An Evaluation of Discharge Flow of Safety Depressurization System Valve using 1D-Computational Fluid Dynamics

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Introduction

> Advanced performance SDS valves will be applied to nuclear power plants.

The Safety Depressurization System (SDS) shall provide a safety-grade means of rapidly depressurizing the RCS during the beyond design basis event of a Total Loss of Feedwater (TLOFW). It is used in conjunction with the Safety Injection System to provide once-through-core-cooling.
The SDS shall prevent exposure of the fuel to containment atmosphere when 1) only one of the two HPSI pumps is available together with opened PSV after TLOFW accident, 2) two HPSI pumps are available after 30 minutes from PSV opened.

> The SDS discharge rate can be evaluated using the commercial 1D-Computational Fluid Dynamics after valve replacement.

If the resistance coefficient of the SDS piping decreases, the discharge rate from the SDS may cause exposure of the fuel to containment atmosphere. It is essential to evaluate the discharge rate from the SDS when the flow path, valves, and instruments are changed.
The purpose of this paper is to simulate the discharge rate from the SDS using FloMASTER, the commercial 1D-Computational Fluid Dynamics (CFD) solution and to evaluate its validity by comparing with the results from other evaluation methods when the SDS isolation valves are replaced with other manufacturer's model having different coefficient values (C_v).

Evaluation Methods

> The transient analysis was performed using FloMASTER computer code. It is assumed that a discharge flow at the SDS inlet of pressurizer occurs <u>during 100% power operation and reactor coolant is discharged into the containment atmosphere through the SDS piping</u>.

