1.0 Purpose

1.1 The purpose of this specification is to establish the minimum quality assurance requirements for the shop fabrication of waterwall panels supplied to NRG Energy Inc.

2.0 Scope

2.1 This specification applies to straight, bent, carbon steel and low-alloy steel waterwall panels.

2.2 This specification does not address requirements for corrosion-resistant claddings or overlays that may be subsequently applied. Refer to NRG Specification QAS 1.03.

2.3 This specification shall be used in conjunction with a project specification that contains the material, quantity, bid, contract, schedule, transportation, delivery, and other job, plant and site-specific requirements.

3.0 Definitions

3.1 ASME – American Society of Mechanical Engineers

3.2 ASME B&PV Code – ASME Boiler and Pressure Vessel Code

3.3 ASNT – American Society for Nondestructive Testing

3.4 AWS - American Welding Society

3.5 NRG - The NRG individual responsible for the overall management of the project

3.6 ISO - International Organization for Standardization

3.7 Manufacturer - The organization providing the raw materials (e.g., tubing, membrane, etc.) for the waterwall panels

3.8 Supplier - The organization providing the waterwall panels

3.9 QAS - NRG Quality Assurance Specification

4.0 References

4.1 ASME Boiler & Pressure Vessel Code, Section I, “Rules for Construction of Power Boilers”

4.2 ASME Boiler & Pressure Vessel Code, Section II, Parts A and B, “Ferrous and Nonferrous Material Specifications”

4.3 ASME Boiler & Pressure Vessel Code, Section II, Part C, “Specifications for Welding Rods, Electrodes, and Filler Metals”

4.4 ASME Boiler & Pressure Vessel Code, Section V, “Nondestructive Testing”

4.5 ASME Boiler & Pressure Vessel Code, Section IX, “Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators”

4.6 SNT TC-1A, “Personnel Qualification and Certification in Nondestructive Testing"

4.7 NRG QAS 1.03, Shop-Applied Cladding and Overlay of Boiler Tubing”

The latest edition of the above codes, standards, and specifications shall apply. In the event of conflicts between this specification and the references cited above, the Supplier shall notify NRG, who will make the final judgment and interpretation.

5.0 Responsibility

5.1 The Supplier shall be responsible for fulfilling the requirements as set forth in this specification including all required inspection and testing and the submission of all required documentation. Exceptions to and deviations from this specification shall be clearly delineated in the Vendor's bid for disposition by NRG.

5.2 The Supplier shall hold a valid "S" Certificate of Authorization issued by the ASME.

5.3 The Supplier shall provide a Manufacturer's Partial Data Report (ASME Form P-4)

5.4 The material or tube Manufacturer shall have a Quality Program in compliance with and certified to ISO 9001.

5.5 If the Supplier is not the Manufacturer, the Supplier must have a formal program for qualifying their manufacturers and must have evidence of periodically monitoring their performance.

5.6 The Supplier shall identify clearly in their proposal any and all subcontractors intended to be used. All subcontractors must be approved by NRG prior to the issuance of a purchase order.

5.7 NRG shall provide a project specification that specifies the waterwall panel dimensions and quantities, the diameter, minimum wall thickness, material specification/grade, and spacing of the tubes, and the thickness, material specification/grade, and type of membrane. The project specification shall also indicate whether or not the waterwall panels will be clad or overlayed.

6.0 Material

6.1 Tube materials, fabrication and testing procedures shall comply with ASME SA-450 and the applicable ASME B&PV Code, Section II material specifications.

6.2 Supplier to furnish either cold-finished or hot-finished tubing. If hot-finished tubing is furnished, the Manufacturer shall meet the applicable ASME SA-450 tolerances for cold-finished tubing.

6.3 Tubing shall be seamless unless otherwise specified.

6.4 Membrane, filler bar, and spacer bar dimensions, materials and type or style shall be as stated in the project specification.

6.5 The Supplier shall provide certified material test reports (CMTR) for all tubing and welding electrodes (typical deposit analysis is adequate for electrodes). CMTRs shall report chemical and mechanical test data as required by the applicable ASME B&PV Code, Section II material specification. CMTRs shall be prepared in English units or in metric units with conversions to English units.

