2. Document Title
242-A Evaporator E-A-1 Reboiler - Functions and Requirements Evaluation Document

3. Design Verification Required
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EV-14-1599-D R-0
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   a. Does the change introduce any new failure modes to the equipment? ☐ Yes ☒ No
      Basis is required for Yes:
   b. Does the change increase the probability of existing failure modes? ☜ Yes ☐ No
      Basis is required for Yes:
   c. For Safety Significant equipment, does the change require a modification to Chapter 4 of the DSA and/or FRED? ☒ Yes ☐ No ☐ N/A
      Basis is required for Yes: More information included in FRED about existing failure mechanism. No change to DSA Required.

7. Description of Change and Justification (Use Continuation pages as needed)
More information included in FRED about existing failure mechanism.

8. Approvals

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9. Clearance Review:

Restriction Type:
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☐ Undefined
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☐ Export Control Information (ECI)
☐ Official Use Only Exemption 2-Circumvention of Statute (OUO-2)
☐ Official Use Only Exemption 3-Statutory Exemption (OUO-3)
☐ Official Use Only Exemption 4-Commercial/Proprietary (OUO-4)
☐ Official Use Only Exemption 5-Privileged Information (OUO-5)
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11. TBDs or Holds

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<td>Brent T. Becker 8/21/2014 Troy R. Farris 8/21/2014</td>
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242-A Evaporator E-A-1 Reboiler – Functions and Requirements Evaluation Document

B. T. Becker
Washington River Protection Solutions, LLC

Date Published
August 21, 2014

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800
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LIST OF TERMS

Acronyms and Abbreviations

ASME  American Society of Mechanical Engineers
ASTM  American Society for Testing and Materials
C  Centigrade
C of C  Certificate of Conformance
DOE  Department of Energy
DST  Double Shell Tank
F  Fahrenheit
gpm  gallons per minute
HIHTL  Hose-in-Hose Transfer Line
HVAC  Heating, Ventilation, Air Conditioning
IQRPE  Independent Qualified Registered Professional Engineer
LPG  Liquid Propane Gas
NCR  Non-conformance report
PRV  Pressure Relief Valve
psig  pounds per square inch – gauge
PTFE  Polytetrafluoroethylene
PUREX  Plutonium Uranium Extraction
SECD  Safety Equipment Compliance Database
SpG  Specific Gravity
SSCs  Structures, Systems, and Components
TEDF  Treatment Effluent Disposal Facility
TEMA  Tube Exchanger Manufacturers Association
TOC  Tank Operations Contractor
VFD  Variable Frequency Drive
WRPS  Washington River Protection Solutions
1.0 PURPOSE

The purpose of this document is to describe the evaluation of the E-A-1 Reboiler’s ability to perform its safety function(s) under those conditions and events for which the safety function is required. This document identifies the related system, structure, and components (SSCs); critical characteristics; functional and performance requirements; failure modes; boundaries; interfaces; required support systems, and the Key aspects.

2.0 APPROACH

The safety function of the E-A-1 Reboiler was developed based on hazardous conditions identified in RPP-48900, 242-A Evaporator Hazard Evaluation Database Report. Functional/performance requirements were developed by evaluating the required performance needed to accomplish the safety functions (i.e., prevent or mitigate accidents). Additional applicable functional requirements were developed during engineering evaluations of failure modes when the E-A-1 Reboiler must perform its safety function.

This evaluation was done in accordance with TOC procedure TFC-ENG-DESIGN-C-45, “Control Development Process for Safety-Significant Structures, Systems, and Components.” The following information is provided in this document:

1. Identification of the safety-significant boundaries for the E-A-1 Reboiler

2. Documentation of support systems required for the E-A-1 Reboiler to perform the intended safety function.

3. An evaluation of interfacing systems whose failure could prevent the E-A-1 Reboiler from performing the intended safety function.

4. Documentation of safety SSC functional and performance requirements necessary for the E-A-1 Reboiler to perform the safety function. The safety SSC functional and performance requirements were identified from design requirements, engineering evaluations and calculations, the interactive hazard/accident analysis safety controls development/evaluation process, and process hazard analysis.

5. Critical characteristics necessary for the E-A-1 Reboiler to perform the safety functions, and identification of how the critical characteristics can be verified to be met. Critical characteristics may be used in the commercial grade dedication (CGD) process to provide reasonable assurance the safety SSC is acceptable and will perform its safety-related function.

6. Controls (inspections, tests, evaluations or other provisions) needed to verify compliance with critical characteristics during fabrication or construction, and provisions necessary to provide reasonable assurance that PSV-PB2-1 will continue to perform its intended
safety function during operation (e.g., in-service inspections, tests, evaluations, shelf life, service life).

Using information from the evaluation described above, critical characteristics for the E-A-1 Reboiler were identified. Subsequent to determining the critical characteristics, key performance requirements were identified. This consisted of identifying any inspections, tests, evaluations or controls needed to verify compliance with critical characteristics.

Compliance with the critical characteristics identified in this Functions and Requirements Evaluation Document shall be verified and documented. Acceptable means of verification can be accomplished by one or more of the following means:

- Procurement from a qualified supplier
- Commercial grade dedication
- Technical evaluation (to close an NCR)

NOTE: The NCR process shall be used to upgrade an existing SSC when the SSC was not procured as safety-significant through a qualified supplier or the CGD process prior to the SSC being declared safety-significant. A Technical Evaluation (refer to TFC-ENG-FACSUP-C-02) shall determine how the FRED critical characteristics were verified and shall be listed in the Safety Equipment Compliance Database (SECD).

Documented evidence of compliance is identified in the SECD (refer to TFC-ENG-FACSUP-C-23 and TFC-ENG-FACSUP-CD-23.3).

3.0 SCOPE

The scope of this evaluation focuses on the E-A-1 Evaporator Reboiler. This evaluation also considers interfacing/support systems and the effect they may have on the safety function of the Reboiler.

4.0 SAFETY FUNCTION

The safety function of the E-A-1 Reboiler is to provide confinement of waste (i.e., E-A-1 Reboiler tube/tube sheet integrity). Providing confinement of waste protects facility workers from a flammable gas accident in the steam condensate system due to waste in the steam condensate system resulting from an E-A-1 Reboiler tube/tube sheet leak/failure (i.e., accumulation of flammable gas generated by waste in the steam condensate system piping or components). Providing confinement of waste also protects facility workers from direct radiation hazards and chemical burn hazards (i.e., skin contact with caustic waste) during steam condensate sampling activities due to waste in the steam condensate system resulting from an E-
A-1 Reboiler tube/tube sheet leak. (Note: The direct radiation hazard is only from waste misrouted into steam condensate weir box TK-C-103.)

5.0 SYSTEM DESCRIPTION

5.1 OVERALL DESCRIPTION

The 242-A Evaporator is designed to reduce the waste volume that must be stored in Hanford Tank Farms double-shell tanks (DSTs). This is accomplished through an evaporation process that uses a conventional forced-circulation, vacuum evaporation system operating at low pressure to concentrate radioactive waste solutions.

The waste is pumped from feed tank 241-AW-102 through an underground line to the 242-A C-A-1 liquid/vapor vessel for reduction. While under vacuum (40-80 torr), waste is heated in a steam heated Reboiler to a temperature of approximately 120°F. In the C-A-1 vessel, excess water flashes to steam creating product slurry and water vapor. The slurry is transferred from the 242-A Evaporator by the P-B-2 slurry pump, through underground piping, to the 241-AW-B valve pit in the 241-AW Tank Farm. From this valve pit, slurry can be further directed to one of the 25 double shell tanks in the 200 East Area.

