A Study on Prediction Method for Orifice Adjusting Results using 1D-Computational Fluid Dynamics

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1. Introduction

Reactor Coolant System (RCS) volume control is achieved by automatic control of the charging control valve and letdown orifice isolation valves in accordance with the pressurizer level control program.

The letdown flow is maintained by combinations of opened letdown orifice isolation valves. When letdown orifice isolation valve, #1, is opened, minimum letdown flow is achieved. By opening two (#1 and #2) or three (#1, #2, and #3) letdown orifice isolation valves, normal or maximum letdown flow is achieved, respectively [1].

If the letdown flowrates are measured over or under acceptance criteria of test guideline, orifice adjusting, which is to determine inner diameter of two single orifices to control flowrate, is performed.

The purpose of this paper is to compare actual test with simulation results using FloMASTER [2], the commercial 1D-Computational Fluid Dynamics (CFD) solution.

In this study, a method to predict the results of the CVCS orifice adjusting test before implementation of the test is suggested. Then the estimation using the FloMASTER compare to actual test results for verification. The anticipation for the test results can beneficial for nuclear power plant as it can reduce number of trial for CVCS orifice adjusting tests.

2. Method and Results

The main flowpath of Chemical and Volume Control System (CVCS) for RCS volume control can be expressed as Fig. 1. [3]

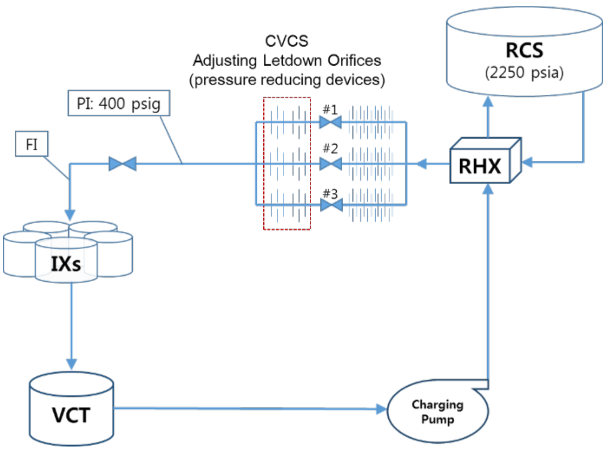


Fig. 1. Schematic of CVCS operation

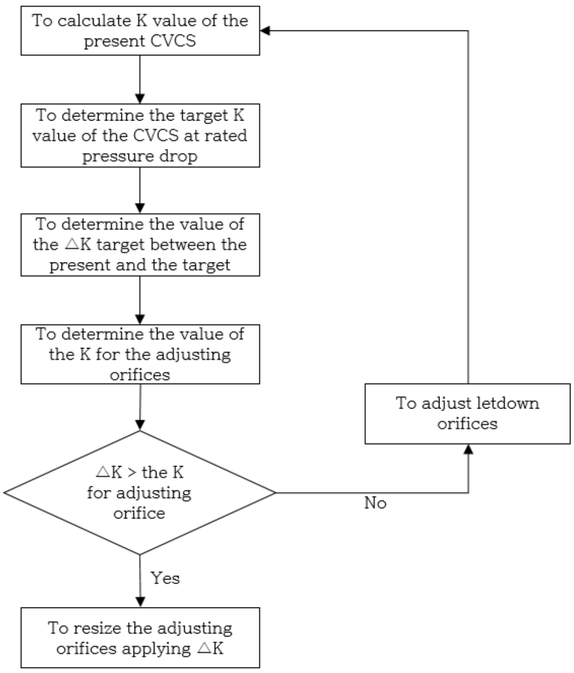
The CVCS letdown system has an orifice manifold which consists of three parallel piping to be operated in three letdown modes and each piping has a valve and orifices. The valve positions in the operations are as Table 1.

