STEAM GENERATOR REPLACEMENT AT BRUCE A UNIT 1 AND UNIT 2

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TABLE OF CONTENTS

1. Introduction..... 4
2. Steam Generator Configuration at Bruce A 4
3. Steam Generator Replacement Methodology 5
4. Steam Generator Replacement Overview 6
5. Interference Removal Activities & Physical Preparations 10
6. Project Status 18
7. Summary 21

Steam Generator Replacement in Bruce A Unit 1 and Unit 2

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Abstract

The Bruce A Generating Station consists of four 900 MW class CANDU units. The reactor and Primary Heat Transport System for each Unit are housed within a reinforced concrete reactor vault. A large duct running below the reactor vaults accommodates the shared fuel handling system, and connects the four reactor vaults to the vacuum building. The reactor vaults, fuelling system duct and the vacuum building constitute the station vacuum containment system.

Bruce A Unit 2 was shut down in 1995 and Bruce A Units 1, 3 and 4 were shutdown in 1997. Bruce A Units 3 and 4 were returned to service in late 2003 and are currently operating. Units 1 and 2 remain out of service. Bruce Power is currently undertaking a major rehabilitation of Bruce A Unit 1 and Units 2 that will extend the in-service life of these units by at least 25 years. Replacement of the Steam Generators (eight in each unit) is required; this work was awarded to SNC-Lavalin Nuclear (SLN). The existing steam drums (which house the steam separation and drying equipment) will be retained. Unit 2 is scheduled to be synchronized with the grid in 2009, followed by Unit 1 in 2009.

Each Bruce A unit has two steam generating assemblies, one located above and to each end of the reactor. Each steam generating assembly consists of a horizontal cylindrical steam drum and four vertical Steam Generators. The vertical Steam Generators connect to individual nozzles that are located on the underside of the Steam Drum (SD). The steam drums are located in concrete shielding structures (steam drum enclosures). The lower sections of the Steam Generators penetrate the top of the reactor vaults: the containment pressure boundary is established by bellows assemblies that connect between the reactor vault roof slab and the Steam Generators. Each Steam Generators is supported from the bottom by a trapeze that is suspended from the reactor vault top structure.

The Steam Generator Replacement (SGR) methodology developed by SLN for Unit 1 and Unit 2 SGR employs a Medium Lift Crane (MLC) located at ground elevation north of the powerhouse to perform all heavy lifts within the reactor buildings, including relocation of the steam drums and removal and replacement of the Steam Generators, through openings created in the reactor building roof structures. Following the removal of components and systems that interfere with SG replacement activities, the connections between the Steam Generators and the steam drums are severed, the roof of the concrete SD enclosure and the steam drum cooling system are removed, and the steam drums are lifted from the steam drum enclosures and placed on temporary supports to the reactor side of the steam drum enclosures by the MLC. The old Steam Generators are then removed and the replacement Steam Generators are installed through the reactor building roof openings by the MLC. The steam drums and all piping connections and equipment will be reinstalled following the installation of the Replacement Steam Generators to establish the “as found” condition.

The replacement of the eight Steam Generators in each unit is a major part of the Unit 1 and Unit 2 rehabilitation program. This work is currently in progress. The Unit 1 and Unit 2 Steam Generator replacement is a “first-of-a-kind” project. These are the first CANDU Steam Generators to be replaced, and the horizontal steam drum configuration is unique to Bruce A.

This paper provides an overview of the Unit 1 and Unit 2 Steam Generator replacement methodology developed and being employed by SLN.

1. Introduction

The Steam Generator Replacement work at Bruce A presents many “first-of-a-kind” challenges. The vacuum containment system employed by the Bruce, Pickering and Darlington stations, and the horizontal steam drum configuration utilized by Bruce A are unique in the world. In the vacuum containment system, the containment structure of each unit in the station connects to a vacuum building. In the event of a loss of coolant accident in a unit, valves connecting the unit containment to the vacuum building open to allow the discharge of steam into the vacuum building where it is condensed. While the Pickering units have cylindrical reactor buildings that house most of the Nuclear Steam Supply System, the Bruce and Darlington units have compact rectangular containment structures that house the reactor and the high pressure reactor coolant system (Heat Transport System): a single vacuum building serves four units. At these plants, the lower portions of the Steam Generators penetrate the top of the rectangular containment structures, which are referred to as the reactor vaults. Another feature that is unique to the Bruce A units is the use of eight vertical Steam Generators, four of which connect to a cylindrical horizontal steam drum at and above each end of the reactor assembly.

