualification Tests.

a. Each weld in each test set for automatic or machine welding shall meet all of the prescribed nondestructive and destructive examinations and test requirements. The failure of one or more welds in any test set shall disqualify that test set. If more than one test set is disqualified, the entire procedure qualification test (20 welds) shall be requalified. If one test set is disqualified, it shall be requalified after corrective action has been taken and the welding procedure specification has been modified to show the changes made. If corrective action and modification involves changes in essential variables (5.2.1) other than those listed in 5.2.3.2, the entire procedure qualification test (20 welds) shall be requalified. If requalification of the test set fails, the entire procedure qualification test (20 welds) shall be requalified.

b. If one or more manual welds fail to meet all of the prescribed non-destructive and destructive examination and test requirements, the entire procedure qualification test (10 welds) shall be requalified.

5.2.4 Repairs. Qualification test welds shall not be repaired.

5.2.5 Qualification Examinations and Tests.

5.2.5.1 Visual Examination. All welds shall be visually examined using optical magnification of not less than 7X. All weld surface and adjacent base metal shall be free of cracks, incomplete fusion, craters, inclusions, porosity, arc strikes, undercut, overlap, spatter or oxidation which results in black or gray flaking or spalling particles. Iridescent temper films and the dark metallic vapor deposits which may occur adjacent to the weld are acceptable. These films and deposits shall be removed by approved cleaning procedures. Fillet welds between the end of the wire and the end cap shall not show concavity. Plug welds on "wire-through-hole" joints shall not show concavity greater than 0.005 inch.

5.2.5.2 Dimensions. Each weld shall meet fuel pin and absorber pin drawing and standards requirements.

5.2.5.3 Radiographic Examination. All welds shall be radiographed in accordance with the requirements of the Ordering Data. Radiographs of welds that show cracks, incomplete fusion, insufficient joint penetration, undercut, porosity, or inclusions shall be unacceptable.

5.2.5.4 Tensile Testing. One-half of the test welds shall be tensile tested. The tensile load shall be applied to the wrap wire parallel to the longitudinal axis of the end cap. The wrap wire to end cap strength shall be equal to or greater than the specified ultimate tensile strength of the wire in the annealed condition or as specified in the Ordering Data.

5.2.5.5 Metallographic Examination. All test weld samples, not used for tensile testing, shall be sectioned longitudinally to permit examination at the approximate centerline of the weld. All welds shall be prepared for examination, metallographically measured and photographed as specified in ASTM E 2 and E 3. Metallographic examination for cracks, microfissures and incomplete fusion in the fusion and heat affected zones shall be done at not less than 100X. Magnification shall be 10X for photographic purposes. The photographs shall become part of the welding records. The cross sections shall be free of cracks, incomplete fusion, heavy-metal inclusions and porosity or slag inclusions in excess of one pore or slag inclusion per sample. The maximum dimension of any pore or inclusion shall not be greater than 10 percent of the wire diameter or 0.002 inch, whichever is less. Plug welds shall have joint penetration of at least 1/2 the wire diameter. In the case of fillet welds, fillet weld leg and throat dimensions shall not be less than the minimum wire diameter in thickness.

5.3 Performance Qualification.

5.3.1 Welders and Welding Operators. Qualification requirements for welders or welding operators shall be the same as for procedure qualification except (1) any setting within the range of essential variables previously qualified may be used, and (2) only ten welds are required. Any welder or welding operator who makes acceptable procedure qualification tests or welding machine and associated fixture performance qualification tests is also qualified.

5.3.2 Welding Machines and Associated Fixtures. Before any welding is performed on production assemblies, the capability of welding machines and associated fixtures shall be demonstrated by welding in accordance with 5.2. Any welding machine and associated equipment used to make acceptable procedure, welder, or welding operator qualification test assemblies shall be considered qualified.

5.3.3 Regualification of Welders, Welding Operators, or Equipment.

a. When 20 percent or more of welds in any weld production lot do not meet specification requirements, the following action shall be taken:

1. It shall be determined whether the cause of the reject welds is due to equipment malfunction, welding operator performance or the welding procedure.
2. If it is determined that the fault is equipment malfunction, corrective action shall be taken and recorded. If more than 20 percent of the next weld lot do not meet specification requirements, a complete equipment regualification test shall be made.
3. If it is determined that the fault is due to welding operator performance, a complete performance qualification test shall be made.
4. If it is determined that the fault is due to an unsatisfactory welding procedure, a complete procedure qualification test shall be made.

b. If a welder or welding operator has not made welds in accordance with the applicable procedure in a 90-day period, he shall be required to weld three consecutive samples which meet all of the requirements of 5.2.5.1 and 5.2.5.2 and 5.2.5.5, before he can make production welds. If any of the three welds do not comply with the requirements, he shall repeat the test except that six consecutive test samples shall be made. If any of the six samples fail to comply with the requirements a complete performance qualification test shall be made.

5.4 Wrap Wire Production Welding.

5.4.1 Definitions.

5.4.1.1 Weld-Lot. A weld-lot shall be defined as a group of wrap wire welds, not to exceed 200, made in succession in one welding cycle by the same welder or welding operator using the same equipment.

5.4.1.2 Welding Cycle. The beginning of a welding cycle shall be defined as the time when the welding of a given lot of material, previously prepared and assembled, was started. The cycle shall be considered terminated when:

- a. All welds in a lot are completed.
- b. Any condition requisite to the beginning of welding ceases to exist.
- c. A change is made in welder, welding operator or associated equipment.

5.4.2 General Production Welding Requirements. Wrap wire welding shall be performed in accordance with qualified welding procedures.

5.4.3 Weldability Tests. Three weldability tests shall be made using a duplicate of the production weld joint configuration and applicable welding procedure for each base material (wrap wire and end cap) heat or combination of base material heats which are intended for welding without filler metal additions. All three test samples shall be evaluated by examining metallographic cross sections of the fusion and heat-affected zones. The welds shall comply with the requirements of 5.2.5.5, except that the presence of tungsten inclusions shall not be cause for rejection.

5.4.4 First and Last Weld. In addition to all other examinations and tests, representative samples of the first and last welds made by a welder or welding operator at the beginning and end of any shift or weld-lot shall be examined visually and dimensionally in accordance with the requirements for such tests specified in 5.2.5.1 and 5.2.5.2. Additional inspections and examinations shall comply with the requirements as specified in the Ordering Data. Test specimens shall duplicate production assemblies and specified material. No welds shall be accepted until results of the test welds are determined. In the event of failure of a test weld, two additional welds shall be examined. Should either of these welds fail, the welds made during the shift shall be considered as nonconforming items.

5.4.5 Wrap Wire Weld Acceptance Examination and Testing. All wrap wire welds shall be examined and tested in accordance with the requirements specified in the Ordering Data.

6. REACTOR CORE COMPONENT WELDING (All Processes Except Resistance Welding)

Except for resistance welding, this section, in addition to Section 3, contains the minimum welding qualification requirements and the minimum welding fabrication requirements for the reactor core components and subcomponents except for the absorber pin and fuel pin end closure and wrap wire welds and test assembly welds which are contained in Sections 4, 5, and 8.

6.1 General Welding Qualification Requirements.

6.1.1 Types of Tests Required. The following tests shall be used for the qualification of welding procedures, welders and welding operators where applicable:

1. Nondestructive examination by a liquid penetrant method, and visually to test for soundness and surface characteristics of the weld.
2. Nondestructive examination by radiographic or ultrasonic methods to test for soundness of the weld.

3. Helium leak testing of the test weld to determine the tightness of the weld joint when this method of testing is required for the production joints.
4. Tension tests, for procedure qualification tests only, to determine the tensile strength of groove welded joints.
5. Sectioning for metallographic examination of weld joints and adjacent areas to test for fusion, weld geometry, weld reinforcement, and soundness of the weld.

6.1.2 Nondestructive Examination and Tests.

- a. Visual. The test weld shall be examined visually prior to welding and after welding in accordance with 6.3.2.
- b. Liquid Penetrant. The test weld shall be examined after the deposition of the root pass and after the final layer in accordance with 6.3.3 using a color contrast method. If joint surfacing is used to provide weld metal in the joint, each layer shall be examined in the same manner and shall meet the same requirements as the root pass and final layers.
- c. Helium Leak Testing. When required, the test weld shall be helium leak-tested in accordance with 6.3.6.
- d. Radiographic or Ultrasonic Examination. Butt joints with complete joint penetration in materials greater than 0.050 inch thick shall be radiographed or ultrasonically examined in accordance with 6.3.4 or 6.3.5. If the configuration of the assemblies is such that these examinations cannot be performed properly, each layer of multiple pass welds shall be liquid penetrant examined.

