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BRUCE UNIT 1 & 2 PREHEATER CONDITION ASSESSMENT & REFURBISHMENT

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ABSTRACT:

Bruce Units 1 to 4 were shut down during the 1990s, largely as a consequence of tube degradation resulting from inappropriate steam generator secondary side water chemistries. Following a condition assessment, Bruce Power restarted Units 3 and 4 and is currently refurbishing Units 1 and 2.

In order to assess the condition of the Unit 1 and Unit 2 preheaters and determine their suitability for extended operation, inspection, maintenance and assessment activities have been conducted. Eddycurrent and visual inspection have revealed vessels in generally good condition. Secondary side internals appear largely undegraded. Some tube to support fretting has been observed, and a number of tubes have been removed from service because of debris fretting concerns. To prepare for return to service, the primary side divider plates have been replaced and the tubes have been ID cleaned to restore the preheater to its original condition.

This paper summarizes the inspection planning, findings, assessment for extended operation and maintenance activities undertaken.

INTRODUCTION

Bruce Units 1 to 4 were shut down during the 1990s, largely as a consequence of tube degradation resulting from inappropriate steam generator secondary side water chemistries. Following a condition assessment, Bruce Power restarted Units 3 and 4 and is currently refurbishing Units 1 and 2.

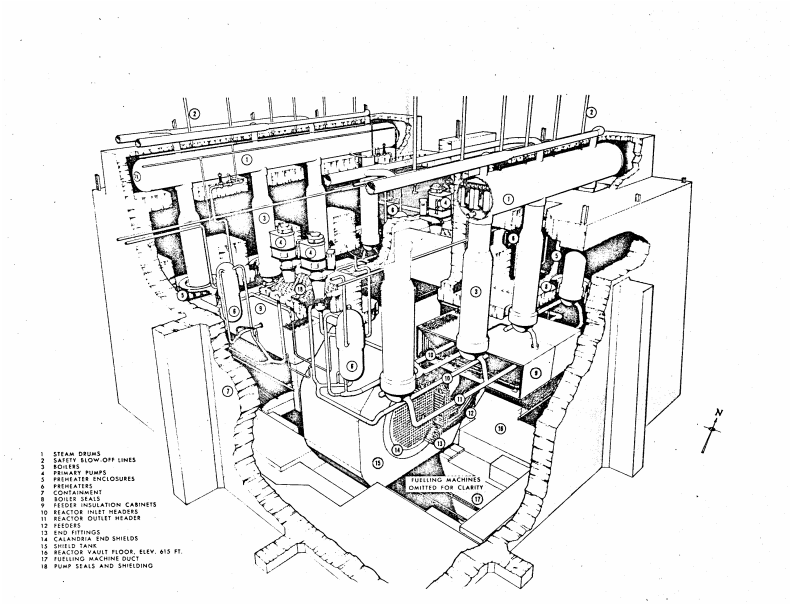

Figure 1 – Cutaway View of Bruce A

In order to assess the condition of the Unit 1 and Unit 2 Preheaters and determine their suitability for extended operation, inspection, maintenance and assessment activities have been conducted. Inspection has revealed that the vessels are in generally good condition with evidence of minor debris fretting, limited tube to support fretting and secondary side internals in good condition. The primary side divider plates will be replaced with corrosion resistant materials to preclude the risk of future flow accelerated corrosion damage. The tubes will be ID cleaned (by AECL) prior to return to service to restore the original thermal performance.

A summary of the inspection scope, findings, maintenance activities and prognosis for extended operation is presented here.

