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Advanced Scale Conditioning Agent (ASCA) Planning, Application Experience, and Results at Seabrook and D.C. Cook Unit 2

Danielle Ramaley[1], Miles Forney[2], Michael Rocheleau[3], Chad Shimunek[4], and Philip Monk[5]

[1,2]Westinghouse Electric Company LLC.

[3]Next Era Energy, Seabrook Nuclear Plant

[4,5]American Electric Power, Cook Nuclear Plant

ABSTRACT

ASCA technology has been applied more than thirty-five times worldwide since its inception in 2000. This technology has continually grown in popularity since its development as a result of the many process benefits while maintaining minimal outage impacts. Utilities have applied ASCAs for a variety of reasons including:

- Partial removal of secondary side deposit inventory
- Improvement in sludge removal quantity over traditional mechanical cleaning processes
- Reduction of tube support plate (TSP) blockage
- Improvement in steam generator thermal performance
- Partial dissolution and softening of consolidated top of tubesheet (TTS) collars

In addition to several international ASCA applications, two U.S. ASCA applications were performed in 2011 and 2012. In 2011, a TTS ASCA application was performed at Seabrook Station Nuclear Plant. The TTS application was the third ASCA to be executed at the plant; Seabrook performed full bundle ASCAs in 2008 and 2009. In 2012, a full bundle maintenance cleaning ASCA was implemented at D.C. Cook Unit 2. This was the first ASCA application to be executed by the utility. This paper will discuss both the Westinghouse and utility perspective on ASCA application planning, site execution, and process results for TTS and full bundle applications.

1. INTRODUCTION

In order to improve upon traditional mechanical deposit removal techniques and to avoid the potential drawbacks of traditional steam generator chemical cleaning, Advanced Scale Conditioning Agent (ASCA) Technology was developed in 2000. ASCAs are dilute cleaning solutions which promote the dissolution of a portion of the overall secondary side deposit inventory along with entrained mineral species from the deposit matrix. ASCAs have continued to grow in the industry as a preferred approach for maintaining overall steam generator health. ASCA technology is designed to provide maximum benefit to the plant while minimizing outage impacts. The following features are included in ASCA technology design:

- Low corrosion-allows many applications over plant life

- Combination Fe-Cu removal without draining and refilling the steam generator (SG)
- Minimal equipment footprint
- Capability to fit in a short outage window
- Low cost maintenance option

Applying ASCA technology helps extend SG operation, maintain SG cleanliness and enhance SG performance by altering secondary side deposit morphology. Application benefits include:

- Immediate and sustained improvements in heat transfer efficiency (decreases in fouling factor and increases in steam pressure)
- Reductions in Tube Support Plate blockage
- Partial dissolution and softening of consolidated Top of Tubesheet (TTS) sludge

Due to the application benefits observed in industry ASCA applications, both Seabrook and D.C. Cook Unit 2 applied ASCA technology to improve and maintain steam generator operation. Seabrook applied a TTS ASCA during their spring 2011 outage, and D.C. Cook Unit 2 applied a Full Bundle (FB) ASCA during their spring 2012 outage. Both of these applications recognized the ASCA process benefits of (1) minimal outage impact, (2) optimized deposit removal, (3) improved deposit morphology, and (4) no equipment or personnel safety concerns.

2. ASCA APPLICATION BACKGROUND

2.1 Seabrook TTS ASCA

Seabrook is a four loop 1200 MWe plant with Westinghouse model F steam generators. The steam generators were placed into service in 1990. Prior to ASCA applications at Seabrook, the secondary side had approximately 3,000 lbs (1,361 kg) of deposit loading per steam generator with a copper content of 8-9% [1]. In order to avoid a large chemical cleaning campaign, a multiple ASCA maintenance program was initiated at Seabrook. Two full bundle ASCA applications were performed in OR12 and OR13. These applications were performed to remove copper from the full bundle and reduce overall deposit loading / improve thermal performance, respectively. The results of the OR12 and OR13 applications were as follows:

OR12 Copper Removal ASCA

- 867 lbs (393 kg) of copper dissolution
- 142 lbs (64 kg) of removal with sludge lancing

OR13 Iron-Copper Maintenance ASCA

- Increase of 8-10 psi in average SG pressure following application

- 2,200 lbs (998 kg) of magnetite dissolution
- 35 lbs (16 kg) of copper dissolution
- 1 lbs (0.45 kg) of lead and 1 lbs (0.45 kg) of chromium dissolution
- 164 lbs (74 kg) of removal with sludge lancing
- 10 psi steam pressure increase following application

Following the OR12 and OR13 applications at Seabrook, a focused cleaning of the TTS was planned [1,2]. A TTS ASCA was performed in OR14 with the following objectives:

- Soften / remove TTS collars
- Reduce TTS deposit inventory
- Reduce potential for tube degradation at the TTS

This application was included in the Seabrook steam generator maintenance plan as a preventative measure to avoid tube degradation issues and maintain steam generator health. For a complete analysis of the performance results, see section 5.1.

2.2 D.C. Cook Unit 2 Full Bundle ASCA

D.C. Cook Unit 2 is a 1100-MWe four loop plant with Westinghouse model 54F steam generators which were placed in service in 1989. Prior to the ASCA application at D.C. Cook Unit 2, each of the steam generators had estimated deposit loading of approximately 2,500 lbs (1,134 kg). The distribution of deposits was reasonably uniform throughout the bundle with slightly heavier deposits in the lower portion of the cold leg and upper portion of the hot leg. Additionally, hard collars/bridging were present in the kidney region of all steam generators on the top of the tube sheet.