6.1.3 Destructive Examination and Tests.

- a. Metallographic Examination. Each test weld shall be sectioned transversely to examine a minimum of:
 1. Two section faces for welds on cylindrical components less than 1-1/4 inch in diameter or for welds that are one to four inches long on non-cylindrical components.
 2. Four section faces for welds in cylindrical components that are greater than 1-1/4 inch in diameter or for welds that are greater than four inches long on noncylindrical components.
 3. One section face for plug welds, arc spot welds, and welds that are less than one inch long on noncylindrical components.

The cross section shall be polished and etched to provide clear definition of the structure in the fusion zone and the heat-affected zones.

For welds in (1) and (2) of this paragraph, one cross section shall be made through a weld start and a weld stop area and the remaining sections shall be made

at random. For welds described in (3) of this paragraph, the cross section shall be made at the approximate centerline of the weld. Examination of the welds shall be in accordance with 6.3.7.

b. Tension Testing. A tensile specimen shall be removed from one of the procedure qualification test welds representing circumferential butt joints (including "butt-lap" type joints) with complete joint penetration in materials 0.090 inch thick or greater in the reactor core component outer assemblies. After nondestructive testing, one tensile test specimen shall be removed by mechanical cutting or machining from the assembly, prepared and tested in accordance with Paragraph Q-6 or QN-6 of Section IX, of the ASME Boiler and Pressure Vessel Code. The tension specimen shall be taken from a location where a weld-start and weld-stop occurred.

6.1.4 Procedure Qualification.

a. Qualification. Each supplier shall record in detail and shall qualify the procedure specification for any welding procedure used on reactor core welded joints and assemblies. All welding used in qualifying a welding procedure shall be performed in accordance with the procedure specification.

b. Procedure Specification. Prior to any production welding, each welding procedure specification and a copy of the detailed results shall be submitted to the purchaser for approval. The procedure specification shall include all of the essential variables as a minimum, together with the additional information listed in Table 1. The essential variables and the additional information shall be specified in sufficient detail to assure that compliance with the requirement of the procedure can be verified.

c. Essential Variables. The welding procedure shall be set up as a new welding procedure specification and shall be completely requalified when any of the changes listed in Table 2 are made in the procedure.

TABLE 1: ADDITIONAL INFORMATION TO BE INCLUDED IN PROCEDURE SPECIFICATION

1. Joint Design: (the joint geometry, fit-up, and other required dimensions of the welded joint) tolerances and material thickness.
2. Interpass temperature and method of measuring (for multiple pass welds only).
3. Methods of arc initiation.
4. Electrode size (for gas tungsten arc welding).
5. Gas type and flow rate (shielding and backing gas).
6. Welding current range for manual welding.
7. Whether tack welds or fixtures are used for assembly of the joint for welding.
8. Method and frequency of cleaning.
9. Number of weld layers and passes.
10. Whether stringer beads or weave beads are used.
11. For automatic or machine arc welding only:
 - 11.1 Method of establishing and controlling arc length or voltage current, welding speed, and filler wire speed.
 - 11.2 If pulsed current is used, the pulse frequency, maximum and minimum current levels, pulse width and interpulse width.
 - 11.3 Torch oscillation amplitude, dwell and frequency.
 - 11.4 Detailed current slope control.
 - 11.5 Torch **angle** (axial and lead) and offset from the joint.

TABLE 2: ESSENTIAL VARIABLES

1. General, All Welding Processes.

- 1.1 A change from a base material type or grade (materials of the same nominal chemical analysis and mechanical property range, even though a different product form) to any other base material type or grade. When joints are made between two different types or grades of base material, a procedure qualification shall be made for the applicable combinations of materials, even though procedure qualification tests have been made for each of the two base materials welded to itself.
- 1.2 A change of filler metal type or classification to any other type or classification.
- 1.3 A change in welding position.
- 1.4 A change in vertical welding direction, i.e., from upward to downward or vice versa.
- 1.5 The omission or addition of integral backing (e.g., "butt-lap" type joint).
- 1.6 The addition or omission of nonfusing metal retainers.
- 1.7 The addition or omission of filler metal to the joint.
- 1.8 Any change in the method by which filler metal is added, such as preplaced shims, preplaced wire, preplaced consumable inserts, wire feed, or prior weld metal surfacing ("buttering") of one or both joint faces.
- 1.9 The addition or omission of any type of preplaced consumable inserts or joint surfacing.
- 1.10 A change in the shape or size of preplaced inserts or a change which exceeds the thickness range qualified for joint surfacing.
- 1.11 A change from multiple pass welds to single pass welds.
- 1.12 The omission of inert gas backing during welding, except that requalification is not required where a qualified welding procedure is changed to omit the inert gas backing and then is used only for a single welded butt joint with a backing strip, or a fillet weld. For multiple pass welding, the omission of inert gas backing during welding until three weld layers or 3/16 inch of weld metal thickness has been deposited, whichever is greatest.
- 1.13 A change from one welding process to any other process or combination of welding processes.

(continued)

TABLE 2: ESSENTIAL VARIABLES (continued)

2. Manual Welding, All Welding Processes.

- 2.1 An increase in the standard size of filler metal used in the first two passes from that stated and qualified in the procedure specification or an increase of more than one standard size for subsequent passes.
- 2.2 A change in joint geometry which violates the tolerances given for the joint geometry elements listed below:
 - 2.2.1 Bevel Angle: State in procedure specification. Tolerance: Minus 5%.
 - 2.2.2 Groove Angle: State in procedure specification. Tolerance: Minus 5%.
 - 2.2.3 Root Face: Assign thickness value and tolerance in procedure specification. Qualify procedure using greatest thickness permitted by tolerance.
 - 2.2.4 Root Opening: Assign value in procedure qualification and tolerances. Qualify procedure using smallest opening permitted by tolerance when filler metal is added. Qualify procedure using largest opening permitted by tolerance when filler metal is not added.
 - 2.2.5 Groove Radius: Assign value in procedure specification including tolerance.
 - 2.2.6 Alignment Tolerance: Assign value in procedure specification. Qualify procedure for single welded joints using maximum permissible misalignment in a portion of the joint.
- 2.3 A change in material thickness greater than minus 1/2 to plus 2 times the thickness qualified when welding parts with the same material thickness, or a change in the thickness of the thin member greater than minus 1/2 to plus 2 times the thickness qualified when welding a thin member to a thick member. However, for materials less than 0.0625 inch thick any change in materials thickness beyond the range qualified shall be completely requalified. No requalification shall be required for groove welds in materials greater than 0.0625 inch thick, regardless of maximum thickness, provided all of the following requirements are met:
 - 2.3.1 The weld joint length is greater than 1-1/2 inches.
 - 2.3.2 Incomplete joint penetration is specified for 100% of the joint length.

(continued)

TABLE 2: ESSENTIAL VARIABLES (continued)

- 2.3.3 The root face is greater than the specified size of the weld.
 - 2.3.4 The root opening is not greater than 0.01 inch.
 - 2.3.5 A groove weld with the same joint geometry and tolerances, excluding root face, has been qualified and is included in the procedure specification.
3. Machine or Automatic Welding, All Welding Processes.
- 3.1 A change from single arc to multiple arc or vice versa.
 - 3.2 Except for electron beam welding, a change in the voltage or amperage outside the range used in the procedure qualification or when only one voltage or amperage is used in the procedure qualification, a change of more than plus ten percent or minus five percent.
 - 3.3 Except for electron beam welding, a change in the travel speed outside the range used in procedure qualification or when only one travel speed is used in the procedure qualification, a change of more than plus five percent or minus ten percent.
 - 3.4 A change in the nominal size of filler metal.
 - 3.5 A change in the wire feed rate outside of the range used in the procedure qualification or where only one wire feed rate was used in procedure qualification, a change of more than five percent.
 - 3.6 A change of any dimension of the weld joint, material thickness, and number of passes beyond the range qualified, or a change in the weld length of more than plus or minus thirty percent.
4. Gas Tungsten Arc Process.
- 4.1 A change of electrode material type.
 - 4.2 A change in arc starting methods.
 - 4.3 A change from a single shielding gas to any other shielding gas or to a mixture of shielding gases or a change in specified composition of gas mixture.
 - 4.4 A decrease in shielding gas flow rate of more than ten percent.
5. Electron Beam Welding Process.
- 5.1 A change in the variables listed below which is outside the range used in the procedure qualification or when single values are

