Steam Generator Chemical Cleaning, EPRI/SGOG Process at Ascó 1 & 2 NPP

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In 2014, Westinghouse applied the EPRI/SGOG chemical cleaning process to remove hard deposits the top of the tube sheet of the Steam Generators (SG) at the Ascó Nuclear Plant Unit 1 and Unit 2. The project was very successful in meeting its goal of removing a large amount of deposits from the SGs while minimizing corrosion of the steam generator materials of construction. The process was successfully implemented with no personnel injuries and no safety or environmental events.

Durante 2014 Westinghouse aplicó el proceso de limpieza química EPRI/SGOG sobre los Generadores de Vapor de las dos unidades de C.N. de Ascó para retirar los depósitos de lodos duros de la placa superior de tubos. El proyecto fue llevado a cabo de una forma satisfactoria removiendo gran cantidad de depósitos a la vez que minimizando la corrosión de los materiales de los Generadores de Vapor. De igual formar el proyecto se culminó sin incidencias personales, de seguridad o medioambientales.

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INTRODUCTION

At the beginning of the 2000's Ascó experienced denting and stress corrosion cracking in Steam Generator tube materials despite attempting to use high pressure lancing to mitigate the problem. Chemical cleaning discussions with Westinghouse began in 2012 and ANAV awarded contract in August 2013.

In May 2014, a chemical cleaning process was applied to the top of the tube sheet region of the three Siemens Model 61W-D3 Steam Generators at the Ascó Nuclear Plant Unit 1. The goal of this chemical cleaning was to remove hard tube-to-tube sheet collar deposits, and aggressive contaminants contained within these deposits, to mitigate under-deposit corrosion which has been experienced at other plants with steam generators of similar design, resulting in denting and stress corrosion cracking of the Steam Generator tubing.

In November 2014, the same chemical cleaning process was applied to the top of the tube sheet region of the three Steam Generators at the Ascó Nuclear Plant Unit 2.

The cleaning process was successful, with more than 900 kg of material removed from the bottom of the three steam generators at Ascó 1 and about 763 kg at Ascó 2. As expected and consistent with lessons learned from prior similar field applications worldwide, the visual inspection demonstrated a very good improvement on free portion of the tubes (gangue) and a removing of a significant layer of hard sludge on the tubesheet. Corrosion of critical SG metal surfaces during the cleaning process was minimal. The chemical solvents used were based on a family of generic solvents developed by EPRI under the sponsorship of the Steam Generator Owners Group (SGOG).

The lead contractor for the cleaning process was Westinghouse Electric France (WEF). Process qualification and testing, as well as on-site technical expertise were carried out by Dominion Engineering, Inc. (DEI). Equipment design, set up and operation was performed by WEF with the support of Westinghouse Electric Company LLC (USA) and Westinghouse Spain (L'Hospitalet). Westinghouse provided corrosion monitoring services, as well as project administration.

Background

The accumulation of deposits in the secondary side of pressurized water reactor steam generators (SGs) increases the potential for thermal performance degradation, water level oscillations, as well as accelerated tube degradation. As these deposits harden and form crevices, they can cause conditions that can lead to tube corrosion or operational concerns. There are a number of different mechanical and chemical cleaning methods available to remove SG deposits. One of these methods, steam generator chemical cleaning (SGCC), involves the introduction of chemicals to dissolve deposits. SGCC is best suited for plants with significant deposit accumulation or in case of hard sludge on the top of the tubesheet.

