Transaction of the Korean Nuclear Society Spring Meeting, Jeju, Korea, May 17-19, 2023

한국원자력학회
Korean Nuclear Society

Korea Atomic Energy Research Institute

dongguk UNIVERSITY

Korea-UK round robin test to establish international standards for ETG

Gujin Kang[ab], Jongbum Kim[a], Kwangjae Son[a], Sangwok Kim[b], Jintae Hong[a]*

[a] Radioisotope Research Division, Korea Atomic Energy Research Institute, Yuseong-gu, Daejeon, Republic of Korea
[b] Department of Advanced Materials Chemistry, Dongguk University, Gyeongju, Republic of Korea
* jthong@kaeri.re.kr

Introduction

Radioisotope thermoelectric generators (RTGs) are devices that convert thermal energy into electrical energy by converting the radiation energy emitted by radioactive isotopes and shielding it from radiation. RTGs are highly useful for planetary exploration missions with high temperature differences and exploration missions where solar panels cannot be used [1-2]. Currently, the countries that produce RTGs worldwide are the United States and Russia, and the countries currently developing them are Korea and the United Kingdom. In 2019, the Korea Atomic Energy Research Institute (KAERI) and the United Kingdom signed an MOU on international standardization for nuclear battery technology cooperation and safety verification. Accordingly, after conducting domestic tests in 2022[3] for calibration and cross-testing of the testing evaluation facility, cross-testing was conducted in the United Kingdom.

Methods and Results

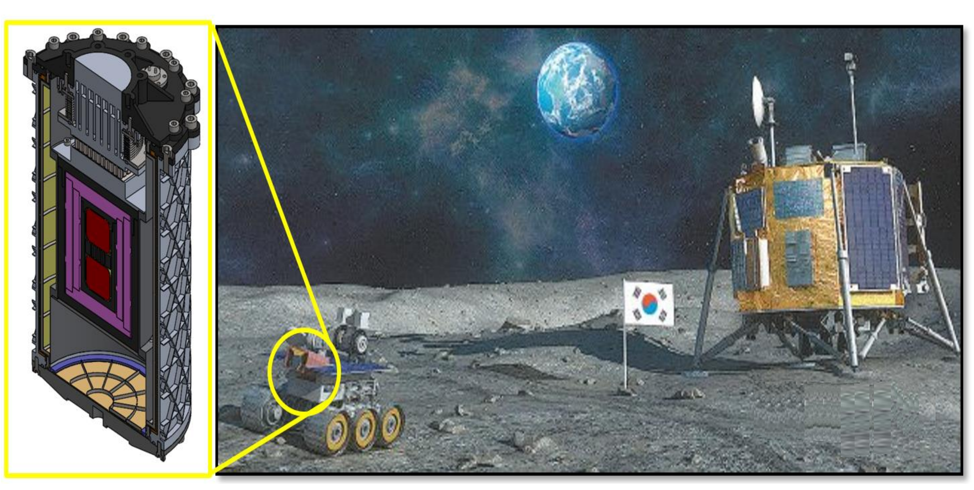

Fig. 1 Schematic of the RTG that will be installed on the lunar rover

RTG

RTG is a device that utilizes the Seebeck effect, which uses radioisotopes as a heat source to generate electricity due to the difference in internal heat and external temperature, It was first developed in the United States in 1954, and was first installed and mission on a satellite in 1961. In 2012 and 2020, it was also installed on a Mars rover. The KAERI is currently developing 120 mW for satellites, 5 W for lunar exploration and 20 W for Arctic applications.

Methods

In Korea, the prototype was placed in a specially manufactured vacuum chamber, and a total of 90 cycles were performed at about 10^{-3} Torr of vacuum state for 8 hours. To provide a temperature gradient, the chiller was set to a value of -10 °C. On the other hand, at the University of Leicester, the inside of the ETG was evacuated through a vacuum line and the operation was carried out twice for 8 hours and 30 hours.

