A New Capsule Control System for Long-Term Irradiation Testing at HANARO

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1. Introduction

The High Flux Advanced Neutron Application Reactor (HANARO) has been operating as a platform for basic nuclear research in Korea, and the functions of its systems have been improved continuously since its first criticality in February 1995 [1]. Various neutron irradiation facilities such as rabbit irradiation facilities, loop facilities, and capsule irradiation facilities for irradiation tests of nuclear materials and fuels have been developed and actively utilized at HANARO [2-5]. Among the irradiation facilities, irradiation capsules have been most actively used for the irradiation of nuclear materials. Figure 1 shows a standard irradiation capsule and an installed capsule in the reactor core.

The temperature of the specimen in the capsule is controlled by a capsule control system consisting of a vacuum and heater control systems. Recently, as user needs for long-term irradiation testing are increasing, some malfunction of the capsule control system of the vacuum control occasionally occurred during irradiation testing. Therefore, a new capsule control system having two gas control lines instead of one gas line was designed and successfully applied at HANARO.

In this paper, the design and reactor performance of the new capsule control system that was introduced for long-term irradiation testing are described.

2. Irradiation Capsule Control System

A typical HANARO irradiation material capsule consists of three main parts that are connected to each other: a protection tube (5 m), a guide tube (9.5 m), and the capsule's main body, as shown in Fig. 1. The main body including the specimens and instruments is a cylindrical shaped tube of 60 mm in diameter and 1170 mm in length. The main body has five stages with independent microelectric heaters, thermocouples, and neutron fluence monitors to measure the temperature and neutron fluences of the specimens, respectively. Heaters and thermocouples are connected to a capsule temperature controlling system through a guide tube and a junction box system.

The remaining space between the parts in the closed capsule is filled with He gas. The temperature of the specimens during irradiation is initially increased by gamma heating, roughly adjusted to the optimum condition by a gas control system adjusting the internal He gas pressure, and then finally adjusted to the desired value by micro-electric heaters.

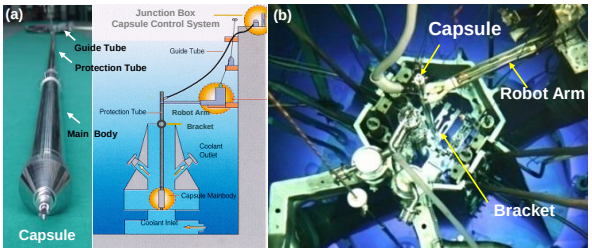

Fig. 1. HANARO irradiation capsule systems: (a) a standard irradiation capsule and (b) an irradiation capsule installed in the reactor core

Figure 2 shows a process diagram of the previous capsule gas control system. He gas input into the capsule and vacuuming are performed through one gas line connected to the top of the capsule main body. The temperature of the specimen located in the central part of the capsule can be controlled by adjusting the He gas pressure inside the capsule. Because heat generated by gamma heating of the capsule parts is conducted outside through gaps between the parts, the temperature of the specimen decreases as the He pressure of the gap increases. However, an abnormal temperature variation of the specimens was observed during long-term irradiation testing, as shown in Fig. 3. The temperature of the specimens sharply increased by increasing the internal He pressure of the capsule.

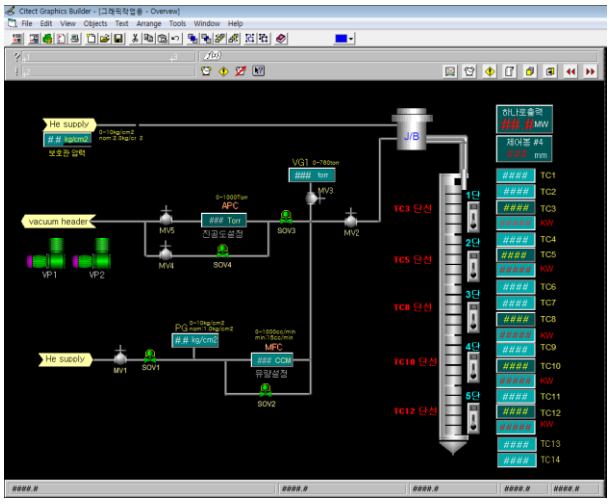

Fig. 2. Process diagram of previous HANARO capsule gas control system

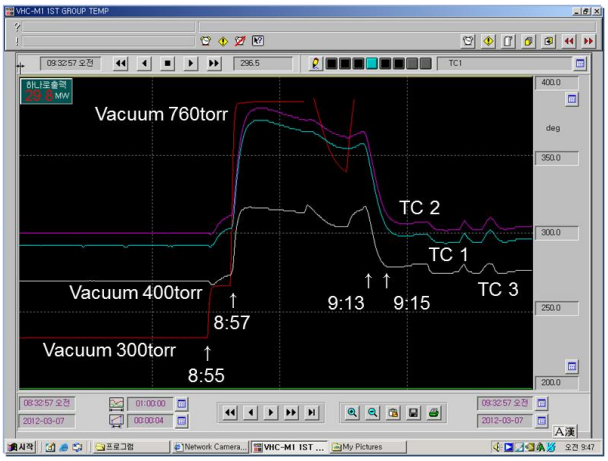

Fig. 3. Abnormal temperature variation of specimens by vacuum control during irradiation testing

