

Exhibit A
Scope of Work Specification

For

**Master: Examination of Boiler Components, High
Energy Piping and General Plant Equipment**

Revision 1

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1.0 Purpose

1.1 The purpose of this document is to provide general scopes of work for boiler evaluations and testing, boiler tube failure analysis and testing, high energy piping evaluations and testing, including general plant evaluations and testing services in accordance with the applicable criteria, specifications and standards.

1.1.1 Definitions of acronyms are found in Section 5.0 of this Specification.

1.1.2 This Specification is to be used in conjunction with the Applicable attachment as identified in the Table of Contents

1.2 Applicable Codes and Standards

As applicable the following codes and standards in effect on the date of the contract shall be the controlling codes and standards during the period of performance of the contract:

1.2.1 ASME/BPVC-Power Boilers and Pressure Vessels

1.2.2 ASME B31.1-Power Piping

1.2.3 NBIC- National Board Inspection Code

1.2.4 AWS – D1.1 and D1.3 Structural Steel

1.2.5 ASTM-American Society for Testing and Materials

1.2.6 ASNT-American Society for Nondestructive Testing

1.2.7 OSHA-Occupational Safety & Health Act

1.2.8 EPRI 1008082 Guidelines for Controlling FAC Fossil & CC Plants

1.2.9 MPC Publications HEP-1 through HEP-28

1.2 In general, boiler evaluations, boiler tube failure analysis as applicable, shall comply with the Electric Power Research Institute (EPRI) recommendations, and shall include but not limited to the following EPRI Publications:

1.2.7 Boiler Tube Failure: Theory and Practice

1.2.7.1 Volume 1: Boiler tube Fundamentals

1.2.7.2 Volume 2: Water-Touched Tubes

1.2.7.3 Volume 3: Steam-Touched Tubes

1.2.8 Boiler Tube Failure Metallurgical Guide:

1.2.8.1 Volume 1: Technical Report

1.2.8.2 Volume 2: Appendices

- 1.3 The Consultant or NDE service provider shall provide the Company plant and corporate representatives with information and recommendations for the application and possible utilization of new technology and processes and any cost savings methods and approaches.
- 1.4 A separate document, for each project shall be issued by Company. A project description will be provided by the Company for each individual Work Release. This project description will provide an overall description of the applicable project and a general outline of the services to be provided by Consultant or NDE services provider.
- 1.5 A detailed description of the Scope of Work will be provided in the individual Work Release for each project.
- 1.6 The Consultant or NDE service provider shall provide all labor, PPE, materials, and equipment (including supplemental lighting and extension cords) necessary to perform the examinations defined by this specification. Erection of scaffolding, removal of insulation, and general surface preparation will be provided by Company, unless otherwise noted in the individual Work Release.
 - 1.6.1 All Consultant's or NDE service provider's personnel shall comply with all applicable OSHA standards, and will be required to attend the Company Energy Safety training course prior to entering the Plant
 - 1.6.2 The Consultant or NDE service provider shall be responsible for obtaining the necessary calibration blocks. At least one week prior to the inspection,
 - 1.6.3 The Consultant or NDE service provider shall provide Company with a list of chemical products to be used in these inspections, the Material Safety Data Sheets for these products, and any special storage or disposal requirements.
 - 1.6.4 The Consultant or NDE service provider shall notify Company, at least one week prior to the inspections or evaluations, of any special auxiliary services (i.e., water, electrical or compressed air) which will be needed to perform specified inspections.
 - 1.6.5 The Consultant or NDE service provider is required to schedule with Company, their work activities including planned activity completion dates.
 - 1.6.6 If other NDE testing or work is being conducted by Company or others, concurrent with Consultant's inspection, Consultant or NDE service provider is expected to make reasonable accommodations for these concurrent inspections.

- 1.6.7 The Company may perform metallographic examinations based upon the Consultant's or NDE service provider findings; therefore, Consultant or NDE service provider is required to schedule their efforts to complete the examinations at each location prior to moving to other locations, unless approved by Company's site representative.
- 1.6.8 In addition to the inspections defined in the project "Scope of Work," Consultant or NDE service provider may be required, as additional scope, to provide additional inspections. When requested, Consultant shall provide unit costs for each inspection method.
- 1.6.9 Prior to completion of field examinations, Consultant NDE service provider shall provide Company's site representative with a field report as described in Section 3.1.
- 1.6.10 The Responsible Company Representative shall be identified by the respective Technical/Engineering Group for each participating Company subsidiary.