6.6 The Supplier shall provide a certification of compliance for membrane material stating the specified material chemistry in accordance with ANSI or other nationally recognized standard.

6.7 All materials of construction shall be new. Previously used tubing and scrap use is prohibited.

6.8 All tubing shall be free of injurious mill scale, grit, flaking, rust, etc. prior to fabrication.

7.0 Fabrication

7.1 The Supplier shall submit general arrangement drawings to NRG for review and approval prior to fabrication, unless specifically exempted in the project specification or purchase order. All construction details and dimensions specified in the project specification shall be clearly shown.

7.2 Butt welds are prohibited unless specified in the project specification, drawings or required for repairs. If butt welds are accepted by NRG, the Supplier shall document their locations on the fabrication drawings.

7.3 The following shall apply to the tube ends of fabricated waterwall panels unless specified otherwise:

7.3.1 Tube end preparation (bevel) shall be 37½° ± 2½°

7.3.2 Tube end preparation shall be free from injurious defects such as pits or scratches greater than 0.010” deep.

7.4 The following requirements apply to membrane welds:

7.4.1 Membrane welds shall be made using either submerged arc welding (SAW) or flux-cored arc welding (FCAW) processes. Other methods shall require prior approval by NRG.

7.4.2 Membrane shall be welded on both sides of the panel.

7.4.3 Membrane shall be continuous unless otherwise shown on engineering drawings. Any splices in the membrane shall have a full penetration weld at the splice.

7.4.4 Membrane welds shall be full penetration for 80% of their length (e.g., 19" out of 24").

7.4.5 Membrane welds shall be blended with the tube surface so that no injurious notches are remaining. The welds shall be free from coarse ripples, grooves, overlaps, abrupt ridges and valleys.

7.4.6 Termination of membrane at openings shall be chamfered with a radius without reducing the membrane thickness.

7.4.7 Membrane recess length and cut back length and width shall be as stated in the project specification.

7.5 The dimensional tolerances for panel fabrication shall be in accordance with Attachment 1.

8.0 Welding

8.1 Welding shall be performed in accordance with the requirements of the ASME B&PV Code, Section I and the quality control requirements of Paragraph 12.0.

8.2 Welding procedures, welders and welding operators shall be qualified per the Supplier's Quality Program and the ASME B&PV Code, Section IX.

8.3 Weld procedure specifications (WPS) and supporting procedure qualification records (PQR) shall be made available to NRG for review prior to the start of fabrication.

8.4 Copies of all welding operator and welder performance qualifications, along with applicable welder continuity data, shall be made available to NRG for review prior to the start of fabrication.

8.5 The Supplier shall identify all proposed filler metals to NRG for review and approval prior to the start of fabrication.

8.6 The following welding practices are prohibited:

8.6.1 Backing rings

8.6.2 The gas metal arc welding process (GMAW) in the short circuiting arc transfer mode.

8.6.3 The Flux Cored Arc Welding process (FCAW) without gas shielding.

8.7 Welding processes shall limit heat input to 60,000 joules/inch maximum. Heat input shall be determined by the following formula:

$$\frac{\text{volts x amps x 60}}{\text{travel speed (in/min.)}} = \frac{\text{Joules}}{\text{inch}}$$

8.8 All circumferential butt welds shall utilize a gas tungsten arc (GTA) welded root pass unless otherwise approved by NRG.

8.9 Welding materials utilized for fabrication shall be in accordance with the ASME B&PV Code, Section II, Part C including the following restrictions:

8.9.1 Low carbon ('L' Grade) filler materials are prohibited when welding ferritic materials.

9.0 Preheat and Post-Weld Heat Treatment

9.1 The maximum interpass temperature shall be 800°F for carbon and low alloy steels.

9.2 Post-weld heat treatment, if required, shall be performed in accordance with the ASME B&PV Code, Section I, Paragraph PW-39 for the subject tube material grade.

9.2.1 For low-alloy steel panels, if straightening is required to meet the requirements of Paragraph 7.5, post-weld heat treatment shall be performed prior to straightening.