(continued)

TABLE 2: ESSENTIAL VARIABLES (continued)

- 5.1.1 Beam current ($\pm 5\%$).
- 5.1.2 Beam voltage ($\pm 2\%$).
- 5.1.3 Welding speed ($\pm 2\%$).
- 5.1.4 Gun-to-work distance ($\pm 5\%$).
- 5.1.5 Beam focus point ($\pm 1/16$ inch).
- 5.2 An increase in the absolute pressure of the vacuum chamber beyond that qualified.
- 5.3 A change in frequency of oscillation beyond that qualified.
- 5.4 A change in size or shape of filament.
- 5.5 A change in beam pulsing frequency or duration beyond that qualified.
- 5.6 A change in beam trajectory (deflection pattern or shape if other than X or Y type oscillation).
- 5.7 For circular or circumferential welds a change in the amount of lap-over, beam power decay program and speed change control program beyond the ranges qualified.
- 5.8 The addition of a wash pass (cosmetic pass).
- 5.9 A change of welding from one side to welding from both sides, or vice versa.
- 5.10 An increase in the root opening beyond that qualified.

d. Test Welds.

1. The procedure qualification shall be made on test welds which duplicate the production weld joint type and which simulate the conditions to be used in production with respect to orientation, the essential variables listed in Table 2, and the dimensions of the parts to be joined to the extent that they affect heat requirements, relative motions, and distortions. All welding used in qualifying a welding procedure shall be performed in accordance with the procedure specification.
2. For automatic or machine welding at least six consecutive test welds representing the range of dimensions to be qualified shall be required.
3. For manual welding, two consecutive test welds shall be made when the weld joint is less than 6 inches in length. Only one test weld shall be required when the weld joint is 6 inches or greater in length.
4. All test welds shall be tested using the required tests listed in this section. To qualify the procedure specification used in making the test welds, each weld shall pass the required tests.

e. Chart Recordings. Current-voltage-time charts shall be made for each procedure and performance qualification weld for automatic or machine welding. Calibrated current and voltage indicating meters may be substituted for trace chart type equipment for manual welding. The current and voltage ranges shall be recorded for manual welding.

6.1.5 Performance Qualification.

a. General.

1. The performance qualification tests are intended to determine the ability of welders, welding operators and welding machines to make sound welds.
2. The performance test may be terminated at any stage of the testing procedure whenever it becomes apparent to the supervisor conducting the tests that the welder or welding operator does not have the skill required to produce satisfactory results. In this event, the welder or welding operator may be tested at the discretion of the supplier in accordance with 6.1.5.b.
3. Each supplier shall maintain a record of the procedures, including the essential variables, under which welders and welding operators are examined and the results of the examinations.
4. Each qualified welder and welding operator shall be assigned an identifying number, letter, or symbol by the supplier which shall be used to identify the work of that welder or welding operator.

b. Qualification of Welders and Welding Operators.

1. Welders. Each welder shall pass the tests prescribed for procedure qualification except that tensile tests are not required. The essen-

tial variables and the test results obtained by each welder shall be recorded in a Performance Qualification Test Report. Any welder who performs acceptable welding procedure qualification tests shall be considered qualified.

2. Welding Operators. The welding operator shall qualify using a welding machine which will be used to make production welds and shall be required to set up the machine with regard to adjustments which affect the welding characteristics. Any welding operator who performs acceptable procedure or welding machine qualification tests shall be considered qualified for the welding procedure used. Each welding operator shall pass the tests prescribed for procedure qualification except that tensile tests are not required and only three test welds shall be required.

c. Welding Machine Qualification. Each welding machine shall have its capabilities demonstrated by welding acceptable test welds. These test welds shall meet the same requirements specified for the test weld in 6.1.4.d, and shall be nondestructively and metallographically examined in accordance with the requirements for the procedure qualification test welds except that only three test welds are required for automatic or machine welding.

d. Renewal of Qualification. Regualification of a welder or welding operator is required when (1) 90 or more days have elapsed since he last produced acceptable welds using the specific welding process including the same P-number base material and the same A or F-number filler material, listed in Section IX, ASME Code, or (2) he has not produced acceptable welds using the production welding procedure. Any time there is a specific reason to question a welder's or welding operator's, or welding machine's ability to make welds meeting the requirements of Section 6, requalification shall be required. Only one test weld shall be required for renewal of qualification. If this test weld fails to meet all of the original requirements, then a complete performance requalification shall be required. However, any automatic or machine welding equipment used to weld acceptance procedure or welding operator qualification tests shall be considered qualified for the welding procedure used provided that the number of welds meets the requirements of this paragraph. Welding machines used for the manual welding of any successful procedure or welder qualification tests shall be qualified for manual welding of all core components covered in this section.

6.1.6 Repair of Welds From Procedure and Performance Qualification Test Welds. Procedure and performance test welds shall not be repaired.

6.2 Welding Fabrication Requirements.

6.2.1 Weldability Test. One weldability test shall be made using a duplicate of the production weld joint configuration and applicable welding procedure for each base material heat or combination of base material heats which are intended for welding without filler metal additions. The weld joint shall be subjected to the same type of restraint as the production joint. The welds shall be evaluated by examining four metallographic specimens consisting of full cross sections of the fusion zone and the heat-affected zone. If the test weld is not

large enough to provide the required number of specimens, additional test welds shall be made to provide the required number. The specimens shall be prepared in accordance with the applicable section(s) of ASTM E 3 and shall be examined at 50X. The welds shall be free of cracks or fissures in the fusion and heat-affected zones and porosity in excess of the requirements of this section. The presence of tungsten inclusions shall not be cause for rejection. If the melting characteristics are sufficiently different to preclude meeting the profile and soundness requirements for the applicable qualified procedure, a new welding procedure shall be established and qualified.

6.2.2 Cleaning Process for Base Materials and Filler Materials. Cleaning processes shall be in accordance with RDT F 5-1. Cleaning agents and solvents shall be technical grade or better. Cleaning procedures for both base material and filler material shall be referenced in the welding procedure specifications.

6.2.3 Handling and Storage of Cleaned Materials Prior to Welding and Subsequent to Welding. Cleaned materials and parts shall be handled and protected from damage and contamination in accordance with RDT F 5-1. Handling and cleanliness protection procedures shall be referenced in the welding procedure specification.

6.2.4 Joint and Weld Surface Preparation.

a. Thermal cutting or gouging processes shall not be used for joint preparation or defect removal.

b. Chipping hammers and similar tools which work harden the base materials shall not be used for joint preparation or defect removal.

c. Shot, sand or vapor blasting shall not be used for cleaning joints or welds.

d. Mechanical cleaning tools such as grinding, polishing, filing, deburring and brushing tools shall be in accordance with the requirements of RDT F 5-1.

e. Joint edges and adjacent surfaces which have been cleaned and subsequently exposed to an atmosphere other than a "clean room" for more than four hours shall be wire brushed and scrubbed with technical grade or better alcohol or acetone and "wipe" tested in accordance with RDT F 5-1.

f. Interpass weld beads shall be clean and free of oxides, dross, slag, oil grease, lint or other foreign material. If these substances are present they shall be removed and the weld and adjacent surfaces shall be cleaned in accordance with 6.2.2 and the other requirements listed in 6.2.4.

6.2.5 Fitting and Alignment Methods. Parts that are to be welded may be fitted, aligned, and retained in position during the welding operation by bars, clamps, fixtures and/or tack welds. Bars, clamps and parts of fixtures which contact the base material parts shall be made of austenitic stainless steel, nickel base alloys or other materials which will not smear, embed or otherwise contaminate the base materials. Temporary attachments to the base materials for the purpose of fitting or aligning shall not be attached by welding.

6.2.6 Joint Alignment and Joint Mismatch. Joint alignment and joint mismatch shall be such that all drawing requirements are fulfilled.

6.2.7 Tack Welds. Tack welds used to secure alignment shall either be removed completely, when they have served their purpose, or their stopping and starting ends shall be properly prepared by grinding or other suitable means so that they may be satisfactorily incorporated into the final weld. Tack welds shall be made by qualified welders or welding operators. When tack welds are to become part of the finished weld they shall be visually examined at not less than 5X and they shall meet the same acceptance standards as the final weld. Defective tack welds shall be removed. Welders or welding operators who have successfully performed procedure or performance qualification tests are qualified to make tack welds.

