SLARette MARK 2 SYSTEM

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ABSTRACT

The SLAR (Spacer Location and Repositioning) Program has developed the Technology and Tooling necessary to Locate and Reposition the Fuel Channel Spacers that separate the Pressure Tube from the Calandria Tube. The In-Channel SLAR Tool contains all the Inspection Probes and is capable of moving Spacers under remote control. The SLAR Inspection Computer System translates all Eddy Current and Ultrasonic signals from the In-Channel Tool into various graphic displays. The In-Channel SLAR Tool can be delivered and manipulated in a Fuel Channel by either a SLAR Delivery Machine or a SLARette Delivery Machine. The SLAR Delivery Machine consists of a modified Fuelling Machine and is capable of operating under totally remote control in automatic or semi-automatic mode. The SLARette Delivery Machine is a smaller less automated version which was designed to be quickly installed, operated and removed from a limited number of Fuel Channels during regular Annual Maintenance Outages. This paper describes the Design and Operation of the SLARette Mark 2 System.

1. INTRODUCTION

The SLAR (Spacer Location and Repositioning) Program developed the Technology to Locate and Reposition the Fuel Channel Spacers that separate the Pressure Tube from the Calandria Tube. The SLAR system must operate on channels with up to 100,000 EFPH (effective full power hours) and to be used on a continuous basis in an automated mode. The SLAR system was developed based on existing fuelling machine technology. The CANDU 6 SLAR Delivery Machine is shown in Fig. 1, it is slightly larger than a CANDU 6 Fuelling Machine. The SLAR Delivery Machine contains a Mechanical Ram which removes the Channel Closure and Shield Plugs and a telescopic Hydraulic Ram which deploys the SLAR Tool into the fuel channel, these two rams are indexed by means of a Turret which is attached to a conventional Fuelling Machine magazine and snout assembly. A large drum is located beneath the magazine to take up the umbilical cable which supplies the SLAR Tool.

