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Commercial Refrigeration Systems with R290 and R1270 –

Criteria for the Selection and Layout of Components and Pipe Work

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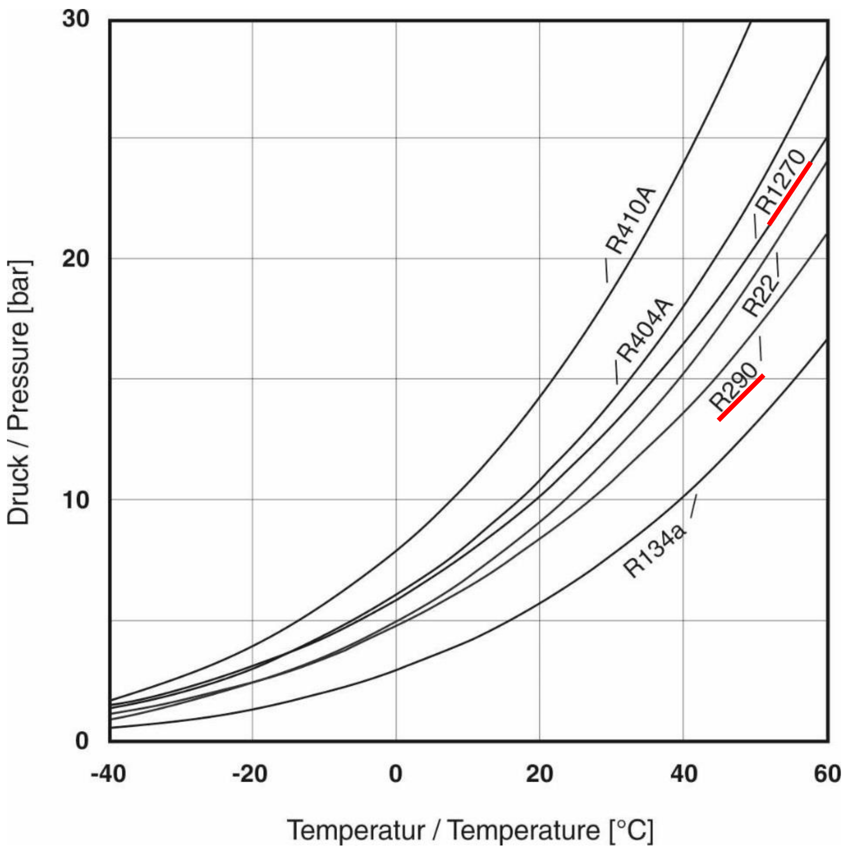
Contents

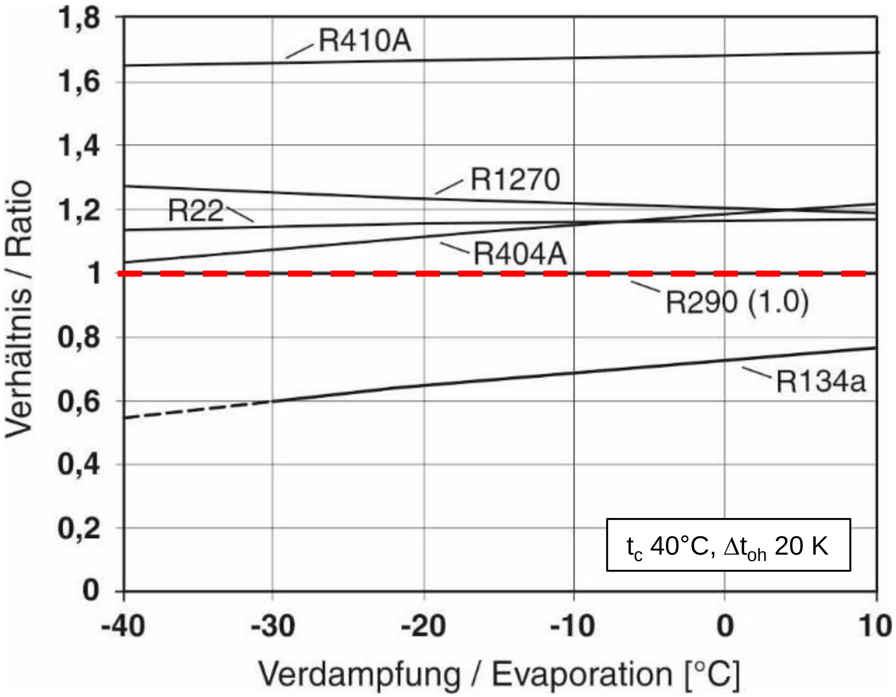
Presentation does not include measures for safety provisions

