Pressure Tube and Calandria Tube Volume Reduction for Large Scale CANDU Retube

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Abstract

After 25 to 30 years of operation, CANDU® power plants may undergo refurbishment in order to keep them running reliably for 60 years. One aspect of refurbishment is the replacement of the pressure tubes and calandria tubes in the reactor. The volume reduction press, developed by AECL, is one of the most important and novel tools used during retube. The press crushes and shears both pressure tubes and calandria tubes to dramatically reduce their waste volume. The first generation tools have now been proven in the field.

1. Introduction

After 25 to 30 years of operation, CANDU power plants may undergo refurbishment in order to keep them running reliably for 60 years. As part of the refurbishment activities, the pressure tubes and calandria tubes in the reactor must be removed and replaced. For the average CANDU plant, this involves removing and replacing all 380 or 480 fuel channels. The replaced components include pressure tubes and calandria tubes, which are about 11.5 cm and 12.7 cm diameter respectively and approximately 6 metres in length. The tubes are considered high-level radioactive waste with contact dose rates up to several hundred thousand R/hr. Clearly, it is desirable to reduce the volume of this waste to reduce the cost to store the waste, simplify the waste handling, and reduce worker dose as well as outage duration. About 10 years ago, the Mechanical Equipment Development (MED) Branch at AECL's Chalk River Laboratories began the design and development of several tools for retube including a unique, patented system for pressure tube and calandria tube volume reduction. The tool, called the volume reduction press, shears the tube material into approximately 5 cm flat square pieces that are efficiently stacked in dedicated waste storage containers. More recently, MED has designed and built retube tooling, including a volume reduction press, that was used successfully for the retubing of Bruce Units 1 & 2. This paper presents some details on the design of the press, and an overview of the experiences with the tool at Bruce Units 1 & 2.

2. Tooling Design Overview

The volume reduction press is one part of the fuel channel removal and processing system. The strategy used for the retubing of Bruce Units 1 & 2 involved removing the tubes at the face and lowering them down to the vault floor where they were processed by the volume reduction press. This paper will focus on this strategy that was used in Bruce Units 1 & 2. Figure 1 shows an illustration of the CANDU reactor face.

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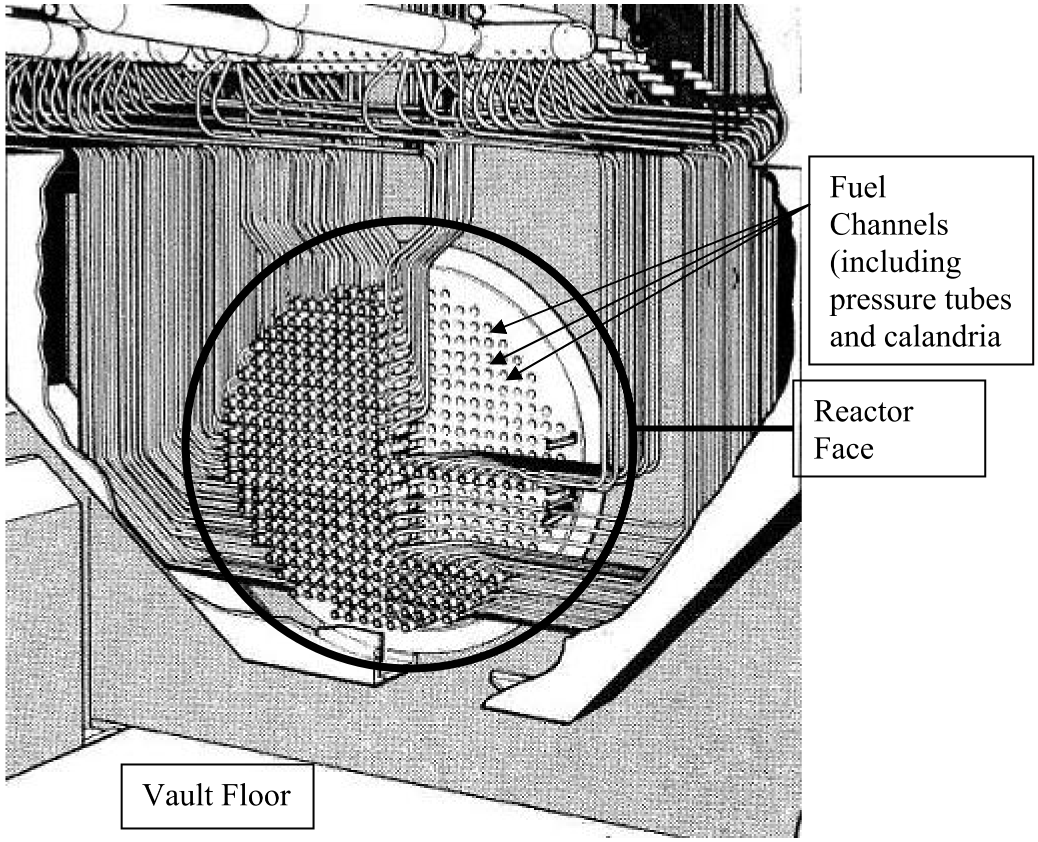

