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C3Po1A-04: Reliability analysis of a 2500W@4.5K/500W@2K helium cryogenic refrigeration system

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In this paper, reliability analysis of a large-scale helium cryogenic refrigeration system with cooling capacity of 2500W@4.5K/500W@2K is studied. Reliability model and failure rate of the refrigeration system based on fault tree is developed. It consists of liquid helium and superfluid helium subsystems. The key components include two helium screw compressors, six gas bearing expansion turbines, eight cryogenic heat exchangers, three cold compressors, six room temperature dry vacuum pumps, three subcooling helium heat exchangers and cryogenic adjusting valves, etc. Combine with the failure rate of similar equipment in our laboratory, and the public database, fault tree of insufficient cooling capacity as top event of liquid helium and superfluid helium subsystems is analyzed in details. By improving the reliability of helium screw compressors and expansion turbines, Mean Time to Failure (MTTF) is optimized to 9360 h, larger than our design target 8000h. In our experiments, it operates more than 2000 hours and hundreds of start-stop sequences, which verifies our theoretical failure data of such key components. Through this work, the failure rate database of this large-scale helium cryogenic refrigeration system is established, which will support the design and development of similar machines in the near future.

Author: Ms PAN, Wei (Technical Institute of Physics and Chemistry, Chinese Academy of Sciences)

Co-authors: Mr YANG, Shaoqi (Technical Institute of Physics and Chemistry, Chinese Academy of Sciences); Prof. XIE, Xiujuan (Technical Institute of Physics and Chemistry, Chinese Academy of Sciences); Mr WANG, Yunlong (Technical Institute of Physics and Chemistry, Chinese Academy of Sciences); Prof. XU, Xiangdong (Technical Institute of Physics and Chemistry, Chinese Academy of Sciences); Prof. GONG, Linghui (Technical Institute of Physics and Chemistry, Chinese Academy of Sciences)

Presenter: Ms PAN, Wei (Technical Institute of Physics and Chemistry, Chinese Academy of Sciences)

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