(a) (b)

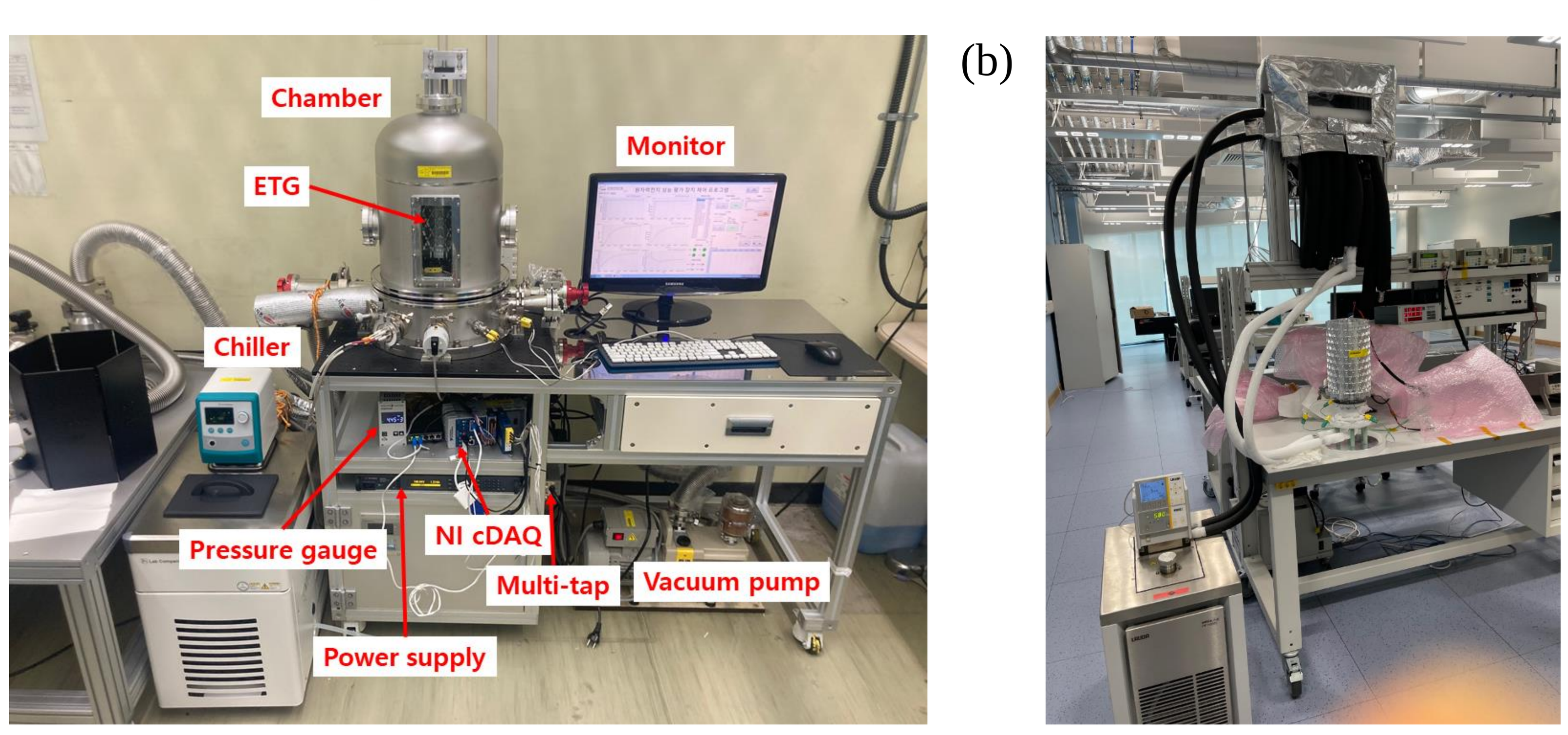

Fig. 2 Structure of nuclear battery performance evaluation device in (a) KOREA and (b) UK

