MODIFICATION OF FUEL BUNDLES AND ASSOCIATED OPTIMIZATION OF FUEL HANDLING EQUIPMENT

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Abstract

This is a continuation of research that started in July 2007 at the Deep River Science Academy. The research was related to the effects of endplate thickness and misalignment of bundles in the fuel channel on pressure losses of reactor coolant.

Based on this research, a new approach to refueling of the CANDU reactor has been developed. It greatly simplifies fuel handling equipment and increases its reliability. It also reduces required staffing, as well as operating and maintenance costs associated with fuel handling.

1. Research at Deep River Science Academy

At the Deep River Science Academy at AECL in July 2007, our experiments were to determine the effects of end plate thickness and misalignment of fuel bundles on the fuel bundle pressure losses. With this we could find the best way to position the bundles in fuel channels and to maximize heat transfer between the coolant and the bundles without losing additional pressure. We used three different end plate thicknesses and four misalignments angles. The misalignment angles were 0º, 15º, 30º, 60º and the endplate thickness was equal to 2, 3, and 4 endplates. Out of all the angles and endplate thickness that were tested, the best way was to use 2 endplates and have the bundles lined up at 0º. This setting created the least amount of hydraulic resistance then the other endplate thicknesses and angles. The hydraulic resistance occurred more with the 3 and 4 endplates because there was more area exposed for friction to be created at the junctions (junction is the place where the next bundle comes into contact with the previous one). Also when the bundles are misaligned, there is a greater pressure drop because there was more bundle cross-section area exposed for the water flow. The pressure drop was lower for the 2 endplates than any of the other endplates because the less area was exposed for the water flow. That, in turn, allows the Primary Heat Transport System pumps to use less energy. Therefore, an arrangement with two endplates with 0º alignment angle was the best way to set up the fuel bundles in the reactor [1]. Obviously, it is very difficult to push the bundles into the fuel channel in absolutely the same position. It will require a modification of the fuelling machine. And this will be very expensive.

Being impressed with the topic, I continued checking other possibilities after we had finished our experiments at Deep River Science Academy. For example, how to make the pressure drop across the bundle the same for any misalignment angle so the fuel bundle can be pushed into the fuel channel in any position.

2. Objectives

After completing the experiment at Deep River Science Academy, I decided to study further in the field of nuclear reactors. To make the pressure drop across the bundle the same for any misalignment angle, the fuel bundle should be round (spherical). But in this case, the fuel bundle will be moved (rolled) by the reactor coolant flow. We should prevent the fuel bundles to leave the reactor. The positive effect is that we do not need a fuelling machine to remove spent fuel bundles from reactor. My final conclusion was that the new bundles could be moved (rolled) into the reactor the same way, by the reactor coolant flow.

3. Suggested nuclear reactor and fuel handling equipment

Pressurized fuel channel type reactors are well known. A pressurized fuel channel type reactor has a group of fuel channels. A fuel channel is a horizontal or vertical pressure tube positioned in a moderator and containing fuel assemblies (fuel bundles). The reactor also has a reactor coolant circulation system that consists of a group of pumps and providing circulation of the reactor coolant through the fuel channels. A fuelling machine inserts the fuel assemblies into the pressure tubes and removes the fuel assemblies from the pressure tubes. A reactor coolant is usually light water or heavy water. A reactor coolant circuit consists of a reactor, a heat consumer (usually a primary side of boilers in case of nuclear power plant), and reactor coolant pumps. The reactor coolant is pumped between fuel elements of fuel assemblies located in the fuel channels absorbing the heat generated by fuel elements and usually through the tube side of boilers of the nuclear power plant releasing the heat. The coolant further returns to the reactor coolant pump and to the reactor channels. The fuelling machine consists of trolleys and fuelling heads.

The suggested reactor [2] has spherical fuel assemblies that can roll in the pressure tubes and in pipes with the flow of the reactor coolant. A fuel assembly distribution header is connected to the pressure tube inlets and has hydraulic cylinders to control the movement of fuel assemblies from fuel assembly distribution header into the pressure tube inlets. A fuel assembly collection header is connected to pressure tube outlets and has hydraulic cylinders to control the movement of fuel assemblies from the pressure tube outlets into the fuel assembly distribution header. This suggested reactor does not need the pressure tube plugs (about 1000 per reactor), fuelling machine trolleys, fuelling heads, and reduces the cost of the fuel handling.

