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CONSIDERATIONS REGARDING THE HORIZONTAL FUEL CHANNELS IN THE CANDU 6 NUCLEAR REACTOR. PART 3 - MAIN STEPS OF THE FUEL CHANNEL ASSEMBLY

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Abstract: *The scope of this paper is to obtain the needed information on main steps necessary to assembly the fuel channel into calandria of CANDU 6 nuclear reactor. The 380 fuel channels of the nuclear reactor are composed of pressure tubes, made of zirconium-niobium alloy, located inside the calandria tubes, with two end fittings mounted, that are connected by the pipes network of the cooling supply feeders. Each CANDU fuel channel consists of four major components: the pressure tube, the calandria tube, the annulus spacers and the end fittings. The install operations to a new fuel channel must comply with the described requirements from the specified documents by AECL. The main installation operations are the roll expansion of the pressure tube ends into the two end fittings, the welding of the end fittings to the bellows and the installation of the positioning assemblies. Following installation and inspection of all 380 channels, the feeder pipes of the cooling system are connected to the end fittings. After each operation, the resulting information must be recorded in the specific registration and verification documents of each component and each operation. The registration documents, the check documents and the related reports of the fuel channel installation are part of the processes records of the assembly history of the nuclear reactor. All these documents and reports will be archived in order to take anytime a sequential picture of each fuel channel. The radiological safety analyses are made by certified experts for assessment of radiation exposure of workers and public.*
Keywords: *Candu reactor, Zirconium alloy, calandria tube, fuel channel, pressure tube, fuel bundle, end fitting, annulus spacer.*

1. GENERAL INTRODUCTION

The fuel channels have a high importance for the operation of CANDU nuclear reactors because they allow new refueling while operating at full capacity.
The reactor assembly consists of a hollow cylindrical structure called the calandria assembly, fuel channels and control mechanisms of reactivity.
The 380 fuel channels are composed of pressure tubes, made of zirconium-niobium alloy, located inside the calandria tubes, with two end fittings mounted, that are connected by the pipes network of the cooling supply feeders.
Each CANDU fuel channel consists of four major components: the pressure tube, the calandria tube, the annulus spacers and the end fittings.
The install operations of a new fuel channel within a calandria CANDU reactor, must to comply the described requirements in the specified documents by AECL.
The required specifications of the install operations of a new fuel channel are defined by:
- the fuel channel installation documentation requirements;
- the general requirements for tools and equipments;
- the welding procedures for structural welding of sealing rings;
- the quality assurance program.

Before installing of a new component in the fuel channel, checks should be made of existing parts into the canal, to observe that are in correct position or if exist non-compliances. Before installation should performed the cleaning and inspection of the component that will be installed and where will be mounted. Any lack of conformity shall be notified to the attention of the supervisor to remedy or replace the component.

After each operation, the resulting information must be recorded in the specific registration and verification documents of each component and each operation.

2. FUEL CHANNEL COMPONENTS ASSEMBLY STEPS

In the CANDU reactor, the main aim of the fuel channel is to support and locate the fuel inside of the reactor. The operations of a new fuel channel installing in the CANDU nuclear reactor calandria, shall satisfy the requirements described in the documents specified by AECL.

2.1. General considerations

The installation of each component is performed according to the design documentation and detailed diagram of a fuel channel from CANDU nuclear reactors, presented in Figure 1.