6.2.8 Shielding and Purging Gases.

a. All welds, backsides of welds and tack welds exposed to air, and adjacent base metal shall be protected with argon, helium or mixture of these gases to prevent contamination and oxidation during heating or cooling when nonvacuum welding processes are used.

b. Shielding, backing and purging gases shall be welding grade (99.995 percent purity) unless otherwise specified.

c. When gas purging is required, the purging gas shall be allowed to flow long enough to provide at least six volume changes within the tube enclosure behind the joint, or within the gas backing groove if a backing fixture is used, or the purging gas shall be analyzed with a gas analyzer at the gas exit to assure that the gas passing the joint contains less than one percent oxygen.

d. Procedures for shielding and purging each joint type shall be described in the welding procedure specification.

6.2.9 Single Welded Joints. Single welded joints with complete joint penetration which do not permit examination of the back surfaces shall have the root pass applied by the gas tungsten-arc process.

6.2.10 Double Welded Joints. Before applying weld metal on the second side to be welded, the root of double-welded joints shall be prepared by suitable methods such as grinding or machining except for those processes of welding by which proper fusion and penetration are otherwise obtained and demonstrated to be satisfactory by welding procedure qualification.

6.2.11 Wash-Pass Welding. Gas tungsten-arc welding without the addition of filler metal shall not be used for the purpose of surface finishing welds.

6.2.12 Arc Strikes. Arc strikes shall be removed from completed welds or adjacent base metal. The arc strike area shall be liquid penetrant inspected. Arc strikes which occur in the weld joint shall be visually examined at not less than 5X magnification and repaired if defects are detected, before welding is continued. During component assembly if arc strikes, ground clamp burns, or

high frequency burns occur on absorber pin or fuel pin cladding, those parts shall be rejected.

6.2.13 Peening. Peening shall not be used.

6.2.14 Disposition of Nonconforming Welds and Repairs.

a. Approval for Repair. Defects in base materials shall not be repaired unless authorized by the purchaser.

b. Repair Procedure. Weld repairs, except those listed below, shall be performed in accordance with approved general weld repair and inspection procedures. Specific approval shall be obtained from the purchaser to make repairs of cracks or fissures which recur in the weld, heat-affected zone, or adjacent base metal after the first cycle of repair.

c. Defect and Repair Verification. Prior to any repair welding, defect removal shall be verified by visual and liquid penetrant inspection. Completed repairs shall be visual and liquid penetrant inspected. Areas which contained defects originally detected by other nondestructive test methods shall be re-inspected by that method after the weld repair is completed. Inspection methods and acceptance criteria shall be in accordance with 6.3 of this standard.

d. Repair Records. Records shall be maintained on all repairs and shall include the following:

1. Location of joint.
2. Location of defect.
3. Description of defect, including type and size.
4. Reference to approved repair procedure.
5. Inspections before and after repair and the results thereof.
6. Identification of repair welders or welding operators.

6.3 Inspection, Examination and Tests of Qualification and Production Welds.

6.3.1 General.

a. All nondestructive testing shall be done in accordance with RDT F 3-6, this standard, and the Ordering Data.

b. When the purchaser has reason to believe that the quality of any weldment is doubtful, he may require additional inspection.

c. All component drawings which show welded joints shall indicate the joints that are to be inspected or tested by means of symbols in accordance with the

Nondestructive Testing Symbols AWS A2.2 or by means of general notes with reference to written instructions.

d. Unless specifically approved by the buyer, acceptance inspection of all welds shall be performed on the welds in the final surface condition. Welds not accessible for inspection after final assembly shall be inspected prior to the final assembly operation. Inspection of root or intermediate weld layers may be performed in the as-welded condition. Unless otherwise specified, inspection of procedure and performance qualification welds shall be performed in the as-welded condition.

6.3.2 Visual Examination. Visual examination of weld joint preparations and welds shall be performed in accordance with the following requirements to verify conformance to the written welding procedure, the design requirements, and the requirements of this standard:

a. Prior to welding, the weld joint edges and adjacent surfaces shall be examined for:

1. Proper edge preparation, dimensions and finish.
2. Alignment and fitup of the pieces being welded.
3. Verification of correct materials by check of records.
4. Verification of cleanliness requirements.

b. After welding the joint shall be examined in the final surface condition for:

1. Size of legs and throat of fillet welds.
2. Contour, reinforcement and surface finish of welds.
3. Degree of underfill, undercut, and overlap.
4. Arc strikes, weld spatter and impression marking.
5. Burn-through and fuse-through.

c. Weld joints and surfaces which are shown by visual examination to have any of the following defects or areas of nonconformance are unacceptable:

1. Any nonconformance revealed by 6.3.2.a.
2. Any zone of incomplete fusion.
3. Insufficient joint or root penetration.
4. Any undercutting, underfill or burn-through.

5. Unless otherwise specified, any concavity on the root side of complete joint penetration welds when the resulting thickness of the weld is less than the minimum thickness required for the base material. Weld reinforcement up to the allowable reinforcement thickness may be included in measurement of weld thickness.
6. Any concavity on the face side of groove welds.
7. Any arc strikes, weld spatter, and impression marking.
8. Any visible inclusions, porosity, cracks and unfilled craters.

d. Groove weld reinforcement shall not exceed the drawing requirements. When no requirements are specified, groove weld reinforcement shall comply with the following:

<u>Part Thickness, inches</u>	<u>Maximum Face or Root Reinforcement Thickness, inches</u>
up to 0.050	1/64
0.051 to 0.125	1/32
0.126 to 0.50	1/16
0.51 to 1.00	3/32
greater than 1.00	1/8

e. The minimum required size of each fillet weld shall be as specified in the applicable drawing or welding procedure. The maximum size of each leg shall be as follows:

<u>Minimum Specified Shorter Fillet Leg</u>	<u>Maximum Length of Either Fillet Leg</u>
Less than 1/8 inch	1.6 times the minimum specified leg
1/8 inch and over	1.4 times the minimum specified leg

f. If the leg size is specified, the throat thickness for equal leg type fillet welds shall be from 0.7 to 1.0 times the minimum required leg size. The throat thickness for unequal leg type fillet welds shall be 0.7 to 1.2 times the minimum specified leg.

g. The edge of all unmachined welds shall blend smoothly and gradually into the adjacent base metal. If necessary, blending by grinding or machining may be performed to meet this requirement provided that (1) neither the weld nor the base metal adjacent to the weld thickness is reduced below the requirements specified on the drawings, and (2) the specified surface finish requirements are met.

h. Machined welds shall meet the drawing requirements.

i. All welds shall be free from surface markings resulting from mishandling, punching, scratching, etc., which exceed the specified surface requirements.

j. All welds shall be free of dross, or slag.

k. All welds shall be free of oxidation due to improper shielding and overheating which produce black or gray spalling or loose particles. Iridescent temper films and the dark metallic vapor deposits which may occur adjacent to the weld are acceptable. These films and deposits shall be removed by approved cleaning procedures when accessible.

6.3.3 Liquid Penetrant Examination. Liquid penetrant examination of welds shall be in accordance with RDT F 3-6. Unless otherwise specified, the root pass surfaces, final weld surfaces and heat-affected zones of both double and single welded joints shall be examined using a color contrast method. If joint surfacing is used to provide weld metal in the joint, each layer shall be examined in the same manner and shall meet the same requirements as the root pass and final weld surfaces.

a. For all welds in materials $1/8$ inch thick or greater the following relevent indications are unacceptable: (Only those indications with major dimensions greater than $1/64$ inch are considered relevent for Item 3).

1. Any cracks.
2. Any linear indications.
3. Rounded indications with dimensions exceeding 10 percent of the nominal weld thickness or $1/8$ inch, whichever is smaller. Rounded indications separated by $1/16$ inch or less edge-to-edge shall be evaluated as a single indication.
4. Four or more rounded indications in a line separated by $1/16$ inch or less edge-to-edge.
5. Six or more indications in any six square inches of weld surface with the major dimension of this area not to exceed six inches with the area taken in the most unfavorable location relative to the indications being evaluated.
6. Aligned indications in which the average of the center-to-center distance between any one indication and the two adjacent indications in a straight line is less than $3/16$ inch.

b. For welded joints in materials less than $1/8$ inch thick the following relevent indications are unacceptable:

1. Any cracks.
2. Linear indications.
3. Indications with dimensions exceeding $1/64$ inch.
4. Rounded indications separated by $1/4$ inch or less edge-to-edge.

