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The Assessment of Fuel Channel behavior in LOCA for CANDU NPP

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1. Introduction

Large loss of coolant accident (LOCA) is the most limiting accident in terms of the amount of damaged fuels in CANDU reactors. The accident assumes pipe break in the reactor header which is large pipe in primary coolant system. The amount of fuel failure determines the source term for dose in the environment. Fuel failure is dependent on the channel flow behavior which determines the temperature of fuel and fuel channel. Detailed study on the fuel channel can help to understand the fuel behavior in LOCA. Here detailed behavior of fuel channels in reactor inlet header (RIH) 35% break is considered .

2. Analysis Methods

The highest fuel channel is designed as channel power at 7.3MW and maximum bundle power at 935KW. Usually O6 channel is the highest power channel even though the channel power is around 6.6MW. In this analysis 7.3MW channel is modeled in regard to conservatism and the channel is called O6m channel.

2.1. Code and model

CATHENA, a one-dimensional, two-fluid non-equilibrium thermal hydraulic computer code is used[1]. Thermal hydraulic behavior in both circuit and fuel channel is assessed with CATHENA. Header pressure and enthalpy are used as boundary condition for fuel channel analysis which is called slave channel analysis. Fuel channel is modeled with detailed geometry of fuel and fuel channel. Fuel is modeled as shown in the Figure 1.

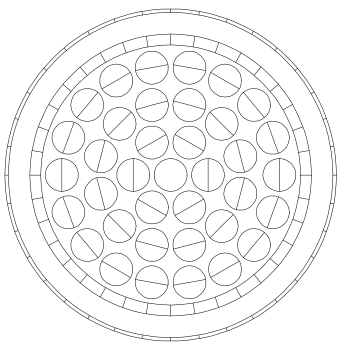

Figure 1 Fuel channel model

Table 1 Steady state value at 103% FP

Parameters		Value
Outlet head pressure (MPa(a))	ROH 1	10.08
	ROH 3	10.08
	ROH 5	10.08
	ROH 7	10.08
Inlet head pressure (MPa(a))	RIH 2	11.41
	RIH 4	11.41
	RIH 6	11.41
	RIH 8	11.41
S/G drum pressure (MPa(a))		4.7
Inlet coolant temperature (℃)		268
Outlet coolant temperature (℃)		311
Core flow per pass (kg/s)		1,922
Pressurizer level (m)		12.6
Pressurizer pressure (MPa(a))		10.04

2.2. Circuit analysis

The steady state of circuit before accident is shown in Table 1. The reactor power is chosen at 103% to account for power measurement uncertainty. The development of 35% RIH break accident is summarized in table 2. LOCA signal is initiated at 8.2 sec when header pressure gets below 5.25MPa(a). Loop isolation is completed at 28 sec after break. Crash cooldown signal which is intended to facilitate ECC injection opens MSSV valve at 38 sec. The flow of pass 4 in the broken loop is dramatically reduced due to the pressure head balance between heat transport pump and pipe break. Flow stagnation is observed 10~20 second and 70~90 second after break as shown in the Figure 2 and fuel temperature is increasing due to deterioration of heat transfer due to the flow stagnation in fuel channel.

Table 2 Circuit behavior for 35% RIH break LOCA

Event sequence	Time (s)
LOCA signal	8.2
Loop isolation completed	28
Crash cooldown initiation	38
High pressure ECC injection	43
Medium pressure ECC	122

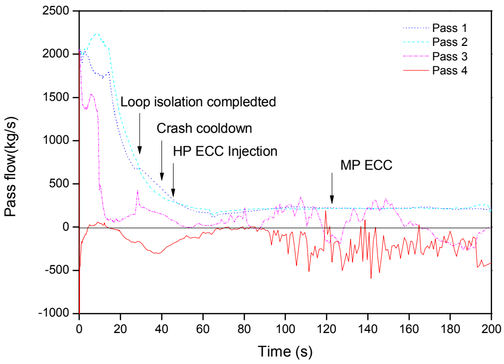

Figure 2 Circuit flow and ECC signal

2.3. Slave Channel Analysis

The detailed fuel channel behavior is concentrated on outer ring of bundle 7 which is located around center of fuel channel. Outer ring is known to show the highest temperature in the fuel. From now on all the following figures are based on outer ring of bundle 7 otherwise specified.