2.0 Technical Requirements

- 2.1 NDE processes, method or technique effectiveness and proficiency shall be established by one of the following methods:
 - 2.1.1 Generally accepted methods, processes, techniques may be accepted by submitting documented techniques to the Company for review and approval in accordance with the applicable codes and Section V of the ASME BPVC.
 - 2.1.2 When new technology, processes, methods, or techniques are to be applied to Boiler tube inspections or to High Energy Piping (HEP) inspections for identification of early stage creep damage. These processes may be accepted by:
 - 2.1.2.1 Demonstrating proficiency by using the Company approved boiler tube FlawTech coupons
 - 2.1.2.2 Demonstrating proficiency using the EPRI boiler tube coupons and presenting documentation of results
 - 2.1.2.3 For HEP by demonstrating proficiency using the Materials Property Counsel (MPC) controlled set of coupons (University of Tennessee, Knoxville, TN)
 - 2.1.2.4 Alternatively new technology, processes, methods, or techniques may be presented to the responsible Company representative for approval.

- 2.2 NDE Technicians' effectiveness and proficiency shall be established by one of the following methods:
- 2.2.1 For generally accepted NDE methods, processes, or techniques; qualification and certification may be in accordance with the latest revision of the American Society of Non-destructive Testing Recommended Practices # SNT-TC-1A and must comply with ASME/NBIC code requirements.
 - 2.2.2 NDE Technicians' utilizing new technology, processes, methods, or techniques to be applied to Boiler tube and HEP inspections shall qualify by testing;
 - 2.2.2.1 Using the Company approved boiler tube FlawTech coupons.
 - 2.2.2.2 By demonstrating proficiency using the EPRI boiler tube coupons and presenting documentation of results.
 - 2.2.2.3 To qualify to perform for High Energy Piping inspections to identify early stage creep-damage in HEP, the Technician shall demonstrate proficiency using the Materials Property Counsel (MPC) controlled set of coupons (University of Tennessee, Knoxville, TN)
 - 2.2.2.4 Alternatively, Consultant or NDE service provider may present a documented and effective In-house training program to the responsible Company representative for approval.
- 2.3 All individuals responsible for data acquisition and/or data analysis shall be certified either Level II or Level III in the appropriate discipline. These individuals shall also have documented and verifiable experience applying to the specific type of inspections being performed.
- 2.4 When requested by Company, the Consultant or NDE service provider site staff shall include at least one individual who has extensive experience with the metallurgical aspects of damage mechanisms. This individual shall be a working member of the inspection team and shall additionally add metallurgical expertise to the process of data interpretation.
- 2.5 Proposals for each Work Release issued shall include recommended staffing level to accomplish the work within the allotted schedule, allowing adequate time for supplemental inspections, if needed, to fully characterize all detected indications. Staffing shall include individual(s), as necessary, depending on specific scope and schedule, to perform data acquisition and independent data analysis.

- 2.6 Resumes of all staff from which the inspection team would be selected should be submitted with the proposal. The specific role of each individual should be clearly identified. Company maintains the right to exclude or otherwise restrict utilization of specific individuals solely at the discretion of Company. No substitution of personnel shall be permitted without the Company's written approval.
- 2.7 PacifiCorp uses ATI Aware Software to document boiler and high energy piping inspections. In addition to all other reporting requirements the Consultant or NDE service provider shall submit results in a software format that can be uploaded into the Aware Program.

3.0 Reporting of Data

3.1 Field Reporting of Data:

- 3.1.1 At the end of each shift, the Consultant or NDE service provider shall submit a daily status report to the Company's Site Representative of the results of each day's inspections:
- 3.1.1.1 Daily status reports for each inspection or evaluation activity for welds and components
 - 3.1.1.2 Prioritized recommendations
 - 3.1.1.3 Work completed on prioritized recommendations.
 - 3.1.1.4 Due to urgency when Service Damage of HEP is identified, a preliminary verbal analysis of results is required immediately.
- 3.1.2 The Consultant or NDE service provider shall provide Company with a preliminary field inspection report at the completion of the field examination. Consultant's or NDE service provider's inspection personnel shall not leave the job site until this preliminary report has been reviewed with Company's Site Representative to allow Company the prerogative of requesting further examinations.
- 3.1.3 The preliminary field report shall include copies of all reader sheets and a summary of the examinations performed (including areas and techniques), a report of all relevant indications and methods of identification. This summary will be in table format listing each weld or component tested, each process used, and the results of each process. Results will be reported using the following wording:

3.1.4 All indications or defects are to be fully described as to locations, sizes and types and shall be reported utilizing the following applicable terminology