D.C. Cook Unit 2 executed full bundle maintenance ASCA during their U2C20 outage. D.C. Cook was seeking to achieve the following objectives by applying ASCAs:

- Remove a significant amount (1000 lbs+/SG) of bulk iron deposits
- Reduce the likelihood of quatrefoil blockage

Since full bundle maintenance ASCA applications are able to modify the secondary side deposit morphology, D.C. Cook Unit 2 was able to recognize improved thermal performance in addition to meeting its cleaning objectives. See section 5.2 for performance results.

3. PRE-ASCA OUTAGE PLANNING OVERVIEW

3.1 ASCA Project Team Interfaces

In order to ensure a successful ASCA project, a strong communication relationship should be built between Westinghouse and the customer early in the planning phase. Both TTS and Full Bundle ASCAs 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).

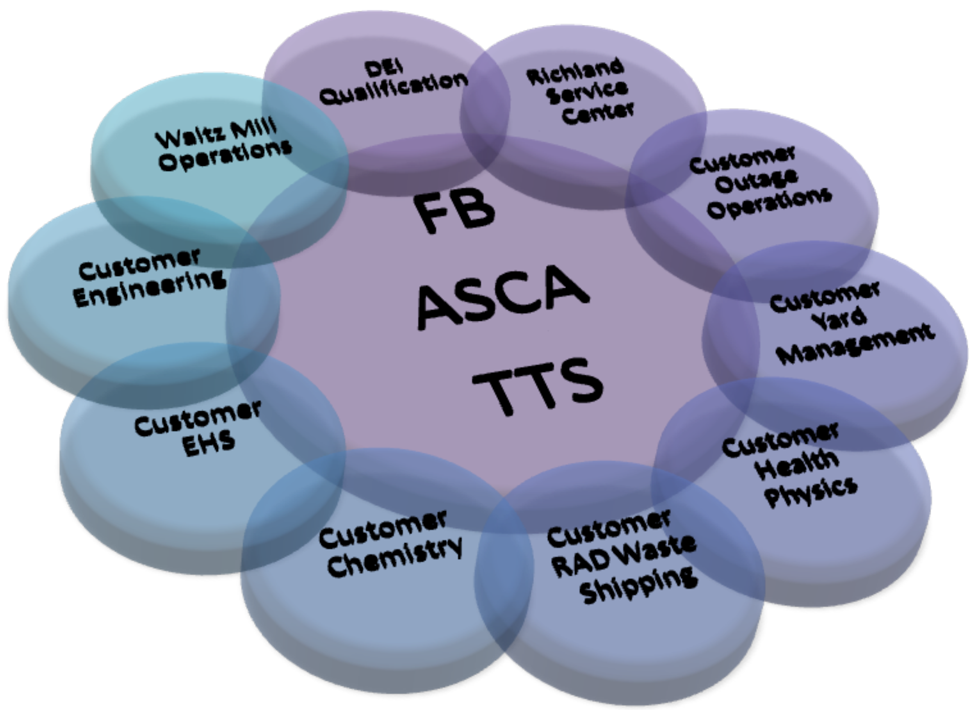

Figure 1: ASCA Stakeholders

The ASCA stakeholder team should be engaged early in the planning process. Planning for both TTS ASCA and FB ASCA applications begins approximately 15-18 months prior to site execution. The key pre-ASCA planning activities include qualification testing, site walkdown and the project kick-off meeting.

3.2 Qualification Testing

Due to the wide variability in the structure and morphology of SG deposits, plant-specific qualification testing is needed to determine the best combination of ASCA 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 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 processes which may be beneficial for meeting steam generator cleanliness and performance objectives.

- *Preliminary ASCA testing*

  Based on the deposit characterization and deposit loading estimates, candidate ASCA 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 ASCA application goals. The test matrix is discussed with utility, Westinghouse, and DEI team members prior to preliminary testing. Preliminary testing is performed on actual steam generator 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, an ASCA formulation and process is chosen for final qualification testing.

- *Final ASCA qualification testing*

  A final qualification test is conducted in order to formally qualify the candidate ASCA 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 ASCA formulation. Cleaning objectives, outage impacts, and ASCA 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 ASCA formulation / process and recommendations for field application.

3.3 Site Walkdown and Project Kick-off Meeting

A site walkdown is performed prior to both full bundle ASCA and TTS ASCA applications. Although not required, it is beneficial to perform the site walkdown following completion of qualification testing. Performing ASCA planning in this sequence allows the walkdown team to include actual process expectations in their site layout decisions.

For TTS applications containment access is necessary since equipment set-up will be in-containment. For full bundle applications, on the other hand, containment access is not necessary since all process equipment is staged outside containment. ASCA walkdowns 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 3.1, an ASCA team communication relationship should be built between Westinghouse and the customer. This communication relationship begins with the project kick-off meeting. This meeting should be held approximately 15-18 months prior to site implementation. The project kick-off meeting is often scheduled in conjunction with the ASCA walkdown. This 15 to 18 month planning time also allows site to perform the design and implementation of plant modifications to support ASCA operations.

This initial site meeting should include all key site stakeholders for the project. The site team includes the SG Manager, the site ASCA Project Manager, Health Physics (HP), Environment Health and Safety (EHS), Operations, Yard Management, Chemistry, Rad Waste Shipping, and Engineering. The team's roles on the ASCA project are discussed in section 4.1.