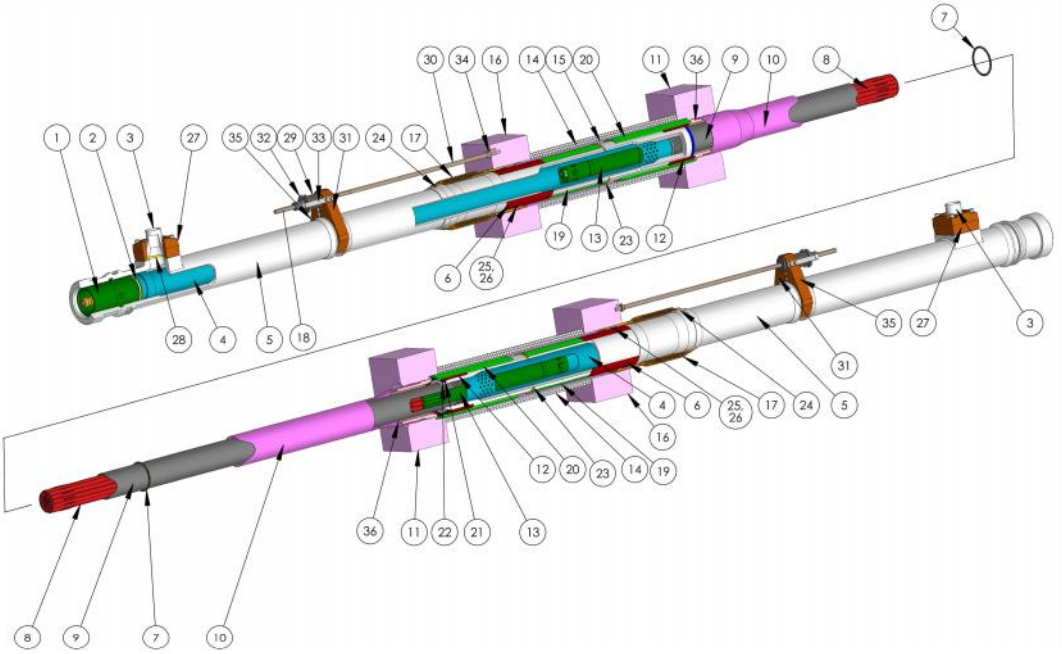

Figure 1: Schematic representation of a CANDU fuel channel component parts

1. Channel closure; 2. Closure seal insert; 3. Feeder coupling; 4. Liner tube; 5. End fitting body; 6. Outboard bearings; 7. Annulus spacer; 8. Fuel bundle; 9. Pressure tube; 10. Calandria tube; 11. Calandria tubesheet; 12. Inboard bearings; 13. Shield plug; 14. Endshield shielding balls; 15. Endshield lattice tube; 16. Fuelling tubesheet; 17. Channel annulus bellows; 18. Positioning assembly; 19. End fitting shielding sleeve; 20. Lattice tube shielding sleeve; 21. End fitting inner ring seal; 22. Elastic safety lock for end fitting inner ring seal; 23. Elastic safety lock for end fitting shielding sleeve; 24. Support ring for annulus bellows; 25. Annulus bellows outer ring seal; 26. Elastic safety lock for Annulus bellows outer ring seal; 27. Feeder coupling attachment; 28. Feeder gasket; 29. Rod positioning threaded part; 30. Rod positioning; 31. Right fastening piece for rod positioning; 32. Counter nut locking; 33. Safety lock for counter nut; 34. Lock pin for rod positioning; 35. Left fastening piece for rod positioning; 36. Crimping ring for calandria tube;

2.2. Initial conditions

The fuel channel components assembly is performed when the following components are pre-assembled (see Figure 2):

- the calandria tube (10) is mounted with crimping rings in calandria tubesheet (11);
- the endshield lattice tube (15) is also mounted and fixed between the calandria tubesheet (11) and fuelling tubesheet (16);
- the space between the calandria tubesheet (11) and fuelling tubesheet (16) is filled with endshield shielding balls (14).

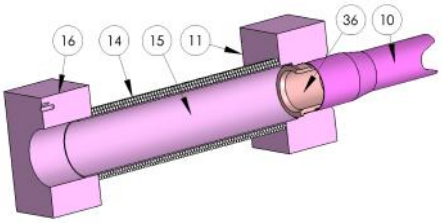

Figure 2: Schematic representation of fuel channel pre-assembled components

2.3. Lattice tube shielding sleeve mounting

The operations of this procedure are the following (see Figure 3):
- defects inspection, lattice tube shielding sleeve dimension check and body cleaning, defects inspection, inboard bearings dimension check and cleaning it before installation; if, after inspection and verification operations; if they correspond, proceed to the next step;
- insert the shielding sleeve (20) into endshield lattice tube (15) up to the crimping ring for calandria tube (10) fixed to the calandria tubesheet.
- insert the inboard bearings (12) in the shielding sleeve (20) and fixing it in the end of calandria.
- after each operation, the resulting information must be recorded in the specific registration and verification documents of each component and each operation.

