FUEL HANDLING SOLUTIONS TO POWER PULSE AT BRUCE NGS A

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ABSTRACT

In response to the discovery of the power pulse problem in March of 1993, Bruce A has installed flow straightening shield plugs in the inner zone channels of all units to partially reduce the gap and gain an increase in reactor power to 75% FP. After review and evaluation of solutions to manage the gap, including creep compensators and long fuel bundles, efforts have focused on a different solution involving reordering the fuel bundles to reverse the burnup profile. This configuration is maintained by fuelling with the flow and providing better support to the highly irradiated downstream fuel bundles by changing the design of the outlet shield plug. Engineering changes to the fuel handling control system and outlet shield plug are planned to be implemented starting in June 1996 thereby eliminating the power pulse problem and restrictions on reactor operating power.

1. INTRODUCTION

1.1 Fuel String Relocation Effect

Fuel channels in CANDU 850 MW reactors each have a 13 bundle fuel string which is supported against the flow at the downstream or channel outlet by a latch. The latch consists of four spring fingers which contact the ends of several peripheral fuel bundle elements comprising the fuel bundle. On-power fuelling is achieved by pushing in fresh fuel bundles against the flow through this latch into the fuel channel, displacing spent fuel out into the upstream fuelling machine.

Initially, the fuel bundle at the inlet end of the fuel channel is partially supported within the skirt of the inlet shield plug. In time, as the pressure tube creeps and elongates, the inlet fuel bundle eventually rests fully in the pressure tube, widening the gap between it and the inlet shield plug. This gap can be as large a 15 cm (6 in).

One of the design basis safety analysis accidents which sets the most demanding requirements on speed and reactivity of the shutdown systems is the large break loss of coolant accident (LOCA). A LOCA can lead to a rapid power increase due to positive reactivity arising from draining of coolant from the fuel channels. This is followed by a rapid power reduction once the trip initiates and the shutoff rods and/or poison injection are activated.

A postulated failure of a reactor inlet header causes a reversal in the channel pressure drop, simultaneously driving the fuel bundles in a large number of channels against the inlet shield plug all in a fraction of a second. This relocation of the fuel bundles to the inlet end introduces positive reactivity as fresher more reactive fuel replaces more irradiated fuel in the central high flux region. The reactivity is proportional to the size of the gap or the relocation distance. Therefore, in addition to the positive reactivity introduced by coolant voiding, the relocation affect causes the "power pulse" to increase in magnitude. Without further confirmation and modeling, the effectiveness of the shutdown systems could only be guaranteed at lower operating power levels.

1.2 Discovery of Power Pulse

Methods of preventing pressure tube fretting at the inlet rolled joint burnish mark was the subject of investigation in the late 70's and early 80's. Studies were initiated to investigate the consequences of removal of the 13th fuel bundle. Consideration was given to the higher reverse impact velocity effect on the integrity of fuel bundles, fuel channels and the calandria structure and limited reactor physics implications. Reverse flow bundle acceleration tests done in 1989, confirmed the potential for rapid fuel string movement. A proposal was made in 1992-1993 to remove the 13th inlet fuel bundle at Darlington to address abnormal fuel support fretting. In response to an AECB question regarding the reactivity effect, analysis of a large break LOCA caused by a postulated inlet header failure for this configuration revealed the significance of the power pulse for a 12 bundle fuel channel. Subsequently, the analysis was extended to address current gaps and found to be a concern for the operating reactors. Until further design review and analysis was completed, Ontario Hydro took a conservative approach where all CANDU 850 MW units, including Bruce A were derated to 60%FP to re-establish acceptable shutdown system margins. Differences in reactor core physics in Bruce B, allowed an uprating back to 80%FP at that station. At Darlington, the reactivity increment was accommodated within available safety margins and the derating was subsequently removed. One contributing factor for Darlington is the dual figure of eight loop primary heat transport system configuration which limits the number of channels affected by a postulated inlet header failure to 120 channels as opposed to 240 channels at Bruce A and B. Another factor of significance is the small gap in Darlington fuel channels due to the short P/T creep life to date.

2. SOLUTIONS

2.1 Background

To eliminate the postulated "power pulse" concern and return the derated reactors back to their high power levels of operation, a multidisciplinary team was setup to define the best alternate design, safety and operational solutions.

