HC Heat Pumps for Light Industrial Applications –

One Key Technology for Sustainable Heating Solutions

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refrigerants delivered by mother nature

Hydrocarbon Heat Pumps for Light Industrial Applications

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- Hydrocarbons in heat pumps – benefits and challenges
- R290 and R1270 thermodynamic properties − favorable for heat pumps
- Selection of compressor(s) and main system components
- Influence of Hydrocarbons on compressor lubrication
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Heat Pumps with Hydrocarbons – Benefits and Challenges

Benefits

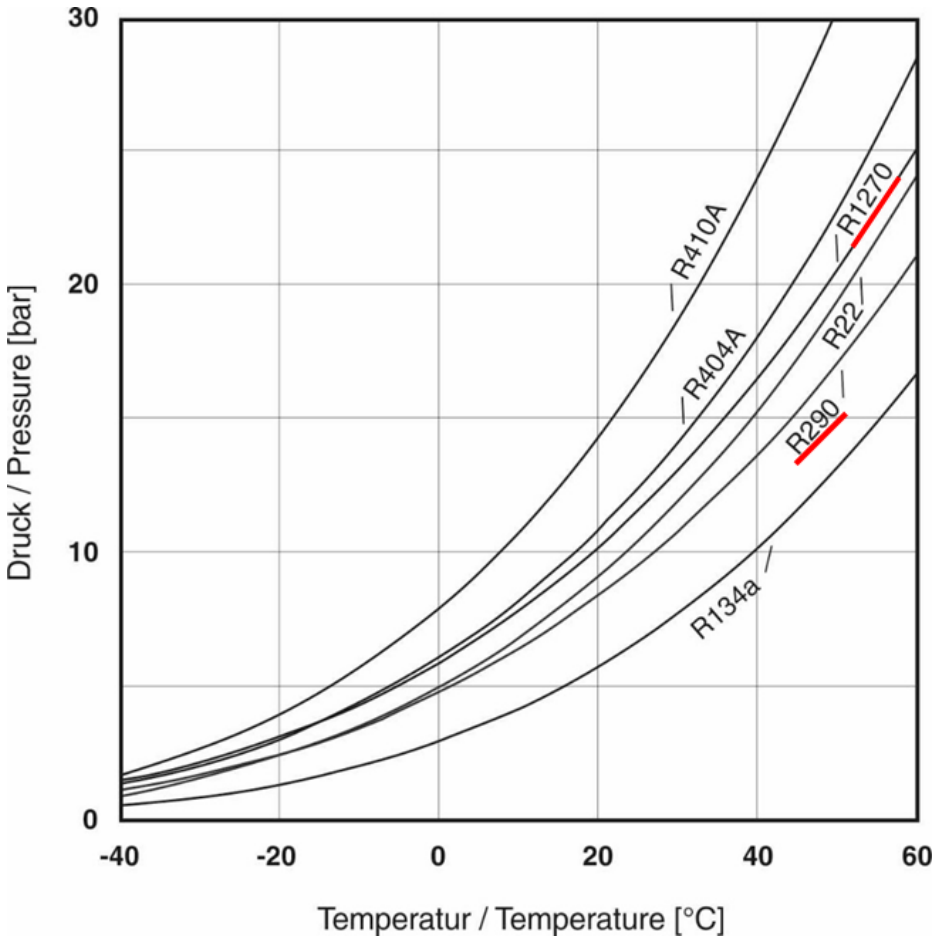
- Favorable thermodynamic properties and COP / SCOP
- Very good heat transfer characteristics
- No special issues with material compatibility

Challenges

- Selection of compressor lubricant and related measures
- Safety provisions in design, installation and operation

R290 and R1270 Properties − Favorable for Heat Pumps

- Moderate pressure levels, low pressure ratio (p/p_o) due to flat temperature/pressure characteristics
  - p/p_o lower than with any HFC, HFC/HFO or HFO alternative
- Volumetric refrigerating (heating) cap. @ +5/50 °C
  - R290 approx. -10 % vs. R22, R448A/449A
    R1270 approx. equal … +5 %
- High enthalpy of evaporation
  - @ +5/50 °C approx. 1.8 times vs. R22 //
    1.9 times vs. R448A/R449A
  - Reduces mass flow, vapour density (pressure drop in gas pipes and HEX) in about the same proportion