9.2.2 For carbon steel and low-alloy steel gang-bent panels, post-weld heat treatment shall be performed after bending.

9.3 The Supplier shall submit the post-weld heat treatment procedure to NRG for review and approval prior to fabrication. Use of localized torch or heating tips is prohibited.

10.0 Inspection and Testing

10.1 Non-destructive examination (NDE) procedures shall be in accordance with the ASME B&PV Code, Section V. The Supplier shall make available all NDE procedures to NRG for review.

10.2 Personnel performing NDE shall have Level II qualifications and certified in accordance with the requirements of SNT TC-1A. The Supplier shall make available all NDE personnel qualifications to NRG for review. Visual inspections may be performed by an AWS Certified Weld Inspector or designated shop QC Inspector.

10.3 If the specification, codes, laws, ordinances, or any state agency or Authorized Inspector having jurisdiction over the Supplier's shop require any work to be specifically tested or approved, the Supplier shall assume the responsibility and cost thereof and shall give NRG timely notice of its readiness for inspection or testing.

10.4 Tube wall thickness shall be measured prior to fabrication on a sampling of tubes to confirm the tubing meets the minimum wall thickness as described in the purchase order. Sample size is determined by Table 1 below.

10.4.1 Wall thickness measurements shall be made using the Ultrasonic Pulse-Echo Contact Method in accordance with ASME B&PV Code, Section V, Subsection B, Article 23, SE-797.

10.4.2 In lieu of the ultrasonic method described in Paragraph 10.4.1, micrometer measurements taken at each tube end may be taken.

10.4.3 Readings are to be taken at the 0, 90, 180 and 270 degree positions at each end of the tube.

10.4.4 Any tube in the sample group found with readings below minimum wall thickness shall cause the entire lot to be rejected. Disposition of the rejected lot shall be discussed and approved by NRG.

Table 1

Lot Size (# of tubes)	Sample Size
1 to 8	Entire Lot
9 to 90	8
Greater than 90	5%

Notes:1) Lot size is the entire number of tubes being provided with the Purchase Order.
2) Each heat of steel provided by the tubing manufacturer is to be considered as a separate lot.

10.5 Eddy current examination shall be performed prior to fabrication on a sampling of tubes to confirm the absence of abrupt imperfections. Sample size determined by Table 1 above.

10.5.1 Eddy current testing shall be conducted in accordance with Paragraph 24 of ASME SA-450 for carbon and ferritic tubes.

10.5.2 Any tube in the sample group found with readings below minimum wall shall cause the entire lot to be rejected. Disposition of the rejected lot to be discussed and approved by NRG.

10.5.3 If eddy current testing was conducted by the tube Manufacturer and satisfactory results are documented on the tube material CMTR, the eddy current testing of Paragraph 10.5 is not required.

10.6 Visual inspection of tubing shall be performed along the entire length to assure proper surface finish and the absence of any harmful defects, gouges, tears, cracks, flat spots and kinks, the presence of which shall be cause for rejection. All weld spatter, slag, and/or flux shall be removed prior to visual inspection.

10.7 Visual inspection of all membrane welds shall be performed in addition to the requirements of Paragraph 7.45. Any of the following are unacceptable and grounds for rejection:

10.7.1 Cracks

10.7.2 Surface undercut greater than 1/32”deep or 10% of wall thickness, whichever is less.

10.7.3 Surface porosity

10.8 Tube bends shall exhibit good workmanship and be free of wrinkles, splits, and surface defects.

10.8.1 Wall thickness and ovality at the bend sections shall be measured on 10% of the bends.

10.8.2 This measurement does not apply to burner panels.

10.8.3 For panels whose spacer or wear bars restrict O.D. measurements on both axes, the flattest section accessible shall be measured and compared to the tube nominal OD.