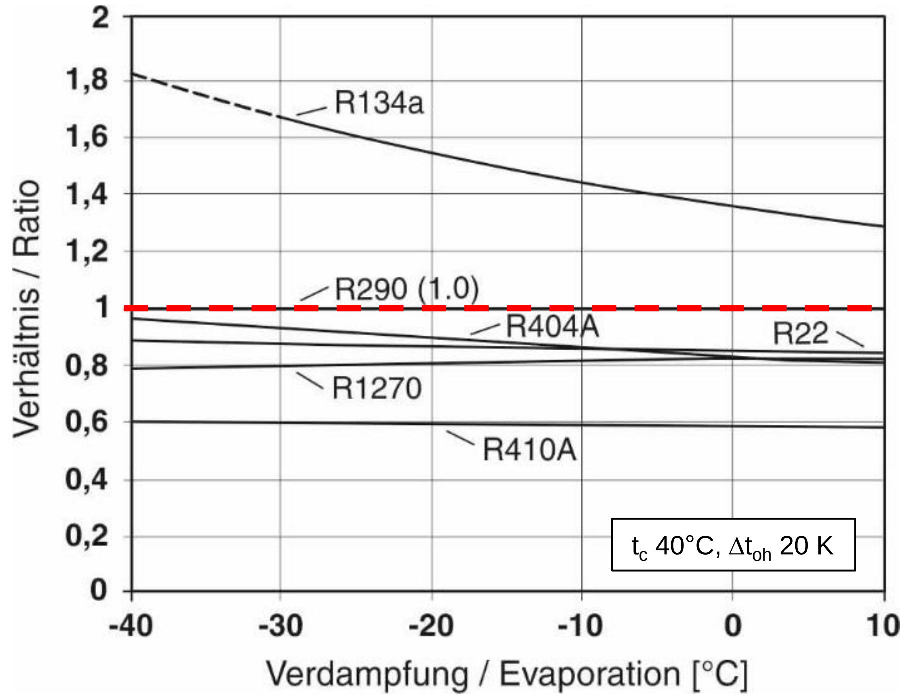
R290 and R1270 Properties and Their Impact (1)

- Moderate pressure levels, low pressure ratio (p/p_o) due to flat temperature/pressure characteristics
  - p/p_o far lower than with any HFC or HFC/HFO alternative
- Volumetric refrigerating capacity +/-20% vs. R22 and R404A/507A
- High evaporation enthalpy
  - @ -10/40°C approx. 1.7 times vs. R22 // 2.5 times vs. R404A/R507A



Volumetric Refrigerating Capacity / Suction Gas Volume Flow





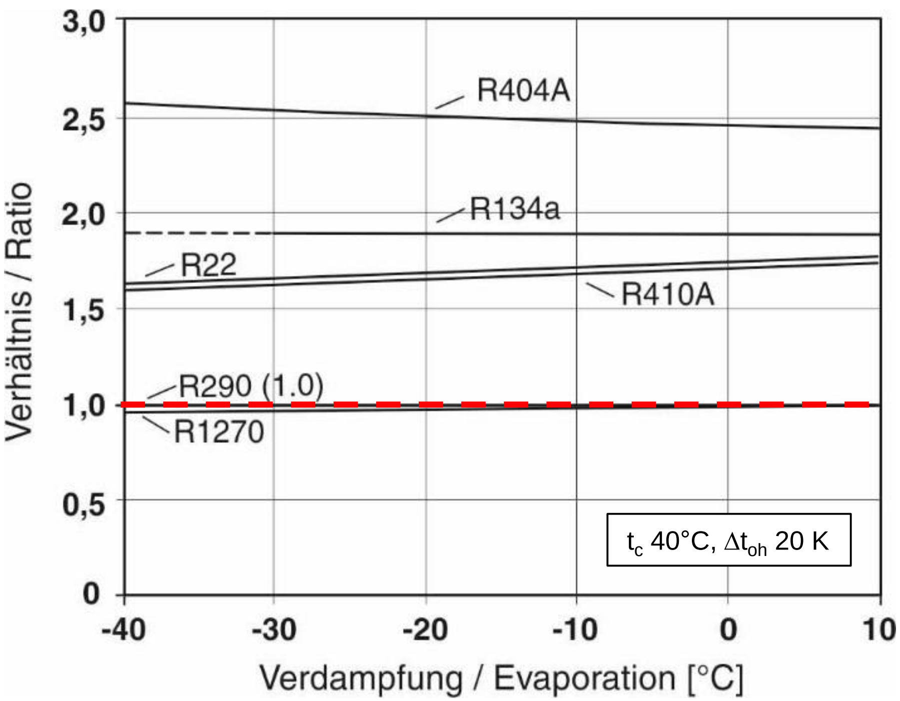
Volumetric refrigerating capacity of different refrigerants compared to R290
⇨ Identical suction volume flow

Suction gas volume flow of different refrigerants compared to R290
⇨ Identical refrigerating capacity

