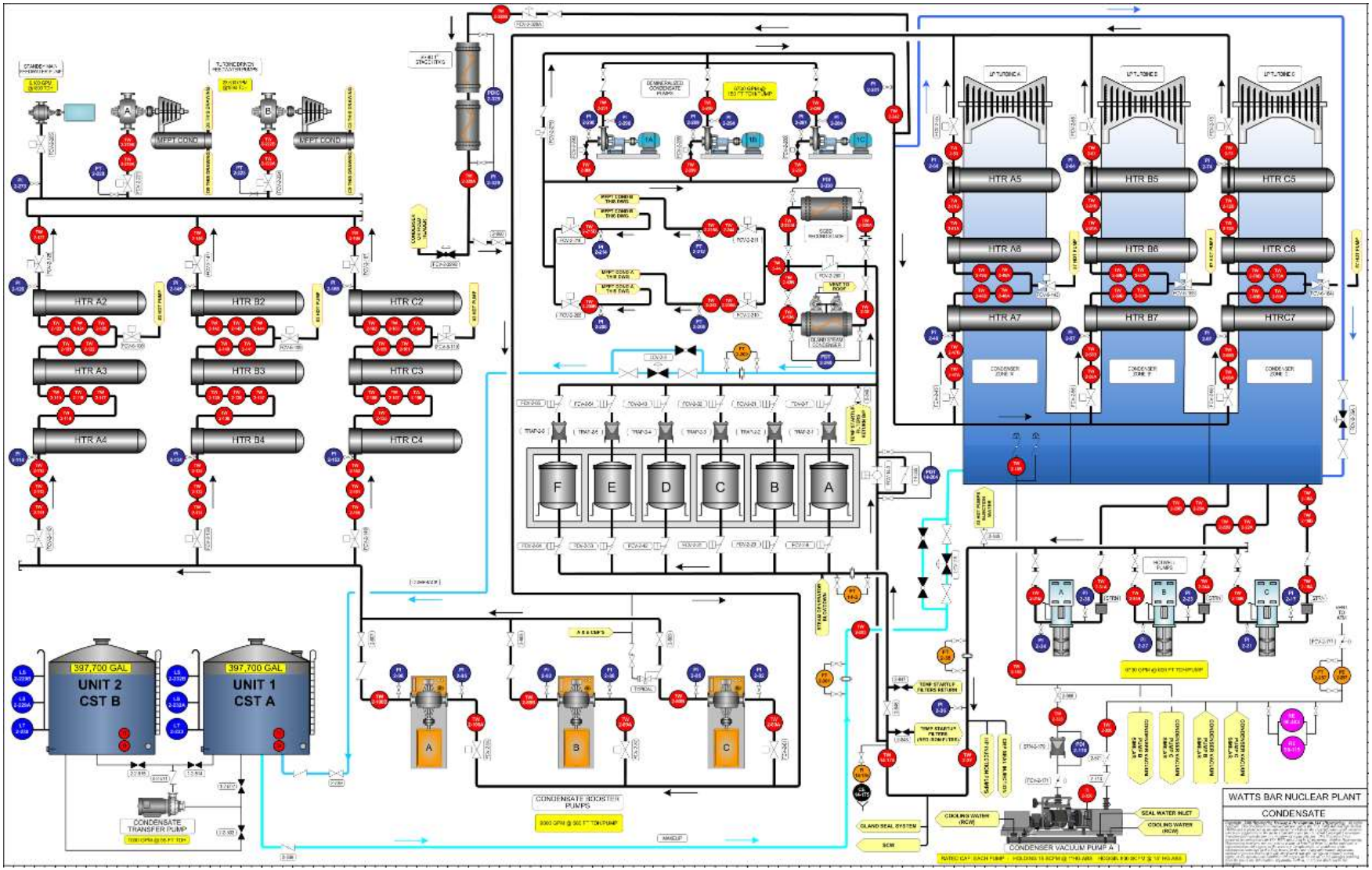
Watts Bar Unit 1 A2 Feedwater Heater Partition Plate Weld Failure

