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FD Performance Repeatability Experimental Procedure

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FD 성능반복 실험절차서

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1. Purpose

This document describes detailed procedures required for systematic execution of "APR 1400 Fluidic Device Verification Experiments" (hereafter, "FD Verification Experiments") and production of reliable experimental results.

2. Scope

This document applies only to "Repeatability experiments to confirm the performance of Fluidic Device applied to APR1400 design (hereafter, "FD performance repeatability experiments") using full-scale SIT & Fluidic Device test facility called VAPER.

3. References

[1] Heung June Chung, et. al., "Construction of the Performance Evaluation Test Facility for Fluidic Device," KAERI/TR-2080/2002, KAERI Technical Report (in Korean).
[2] In-Cheol Chu, et al., “Data Analysis Methodology for Full-Scale Fluidic Device Performance Tests,” KAERI/TR-2044/2002, KAERI Technical Report (in Korean).

4. Experimental Conditions, Check and Preparation Items

4.1 Experimental Conditions

Reference experimental conditions applied to FD performance repeatability experiments are described below:

(1) SIT initial level of SI water : [ ]^{TS} (reference elevation: SIT Bottom)
- SIT water volume above the top of stand pipe : [ ]^{TS} (SI water volume for large flow)
- SIT water volume below the top of stand pipe : [ ]^{TS} (SI water volume for small flow)

(2) SIT Initial Pressure : [ ]^{TS}

(3) Temperature of SI water : [ ]^{TS}

4.2 Check and Preparation Items

4.2.1 Supply power to the control room, control panel, and data acquisition system (DAS).

4.2.2 Supply power to the pressure transmitter, differential pressure transmitter, and signal converter.

4.2.3 Connect the main power of feed-water pump and air compressor. Shut off the main power of hoist and hydraulic power unit.

4.2.4 Check if there is sufficient supply pressure in central demi-water line and compressed air line which feed into VAPER test facility.

4.2.5 Check if the stock tank water level is high enough to fill the SIT. If water is insufficient, open the demi-water supply valve (V010) on top of the stock tank to supply water up to the appropriate water level.

4.2.6 Set the on/off timer for air compressor such that it operates for 1 hour and rests for 1 hour.

4.2.7 Open all vent valves in the pressure & differential pressure transmitters, and equalizing valves of the differential pressure transmitters to check if all the initial value point to zero (verify zero drift occurrence)

4.2.8 Open intermediate valves installed in the pressure impulse lines of the pressure & differential pressure transmitters.

4.2.9 Close drain valves in the pressure & differential pressure transmitters.

5. Experimental Facility and Equipments

5.1 VAPER (VAlve Performance Evaluation test Rig)

VAPER is an experimental test facility to evaluate the flow controlling performance of fluidic device, which has various designs. Details of VAPER are presented in Reference [1].

5.1.1 SIT (Safe Injection Tank)

The SIT of VAPER test facility has the same geometrical shape and size as the SIT of APR1400. Main design specifications of the SIT are presented below:

○ Design pressure/temperature : 50 bar/90℃
○ Inner diameter : [ ]^{TS}
○ Height : [ ]^{TS}

5.1.2 Fluidic Device

Dimensions of insert plate and exit nozzle of the fluidic device for the present experiments are presented below:

○ Insert Plate Model : [ ]^{TS}
- Supply Port Nozzle Width : [ ]^{TS}
- Control Port Nozzle Width : [ ]^{TS}
- Vortex Chamber Height: 140 mm

○ Exit Nozzle : [ ]^{TS}
- Throat Diameter : [ ]^{TS}

5.1.3 Stand Pipe

Dimensions of stand pipe for the present experiments are presented below:

○ Height : [ ]^{TS}
○ Inner diameter : [ ]^{TS}

5.1.4 Air Compressor

Specifications of air compressor for the present experiments are presented below:

○ Capacity : 206 m^3/hr
○ Discharge pressure : 50 kg/cm^2
○ Suction pressure : atmospheric pressure
○ Design pressure/temperature : 50 kgf/cm^2, 80℃
○ Motor Power : 55 kW (440V, 90A)

5.1.5 Feed-Water Pump

Specifications of feed-water pump for the present experiments are presented below:

○ Capacity : 60 m^3/hr
○ Discharge head : 30 m
○ Motor Power : 15 kW

5.2 Data Acquisition System

Data acquisition system for the present experiments consists of industrial computer, DSP Board with A/D Converter, Multiplexer Terminal, and data processing Software Program. Analog signals transmitted from instruments installed in VAPER test facility enter into the A/D converter via multiplexer, and then they are converted into digital signals. Digital signals converted are stored in the internal memory of DSP board and transmitted to PC memory through PCI bus. The data transmitted to PC memory is converted into each physical quantity through data processing program.