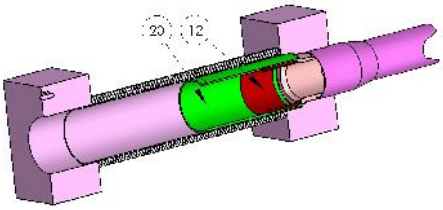

Figure 3: Schematic representation of the lattice tube shielding sleeve assembling

2.4. Pressure tube mounting

The pressure tube (9) mounting is carried out after the assembly and fixation of the lattice tube shielding sleeve into the lattice tube (see Figure 4).
The operations of this procedure are the following:
- defects inspection, pressure tube and calandria tube dimension check and body cleaning before installation; after inspection and verification operations, if they correspond, proceed to the next step;
- the platform moving to maintenance position for the pressure tube installation into the fuel channel pushing device; the pressure tube will be covered with a protective sleeve and will be mounted the calandria tube guide cones;
- movement of the platform in the fuel channel front position where the pressure tube will be mounted;
- pushing the pressure tube, inside the calandria tube until the established quota by working procedure;

Figure 4: Schematic representation of the pressure tube mounting

- after each operation, the resulting information shall be recorded in the specific registration and verification documents of each component and each operation.

2.5. Annulus spacer mounting

In a fuel channel, is necessary to have a constant maintained annular space between the pressure tube and the calandria tube, to allow the gas circulation which provides thermal insulation of the pressure tube to relatively cold calandria tube. Therefore, the annulus spacers (7) have been used to maintain the space between the

pressure tube and the calandria tube. They must be installed on the pressure tube after the tube has been placed inside calandria tube and secured at one end.
The operations for positioning of annulus spacers are the following:
- inspection for defects, annulus spacers dimension check, cleaning before installation; after inspection and verification operations; if they correspond, proceed to the next step;
- installing of annulus spacers is carried out as follows (see Figure 5): are mounted two annulus spacers from the plan R, the pressure tube is blocked from the plan R, first spacer no. 2 then spacer no. 1 and the other two first spacer no.3 then spacer no. 4, from the plan R, the pressure tube is blocked from the plan R; the operation is carried out by the aid of a device for introducing onto the pressure tube and with the annulus closing positioned at the bottom;

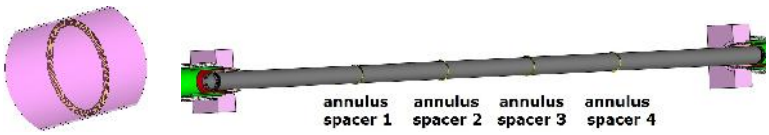

Figure 5: Schematic representation of the annulus spacers mounting

- after each installation, the position of each annulus spacing, shall be recorded in the specific registration and verification documents of each component and each operation.

2.6. End Fitting pre-assembly

The end fittings and related accessories are assembled before their introduction into the fuel channel.
The operations of this procedure are the following:
- end fitting selection and placing it on the workbench (see Figure 6);

Figure 6: Schematic representation of the end fitting

- inspection for defects, end fitting dimension check, feeder holes and threads check and end fitting cleaning; end fitting components inspection for defects, dimension check and components cleaning that will be installed at the end fitting, if they correspond go to next step;
- shall be mounted on the outside end of the canal, the inner ring seal (21) and secured with an elastic safety lock (22) (see Figure 7);

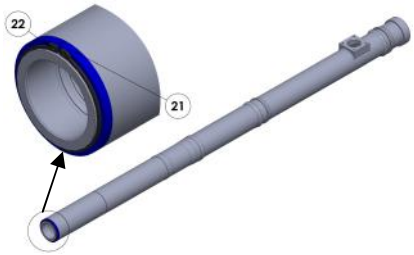

Figure 7: Schematic representation of the inner ring seal mounting

- shall be mounted the outboard bearing (6) then, in extension, the end fitting shielding sleeve (19); the shielding sleeve is secured by a elastic safety lock (23) (see Figure 8);

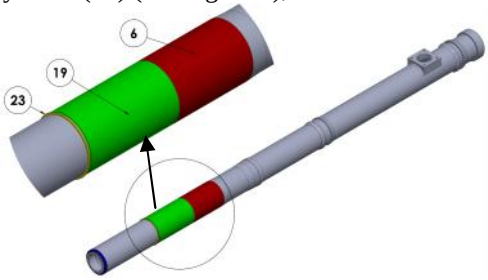

Figure 8: Schematic representation of the outboard bearing and the shielding sleeve mounting

- the end fitting is welded on the support ring (24) for mounting of the channel annulus bellows isolation (17) (see Figure 9);