2.3.1 Fuel temperature

The fuel cladding temperature in the top pin and bottom pin in the outer ring is shown in Figure 3. The temperature of top pin is usually higher than bottom pin if flow stratification occurs. Maximum fuel centerline temperature reaches around 2350 ℃ in the outer ring as shown in Figure 4.

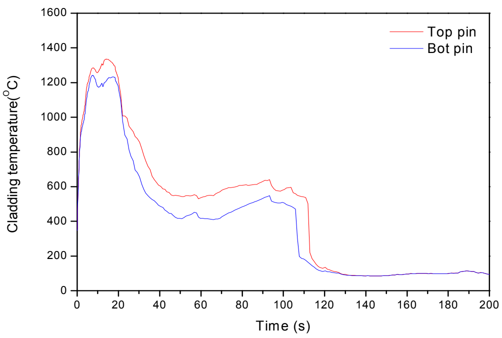

Figure 3 Fuel cladding temperature

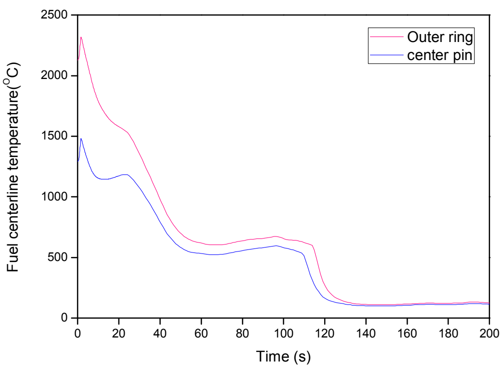

Figure 4 Fuel centerline temperature

2.3.2 Channel flow and void

The channel flow and void at channel center is shown in the Figure 5,6. Channel is refilled around 92 sec after break and channel flow is stagnated around 8~15 sec and 70~90 sec after break.

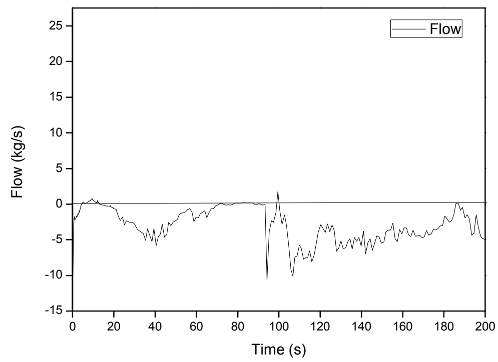

Figure 5 Channel flow

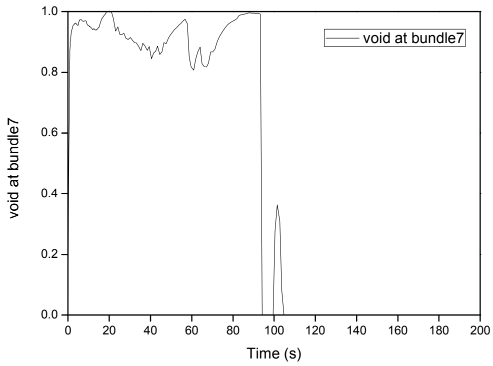

Figure 6 Channel void fraction

3. Results

The behavior of fuel channel in 35% RIH break is examined. The top pin of outer ring shows the highest temperature and channel flow stagnation is the most important factor for fuel failure. It is expected that most of fuel failure will occur before 100 sec after break for 35% RIH LOCA. The understanding of fuel channel behavior is important for fuel failure analysis. The fuel failure analysis will be followed in the near future.

REFERENCES

[1] CATHENA Mod-3.5c Input Reference, 1999, AECL
[2] FSAR for Wolsong-2,3,4
[3] 86-03500-AR-009 CATHENA fuel channel model, AECL