A TOOL FOR THE REMOVAL AND STORAGE OF HORIZONTAL IN-CORE FLUX DETECTORS (ICFD)

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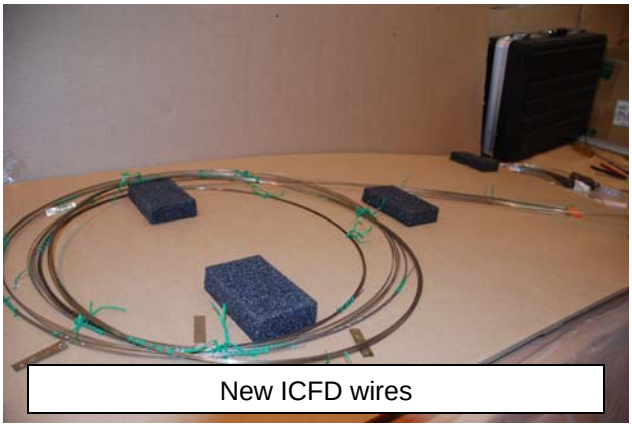
Introduction

Each CANDU reactor is monitored internally in both horizontal and vertical positions, by numerous self-powered neutron flux detectors during high power conditions. After approximately 9 -11 years they start to degrade and eventually cannot function as designed. Although flux detector assemblies contained spare wells to accept new detectors as old detectors started to fail, many CANDU reactors have reached a point where they no longer have spare wells left. Therefore the old detectors need to be removed, safely disposed and replaced with new ones.

The Detector

The ICFD is a straight individually replaceable (SIR) self-powered co-axial probe 3 mm in diameter and up to 900 mm long, with a smaller diameter lead wire (about 1.4mm diameter) up to about 12 m long. The detector wire is insulated from the Inconel sheath with MgO. The detectors are housed in tubes, called wells, located at various positions within the core and are brought out through the calandria vessel in groups of 11 or 12 where the connections are made.



New ICFD wires

The challenges of removal

The challenges of removing the detector are 1) dose, 2) contamination and 3) storage

Dose: The radiation field starts to increase when the detector is pulled out from the well. The field becomes very high when the detector is cut. Radiation fields of 900-2,000 mrem/hour have been observed. Furthermore, based on Health Physics calculations, when the bulb section is cut, the maximum field detected was in the range of 9,000 rem/hour from 2.7 ft away.

Contamination: When the detector wire is cut, there is a risk of contamination spread.

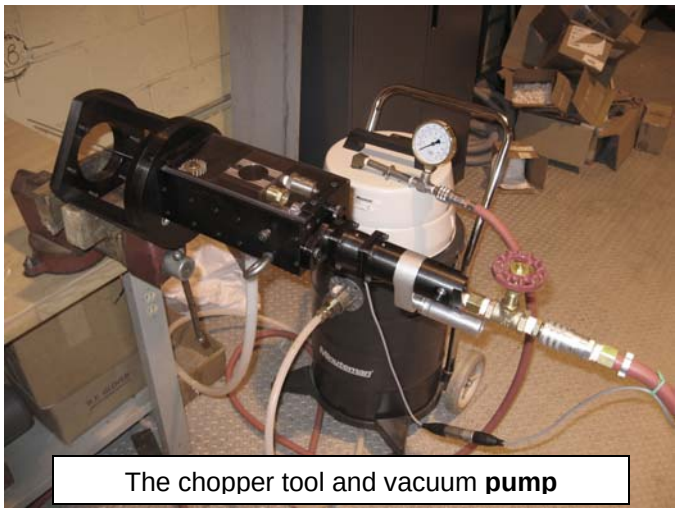
Storage: The removed detectors have to be treated as radioactive waste as far as storage or disposal is concerned.

The tool

There have been different designs of tooling for the removal of the ICFDs in the past. A previous design tool was used at Bruce Power in 2003. Please see note at the end of this paper about this tool.