4. ON-SITE EXECUTION

4.1 ASCA Team Overview

Communication within the ASCA stakeholder team is critical to successful ASCA execution. This involves transparent communication among the Westinghouse, DEI, and site team. Westinghouse ASCA planning activities require coordination with DEI, Westinghouse Waltz Mill Operations, and Westinghouse Richland Service Center (RSC). Following the DEI qualification testing discussed in section 3.2, RSC reviews the Qualification Report and manufactures the optimized ASCA chemicals.

Figure 2 displays a high level view of the project process flow and the involvement between Westinghouse, DEI, and site. 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 Environmental Health and Safety (EHS) works closely with RSC Chemistry to determine the proper permitting for both waste and outfall discharges. When Reverse Osmosis (RO) is performed following ASCA application to reduce the waste volume approximately tenfold, the waste streams consist of Permeate and Reject. Permeate is "clean" solution resulting from filtration of ASCA waste through the RO Unit. Reject consists of the heavy metals removed from the Steam Generators (SG). The reject is characterized by an independent lab using Resource Conservation Recovery Act (RCRA) guidelines for waste disposal.

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 off to an independent lab. Another function of Chemistry is on-line analysis of both TTS and FB ASCA soaks to determine real time species removal from the SGs.

The Protected Area (PA) is the lay down area for both TTS and FB ASCA process. The lay down area consists of the ASCA pumping systems, Frac Tanks or Poly Tanks used to hold the waste/rinse, and the RO Control and Process Modules. The area is completely enclosed by a containment berm to control any undesirable discharges from reaching ground water. If rain water is captured within the berm area, analysis on the rain water is performed before discharging to 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 ASCA Process. Operations controls plant side instrumentation and inputs concerning SG temperature, chemical injections, level monitoring, rinse injection, and draining of waste. Engineering provides the interface on the blowdown system. Usually, the interface is a single point where both chemical injection and waste draining takes place. This single point for injection and draining minimizes plant modifications and reduces cost.

In addition, sparging occurs through the blowdown system through smaller diameter intersecting pipes. Sparging connections typically do not require plant modifications. Valved ¾-1" connections typically exist on the existing individual SG blowdown lines. Sparing performs two functions. First is agitation which creates a homogenous mixture within the SG. The second function is dependent on the goal of the ASCA dissolution step being performed. Nitrogen sparge is used to create a reducing environment for the iron removal step. Instrument air is used for a copper step to create an oxidizing environment within the SG.

Lastly, Health Physics (HP) plays a broad role for ASCA. They are involved in the shipping and setting up of equipment and monitoring of on-line systems used in the ASCA 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 project, their presence is important during the kick-off meeting of ASCA stakeholders.

