Development of EQ Profile for Hydrogen Monitors with Consideration of Operator Actions

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1. Introduction

The Fukushima nuclear accident demonstrated that hydrogen control is one of the most important issues in nuclear power plants. Korean nuclear regulatory body requested to install PARs and hydrogen monitors in operating nuclear power plants. PARs are located inside the containment building to reduce the hydrogen concentration, while hydrogen monitors are generally located in mild environmental area.

However, the hydrogen monitors in Hanul 1&2 have been decided to locate in harsh area of the auxiliary building, which require the equipment qualification (EQ) of the hydrogen monitors. With the original EQ profile, the hydrogen monitors could not be qualified by suppliers. Thus, the development of a modified EQ profile was highly needed.

In this paper, the new modified EQ profile has been developed considering the optimized mass/energy (M/E) release data and the operator action to isolate the broken piping.

2. Analysis Methods

2.1 Analysis Model

GOTHIC 7.2a[1] computer program has been used for the analysis of pressure and temperature due to the CVCS letdown line break. As shown in Fig. 1, the hydrogen monitor is located in the auxiliary building close to the containment outside wall. CVCS letdown lines pass through these areas. In case the letdown line breaks, the HELB barrier envelopes the yellow line in Fig.2. For the depressurization following a HELB, tentative pressure relief path was assumed following the red arrow direction.

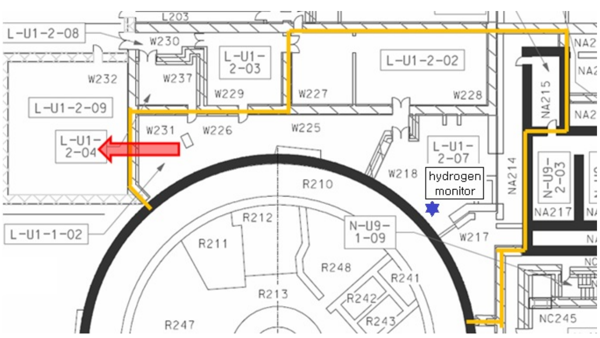

Fig.1 Location of hydrogen monitor in auxiliary building

Based on the design drawings [2] and the data obtained from site survey, multi-compartment Lumped Parameter (LP) GOTHIC model was developed, which is composes of 14 control volumes and 28 flow paths. Two additional volumes and flow paths are incorporated for the simulation of the sources, i.e., mass and energy release. Fig.2 shows the GOTHIC model for the nodalization.

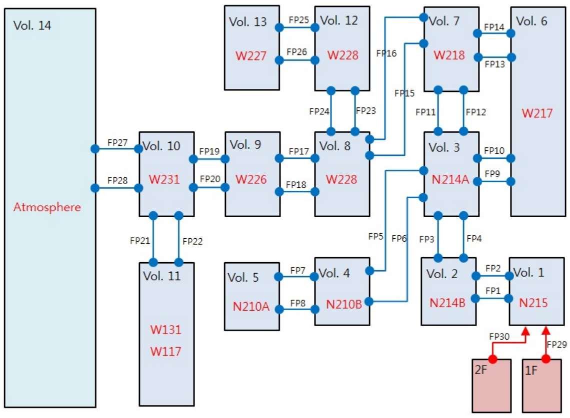

Fig.2 GOTHIC model for nodalization

2.2 Mass/Energy Release Data

In the previous analysis, the break flow was assumed to be continuously released at a critical flow rate. In this analysis, the M/E release data was optimized by assuming that the water contained in the pipe is discharged as critical flow, but flow rate is limited by the orifice flow thereafter, which is still conservative.

The initial temperature and pressure in the auxiliary building are set to 104 ^{o}F, 14.6 psia, respectively. And the initial relative humidity is set to 7 %[3]. The calculated mass and energy release data are summarized in Table 1.

Table 1. Mass & Energy Release Data

Flow Direction	Time(sec)	Mass Flow	Enthalpy	Remark
Forward	0≤t≤0.01	351.1 kg/s (774.10 lbm/s)	822.28 kJ/kg (353.54 Btu/lbm)	Ø3″
	0.01≤t≤1.8	159.5 kg/s (351.59 lbm/s)	822.28 kJ/kg (353.54 Btu/lbm)	Ø2″
	1.8≤t≤1800	3.78 kg/s (8.33 lbm/s)	822.28 kJ/kg (353.54 Btu/lbm)	orifice flow
	1800≤t	0	0	
Reverse	0≤t≤0.01	351.1 kg/s (774.10 lbm/s)	822.28 kJ/kg (353.54 Btu/lbm)	Ø3″
	t≥0.01	0	0	

3. Analysis Results

3.1 Consideration Operator Action Time

Fig. 3 shows the original EQ profile developed with no consideration of operator's action. In this analysis, the operator action for isolating the broken piping was assumed in order to develop the optimized EQ profile.