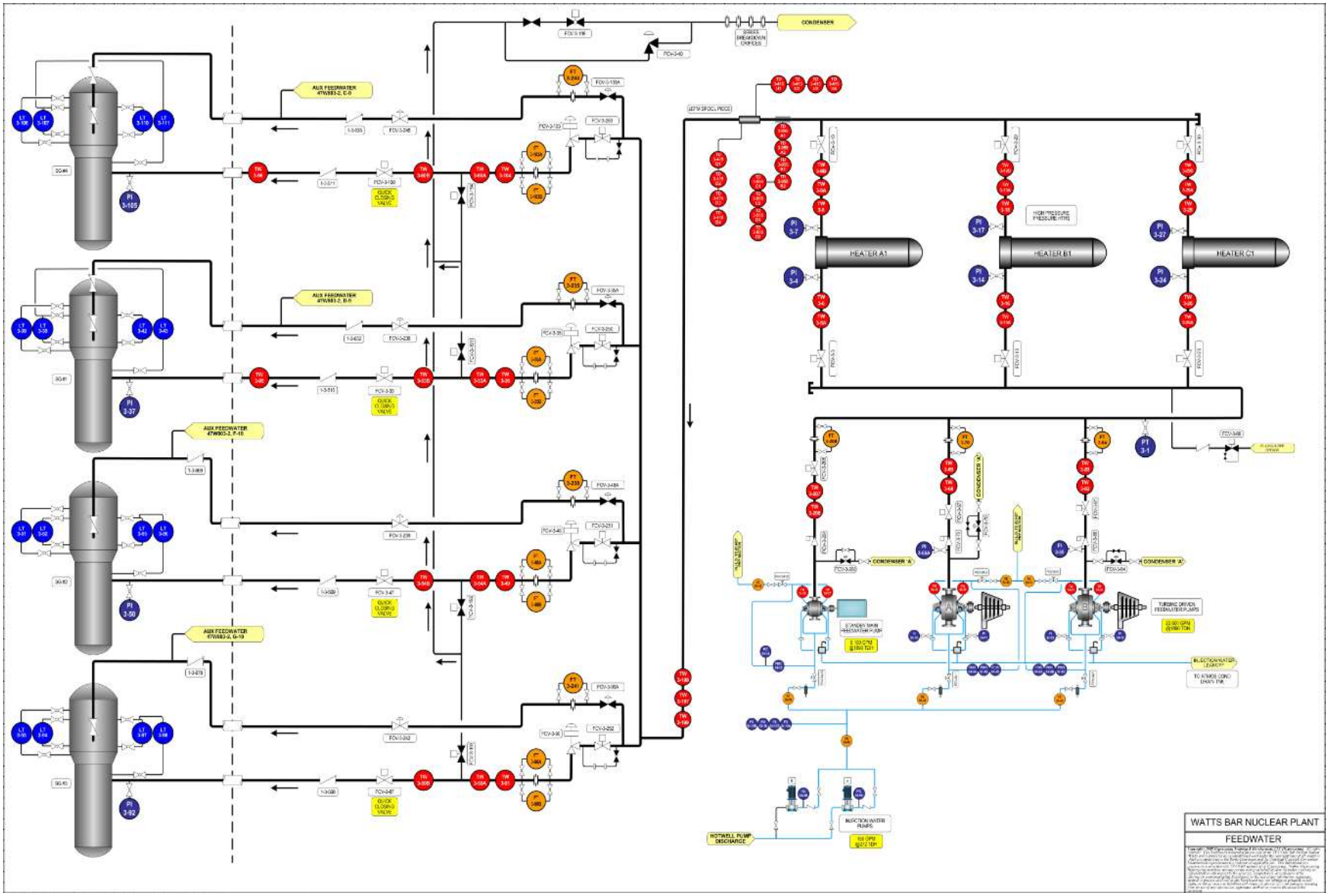
Watts Bar Unit 1 Feedwater Heating Overview

- Watts Bar Unit 1 is a PWR 4 Loop Westinghouse Design with a Siemens/Westinghouse Turbine/Generator
- Watts Bar Unit 1 began Commercial Operation in May 1996
- The Watts Bar Unit 1 Condensate System consists of the following in terms of Feedwater Heating:
- 3 Feedwater Heater Strings/Trains (A, B, & C) comprised of 21 total Feedwater Heaters
  - Each String consists of 3 Low Pressure Condensate Heaters (#5, #6, and #7)
  - Each String consists of 3 Intermediate Condensate Heaters (#2, #3, and #4)
  - Each String consists of 1 High Pressure Feedwater Heater (#1)
- 3 Condensate Booster Pumps
- 3 Hotwell Pumps
- 2 Turbine Driven and 1 Motor Drive Main Feedwater Pumps
- 3 Condensate Demineralized Pumps