Description of the EPRI/SGOG Process

In the early 1980's, Westinghouse participated in an Electric Power Research Institute (EPRI) project to develop a solvent and application method to remove iron oxide and copper corrosion products without compromising SG integrity. The resulting EPRI/Steam Generator Owners Group (SGOG) process has been used to perform many successful SGCC operations worldwide. Westinghouse, with the support of DEI, designs the specific SGCC cleaning processes that meet the utilities' specific needs. These methods include a low-temperature process (< 100°C) and a high-temperature process with or without venting. SGCC processes are applied using Westinghouse-designed dedicated external equipment, which meets all cleaning application needs for heating, pumping, chemical analysis, chemical batching, process control and ion exchange. Westinghouse offers three EPRI/SGOG-approved solvents:

- Magnetite solvent for iron oxide removal (EDTA-based).
- Copper solvent for copper metal removing (EDTA,-EDA,-H_2O_2-based).
- Crevice cleaning solvent for removing deposits in tube support plates crevices (EDTA-based).

These performance-proven solvents and field-demonstrated equipment are used by experienced Westinghouse personnel to provide customer-specific SGCC processes to meet or exceed the desired outcome.

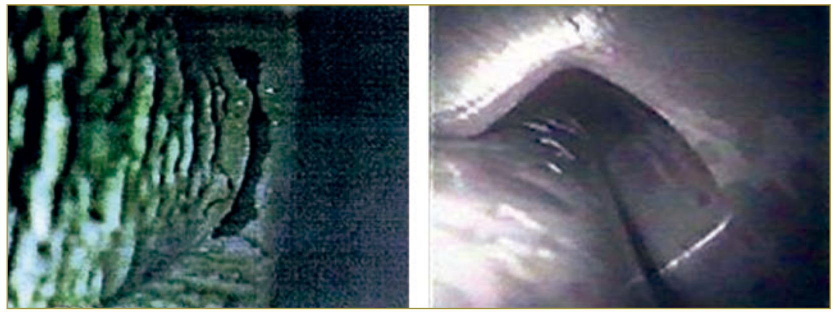
Benefits

Performance of an SGCC process provides several benefits to the plant:

- Removes large amounts (>85%) of deposits from the SG without excessive corrosion of surface materials.
- Helps extend SG operation.
- Helps prevent plant capacity loss.
- Enhances steam generator and plant performance.
- Prevent costly steam generator replacement.
- Can be customized to meet plant-specific needs.

There are also several benefits of utilizing the Westinghouse equipment, processes and personnel:

- Westinghouse has state of the art equipment to perform SGCC operations.
- Westinghouse and DEI personnel have a great deal of experience performing SGCC projects worldwide.
- Online, real-time chemistry and corrosion monitoring allows for tight control of chemical process.



Typical visual inspection on tube support plate before/after EPRI/SGOG chemical Cleaning.

- Process monitoring and operational systems allow for dynamic and solid control of the operating system.

Experience

Westinghouse's field experience includes more than 35 successful Steam Generator Chemical Cleanings (SGCC) worldwide. Westinghouse France performed 10 curative EPRI/SGOG implementation on 3- and 4-loops NPP in France between 2008 and 2011, including high temperature crevice cleaning. Most recently (2010-2014) and with the same team and part of the equipment of the above mentioned experiences, Westinghouse France (along with DEI) also performed 4 preventive chemical cleanings, referred to as "ASCA" and "iASCA" operations in France. These processes utilize dilute chemicals and simpler equipment configurations than the EPRI/SGOG process and are designed to achieve partial deposit removal and improved SG performance (reduced TSP blockage and increased heat transfer efficiency) without negligible corrosion.