5. Five or more rounded indications in any six square inches of weld surface with the major dimension of this area not to exceed six inches with the area taken in the most unfavorable location relative to the indications being evaluated.

6.3.4 Radiographic Examination. Radiographic examination of welds shall be in accordance with RDT F 3-6 and the written examination procedure required therein.

a. Partial penetration welds and plug welds shall not require radiographic examination unless otherwise specified.

b. Welds that are shown by radiography to have any of the following discontinuities are unacceptable.

1. Any type of crack or zone of incomplete fusion or penetration.
2. Any inclusions, such as slag, exceeding dimensions and quantities given in Figure 1, except that tungsten inclusions shall be evaluated as porosity.
3. Any group of inclusions in a line that have an aggregate length greater than t in a length of $12t$ (where t is the thickness of the thinner portion of the weld), except when the distance between successive imperfections exceeds $6L$ (where L is the length of the longest imperfection).
4. For welds with thickness of $1/8$ inch or greater, porosity in excess of that shown as acceptable by the porosity standards in Table VI-1132-1, Appendix VI of Section III of the ASME Boiler and Pressure Vessel Code. Tungsten inclusions and porosity shall both be considered as porosity. In no case shall there be more than 5 tungsten inclusions in any 6 inch length of weld. Tungsten inclusions shall have no dimension larger than that shown for medium pore size in Table VI-1132-1, Appendix VI of Section III, or $1/16$ inch whichever is smaller.
5. For welds less than $1/8$ inch, porosity in excess of the following:
 - Any pore with maximum dimension greater than 20 percent of T , where T is the specified weld thickness.
 - Total area of porosity in excess of $0.005 T$ square inch in any one inch length of weld with this length taken in the most unfavorable location relative to the porosity indications being evaluated.
 - Pores that are separated from one another by less than $3/16$ inch center-to-center.

Base Material Thickness, Inches

Figure 1 - Allowable Inclusions

6.3.5 Ultrasonic Examination.

- a. Ultrasonic examination of welds and joint surfacing shall be in accordance with RDT F 3-6.
- b. Welds that are shown by ultrasonic examination to have any of the following types of discontinuities are unacceptable.

1. Any cracks, lack of fusion, or incomplete penetration.
2. Any discontinuity whose signal amplitude exceeds the reference level and that has a length exceeding the dimensions given in Figure 1.

6.3.6 Helium Leak Testing. Unless otherwise specified in the Ordering Data, helium leak testing shall be performed in accordance with RDT F 3-6 using the "sniffer" method at a sensitivity of 1×10^{-8} cc/sec. Any leakage at the specified sensitivity shall cause the test assembly to be rejected.

6.3.7 Metallographic Examination. Metallographic examinations shall be performed on qualification test welds at not less than 50X on test welds as required in this section in accordance with ASTM E 2. Any cross section which is shown by metallographic examination to contain any of the following relevant defects shall be cause for rejection of the test welds:

1. Any cracks.
2. Incomplete fusion, or insufficient joint or root penetration.
3. Any tungsten inclusions, slag inclusions, or porosity having a maximum dimension greater than 20 percent of the weld thickness or 1/32 inch, whichever is smaller.
4. More than four tungsten inclusions or pores which have a maximum dimension less than in 3. above.
5. Any deviation from specified weld geometry or weld reinforcement.

7. REACTOR CORE COMPONENT RESISTANCE WELDING

This section, in addition to Section 3, contains the minimum welding qualification requirements and the minimum welding fabrication requirements for resistance spot, seam and projection welding.

7.1 Equipment.

7.1.1 Welding Equipment. Welding equipment shall include a suitable source of electrical energy, electrodes, means for cooling the electrodes, means for applying force between the electrodes, and means for reliably controlling current, electrode force, and time of application.

- a. The force and current controls shall operate so that no current flows until the full force is applied at the welding electrodes and the current shall be switched off before the force is removed.

b. The magnitude of the welding current and the time during which it flows shall be accurately and positively controlled so that there will be no appreciable variation of either, between individual welds for a single setting of the controls.

7.1.2 Shear Testing Machines. The supplier shall provide spot weld shear testing machines as required. All shear testing machines shall be accurate within ± 2 percent of the indicated reading.

7.1.3 Jigs and Fixtures. All tooling that is required to locate welds or assist in the assembly of welded parts that must pass through the magnetic field during the welding operation in a manner that would cause magnetic disturbances to the welding cycle, shall be made of nonmagnetic materials insofar as possible. When the presence of the magnetic material requires a change in the welding current setting of more than 10 percent from the established setting, a separate welding procedure shall be established and qualified. Jigs and fixtures shall be designed so that no welding current shunts through the locating devices rather than the work pieces.

7.1.4 Maintenance of Equipment. Unless otherwise specified, each item of equipment shall be inspected periodically as recommended by the manufacturer. Adequate maintenance shall be furnished, and defective parts affecting machine operation shall be replaced before production welding is resumed.

7.2 Surface Preparation. The surfaces of the parts to be welded shall be clean and free of contaminants such as oxides, scale, ink, grease, or other substances which would be detrimental to the welding process. Cleaning processes shall not use materials which may become embedded in the base materials (e.g., sand or alumina grit). Steel grit blasting shall not be permitted. Cleaning processes shall comply with RDT F 5-1.

7.3 Mating Parts. Mating parts assembled for welding shall fit so that before the first weld and successive welds are made, the surfaces to be joined by the weld are in contact with each other or can be made to contact each other with manual pressure at the area where the weld is to be placed.

7.4 Joint Thickness. Joint thickness shall be limited to those thicknesses or combination of thicknesses on which welding procedures can be established and production parts made to meet the requirements of this standard.

7.5 Procedure Qualification.

7.5.1 Qualification. Each supplier shall record in detail and shall qualify the procedure specification for any resistance welding procedure used on reactor core components. All welding used in qualifying a procedure shall be performed in accordance with the procedure specification.

7.5.2 Procedure Specification. Prior to any production welding, each welding procedure specification and a copy of the detailed results shall be submitted to the purchaser for approval. The procedure specification shall include

all of the elements required to produce acceptable welds and shall be specified in sufficient detail to assure that compliance with the requirements of the procedure can be verified. The following information shall be specified as a minimum:

1. Manufacturer of machine and control panel.
2. Type machine and model number.
3. Electrical rating or capacity.
4. Type of electrical energy.
5. Type of pressure application.
6. Resistance welding process.
7. Base material and condition.
8. Surface preparation.
9. Joint design including contacting overlap, weld spacing, type and size of projection (for projection welding).
10. Type, size and shape of electrodes.
11. Machine setting, including electrode force, squeeze time, weld time, forging force, forge delay time, pulses, hold time, off time, welding speed, welding current and other such factors controlled by machine settings.
12. Weld size and strength.
13. Surface appearance of completed welds, including indentation.
14. Inspection and examination methods and requirements.

7.6 Procedure Qualification Test Welds.

7.6.1 Test Welds. The procedure qualification test welds shall be made on the same machine using the same material and material condition and joint types as will be used in production.

7.6.2 Material Thickness Combinations. Material thickness combinations falling within the following limits shall not require separate procedure qualification provided acceptable welds can be produced with the control limits of 7.9.2.

1. Twenty percent variation in thickness of any outer sheet.
2. Ten percent variation in the overall thickness of the combination to be welded.

7.6.3 Spot Welding. Ten spot weld tests using one of the joint configurations shown in Figure 2 shall be made and tested as follows:

- a. Spot welded surface condition shall conform to 7.10.3.
- b. When process control is to be based upon strength, seven welds shall be tested in tensile shear. They shall meet the requirements of 7.10.2.
- c. When process control is to be based on size, seven welds shall be tested by etch or peel tests. They shall meet the requirements of 7.10.1.
- d. The remaining three welds shall be sectioned and examined for penetration and internal defects. Internal quality shall conform to 7.10.4 and 7.10.5.a.

