Westinghouse Electric Company
Nuclear Innovation through Collaboration

Advanced Scale Conditioning Agent and Consolidated Deposit Extraction Planning, Application Experience, and Results at Comanche Peak Unit 2 and industrial Super Critical Water Oxidation Waste Reduction

Miles Forney[1], Danielle Ramaley[2], William Bryant[3]

[1,2]Westinghouse Electric Company

[3]Luminant Energy, Comanche Peak Nuclear Power Plant

Sonya Forrai, Presenter

BACKGROUND

Westinghouse Electric Company has had a long standing collaborative relationship with Dominion Engineering for Steam Generator Secondary Side Services. The companies work together to bring new technologies to market. The most recent example of how this collaboration has yielded benefits to our customers is described below with a first-of-a-kind application of a chemical-based cleaning in the United States. A similar process was implemented in France, also as part of the Westinghouse/Dominion Engineering collaboration. This application yielded significant corrosive deposit removal totals in its full bundle application.

The cleaning process used in France included a waste reduction technology called Super Critical Water Oxidization (iSCWO). Westinghouse collaborated with General Atomics to bring this technology to industrial customers, delivered via a mobile, modular process. iSCWO destroys organic compounds in the waste using the unique properties of water. At the thermodynamic critical point of 374°C (705°F) and 3,206 psi (pounds per square inch) of water, organic materials, oxidation reactants, and oxidation products are miscible, thus allowing complete oxidation reactions to take place. The products of SCWO processing include CO2, H2O, and salts, with NOX, SOX, and particulate concentrations at or below detection limits, all without any post-treatment. Following the iSCWO process, the waste was dried to convert the liquid into a solid format for disposal. The iSCWO process resulted in a 100 to 1 reduction in the waste generated.

ABSTRACT

Advance Scale Conditioning Agent (ASCA) technology has been applied more than forty times worldwide since its inception in 2000. This technology has continually grown in popularity since its development due to the combination of several process benefits and minimal outage impacts.

Comanche Peak Unit 2 applied a Top of Tubesheet (TTS) ASCA in 2014 for partial dissolution and softening of consolidated TTS collars. In addition to the ASCA application, a Consolidated Deposit Extraction (CODE) step was applied to the TTS. CODE is a chemical treatment technology that effectively targets and dissolves “binding species” such as those containing aluminum and silicon from steam generator deposits. Since magnetite dissolution technologies

are not wholly effective in removing consolidated TTS "collars," CODE technology was developed to address this need in the industry.

This paper will discuss both the Westinghouse and utility perspective on TTS ASCA/CODE application planning, site execution, and process results.

1 INTRODUCTION

Today, nuclear power plants are coming upon life cycle milestones, with challenges to operating costs from oil and natural gas competition. Extending plant life is critical to remain competitive in the energy market. Steam Generators (SGs), one of the vital pieces of plant equipment, though static in operation, require monitoring and maintenance just the same. Costs for fabrication and installation of new Steam Generators are approximately $300M to $600M. Costs for new plant pre-construction and regulatory fees are upward of $400M plus. These cost alone warrant careful attention to maintenance practices and the formation of a Steam Generator Management Teams (SGMT) to keep the SGs running optimally.

ASCA and CODE are two mild chemical cleaning methods that can provide performance enhancement and longevity to SGs.

ASCAs, in particular, continue to grow in the industry as a preferred approach for maintaining overall SG health. ASCA technology is designed to provide maximum benefit to the plant while minimizing outage impacts. CODE compliments the effectiveness of the ASCA by targeting binding agents that make up the skeletal structure of the hardened deposits at the TTS. Working together, these chemical agents increase the effectiveness of mechanical deposit removal such as Sludge Lancing or Ultrasonic Energy Cleaning (UEC). The following discussion provides insight for an effective cleaning campaign from the planning to execution phases of an ASCA/CODE process.

2 OUTAGE PLANNING OVERVIEW

2.1 ASCA/CODE Project Team Interfaces

In order to ensure a successful ASCA/CODE project, close communication is established between Westinghouse and the customer early in the planning phase. TTS applications require multiple interfaces. The involvement for this collaboration ranges from tailoring formulations for plant specific loading conditions to environmental reporting to state and federal agencies (See Figure 1 for Stakeholders).

In order to ensure a successful ASCA/CODE project, close communication is established between Westinghouse and the customer early in the planning phase