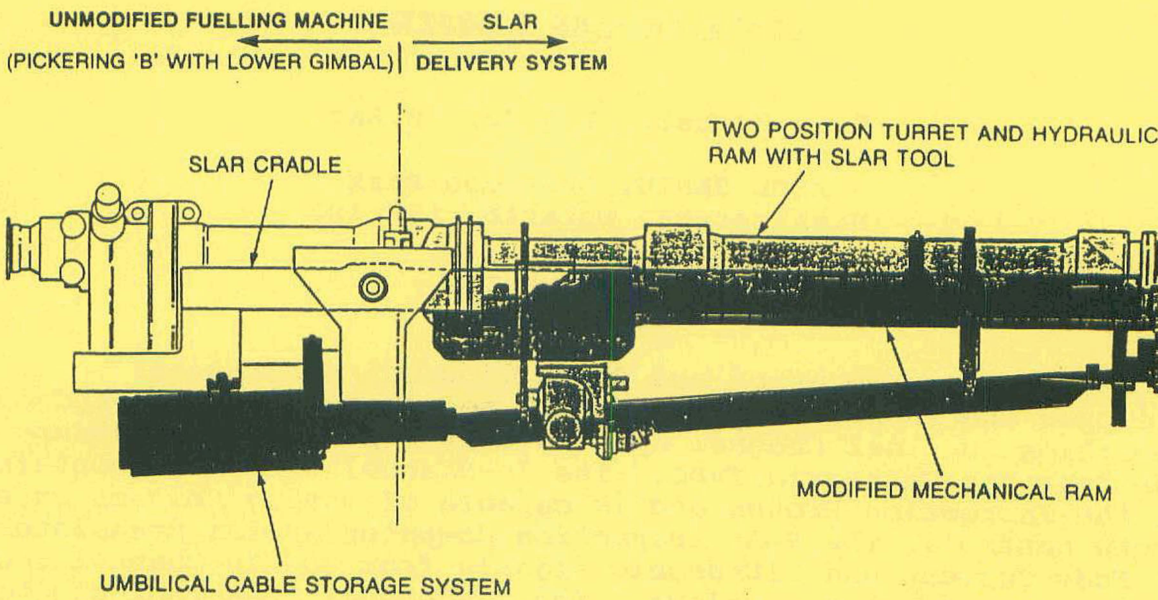


FIGURE 1 SLAR DELIVERY MACHINE

SLAR requires the removal of • Fuelling Machine which is replaced by the SLAR Delivery Machine. The SLAR Delivery Machine works in conjunction with the other fuelling machine to defuel the channel and in effect becomes part of the Fuel Handling system with the operation run from the Fuel Handling Control Console. The SLAR operating system is shown in Fig.2. It is expected that the SLARing of a complete reactor in this manner will take 3-8 months (depending on the amount of spacer movement needed).

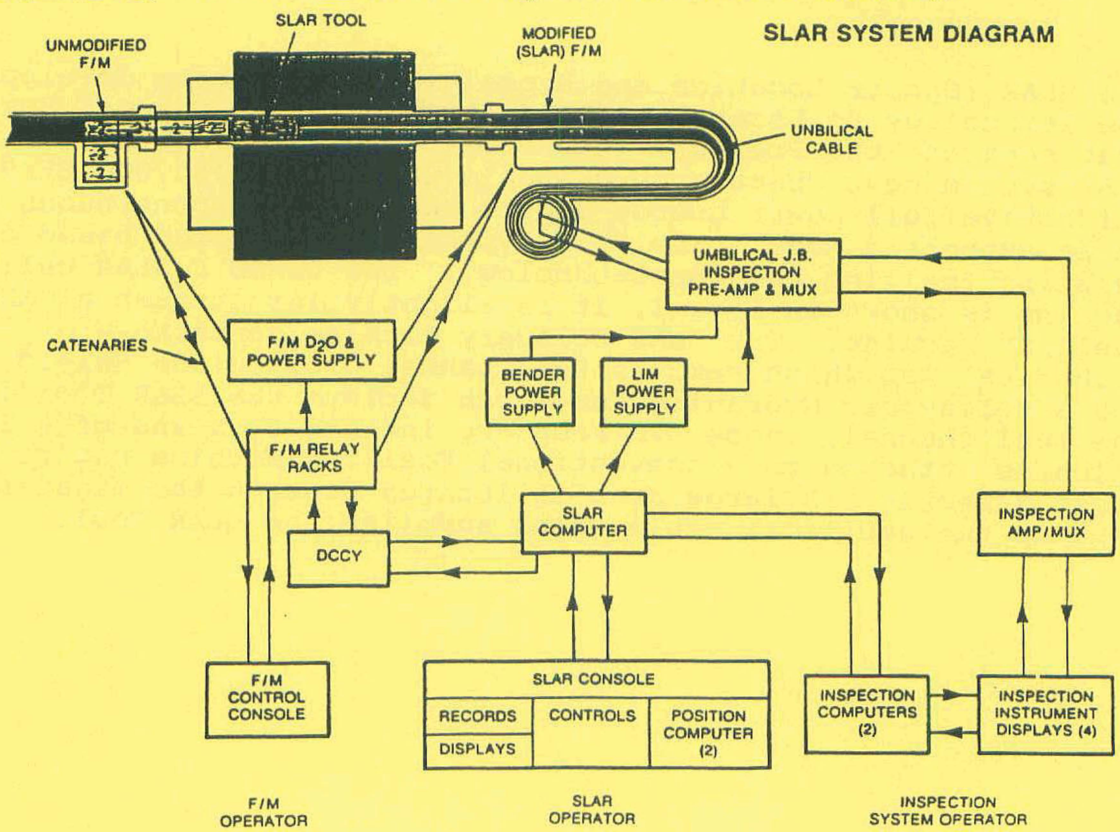


FIGURE 2: SLAR SYSTEM DIAGRAM

The SLARette system evolved from SLAR in response to a need by some utilities to avoid the long outage associated with SLAR and achieve the same results over several annual outages. The basic requirements for SLARette were therefore still to be operable on channels with up to 100,000 EFPH, to make maximum use of developed SLAR technology and to be quick and easy to install and remove.