3.1.4.1 New and repaired welds, components or materials:

3.1.4.1.1 Acceptable

3.1.4.1.2 Rejected.

3.1.3.2 Material or wall loss:

3.1.4.2.1 Nominal thickness

3.1.4.2.2 Minimum allowable thickness

3.1.4.2.3 Actual wall thickness

3.1.4.2.4 Areas of concern in Red (Report Immediately)

3.1.4.2.5 Company representative shall make the determination

3.1.4.3 Fatigue Service Damage

3.1.4.3.1 No Service Damage

3.1.4.3.2 Size and Location of Crack(s)

3.1.4.4 Creep Service Damage (Advanced Ultrasonics)

3.1.4.4.1 No Relevant Indication (NRI)

3.1.4.4.2 Unknown Damage (PacifiCorp internal used only)

3.1.4.4.3 Light Banding

3.1.4.4.4 Moderate Banding

3.1.4.4.5 Heavy Banding

3.1.4.4.6 Aligned Voids

3.1.4.4.7 Micro Cracking

3.1.4.4.8 Macro Cracking

3.1.4.5 Creep Service Damage (Metallurgical Sample)

3.1.4.5.1 No Damage

3.1.4.5.2 Isolated Voids (size <1.5 μm)

3.1.4.5.3 Light Clustering of Voids (size 1.5 to 2.5 μm)

3.1.4.5.4 Moderate Clustering of Voids (size 2.5 to 3.0 μm)

3.1.4.5.5 Heavy Clustering of Voids (size 3.0 to 3.5 μm)

3.1.4.5.6 Aligned Voids (size 3.5 to 5.5 μm)

3.1.4.5.7 Micro Cracking (size 5.6 to 6.5 μm)

3.1.4.5.8 Macro cracking (size 6.5 to 7.0 μm)

- 3.1.5 Electronic copies of all daily reports and the preliminary written field report will be provided to the Company at completion of the examinations and prior to Consultant or NDE service provider personnel leaving the plant site.

3.2 Final Report

- 3.2.1 Within six weeks of completing the field inspection, the Consultant or NDE service provider shall provide a detailed final report of those examinations. The final report shall include, as a minimum, the following information:
 - 3.2.1.1 Inspection methodology and procedures incorporated.
 - 3.2.1.2 Inspection findings, condition assessment, and documentation of all completed and uncompleted work.
 - 3.2.1.3 Recommendations and prioritization for the next overhaul.
 - 3.2.1.4 Final report to include (2) hard copies and one (1) electronic copy to plant site and one (1) electronic copy to corporate office.
 - 3.2.1.5 Inspection data shall be supplied to Company in the agreed upon format utilizing the same damage/defect descriptions as defined in section 3.1.4 of this specification

4.0 Component Description of Work

- 4.1 Boiler tube evaluations shall include sizes and types of boiler tubing to be examined using UT during boiler overhauls will typically be between 1.75” OD and 3.50” OD, between 0.148” MWT and 0.500” MWT, and meet material specifications from ASME, BPVC, Section 1, Power Boilers, Part PG-9, “Pipes, Tubes, and Pressure Containing Parts”.
 - 4.1.1 Dissimilar Metal Welds (DMWs) shall be investigated the entire circumference and completely through-wall thickness of the tubing to assure there is no creep-fatigue damage.
 - 4.1.2.1 Creep-fatigue damage (CFD) typically concentrates along the ferritic (low alloy steel) side of the weld, initiating along the ID surface, the mid-wall of the tube, or along the OD surface.
 - 4.1.2.2 Linear Phased Array (LPA) shall be used for evaluations.

- 4.1.2 Oxide scale measurement (OSM) and performing remaining life calculations of temperature tube requires the accurate measurement of tube wall and steam side scale thickness.
 - 4.1.2.1 The acquisition system must provide for high minimum resolution, typically from 0.005” to 0.030” over the life of the tubing.
- 4.1.3 Life assessment and tube remaining creep life (LARL) is calculated using, a remaining life analysis computer code that assists with the interpretation of the collected ultrasonic signals.
 - 4.1.3.1 Based on analyst input, the software module calculates the tube wall thickness, oxide thickness, and tube remaining life for each analyzed signal. The results are subsequently reported as text documents and database file formats.
 - 4.1.3.2 An effective temperature is determined for each measurement by using a variety of oxide thickness-to-temperature correlations. For PacifiCorp Units, typically the French correlation has been used. Based on this temperature estimate, remaining creep life values are predicted using standard Larson-Miller parameter (LMP) calculations for the appropriate material.
 - 4.1.3.3 The actual prediction of remaining life is based on published stress rupture data typically reported as log stress versus LMP. Because of data scatter, curves are typically plotted through the data to provide minimum and mean remaining life values. For a given stress, exhausted remaining life is predicted to occur when the combination of time and temperature (LMP) reaches the test population.
- 4.1.4 Header Socket Weld of the tube to header socket welds (HSW) shall be performed to detect subsurface damage that can occur at the socket weld root and fusion line.
 - 4.1.4.1 A customized Linear Phased Array (LPA) technique that permits socket interrogation via the tube stub surface shall be used.
 - 4.1.4.2 The circumferential extent of the defect is important since actively growing flaws will exhibit crack propagation in both the radial and circumferential directions.