Although Steam Generators have been replaced in many Pressurized Water Reactors (PWRs) world wide, this experience is not directly applicable to the Steam Generator replacements at Bruce A, as all PWRs, except the early models designed in Russia, have cylindrical full pressure containment systems. The Bruce A Unit 1 and Unit 2 Steam Generator replacements require novel Steam Generator replacement methodologies due to the unique design features.

Bruce A Unit 1 and Unit 2 are de-fueled and the Primary Heat Transport Systems are drained and dried. The Unit 1 and Unit 2 reactor vaults are isolated from the station vacuum containment system, thereby facilitating reactor vault access and allowing openings between the reactor vaults and the reactor building environment.

2. Steam Generator Configuration at Bruce A

Each Bruce A Unit has two Steam Generation Assemblies, each consisting of a horizontal cylindrical steam drum (30m/96 feet long, and 3m/114 inches OD and weighing approximately 300 tons/270,000 kg) and four vertical Steam Generators (each 12m/39 feet tall and weighing about 120 tons/109,000 kg.)

The vertical Steam Generators connect to individual nozzles (5'-10"/1.8m OD) that are located on the underside of the steam drum. The steam drums are located in reinforced concrete shielding structures (steam drum enclosures). The Steam Generators span the reinforced concrete boiler rooms (located between the reactor vaults and the steam drum enclosures) vertically, with their lower sections penetrating the top of the reactor vault, where the containment pressure boundary is established by cylindrical bellows assemblies that connect between the reactor vault roof slab and the Steam Generators secondary shells. Each Steam Generator is supported from the bottom by a trapeze that is suspended from the reactor vault top structure. The general arrangement of the Steam Generator assemblies is shown in Figure 1-1.

3. Steam Generator Replacement Methodology

The Steam Generator replacement methodology developed by SLN resulted from a thorough evaluation of potential methodology options. These evaluations included an in-depth review of the Bruce A layout, arrangement and structural drawings covering the areas of the station affected by the Steam Generator replacement activities. Several 'walk throughs' of the areas in the vicinity of the steam generation equipment were completed, and discussions were held with specialist in heavy lifting and material handling. High resolution laser scans of the areas that house the steam generation equipment (steam drum enclosure, areas in the vicinity of the steam drum enclosure, boiler rooms and reactor vault below the Steam Generators) were completed and 'intelligent' 3-D images were produced. Data from the laser scans facilitated the production of the drawings required to support the identification and assessment of Steam Generator replacement concepts.

