PLANNING THE RETUBING OF A CANDU 6 REACTOR

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Introduction:

The reactor fuel channel pressure tubes at the New Brunswick Power Corporation CANDU 6 Nuclear Generating Station at Point Lepreau, are known to have a number of design related mechanisms which will limit their performance life. Most of these mechanisms are of concern only near the end of the nominal 30 year life of the pressure tubes.

One mechanism which deters the useful life of pressure tubes is contact between the pressure and calandria tubes caused by movement of spacers (four in all) away from their correct design position. Once the pressure tube has been in contact with the calandria tube over a period of time, cracking of the pressure tube can occur.

In 1993, utilizing the latest techniques in pressure tube inspection and maintenance technology, both Ontario Hydro and NB Power demonstrated for the first time that pressure tube to calandria tube contact could be eliminated without pressure tube replacement. This process, known as Spacer Location and Relocation (SLAR) offers an alternative to retubing and is being considered by NB Power for implementation in 1995.

Consequently, NB Power has been studying the retubing of all 380 pressure tubes either for implementation in 1998 or 1999 as a fallback position to SLAR or in 2008, following the 1995 SLAR, when the pressure tubes will require replacement for other reasons. Either strategy would have the objective of achieving a 40 to 50 year plant life from the 1983 in-service date of Lepreau.

Large Scale Fuel Channel Replacement (LSFCR):

The replacement of pressure tubes in a CANDU reactor core, is the most significant undertaking in a Plant Life Management Program for a CANDU station. LSFCR is often known simply as Retubing.

This operation has been successfully performed on the four CANDU units at the Pickering A Nuclear Generating Station in order to gain an additional 25 years of life. The engineering of the retubing the four Ontario Hydro Bruce 'A' units is well advanced.

However, this is the first time that the methods of undertaking retubing on a Candu 6 have been studied in any detail.

In 1992 NB Power started preparing a project plan to be ready, if necessary, to undertake retubing on Lepreau as early as 1998.

The initial focus of the Lepreau retube planning is to see how the equipment and facilities similar to that used in the Pickering and Bruce retubing operations, can be applied to Lepreau.

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NB Power prepared a 3D CAD's model of areas that will be involved in retubing and in the movement of large/long components in and out of both east and west fuelling machine vaults, from the main airlock, through the reactor building, including existing cranes. This has been checked by taking measurements in the east and west vaults during the 1993 April outage.

NB Power's studies on a method of retubing the Lepreau reactor show that the reactor building and facilities are significantly different from the Pickering and Bruce layouts and some major engineering is required to achieve an efficient retubing process. This paper identifies these layout problems and describes some potential solutions.

Shielded Cabinet/Fuelling Machine Bridge:

Shielded cabinets are required in each fuelling machine vault for workers who require direct access to both ends of the radioactive fuel channels. In accordance with the ALARA principle, radiation doses should be kept as low as reasonably achievable.

The obvious arrangement is to support the shielded cabinet either above or below the fuelling machine bridge.

The normal weight carried on the fuelling machine bridge is only 30 tons, compared with a shielded access cabinet of 70 tons. The capacity of the existing two pairs of ball screws to take the eccentric loading of the weight of the shielded cabinet will be exceeded. It may be possible to increase the size of one of the inner ball screws from 3½ inch diameter to 4 inch diameter to handle this extra duty.

Unlike the Pickering fuelling machine bridge which can be lowered into a pit in the vault floor, the top of the Lepreau fuelling machine bridge only comes down to 13 ft 9 in. above the floor. Mounting a shielded cabinet below the bridge has been considered but this arrangement does not give adequate access to the top 3 rows of fuel channels; mounting above the bridge does not give any access to the bottom 9 rows of fuel channels (refer Figure 1.1).

In order to provide adequate access to each of the 22 horizontal rows of fuel channels, it is proposed to disconnect the bridge and then suspend it from the existing ball screw drive elevators, by means of 10 ft. long hangers at each corner. The shielded cabinet would then be placed on the top of the bridge. (Refer Figure 1.2).

The normal access to the vaults is through a 25 ft. long by 5 ft. wide by 6 ft. 6 in. high opening , on the D side, served by the 15 ton New Fuel Handling crane. This leads to the fuelling machine maintenance locks; then through a right angle turn into the fuelling machine vaults. The main body of the shielded cabinet will be about 26 ft. long by 10 ft. wide plus roof and floor overhangs. The shielded cabinet could be designed in four collapsible modules to make this journey into the fuelling machine vault; then moved onto the bridge by jacking techniques. The heaviest module may be 35 tons.

