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Determination of Pressure Tube Rupture Location in CANDU

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1. Introduction

This paper presents the analysis for break discharge energy of the structures from pressure tube rupture (PTR). The PTR in single parallel channel is analyzed for CANDU and found out at the condition of the highest discharge energy. To analyze the systematic response of the heat transport system following PTR, breaks of different locations are considered.

2. Methods and Assumptions

2.1 System model

The thermalhydraulic analysis was performed with the CATHENA 3.5.4.4 code [1, 2] on the PC platform. The initial reactor power was assumed to be at 103% to account for bulk reactor power uncertainties. The effects of reactor aging are considered by modeling the initial conditions at 8000 EFPD (Effective Full Power Day).

2.2 Circuit model

For all simulations the CATHENA model consists of two-loop representation of the heat transport system, steam and feedwater system, and ECC system. As shown Fig. 1 and 2, the 95 channels in each core pass are represented by 7 average channel groups. Since the geometry of all fuel channels (i.e., inlet end-fitting, the portion of the channel which contains the fuel bundles and outlet end-fitting) is the same, the modeling of fuel channels is performed for just one fuel channel. However, the geometry of inlet and outlet feeders connected to the end-fittings is different for each channel. The feeder geometry of average channel group is obtained by performing the feeder geometry averaging required to combine a group of channels together to form an average channel and to generate an average value for CATHENA input. In CATHENA heat transfer modeling, the default heat transfer coefficient correlations are used. For critical heat flux (CHF), the modified 37-element bundle CHF correlation without PDO option is used. Core pass 4 is represented by seven (7) channels (94 averaged) in parallel with a single channel (the broken channel).

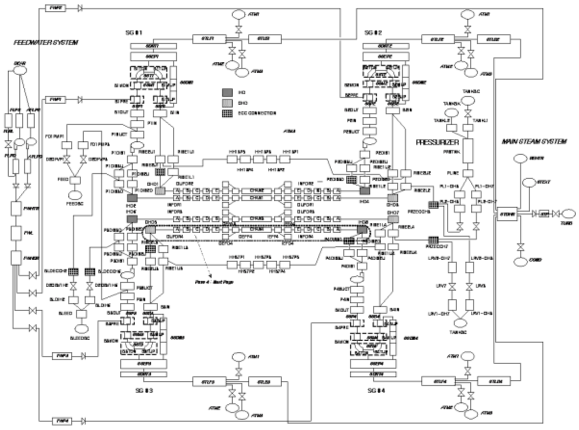

Fig. 1. CATHENA Primary and Secondary Heat Transport System Nodalization

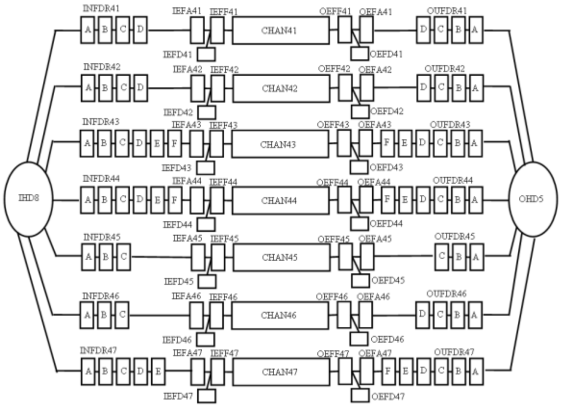

Fig. 2. Affected Channel coupled Circuit Model (Core Pass 4)

2.3 Break model

The CATHENA Henry-Fauske model with D_2O properties is used. The break developing time is assumed to be 0.01 seconds and the two-phase discharge coefficient (C_D) is assumed to be unity. A guillotine break is modeled by disconnecting the normal flow link and implementing an artificial valve model. The calandria tube is assumed to fail and all the fuel is ejected into the calandria vessel. The break boundary condition is assumed to be atmospheric pressure because this is considered to be conservative for the analysis. An example of the break set-up is shown in Fig. 3.