Condensate Flow Drawing



Feedwater Flow Drawing



Thermal Performance Review

- Terminal Temperature Difference (TTD) – Parameter used to evaluate a Feedwater Heater's performance related to Heat Transfer; TTD is the Saturation Temperature of the Extraction Steam minus the feedwater outlet temperature; Normal Operating TTD is 5 Deg F

  $T_{sat} - T_{FW\ Out} = TTD$

- Drain Cooler Approach Temperature (DCA) – Method used to validate Feedwater Heater levels; DCA is the difference between the drain cooler outlet and the feedwater inlet; Normal Operating DCA is 10 Deg F

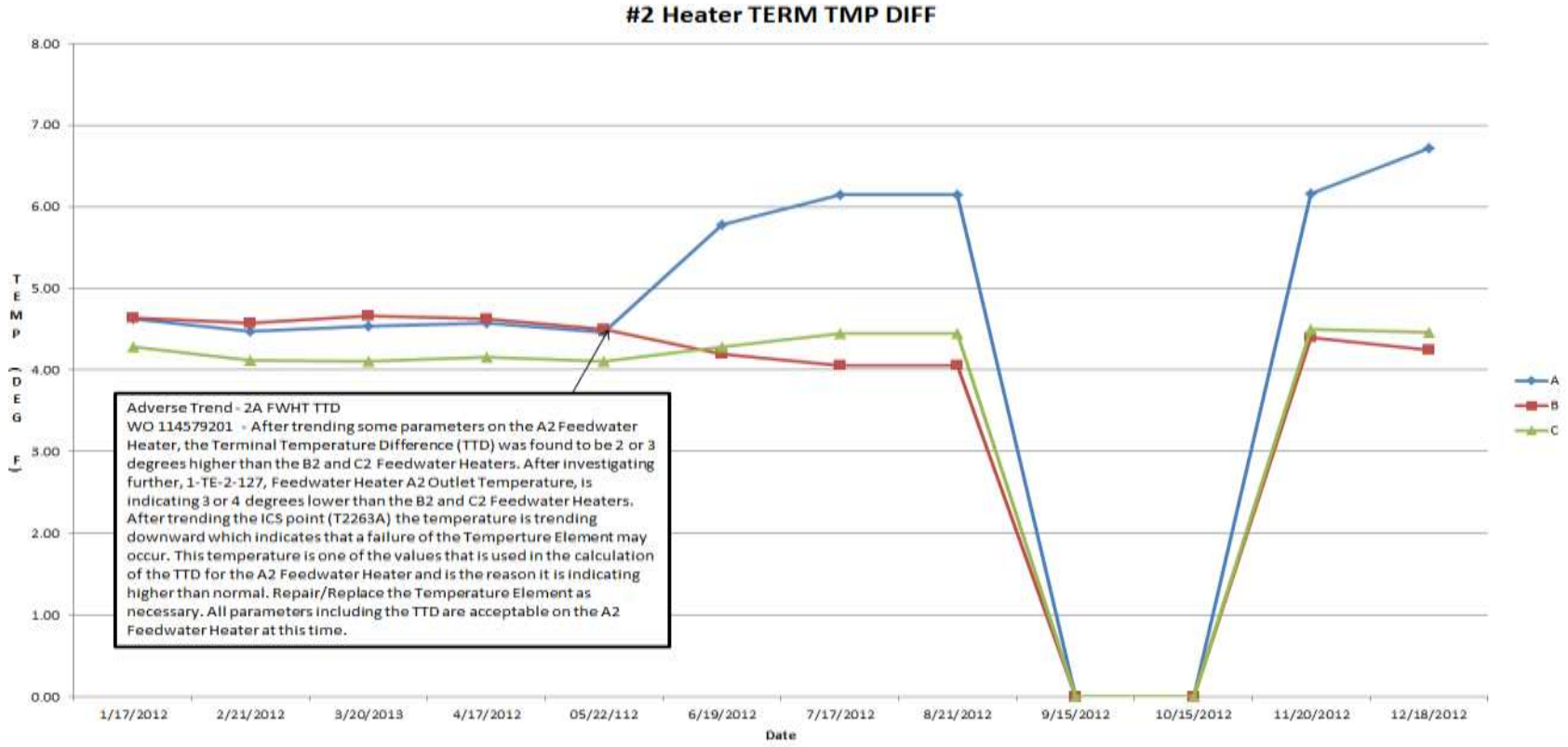
  $T_{Drains\ Out} - T_{FW\ In} = DCA$

- Feedwater Temperature Rise (FW ΔT) - FW ΔT is the difference between the feedwater outlet temperature and the feedwater inlet temperature; Normal FW ΔT is 40 Deg F

