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Improvement of a measurement method of purified flows in a reflector of HANARO by an ultra-sonic flowmeter

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1.0 Introduction

Heavy water is used in the reflector system in HANARO and the flow in the system is measured by a flowmeter and indicated in a control room. The Turbine Flowmeter to measure the purified flow, which had been used from the start up of reactor was broken down in the end of 2001. In order to avoid the exposure of tritium generated from heavy water leaked during a replacement, instead of fixing the flowmeter, an ultrasonic flowmeter was selected and installed and has been used to measure the flow.

This paper describes the measurement principles, issues and calibration errors of the turbine flowmeter that was broken down. Also, it explains in detail the measurement principles of the ultrasonic flowmeter, the results of its field test and the results of its periodic tests for five years after the installation.

2.0 Composition of Purification Circuit

The reflector system has two cooling pumps to perfect two functions of a cooling and purifying a coolant. The normal flow of coolant that is purified by one pump is more than 0.15 ℓ/sec and the normal flow is always maintained to prevent a corrosion of the system and to maintain the conductivity at 0.5 mS/m and lower[1].

This flowmeter has a structure that combined an electronic part and a mechanical sensor. The measurement principle is: when the turbine inside the flow rotates, angular velocity in proportion to the flow increases and this number of rotations is detected by a pick-up coil and transformed into a electric frequency. Purified flow is indicated by a turbine flow meter. The turbine flowmeter is composed of a turbine, pick-up coil and indicator, as shown in Figure 1.

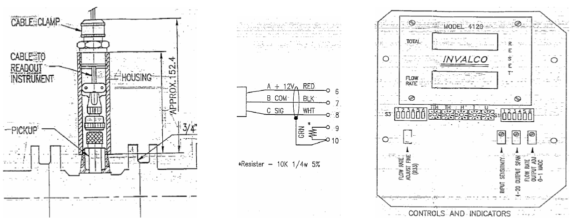


Figure 1. Composition of the turbine flow meter

From 1997 to 2001, the device was inspected once a year and used for measuring a flow without any trouble as shown in Table 1 [3].

Table 1. Test Results of the Local Application

Date	Zero(mA)	Span(mA)	Remark
1997. 8.	4.00	19.97 → 20.00	Good
1998. 4.	4.00	19.81 → 20.00	Good
1999. 4.	4.00	20.00	Good
2000. 5.	4.00	20.00	Good
2001	4.00	19.99	Good

At the end of 2001, it was found that the turbine flowmeter for measuring the purified flow was operating abnormally. Even when the reflector pump was operating normally, it could not indicate the flow. Depending on the inspection procedure, electric inspection was performed for the magnetic pick-up and the signal transmitter, but no problem was found. It was decided that this phenomenon resulted from a irregular rotation of the turbine rotor. That is, it seems that It's rotation is hindered because foreign matter attached to the blades or the bearing inside the rotor is damaged.

To replace the turbine installed in the form of flange, a large amount of heavy water should be flown; even when the tritium removing device was operated, an operator's exposure was an issue. As it was expected to adjust the schedule of the reactor operation, instead of the current turbine flowmeter, a possibility to install an ultra-sonic flowmeter was examined.

3.0 Characteristics of the Ultrasonic Flowmeter

The selected ultra-sonic flowmeter uses a measuring method using the Ran sit Time, its error of measurement is ± 2%, and its principle is as follows: When ultrasound passes through the flow, the speed of ultrasound changes in proportion to the speed of flow. As shown in Figure 2, Ultrasound is discharged in the same direction with the flow on one side and in the opposite direction to the flow on the other side. When the speed of sound in the stopped flow is C and the velocity of the flow is v, the speed of forward ultrasound is C + v cosθ, while the speed of backward ultrasound is C – v cosθ.

$$t_1 = \frac{L}{C + v\cos\Theta} \qquad t_2 = \frac{L}{C - v\cos\Theta}$$

The distances between T_1 and R_1 and between T_2 and R_2 are the same (L) and they can be expressed as shown in Figure 2 when the arrival time of forward ultrasound is t_1, and the arrival time of backward ultrasound is t_2. The sonic speed(c) of generic liquid is about 1500 m/s and it's velocity(v) does not exceed 10 m/s, so it is

$C^2 \gg v^2$. Time difference (Δt) can be obtained in the following way, and in the result formula, when you know L and C, the velocity, v, can be obtained by the measuring time difference[4].

