GENTILLY 2 STEAM GENERATORS SPRING 2000 OUTAGE: TUBESHEET WATERLANCE CLEANING AND INSPECTION; UPPER BUNDLE INSPECTION

by
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A review of the secondary side maintenance activities recently completed during the Gentilly 2 Annual Spring 2000 Maintenance Outage. Activities included: 1) Tubesheet intertube waterlance cleaning and visual inspection, 2) First tube support plate, in-bundle visual inspection of the hot leg, and 3) Upper bundle tube support plate visual inspection. A description of the waterlancing and inspection equipment and setup in the RB at Gentilly 2 is provided. Several innovative techniques were successfully employed and yielded savings in critical path duration, labour and personnel radiation dose. These included accessing the SG tubesheet region through one handhole only and sludge removal utilizing the SG blowdown system. Plant personnel judged tubesheet sludge removal successful. Before and after results of the cleaning process along with samples of the visual inspection results are provided. Inspection of the first support plate, which was a repeat of an inspection done in 1997, was conducted along with an in-bundle inspection of the upper tube supports. Results are presented along with a discussion of the implications for future steam generator maintenance.

1. PROJECT SUMMARY

Foster-Miller was contracted by Hydro Québec to provide waterlance cleaning, video (visual) inspection, and sludge pile mapping of steam generators tubesheet hot leg region[1] at the Gentilly 2 Nuclear Generating Station during the spring 2000 scheduled maintenance outage. Also included in the outage work scope was an upper bundle visual inspection of one (1) steam generator GV-4[2] through 2 in. diameter access ports installed between tube support plates (TSP) 6-7, and 8-9.

Key preparation activities prior to the start of the outage included:

1. Submission and receipt of an approved AECB Form 7 for the performance of the work.
2. Registration of the process system pressure components with the Regie du bâtiment du Quebec (RBQ).
3. Performance of a tube erosion test for the G-2 steam generator Incoloy (I800) tubes to verify a safe operating pressure range for the hard sludge lance.
4. Modifications to the Foster-Miller CECIL®[3] robot to permit operation in the G-2 steam generator geometry.
5. Design of the CECIL® system to efficiently operate in the G-2 reactor building. This included special efforts to reduce work activities in the high radiation intercabinet area[4] as well as making the work as efficient as possible to maximize tubesheet-cleaning time while at the

[1] Gentilly 2 steam generators Figure 1 have integral preheaters. The cold leg portion of the tubesheet is below the preheater floor (thermal plate).
[2] Steam generator (SG) and generateur de vapeur (GV) are used interchangeably throughout the report.
[3] CECIL® Consolidated Edison Combined Inspection and Lancing System developed by Foster-Miller under Electric Power Research Institute (EPRI) and Consolidated Edison sponsorship. Foster-Miller is the exclusive EPRI licensing agent for the CECIL® technology.
[4] Inter cabinet is space between SG insulation cabinets Figure 2.

