Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22-23, 2025

Functional Qualification of Active Valve used in Ki-Jang Research Reactor

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***Keywords : Functional Qualification, Active Valve, Ki-Jang Research Reactor, KEPIC MFC, ASME QME-1**

1. Introduction

The Korea Atomic Energy Research Institute (KAERI) is currently constructing the Ki-Jang Research Reactor (KJRR) in Ki Jang-gun, Busan. The KJRR is an open-pool type research reactor with a thermal power output of 15 MW. The heat generated in the core is removed through the primary cooling system pump and heat exchanger. ASME Class 150# 14-inch cast type swing check valve is installed downstream of the heat exchanger to prevent backflow. According to the definition in KEPIC MFA 1500[1], this valve is classified as an active component, necessitating verification of its function and operability. The functional qualification of these valves was conducted using a prototype valve in accordance with KEPIC MFC[2] (ASME QME-1[3]).

2. Test Overview

The functional qualification of active self-operated check valves should be conducted based on the technical standard requirements through testing, analysis, or a combination of both, to verify the following items:

A. Valve sealing capability
B. Operability under maximum piping-reaction end loading
C. Operability during and after loading representative of the maximum seismic or vibratory incident
D. Flow interruption and functional capability
E. Adequacy of the materials of construction to survive environmental and aging effects

KEPIC MFC requires that the following sequence of tests be performed to verify these aspects: Pre-test inspection – Environmental and aging simulation – Intermediate inspection – End-load testing – Intermediate inspection – Flow shutoff and operational capability verification – Intermediate inspection – Fully open valve disc flow test – Post-test inspection.

3. Pre-Test Inspection

The pre-test inspection was conducted in accordance with MFC 4431.2. This step determines the suitability of the test valve assembly before actual testing and establishes baseline values to assess potential performance degradation - primarily increased valve seat leakage - during subsequent tests. The pre-test inspection included a visual examination of the test valve assembly and calibration of test equipment. The primary seat leakage was measured for at least 5 minutes, with an allowable leakage rate of 0.6 in³/hr per nominal pipe size (NPS) of the valve.

4. Environmental and Aging Simulation

The environmental and aging simulation was conducted per MFC 4450. Since most components of the valve, except for stem packing and gaskets, are made of metal, the effects of radiation, high temperatures, and chemical conditions were considered negligible. Corrosion and erosion effects were addressed by designing the valve to meet precise technical requirements. Environmental qualification was performed for non-metallic components such as packing and gaskets. The environmental conditions for the installation site were specified in the valve design specification, and the qualification was performed accordingly. The environmental conditions for the installation site and the qualification criteria for graphite packing and gaskets are as follows:

	KJRR Condition	Qualification Condition
Duration (Year)	50	40
Temp. (℃)	50	50
Humidity (%)	90	90
Pressure (psig)	Atm.	60
Radiation Doses (Gy)	2.5×10^3	2.0×10^6
Chemical condition	N/A	Boron + Hydrazine $4.0 \leq pH \leq 10.0$

According to the Fillar's Technical Report[4], the graphite packing material was irradiated to 1.5E7 Gy gamma, which exceeds the total radiation requirement of 2.0E6 Gy and there was no apparent effects. Thus, the graphite packing material was deemed qualified for the specified radiation environment. The maximum operating temperature of the graphite packing material is 600℃, with a melting temperature range of 3,300℃ to 3,650℃. Therefore, the graphite packing material is considered resistant to normal and accident temperature conditions.

Based on the existing verification results and studies, additional environmental and aging tests was omitted.

5. End-Load Testing

The piping reaction end-load test was performed per MFC 4470.2. The objective of this test was to verify that the test valve assembly operates normally while subjected to all required piping end loads in addition to normal loads. The valve inlet side was fixed to a support, while the outlet side was attached to a movable fixture. Opposing forces were applied to the top and bottom of the valve to generate the test moment required by the technical standard. This state was maintained for 5 minutes, after which the test moment was reduced to 2/3, and the primary seat leakage was measured for 5 minutes.

6. Intermediate Inspection

An intermediate inspection was conducted after the end-load test. This inspection, performed in the same manner as the pre-test inspection, measured primary seat leakage. If a significant increase in leakage was observed compared to the pre-test inspection, it would indicate potential integrity degradation due to previous test conditions.

7. Flow Shutoff and Operational Capability Verification

This test was conducted in accordance with MFC 4490.2. It evaluates the valve's operational performance under backflow conditions and the tendency of the disc to deform due to differential pressure upon closure. The test also confirms that the valve disc remains in a fully open position during normal operation. The test valve was installed in reverse between a water storage tank and a quick-opening valve. After ensuring that the valve disc was held open, the quick-opening valve at the end of the test loop was opened, creating an instantaneous backflow condition.

If the test was conducted at the highest required closing velocity, a single test was sufficient. Otherwise, three tests were required at different closing velocities.

8. Intermediate Inspection

Following the flow shutoff and operational capability verification, another intermediate inspection was performed, measuring the primary seat leakage in the same manner as the pre-test inspection. Any significant deviation from the initial leakage value would indicate potential integrity degradation during the backflow test.

9. Fully Open Valve Disc Flow Test

This test was conducted per MFC 4491.2 to determine the velocity and mass flow rate when the valve reaches a fully open and stable position. To protect the valve from turbulence, a straight pipe section of 10D was installed upstream. The flow rate was gradually increased, and once the valve disc reached its fully open position, velocity, density, and pressure were measured. This test was repeated three times to obtain stable data.

10. Post-test Inspection

Upon completion of all tests, a final seat leakage test was conducted, following the same procedure as the pre-test and intermediate inspections. The test valve assembly was then completely disassembled and thoroughly inspected for visible wear or damage, with all observations recorded.

11. Conclusion

Functional qualification tests were successfully conducted for the check valve to be installed in the primary cooling system of the KJRR. All tests met the requirements specified in the technical standards. The experience gained from these tests will serve as a valuable reference for the future functional qualification of other active valves.

ACKNOWLEDGEMENTS

This study was carried out with financial support from the Ministry of Science and ICT of Korea (2710007312).

REFERENCES

[1] KEPIC MFA-2005 Ed, Qualification of Mechanical Equipment - General Requirements
[2] KEPIC MFC-2005 Ed, Qualification of Active Valve Assemblies
[3] ASME QME-1, Section QV-2002, Qualification of Active Mechanical Equipment Used in Nuclear Power Plant
[4] Fillar's Catalog and Technical Report for Graphite Packing Material (REPORT NO. BC-01044)