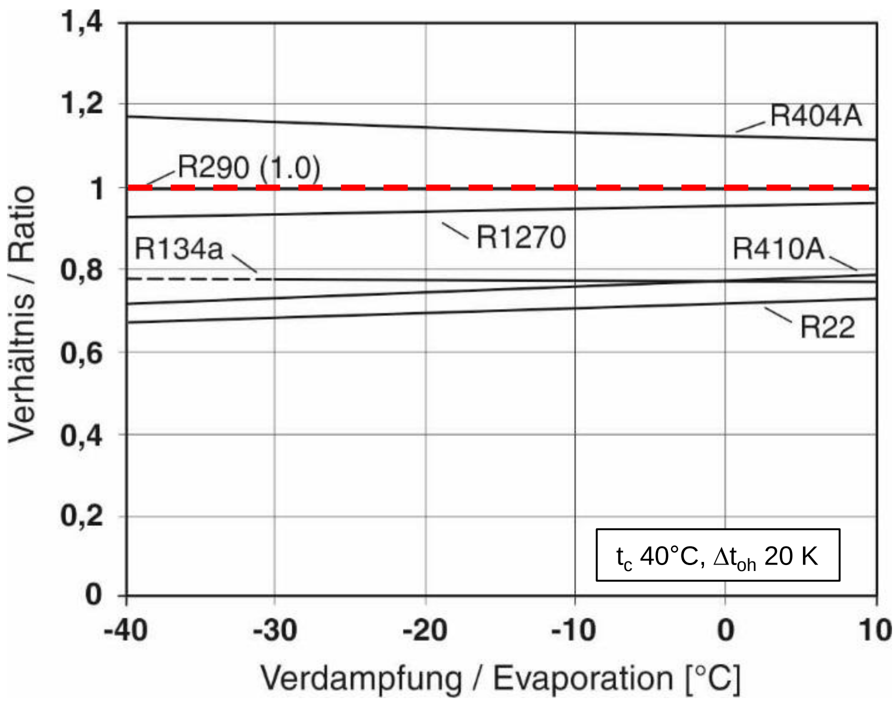
R290 and R1270 Properties and Their Impact (2)

- Low refrigerant mass flow
  - @ identical Qo ⇨ ≈ 55..60% vs. R22 // ≈ 40% vs. R404A/R507A
- Very low vapour and liquid densities
  - Vapour (suction): ≈ 35..55% vs. R22 and HFCs
  - Liquid: ≈ 40..50% vs. R22 and HFCs
  - Low pressure drop in heat exchangers (HX) and pipe work
- High superheat enthalpy in relation to volume change
  - Rising volumetric refr. capacity with increasing useful superheat
  - Increase of capacity and COP with liquid/suction line HX

Refrigerant Mass Flow / Liquid Volume Flow

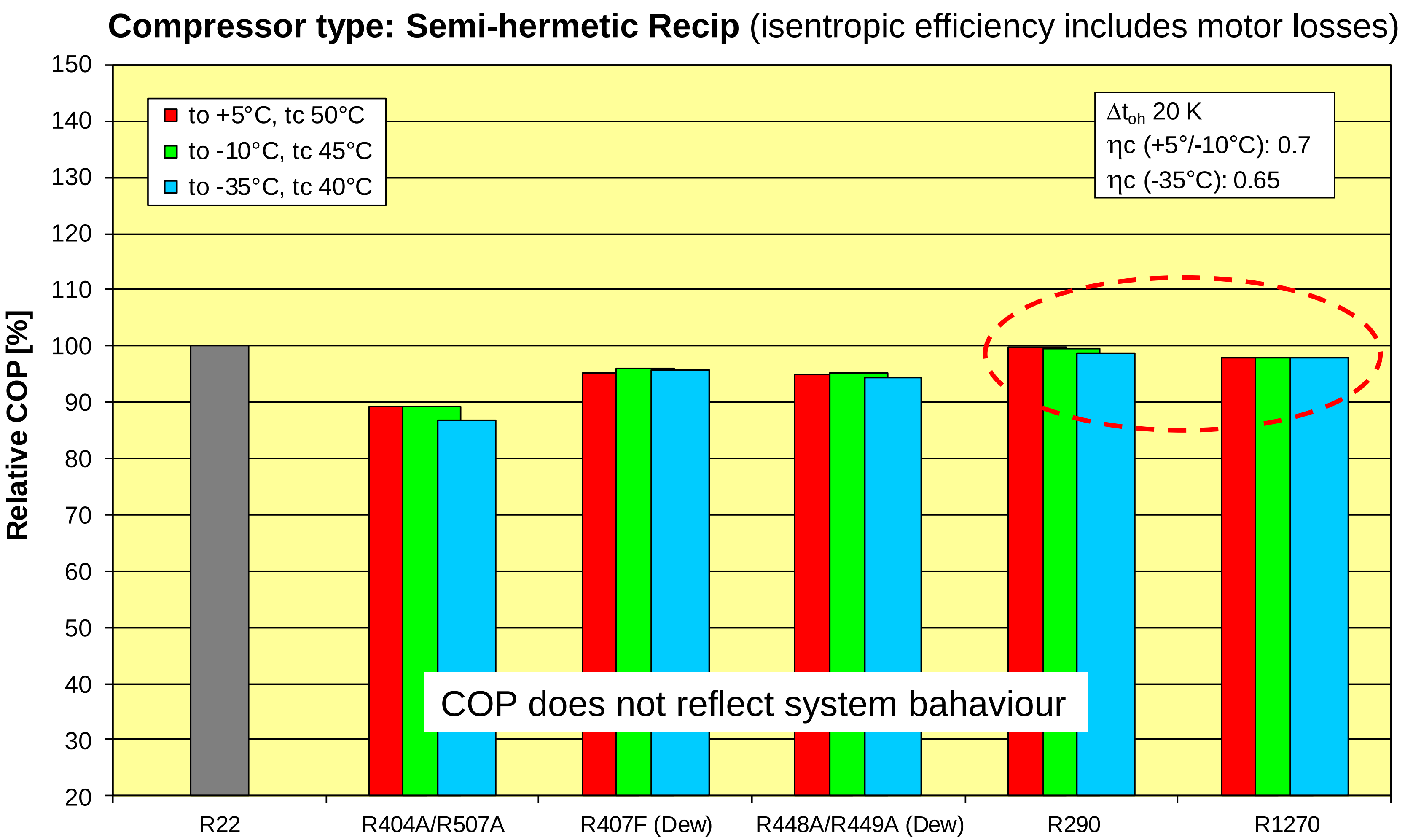


Mass flow of different refrigerants compared to R290
⇨ Identical refrigerating capacity