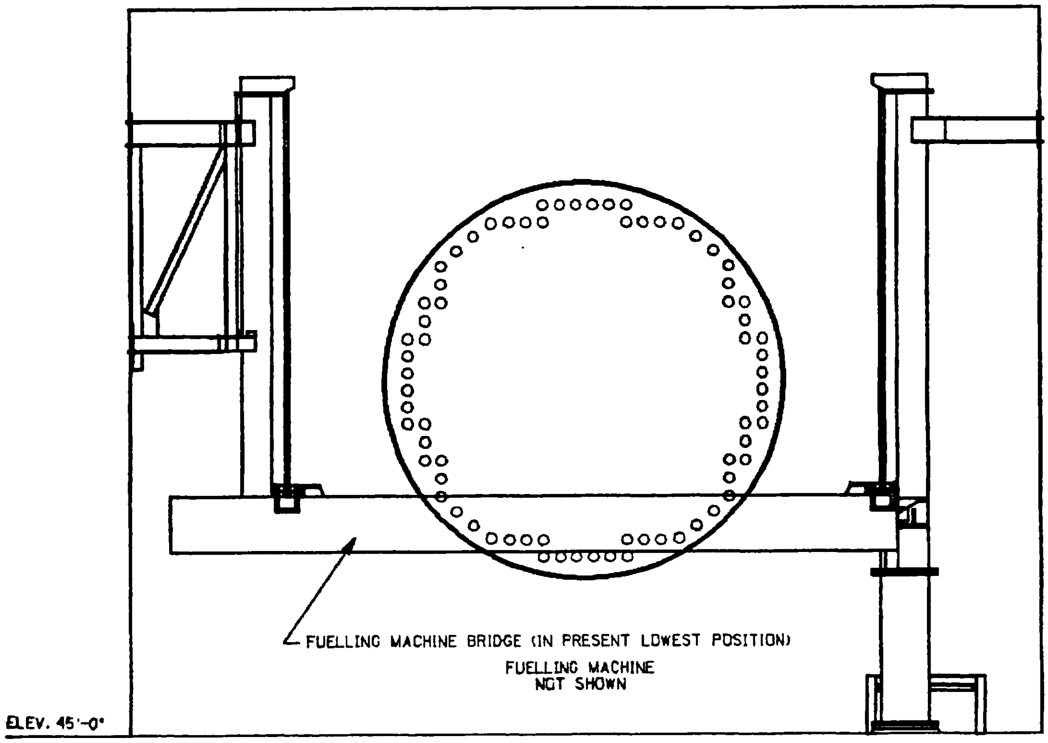
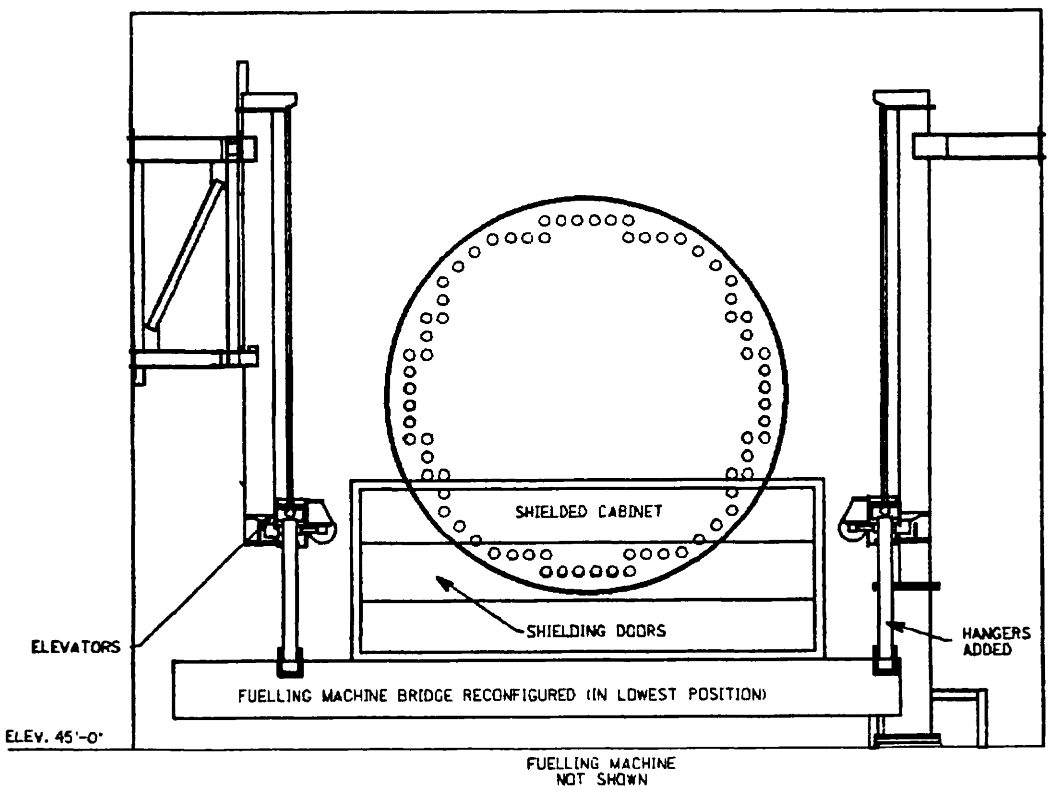


