Wrocław University of Technology

Performance Analysis of Joule-Thomson Cooler Supplied with Gas Mixtures

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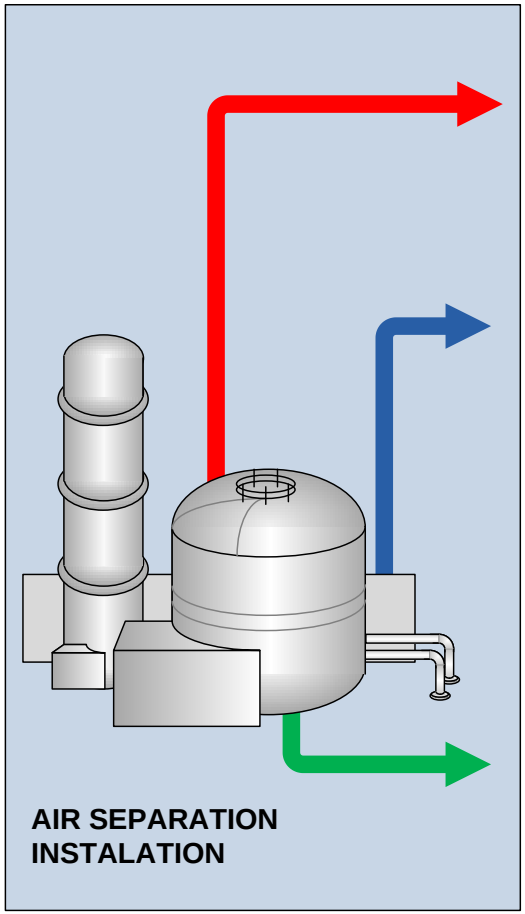
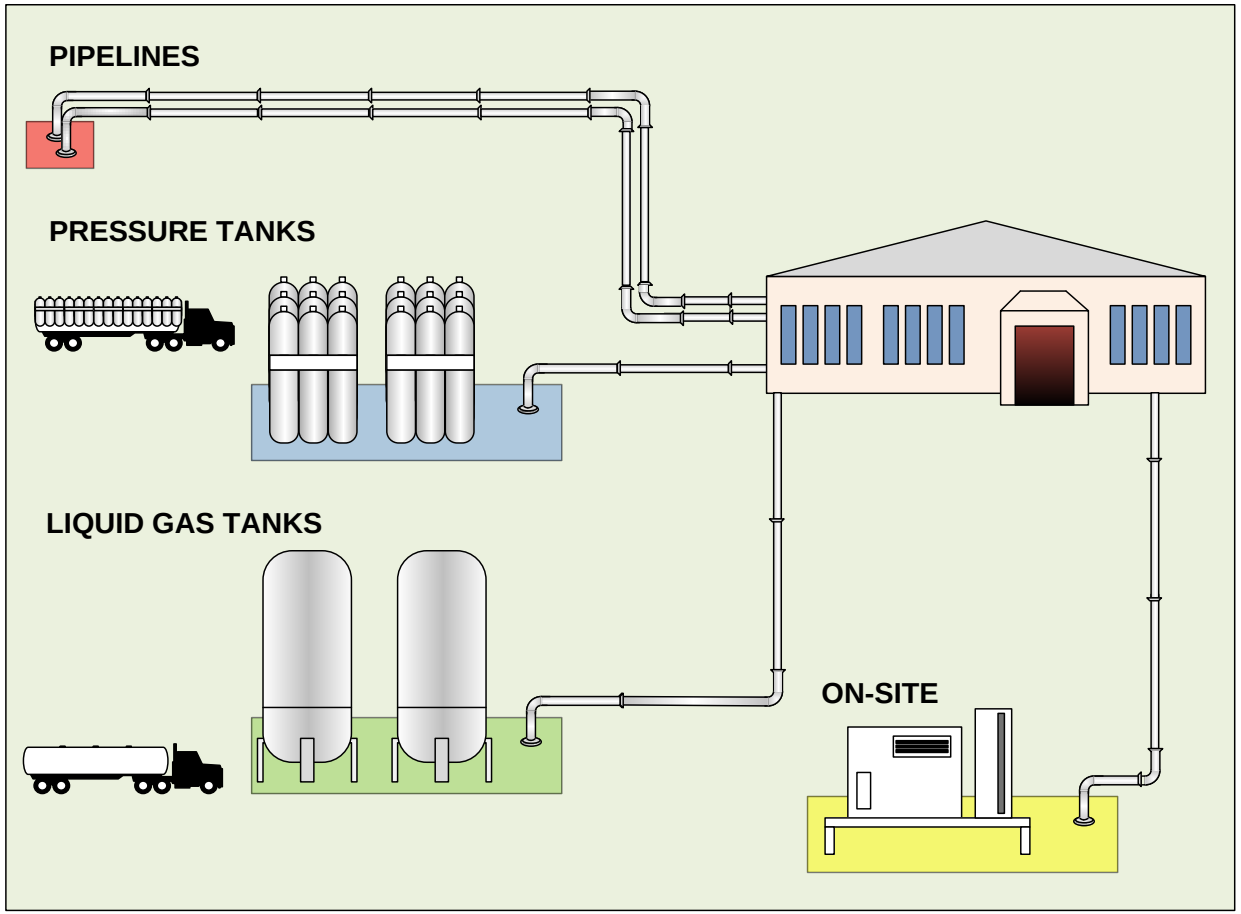
Outlines