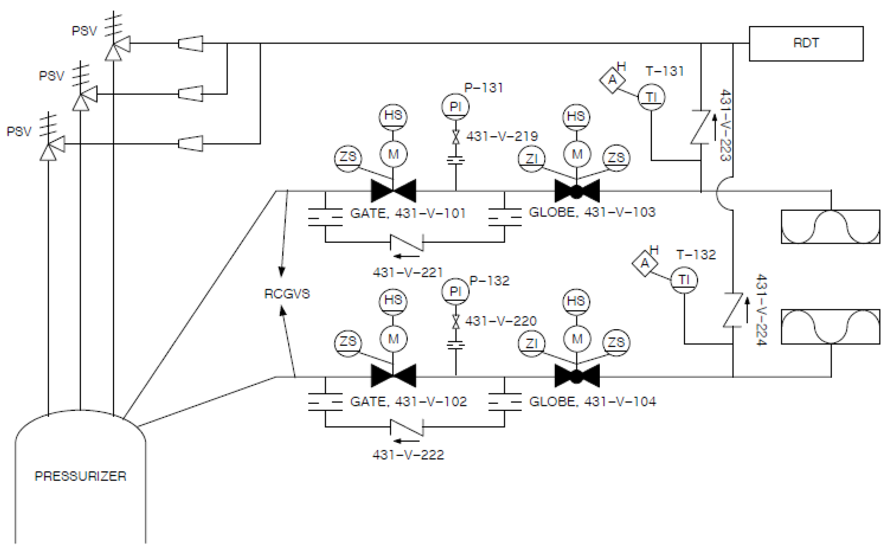


Figure 1. Piping and Instruments Diagram for SDS

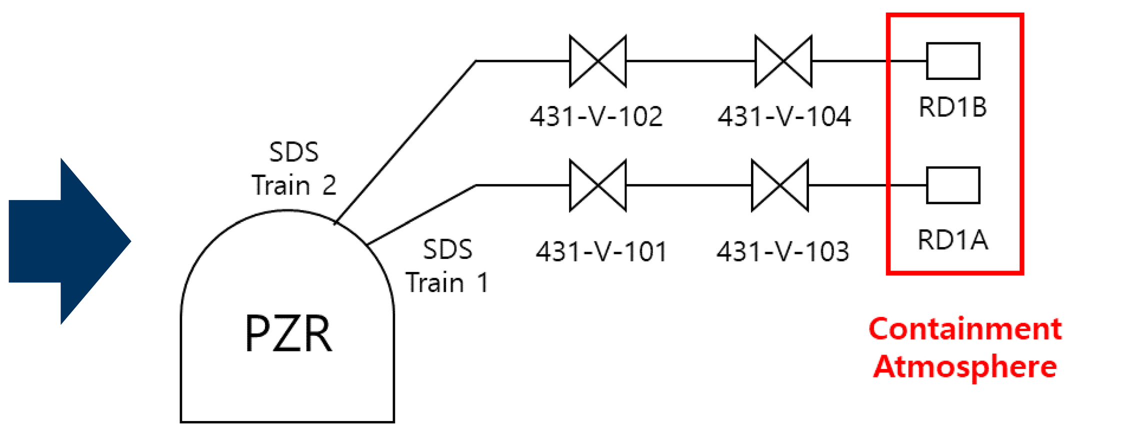


Figure 2. Schematic configuration for OPR1000 SDS piping

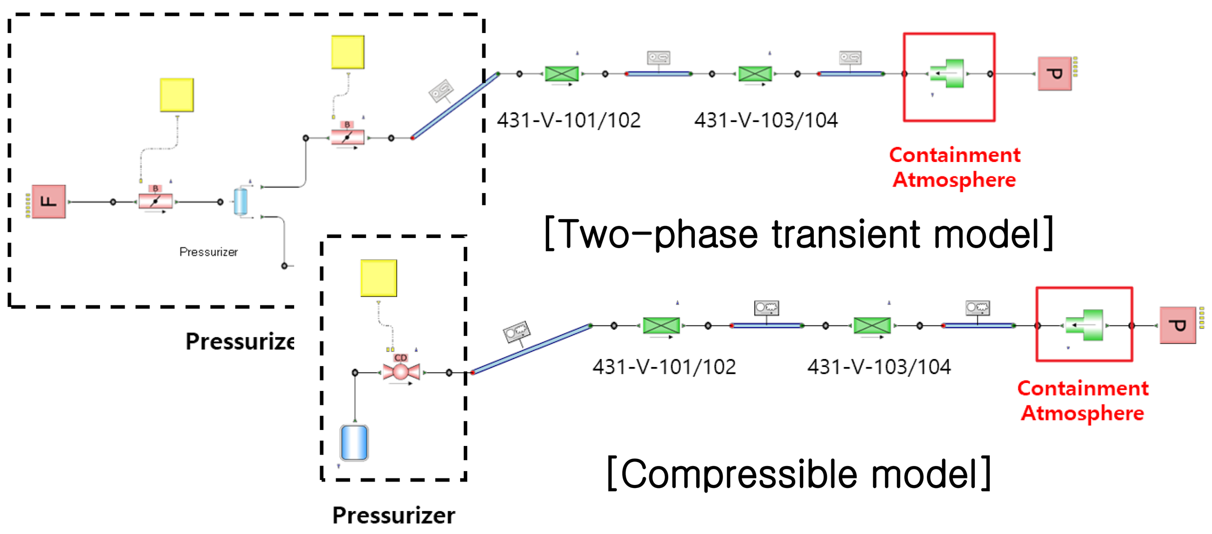


Figure 3. FloMASTER network diagram for system modeling

Analysis model for the SDS discharge flow is as shown in Figures 2 and 3. Two analysis models, which show <u>the SDS piping including before and after valve replacement, were simulated under two-phase and compressible transient conditions</u>. Loss-discrete modules, such as opened valves when steam is discharged through the SDS piping, are used to describe flow resistances of the valves. In these modules, the flow coefficient of the valves (C_v) was converted to the pressure loss resistance (K) to construct the SDS piping with FloMASTER modeling. The two-phase and compressible transient models were simulated for 120 seconds with the time-step of 0.1 seconds. In two-phase transients, flash tank module, such as pressurizer when the SDS discharge occurs, is components that continuously separates compressed water into condensate water and steam from the boiler or steam-jet system. In compressible transient, accumulator module is components which simulate pressurizer when the SDS discharge occurs. <u>The SDS discharge flow is simulated by suddenly opening virtual valves (C_v = 0) within stroke time of the SDS isolation valves (431-V-101/102). The discharge of steam from the SDS piping to a containment atmosphere is simulated by giving abrupt flow area change.</u>

Analysis Results and Evaluation

The results of the transient analysis for the 16 cases used in Tables I and II. The results of the simulation show that some hunting while the SDS isolation valve is being opened and also after 100% opened. The maximum discharge flow is also reached just before fully valve opening.

The maximum discharge flow using the FloMASTER was extracted from the data which was applied with 95% confidence level (5% uncertainty) to minimize the error due to hunting.

<u>The results of the FloMASTER simulation show that discharge flow from 72.0% to 87.4% are evaluated comparing to the hand calculation</u>. The change rates of discharge flow between before and after <u>valve replacement are −0.06% to +7.10%</u>. The change ratio of compressible transient shows the greater change ratio than that of hand calculation.

