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C2Po1F-02: Modeling and Dynamic Simulation for the Cold Box of 6kW Helium Refrigerator

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The CRAFT 6kW helium refrigerator is used for magnet performance testing and magnet performance research, and the project is designed to build a cryogenic control system adapted to the future direction of fusion reactor development. However, a detailed and accurate modeling and simulation of a specific 6 kW helium refrigerator cold box, especially considering its unique structural characteristics and operating conditions, is the focus of the research on how to model and simulate a helium refrigerator cold box using EcosimPro. The objective of this work is to model and simulate a 6 kW helium refrigerator cold box to understand its thermodynamic performance, flow characteristics and heat transfer process under different operating conditions, aiming to be a reference for optimizing the design and operation of the cold box as well as the design of the automatic control strategy. The main object studied is the 6 kW helium refrigerator cold box, which consists of various components such as Including 80K liquid nitrogen pre-cooling stage, 7-stage heat exchanger, 80K adsorber, turbine expander, throttle circuit, cryogenic valves and pipings.The helium gas enters the cold box and is first compressed by the compressor to raise the temperature and pressure, then cooled down by the heat exchanger, and finally cooled by adiabatic expansion in the turbine expander. The modeling approach is based on thermodynamic and fluid dynamic principles. The key variables considered include the inlet and outlet temperatures and pressures of helium at different points within the cold box, the mass flow rate, and the heat transfer coefficient. The helium refrigerator cold box was modeled and simulated using the specialized simulation software EcosimPro. At present, a model of the helium refrigerator cold box has been completed, and its structural rationality and logical rigor have been ensured through theoretical verification, laying a foundation for subsequent data input and simulation analysis. The dynamic simulation of the cool-down process from 300K to 4.5K will be presented in this paper, and the main control loops will be simulated and analyzed in the end.

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