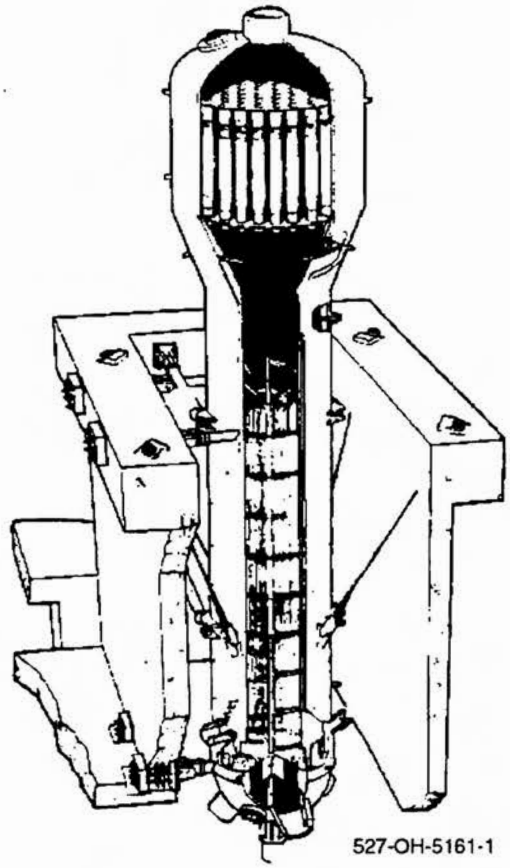

Figure 1. *Gentilly 2-steam generator*

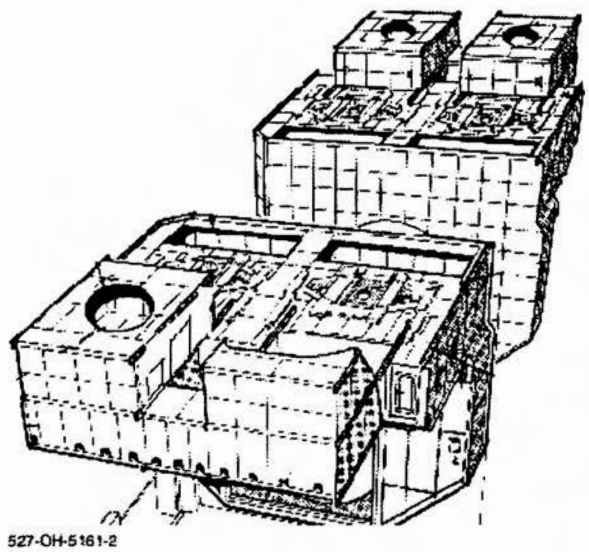

Figure 2. *Insulation cabinet layout*

same time respecting the station outage schedule.

The purpose of the tubesheet waterlancing process is to remove soft and hard sludge from the critical tube-to-tubesheet interface. This procedure is recognized by the industry as effective preventative maintenance to reduce the likelihood of stress corrosion cracking occurring in the steam generator tubes in this critical high heat flux region.

The Foster-Miller's CECIL® waterlancing process consists of two basic steps: Step 1 is a medium pressure (3,000 psi was used at G-2) high volume automated flushing process (referred to as barrel spray) and Step 2 is a high-pressure intertube lancing process (7,500 psi was used at G-2). In this outage the tubesheet waterlancing process removed a combined total of 92 lb from all four (4)-steam generator tubesheet hot leg regions.

Visual (video) inspection utilizing the lance onboard fiberscope is used to both plan and to continuously monitor in "real time" lancing progress as well as gathering data, which can be utilized to observe and analyze SG condition.

The CECIL® standard lancing method utilizes "onboard" fiberscopes – the operator only lances areas where he can visually confirm sludge is present. This greatly improves the lancing efficiency and reduces outage duration. Continuous collection of visual (video) data is valuable for the utility to follow the changes of SG condition over time for use in planning future maintenance activities as well as evaluating SG life.

The post barrel spray [after Step 1 but before Step 2] waterlancing inspections found the "hot leg" region of the tubesheet was similar in all boilers. Hard sludge deposits approximately 1/2 in. to 1 in. high remained in a central portion of the tubesheet (see maps). These deposits were located at an approximate depth of 14 in. to 20 in. into the tube bundle from the no-tube-lane, and from 27 in. to 41 in. from the handhole. These deposits were subsequently removed by the [Step 2] hard sludge lancing process. Scale (or collars) still remains on the tubes in this area.

2. REGULATORY APPROVALS

The Canadian Nuclear Safety Commission (CNSC) classified the pressure retaining components of the waterlancing system with a Class 6 Design Classification in accordance with CSA N285.0-95 Clause 5.3.4.1.

In order to comply with this requirement prior to the outage the CECIL® process system was rebuilt. All pressure vessels, fittings, gauges, and hoses were replaced with CRN registered fittings for registration of the system with the RBQ.

3. DESCRIPTIONS OF EQUIPMENT AND LAYOUT IN CONTAINMENT

The Foster-Miller waterlancing system consists of four basic stations as illustrated in the sketch of Figure 3, i.e.,

1. SG robot equipment.
2. Process equipment consisting of pumps and filters.
3. Suction pumps for removal of suspended sludge from the SG.
4. A remote operator control station.

3.1 Steam Generator Robot

The in boiler robot is designed to access the steam generator tube bundle through only one 2-3/4 in diameter access hole located at the end of the no-tube-lane (NTL).

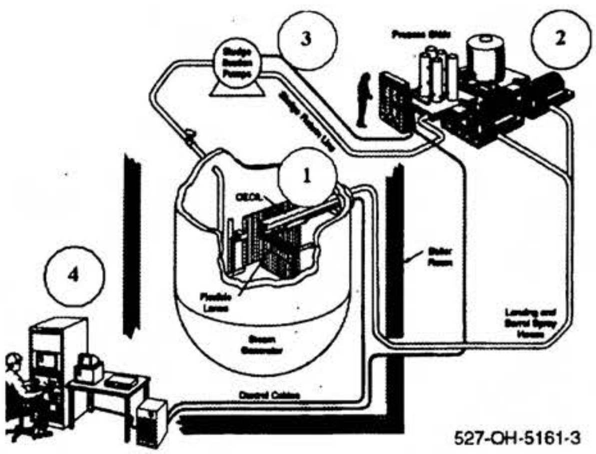

Figure 3. CECIL® waterlancing and inspection system

The CECIL® robot Figure 4 consists of a rail section installed the entire length of the NTL. The robot riding on the rail provides complete x-y-z axis motion of the lance or barrel spray within the tube bundle.