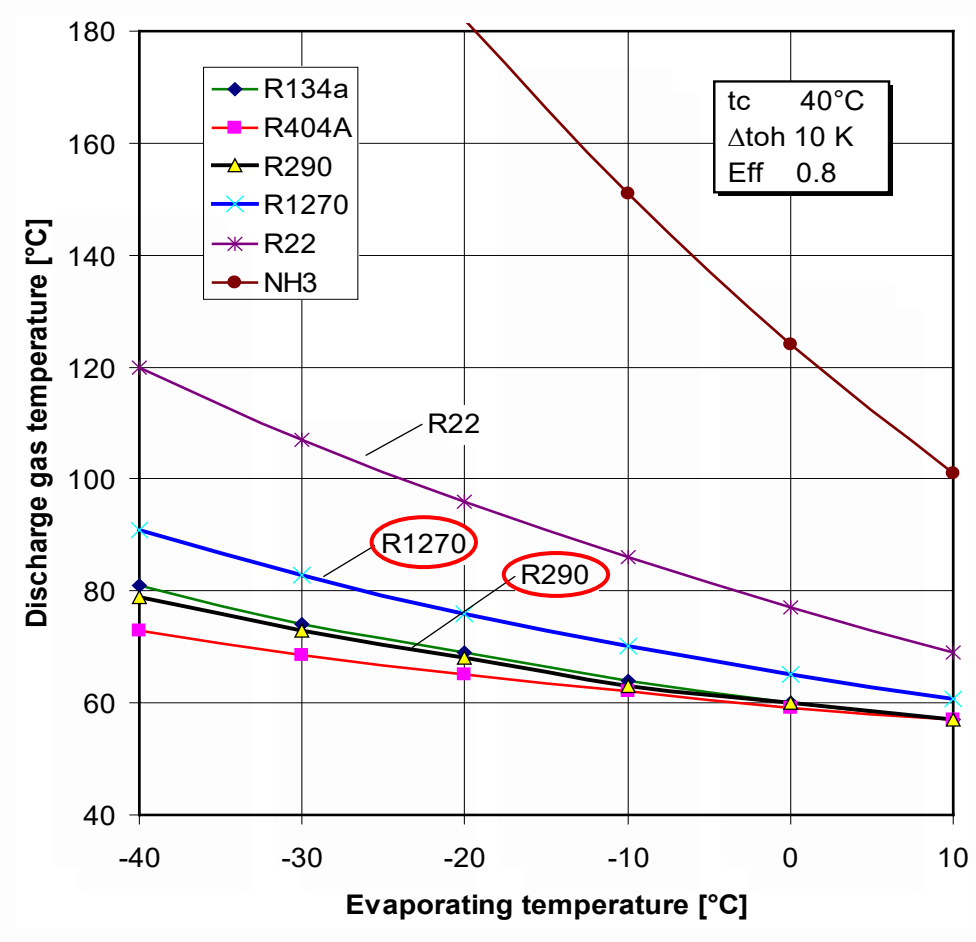


R290 and R1270 Properties − Favorable for Heat Pumps

- High superheat enthalpy in relation to volume change
  - Rising volumetric refrigerating (heating) capacity with increasing <u>useful</u> superheat

$$q_{Oth} = \frac{\Delta h}{v_O} \nearrow \nearrow$$

  - Increase of capacity and COP with liquid/suction line HEX
- High critical temperature (96.7 / 91.1°C)
  - Favorable COP also at high condensing temperatures
- Low discharge and oil temperatures (low c_p/c_v)
  - Low thermal load even with high pressure ratio



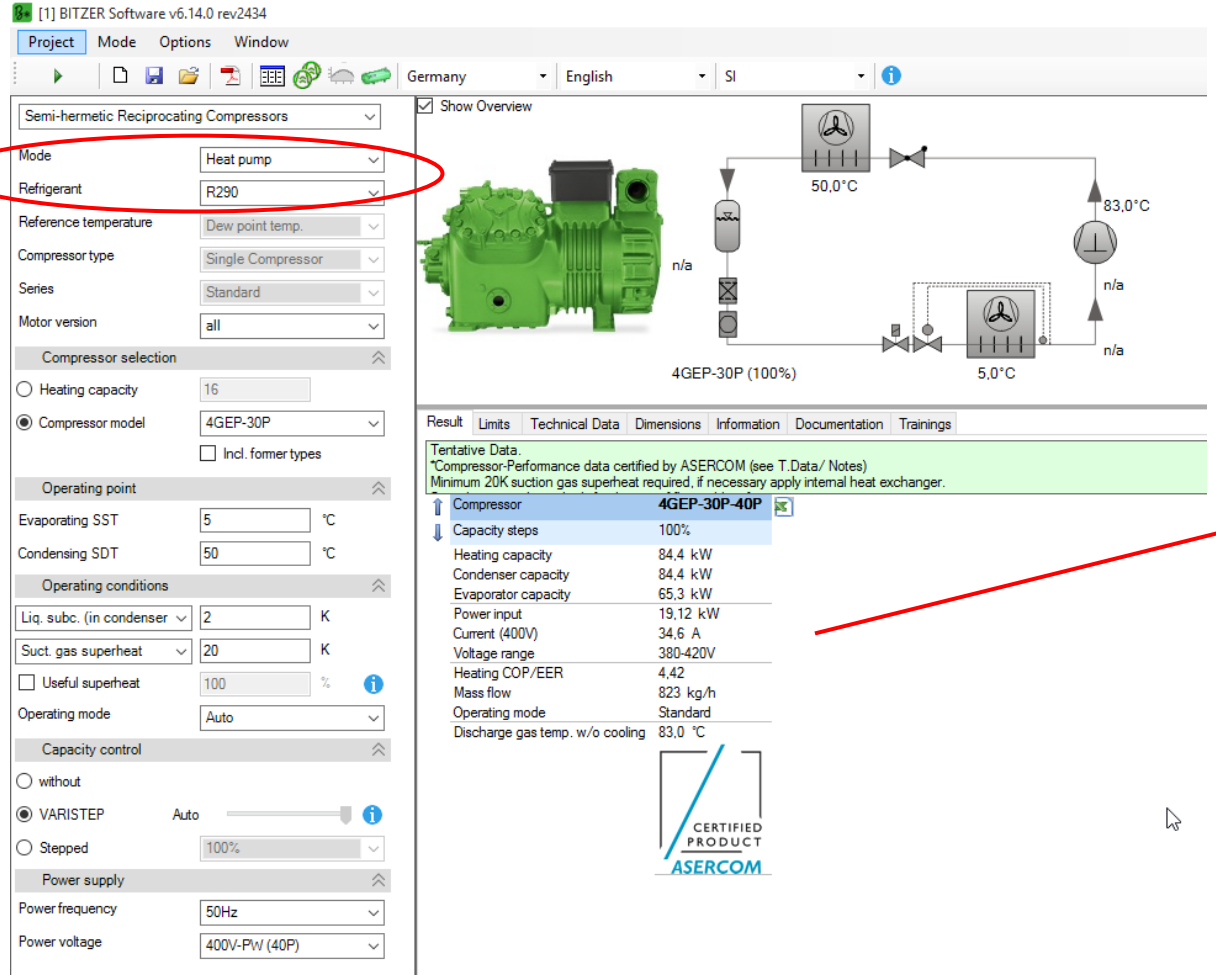
R290 and R1270 Properties − Favorable for Heat Pumps

- Good heat transfer due to intensive boiling and excellent solubility and miscibility with oil
  - Single fluids ⇨ no temperature glide ⇨ allows for very small TD in (e.g.) condenser
  - Good oil transport, low viscosity also in superheat section of evaporators

- Material compatibility similar to R22 and HFCs
  - Allows the use of specifically adapted semi-hermetic (hermetic) compressors
    - Copper windings also suitable
  - Elastomers/plastics ⇨ some special requirements with R1270
    (see also “Forschungsrat Kältetechnik“ Research Report FKT61_99)