The SLARette system as described below meets these requirements. SLARette utilizes essentially the same in channel tool and inspection system as SLAR, the SLARette delivery system is however quite different.

2. SLARette Tool

The In-Channel tools for the SLARette system are basically identical to the SLAR Tools with the exception that the Umbilical Cable is considerably longer and has no armour between the cable bundle and the urethane jacket. (Fig.3)

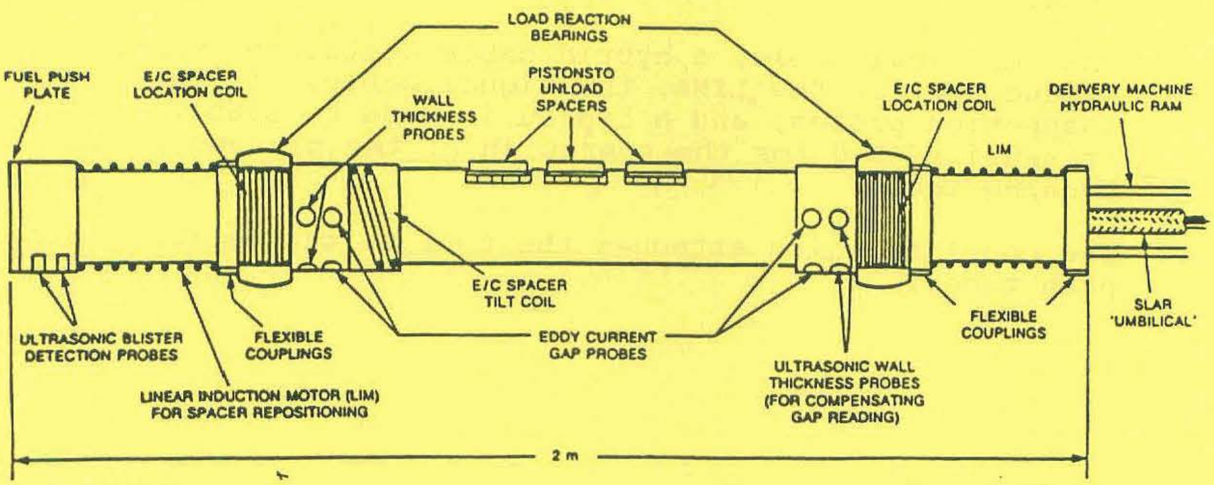


FIGURE 3: **SLAR TOOL**

The Tool is approximately 185 cm long, 8 to 10 cm in diameter, and weighs 80 kg. The Tool consists of the following components:

- A central Bending Tool for unpinching the Spacers.
- Two LIMs (<u>L</u>inear <u>I</u>nduction <u>M</u>otors), one located on each end of the bending tool, for moving unpinched spacers.

- Two Eddy Current Spacer Location Probes, mounted concentrically under the bearings of the Bending Tool.
- A Spacer tilt Eddy Current coil mounted inboard of the free end location probe.
- Four pressure tube to calandria tube Gap Eddy Current detection Probes, one mounted at each of the 6 and 9 o'clock positions, adjacent to the Location Probes.
- Four ultrasonic pressure tube Wall Thickness Probes, one mounted immediately inboard of each of the gap eddy current probes, for compensation of the gap readings.
- A cluster of six line focused Ultrasonic Blister Detection Probes, mounted on the free end of the Tool, which scan the bottom 60^{o} of the pressure tube, between 5 and 7 o'clock, for indications of cracked blisters.
- Articulated Joints at the Ram end of the Tool, and between each of the LIMs and the Bending Tool to allow the tool to be sufficiently flexible to pass through a sagged pressure tube.
- The Umbilical Cable, a hybrid cable containing the power conductors for the LIMs, the signal cables for the inspection probes, and a hydraulic hose to supply pressurized D_2O for the operation of the pistons of the bending tool.
- The coupling which attaches the tool to the delivery machine push tubes.

