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C2Po1F-03: RAMI analysis of 6kW helium refrigerator system

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Helium refrigeration systems, as a critical low-temperature technology, are widely used in high-energy physics experiments, nuclear fusion devices, and cryogenic engineering. These systems serve as essential infrastructure to ensure the normal operation of superconducting magnets, cryogenic equipment, and other related systems. This study focuses on the periodic operation characteristics of a 6 kW helium refrigeration system, employing RAMI (Reliability, Availability, Maintainability, and Inspectability) analysis to investigate the functional decomposition and fault analysis of its critical subsystems. The study covers the functional identification of major subsystems (such as compressors, oil removal systems, and refrigerators), the synergistic interactions between subsystems, and a comprehensive analysis of potential fault modes. By establishing a functional fault mode list, the basic functions, common fault modes, main fault causes, and their impacts on overall system performance are systematically summarized.Building on this foundation, the study conducts a detailed evaluation of the fault modes and impacts of key components (such as turbo-expanders, heat exchangers, and compressors), offering optimization measures from the perspectives of equipment design, operating conditions, and maintenance strategies. By integrating operational data and typical fault cases, the research further evaluates and enhances existing maintenance models, proposing feasible solutions to improve system reliability and operational efficiency.The findings of this study are not only significant for enhancing the safety, reliability, and efficiency of 6 kW helium refrigeration systems but also provide theoretical support and technical references for the design optimization, operation, and performance improvement of similar refrigeration systems

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