WHEC 2012
19th WORLD HYDROGEN ENERGY CONFERENCE 2012
Toronto, Canada | June 3rd–7th

Design Principles for High-Efficiency Hydrogen Liquefaction Processes

Kawasaki
PLANET GbR
WEKA
NORTH ENERGY
TECHNISCHE UNIVERSITÄT DRESDEN
Loughborough University
Linde
New Energy World JU
fuel cells & hydrogen for sustainability
idealhy
Integrated Design for Efficient Advanced Liquefaction of Hydrogen
SINTEF

The research leading to these results has received funding from the European Union's Seventh Framework Program (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n° [278177]

Authors:
David Berstad, Harald T. Walnum, Michael Drescher, Jacob Stang and Petter Nekså
SINTEF Energy Research

Hans Quack and Christoph Haberstroh
Technical University of Dresden

Lutz Decker, Linde Kryotechnik AG

Michael Börsch and Fridolin Holdener
WEKA AG

Contact: David.Berstad@sintef.no

Abstract

The recently started IDEALHY project targets substantial reductions of power consumption for large-scale hydrogen liquefaction through conceptual process design and components development. Compared to current state-of-the-art mid-scale liquefiers with approximately 5 tons/day capacity, a goal of 45–48% reduction in specific liquefaction power is stated for a conceptual large-scale plant.

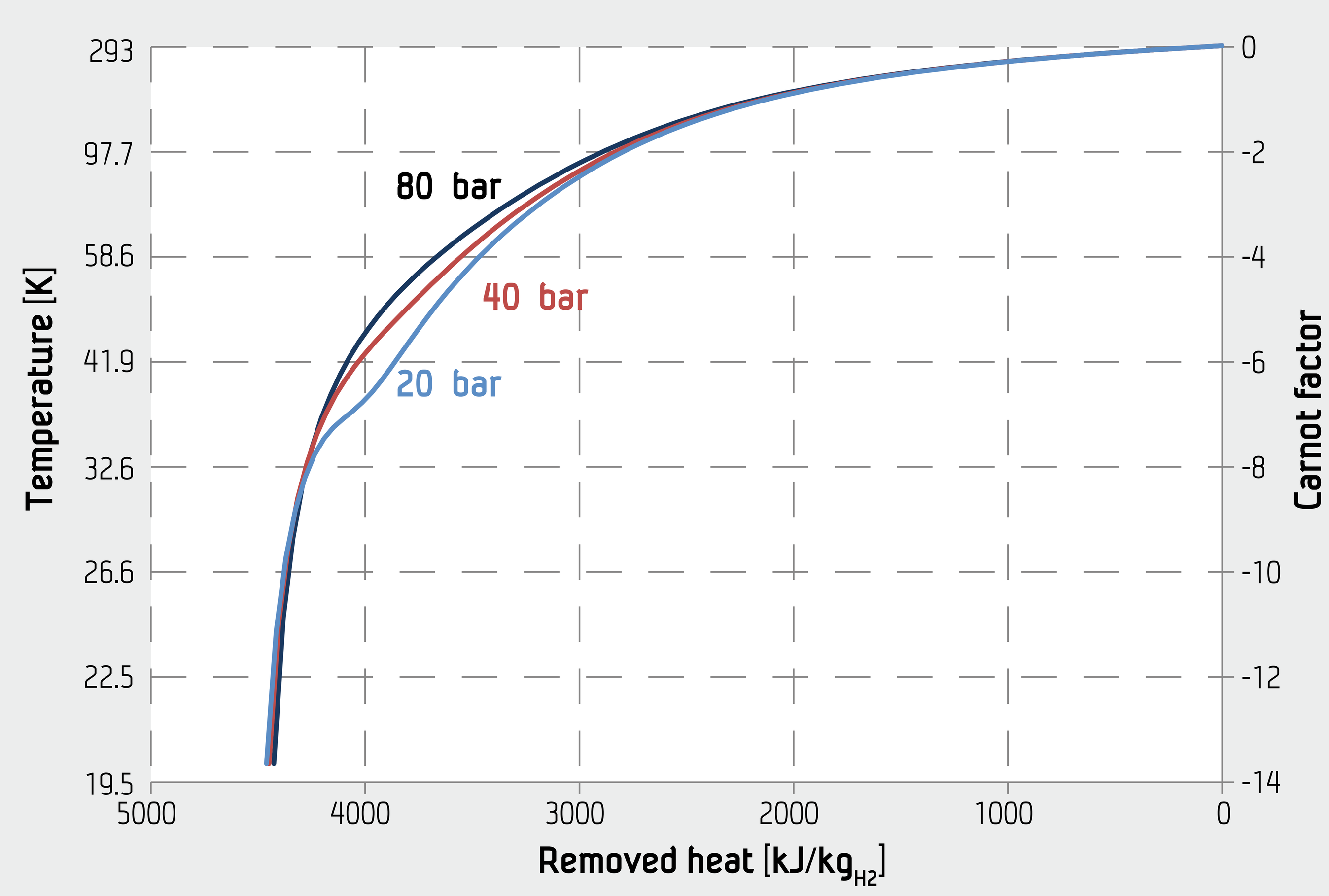
Achievement of such ambitious goals requires thorough and systematic screening and selection of process components and required sub-systems with high focus on energy efficiency in the process design and integration task.