3. SLARette Inspection System

Schematic of the SLARette system is shown in Fig.4. Signals from the probes in the Tool are transmitted through the Umbilical Cable and processed through three Inspection System Computers and displayed to the Inspection System Operators. The SLARette Inspection System is basically identical to the SLAR Inspection System.

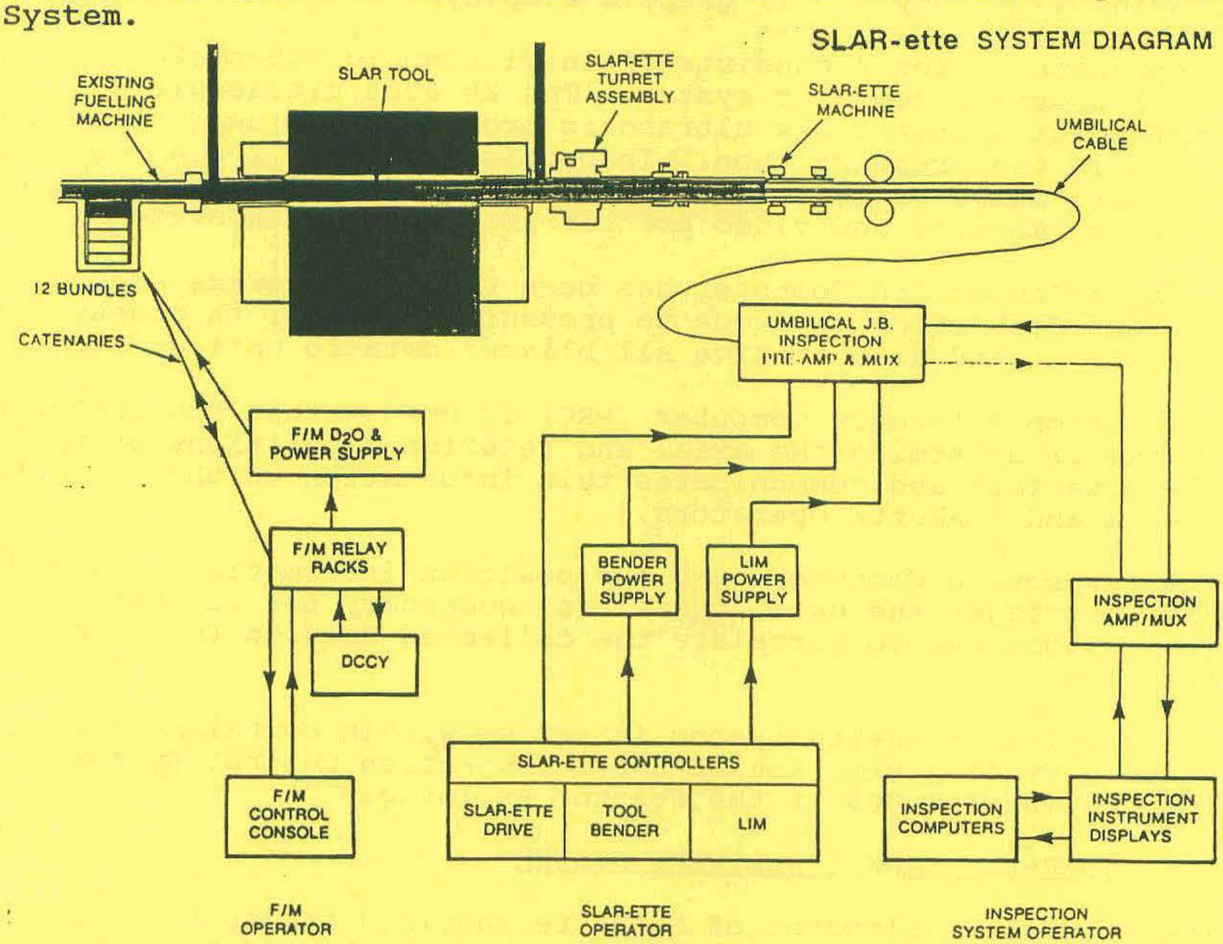


FIGURE 4: SLARette SYSTEM DIAGRAM

Inspection System 1 basically consists of an Eddy Current sub system and Ultrasonic sub system and a DEC Inspection Computer sub system.

