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The Safety Analysis to Increase for the Water Temperature of the HPECC in WSNPP-1

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1. Introduction

For continuous operation, Wolsong Nuclear Power Plant Number One (WSNPP-1) developed Improved Technical Specification. The selection criteria for Limiting Conditions for Operations (LCOs) conform to Announcement No. 2009-37, which is based on 10 CFR 50.36[1]. The LCO of the water temperature (30 °C) of the High Pressure Emergency Core Cooling (HPECC) was established based on safety analysis of WSNPP-1, which did not consider the climate condition of the present status. Analysis of LOCA events was conducted in order to determine whether on increase in the LCO of the water temperature of the HPECC from 30 °C to 45°C would result in adverse effects.

2. Description of CANDU-6

WSNPPs are CANDU 6 Pressurized Heavy Water Reactor (PHWR). It has 380 horizontal fuel channels surrounded by a cool low pressure heavy water moderator. Each fuel channel is six meters long and contains twelve fuel bundles within a pressure tube. A bundle is made up of 37 elements which contain natural uranium in the form of compacted sintered cylindrical pellets of uranium dioxide (UO_2). Each channel has an end fitting at each end, which allows for the fueling machines to attach facilitating on power refueling. Coolant enters the channel from an inlet feeder pipe which is connected to the inlet end fitting. The coolant then enters the fuel string, flowing within the channels between the fuel elements inside the pressure tube. The coolant leaves the channel via the outlet feeder pipe which is attached to the outlet end fitting. The coolant enters the channel at about 11 MPa and 263 °C. It leaves slightly above 10 MPa and 310 °C.

When a channel is fueled, its power is increased and the coolant at the end of the channel contains D_2O vapor. As the fuel in the channel burns up, the channel power decreases, and the length of the boiling region decreases. When the power has reduced sufficiently, the channel drops out of boiling until it is refueled again.

Figure 1 shows a simplified overview of the Primary Heat Transport System (PHTS). The core is subdivided into two symmetrically located figure of eight loops. Each loop consists of two core passes of 95 channels each. Each pass contains a pump feeds an inlet header. This inlet header is connected to 95 inlet feeders connect to the channels as described above.

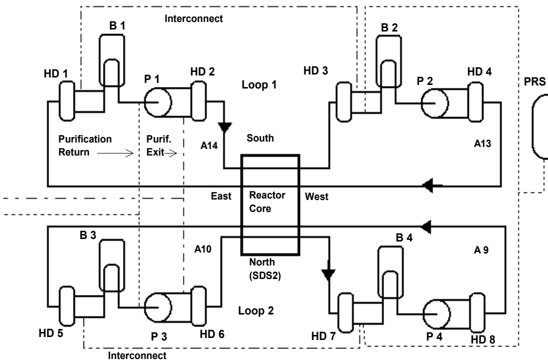

Fig. 1. CANDU Simplified Circuit Diagram

The 95 outlet feeders connect to an outlet header. Coolant flows through the vertical steam generator u-tubes to the steam generator outlet where it flows to the pump suction line of the pump in the other core pass in the loop. Because it is a figure of eight loop, flow in channels in one core pass is in the opposite direction to the other. As the channels in each core pass are laid out adjacently, it follows that the flow in adjacent channels are in opposite directions, forming a checker-board pattern. The two PHTS loops are connected at each end of the reactor through the pressurizer interconnect line and the purification and feed interconnect lines. The pressurizer is connected to the discharge pipes of outlet headers 3 and 7. The purification feed flow is associated with inlet headers 2 and 6, while the purification return flow enters the PHTS at the suction of pumps 1 and 3. The PHTS also contains stability pipes which connect outlet headers 1 and 3 in loop 1, and outlet headers 5 and 7 in loop 2 [2].

3. Emegency Core Cooling System

The flow diagram of the emergency core cooling system is shown in Figure 2. The ECC system consists of three stages of operation. In the high pressure ECC injection stage, high pressure nitrogen gas from the ECC gas tank (TK2) forces the light water from the ECC water tanks (TKl, 3) into the PHTS. In the medium pressure injection stage, the ECC pump takes water from the dousing tank. In the low pressure injection stage, the same ECC pump re-circulates the H_2O - D_2O mixture collected in the basement of the reactor building through heat exchangers back to the PHTS.

When the Loss of Coolant Accident (LOCA) signal and conditioning signal of ECC are received, the gas isolation valves (PV 81, 82), high pressure injection valves (MV 79, 80), and D_2O isolation valves (MV 39 to 46, MV 59 to 66) will open automatically. The ECC piping downstream of the D_2O check valves (PV 33, 34, 47, 48) is pressurized to the PHTS pressure. The rupture discs burst open at a differential pressure of 0.38 MPa. Thus, the high pressure injection flow will begin when the pressure in the PHTS is about 0.38 MPa less than the high pressure injection pressure from the ECC water tanks. The initial condition of water temperature is 30 ^{o}C. High pressure injection will continue until a low ECC water tank level signal is reached. At this time, the gas isolation valves and high pressure injection valves are closed automatically.

Upon receipt of the LOCA signal, one ECC pump will automatically start and the dousing tank isolation valves (PV 10, 11) will open. The medium pressure injection valves (MV 31, 50) will open 90 seconds after the LOCA signal. When the pressure downstream of the medium pressure check valves (V 76, V 77) is less than the ECC pump discharge pressure, medium pressure injection flow will start. Before this pressure is reached, ECC pumps will re-circulate water via the pump recirculation lines. The check valves (V 76, V 77) isolate the medium pressure injection system piping during the high pressure injection stage.