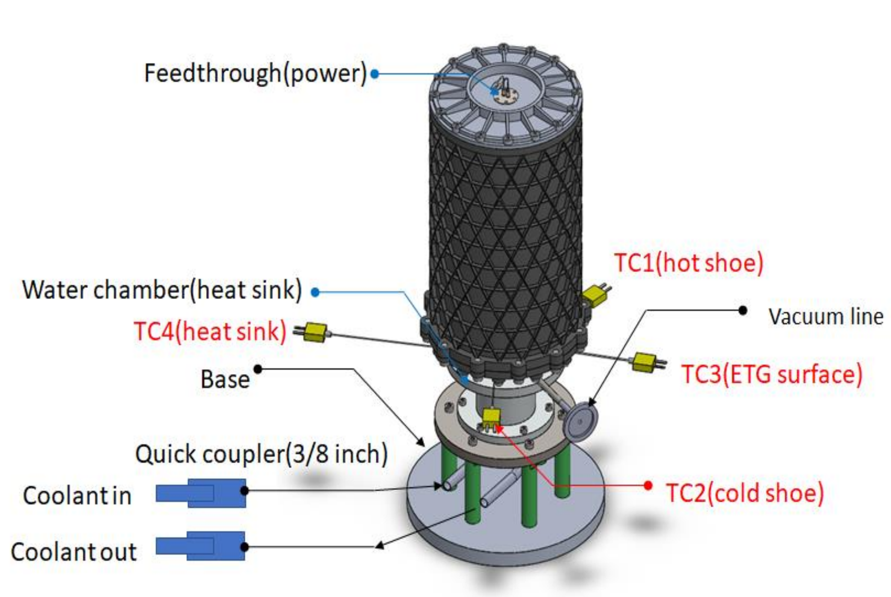

Fig. 3 Schematic of the prototype ETG.

There are a total of 4 sections for measuring the changing temperature during the experiment. The hot shoe(TC1) is located on the thermoelectric element, the water chamber(TC2), the ETG surface(TC3) and the heat sink(TC4) that dissipates heat and generates electricity. The data for each cycle is the average of the 100 seconds of data before the end.

Results

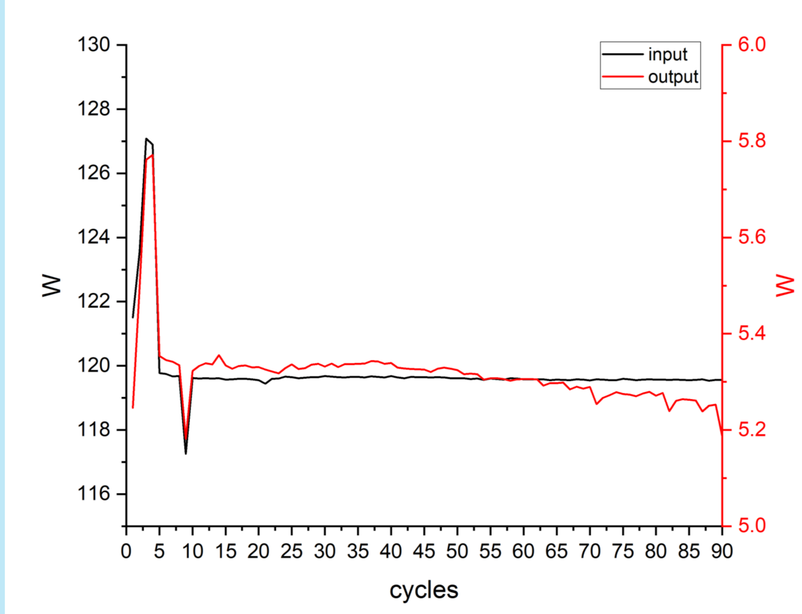

Fig. 4 Input power and output power during the 90 days cycle

- After conducting 90 cycles, the average temperature of the hot shoe was 209 °C and that of the cold shoe was 28 °C, with an average current of 1.18 A.
- In figures 4, The output power went down from 5.32 W to 5.2 W
- It was confirmed that when ETG uses a pressure of 10^{-3} torr and a temperature difference of about 181 °C, an efficiency of about 4.45% is obtained.
- In the UK test, conducted for 8 hours, the temperature of the hot shoe was 193 °C, that of the cold shoe was 27 °C, and the output power was 5.59 W.
- In the test conducted for 30 hours, the temperature of the hot shoe was 195 °C, that of the cold shoe was 27 °C, and the output power was 5.16 W.