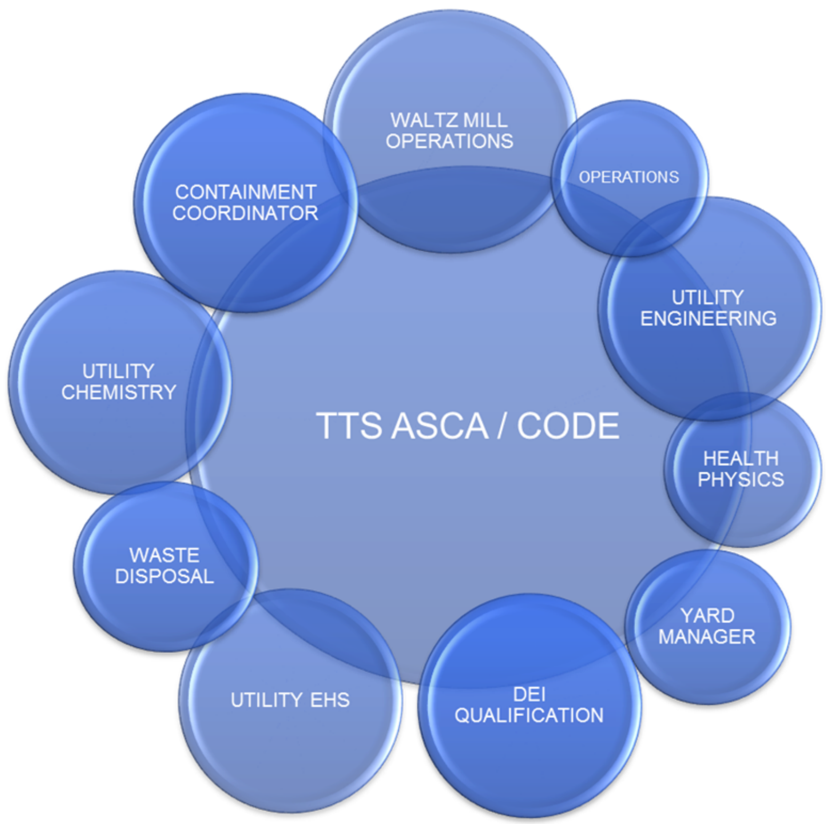


Figure 1: ASCA/CODE Stakeholders

The ASCA/CODE stakeholder team is engaged early in the planning process. Planning for ASCA/CODE applications begins approximately 15-18 months prior to site execution. The key activities include qualification testing, site walkdown(s) and the project kick-off meeting.

2.2 Qualification Testing

Due to the wide variability in the structure and morphology of SG deposits, plant-specific qualification testing is needed to determine the formulation and method of treatment prior to application. Qualification testing is performed at Dominion Engineering, Inc. (DEI). The testing typically consists of the following activities:

- *Deposit characterization and test plan development*

  As part of this task, DEI characterizes the chemical and physical properties of SG deposit samples from the utility. (This task is critical to the development of optimal ASCA/ CODE formulations.) This deposit characterization study includes the following activities:

  - ✓ Sample Preparation, Inspection, and Separation
  - ✓ Chemical Analysis
  - ✓ Physical and Structural Analysis

  The results of the deposit characterization are documented in a DEI letter, which also identifies various ASCA/CODE processes that may be beneficial for meeting steam generator cleanliness and performance objectives.

- *Preliminary ASCA/CODE testing*

  Based on the deposit characterization and deposit loading estimates, candidate formulations/processes are designed to achieve the site cleaning objectives identified. Typically, up to eight preliminary tests are performed as part of a test matrix to determine the best suited process to meet utility cleaning goals. The test matrix is discussed with utility, Westinghouse, and DEI team members prior to preliminary testing. Preliminary testing is performed on actual SG deposits using representative SG materials of construction. Both cleaning effectiveness and expected corrosion are monitored during the testing. Following completion of preliminary testing, the results are communicated in a DEI letter which is discussed with the utility and Westinghouse team. Based on the results and discussion, a formulation and process is chosen for final qualification testing.

- *Final ASCA/CODE qualification testing*

  A final qualification test is conducted in order to formally qualify the candidate formulation and process that is expected to be most effective. This test is conducted in a larger vessel, which allows a more realistic simulation of the selected formulation. Cleaning objectives, outage impacts, and process time/temperature profile are all taken into account for final qualification testing. Upon completion of qualification testing, the results are communicated in a DEI technical report which includes conclusions regarding the potential effectiveness of the qualified formulation/process and recommendations for field application.

2.3 Site Walkdown and Project Kick-off Meeting

A site walkdown is performed prior to TTS ASCA/CODE applications. Although not required, it is beneficial to perform the site walkdown following completion of qualification testing. Planning in this sequence allows the walkdown team to include actual process expectations in its site layout decisions.

For TTS applications containment access is necessary, since equipment set-up will be in-containment. ASCA/CODE walk downs are performed using a detailed checklist developed from previous field experience and lessons learned. The walkdown will determine the optimum points for connection of process equipment.

As discussed in section 2.1, close communication is established between Westinghouse and the customer. This relationship begins with the project kick-off meeting. This meeting is held approximately 15-18 months prior to site implementation. The project kick-off meeting is often scheduled in conjunction with the walkdown.

This initial site meeting should include all key site stakeholders for the project. The site team includes the SG Manager, the site Project Manager (PM), Health Physics (HP), Environment Health and Safety (EHS), Operations, Yard Management, Chemistry, Rad Waste Shipping, and Engineering. The team's roles on the ASCA/CODE project are discussed in section 3.1.

3 EXECUTION

3.1 ASCA/CODE Team Overview

Communication within the ASCA/CODE stakeholder team is critical to successful execution. This involves transparency among the Westinghouse, DEI, and the site team. Westinghouse planning activities require coordination with DEI, Westinghouse Waltz Mill Operations, and Westinghouse Richland Service Center (RSC). Following the DEI qualification testing discussed in section 2.2, RSC reviews the Qualification Report and manufactures the optimized ASCA chemicals. CODE chemicals are brokered through commercial chemical manufacturer under specification set by DEI qualification report and Westinghouse Quality Systems.

Figure 2 displays a high level view of the project process flow and the involvement between various groups. It is the responsibility of Westinghouse Waltz Mill Operations to initiate the planning process by involving both customer and internal operations to create a successful project.