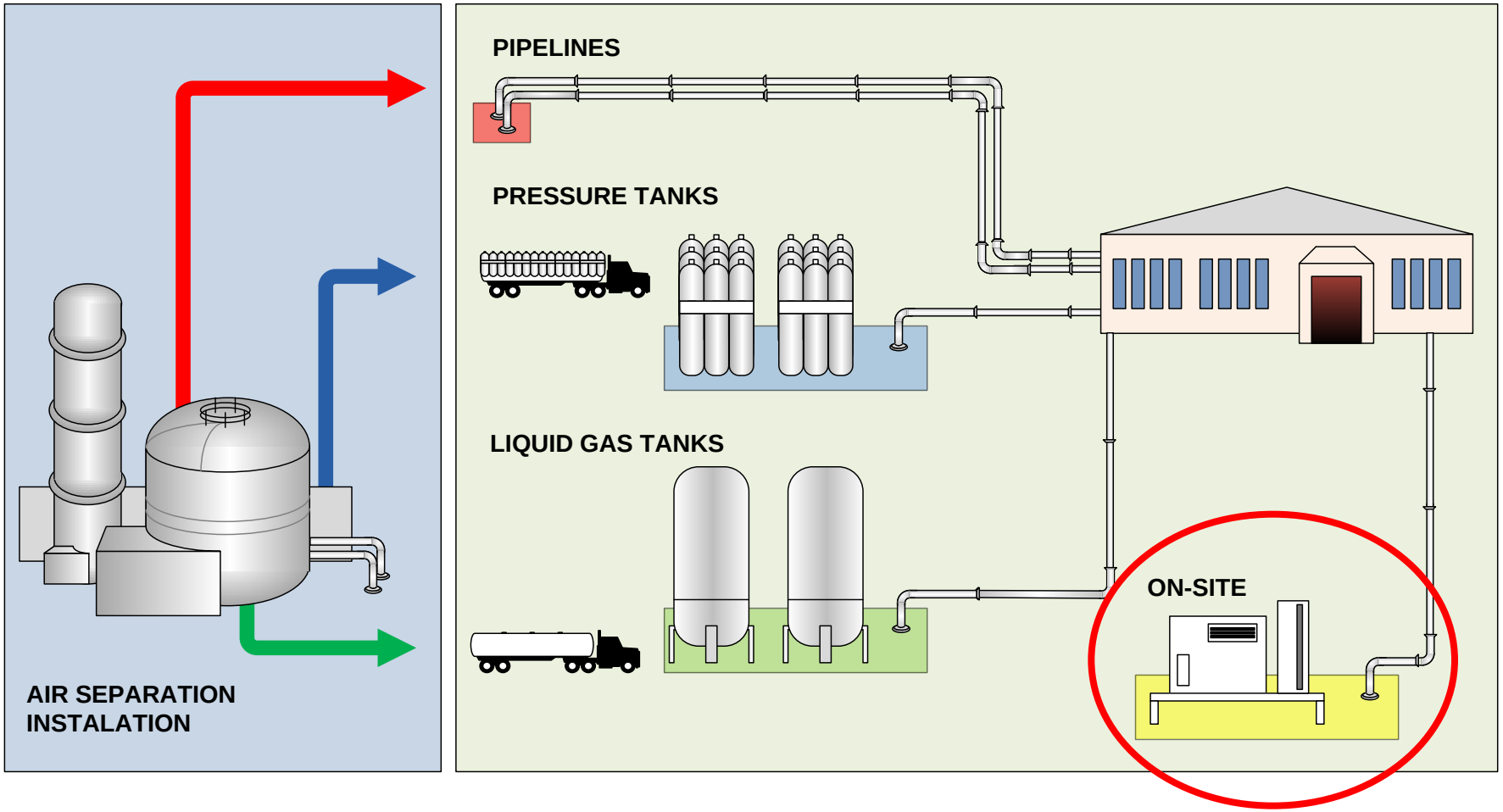
1. Introduction – motivation of J-T coolers development
2. Hybrid systems
3. J-T technology key points
4. J-T test stand and tests
5. Conclusions

Motivation of J-T cooler development

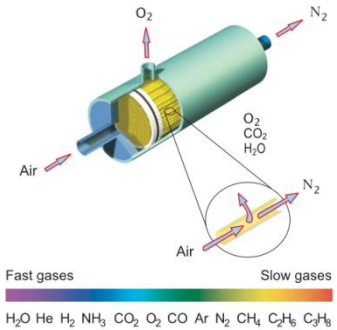




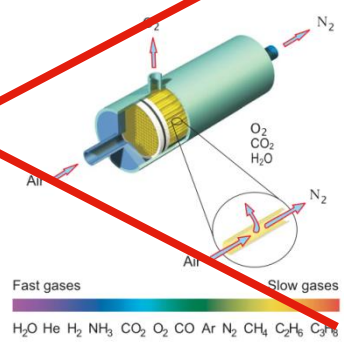
Motivation of J-T cooler development



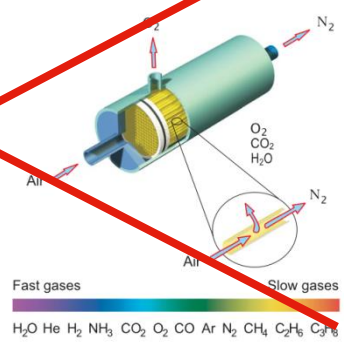
On-site system for liquid O_2 production

AIR SEPARATION SYSTEM	COOLER
PRESSURE SWING ADSORPTION up to 95% for single stage system up to 99.5% for multi-stage system product @ 6 bar <u>Commercially available</u> 	
POLYMER MEMBRANE up to 45% product at 1 bar <u>Commercially available</u>  Courtesy of GRASYS	