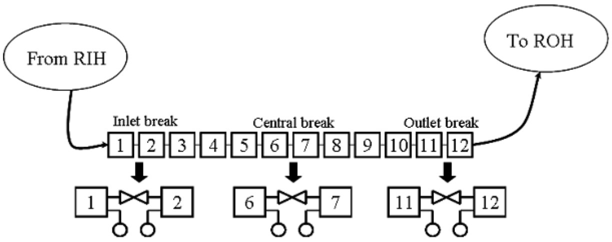

Fig. 3. Analyzed Break Location and Break Modeling For Pressure Rupture Analysis

3. Results

The circuit simulation with single parallel channel model O6_mod produced the highest break discharge flow (Fig. 4). As shown in Fig. 5, the break discharge powers were shown to be very similar for all three break locations (i.e., inlet, middle and outlet) along single parallel channel O6_mod for the first 500 seconds of the transient. It means the discharge power is insensitive to the location where a break occurs. This may be expected since the fuels in the channel are assumed to be ejected from the channel at the beginning of the transient.

In view of fuel cooling, however, it would be conservative that the break is assumed to occur at the inlet side of the channel with aged core conditions because the inlet side break reduces the flow to the core pass more than other break locations (Fig. 6).

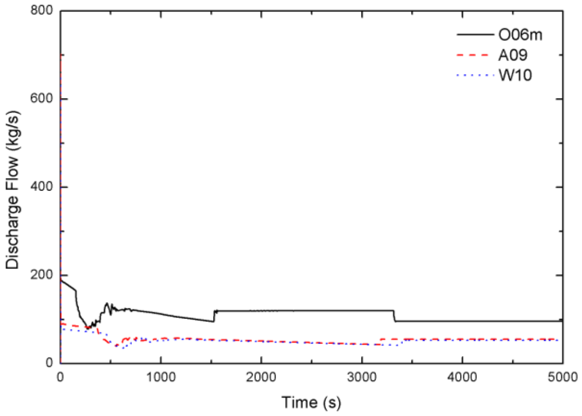

Fig. 4. Channel O6_mod, A09 and W10 PTR: Discharge Flow

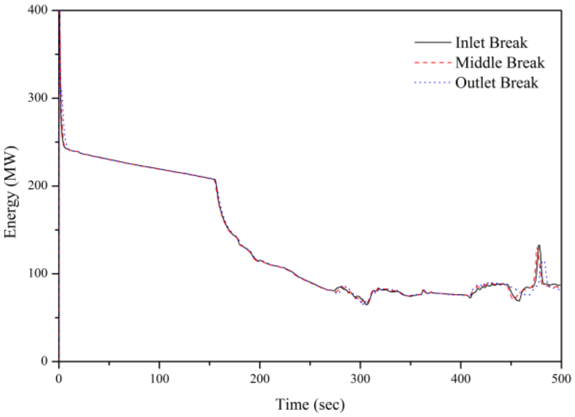

Fig. 5. Channel O6_mod PTR: Total Discharge Energy with each location

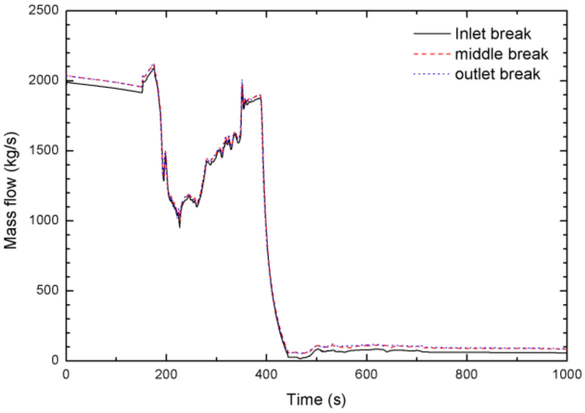

Fig. 6. Channel O6_mod PTR: Channel Flow

4. Conclusions

From the results, the discharge power is insensitive to the location where a break occurs. But considering channel geometry, it would be conservative that the break occurs at the inlet side of the channel. Therefore, the PTR at inlet side is considered as the representative of this event.

REFERENCES

[1] “CATHENA 3.5.4.4 INPUT REFERENCE Rev.0”, (153-112020-UM-006), Oct. 2013, AECL, and “CATHENA 3.5.4.4 GENHTP INPUT REFERENCE Rev.0”, (153-112020-UM-007), Oct. 2013, AECL.

[2] “CATHENA 3.5.4.4 Theoretical Manual”, 153-112020-STM-001, Rev.2, Nov. 2013.