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C3Po1A-04: Fabrication of the HFVMTF Double-Bath Cryostat

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The High Field Vertical Magnet Test Facility (HFVMTF) is an advanced experimental platform currently under construction at Fermi National Accelerator Laboratory (FNAL). Designed to test large superconducting magnets weighing up to 20 tons and measuring up to 1.3 meters in diameter, the facility features a double-bath superfluid helium cryostat capable of reaching temperatures as low as 1.8 K at a pressure of 1.2 bar. A key component of HFVMTF's capabilities is its integration with a superconducting dipole magnet developed by Lawrence Berkeley National Laboratory (LBNL), enabling the testing of high-temperature superconductor (HTS) cables for future fusion magnets under a background magnetic field of 15 T. This state-of-the-art facility aims to advance research and development in superconducting magnet technology, with a particular focus on fusion energy applications.

The double-bath cryostat was fabricated by Ability Engineering Technology Inc., and this paper highlights its innovative design and the challenges encountered during the fabrication of its two most complex components: the lambda plate and the 2 K heat exchanger. The 2 K heat exchanger, comprising multiple copper tubes that thermally link the saturated superfluid bath to the pressurized superfluid bath, was specifically designed to comply with the ASME Boiler and Pressure Vessel Code. It is engineered to withstand a maximum pressure of 6.9 bars while minimizing thermal resistance between the sub-atmospheric and pressurized helium baths.

The lambda ring, a critical sealing surface that thermally insulates the superfluid helium at 1.8 K from the liquid helium at 4 K, has an inner diameter of 1.4 meters. This component must support the combined weight of the magnet and top plate—exceeding 20 tons—while withstanding a pressure differential of 1.3 bar between the two sides of the lambda plate. Fabricated with an overall flatness tolerance of ±0.05 mm, the lambda ring ensures effective sealing between the 4 K and 1.8 K baths. A Finite Element Analysis (FEA) of the entire helium vessel was conducted to validate the unique design of these components and to verify the mechanical stress limits of the vessel walls under maximum pressure conditions.

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