Figure 1 Illustration Showing the CANDU Reactor Face

2.1 Pressure Tube and Calandria Tube Removal Tooling

Pressure tubes and calandria tubes are removed using a push tool on the west side of the reactor and a receiving tool on the east side. The tools are installed on work tables that allow them to traverse the face of the reactor horizontally. The work tables are in turn installed on a work platform that moves vertically to align the tools with a given row of fuel channels. A push tool is shown in Figure 2 and a receiving tool is shown in Figure 3.

Figure 2 Pressure Tube Push Tool

Figure 3 Pressure Tube Receiving Tool

With the push and receive tools aligned with the target channel, the automated removal sequence can be initiated. During the sequence the tube is pushed from west to east into a thin walled "transfer can". Figure 4 shows the push and receive tools installed in a test facility at the Chalk River Laboratories with a full length fuel channel mock-up between them.

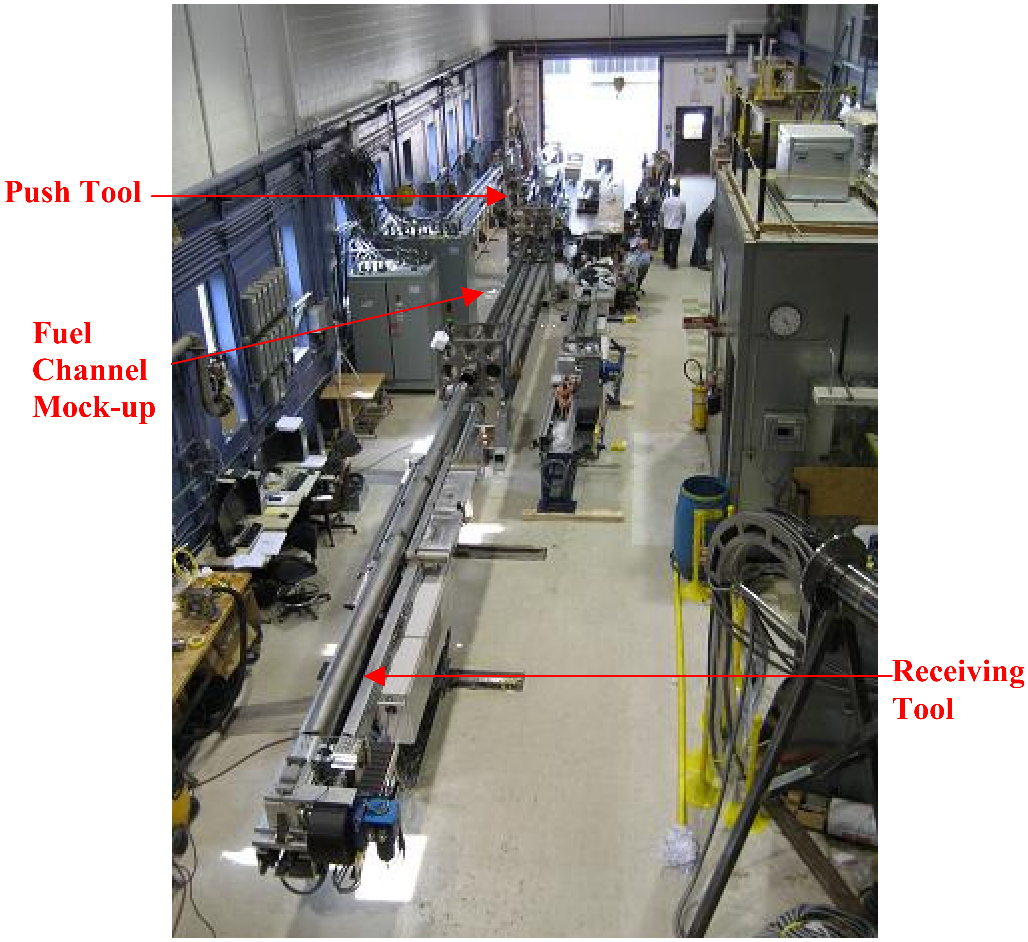

Figure 4 Push and Receive Tools Installed on a Fuel Channel Mock-up

Once the tube is in the transfer can, it is lowered down to the vault floor for processing. On the vault floor, the transfer can is placed on an unloading pallet. This tool pushes the tube out of the transfer can in a controlled manner into the volume reduction press. Figure 5 shows a layout of the processing equipment on the vault floor.

This section has only presented a very brief overview of the removal-tooling infrastructure. Subsequent sections will go into depth on the volume reduction press itself.

Figure 5 Layout of Pressure Tube and Calandria Tube Processing Equipment on the Vault Floor
(test facility at AECL Chalk River Laboratories)

3. Volume Reduction Press Design

The volume reduction operation is achieved using two horizontally opposed die sets. They contain an interlaced set of hardened tool steel shear cutters, which flatten and then cut the pressure tube or calandria tube into approximately 5 cm squares. A 35 cm length of pressure tube or calandria tube is sheared with each cycle of the volume reduction press. This approach was in part chosen