USE OF INNOVATIVE *PMCap* (Patent 6,860,297) REPAIR FOR LP FEEDWATER HEATER SHELLS AT WOLF CREEK

By

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ABSTRACT

Wolf Creek Generating Station has saved substantial outage expense and increased service life of degraded feedwater heater shells. This was accomplished by addressing shell erosion using an innovative alternative to flush patch repairs during refueling outage RF13.

Wolf Creek Generating Station FAC Engineers have been monitoring twelve, ASME stamped, low-pressure feedwater heaters due to Flow Accelerated Corrosion (FAC). Shell wall thinning was found near drain nozzles in three low-pressure heaters that run through the main condenser. Projected localized metal loss indicated that minimum wall thickness would be violated within the next fuel cycle. Repair plans were made and funds were budgeted for flush patch repair of all three low-pressure feedwater heaters during Wolf Creek's 2003 fall refueling outage.

Unexpectedly, projected thinning along the water line in the same three heaters was also determined to be below or near minimum wall. These eroded areas ran along the outside, below the drain nozzles and extended inside the main condenser. These new repairs presented additional challenges that were not in the original plan and resulted in a significant increase in the repair plan scope, cost and outage time. In addition, working inside the condenser increased the risk to personnel and condenser internals. Estimates for the new repairs using traditional flush patches totaled more than five times the amount previously budgeted and became the critical path job during the outage. Due to the high cost and impact on the outage schedule, Wolf Creek assembled a team to determine the best plan to return the feedwater heaters to service while maintaining the highest safety standards, restore Code compliance and remain consistent with the feedwater heater life cycle management strategy to ensure a minimum of 15 years of service life.

The team selected an innovative approach that was referenced in EPRI Task 91, 1003286, Technical Report, Repair Technology for Degraded Pressure Vessel and Heat Exchanger Shells, and at EPRI RRAC and FRAC conferences. This approach involved encapsulating the eroded shell using a newly developed ASME Section VIII Code compliant component called a *PMCap* Patented. The *PMCap* was developed by PMC Engineering Solutions, Inc., Pottstown, PA and was supplied to Wolf Creek through MLEA Inc., Exton, PA.

After review of the FAC data and feedwater heater design, two *PMCap* encapsulation designs were developed to bound all nozzle and water line thinning. These designs would allow all three low-pressure feedwater heaters to return to service for an additional 15 years. A total of six *PMCap*s were installed on the three low-pressure heaters.
Installation of the *PMCap* encapsulations for repair of degraded vessel wall is treated as an alteration under the National Board Inspection Code (ANSI/NB-23). Wolf Creek worked closely with the *PMCap* supplier, state jurisdictional authorities, Authorized Inspecting Agency, and the National Board to ensure that all code and regulatory requirements were met.

By using the *PMCap*s, Wolf Creek restored all three feedwater heaters ahead of schedule and at a cost significantly below that of a flush patch repair.

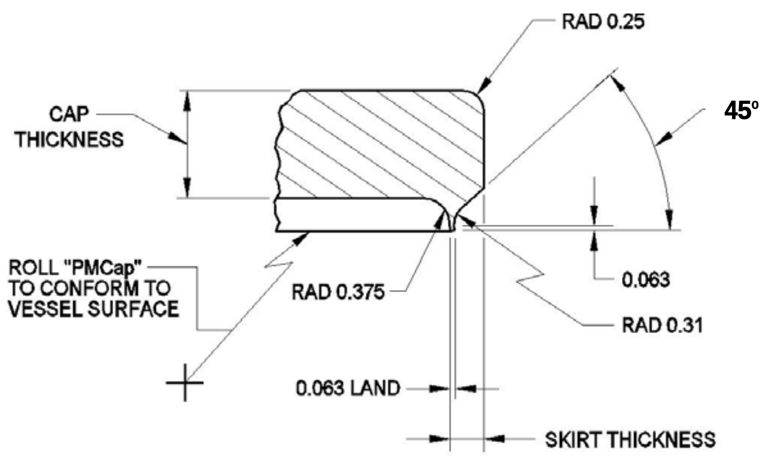
BACKGROUND

The objective of the Wolf Creek feedwater team was to provide and implement a simple, safe, and cost effective method of repairing the degraded feedwater heaters in compliance with original design codes. This required satisfying the following criteria:

- Provide for a minimum of 15 years additional service life
- Minimize breech of pressure boundary and removal of shell wall.
- Minimize shell preparation work.
- Having installation capability that does not require weld joint backing strips.
- Minimize risk of damage to main condenser internals.
- Minimize risk of intrusion of foreign materials into heaters.
- Minimize personnel time required to work inside condenser.
- Ensure compliance with Wolf Creek QA and purchasing requirements.
- Ensure compliance with ASME Code, NBIC, state, and regulatory requirements.
- Having a load path access to job site capability requiring minimal changes to area piping and equipment.
- Maximize pre-outage work to minimize outage work.
- Minimize cost.

The feedwater team concluded that the *PMCap* encapsulation repair method satisfied all selection criteria and offered a superior cost effective alternative to a traditional flush patch repair. *PMCap* components restore vessels to original design condition by encapsulating localized metal loss without the need to remove degraded shell sections or breech the pressure boundary. This approach allows for all installation work to be performed outside the vessel. The *PMCap* is welded to the outside surface of a vessel using full penetration ASME Category D welds. After installation, the *PMCap* provides a new pressure boundary.

The addition of a *PMCap* is analogous to adding a very short nozzle to a vessel that is capped off for future use. Their design and construction is based on full compliance with ASME code rules. *PMCaps* have a machined undercut that forms a new pressure chamber between the *PMCap* and the vessel surface.



Detail of *PMCap* Undercut and Skirt to Vessel Weld Prep

PMCaps can be constructed to encapsulate shell, head, or nozzle regions in any shape but are commonly supplied as round or obround. They can be supplied as "material" or as a U-stamped component with partial data report, shop fabrication drawing, and certified calculation.

PMCap DESIGN

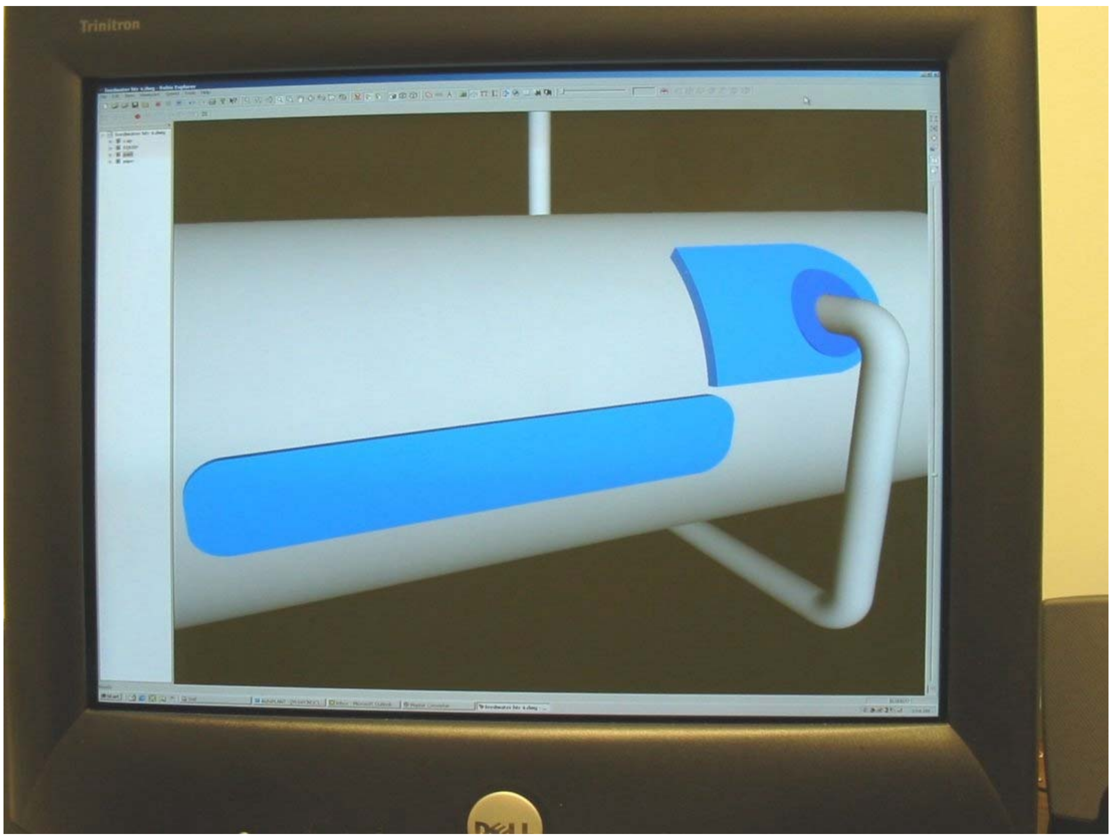
PMCaps are designed in accordance with latest ASME code requirements. For Wolf Creek the design used the lower 1998 ASME code material stress allowables as required by the state jurisdictional authority.