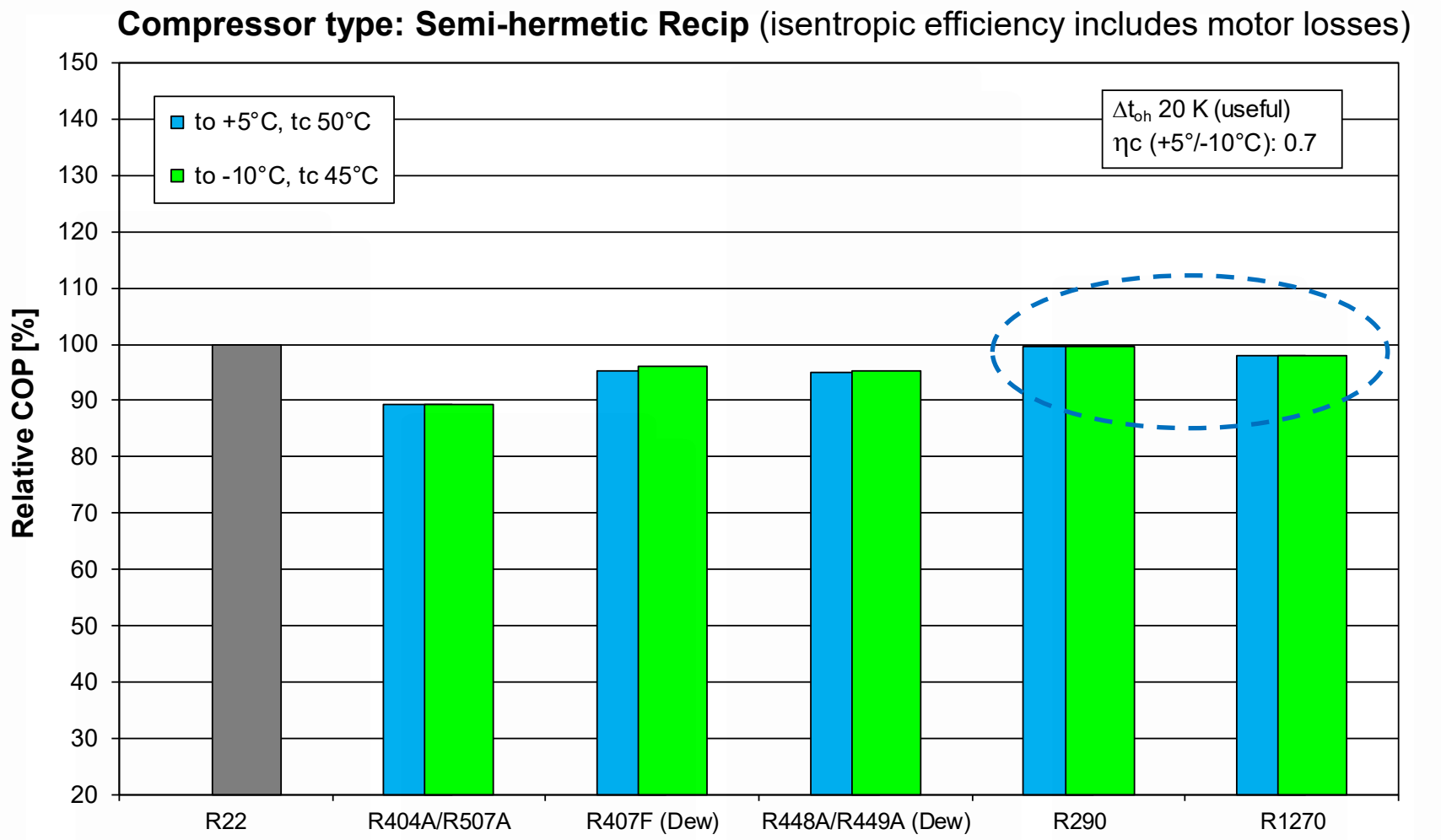
Selection of Compressor(s) and Main System Components

- Compressor selection with Software − Heat Pump Mode



Compressor	4GEP-30P-40P
Capacity steps	100%
Heating capacity	84,4 kW
Condenser capacity	84,4 kW
Evaporator capacity	65,3 kW
Power input	19,12 kW
Current (400V)	34,6 A
Voltage range	380-420V
Heating COP	4,42
Mass flow	823 kg/h
Operating mode	Standard
Discharge gas temp. w/o cooling	83,0 °C

Selection of Compressors –
Relative Compressor COP – R22, HFCs vs. R290 and R1270



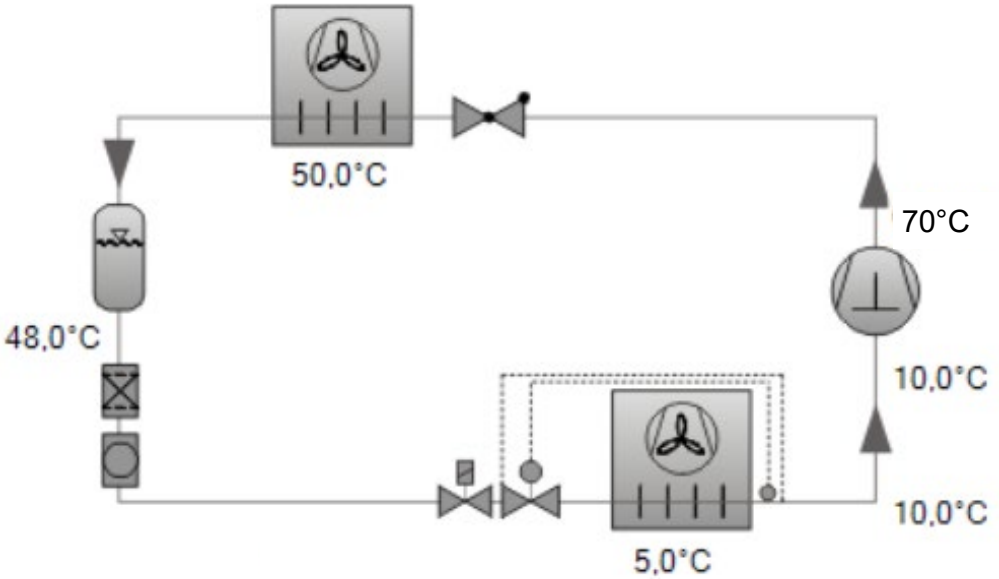
Potential for improved System COP / SCOP