  $T_{FW\ Out} - T_{FW\ In} = FW\ \Delta T$

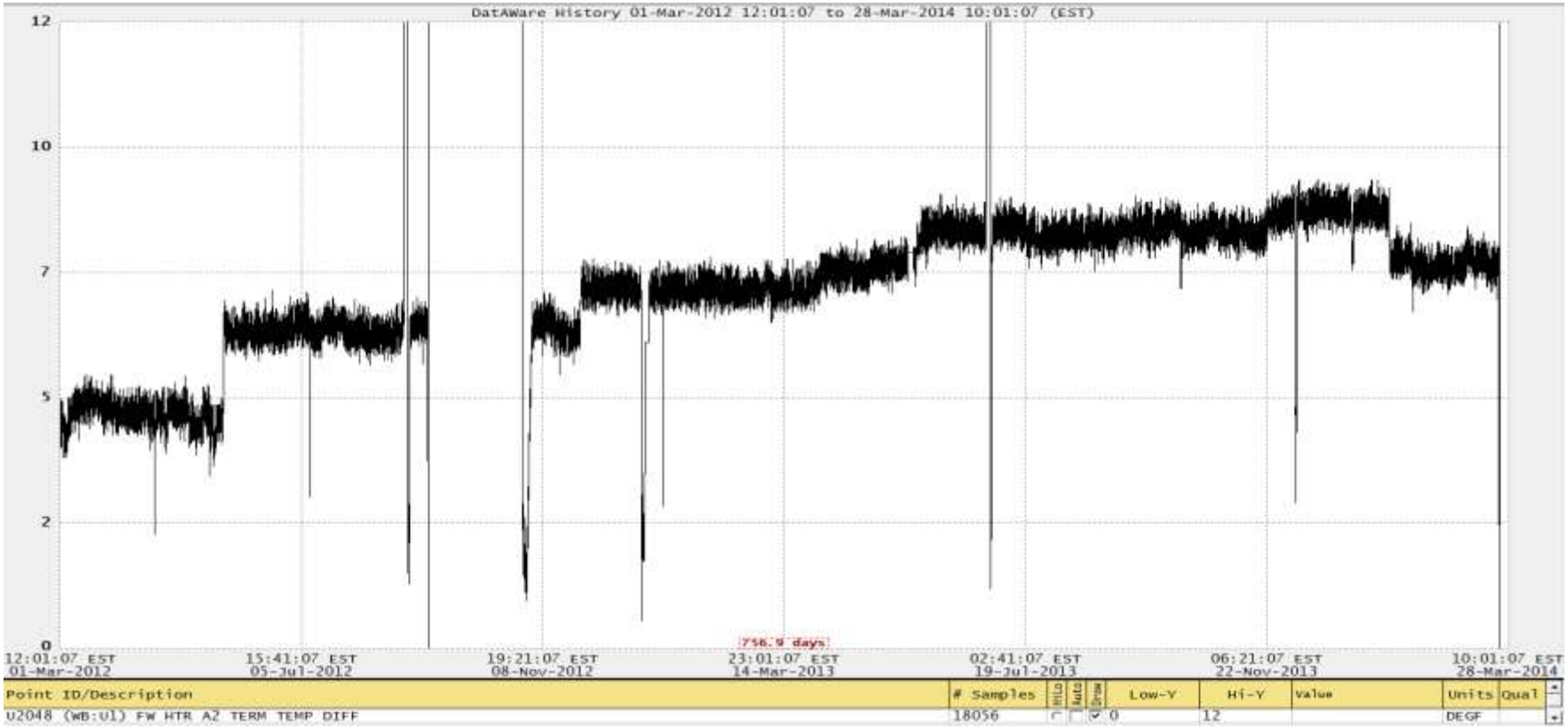
Initial Event Discovery Information for 1A2 Feedwater Heater

