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LP Feedwater Heater Repaired to Guarantee Reliability

by

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Abstract:

Tube leaks in the 6th point LP feedwater heater 1-FW-E-6B at Surry Nuclear Unit 1 had resulted in two forced outages in 2008/2009. Eddy current test results in 2008 revealed damage to tubes in the bottom rows of the heater. The destruction of the bottom tubes was caused by high velocities of condensate/steam flashing through the anti flash baffle between the condensate level and the bottom row of tubes. The anti flash baffle is used to reduce the amount of flashing condensate from damaging the turbine on a turbine trip. At a turbine trip the vacuum in the condenser reduces the pressure in the feedwater heaters causing the condensate in the heater shell to flash and possibly be drawn into the turbine causing turbine damage. The anti flashing baffle in the 6th point feedwater heater at Surry Nuclear Unit 1 during a turbine trip failed to protect the bottom rows of tubes in the heater because of the design of the anti-flashing baffle and it's location ¼" below the last row of tubes. The baffle failed to protect the tubes from high velocity flashed condensate causing the destruction of tubes up to the 13th row of tubes from the bottom of the heater.

This paper describes the testing, inspection and failure analysis, the re-engineering and repair plan and the repairs made to protect the remaining good tubes and new replacement tubes installed during the partial retubing. The objective was to guarantee the reliability of the Unit 1 6B heater through the next run cycle which would allow time to plan, bid, purchase and fabricate a new replacement feedwater heater.

The heater was removed from the condenser neck by the Surry Station personnel and retubed on the turbine deck by American Power Services (APS). The repairs and partial on site retubing had to be completed in six (6) days. Repairs were made to reduce the velocity through the modified anti flash baffle and solid stainless bars were installed to protect the new and existing tubes from damage until the next outage in about 18 months.

This paper will discuss the recommendations made by APS and decisions made during the evaluation process prior, during and after the rebuilding process by Dominion Resources Services Surry Nuclear Station Management. The performance and operation of the heater since the project was completed on May 2nd 2009 will be discussed.

1-FW-E-6B LP Feedwater Heater Description:

1. 1-FW-E-6B is a horizontal, 2 pass, U-tube heat exchanger that is mounted in the condenser.
2. The HX has a condensing zone only (no drain cooler)
3. Operates at saturated conditions (6.9 psia and 176ºF).
4. The 6th point FW heater does not have automatic level control.
5. A loop seal drain is maintained between the HX and the condenser.
6. All condensed steam returns to the condenser via the loop seal.
7. The HX is designed to flow 243,452 lbs/hr on the shell side with a maximum rate of 350,000 lbs/hr during abnormal operation.
8. The HX is designed to flow 3,545,506 lbs/hr on the tube side.
9. The shell side flow is also affected by the corresponding temperature of the incoming condensate.
10. A lower inlet condensate temperature will cause the HX to perform additional work to raise the temperature to that required at the outlet of the HX

Timeline:

1. 1986 – New 1-FW-E-6B Installed
2. 1995 – Core Uprate implemented on Unit 1
3. 2001 – One Tube Plugged on 1-FW-E-6B
4. 2003 May – Flash Evaporator Extraction Steam Pipe Cut and Capped.
5. 2004 Dec 22 – Tube leaks identified in 6B (1200 gpm)
6. 2005 Feb – Forced Outage (Air tested) 22 tubes failed, 44 plugged.
7. 2005 Oct – Identified Flow in Loop Seal w/unit in Cold Shutdown
8. 2006 Spring Outage –Eddy Current testing 19 plugged 1-FW-E-6B
9. 2007 Fall Outage – Eddy Current 6A no damage 6B no Eddy Current
10. 2008 April –Forced Outage plugged 59 tubes
11. 2009 Oct – Forced Outage plugged 83 tubes

FEEDWATER HEATER 6B LIMITED EDDY INSPECTION SUMMARY 10/08

	Total	Inlet	Outlet
Total Tubes (U-Tubes)	1520	-	-
OD Damage Wall Losses >=50%	11 (3.0%)	11	-
OD Damage Wall Losses 30%<=WL<50%	6 (1.6%)	6 (1.6%)	-
OD Damage Wall Losses < 30%	25 (6.7%)	6 (6.7%)	-
Total: Plugged (previous + Current)	231 (15.2%)	-	-

