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C3Or4B-05: Discussions of real gas effects on the regenerative refrigerators

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Practical regenerative refrigerators are capable of working down to 4 K and largely fulfill the refrigeration requirement of modern technologies in many fields, especially for space applications. However, the enthalpy flow associated with the pressure dependence, abbreviated as pressure-induced enthalpy flow, brought about by real gas effects degrades the theoretical COP of the refrigerator to below about 30% of the Carnot efficiency at the temperatures of below the critical point. This paper summarizes important explorations of uncovering the loss mechanism and reducing such losses in the regenerator. It is emphasized in this paper that the main factor leading to the real gas losses in the regenerator is the heat-associated enthalpy flow, which is used to balance the variation of the pressure-induced enthalpy flow, resulting in an entropy generation. The physical mechanism of reducing real gas losses, including the heat input or removal method and the DC flow method will be discussed. We further carry out analyses on the expansion component of the pulse tube. The real gas effects on the pulse tube is mainly the enlargement of the heat-associated enthalpy flow in the case when the pressure-induced enthalpy flow is negative, thus the heat transfer between the gas and the wall gets enhanced. Several inferences are made in order to explore the long-lasting puzzles about real gas effects, including the synthetic effect of the DC flow through the whole refrigerator. It is emphasized that the underlying cause of the loss in the regenerator is an indirect effect of the real gas properties. Further study about carrying out a direct verification of the theory is proposed.

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