On a low dousing tank level, the low pressure injection valves (PV 1, 2) open and the dousing tank isolation valves (PV 10, 11) close. The ECC pump re-circulates H_2O - D_2O mixture collected in the basement of the reactor building through heat exchangers back into PHTS [3].

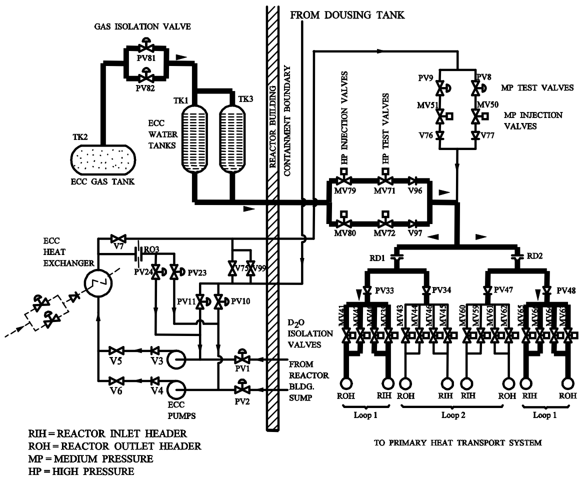

Fig. 2. ECC System Simplified Diagram

4. Analysis Results

Analysis of LOCA events was conducted in order to determine whether on increase in the LCO of the water temperature of the HPECC from 30 ^{o}C to 45^{o}C would result in adverse effects. This tempreature is based on WSNPP-2,3,4 LCO. The thermal hydraulic safety analysis code of the Canadian Algorithm for THErmalhydraulic Network Analysis (CATHENA) was used as a safety code [4]. The acceptance criterias (fuel centerline melting temp : 2805 ^{o}C, fuel sheath temp : 800 ^{o}C) for these assessments are the same as those applied to the WSNPP-1 Final Safety Analysis Report Ch. 15.

4.1 Large Loss of Coolant Accident(LBLOCA)

Analysis results in the event of the 100% break of the outlet header accident are shown in Fig. 3, 4 and Table 1. For LBLOCA, even though the change of the HPECC temperature, the limiting accidents for each break location are same with the existing results of WSNPP-1 safety analisis. That is, in respect of the fuel temperature and fuel failure number, 35% reactor inlet header break, 55% pump suction break and 100% reactor outlet header break are still limiting accidents for each break location. Also, in thermalhydraulic results of these limiting accidents, there are not noticeable differences as shown in Fig. 3, 4 and Table 1.

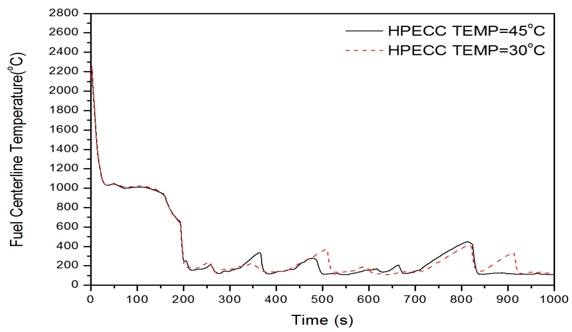

Fig. 3. Temperature of the Fuel Centerline

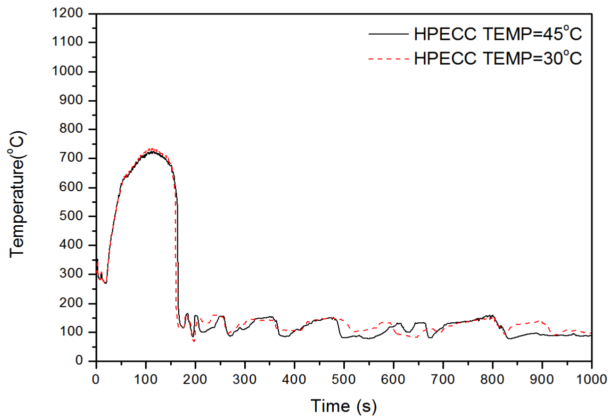

Fig. 4. Temperature of the Pressure Tube

Table 1. The number of Fuel Failure

Channel Power	HPECC water	
	45℃	30℃
O06_7300kW	5	5
O06_7000kW	4	4
S10_6600kW	2	2
G05_6000kW	2	2
B10_5000kW	0	0
W10_4000kW	0	0

4.2 Small Loss of Coolant Accident

Analysis result for the event of small break (3% break size) of LOCA is shown in Fig. 5. It is not noticeable differences as shown in Fig. 5

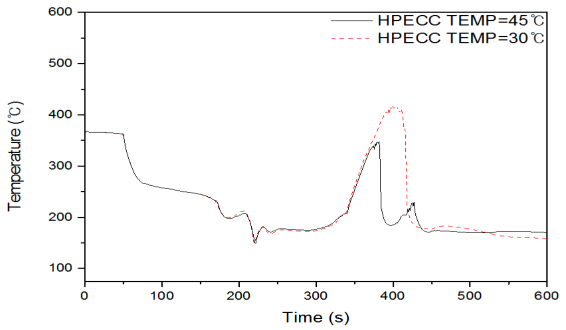

Fig. 5. Temperature of the Fuel Sheath

5. Conclusion

A safety analysis was performed with CATHENA code to evaluate the safety of increasing the temperature of the HPECC in WSNPP-1.

The analysis results for LOCA confirm that the HPECC temperaure increase would bring no adverse to the safety of the plant from the viewpoint of fuel and fuel channel integrity. The new LCO of water temperature of the HPECC will be incorporated into the Technical Specifications of WSNPP-1.

REFERENCES

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