Solutions fell into two basic categories; those that served to reduce and/or manage the size of the gap and those that eliminated the insertion of positive reactivity. After evaluation of a number of potential solutions, several options were pursued in parallel. Gap management has been pursued at all three stations, however because of its uniqueness, Bruce A has adopted a separate long term approach.

3. GAP MANAGEMENT

To quickly reduce the gap and allow a commensurate increase in power, two gap management solutions, creep compensators (CC) and flow straightening inlet shield plugs (FSISPs) were considered.

3.1 Creep Compensators

3.1.1 Design

Installation of a cylindrical spacer in the downstream latch serves to relocate the fuel string upstream and reduce the size of the gap at the inlet. The spacer or "creep compensator" varies in length by 1.3 cm (0.5 in) increments, reducing the inlet gap from 3.8 cm (1.5 in) to as much as 15.2 cm (6 in) depending on the amount of creep in the particular fuel channel. The increasing gap size caused by pressure tube creep could be compensated for by installing an incrementally larger size of creep compensator. The cylindrical CC is held in the downstream latch fingers by a shoulder on the outer diameter. The upstream end is shaped to match the outer two rings of a fuel bundle end plate and reacted the 6675 N (1500 lbf) hydraulic load of the fuel string through the downstream end plate of the 1st fuel bundle. The coolant flow goes down through the center or through 10 angled elliptical holes in the wall of the cylinder near the upstream end. The pressure drop across this end of the fuel string actually reduces slightly with the installation of a creep compensator because the flow is effectively redirected away from the latch fingers.

3.1.2 Installation

The creep compensator installation tool occupies a magazine position and functions to install and remove the CC from the downstream fuel channel latch. It consists of a fuel carrier, which is picked up by the fuelling machine ram and charge tube assembly, and is capable of opening the channel latch. Within the carrier is a spring loaded plunger assembly which interfaces with the ram. The front of the plunger is fitted with spring loaded fingers which engage with the CC. During removal of the CC, the ram and plunger are advanced, engaging the fingers with the CC and pushing the fuel string upstream off the latch. The charge tube advances the carrier, opening the latch. The ram is then retracted to a given position. The carrier is then retracted, closing the latch onto a taper on the upstream end of the CC. Retracting the ram then allows the latch to close and support the fuel string. Installing the CC, simply involves advancing the ram and plunger with the CC attached, until the latch fingers close into the groove on the outside of the CC. The ram is then retracted, whereby the spring loaded fingers engaged with the CC are pulled free from the CC by the larger spring force of the plunger. The removal and installation activities requires approximately 10 minutes each to complete.

3.1.3 Outcome

The viability of this concept was jeopardized by the additional 20 minutes of fuel handling time required to remove and reinstall the CC for each channel fuelled and the loss of one magazine position. Fuel handling time was also required to replace CC's with longer ones to account for P/T creep. This 24% reduction in capacity could not be tolerated by the two trolley fuelling system at Bruce A when operating at high reactor powers. The third, or south extension trolley has been removed from fuelling service and dedicated to the fuel channel spacer location and repositioning (SLAR) rehabilitation program. Consequently, this solution was abandoned at Bruce A and at other stations.

3.2 Flow Straightening Inlet Shield Plugs

3.2.1 Design

The existing fuel channel inlet shield plug (MKIIIA) was modified to a MKIIID flow straightening inlet shield plug by crimping a flow straightener in the shield plug skirt. The primary function of the shield plug is to provide radiation attenuation. It is removed during fuelling operations and otherwise remains engaged with the liner locking lug in the fuel channel. The flow straightener is a solid disc made of low cobalt modular ductile iron, identical to the shield plug material, 10.3 cm (4 in) in diameter and 4 cm (1.6 in) thick, with 121 flow holes, 6.3 mm (0.25 in) in diameter (figure 1). This insert provides a flow straightening function which has been proven to reduce flow turbulence and fuel bundle inlet fretting[1]. It also provides a one time reduction of 4 cm (1.6 in) in the size of the gap.