The E-A-1 Reboiler (see Figure 1) is a single pass shell and tube heat exchanger with 2000 ft² of conductive surface area. It is positioned in the 28” recirculation loop within the 242-A Evaporator Room in a vertical orientation. Because the Reboiler is located downstream of the P-B-1 recirculation pump, waste enters the Reboiler at the bottom of the heat exchanger, flows through the internal tubes where it exits at the top of the exchanger, and enters the C-A-1 Evaporator Vessel. Concurrently, counter flowing steam enters at the top of the heat exchanger and exits at the bottom of the exchanger. As a heat exchanger, the E-A-1 Reboiler has two pressure temperature ratings. The first rating, for the shell side of the exchanger, limits shell and external tube pressure to 100 psig at maximum temperature of 350°F. The second rating, for the tubes, limits internal tube pressure to full vacuum to 20 psig at a maximum temperature of 250°F.

Two dedicated 15 psig boilers provide 11-12 psig saturated steam to the Reboiler. During the heating process steam is reduced to condensate in the Reboiler. Condensate then drains to the Treated Effluent Disposal Facility (TEDF), via Tank 103, or is diverted to 241-AW-102 upon detection of radiation in the condensate.
Figure 1. 242-A Reboiler and Interfacing Systems
5.2 BOUNDARIES

The E-A-1 Reboiler is welded into the Evaporator recirculation loop, making it an integral component of the system. An obvious boundary for this component exists at the tube sheets where the waste enters and exits the tube bundle. On each end of the Reboiler are conical plenums, used to connect the 28” recirculation line to the larger 40” diameter Reboiler. The steam used for heating is on the shell side of the exchanger while waste flows through the tubes. Thus, the waste boundary exists at the tube sheets and the exchanger tubes which maintain separation between the two fluid streams. The steam side boundary exists at the flanges connecting the shell branch inlet and outlet to associated steam and condensate piping.

5.3 INTERFACES

The saturated steam system, steam condensate system and the process air system interface with the Reboiler, and are depicted in Figure 1. Steam is provided to the 242-A Evaporator facility by the Johnson Controls Industries (JCI) Boiler Annex. Inside of the Annex are two boilers capable of producing saturated steam at 15 psig and one boiler capable of producing saturated steam at 90 psig. Saturated steam at 15 psig corresponds to temperature of 250°F which is the design temperature of the Reboiler tube bundle. Saturated steam at 90 psig (used to create the vacuum in the C-A-1 liquid vapor separator vessel) corresponds to a temperature of 331.13°F, which exceeds the design temperature of the tube bundle. Because the 90 psig boiler has the potential for exceeding the design temperature, this boiler cannot be used as a source of steam for the Reboiler. To eliminate this boiler as a failure mode, the 90 psig steam line has been isolated from the dedicated Reboiler steam system.

Each of the low pressure boilers are protected by a pressure relief valve with a set pressure of 15 psig. These valves are designed, manufactured and installed in accordance with ASME Section VIII, Division 1, UG-125. Further downstream, and within the 242-A Evaporator facility, are two additional pressure relief valves (PSV-EA1-2 and PSV-EA1-4 (H-2-98992, P&ID Steam System)) set at 20 psig. These valves too, are designed, manufactured and installed in accordance with ASME requirements.

The process air system is comprised of two rotary air compressors rated at 100 scfm (min) at 100 psig. Each compressor has a pressure safety valve rated at 155 psig. Located in the AMU room, these compressors are connected to the R-E-1 air receiver via a 1-1/4” supply line (H-2-99001, P&ID Process & Instrument Air System). Upon failure of the in-plant compressors, portable compressors can be connected to the Process Air header downstream of the air receiver. In addition to both compressor relief valves, the air receiver is fitted with a 125 psig pressure relief valve. If portable air compressors are used, HV-RE1-8A must remain open. In this manner the R-E-1 pressure safety valve will aid in protecting the system. From the air receiver, air is delivered to the Reboiler via solenoid valve HV-EA1-3. When steam flow is isolated from the Reboiler, valve HV-EA1-3 opens and 18 psig air is provided to the Reboiler shell. When process activities are ongoing, and steam is supplied to the Reboiler, solenoid valve HV-EA1-3 closes to isolate the air to the Reboiler. Two vacuum breakers PSV-1 and PSV-2 connected to the steam feed line prevent vacuum from forming in the event of a steam column collapse.
6.0 SYSTEM EVALUATION

6.1 FUNCTIONAL/PERFORMANCE REQUIREMENTS

The functional requirement for the E-A-1 Reboiler is no leakage of waste (leak tight pressure boundary). This is accomplished by using a vessel that is designed to the requirements of ASME Section VIII, Division 1. The 242-A Evaporator Reboiler has been in service for over thirty years. Prior to being placed in service, the Reboiler was pressure tested to 1.5 times the design pressure (Certified Vendor file CVI-20253, RPP-TE-54842). Thus, the integrity of the design is not under scrutiny, but rather, the integrity of components due to potential degradation with use. Based on design life and operating conditions, the ability of the E-A-1 Reboiler to perform its safety function can degrade and periodic testing is required.

IQRPE conducts evaluations of transfer lines and Evaporator recirculation loop piping every ten years. Acknowledging that the transfer lines are schedule 40 pipe (0.154” wall) and the Reboiler tubes are 14 gage (0.083” wall – roughly half the thickness of pipe), the test frequency for the Reboiler tubes is reduced to half of that for transfer lines. Further reduction in the test frequency is not warranted as UT measurements of the recirculation loop indicate little or no corrosion/erosion has occurred since operations have begun. A test frequency of 5 years is judged to be practical since corrosion of the tubes/tubesheet will not result in leakage of sufficient magnitude to result in a significant facility worker hazard over the functional test frequency.

Steam chest pressure is approximately atmospheric during processing operations. Losing process vacuum would bring full atmospheric pressure to bear on the waste in the C-A-1 vessel, thus increasing the waste pressure at the Reboiler tubes and tube sheets. At atmospheric pressure in the C-A-1 vessel, the waste hydrostatic pressure exerted on the tube sheet, and thus the lower end of the tubes, is calculated to be 13.37 psi. The pressure drop as waste flows through the exchanger tubes is calculated to be 3.4 psi with a fluid specific gravity of 1.6. The combined pressure is therefore 16.77 psi, which is the differential pressure across the tube/tubesheet to the shell side of the Reboiler when the shell is at atmospheric pressure.

Based on pressure differential established above, the following pneumatic pressure decay test has been established:

- Pneumatic pressure decay leak test where the shell side is pressurized to 16 - 18 lb/in gauge and held for a minimum of 10 min with no decrease in pressure. Consistent with other pressure decay tests, pressure will be isolated and held for ten minutes with no decrease in pressure.

Alternatively a liquid trace leak test can be used to verify the integrity of the currently installed Reboiler. RPP-CALC-57003, Fluorescein Tracer Test Analysis, shows that a liquid trace leak test is more sensitive than the pressure decay test. The liquid trace leak test is as follows:

- A liquid tracer leak test where tracer (e.g., fluorescein) is mixed into water in the C-A-1 vessel and held for 24 hours with the C-A-1 vessel water level at or above the normal
operating level and the E-A-1 Reboiler shell side at atmospheric pressure. The sensitivity of the test shall not be less than one drop/hr.