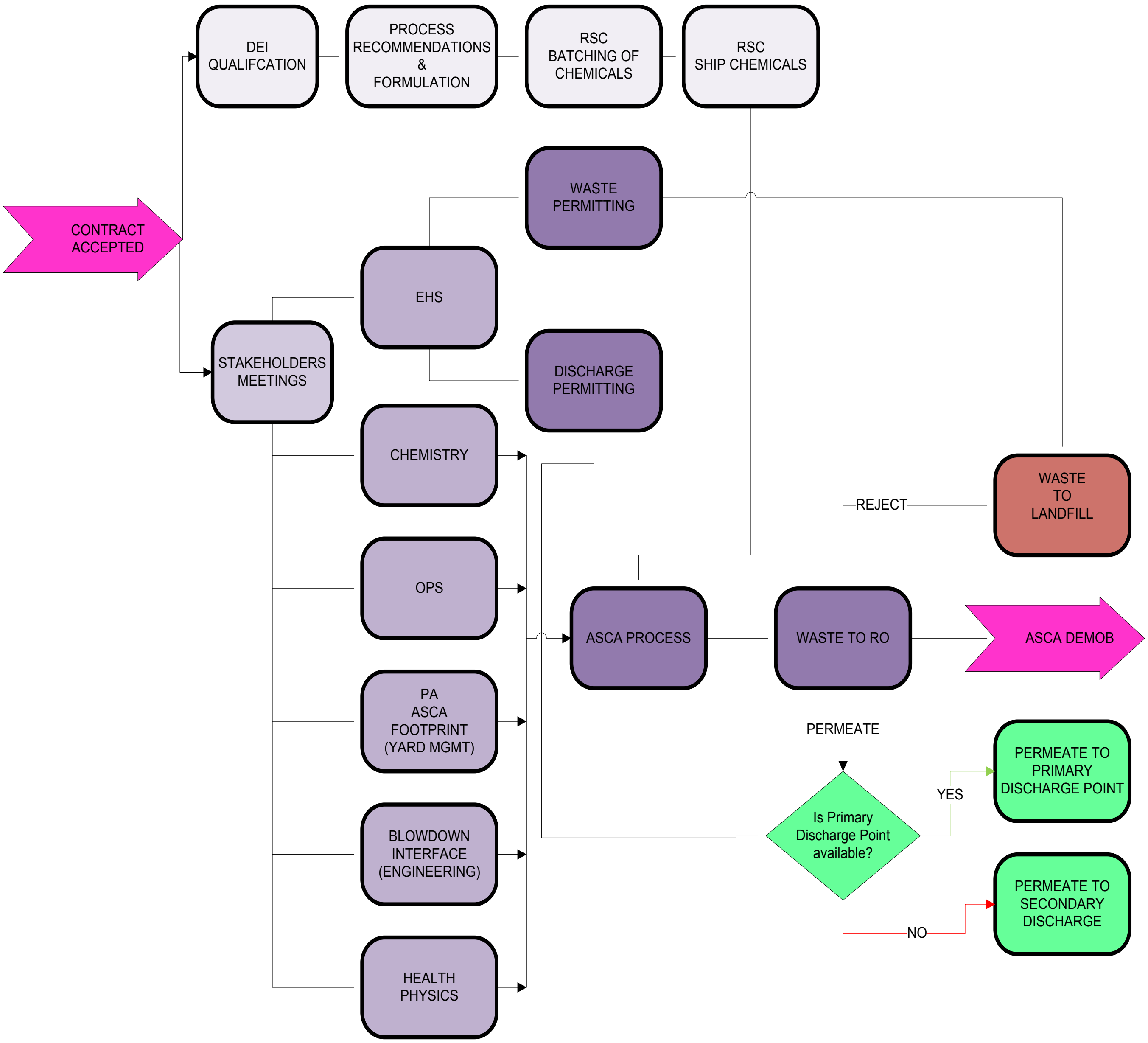

Figure 2: ASCA High Level View with Stakeholders

4.2 TTS ASCA vs. FB ASCA Equipment

ASCA pre-outage planning and the ASCA stakeholder team remain the same for both TTS and FB applications. However, characteristics start to diverge when considering TTS ASCA versus FB ASCA for equipment. Since the TTS ASCA system is designed for containment setup and FB ASCA equipment is external to containment, the site layouts for the two processes are very different.

TTS ASCA requires pre-ASCA sludge lancing before the ASCA process is applied. Pre-ASCA lancing is used to remove loose scale from the tubesheet, allowing chemicals to act on the hardened TTS deposits which aren't removed with traditional lancing. After lancing, TTS ASCA chemicals can be applied. Since the tubesheet is the focus for the chemicals, volumetric requirement for the system are considerably less than a FB ASCA. Smaller volume allows for a smaller footprint for both heater and circulation pumps, which are placed in containment.

The TTS ASCA pump skid is used to circulate the fluid through the heater and SG. The ASCA 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, below, for TTS ASCA in-containment setup.

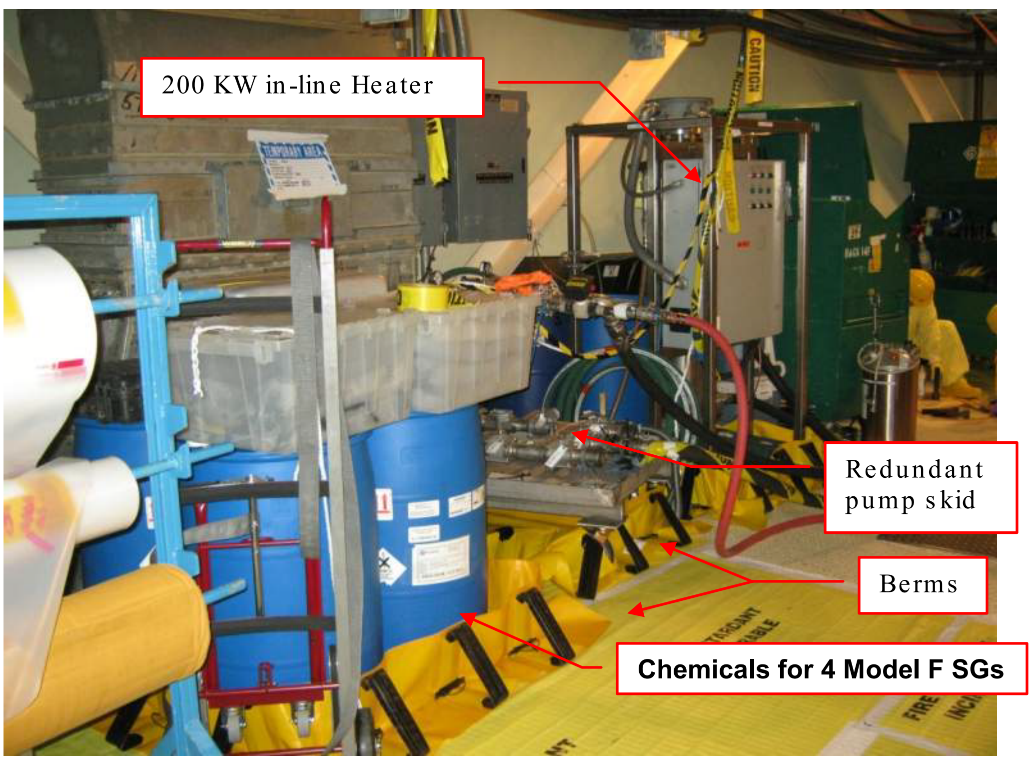

Figure 3: TTS ASCA Process Equipment Seabrook Station

Smaller process volume means small waste storage areas. The temporary waste storage area for TTS is usually half the size of FB. See Figure 4, below, for TTS waste area.

Figure 4: TTS ASCA Waste Area Seabrook Station

FB ASCA uses plant residual heat (Mode 5) to heat the mixture; hence, there is no need for a heater or other support equipment in containment. All FB activities are outside containment.

FB ASCA utilizes a larger footprint for waste storage equipment, line sizes, and pump size. Size increases to expedite injection and removal of fluids from the SGs. Soak times for both processes are relatively the same, but volume movement is much greater in the FB ASCA. Berm size for FB ASCA is typically 80 feet by 100 feet. However, this berm contains the ASCA Process Module, Frac Tanks, and RO Modules for waste processing. As Protected Area real estate is usually in high demand; this dimension can be changed or berms can be separated to accommodate site requirements. Two separate berms to accommodate site laydown is typically the limit. Any further division makes fluid transfer logistically difficult. Figures 5 and 6 depict FB ASCA Berm and RO Berms, respectively.