FIG. 1.1



CADD SECTION IN WEST FUELLING MACHINE VAULT

FIG. 1.2

Retube Remote Tool Carrier (RTC):

The RTC is used to remove and install the pressure tubes and end fittings, and to move various tools required for retubing. The most important task of the RTC is removing the 20 ft. long highly irradiated pressure tubes from the reactor face. The RTC then lowers the pressure tubes into a shielded transporter flask for removal from the vault area. Due to the nature of this task the RTC is required to be remotely operated, to be completely dependable and accurate in moving long items.

The Ontario Hydro Pickering A units have successfully used RTC's designed about 10 years ago but without benefit of actual retubing experience (Reference No. 3). For Bruce, a more advanced type of RTC has been designed and prototype tested (Reference No. 1). The RTC support beams project beyond the end of the shielded cabinet by 7 ft. (2.1 m) at Pickering (Fig. 2.1) and 11 ft. (3.3 m) at Bruce (Fig. 2.2)

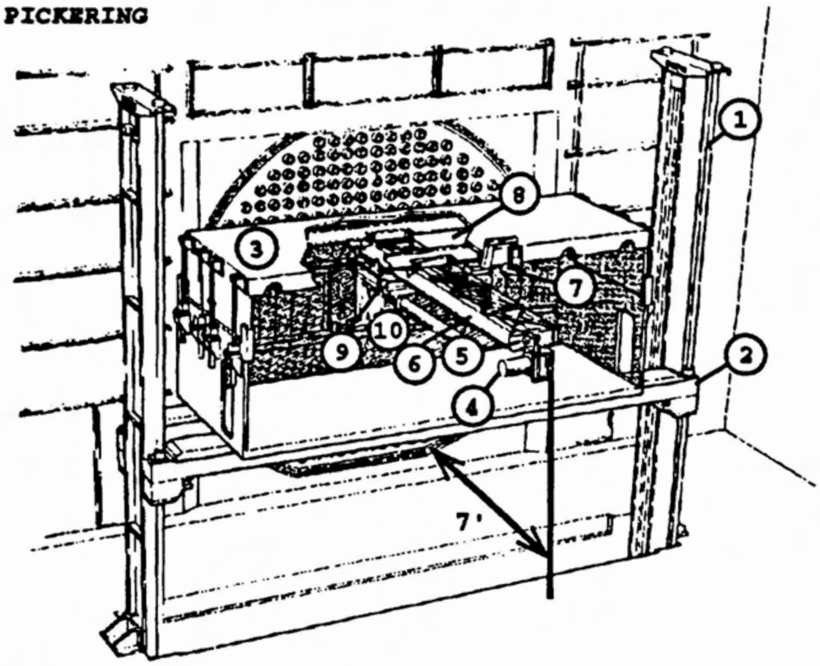
At Lepreau (Fig. 2.3), the clearance from the fuelling machine bridge (which defines the width of the shielded cabinet) and the horizontal space for the RTC support rail at the top fuel channel is only 3 ft. 8 in. (1.1 m) This is due to the interference of steel members and the instrument tubing trays they support. The RTC gripper frames have to lower components such as irradiated pressure tubes down through this horizontal space with adequate clearance which is impossible with the existing RTC design; the Bruce RTC gripper frames are 4 ft. 2 in. (1.25 m) square.

There are two solutions to this problem.

The first would require removing the interfering tubing trays and supports. This tubing is part of the fuel failure by delayed neutron (DN) monitoring system, consisting of 190 tubes in each vault. Due to the radiation field from the feeders above this option would result in radiation doses to workers disassembling and reassembling the tubing and supports, including erecting scaffolding for that purpose, and not meet ALARA objectives. This work would likely be on the critical path of the retube operation due to requirements for scaffolding, etc., being in the way of other vault preparation activities (e.g. shield cabinet installation). Finally, after retubing, the system would require recommissioning to prove by a flow method that each fuel channel is connected to the correct DN monitoring address. This procedure would be on the critical path of the recommissioning of the plant.