Liquid volume flow of different refrigerants compared to R290
⇨ Identical refrigerating capacity

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



R290 and R1270 Properties and Their Impact (3)

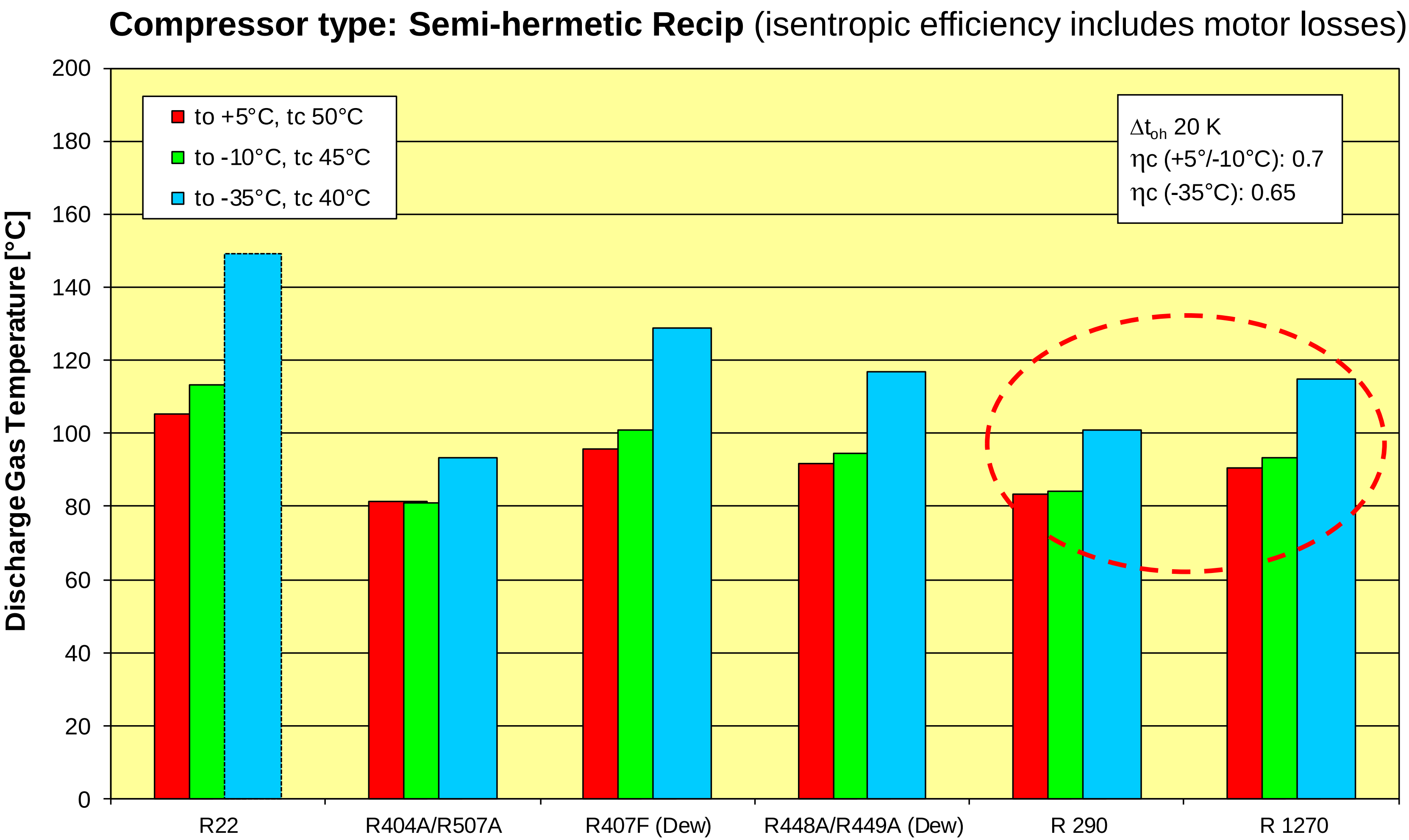
- Low discharge gas and oil temperatures (low c_p/c_v)
  - Moderate thermal load even with high pressure ratio (LT single stage)
- High critical temperature (96.7 / 91.1°C)
  - Favorable compressor and system COP also at high condensing temperatures and lift conditions

R290 and R1270 Properties and Their Impact (4)

- Good heat transfer due to intensive boiling and excellent solubility and miscibility with oil
  - Single fluids ⇨ no temperature glide
  - Good oil transport, low viscosity also in superheat section of evaporators
- Material compatibility similar to R22 and HFCs
  - Elastomers/plastics ⇨ some stronger limitations with R1270

