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C1Or2C-04: Conceptual Design and Initial Operation of a Single-Shot Dilution Refrigerator with a Small Helium-3 Inventory

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A single-shot dilution refrigerator (SDR) features a compact and lightweight design without the need for heat exchangers, allowing it to achieve approximately 0.1 K with a small amount of Helium-3. This study conducts a conceptual design of the key components of the SDR, including mixing chamber, still, and thermal shield, to achieve the target temperature. To utilize the auxiliary cooling from an ADR capable of providing 1 J of cooling at 0.8 K, a unidirectional heat transfer structure is applied to the mixing chamber and still. To reduce the weight and minimize the heat capacity, the shield is constructed with thin sheets of copper, while 1 mm thick copper plates are added only to the thermal transfer pathways to account for initial cooling of the mixing chamber by the ADR. To overcome Kapitza resistance at cryogenic temperatures, the mixing chamber is sintered with silver powder to increase the effective collision surface area. Additionally, to minimize the cooling loss from the mixing chamber to the still, the stainless-steel capillary tube having diameter of 0.7 mm is coiled to extend its length to 50 cm, ensuring that the cooling loss remains below 1% under the steady-state conditions at 0.1 K. During the initial operation test, it is verified whether each component operates properly according to the intended physical design. This paper validates the conceptual design of the SDR's key components and provides foundational data for equipment development and future SDR experiments.

Author: AN, Byeungcheol (Korea Advanced Institute of Science and Technolog)

Co-authors: KWON, Dohoon; Ms KU, Minseung (Korea Advanced Institute of Science and Technology); JEONG, Sangkwon (Korean Advanced Institute of Science and Technology)

Presenter: AN, Byeungcheol (Korea Advanced Institute of Science and Technolog)

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