Site EHS works closely with RSC Chemistry to determine the proper permitting for waste. Waste consists of the heavy metals removed from the SGs suspended in the ASCA/CODE spent solutions. The reject is characterized by an independent lab using Resource Conservation Recovery Act (RCRA) guidelines for waste disposal. The Toxicity Characteristic Leaching Procedure (TCLP) is a soil sample extraction method for chemical analysis employed as an analytical method to simulate leaching through a landfill. The testing methodology is used to determine if a waste is characteristically hazardous, hence determining the cost of disposal to the waste owner.

However, before official characterization of waste is sent to an independent lab, the utility's Chemistry Department can assist in a pre-analysis before shipping. Another function of Chemistry is on-line analysis of the process soaks to determine real-time species removal from the SGs. However, the utility can forego sampling to reduce demands on the utilities chemistry department and rely on DEI qualification testing as a guide for saturation rates of the formulation being used.

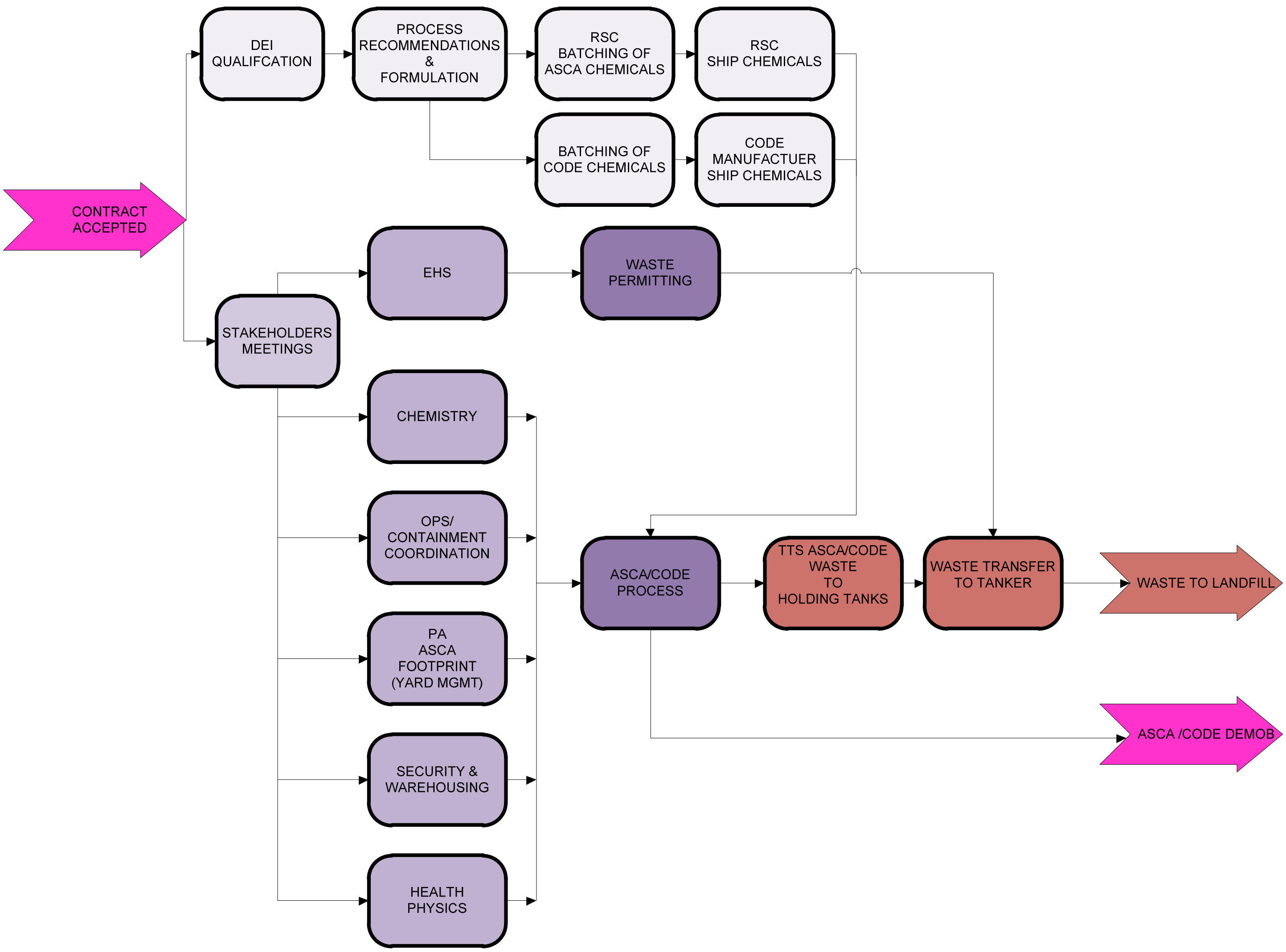


Figure 2: ASCA/CODE High Level View with Stakeholders

The Protected Area is the lay down area for waste during the TTS ASCA/CODE process. The lay down area consists of poly tanks used to hold the waste/rinse, and tanker loading pumps. The area is completely enclosed by a containment berm to control any undesirable discharges from reaching ground water, should they occur. If rain water is captured within the berm area, analysis on the rain water is performed before discharging to the ground. The permission is usually obtained from Chemistry, EHS, or Operations before discharge. The interaction between Yard Management and Operations is crucial, since real estate is at a prime commodity in the Protected Area.