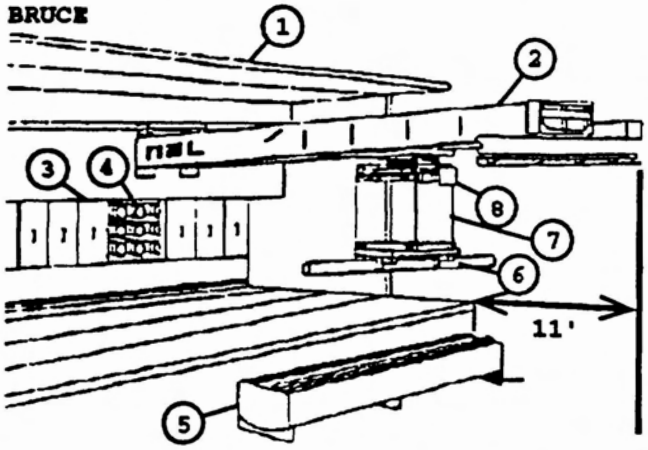
The preferred alternative is to redesign of the RTC and supporting rails. The RTC gripper frames, bearings and drives will have to be much less in width in one direction than the 3 ft. 8 in. space available, in order to have adequate clearance for risk free movement of irradiated components.

FIG. 2.1
PICKERING



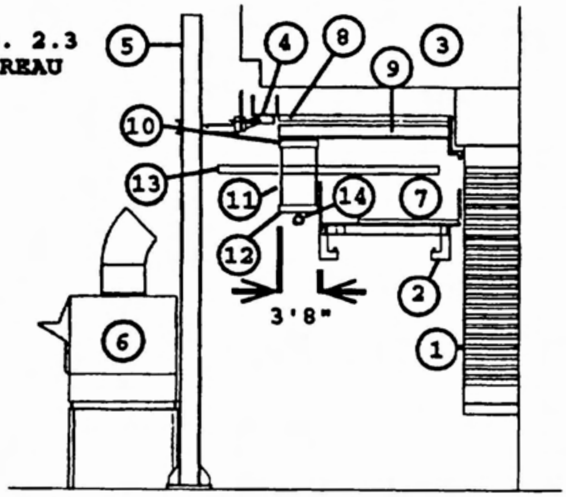
1. F/M Y DRIVE COLUMN
2. F/M BRIDGE
3. SHIELDING CABINET
4. POWER CABLE TAKE-UP REEL
5. Z-DRIVE MOTORS
6. XZ FRAME
7. TV CAMERA
8. SHIELDING CABINET X RAILS
9. GRIPPER FRAME
10. PRESSURE TUBE CAN

FIG. 2.2
BRUCE



1. SHIELDING CABINET
2. RETUBING TOOL/CARRIER GANTRY
3. SLIDING ACCESS DOORS
4. REACTOR FACE
5. TRANSFER CASK
6. PRESSURE TUBE IN GRIPPER JAWS
7. FOUR HOIST WIRES
8. GRIPPER SUPPORT

FIG. 2.3
LEPREAU



1. END FITTINGS
2. FUELLING MACHINE BRIDGE
3. FEEDER INSULATION CABINET
4. INSTRUMENT TUBING RACK
5. STEAM GENERATOR SUPPORT COLUMN
6. LOCAL AIR COOLER (LAC)
7. SHIELDING CABINET (SC)
8. SHIELDING ROOF ON SC
9. REMOTE TOOL CARRIER (RTC) GANTRY
10. GRIPPER SUPPORT
11. FOUR HOIST WIRES
12. RTC GRIPPER FRAME
13. PRESSURE TUBE CAN IN TURNING POSITION
14. PRESSURE TUBE CAN IN LOWERING POSITION

Local Air Coolers (LAC's):

The ideal procedure for installation of pressure tubes is to assemble one end fitting onto a pressure tube to form a subassembly. This could be done in a workshop outside the reactor building, with each of the 380 subassemblies moved separately into the vault as required.

The new pressure tube/end fitting subassembly is 29 ft. long and is longer than the normal access to the vaults. However by lowering at an angle, this can be moved through the limited normal access to the vaults. Once in the vault, this long subassembly has to be turned through a right angle and presented to the fuel channel site. This has been demonstrated by making a large wooden model (29 ft. x 2 ft. x 2 ft.) and moving it through the fuelling machine vault during the 1993 April shutdown. However these subassemblies would be too long to turn in the space (distance 26 ft.) between the reactor face and the local air coolers (LAC's), so three of the LAC's would have to be removed.

