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Mixed Refrigerants for High Efficiency Hydrogen Pre-cooling

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 5 tons/day capacity, a goal of 45–48% reduction in specific liquefaction power is stated for a conceptual large-scale plant.

The liquefaction of Hydrogen is often divided into 4 steps: compression at ambient temperature, pre-cooling to about 80 K, cooling from 80 to 30 K and the final liquefaction and vapour handling. State-of-the-art hydrogen liquefiers commonly rely upon LN2 vaporization for pre-cooling. Due to the large temperature differences at low temperatures this is a very inefficient process.

In the well developed LNG industry, mixed refrigerants (MR) are commonly used due to their ability to obtain tight temperature integration and thereby reduced exergy losses.

This poster summarizes some of the most relevant mixed refrigerant processes from the LNG technology and describes some possibilities for transferring the technology to hydrogen liquefaction plants. LNG plants operate down to 110 K and modifications such as adding stages and using refrigerants less vulnerable to freeze-out might be necessary to reach lower temperatures.

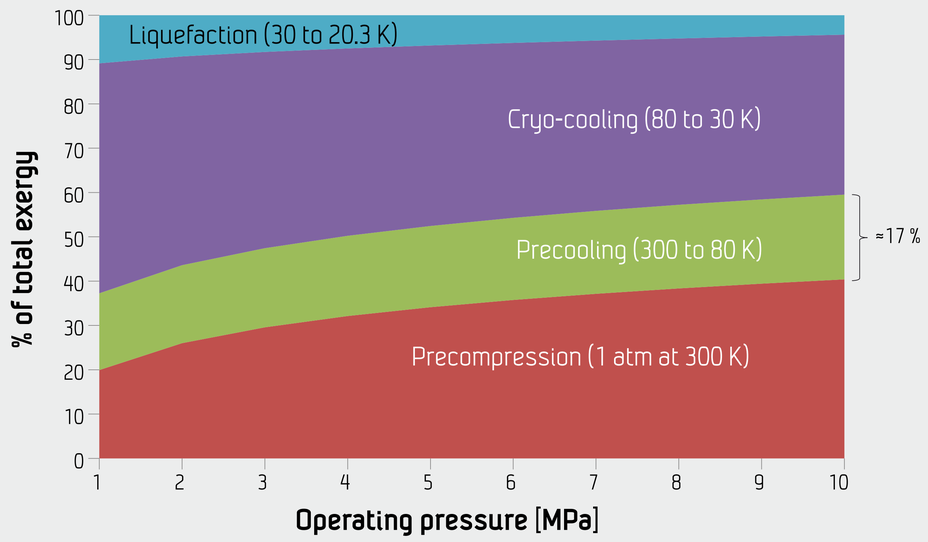
Hydrogen liquefaction

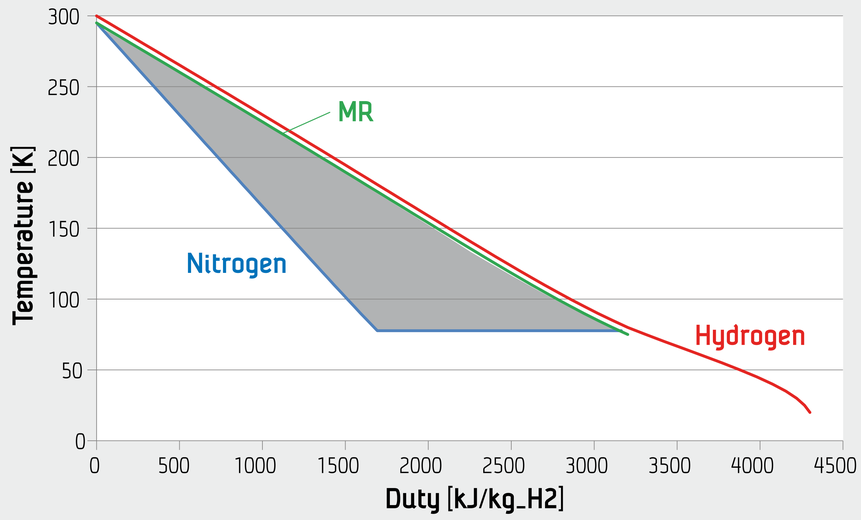
Liquid hydrogen can be an important part of a future hydrogen infrastructure.
The liquefaction process can be divided into 4 stages:

- Precompression
- Precooling
- Cryocooling
- Liquefaction

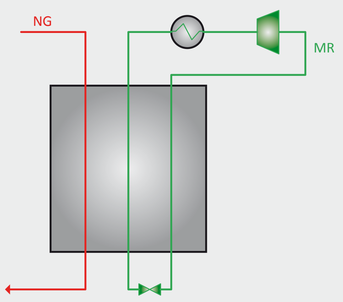
Precooling

- 17 % of the total exergy is needed for precooling, but it is the stage with most degrees of freedom in design
- State-of-the-art liquid hydrogen plants use liquid nitrogen
- This is by definition inefficient due to the large temperature differences that occur in the lower temperature range (80 K)
- It is also impractical for large scale liquefaction plants
- More efficient solutions would be:
  - Integration of nitrogen process
  - Mixed refrigerant
  - A combination of the above

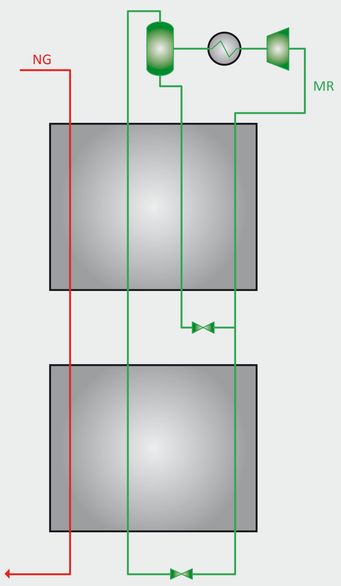




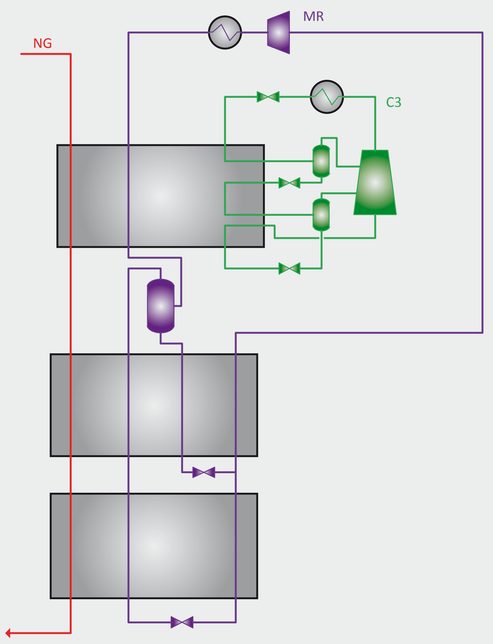
Mixed refrigerant processes adopted from LNG industry



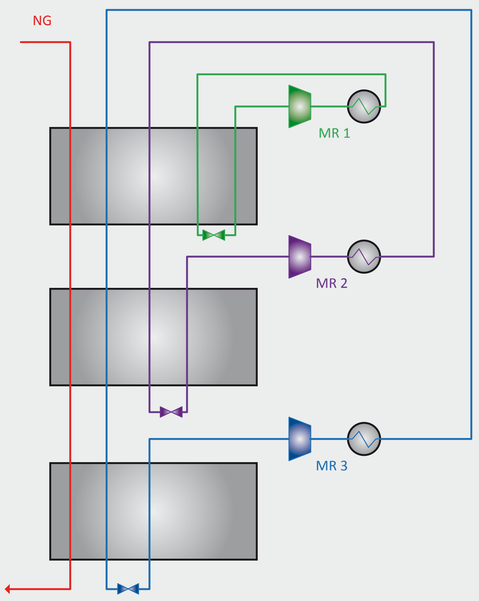
Adopted from U.S. Patent no. 3,914,949



Adopted from U.S. Patent no. 3,932,154



Adopted from U.S. Patent no. 3,763,658



Adopted from U.S. Patent no. 6,253,574

Adoption to LH_2 processes

Precooling of liquid hydrogen to about 80K

- Improves efficiency compared to liquid nitrogen process
- The refrigerant eases compression compared to hydrogen or helium reversed Brayton stages due to higher molecular weight
- Must take care of potential freeze-out of less volatile components.

Used in a precooled closed nitrogen precooling process

- Can keep the liquid nitrogen for temperature stabilization at 80 K
- Reducing the heat load on the nitrogen cycle reduces the necessary number of compressor and expansion stages

idealhy
Integrated Design for Efficient Advanced Liquefaction of Hydrogen

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