    (see also “Forschungsrat Kältetechnik“ Research Report FKT61_99)

Comparison of Discharge Gas Temperatures with Single Stage Operation



Resulting Design and Layout Criteria (1)

- Reduced cross sections in HX, suction and discharge lines vs. R22 / HFC
  - Due to far lower vapour density / pressure drop
- Identical dimensions of liquid line as with R22
  - Higher liquid volume flow but less pressure drop ⇨ lower density
- Potential for minimum refrigerant charge
  - mass 40..60% vs. R22 / HFCs

Resulting Design and Layout Criteria (2)

- Select HX and line components according to mass and volume flow
  - Evaporator: e.g. injection distribution, pipe length and pipe geometry
    - Danger of uneven distribution and liquid overfeed in part load
  - TXV / EXV ⇨ capacity* vs. R22 − same nozzle (bulb charge adapted):
    - R290 ≈ HT / MT: 0..+5% // LT: -2..+2.5%
    - R1270 ≈ +13..18%

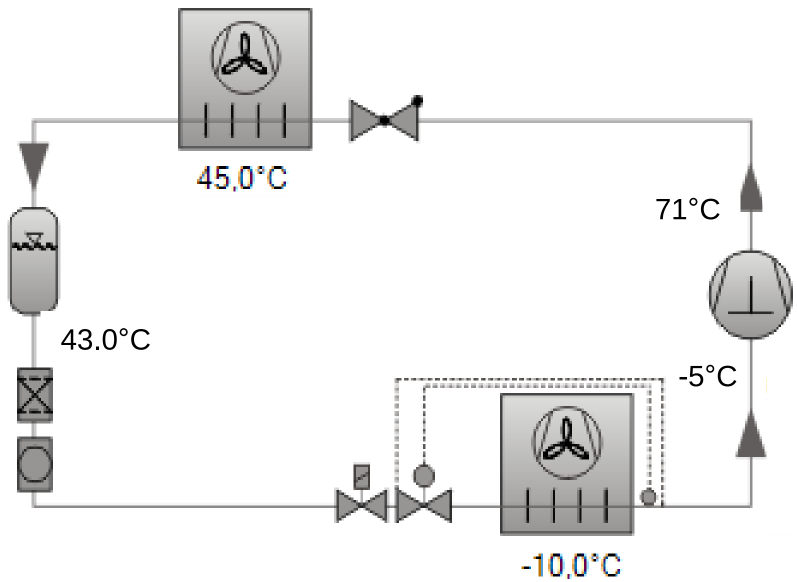
  Higher numbers with lower condensing temperatures (15 K < reference tc)

* Source: Danfoss / Honeywell calculation methodology

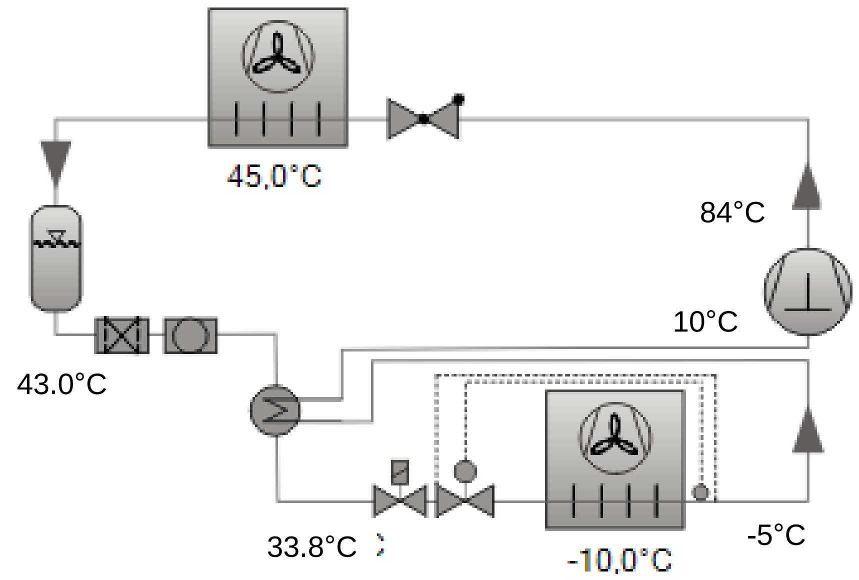
Resulting Design Criteria and Measures (3)

- Preferred use of liquid/suction line HX ⇨ target $\Delta t_{oh} \approx 20$ K (HT, MT)
  - Benefit in capacity, COP and reduced oil dilution ⇨ higher oil temp

Examples of Cycle Configuration (R290)