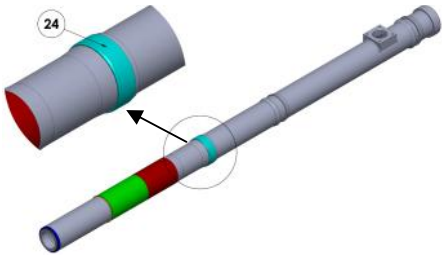

Figure 9: Schematic representation of the support ring for mounting the channel annulus bellows isolation mounting

- inside of the channel annulus bellows (17), into channel side, is mounted the annulus bellows outer ring seal (25) which is secured against movement by two elastic safety locks (26);
- shall be mounted the channel annulus bellows (17) on the end fitting over the annulus bellows outer ring seal (25) and the outer end is welded on the support ring (24) (see Figure 10);

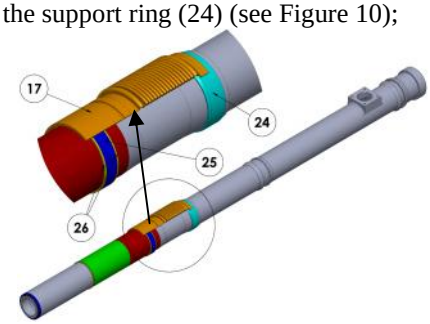

Figure 10: Schematic representation of the channel annulus bellows mounting

- end fitting testing with the leaks test facility and then move to the next step; if the tightness that does not correspond proceeds to replace the parts;
- after testing, the end fitting it clean up and wiped; shall be mounted plugs at both ends to prevent ingress of dirt inside; shall be stored in dry and clean atmosphere before installation;
- after each operation, the resulting information shall be recorded in the specific registration and verification documents of each component and each operation.

2.7. End Fitting mounting into the fuel channel

The end fitting shall be mounted into the fuel channel provided that the pressure tube is fixed and blocked to the other end to prevent the displacement at the time of the end fitting introduction into fuel channel for mounting.
The operations of end fitting mounting into fuel channel are the following:
- selection, inspection for defects, checking for dimension and final cleaning of end fitting before mounting in relation to the selected channel; after inspection and verification operations, if they correspond, proceed to the next step;
- moving the platform in maintenance position for installing of the end fitting into the introduction device in the fuel channel; the end fitting will be positioned into the introduction device relative to the channel position where will be introduced, that is, no. area, line, column, front or rear calandria zone, so the end fitting mounting position relative to the feeder coupling position (3) to be 0 °, left 32 °, 58 °, 90 ° , right 32 °, 58 °, 90 ° (see Figure 11); the end fitting will be covered with an protection sleeve against possible impurities;

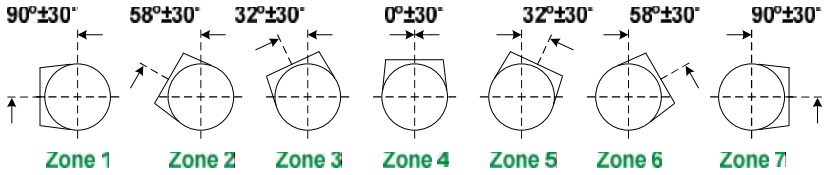

Figure 11: Schematic representation of the end fitting orientation for the feeder coupling

- platform moving to the fuel channel front position where the end fitting will be inserted;
- the end fitting introducing command inside calandria, up to established position from working procedure; the end fitting is inserted into the lattice tube shielding sleeve (20), taking care to be horizontality maintained the end fitting; also should be considered that inside fitting, has to enter the pressure tube was centered in advance (see Figure 12);

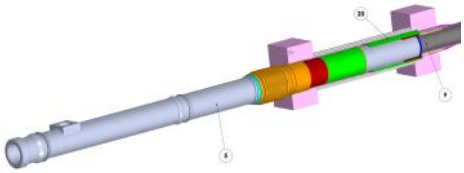

Figure 12: Schematic representation of the end fitting mounting into fuel channel

- inside the end fitting shall be inserted the crimping head (rolling) up to the beginning of pressure tube (10); the pressure tube is rolled inside of the end fitting, positions determined by the working procedure (see Figure 13);