for the advantage that no subsequent material handling is required. The pieces simply drop into a cavity in random order and orientation. Any system that requires mechanisms to align or stack material adds complexity and potential risks. By using the volume reduction press, the waste volume is reduced by a factor of about 3 or 4 for pressure tubes and a factor of 4 or 5 for calandria tubes when compared to the shearing and manual (orderly) stacking of the round tube material in “logs”. Further, material handling is simplified since processed tube material can be removed from the vault in shielded waste containers that can hold dozens of tubes rather than in long shielded flasks that only contain one or two tubes. The press operated in a fully automated fashion and workers need not enter the vault except for waste container changes.

Figure 6 and Figure 7 show views of the volume reduction press assembly and Figure 8 shows a view of pressure tube material processed by the press. Two opposing high capacity hydraulic cylinders driven by a 10,000-psi hydraulic pump actuate the volume reduction press. The two opposing die sets are assembled together with four guide rods and the guide rod centring plates. The die set module is restrained with support blocks with wear plates and gibs to limit vertical and lateral die set movement. The cutters are arranged in a stepped manner such that only one column of cutters shears through the tube at a time. This arrangement reduces the maximum shear force as 5 cm sections are sheared sequentially as opposed to all 35 cm of tube at once. The checkerboard arrangement features seven columns of cutters in the horizontal direction and four rows vertically. The cutters are capable of shearing any annulus spacers that remain on the pressure tube or in the calandria tube and get fed into the press. Recessed pockets between each column of cutters in the die blocks contain an ejector pin to discharge the pieces after shearing. The ejector pins are braced against the lower stops assembled on top of the support blocks and the stops assembled to the press top module, so that the ejectors are actuated passively when the press opens.