CREVICE CLEANING EPRI/SGOG PROCESS – ASCÓ 1 & 2

Specific Objective for Crevice Cleaning at Ascó – process qualification

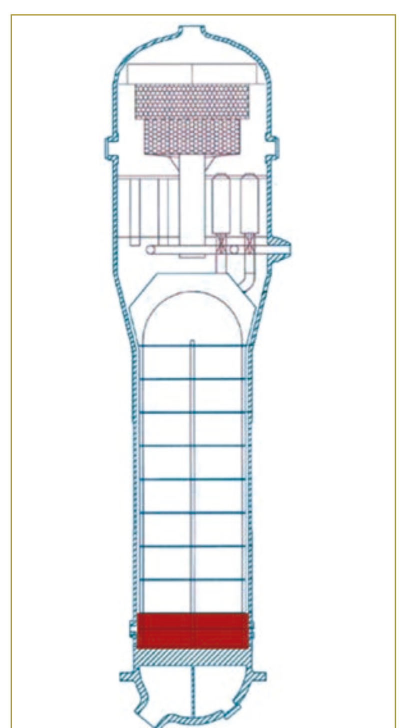
The purpose of the SGCC on the top of tube sheet (TTS) done at Ascó 1&2 is to remove the deposit of collars and deposit bridging from the tube sheet and to reduce the potential for initiation of tube degradation mechanisms (Stress Corrosion Cracking, denting).

The chemical cleaning process for Ascó was customized to achieve the most effective cleaning possible.

In order to verify that the proposed process would successfully remove the deposits without unacceptable corrosion to the SG construction materials, Westinghouse contracted Dominion Engineering, Incorporated (DEI) to perform independent site-specific process verification testing. This laboratory testing was performed using site-specific conditions to establish baseline deposit dissolution and corrosion rates expected for the field application. This testing also served as a demonstration of the electrochemical corrosion monitoring system.

The selected process included the following solvent steps:

- Bulk Iron Oxide Dissolution - to effect removal of tube free span deposits and loose deposits at the top of the tube sheet. This step was performed to ensure good access to tubesheet collars during the follow-on collar deposit removal step, and to minimize ferric ion corrosion during the collar removal step.
- Crevice cleaning - to effect removal of the collar deposits. This step is applied at high temperature (~ 120°C) with nitrogen gas overpressure. Periodically during this step, the SG atmospheric relief valves are opened to promote boiling. These periodic vents have resulted in con-



sistently rapid cleaning of crevices and softening of the hard collar deposits on the TTS.

Residual sludge is also expected to be fragile and more amenable to removal by sludge lancing following the chemical cleaning.

Outside Containment Installation

The equipment installed outside the containment (set-up area) is composed of:

- SG circulation loop (main process pump, booster pumps, steam heat exchanger, process filters, Ion Exchange vessel, …)
- Chemical Mix tanks and chemical handling system
- Waste tanks
- Mobile chemistry laboratory, which includes all of the instrumentation and equipment necessary to perform the chemical analyses required to monitor the chemical cleaning process
- Instrumentation and controls system (two redundant control computers, programmable logic controllers PLCs, remote sensing instrumentation, valve controls and limit switches, dedicated audio and video communication system)
- Boiler and steam system used to heat the solvent
- Air blower to ventilate the SG after draining of the rinse water
- Cooling system: heat exchangers and cooling towers
- Nitrogen sparge system (tank, evaporator, etc)
- Diesel generator for power supply
- Electrical distribution system
- Berms
- Associated pumps, valves, and lines
- Safety Equipment

Ascó and Westinghouse employees worked very closely together throughout the planning and implementation of the cleaning.

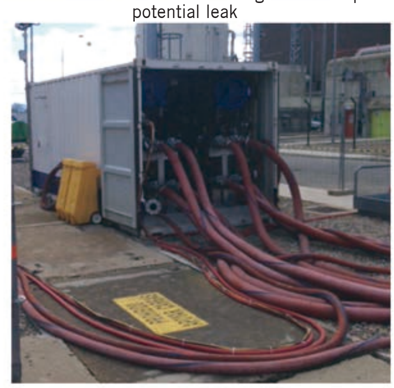
Inside containment installation

The equipment installed inside the containment is composed of Manifolds (supply and return), Auxiliary booster pump, By-pass system, various valves, fittings, hoses through each SG cubicle, Corrosion monitoring system (corrosion coupon mounting assembly and online electrochemical monitoring) and SG adaptors installed on the four hand holes The SG adaptors are used for chemical injection, recirculation and draining. Adaptors also allow for system pressurization, nitrogen sparging of the solvent, system parameter monitoring such as temperature, solvent level and pressure.