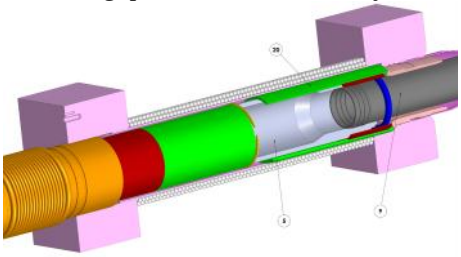

Figure 13: Schematic representation of the pressure tube crimping on the inside of end fitting

- the liner tube (4) shall be inserted into the end fitting, using the introduction device by cold pressing, up to the end of the pressure tube (9) rolled inside the end fitting (see Figure 14);

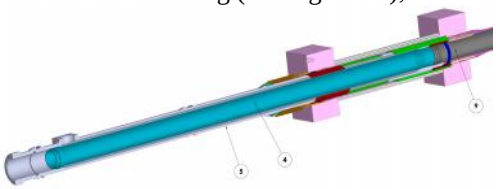

Figure 14: Schematic representation of the liner tube mounting inside of end fitting

- in the outer end of end fitting is mounted one elastic safety lock (2) (see Figure 15);

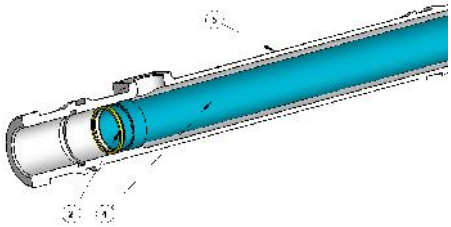

Figure 15: Schematic representation of the elastic safety lock mounting inside of end fitting

- the shield plug (13) shall be inserted in the head of introduction device; the shield plug is unlocks to be inserted into the end fitting; the device shall be inserted into the end fitting up to the position where the plug locks are inside the groove of the end fitting; the shield plug is blocked by decoupling the introduction device (see Figure 16);

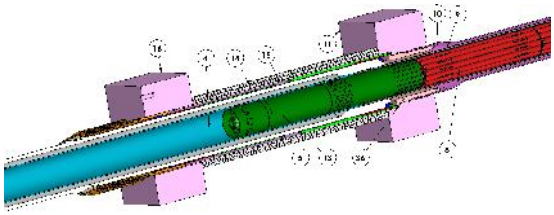

Figure 16: Schematic representation of the shield plug mounting inside of end fitting

- the channel closure (1) shall be inserted in the head of introduction device; the channel closure is unlocks to be inserted into the end fitting; the channel closure is unlocks to be inserted into the end fitting; the device shall be inserted into the end fitting up to the position where the closure locks are inside the groove of the end fitting; the channel closure is blocked by decoupling the introduction device (see Figure 17);

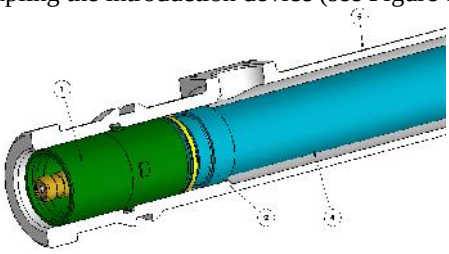

Figure 17: Schematic representation of the channel closure mounting inside of end fitting

- the feeder coupling (3) is mounted for connection to the cooling system; the installation is performed using the feeder coupling attachment (27) and four screws with locking rings against unscrewing; between the feeder coupling and slot of the end fitting is mounted a feeder gasket (28) as a sealing clamp (see Figure 18);

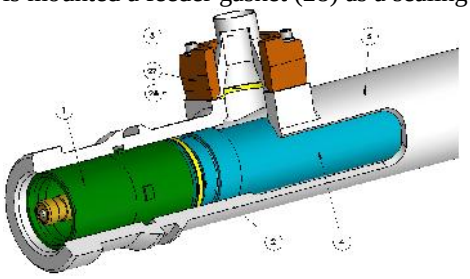

Figure 18: Schematic representation of the feeder coupling mounting at the end fitting

- after each operation, the resulting information shall be recorded in the specific registration and verification documents of each component and each operation.