- 4.1.4.3 The specific location of defects around the tube circumference is important and can provide insight into the potential cause of the cracking.
- 4.2 Boiler Condition Inspections of areas of high priority and estimated manpower requirements will be provided in the individual Work Release for each project. The basic outline will be as follows:
 - 4.2.1 Defined areas for UT inspection
 - 4.2.2 Defined areas for Visual Inspection
 - 4.2.3 Component Condition Assessment
 - 4.2.4 Specific Recommendations
- 4.3 High Energy Piping (HEP) is categorized into three types of service damage mechanisms with affected systems, welds or components listed with the affecting service damage mechanisms as follows:
 - 4.3.1 Creep Affected
 - 4.3.1.1 Main Steam
 - 4.3.1.2 Hot Reheat
 - 4.3.1.3 Boilers Headers
 - 4.3.1.4 Boiler Leads
 - 4.3.1.5 Boiler Links
 - 4.3.1.6 Turbine Piping
 - 4.3.1.7 Boiler Feed Pump Turbine Piping
 - 4.3.2 Corrosion-Fatigue and Simple Fatigue-Affected
 - 4.3.2.1 Cold Reheat
 - 4.3.2.2 Deaerators
 - 4.3.2.3 Deaerator Storage Tanks
 - 4.3.3 Flow Accelerated Corrosion (FAC)-Affected
 - 4.3.3.1 Feedwater piping and components
 - 4.3.3.2 Condensate piping and components
 - 4.3.3.3 Extraction Steam piping and components
 - 4.3.3.4 Deaerators

- 4.3.3.5 Deaerator Storage Tanks,
- 4.3.3.6 Re-Heat Spray piping and components
- 4.3.3.7 Superheat Spray Lines piping and components
- 4.3.3.8 Heater Vents piping and components
- 4.3.3.9 Heater Drains piping and components
- 4.3.3.10 Boiler Blowdown piping and components,
- 4.3.3.11 Boiler Start-Up piping and components
- 4.3.3.12 Re-Circulation piping and components
- 4.3.3.13 Heater Shells inlet nozzles and surrounding areas

4.4 General Plant and other applications of testing and evaluation methods, processes, and techniques shall be in accordance with the applicable code, Company requirements. Note: Full definitions of acronyms are found in Section 5.0 of this Specification.

4.4.1 New and repaired welds in components and materials with an expected safety and reliability of 30 years. These types of welds are to be evaluated in accordance with design specifications, and the applicable paragraphs of the ASME-BPVC Section V.

4.4.1.1 ASME B31.1 Piping (New and repair welds):

4.4.1.1.1 Butt Welds on NPS >2" (NPS =National Pipe Size)

- VTWLD (Visual Testing Weld)
- MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
- RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.1.2 Butt Welds on NPS < 2"

- VTWLD (Visual Testing Weld)
- MT (Magnetic Testing)
- or
- PT (Penetrant Testing)

4.4.1.1.3 Branch Connections NPS >4

- VTWLD (Visual Testing Weld)
- MT (Magnetic Testing)

or

- PT (Penetrant Testing)
- RT (Radiographic Testing)

or

- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.1.4 Branch Connections NPS <4”

- VTWLD (Visual Testing Weld)
- MT (Magnetic Testing)

or

- PT (Penetrant Testing)

4.4.1.1.5 Fillet, Socket, Attachment and Seal

- VTWLD (Visual Testing Weld)
- MT (Magnetic Testing)

or

- PT (Penetrant Testing)

4.4.1.1.6 P91 materials (As applicable)

- VTWLD (Visual Testing Weld)
- MT (Magnetic Testing)

or

- PT (Penetrant Testing)
- RT (Radiographic Testing)

or

- LPA (Ultrasonics Testing-Linear Phased Array)
- HT (Hardness Testing)

or

- PHT (Portable Hardness Testing)

4.4.1.1.7 Temper Bead Welding on piping (Only allowed if approved by the responsible company representative with a ASME Section IX WPS and supporting PQR)

- VTWLD (Visual Testing Weld)
- MT (Magnetic Testing)

or

- PT (Penetrant Testing)
- RT (Radiographic Testing)

or

- LPA (Ultrasonics Testing-Linear Phased Array)
- HT (Hardness Testing)

or

- PHT (Portable Hardness Testing)

4.4.1.2 ASME Section I Boiler (New and repair welds):

4.4.1.2.1 Steam or Water: (Subjected to radiant heat)

4.4.1.2.1.1 Longitudinal Welds

- VTWLD (Visual Testing Weld)
 - RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.2.1.2 Girth Drum or Shell Welds, NPS >10" or >1.125" T

- VTWLD (Visual Testing Weld)
 - RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.2.1.3 Girth Tubes, Pipes or Header Welds > NPS 4" or ½" T

- VTWLD (Visual Testing Weld)
 - RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.2.2 Water: (Not subjected to radiant heat)

4.4.1.2.2.1 Girth Tubes, Pipes or Header Welds NPS >10" or >1.125" T

- VTWLD (Visual Testing Weld)
 - RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.2.3 Steam: (Not subjected to radiant heat)

4.4.1.2.3.1 Girth Tubes, Pipes or Header Welds NPS >16" or >1.625" T

- VTWLD (Visual Testing Weld)

- RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.3 ASME Section IIIV Pressure Vessels (New and repair welds):