7.6.4 Seam Welding. Seam welding procedures shall be qualified as follows:

- a. Three test specimens welded to configuration shown in Figure 3 shall conform to the external requirements of 7.10.3.
- b. One specimen shall be cross sectioned (transversely) and shall meet the requirements of 7.10.4 and 7.10.5.b.
- c. One specimen shall have a one inch (minimum) longitudinal section removed and tested to conform to 7.10.4 and 7.10.5.b.
- d. One specimen shall be peel tested and shall conform to the requirements of 7.10.1.

7.6.5 Projection Welding. Five test welds shall be made and tested as follows:

- a. Surface condition shall conform to 7.10.3.
- b. Tests for each weld shall conform to tensile or weld size requirements specified on the drawing or in the Ordering Data.

7.7 Welding Machine Qualification. Each welding machine to be used for production welding of core components shall have its capabilities demonstrated by welding acceptable test welds. These test welds shall meet the same requirements specified for the test welds in 7.6 and shall be tested in accordance with the requirements for the procedure test welds. Any machine used to weld acceptance procedure qualification tests shall be considered qualified for the welding procedure used. A welding machine shall be requalified if it has been rebuilt or if significant operational changes have been made to the machine or its controls.

7.8 General Resistance Welding Fabrication Requirements.

7.8.1 Parts to be joined must be in contact over at least the area of the weld and have sufficient material surrounding the weld to prevent expulsion of molten metal.

7.8.2 Spot welds shall be generally circular in shape when made on flat stock (in a plane parallel to the faying surface). On curved surfaces the shape may become elliptical with the same approximate area as the specified minimum weld size.

7.8.3 Seam welding equipment may be used for spot welding. When spot welding materials that require a forging action (dual pressure) to obtain sound welds or when the work pieces are too thick to be welded satisfactorily by continuous motion, the seam welding equipment shall be equipped with intermittent drive. The work pieces shall be stationary during the welding cycle.

7.8.4 Seam welds may be produced by spot welding equipment, provided overlapping nuggets are maintained.

7.8.5 Spot welds may be used to align a joint to be spot or seam welded; however, arc tack welds are not permitted for this purpose.

7.8.6 When the drawing does not specify whether simultaneous welding or sequence welding is to be used for joints with more than two plies, the procedure to be used shall be specified in the welding procedure specification.

7.8.7 Welds in production parts shall meet the requirements of 7.10.

7.8.8 Unless dimensioned otherwise, the centerline for spot or seam welds shall be the centerline of the contacting overlap. A plus or minus 0.06 inch spot displacement with respect to the centerline is acceptable, provided each spot is in alignment with adjacent spot welds within 0.06 inch.

7.8.9 Assembly spot welds (spot weld tacks) shall be in alignment with joint spot welds within the tolerances prescribed in 7.8.8. Assembly spot welds shall be in alignment with a seam weld so that no fused surface extends more than 0.06 inch beyond the outer edges of the seam weld.

7.8.10 The dimension shown on the drawing from the edge of a sheet to the first spot weld (or beginning of seam weld) shall also apply to the distance from the last spot weld (or end of seam weld) to the edge unless dimensioned otherwise.

7.8.11 All parts to be resistance welded shall be checked prior to assembly to assure that fit-up is satisfactory.

7.9 Resistance Welding Fabrication Process Control Tests.

7.9.1 All welding test specimens shall be prepared from the same material including heat treatment conditions, thickness, surface finish and surface preparation and by the same procedures used for preparation of production parts to be welded. Mill stock may be used for making specimen joints when production part requires machining provided the surface roughnesses are comparable.

7.9.2 All welding shall be done in accordance with a procedure specification. When routine process control check tests indicate that adjustment of the

welding machine control settings is desirable, the settings may be varied by ± 5 percent from the established values or by ± 10 percent when only one setting is adjusted. If satisfactory welding quality cannot be maintained within these limits of adjustment, welding shall be stopped and the machine shall be checked for faulty operation.

7.9.3 Process control examinations for nugget, size, penetration, and internal defects shall be made at not less than 10X magnification.

7.9.4 Test specimens may contain either single or multiple welds as shown in Figure 2. Coupon sizes must be such that the overlap distance shall be representative of that used for production parts or "W" shown in Figure 2, whichever is the lesser. For unequal plies, the overlap shall be governed by the thinner ply.

7.9.5 Weld Size Tests. The weld size may be determined by either macroetch test or peel test of specimens made on flat coupons as shown in Figure 2 or in Figure 3, or on coupons simulating the contour or conditions of the production part.

a. Macroetch Test. A cross section of the weld through the center of the spot or perpendicular to the seam and perpendicular to the plane of the joint is polished, etched and visually examined at not less than 10X magnification. The etch-weld-size is the width of the weld (diameter for circular spots welds) measured to the nearest one hundredth of an inch at the faying surface.

b. Peel Test. Welded specimens are mechanically peeled apart with the resulting destruction of the parent material around the weld, or the weld itself. (In seam welded specimens, peeling shall be done from the finishing end, not from beginning of the test weld). The size of the weld is measured at the faying surface and is the diameter or width of the "button" or of the fractured metal, if failure occurs along the faying surface.

7.9.6 Tensile Shear Test. The weld strength is determined by pulling a specimen to failure on a standard testing machine. Failure may occur either by shear of the weld metal or by tearing of the parent metal. The written procedure shall specify when tensile shear tests are to be used for test welds.

7.9.7 When spot weld pitch is equal to the weld diameter such joints shall be tested as a seam weld and process control and testing shall be as required in 7.9.9.

7.9.8 Process Control of Spot Welding.

a. A minimum of three welds shall be tested for either of the following, at intervals specified in 7.9.8.c.

1. Weld size in accordance with 7.9.5 for conformance to requirements of 7.10.1.
2. Weld strength in accordance with 7.9.6 for conformance to requirements of 7.10.2.

Multiple Spot Weld Specimen

<u>Nominal Sheet Thickness, in.</u>	<u>Width (W), in.</u>	<u>Length</u>
0.001 to 0.030 Incl.	0.63	As Required
0.031 to 0.100 Incl.	1.00	For Test
Over 0.100	1.25	Purposes

Figure 2 - Single and Multiple Spot Weld Specimens

Nominal Sheet Thickness
Of Thinner Sheet, in.

Minimum Width of
Test Piece (W), in.

Up to 0.030 Incl.
0.03. to 0.050 Incl.
0.051 to 0.130 Incl.
Over 0.130

0.63
1.00
1.50
2.00

Figure 3 - Seam Weld Specimen

b. A minimum of two welds shall be inspected for the following, at intervals specified in 7.9.8.c.

1. Surface condition in conformance to requirements of 7.10.3.
2. Penetration at cross section in conformance to requirements of 7.10.4.
3. Internal condition at cross section in conformance to requirements of 7.10.5.a.

c. Tests and inspections of test specimens required shall be made at the following intervals unless otherwise specified in the Ordering Data:

1. At completion of initial machine set-up prior to any production welds.
2. After any change in electrodes or change in machine or control panel adjustment.
3. After each group of 90-100 production welds or after every four hours of production whichever represents a lesser number of production welds.
4. At end of production run, if more than one hour has elapsed since the last test.

7.9.9 Process Control of Seam Welding.

a. The size (width) of the seam weld specimen shall be tested in accordance with 7.9.5 for conformance to the requirements of 7.10.1 at intervals specified in 7.9.8.c.

b. The seam weld specimen shall be inspected for the following, at intervals specified in 7.9.8.c.

1. Surface condition for conformance to requirements of 7.10.3.
2. Penetration in both longitudinal and cross sections for conformance to requirements of 7.10.4.
3. Internal conditions in both longitudinal and cross sections for conformance to requirements of 7.10.5.b.

7.9.10 Process Control of Projection Welds.

a. A minimum of three welds shall be tested for either of the following at intervals specified in 7.9.8.c.

1. Weld size in accordance with 7.9.5 for conformance to requirements of drawings or Ordering Data.
2. Weld strength in accordance with 7.9.6 for conformance to requirements of drawings or Ordering Data.

b. A minimum of two welds shall be inspected for the following, at intervals specified in 7.9.8.c.

1. Surface condition in conformance to requirements of 7.10.3.
2. Penetration at cross section in conformance to requirements 7.10.4.
3. Internal condition at cross section in conformance to requirements of 7.2.10.5.a.

7.10 Quality Requirements for Fabrication and Test Welds.

7.10.1 Weld Size Tests. Weld size determined in accordance with 7.9.5 shall be within ± 10 percent or ± 0.015 inch, whichever is less, than the values of Table 3 or as specified in the drawing.