2.8. Positioning assembly mounting

The positioning assembly is mounted on the end fitting and connected to one end shield. A second positioning assembly is installed at the other end fitting of the fuel channel, but not attached to the end shield, so the point of channel restraint can be readily changed once the elongation allowance is used up at one end of the reactor.
The operations of positioning assembly mounting on fuel channel are the following:
- positioning assembly selection in relation to the selected channel for installation, inspection for defects, checking for dimension and final cleaning for installation; after inspection and verification operations, if they correspond, proceed to the next step;
- in the threaded part (29) shall be inserted the rod positioning (30) (see Figure 19);

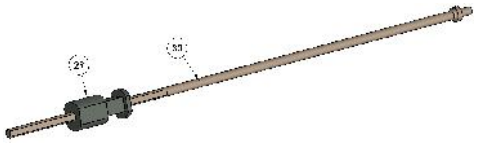

Figure 19: Schematic representation of the rod positioning mounting

- after subassembly achieving from the preceding paragraph, is mounted on the end fitting (5), in special allocated position, two clamping and fastening pieces (31, 35) of the positioning assembly, left and right side of the end fitting; these two pieces are riveted in the final position;
- the rod positioning (30) is screwed in the fuelling tubesheet (16) of calandria to the maximum position (see Figure 20);

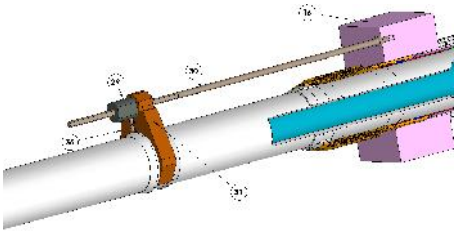

Figure 20: Schematic representation of the clamping and fastening pieces mounting for the rod positioning

- after rod positioning (30) is screwed, are mounted, on the left and right side of the clamping and fastening pieces (31), the two safety lock for counter nut (33), spring plate type, fastened with screws (see Figure 21);

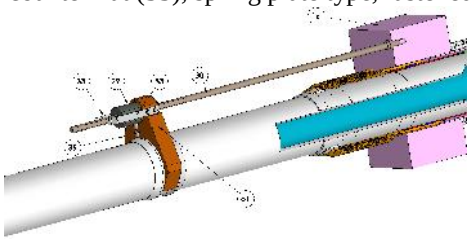

Figure 21: Schematic representation of the safety lock for counter nut mounting

- the two safety lock (33) are maintained spread apart and on the positioning rod (30) is mounted the counter nut locking (32); that is tightened up to the mentioned quota in the mounting procedure for the positioning assembly; if safety lock (33) recesses does not coincide with their position, the counter nut locking (32) is unscrewed to the first correct position; the two safety lock are left off in the free recesses, for counter nut locking (32) (see Figure 22);

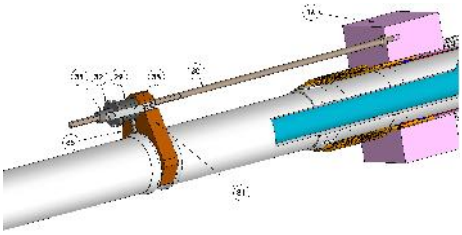

Figure 22: Schematic representation of counter nut locking mounting and blocking

- upon completion of the rod positioning (30), in the calandria fuelling tubesheet (16) is made a hole for the lock pin; the lock pin shall (34) be inserted into the recess of the rod positioning (see Figure 23);

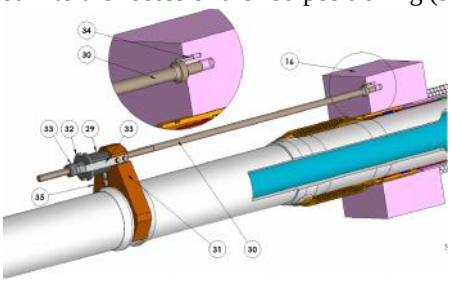

Figure 23: Schematic representation of lock pin mounting for rod positioning

- after each operation, the resulting information shall be recorded in the specific registration and verification documents of each component and each operation.

3. CONCLUSIONS

The fuel channels from CANDU nuclear reactors, using the pressure tubes with thin-walled of zirconium alloy, are the most important part of the calandria and designed to resist to the cooling fluid flow, temperature, pressure and imposed conditions by the of the heat transport system.
Operations of the fuel channel installation shall comply the described requirements from the specified documents by AECL. All performed measurements in accordance with reference procedures are documented reference to the fuel channel installation. Registration documents, checking documents and reports relating to the required operations of fuel channel installation will be archived to have any time a sequentially image of each fuel channel.
Fuel channels have a large contribution for the operation of CANDU nuclear reactors because they allow new refueling while operating at full capacity.

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