Waste area

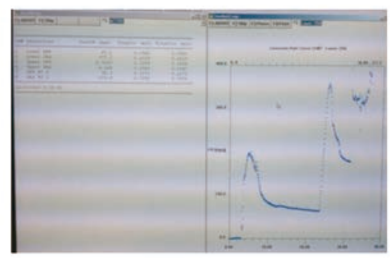
Hoses and Flange box to capture potential leak

Process module



Booster pump

Controle module



Corrosion monitoring

Deposit removal summary

Following completion of the chemical cleaning application, the three SGs were rinsed and purged with air (to facilitate displacement of nitrogen in preparation of hand hole removal), then water lanced to remove insoluble deposits that had collected on the tube sheet.

- The chemical cleaning process at Ascó 1 removed a total of 786 kg of deposits from the tube sheet region of the three SGs. An additional 98 kg of deposits was removed from the SGs by pre-sludge lancing and an additional 43 kg of deposits was removed by post-cleaning sludge lancing.

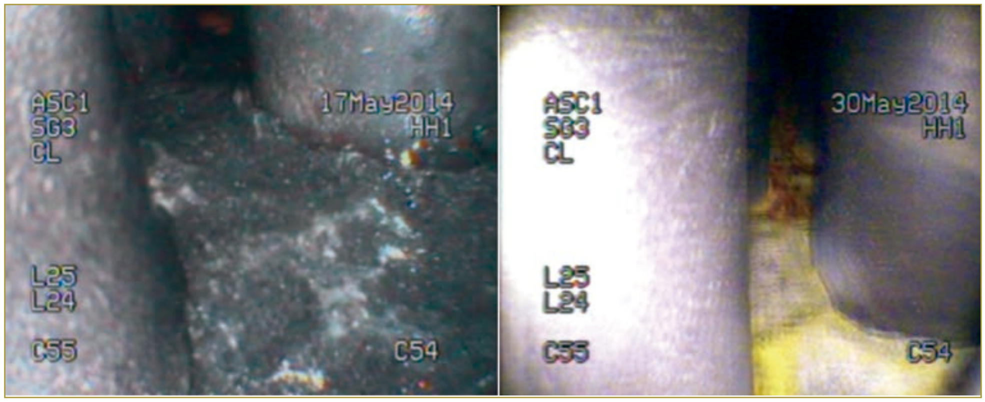
	Ascó 1	Ascó 2
Metal Oxides, including :	786	664
Iron Oxide as Fe3O4 (Magnetite)	775	644
Copper (metal) as Cu	0,7	0,5
Aluminum Oxide as Al2O3	1,6	3,9
Calcium Oxide as CaO	0,2	0,3
Zinc Oxide as ZnO	0,4	0,4
Nickel Oxide as NiO	2,4	4,8
Chromium Oxide as Cr2O3	0,8	1,3
Silica as SiO2	1,3	1,0
Manganese Oxide as MnO	3,2	7,6
Pre-Sludge Lancing (dry deposits)	98	28,2
Post-sludge Lancing (dry deposits)	43	77,5
Corrosion Iron	-9	-6,8
Total Material Removed	**918 kg**	**763 kg**

Table 1. ASCÓ SGCC Deposit Removal Summary (kg).

- The chemical cleaning process at Ascó 2 removed a total of 664 kg of deposits from the tube sheet region of the three SGs. An additional 28 kg of deposits was removed from the SGs by pre-sludge lancing and an additional 78 kg of deposits was removed by post-cleaning sludge lancing.

These results (Table 1) are consistent with the DEI deposit characterization of sludge from analysis of previous Ascó outages for both powdered sludge deposits and tube scale deposits, where magnetite was found to account for 93-95% of the tube scale deposit mass, and 96-97% of the powdered sludge deposit mass.