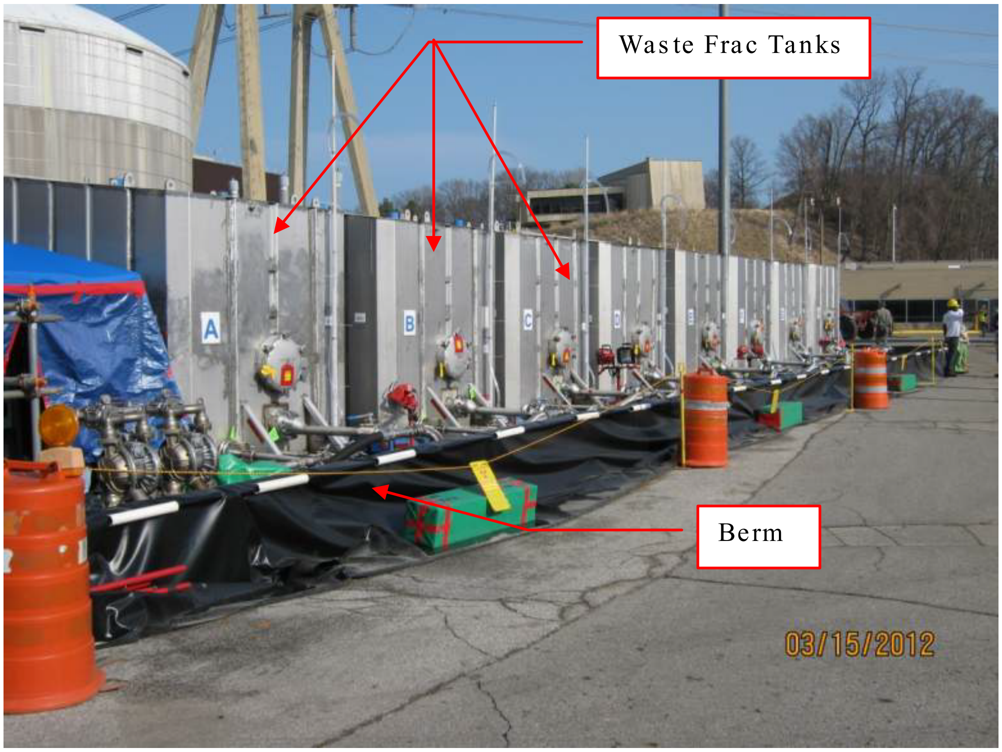

Figure 5: FB ASCA Berm DC Cook

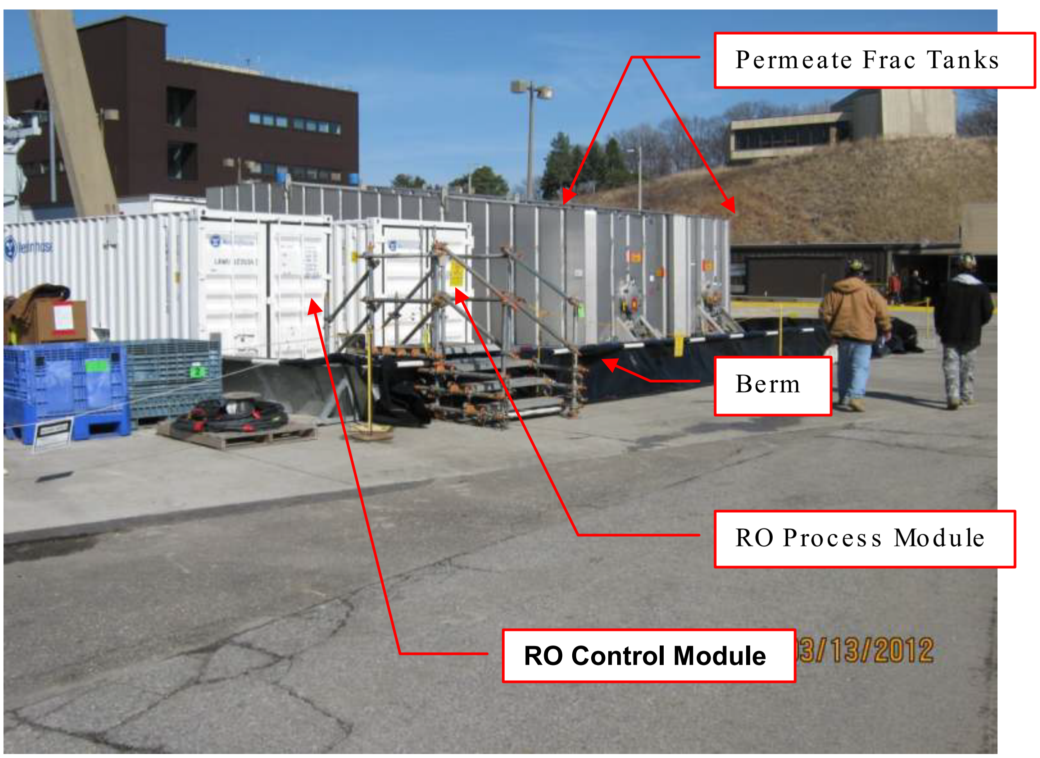

Figure 6: RO Berm D.C. Cook

The final equipment difference between TTS and FB ASCA is related to steam generator draining. A TTS ASCA drain can be transferred directly out of containment through a 2" line via the equipment hatch or, if the site has previously performed a FB ASCA, the 3" blowdown connection can be utilized.