10.8.4 Maximum allowable wall thinning shall be 10% of the specified minimum wall thickness.

10.8.5 Maximum ovality, as defined by the following equation, shall be 10%.

Ovality = [(Major OD – Minor OD) X 100] / Nominal Tube OD

10.9 Ten percent (10%) of all tubes with a specified minimum wall thickness less than 0.180” shall be inspected for weld burn through (as indicated by ID blistering, distortion or other surface imperfections other than discoloration) using a borescope or equivalent device. All burn-through indications observed during borescope examination shall be considered detrimental to the tubing integrity and shall be rejected. NRG reserves the right to perform borescope examination of additional tube internal surfaces.

10.10 All completed panels shall be inspected to assure the absence of any obstruction or constriction inside the tubes. This shall be done by passing steel balls through the inside diameter of each tube following membrane welding and prior to assembly of welded inserts or panel bending. The Supplier shall set up an accountability system to assure recovery of all balls inserted into the tubes.

10.10.1 Ball Size = 0.9 X (Minimum tube OD – 2 X Maximum Wall Thickness) where:

Minimum tube OD = specified OD – SA-450 tolerance
Maximum wall thickness – specified wall + SA-450 tolerance

10.10.2 Balls shall be selected from the next smallest commercial size from the result obtained in Paragraph 10.10.1, but not less than 1/16" of the result obtained in Paragraph 10.10.1

10.11 Twenty percent (20%) of all tube bends, panel membrane welds, and attachment welds on the tension side of gang-bent panels shall be examined by magnetic particle testing. The inspections of tube bends shall be conducted between the bend tangent points. Any of the following are unacceptable and grounds for rejection:

10.11.1 Any cracks or linear indications

10.11.2 Rounded indications with dimensions greater than 3/16"

10.11.3 Four or more rounded indications in a line separated by 1/16" or less, edge to edge.

10.12 One hundred percent (100%) of all butt welds shall be inspected by radiography.

10.13 The radiographic examination shall be performed using the single shot elliptical technique in accordance with the ASME B&PV Code, Section V.

10.14 Acceptance criteria for radiography shall conform to the ASME B&PV Code, Section I, PW-51. The radiograph film, copies thereof, or an electronic copy of digital radiographs shall be provided to NRG for review. The film will be returned after review.

10.15 A hydrostatic test shall be conducted for each tube panel that contains butt welds. Tests shall be performed in accordance with the ASME B&PV Code, Section I at 1.5 times the design pressure. Water used for testing shall not exceed 5 ppm of chlorides and fluorides. After testing, the assembly shall be drained and air dried. Air used for drying shall be free from all oil or oil vapors.

10.16 Final inspections shall be performed prior to the application of any protective coating and capping of the tubes or panels for shipping or storage.

11.0 Repairs

11.1 Through-wall defects shall not be repaired by welding. A new tube or tube section shall be installed.

11.2 When a new tube section is installed, the following applies:

11.2.1 Butt welds shall be examined per Paragraphs 10.13 and 10.14.

11.2.2 The repair procedure, including welding and NDE procedures, shall be submitted to NRG for approval prior to performing the repair. NDE shall be in accordance with Paragraphs 10.1 and 10.2.

11.2.3 The repair shall be documented on an NCR and submitted to NRG for approval.

11.3 If it becomes necessary to rework the outside surfaces of the tubes due to arc strikes or other physical damage, this shall be done by previously-approved methods so as to maintain the minimum wall thickness. Following re-working, liquid penetrant testing shall be performed to assure that no harmful defects are left on the pressure boundary of the tubes.

12.0 Quality Control Requirements

12.1 The Supplier shall develop and implement a Quality Program for the control of quality for all materials and services to be supplied. The Supplier's Quality Program shall be documented by written policies, procedures, and instructions, which, as a minimum, shall comply with the requirements of the codes and standards in Paragraph 4.0. The Supplier's Quality Program shall be submitted to NRG for review and approval with the bid documents.

12.2 Supplier's Quality Program shall address inspection planning, inspections, inspection personnel, and inspection results, and shall include, but not be limited, to the following:

12.2.1 The Supplier shall establish a documented, pre-planned inspection program that shall be used by the Supplier for inspections to be performed at receiving, during storage, during in-process work, upon completion of fabrication, and prior to shipment.