7.10.2 Tensile Shear Tests. Weld strength determined in accordance with 7.9.6 shall:

a. Equal or exceed the strength values of Table 4 unless otherwise specified in the drawings or Ordering Data.

b. Have variation in strength for a set of welds (3 welds at each test interval; 7 welds for qualification) equal to or less than 0.30 when:

$$\text{Variation} = \frac{\text{highest value} - \text{lowest value}}{\text{average value}}$$

7.10.3 Weld surface conditions shall be as follows:

a. Uniform contour free from pits, surface burns, tip pickup, expulsion (see d below), and other defects.

b. Indentation caused by the electrodes shall not exceed ten percent of the original thickness of the respective sheet or 0.005 inch, whichever is greater.

c. Cracks extending to the outer surface are not acceptable.

d. Spot or seam welds shall be free from expulsion of metal at interfaces. On production parts exposed disassociated flash on adjacent surfaces (due to metal expulsion) shall be removed.

7.10.4 Penetration requirements in either outer sheet as shown in the etched sections are as follows:

1. Minimum penetration shall be twenty percent of the original thickness of the thinner outer sheet over an area whose major axis is eighty percent of the weld diameter or width at the interface.
2. Maximum penetration shall be ninety percent of the original thickness.

7.10.5 Internal condition requirements as shown in the etched sections are as follows:

TABLE 3 - SPOT AND SEAM WELD SIZE REQUIREMENTS

<u>NOMINAL THICKNESS OF THINNER SHEET, INCHES</u>	<u>SEAM WIDTH OR SPOT DIAMETER, INCH*</u>
.006	.045
.008	.055
.010	.065
.012	.076
.014	.082
.016	.088
.018	.093
.021	.100
.025	.120
.031	.130
.034	.150
.040	.160
.044	.180
.050	.190
.056	.210
.062	.220
.070	.250
.078	.275
.094	.285
.109	.290
.125	.300

*DIAMETER in inches, at interface for (circular)spot welds.

WIDTH, in inches at interface for seam welds.

TABLE 4 - STRENGTH FOR SINGLE SPOT SHEAR SPECIMENS

Nominal Thickness of Thinner Sheet, Inches	Strength In Pounds For Single Spot Specimens (Stainless Steels and Nickel Base Alloys)		
	Material Ultimate Tensile Strength 150,000 psi and higher	Material Ultimate Tensile Strength 90,000 to 150,000 psi	Material Ultimate Tensile Strength 70,000 to 90,000 psi
.006	85	70	60
.008	145	130	100
.010	210	170	150
.012	250	210	185
.014	320	250	240
.016	380	300	280
.018	470	360	320
.021	500	470	370
.025	680	600	500
.031	930	800	680
.034	1100	920	800
.040	1400	1270	1000
.044	1700	1450	1200
.050	2000	1700	1450
.056	2450	2000	1700
.062	2900	2400	1950
.070	3550	2800	2400
.078	4000	3400	2700
.094	5300	4200	3550
.109	6400	5000	4200
.125	7600	6000	5000

NOTE: See material specification for applicable Ultimate Tensile Strength.

a. Spot weld defects shall not extend into outer sheets in a direction perpendicular to the surface of the sheets, more than one third of the weld penetration into either outer sheet. The total length of defects, measured in a direction parallel to the plane of the sheets, shall not exceed one quarter of the weld diameter. Defects shall not extend into the peripheral region of the weld that is within 10 percent of the boundaries of the nugget (fusion zone) structure.

b. Seam weld defects shall not extend into outer sheets in a direction perpendicular to the surface of the sheets more than one third of the weld penetration into either outer sheet. The combined defects, measured in a direction parallel to the plane of the sheets, shall not exceed one third of the width of the weld as shown by a cross section, or one third of the pitch of nuggets as shown by a longitudinal section. Defects shall not extend into the peripheral region of the weld that is within 10 percent of the boundaries of the nugget (fusion zone) structure.

7.10.6 Production welds, welded parts, or both shall be identified and segregated in such a manner that the welds or welded parts may be released or rejected when the results of the periodic production specimen tests are known.

7.10.7 Records. In addition to the information required under 3.17, the following applicable information covering qualification and inprocess test results shall be maintained for each resistance welded joint:

1. Average tensile strength.
2. Minimum tensile strength.
3. Average size.
4. Minimum size.
5. Type of size test (etch or peel).
6. Nugget penetration (percentage of thickness).
7. Defects.
8. Machine identification.
9. Operator identification.

8. TEST ASSEMBLY WELDING

This section in addition to Section 3 defines the minimum welding and evaluation requirements of test assemblies and associated hardware. Since test assemblies and their components utilize a variety of joint designs and weld types and are designed to perform under a variety of test and environmental conditions, Test Assembly Weld Categories have been established and defined. Welding qualification and production welding requirements have been assigned to each category. These requirements shall be considered as minimum requirements.

After the organization having the design and experiment responsibility has completed the analyses to determine the consequences of failure with respect to nuclear safety hazards, reactor operations, and experimental objectives, it may be necessary to specify additional or alternate requirements.

8.1 Test Assembly Weld Categories. Test assembly weld categories are listed as follows:

1. Closure welds in fuel and absorber elements or pins which are to be unencapsulated or encapsulated.
2. Spacer wrap wire welds for fuel and absorber elements or pins.
3. Closure welds in fuel and absorber elements or pins with previously qualified end closure welding procedures which are modified by a change in the end cap mass only by the machining of cavities or holes through the end cap (e.g., to accommodate instrumentation), by changes in end cap length, or both.
4. Closure welds in capsules which contain the following:
 - a. Fissile or absorber elements or pins.
 - b. Intentionally pressurized gases.
 - c. Nonfissile materials which may generate significant quantities of gas during irradiation or other experimental testing.
 - d. Nonfissile materials whose compatibility with the primary coolant is unknown.
5. Closure welds in capsules which are not intentionally pressurized prior to irradiation and which contain materials that:
 - a. Are known to be compatible with the primary coolant.
 - b. Do not generate significant quantities of gas under irradiation.
6. Closure welds in capsules which allow intentional ingress of primary coolant sodium into the capsules ("weep" capsules).
7. Welds which are not designed to be fluid containing welds but require structural integrity.
8. Welds (does not include brazing) between instrumentation and items in above categories except 1, 3 and 4.
9. Welds (does not include brazing) between instrumentation and end caps or bulkheads in items listed under categories 1, 3 and 4.
10. Welds less than 1/2 inch in length or less than 1/4 inch in diameter which are used to attach parts which are designed to provide mechanical support to maintain location or position of other components in the capsule assembly (e.g., intermittent fillet welds, plug welds, etc.).

11. Brazes used to effect seals around instrumentation components.

8.2 Welding Qualification Requirements. Table 5 outlines the test assembly weld categories and the sections of this standard which should be followed in performing the qualifications. The table specified deviations from the referenced sections for the number of samples required and their evaluation for the various test assembly categories.

8.3 Production Welding Requirements. Table 5 specifies the production welding requirements for the various test assembly weld categories by referencing the appropriate section of this standard. Deviations from the referenced sections shall be specified by the designer/experimenter and approved by the purchaser.

8.4 Base Materials and Filler Materials. Base materials and filler materials shall comply with 3.3 unless approved by the purchaser.

8.5 Brazing Requirements for Test Assembly Instrumentation Components. Brazing of test assembly instrumentation components shall be performed in accordance with RDT F 6-14.

8.6 Records. Records of welding and associated processing and inspection shall be maintained for all welds. The records shall comply with the requirements listed in 3.17.

9. DATA CHECKLIST

The following technical and procurement data will be furnished by the purchaser. If not furnished with the purchase documents, the supplier shall request any necessary data before submitting his bid.