Site Operations and Engineering play key roles in implementing the Process. Operations controls plant-side instrumentation and inputs concerning timing of chemical injection, draining of waste, operation of SG Automated Relief Valves (ARVs), and any maintenance operations occurring downstream of the secondary side of the SGs. In addition, sparging occurs through SG secondary side interfaces at tube sheet access ports. Sparing performs two functions. The first function is agitation, which creates a homogenous mixture within the SG. The second function is dependent on the goal of the ASCA or CODE dissolution step being performed. Nitrogen sparge is used to create a reducing environment for the iron removal step. The CODE step uses nitrogen, to maintain an inert atmosphere within the SG.

Lastly, HP plays a broad role for ASCA/CODE. They are involved in the shipping and setting up of equipment and monitoring of on-line systems used in the ASCA/CODE Process. Some of the final participation for HP consists of sample transmittal, waste transport, and equipment demobilization (Demob). Due to HP's extensive role in the ASCA/CODE project, this group's presence is important during the kick-off meeting of ASCA/CODE stakeholders.

3.2 TTS ASCA/CODE Equipment

TTS ASCA/CODE requires pre-sludge lancing before the ASCA/CODE process is applied. Pre-lancing is used to remove loose scale from the tubesheet, allowing chemicals to act on the hardened TTS deposits that aren't removed with traditional lancing. After lancing, TTS chemicals can be applied. Since the tubesheet is the focus for the chemicals, volumetric requirements for the system are considerably less than a Full Bundle ASCA. Smaller volume allows for a small footprint for both heater and circulation pumps, which are placed in containment. Figure 3 identifies equipment location within containment, while Figure 4 displays the actual heater, pumping, and injection station.