12.2.2 The inspection program shall identify those elements, characteristics, and processes essential for verification by the Supplier's inspection personnel to assure conformance to applicable specification and drawing requirements. The

Supplier shall prepare inspection checklists identifying the specific elements, characteristics, and steps in the process to be inspected, and shall include the accept/reject criteria for each. Criteria and recording of inspection results shall be quantitative where possible.

12.2.3 The Supplier's inspection checklist or shop traveler shall be submitted to NRG for review, approval, and identification of those inspection activities to be witnessed by NRG. The Supplier shall submit checklists at least four (4) weeks in advance of scheduled inspections to which they apply.

12.2.4 The Supplier's utilization of approved inspection checklists does not relieve the Supplier of responsibility for compliance with the requirements of the contract, specifications, and drawings.

12.2.5 The Supplier shall implement the pre-planned inspection program by performing the inspections identified on the checklists and documenting actual inspection observations, measurements, and results. The inspection shall be performed and documented as work progresses. A copy of the actual results of each inspection shall be submitted to NRG at the completion of the work.

12.2.6 Supplier personnel performing NDE shall be qualified and certified in accordance with the Supplier's written program. Evidence of their qualification and certification shall be available to NRG for review.

12.3 The Supplier shall arrange for NRG to have free access to all Supplier's or Supplier's Subcontractor's facilities concerned with the supply or manufacture of materials, for the purpose of performing inspection or surveys of parts, prior to or during assembly and to witness any or all fabrication processes, testing, or NDE. The Supplier shall advise NRG of any advance-notice requirements which must be met in order to gain access to the Supplier's or Supplier's Subcontractor's facilities.

12.4 Inspection Witness Points will be indicated by NRG on the Supplier's inspection checklist or shop traveler and returned to Supplier (see Paragraph 12.2.3). Supplier shall notify NRG of the expected fabrication start date, expected dates of Witness Point(s), and expected date of final inspection by the Supplier.

12.5 The Supplier shall provide any documents and copies of or access to all drawings, procedures, or test reports related to the job as deemed necessary by NRG.

12.6 NRG inspection or surveys at the Supplier's facilities and the Supplier's Subcontractor's facilities may be performed at NRG's discretion. Specific NRG inspections may be identified upon receipt of the Supplier's Quality Program.

12.7 Supplier shall initiate, disposition, and control Nonconformance Reports (NCRs), to report deficiencies in characteristics, documentation, or procedures, which do not comply with specification or drawing requirements. Items which can be corrected (reworked) by completion, re-machining, reassembly, or other means to conform to drawing/specification requirements shall be documented by Supplier on the appropriate inspection checklists. Items which cannot be corrected to original drawing/specification requirements shall be reported immediately on an NCR. Supplier shall provide recommended disposition for each deficiency and shall route the NCR form to NRG for review and approval. Upon NRG's approval of the recommended disposition of the NCR, Supplier shall take the necessary actions to correct the nonconforming item in accordance with the disposition on the approved NCR.

12.8 The Supplier's work shall comply in all respects with applicable drawings, specifications, and contract documents. NRG's final acceptance of Supplier's work shall be based upon satisfactory completion of inspection/tests, and upon resolution of all open or incomplete items.

13.0 <u>Shipping</u>

13.1 All weld spatter, mill scale, arc strikes, rust, loose particles, and any potentially harmful foreign matter shall be removed from the completed panels. All sharp edges and roughness shall be ground smooth to a rounded contour. Sponging shall be performed to ensure internal tube cleanliness. Unless otherwise specified in the project specification, preservatives shall not be used on the tube internal surfaces.

13.2 All completed panels shall be permanently marked with the material designation and size, panel number, Supplier's Job Number, and the NRG Purchase Order Number. This information shall be

stamped onto a 1/8" or 10 gage carbon steel plate using letters not less than 1/4" in height. Each waterwall panel shall have this identification plate located 18" from either end at the panel centerline. The plate shall be attached to the casing side of the panel by welding to the membrane and not the tubes.