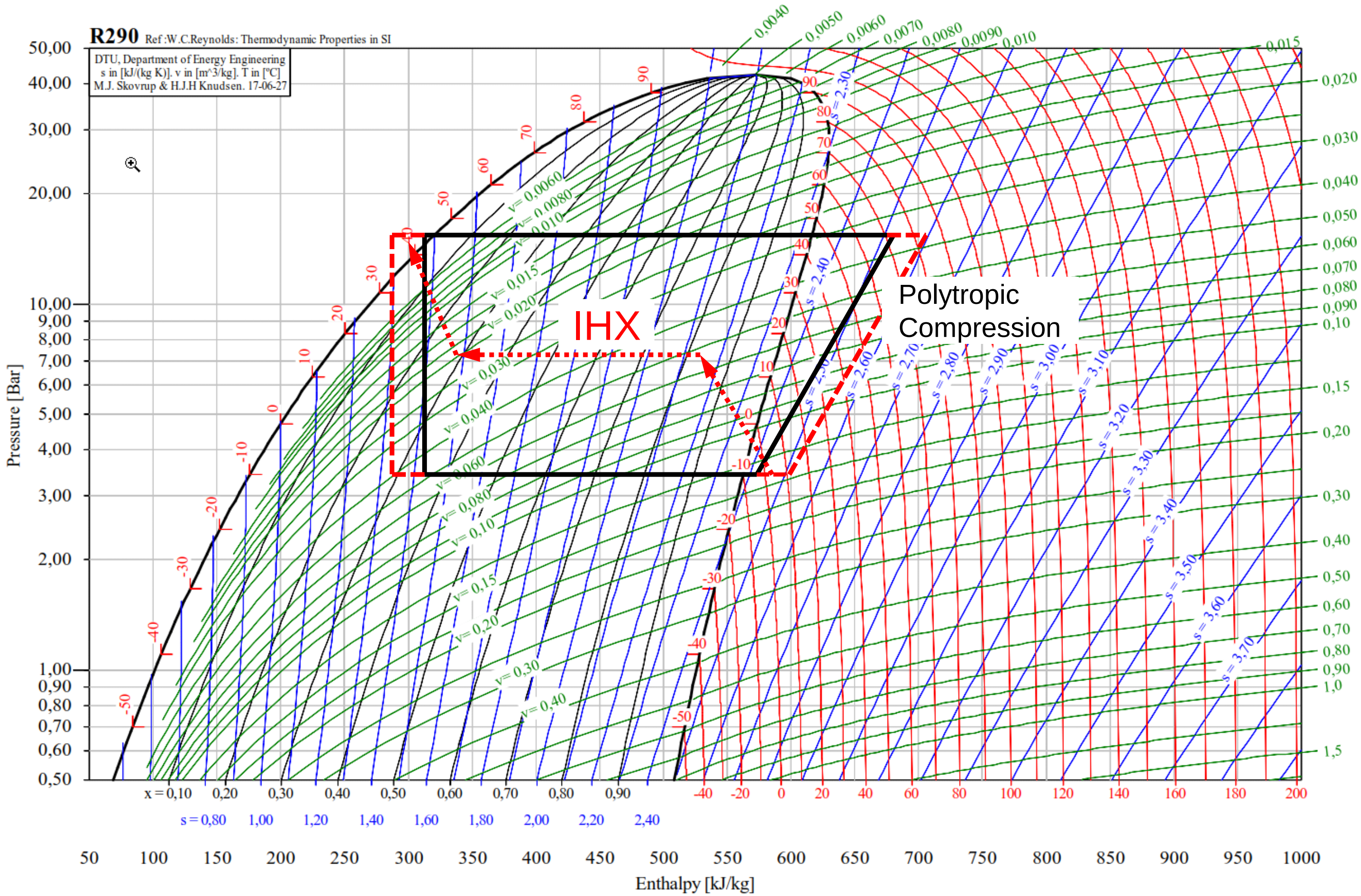


w/o IHX



w/ IHX ⇨ COP ≈ +5..6%
incl. higher isentropic eff. of compressor

R290 Cycle Diagram – Capacity and COP Increase by IHX



Influence of Hydrocarbons on Compressor Lubrication (1)

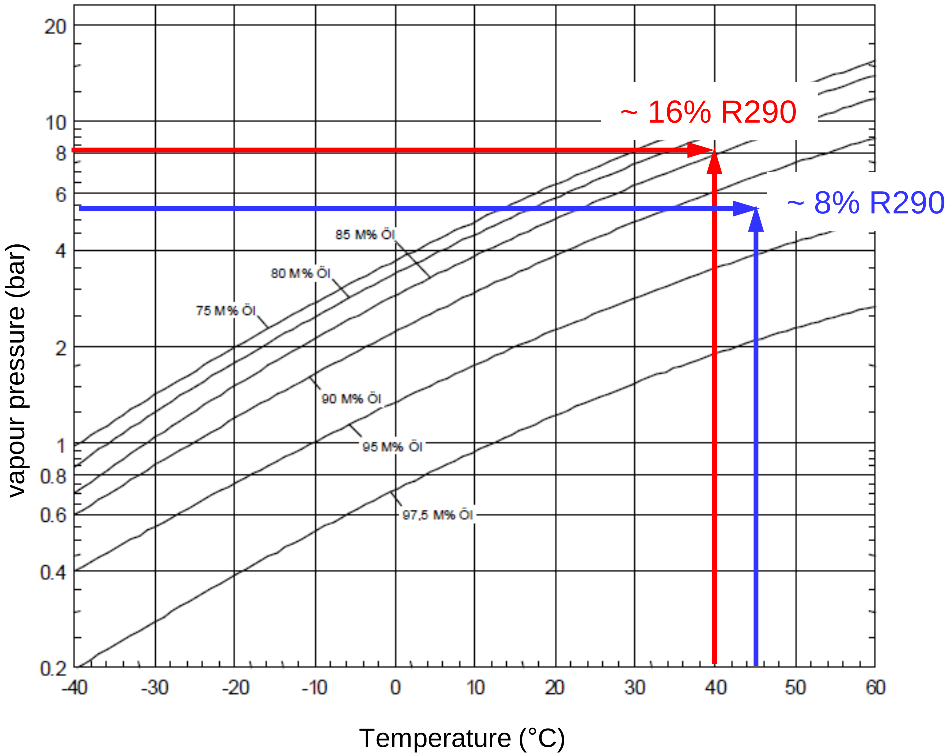
- HC's have exceptionally good solubility/miscibility behaviour in oil especially with lubricants of low polarity like MO
  - Strong oil dilution / reduced viscosity / solvent effect
  - Strong degassing and foaming with pressure fluctuation
- Operating temperatures (discharge gas, oil) remarkably low
  - Increased amount of dissolved HC in oil especially at small pressure ratios, high evaporating temperatures and low superheat