4.4.1.3.1 Longitudinal and Girth Welds

- VTWLD (Visual Testing Weld)
 - RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.3.2 Nozzle, Fillet and Attachment Welds

- VTWLD (Visual Testing Weld)
 - RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)

4.4.1.4 Temper Bead Welding on ASME Sections I and IIIV components (Only allowed if approved the responsible company representative with a ASME Section IX WPS and supporting PQR)

- VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)
 - HT (Hardness Testing)
- or
- PHT (Portable Hardness Testing)

4.4.1.4 Structural Steel (New and repair welds): See AWS D1.1

- VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - RT (Radiographic Testing)
 - UT (Ultrasonics Testing)
 - RT (Radiographic Testing)

4.4.1.5 General Base Metal Repairs (such as Casings, Shafts, Blades)

- PMI (Positive Material Identification)
 - VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - PHT (Portable Hardness Testing)
 - ME (Metallography Evaluation)
 - RT (Radiographic Testing)
- or
- LPA (Ultrasonics Testing-Linear Phased Array)
 - Other methods, processes, and techniques as approved by the Responsible Company Representative

4.5 Service Damage Inspection and Evaluations

4.5.1 Boiler Tube Conditions Inspections:

- VTWLD (Visual Testing Weld)
 - VTBC (Visual Testing Boiler Conditions)
 - VTBO (Visual Testing Boroscopy)
 - UTT (Ultrasonics Testing Thickness)
 - LPA (Ultrasonics Testing-Linear Phased Array)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - Other methods, processes, and techniques as approved by Responsible Company Representative

4.5.2 Creep Affected:

4.5.2.1 Required assurance of safety and reliability – 5-8 years (High Energy systems or components operating at 850°F or greater)

4.5.2.1.1 Girth Welds are evaluated using: first, VTWLD, secondly, MT or PT, and thirdly with Advanced Ultrasonics. The additional testing methods listed are to be utilized at the directions of the responsible Plant and or Corporate HEP Engineers.

- VTWLD (Visual Testing Weld)

- MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - UTT(Ultrasonics Testing Thickness)
 - AE (Acoustic Emission Testing)
 - LPA (Ultrasonics Testing-Linear Phased Array)
 - FPAD (Focused Phased Array Depth)
 - PHT (Portable Hardness Testing)
 - Rep (Replication)
 - VTBO (Visual Testing Boroscopying)
 - VTGM (Visual Testing Geometry Measuring)
 - GWUT (Guided Wave Ultrasonics Testing) ME (Metallography Evaluation)
 - Other methods, processes, and techniques as approved by Responsible Company Representative

4.5.2.1.2 Longitudinal Seam Welds are evaluated using: first, with VTWLD, secondly, MT or PT, and thirdly with Advanced Ultrasonics is to be utilized to further evaluate specific locations which are identified by the high stress points along the seam weld. The additional testing methods listed are to be utilized at the directions of the responsible Plant and or Corporate HEP Engineers.

- VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - UTT(Ultrasonics Testing Thickness)
 - AE (Acoustic Emission Testing)
 - LPA (Ultrasonics Testing-Linear Phased Array)
 - FPAD (Focused Phased Array Depth)
 - TOFD (Ultrasonics Testing-Time of Flight Diffraction)
 - PHT (Portable Hardness Testing)
 - Rep (Replication)
 - VTBO (Visual Testing Boroscopying)
 - VTGM (Visual Testing Geometry Measuring)
 - GWUT (Guided Wave Ultrasonics Testing) ME (Metallography Evaluation)
 - Other methods, processes, and techniques as approved by Responsible Company Representative

4.5.2.1.3 Wyes & Branch Connection Welds are evaluated using: first, with VTWLD, secondly, MT or PT, and thirdly with Advanced Ultrasonics as much as possible. The additional testing methods listed are to be utilized at the directions of the responsible Plant and or Corporate HEP Engineers.

- VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - UTT(Ultrasonics Testing Thickness)
 - AE (Acoustic Emission Testing)
 - LPA (Ultrasonics Testing-Linear Phased Array)
 - FPAD (Focused Phased Array Depth)
 - PHT (Portable Hardness Testing)
 - Rep (Replication)
 - VTBO (Visual Testing Boiler Conditions)
 - VTGM (Visual Testing Geometry Measuring)
 - GWUT (Guided Wave Ultrasonics Testing) ME (Metallography Evaluation)
 - Other methods, processes, and techniques as approved by Responsible Company Representative

4.5.2.1.4 Gama Plug, Seal, and Socket Welds are evaluated using: first, with VTWLD, and secondly, MT or PT. The additional testing methods listed are to be utilized at the directions of the responsible Plant and or Corporate HEP Engineers.

- VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - AE (Acoustic Emission Testing)
 - PHT (Portable Hardness Testing)
 - Rep (Replication)
 - VTBO (Visual Testing Boroscopying)
 - VTGM (Visual Testing Geometry Measuring)
 - ME (Metallography Evaluation)
 - Other methods, processes, and techniques as approved by Responsible Company Representative

4.6 Fatigue and Corrosion Fatigue Affected:

4.6.1 Cold Reheat

4.6.1.1 Required assurance of safety and reliability – 5-8 years

4.6.1.2 Girth Welds are evaluated using: first, with VTWLD, secondly, MT or PT, and thirdly with Advanced Ultrasonics. The additional testing methods listed are to be utilized at the directions of the responsible Plant and or Corporate HEP Engineers.

- VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - LPA (Ultrasonics Testing-Linear Phased Array)
 - FPAD (Focused Phased Array Depth)
 - UTT(Ultrasonics Testing Thickness)
 - GWUT (Guided Wave Ultrasonics Testing)
 - ME (Metallography Evaluation)
 - Other methods, processes, and techniques as approved by Responsible Company Representative

4.6.1.3 Longitudinal Seam Welds are evaluated using: first, with VTWLD, secondly, MT or PT, and thirdly with Advanced Ultrasonics is to be utilized to further evaluate specific locations which are identified by the high stress points along the seam weld. The additional testing methods listed are to be utilized at the directions of the responsible Plant and or Corporate HEP Engineers.

- VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - UTT(Ultrasonics Testing Thickness)
 - LPA (Ultrasonics Testing-Linear Phased Array)
 - FPAD (Focused Phased Array Depth)
 - TOFD (Ultrasonics Testing-Time of Flight Diffraction)
 - PHT (Portable Hardness Testing)
 - Rep (Replication)
 - VTBO (Visual Testing Boroscopying)
 - VTGM (Visual Testing Geometry Measuring)
 - ME (Metallography Evaluation)
 - Other methods, processes, and techniques as approved by Responsible Company Representative

4.6.1.4 Wyes & Branch Connection Welds are evaluated using: first, with VTWLD, secondly, MT or PT, and thirdly with LPA as much as possible. The additional testing methods listed are to be utilized at the directions of the responsible Plant and or Corporate HEP Engineers.

- VTWLD (Visual Testing Weld)
 - MT (Magnetic Testing)
- or
- PT (Penetrant Testing)
 - UTT(Ultrasonics Testing Thickness)
 - LPA (Ultrasonics Testing-Linear Phased Array)
 - Other methods, processes, and techniques as approved by Responsible Company Representative

4.6.1.5 Gama Plug, Seal, and Socket Welds are evaluated using: first, with VTWLD, and secondly, MT or PT. The additional testing methods listed are to be utilized at the directions of the responsible Plant and or Corporate HEP Engineers.

- VTWLD (Visual Testing Weld)
- MT or (Magnetic Testing)
- PT (Penetrant Testing)
- Other methods, processes, and techniques as approved by Responsible Company Representative

4.6.2 Deaerator Heaters and Deaerator Storage Tanks

4.6.2.1 Required assurance of Safety and Reliability–5-8 years

4.6.2.2 All Welds

- VTWLD (Visual Testing Weld)
- UTT(Ultrasonics Testing Thickness)
- ACFM Alternating Current Field Measurements)(
- MT or (Magnetic Testing)
- PT (Penetrant Testing)
- Other methods, processes, and techniques as approved by Responsible Company Representative

4.7 Flow-Accelerated Corrosion FAC Affected

4.7.1 EPRI Gridding recommendations shall be followed.

4.7.2 Required assurance of safety and reliability–5-8 years per component

4.7.3 Component evaluations

- UTT(Ultrasonics Testing Thickness)
- RT (Radiographic Testing) for small bore (Company HEP Engineer for procedure)

4.7.4 System survey evaluations

- INCOTEST (An acronym for INSulated Component TEST)
- GWUT (Guided Wave Ultrasonics Testing)
- DDRT (Digital Display RT)

5.0 Inspection, Testing and Evaluation Methods Descriptions

5.1 Destructive Testing

5.1.1 Metallurgical Services (MS) – Is the science of evaluating metals usually in a laboratory setting. Common laboratory testing includes but not limited to:

5.1.1.1 Failure Analysis (FA)

5.1.1.2 Chemical Analysis (CA)

5.1.1.3 Physical Property Tests (PPT)

- Tensile Testing (TT)
- Bend Testing (BT)
- Hardness Testing (HT)
- Notch Toughness Testing (NT)
- Portable Hardness Testing (PHT)

5.1.2 Service Condition Metallography Evaluation (ME) - Is the science and art of preparing a metal grinding, polishing, and etching to reveal micro-structural constituents. After preparation, the sample can easily be analyzed using optical or electron microscopy. A skilled technician is able to identify alloys and predict material properties, as well as processing conditions. Metallography sample is obtained by removing a portion of the metal. The common terminology is Plug or Boat sample. (Also see “Replication” in the NDE section of this Specification).

