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Letdown Line Break Analysis with CVCS Design Improvement for HBN 5&6

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1. Introduction

During the periodic safety review (PSR) of HBN 5&6, it was found out that the atmospheric dispersion factor (χ/Q) was increased to approximately 1.67 times compared to that of the initial operating license (6.188×10^{-4} s/㎥→ 1.03×10^{-3} s/㎥). This factor increased the dose at the exclusion area boundary (EAB) above the relevant acceptance criteria.

To meet the relevant dose acceptance criteria, a letdown line design has been improved. This design improvement is described herein, and representative results of the letdown line break (LDLB) analysis are presented.

2. Design Improvements and Analysis Method

In this section, the chemical and volume control system (CVCS) design improvements used to model the letdown line break are described. The letdown line model includes additonal temperature indicator and related designs, the regenerative heat exchanger (RHX) temperature setpoint, and LDLB models.

2.1 Atmospheric Dispersion Factor

Atmospheric dispersion factor is determined based on the regional (site-specific) meteorological data accumulated during the latest 3 years. It is found out the atmospheric dispersion factor was increased to approximately 1.67 times that of the initial operating license (6.188×10^{-4} s/㎥ →1.03×10^{-3} s/㎥). This increase is based on the new calculation method for the HBN 5&6 site atmospheric dispersion factor required by Nuclear Safety and Security Commission 2012-19, and the adverse meteorological data caused by the elevation change of weather observation tower (sea level change from 80 m to 10 m).

Current LDLB analysis shows the event is terminated by safety injection actuation signal (SIAS) because the containment isolation valves (CV-515, CV-516) are closed on SIAS. The radiation dose (283 mSv) at EAB is close to the acceptance criteria of 10% of 10CFR100.11 guideline values (300 mSv).

With the increased χ/Q, it is expected the predicted radiation dose will violate the acceptance criteria. Table 1 shows the increase in the predicted dose at EAB with the new χ/Q.

Table 1: Comparison of dose at EAB

AC	FSAR	PSR	Rate
300 mSv	283 mSv	471.06 mSv	66.5%↑

2.2 LDLB Analysis w/o CVCS Design Improvement

Direct release of reactor coolant may result from a break or leak, outside the containment, of the letdown line, instrument line, or sample line [1]. A double-ended break of the letdown line outside the containment upstream of the letdown isolation valve is selected for this analysis because it is the largest line and thus results in the largest release of reactor coolant outside containment.

Single active failure of an isolation valve was not considered in the analysis because the letdown line includes two isolation valves in series situated inside the containment. Hence, failure of one isolation valve does not make the consequences of the event more severe.

A letdown line break can range from a small crack in the piping to a complete double-ended break. The cause of the event may be attributed to corrosion, which forms etch pits, or to fatigue cracks resulting from vibration or inadequate welds.

With a loss of offsite power (LOOP) after the turbine trip, all letdown isolation valves are closed because the power to relevant valves is unavailable. This results in less adverse radiological consequence because it terminates primary fluid release to the auxiliary building. Therefore, a LOOP is not considered for the LDLB analysis.

In order to maximize the break flow, a letdown line isolation caused by SIAS is delayed with the maximum charging flow. All control systems are assumed to be in the automatic mode to maximize the total primary mass release. The break area is assumed to be the full cross-sectional area (double-ended) of the pipe. Table 2 shows the current relationship between containment isolation valves and the relevant signal.

If there is a double-ended break of the letdown line outside the containment upstream of the letdown isolation valve, primary fluid is released to the auxiliary building at a rate of more than three times the maximum expected letdown flow [2].

Two letdown isolation valves (LDIVs, CV-515 and 516) are serially installed in letdown line inside the containment. These valves are designed to be automatically closed by safety grade SIAS, which is generally generated within 30 minutes after LDLB event initiation. In addition, CV-515 valve is currently designed to be automatically closed by control grade RHX downstream high-high temperature signal, which is generated within a few minutes after the event initiation.

Sequence of LDLB event shows this event is terminated about 25 minutes after the event initiation by SIAS generated by the pressurizer pressure low, because the two isolation valves in series situated inside the containment are closed on SIAS. At 30 minutes into the event, the operator is assumed to take appropriate steps for a controlled reactor shutdown.

Table 3 shows the quantity of primary coolant released, and the radiological consequences based on old and new χ/Q. As shown in Table 1, the resultant dose at EAB is exceeding the relevant acceptance criteria with the current chemical and volume control system (CVCS).

Table 2: Current relationship between containment isolation valves and the relevant signal

LDIVs		Signal		Parameter
		SIAS	CIAS	RHX H-H Temp.
Inside Containment	CV-515	O	X	O
	CV-516	O	O	X
Outside Containment	CV-523	X	O	X

Table 3: Radiological consequences

LDIV Isolation Signal		SIAS
LDLB Termination Time		About 25 minutes
Released Primary Coolant		76,146.7 lbm
Dose at EAB	Old χ/Q	283 mSv
	New χ/Q	471.06 mSv

2.3 CVCS Design Improvement

The RHX is a vertically mounted, shell and tube (U-tube) heat exchanger. Coolant leaving the reactor coolant system (RCS) flows through the tube side. The RHX conserves RCS thermal energy by transferring heat from the letdown fluid to the charging fluid. [3].