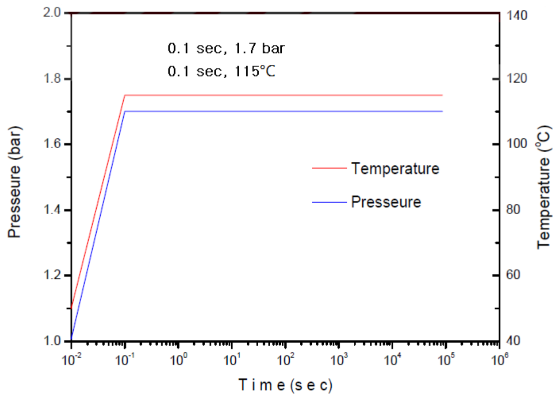

Fig.3 Original EQ profile

The response time required for the operator to isolate the accident is set based on ANSI 58.8 (Time Response Design Criteria for Safety-Related Operator Actions)[4]. Table 2 is the minimum response time required for each plant condition. The CVCS letdown line break corresponds to the plant condition 4 or 5, which requires 20 minutes for diagnosis time plus 6 minutes for action time at the least. Thus, the total operator action time to terminate the accident was selected as 30 minutes conservatively.

Table 2. ANSI 58.8 Time Response Design Criteria for Safety-Related Operator Actions

Plant Condition	Estimated Frequency of Occurrence(F) per Reactor Year	Minimum TI	Minimum To
1	Normal Operation	-	-
2	$F > 10^{-1}$	5 minutes	1+n minutes
3	$10^{-1} > F > 10^{-2}$	10 minutes	3+n minutes
4	$10^{-2} > F > 10^{-4}$	20 minutes	5+n minutes
5	$10^{-4} > F > 10^{-6}$	20 minutes	5+n minutes

3.2 Pressure and Temperature Analysis

The GOTHIC results of time-dependent pressure and temperature analysis are show in Fig. 4 and 5, respectively. As the mass and energy release ceases by operator action, the pressure and temperature decrease 30 minutes after the accident.

The new EQ profile has been finally developed with consideration of engineering margins and by extending the maximum boundary until 2 hours from the accident.

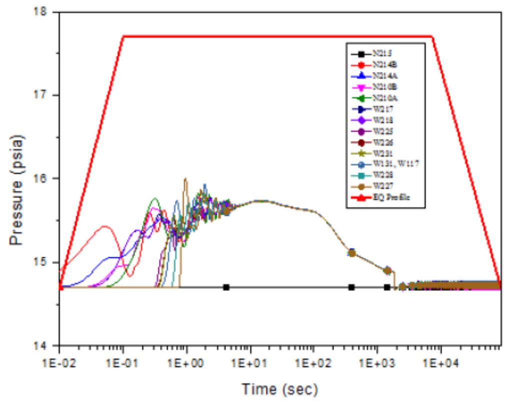

Fig 4. Pressure results and EQ profile

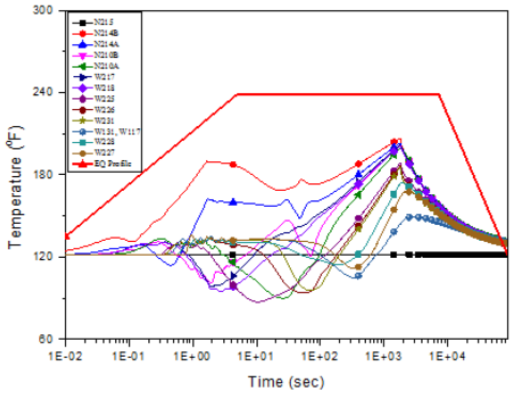

Fig 5. Temperature results and EQ Profile

4. Conclusions

For the qualification the hydrogen monitors to be located in the auxiliary building of Hanul 1&2, the pressure and temperature analysis has been performed by assuming the CVCS letdown line break. The mass and energy release data was optimized and operator action was considered to stop the M/E release by isolating the broken piping. As a result, the new EQ profile was created.

Therefore, the EQ profile developed in this study can be used as the environmental test condition of the newly installed hydrogen monitors.

5. REFERENCES

[1] GOTHIC Technical Manual Version 7.2a(QA) Jan. 2006.
[2] Nuclear Island and Turbine Hall General Arrangement, July.1983
[3] Hanul 1&2 FSAR
[4] Time Response Design Criteria for Safety-Related Operator Actions, ANSI 58.8-1996