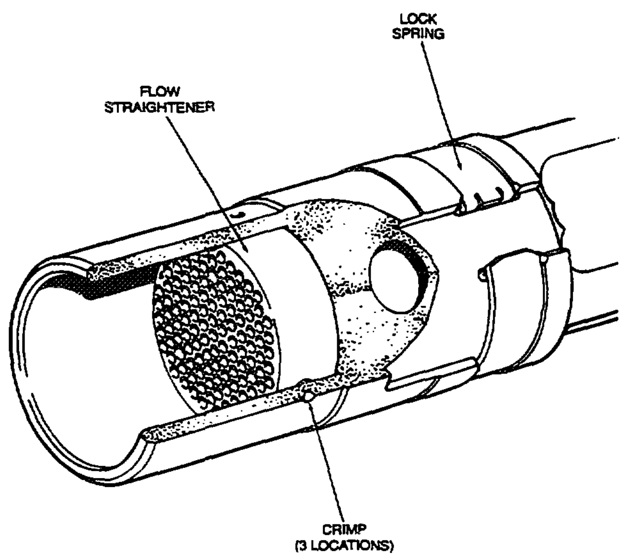

Figure 1: Flow straightening Inlet shield plug.

3.2.2 Installation and Commissioning Operations

Crimping machines used to install and crimp the inserts into the shield plugs were installed and commissioned on the fuel bay gantry.

The FSISP crimping campaign was initiated by taking a dedicated trolley to the target unit, where each fuelling machine (F/M) head installed 8 new inlet shield plugs complete with crimped insert and removed 8 regular inlet shield plugs, taking approximately 1 hour per channel visit. These 16 new FSISPs were removed at the end of the campaign and stored for use on the following unit and finally sent for disposal. One control room fuel handling operator operated the dedicated trolley. Two F/M heads were locked onto the ends of the channel for each inlet shield plug removed or installed in order to perform a pressure drop measurement ensuring no flow blockage. Channel outlet temperatures were also monitored for the same purpose. The trolley was then taken to the central service area and the F/M heads locked onto the east and west ancillary ports. On the bay side, one crimping machine was aligned with one of the ports and prepared to receive the shield plugs. On average, 2 field operators worked in the fuel bay area, operating the crimping machines. The fuelling machine ram and charge tube assembly picked up a shield plug and pushed it through the port to the crimping machine. An flow straightener insert, cooled in liquid nitrogen, was then remotely installed into the skirt and 3 crimps were applied to the outside of the skirt. The flow straightener was therefore secured by the combination of the shrink fit and the crimps. The plug was then retrieved back into the fuelling machine head and the process was repeated for the next and remaining shield plugs in that head.

When all 8 plugs were modified, operations were completed for the shield plugs in the opposite F/M head. The trolley then returned to the unit with each of the 2 F/M heads carrying 8 modified shield plugs which were then swapped for regular shield plugs. The process was repeated until all 280 inner zone fuel channel inlet shield plugs were modified.

3.2.3 Outcome

Early in the installation campaign on the first targeted unit, after approximately 1 week of operations, the crimp depth on test coupons (1 test coupon every 8 shield plugs) began to wander out of specification. A delay of 2 months was incurred resolving this problem.

Typically, the process of installing 16 FSISPs and removing 16 regular shield plugs took 16 hours. The fuel bay crimping operations for the 16 shield plugs took approximately 4 hours. On average, accounting for shift change and breaks, the rate of processing was 80 shield plugs per week. The total effort (engineering and operations) associated with conversion of 4 units required approximately 12,000 man-hours with a dose expenditure of 1.97 rem.

Flow Straightening Inlet Shield Plugs installed in the 280 inner zone channels of all 4 units at Bruce A permitted an increase in reactor power from 60% FP to 70% FP. Subsequent additional safety analysis permitted a further increase to 75%FP. Table 1 shows the dates for completion of installation of FSISPs and subsequent increases in reactor power.

3.3 Long Fuel Bundles

To eliminate the "power pulse" concern, two long term solutions; long fuel bundles and fuelling with the flow (FWF) were devised. Bruce B opted for the long fuel bundle solution, thereby controlling the gap, while Bruce A chose to eliminate the problem by adopting FWF. Lower channel flow rates made the FWF option undesirable at Darlington.