- 5.1.3 Replication (Rep) - is a form of non-destructive testing which provides a metallographic replica of the surface microstructure of a material.
- 5.1.4 Positive Material Identification (PMI) – PMI quickly and accurately identifies the composition of more than 100 different engineering alloys and can be performed on site.
 - 5.1.4.1 X-Ray Fluorescence (XRF) - X-ray fluorescence is a technique of chemical analysis. An X-ray beam is aimed at the surface of an object which causes secondary (fluorescent) X-rays to be generated. Each element present produces X-rays of different energies. These X-rays are detected and displayed as a spectrum of intensity against energy: the positions of the peaks identify which elements are present and the peak heights identify how much of each element is present.
 - 5.1.4.2 Spark Emission Spectrography (SES) - Is used to analyses elements in solid metals. An electric arc or spark is passed through a sample, heating it to a high temperature exciting the atoms. In modern spark sources with controlled discharges under an argon atmosphere SES is considered quantitative. Both qualitative and quantitative spark analysis are widely used for production quality control in foundries and steel mills.
- 5.1.5 Engineering Services (ES) – Includes stress analyses, special repair plans, engineering inspections and evaluations such as warping, bulging, and ovality.
- 5.2 Nondestructive Examination (NDE) -
 - 5.2.1 Acoustic Emission Testing (AE) - A method of nondestructive testing that uses mechanical waves moving through materials. Sensors attached on the surfaces of the material detect these waves, known as acoustic emission signals. The Signals emitted by active cracks are then analyzed based on the frequency, amplitude and location.
 - 5.2.2 Acoustic Pulse Reflectometry (APR) - Is based on the measurement of one-dimensional acoustic waves propagating in tubes. Any change in the cross sectional area in the tubular system creates a reflection, which is then recorded and analyzed in order to detect defects.
 - 5.2.3 Alternating Current Field Measurements (ACFM) – The use of ACFM provides reliable detection and sizing of cracks in metallic components. There is no weld or base metal cleaning required. ACFM effectively provides readings through paint, coatings, scale and process related residue. The

technique yields excellent sensitivity and is able to determine defect width, length, and depth up to 3/16 of an inch. The Air multidirectional array sensor is to be used.

- 5.2.4 Eddy Current Testing (ET) - In standard eddy current testing, a circular coil carrying an AC current is placed in close proximity to an electrically conductive specimen. Variations in the electrical conductivity or magnetic permeability of the test object, or the presence of any flaws, will cause a change in eddy current flow and a corresponding change in the phase and amplitude of the measured current. This is the basis of standard (flat coil) eddy current inspection.
- 5.2.5 INCOTEST (NCT) – (An acronym for INSulated Component TEST) is a unique corrosion survey method that allows ferrous pipes and vessels to be surveyed without the time and expense of removing insulation, asbestos, fireproofing concrete or similar coatings.
- 5.2.6 Magnetic Flux Leakage Testing (MFL) - A magnetic field is passed through ferromagnetic steel, flux leakage caused by pitting and corrosion is detected by MFL detectors in the scanning unit and displayed for the operator.
- 5.2.7 Liquid Penetrant Testing (PT) - Is used to reveal surface breaking flaws by bleedout of a colored or fluorescent dye from the flaw and contrasted between developers. Test objects are coated with visible or fluorescent dye solution the excess dye is then removed and a developer is applied. The developer acts as blotter, drawing trapped penetrant out of imperfections.
 - 5.2.7.1 Visible Color Dyes (CD)
 - 5.2.7.2 Fluorescent Dyes (FD) - enable viewing under a UV lamp.
- 5.2.8 Magnetic Particle Testing (MT) – A nondestructive examination method applied to detect cracks and other discontinuities on or near the surfaces of ferromagnetic materials.
 - 5.2.8.1 Dry Particle (DP) - materials commonly used are black iron particles and red or yellow iron oxides.
 - 5.2.8.2 Wet Fluorescent (WF) - materials enable viewing under a UV lamp.
- 5.2.9 Radiography Testing (RT) - This technique involves the use of penetrating gamma or X-radiation to examine parts and products for imperfections.

- 5.2.9.1 Computed Tomography (CT) - Computed Tomography (CT) is a powerful nondestructive evaluation (NDE) technique for producing 2-D and 3-D cross-sectional images of an object from flat X-ray images. Characteristics of the internal structure of an object such as dimensions, shape, internal defects, and density are readily available from CT images.
- 5.2.9.2 Digital Display RT (DDRT) - is a form of x-ray imaging, where digital X-ray sensors are used instead of traditional photographic film. Advantages include time efficiency through bypassing chemical processing and the ability to digitally transfer and enhance images. Also less radiation can be used to produce an image of similar contrast to conventional radiography.
- 5.2.9.3 Distributed Source Positron Annihilation (DSPA) – Uses a positron source emitter to deposit positrons into the subject material. The process is similar to PIPA after the positrons are deposited and attracted to nano-sized defects in the material. DSPA technology can detect fatigue, embrittlement, and other forms of structural damage in materials at the atomic level, before cracks appear.
- 5.2.9.4 Photon Induced Positron Annihilation (PIPA) - Photon Induced Positron Annihilation (PIPA) involves penetrating materials with a photon beam which are attracted to nano-sized defects in the material. The positrons collide with electrons in the material and are annihilated, releasing energy in the form of gamma rays. The gamma ray energy spectrum creates a distinct and readable signature of the size, quantity and type of defects present in the material. PIPA technology can detect fatigue, embrittlement, and other forms of structural damage in materials at the atomic level, before cracks appear.
- 5.2.9.5 Neutron Radiography (NR) - is an imaging technique which provides images similar to X-ray radiography. The difference between neutron and X-ray interaction mechanisms produce significantly different and often complementary information.
- 5.2.9.6 Traditional (RT) - An X-ray machine or radioactive isotope is used as a source of radiation. Radiation is directed through a part and onto film. The resulting shadowgraph shows the internal soundness of the part. Possible imperfections are indicated as density changes in the film.