FB ASCA requires 3" or greater, drain line. To minimize cost, usually a manifold is constructed where the blowdown lines for all SGs converge to a single a drain point. This minimizes the effects of plant modifications and reduces intricacies of alignment from a Westinghouse and site operations viewpoint. Figure 7 below shows the 3 " drain line modification for D.C. Cook Unit 2, while Figure 8 displays the modification to Seabrook's blow down system.

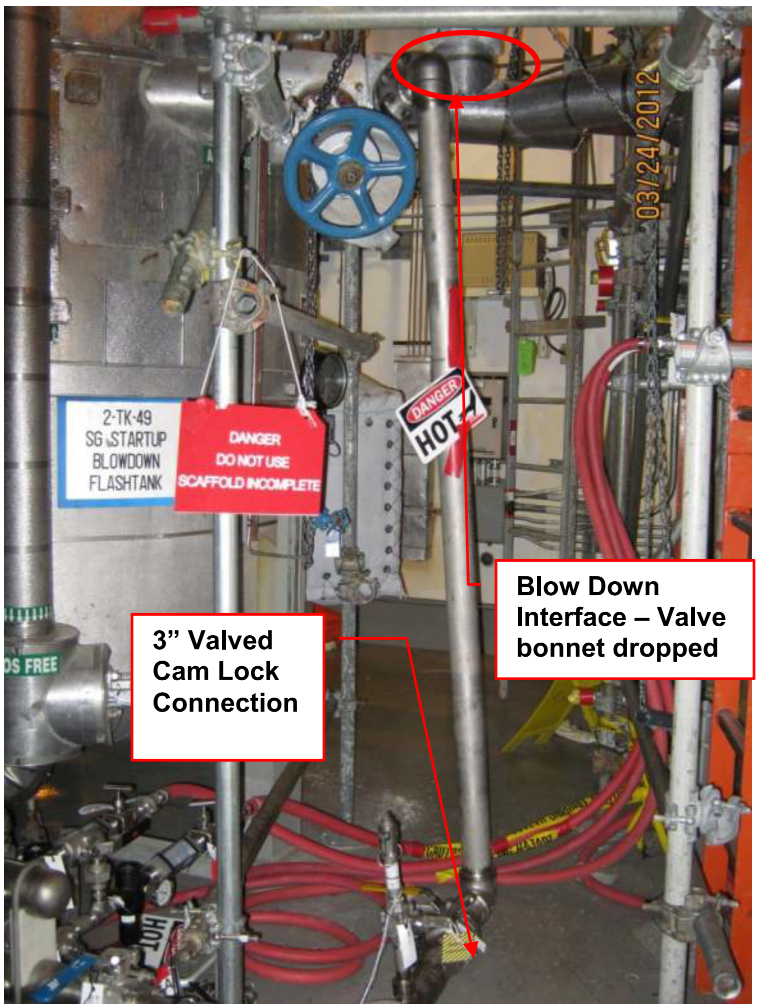

Figure 7: 3" Blowdown Tie-in for ASCA at DC Cook

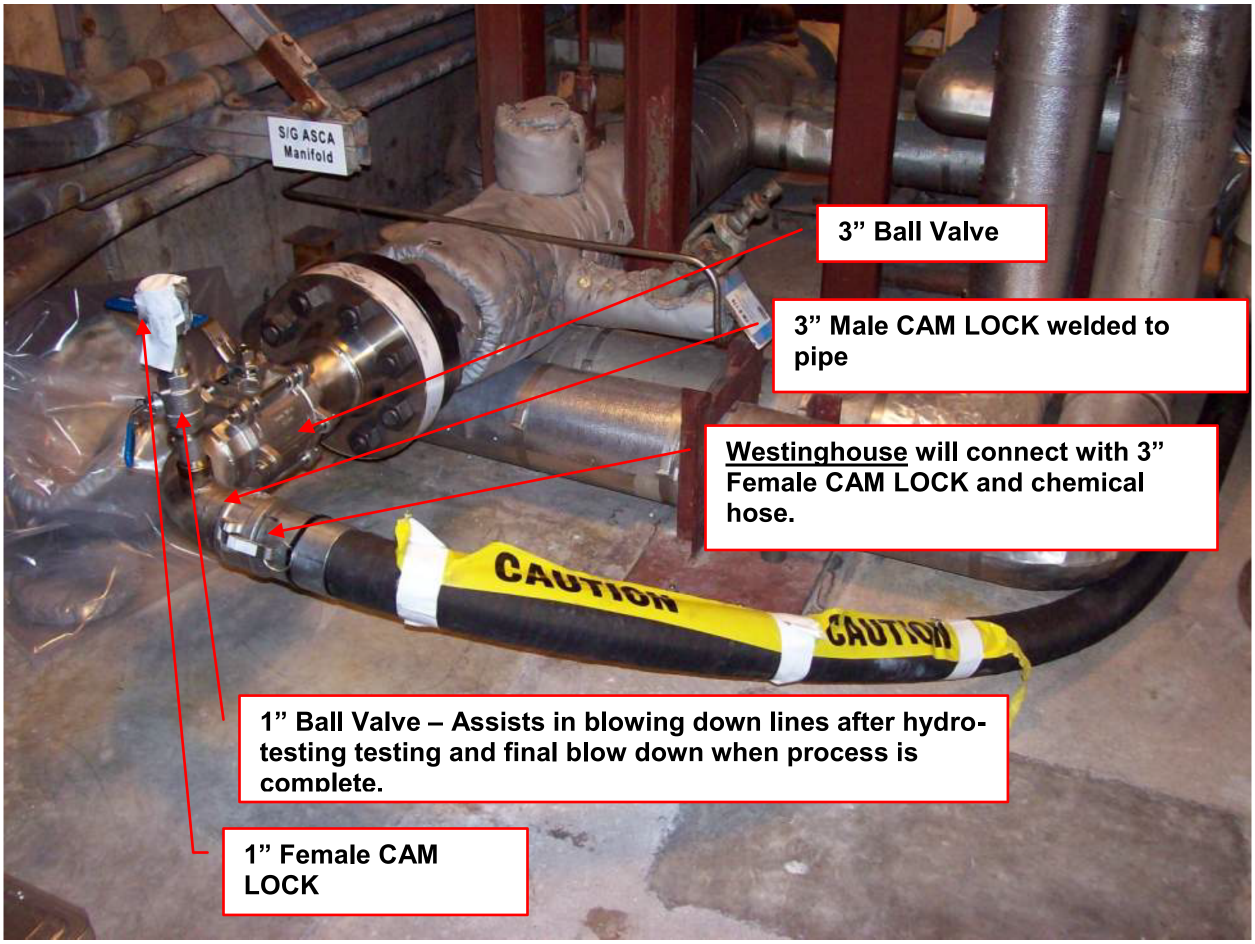

Figure 8: Blowdown Tie-in for ASCA at Seabrook Station

(Note: Since Seabrook has performed both FB and TTS ASCAs, during their TTS ASCA it was simpler to use the existing FB connection. This was more efficient than routing hoses through the equipment hatch.)

4.3 ASCA Schedule Considerations

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

For FB ASCA applications plant heat (Mode 5) is typically used to maintain temperature during the process. FB ASCA processes are designed based on the time-temperature profile expected during a plant's crud burst step, when the primary side temperature is typically maintained at about 176°F (80°C) for a period of 12-36 hours. Each FB ASCA process is specifically designed based on the plant's (1) time-temperature profile, (2) available cleaning window, (3) cleaning objectives, and (4) other plant specific considerations [3].

For TTS ASCA applications an external heater is used to maintain temperature during the process. TTS ASCA 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 (due to the typical temperature of 176°F (80°C) maintained during the ASCA process). Any primary inspection impacts are minimized by communication and coordination between SG secondary and primary services.

4.4 Sludge Lance Expectations

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