Figure 1. Tube Sheet Map Showing Location of the Damaged Tubes:

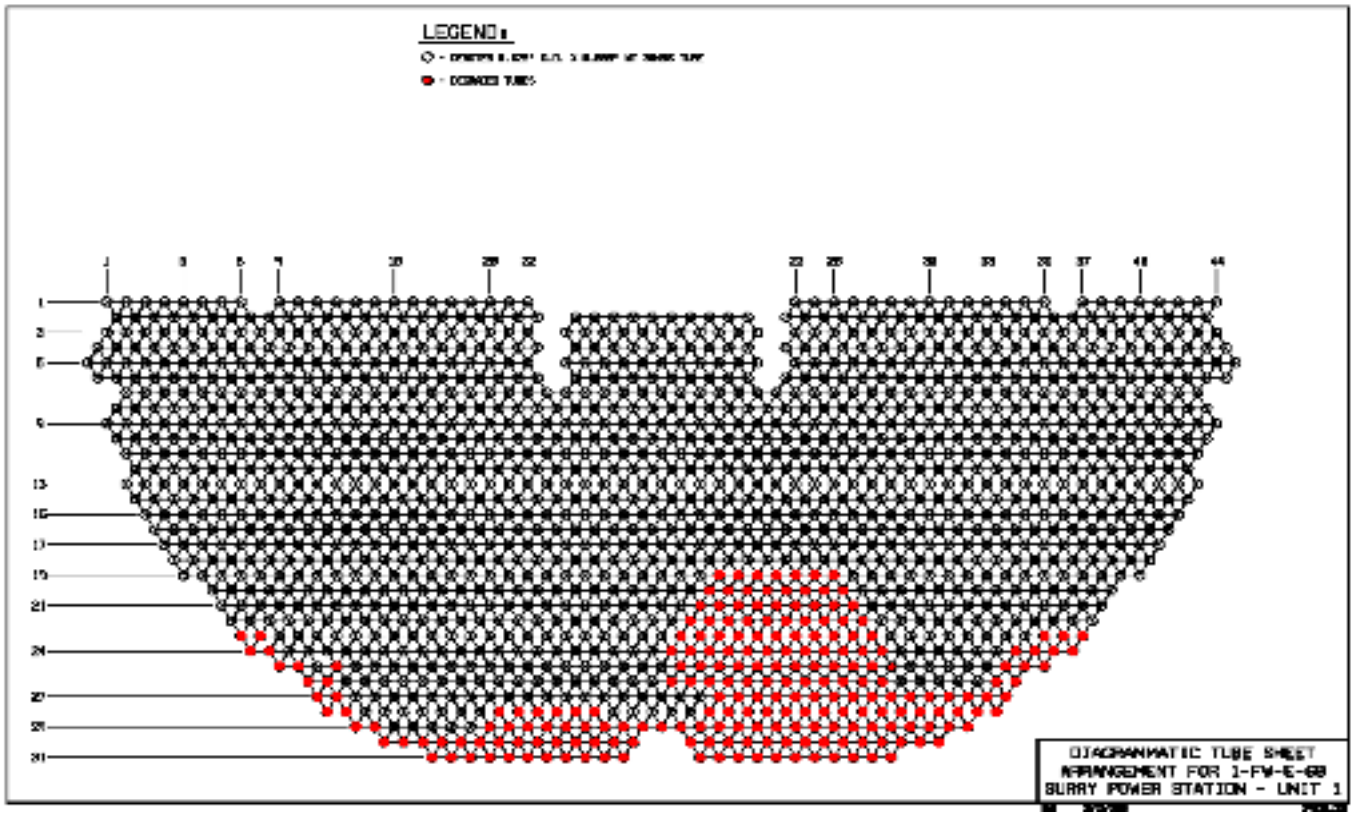


Figure 2: The anti-flash baffle side view located between the water level and tubes.