The abnormal temperature behavior of the specimens occurred frequently during long-term irradiation testing and seems to be caused by the air inflow at the connection parts of the system [6]. During a process increasing the He gas pressure in the capsule to decrease the temperature of the specimens, accumulated air might be purged into the gaps, resulting in a sharp decrease in conductivity of the gaps and a sharp increase in the temperature of the specimens.

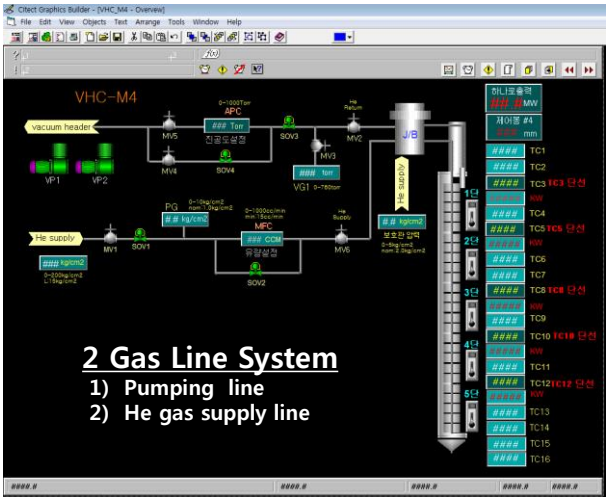

Fig. 4. Process diagram of a new HANARO capsule control system having two gas lines

3. Design and Evaluation of New Control System

To prevent a malfunction of the control system, a new gas control system having two gas lines was developed, as shown in Fig. 4. In this system, He gas flows through an inlet gas line to the bottom of the capsule main body, and flows out through another vacuuming gas line attached at the top of the main body of the capsule. The two gas line system has been used for fuel irradiation testing in other research reactors [7, 8].

The new control system was installed at HANARO, as shown in Fig. 5 and applied for irradiation testing of the 16M-02K material irradiation capsule. The new system has been successfully operated for the last three irradiation cycles (approximately 90 days). The verification test will be continued at up to eight irradiation cycles, and all of the old type of control systems will be replaced by the new control systems at HANARO.

Fig. 5. A new capsule control system (VHC-M4) installed at HANARO

5. Summary

A new capsule control system having two gas control lines instead of the previous single gas line was designed and installed at HANARO for a precise temperature control of the specimens during irradiation testing. The new capsule control system has been successfully applied for an irradiation testing of the 16M-02K capsule during the last three irradiation cycles (approximately 90 days). After verification testing of the new control system scheduled for eight irradiation cycles, all of the old type capsule control systems will be replaced by the new control systems at HANARO.

ACKNOWLEDGEMENTS

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REFERENCES

[1] K.N. Choo, M.S. Cho, B.G. Kim, Y.H. Kang, and Y.K. Kim, "Material Irradiation at HANARO, Korea," Research Reactor Application for Materials under High Neutron Fluence, IAEA-TECDOC-1659, 2011, IAEA.
[2] M.S. Cho, et al., "Material Irradiation by Capsules at HANARO," *Nucl. Technol.*, **193**, 330 (2016).
[3] K.N. Choo, B.G. Kim, M.S. Cho, Y.K. Kim, and J.J. Ha, "Development of a Low-Temperature Irradiation Capsule for Research Reactor Materials at HANARO," *Nucl. Technol.*, **195**, 213 (2016).
[4] K.N. Choo, M.S. Cho, S.Y. Yang, B.J. Jun, and M.S. Kim, "Design Optimization of HANARO Irradiation Capsule for Long-Term Irradiation Testing," *Science and Technology of Nuclear Installations*, **Volume 2018**, Article ID 3908610, (2018).

[5] K.N. Choo, M.S. Cho, S.W. Yang, and S.J. Park, "Contribution of HANARO Irradiation Technologies to National Nuclear R&D", *Nuclear Engineering and Technology*, **46**, 4, 501 (2014).
[6] K. N. Choo, "Evaluation of performance of vacuum control of a new capsule control system, HANARO internal report, HAN-IC-CR-18-001, 2018.7.
[7] W.W. Godsin, "Temperature Control of Fueled Irradiation Capsules by Variable Conductance", *Nuclear Science and Engineering*, **8**, 340 (1960).
[8] B.P. Collin, et als, "The AGR-3/4 fission product transport irradiation experiment", *Nuclear Engineering and Design*, **327,** 212 (2018).