The 40th International Conference on
Mechanics of Solids, Acoustics and Vibrations &
The 6th International Conference on
"Advanced Composite Materials Engineering"
COMAT2016 & ICMSAV2016
Brasov, ROMANIA, 24-25 November 2016

RESEARCHES FOR THE CANDU NUCLEAR REACTOR FUEL CHANNELS DECOMMISSIONING. PART 2 - FUNCTIONING AND OPERATING OF THE DECOMMISSIONING DEVICE

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Abstract: *The paper scope is to present the main functioning steps of the decommissioning device and to achieve the operating panel of the horizontal fuel channels decommissioning device and its operating presentation. The horizontal fuel channels decommissioning device from the CANDU nuclear reactors is a electromechanical system with many freedom degrees, capable to perform the internal components extraction of the horizontal fuel channels, operations performed under a control system equipped with a Programmable Logic Controller (PLC) and monitored by an operator panel, Human Machine Interface (HMI) type. The system is automated, each operation step shall be confirmed by the operator after its finalization, to preparing the next operation step. The system is designed to control the actuators and sensors, to supervise the proper performance of the operations execution. The operations performed from the operator panel (HMI) consists of platform positioning, coupling and locking the device at the fuel channel, unblock, extract and store the channel closure plug, unblock, extract and store the channel shield plug, block and cut the middle and the end of the pressure tube, block, extract and store the end fitting, block, extract and store the half of pressure tube, mounting of the extended closing plug. The operations are monitored by the internal sensors and transducers, by pyrometer for temperature during the cutting process and cameras for the dismantling components video surveillance. The operations steps are performed by the cutting and extraction device and by the extraction actuator from the device handling elements assembly. After each dismantling step is necessary the confirmation its finalization in order to perform the next operation step. The dismantling operation steps of the fuel channel components are repeated for all the 380 reactor fuel channels, from the front of calandria side (plane R) as well as the rear side (plane R'). The fuel channel decommissioning device shall provide radiation protection during the dismantling stages, ensuring radiation protection of the workers.*
Keywords: *Candu reactor, fuel channel, device, decommissioning, dismantling, radiation protection*

1. GENERAL CONSIDERATIONS

Many of the decommissioning activities involve the remote devices coordination to prevent the contact or some removed components proximity, of the operators. Dismantling of the fuel channels refers to the technical operations taken to extract the components and requires activities such as locking/unlocking the channel closure and the shield plug, pressure tube cutting, extracting of each component from the channel, as well as radioactive waste management.

2. THE DECOMISIONING DEVICE FUNCTIONING AND OPERATING PRESENTATION

The fuel channel decommissioning activities involve the remote devices coordination to prevent the contact of the operators with some removed components proximity. Dismantling of the fuel channels, piece by piece, it is a complex process and requires many activities, such as assembly/disassembly decommissioning device, locking/unlocking the channel closure and the shield plug, pressure tube cutting, extracting of each component from the channel, as well as radioactive waste management.

2.1. General considerations

The decommissioning device for the horizontal fuel channels, is a device allowing retrieval of the internal fuel channels components of the horizontal calandria nuclear reactor, providing the biological protection and the containment of contamination. The fuel channel decommissioning device is a electromechanical system with many freedom degrees, capable to perform the extraction of the internal components from the horizontal fuel channels. The decommissioning device system is automated, each operation step shall be confirmed by the operator after its finalization, to preparing the next operation step. When the extraction step is completed, the decommissioning device is displaced to the transport container for transfer and storage the dismantled components in the dedicated facilities.