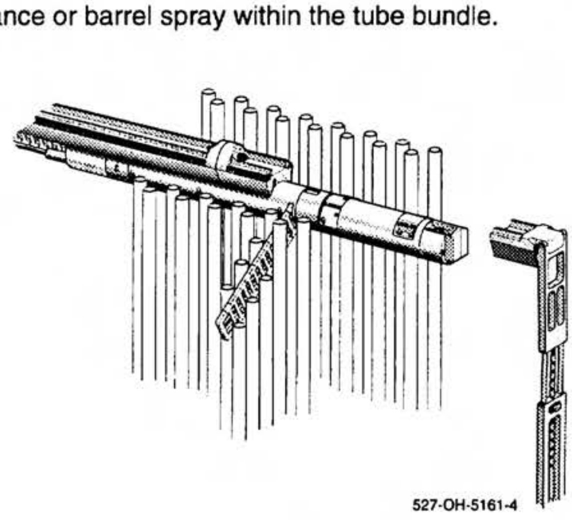

Figure 4. Intertube robot on NTL rail

The ability to perform all the work through a single access hole in the steam generator is particularly advantageous to reduce manpower required for equipment installation, installation duration (outage critical path) and the consequent overall personnel radiation dose required for the project.

The photograph of Figure 5 illustrate the installation of the robot in the GV4 steam generator.

The NTL access handhole in the pressure boundary is located directly under the seismic lug and on the

Figure 5. System installed in inter-cabinet

same axis as the seismic lug pin shown in Figure 6. At G-2 the lug was blocked in place (not removed), the pin was removed and the robot installed on the inter cabinet side of the steam generator NTL.

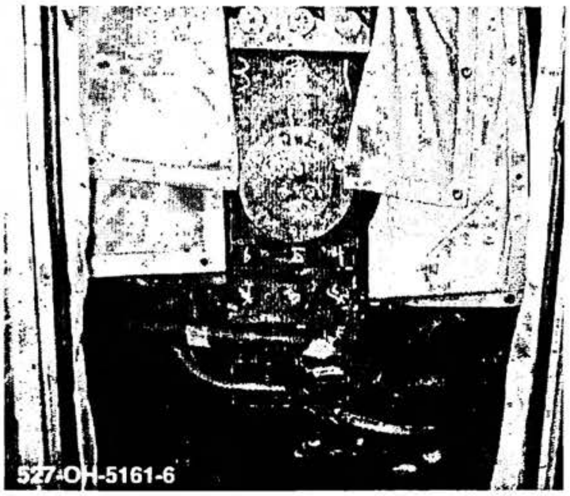

Figure 6. Seismic lug pin

3.2 Process Equipment

The process equipment supplies high-pressure water to the waterlancing robot as well as filtering the returned water suctioned from the steam generator tubesheet.

At Gentilly the Process Equipment was installed on the RB floor at elevation 501.

To reduce the volume of water being dumped to station active liquid waste the Foster-Miller process recirculates the water from the steam generator. At Gentilly diaphragm suction pumps were located in the basement of the reactor building (RB). The lancing water is pumped from the basement to a surge/ collection tank at elevation 501 and then through a series of bag filters and polishing cartridge filters. The 3μ bag filters are taken off line at frequent intervals as the pressure drop across the filter approaches approximately 20 psi and the bags are changed out. The bag filters collect the bulk of the sludge pulled from the steam generator.

Before returning to the clean water storage tank the water passes through 0.5μ polishing cartridge filters.

3.3 Suction Pumps

Another unique feature introduced for the Hydro Québec waterlance cleaning was to utilize the SG blowdown system for removal of sludge from the SG. The suction pumps were connected to a removable spool piece in the basement of the RB. This method worked very well and contributed a significant saving to outage critical path time and as well the projects ALARA objectives.

3.4 Control Station

At Gentilly the control station for the CECIL® system was installed outside the vault at elevation 401.

4. FIELD WORK SUMMARY

The tubesheets were waterlance cleaned utilizing the CECIL® barrel sprays in order to remove loose sludge and expose as much of the tubesheet as possible. Typically the barrel spray operation is found to be an efficient method to bulk clean the tubesheet in a short time. The combination of pressure (up to 3,000 psi) and high washing flow (up to 35 gpm) removes the loose and semi-hard sludge. The relatively high flow rate of 35 gpm serves to fluidize the sludge particulate thus enabling it to be readily removed from the SG with the diaphragm suction pumps. The barrel spray is run until sludge return at the filters indicated continuing the barrel spray process would not yield further gains in cleaning.

