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Break Survey at Reactor Inlet Header for Large Break LOCA of a CANDU 6 with a New 37-element Fuel Fully Loaded

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1. Introduction

Thermal margin in CHF is decreased with aging of CANDU reactors due to pressure tube (PT) diametral creep. A new 37-element fuel (37M) has been adopted in Canadian utilities in order to enhance CHF, and the new fuel is geometrically the same as the existing 37-element fuel except a little reduced center pin diameter.

Now KHNP is preparing to commercialize the new fuel in Wolsong site, and full scope of safety analysis for a CANDU 6 with the new fuel fully loaded have been almost completed. On the way of performing Large Break (LB) LOCA analysis, break survey was performed to identify limiting break sizes in terms of fuel failure and fuel channel failure. In this paper, break survey at reactor inlet header (RIH) was performed in order to find limiting break sizes in terms of fuel and PT integrity.

2. Analysis Method and Assumptions

In the present analysis, power pulse data were produced by an engineering service contractor, KEPCO-E&C performing LBLOCA. CATHENA [1] models of Primary Heat Transport System (PHTS) and several representative channels at an aged condition, 8000 EFPD for Wolsong NPP Unit 2 were prepared by KHNP-CRI[2,3,4]. The CATHENA PHTS circuit model consists of 7 multiple average channels per core pass and total 28 multiple average channels in two loops, and is linked with secondary side and emergency core cooling systems.

Initial RIH temperature and reactor power were assumed to be 268.5℃ and 103% FP, respectively, and only response of shutdown system No. 1 (SDS1) was credited in the power pulse calculation assuming that the second trip of neutronic trips of SDS1 was effective. PHTS pump continued to run before automatic pump trip was initiated when reactor power was less than 10% FP and pressure in any of the outlet headers fell below 2.5 MPa(g), and the PHTS pressure and inventory control was assumed to be available before loop isolation following LOCA signal. In the secondary side model, steam generator crash cooldown was credited, and normal feed water control was available. Table 1 shows the initial PHTS thermal-hydraulic conditions for LBLOCA analysis.

Several cases of 20%~45% break sizes at RIH were analyzed to 100 seconds. Four break sizes of 30%, 35%, 40% and 45% with high fuel sheath temperatures were analyzed in detail with the representative single channel models (B10, G05, O6, S10, W10, O6mod channels). CATHENA 3.5.4.4 version including the new fuel CHF correlation was used in the analysis.

Table 1 Initial PHTS conditions for LBLOCA

Parameter	Value
RIH2 Temperature (℃)	268.5
RIH4 Temperature (℃)	268.6
RIH6 Temperature (℃)	268.6
RIH8 Temperature (℃)	268.6
RIH2 Pressure (MPa(a))	11.34
RIH4 Pressure (MPa(a))	11.34
RIH6 Pressure (MPa(a))	11.34
RIH8 Pressure (MPa(a))	11.34
ROH1 Pressure (MPa(a))	10.04
ROH3 Pressure (MPa(a))	10.04
ROH5 Pressure (MPa(a))	10.04
ROH7 Pressure (MPa(a))	10.04
ROH1 Void Fraction	0.305
ROH3 Void Fraction	0.300
ROH5 Void Fraction	0.306
ROH7 Void Fraction	0.305
Copepass1 Mass Flowrate (kg/s)	2033.8
Copepass2 Mass Flowrate (kg/s)	2030.5
Copepass3 Mass Flowrate (kg/s)	2027.7
Copepass4 Mass Flowrate (kg/s)	2030.5
Pressurizer Level (m)	12.47
Pressurizer Level Setpoint (m)	12.41

3. Results

Six event cases with 20%, 25%, 30%, 35%, 40% and 45% break sizes at RIH of core pass 4 were analyzed to 100 seconds. Figure 1 shows total coolant mass flowrate of core pass 4 (critical pass) from the circuit runs. At early stage (5 to 20 s) of the RIH break events, the cases of 30~45% break sizes show severe flow stagnation. In Figure 2, it was shown fuel sheath temperatures at bundle 7 of averaged channel 4 in core pass 4. In the case of 45% break size, the highest sheath temperature was predicted, but the case of 35% or 40% break size could be in longer duration of high sheath temperature.

With the cases of 30% ~ 45% break sizes showing high sheath temperatures from the results of circuit runs, single channels were analyzed in detail in order to investigate fuel sheath and PT temperatures. Figure

3 shows maximum sheath temperatures in the high power channels (O6mod). Like the circuit runs, it was in 45% break size case of the O6mod channel analysis that the highest sheath temperature was predicted, and the 40% break size case showed longer duration of high sheath temperature. Based on the detailed fuel analysis results using ELESTRES and ELOCA codes, 40% and 45% break cases had the same number of failed fuel elements, with one more failed element than 35% break size. Therefore 40% break was determined to be a limiting case regarding to fuel failure and high sheath temperature duration.