2.2. Decommissioning device automation presentation

The dismantling operations of the decommissioning device are performed under the control of a system equipped with a Programmable Logic Controller (PLC) and monitored by an operator panel type Human Machine Interface (Touch Screen HMI). The system is automated, each operation step shall be confirmed by the operator after its finalization, to preparing the next operation step. In the Touch Screen HMI operator panel are designed, using specialized software, viewing and operating screens of the decommissioning stages. The operating structure screens are designed on three operating levels, Level 1 - start up main screen, Level 2 - calandria fuel channels plan screen, calandria positioning platform screen and general decommissioning device screen, general alarms screen, Level 3 - removal of the plugs by Cutting and Extraction Device screen, pressure tube cutting end extraction by Cutting and Extraction Device screen and end fitting extracting screen, illustrated in Figure 4.

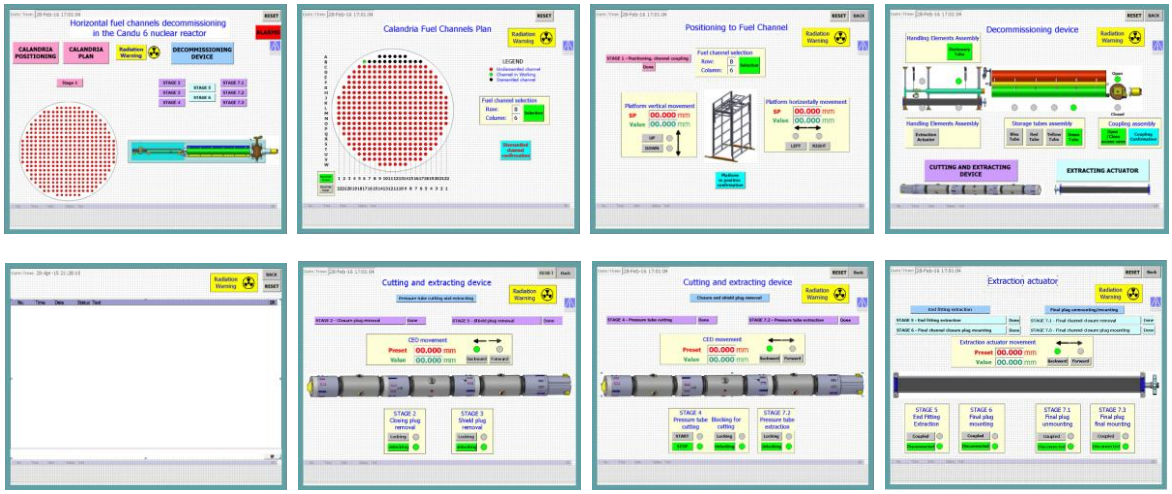

Figure 1: Representation of the HMI screens

2.2. Decommissioning device mounting presentation

In order to positioning the device front of the channel and coupling to end fitting, for the fuel channel dismantling, it is necessary to mount the decommissioning device on a platform. With this platform can be performed the movement of the device, parallel with the plane of the reactor (horizontal and vertical movement), in order to position in front of one of the 380 fuel channels (Figure 2).

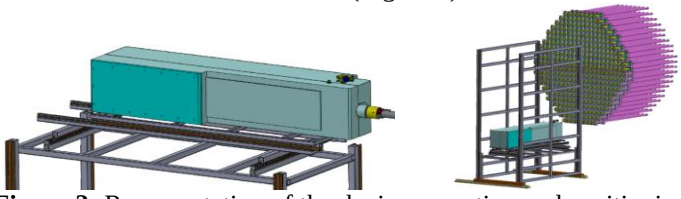

Figure 2: Representation of the device mounting and positioning

The platform support, for moving and positioning device front of the fuel channel, is an assembly that can be moved vertically and horizontally, in parallel plane front of calandria, to the fuel channel to be decommissioned.

The platform support for moving and positioning device has 2 freedom degrees due to the X-axis movement (horizontal movement) and Z axis (vertical movement). The cutting and extraction device perform a forward/retreat movement along the Y axis and a rotational movement along the Y axis, so that it has two freedom degrees, as exemplified in Figure 3.