Following completion of the barrel spray process the CECIL® hard sludge lance is inserted. Prior to commencing hard sludge lancing the remaining areas of sludge pile and/or tube scale are mapped by the operator to guide the next stage of high pressure intertube waterlancing.

The operator then initiates high pressure intertube lancing in the hot leg region to reduce and remove the remaining hard sludge pile, and tube scale. In this process the operator manipulates the lance along each tube row. Where areas of sludge or scale are observed the lance jets are initiated.

At the completion of high-pressure water lancing final condition maps of remaining tube scale are made. At Gentilly the tubesheet surface was exposed in all areas of the steam generator. Areas where tube scale was observed to remain is recorded on Tubesheet

Surface Maps for future reference. Figure 7. These maps are good reference tools of SG condition and can be utilized for planning NDE inspections, future cleaning etc.

In all, the tubesheet waterlancing process removed a combined total of 92 lb of sludge from the four (4) SG tubesheets. Sludge samples from each steam generator were retained for analysis. Average chemical composition was determined to be 75% Magnetite (Fe_3O_4) and 15% Copper (CuO).

5. PROJECT SCHEDULE

The tubesheet waterlancing project was planned as the critical path for the station outage. The contractor was given full access to the reactor building with 24 hr coverage for radiological support and steam generator access provided by station support personnel.

The waterlancing was completed in accordance with the original plan. Table 1 provides a summary.

6. UPPER BUNDLE INSPECTIONS GV4

Upper bundle visual inspections were completed on the first Hot Leg support above the tubesheet and upper bundle tube supports 8–9 and 6-7. The first hot leg support was accessed through the tubesheet waterlancing handhole the top support plates were accessed through existing 2 in. diameter inspection nozzles. High fields and loose contamination in the area made this a difficult inspection.

6.1 First Hot Leg Tube Support Inspection

This inspection was designed as a repeat of the inspections previously conducted by Foster-Miller in 1996 and 1997. The purpose of the inspection was to view the condition of the support plate and especially to observe for any signs of fouling and/or blockage of the tube support "broached" flow openings. In order to maintain a good basis for comparison of the results of the previous inspection and the current inspection the same fiberscope, light source and techniques were employed as before.