3.3.1 Design

Loading a fuel channel with a combination of regular fuel bundles and bundles that are 1.3 cm (0.5 in) longer than regular fuel bundles (long fuel bundles) results in a fuel string length that can be managed to minimize the inlet gap and position the 13th bundle bearing pads away from the burnish mark. This solution therefore addresses the power pulse problem as well as preventing bearing pad interaction with the highest stress area of the pressure tube. The

Unit	3	1	2	4
FSISP Installation Complete Date	January 1994	February 1994	March 1994	July 1994
Reactor Power to 70%FP	March 1994	March 1994	April 1994	August 1994
Reactor Power to 75%FP	October 1994	October 1994	October 1994	October 1994

Table 1 - Flow Straightening Inlet Shield Plug Installation and Power Increase Dates

design of the long fuel bundle is identical to the regular fuel bundle except the distance between the center bearing pad and the intermediate bearing pad on each side of the bundle center line is increased by 6.3 mm (0.25 in). This design has been tested in-reactor and approved for use.

3.3.2 Installation

Although it is desirable to minimize the average core gap from a power pulse perspective, it is also necessary to ensure that the gap in any one fuel channel does not get smaller than a specified minimum gap size. A postulated large break LOCA causes the fuel string to expand and therefore reduce the gap. If the gap is too small prior to the event, the fuel string expands into compression which may lead to pressure tube failure. The gap management system must therefore continually function with high reliability to ensure that the average core gap is maintained low enough to prevent power pulse yet not exceed the allowable minimum gap size in any one fuel channel. Channels are fuelled with sufficient long fuel bundles to prevent fretting on the burnish mark and reduce the gap at the inlet. During the normal course of fuelling, spent long fuel bundles removed from the channel must be replaced and additional long bundles installed to account for pressure tube creep. However at the same time, the inlet gap in each fuel channel must be maintained greater than the minimum allowable gap size. This management system impacts a number of work group activities i.e. new fuel loading, spent fuel storage, generation of fuel change orders, fuel handling.

3.3.3 Outcome

Pressure tube fretting at Bruce A has been identified as a concern, however, levels of fretting are more severe at sister stations. The installation of the FSISPs in the inner zones of all units will help to minimize fretting damage.

The core physics at Bruce A is different than sister stations. The unique peaked neutron flux makes the response to fuelling operations more difficult to simulate and reduces the ability to accurately predict in advance, fuelling sequences long enough to allow for the required control of long fuel bundle fuelling.

Also, the requirement for a minimum gap has great potential to limit the maximum achievable power output from the Bruce A units. A minimum gap size 3.2 cm (1.25 in) would be required to achieve 92%RP which is the full electrical equivalent of the Bruce A units. The currently approved minimum gap size is 5.1 cm (2 in).

This gap management solution utilizing long fuel bundles was not pursued at Bruce A. However, Bruce A has pursued a contingency plan involving the loading of one long fuel bundle at one time into all inner zone channels to gain a temporary reduction in average core gap without violating the minimum gap requirement of 5.1 cm (2 in). This would permit an increase in reactor power to 80%FP for a period of time. Although approval has been received to proceed with this program, Bruce A has chosen not to implement it at this time.

4. REVERSAL OF FUEL BURNUP PROFILE

4.1 Fuelling With The Flow

Changing the direction of fuelling from against the flow to with the flow, can be used to maintain a reversal of the fuel burnup profile. The most irradiated or spent fuel bundle would reside at the outlet end of the fuel channel and the new fuel at the inlet. Therefore, given the postulated inlet header failure, the relocation of the fuel string would introduce negative reactivity as irradiated fuel would replace newer, more reactive fuel in the central high flux region. The size of the inlet gap would no longer be of concern and the remaining power pulse caused by voiding could be negated by the shutdown systems. There has also been some indication that having new fuel at the inlet of the channel does not cause fretting damage to the same extent as highly irradiated fuel[2]. After reviewing the alternatives and performing business case evaluations, Bruce A has committed to resolve the power pulse problem by pursuing reordering the fuel bundles and FWF.

4.1.1 Design

Prior to implementing FWF, it is necessary to reverse the order of the fuel bundles in the fuel channels. Without doing this, the most irradiated fuel would be pushed back through the core, causing a loss in reactivity and subsequent shutdown. In addition, new fuel string supporting shield plugs were designed to prevent fuel bundle end plate cracking during a hot shutdown once the channels have been reordered. These are discussed in following sections.