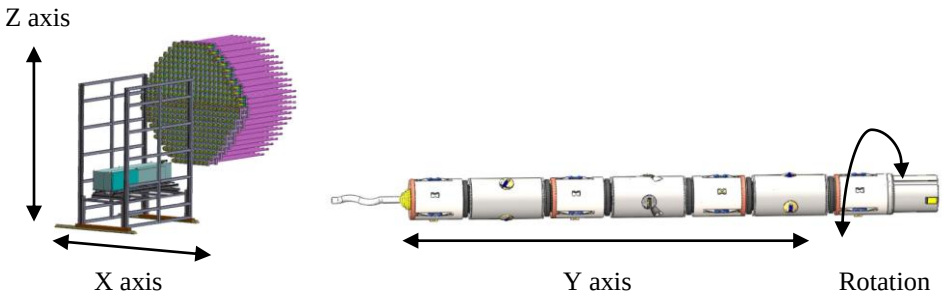

Figure 3: Schematic representation of the platform support and cutting and extraction device degrees of freedom

In conclusion, the decommissioning device assembly can be compared to an industrial robot capable to execute handling operations, autonomously and automatically, under a control system, which has 4 freedom degrees, three movements on the X, Y and Z axis, as well as a rotational movement around the Y axis.

2.3. Positioning Assembly dismantling

First step before start fuel of the channels decommissioning shall be the dismantling of the positioning assembly of all 380 fuel channels, operation manually performed by the operator, illustrated before and after removal in Figure 4. The dismantling operation stages of the positioning assembly shall be repeated for all the channels, from the front of calandria side (plane R), as well as the rear side (plane R '). All removed components are placed in a special container for storage.

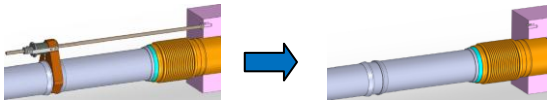

Figure 4: Representation of the positioning assembly before and after dismantling

2.4. Coupling and locking module presentation

The coupling of the device to the fuel channel is performed manually by the operator. The coupling and fixing steps are illustrated in Figure 5, and are as fallow:
- moving platform to position of the fuel channel to be dismantled;
- bring the container to the position that the coupling/extraction head is under the end fitting and then the container is lifted to a position in contact with the end fitting;
- place the auxiliary piece (brown piece) for coupling/extraction head closing;
- moving the locking cylinder (yellow piece) of the head of the coupling/extraction head in the "locked" position;
- mounting of the protective cylindrical screen, made from two semicircular pieces by screws joined, which cover the end fitting, for the operator radiation protection after the fuel channel end fitting extraction;

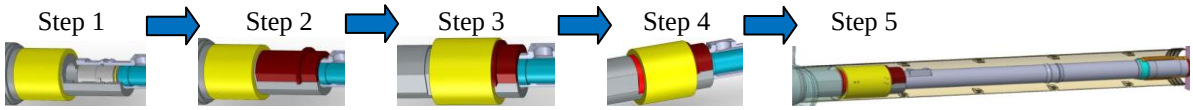

Figure 5: Representation of the device coupling steps and the protective cylindrical screen mounting

2.5. Fuel channel components dismantling

After the finalization of the device coupling and securing preparation operations to the fuel channel it is possible to proceed to the fuel channel dismantling operations.

The dismantling operations of the fuel channel components are performed , by the operator , with the operator panel from the decommissioning device control panel.

2.5.1. Removal of the fuel channel closure plug and the shield plug

The preliminary operations for the closure plug removal are, the rotation command of the storage tube assembly so that the tube for the pressure tube storage (the blue tube) to reach the working position (coaxial with the axis of the fuel channel reactor), the opening command of the device access valve assembly and the movement command of the handling elements assembly that the stationary tube of the cutting and extraction device to reach the working position. After completing the preliminary operations, the operator command the cutting and extraction device to moving, unlocking, extraction and storage of the channel closure plug and the shield plug in the yellow tube (see Figure 6).