Pre-ASCA lancing must be performed for TTS ASCA. The primary purpose is to remove as much loose sludge off the tube sheet as possible. This allows the ASCA chemicals to effectively soften any hardened deposits on the tubesheet. Once pre-ASCA lancing is performed, ASCA can be set up on the target generator, while the sludge lancing crew moves onto the next SG. Post-ASCA lancing can begin upon the final rinse of the first steam generator and each subsequent SG thereafter. FB ASCA does not require pre-ASCA lancing. Once the FB ASCA is complete, then lancing can begin on all generators.

Sludge Lancing after a FB ASCA will yield more than traditional sludge lancing alone however, this should not add to schedule time in any significant manner.

5. ASCA APPLICATION RESULTS

5.1 Seabrook TTS ASCA

Overall, the TTS ASCA performed in OR14 at Seabrook met the following application objectives:

- Soften / remove TTS collars
- Reduce TTS deposit inventory
- Reduce potential for tube degradation at the TTS

Since TTS applications are not performed over the full bundle, thermal performance improvement is generally not expected following TTS ASCA applications. [3] Below, in Table 1, are the removal results from Seabrook Station for their TTS ASCA and sludge lancing. It is interesting to note, the pre-ASCA lancing yield is approximately the same amount of sludge removed as during non-ASCA outages.

Table 1: Seabrook OR14 TTS ASCA and Sludge Lance Removal

Steam Generator	Pre-ASCA Sludge Lance (lbs)	ASCA Soak (lbs)	Post-ASCA Sludge Lance (lbs)	Total
A	28.0	23.6	55.5	**107.1**
B	31.5	25.5	50.0	**107**
C	29.0	25.5	67.0	**121.5**
D	22.5	23.6	39.5	**85.6**
Total	**111**	**98**	**211.5**	**420.5**

Historical sludge lancing removal to date for Seabrook station is depicted below in Figure 9. The removal totals from OR12, OR13, and OR14 include sludge removal via ASCA dissolution and sludge lancing. In comparison to recent non-ASCA outage average sludge lancing removal totals (e.g. OR7-OR11), the TTS ASCA and sludge lancing application in OR14 resulted in greater than 50% additional removal from the TTS.