Software design changes to the fuel handling control system, namely the controller software, protective software, operations and sequences, control console, termination cabinet and wiring are required to implement a fully automatic operation of the FWF process.

Control software changes have been made to permit synchronization of the rams based on encoder inputs. A channel status map is contained within the control software, to record the state of various channel parameters. The status for each fuel channel is updated as changes are made such as new shield plugs installed, channel reordered and channel ready for FWF. Also the map is automatically interrogated prior to a change being made, in order to verify that the change is appropriate. This verification step serves as one of at least two barriers to performing erroneous operations.
The fuelling machine ram encoder signals have been directly wired from one control 'quadrant' to the controller of the other fuelling machine on the trolley, to provide better ability to track the ram motion of the other machine for FWF. Additionally, signals have been wired between the systems which indicate status of ram brakes and clutches and facilitate ram and fuel position sensing. Power supply and brake release logic changes have been made to ensure the brakes will hold the fuel string during a Class III or IV power failure.

New outputs have been assigned to command the redundant brakes added for fuelling machine ram and charge tube axial and rotary drives. These F/M signals are used in the control and protective logic to prevent applying excessive forces to the fuel string. Protective software changes include additional interlocks to ensure latch operation and the fuel is not damaged. A separate set of protective logic has been provided for 'abnormal' or maintenance operations.

The operating data includes new sequences and operations that define FWF operation. The sequences for fuelling against flow have been retained since during the transition to FWF, both modes of fuelling will be required.

Console panels have been modified to add the protective normal and abnormal indications and the redundant ram, charge tube axial, and charge tube rotary brakes. Interlock bypass switches have been allocated for FWF and charge tube rotary interlocks. All operations executed by the control computer, as well as those executed manually while the controller is active will be logged. This information will be used for confirmation of proper completion of operation if manual intervention becomes necessary.

The fuelling carriers required modification to permit them to open the latches and a taper is required on the back of the ram head to allow it to return through the latches.

Basically all design work was done by General Electric Canada and commissioning and testing done by Bruce A Fuel Handling Operations. Bruce A Engineering Services Department functioned as the design authority.

4.1.2 Installation, Commissioning and Testing

In order to permit installation and commissioning of FWF without adversely affecting the north and south trolleys from normal fuelling or to adversely affect fuel handling outage support work several initial changes were required. The purpose of these changes was to have the trolley quadrants converted to a state where changing from FWF commissioning mode over to regular fuelling mode on a frequent basis could be done expeditiously. These changes were declared in-service in May 1995.

Commissioning work plans were prepared based on GE commissioning test specifications by Fuel Handling Technical. The work plans were implemented by the Fuel Handling Operations shift crews. Completed commissioning work plans were reviewed by Fuel Handling Technical and GE.

Due to the demands on Fuel Handling systems and resources to provide regular fuelling for 4 units at 75%FP with 2 trolleys, subsequently reduced to 3 units, support outage work such as defuelling channels for CIGAR inspections and mini-SLAR operations, supply fuel handling operators to SLAR operations, defuel unit 2 and perform preventative and forced system maintenance, progress on commissioning FWF software has been delayed. A total of approximately 13,000 man-hours of engineering and operations labor have been used to date to perform FWF commissioning related activities which commenced in late 1994.

4.1.3 Status and Plans

A full set of interlock checks and follow-ups have been completed on the south trolley. The north trolley system interlock checks are scheduled for May 1996. Controller software checks, follow-ups and tests have been completed. North and south trolley protective checks have also been completed.

The FWF control and hardware changes were tested on the Maintenance Area Test Facility and the Service Area Rehearsal Facility. These facilities provide the necessary mockups to test the interface between the fuel handling system and fuel channel components. An on-reactor test is also planned. Two outer zone channels will be fuelled with new fuel (done to reduce contamination if fuel damage occurs) and FWF operations will be fully tested.

Hardware modifications to the fuel handling carriers and ram heads were completed at site with components designed and supplied by GE.

Fuel Handling operations staff have been trained. Operating documentation has been revised. The Operations ECN walkdown and design authority approval is expected to be completed in the second quarter. Submissions have been made to the AECB and approval is expected prior to the putting FWF in-service by the end of the second quarter.