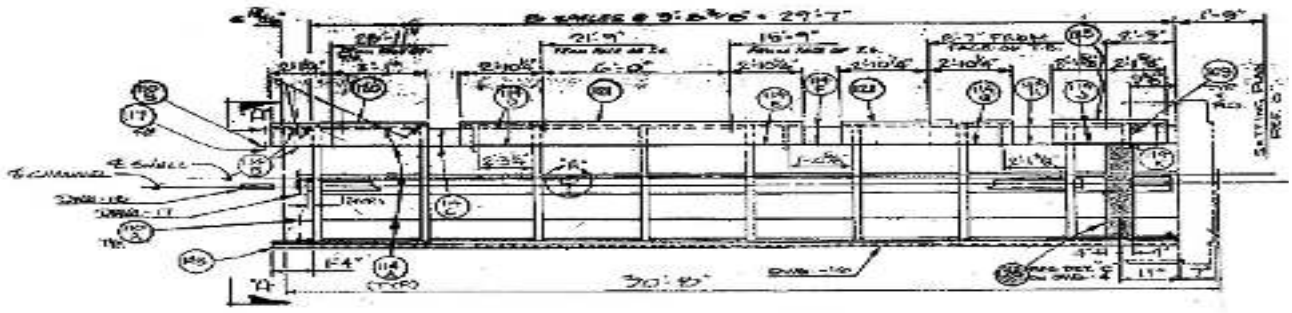
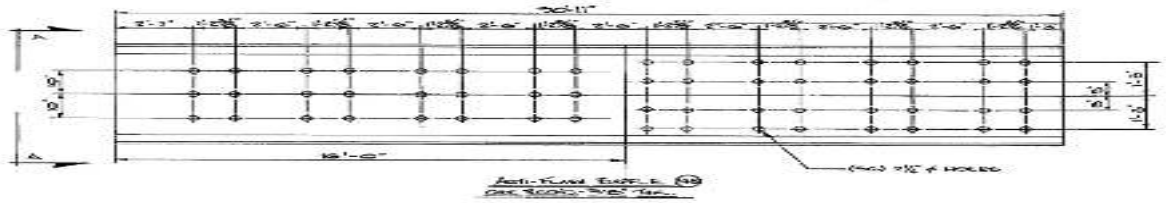


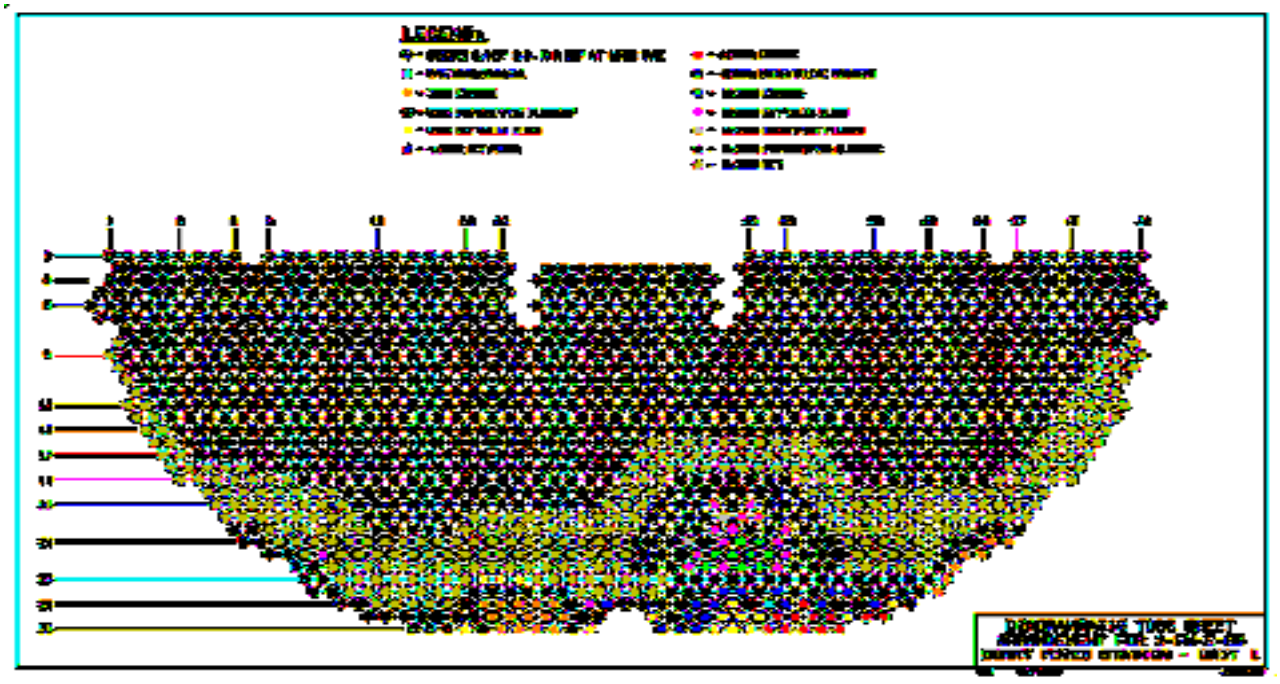
Figure 3: The anti-flash baffle top view drawing showing 2 ¼" hole location:



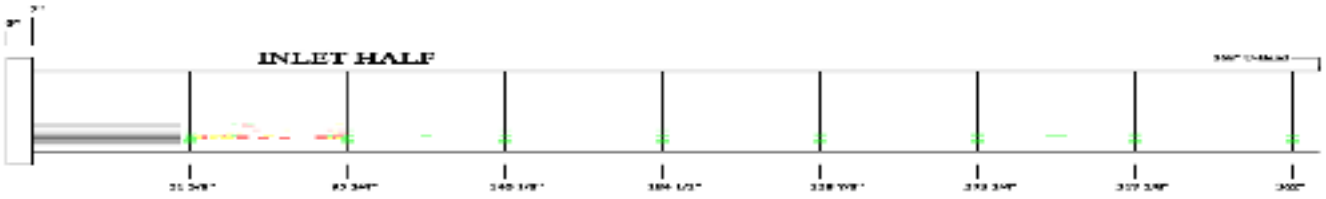
Condenser Neck LP Feedwater Heater Condition:

An eddy current test and visual inspection of the heater tubes and tube sheet revealed the tubes with defects, tubes with no defects and tubes that failed and were previously plugged. The following tube sheet map (Figure 4) shows the tubes plugged between 2005 and October 2008 and the tubes eddy current tested during the October 2008 outage and left in service. Tubes in yellow and above had no indications and were in like new condition. All tube defects were a result of the anti-flash baffle failing to protect the tubes in the bottom of the heater closest to the condensate that flashed and damaged more tubes at each turbine trip.

Figure 4. Tube sheet map indicating inspection and test results.



The location of the tube defects along the length of the tubes were documented in the eddy current report and on the attached bundle drawing. Figure 5 Tube defects along the length of the tubes shows most defects near tube sheet.



Condition Assessment and Recommendations:

During the past four years the plant experienced a number of turbine trips which caused the turbine extraction line to the 6th point condenser neck LP Feedwater Heater to go from 6.9 positive pressure to a vacuum. When this occurred condensate in the bottom of the LP FWH shell would flash resulting in high velocity steam and water moving vertically through the anti-flash baffle and past the tubes in the FWH bundle. The location of the anti-flash baffle only ¼" below the bottom row of tubes and the 2 ¼" OD baffle holes in the anti-flash baffle contributed to high velocity water vapor and steam attacking the 5/8" OD X 20 BWG SA-688-304 stainless steel U-tubes causing erosion and vibration damage to the tubes resulting in tube leaks which needed to be plugged. With additional turbine trips the tube damage continued to work it's way up the bundle until in April 2009 a total of 232 tubes were plugged and the damage worked it's way to the eleventh (11) row from the anti-flash baffle.

The first recommendation is to increase the size of the holes in the anti-baffle from 2 ¼" to 3" OD. The turbine manufacturer was notified of the increase area available to flash.

The second recommendation was to protect the new replacement tubes with 5/8" OD stainless steel bars in place of the first two rows of tubes to slow the flash velocity and protect the new 5/8" X 20 BWG 304 stainless U-tubes installed in rows three to eleven. The total number of tubes removed from service would be 107 of the total 1,520 U-tubes in the heater or seven (7%) of the total number of tubes.

It is also recommended to install staking bars in two rows of tubes going up both sides of the heater by nine (9) rows. This is to prevent new tube damage from high velocity flashing condensate that may bypass the anti flash baffle and damage open tubes outside the protective anti flash baffle area.

