New air-based refrigeration system developed to replace harmful refrigerants

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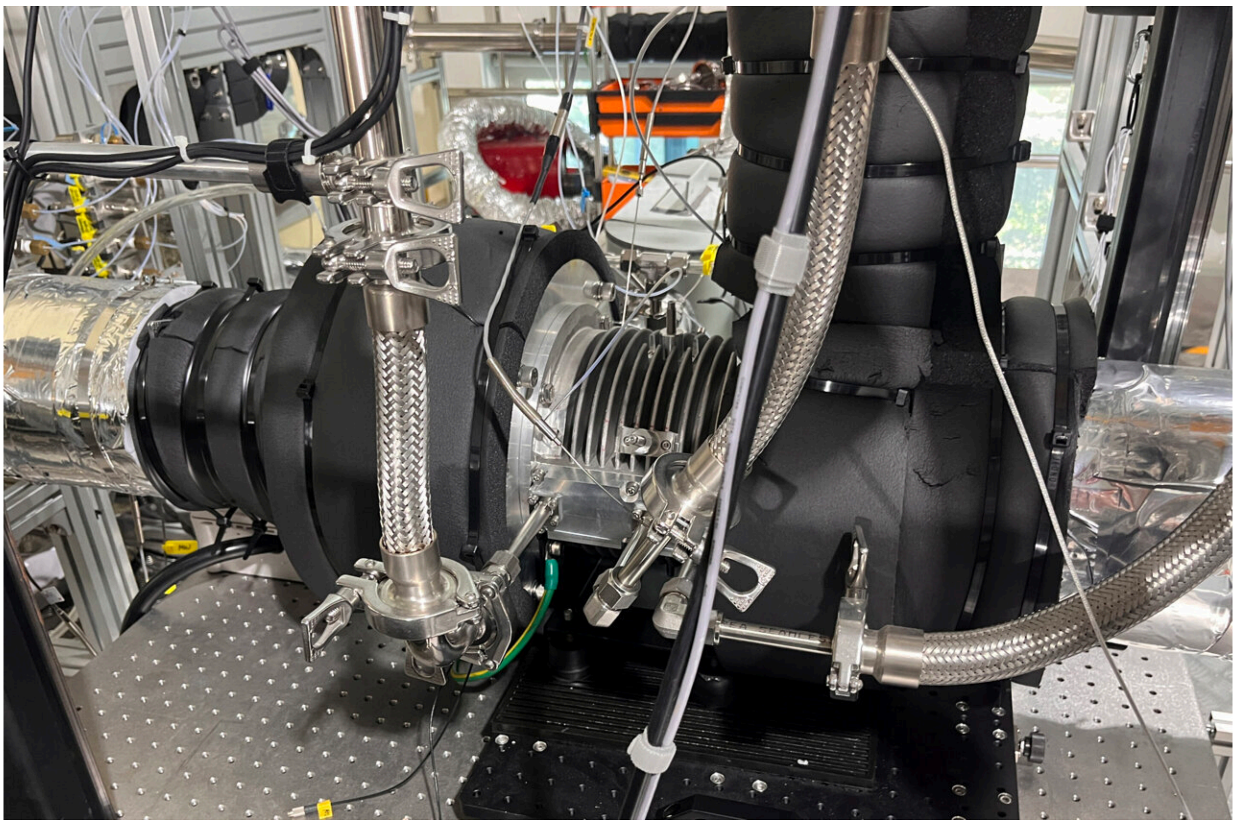

The ultra-high-speed compander develped by the research team. Credit: Korea Institute Of Energy Research

The Korea Institute of Energy Research (KIER) has developed, for the first time in the country, a refrigeration technology that uses air as a refrigerant instead of Freon gas, hydrofluorocarbons (HFCs), and other refrigerants that cause global warming.

The European Union's revised regulation on fluorinated greenhouse gases (F-gases) took effect in March this year. Starting in 2025, the sales of the products containing F-gases will be gradually phased out. Additionally, regulations on processes using F-gases are expected to be strengthened. Since F-gases are used in key Korean export products such as air conditioners, automobiles, and semiconductor processes, there is a urgent need to develop alternative technologies.

The research team successfully developed an integrated ultra-high-speed compander used in air refrigeration and, for the first time in Korea, created an air cooling system. By using this system, it is possible to achieve a temperature environment of -60 degrees Celsius using air as a refrigerant.

Traditional refrigeration and cooling systems have primarily used the vapor compression cycle. In this method, cooling is achieved as the liquid refrigerant evaporates and absorbs heat. Due to its simple structure and design, it is widely used across various fields. However, a key drawback is its dependence on fluorinated greenhouse gases as coolants, leading to the impact of global warming.

In response, the research team focused on implementing a cooling system based on the reverse-Brayton cycle, which uses air as the refrigerant. Unlike the traditional method that involves evaporating a liquid, this system compresses a gas and then goes through heat exchange and expansion to produce a low-temperature gas, enabling cooling without the need for liquid refrigerants.

The performance and data of the air-based cooling system are currently being validated and tested. Credit: Korea Institute Of Energy Research

However, the complexity of designing and building such a system has been a significant challenge, preventing its application in refrigeration systems until now. The compander must be designed with extreme precision due to the ultra-high-speed rotation during the cooling process. For instance, the gaps between components and shaft displacement require a tolerance within 0.1 millimeters.

To implement the reverse-Brayton cycle system, the research team devised a compander system that connects the compressor, expander, and motor on a single shaft. Although the compressor and expander are connected to a single shaft, each device must operate at its own maximum efficiency. Additionally, the shaft system design ensures stable operation even at ultra-high rotational speeds, further enhancing the reliability and performance of the system.

The cooling system utilizing the developed compander successfully cooled air to below -60 degrees Celsius within just one hour. Notably, when generating cold temperatures below -50 degrees Celsius, the system demonstrated higher refrigeration efficiency compared to traditional vapor compression systems. Theoretically, it is capable of cooling down to -100 degrees Celsius, and at that temperature, the refrigeration efficiency is expected to improve by more than 50% compared to vapor compression systems.

Dr. Beom Joon Lee, the lead researcher, stated, "Due to environmental regulations, refrigeration systems that primarily use refrigerants with a high global warming potential are rapidly transitioning to the use of eco-friendly refrigerants."

He added, "We are currently working on improving the system's performance to enable the production of cold temperatures below -100 degrees Celsius. We anticipate that this technology will be applied in fields that require ultra-low temperatures, such as semiconductor processes, pharmaceuticals, and biotechnology."

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