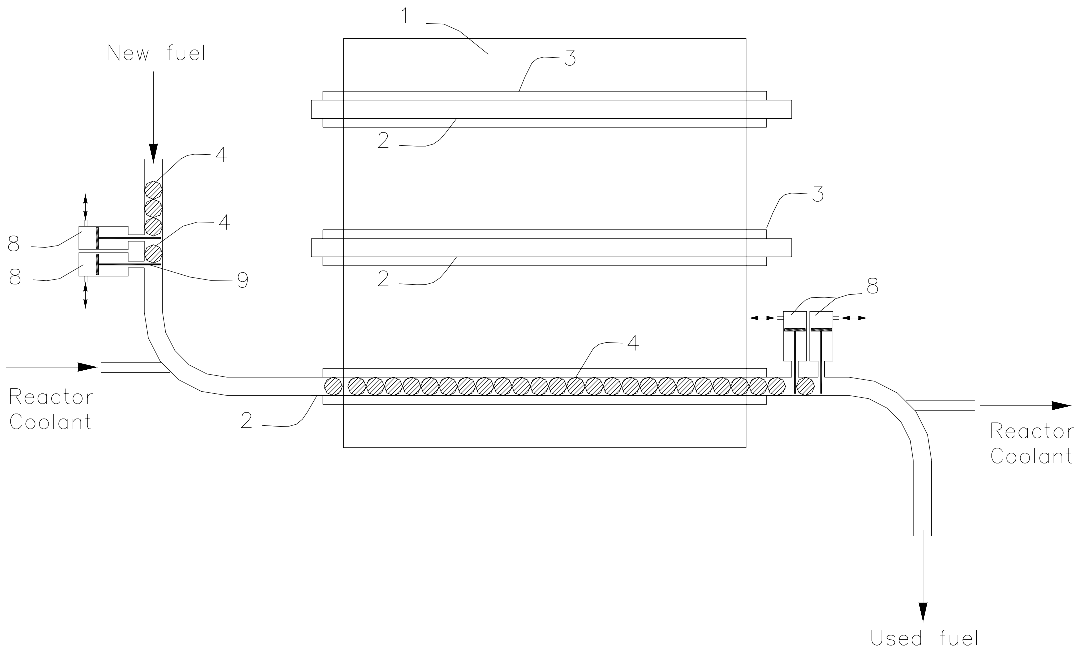

Fig. 1. Suggested nuclear reactor

Suggested reactor has a group of fuel channels in a moderator 1. A fuel channel consists of a horizontal pressure tube 2 inside the calandria tube 3. The pressure tubes contain fuel assemblies (fuel bundles). A reactor coolant for CANDU reactors is heavy water. Spherical fuel assembly can roll in the pressure tubes and in pipes with the flow of the reactor. Each pressure tube 2 has two connections to the reactor coolant circulation system. Inlet of the pressure tube 2 is connected to the pipe (header) supplying new fuel assemblies 4. The pipe has two hydraulic cylinders 8, each of them having a piston and attached stem 9. The stem moves into the pipe and controls the movement of the fuel assemblies with the flow of the reactor coolant. The stem can be of any form (shape).

To remove one used fuel assembly from the pressure tube 2, the stem 9 of the right of two hydraulic cylinders 8, located downstream of the outlet of the pressure tube 2, retracts. The first fuel assembly 4 rolls with the flow from the outlet of the pressure tube 2 and stops when it reaches the used fuel storage. After that, the stem 9 extends back into the pipe. When the stem 9 of the left of two hydraulic cylinders 8 retracts, all fuel assemblies upstream of the stem inside the pressure tube 2 roll with the reactor coolant flow toward the outlet of the pressure tube 2 until the stem of the right hydraulic cylinder 8 stops them.

To insert one new fuel assembly into the pressure tube 2, the stem 9 of the lower (as seen on Fig.1) of two hydraulic cylinders 8, located upstream of the inlet of the pressure tube 2, retracts. One new fuel assembly 4 rolls with the flow toward the inlet of the pressure tube 2 and stops at the first from the left side fuel assembly. After that, the stem 9 extends into the pipe. When the stem 9 of the upper hydraulic cylinders 8 retracts, all new fuel assemblies roll with the reactor coolant flow toward the inlet of the pressure tube 2 until the stem 9 of the lower hydraulic cylinder 8 stops them.

Spherical fuel assembly has fuel elements 6 installed inside the outer shell 5. The shell has many holes 7 for the reactor coolant circulation (see Fig. 2).

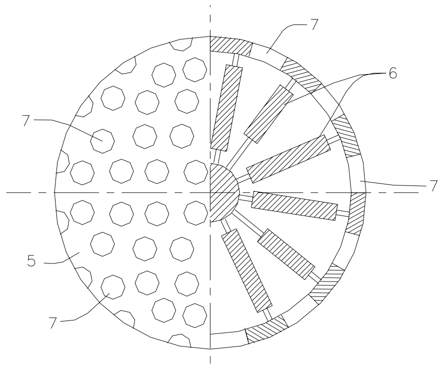

Fig. 2. Spherical fuel assembly

The spherical fuel assembly can be filled with spherical fuel elements (see Fig. 3).

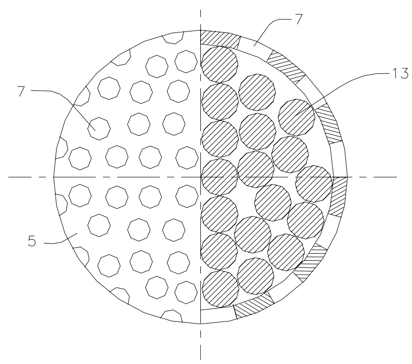

Fig. 3. Spherical fuel assembly with spherical fuel elements

4. Conclusion

This suggested nuclear reactor and the fuel handling equipment does not need the pressure tube plugs (about 1000 per reactor), fuelling machine trolleys, fuelling heads, and reduces the cost of the fuel handling.

5. References

[1] Ponomaryov P., Trazwell, C. "Effects of endplate thickness on fuel bundle pressure losses", Deep River Science Academy report, August 2007.

[2] Ponomaryov P., "Pressurized fuel channel type nuclear reactor", patent application, Canada, February 2008.