- System Monitoring/Trending identified an adverse trend in the TTD associated with the 1A2 Feedwater Heater (Began in May 2012 when values increased to approximately 6 Deg F)
- Initial thoughts were the Thermocouple measuring Feedwater Outlet Temperature was failing



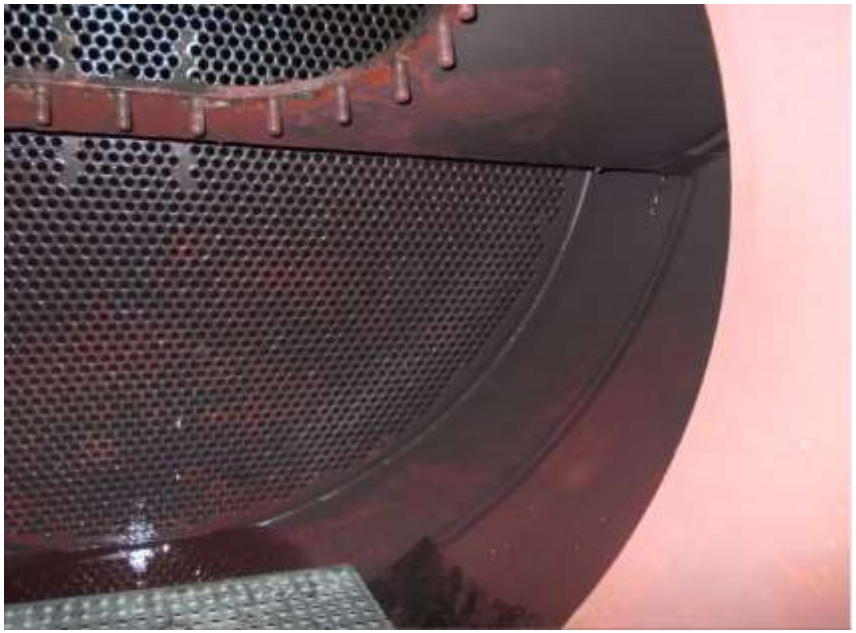
Troubleshooting and Additional Findings

- Adverse Trend in TTD continued to worsen to approximately 8.5 Deg F (January 2014)
- Feedwater Outlet Thermocouple was replaced and the condition did not change (March 2014)
- Eddy Current Testing scheduled for WBN U1C12 Refueling Outage (Spring 2014)