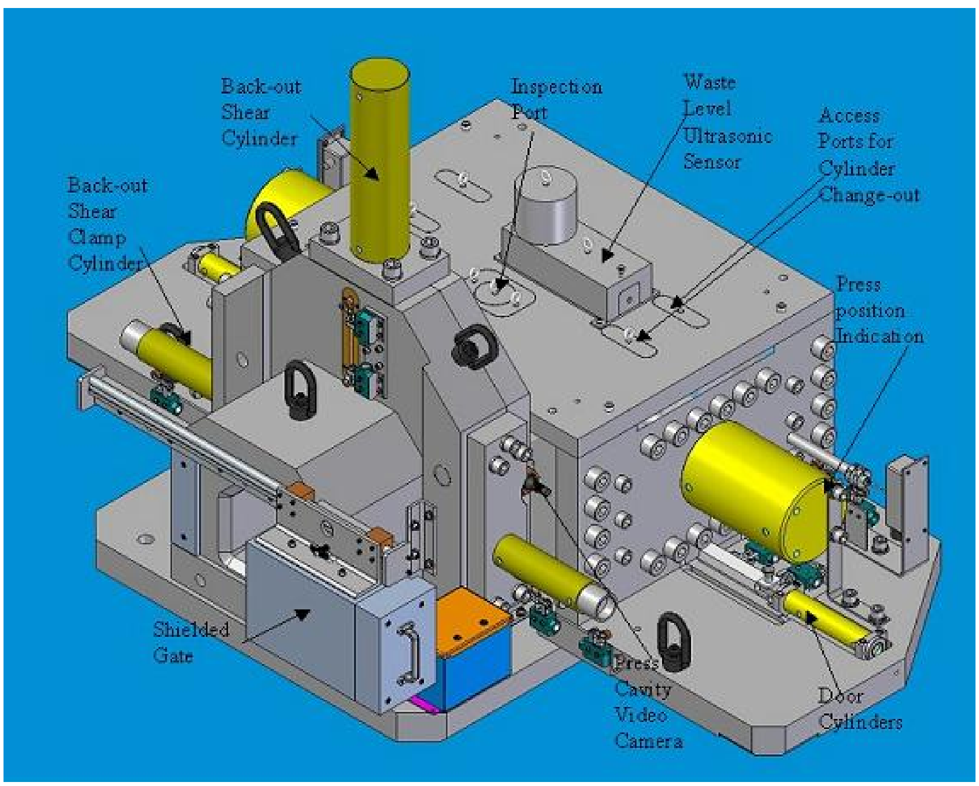

Figure 6 Volume Reduction Press and Back-out Shear

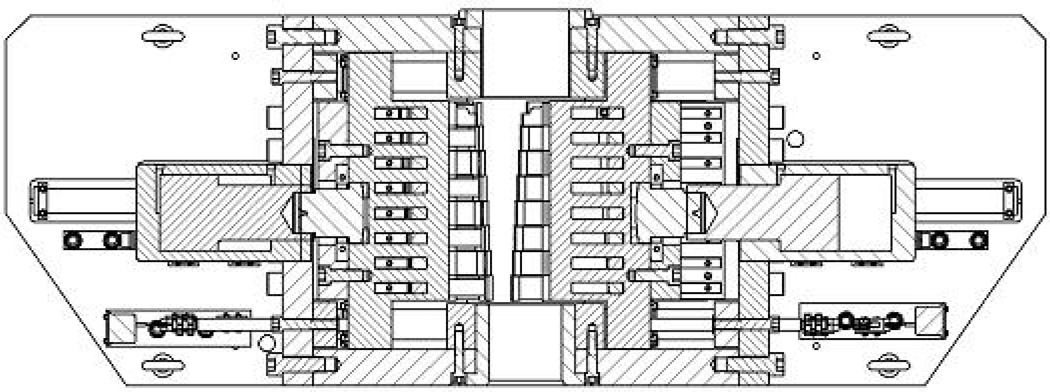

Figure 7 Section View of Volume Reduction Press (left side open, right side closed)

Figure 8 Two Pressure Tube Coupons Processed by the Volume Reduction Press

Any pieces of pressure tube or calandria tube that do not fall from the cutter surfaces when the press first opens are forced out by the ejectors. A waste container is loaded below the press, enabling the system to simply let the sheared tube pieces fall through the opening in the press deck plate.

The press assembly includes a trap door arrangement, mounted immediately below the die set module, as part of the base plate module. The trap doors (which are actuated by hydraulic cylinders) serve two purposes. First, they confine all waste material within the press cavity during the shear cycle to ensure complete volume reduction. Secondly, they also provide a means to close off the opening leading through the press deck plate during waste container change-out. This will reduce the potential spread of contamination, eliminate the possibility of a small tube piece falling from the system during waste container changes, and even allow a waste container change to be performed with the tube inside the press in a recovery situation.