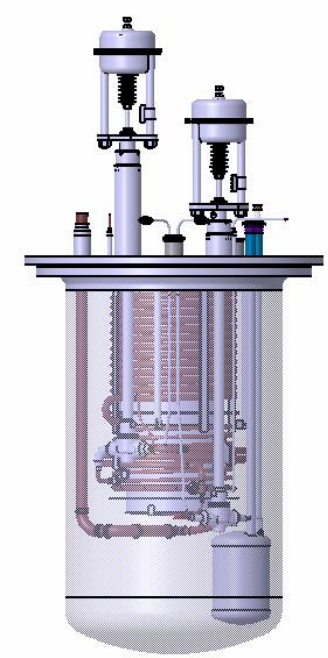
On-site system for liquid O_2 production

AIR SEPARATION SYSTEM	COOLER
PRESSURE SWING ADSORPTION up to 95% for single stage system up to 99.5% for multi-stage system product @ 6 bar <u>Commercially available</u> 	
POLYMER MEMBRANE up to **45%** product at 1 bar <u>Commercially available</u>  Courtesy of GRASYS	

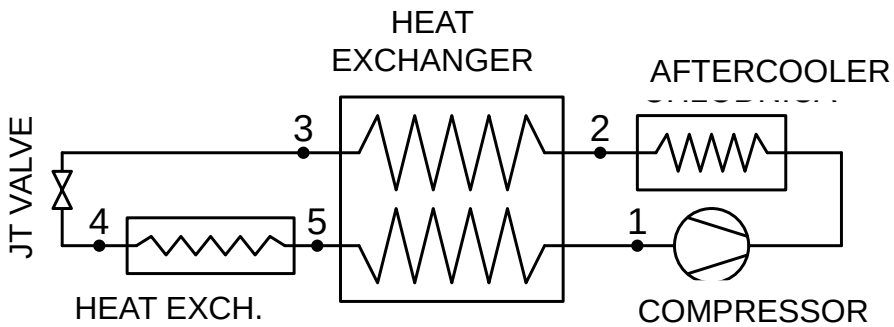
On-site system for liquid O_2 production

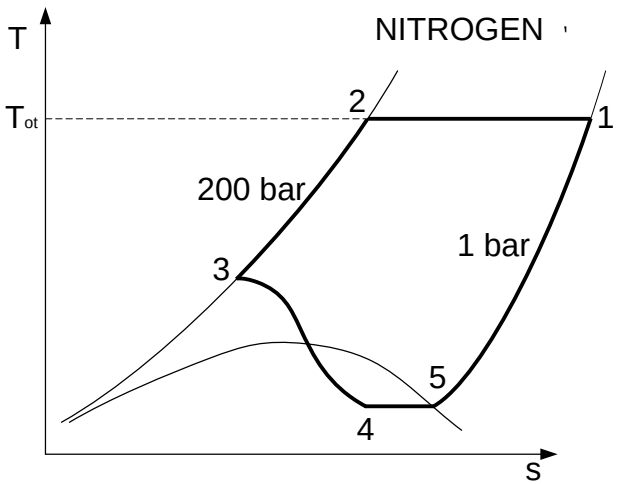
AIR SEPARATION SYSTEM	COOLER
PRESSURE SWING ADSORPTION up to 95% for single stage system up to 99.5% for multi-stage system product @ 6 bar Commercially available 	To produce 0.5 dm3/h of LO2 @ 1bar, 85W of cooling power produced at 90-105 K is required
~~**POLYMER MEMBRANE**~~ ~~up to **45%**~~ ~~product at 1 bar~~ ~~Commercially available~~  Courtesy of GRASYS	

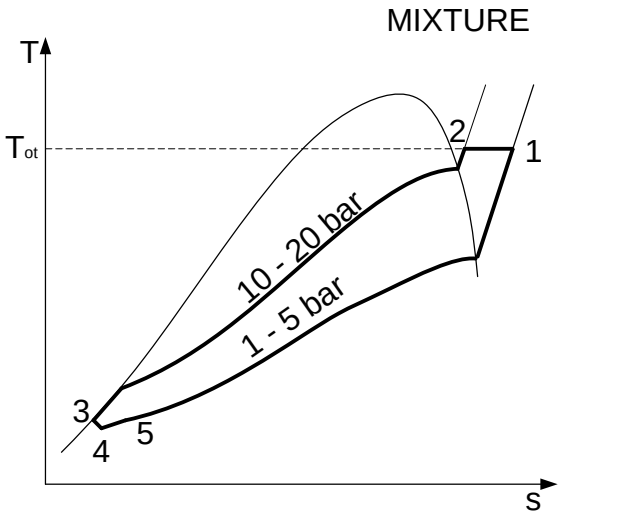
On-site system for liquid O_2 production

AIR SEPARATION SYSTEM	COOLER
PRESSURE SWING ADSORPTION	**JOULE-THOMSON**
up to 95% for single stage system up to 99.5% for multi-stage system product @ 6 bar <u>Commercially available</u> 	- simple construction - no moving parts working at low temperatures - high reliability - short start-up time  

Joule-Thomson cooler







Working fluid	Nitrogen	Gas mixture
Working pressure	100 – 200 bar	10 – 20 bar
Temperature at 1 bar	77.8 K	80 – 120 K
Phase change inside the heat exchanger	NO	YES
Temperature difference at the cold end of HE	70 – 90 K	5 – 15 K