6.2 FAILURE MODE EVALUATIONS

6.2.1 Failure Modes and Effects Analysis

To determine the potential failure modes and failure mechanisms of the E-A-1 vessel, a Failure Modes and Effects Analysis (FMEA) was performed. Failure modes and failure mechanisms of components were identified. Necessary critical characteristics and controls were then applied to this safety-significant component.

A failure mode is the manner in which a component of the system may fail. For example, two failure modes of a pipe is a loss of integrity or plugging. A failure mechanism is the cause of the failure mode. A failure mode may have several failure mechanisms. For example, a pipe loss of integrity could be the result of over pressurization, or could result from corrosion. When the mechanisms for failure are understood, critical characteristics and/or controls may be applied to ensure that the safety system performs its safety function, without failure. A list of potential failure mechanisms is provided in Attachment A of TFC-ENG-DESIGN-C-45. These tables were used to ensure that all potential failure mechanisms were considered.

Attending these FMEA meetings were System and Facility Engineering, Nuclear Safety, Operations, the Engineering Discipline Lead, and an FMEA facilitator. Personnel from maintenance, safety, and environmental organizations were invited on an as-needed basis. Results of the FMEA meetings and subsequent evaluations are listed in Appendix A for the E-A-1 Reboiler vessel.

Appendix A provides the following information from the FMEA analysis, and the evaluation of failure mechanisms, critical characteristics and controls:

- Column 1: “Component”. This column lists the components within the safety systems that were evaluated. Each component in the safety system was evaluated for the effect of its failure on the safety function of the system.
- Column 2: “Failure Mode”. This column lists the various failure modes that are possible for the evaluated component from Column 1.
- Column 3: “Effect on (System) Safety Function”. This column lists the effect of the failure mode on the safety function of the system. Note that not every equipment failure results in a failure of the system to perform its safety function.
- Column 4: “Consider for Failure Mechanisms”. This column lists a “Yes” or a “No”, depending upon whether the identified failure was determined to be a failure of the system to perform its safety function. If a “No” was identified, then there was no further need to determine the failure mechanisms that could result in failure (see next paragraph).
- Column 5: “Failure Mechanisms”. When an equipment failure has the potential to result in a failure of the system to perform its safety function, then the possible mechanisms for
failure were identified. These mechanisms were chosen based on the experience of the FMEA group, and upon engineering evaluation of the system.

- Column 6 and 7: “Potential Controls” and “Potential Critical Characteristics” respectively. These columns represent the controls and critical characteristics that the team identified to help prevent the identified failure. This column will be used to identify the final list of controls and critical characteristics at the end of this document.

- Column 8: “Codes/Standards”. This column lists codes and standards that should be considered when applying a potential critical characteristic or control.

- Column 9: “Notes”. This column includes any information pertinent to the FMEA discussions. In particular, this column justifies failure modes identified as “fail-safe” (see next paragraph).

Not all equipment failures result in a failure of the safety system to perform its intended safety function. An equipment failure mode often results in a failure that is “fail-safe”. That is, although some failures may cause equipment damage or an instrument reading error, that damage or error doesn’t result in a failure of the system to perform it safety function. For such “fail safe” failure modes, failure mechanisms were not considered, and critical characteristics and controls are not necessary. In Attachment A, these “fail-safe” failures are identified as “safe direction” or “no failure” in column 3 “Effect on Safety Function” and as a “No” in column 4 “Consider for Failure Mechanisms”. In column 9 “Notes”, a justification is provided to explain why the failure mode is considered to be fail-safe.

The next two sections will present the results of the FMEA analysis for the E-A-1 vessel. In each section, a table is used to summarize which failure modes could affect the ability of the safety system to perform its safety function. The remainder of the section contains a discussion of the failure mechanisms and the proposed controls and critical characteristics.

### 6.2.2 Failures Modes and Mechanisms of E-A-1 Reboiler

An FMEA evaluation of the E-A-1 Reboiler vessel was performed, evaluating which system failures resulted in a failure of the Reboiler to perform its safety function, as stated in Section 4.0. The discussion of the failure modes, as well as the effect of that failure mode on the safety function of the system, is shown in Table 6-1, below:

#### Table 6-1. Failure Modes of the E-A-1 Reboiler

<table>
<thead>
<tr>
<th>Component</th>
<th>Failure Mode</th>
<th>Effect on Reboiler Tube and Tubesheet Integrity Safety Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reboiler Tubes and Tubesheets</td>
<td>Leak</td>
<td>Loss of integrity</td>
</tr>
<tr>
<td></td>
<td>Plug</td>
<td>None</td>
</tr>
</tbody>
</table>

Failure mechanisms for the failure mode “Leak” are identified below. Critical characteristics and controls, as well as applicable codes and standards, are also discussed for each failure mechanism when applicable. Necessary critical characteristics and controls are in bold type.
6.2.3 Mechanisms of E-A-1 Reboiler Failure

Mechanism 1 – Erosion of the Tubes, Tube Sheet or Weld

The tube sheet is fabricated from 1-1/4 inch stainless steel plate. The tubes are 14 gauge (0.083 wall) stainless steel seamless tubing. Excessive erosion of either component of the tube bundle will result in a breach of the safety significant boundary and potentially expose the shell side of the Reboiler to contamination. However, due to the difference in thickness, it is expected that the thin walled tubes will be affected by erosion before the tube sheets. Although RPP-RPT-33306, Independently Qualified Registered Professional Engineer (IQRPE) Integrity Assessment Report for the 242-A Evaporator Tank System, evaluates the process loop piping, which includes the Reboiler, only the Reboiler shell is evaluated. Due to the remote nature of the internal tube bundle, it is not accessible for quantitative evaluation. Rather, the integrity of the tube/tubesheet will be assessed every five years by testing (see Section 6.1). Since erosion of the tubes/tubesheet is a slow failure mechanism, a 5-year leak test is adequate for detection of a leak by this failure mechanism.

Mechanism 2 – Corrosion of the Tubes, Tube Sheet or Weld

See Mechanism 1 (above). Corrosion of the materials of construction in the tank farms including carbon and stainless steels exposed to waste constituents are well understood and mitigated through a comprehensive chemistry envelope. A significant amount of literature data is available regarding the potential corrosion of stainless steels in similar environments. Utilizing the data available, the corrosion mitigation program of the tank farms, the known chemistries to which the evaporator will be subject and the materials of construction, the corrosion mechanisms are understood and evaluated. In addition, operational experience of the evaporator was used to determine the potential corrosion mechanisms. The fact that these alloys are acceptable for fabrication under ASME BPVC, Section III (Rules for Construction of Nuclear Facility Components) indicates that these materials perform adequately when irradiated.

The current Reboiler tube sheets are fabricated from ASME SA-240, Grade 304L stainless steel plate while the tubes are SA-213, Grade 304L stainless steel tube. Given the temperature and chemistries (halide and hydroxide content) of waste, localized corrosion in the form of stress corrosion cracking and pitting corrosion are possible. However, the use of 304L material (low carbides to prevent sensitization); the chemistry envelope (high pH>13 and high [NO<sub>3</sub>]/[Cl<sub>-</sub>] >2 ratio) and flushing procedures to remove any corrosive deposits have prevented consequential corrosion during service. Utilizing the iso-corrosion curve for stainless steels [Nickel Development Institute, Publication N 10019, C.L. Schillmoller] in caustic service in comparison with the expected hydroxide concentration (<9M OH<sup>-</sup>) have prevented any caustic stress corrosion cracking. Further evaluation of the waste stream on the Reboiler can be found in RPP-RPT-58179.