4.2 Reordering

Reordering reverses the burn-up profile in each channel so at the next fuelling visit, the channel can be fuelled with the flow. Bruce A undertook extensive design and safety analysis to support the selected reorder scheme. In addition, a reorder trial was performed to test the selected reorder process.

4.2.1 Design

The selected reorder scheme is a 12 bundle cascade which is done against the flow. The process is started by displacing 12 fuel bundles in the seed channel with new and depleted fuel. The fuel from the seed channel is then loaded into a neighboring channel, in order, with least irradiated first to most irradiated last. The displaced fuel is then loaded into the next channel and the cascade continues for approximately 14 channels. The final channel loaded is the original seed channel. The displaced new and depleted bundles are then used to fuel for reactivity gain as usual. The Bruce A Fuel and Physics section are responsible to conduct SORO simulations predicting maximum channel and bundle powers during the reorder push of the selected channels to be reordered.

4.2.2 Testing

Reordering of fuel bundles using the 12 bundle cascade scheme while at power was analyzed to show that the degree of power ramping of high burnup bundles would not lead to increased fuel defects. However, a reorder test was done to verify the conditions and parameters under which production reordering will be performed. In August of 1995, fuel bundles from 12 channels containing F3SPs were successfully reordered in unit 4. The conclusions were that the test confirmed predictions and verified limits pertaining to the reactor regulating system, maximum channel power peaking factor, maximum channel power, neutron overpower protection and fuel performance. A FWF Reorder Specification has been prepared incorporating test results which specifically describes the conditions and parameters under which reorder will be safely performed.

4.2.3 Plans

It is planned to reorder the 280 inner zone channels on each unit at a power level of approximately 70%FP before returning to complete the 200 outer zone channels for safety and economic reasons. Based on the reorder trial on unit 4, it is estimated that the reordering of one unit will take approximately 9 weeks. A dedicated fuel handling trolley will be used to reorder batches of approximately 14 channels at a time, with about 1 to 2 days of regular fuelling between batches. The fuelling for reactivity gain between reorder batches will be either fuelling against the flow or fuelling with the flow. Therefore, reordering will not commence until FWF has been declared in-service and new fuel string supporting shield plugs installed.

4.3 Fuel String Supporting Shield Plugs

4.3.1 Design

The most significant impact of reordering and FWF, is the relocation of the most irradiated fuel bundle from the inlet to the outlet. The outlet bundle is supported by the latch fingers reacting against the outer elements of the most downstream fuel bundle and is subjected to the highest hydraulic load (6675 N). Although fuel bundle end plate cracking due to PHT pump pressure oscillations had not been seen in Bruce A reactors, a test was done to confirm the integrity of highly irradiated bundle end plates in this new configuration. In the fourth quarter of 1993, 12 fuel bundles were positioned in the reverse flow direction into fuel channel position #1 after cycling through the reactor in Unit 2 and left there for 7 weeks of operation. They were removed from the core after a hot shutdown. External visual inspection of the end plates showed no through wall cracking. However, a short time after the completion of the design review for FWF, scientists at Ontario Hydro Technologies warned against the potential for delayed hydride cracking in the highly stressed fuel bundle end plate during a hot shutdown. A total of 6 fuel bundles from the test and 2 control bundles were sent to Chalk River Laboratories for destructive examination. The 6 bundles displayed numerous cracks, up to several millimeters into the spigot to end plate weld. As a result, a change to the design of the outlet shield plug was made to fully support the outlet fuel bundle end plate, reduce the stress and prevent cracking.

A nosepiece was designed to be added to the front of the body of the existing outlet shield plug to fully support the end plate of a fuel bundle against the hydraulic load on the fuel string (figure 2 see next page). The 410 stainless steel nosepiece is a cylindrical arrangement which fits over the end of the existing cast iron shield plug body, increasing its length by approximately 7.6 cm (3 in). It is attached to the body by a special bolt which limits the nosepiece to rotation on a thrust bearing. The back of the nosepiece is keyed to the shield plug liner locking lug during installation and removal thus preventing relative motion between the nosepiece and the fuel bundle. A formed leaf spring in the back of the nosepiece provides a detent between the nosepiece and the shield plug body. This ensures that nosepiece orientation, relative to the shield plug, will be correct during installation.