Also many of the tools required in the retubing operation are long (30 ft.) and could not be used in the available space. (see Figure 2.3).

One solution would be to remove three of the four LAC's from each vault. However this could cause major interference problems with some of the vault preparation and restoration activities.

Two consequences of not removing the LAC's have to be examined:

1) Insertion of new pressure tube/end fitting subassembly. Ideally these subassemblies should be put together out of the reactor building, but are too long if LAC's remain. They could be assembled in the shielded cabinet, as a parallel operation to other activities. This could be done with a pressure tube half inserted in a fuel channel site, before the rolled joint is made. The subassembly would then be fully inserted into the fuel channel site. Special shielding would be required.

2) Design two-piece tools which can be quickly assembled/disassembled. One such device had been used in a Single Fuel Channel Replacement at Lepreau during the 1989 outage. However the operators found it very awkward to use. However it should be possible to design a better two-piece arrangement which can be put together and separated quickly when working in a well laid out shielded cabinet.

Another option is to remove three of the four LAC's from one vault only, and to devote this vault to the moving in and installation of the new pressure tube/end fitting subassemblies.

It has been demonstrated on the CAD model that the LAC's can be moved out through both the 'B' side vault openings, but with minimum clearances and some manoeuvring during the vertical lift by the 60 ton Boiler Room crane to avoid cable trays, piping and steel structures.

Material Handling:

The longest irradiated components are the pressure tubes and calandria tubes. These and other irradiated components are remotely placed into a shielded flask (23 ft. long) on the vault floor which can be moved from the vault by the route described. Detailed studies and a custom designed 30 ton shielded flasks with drive motors are required to ensure trouble free movement in a production operation. Also, the capacity of the existing 15 ton New Fuel Handling crane will have to be increased; possibly up to 50 tons. A structural analysis has been undertaken to show that this weight could be taken by structures supporting the crane rails; but a new crane will be required.

There are no built in hoisting facilities in the fuelling machine vaults to facilitate any of the various vault preparation or other retubing activities, so all hoisting requirements have to be identified early in the design and somehow avoided or accommodated.

Schedule:

Retubing a Candu reactor is a major project requiring years of planning, engineering procurement and staff training prior to the start of the retube outage, and has to be customized for the particular type of station design; a Candu 6 in the case of Lepreau. The project schedule may be summarized into the following phases:

Preproject Phase: One year during which a retube concept, schedule and detailed estimate is developed and major technical problems unique to Lepreau are to be resolved.

Detailed Engineering & Procurement: Three years consisting of detailed design of all tooling, equipment such as shielded cabinets and site facilities. All components are procured and tested prior to training of personnel.

Personnel Training: One year prior to start of the outage, personnel are hired and trained to complete the complex reactor face work. These personnel also assist in procedure preparation and tool testing.

Retube Process: 18 months for defuelling and draining the reactor, installation of shielding cabinets, removal of the old pressure tubes, installation of new pressure tubes, recommissioning and start-up the unit. The process requires significant construction manpower to operate a mix of manual and semiautomatic tooling. Estimates of Retube staff required range between 250 - 400 personnel depending on the activity being completed.

Lead Time - The decision to retube must be made almost four years before the planned retube outage start, provided the major technical problems identified are resolved as part of the conceptual design during the Pre-project phase.

Conclusion:

NB Power's studies to determine a retube method for the Lepreau 1 Candu 6 show that the reactor building and facilities are significantly different to the Pickering and Bruce layouts. Potential solutions to these layout problems have been identified, but require conceptual design work to define an acceptable retube process.

The erection and disassembly of retubing facilities in the fuelling machine vaults is generally on the critical path of the shutdown. In addition there are limits on the radiation dose to workers in the fuelling machine vaults. Thus the design must minimize the time required to reconfigure the fuelling machine bridge and to erect the shielded cabinet modules on it.

Note: Dimensions and weights given in this abstract are approximate.

Acknowledgments:

- Ontario Hydro who demonstrated the retubing in progress at Pickering.
- AECL CANDU for general information on retubing.
- Numet Engineering Ltd., who are designers of the Bruce RTC.
- GE Canada, the original designers of the Candu 6 fuelling machine bridge, also the Pickering and Bruce shielded cabinets, were commissioned by NB Power to undertake design studies on the modification to the fuelling machine bridge, the shielded cabinet and the irradiated component shipping flask to meet the above requirements for retubing at Lepreau 1.

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