- Lower pressure drop in pipes and HEX
- Excellent heat transfer in HEX

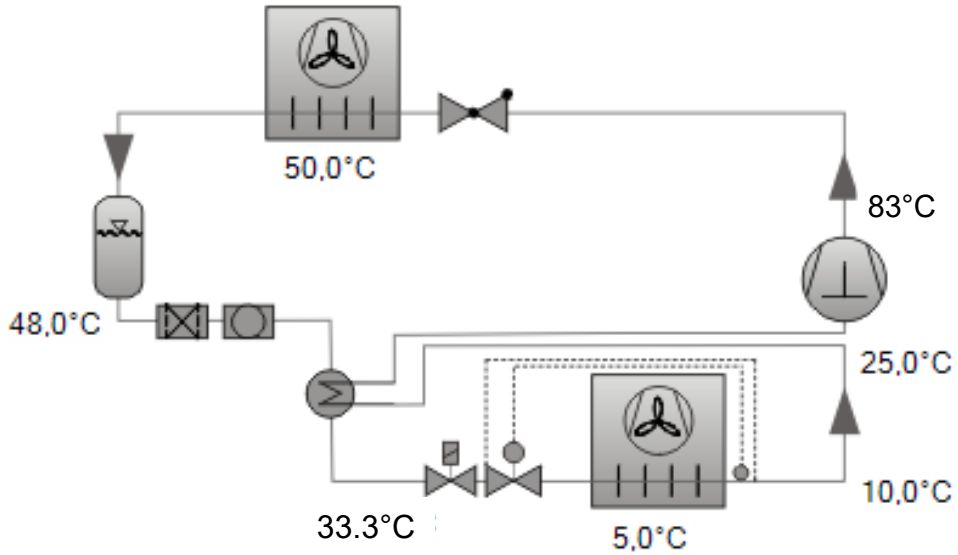
Selection of Compressor(s) and Main System Components

- Liquid/Suction Line HEX essential ⇨ target $\Delta t_{oh} \approx 20$ K (HP, HT, MT)
  - Benefit in capacity, COP and reduced oil dilution ⇨ higher oil temperature

Examples of Cycle Configuration (R290)



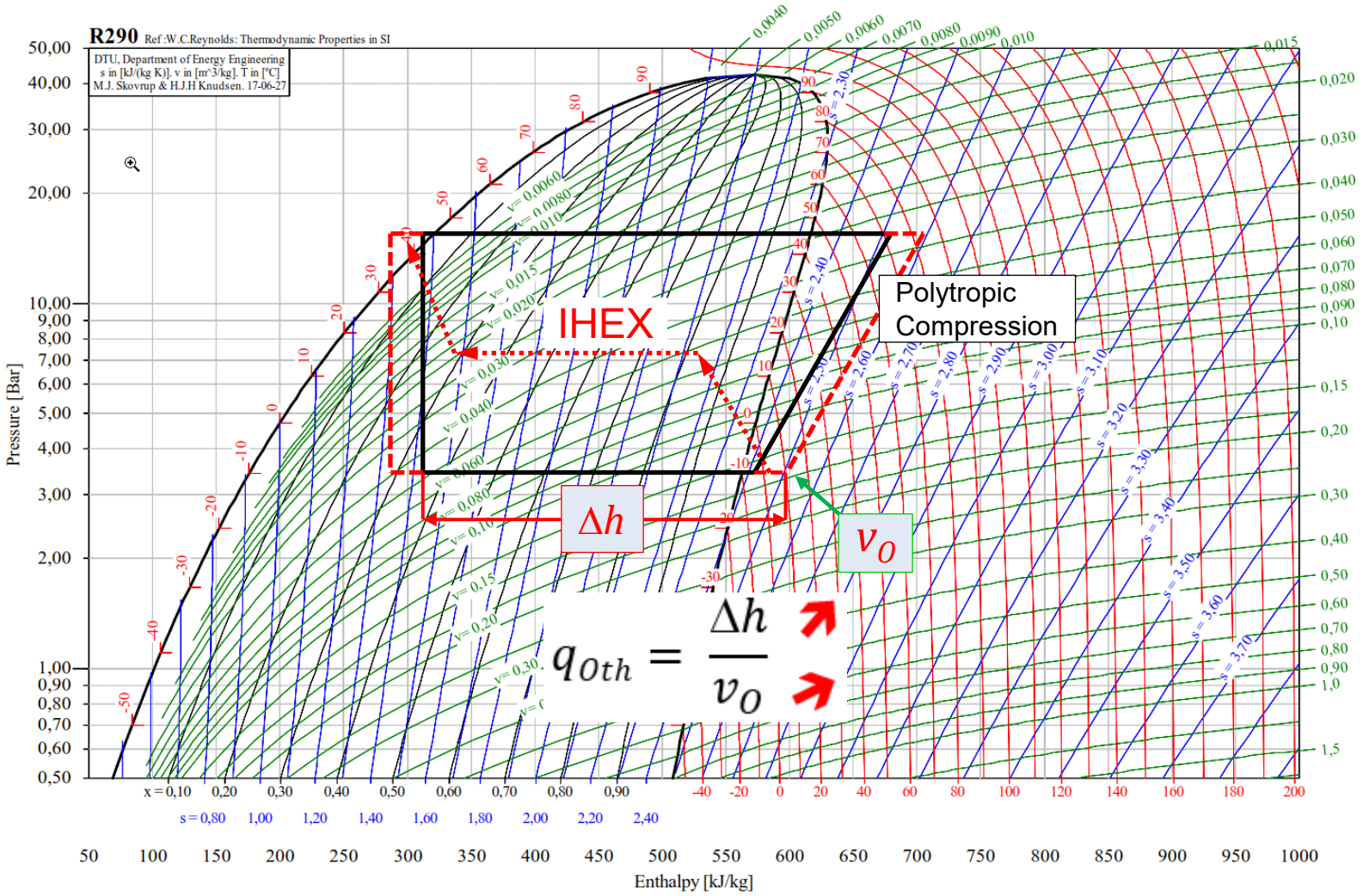
w/o IHX



w/ IHX ⇨ COP ≈ +5..6%

incl. higher isentropic eff. of compressor

R290 Cycle Diagram – Capacity and COP Increase by IHEX



Selection of Compressor(s) and Main System Components

- Selection of evaporators, condensers and line components according to mass and volume flow
  - Evaporator: Special attention on injection distribution, pipe length and pipe geometry
    - Potential of uneven distribution and liquid overfeed in part load
  - TXV / EXV ⇨ capacity* vs. R22 − same nozzle (bulb charge adapted):
    - R290 ≈ HT / MT: 0..+5%
    - R1270 ≈ +13..18%