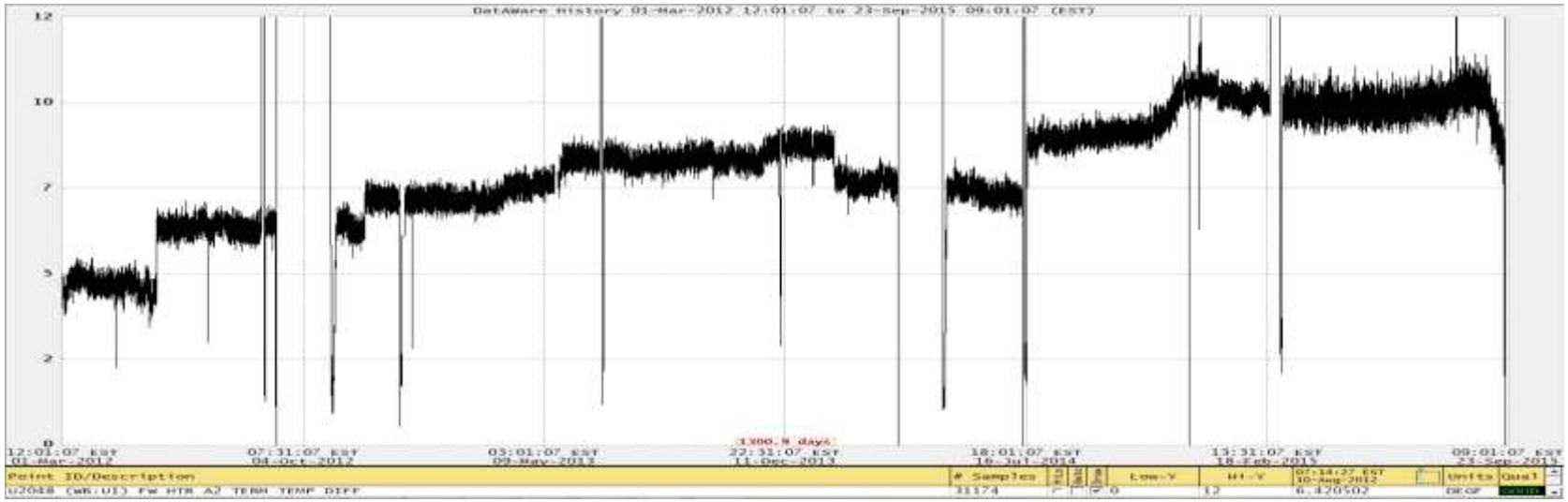
WBN U1C12 Refueling Outage

- During WBN U1C12 Refueling Outage (Spring 2014), Eddy Current Testing was performed on the 1A2 Feedwater Heater and as a result, 4 tubes were plugged
- During the Eddy Current Testing, a black, slippery substance was found on the inside of the tubes which was a result of solidifying of the following substances:
  - Ethanolamine (ETA) – Condensate Corrosion Inhibitor
  - Iron
- No abnormalities were noted other than the ETA/Iron mixture that had plated out inside the tubes



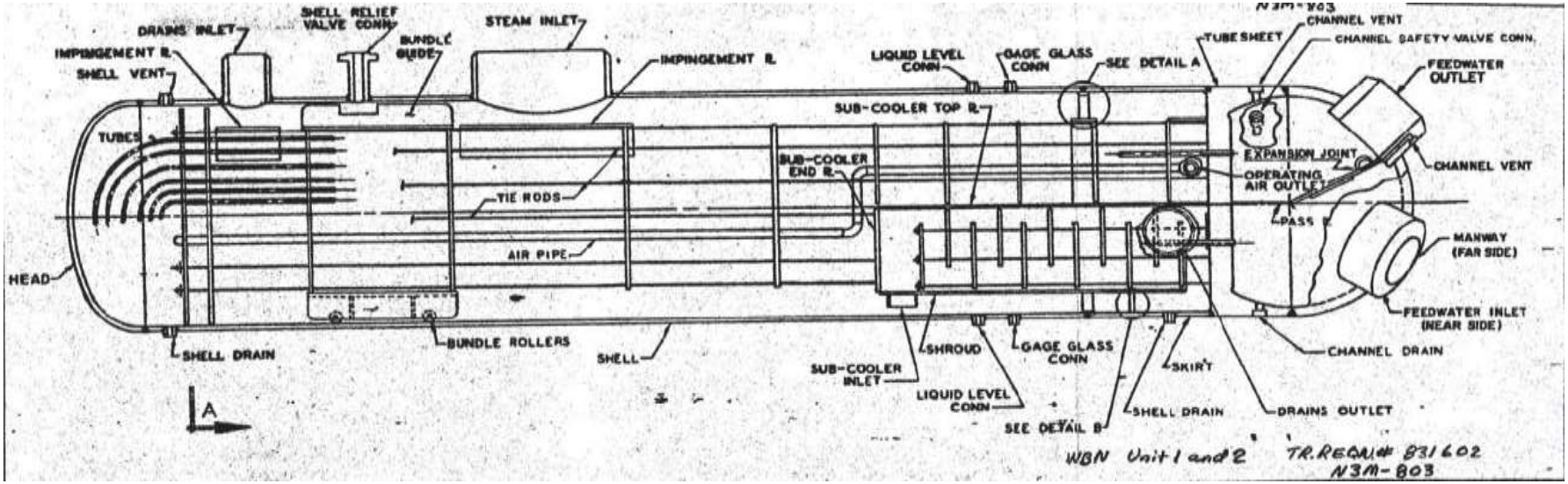
WBN U1C13 Outage Preparations

- After WBN U1C12 Refueling Outage, the TTD worsened to approximately 10 Deg F
- Plans were made to re-open the 1A2 Feedwater Heater during WBN U1C13 Refueling Outage once extensive research was performed and the issue was better understood
- The troubleshooting plan consisted of the following:
  - Engineering to Inspect the inlet tubesheet, inlet piping, and hemi-head (shell) before removing the Pass Partition Plate Cover
  - Engineering to Inspect the outlet tubesheet, outlet piping, and hemi-head (shell) after removing the Pass Partition Plate Cover
  - Vendor to clean the tubes using high pressure demineralized water (This was to clean the tubes prior to Eddy Current Testing)
  - Obtain sample of black sludge to have tested by Chemistry
  - Fill shell side of Feedwater Heater to ensure no tubes are leaking (Water would visually flow from the tubes depending on the location of leak)
  - TVA Inspection Services to perform Ultrasonic Thickness Measurement
  - TVA Inspection Services to perform Eddy Current Testing