Joule-Thomson cooler supplied with gas mixtures

Key points of the J-T cooler supplied with gas mixtures technology:

1. Investment costs - compressor
2. Working parameters - mixture composition
3. Commercialization of the system – repeatability of the working parameters

Compressors

COMPRESSORS OF J-T COOLERS

NITROGEN

- High pressure
- Oil free
- **Expensive**

GAS MIXTURE

- Low pressure
- Oil compressor
- Comercially available = low price

Compressors

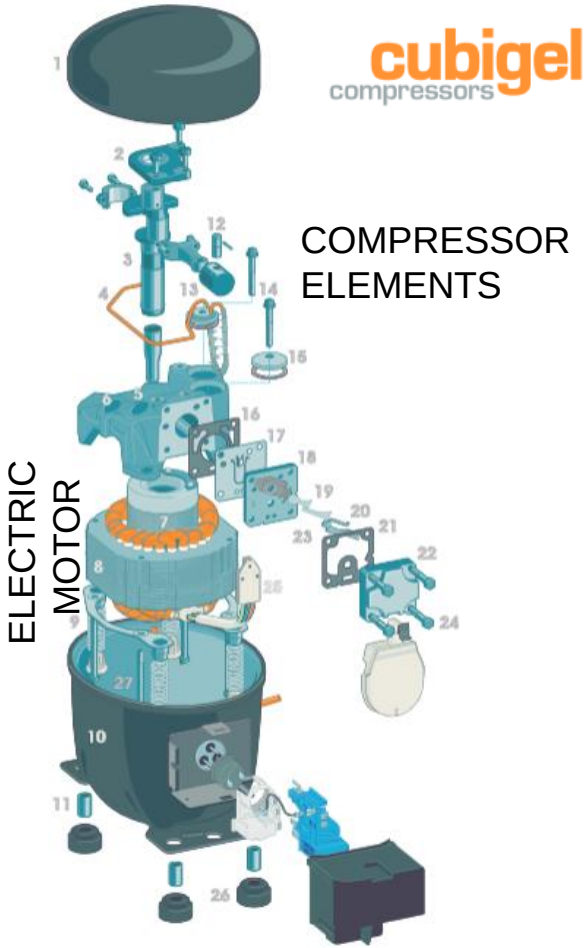
COMPRESSORS OF J-T COOLERS

NITROGEN

- High pressure
- Oil free
- **Expensive**

GAS MIXTURE

J-T cooler with hermetic piston compressor



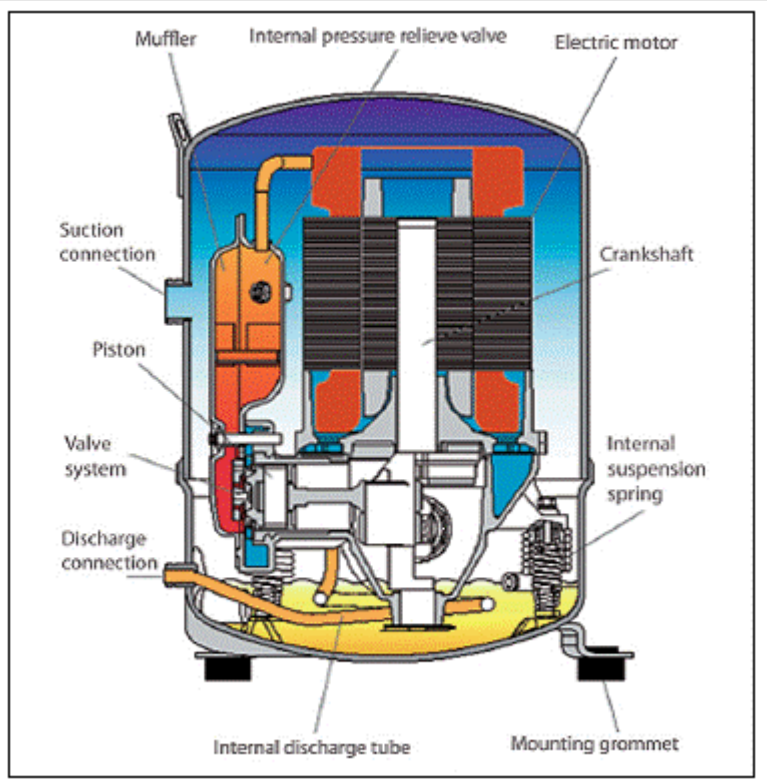
	Refrigeration technology	Cryogenics
Working medium	Refrigerants (both one component or mixtures) R 134a, R404a Pure hydrocarbons R290, R600a	3, 4 and 5-component mixtures of nitrogen and hydrocarbons (methane, ethane, propane and isobutene)
Temperature limit of outlet medium (discharge side)	**150°C** (to avoid thermal decomposition of the oil)	
Pressure ratio limit	6	25
Inlet medium (cooling of the electric motor winding)	Low temperature vapor of the refrigerant	Gas mixture vapor at ambient temperature
Lubrication	Oil (mineral or synthetic)	Oil (mineral or synthetic) - oil change not needed
Oil removal	either oil trap in the installation or oil separator required	Oil separator required

Compressor cooling systems

Outside cooling system – air cooling

Small capacity systems

Inside cooling system



TO BE SOLVED

Desired properties of the mixture

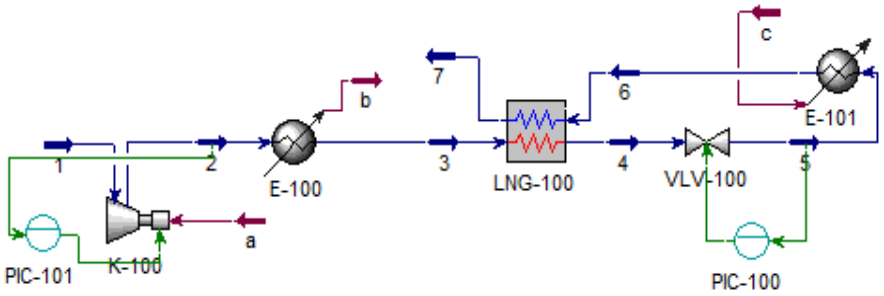
1. High isothermal throttling effect of the isenthalpic expansion Δh_T, even for a relatively low compression pressure, to allow the use of commercially available compressors.