    Higher numbers with lower condensing temperatures

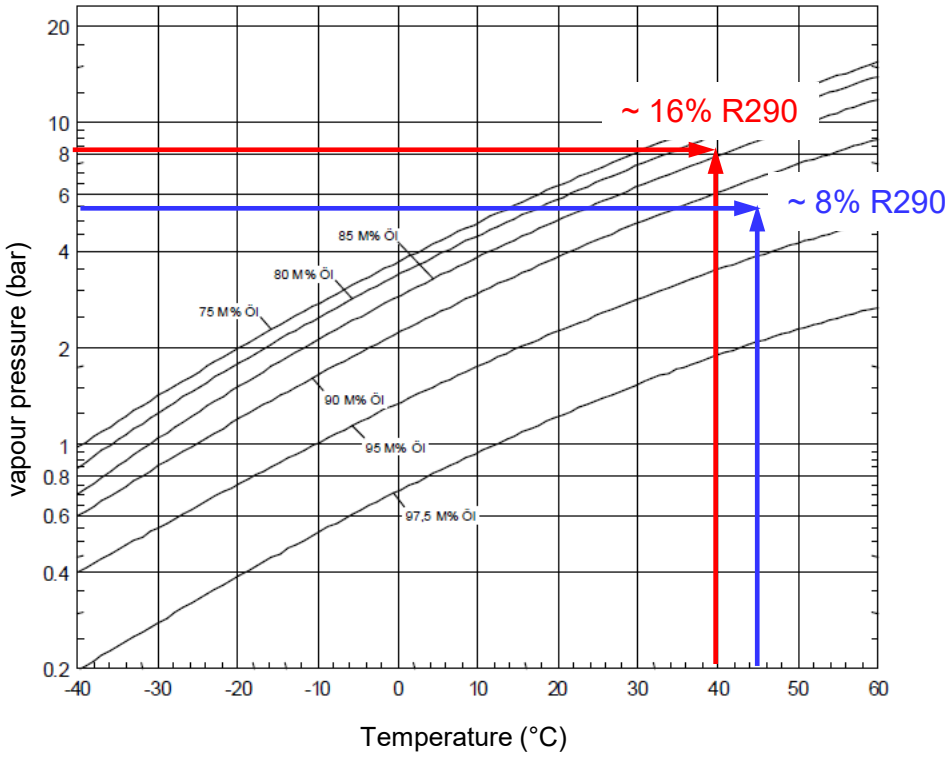
* Reference: Danfoss / Honeywell calculation methodology

Influence of Hydrocarbons on Compressor Lubrication

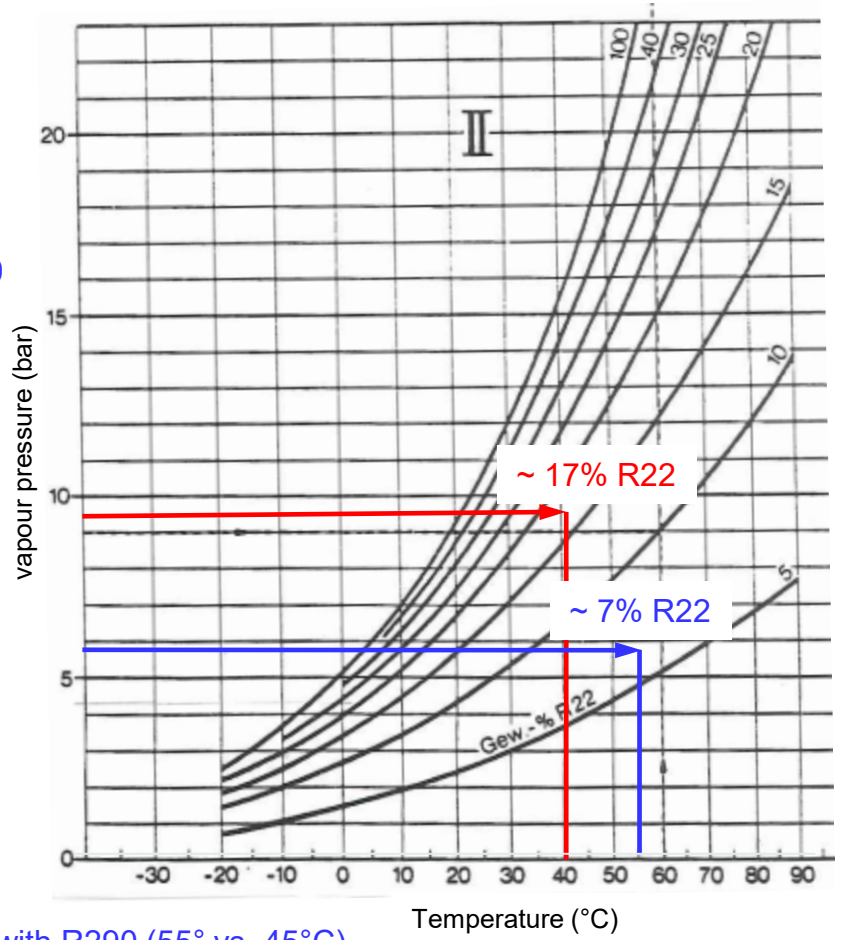
- HC‘s have exceptionally good solubility/miscibility behavior in oil especially with lubricants of low polarity like mineral oil (MO)
  - Strong oil dilution / reduced viscosity / solvent effect
  - Strong degassing and foaming with pressure fluctuation
- Operating temperatures (discharge / oil) remarkably low
  - Increased amount of dissolved HC in oil especially at small pressure ratios, high evaporating temperatures and low superheat
- Solubility (oil/refrigerant) usually measured in **“mass %“**
  - With MO no severe difference in mass % vs. R22 or HFC‘s w/ POE − however …
  - Low liquid density of HCs (40 – 45% vs. R22) leads to more than double volume of dissolved refrigerant in oil ⇨ Far stronger oil dilution than with R22 and HFCs