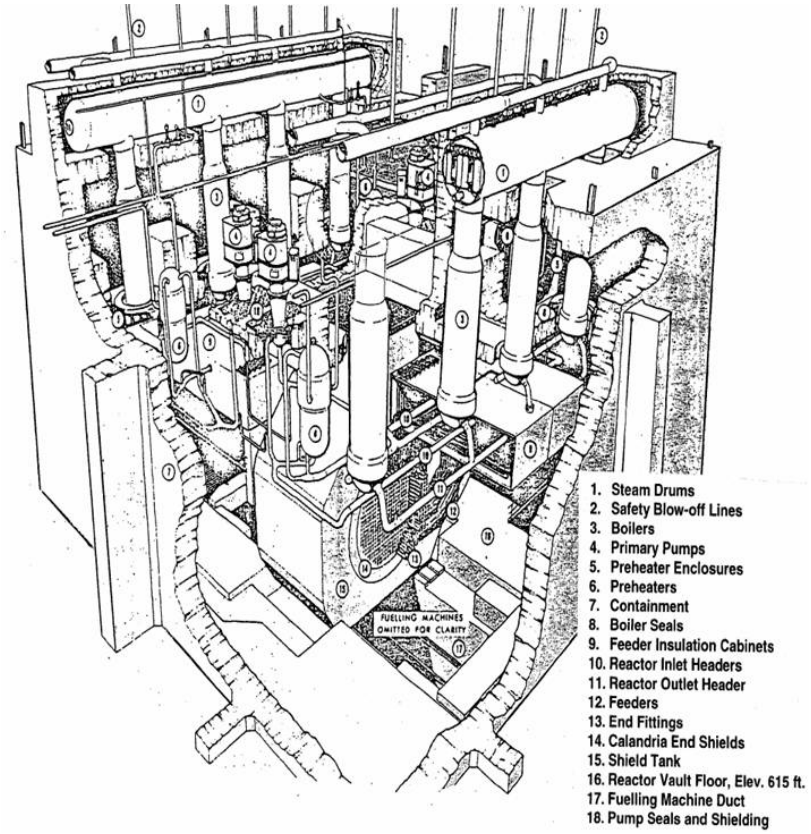

Figure 1-1: General Steam Generator Assembly Arrangement

Four basic Steam Generator replacement concepts were selected by SLN from the identified potential Steam Generator replacement concepts for detailed evaluation. The evaluation of the selected Steam Generator concepts, based on technical merit, risk, cost, and schedule, resulted in the selection of the reference Steam Generator replacement concept described in this paper. This concept utilizes a robust Medium Lift Crane (MLC), located north of the reactor building to lift the steam drum and Steam Generators through openings in the reactor building roof.

4. Steam Generator Replacement Overview

Many activities must be completed prior to lifting and moving the steam drum and removing the old Steam Generators. These activities include the removal of systems and components that interfere with the Steam Generator replacement activities in the reactor vaults, boiler rooms, steam drum enclosures, and in the areas above and to the reactor bay side of the steam drum enclosures, cutting of the heat transport system connections to the primary nozzles of the Steam Generators, removing the steam mains that are located above the steam drum, cutting the feedwater connections to the steam drum, and the cutting of temporary openings in the reactor building roof above each Steam Generator.

Following the completion of interference removal, the MLC is utilized to lift the steam drum clear of the steam drum enclosure (refer to Figure 4-1 and Figure 4-2) and place it on temporary supports located to the reactor bay side of the steam drum enclosure. The old Steam Generators, after being sealed, are then lifted from the reactor building by the MLC through the temporary openings in the reactor building roof. The MLC then moves the old Steam Generators to a position north of the reactor building and lowers them to ground elevation, placing them on a transporter. The MLC then lifts the replacement generators from their horizontal position at ground elevation, and places them in position (vertical) in the boiler rooms, supported by the Steam Generator trapeze supports. The MLC is positioned north of the reactor building such that it can lift all eight Steam Generators from one unit from a single MLC location.

Following their placement in the boiler room, the replacement Steam Generators are positioned precisely to align with the Heat Transport System (HTS) piping based on accurate measurements utilizing the adjustment devices provided in the boiler rooms. After aligning the Steam Generator primary nozzles within the Heat Transport System, the HTS pipes are welded to the Steam Generator primary nozzles (inlet and outlet), and the welds are then inspected and heat treated. The steam drum is moved into position above the Steam Generators by the MLC and lowered into position for welding the steam drum nozzles to the Steam Generator connections following the placement of all four Steam Generators of one Steam Generator assembly. The auxiliary components and systems (i.e., bellows containment seal, steam relief valves, steam mains, ASDVs, instrumentation, steam drum cooling, system, etc.) are then reinstalled. Inspection of the systems is then completed to assure that all components and systems are in the “as-found” condition and in compliance with Code requirements.