13.3 Suitable weather protection shall be provided to protect the equipment from damage in transit and during storage for up to six months. Such protection shall include, but not be limited to, applying deoxaluminate on weld end preps and protective end caps. Capping shall not be done prior to final inspection or release by NRG, as specified in Paragraph 10.16. The method of protection shall be submitted to NRG for review and approval.

14.0 Documentation

The Supplier's final documentation package shall include the following:

14.1 Signed P-4 forms
14.2 Certified material test reports
14.3 Copy of tube manufacturer's ISO 9001 certification
14.4 Filler metal identification
14.5 General arrangement drawings
14.6 Hydrostatic test certificate of compliance
14.7 Heat treatment charts or certificate of compliance (when applicable)
14.8 NDE reports including:
- 14.8.1 Visual/dimensional results
- 14.8.2 Tube wall thickness report
- 14.8.3 Eddy current examination (when applicable)
- 14.8.3 Radiography examination of butt welds (when applicable)
- 14.8.4 Magnetic particle testing (when applicable)
- 14.8.5 Borescope Inspection (when applicable)

14.8 Repair procedures (when applicable)
14.9 Nonconformance reports

15.0 Attachments

1. Waterwall Panel Dimensional Tolerances

Waterwall Panel Dimensional Tolerances

1.0 The following are the allowable tolerances for waterwall panel fabrication.

Dimension	Tolerance (inches)
Panel Width	+0,-1/4"

Panel Length	±1/8”
Tube Centerline to Centerline	±1/16”
Membrane Recess Length	±1/4”
Membrane Cut Back Length	±1/4”
Membrane Cut Back Width	3/16” max.
Membrane Length	±1/4”
Tube End OD Scarfing	+1/8”, -0”
Outside Tube to Outside Tube Centerline	+0”, -1/4”
Bowing	±1/4”
Crowning	±1/4”
Membrane Flatness	±1/4”
Panel Squareness	±1/4”
Tube End Parallelism	±1/16”
Tube Ovality (straight tubes only)	2%

2.0 Gang bent panels shall be supplied such that the first panel bend radius is within ±3/8" of the drawing dimension, and each subsequent panel of the order or item is within ±1/8" of the first panel, unless other tolerances are agreed upon by the Purchaser and Vendor prior to the pressure part arrangement drawings.

3.0 The inspection definitions and terminology are as follows:

3.1 Bowing – a measure of the flatness of the panel, top to bottom. Bowing is measured by stretching a tape from one end of the panel to the other end of the panel on a randomly selected tube of each panel. This measurement shall be done on both the front and back of the panel. The largest distance between the tape and the tube shall be the maximum bowing.

3.2 Crowning – a measure of the flatness of the panel, side to side. Crowning is measured by stretching a tape from the panel’s left side tube to the panel’s right side tube. This measurement shall be done on both sides the front and the back of the panel at two different locations along a panel's length. The largest distance between tape and the tube shall be the maximum crowning.

3.3 Flatness (for bars only) - shall be measured on membrane bars by stretching a tape from one end to the other lengthwise along the bar and perpendicular to the ends. The maximum distance between the tape and the bar shall be the out-of-flatness.

3.4 Panel Squareness - a combination of how parallel the opposite sides of a panel are to how perpendicular the adjacent sides of the

same panel are. This condition is achieved when the diagonal distance from panel corners are equal to each other within the tolerance specified.

3.5 Tube End Parallelism - a measure of the straightness or "saw-toothing" of the tube ends of a panel. This attribute shall be measured by first checking the tubes at each corner for squareness (see definition of squareness). Next, stretch a line taut from one side of the panel to the other across the tube faces. The line shall be tangent to the tube faces. The distance from the line to each tube face is the deviation from tube end parallelism.

3.6 Tube End Squareness - a measure of how closely the tube ends match a right angle. This property shall be measured with a template at two points around the tube end's circumference. The points shall be opposite each other.

3.7 Tube Ovality - the out-of-roundness of the tube. The measurement shall be made at each end and at the tube center. At the tube ends, the inner diameter shall be checked at four equally spaced locations. The center of the tube shall be tested for ovality by measuring the outside diameter at four different, equally spaced points.