Influence of Hydrocarbons on Compressor Lubrication (2)

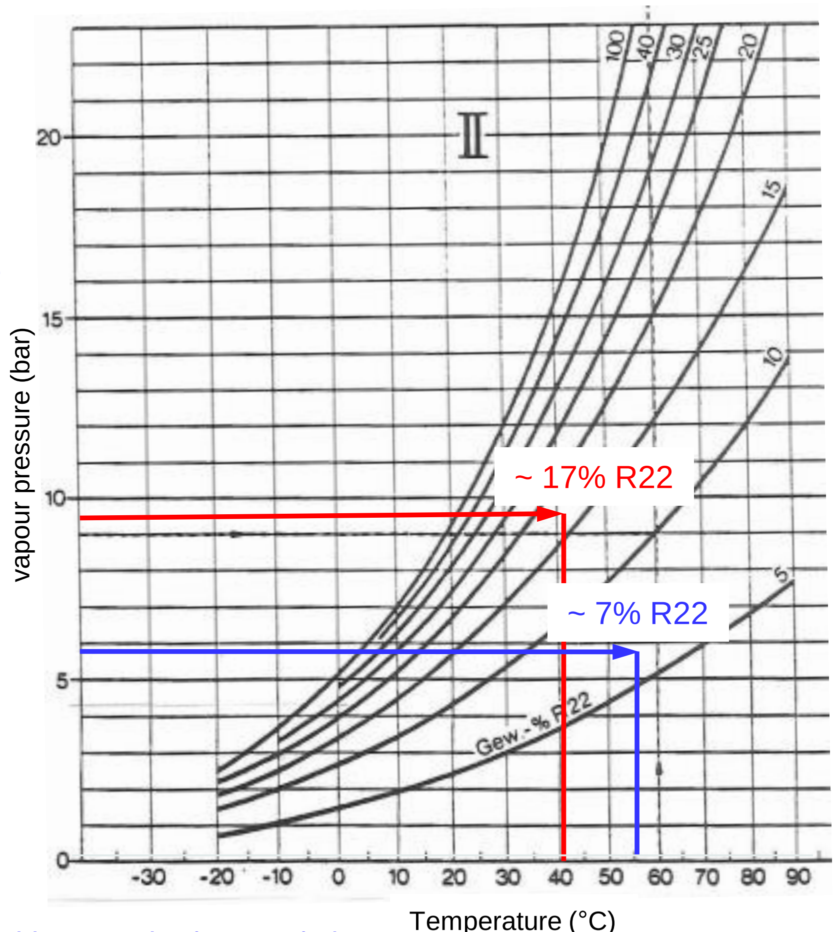
- Solubility (oil/refrigerant) usually measured in **“mass %“**
  - With MO no severe difference in mass % vs. R22 or HFC‘s w/ POE − however …
  - Low liquid density of HC‘s (40 – 45% vs. R22) leads to more than double volume of dissolved refrigerant in oil
  - Far stronger oil dilution than with R22 and HFC‘s