Figure 4 shows maximum PT temperatures of the high power channels (O6mod). The 40% and 45% break cases showed nearly the same maximum PT temperature, but the case of 40% break was in longer duration of high sheath temperature. So, 40% break was selected to be a limiting case with respect to PT failure.

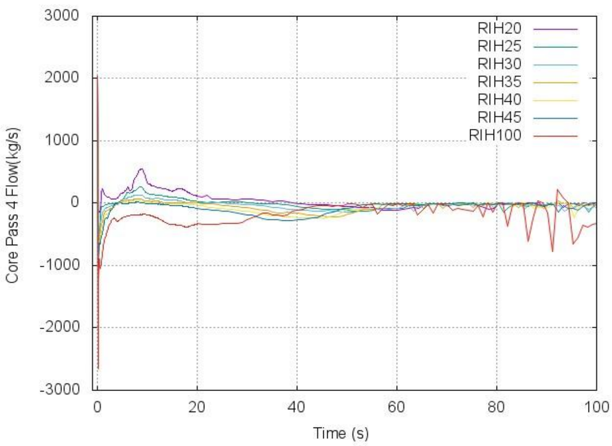

Fig 1 Coolant flowrate at core pass 4

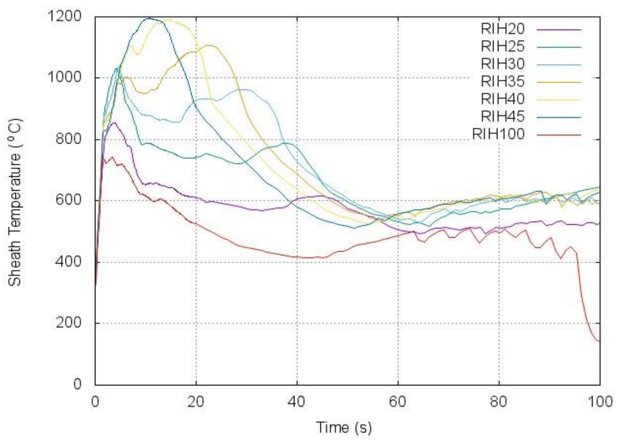

Fig 2 Fuel sheath temperature at bundle location 7 in averaged channel 4 of core pass 4

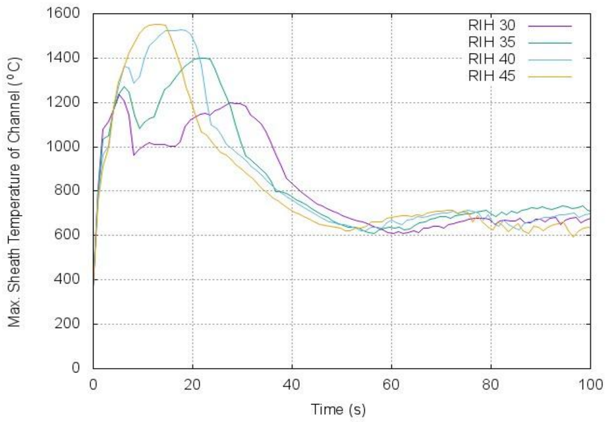

Fig 3 Maximum sheath temperatures in O6mod channels

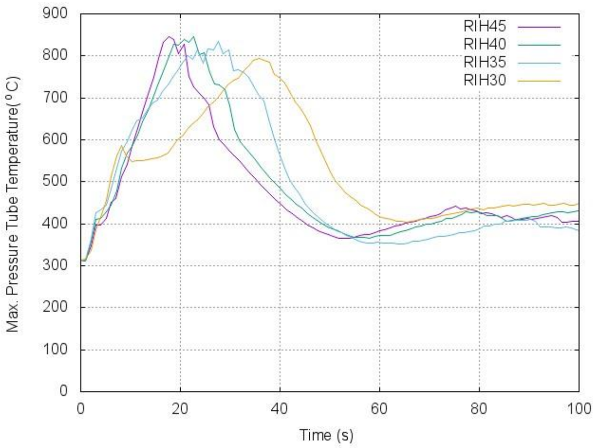

Fig 4 Maximum pressure tube temperatures in O6mod channels

4. Conclusion

Break survey at RIH for a CANDU 6 with a new 37-element fuel fully loaded was performed using CATHENA 3.5.4.4 version. Thermal-hydraulic analysis results of 20~45% break sizes was reviewed, and 40% RIH break was selected as the limiting case in terms of fuel and PT integrity for further analysis of longer term blowdown and ECC refill calculations.

REFERENCES

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