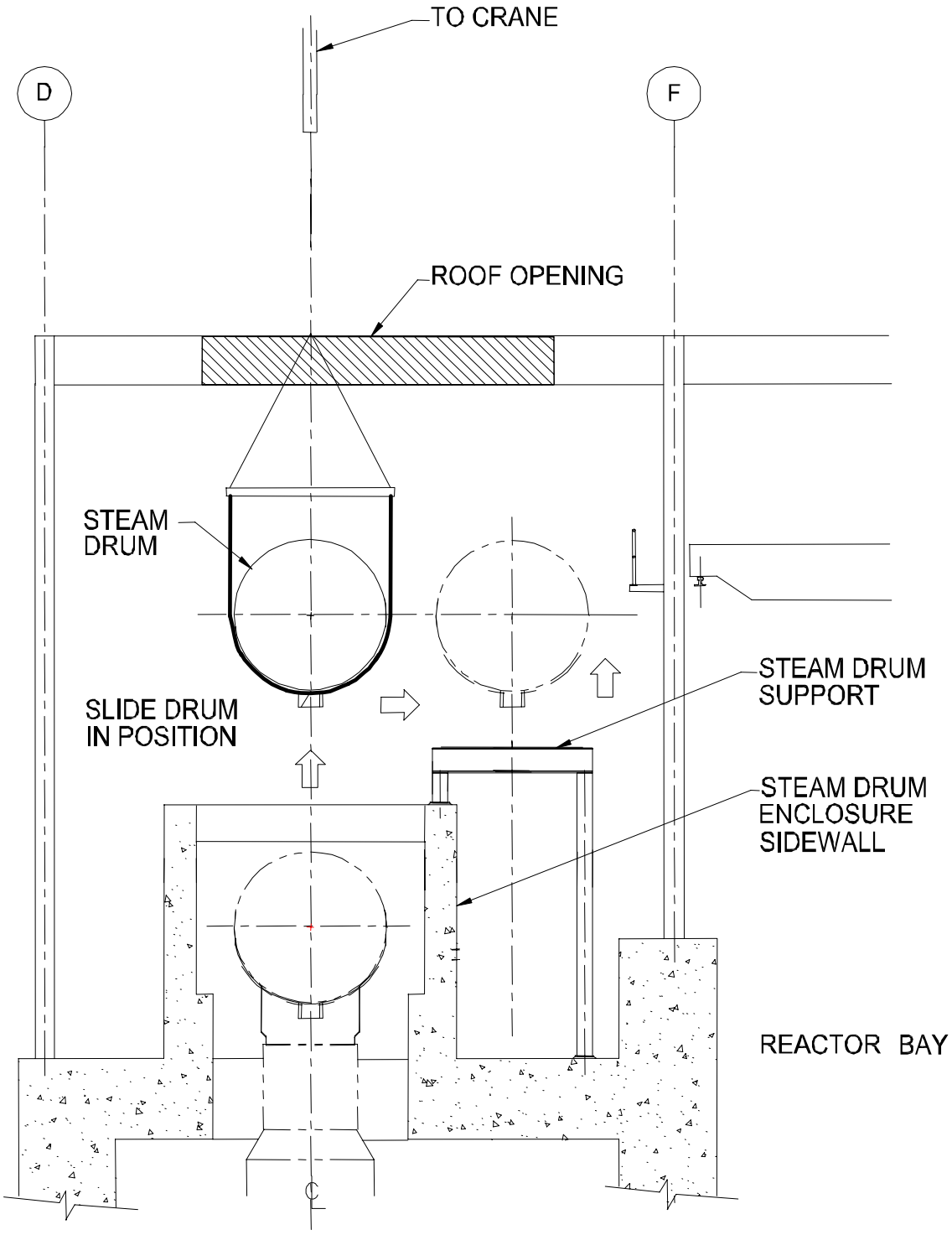

Figure 4-1: Steam Drum Repositioning – End View

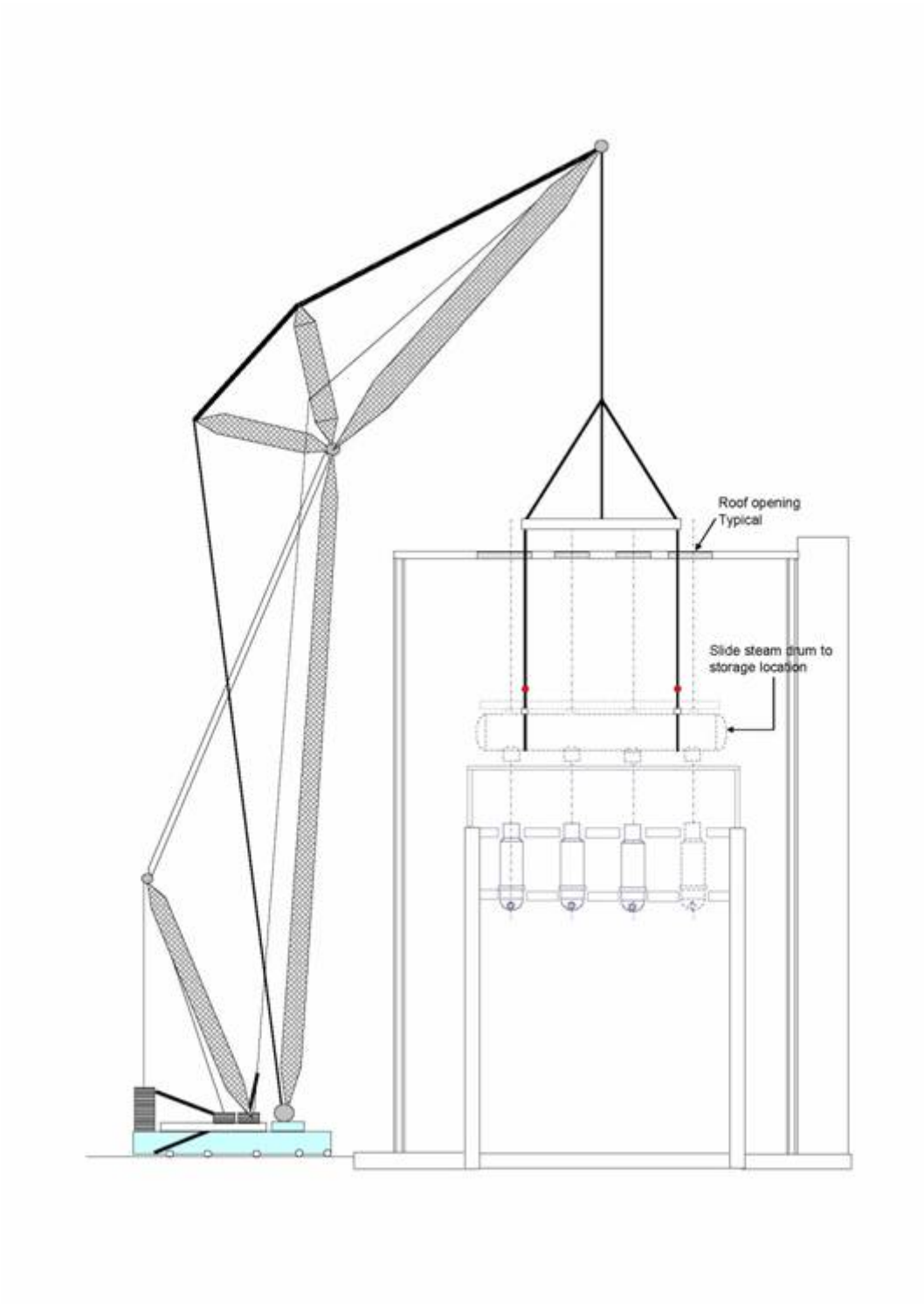

Figure 4-2: Steam Drum Repositioning – Side View

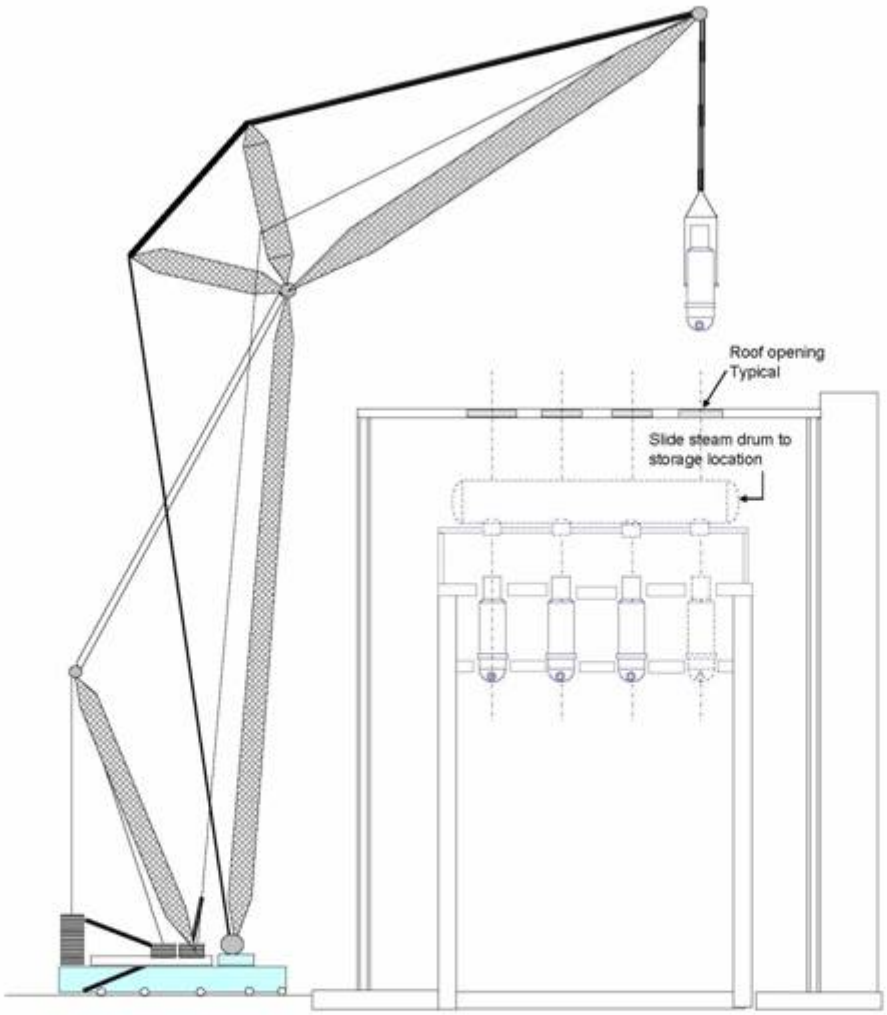

Figure 4-3: Steam Generator Removal/Replacement

5. Interference Removal Activities and Physical Preparations

Replacement of the Steam Generators at Bruce Unit 1 and Unit 2 requires the removal of all systems, components and structures that interfere with or impede the removal of the Steam Generators. Although this is technically interference removal, the removal and repositioning of the steam drum is considered, as in conjunction with the removal of the Steam Generators, an integral part of the Steam Generator assembly. The interferences to be removed include sections of the reactor building roof structure, steam lines, Steam Relief Valves and Atmospheric Steam Relief Valves (ASDVs), the concrete top of the steam drum enclosures, a large portion of the steam drum cooling system, blowdown lines and Steam Generator hydraulic restraints, the top seal plates of the containment bellows assemblies and a substantial amount of wiring and instrumentation.

In addition, restraints must be installed to maintain the heat transport system piping position following the severance of the connections to the Steam Generators. Temporary supports must also be installed, the largest of which supports the steam drum when relocated from above the Steam Generators. Adequate physical protection must also be provided for critical components such as the containment bellows seal.

The removal of interferences and the physical preparations in the boiler rooms and the reactor vaults is further complicated by the limited space available and difficult access. The following images give an indication of the working conditions in these areas.

