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Analysis of Heat Load to Moderator in Large LOCA for CANDU NPP

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1. Introduction

Large loss of coolant accident (LOCA) is one of the most limiting accidents in terms of fuel failure in CANDU reactors. LOCA assumes pipe break occur in the reactor header which is the largest pipe in primary coolant system. Typically most limiting break sizes for reactor inlet header, reactor outlet header and pump suction locations are 35%, 100% and 55% respectively. The ultimate source in fuel cooling for large LOCA with ECC system failure is moderator system. Here heat load to moderator system is analyzed for large LOCA with ECC system failure.

2. Analysis Methods

The behaviors of coolant and heat load to moderator for large LOCA are analyzed with CATHENA [1]. CATHENA is a one-dimensional, two-fluid non-equilibrium thermal hydraulic computer code.

2.1 Circuit behavior

Following break, broken loop depressurizes rapidly and LOCA signal is generated when header pressure decreases below 5.25 MPa(a). In this analysis, ECC injection is assumed to fail and crash cooldown is not available. After coolant inventory in broken loop is depleted, fuel channel is filled with steam and fuel and pressure tube begins to heat-up. The heat-up of fuel and pressure tube in intact loop is mitigated with the open of over-pressure relief valve in steam line.

2.2. Circuit model

The reactor core with 380 fuel channels is represented with 28 channel groups. Local power pulse due to void generated from break via void reactivity is simulated with 28 channel groups for more detailed analysis in terms of power distribution. Power pulse is generated with RFSP/CATHENA coupling calculation.

2.3. Slave model

Six representative channels are used for detailed fuel and fuel channel analysis. These channels are selected based on channel power, channel elevation and header/feeder connection elevation in core pass as can be seen in table 1.

The header conditions from circuit model are used in slave model up to the time when broken loop is empty. After the broken loop empties, low steam flow is assumed to maximize Zr-steam reaction.

Table 1 Representative channel groups in large LOCA

Channel	Power (MW)	Number of channels	Remarks
W10	4.0	14	Lowest elevation
B10	5.0	14	High elevation
G05	6.0	17	Mid-high elevation
S10	6.6	31	Mid elevation
O06	7.0	17	Mid elevation
O6MOD	7.3	2	Licensed limit

3. Analysis Results

Analysis results for large LOCA are performed with limiting break sizes at RIH, ROH, and PS break position.

3.1. Circuit analysis

3.3.1 Broken loop behavior

At 50 sec after break, broken loop is depressurized and emptied because ECC injection is failed. Figure 1 and Figure 2 shows coolant flow and header pressure.

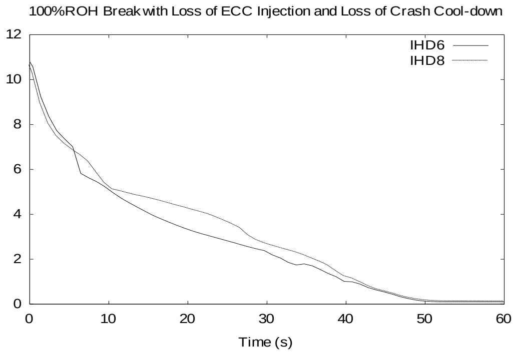

Figure 1 Inlet header pressure in ROH 100% break

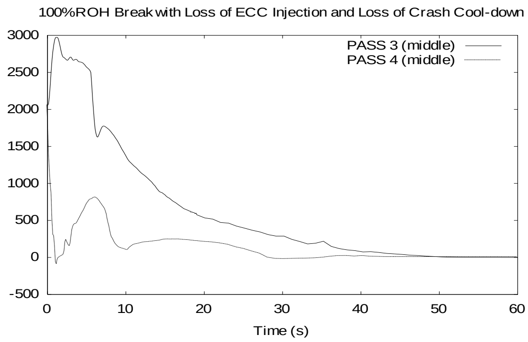

Figure 2 Broken loop flow in ROH 100% break

3.3.2 Limiting steam flow

After broken loop empties, low steam flow is assessed to maximize the Zr-steam reaction. To cover various range of steam flows, header-to-header differential pressures are studied parametrically. Table 2 shows the relation of steam flow with differential pressure for O6MOD channels. Maximum fuel centerline and pressure tube temperature are plotted according to different header-to-header differential pressures[Figure 3, 4]. From Figure 3, 0.2kPa shows most limiting results.