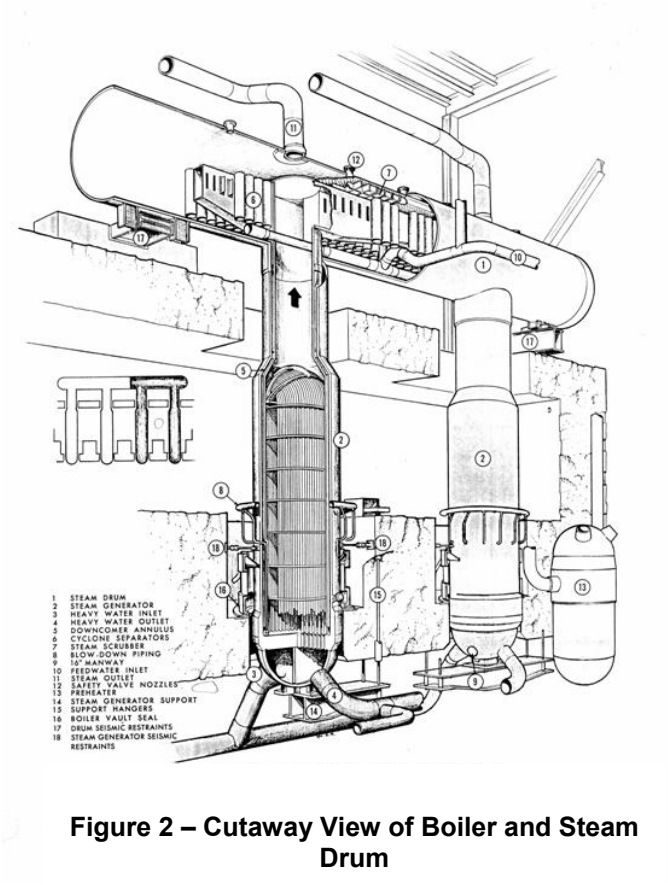

Figure 2 – Cutaway View of Boiler and Steam Drum

PREHEATER ARRANGEMENT

The arrangement of the Bruce Power steam generating equipment is unique in the CANDU world. This equipment consists of eight steam generators and four separate, external preheaters. The preheater arrangement is similar to a recirculating SG on the primary side, with approximately 2900 Alloy 600 U-tubes, but is inverted from the typical SG configuration with the tubesheet and tube openings at the top.

The secondary side tube supports are quite typical of industrial heat exchangers, with segmented baffles joined together with tie rods and a longitudinal secondary side divider plate. The U-bend supports consist of three in-line scallop bar stacks held together with forks, similar to that in the Bruce A steam generators. All secondary side internals are carbon steel. The preheaters were supplied without manways or handholes to provide access to the secondary side, and interference from adjacent equipment and structures severely restricts access.

INSPECTION AND MAINTENANCE SCOPE

Background

Initially, Bruce Power considered replacing the preheaters along with the steam generators prior to restarting Units 1 and 2. However, previous assessments suggested that this approach would not be necessary. Bruce A preheaters have been largely free of in-service degradation. Inspections conducted in Unit 3 and Unit 4 in 2000-2002 prior to the return to service these reactor units, after extended layup, discovered some minor tube to support fretting but no other significant degradation of the tubes.

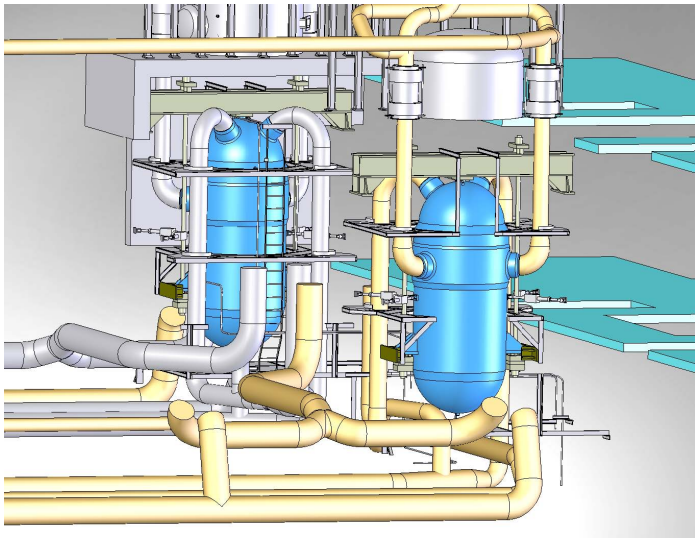

Figure 3 – Preheater with Piping & Supports

The preheater tubes are Alloy 600, a material which is known to be susceptible to IGA/SCC. However, the preheaters operate at significantly cooler temperatures than do steam generators, with little boiling to concentrate corrosive species, and the inverted design precludes the formation of a tubesheet sludgepile. For these reasons the risk of IGA/SCC is considered small.

Based on this information and the knowledge that the arrangement of the equipment makes replacement of the preheaters very difficult, it was decided by Bruce Power that the preheaters would not be replaced along with the steam generators and, therefore, an additional 30 years of service is required from the existing equipment. In order to increase confidence in the initial condition assessment an inspection and refurbishment program was instituted.