<u>Item</u>	<u>Refer to Paragraph</u>
Base Materials and Filler Materials	3.3.1
Check Analysis of Filler Materials	3.3.2
Nondestructive Examination	3.13
Restriction on Halogen and Sulfur Content	3.15
Disposition of Nonconforming Welds	3.16
Welding Chamber Requirements (Helium Purity)	4.2.2
Radiographic Examination	4.2.7.4
Radiographic Examination (Actual Throat Thickness)	4.2.7.4 (Item 6)

<u>Item</u>	<u>Refer to Paragraph</u>
Metallographic Examination (Actual Throat Thickness)	4.2.7.7.c
Closure Welding Acceptance Examination and Testing	4.4.5
Radiographic Examination	5.2.5.3
Tensile Testing	5.2.5.4
First and Last Weld	5.4.4
Wrap Wire Weld Acceptance Examination and Testing	5.4.5
Nondestructive Examination	6.3.1.a
Helium Leak Testing Method	6.3.6
Projection Welding	7.6.5.b
Process Control of Spot Welding (Test Intervals)	7.9.8.c
Process Control of Projection Welds (Size and Strength)	7.9.10.a (1 and 2)
Tensile Shear Tests	7.10.2.a

TABLE 5 - WELDING QUALIFICATION AND PRODUCTION WELDING REQUIREMENTS

FOR TEST ASSEMBLY WELD CATEGORIES

Welding Qualification Requirements														Production Welding Requirements		
Test Assembly Weld Category	RDT F 6-2 Section References	No. of Test Welds Required				Evaluation								RDT F 6-2/Section References		
		Procedure		Performance		Visual (>7 X mag)	Radiography	Liquid Penetrant	He Leak Test	Metallography	Pneumatic	Tensile	Elec. Continuity		Dimensional	
		Auto-matic	Manual	Auto-matic	Manual											
		(Unless otherwise specified by the designer/experimenter and approved by the purchaser)														
1	3 & 4	40	-	20	-	X	X	X	X	X	X			X	3 & 4	
1a*	3 & 4	6	-	3	-	X	X	X	X	X				X	3 & 4	
2	3 & 5	20	10	10	10	X	X		X			X	X	X	3 & 5	
2a*	3 & 5	5	5	3	3	X						X	X		3 & 5	
3	3 & 4	6	-	3	-	X	X	X	X	X				X	3 & 4	
4 & 9	3 & 6	6	2	3	2	X	X	X	X	X		X	X		3 & 6	
5 & 6	3 & 6	3	2	3	2	X	X	X	X	X				X	3 & 6	
5a & 6a*	3 & 6	3	2	3	2	X			X	X				X	3 & 6	
7	3 & 6	3	2	3	2	X	X	X		X				X	3 & 6	
7a*	3 & 6	3	2	3	2	X				X				X	3 & 6	
8	3 & 6	3	2	3	2	X	X		X	X		X	X		3 & 6	
10	No proced.	qual.	required.	Performance	qual.	required per ASME Codes, RDT F 6-5 or F 6-2.										3 & 6
11	3 & 8	2	-	1	-	X			X	X		X	X		3 & 8	

*Alternate minimum requirements - may be used when specified by designer/experimenter and approved by the purchaser.

APPENDIX A

A.1 WELDING AND ASSOCIATED TERMS AND THEIR DEFINITIONS

Terms used in this standard are in substantial agreement with AWS A3.0, Terms and Definitions, and with terms employed by Section IX of the ASME Code. Several definitions are repeated in this standard for convenience and clarification.

A.1.1 Actual Throat of Fillet Welds. The shortest distance from the root of the weld to the face of the weld.

A.1.2 Arc Strike. Any localized melting, heat affected zone, or change in the contour of the surface of the finished weld or adjacent base metal resulting from an arc or heat generated by the passage of electrical energy between the weld or base metal and a current source; such as welding electrodes, electron beams, ground clamps, high frequency arcs, etc.

A.1.3 Automatic Welding. Welding with equipment which performs the entire welding operation without constant observation and adjustment of controls by an operator. The equipment may or may not perform the loading and unloading of the work.

A.1.4 Concavity. The maximum distance from the face of a concave fillet weld perpendicular to a line joining the toes of the weld.

A.1.5 Concave Root Surface. A root surface which is concave.

A.1.6 Convexity. The maximum distance from the face of a convex fillet weld perpendicular to a line joining the toes of the weld.

A.1.7 Electrode, Arc Welding. A component of the welding circuit through which current is conducted between the electrode holder and the arc.

A.1.8 Electrode, Resistance Welding. The part or parts of a resistance-welding machine through which the welding current and, in most cases, pressure is applied directly to the work. The electrode may be in the form of a rotating wheel, rotating roll, bar, cylinder, plate, clamp, chuck, or modification thereof.

A.1.9 Face Reinforcement. Reinforcement of weld at the side of the joint from which welding was done.

A.1.10 Face of a Weld. The exposed surface of a weld on the side from which welding was done.

A.1.11 Faying Surface. That surface of a member which is in contact or in close proximity with another member to which it is to be joined.

A.1.12 Joint Design. The joint geometry together with the required dimensions of the welded joint.

A.1.13 Joint Geometry. The shape and dimensions of a joint in cross-section prior to welding.

A.1.14 Joint Penetration. The minimum depth a groove or flange weld extends from its face into a joint, exclusive of reinforcement.

A.1.15 Joint Welding Procedure. The materials, joint design, methods and practices employed in the welding of a particular joint.

A.1.16 Lap-Over. That portion of a circumferential weld bead which overlaps the starting point of the weld bead.

A.1.17 Machine Welding. Welding with equipment which performs the welding operations under the constant observation and control of an operator. The equipment may or may not perform the loading and unloading of the work.

A.1.18 Nugget. The weld metal joining the parts in spot, seam or projection welds.

A.1.19 Nugget Penetration. The distance that fusion extends into the base metal measured from the faying surfaces.

A.1.20 Nugget Size. The diameter or width of the nugget measured in the plane of the interface between the pieces joined.

A.1.21 Oscillation Amplitude. The distance normal to the direction of welding between the outer-most positions which a welding arc or beam reaches while oscillating transversely.

A.1.22 Oscillation Dwell. The time which the welding arc or beam rests at the end of each oscillating swing.

A.1.23 Oscillation Frequency. The completed number of cycles which the oscillating welding arc or beam makes per unit of time.

A.1.24 Overlap. Protrusion of weld metal beyond the toe or root of the weld.

A.1.25 Position of Welding. The terms related to positions of welding for joint types and welding processes and the position limits are defined in Section IX, ASME Boiler and pressure Vessel Code.

A.1.26 Root of a Joint. That portion of a joint to be welded where the members approach closest to each other. In cross section the root of the joint may be a point, a line or an area.

A.1.27 Root Penetration. The depth a groove weld extends into the root of a joint measured on the centerline of the root cross section.

A.1.28 Root Reinforcement. Reinforcement of weld at the side opposite that from which welding was done.

A.1.29 Root Surface. The exposed surface of a weld on the side opposite that from which welding was done.

A.1.30 Root of a Weld. The points, as shown in cross section, at which the back of the weld intersects the base metal surfaces.

A.1.31 Size of a Fillet Weld. For equal leg fillet welds, the leg length of the largest isosceles right-triangle which can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg length of the largest right-triangle which can be inscribed within the fillet weld cross section.

A.1.32 Size of a Groove Weld. The joint penetration (depth of chamfering plus root penetration when specified).

A.1.33 Toe of Weld. The junction between the face of a weld and the base metal.

A.1.34 Undercut. A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

A.1.35 Underfill. A depression on the face of the weld or root surface extending below the surface of the adjacent base metal.

A.1.36 Wash Pass Welding. Smoothing the surface of a weld pass or a weld layer by rewelding without the addition of filler metal.

A.1.37 Wash Pass. A smoothing pass made by wash pass welding (often referred to as a "cosmetic" pass).

A.1.38 Welder. One who is capable of performing a manual or semiautomatic welding operation (sometimes erroneously used to denote a welding machine).

A.1.39 Weldment. An assembly whose component parts are joined by welding.

A.1.40 Welding Operator. One who operates machine or automatic welding equipment.

A.1.41 Welding Procedure. The detailed methods and practices including all joint welding procedures involved in the production of a weldment.

A.1.42 Welding Procedure Qualification. The tests to demonstrate that welds made by a specified procedure can meet prescribed standards.

A.1.43 Welder and Welding Operator Performance Qualification. The tests to demonstrate a welder's or welding operator's ability to produce welds meeting prescribed standards.

A.1.44 Welding Procedure Specification. A written welding procedure which specifies the detailed methods and practices to be used in the production of a weldment and how they shall be carried out. A specification includes all elements of a procedure necessary to produce a satisfactory weldment. Examples of some of the elements included in a specification are: materials used, preparation of base materials, preweld and postweld cleaning, assembly method and sequence, fixturing, heat treatments, joint welding procedures, preweld and postweld nondestructive examinations, repair, rework, etc.