Baseline UT Thickness Measurement of HANARO 28-inch Secondary Cooling Piping

Taeho Kim *, Minsu Kim, Kyungsu Park, Hyeonwoo Park, Byunghun Hwang
HANARO Management Division, Korea Atomic Energy Research Institute
111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon 3457
**Corresponding author: taehokim@kaeri.re.kr*

***Keywords :** HANARO, ultrasonic thickness measurement, secondary cooling piping, wall thinning, baseline data

1. Introduction

HANARO (High-flux Advanced Neutron Application Reactor) is a research reactor operated by the Korea Atomic Energy Research Institute (KAERI). The secondary cooling system removes heat from the reactor and auxiliary systems and ultimately rejects it to the atmosphere via a cooling tower. The secondary cooling water circulates through large-diameter carbon steel piping installed in an underground utility tunnel, connecting major equipment such as heat exchangers, circulation pumps, and the cooling tower. This piping has remained in continuous service for approximately 30 years since installation.

As non-safety-related piping, this section is not subject to the domestic In-Service Inspection (ISI) requirements applicable to safety-related piping, and consequently no baseline thickness records have existed to date. To establish reliable baseline data for tracking potential long-term wall thinning, an ultrasonic thickness (UT) survey was conducted on the 28-inch pipe section in the underground utility tunnel. These results will serve as the baseline for establishing future wall-thickness management criteria. This paper presents the inspection methodology, the minimum required thickness based on KEPIC MGE (2020 Edition), and the resulting baseline thickness data.

2. Scope and Methodology

2.1 Pipe Specifications

The inspected pipe section is an NPS 28 (711.2 mm O.D.) horizontal run located within the underground utility tunnel of the HANARO secondary cooling system, with a total length of approximately 142.22 m. This section includes two elbows and one reducer (28 in. → 24 in.) and was fabricated from ASTM A671 Grade CB70, Class 20 material (stress-relieved, electric-fusion-welded, and non-radiographed) in accordance with the original piping class specification (ANSI B16.5 Class 150; design code: ANSI B31.1 Power Piping).

2.2 Ultrasonic Thickness Measurement

Pipe wall thickness was measured on July 22, 2026, using a Dakota Ultrasonics MX-3 digital thickness gauge calibrated against a carbon steel reference block prior to the inspection. A velocity correction factor of 0.99301 was applied to compensate for the difference between the calibration ultrasonic velocity (6009 m/s) and the nominal ultrasonic velocity of the pipe material (5967 m/s). Measurements were performed at 31 cross-sections, for a total of 124 measurement points, using a four-point circumferential method (12, 3, 6, and 9 o'clock positions). The measurement locations included elbow inlet and outlet joints, elbow bodies, high-density measurement zones downstream of the elbows, and straight-run sections.

2.3 Minimum Required Thickness

The code-based minimum required thickness, t_m, was calculated in accordance with KEPIC MGE Para. 104.1.2 for straight pipe subjected to internal pressure, as follows:

$$t = \frac{P \cdot D_0}{[2(S \cdot E \cdot W + P \cdot Y)]t} \quad (1)$$

$$t_m = t + c \quad (2)$$

where P is the design pressure, D_0 is the outside diameter of the pipe, S is the allowable stress, E is the longitudinal weld joint efficiency, W is the weld strength reduction factor, Y is the temperature-dependent coefficient, and c is the corrosion and mechanical allowance.

For the inspected piping, the input parameters were P = 1.0 MPa, D_0 = 711.2 mm, S = 138 MPa (based on the low-temperature allowable stress of ASTM A671 CB70), E = 0.9 (Class 20, non-radiographed), W = 1.0 (design temperature of 50°C, below the creep range), Y = 0.4 (ferritic steel), and c = 0 mm (corrosion allowance specified in the original design specification). Substitution of these values into the equations gives t_m= 2.85 mm.

3. Results

Table I summarizes the velocity-corrected wall thickness measurements obtained for each inspection zone. The corresponding thickness margins were evaluated against the code-based minimum required thickness, t_m = 2.85 mm.

Table I. Summary of Ultrasonic Thickness Measurement Results (Corrected Values)

Section	Points	Min t (mm)	Avg t (mm)	Min Margin* (mm)	Result
Elbow ①-1 joints (No.1–5)	5	9.61	10.25	6.76	Pass
Elbow ①-1 downstream dense zone	3	9.43	9.91	6.58	Pass
Straight run ①	6	9.63	9.88	6.78	Pass
Elbow ②-2 joints (No.12–16)	5	9.90	10.16	7.05	Pass
Elbow ②-2 downstream dense zone	3	9.81	9.92	6.96	Pass
Straight run ② (incl. reducer)	9	9.48	9.84	6.63	Pass
Total / Overall	**31 (124 pts)**	**9.43**	**9.99**	**6.58**	**Pass**

**Margin = Minimum measured thickness − t_m (2.85 mm)*

All 31 cross-sections (124 measurement points in total) exceeded the code-based minimum required thickness, t_m, with the minimum thickness margin of 6.58 mm observed in the high-density measurement zone downstream of Elbow ①. Circumferential thickness variations of up to approximately 1.2 mm were observed at some elbow joints. These variations are consistent with fabrication-induced thickness variations previously identified through UT surveys of the facility's 20-inch and 24-inch piping systems and are not considered indicative of flow-accelerated corrosion (FAC) progression.

4. Discussion

The t_m (= 2.85 mm) derived in this study represents the minimum required thickness for pressure design in accordance with KEPIC MGE Para. 104.1.2 and does not account for sustained loads or expansion stresses arising from dead weight, thermal expansion, or vibration. These effects must be evaluated separately through piping flexibility analysis. In particular, elbow sections are locations subject to a stress intensification factor (SIF), where expansion stresses can be locally amplified. The circumferential thickness variation (approximately 1.2 mm) observed at the elbow joints in Section 3 warrants further review in conjunction with these loading conditions. Accordingly, the t_m value presented here should be interpreted as the minimum requirement from a pressure-design standpoint, and the overall structural integrity of the piping should be assessed through a separate stress analysis.

Meanwhile, since this survey represents the first baseline measurement for this piping, the obtained thickness margins should be regarded as baseline data rather than corrosion-rate information. Given that the original design specification did not include a corrosion allowance (c = 0 mm), periodic thickness re-measurements based on this baseline data are recommended to track any progressive wall thinning.

5. Conclusion

A baseline ultrasonic thickness measurement survey was conducted on the 28-inch piping installed in the underground utility tunnel of the HANARO secondary cooling system to establish baseline data for long-term wall-thinning trend monitoring. All 31 cross-sections (124 measurement points in total) exceeded the KEPIC MGE (2020 Edition) code-based minimum required thickness (t_m = 2.85 mm) by margins ranging from 6.6 to 7.1 mm, indicating sufficient wall-thickness margin for the pressure design requirement at the time of inspection. Given that no corrosion allowance was specified for this piping in the original design specification, the dataset established through this survey will serve as an essential baseline for future periodic inspections and long-term wall-thinning trend management.

REFERENCES

[1] KEPIC-MGE, General Machinery – Piping, Korea Electric Association (KEA), 2020 Edition.

[2] KEPIC-MDP, Allowable Stresses (Metric), Korea Electric Association (KEA), 2020 Edition.

[3] KM-135-DS-P001_R5 Piping Material Classification & Standard Details KMRR, 1990