5.2.9.7 X-ray Diffraction (XRD) - is a versatile, non-destructive technique that reveals detailed information about the chemical composition and crystallographic structure of natural and manufactured materials.

5.2.10 Ultrasonic Testing (UT) – The examination of materials by introducing ultrasonic waves into, through, or onto the surface of the article being examined and determining various attributes of the material from effects on the ultrasonic waves.

5.2.10.1 Focused Phased Array Depth - (FPAD) utilizes transducers that have multiple elements, each having its own pulsar and receiver and is controlled by a computerized system. By timing, or phasing the individual elements, various converging wavefronts can be created. Using varied phase patterns, different focal depths can be achieved. Data may be interpreted and analyzed by qualified individuals or by means of computer software. FPAD is typically used to evaluate early stage creep damage in High Energy Piping.

5.2.10.2 Automated Ultrasonic Testing (AUT) – uses an automated mechanical tracking device and or a system that gathers and records the data.

5.2.10.3 Guided Wave UT (GW) - Uses low frequency guided waves to detect thickness changes caused by corrosion/erosion and or weld locations in piping. A band comprising five rings of piezoelectric transducers is clamped around the pipe and ultrasound is sent in both directions along the pipe. Three of the rings excite longitudinal waves in the pipe and two excite torsional waves. The signals are displayed from three different wave modes, namely symmetrical, horizontal flexural and vertical flexural. The signal obtained is similar to a conventional ultrasonic A-scan, where the horizontal axis represents distance along the pipe and the vertical axis represents thickness change.

5.2.10.4 Linear Phased Array– (LPA) utilizes a transducer that has multiple elements, each having its own pulsar and receiver and is controlled by a computerized system. By timing, or phasing the individual elements, various converging wavefronts can be created. Using varied phase patterns, different focal points can be achieved. Recently LPA is often utilized when RT is not practicable.

5.2.10.5 Pulse-Echo Imaging (EPI) - Using standard ultrasonic probes, pulse-echo thickness measurement and weld inspection with a

position encoder and appropriate software produces images of flaws which can be electronically saved.

- 5.2.10.6 Shear Wave or A-SCAN UT (SW) – An ultrasonic wave is transmitted at a predetermined angle into the test material. Surfaces normal to the beam path and corner-traps reflect the wave energy back to the transducer. The display shows the distance the wave traveled to the imperfection and the relative strength of the energy.
- 5.2.10.7 Time of Flight Diffraction – (TOFD) the detection of flaws based on analyzing the arrival time of diffracted sound waves emitted from a flaw's extremities.
- 5.2.10.8 Thickness Measurements (UTT) - are performed using a conventional flaw detector and a compression wave probe, which sends longitudinal waves into the component at normal incidence to the surface. Signals are displayed on the flaw detector screen in the form of an A-scan, in which the horizontal axis represents distance and the vertical axis represents signal amplitude. Since a 0° compression probe is being used, the horizontal axis is equivalent to depth from the scanning surface. For FAC see EPRI Gridding Recommendations.
- 5.2.11 Thermography (TG) - is the use of an infrared imaging and measurement camera to "see" and measure thermal energy emitted from an object.
- 5.2.12 Visual / Optical Testing (VT) - is used extensively to evaluate the condition or the quality of a weld or component. It is easily carried out, inexpensive and usually doesn't require special equipment. It requires good vision, good lighting and the understanding and knowledge of what to look for.
 - 5.2.12.1 Welds (WLD) Note: Technicians must be AWS CWI or Company approved
 - 5.2.12.2 Geometry Measuring (GM)
 - 5.2.12.3 Boroscopying (BO) Note: Technicians must be Company approved
 - 5.2.12.4 Boiler Conditions (BC) Note: Technicians must be Company approved
 - 5.2.12.5 Pressure Vessels Conditions (PV) Note: Technicians must be Company approved

5.2.12.6 Piping Conditions (PC) Note: Technicians must be Company approved

5.2.12.7 Hangers (HNG) Note: Technicians must be Company approved