The *PMCaps* were designed for vessel internal and external design pressures, including pressurization of the cavity should the encapsulated wall be breeched. Local nozzle loads, where applicable, were also considered in the design. These loadings cause both membrane and bending stresses in the skirt and flat head portion of the *PMCap*. The *PMCaps* were designed to satisfy these loadings per ASME code rules and stress acceptance criteria. Thickness determinations were based on design pressure, area replacement criteria, and associated local nozzle loadings. As a minimum, code criteria, contained in Sections UG-27, "Thickness of Shells Under Internal Pressure", UG-28, "Thickness of Shells Under External Pressure", UG-34, Unstayed Flat Heads and Covers, and Appendix 13, Vessels of noncircular Cross Section as applicable, were followed. Additionally, Code rules contained in Appendix 1, Supplementary Design Formulas, and Appendix 4, Integral Flat heads with a Large, Single, Circular, Centrally Located Opening, were considered. Local nozzle loads were evaluated per Welding Research Council Bulletin 107. The *PMCap* skirt and all internal machined undercut radii were additionally designed to reduce stress concentrations.

PMCaps are designed as integrally reinforced components that strengthen the shell. Code rules contained in Section UG-37, Reinforcement Required for Openings in Shells and Formed Heads, are followed to determine the thickness of the flat head portion of the *PMCap* required for reinforcement of the encapsulated thin area. Vessel wall encapsulated by and adjacent to the *PMCap* is not included in strength or reinforcement design. The encapsulated vessel wall provides an erosion/corrosion barrier to the *PMCap*, or the caps can be constructed with corrosion/erosion resistant liners. The *PMCap* alterations were designed to meet or exceed original code design requirements and have improved feedwater heater shell erosion/corrosion resistance at the installed locations.

Throughout the design process, Wolf Creek engineering maintained frequent communication with all involved parties to assure compliance with code design rules, to address internal maintenance and operations concerns, and to assure that requirements and concerns from both the National Board and State Jurisdictional Authority were satisfied.

Wolf Creek NDE shell thickness data was evaluated using a priority Fitness for Service program. The program was used to determine shell areas requiring encapsulation and to optimize the size and shape of the *PMCaps*. For repair of the Wolf Creek low-pressure feedwater heaters, two shapes, one obround and one rectangular with rounded corners, were selected to bound all degraded areas. Three of each shape were constructed to encapsulate the areas as shown below:



***PMCap* Encapsulated Shell Areas**

Fabrication

The *PMCaps* were constructed in accordance with the latest ASME code. Each cap was fabricated from a single piece of code approve plate material (SA516GR70) that was machined and formed to fit the outer contour of the feedwater heater shell. The undercut area of the *PMCaps* was lined with stainless steel to add additional erosion/corrosion protection if the encapsulated section was breeched.