Pressure / Temperature / Solubility Relation – Example MO / R290 vs. R22

MO VG 68 cSt – **R290**



MO VG 68 cSt – **R22**



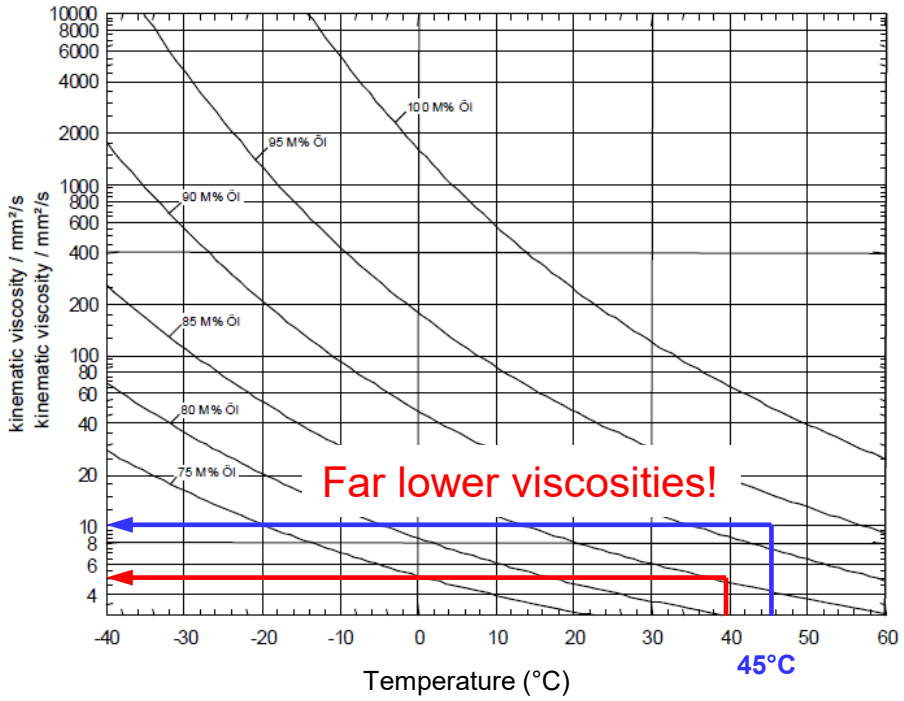
Standstill @ 20°C

Operation @ to +5°C

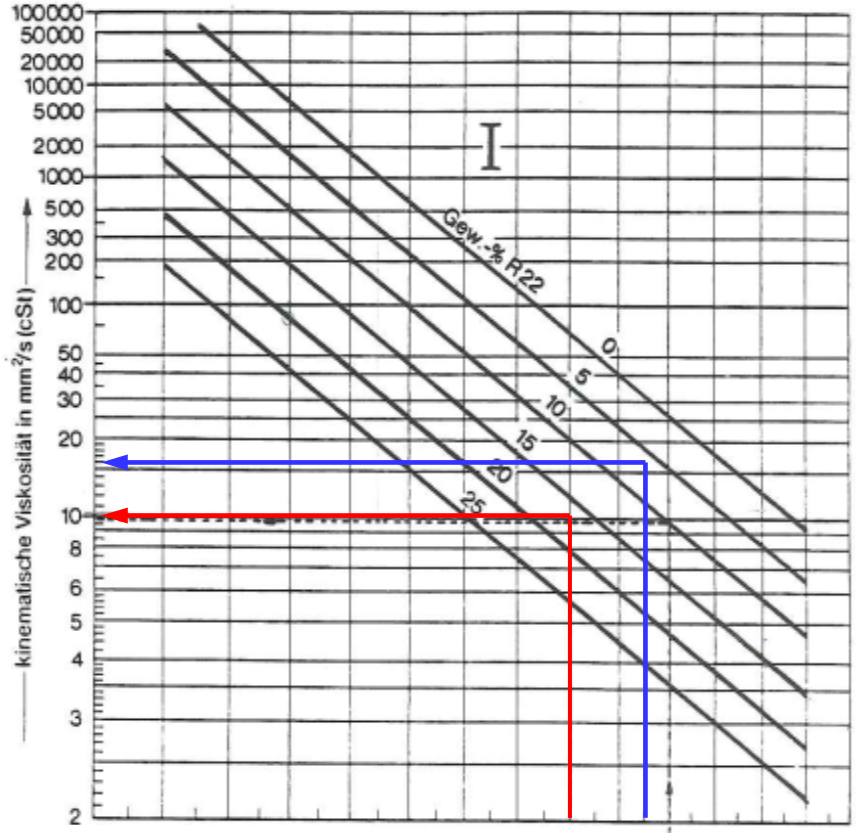
Oil temp R22 10 K higher than with R290 (55° vs. 45°C)

Solubility / Viscosity Relation – Example MO / R290 vs. R22

MO VG 68 cSt – **R290**



MO VG 68 cSt – **R22**



Standstill @ 20°C
Oil temp 40°C

Operation @ to +5°C
Oil temp R22 10 K higher than with R290 (55° vs. 45°C)

Lubricants: Required Measures for Reliable Operation

- Best suitable lubricant − acc. to compressor manufacturer specification
  - Higher basic viscosity ⇨ MO or AB
  - Or lubricants with higher viscosity index (Vi) ⇨ PAO
  - Or high polarity oils (lower solubility) ⇨ POE or PAG (PAG very hygroscopic)
- Generously sized and temperature controlled crankcase heater
- Thermal insulation of compressors especially with outdoor installations
- Minimum refrigerant charge
- Measures against ”wet operation“ during start and operation
  - Avoid refrigerant migration to suction side during standstill
  - Maintain sufficiently high suction gas superheat