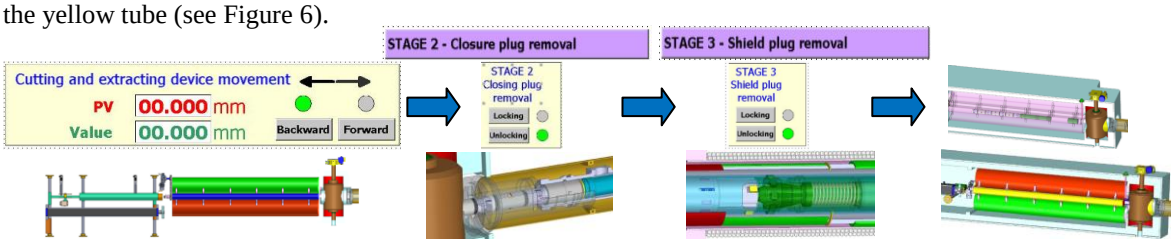

Figure 6: Representation of the preliminary operations and the channel closure plug extraction

2.5.2. The cutting of the fuel channel pressure tube

For pressure tube cutting it is necessary to bring the blue tube in the working position. The operator command the cutting and extraction device to move in the middle of the pressure tube, the positioning is performed by the encoder value. After cutting and extraction device positioning and fixing claws blocking (from the guiding-fixing module), the operator can command the cutting module to start the cutting operation (see Figure 7). The cutting operation is monitored by video camera, for cutting viewing, and pyrometer for temperature recording in the cutting area.

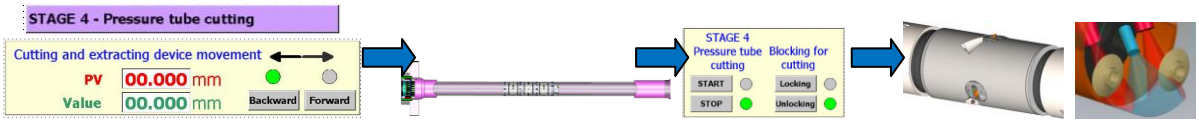

Figure 7: Representation of the cutting device positioning in the middle and cutting operation

The second step of the pressure tube cutting operation is the positioning of the cutting and extraction device at the end of the pressure tube at the joint with the end fitting and blocking the guiding-fixing module claws. The operator command the cutting module to start the cutting operation (see Figure 8). The cutting operation is monitored by video camera, for cutting viewing, and pyrometer for temperature recording in the cutting area.

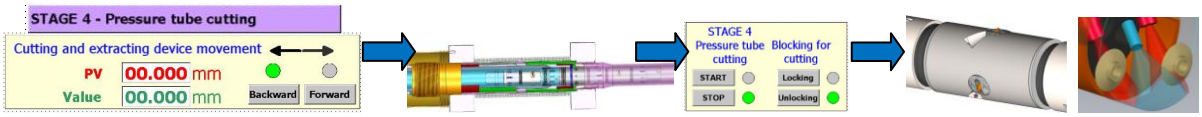

Figure 8: Representation of the cutting device positioning at the end and cutting operation

After the end of the cutting operations, the cutting and extraction device is retreated in the stationary tube from the handling elements assembly (see Figure 9).

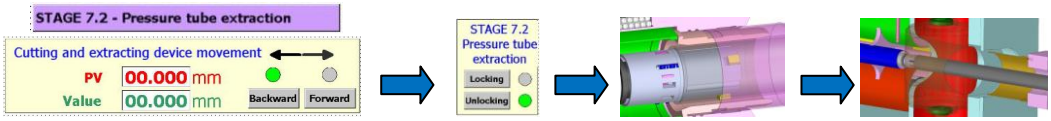

Figure 9: Representation of the pressure tube extracting operating

Confirmation of each finalization step in order to perform the next operation step (see Figure 10).