Overall amount of deposit removed is also consistent with the deposits loading located below the solvent fill heights projected by DEI at the end of the cycle just prior to the SGCC, i.e. about 300 kg/SG (equivalent to 900 kg/unit).



Television inspection in the hard collar area before and after Ascó 1 chemical cleaning.

Harmlessness - corrosion

Corrosion to the SG tube sheet and SG shell was monitored in real time throughout the cleaning process using electrochemical probes. After completion of the cleaning, corrosion to selected materials was determined by weight loss measurements of coupons exposed to the cleaning solvents inside the SGs. The coupon holders were mounted just below the 90° hand-hole adapter inside each SG. For all materials evaluated, corrosion was less than the assigned corrosion allowance and consistent with the expected corrosion based on the laboratory testing.

As expected, the Alloy 800, and stainless steel coupons experienced negligible corrosion over the duration of the process (< 1 µm). Corrosion of carbon steel coupons ranged from 10 µm (isolated coupons) to 50 µm (coupons galvanically coupled with Alloy 800) and no localized attack of the heat-affected zone was observed on the surface of weld coupons.

Hard collar deposits removal performance

Based on information provided to Westinghouse (visual inspection performed before and after the SGCC operations), the following conclusions can be drawn:

- Very good improvement on free portion of the tubes (gangue).
- Removing of a significant layer of hard sludge.
- Hard sludge completely eliminated in some places.
- Residual adherent sludge remains in some locations despite hard chemical cleaning and reinforced sludge lancing.

These results are consistent with those observed in prior EPRI/SGOG experiences.

Project Milestones

See Table 2.

Waste

For each unit, about 35 m³ of solvent and 65 m³ of rinse water have been drained to waste tanks. ANAV managed the way of waste treatment processing and disposal of this 100 m³ of waste per unit.

Note that water used for the final rinses of the SG (about 50 m³ for each unit), was cleaned (deionized) by recirculating through Westinghouse's ion exchange (IX) module. As a result, this final rinse water did not contain detectable radioactivity. As this final rinse water met the ANAV criteria to be released, it has been emptied to the appropriate waste system as indicated by ANAV.

ANAV also managed the disposal of the 2.5 m³ of resin from the IX module used for both the Ascó Unit 1 and Unit 2 SGCC operations. The two sets of process filters were also removed and disposed of by ANAV.

Project Implementation and conclusions

Thanks to hard joint work with the ANAV project team during the preparation phase, associated with a flawless execution, Westinghouse has delivered a quality of service beyond the requirements which allowed the operator to maximize steam generators integrity and operational performance, as well as extend the life of its generators.

Plant and Westinghouse personnel worked together to ensure all project objectives were performed with a high level of efficiency and in safe conditions.

Activity	Date	Duration
Technical and commercial discussions	May-2012-May 2013	1 year
Contract Award	Aug 2013	-
Submit Draft Operating Procedures	Sept 2013 - Feb 2014	6 months
Set up area, Waste area, Boiler and Nitrogen system installation, Outside containment final tests	March-April 2014	2 months
Training week	April 28 – May 02, 2014	1 week
Inside Ascó 1 containment installation	May 02 – May 17, 2014	2 weeks
SG Chemical Cleaning Process Ascó 1	May 18 – May 24, 2014	6 days
Inside containment Ascó 1 Demobilization complete	May 28, 2014	5 days
Partial Outside containment Demobilization complete	June 03, 2014	1 week
Partial Set up area (re)installation prior Ascó 2	Oct 2014	1 month
Inside Ascó 2 containment installation	Nov 02 – Nov 17, 2014	2 weeks
SG Chemical Cleaning Process Ascó 2	Nov 17 – Nov 21, 2014	5 days
Inside containment Ascó 2 Demobilization complete	Nov 24, 2014	4 days
Final Outside containment Demobilization	Jan 14, 2015	1 month

Table 2. ASCÓ 1&2 SGCC Project Milestones.