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Thermal characterization of a three-fluid cryogenic heat exchanger

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Magnetic refrigeration, a well-established technique employed to attain temperatures below the Kelvin scale, is currently gaining prominence for its application at temperatures corresponding to liquid helium and liquid hydrogen. This surge in interest is attributable to the elevated Carnot efficiency associated with magnetic refrigeration in such temperature ranges. A test stand has been developed for evaluating heat transfer coefficients of magnetocaloric materials using the single-blow transient test technique. The system involves a hermetic helium gas circuit cooled to cryogenic temperatures, flowing through a packed bed of magnetocaloric material. A three-fluid heat exchanger is used to cool down the helium gas flowing through the magnetocaloric packed bed. This paper presents the test setup, experimental performance results and the analysis of the three-fluid heat exchanger in the 4.2 K–290 K temperature range. The recorded measurements are juxtaposed against numerical predictions across various mass flow rates and fluid stream pressures. Under nominal operational conditions with helium gas, a maximum average effectiveness of 99.9% is attained, accompanied by a combined pressure drop of merely 15 mbar. The study also entails the evaluation of static losses and a comprehensive examination of the numerical model in alignment with experimental observations. Furthermore, recommendations for enhancing the design are proposed based on the findings.

Submitters Country

Spain

Authors: HERNANDO, Carlos (CYCLOMED TECHNOLOGIES); Mr CASTRO, Ivan (CYCLOMED TECHNOLOGIES); MUNILLA, Javier (CIEMAT); Dr GARCIA-TABARES RODRIGUEZ, Luis

Presenter: HERNANDO, Carlos (CYCLOMED TECHNOLOGIES)

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