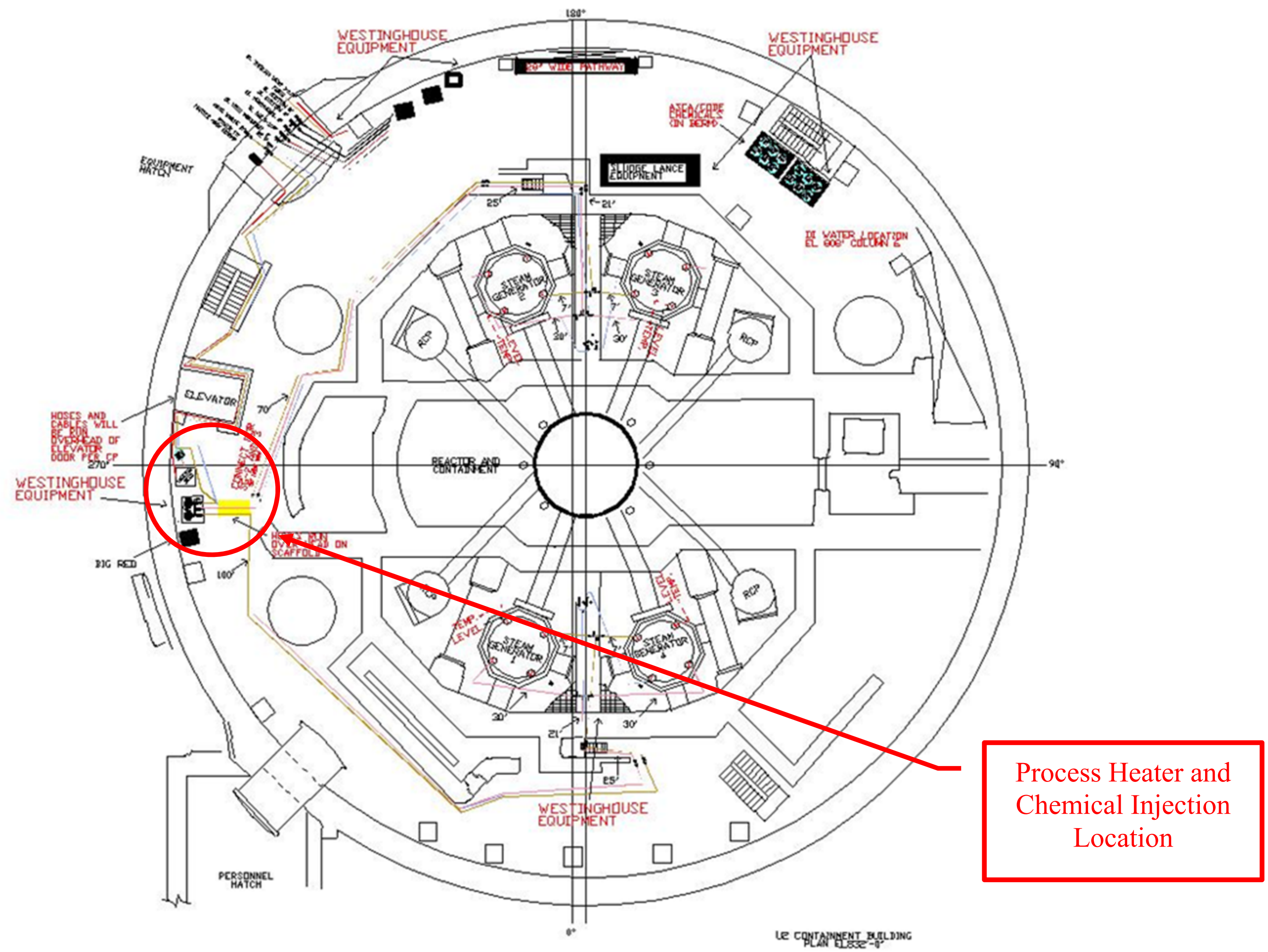


Figure 3: ASCA/CODE Heater, Pumps, and Chemical Injection Location

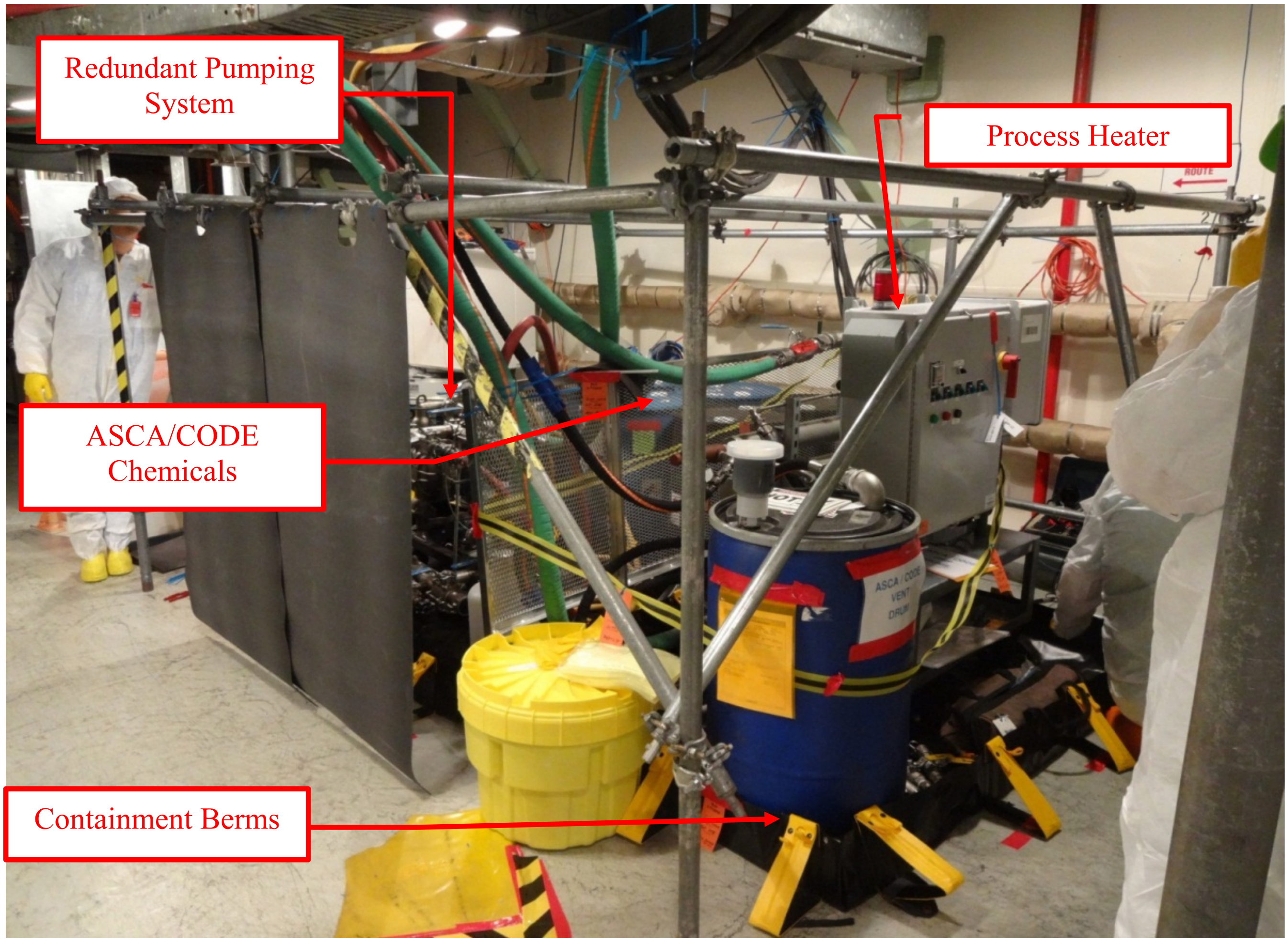


Figure 4: TTS ASCA/CODE Process Equipment, Comanche Peak Unit 2

The TTS ASCA/CODE pump skid is used to circulate the fluid through the heater and SG. The pumping system is redundant to mitigate any potential pump concerns during the heating process. Pumps can be switched out with a simple valve re-alignment with no interruption to process. See Figure 3 & 4, above, for TTS ASCA/CODE in-containment setup. Smaller process volume means small waste storage areas. The temporary waste storage area for TTS is usually a 30' X 30'. See Figure 5 & 6, below, for TTS waste area.