New shield plugs have been manufactured and delivered to site. It is planned to replace the existing outlet shield plugs with the new F3SPs. A shield plug handling system designed by GE, has been installed and commissioned in the fuel bay. This system is used to handle and load the F3SPs and old shield plugs. Modules, each holding 8 F3SPs were designed for transportation, storage and handling. The module consists of 8 horizontally arranged tubes which are welded to a handling frame. Locating lugs in each tube serve to control the orientation of the F3SP which facilitates pickup by the fuelling machine ram and charge tube assembly.

The modules are handled in the fuel bay by a module handling tool which is suspended from the fuel bay crane. The handling tool provides shielding and functions to attach to the module frame and rotate in a horizontal plane. The fuel bay crane has been modified to permit remote infrared control to reduce radiation dose to the operator. Modules are lifted by the handling tool from the 615' elevation up to positioning

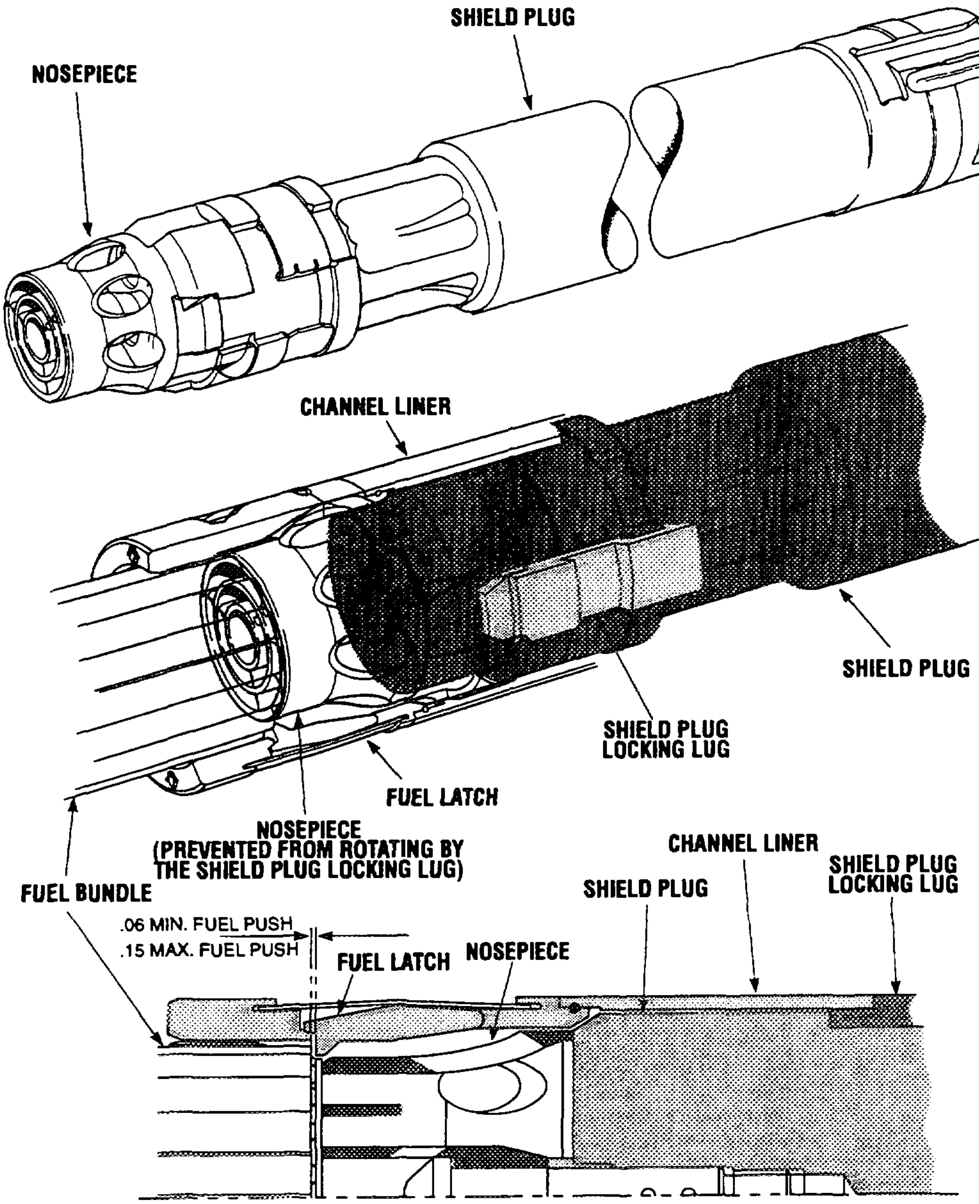

Figure 2: Fuel string supporting shield plug.