The carbon steel plate material was procured in the normalized condition and 100% ultrasonically examined. Each separate piece of plate used to fabricate a *PMCap* was further tested for thru thickness properties at two locations adjacent to the *PMCap* skirt. Thru thickness tensile tests were performed to assure that strength, elongation, and reduction of area complied with UW-13(f)(2) and Appendix 20 requirements.

Following machining and forming, the skirt area of the cap was again ultrasonically examined to assure soundness. The stainless steel liners were formed to fit into the underside cavity of the *PMCap* and were welded in place. The skirt weld preparation area was 100% LP examined per Code requirements.

A Manufacturer's Partial Data Report Form U-2A was prepared and code nameplates, stamped "U" PARTS, attached to the *PMCaps*. Final inspection was performed by a code authorized inspection agency.

***PMCaps* – Ready for Shipment**

As-Constructed Split *PMCap* (Underside View)

7’ x 14” Rectangular *PMCap*

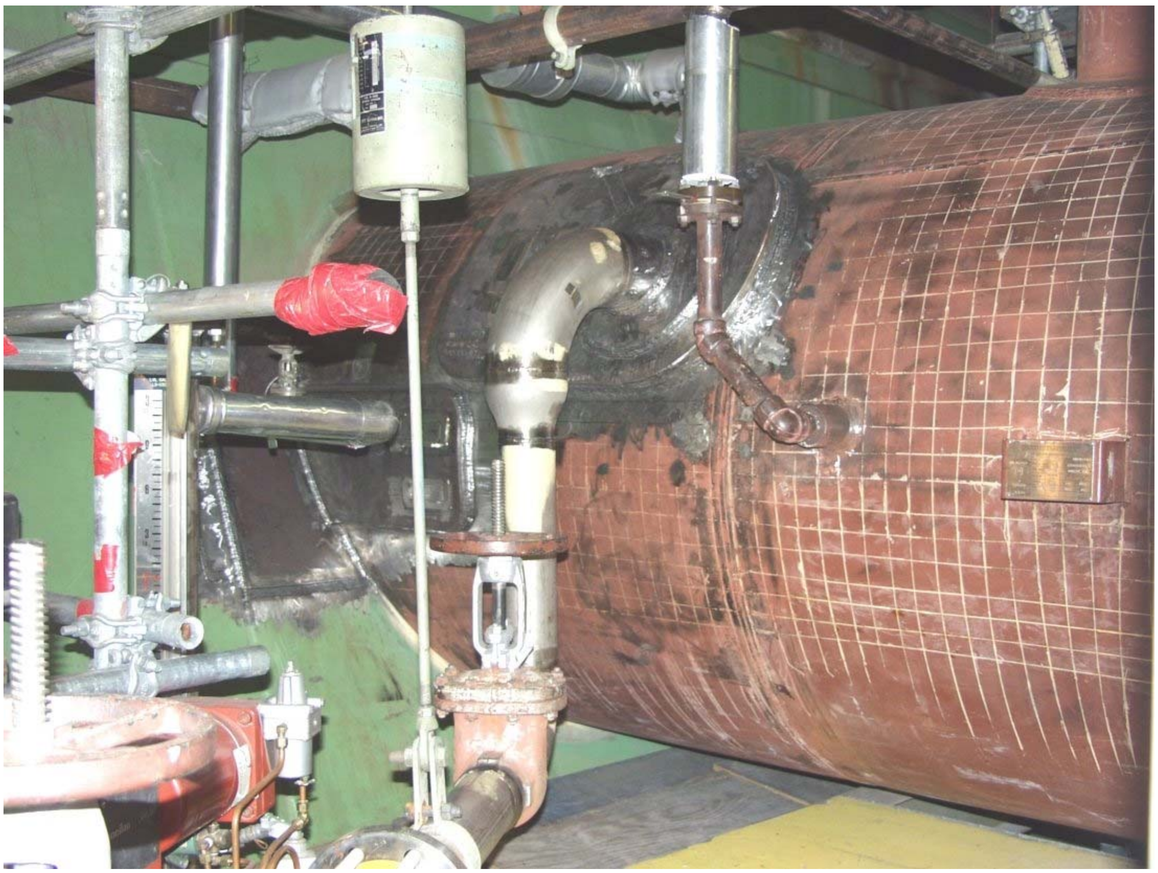
Installation

The nozzle cap was supplied in two pieces so that it could be installed around the drain inlet nozzle without having to cut the piping. All caps were brought to the job site without having to remove any obstructions. It is noted that the suggested flush patch was required to be so large that it would not have been possible to negotiate the congested turbine building area without additional work, including removal of adjacent piping. Lifting lugs were welded on to the caps by Wolf Creek to allow for easier handling and final positioning on the shell. Jack screws were attached to the shell to secure the caps in position during the welding. Wolf Creek elected to utilize an elevated preheat on all welds to assure final weld integrity. On all full penetration welds, the root pass and final weld pass were MT examined. Prior to installation of the caps, UT thickness measurements were taken of the degraded shell sections and flaw detection UT was utilized to verify shell integrity at the location of the attachment weld. Post installation, UT baseline thickness measurements were taken around the periphery of the caps at the Category D welds.

Following installation of an alteration the NBIC Code specifies that the integrity of alterations be verified by examination or test. Further, the NBIC states that examinations and test to be used shall be subject to acceptance of the Inspector and, where required, acceptance of the jurisdiction. The combination of MT and UT examinations performed on the pressure cap to shell welds was considered acceptable to both the Inspector and jurisdiction for verification of weld integrity. It should also be noted that per NBIC Interpretation 01-15, it would have been permissible to verify the integrity of the welds by locally pressuring the cavity formed by the *PMCap* between the pressure cap and the shell.

