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Themalhydraulic Response of CANDU6 in the End Fitting Failure Event

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1. Introduction

Failure of a fuel channel end fitting is one of the design basis events in CANDU6. An end fitting failure (EFF) in a single channel of CANDU6 would result in thermalhydraulic response of the primary circuit and the containment building similar to that of a small reactor header break, except for all the fuel bundles in the affected channel to be ejected into the fuelling machine vault. In this paper, the thermalhydraulic response of CANDU6 PHT system in the end fitting failure event with all safety systems available is presented.

2. Analysis Scope and Methodology

The end fitting failure event is scoped to assess the thermalhydraulic behavior as a typical case of CANDU6 safety analysis in this work. The similar analysis methodology and assumptions are used as Wolsong Unit 2,3,4 safety analysis.

2.1 Themalhydraulic Analysis Scope

Full circuit analyses at full power with three different broken channels were performed. The three broken channels were A9, O6_mod and W10. For each broken channel, two break locations (inlet and outlet EFF) were simulated to identify the worst break location for containment analysis. The worst location for a high power channel (O6_mod) is where the break discharge is the highest. For the low power channel (A9 and W10), the worst location is where the break discharge is the lowest such that the high reactor building signal and/or dousing may not come in. The thermalhydraulic analysis is performed assuming the reactor is tripped on the second process trip.

The break discharge data are input to the containment analysis. The header conditions are used as boundary conditions for intact single channel simulations to demonstrate the fuel and fuel channel integrity.

2.2 System Modeling

The end fitting failure thermalhydraulic analysis was performed with the CATHENA computer code was used for the circuit and single channel analysis. The initial reactor power was assumed to be at 103% to account for bulk reactor power uncertainties.

The circuit model consists of two loops and includes the PHT system, steam and feedwater system, and ECC system. In the average channel circuit model, core passes 1, 2 and 3 are represented by an average channel. Core pass 4 is represented by an average channel (94 averaged) in parallel with a single broken channel.

Two break locations are considered. One is at the inlet end fitting and the other is at the outlet end fitting. The break is assumed to be a guillotine break between the end fitting annulus and flow tube (Fig. 1). Since the discharge from the dead space is small and short, only the discharges from the annulus and flow tube are modelled.

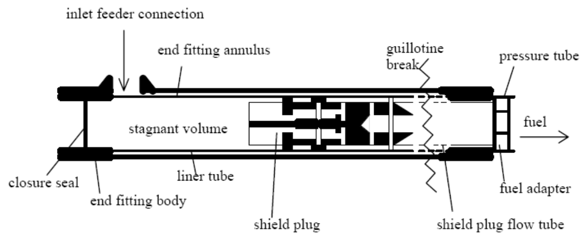

Figure 1. Inlet End Fitting Sketch

Two single channels (O6_mod and B10) are modelled. Each model includes the inlet feeder, inlet end fitting, fuel channel, outlet end fitting and outlet feeder. The inlet and outlet header are boundary conditions taken from the circuit result. The required header boundary conditions are pressure, vapor enthalpy, liquid enthalpy, void fraction and flow regime indicator. Channel O6_mod has the same geometry as O6 but the channel power and the bundle power of the two center bundles have been modified to the licensing limits of 7.3 MW and 935kW respectively. Channel B10 is a low power, high elevation, flow–instrumented channel.

3. Analysis Results

Three channels (A9, O6_mod and W10) were selected as broken channel to represent channels at different initial power and flow. Inlet and outlet end fitting failures were simulated for each of the three channels. Fig. 2 and 3 show the total break discharges and average break enthalpies. For the high power, high flow channels, the first trip is low ROH pressure and the second trip is low pressurizer level. For the low power, low flow channels, low pressurizer level is the first trip followed by low ROH pressure.