During the tube removal process APS eddy current tested the the tubes adjacent to the previously plugged tubes to verify that no additional tube damage occurred since the 2006 and 2008 eddy current test. If the test shows any damage to the tubes planned to be kept in service these tubes are also be replaced.

WORK SCOPE to complete the particle retubing and staking in six (6) days (144 hours). APR 23 01:00 (AM) TO APR 29 01:00 (AM)

1-FW-E-6B Scope of work:

1. Root Cause Evaluation (RCE) team to be developed for analysis and testing (pre-outage).
2. All repairs, retubing and plugging to take place without removing the hemi-head channel.
3. Remove parts of pass partition to gain full access to the tube sheet.
4. Eddy current to verify tube damage and determine tubes to be replaced.
5. All 2-1/4" flash baffle plate holes to be increased to 3" in order to reduce flash flow velocity.
6. Removal and replacement of new shell cut line backing ring.
7. Remove, prep, fit-up, and install (2) new 2" sock-o-lets and (2) new 3" nozzles. The nozzles and sock-o-lets interfered with the shell cutting machine clearance.
8. Surry engineers and Root Cause Evaluation (RCR) team members to be present during tube removal, to tag and identify tubes and tube parts for inspection and analysis later.
9. There is potential that some of the plugged tubes may be under pressure therefore all tubes to be replaced must be cut from the OD before removing plugs.
10. Remove tube plugs and capture cable installed in the severed tubes.
11. Cut tubes ends internally 1" behind tube sheet
12. Machine tube joint TIG welds to allow tube stub removal from the tube sheet.
13. Inspect and repair the impingement plate and other heater internals.
14. Remove tube stubs from tube sheet using hydraulic tube puller inside Hemi-head.
15. Install 107 full length stainless steel solid rods in the bottom three rows and on the sides to protect the new and existing tubes. The top half of the U-tubes to be left out and plugged to the tube sheet.
16. Install (214) 5/8" OD explosively welded or fusion welded thimble plugs to permanently seal the 107 U-tubes to be permanently removed.
17. Clean and debur the tube support plate holes and the flash baffle plate.
18. Clean the tube sheet holes and face for TIG welding of the new tubes.
19. Install 124 new stainless steel U-tubes.
20. Set tubes to tubesheet
21. TIG weld the 124 new tubes with 248 tube to tube sheet joints.
22. PT test the tube joint welds.
23. Expand the full depth (7 ½" less 1/8") the 124 new U-tubes
24. Measure the expansion, record and provide report.
25. Reinstall pass partition.
25. Clean up job site
26. Demobilize.
27. Bundle to be reinstalled into condenser neck heater shell by the plant.
28. Air pressure test entire bundle in condenser neck and repair any tube joint leak (none found).
29. ASME Code Inspection, sign paper work and install name plate.

Work Schedule:

Figure 6. The work schedule for the project to be completed in twelve days (6 days to retube and stake bottom two rows of tubes).