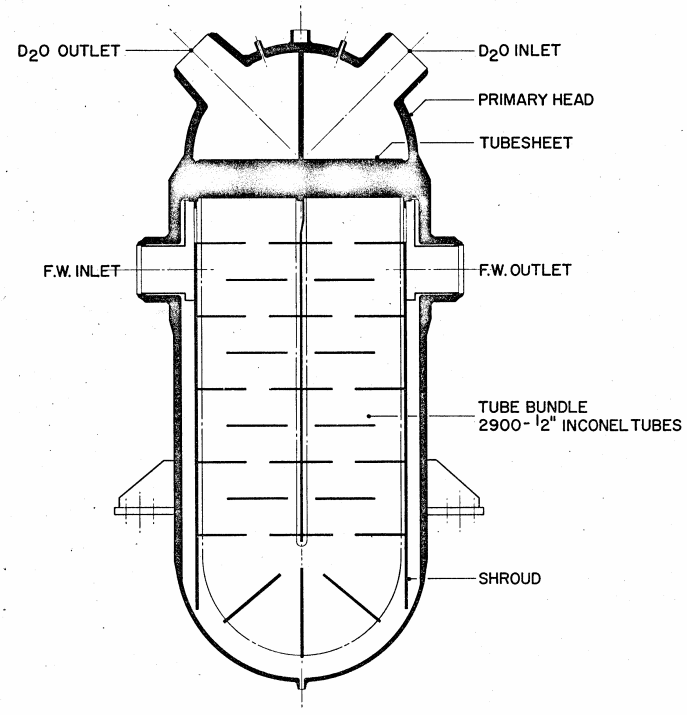

Figure 4 – Preheater General Arrangement

Areas at Risk

The inspection and maintenance scope was set based on ensuring safety and performance of the preheaters over the long term. Tube condition is paramount, as the tubes form the primary barrier between the reactor coolant and the environment. In order to ensure tube integrity, the tube support structures must also be intact. Condition of the miscellaneous secondary side internals, such as the feedwater inlet box, is important to maintain performance and to ensure the risk from loose parts remains low. In order to maintain thermal performance, the primary side divider plate condition must not permit significant bypass leakage and the fouling of the ID of the tubes with magnetite must be controlled.

Bruce Power maintains a periodic inspection plan, in compliance with ASME and regulatory codes, for the pressure boundary; inspection scope addressed by this plan is not addressed in this paper.

Eddycurrent Inspection

Eddycurrent inspection was conducted in all Unit 1 and Unit 2 preheaters, using bobbin as the primary detection probe. Nominal inspection scope was 25% of the tubes in each preheater, full length as practicable. Tube selection was biased to the periphery where the risk of both debris fretting and tube to support fretting is considered higher. In most cases, a CSA pattern expansion (two rings of adjacent tubes) was completed around all indications. Later in the campaign, some limited characterization using X-Probe was conducted on fret indications and possible loose parts.

Visual Inspection

As noted above, access to the secondary side of the preheaters is extremely limited. A number of approaches were considered, including severing the feedwater inlet and outlet lines to provide access. In the end, it was decided to remove a number of tubes of varying lengths from each preheater to permit visual inspection of the secondary internals by inserting a video probe from the primary side of the preheater through the removed tube locations. This provided access to various regions within the preheater and was, therefore, more useful and less intrusive than other options. Additionally, inspection through the drain lines at the bottom of the preheaters, which will provide some access to the U-bend support, is planned but not complete at this time.

Metallurgical Examination

A total of twenty-eight tube sections were removed to permit secondary side visual inspection, and an additional tube was removed in response to eddycurrent findings, as discussed below. Metallurgical examination of all tube sections is anticipated to better characterize the condition of the preheater tubes, but this work has not been completed at this time.

Divider Plate Replacement

The original divider plates and retrofitted sealing skins were removed from all Unit 1 and 2 preheaters, and will be replaced with a modified design which is similar to the original but uses corrosion resistant materials and includes improved design features. During this process, the seat bar (on the primary head) was clad with Inconel and re-machined in situ. The replacement divider plate is constructed from SA516 Gr70 with faint chrome content. Bolted construction is maintained, but as a result of tight joints and no through holes, the need for a sealing skin has been eliminated. The construction is more robust in most areas, with a sturdier ear piece design. The locking tabs are designed with a low profile, and supplied pre-bent with special tooling for installation.

ID Tube Clean

The ID cleaning of the tubes has been subcontracted to AECL and uses a shot blasting processes similar to that used in a number of Bruce B steam generators. Although the process has been used successfully elsewhere, this will be the first time it has been attempted in U-tubes which open up.