2. The lowest evaporation temperature should not exceed the value resulting from the refrigerator application field, e.g. to guarantee the oxygen liquefaction it should be of about 90-100 K.

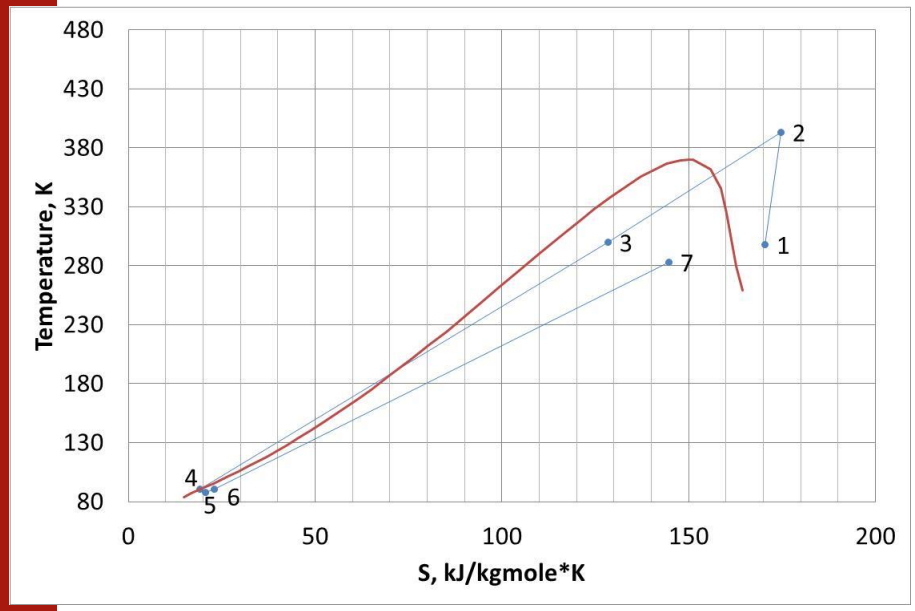
3. The compression temperature should not exceed 150°C. In the case of closed systems this enables the use of standard refrigeration compressors.

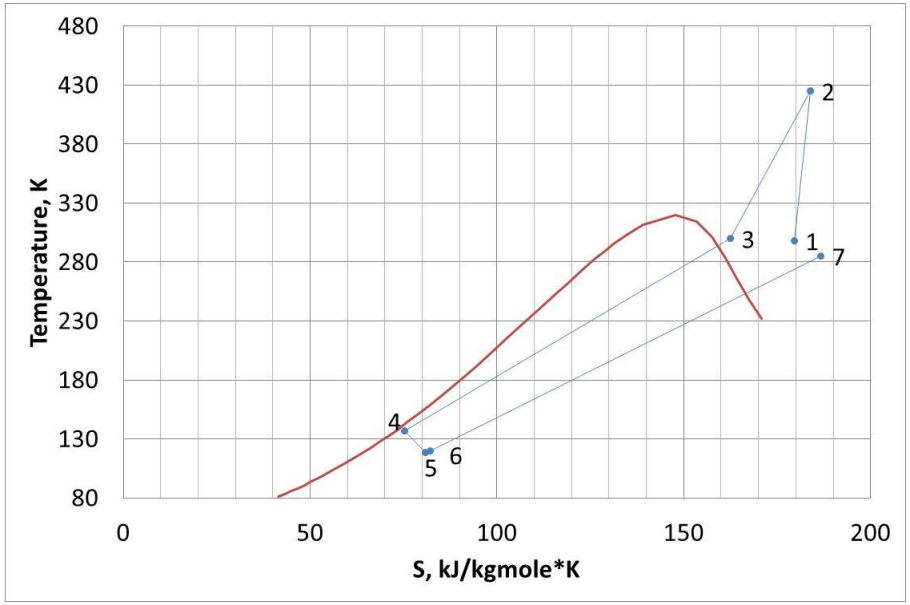
4. No solid phase in any point of the system

Mixture composition



Aspen HYSYS simulation:





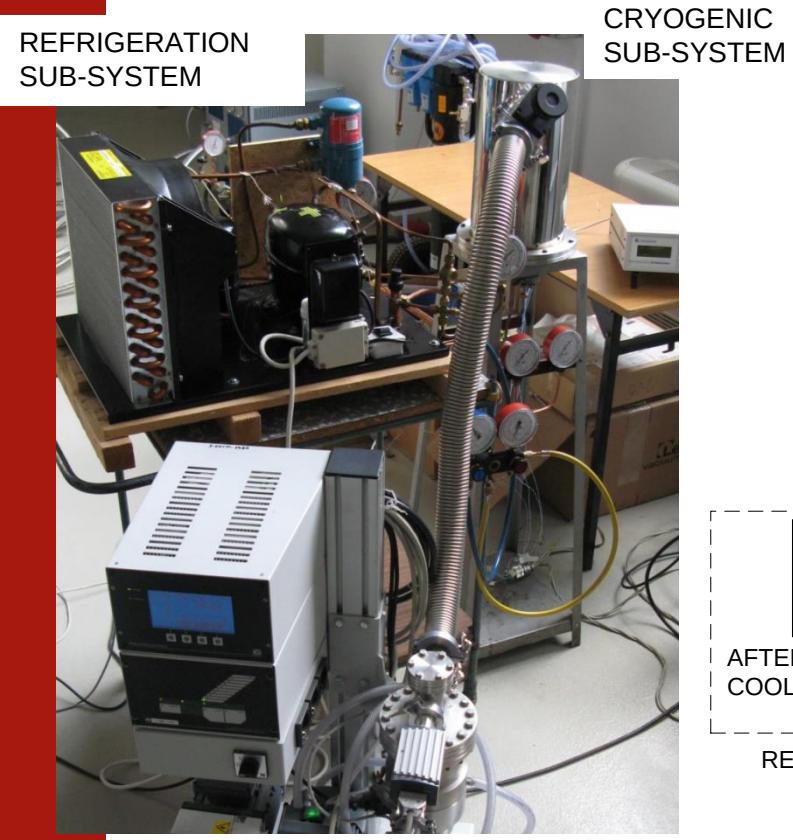
Mixture composition:
nitrogen 10%, methane 20%, ethane 20%, propane 20%, i-butane 40%

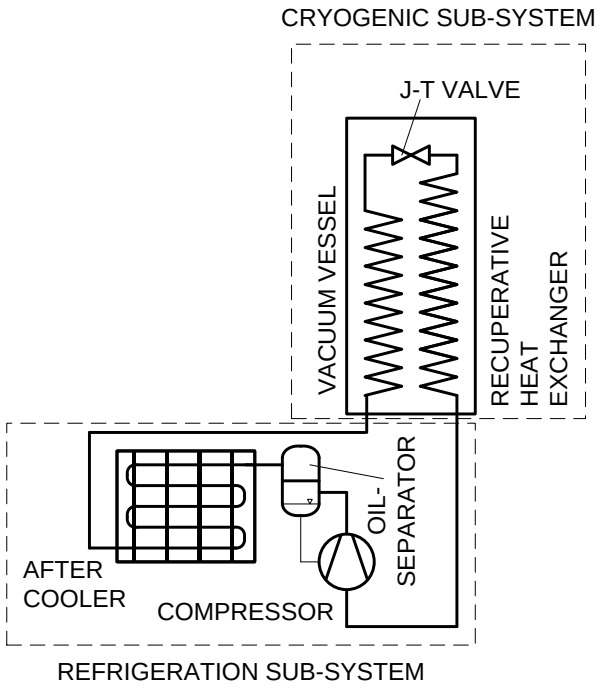
Working pressure: 20 bar

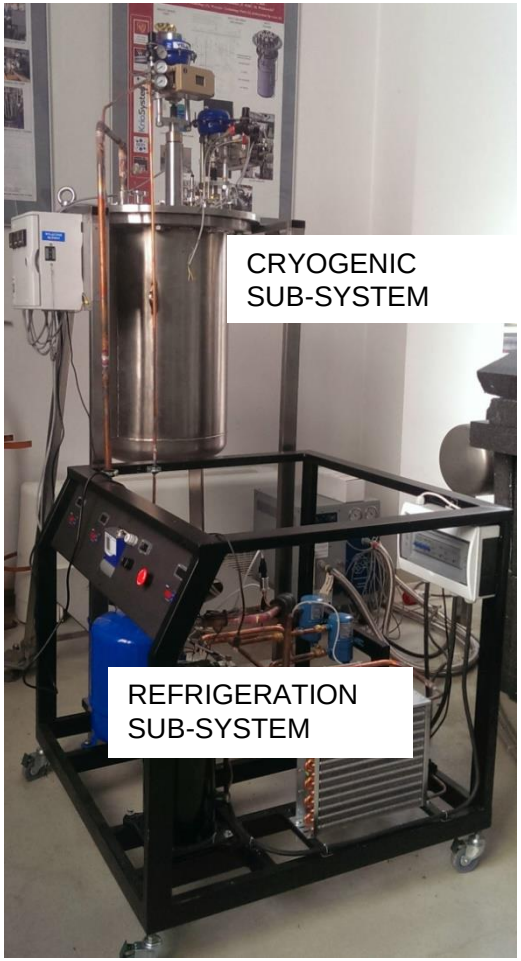
Mixture composition:
nitrogen 20%, methane 20%, ethane 40%, propane 10%, i-butane 10%