In the case that stress corrosion cracking, or pitting develops as a result of the chemistry envelope not being maintained, the leak rates through these localized corrosion mechanisms are very low. Grade 304L stainless steel is not sensitized and has a high fracture toughness. In addition, the Reboiler does not experience the stresses necessary to create rapid crack
growth. Therefore, although through wall crack growth is expected, only very small leaks would occur, rather than catastrophic failure (‘leak-before-break’). Through wall crack growth is expected (‘leak-before-break’) for the case of transgranular stress corrosion cracking given the high fracture toughness of the 304L stainless steel material rather than catastrophic failure. Pitting corrosion is a localized phenomenon most likely under corrosive anionic deposits in crevice areas and will potentially induce a weep leak in localized areas in contrast to general corrosion.

Service experience has shown these materials provide adequate service performance in this application. Due to the remote nature of the internal tube bundle, it is not accessible for quantitative evaluation. Rather, the integrity of the tube/tubesheet will be assessed every five years by testing (see Section 6.1). Since corrosion (i.e., halide induced stress corrosion cracking and pitting) of the tubes/tubesheet is a localized corrosion mechanism, a 5-year leak test is adequate because any leakage will be of insufficient magnitude to result in a significant facility worker hazard over this functional test frequency.

**Mechanism 3 – Thermal Cycling of the Tube Bundle that Leads to Fatigue Failure**

Excessive flexure due to thermal expansion and contraction can lead to fatigue failure of the safety-significant boundary within the Reboiler. Although all components comprising this heat exchanger are made of 304L stainless steel, different thickness will dictate that expansion and contraction occurs at different rates. This matter is addressed through design: ASME BPVC Section VIII, Division 1 contains provisions that account for differences in thermal expansion and contraction and the welds used to join these components together.

**Mechanism 4 – Steam Induced Transient Event that Leads to Rupture**

RPP-RPT-41041, *Technical Evaluation of the 242-A Evaporator Facility Steam and Steam Condensate System*, suggests that steam induced pressure transients have occurred during previous process campaigns. This report contends that the previous steam condensate system was unable to address condensate from 10 psi steam at a rate of more than 20,000 lb./hour, and that these steam induced transients occur when condensate backs up into the Reboiler. ECN-11-002072, *242-A Evaporator Reboiler Condensate System Upgrade*, was incorporated under Project #T1P64 to address this deficiency in. The new design allows for enhanced gravity flow and eliminates system restrictions leading to condensate buildup. Recent Cold Run activities show that this redesigned has increased efficiency allowing up to 27,000 lb./hour steam while maintaining the shell side of the Reboiler near atmospheric pressure.

**Mechanism 5 – Mechanical Vibration that Leads to Fatigue Failure**

Vibrations arise from harmonic resonance induced from fluid flow. The 242-A Evaporator has accumulated over 30 years of operation without fluid induced harmonic vibrations. Since the last campaign, the system has not changed nor are the operating parameters expected to change. Procedural compliance dictates the Evaporator to operate within specified criteria that has a demonstrated record of sound operation.
Vibration in the shell side of the Reboiler can develop from flutter associated with the flow control valves in either the steam system or process air systems. These are compressible fluids, however, and pressure transients originating from control valves will dissipate along the flow path. Additionally, fluid velocities are relatively slow which will help to minimize transient effects.

Due to the remote nature of the internal tube bundle, it is not accessible for quantitative evaluation. Rather, the integrity of the tube/tubesheet will be assessed every five years by testing (see Section 6.1). Since fatigue failure of the tubes/tubesheets as a result of vibration is a slow failure mechanism, a 5-year leak test is adequate for detection of a leak by this failure mechanism.

**Mechanism 6 – Seismic Event**

The 242-A Evaporator Reboiler and associated process loop piping is not required to perform its safety function during or after a seismic event per HNF-14755, *Documented Safety Analysis for the 242-A Evaporator*. However, the Reboiler and associated piping have been designed to ASME code criteria. This requires the design to address loading due to seismic events.

A seismic event that would compromise the integrity of the Reboiler is a readily identifiable event. Such an event will result in personal being evacuated from the condenser room and the inspection of the Reboiler. Seismic activity will result in inspection and, if necessary, the testing/repair/replacement prior to returning the Reboiler to service.

**Mechanism 7 – Excessive Pressure from Process Air**

During the control development meeting, a failure modes and effects analysis (FMEA) was performed during which it was determined that this is not a credible failure mode. Redundant mechanisms will prevent an over pressure failure of the 242-A Evaporator Reboiler.

Instrument and process air at 242-A is typically supplied by facility air compressors, but can also be provided by portable air compressors. Each compressor has a dedicated pressure safety relief valve. The pressure setting for the facility compressors is 155 psig while the portable compressors have a 200 psig set pressure. Facility compressors fill the facility air receiver tank R-E-1. The portable air compressors can be configured to bypass the receiver while still supplying process or instrument air. From the R-E-1 receiver, air is reduced to either 3 psig during process activities or 18 psig during times of inactivity (H-2-99001). To ensure air pressure does not exceed the shell side pressure rating, PSV-EA1-3 is set at 25 psig. Additionally, PSV-EA1-4, located on the steam supply line further protects the system with a set pressure of 20 psig. Although this valve is located on the steam supply line, it is still a significant component in mitigating over-pressurization of the Reboiler. The process air line is directly connected to the steam line and cannot be isolated from PSV-EA1-4. These features provide reasonable assurance that the Reboiler shell will not be over pressurized.

**Mechanism 8 – Excessive Temperature from Air**

During the control development meeting, a failure modes and effects analysis (FMEA) was performed during which it was determined that this is not a credible failure mode. Redundant
mechanisms will prevent a failure of the 242-A Evaporator Reboiler due to excessive temperatures.

As previously indicated, instrument and process air at 242-A is typically supplied by facility air compressors, but can also be provided by a portable compressor. The maximum discharge temperature of facility compressors is 230°F (Email from manufacturer – Appendix D). The maximum discharge temperature for a portable compressor (375 cfm unit) is approximately 248°F (Vendor literature). Upon reaching these maximum discharge temperatures, the respective compressor will shut down. Neither of these maximum discharge temperatures approach the Reboiler’s maximum design temperature of 350°F. This alone demonstrates that the Reboiler’s design temperature cannot be surpassed by compressed air alone. Additionally, the facility air compressors employ a number of safety features that prevent excessive air temperatures. The first safety feature that would trigger a shutdown of the compressor is the high oil temperature indication. The second safety feature is the high discharge temperature switch. As stated above, if the discharge temperature exceeds 230°F, the compressor will shut down. Third is the high unit temperature switch. The compressor is designed for an operating range of 40 to 115°F. If the compressor, as a unit, exceeds the high temperature then the compressor will shut down. Lastly, if the temperature increase for a given time interval is too great, then the compressor will shut down.

Similarly, the portable compressors also have multiple safety features that prevent excessive air temperatures. These compressors include features such as a maximum oil temperature switch and a maximum discharge temperature switch. Additionally, discharge air is routed to receiver tank R-E-1 using rubber air hoses typically rated for temperatures of 190°F or 220°F. Hose integrity will be compromised before the Reboiler’s design temperature of 350°F is reached. Air must then travel through several feet of small (typically 3/4”) un-insulated air-line. Due to air’s low heat capacity, air flowing from the compressor discharge through the small process air piping would experience significant heat loss and greatly reduce air temperature. These features provide reasonable assurance that the shell will not exceed its design temperature rating.