WBN U1C13 Refueling Outage

- During Engineering Inspection with the Partition Plate Cover removed, a degraded weld was identified on the partition plate expansion joint (Found during Tube Cleaning for Eddy Current)
- 75% of the hemispherical weld on the expansion joint was eroded away which created a ¼ to ½ inch wide gap
- The degraded weld allowed a portion of the flow entering the 1A2 Feedwater Heater to pass through without gaining any heat load
- As a result, the performance/heat transfer associated with the 1A2 Feedwater Heater was accurately displayed in the TTD trends.
- The decision was made to grind out the degraded weld and re-weld back like the original design



Videos/Pictures of Weld Failure

Video:

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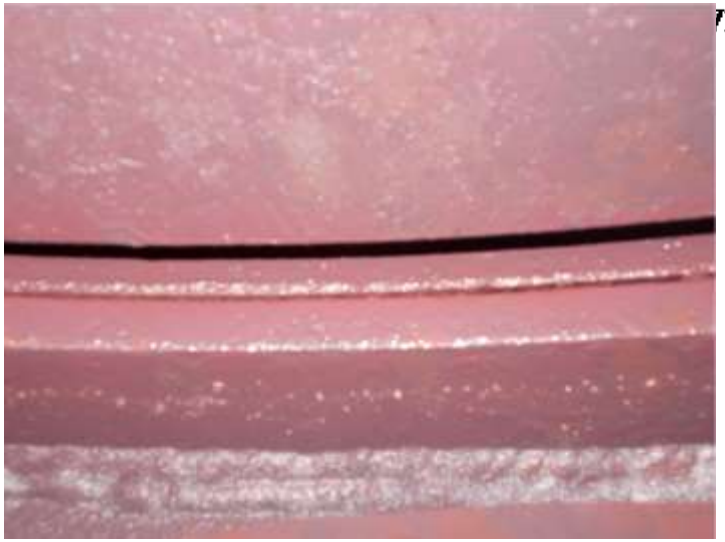

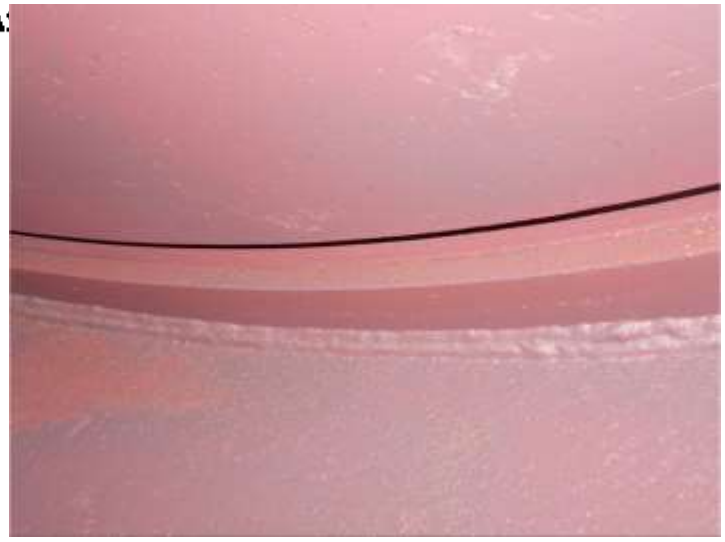

Pictures of the Weld Repair

Conclusion/Future Actions

- It is believed that the weld failed in the 1A2 Feedwater Heater due to an ineffective weld from the factory
- The 1B2 Feedwater Heater is scheduled for Eddy Current Testing during WBN U1C14 (Spring 2017) and a contingency work order will be planned to execute the same repairs if the same condition exists
- If the same condition exists in the 1B2 Feedwater Heater, a contingency will exist to also open the 1C2 Feedwater Heater instead of waiting until WBN U1C16 when it is scheduled for Eddy Current Testing
- The same condition is not believed to exist in the 1B2 or 1C2 Feedwater Heater because an adverse trend in TTD does not exist
- The current plan is to monitor the performance of the 1A2 Feedwater Heater until U1C20 (Spring 2026) when the next scheduled Eddy Current Testing will occur
- Corrective actions will be executed if the adverse TTD trend returns.

Questions?