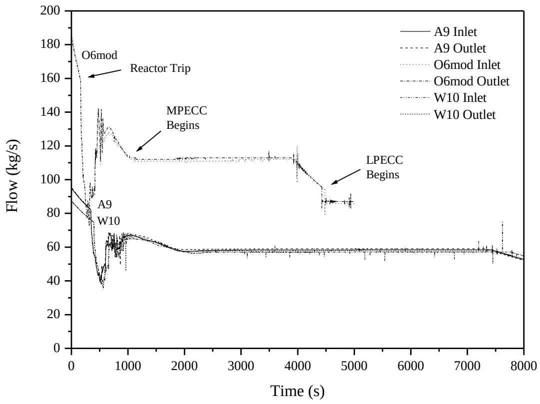

Figure 2. Total Discharges for Inlet EFF at Channel A9, O6_mod and W10

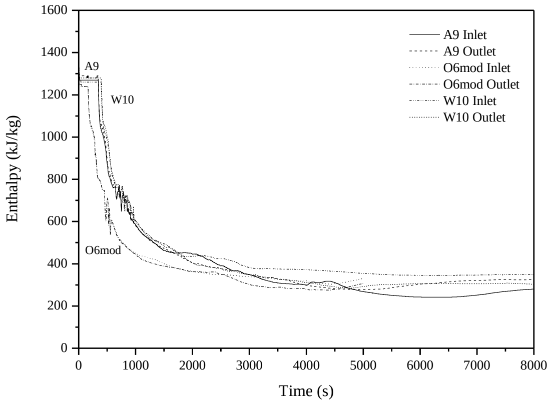

Figure 3. Average Break Enthalpies for Inlet EFF at Channel A9, O6_mod and W10

Since all fuels are ejected right after the break, the pressure drop across the empty fuel channel is small, no significant difference in break discharge and enthalpy is found between the inlet and outlet end fitting failures (Fig. 2 and 3). In CANDU6, flow is matched to power; therefore, high power channels have larger feeders and consequently, have higher discharge flows. Since the broken channel becomes empty right after the break, the average break enthalpy depends on the relative contribution of discharge flows from the two sides of the break (annulus side and flow tube side) and their enthalpies. Although O6_mod is a high power channel, its average break enthalpy is lower than the other two low power channels (Fig. 3).

The system behavior for an inlet and outlet end fitting failures is similar. Before reactor trip, the PHT pressure decreases gradually. The intact loop pressure follows closely of the broken loop. PHTS inventory continues to decrease even though the pressurizer is making up part of the loss (Fig. 4). Inventory increases right after reactor trip by the coolant in the pressurizer until loop isolation is completed.

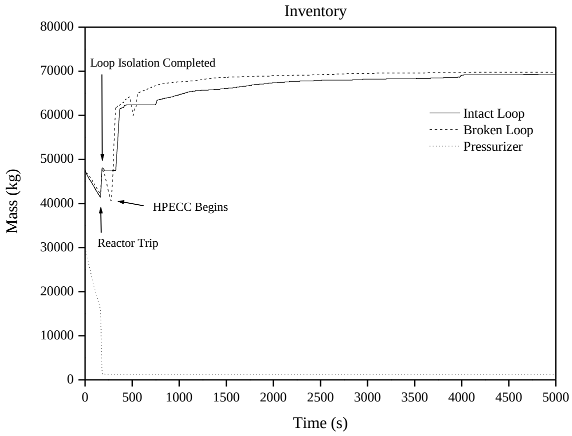

Figure 4. Inventory for Inlet EFF at Channel O6_mod

After loop isolation, the broken loop continues to lose coolant for a short while. Both loops begin to refill when the coolant pressure falls below the ECC injection pressure. Both loops refill and flow in the forward direction for all cases. No fuel sheath or pressure tube heat up is observed in any channel. Heat is continually removed by the steam generators in both loops. Long term cooling of the broken loop is maintained by LPECC injection. Long term cooling of the intact loop is maintained by LPECC injection and by thermosyphoning after the loop is completely refill.

4. Conclusions

After an end fitting failure, reactor power is maintained constant by the reactor regulating system until shutdown system trip by either a low pressurizer level or a low outlet header pressure signal. Results for an inlet and outlet end fitting failures are similar to each other. All intact channels refill by ECC injection and there is no fuel heat up predicted. This satisfies the criteria for prevention of systematic fuel failures and maintenance of fuel channel integrity.

REFERENCES

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