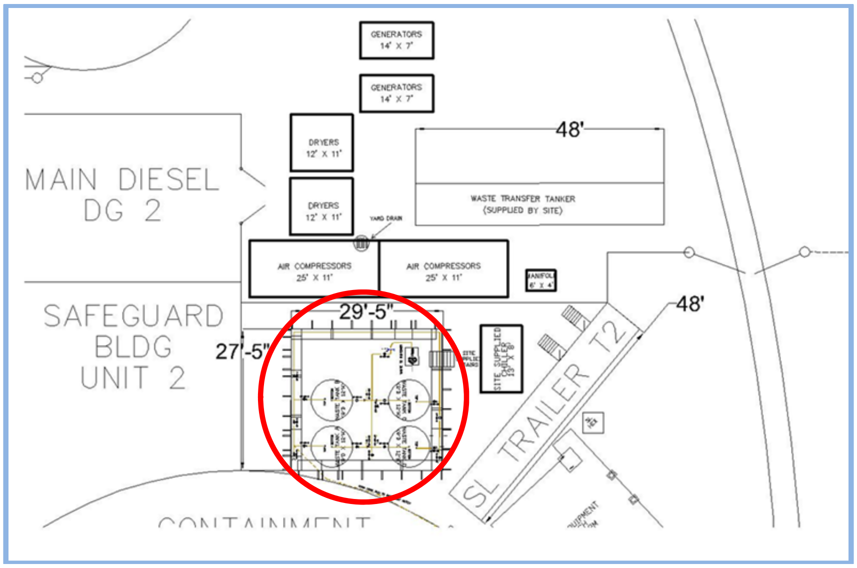


Figure 5: Location of Waste Area

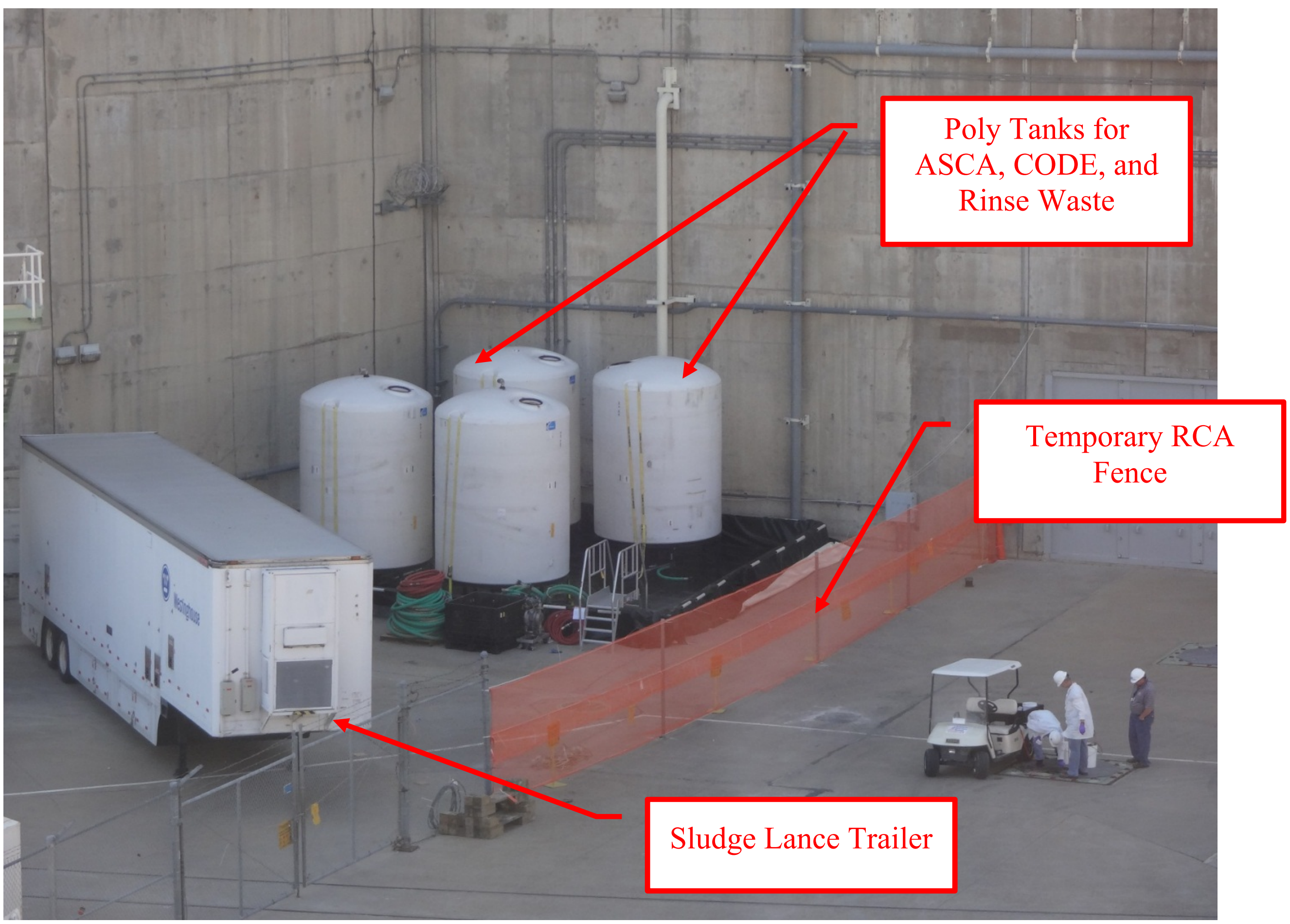


Figure 6: TTS ASCA/CODE Waste Area, Comanche Peak Unit 2

3.3 Schedule Considerations

TTS ASCA/CODE processes are designed to minimize impact to site schedule during implementation. Site schedule requirements are taken into consideration during process qualification testing, and each application schedule is plant specific.

For TTS ASCA/CODE applications, an external heater is used to maintain temperature during the process. TTS ASCA/CODE application requires a fully drained SG primary side to permit heat up of the small secondary inventory required for cleaning. This requirement necessitates coordination with the site outage group when building the outage schedule and may impact the SG primary inspection schedule. Any primary inspection impacts are minimized by communication and coordination between SG secondary and primary services.