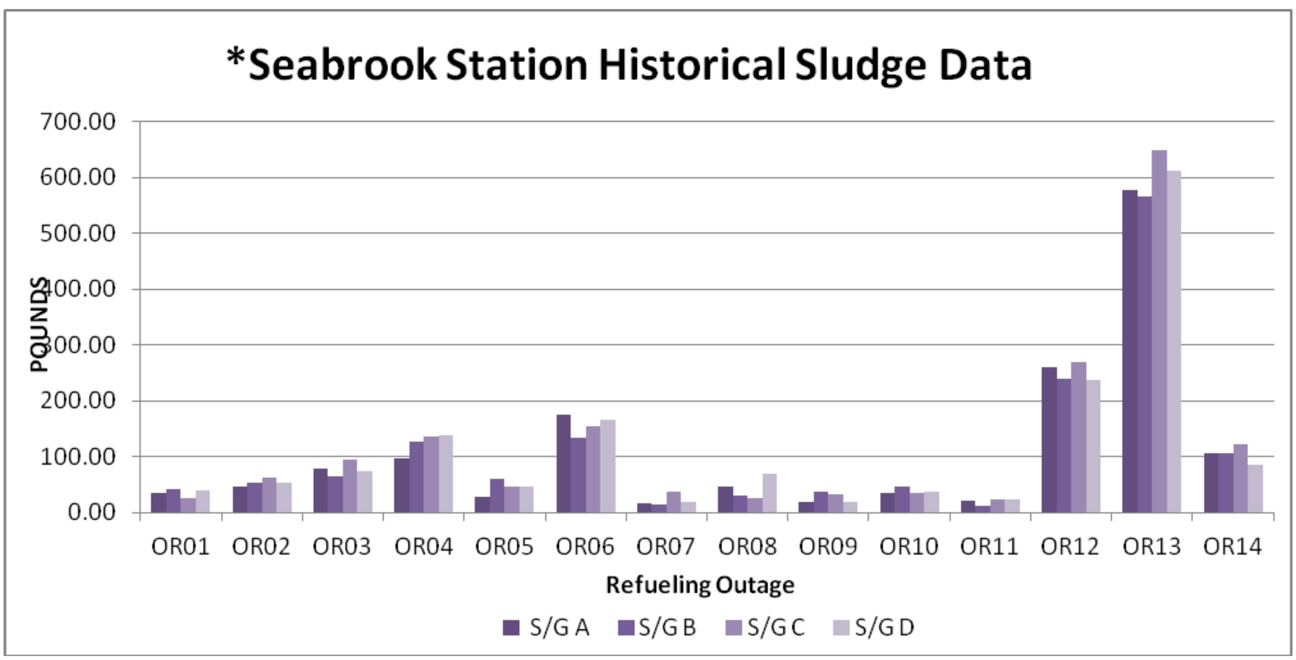

Figure 9: Seabrook Station Historical Sludge Data

5.2 D.C. Cook Unit 2 FB ASCA

The FB ASCA process performed at D.C. Cook Unit 2 in the spring 2012 outage met or exceeded all requirements for the project [4]. The D.C. Cook Unit 2 ASCA objectives to (1) remove a significant amount (1000 lbs+/SG) of bulk iron deposits, and (2) reduce the likelihood of quatrefoil blockage were both met by the ASCA application.

Additionally, a significant improvement in thermal performance was recognized as a result of the FB ASCA application. A FB ASCA application has the capacity to structurally modify the SG deposits over the free span tube areas corresponding to improved thermal hydraulic performance. For D.C. Cook, the ASCA application resulted in a steam pressure improvement of approximately 8-10 PSIG after restart of the plant. This type of immediate and sustained thermal hydraulic benefit has been recognized in all FB ASCA applications aimed at deposit structural modification to date. [4]

Table 2 shows deposit removal via dissolution for the ASCA process. Sludge lancing for this application was performed by another field service vendor, therefore sludge lancing totals are not included in this table. However, sludge removal via lancing following the ASCA application was approximately 17 times higher than average sludge lancing removal for D.C. Cook Unit 2.

Table 2: D.C. Cook Unit 2 ASCA Dissolution

Steam Generator	Fe_3O_4 Dissolution (lbs)	Cu Dissolution (lbs)	Total (lbs)
1	1,049	29	**1,078**
2	1,181	25	**1,206**
3	1,296	30	**1,326**
4	1,205	20	**1,225**
Total (lbs)	**4,741**	**104**	**4,835**

6. ASCA WASTE REDUCTION

Following the TTS ASCA application at Seabrook and the FB ASCA application at D.C. Cook Unit 2, a RO waste reduction service was performed. The waste reduction at Seabrook was provided by a waste processing vendor. The waste reduction service at D.C. Cook Unit 2 was the initial Westinghouse implementation of mobile RO technology. The Westinghouse mobile RO Unit is shown in Figure 10 below.

Figure 10: Westinghouse Mobile Reverse Osmosis Unit

The Westinghouse mobile RO system was used at D.C. Cook Unit 2 to reduce the volume of ASCA process and rinse waste, thus decreasing the amount of waste that must be shipped from site. A ten-to-one reduction was achieved. The implementation of RO technology following ASCA significantly reduced the waste disposal costs. [4]

7. UTILITY FUTURE PLANS

Seabrook is currently planning another FB maintenance ASCA application for their spring 2014 outage. This application is planned as part of the multiple ASCA application maintenance approach to maintain and improve SG cleanliness and health.

D.C. Cook was very impressed with the results of the U2C20 ASCA application. The site is currently assessing optimum ASCA frequency for future applications.

8. CONCLUSIONS

Both the Seabrook and the D.C. Cook Unit 2 ASCA applications were successful in meeting and exceeding utility application objectives. These applications were performed while recognizing the following ASCA application process benefits:

- Minimal outage impact
- Optimized deposit removal
- Improved deposit morphology
- No equipment or personnel safety concerns

In order to recognize these ASCA process benefits, a strong communication relationship was built between Westinghouse and both Seabrook and D.C. Cook respectively. This relationship was formed early in the planning phase. A key ASCA stakeholders' team for each ASCA application allowed transparent communication throughout process planning and site execution. Experience and lessons learned from the more than 35 world-wide ASCA applications were incorporated into ASCA planning and execution for both applications. The successful site execution of ASCA services at site has led to long term repeat ASCA planning at both utility sites.

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