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An Experimental Study on the Mass Release for a Hot Leg Break LBLOCA in Post Blowdown

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ABSTRACT

New methodology for mass and energy release assessment in LBLOCA post blowdown is needed and, first of all, the phenomenologically improved and quantitative assessments through experiment are essential. For the experiment of a hot leg break LBLOCA in post blowdown, the test facility was set and its feature is that the broken hot leg has two broken sections in the core side and in the SG side respectively and a separation valve between the two in order to measure the release rate dividedly. Specially it was focused on whether the mass release through the SG side broken section happened or not. The mass release through the core side broken section is dependent on the safety injection flow and that through the SG side broken section varies depending on several factors. The principal factor is the primary system pressure and the subfactors such as SI flow rate, SI temperature and initial primary pressure, may contribute, too.

I. Introduction

The mass/energy release in LOCA contributes to containment pressure rise, and it has been analyzed mainly with conservative. Specially in the YGN3&4 safety analysis, the DBA was different in PSAR and FSAR. This is due to the different methodologies between the two in mass/energy release; there are no methodologies with adequate description of system. So it is urgent to set up a new methodology on the mass/energy release in hot leg break LOCA and so preceeding experiments whose data can verify the methodology are highly required.

Many studies on the LOCA from the LBLOCA to the SBLOCA have been conducted analytically and empirically. However most of the studies focused on the system behaviors but not on the mass/energy release analyses. The objective of this study is that through the series of experiments the exact mass release phenomena and the behaviors of the system are observed and the quantitative mass release is obtained.

II. Test Facilities

1. System

The scaling bases on the reduced height, volume scaling suggested by Ishii etc.. The flow path length ratio, λ, is 1/6.4, the flow cross sectional area ratio, σ, $(1/13.4)^2$ so the total volume ratio 1/1140. Specially the broken hot leg is composed of two guillotine broken sections, i.e. the core side broken section and the SG side broken section, and a separation valve which divides the two broken section, in order to measure the release independently in post blowdown.

2. Instruments for Measurement

The mass release rate is based on measuring the total amount of condensed water through the broken sections. The temperatures are measured as shown in Fig 2., the absolute pressure in the reactor top head, and the flow rate in the SI.

III. Experiments and Results

1. Procedure

The procedures are as follows;

(1) Normal operation of the systems at 6 atm(gauge)

(2) Blowdown

Primary coolant drain until the primary inventory remain at the lower plenum.

(3) Start experiment

SI pump operates, main power on, SI operates and each discharge valve opens which simulates breaks, and separation valve closes at the same time.

2. Results

2.1 Base Case Experiment

The base case experiment are performed under the condition of Table 1.

Table 1 Base case experiment condition

Normal operation condition	Primary pressure Mode Core main power	: 0.6 Mpa : Forced convection : 60 kW
EOB condition	Primary pressure Secondary pressure SI flow rate SI temperature Core power	: 0.22 Mpa : 0.3 Mpa(saturated) : 1.7 lit/sec : 60 ℃ : 60 kW

2.1.1 Phenomenological Assessment

The phenomenological assessments are as follows;

- The SI water refills the cold leg slightly ahead and then the reactor.
- The transformation of the release phenomena in the core side broken section proceeds from gas single phase to water single phase through two phase according to the reactor water level. The measurable release can be shown at 80 sec.
- A small amount of steam with slightly entrained water is released through the SG side broken section after considerable time(about 140 sec) in some cases.
- The primary system pressure decreases rapidly, increases slightly and then decreases slowly toward a steady state. The early rapid decrease is due to the steam release, the second slight increase due to the steam generation in the core and the last slow decrease due to the cold SI water and the mass release. The slight increase in second step is an important factor on the mass release through the SG side broken section. There is a little time gap between the time of the pressure extreme value and that of the mass release through the SG side broken section.
- The temperature of the secondary system remains nearly constant at first but decreases rapidly when the mass release through the SG side broken section is observed.

2.2 Sensitivity Study

2.2.1 SI Flow Rate (Table 2)

Since too little SI flow causes enough pressure release without the allowance of pressure recovery, there is not the mass release through the SG side broken section. But in the case of large SI flow, the mass release through the SG side broken section occurs because the primary pressure is not released sufficiently, and its initial release time is same with that of core side broken section.

2.2.2 SI Temperature (Table 3)

In the case of the higher SI temperature the mass release phenomena is different readily from that of the lower SI temperature. The mass release through the SG side broken section begins from the initiation of experiment.

2.2.3 Primary System Pressure (Table 4)

Because the lower primary pressure allows considerable heat loss in core which can generate the slight pressure increase to overcome the U-tube height head, the mass release through the SG side broken section does not happen.