Table 1: The Minimum, Normal and Maximum Flow Operations

Modes	Valve #1	Valve #2	Valve #3
#1 (Minimum Flow)	Open	Close	Close
#1&2 (Normal Flow)	Open	Open	Close
#1,2&3 (Maximum Flow)	Open	Open	Open

2.1 Orifices Adjusting

If measured flowrates deviate from the allowable range, the deviations can be compensated by following methodology, Fig. 2. [3]



*K: Coefficient of resistance

Fig. 2. Methodology to adjust orifices at site

2.2 Simulation Model for the CVCS letdown system

Simulation model, which is FloMASTER network diagram, is presented as in Fig. 3 based on the CVCS flowpath of Fig. 1 and simulated in the incompressible steady state. Such as pressure and temperature, the measured fluid properties at the actual test are used as input of the simulation model. The RCS pressure is based on the pressurizer pressure under normal water level conditions during the actual test. 2 case simulations were performed to consider difference of water level as shown Table 2.

The fluid properties used in the simulation are corrected to the density at the same temperature in order to consider density change of incompressible fluid model. The initial conditions for the simulation are listed in Table 3.

Table 2: Simulations Case for pressurizer water level

Condition	Case 1	Case 2
Water level	30%	50%

Table 3: Initial Conditions for the Simulations

Modes	#1 (Min.)	#1&2 (Normal)	#1,2&3 (Max.)
Measured Flowrate	40.4 gpm (152.8 L/min)	79.5 gpm (300.9 L/min)	137.0 gpm (518.5 L/min)
Converted Flowrate*	40.7 gpm (154.0 L/min)	80.1 gpm (303.1 L/min)	137.6 gpm (521.0 L/min)
RCS Pressure	2267.2 psia (159.4kg/cm^2)	2267.1 psia (159.4kg/cm^2)	2257.2 psia (158.7kg/cm^2)
FI Temp.	81.7˚F (27.6˚C)	86.0˚F (30.0˚C)	99.1˚F (37.3˚C)
PI Pressure	400 psig (28.1kg/cm^2)	400 psig (28.1kg/cm^2)	400 psig (28.1kg/cm^2)

* Converted values at 120 °F

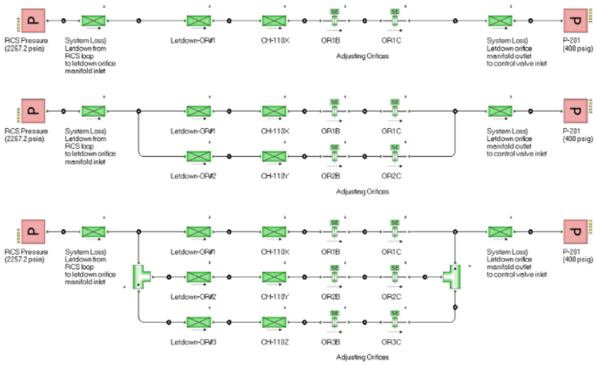


Fig. 3. Configuration of geometry and boundary conditions

2.3 Results and Verification

The results of simulation for 3 flow modes are as shown in Table 4. The pressure drop between each mode is shown Fig. 4. The CVCS letdown flowrate between the actual test, allowable range and FloMASTER are compared in Table 4.

Table 4: Comparison of the CVCS letdown flowrate

Modes*	Allowable Ranges	Site Test Results	FloMASTER (Case 1 / Case 2)
#1	38.8 gpm (146.9 L/min) ~ 41.2 gpm (155.9 L/min)	40.7 gpm (154.0 L/min)	40.7 gpm (154.1 L/min) ~ 40.8 gpm (154.3 L/min)
#1&2	77.6 gpm (293.7 L/min) ~ 82.4 gpm (311.9 L/min)	80.1 gpm (303.1 L/min)	79.0 gpm (299.0 L/min) ~ 79.1 gpm (299.4 L/min)
#1,2&3	135.8 gpm (514.1 L/min) ~ 140.0 gpm (530.0 L/min)	137.6 gpm (521.0 L/min)	135.9 gpm (514.4 L/min) ~ 137.2 gpm (519.4 L/min)

* Converted values at 120 °F

The results of simulation satisfy allowable flowrate range and have a tendency to flow equal or lower than the actual test flowrate. The flowrate is proportional to the elevation head, but it had only a slight effect on the overall flowrate.