3.4 Sludge Lance Expectations

After a TTS ASCA/CODE there will be more sludge dislodged from steam generator components than during a standalone sludge lancing operation.

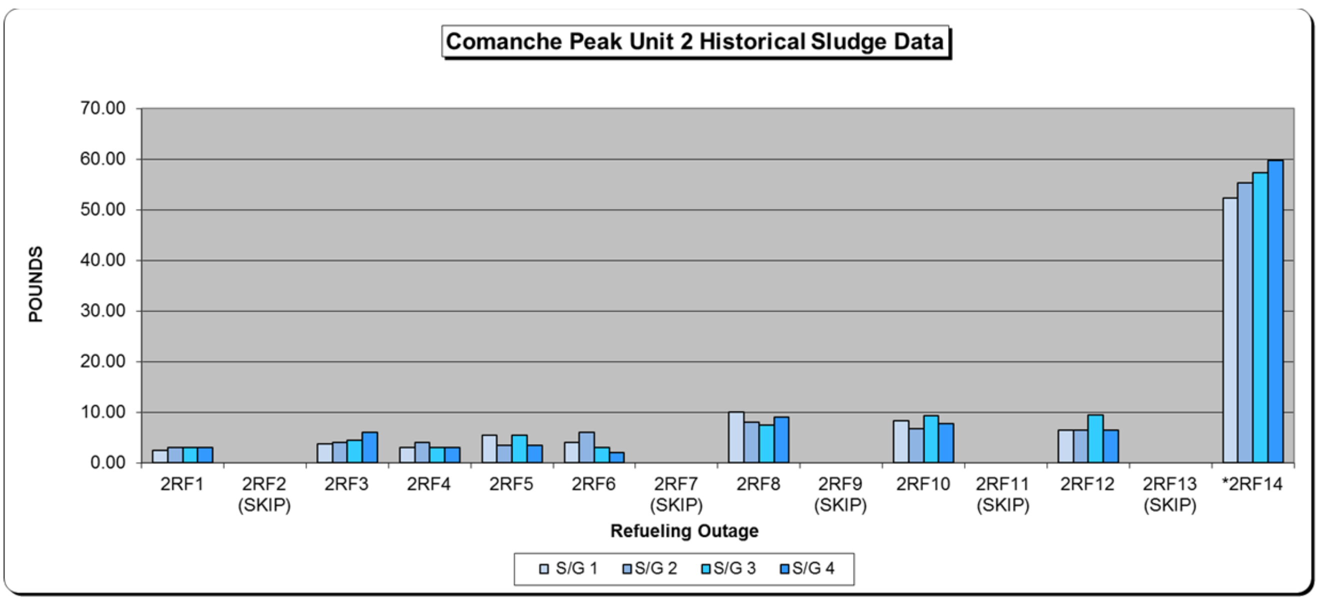
As discussed in Section 3.2, Pre-ASCA sludge lancing is performed to remove loose sludge from the TTS to allow the chemicals to effectively target hardened TTS deposits. Pre-ASCA/CODE sludge lancing removal quantities are typically similar to sludge removal totals during a normal lancing campaign. Once pre-lancing is performed, ASCA/CODE can be set up on the target SG, while the sludge lancing crew moves onto the next SG. Post-lancing can begin upon the final rinse of the first SG and each subsequent SG thereafter. Post ASCA/CODE sludge lancing removal totals are typically higher than those seen during a traditional sludge lancing campaign due to removal of TTS sludge that has been loosened during chemical dissolution.

4 RESULTS

Estimated loading of hardend deposits on TTS was between 30 and 65 pounds per SG. The application removed at least 85% of deposits. It was estimated that approximately, 400 pounds of TTS Sludge has been removed over the life of the SGs. 57% of this removal total is attributed to the ASCA/CODE Process. Details for removal totals are summarized on Table 1.

Table 1: Removal Totals for Comanche Peak Unit 2 Steam Generators

Steam Generator	Pre-Sludge Lance (lbs.)	ASCA / CODE Fe /Al / Si (lbs.)	Post-Sludge Lance (lbs.)	Totals
1	2.8	36.6	13.0	52.4
2	2.8	36.6	16.0	55.4
3	2.8	36.6	18.0	57.4
4	2.8	36.6	20.5	59.9
Total	11.2	146.4	67.5	**225.1**



*Combined total of deposit removal by chemical dissolution and mechanical means.

Figure 7: Historical Sludge Removal Data, Comanche Peak Unit 2

Mass removal is one indicator for TTS cleaning effectiveness. Visual inspections are another. Figures 8-10 are before and after pictures of SG 1, 3, and 4. Note that SG 1 images are from spring 2011, since Pre-Sludge Lancing Inspections were not performed on SG 1 for schedule considerations. SG 2 Pre-Sludge Lance Inspection pictures were not scheduled.