Table 2 Diff. pressure and steam flow for O6mod

Differential pressure (kPa)	Steam flow (g/s)
4.0	42
2.0	30
0.4	13
0.2	9
0.04	4
0.0	0

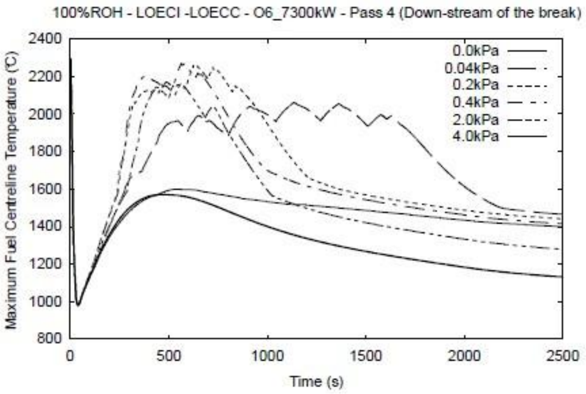

Figure 3 Fuel centerline temperature for O6mod channel in ROH 100%

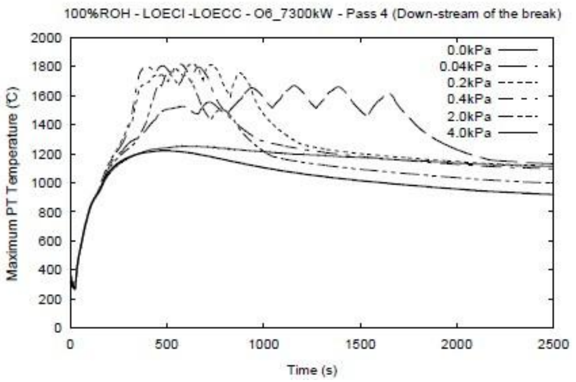

Figure 4 Pressure tube temperature for O6mod channel in ROH 100%

3.3.3 Heat load

For ROH 100% break, PT/CT ballooning contacts are not predicted [Figure 5] and sagging contact occurs later in the transient. For RIH35% and PS 55% break, PT/CT ballooning contact are predicted earlier in the transients and some sagging contact occurs later in the transients. The largest heat load occurs from RIH 35% break.

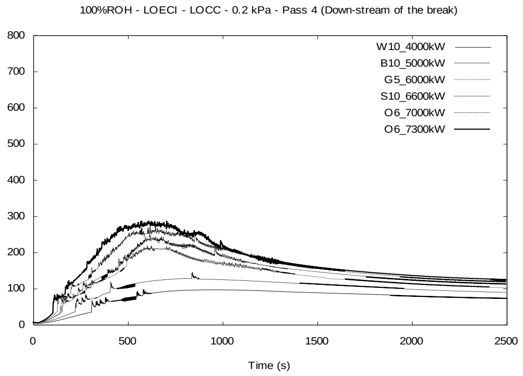

Figure 5 Heat Load for ROH 100% break

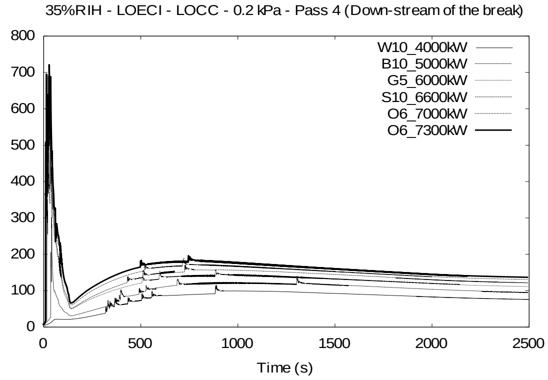

Figure 6 Heat Load for RIH 35% break

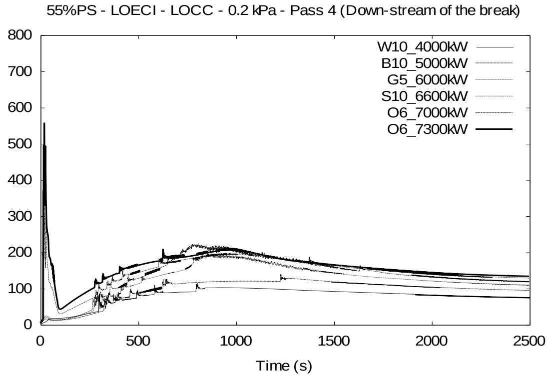

Figure 7 Heat Load for PS 55% break

3. Results

There is not conductive heat transfer to moderator due to PT/CT ballooning contact. This result in higher fuel, sheath and pressure tube temperature for ROH 100% break compared with RIH 35% and PS 55%. The largest heat load is shown to be come from RIH 35% break and it will be used in moderator analysis to confirm moderator as heat sink.

REFERENCES

[1] CATHENA Mod-3.5D Input Reference,1999, AECL
[2] FSAR for Wolsong-2,3,4
[3] CATHENA Mod-3.5D/Rev 0 Theory Manual,2005, AECL