Based on the selection of process principles, the number of options for process design will be narrowed down to a selection of promising candidates and ultimately one or two process candidates for detailed elaboration.

This presentation will give an overview of the current findings from the work on process development of the conceptual large-scale hydrogen liquefier. Findings will include process layout, configuration of refrigeration cycles for pre-cooling and cryogenic cooling of hydrogen, refrigerants selection, components and process integration issues. Moreover, the impact of feed and product specifications on process design will be discussed.

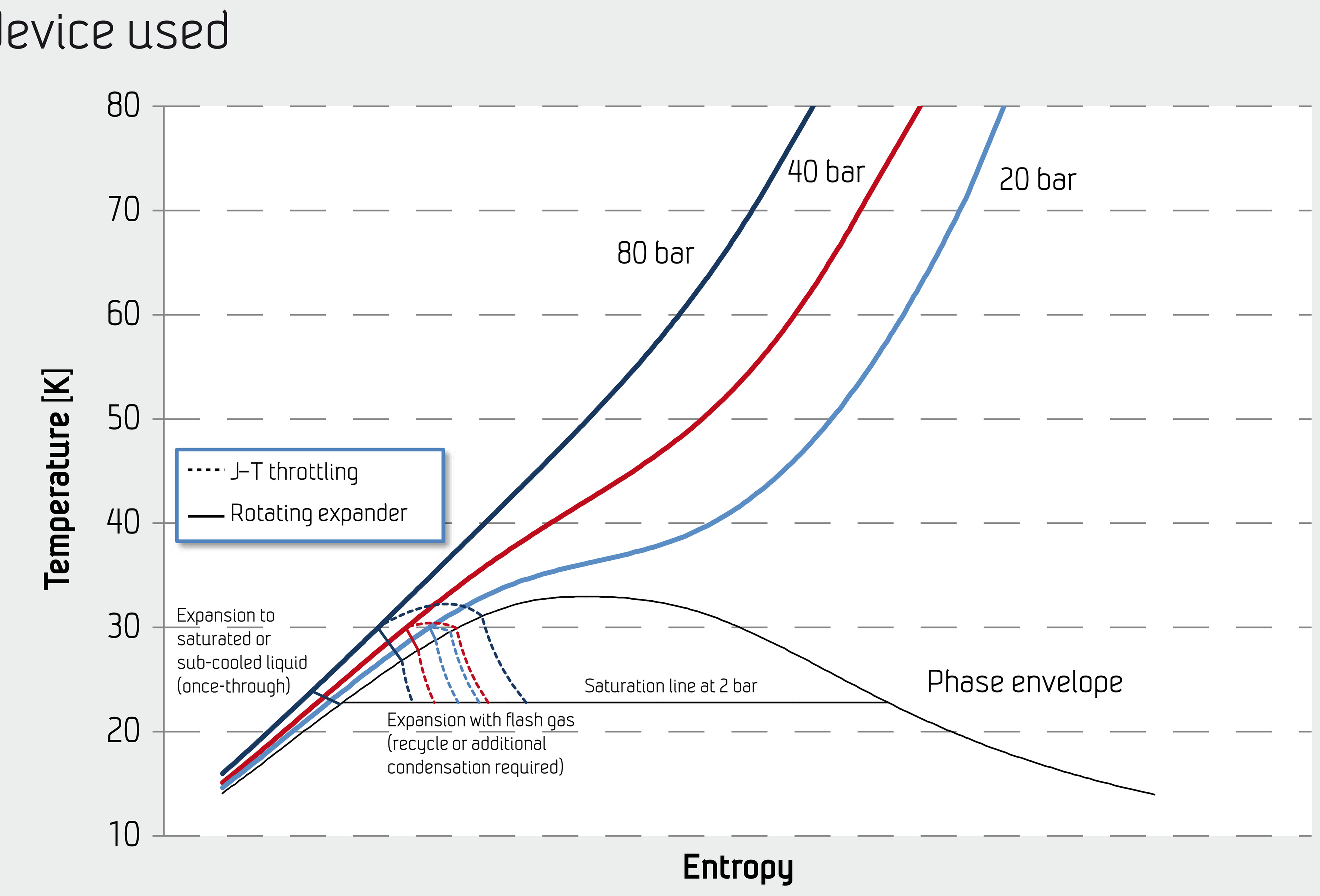
H_2 process pressure

- Hydrogen feed pressure: 20 bar (common process pressure for state-of-the-art liquefiers)
- Higher pressure may be beneficial for overall energy efficiency as more heat is rejected at higher temperature, requiring less exergy transfer in cooling process