Specifications of the A/D converter for the present experiments are presented below:

○ Resolution : 16 bit
○ Sampling rate : 100 kS/sec
○ Input Range : -10V ~ +10V

5.3 Measuring Instruments

A list of main measuring instruments used to evaluate flow controlling performance of Fluidic Device and their specifications are presented below:

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6. Experimental Method and Procedures

6.1 DAS Startup

6.1.1 Start DAS data processing program to monitor all measurements.

6.2 SIT Filling

6.2.1 Close all vent valves in the pressure transmitters and differential pressure transmitters as well as the equalizing valve.
6.2.2 Close the SIT drain valve (V016).
6.2.3 Close the quick opening valve (FSV-102) in the 12" main discharge pipe.
6.2.4 Open the vent valve (V015) on the top of SIT.
6.2.5 Open the demi-water circulation valve (V007) on the top of SIT to supply demi-water from stock tank to SIT.
6.2.6 Open the connection valve of visual water level gauge installed in SIT.
6.2.7 Start the feed-water pump and feed SI water from stock tank into SIT.
6.2.8 Stop the pump when the SIT water level gauge points to [ ]^{TS}.
6.2.9 Drain water in the stock tank until the water level in the stock tank reaches below 1 m.

6.3 Venting of Pressure and Differential Pressure Transmitters

6.3.1 Open all vent valves in the pressure transmitters and differential pressure transmitters as well as drain valves for a sufficient time so that gas in the pressure impulse lines can be completely removed. Close the drain valve after 1 minute and close vent valves after 3-5 minutes. Be careful that the indicated value of SIT water level on the visual water level gauge does not go down below [ ]^{TS}.

6.4 SIT Pressurization

6.4.1 Open the quick opening valve for a brief time so that SIT water level reaches around [ ]^{TS}.
6.4.2 Verify that the indicated values of SIT water level on the visual water level gauge

and differential pressure transmitters for SIT water level (LT-101, LT-101-1) match within [ ]^{TS}.

6.4.3 Close the SIT vent valve (V015), demi-water circulation valve (V007), and visual water level gauge connection valve.

6.4.4 Close the valve on the bypass line of the main air compressor (V013).

6.4.5 Open the compressed air supply valve (FSV-101) from the air compressor to the SIT.

6.4.6 Start the air compressor.

6.4.7 Stop the air compressor for a while when the pressure in the SIT reaches 4.0 MPa.

6.4.8 Open the SIT drain valve a little to lower the SIT water level slowly until it reaches the reference experimental condition. Operate the air compressor intermittently to compensate SIT pressure decrease which was caused by water level decrease.

6.4.9 Close the SIT drain valve and stop the air compressor when SIT water level and pressure reach reference experimental conditions.

6.4.10 Close the compressed air supply valve (FSV-101).

6.4.11 Start the small air compressor exclusive for the quick opening valve (FSV-102) so that the startup pressure of the quick opening valve reaches 9 bar.

6.5 Discharge of Safety Injection Water

6.5.1 Verify that SIT pressure and water level are within [ ]^{TS} of error range of reference experimental conditions in Section 4.1.

6.5.2 Verify that the indicated values of the pressure transmitters on the top (PT-104) and bottom (PT-102) of SIT are consistent as much as pressure difference corresponding to SIT water level is. In addition, verify that errors of indicated values of LT-101 and LT-101-1 are within [ ]^{TS}.

6.5.3 Switch the data acquisition and processing program to a "SAVE" mode to save all measurements for 10 seconds (verification of operational integrity of DAS data processing program).

6.5.4 Re-operate DAS data processing program in a "Monitoring" mode.

6.5.5 Switch DAS data processing program to "SAVE" mode and simultaneously open the quick opening valve (FSV-102) to discharge the safe injection water in the SIT.

