Cryogenic Helium Process Systems

The Facility for Rare Isotope Beams (FRIB) built and runs its own cryogenic plant, or cryoplant, that operates at 4 kelvin (K), or 4 degrees above absolute zero.

Helium is the only fluid refrigerant capable of reaching the extremely low temperatures required to cool the superconducting devices used to accelerate, steer, and focus a beam of high atomic weight charge particles, known as heavy-ions. Since the temperature required for these devices is a few degrees above absolute zero, every other fluid would freeze solid. The helium starts the process cycle as an ambient temperature gas, and is then liquefied to a few degrees above absolute zero.

The process cycle is a closed loop, such that the liquid evaporated by the load from these devices eventually returns as ambient temperature gas to preserve the helium.

State-of-the-Art Cryogenic Plant

The FRIB cryoplant supplies helium at 4 K—which can be further cooled to 2 K—to superconducting resonators made of niobium and 4.5 K helium to superconducting magnets. In their supercondcuting state, these devices have virtually no electrical resistance, allowing them to accelerate, steer, and focus the beam of heavy-ions. The cryoplant operates 24 hours per day, 365 days per year to cool these devices, which are used in FRIB's heavy-ion linear accelerator and experiental system.

The cryoplant is comprised of many sub-systems, and is a large but compact facility. It is similar to an air-separation or liquefied-natural-gas processing plant.

The cryogenic distribution system is 2,000 feet long. It extends to the linear accelerator (linac) that is 30 feet underground and two football fields in length. It also extends to the 14 superconducting magnets in the experimental systems area that follow the accelerator. It is a multi-process-line thermally-shielded distribution line. In the linac, the cryogenic helium is supplied to 46 cryomodules, which are vacuum-insulated vessels housing niobium cavities and superconducting magnets. The cavities accelerate the heavy-ion beam, and the magnets focus and steer the beam.

Learn more at frib.msu.edu

Michigan State University operates the Facility for Rare Isotope Beams as a user facility for the U.S. Department of Energy Office of Science (DOE-SC), supporting the mission of the DOE-SC Office of Nuclear Physics.

Cost-Effective and Energy-Efficient Solution

FRIB's integrated design of the cryogenic refrigeration, distribution, and cryomodule systems is key to energy-efficient and reliable operations. The cryoplant uses a unique process, the patented Floating Pressure—Ganni Cycle process, which automatically optimizes the operation of the cryogenic system. It provides the highest efficiency and reliability for a wide range of capacities and operating modes. At maximum capacity, supporting a 2 K in the linac, the cryoplant can provide an equivalent 4.5 K refrigeration cooling capacity of about 18.5 kilowatts at a 30-percent overall exergetic efficiency (i.e., or about 240 watts of input power for every one watt of cooling provided at 4.5 K).

Cryogenic Education and Research

Cryogenic engineers are responsible for the design of these low-temperature refrigeration systems. The demand for cryogenic engineers has increased in the last decade. Having FRIB at MSU offers a unique opportunity to attract and train the next generation of cryogenic system innovators to prepare them for opportunities in cryogenic engineering and related fields. A collaboration between FRIB and MSU's College of Engineering, the MSU Cryogenic Initiative combines classroom education with training on the nation's largest helium liquefaction plant at FRIB. It is the focal point for the investigation of efficient cryogenic process designs and the research and development (R&D) of equipment for these processes. FRIB staff teach two undergraduate and one graduate cryogenic engineering courses offered through MSU's Mechanical Engineering Department. These courses teach both the therma-process and mechanical design aspects involved in cryogenic engineering.

In addition to student research on the FRIB cryoplant, the Cryogenic Assembly Building at FRIB is planned for cryogenic system R&D activities. Such activities include helium-compressor efficiency investigations, the development and investigation of freeze-out purification for the conservation of helium, and the development of small 2 K process and refrigeration system.The cryoplant operates on a unique process to optimize operation and design of helium systems.

The Floating Pressure—Ganni Cycle process was invented by Professor Rao Ganni, who helped design and build FRIB's cryoplant. The Ganni Cycle reduces energy consumption while increasing the reliability, flexibility, and stability over a wide operating range and different operating modes. FRIB's cryoplant is comprised of many sub-systems, each designed to capitalize on the Ganni Cycle.

For more information

Visit frib.msu.edu/cryoinitiative.

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