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# Development of Density Measuring Equipment for Hot cell Testing

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## 1. Introduction

The construction project of the Kijang research reactor (KJRR), aiming at production of medical and industrial radioisotopes, is underway. Plate type U-Mo fuel will be loaded in the KJRR to achieve greater efficiency and higher performance. For comprehensive qualification of the U-Mo fuel, HANARO miniplate irradiation tests (HAMP-1,2,3) were planned and post-irradiation examination (PIE) have been performed. PIE of HAMP-1,2 [1,2] were completed and PIE of HAMP-3 is currently progress.

A density measurement for evaluating the swelling of fuels, one of the non-destructive tests, has been conducted, and for this purpose, a density measuring equipment for HAMP-3 has been developed. The equipment has been designed to be available for testing inside a hot cell, and it has been optimized considering the hot cell environment.

The equipment has been successfully validated through the commissioning tests conducted both inside and outside the hot cell before the density measurement of the irradiated fuel.

## 2. Methods

### *2.1. Density Measuring Equipment*

The density measuring equipment has been developed, as shown in Fig. 1. It mainly consisted of a balance, a water container, and a controller. The testing method based on Archimedes's principle, which is widely used in density measurement, was applied in this study. Considering the specimen size and handling within the hot cell, a weighing arrangement was implemented by attaching a hook below the balance pan.

The testing equipment installed in the hot cell must be operable using a manipulator and should be designed to account for potential failures caused by radiation damage from irradiated materials. Therefore, the testing specimen support of the density measuring equipment was designed with an open structure to allow handling by the manipulator, and the water container was designed to move up and down remotely using an air cylinder. The control components, such as the balance controller and temperature indicator, were separated by a connection line over 10 m long and installed in the operating are outside the hot cell. The balance was shielded with a 5 cm thick lead block to prevent malfunctions caused by radiation damage during testing.

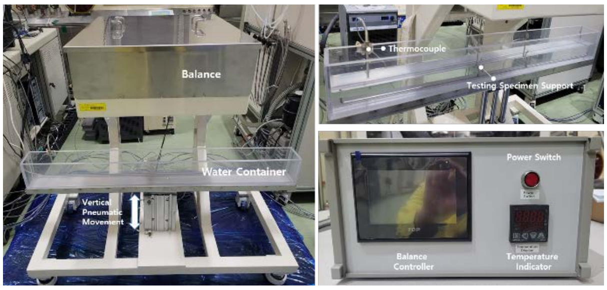


Fig. 1. Density measuring Equipment for plate type fuel

### *2.2. Optimization of the density measuring equipment*

Testing within the hot cell is influenced by various environmental factors. The environmental factors affecting the density measurement include vibrations and air drafts caused by the HVAC system. Specifically, vibrations were the main factor affecting the balance.

To mitigate the impact of vibrations, anti-vibration rubber pads were installed beneath the testing equipment, and the testing specimen support was redesigned. The testing specimen support was redesigned to hang freely from the balance beam hook and manufactured to be thin and lightweight, minimizing the effects of vibrations and air drafts. A vinyl cover was made to fully enclose the testing equipment, completely eliminating the effects of air drafts. Finally, by removing all environmental influences, the balance stabilized.

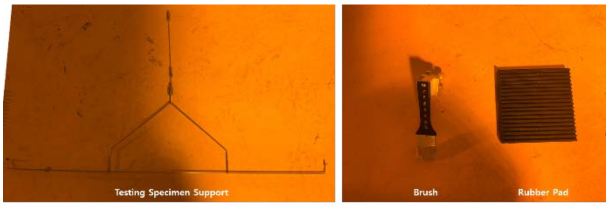


Fig. 2. Testing Specimen Support, Brush and Rubber Pad

Additionally, the reduction in the weight of the testing specimen support contributes to improving the precision of the test data by reducing the volume of the immersed support and decreasing the air bubbles formed on the support surface. As shown in Fig. 3, the decrease in support thickness significantly reduced the air bubbles on the surface. The weight measurement of the support after immersion showed that the weight of the air bubbles was 0.28–0.34 g for the thick support and 0.03–0.06 g for the thin support. The influence of the bubbles was reduced by approximately 1/5 to 1/10.


Fig. 3. Comparison of air bubble formation depending on the testing specimen support

### 3. Results

A commissioning test of the fabricated density measuring equipment was conducted before and after installation in the hot cell. The results were verified by comparing them with density measurement results obtained using reference density measuring equipment installed in another laboratory. In the commissioning test, distilled water was used, and an Al plate was used as the specimen. The weight of the specimen was measured in air and in water, excluding the weight of the testing specimen support. Additionally, the temperature was recorded using a thermocouple to accurately calculate the density of the distilled water. Air bubbles formed on the surface of the support and specimen were removed using a brush as shown in Fig.2. The measured data were substituted into Equation (1) to calculate the density of the specimen, and the results are presented in Table 1.

$$\rho = \frac{A}{A-B}(\rho_\omega - \rho_a) + \rho_a \quad (1)$$

Where $\rho_\omega$ is the density of water (g/cm$^3$), $\rho_a$ is the density of air (g/cm$^3$), A is the weight of the specimen in air (g), B is the weight of the specimen in water (g).

Table 1. Density measurement results from the commissioning test

| | | Weight in air (g) | Weight in water (g) | Temp. (℃) | Density (g/cm$^3$) |
|---|---|---|---|---|---|
| Reference Equip. | | 156.21 | 98.69 | 21 | 2.708 |
| Equip. for Hot Cell | Operating area | 156.20 | 98.75 | 25.7 | 2.708 |
| | Hot cell | 156.20 | 98.77 | 25.4 | 2.709 |

### 3. Conclusion

The density measuring equipment for plate-type irradiated fuel was developed and optimized for the hot cell environment. Before conducting tests on irradiated fuel, the density measuring equipment was verified through the commissioning test using Al plate. Even during the density measurement of irradiated fuel conducted after the commissioning test, the measurement was successfully carried out without any malfunctions caused by radiation. A comparison of the fuel density before and after irradiation showed an approximately 4% decrease in density. The results obtained using this developed equipment will serve as fundamental data for evaluating the performance of plate type U-Mo fuels in the future.

### REFERENCES

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