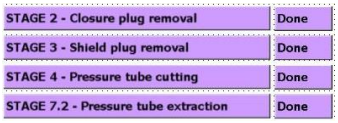

Figure 10: Representation of the pressure tube operating confirmation

2.5.3. Extracting of the End Fitting

The preliminary operations to the end fitting extraction is performed by dragging the handling elements assembly that the extracting actuator of the end fitting and the red tube from the storage tubes assembly reach the working position. The operator command the extension of the extracting actuator until the coupling and blocking with the end fitting. After coupling and blocking to the end fitting it is possible to command the withdrawal of the extracting actuator to the storing position in the red tube (see Figure 11).

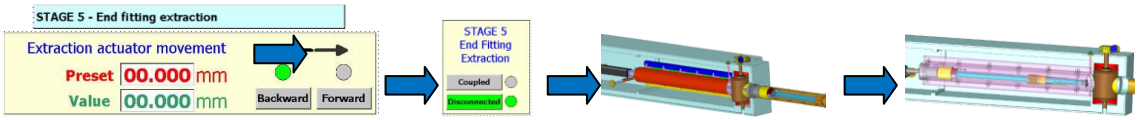

Figure 11: Representation of the end fitting extraction preliminary operations

After performing the extraction of the end fitting, it is necessary to close the fuel channel, until the pressure tube extraction. To perform this operation, the operator should turn the storage tubes assembly until the green tube reach the working position (see Figure 12). In this tube is located the extended channel closure plug. When the green tube is in working position, the operator command the extension of the extracting actuator, to push from the green tube the extended channel closure plug until the closing of the fuel channel. After fuel channel closing, the extracting actuator is withdrawn to the handling elements assembly.

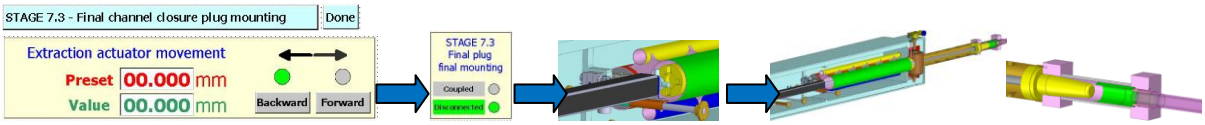

Figure 12: Representation of the extended channel closure plug mounting

Confirmation of each finalization step in order to perform the next operation step (see Figure 13).

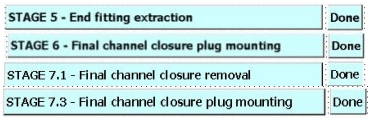

Figure 13: Representation of the mounting / removal of the final channel closure plug operating confirmation

The next step is to close the access valve. The closing operation of the fuel channel is necessary to ensure a radiation protection during the dismantling of the protective cylindrical screen (see Figure 14).

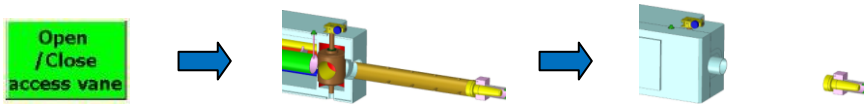

Figure 14: Representation of the protective cylindrical screen dismantling

After installing of the extended channel closure plug, closing of the access valve and the manually dismantling of the protective cylindrical screen, the operator can prepare the decommissioning device for the pressure tube extraction stage.

2.5.3. Removal of the fuel channel pressure tube

The preliminary operations for the pressure tube extraction are:

- manually coupling of the decommissioning device to the fuel channel;
- protective cylindrical sleeve mounting;

- the rotation command of the storage tube assembly so that the green tube to reach the working position;
- the opening command of the device access valve assembly (see Figure 15);

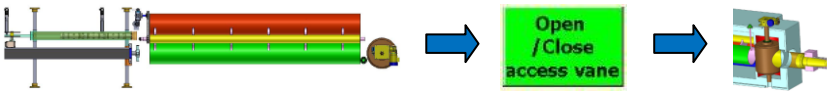

Figure 15: Representation of the preliminary operations

After completing the preliminary operations, the operator command the extension of the extracting actuator, to extract the extended channel closure plug and store it in the green tube (see Figure 16). After storage of the extended channel closure plug, the extracting actuator is withdrawn to the handling elements assembly.