PRE-SLUDGE LANCE POST-SLUDGE LANCE

Figure 8: SG 1 Column 63/64, Row 20

PRE-SLUDGE LANCE POST-SLUDGE LANCE

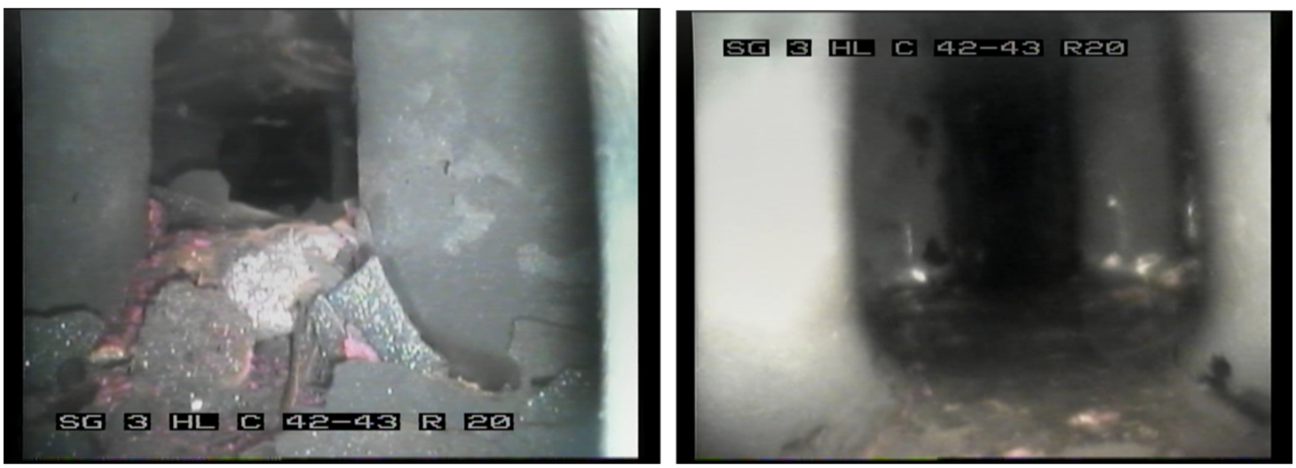


Figure 9: SG 3 Column 42/43, Row 20

PRE-SLUDGE LANCE POST-SLUDGE LANCE

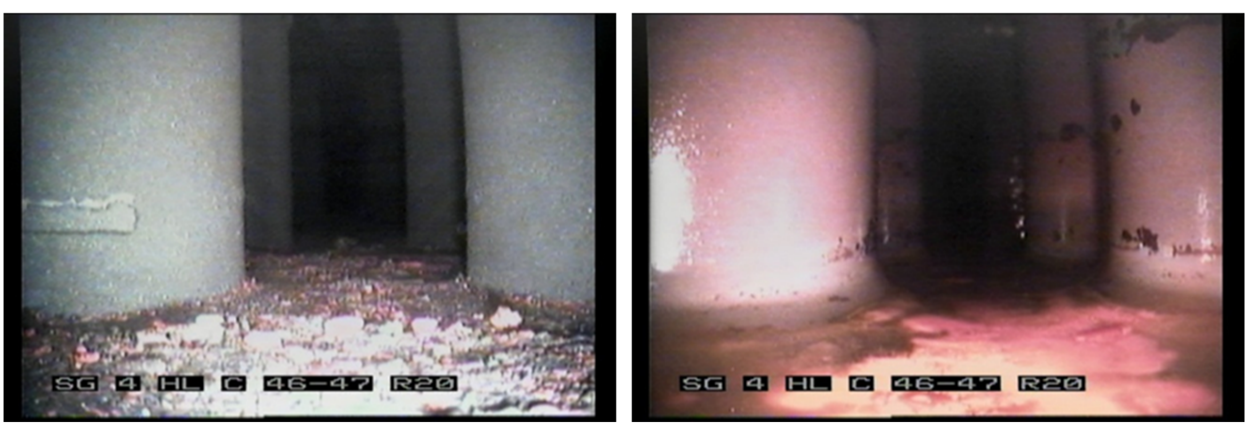


Figure 10: SG 4 Column 46/47, Row 20

5 CONCLUSIONS

TTS ASCA/CODE application was successful in meeting and exceeding utility objectives in the areas below:

- No equipment or personnel safety concerns
- Optimized deposit removal
- Improved deposit morphology
- Eliminated the environment that would support corrosion species growth.
- Process cleaned 100% of the TTS (Eliminated shadow zones)
- Allows Comanche Peak to continue their Secondary Side Skip maintenance plans.
- Eliminates accumulation of TTS Sludge improving future outage efficiency.
- Finished on schedule and off Critical Path.
- Project Dose < 1 REM

In order to realize the safety, performance and economic benefits, recognized during the ASCA/CODE application close communication was established between Westinghouse and Comanche Peak. This relationship was formed early in the planning phase and followed through in execution and close out.

The target area of the application was the TTS with expected loading between 30 and 65 pounds per SG. The application removed up to 85% or more of the deposits.

The application sludge removal exceeded the historical combined removal totals from previous outages. Approximately 225 pounds were removed in this one application.

Experience and lessons learned from the more than 40 world-wide ASCA applications were incorporated into ASCA/CODE planning. The results obtained at Comanche Peak Unit 2 opens the gateway to future applications and even greater potential for this process forward-looking.

6 REFERENCES

1 Ramaley, Danielle; "Advanced Scale Conditioning Agent (ASCA) Planning, Application Experience, and Results at Seabrook and D.C. Cook Unit 2"; September 2012.

2 McCree, Anisa; "Memo: Summary of Comanche Peak iASCA/CODE Process (April 2014)", No. M-8857-00-04, Rev. 1; August 18, 2014.

3 Spies, Radonna; "Toxicity Characteristic Leaching Procedure Analysis for Luminant Generation Company, LLC.; SwRI Project Number: 14684.02.00X; SwRI Task Order Number: 140417-10; April 14, 2014.