Installation Experience of the Ultrasonic Flow Meter Applied in the Feedwater Flow Measurement of Nuclear Power Plants

Insoo Jeong, Woohyun Jang, Jaehee Yun, Hangbae Kim
Korea Power Engineering Company, Inc., 150 Deokjin-dong, Yuseong-gu, Daejeon, 305-353

1. Introduction

The Ultrasonic Flow Meter(UFM) installed in feedwater line of nuclear power plants is used for calibration of venturi flowmeter which is used for thermal power calculation. The measurement accuracy of UFM is very important because the measured value affects the thermal power calculation. The measured value is sensitive to installation and measuring methodology of UFM.

The purpose of this report is to review the considerations of installation of UFM and to share the experience of installation of UFM in nuclear power plants.

2. Considerations and Methods

2.1 Considerations for UFM Installation

In order to install the UFM for measuring of the feedwater flow accurately, the followings should be considered.

- Configuration and location of the transducer
- Pipe diameter and thickness
- Condition of couplant appliction
- Temperature suitability of the transducer and the couplant
- Thermal expansion coefficient of the block gauge

The errors appeared in UFM can remove or reduce through the proper consideration.

2.2 Straight Line

Since it is assumed that the distribution of flow rate maintains axis symmetry as a fully well developed profile affected by fluid type, Reynolds number, roughness of pipe interior surface, and pipe figuration, the UFM needs proper straight line lengths for upstream and downstream of detector. Therefore enough long straight line is required for flow measurement of high accuracy. The straight line requirements per the standards is upstream 10D and downstream 5D for 90 degree bent pipe and upstream 30D and downstream 10D for each valve. The required straight line of vendor is also similar to standard requirements.

The UFM location is determined by considering the front and rear establishments in the pipe. And the UFM application of feedwater flow measurement in domestic nuclear power plants meets well developed flow profile required as well as the required distances per the standards. The table I shows the actual UFM location in the feedwater line of domestic nuclear power plants according to the plants.

Table I: The formation of the straight line when UFM installs in the feedwater line of domestic nuclear power plants

Plants	The fore establishments in the pipe	Up-stream	Down-stream	The rear establishments in the pipe	Out dia-meter (mm)
Kori NPP #3	bent pipe	12D	7D	Check Valve	457.2
			48D	Feedwater Control Valve	
Kori NPP #4	bent pipe	12D	7D	Check Valve	457.2
			48D	Feedwater Control Valve	
Wolsong NPP #1	bent pipe	125D	93D	Elbow tap	322.5
Wolsong NPP #2	double bent pipe	40D or more	10D or more	Elbow tap	324.95
Younggwang NPP #5	bent pipe	29D	118D	Feedwater Control Valve	510.6

2.3 Attached Equipment of UFM

Most transducers are installed at fixed location using clamping mechanism because of the required accurate propagation of ultrasonic wave through the pipe at a uniform angle. The flow rate measuring and the cross section of the pipe can be calculated easily on a micro processor but the alignment of the transducer is the most important element for the flow calculation. The installation equipment that uses chain and strap is not affected by the pipe size. But it does not fit the high temperature condition for the feedwater pipe and long term measuring. An exclusive bracket that endures high temperature and is tightly attached to the pipe is needed for domestic plants.

The exclusive bracket which minimizes the temperature effect and is composed of the coupling plate for signal transmission between the transducer and the pipe and the attached equipment for fixing the coupling plate has been realized through a series of technical conferences with the manufacturer to improve the accuracy and reliability of the UFM.

The attached equipment of the UFM is manufactured using the same material as the feedwater pipe. Otherwise, the different thermal expansion coefficient can cause fracture. The feedwater pipe is exposed to high temperature condition of over 190 degrees centigrade, when the attached equipment is produced using different material from the feedwater pipe. The coupling plate between the transducer and the pipe were designed so that ultrasonic signal transmits without scatter and attenuation. The coupling plate is thin and is effective in heat resistance because temperature transmission of the pipe surface to transducer via coupling plate is discouraged. According to the heat difference between the pipe surface and transducer, the coupling plate prevents heat from rising over limit temperature.