The version described in this paper was designed and developed as a Joint Project Managed by CANDU Owners Group (COG) Inc. The participants in this Joint Project are Ontario Power Generation, Bruce Power LP, Korea Hydro and Nuclear Power Company, Hydro Quebec and COG. The Project history of this COG Joint Project is listed below:

- Agreement signed — Sep 26, 2006
- KHNP Acceptance Test — Apr 4, 2007
- KHNP Training — Apr 6, 2007
- Tool shipped to Wolsong — Apr 15, 2007
- 8 HICFDs removed at Wolsong 3 — May 10, 2007
- Tool Modifications — Jul 30, 2007
- Review of Wolsong campaign — Aug 15, 2007
- 9 HICFDs removed at Wolsong 4 — April 13, 2008
- BPLP Acceptance Test2 — April 9, 2008
- Tool shipped to BPLP — April 24, 2008
- BPLP 8 HICFD removed — May 26, 2008



The chopper tool and vacuum **pump**

The tool consists of four main components working together: 1) a chopper tool, 2) a vacuum system with its associated tubing, 3) a flask with a removable storage canister inside, and 4) a remote tool control and video monitoring station. The tool is remotely operated with the chopping chamber monitored by video camera. It chops the ICFD into small piece in an enclosed vacuum chamber. The chopped pieces are vacuumed to a canister which is located inside a flask for radiation shielding, temporary storage and local transportation.

Setup and Operation

The portable flux detector removal tool is a device that can be used in all CANDU stations that use SIR type flux detectors and can be easily adapted to each station. In operation the tool can be mounted directly on the flux detector housing.

The basic operation of the tool can be described as; the connection to flux detector housing, the alignment to a specific well and the connection to the flux detector to be removed followed by the chopping of each detector. During this operation the chopped pieces are sucked by vacuum and gravity into an internal storage canister and filter assembly located inside a shielded flask

that will hold up to 12 detectors. At all times, this operation is being remotely monitored/controlled by a tool operator and each detector removal will take approximately 10 minutes to complete plus some setup time. The full flask assembly would then be off-loaded to either an underwater storage bay or in ground storage tile hole for medium dose radiation waste. The flask is designed such that the canister can be removed and stored in the fuel bay, in an in-ground storage tile hole or off-loaded into a licensed road transport flask.

A prototype chopper tool was initially developed and built at Bruce Power L.P. by the Reactor Maintenance Department. Two production tools have been designed and fabricated at Stern Laboratories Inc. with assistance from the original design individuals acting as technical consultants.

Operating Experiences (brief summary):

The tool has been used at Wolsong Nuclear Power Plant of KHNP twice – in May 2007 and April 2008. It was also used in Bruce Power L.P in May of 2008. The tool evolved and improvements were made following field-use experience.

Wolsong unit 3 May 2007: Removed 8 detectors from 2 assemblies. The net time for vault entry to tool storage was about 5 hours. Three days were spent on Wolsong staff training. Contact dose rate on cutting tool was about 3 R/hour and the remainder of the equipment was decontaminated. The contact field on the outside of the flask was 4 mrem/hour. On 3 detectors, the last ¼" of the bulb became stuck in the ledger bushing, but they were easily freed manually.

Tool installation at Wolsong unit 3

Wolsong unit 4 April 2008: Removed 9 detectors from 2 assemblies. The total campaign took 7 days (total, not net). A chopping problem occurred due to movement of the ledger bushing and a temporary fix was required to complete the job. Dose information was not available.

Tool installation at Bruce Power unit 5

Bruce Power unit 5 May 2008: Removed 8 detectors from 2 assemblies. The work was done in 2 time slots. The net job time was 2 days. Very high contact dose rate was observed on the cutting tool after it has completed 8 removals – 50R/hour. The tool was contaminated but the contamination was well contained in the enclosed areas.

At the completion of the Bruce Power May 2008 campaign, the improvements made to the tool enabled it to successfully removed

ICFDs without major problem. The improvements made included:

- Ledger bushing mounting
- Setup procedure improvements such as in setting of the ledger bushing and cutter clearance.
- Enhancing the manual remote “choke cable” to free stuck particles in emergency.

Next phase development:

Based on the current capabilities of the tool and the 3 major operating experiences, the following development is planned for the next phase:

- Although the tool was designed without limiting it to removing horizontal ICFDs, there has been no experience in removal of vertical ICFDs. Work is required to fully adapt the tool for the removal of vertical ICFDs.
- Improvement or re-design of the canister and/or flask to ensure safe transportation within and between sites.
- General improvement on the chopper body, motor module, ledger bushing clearing device, canister plug & its installation tool, and cutter and ledger bushing. These improvements are for increase reliability and reduced dose and contamination.

Notes:

The old process would require approximately 2 days of setup time before the first detector would be ready for removal and a full shift (10hours) to remove one detector. Each detector removal would be one day with both in vault and out of vault time. It would also require the establishment of alternate containment boundaries. The post removal activities would require two days for cleanup and restore the wall on the LISS tank room.
This new tool has greatly decrease outage time and complexity.