Lastly, steam exits the Reboiler as condensate through steam traps arranged in parallel. The functionality of the steam traps dispenses of accumulated condensate but prevents air from flowing through them – thus, air can only pressurize the boiler. As such, air cannot be used as a transport mechanism to convey heat to the Reboiler.

**Mechanism 9 – Collapse of the Steam Column Generating a Vacuum on the Shell Side**

During the control development meeting, a failure modes and effects analysis (FMEA) was performed during which it was determined that this is not a credible failure mode. Redundant features will prevent a vacuum from forming on the shell side of the Reboiler in the event of a steam column collapse. During inactivity, air is delivered to the Reboiler via a pressure control loop in which valve 5-10 is normally closed and valves 5-5 and 5-7 are normally open. When steam flow is isolated from the Reboiler, solenoid valve HV-EA1-3 opens and 18 psig air is provided to the Reboiler shell. When process activities are ongoing, and steam is supplied to the Reboiler, solenoid valve HV-EA1-3 closes to isolate the air to the Reboiler. Further preventing a vacuum condition in the Reboiler are two vacuum breakers installed in the process air supply line. The first vacuum break, PSV1, is set to crack at -0.05 psig. The second vacuum break,
PSV2, has a cracking pressure of -1.0 psig. Combined, these features provide reasonable assurance that the shell will not be exposed to negative pressures.

**Mechanism 10 – Excessive Pressure from Steam**

During the control development meeting, a failure modes and effects analysis (FMEA) was performed during which it was determined that this is not a credible failure mode. Redundant features will prevent the over pressurization of the Reboiler by the steam system. Steam is supplied to the Reboiler shell by a pair of packaged boiler units providing saturated steam at a set pressure of 11-12 psig during normal operation. Each boiler is protected by a pressure safety valve with a set of 15 psig. Inside of the Evaporator facility, PSV-EA1-2 has a set pressure of 20 psig. Further downstream of this pressure relief valve is another, PSV-EA1-4 also with a set pressure of 20 psig. Additionally, the steam supply boilers are rated at 15 psig. With a Reboiler design pressure rating of 100 psig, it is likely that the boilers will experience failure before the Reboiler. Combined, these features provide reasonable assurance that the shell will not be under negative pressures.

**Mechanism 11 – Excessive Temperature from Steam**

During the FMEA it was determined that this is not a credible failure mode. Redundant features will prevent the steam from generating excessive temperatures in the Reboiler. The maximum shell side design temperature of the E-A-1 Reboiler is 350°F. Saturated steam at 350°F coincides with 119.9 psig. As described above, it is expected that the steam boilers will reach the limits of their 15 psig pressure rating before the 100 psig Reboiler design pressure is reached. This fact alone ensures that Reboiler will not be exposed to excessive temperatures. However, each boiler draws upon three safety relief valves to regulate steam pressure. As identified previously, the first PSV is located on the boiler in the JCI Annex with a 15 psig set pressure. The other two, PSV-EA1-2 and PSV-EA1-4 (H-2-98992), are located in the Evaporator facility. PSV-EA1-2 and PSV-EA1-4 each have set pressures of 20 psig. At 20 psig, the temperature of saturated steam is 258.74°F significantly less than the design temperature of the Reboiler shell. Combined, these features provide reasonable assurance that the shell will not be under negative pressures.

**Mechanism 12 – Structural Failure due to Excessive Weight: Back-Up of Condensate Line**

Structural failure of the Reboiler due to excessive weight, i.e. condensate filling the vessel is very unlikely. The condensate system incorporates three steam traps. Prior to start-up these traps are verified to be in proper working order. During start-up, a significant amount of condensation is formed which requires two of the three steam traps to be functioning. Once the Reboiler is at operating temperature, only one steam trap is required to dispense with forming condensate. During these operations (start-up and normal operation) there is at least one back-up steam trap that can be utilized.

The original design calculations conducted by Struthers-Wells sized the support structure considering the effects of the Evaporator vessel loading, Reboiler vessel loading, as well as, seismic and temperature effects. The combined loadings resulted in the minimum required beam size of W12x27 and W18x45 structural members to support the Reboiler. The seismic analysis
consisted of a 0.28 g vertical seismic response spectra that was applied to the static design load of 27 kips. The resulting seismic load equates to approximately 34.5 kips. Considering the effect of condensate filling the Reboiler, the loading condition closely matches the seismic design load (within 10%) for which the W12x27 and W18x45 beams were prescribed. Given the structural members selected for the design loading, there is sufficient confidence that the higher capacity W12x40 and W18x50 members used during construction (H-2-69280 and H-2-69285) will support the bearing load of the Reboiler when full of slurry and steam condensate.

Bolted connections were designed in accordance with AISC 7th ed., Table 1 (H-2-69281). Table 1 shows that the weakest connection used during construction of the Reboiler support structure is acceptable for 15 ksi in shear or 21 ksi in bearing load: an equivalent Reboiler weight of approximately 48 kips.

Given the structural members used in the design calculations and the structural members used in construction, the support structure is sufficient for the bearing load of the Reboiler when full of 1.6 SpG slurry and steam condensate.

6.2.4 Other Failure Modes

No other unsafe failure modes of the Reboiler were identified during the FMEA evaluations.

6.2.5 Failure Modes and Mechanisms of Sample Analysis

Because sample analysis will be used to support qualification of the Reboiler, a safety related structure, the sample analysis will be defined as a safety related function as well. This service must be performed by a supplier with an evaluated NQA-1 program or a current International Laboratory Accreditation Cooperation (ILAC) accreditation and listed on the Evaluated Suppliers List (ESL). ILAC signatories include (but not limited to) the following:

a. The American Association for Laboratory Accreditation (A2LA)
b. National Voluntary Laboratory Accreditation Program (NVLAP)
c. International Accreditation Service, Inc. (IAS)
d. ANSI-ASQ National Accreditation Board (AClass)
e. Perry Johnson Laboratory Accreditation, Inc. (PJLA)
f. Accreditation Services Bureau (A-S-B)
g. American Industrial Hygiene Association Laboratory Accreditation Program (AIHA-LAP).

Alternatively, the service supplier may be dedicated using TFC-ENG-DESIGN-C-15 which would require a survey or source verification. To determine the potential failure modes and failure mechanisms of sample analysis in the laboratory, a Failure Modes and Effects Analysis (FMEA) was performed, evaluating which analytical failures led to a failure of the Reboiler’s ability to perform its safety function, as stated in Section 4.0. Failure modes and failure mechanisms of this service were identified. Necessary critical characteristics and controls were then applied to safety-significant analysis of leak test samples.
The discussion of the failure modes, as well as the effect of that failure mode on the safety function of the system, is shown in Table 6-2, below:

Table 6-2. Failure Modes of the E-A-1 Reboiler

<table>
<thead>
<tr>
<th>Component</th>
<th>Failure Mode</th>
<th>Effect on Reboiler Tube and Tubesheet Integrity Safety Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>QA Program</td>
<td>High Bias Results</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Low Bias Results</td>
<td>False indication of sound Tubes and Tubesheets</td>
</tr>
</tbody>
</table>

Failure mechanisms for the failure mode “Low Bias Results” are identified in Table A-2. In response to these failure mechanisms, Controls and Critical Characteristics were identified to mitigate erroneous data.