The Eddy Current sub-system consists of transmit and receive channels and is used for spacer location, spacer tilt and gap measurements.

The Ultrasonic sub-system consists of two Novascope 3000 UT instruments for the wall thickness probes. Wall thickness data is collected from either the two Ram end probes or two Free end probes and transmitted directly in digital form to Inspection Computer 1.

The analog Eddy Current and digital Ultrasonic outputs are sent to Inspection Computer 1 which is a DEC LSI-11 computer board and module. This Inspection Computer System 1 performs all calculations and outputs a wide variety of graphic displays for the Spacer Location, Spacer Tilt and pressure tube to calandria tube Gap capabilities. A video printer is also connected to provide hard copy of all graphic displays.

Inspection System 2 consists of an Ultrasonic sub-system and a DEC Inspection computer system. The KB 6000 ultrasonic instrument operates six ultrasonic probes and is used to detect flaws in the pressure tube. Inspection computer 2 also contains hardware based on DEC LSI-11 computer boards and modules. The graphics monitor and video printer are shared with System 1.

A third Inspection Computer has been added to process eddy current distortion data due to pressure tube wall thickness variations and also archive all blister data to optical disk.

A Position Reference Computer (PRC) is used within the SLARette system to determine the axial and rotational positions of the SLARette Tool and communicates this information to the Inspection System and SLARette Operators.

The Inspection Computers use the position information from the PRC to trigger the data acquisition necessary for SLARette inspections and to correlate the collected Data to Fuel Channel position.

The complete SLARette system is set up within containment at a CANDU 6 station with the SLARette Inspection Control System located in Room 005 of the Reactor Building.

4. SLARette MARK 1 DELIVERY SYSTEM

The initial development of SLARette required feeder freezing to isolate the Fuel Channels. The Fuelling Machine defuels the channel and removes the Shield Plug and replaces the Channel Closure. Freeze plugs are then installed in the inlet and outlet feeders, a process that can take up to 15 hours. Once the adequacy of the plugs are confirmed by a hydrostatic test the Channel is drained by the downstream Fuelling Machine. At the SLARette end the Channel Closure is removed manually and the SLARette Delivery Machine is aligned and clamped onto the End Fitting. The Channel is then back flooded from the downstream Fuelling Machine and is then ready to receive the SLARette Tool.

The SLARette Mark 2 Delivery system was developed to eliminate the need for feeder freezing thereby improving the productivity of SLARette. Many of the features of the Mark 1 system have been retained or improved on in the Mark 2 version. A detailed description of the full SLARette Mark 2 system is given below.

5. SLARette MARK 2 DELIVERY SYSTEM

The Delivery System is shown in Fig.5 & 6. It consists of a Carriage/Platform assembly to support the Delivery Machine from the Fuelling Machine Bridge, an Elevating Platform to position the Delivery Machine, a Turret to provide access to non isolated fuel channels, Axial and Rotary Drives to control the position of the Tool in the channel, a Calibration Tube to calibrate the functions of the Tool and a D_2O Supply System to fill and drain the Delivery Machine. The functions of each component are described below.