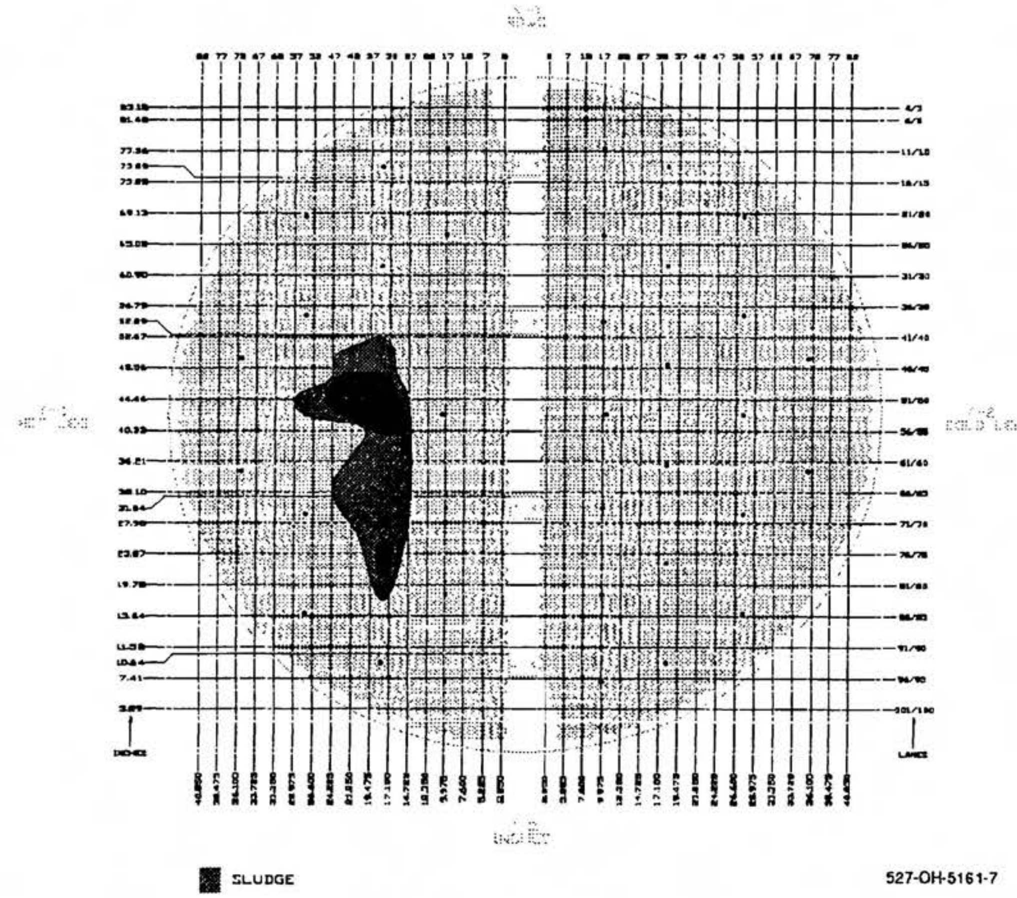

Figure 7. ***Tubesheet map of final condition. The large area is the footprint of the sludge pile after barrel spray flushing. The smaller dark area records areas of tube with scale "collars" remaining***

Table 1.   Schedule summary

Boiler	Start Date	End Date	Hours/ Shift	Shifts/ Day	Days/ week
Dates and Duration on Boilers					
GV 1 – 3 Intercabinet					
Initial setup	4-Apr	7-Apr	12	2	7
Boiler 3	7-Apr	10-Apr	13	2	7
Boiler 1	10-Apr	13-Apr	13	2	7
GV 2 – 4 Intercabinet					
Initial setup	13-Apr	13-Apr	13	2	7
Boiler 4	14-Apr	17-Apr	13	2	7
Boiler 2	17-Apr	20-Apr	13	2	7
Pack out	20-Apr	20-Apr	12	2	7

The support plate and tubes appeared dull compared to the previous inspection but no signs of flow hole fouling or blocking was observed. Overall little change appeared to have occurred in this region.

6.2 Inspection Top Supports 8-9 And 6-7

The upper bundle inspection using a CECIL® lance and fiberscope achieved good quality video records of the tubes and broach support condition. Visual observation identified that plugging is occurring in the support plates at this elevation.

Scale deposits (fouling) on the tubes made progression of the lance along the tube lanes very difficult. In a large part of the bundle the lance could only move approximately 24 in. along the lane from the NTL. At this depth the broach flow lobes were observed to be significantly blocked and many were closed.

Figure 8 records the blockage observed at the top support plate.

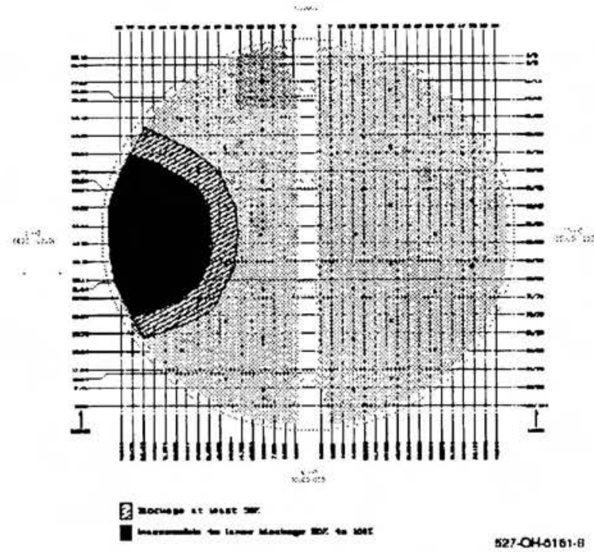

Figure 8.   Plot of support plate #9 flow blockage

7. DISCUSSION AND INTERPRETATION OF UPPER BUNDLE INSPECTION RESULTS

Plugging of the tube support flow holes is significant and may cause a number of possible detrimental impacts on steam generator life. Potential impacts that should be examined further include:

1. Reduced steam generator circulation. Blockage of the supports will add resistance in the two-phase riser section of the steam generator.
2. Water level instability (water level oscillations directly attributable to support plate blockage occurred at OPG's Bruce A Units). If water level oscillations begin the only remedy to control oscillations is a power reduction or cleaning.
3. Tube lockup in the tube supports. Due to the difference in thermal expansion coefficient between the carbon steel steam generator shroud and the Incoloy 800 tubes the tubes must slide relative to the support plates during heat-up and cool-down. This effect is much more pronounced than in an I600 tube steam generator [Bruce A]. If the tube is locked it will bow as well as seeing higher stresses at the support.

Bowing of the tubes may be the reason why the lance was not able to pass through the tube bundle.

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