Example of R290 Heat Pump

- Heat pump for ground source loop and (waste) heat recovery (1)
  - Designed for indoor and outdoor installation
  - Heating capacity up to 250 kW
    - 2 separate refrigerant circuits max. 15 kg R290
    - SCOP / Space Heating Energy Efficiency ($\eta_{s,h}$) by far exceeding EU Regulation 813/2013 MEPS
  - 2 Semi-hermetic reciprocating compressors HC version
    - One compressor VSD with frequency inverter
    - One compressor with “Varistep” capacity control

Source: FRIGOPOL (Austria) Heat Pump Unit “ES”

Example of R290 Heat Pump

- Heat pump for ground source loop and (waste) heat recovery (2)
  - Plate type evaporator and condenser for very small TD
  - Electronic TX valves
  - 3-way motorized liquid valve for suction superheat control
    - By-passing IHEX
  - Intelligent system controller − also for liquid pumps
  - Far-reaching protection system incl. two independent gas sensors and control for ventilation system
  - Gas sensors and ventilation system with separate power supply

Source: FRIGOPOL (Austria) Heat Pump Unit “ES”

R290 Heat Pump – Safety Provisions in Design

- Safety concept of a ground source heat pump − Risk assessment by Certified Body
  - Isolated control cabinet and refrigeration compartment with controlled ventilation

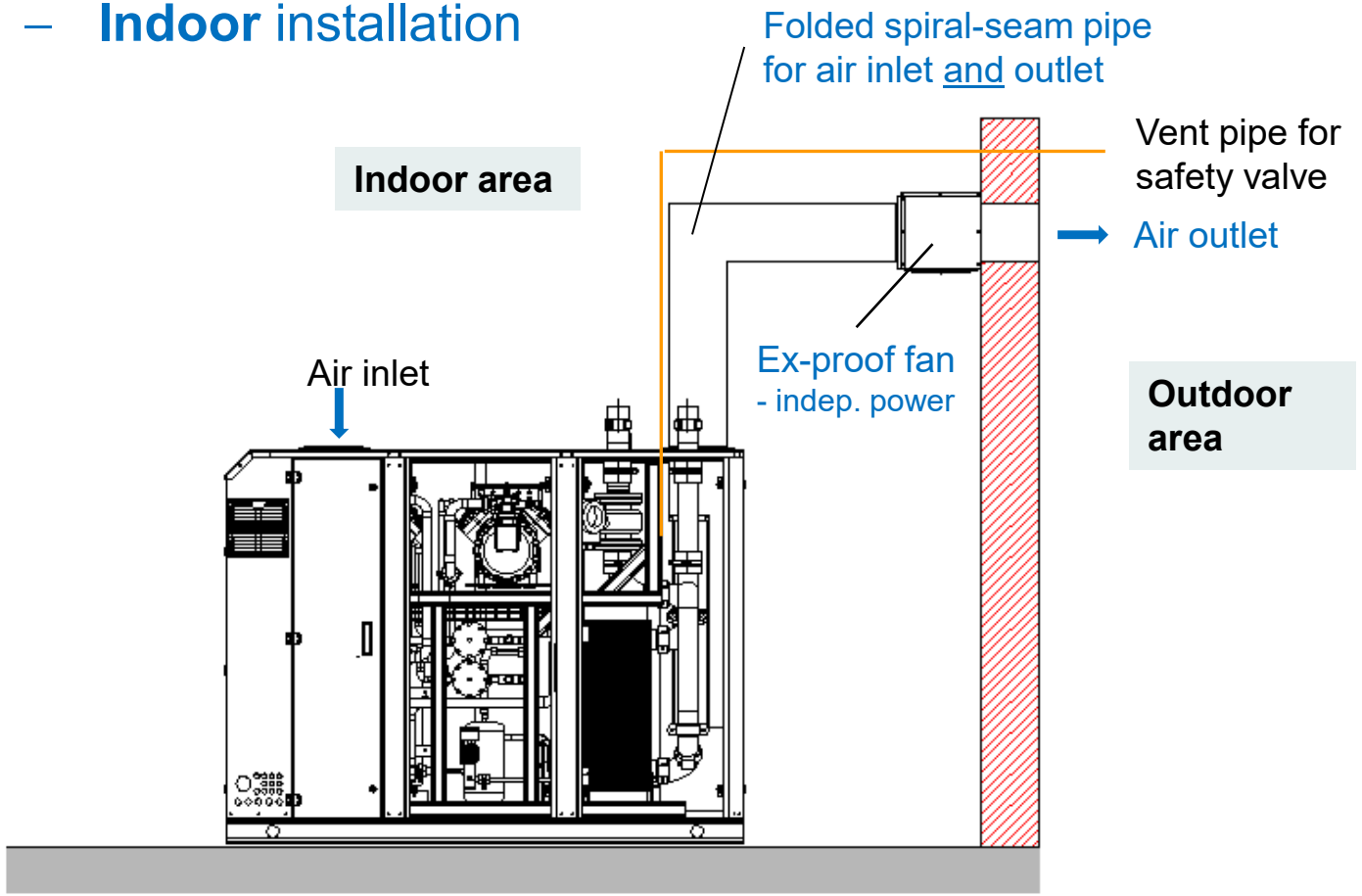
Control cabinet incl.
- Switch board
- System controller
- Gas sensor control with independent power supply
- Frequency inverter
- IP66 against heat pump compartment