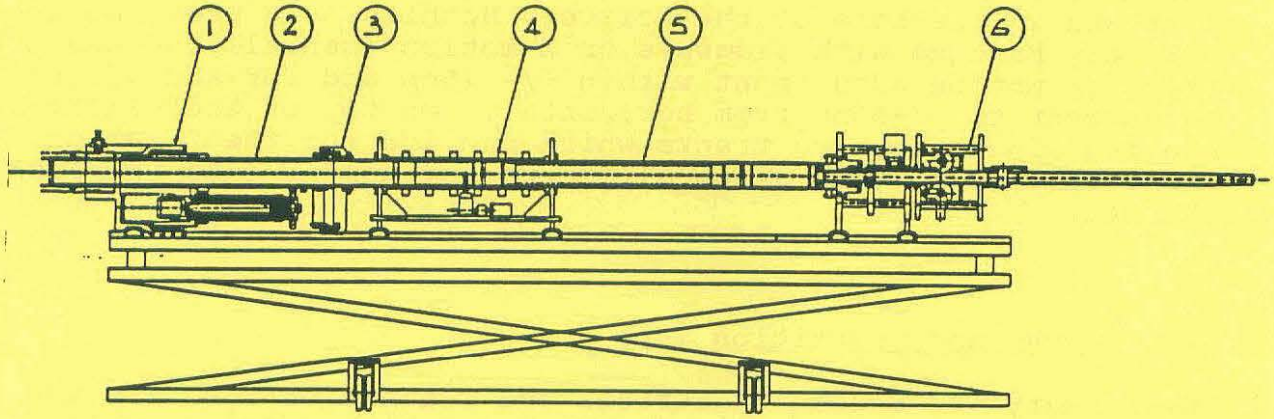
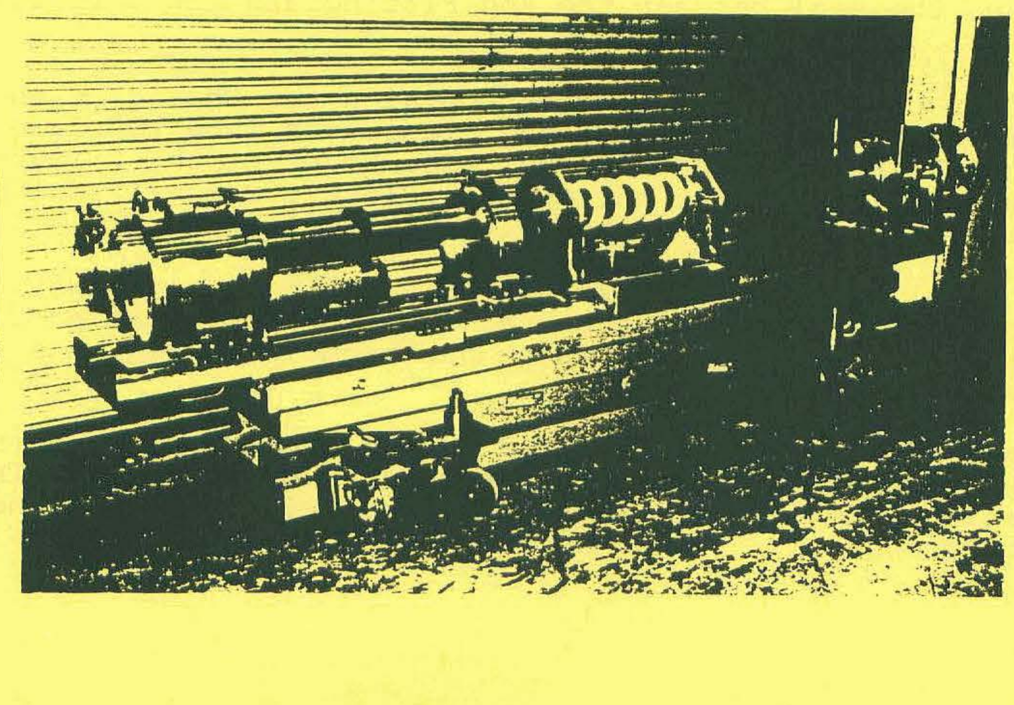


FIGURE 5: SLARETTE DELIVERY SYSTEM Mk II



5.1 Carriage and Platform

The SLARette Platform is approximately 1.5 m wide and 6.6 m long and is constructed of structural steel and aluminum. The Platform is hung from a SLARette carriage which is supported by the rails of the fuelling machine bridge. The platform/carriage provides for a stable surface for the Delivery Machine and the Operators. The Carriage and Platform is supplied with its own electric motor and drive to provide X motion along the bridge. It can travel between 0.9 and 1.8 m/min.