6.2.6 Aging

The Evaporator Reboiler is fabricated from 304L Stainless Steel. As such, any degradation due to time based aging is academic. 304L is unaffected by natural phenomena such as ambient temperature swings. Damaging effects are brought about by erosion/corrosion through service applications (see Mechanisms 1 and 2 above).

6.3 SUPPORTING SYSTEMS

The 242-A Building is designated safety-significant to prevent its failure due to ash, snow and wind loads and, therefore, protect the E-A-1 Reboiler from damage due to these loads. The 242-A Evaporator Facility structure offers protection from many natural phenomena hazards and off normal accident scenario conditions. Additionally, this facility acts as a supporting structure for the process circulation loop. Should a failure of the building structure occur, this would obviously be detrimental to the integrity of the evaporation process loop and the Reboiler. This facility, however, was designed for a 0.25 g horizontal seismic load. With the added conservatism built into this calculation, this structure is designed to the equivalent of a PC-2 structure (RPP-RPT-52517, 242-A Evaporator Facility Assessment for Performance Category 2 Natural Phenomena Hazards).

7.0 CONTROLS

Controls necessary to protect the E-A-1 Reboiler vessel were identified during the FMEA process, as outlined in sections 6.2.1 thru 6.2.5. The controls recommended for these systems are carried forward and summarized in this section. If any of these controls cannot be met in the design and installation phase, then this document must be revised to identify new controls.
7.1 CONTROLS

To assess the integrity of the tube bundle, a liquid dye leak test will be performed every five years (see Section 6.1). Documentation showing how this control is to be fulfilled is presented in Appendix C.

8.0 CRITICAL CHARACTERISTICS

Critical characteristics necessary to protect the E-A-1 Reboiler were identified during the FMEA process, as outlined in Sections 6.2.1, 6.2.2, and 6.2.3. The critical characteristics recommended for these systems are carried forward and summarized in this section. Appendix C documents how the critical characteristics described in Table 8-1 are to be met.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Shell</th>
<th>Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Pressure</td>
<td>Design of the Reboiler must allow for a Shell side working pressure of at least 100 psig.</td>
<td>Design of the Reboiler must allow for a Shell side working pressure range of 0.0 psia to at least 20 psig.</td>
</tr>
<tr>
<td>Design Temperature</td>
<td>Design of the Reboiler must allow for a Shell side working temperature of at least 350° Fahrenheit.</td>
<td>Design of the Reboiler must allow for a Tube side working temperature of at least 250° Fahrenheit.</td>
</tr>
<tr>
<td>Material Compatibility</td>
<td>Design of the Reboiler shall be constructed of a material compatible with 10# saturated steam and capable of being welded to the exchanger tubes/tubesheets.</td>
<td>Design of the Reboiler tubes/tubesheets shall be compatible with caustic wastes as identified in best basis inventory, such as 304L. Tubes shall be of a seamless construction,</td>
</tr>
</tbody>
</table>

Design must be in accordance with ASME BPVC Section VIII, Div. 1 and TEMA “C” (General Service).

In the event that an NQA-1 or ILAC certified lab on the ESL that can test for fluorescein cannot be located, it may be necessary to dedicate a commercial lab under TFC-ENG-DESIGN-C-15. In this case an FMEA for services was performed and documented in Appendix B. This FMEA identifies the critical characteristics necessary to provide reasonable assurance that the analytical results are accurate.

9.0 REFERENCES

ASME Boiler and Pressure Vessel Code, 2004, Section VIII, Division 1, American Society of Mechanical Engineers, New York, New York


NiDI Technical Series No. 10 019, 1988, Alloy Selection for Caustic Soda Service, Nickel Development Institute, Toronto, Canada.


RPP-RPT-52517, 242-A Evaporator Facility Assessment for Performance Category 2 Natural Phenomena Hazards, Rev. 0, Washington River Protection Solutions, Richland, Washington.


APPENDIX A

E-A-1 REBOILER FMEA
### APPENDIX A - E-A-1 REBOILER FMEA

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>FAILURE MODE</th>
<th>EFFECT ON REBOILER SAFETY FUNCTION</th>
<th>CONSIDER FOR FAILURE MECHANISMS?</th>
<th>FAILURE MECHANISMS</th>
<th>POTENTIAL CONTROLS</th>
<th>POTENTIAL CRITICAL CHARACTERISTICS</th>
<th>CODES/STANDARDS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reboiler Tubes and Tube Sheets</td>
<td>Leak</td>
<td>Loss of integrity</td>
<td>Yes</td>
<td>Erosion</td>
<td>Functional Test (Fluorescein Dye test), IQRPE evaluation</td>
<td>Material selection, Thickness, Correct welding process</td>
<td>ASME B&amp;PVC, Sec. VIII, Div. 1, TEMA C</td>
<td>Current Reboiler fabricated from SA-240 Type 304L, SA-213 Type 304L.</td>
</tr>
<tr>
<td></td>
<td>Halide Induced Stress Corrosion Cracking</td>
<td>Functional Test (Fluorescein Dye test), IQRPE evaluation</td>
<td>Material Selection, Thickness, Correct welding process</td>
<td>ASME B&amp;PVC, Sec. VIII, Div. 1, TEMA C</td>
<td>Waste temperatures and the presence of halides create the potential for halide induced stress corrosion cracking. However, the Reboiler does not experience the stresses necessary to create a catastrophic failure. Leak rates through stress cracks are very small due to the very small thickness of the cracks. Leaks are not of sufficient magnitude to result in a significant facility worker hazard over the functional test frequency. Managing waste chemistry to allow for sufficient Nitrates and Hydroxides will minimize halide induced corrosion.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Halide Induced Corrosion Pitting</td>
<td>Functional Test (Fluorescein Dye test), IQRPE evaluation</td>
<td>Material Selection, Thickness, Correct welding process</td>
<td>ASME B&amp;PVC, Sec. VIII, Div. 1, TEMA C</td>
<td>Corrosion pitting has the potential to create localized areas of through wall penetrations (very small leaks). Although this is an aggressive failure mechanism, it is limited to under deposits and crevices and manifests itself as drip wise leakage or weeping. Leaks are not of sufficient magnitude to result in a significant facility worker hazard over the functional test frequency. Conducting a deep flush of the C-A-1 vessel and recirculation loop after pot has been emptied of waste will minimize pitting corrosion.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fatigue (thermal cycle): Ambient to 250°F</td>
<td>None</td>
<td>Material selection, Design parameter, Correct welding process</td>
<td>ASME B&amp;PVC, Sec. VIII, Div. 1, TEMA C</td>
<td>90º to 105º crossover outside the evaporation must be removed to limit max temperature.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transient pressure event (steam/condensate side)</td>
<td>Maintain all 3 steam traps open</td>
<td>NA</td>
<td>ASME B31.1</td>
<td>New design of condensate will prevent water hammer. Recommended as Operational Control, not as a Safety Control.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mechanical fatigue (vibration)</td>
<td>Functional Test (Fluorescein Dye test), IQRPE evaluation</td>
<td>Material selection, Thickness, Design Calculation</td>
<td>ASME B&amp;PVC, Sec. VIII, Div. 1, TEMA C</td>
<td>years of operation without failures/noticeable vibration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seismic event</td>
<td>None</td>
<td>Previously seismically qualified design</td>
<td>ASME B&amp;PVC, Sec. VIII, Div. 1, TEMA C</td>
<td>The E-A-1 Reboiler may not perform its safety function during or after a seismic event. Seismic evaluation of Reboiler and 28” recirculation piping: RPP-RPT-52517, 342-A Evaporator Facility Assessment for Performance Category 2 Natural Phenomena Hazards.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High air pressure</td>
<td>SS PRV?</td>
<td>Redundant controls are in place to regulate the system air pressure. Not a credible failure mode.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High air temperature</td>
<td>Redundant GS controls</td>
<td>Redundant controls are in place to regulate the system air temperature. Not a credible failure mode.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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## APPENDIX A - E-A-1 REBOILER FMEA