(a) (b)

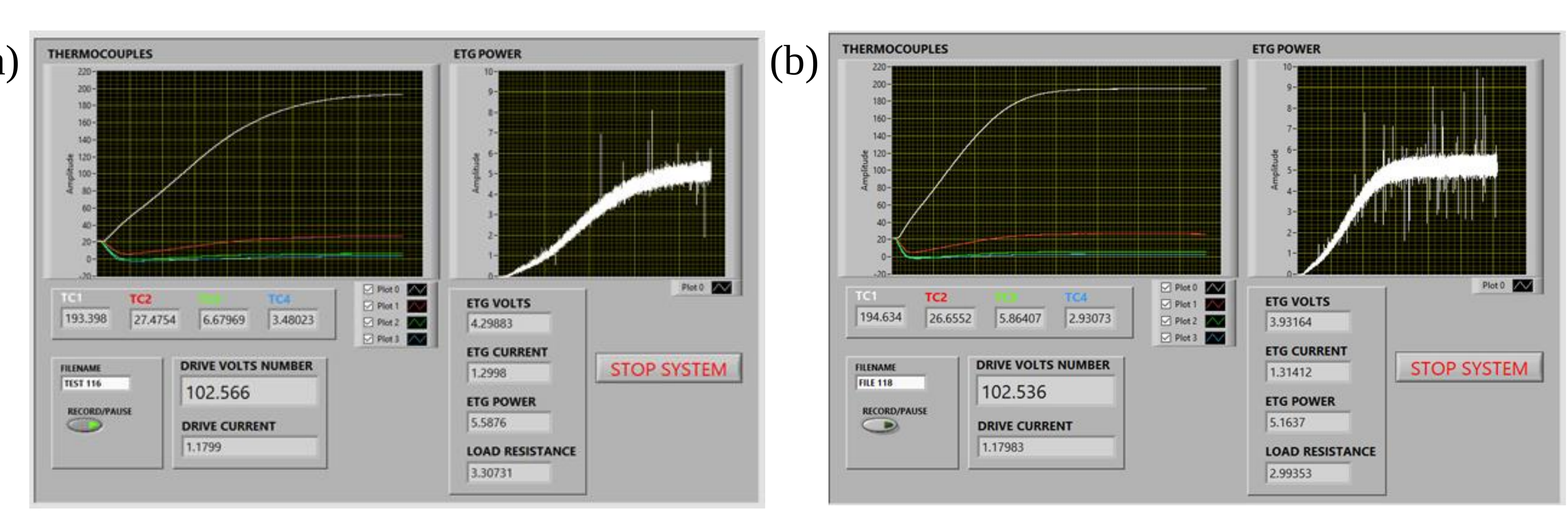

Fig. 4 Results of the ETG test conducted in the UK (a) 8 hours, (b) 30 hours.

- The reason for the difference in temperature of the hot shoe between the two countries' tests is due to the difference in the method of vacuuming the inside the ETG.
- The British approach is to maintain low temperatures through convective heat loss as a vacuum is created directly inside the ETG.
- Since the thermoelectric component generates electricity based on the temperature difference of the component, the experiment in the UK, where the temperature difference was smaller, resulted in a decrease in output of about 0.1 W compared to the experiment conducted in Korea, with an output of 5.2 W.

Table. 1 A comparison table of test results conducted in Korea and the UK.

	voltage	current	power	efficiency
KOREA	3.96 ~ 4.02 V	1.32 ~ 1.34 A	5.2 ~ 5.32 W	4.45%
UK	3.93 ~ 4.30 V	1.30 ~ 1.31 A	5.2 W	4.29%

Conclusion

As a result of the MOU signed to establish international standards for nuclear batteries, experiments on nuclear batteries were conducted not only in Korea but also in the UK, and round robin test was completed. Although there were differences in equipment and environmental conditions between the two countries, the ETG developed by the KAERI showed an output of 5.2 W with a 2% error in the UK. Based on this, we will continue to exchange and verify various nuclear batteries and establish international standards.

ACKNOWLEDGMENTS

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No.2021M2D1A1039965).

[1] John R. Howell, M. Pinar Menguc, Robert Siegel, Thermal Radiation Heat Transfer. 5th, GRC press, 2010
[2] D. M. Rowe, Applications of Nuclear-Powered Thermoelectric Generators in Space, Applied Energy, Vol.40, P. 241-271, 1991
[3] G. J. Kang, J. B. Kim, J. T. Hong, C. D. de Souza, J. J. Kim, K. J. Son, S. W. Kim, Evaluation power generation efficiency of space ETG for in vacuum, Transactions of Korean Nuclear Society, Autumn meeting, 2022