In the event that there is the need to execute a back-out scenario, the shear module (Figure 6) may be utilized. The shear module is installed just before the inlet of the press and can be used to shear an unprocessed length of tube. Once sheared, the unprocessed length of tube can be put into the shielded storage container (in its transfer can) on the vault floor (Figure 5) and personnel can enter the vault safely. The shear module operates off of the same hydraulic power supply as the press. Specifically sized clamps are installed in the shear module depending on whether pressure tubes or calandria tubes are being processed. The horizontally opposed clamps hold the tube round while the shear blade is actuated vertically downward.

An ultrasonic sensor is mounted to the top of the top shielding plate of the press. The device sends an ultrasonic signal down through the press cavity. The signal bounces off of the top of the pile of pressure tube or calandria tube sheared pieces in the waste container and returns to the transducer. The signal is read and the height of the pile of waste can be determined. The ultrasonic signal is emitted in a horizontal direction and reflected downwards with a metallic surface at 45 degrees to the sensor. This arrangement keeps the sensor out of the direct radiation from the press and waste container.

A video camera is mounted to the shear module to provide a remote view of the die set module cavity. The camera is capable of operating in a highly radioactive environment. It features a non-browning quartz lens, LED lights and a right angle, rotating viewing head. The camera is positioned to provide a view of the die set module cavity as well as a limited view into the waste container through the opening in the press deck plate. The camera is controlled remotely. Access ports are provided in the top shielding plate of the press to allow for an inspection of the die set module cavity with a video camera and to facilitate easy press cylinder change-out. The ports are shown in Figure 6.

The equipment includes its own ventilation system which maintains the equipment working cavities at a pressure slightly below atmospheric to prevent the spread of loose radioactive contamination. The ventilation circuit includes a cyclone separator, which removes almost all airborne particulate generated during tube processing. Downstream air is then drawn through a HEPA filter. Finally, the vacuum exhaust is piped into the stations active ventilation system.

A 10,000-psi hydraulic power unit located outside the vault provides hydraulic power for the volume reduction press and waste container handling equipment. The hydraulic power unit consists of dual pump/motor units for redundancy and increased flow capacity. Each pump has a directional control valve with dual solenoids. The maximum pressure is limited by the setting of the pressure relief valves. A 10,000-psig manifold is connected to the output of each pump. A unique feature of the system is that a 3000 psig circuit is fed from the 10,000-psig manifold. A pressure relief valve limits the pressure that is supplied to the 3000-psig manifold.

Limit switches are provided at each end of travel on the press cylinders, the back-out shear blade, the back-out shear clamps and the press trap doors to provide position feedback to the operator.

The volume reduction equipment as well as the pressure tube and calandria tube removal equipment has been designed to be fail-safe. Formal failure modes and effects analyses were completed for each process. In general, removal and processing activities are stepwise, allowing the operation to be paused and resumed at many points. Key steps in the process have been designed with redundant drives. In general all actuators are located such that they may be serviced or replaced without significant tool disassembly. Further, key actuators are installed in low dose areas, to minimize the radiation exposure to the maintenance worker and to the actuator itself.

4. Field Experience

The volume reduction press as well as the pressure tube and calandria tube removal tooling have been used successfully at Bruce Units 1 & 2. The use of these tools on reactor provides real world operating experience and feedback from this “first time use” has generated some small design improvements to increase the reliability, maintainability and efficiency of the tools.

5. Path Forward

In order to keep the current fleet of CANDU reactors around the world in operation for 60 years, retubing of the reactor may be necessary. With the first reactor retubes nearing completion, utilities can move new retube efforts forward with better schedule and cost estimates and with a high degree of confidence in the technology.

Atomic Energy of Canada Limited is currently developing the next generation tooling for retube based on the field experiences to date. These tools will help improve the retube process and work towards shortening retube outages, reducing worker dose and simplifying maintenance activities.

6. Conclusion

Pressure tube and calandria tube volume reduction is a novel technology that, when used in conjunction with other custom retube tooling, can safely and efficiently reduce the volume of high level radioactive waste. The advantages of reducing waste volume include reduced worker dose, cost savings for waste disposal and shorter retube outages due to increased efficiency.

Next generation tooling, with improvements addressing issues found with the first generation of tools, will help the retube campaigns of the future run more efficiently than ever.

7. Acknowledgements

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