Working pressure: 20 bar

J-T coolers designed, manufactured and tested at WUT

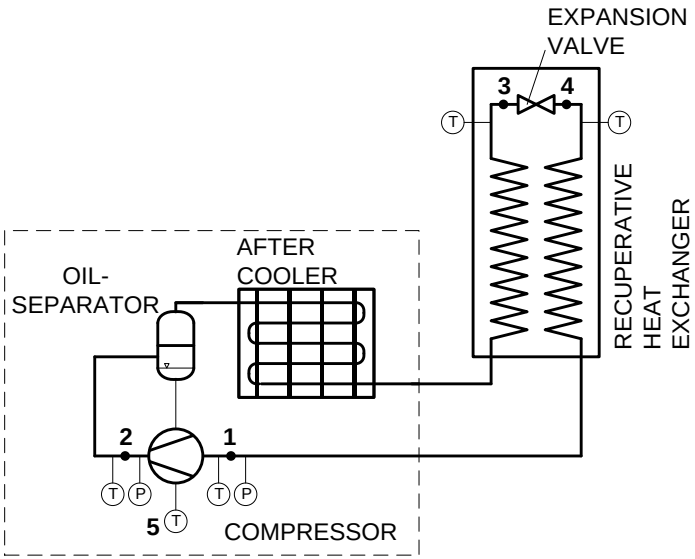


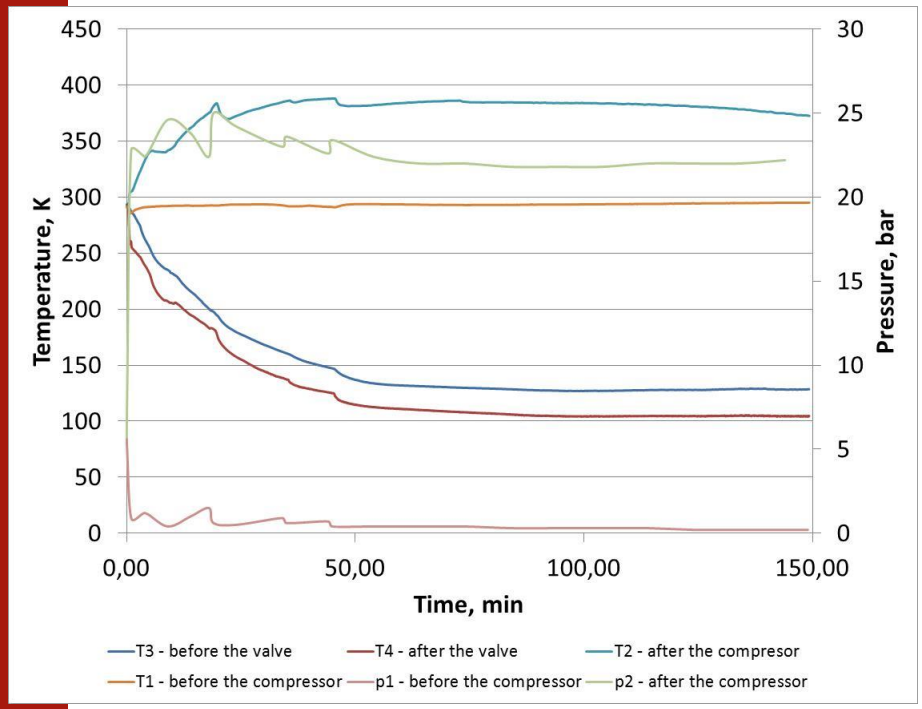


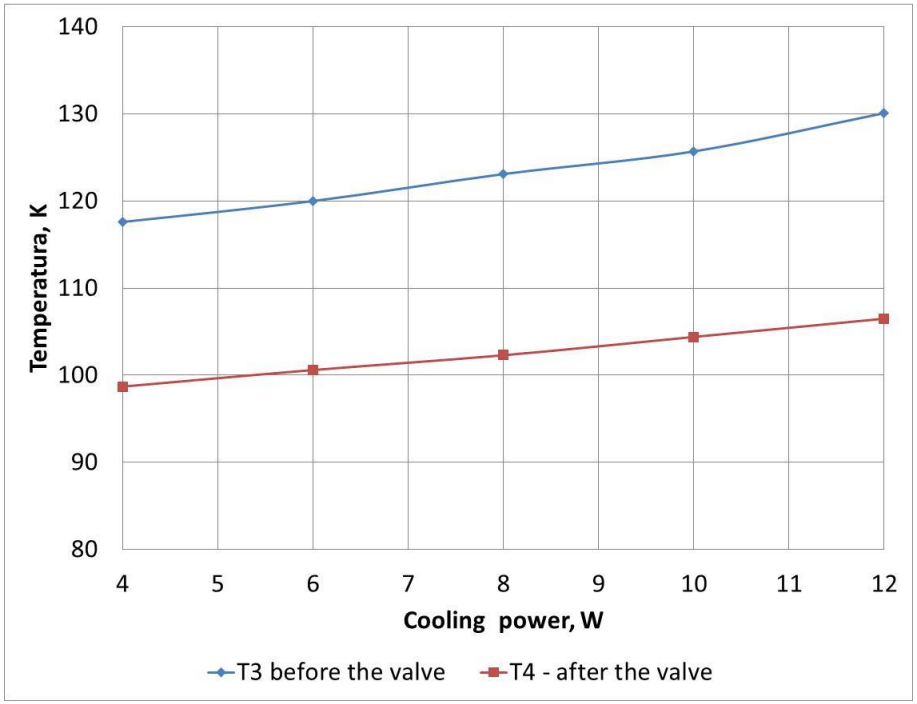


Test results

Mixture composition: Nitrogen 20%, Methane 30%, Ethane 11%, Propane 20%, I-butane 20%