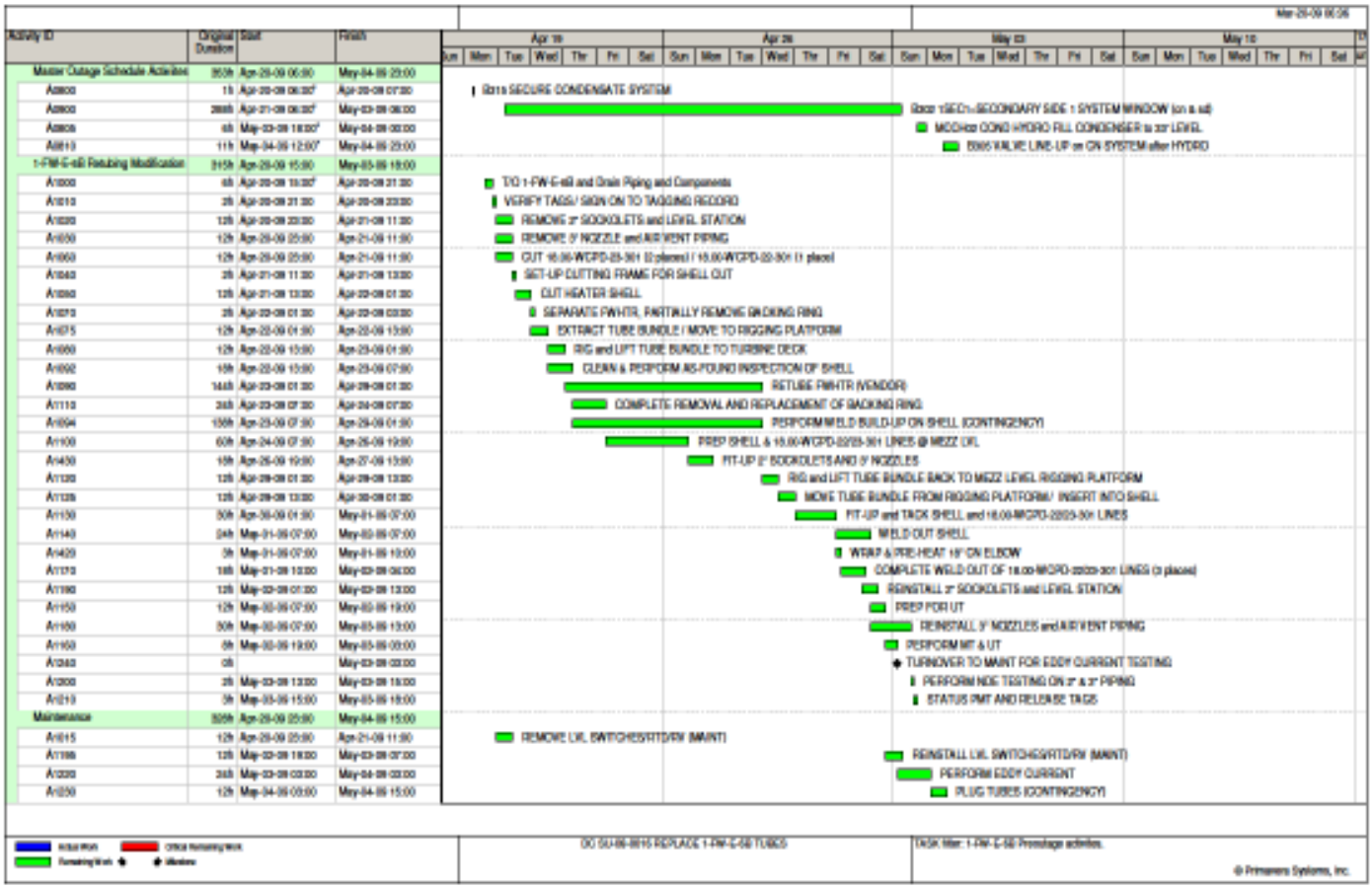


Fig 7. Condenser neck heater prior to removal.

Fig. 8. Rigging through turbine deck.

Fig. 9. Erosion at flash baffle holes.

Fig. 10. Damaged tubes seen through baffle hole.

Fig. 11. Erosion from flashing condensate.

Fig. 12. Damaged tubes removed from bundle.

Fig. 13. Cleaned for TIG welding new tubes.

Fig. 14. Installing new 304 SS U-tubes.

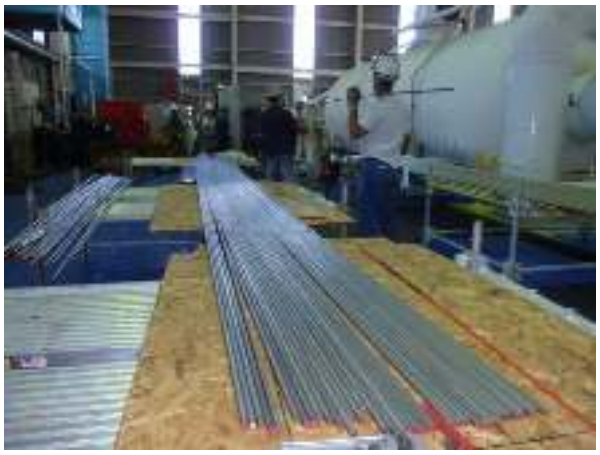


Fig. 15. 5/8” OD SS bars to protect new tubes.

Fig. 16. Welded bar stock to last tube support.