2.2.4 Primay Loop Condition (Table 5)

If there is a residue in the cold leg lower part, it is released through the SG side broken section at the beginning of experiment.

Table 2 Sensitivity for SI flow rate

SI flow [lit/sec]	1.1	1.7	3.6
Core side[lit/sec]	1.1	1.2	*
SG side[lit/sec]	~0	.07	2.1

* Full scale release does not occur yet but only a little steam release.

Table 3 Sensitivity for SI temp.

SI temp[℃]	60	90
Core side[lit/sec]	1.2	1.7
SG side[lit/sec]	.07	.07

Table 4 Sensitivity for primary press.

Primary press[Mpa]	0.17	0.22
Core side[lit/sec]	1.6	1.2
SG side[lit/sec]	~0	.07

Table 5 Sensitivity for loop condition

Loop condition	base	this
Core side[lit/sec]	1.2	Little affected
SG side[lit/sec]	.07	Residue released

IV. Conclusion

The mass release phenomena varies case by case according to the initial condition. The principal factor determining the mass release is supposed to be the primary system pressure and the subfactors which attribute to the primary pressure increase are the SI flow rate, the SI temperature and the the initial primary pressure. Besides, loss coefficients of the broken sections are supposed to be significant factors.

A small amount of steam with slightly entrained water is released through the

SG side broken section in some cases. But additional experiments are necessary for the obvious conclusion.

In further study, the more exact quantitative analysis in both the mass release and, moreover, the energy release should be carried out. Additionally the effects of the broken section geometry, specially loss coefficients effects, should be studied.

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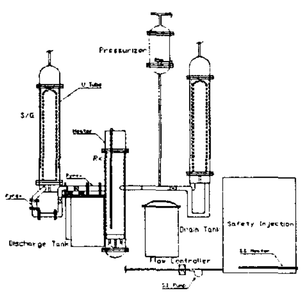

Fig. 1 Test Facility

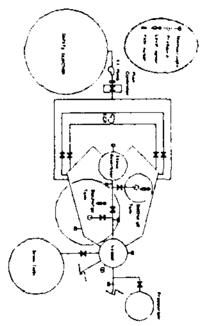

Fig. 2 Test Facility-Top View

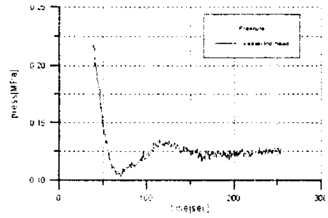

Fig. 3 Press. in Rx. Top Head

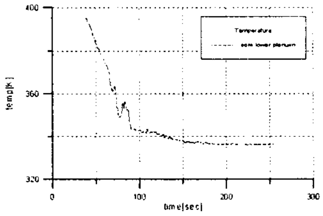

Fig. 4 Temp. of Core Lower

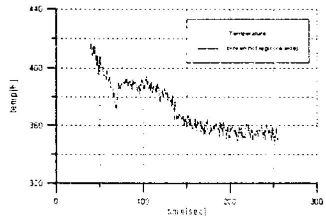

Fig. 5 Temp. of Core Side BS

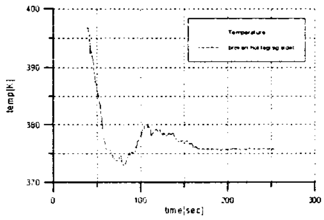

Fig. 6 Temp. of SG Side BS

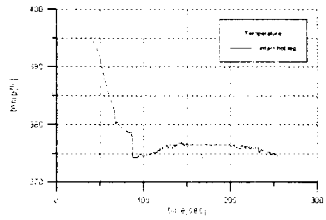

Fig. 7 Temp. of Intact Hot Leg

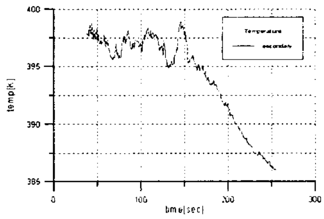

Fig. 8 Temp. of Secondary Sys.

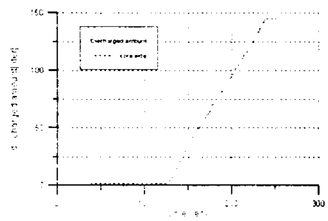

Fig. 9 Mass Release through Core Side BS

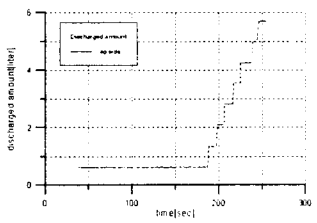

Fig. 10 Mass Release through SG Side BS

(BS : Broken Section)