mechanisms, mounted on each end of the fuel bay gantry. The positioning mechanism supports and shields a module and positions the module tubes with respect to the ancillary port. The positioning mechanisms are also operated by remote infrared controllers.

The fuelling machine exchanges old shield plugs for new F3SPs at the ancillary ports. The modules containing the old shield plugs are loaded into shielded storage containers located on the 615' elevation. Each container holds 14 modules (112 shield plugs) and when full will be transported to the Radioactive Waste Operations Site (RWOS) for storage in concrete trenches. Lifting beams have been provided to handle the containers by both the fuel bay crane and the crane used at the RWOS. The module handling tool is also used to handle the shielded lids on the container. Specially designed portable steel tanks (1.2 m wide by 0.8 m thick by 1.9 m high) containing water are used to provide additional shielding for the storage containers and the control center. A number of video cameras have also been strategically located to facilitate operations when handling the old radioactive shield plugs. The control center is located at the extreme north end of the fuel bay so that both the activities on the 615' elevation and at the fuel bay level can be seen by the operators. Video monitors, infrared controllers for the fuel bay crane and positioning mechanisms and electrical controls for the module handling tool are located at the control center.

4.3.2 Testing and Installation

An extensive out-reactor testing program was conducted to verify the performance characteristics of the new shield plug and the impact on interfacing components such as the fuel channels components and fuel. Parameters tested included pressure drop, vibration, strength and crudding. Functional tests were performed on MATF to confirm the fuelling machine and fuel channel interface. A total of 14 prototype F3SPs were used in a delayed hydride cracking test in-reactor prior a unit 4 outage in March 1995. Each prototype supported highly irradiated fuel bundles which were subject to a hot shutdown. These bundles were then defuelled and inspected by a specially designed ultrasonic end plate inspection tool developed at Ontario Hydro Technologies. Underwater fuel bay inspections using this tool showed no cracking. The results were confirmed by sending a number of these fuel bundle elements with controls to Chalk River Nuclear Laboratories for destructive examination. Controls were selected from the previous unit 2 test bundles which displayed cracking.

Changes to fuel handling control software necessary for the installation and removal of the F3SP were included in the latest release of the FWF control software. Specific opdata testing has also been completed. The channel status map will also be used to monitor the installation of the F3SPs and serve as a barrier to preventing erroneous operations.

The shield plug handling system has been installed and commissioned. Training of fuel handling operators is complete.

4.3.3 Plans

It is planned to start installation of F3SPs into the 280 inner zone channels of the first unit this summer and complete all three unit inner zones by the end of the year. This is a prerequisite to reordering. A dedicated trolley will be used on a continuous basis to remove the old shield plugs and install the F3SPs. Based on experience with the FSISP program, it is estimated that the inner zone of one unit can be completed in 2 weeks. Once all inner zones are complete, the 200 outer zone channels will be converted by the first quarter of 1998 for ease of configuration management.

5.0 CONCLUSIONS

The impact of the power pulse problem on the production of electricity at Bruce A over the past 3 years has been significant. Although almost all station work groups and several Ontario Hydro service organizations have been affected to some degree, the Fuel Handling section has experienced a extraordinary demand on human and equipment resources. Not only were solutions born, but developed and ultimately will be implemented by them. The engineering changes to the fuel handling system to convert to fuelling with the flow were interrupted in August 1994 with the discovery of the end plate cracking problem. The need to replace outlet shield plugs with a new design has added to the work load and resulted in delays to the schedule. It remains as a challenge to Fuel Handling in next two years, to implement power pulse solutions by installing F3SPs, reordering fuel bundles and placing FWF in-service, in addition to supporting SLAR outages and providing normal fuelling in order eliminate reactor operating power restrictions imposed by the power pulse problem.

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