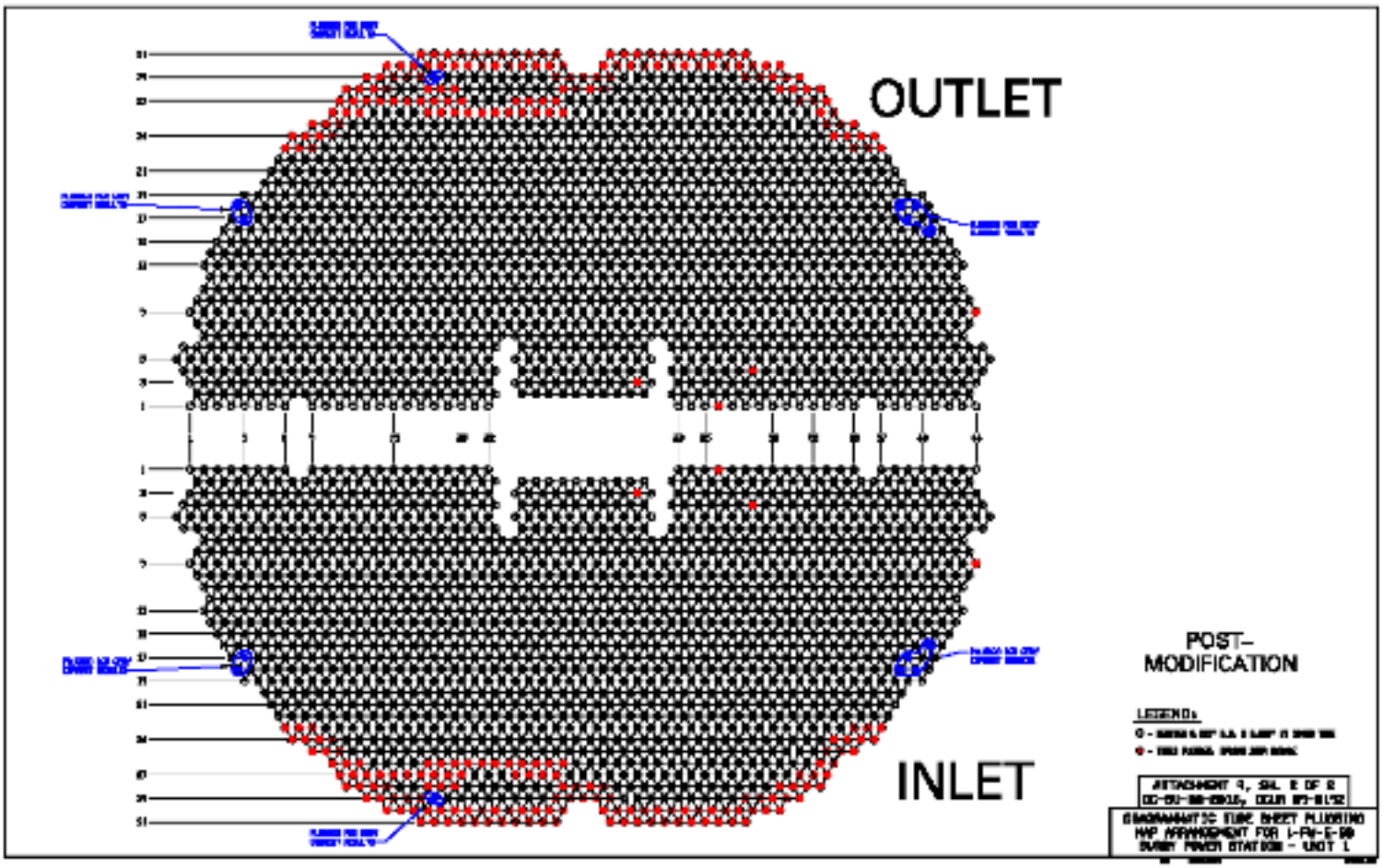


Figure 17. 107 tubes staked and plugged to protect the new and existing tubes from future damage.

Conclusion and Results:

The FW-E-6B feedwater heater was put into service in May 2009. It has been operating without a leak since the unit start up in May 2009. The heat transfer performance has been improved by increasing the surface area with 124 new 304 stainless steel U-tubes. The improved reliability of the rebuilt 1-FW-E-6B feedwater heater met Dominion Surry Nuclear Station's expectations.

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