6.5.6 Stop DAS data processing program when all of safe injection water is discharged.

6.6 Post-experimental Treatment

6.6.1 Open the SIT vent valve (V015) and drain valve (V016).
6.6.2 Open the air compressor bypass valve (V013).
6.6.3 Verify that saved data is not damaged and back up the data in other computer.
6.6.4 Prepare the first experiment report after calculating physical quantities required for FD performance evaluation from the saved raw data.
6.6.4 Turn off the power and finish the experiment.
6.6.5 Distribute an experimental log for each experiment and quick look report to the applicable departments.

7. Analysis of Experimental Results

7.1 Water Level Change in SIT and Stand pipe

7.1.1 For SIT water level change, use the indicated values of two differential pressure transmitters (LT-101, LT-101-1).
7.1.2 For water level change in stand pipe, use the indicated value of differential pressure transmitter (LT-102).
7.1.3 The water level is calculated from differential pressure measured using the following equation:

$$h_{SIT} = \frac{(\rho_w - \rho_{air})gH - \Delta P}{(\rho_w - \rho_{air})g} \quad (1)$$

where,

ρ_w : Water density in the pressure impulse line and inside the SIT
ρ_{air} : Air density inside the SIT
H : Height difference between upper/lower pressure impulse lines
h_{SIT} : SIT water level (from LT-101, LT-101-1)
ΔP : Differential pressure measurement.

7.2 Discharge Flow Rate of Safe Injection Water

7.2.1 The discharge flor rate of safe injection water in the SIT is calculated from SIT water level change rate as follows:

$$W_{SIT}(t) \approx \rho_w A_{SIT} \frac{h_{SIT}(t) - h_{SIT}(t+\Delta t)}{\Delta t} \qquad (2)$$

where,

A_{SIT} : Cross-sectional area of SIT

Δt : [ ]TS.

7.3 Pressure Loss Coefficient (K Factor)

7.3.1 When safe injection water is discharged from SIT, the pressure loss coefficient of Fluidic Device and discharge pipe is calculated from measurements of applicable differential pressure transmitters and pressure transmitter (DPT-101, DPT-102, PT-102) as follows:

$$K_i = \Delta P_i \frac{2\rho_w A_{pipe}^2}{W_{SIT}^2}; \qquad i = FD \; or \; Piping \qquad (3)$$

where

A_{pipe} : Cross-sectional area of discharge pipe

W_{SIT} : Discharge flow rate of safe injection water, from Eq. (1).

7.4 Acceptance Criteria

For the following cases, the experimental data is not included in the results of repeatability experiments for Fluidic Device performance determination.

7.4.1 If the initial experimental conditions deviate more than [ ]TS from the reference experimental conditions specified in Section 4.1.

7.4.2 If the opening time of quick opening valve (FSV-102) exceeds [ ]TS.

7.4.3 If part of measurement data are damaged when saving the data using data acquisition program.

8. Forms Used

8.1 Calibration Sheet

8.1.1 Calibration of pressure controller shall be entrusted to a nationally certified institute and its calibration sheet shall be used.

8.1.2 Table 1 represents a sample calibration sheet for differential pressure transmitters for SIT water level measurement (LT-101, LT-101-1). When calibrating, more than [ ]^{TS} points should be measured toward the directions of differential pressure increase and decrease.

8.1.3 Table 2 represents a sample calibration form for pressure transmitters and differential pressure transmitters except LT-101 and LT-101-1. When calibrating, more than [ ]^{TS} points should be measured toward the directions of pressure increase and decrease.

8.1.4 Calibration of RTD and thermocouple shall be entrusted to a nationally certified institute and its calibration sheet shall be used.

8.2 Experimental Check List

8.2.1 Table 3 presents a check list for key items that must be followed during the preparation and execution of the experiments.

8.3 Inspection Plan

8.3.1 Table 4 presents an inspection plan for the QA manager to select inspection points.

Table 1 Sample calibration sheet for SIT water level transmitter

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Table 2 Sample calibration sheet for other pressure and differential pressure transmitters

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Table 3 Check List for FD Performance Repeatability Experiments

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Table 4 Inspection Plan for FD Performance Repeatability Experiments

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