Table I: Piping Length and Elevation for the SDS Discharge

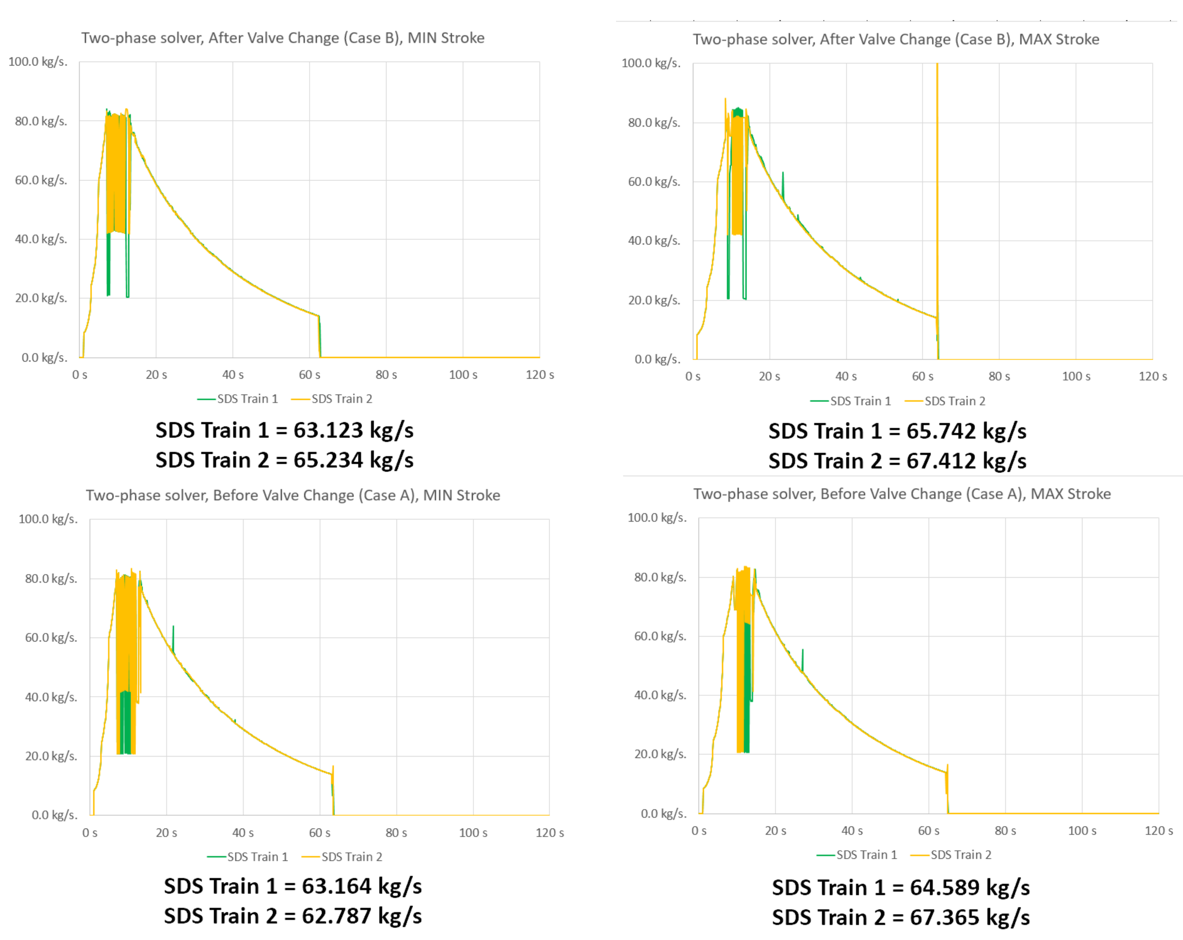
	Piping Length	Elevation
<u>Train 1</u>		
Pressurizer to 431-V-101	9.249 m	+1.67 m
431-V-101 to 431-V-103	0.743 m	−0.024 m
431-V-103 to RD1A	1.829 m	−0.107 m
<u>Train 2</u>		
Pressurizer to 431-V-102	9.101 m	+1.654 m
431-V-102 to 431-V-104	0.735 m	+0.035 m
431-V-104 to RD1B	1.613 m	−0.102 m

Table II: Initial Conditions for the Simulation [Before (Case A) and After (Case B) Valve Replacement]