5.2 Elevating Platform

The Elevating Platform is an electromechanically operated scissor lift and is the base of the Delivery Machine. It provides the Delivery Machine with sideways or X motion (manual), up and down (fine Y) motion adjustment within +/- 75mm and for and aft tilt adjustment to +/-50mm from horizontal. On top of the platform are two linear bearing tracks which provide for the Z-motion. These various motions allow alignment and homing onto any Fuel Channel.

5.3 Turret and Transition Tube

The Primary and Secondary Turrets and Transition Tube are the main components of the SLARette Mark 2 Delivery System which allows the system to access a non-isolated fuel channel. The Primary Turret has a housing which attaches to the End Fitting and is securely clamped by four mechanical jaws which draw the Turret housing against the End Fitting "E" face. An O-ring provides the seal between the End Fitting and the Delivery Machine.

The Rotor of the Primary Turret contains the Channel Closure Removal Tool and also allows the Transition Tube to slide axially through it into the End Fitting. The Rotor of the Primary Turret rotates to allow either the Channel Closure Removal Tool or the Transition Tube to be aligned with the fuel channel.

The Channel Closure Removal Tool is capable of removing, storing and installing a channel closure. The Tool is capable of removing a Channel Closure which has been installed by a Fuelling Machine at a standard Force 4.

The calibration tube is attached to the Secondary Turret housing and the Transition Tube to the secondary turret rotor. The transition tube is the link between the Primary and Secondary Turret Rotors.

When the Channel Closure is removed and stored in the Primary Turret, the Turret Rotors and Transition Tube are rotated to align the Transition Tube with the fuel channel. The Transition Tube, Secondary Turret, Calibration Tube and Drive Unit Assembly are all advanced forward approximately 300 mm to allow the Transition Tube to enter the End Fitting. A manually driven ball screw arrangement is provided to accomplish this axial movement. The Transition Tube has the same internal diameter as the Calibration Tube, End Fitting Liner and Fuel Channel Pressure Tube. Clear access to the fuel channel is now available for the SLARette Tool.

The pressure boundary of the Primary and Secondary Turrets, Transition Tube, Calibration Tube and main Seal Assembly are Nuclear Class 1 components.

5.4 Axial and Rotary Drive

The SLARette Drive produces and transmits both Rotary and Axial motions to the SLARette Tool while producing position indication signals, of both rotary and axial positions. The Assembly consists of a fixed structure which attaches to the Calibration Tube and an outboard structure which is supported by the fixed structure and can rotate relative to it. The fixed frame houses, the Rotary Drive and the Rotary Position Encoder while the rotable frame houses the Axial Drive Assembly, Drive Rollers and the Axial Position Encoder.

The Drive Rollers are pressed against sectional Push Tubes. There are five Push Tubes each about 2.4m long and they form a flexible attachment to the Tool (to negotiate a bent channel) and are joined together by a special quick disconnect. The Push Tubes are cylindrical (50mm OD) and have a flat of about 12 mm wide machined full length. This flat engages with a flat on one of the drive rollers to prevent rotation or spiralling of the Tool. The Push Tubes are externally pressurized when in the Fuel Channel and as such are a part of the Class 1 pressure boundary. The Push Tubes travel through a special seal package located on the fixed structure of the Drive. The Tool Umbilical Cable passes through the internal of the Push Tubes.

A Conveyor is attached to the back end of the Elevating Platform and is used to support the Push Tubes and provides a surface for adding and removing the sectional push tubes.