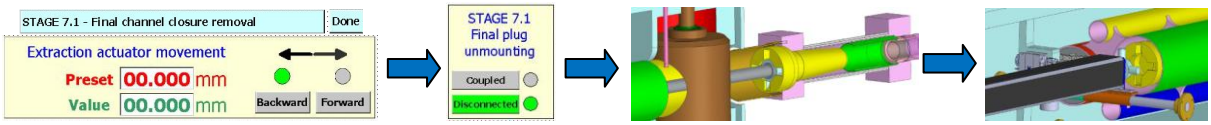

Figure 16: Representation of the extended channel closure plug extraction and storage

The operator command the blue tube movement for the pressure tube storage from the storage tube assembly and the handling elements assembly that the stationary tube of the cutting and extraction device to reach the working position. After positioning of the storage tube assembly and the handling elements assembly, the operator can command the cutting module to extract and store the pressure tube into the blue tube from the storage tube assembly (see Figure 17).

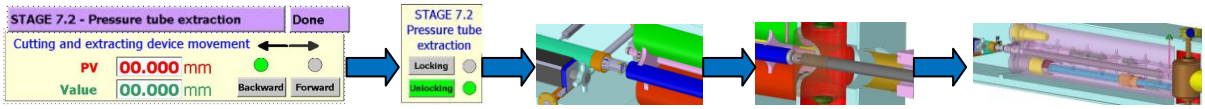

Figure 17: Representation of the extraction and storage of the pressure tube

Confirmation of each finalization step in order to perform the next operation step.
The next step is to close again the fuel channel. To perform this operation, the operator should turn the storage tubes assembly until the green tube, where is located the extended channel closure plug, and the extracting actuator from the handling elements assembly, reach the working position.
The operator command the extension of the extracting actuator, to push from the green tube the extended channel closure plug until the closing of the fuel channel. After fuel channel closing, the extracting actuator is withdrawn to the handling elements assembly (see Figure 18).

Figure 18: Representation of the extended channel closure plug mounting

The last operation after fuel channel closing is to close the access valve and withdrawal of the decommissioning device from the front of the fuel channel. The closing operation of the fuel channel is necessary to ensure a radiation protection during the dismantling of the protective cylindrical sleeve (see Figure 19).

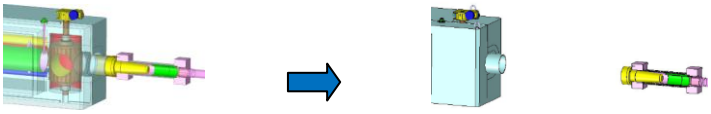

Figure 19: Representation of the access valve closing and withdrawal of the decommissioning device

After dismantling of the fuel channel components, the charged decommissioning device is moved with the moving platform to the transfer position, at the transport container, for the decommissioned materials storage transfer.
The dismantling operation stages of the fuel channel components are repeated for all the 380 channels of the reactor, from the front of calandria side (plane R) as well as the rear side (plane R').

4. CONCLUSIONS

The decommissioning of the fuel channels is a complex process that requires piece by piece removal activities of the components, transport and storage in the dedicated facilities, records and specific documents preparation of the decommissioning operations.
The presented device is a device that extracts the internal components of the horizontal fuel channels, ensuring a radiation protection during the stages of decommissioning.
The design of the device, moving platform and the device support assembly shall be achieved according to the particular features of the fuel channel components to be dismantled in the nuclear reactor decommissioning program, with respect of all security aspects, environmental protection during decommissioning activities and working procedures resulting from decommissioning plan developed.

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