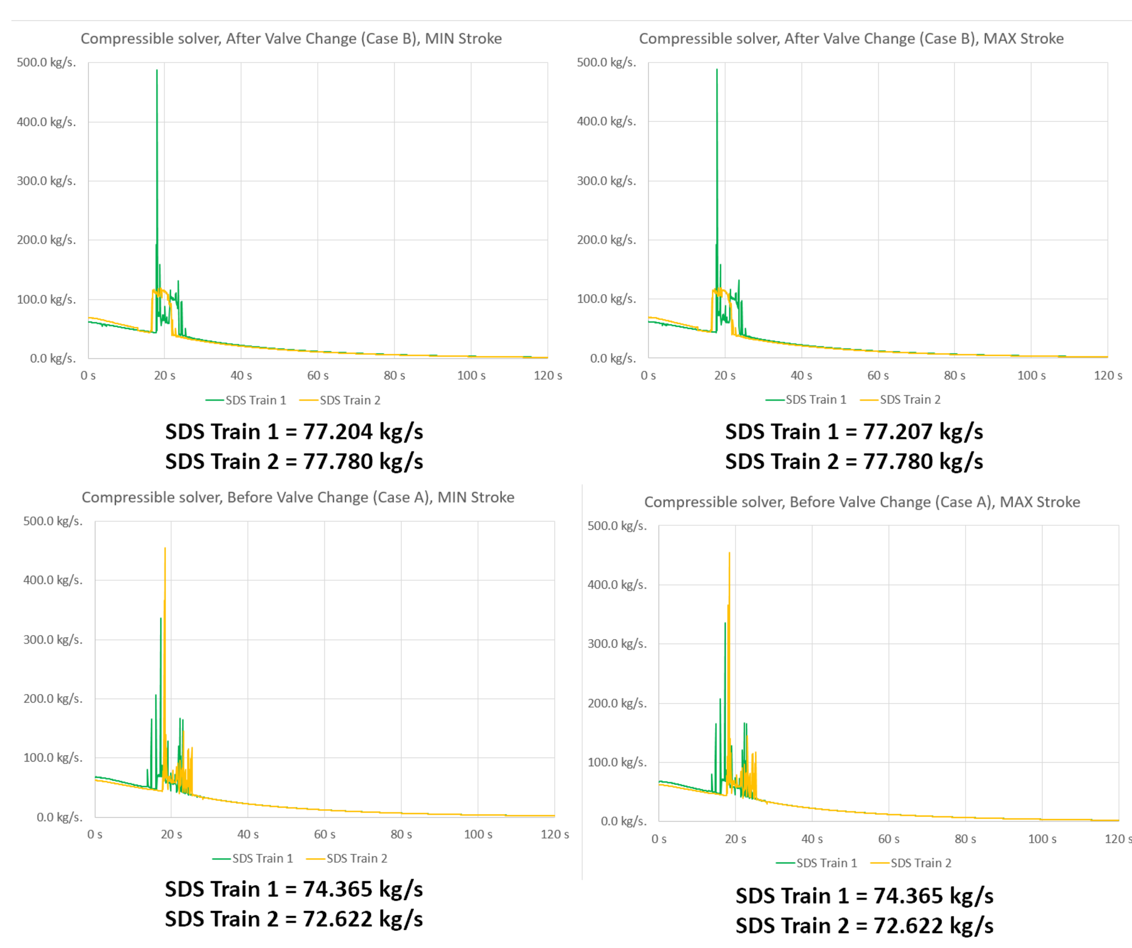
	Case A	Case B
<u>Fluid</u>		
Fluid Model	Separated Mixture Model	
Pressure	2,500 psia (17.2 MPa)	
Temperature	668.2°F (353.4℃)	
<u>Piping and valves</u>		
Pipe Heat Transfer	Adiabatic	
Absolute Roughness	0.00015 in (3.81 μm)	
431-V-101/102 Valve C_v	580 (Manufacturer A)	1080 (Manufacturer B)
431-V-103/104 Valve C_v	157 (Manufacturer A)	
Min./Max. Stroke Time	20s / 27s	

Results of Transient Simulation

> The change in the change of discharge flow rate is <u>within a maximum of 10% after the SDS isolation valves is replaced</u>.



[two-phase transient solver]



[compressible transient solver]

Conclusions

Simulation results show that the change in the <u>discharge flow rate is **within a maximum of 10%** after the SDS isolation valves is replaced</u>. Therefore, the decrement of resistance coefficient from valve replacement shows that the increment of the SDS discharge flow is within the safety margin.

This paper evaluated and compared the SDS discharge flow between FloMASTER and hand calculation. It was identified that the discharge flow using FloMASTER has less discharge flow than hand calculation.

In conclusion,the results between FloMASTER and hand calculation are about 20-30% different, so it is estimated that <u>FloMASTER can be utilized in preliminary discharge evaluation</u>.