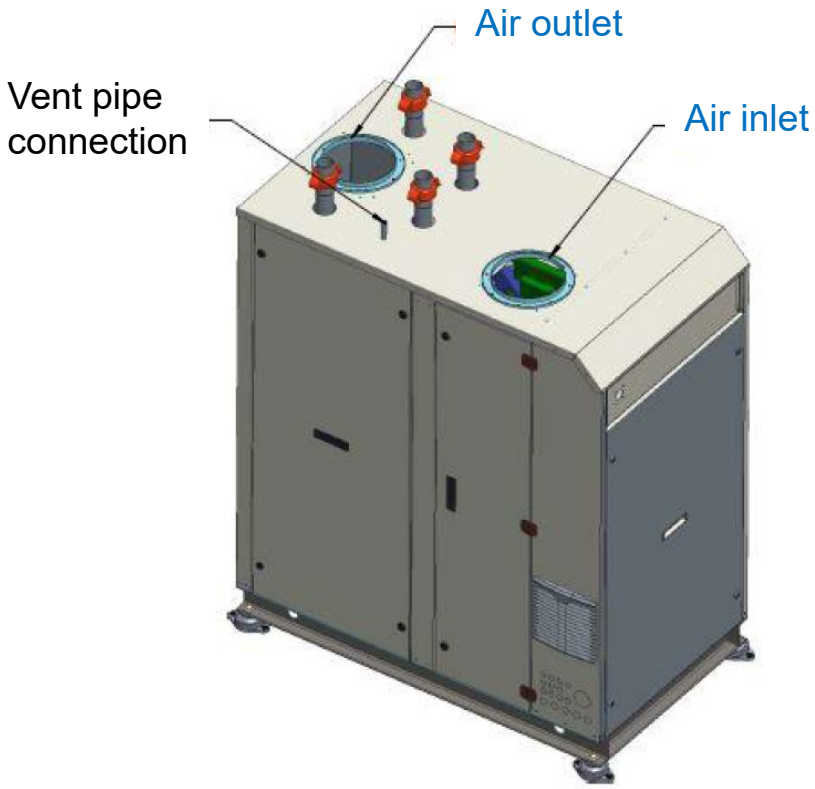
Refrigeration / heat pump compartment
- SH compressors special HC version (risk assessment by Certified Body)
- PED approvals for HEX, pipe work, controls according to PED fluid group 1

Source: FRIGOPOL (Austria) Heat Pump Unit “ES”

Safety Provisions in Design, Installation and Operation

- Safety concept of a ground source heat pump − Risk assessment by Certified Body
  - **Indoor** installation

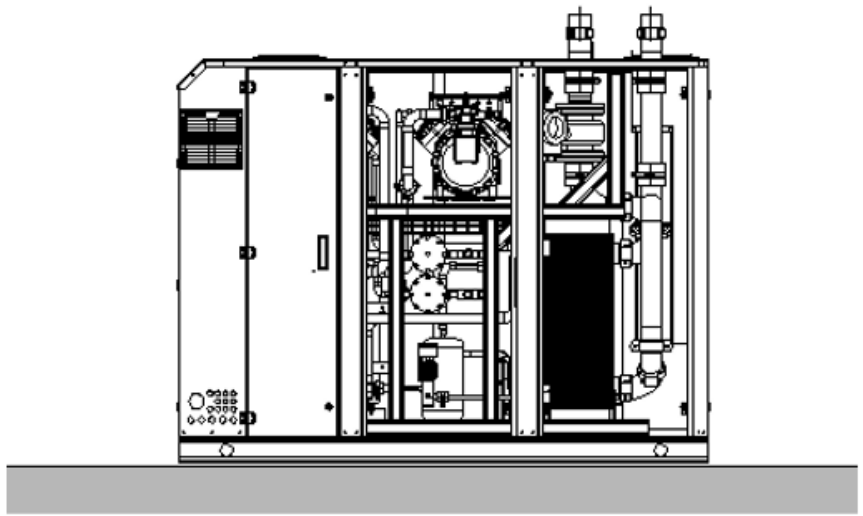




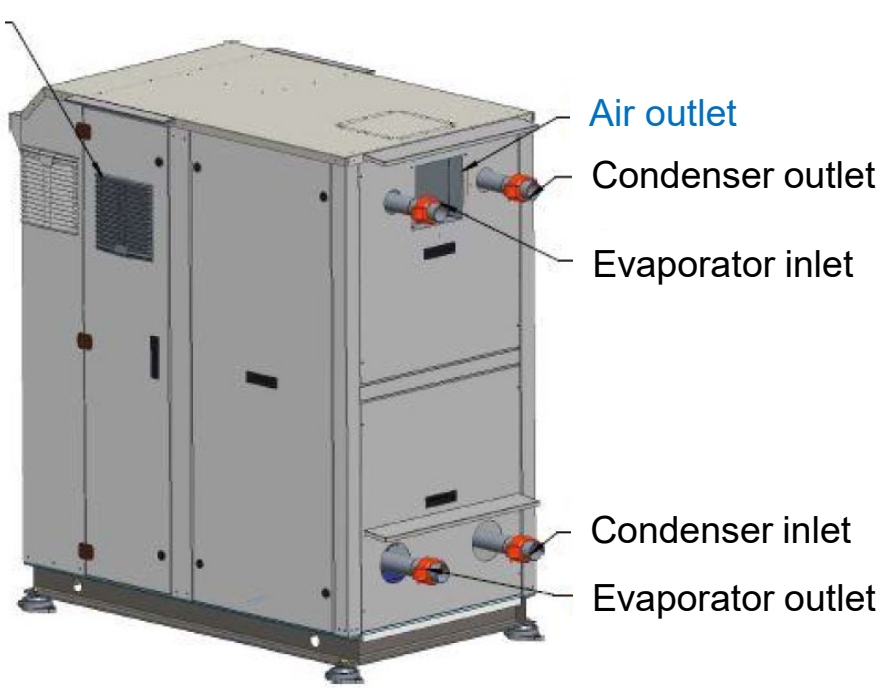
Source: FRIGOPOL (Austria) Heat Pump Unit “ES”

Safety Provisions in Design, Installation and Operation

- Safety concept of a ground source heat pump − Risk assessment by Certified Body
  - **Outdoor** installation



Integrated Ex-proof fans
- Independent power supply



Source: FRIGOPOL (Austria) Heat Pump Unit “ES”

Summary

- Hydrocarbons like R290 and R1270 show convincing features for efficient and reliable heat pump solutions – also for use in light industrial applications
- Selection and layout of compressors, suitable lubricants as well as main circuit components require specific consideration of fluid properties which differ from commonly used synthetic refrigerants
- Special care must be taken in terms of safety provisions in design, installation, operation, service – and disposal
- Risk assessment is essential – involvement of a Certified Body is recommended

Thank You for Your Attention!

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