Discharged mass and enthalpy in 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 containment environment in CANDU reactors. LOCA assumes pipe break occur in the reactor header which is the largest pipe in primary coolant system. The high enthalpy coolant is discharged into containment from the high pressure primary system and makes the environment of the containment very adverse to equipments in the containment. Also the containment of CANDU is designed to maintain integrity at pressure below 124 kPa(g). Here discharged mass and enthalpy of coolant contributing to harsh environment in containment for typical break positions in large LOCA are considered.

2. Analysis Methods

The amount and the enthalpy of discharged coolant are determined from CATHENA [1]. CATHENA is a one-dimensional, two-fluid non-equilibrium thermal hydraulic computer code.

2.1. Code and model

The discharged coolant at break position introduces positive reactivity into the core via coolant void reactivity. The power pulse for large LOCA is calculated with WIMS based RFSP coupled with CATHENA. The containment environment is calculated with GOTHIC.

2.2. Circuit model

The steady state of circuit before accident is shown in Table 1. The reactor core is represented with 28 channel groups. In each core pass, channel group 1 to 4 contains high power channels from the inner region of the core. Channel group 5 to 7 contains lower power channels from the periphery of the core. Most of the high power channels have powers of 6 MW or higher and no orifice in the inlet feeder. The lower power channels have powers less than 6MW and a pressure breakdown orifice in the inlet feeder.

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

3. Analysis Results

Analysis results for LOCA are performed with 100% break accidents at RIH, ROH, and PS break position. In terms of break size, 100% break is used because 100% break gives the most limiting results.

3.1. Discharged mass and enthalpy

3.3.1 RIH 100% break

At the initial time after break, discharged flow is 8195 kg/s at the break time and reduced to around less than 1000 kg/s. But due to the flow stagnation, discharged enthalpy is 1128 kJ/kg at the break time.

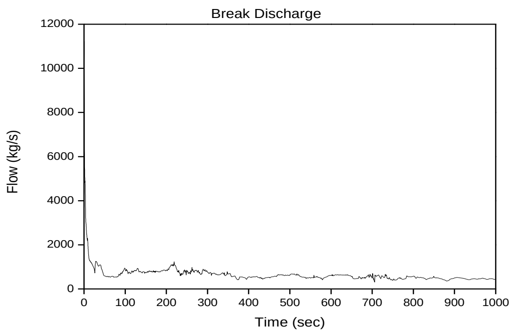

Figure 1 Discharged mass in RIH 100%

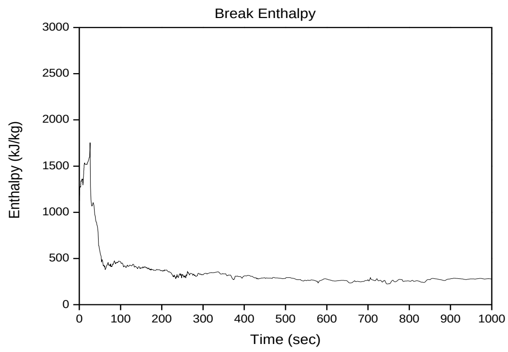

Figure 2 Discharged enthalpy in RIH 100%

3.3.2 ROH 100% break

At the initial time after break, discharged flow is 9226 kg/s at the break time and reduced to around less than 1000 kg/s. But due to the flow stagnation, discharged enthalpy is 1368 kJ/kg at the break time.

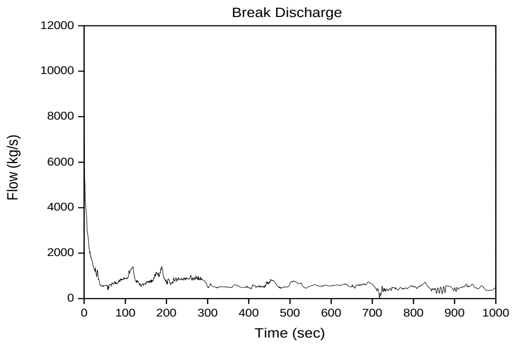

Figure 3 Discharged mass in ROH 100%

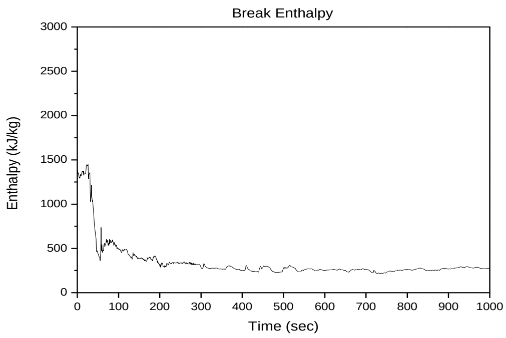

Figure 4 Discharged enthalpy in ROH 100%

3.3.3 PS 100% break

At the initial time after break, discharged flow is 7473 kg/s at the break time and reduced to around less than 1000 kg/s. But due to the flow stagnation, discharged enthalpy is 1125 kJ/kg at the break time.

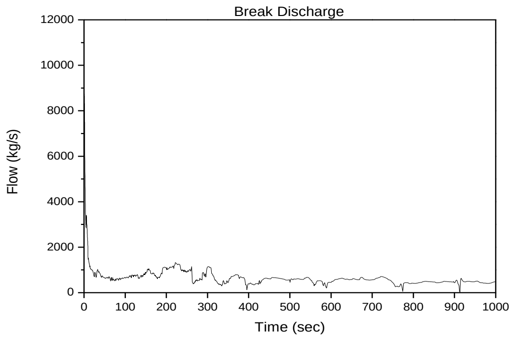

Figure 5 Discharged mass in PS 100%

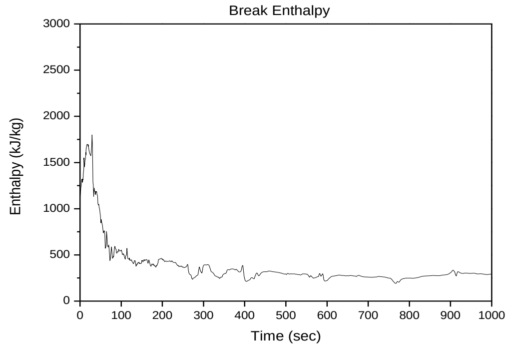

Figure 6 Discharged enthalpy in ROH 100%

2.4 Containment pressure and temperature

The harshest environment occurs at ROH 100% break position. The highest pressure reaches at 90 kPa(g) at 23 sec and the highest temperature reaches at 199℃ at 26 sec after break.

3. Results

The discharged mass and enthalpy are analyzed in LOCA for 3 typical break positions. The harshest environment occurs at ROH 100% break case. The ROH position has largest pipe diameter and the coolant temperature is the highest compared with RIH and PS position. This environment is used for containment analysis and equipment qualification.

REFERENCES

[1] CATHENA Mod-3.5c Input Reference, 1999, AECL
[2] FSAR for Wolsong-2,3,4
[3] 86-03500-AR-010 CATHENA above header model, AECL