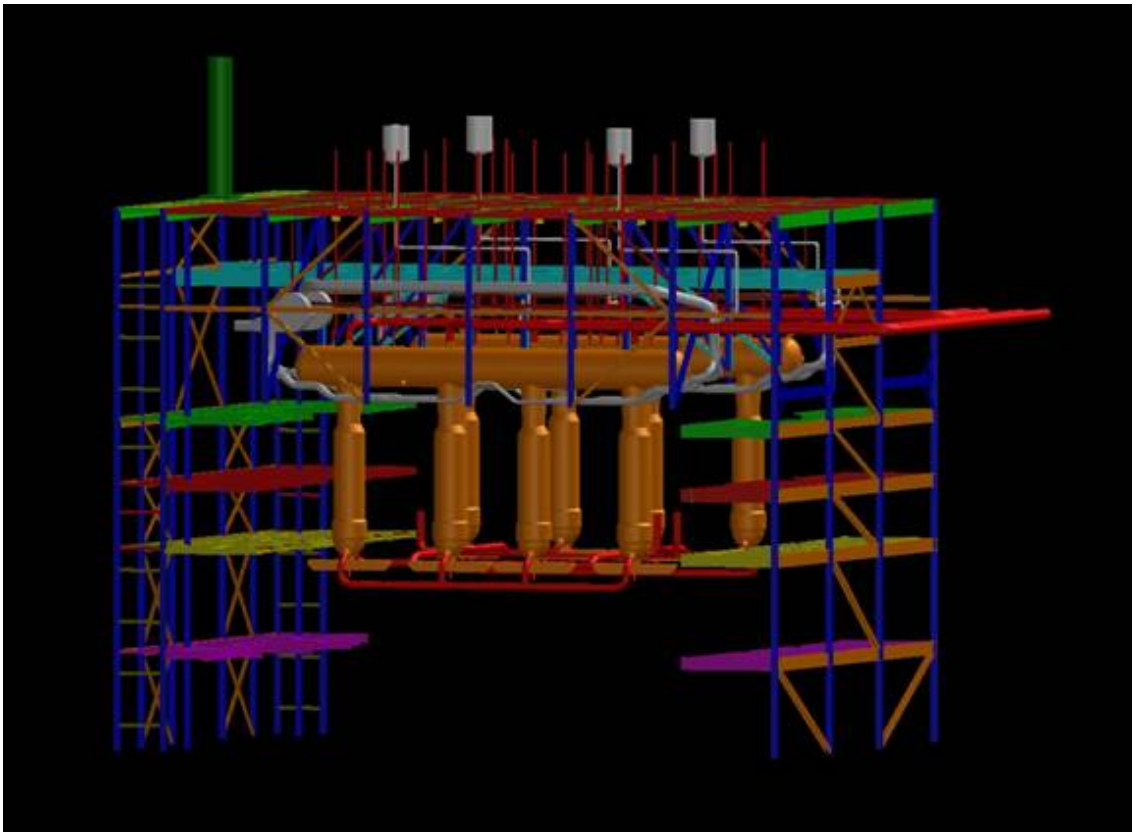

Figure 5-1: 3D Model of the Steam Generators and Steam Drum Assembly

Figure 5-2: Boiler Room, top of the Containments Seal Assembly & Seismic Restraint

Figure 5-3: Boiler Room, Supporting Rods Closure

Figure 5-4: View Inside Boiler Room Above Vault Showing Containment Expansion Joint & Blow Down Lines

Figure 5-5: View Inside Boiler Room Showing Bank of Steam Generators

Figure 5-6: Top of Reactor Building, Crane Bay & Steam Drum Closure

Figure 5-7: View Above Steam Drum Enclosure Roof

Figure 5-8: View of Top of Steam Drum Enclosure Showing MSSVs & Cooling Fan

Figure 5-9: Steam Generator to Steam Drum Connection

Figure 5-10: Steam Drum Face Showing Cooling Ducts

Figure 5-11: Vault Showing Trapeze Support, PHT Outlet Piping & Part of Balance Line

Figure 5-12: Vault Showing Limited Head Room between Top of Support (Trapeze) & Vault Ceiling

Figure 5-13: Vault PHT Piping & Support Arrangement

Figure 5-14: Vault PHT Inlet & Supporting (Trapeze) Arrangement

Figure 5-15: HTS Inlet Piping

6. Project Status

SLN mobilized at the Bruce site in 2006 May, and Steam Generator activities are well underway, with a focus on Unit 2. Comstock is the principal sub-contractor to SLN, undertaking most of the Steam Generator replacement activities, and B&W Canada is supplying the replacement Steam Generators. As of 2006 September 01, three (3) replacement Steam Generators were delivered to site. The replacement Steam Generators are being temporarily stored in a building provided by SLN where the new Steam Generators are prepared for installation. This work includes the detailed inspection and mapping of each new Steam Generator to permit, matching to a specific location. The closure covers on the replacement Steam Generators are removed and a work platform above the tube bundle is installed. PHT nozzle weld end preparation is then made and the shell section that will be enclosed within the containment bellows assembly following installation is insulated.

The following photos show some of the work completed as of 2006 September 25. This includes the MLC and the storage building with the Replacement Steam Generators.

Figure 6-1: Medium Lift Crane (MLC)

Figure 6-2: Temporary Storage Provided for Replacement Steam Generators

7. Summary

The replacement of all 16 Steam Generators for Bruce A Unit 1 and Unit 2 represents a major portion of the Bruce A rehabilitation program for the above units. SLN developed and is implementing a first-of-a-kind Steam Generator replacement methodology that minimizes risk, cost, and schedule. This project will contribute to the successful return-to-service of Bruce A Unit 1 and Unit 2, and establish the technical basis for the replacement of Steam Generators in other CANDU plants, with applicability in particular to the Ontario Bruce and Darlington plants.