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Review

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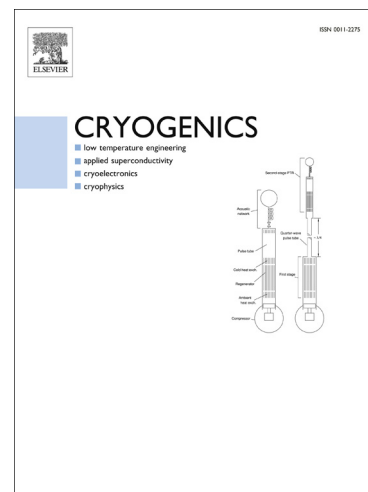
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A thermodynamic review of cryogenic refrigeration cycles for liquefaction of natural gas

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Abstract

A thermodynamic review is presented on cryogenic refrigeration cycles for the liquefaction process of natural gas. The main purpose of this review is to examine the thermodynamic structure of various cycles and provide a theoretical basis for selecting a cycle in accordance with different needs and design criteria. Based on existing or proposed liquefaction processes, sixteen ideal cycles are selected and the optimal conditions to achieve their best thermodynamic performance are investigated. The selected cycles include standard and modified versions of Joule-Thomson (JT) cycle, Brayton cycle, and their combined cycle with pure refrigerants (PR) or mixed refrigerants (MR). Full details of the cycles are presented and discussed in terms of *FOM* (figure of merit) and thermodynamic irreversibility. In addition, a new method of nomenclature is proposed to clearly identify the structure of cycles by abbreviation.

Keywords Thermodynamics, refrigeration cycle, LNG, natural gas, liquefaction

Nomenclature

| | |
|-----------------|-----------------------------------|
| <i>FOM</i> | figure of merit |
| <i>h</i> | specific enthalpy |
| <i>m</i> | mass flow rate |
| \dot{Q} | heat transfer rate |
| <i>s</i> | specific entropy |
| \dot{S}_{gen} | entropy generation rate |
| <i>T</i> | temperature |
| <i>U</i> | overall heat transfer coefficient |
| \dot{W} | power or work rate |

Greek letters

| | |
|---------------|------------------------------|
| ε | heat exchanger effectiveness |
|---------------|------------------------------|

Subscripts

| | |
|--------------------|---------------------------------|
| <i>0</i> | ambient |
| <i>1, 2, 3, ..</i> | location in refrigeration cycle |
| <i>AC</i> | after-cooler |
| <i>C</i> | compressor |
| <i>E</i> | expander |
| <i>F</i> | natural gas feed |
| <i>HX</i> | heat exchanger |
| <i>JT</i> | JT valve |
| <i>L</i> | LNG or liquefied natural gas |

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