FINDINGS AND ASSESSMENTS

Tube to Support Fretting

Inspections completed to date have revealed a limited amount of tube to support fretting. Most preheaters have a small number of frets, typically less than ten per vessel detected. Maximum fret size was 33%, and the majority of frets are less than 20% tw. With some exceptions, fretting appears to be concentrated in peripheral tubes.

It appears that fretting does not pose a significant risk to extended operation of the preheaters. Monitoring inspection will be required to track the growth of the existing frets and to monitor for new degradation, but

it is unlikely that significant plugging will be required because of this degradation mechanism within the planned life of the preheaters.

Debris Fretting and Possible Loose Parts

Although no evidence of debris fretting was detected, a small number of possible loose parts were identified during eddycurrent inspection. In general, tubes with possible loose part calls were conservatively plugged to reduce the risk of debris fretting.

There has been little evidence of loose part or debris fretting in Bruce A preheaters. Although the risk is always present, and may be heightened in Units 1 and 2 as a result of extensive refurbishment, debris fretting is not expected to be a significant threat to extended operation of the preheaters.

OD Indications

A number of OD indications were detected by bobbin in peripheral tubes of Unit 2 preheater 3. In total, twenty peripheral or near peripheral tubes were affected, with the indications located in the free span near the feedwater inlet. The bobbin signal voltage was small in all cases, indicating a small defect volume and potentially questionable sizing. The majority of the indications were reported to be less than 20% tw, with a small number of indications in the 20%-40% range and a single indication with a reported depth of 71% tw. The tube with this largest indication has been removed and will be metallurgically examined to determine the degradation mechanism.

Because of the location of the indications, debris fretting or manufacturing related damage are considered the likeliest damage mechanisms. Although not detected previously in Bruce A preheaters, pitting and/or IGA are present to a limited extent in Bruce B preheaters and have not been eliminated as potential causes of these indications.

As an interim measure, indications >20% throughwall were removed from service and it is anticipated that this preheater will be reinspected at the first scheduled outage following restart. Final determination of the degradation mechanism will be made after the metallurgical examination has been completed.

Obstructed Tubes

A number of tubes were obstructed to inspection in the preheaters. The majority of these obstructions were due to the interference between the manway/davit arm and the inspection arm. In the later inspections new tubesheet mounted arms were deployed which were able to access more tubes. In Unit 1 preheater 3 a number of tube ends were dented and the tubes were obstructed. The tube end damage appears to have been caused during previous maintenance activities and does not indicate in-service degradation.

Miscellaneous Eddycurrent Indications

A small number of tubes were reported to have distorted roll indications by bobbin. These tubes where further inspected with X-Probe and found to have no detectable degradation.

A small number of tubes were reported to have unexpanded tubes within the tubesheet. These tubes where further inspected with X-Probe and found to have no detectable degradation.