The simplified weld-on installation of the *PMCaps* minimized concerns of foreign material intrusion into the feedwater heater tube bundle and the main condenser. A small dedicated crew performed all outside and inside condenser work.

Total installation time for the six *PMCaps* was only 12 days. Additionally, use of *PMCaps* minimized the amount of cutting and restoration required to gain access to the heaters inside the condensers. The size of the required condenser opening for flush patches would have been significantly larger.



Completed *PMCap* Installation

SAVINGS

Substantial cost and schedule savings were realized using the *PMCap* repair method.

The repair method using a traditional flush patch would have required:

- Cutting large openings in the condenser wall to provide access for the flush patches;
- Cutting and removal of large sections of degraded shell and nozzle;
- Temporary supporting of shell both inside and outside the condenser;
- Temporary supporting of drain piping after nozzle removal;
- Extensive shell and nozzle weld preparation, and flush patch and nozzle fit-up;
- Substantial FME requirement for both main condenser and feedwater heaters;
- Removal and reinstallation of piping to allow repair plate access to the worksite;
- More welding;
- Spot Radiography, or Ultrasonic Examination if acceptable to the Inspector.
- Cleaning of heater internals; and,
- Critical path outage work.

The *PMCap* repair method reduced or eliminated the above requirements.

Total cost to install six *PMCaps* and return all three feedwater heaters to service was less than the estimated cost for one flush patch repair.

SUMMARY

The *PMCap* encapsulation repair method provided a low-cost, non-intrusive, ASME Section VIII Code compliant, simplified approach to address feedwater heater shell-wall thinning at Wolf Creek. The net result was reduced modification costs, as well as increased heater service life. Wolf Creek is currently working on resolving additional component thinning issues using *PMCap* encapsulations.

We believe *PMCap* method will result in a successful low cost alternative to the traditional weld overlay or flush patch repair methods. This approach should be considered for any ASME pressure vessel or piping systems, not only in nuclear and fossil power generating facilities, but also any industry that has similar component wall thinning problems.