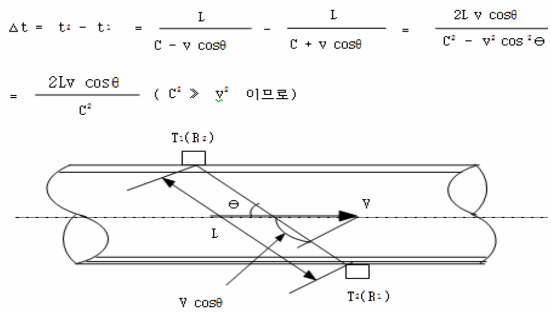


Figure 2. Measurement principal of a USF

For a field application and installation, a field test was performed with a manufacturer. The straight length of pipe, which is a condition to install an ultrasonic sensor, was sufficient, so it was possible to easily install the existing pipe without an additional processing so there was no problem in a field application. No. 1 sensor was installed in the 1/2" pipe inside the reflector room, and the existing indicator was removed from the reflector valve room and the ultrasonic flowmeter indicator was installed, which is as shown in Figure 3.

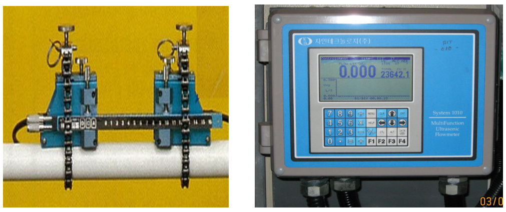


Figure 3. Installed sensor and Flowmeter

In the field test, apart from the installed ultrasonic flowmeter, a standard ultrasonic flowmeter was installed by the manufacturer. While controlling the flow valve, the flow of the two flowmeters was compared ten times. As a result, a correction was completed with errors of a correction between 2.6% and 1.7%, and the degrees of the accuracy, stability of indicated values, and repetition were all satisfactory. The results of the tests are shown in Table 2.

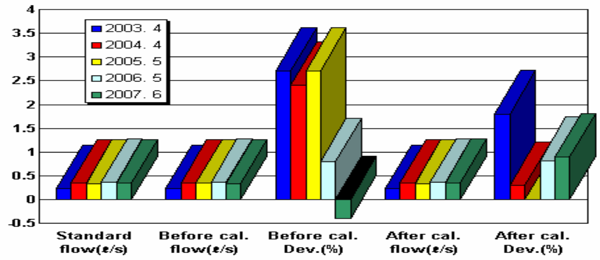
Table 2. Test Results of Local Application

Num.	Standard flow(ℓ/s)	Before cal. flow(ℓ/s)	After cal. flow(ℓ/s)
1	0.223	0.229	0.228
2	0.223	0.230	0.229
3	0.224	0.231	0.228
4	0.223	0.230	0.227
5	0.224	0.229	0.226
6	0.225	0.230	0.227
7	0.224	0.230	0.228
8	0.225	0.229	0.229
9	0.224	0.232	0.230
10	0.225	0.229	0.229
Avg.	0.224	0.230	0.228
Dev.		2.6%	1.7%

Since 2003, the flowmeter was calibrated by the plant once a year.[3] The method of calibration is: after the national calibration laboratory completed the calibration of a portable ultrasonic flowmeter owned by the plant, its measured values of flow is compared with that of the ultrasonic flowmeter for measuring purified flow. The results are shown in Table 3 and Figure 3.

Table 3 and Figure 3. Test Results of self calibration

Date	Standard flow(ℓ/s)	Before cal. flow(ℓ/s)	After cal. flow(ℓ/s)
2003. 4	0.225	0.231	0.229
2004. 4	0.340	0.348	0.341
2005. 5	0.339	0.348	0.339
2006. 5	0.366	0.369	0.369
2007. 6	0.352	0.338	0.355
Dev.		**1.6 %**	**0.8%**



After regular check-ups were performed for five times, the mean errors of pre-calibration and post-calibration were 1.6% and 0.8%, indicating that sufficiently accurate flow signals are obtained.

4.0 Conclusion

To solve a defect in a reflector purification flowmeter, the ultrasonic flowmeter that does not require a separate treatment of the existing pipes was selected and installed, and the following results were obtained.

* After 10 field measurements, it was possible to obtain accurate flow signals.

* After a field application and five periodic tests, the mean error was only 0.8%, confirming that a very accurate measurement was done.

* More stable and accurate flow measurements have become possible.

* It completely removed any risks related to heavy water during replacement or a defect of a flowmeter that could occur in the future.

REFERENCES

[1] "Safety Analysis Report", KAERI/TR-710/96, KAERI, 1996.
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[3] "Periodical Test Procedure for Reflector Flowmeter", KAERI, 2002.
[4] "Operating Instructions for Multifunction Flower", CONTROLOTRON.