The flowrate using FloMASTER shows that the flowrate is at least 0.301% to up to 1.35% less than the actual test results. This difference is very small values than the allowable range of ±3% flowrate and FI indicator accuracy of ±2%.

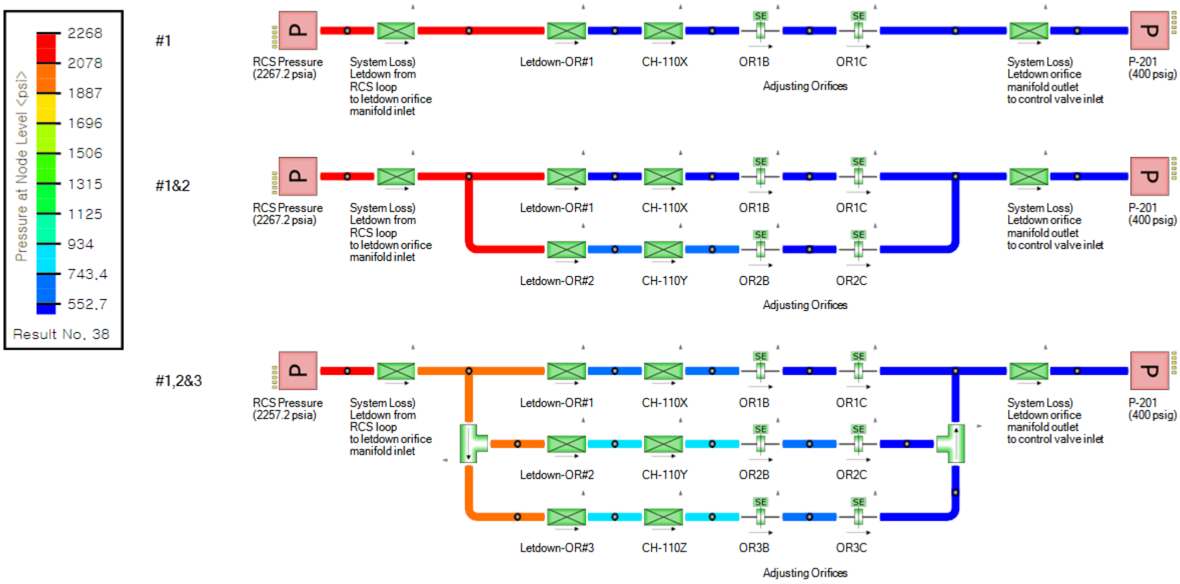


Fig. 4. Pressure drops at CVCS letdown system

3. Conclusions

This paper calculated 3 mode flowrates at CVCS letdown system using FloMASTER computer code. It was confirmed that FloMASTER has equal or less flowrate than the actual test results.

Simulation techniques using FloMASTER can be useful tools for prediction of test result before implementation of the actual test and for calculation review for the orifice adjusting at site. These can help to save time and cost in aspect the test result is estimated before implementation of the test, which minimize number of experiments.

In conclusion, the results using FloMASTER is about less 2% difference, so it is estimated that FloMASTER is utilized in prediction tools before the actual test.

REFERENCES

[1] Final Safety Analysis Report for Shin Hanul Nuclear Power Plant Unit 1 and 2.

[2] Simcenter Flomaster Components Reference Manual-Software Version 2019.3, Siemens, Nov. 2019.

[3] Jungdae Choi, Kunwoo Yi, Hongsik Park, Byungryul Jung, Seongchan Park, A Study on Adjusting Method for CVCS Letdown Orifices, Transactions of the Korean Nuclear Society Autumn Meeting, Yeosu, Korea, 2018