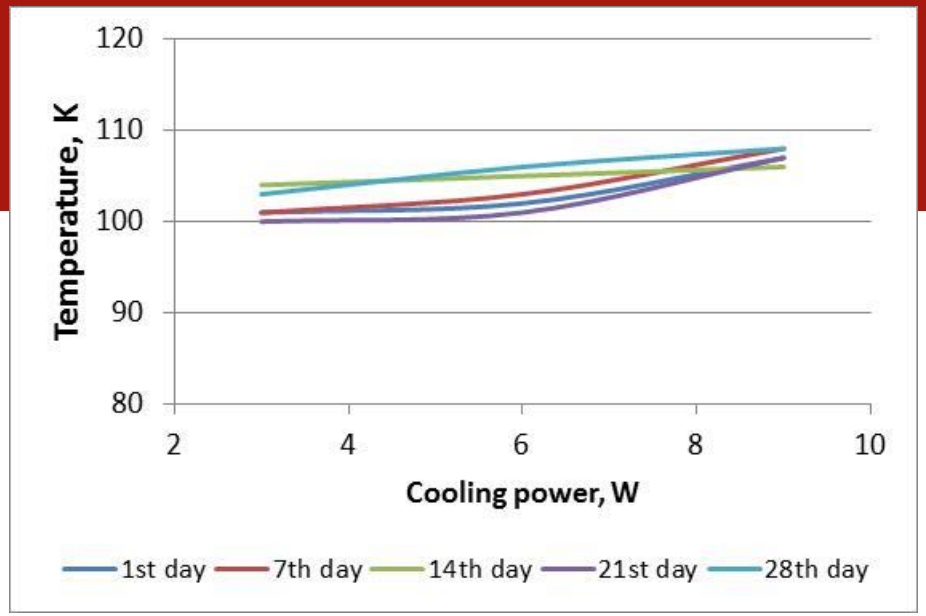


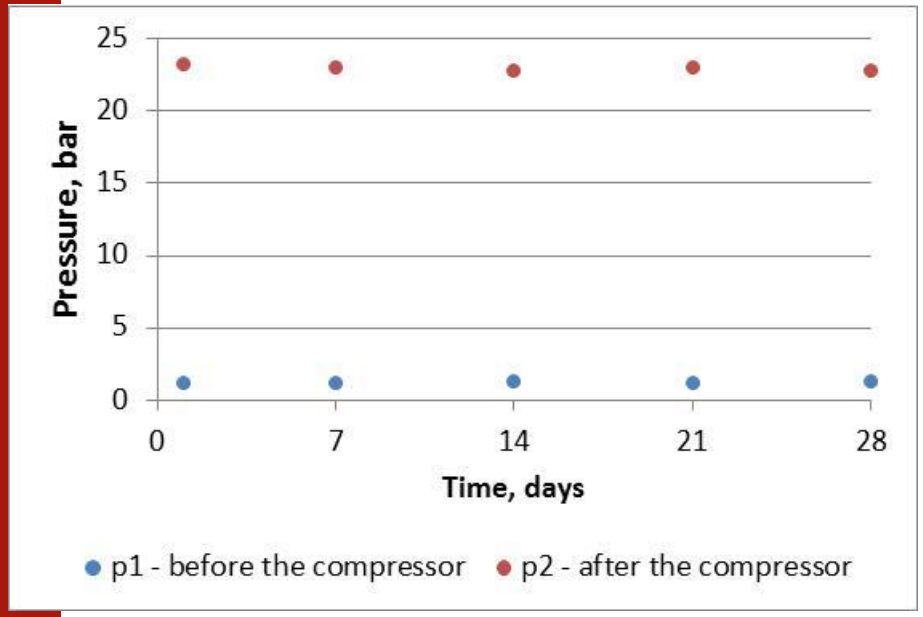


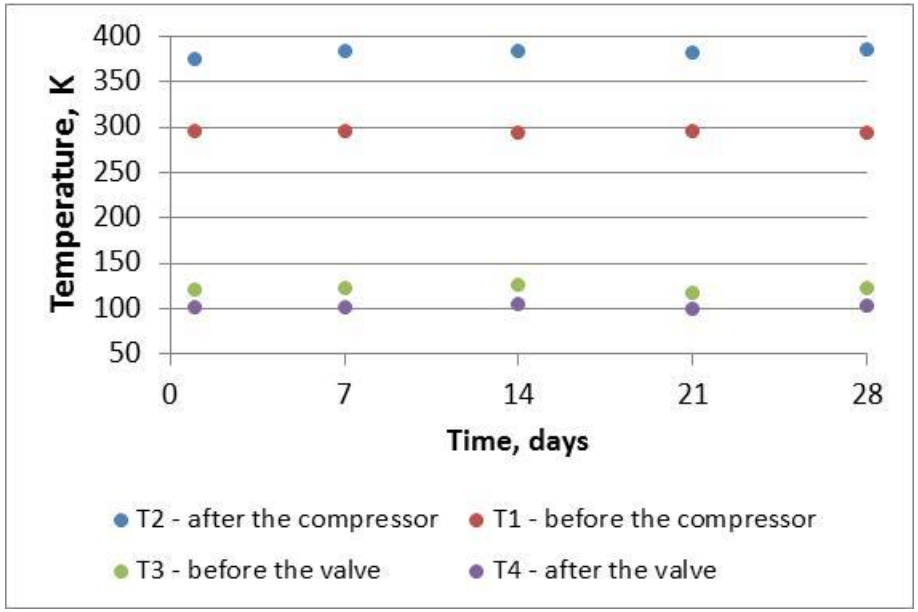


Repeatability of the working parameters

Mixture composition: Nitrogen 20%, Methane 30%, Ethane 11%, Propane 20%, I-butane 20%







Conclusions

1. Hermetic piston compressor can be used for Joule-Thomson cooler supplied with gas mixtures.

2. Joule-Thomson cooler supplied with 5-components mixture of nitrogen, methane, ethane, propane and i-butane :
   - The lowest temperature achieved 98 K
   - Cooling power of 3-9 W at 100-108 K has been produced.

3. The repeatability of the cooler parameters has been observed.

Acknowledgments

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