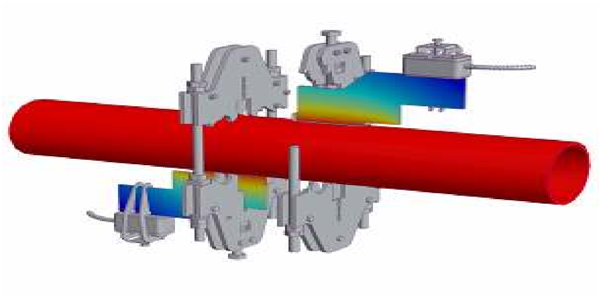

Fig. 1 The configuration of the attached equipment and temperature contour

2.4 Couplant

The couplant is adopted for creditable ultrasonic signal transmission between the transducer and the pipe. The couplants are categorized into two classes, one is the liquid type such as silicone and the other is the metal type such as Au, Pt, Ag, Al, Pb, etc. The liquid couplant is widely used from low temperature to high temperature and applies. However, the measuring sensitivity can go down at high temperature during long term use due to evaporation. To use a couplant for a long time, it is desired that the metal couplant is used. In case of the liquid couplant, a small quantity can produce signal scatter due to a gap between the transducer and the pipe and a large quantity can reduce the sensitivity of signal transmission. In case of the metal couplant, it might be necessary to roughen the surface to ensure the condition of complete adhesion between the transducer and the pipe. And generally, a commercial liquid couplant is used below 200 degrees centigrade. During an actual field measurement used the liquid couplant, there are lots of noise in UFM signal and UFM has shown incorrect output. The surface temperature of the feedwater pipe is about 189 degrees centigrade in Wolsong units 1&2 and about 220 - 230 degrees centigrade in Koran Standard Nuclear Power Plant and Kori units 3&4. Therefore, the couplant for the feedwater measuring in domestic nuclear power plants should be the metal couplant during a long time measuring but the liquid couplant may be used in a short period measuring.

Since the air layer can result in when thin couplant is used due to the pipe roughness, the couplant should be determined on the average roughness of the pipe and the couplant with about 10 times of the average roughness is suitable. The Pb and the Ag couplant are used to the feedwater flow measurement in domestic nuclear power plants. The thickness of the couplant is 60 μm in case of Pb and 56 μm in case of Ag. The Pb couplant is soft and well adheres to the pipe. The Ag couplant is hard and there is no problem for pressure adhesion to the pipe.

2.5 Block Gauge

The ultrasonic thickness measuring instrument for measuring the pipe thickness should be calibrated prior to use like other instruments. The calibration is provided by manufacturer or the block gauge is used. A material of the block gauge is desirable the same as the material of the pipe. If the material of the block gauge is not the same as the material of the pipe, the difference of the sound speed owing to the quality of the material should be compensated. The calibration of the instrument is desirable at site. The temperature of the block gauge should be the same as the temperature of the pipe. In order to calibrate the thickness instrument using the block gauge which is the same as the temperature of the pipe, the reference thickness of the block is applied posterior to measure with micro calipers or the reference value of the block gauge is arithmaticaly recalculated.

The block gauge produces the error which corresponds to the thermal expansion coefficient of the quality of the material according to the temperature. If the ultrasonic thickness instrument shows the difference between the calibration temperature and the measuring temperature, the error is produced by increase in the thickness of the block gauge itself due to the temperature difference. The applied value of the block gauge for domestic nuclear power plants is generated to the measuring temperature. The actual reference value of the block gauge is calculated using pipe temperature at measuring time in site, and then recalculated reference value of the block gauge in accordance with the pipe temperature is used.

3. Conclusions

In order to improve the measuring accuracy and reduce the human error and improve the accuracy of the pipe measuring data, the standardized equipment installation procedure and measuring procedure documents were developed. Also in order to minimize the influence of the measuring error, the considerations and installation methods shown above were incorporated in the actual site tests. The reverified procedures of the results are being performed through continued and repeated site tests.

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