Current HBN 5&6 letdown line has one temperature indicator (T-221) to close the containment isolation valve (CV-515) on RHX high-high temperature of 221^{o}C (430^{o}F). With this design, the letdown would be isolated within 1 minute after the event initiation. However, no credit is taken for this isolation action in the analysis.

To provide the reliable letdown line isolation on RHX high-high temperature, a separate temperature indicator (T-222) is added to close the containment isolation valve (CV-516) on RHX high-high temperature independently. T-222 is also qualified for all relevant qualification requirements.

With this design, CV-515 could be closed with TIC-221, and CV-516 could be closed with TIC-222, independently and separately. Table 4 shows the modified relationship between containment isolation valves and the relevant signal with the design improvement. Figure 1 shows information of CVCS design improvement.

Table 4: Modified relationship between containment isolation valves and the relevant signal

LDIVs		Signal		Parameter
		SIAS	CIAS	RHX H-H Temp.
Inside Containment	CV-515	O	X	O
	CV-516	O	O	O
Outside Containment	CV-523	X	O	X

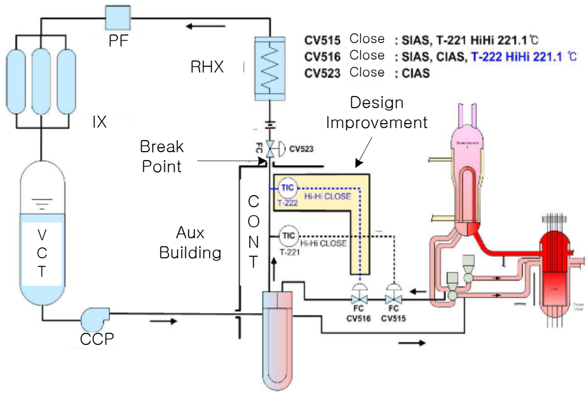

Fig.1.Schematic Diagram of CVCS Design Improvement

2.4 LDLB Analysis with CVCS Design Improvement

With the credit for the letdown line isolation on RHX high-high setpoint, LDLB analysis was performed based on LDIV close time to terminate the event, and all initial conditions and assumptions remained the same as those of current HBN 5&6 FSAR to evaluate the LDLB methodology with respect to radiological consequences.

CV-515 or CV-516 valve would be closed on RHX high-high temperature signal within one minute after the initiation of LDLB event because primary fluid is released to the auxiliary building more than three times the maximum expected letdown flow. Therefore, the time to reach the relevant setpoint will be immediate. However, the LDIV closure time of 900 seconds was assumed for conservatism. In addition, this time will provide enough time for the operator to response.

Table 5 provides the bases for LDIV closure time on RHX high-high temperature.

Table 5: Bases for LDIV closure time

Parameter	Time Actual seconds	Time Used seconds
Temp. Detection Time	30±4.5	900*
Signal Transfer Time	2.03	
Total Delay Time	36.53	

*included LDIV stroke time (maximum 5 seconds)

3. Results and Discussion

The primary fluid released to the auxiliary building with the LDIV isolation time on SIAS (current CVCS design) or RHX high-high temperature (improved CVCS design) is shown in Table 6, and the amount of the primary fluid released based on the new case is about 62% of that based on the current case.

Table 6: Primary fluid released to the auxiliary building

	Current Case	New Case
Signal for LDIV Closure	SIAS	RHX high-high temperature
Letdown Isolation Time	25 minutes	15 minutes
Released Primary Fluid	76,147.7 lbm	47,000 lbm

With the primary fluid released to auxiliary building, it is expected that radiological dose consequences will be less than 10% of 10CFR100 guideline values for whole body and thyroid doses at the EAB and outer boundary of LPZ with new χ/Q based on the reliable letdown line isolation on RHX high-high temperature.

The margin to the relevant acceptance criteria is expected to be 30% or above based on the amount of primary fluid released even though there are other parameters to be considered to calculate the doses.

4. Conclusions

It was found out the atmospheric dispersion factor was increased to approximately 1.67 times that of the initial operating license for HBN 5&6.

To meet the radiological dose criteria at EAB, a reliable letdown line isolation with a separate temperature indicator (T-222) is added to independently close one of the containment isolation valves (CV-516) on RHX high-high temperature.

For LDLB analysis, with the reliable letdown line isolation on RHX high-high temperature, the LDIV closue time of 900 seconds was assumed for conservatism, and the radiological doses at EAB are expected to meet the relevant acceptance criteria with the new χ/Q, and the expected margin will be 30% or above.

REFERENCES

[1] USNRC, NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, Subsection 15.6.2, March 2007.
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[3] KHNP, HBN 5&6 Final Safety Analysis Report, Subsection 9.3.4, May 2012.