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>FAILURE MODE</th>
<th>EFFECT ON REBOILER SAFETY FUNCTION</th>
<th>CONSIDER FOR FAILURE MECHANISMS?</th>
<th>FAILURE MECHANISMS</th>
<th>POTENTIAL CONTROLS</th>
<th>POTENTIAL CRITICAL CHARACTERISTICS</th>
<th>CODES/STANDARDS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>High steam pressure</td>
<td>High steam pressure</td>
<td>Rated to full vacuum?</td>
<td>Not a credible failure mode.</td>
<td>Rated to full vacuum?</td>
<td>Rated to full vacuum? (verify)</td>
<td>Not a credible failure mode.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High steam temperature</td>
<td>High steam temperature</td>
<td>Rated to full vacuum?</td>
<td>Not a credible failure mode.</td>
<td>Rated to full vacuum?</td>
<td>Rated to full vacuum? (verify)</td>
<td>Not a credible failure mode.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full of water from blocked condensate line</td>
<td>Full of water from blocked condensate line</td>
<td>Full of water from blocked condensate line</td>
<td>Not a credible failure mode.</td>
<td>Full of water from blocked condensate line</td>
<td>Full of water from blocked condensate line</td>
<td>Not a credible failure mode.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load handling/Impact event</td>
<td>Load handling/Impact event</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Not a credible failure mode.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Live and Dead Loads</td>
<td>Live and Dead Loads</td>
<td>The evaporator process loop, including the Reboiler, is designed to ASME B&amp;PVC, Sec. VIII, Div. 1. This code requires dead and live loads to be taken into account when designing a piping system. The process loop is therefore designed for anticipated loads.</td>
<td>Not a credible failure mode.</td>
<td>The evaporator process loop, including the Reboiler, is designed to ASME B&amp;PVC, Sec. VIII, Div. 1. This code requires dead and live loads to be taken into account when designing a piping system. The process loop is therefore designed for anticipated loads.</td>
<td>The evaporator process loop, including the Reboiler, is designed to ASME B&amp;PVC, Sec. VIII, Div. 1. This code requires dead and live loads to be taken into account when designing a piping system. The process loop is therefore designed for anticipated loads.</td>
<td>Not a credible failure mode.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind, snow, ash loads</td>
<td>Wind, snow, ash loads</td>
<td>Not a credible failure mode.</td>
<td>Not a credible failure mode.</td>
<td>Not a credible failure mode.</td>
<td>Not a credible failure mode.</td>
<td>Not a credible failure mode.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### APPENDIX A - E-A-1 REBOILER FMEA

<table>
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<tr>
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<th>EFFECT ON REBOILER SAFETY FUNCTION</th>
<th>CONSIDER FOR FAILURE MECHANISMS?</th>
<th>FAILURE MECHANISMS</th>
<th>POTENTIAL CONTROLS</th>
<th>POTENTIAL CRITICAL CHARACTERISTICS</th>
<th>CODES/STANDARDS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
<td>Extreme temperatures</td>
<td></td>
<td>Environmental design temperature requirements are identified in TFC-ENG-STD-02, Environmental/Seasonal Requirements for TOC Systems, Structures, and Components. This standard identifies a design temperature of -25° to 115°F for SSC’s that are exposed to outdoor ambient conditions. It is expected that temperatures within the facility will not exceed outdoor conditions. High environmental temperatures are bounded by process temperatures. Failure due to low temperatures (&lt; 32°F) or freezing is not a credible failure mechanism during Operations Mode as evaporator operations would be stopped prior to reaching a freezing condition within the building. Damage when not in Operation Mode will result in an inspection and the necessary testing/repair/replacement prior to returning the E-A-1 Reboiler to service.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
<td>Ash/dust exposure</td>
<td></td>
<td>Not a credible failure mechanism.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
<td>Loss of external power</td>
<td></td>
<td>Not a credible failure mechanism.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
<td>External fire</td>
<td></td>
<td>Not a credible failure mechanism.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
<td>High differential pressure across Reboiler</td>
<td>NA</td>
<td>NA</td>
<td>Requires plugging of tubes and max head of pump. Not a credible failure mode.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plug</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No

Extreme temperatures

No

Ash/dust exposure

No

Loss of external power

No

External fire

No

High differential pressure across Reboiler

NA

NA

Environmental design temperature requirements are identified in TFC-ENG-STD-02, Environmental/Seasonal Requirements for TOC Systems, Structures, and Components. This standard identifies a design temperature of -25° to 115°F for SSC’s that are exposed to outdoor ambient conditions. It is expected that temperatures within the facility will not exceed outdoor conditions. High environmental temperatures are bounded by process temperatures. Failure due to low temperatures (< 32°F) or freezing is not a credible failure mechanism during Operations Mode as evaporator operations would be stopped prior to reaching a freezing condition within the building. Damage when not in Operation Mode will result in an inspection and the necessary testing/repair/replacement prior to returning the E-A-1 Reboiler to service.

No

Ash/dust exposure

No

Loss of external power

No

External fire

No

High differential pressure across Reboiler

NA

NA

Requires plugging of tubes and max head of pump. Not a credible failure mode.
APPENDIX B
LABORATORY SAMPLE ANALYSIS FMEA
## APPENDIX B – LABORATORY SAMPLE ANALYSIS FMEA

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>FAILURE MODE</th>
<th>EFFECT ON SAMPLE RESULTS</th>
<th>CONSIDER FOR FAILURE MECHANISMS?</th>
<th>FAILURE MECHANISMS</th>
<th>CHALLENGES THAT COULD LEAD TO THESE FAILURE MECHANISMS</th>
<th>POTENTIAL CONTROLS</th>
<th>POTENTIAL CRITICAL CHARACTERISTICS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>QA Program</td>
<td>Bad Results</td>
<td>Bias High</td>
<td>No</td>
<td></td>
<td>Use of Un-Calibrated Equipment, Expired Calibration</td>
<td>Verify Current Calibration Per Procedure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Improperly Calibrated (Equipment) Addressed in Procedure</td>
<td>Verify Procedure Addresses Daily Calibration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Use of Improper Laboratory Standard (Fluorescein) Expired Standards Addressed in Procedure</td>
<td>Verify Within Expiration Date if Applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Incorrect Standard Addressed in Procedure Verify Calibration Standard as Appropriate (e.g. NIST)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Improperly Prepared Standard Addressed in Procedure Verify Adherence to Procedure</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yes</td>
<td></td>
<td>Lack of QC Analysis Not following QA Plan QC Analysis within Specified Limits</td>
<td>Verify Lab Blank/Matrix Spike/Matrix Spike Duplicate and QA Plan</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Improper Analysis Methods Improper Use of Procedure Following Procedure</td>
<td>Verify adherence to Approved Procedure</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Improper Test Specimen Preparation Verify Approved Fluorescein Analysis Procedure</td>
<td>Verify adherence to Approved Procedure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Unqualified Personnel Performing Analysis Adequate Training/Qualifications</td>
<td>Examine Qualifications of Lab Personnel.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Improper Procedure/Accessibility to Procedure Availability of Approved Procedure</td>
<td>Verify Approved Procedure Verify Availability of Procedure</td>
<td></td>
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</tr>
</tbody>
</table>