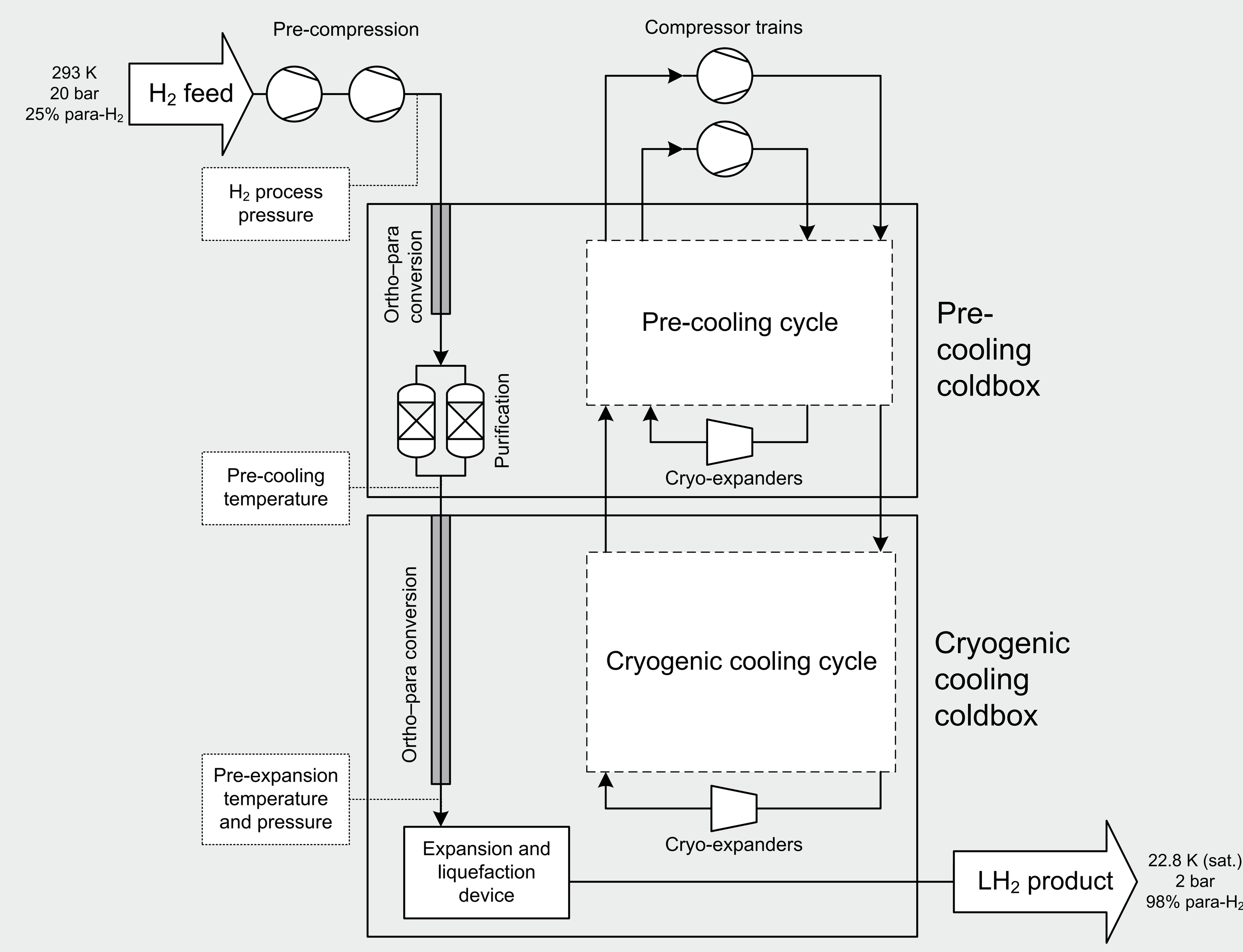


Expansion and liquefaction device

Optimal combination of hydrogen pressure and temperature before final expansion and liquefaction depends partly on the expansion device used



Generic process structure and sub-systems



Liquefaction plant size

"Medium" size – built in workshop

\+ State-of-the-art
\- Limited efficiency

Large size – site assembly

\+ Efficiency increasing with size
\- 'Poor' assembly conditions

Expanders

Energy recovery by compander

\+ State-of-the-art
\- Reciprocal interference of efficiencies
\- Sealing losses
\- Narrow operating field

Energy recovery by generator

\+ 'Freedom' of design
\+ Wide operating field
\- Hydrogen embrittlement
\- Sophisticated design

Refrigeration cycles

Pre-cooling cycle alternatives

- Nitrogen (external LN_2 feed or closed-loop cycle) ➔ 80 K
- Hydrocarbons or mixed refrigerants ➔ Temperature depending on components
- Light gas: H_2, He, Ne – integrated part of cryogenic cycle
- LNG re-gasification in the case of adjacent LNG terminal ➔110 K

Cryogenic cooling cycle alternatives

- Claude cycle (state-of-the-art)
- Reversed Brayton cycle (higher energy efficiency potential than Claude cycle due to use of rotating expanders with possible power recovery)
- H_2, He, Ne or combinations of these as refrigerant

Compressors

Turbo-compressors

\+ Highest efficiency
\+ Very high availability
\+ Largest suction volume available
\- Very low pressure ratio per stage for light gases
\- Hydrogen embrittlement

Reciprocating compressors

\+ High efficiency
\+ State-of-the-art for hydrogen
\- Limited suction volume per machine
\- High maintenance demand