The Axial Drive is capable of moving the Push Tubes between 5 and 55mm/sec. The Rotation Drive is capable of rotating the Tool at speed of 0.3 to 3 rpm. The Rotational Drive and therefore the Push Tubes can be rotated plus and minus 200 degrees at which point limit switches are contacted to stop further rotation. Mechanical stops are provided at plus and minus 205 degrees in case of failure of the limit switches.

5.5 Calibration Tube

The Calibration Tube is a Reactor Grade Pressure Tube which has been specially selected to have a circumferential wall thickness variation of at least 0.25 mm and have a sinusoidal wall thickness change. This Tube is required to calibrate the Tool which is located inside it as well as provide a carrier/storage location for the Tool. The Calibration Tube forms part of the Class 1 Pressure Boundary, and is attached to the Axial and Rotary Drive on one end and the Secondary Turret at the other end.

The Calibration Tube has several machined features which can be used for Tool Calibration. These include a Slanted Groove, Wall Thickness Reduction Constriction, Ultrasonic Notches and Flat Bottom Holes.

The Gap Calibration device consists of a movable section of Calandria Tube which is held round by a series of Nylon Rings. The Calandria Tube moves radially up and down with respect to the Calibration Tube. This is accomplished by horizontally pivoting the Calandria Tube and providing an electrical stepping motor and jack screw assembly to provide fine adjustment of the Calandria Tube's vertical movement. The annular gap between Pressure Tube and Calandria Tube is measured by a LVDT (Linear Variable Differential Transformer).

5.6 D_2O Supply Station

The D_2O Supply Station incorporates three 10 gallon Stainless Steel tanks. Two of the Tanks are interconnected and used for Filling Venting and Draining of the Delivery Machine. The third tank is used exclusively for leakage collection from the Push Tube Main Seal.

6.0 SEQUENCE OF OPERATIONS (MARK 2 DELIVERY SYSTEM)

The Mark 2 Delivery System works in conjunction with the Fuelling Machine and is set up to SLAR in the following sequence:-

- Fuelling Machine defuels channel, removes Shield Plug and reinstalls Closure Plug.
- SLARette Delivery Machine manually clamped onto End Fitting.
- Fill and Vent Delivery Machine.
- Manually operate Channel Closure Removal Tool and open the End Fitting.

. Rotate the Turret 180° to align Transition Tube with the End Fitting and Calibration Tube.

.Advance Transition Tube into the End Fitting.

.Move Tool into the Channel by adding Push Tubes as required.

.Perform SLAR activity on Channel Spacers.

.Removal Operations basically the reverse of the above.

7. SUMMARY

The SLARette System (Mark 1) has been modified by incorporating a Turret Assembly into the Delivery System thereby eliminating the need to isolate the Fuel Channels by Feeder Freezing. The Turret incorporates a Channel Closure Removal Tool and is rotatable to align the SLAR Tool with the Channel. The elimination of Feeder Freezing is a major productivity improvement that should significantly reduce the duration of SLARing a Channel. The Target of one channel per 12 hour shift or better should be achievable. The SLARette Mark 2 system incorporates the current SLAR Inspection System and Tool designs and has been successfully tested at AECL-CANDU. This complete Mark 2 SLARette System was delivered to Point Lepreau NGS in March 1991. It was used successfully on four fuel channels during a short maintenance outage in April 1991 and again on a further five fuel channels in April 1992. Point Lepreau will be using the SLARette System on 10 to 20 fuel channels per year during their upcoming yearly maintenance outages. The SLARette Mark 2 System as designed can be used on all CANDU 6 Reactors as well as the Pickering Reactors. With some modifications the Systems can be adapted to the Bruce End Fitting/Closure configuration.

The complete SLARette Delivery and Control System can be set up and operational in a CANDU 6 station in less than 48 hours and dismantled and removed for storage in less than 24 hours.

The SLARette Delivery System is a versatile system that could be used to deliver other (i.e. non SLAR) Probe Assemblies into the Fuel Channel.