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### APPENDIX B – LABORATORY SAMPLE ANALYSIS FMEA

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>FAILURE MODE</th>
<th>EFFECT ON SAMPLE RESULTS</th>
<th>CONSIDER FOR FAILURE MECHANISMS</th>
<th>CHALLENGES THAT COULD LEAD TO THESE FAILURE MECHANISMS</th>
<th>POTENTIAL CONTROLS</th>
<th>POTENTIAL CRITICAL CHARACTERISTICS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Improper Custody of Samples</td>
<td>Adequate Chain of Custody</td>
<td>Chain of Custody Procedure Document (Internal and External as Applicable)</td>
<td>Verify Tracking Method</td>
<td>Signature/Date/time on Chain of Custody</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inadequate Control of Samples</td>
<td>Addressed in Procedure</td>
<td>Tracking/Traceability/Report Format/Functionality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degradation/Contamination of Samples</td>
<td>Improper Handling/Storage of Sample Media</td>
<td>Addressed in Procedure</td>
<td>Verify adherence to procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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APPENDIX C
242-A EVAPORATOR E-A-1 REBOILER DESIGN REQUIREMENTS
## APPENDIX C – 242-A EVAPORATOR E-A-1 REBOILER DESIGN REQUIREMENTS

<table>
<thead>
<tr>
<th>CONTROL OR CRITICAL CHARACTERISTIC</th>
<th>REQUIREMENT</th>
<th>HOW CONTROL OR CRITICAL CHARACTERISTIC MET</th>
<th>DRAWING/ECN/P&amp;ID</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reboiler Integrity Assessment</td>
<td>The E-A-1 Reboiler (tubes/tubesheets) shall be leak tested every 5 years to VERIFY no leakage.</td>
<td>Preventive Maintenance PM# EE-108893</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Pressure (Shell)</td>
<td>Design of the Reboiler must allow for a Shell side working pressure of at least 100 psig.</td>
<td>RPP-TE-54842</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Pressure (Tubes)</td>
<td>Design of the Reboiler must allow for a Shell side working pressure range of 0.0 psia to at least 20 psig.</td>
<td>RPP-TE-54842</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Temperature (Shell)</td>
<td>Design of the Reboiler must allow for a Shell side working temperature of at least 350° Fahrenheit.</td>
<td>RPP-TE-54842</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Temperature (Tubes)</td>
<td>Design of the Reboiler must allow for a Tube side working temperature of at least 250° Fahrenheit.</td>
<td>RPP-TE-54842</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Compatibility (Shell)</td>
<td>Design of the Reboiler shall be constructed of a material compatible with 10# saturated steam and capable of being welded to the exchanger tubes/tubesheets.</td>
<td>RPP-TE-54842</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Compatibility (Tubes)</td>
<td>Design of the Reboiler tubes/tubesheets shall be compatible with caustic wastes as identified in best basis inventory, such as 304L. Tubes shall be of a seamless construction.</td>
<td>RPP-TE-54842</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASME BPVC, Sec. VIII, Div. 1/TEMA C Compliant Design</td>
<td>Pressure vessel shall be a Code stamped component.</td>
<td>RPP-TE-54842</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Compliance with 242-A Evaporator Technical Safety Requirements HNF-15279, Rev. 1-A, Section 6.0 Design Features, 6.1.1 In-Service Inspection/Test
APPENDIX D
E-MAIL STATEMENT OF MAXIMUM DISCHARGE TEMPERATURE
Becker, Brent T

From: Bragg, David A  
Sent: Thursday, May 17, 2012 4:12 PM  
To: Becker, Brent T; Brown, Todd M  
Subject: PW: ASD 30 T Questions

Updated air discharge temperature for Kaezer ASD 30 T compressors.

Thanks,

David A. Bragg

Mechanical Engineer  
Base Ops Mechanical Engineering/HVAC  
Washington River Protection Solutions,  
Contractor to the United States Department of Energy  
MO-493, rm 9  
(509) 373-2859/308-7345  
David_A_Bragg@llgov

From: Chris G [mailto:chrisg@airelectrictools.com]  
Sent: Thursday, May 17, 2012 11:24 AM  
To: Bragg, David A  
Subject: RE: ASD 30 T Questions

David,

The discharge temperature statement below is correct for the machine running without a dryer, with the dryer running the outlet temp would be closer to the ambient temp.

The normal air end discharge temperature before it reaches the air cooled after cooler and dryer is 167-200 degrees F. the maximum air end temperature is 230 degrees F at this point the compressor will shut down automatically for safety reasons.

Please keep in mind that there would have to be multiple component failures for you to see a discharge temperatures like that.

Regards,

Chris Gering  
General Manager  
Air Electric Equipment & Tools, Inc.  
5603 E 3rd Ave, Spokane, WA 99212  
800-348-8337 – 509-534-3698  
Fax – 509-534-3752  
www airelectrictools.com  
chrisg@airelectrictools.com
From: Bragg, David A [mailto:David_A_Bragg@rl.gov]
Sent: Thursday, May 17, 2012 10:05 AM
To: Chris G
Subject: RE: ASD 30 T Questions

Chris,

Can you tell me if the discharge temperature is with or without the air dryer operating? Would the discharge temperature be higher if the dryer is not in operation?

Thanks,

David A. Bragg

Mechanical Engineer
Base Ops Mechanical Engineering/HVAC
Washington River Protection Solutions
Contractor to the United States Department of Energy
MO-403, Rm 9
(509) 373-2899/808-7345
David_A_Bragg@rl.gov

From: Chris G [mailto:chris@airelectrictools.com]
Sent: Tuesday, January 17, 2012 1:26 PM
To: Bragg, David A
Subject: FW: ASD 30 T Questions

Regards,

Chris Gering
General Manager
Air Electric Equipment & Tools, Inc.
5603 E 3rd Ave
Spokane, WA 99212
800-348-8337 - 509-534-3698
Fax - 509-534-3752
www airelectric tools.com
chrisg@ airelectric tools.com

From: Hartshorn, Richard [mailto:richard.hartshorn@kaeser.com]
Sent: Tuesday, January 17, 2012 11:27 AM
To: Chris G
Subject: ASD 30 T Questions

Chris,

#1) In order to change the pressure on the compressor, you have to be an authorized user. Local level password or now (Key fob for the SC2) required. They would only be able to increase the pressure to max configured pressure (i.e. either 125psig, 175psig or 217psig) at the local level. They cannot change pressure beyond the set configuration.

#2) The discharge temperature from the ASD30 T with an ambient of 115 F and 50% Relative Humidity would be 134.3 F.
If you have any questions or need additional information, do not hesitate to contact me.

Best Regards,

Richard Hartshorn
Project Support Engineer
540-554-4508 direct
540-898-5500 main (Ext 254)
540-898-5521 fax
richard.hartshorn@kaeser.com

No virus found in this message.
Checked by AVG - www.avg.com
Version: 2012.0.2171 / Virus Database: 2425/4998 - Release Date: 05/14/12