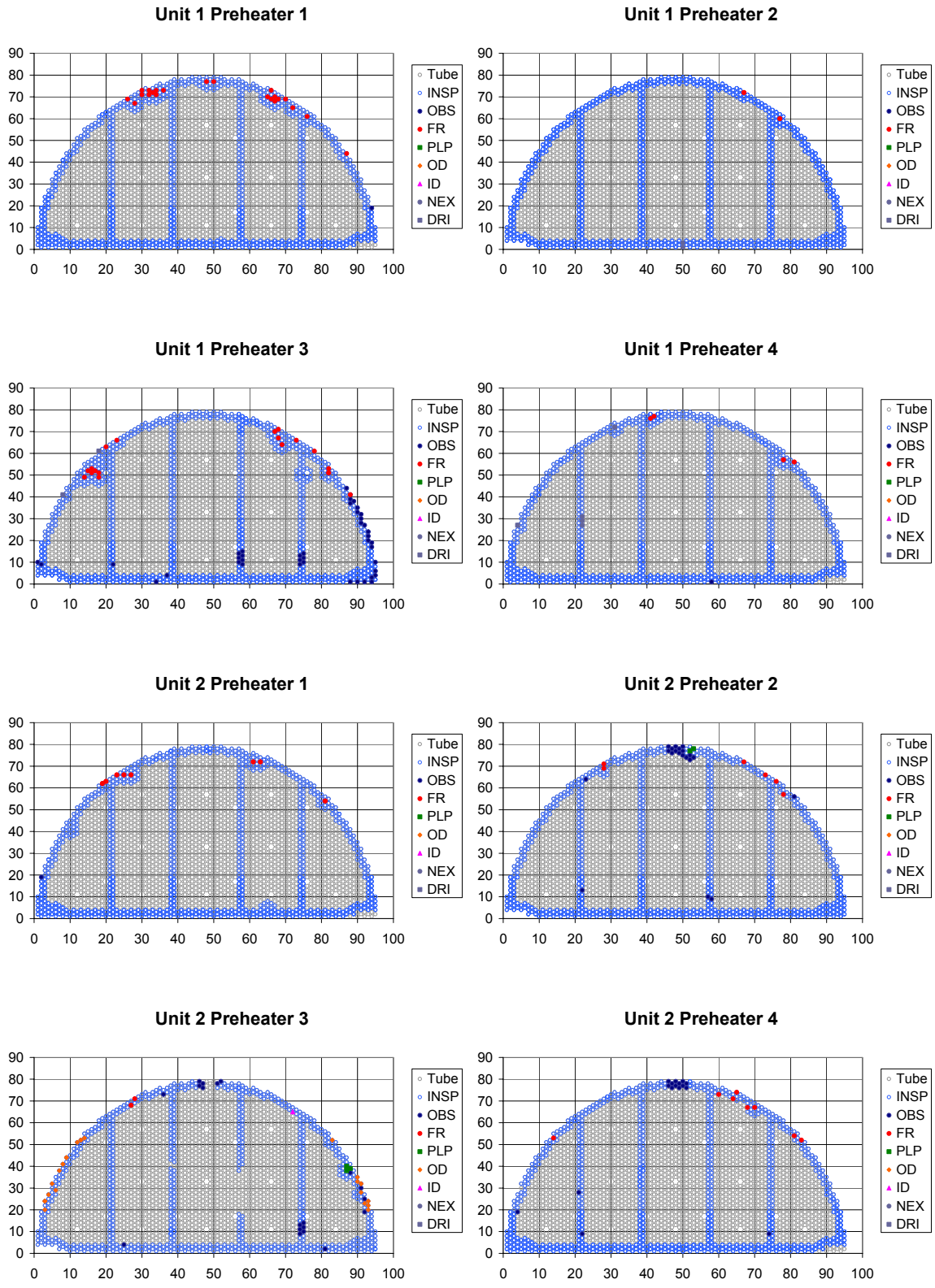

Figure 5 – Eddycurrent Indications

Secondary Side Condition

Visual inspection of the secondary side internals, conducted through removed tube holes revealed generally good conditions, with no significant corrosion or deposits detected to date. Inspection of the U-bend support structures through the drain nozzle is scheduled, but has not been completed at this time.

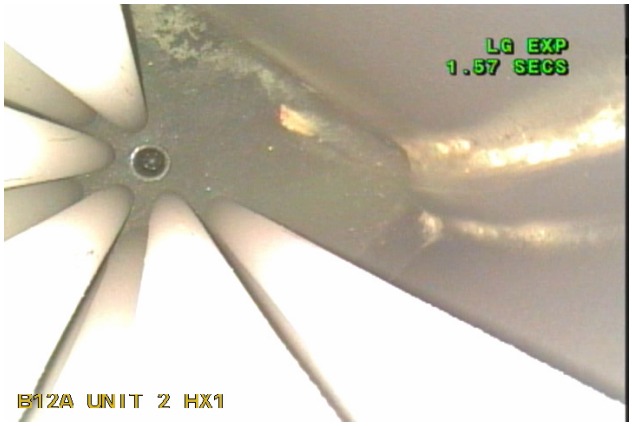

Figure 7 – Preheater Secondary Side (Tubes, Baffle Plate, Shroud and Divider Plate)

Figure 6 – Preheater Secondary Side (Tie Rod Location on Baffle Plate)

DISCUSSION

Generally, the Bruce A preheaters are in very good condition, with no secondary side findings indicative of in service degradation. Tube to support fretting is present to a limited extent, and periodic inspection will be required to monitor fret growth, but the expectation is that tube plugging because of support fretting will be easily manageable over the planned life. Final resolution of the degradation mechanism which caused the OD indications is required; however, the limited extent of degradation provides some assurance this will not be a life limiting concern.

The corrosion resistant replacement divider plate is expected to maintain good performance without risk of significant in-service degradation. Thermal performance will be restored to near design through ID tube cleaning.