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

MO VG 68 cSt – **R290**



MO VG 68 cSt – **R22**



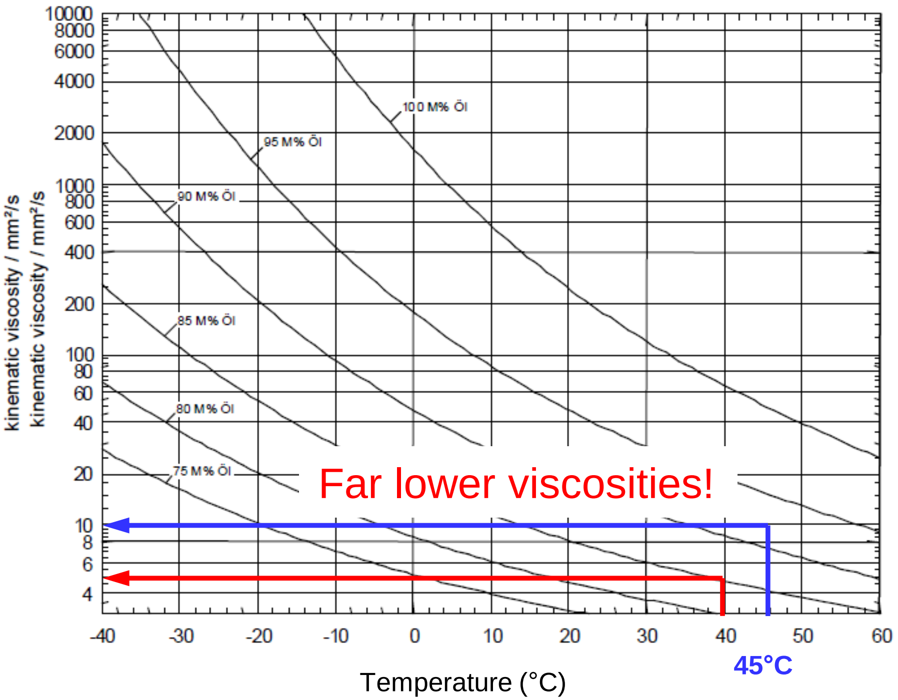
Standstill @ 20°C

Operation @ to +5°C

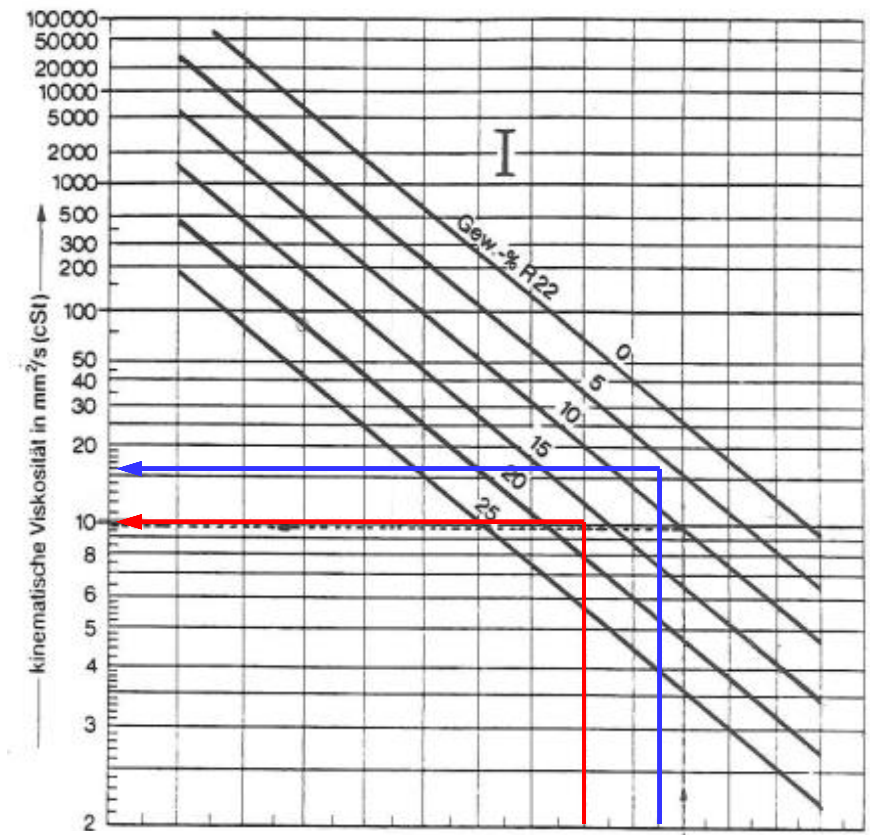
Oil temp R22 10 K higher than with R290 (55° vs. 45°C)

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

MO VG 68 cSt – **R290**



MO VG 68 cSt – **R22**



40°C **55°C**

Temperature (°C)

Standstill @ 20°C

Oil temp 40°C

Operation @ to +5°C

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

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Lubricants: Required Measures for Reliable Operation (1)

- Best suitable lubricant − acc. to compressor manufacturer specification
  - Usually higher basic viscosity and/or lubricants with higher viscosity index (Vi) or high polarity (lower solubility)
- Minimum refrigerant charge
- Generously sized crankcase heater
- High suction pressure during standstill periods?
  - Pump down cycle may become necessary
- Possible insulation of compressors in case of outdoor installation

Lubricants: Required Measures for Reliable Operation (2)

- Superheat in MT & HT should be 20 K or higher, LT > 10 K
  - Liquid/suction line heat exchanger ⇨ especially AC & Heat Pumps
- Measures against ”wet operation“ during start and operation
  - Avoid refrigerant migration to suction side during standstill
  - Maintain sufficiently high suction gas superheat

Summary

- The extended use of R290 and R1270 in commercial RAC systems can be seen as one of the promising future solutions
- High system efficiency and reliability can be reached with component and system design precisely matched to the specific refrigerant properties
- This as well includes to consider the necessary measures with regard to lubricant related issues

Example of Chiller / Heat Pump Unit

- Outdoor Units with a cooling capacity range up to 190 kW
  - Reversing cycle chiller / heat pump unit
  - 3-pipe water loop
- Refrigerant: R290/1270 blend

Source: Unichemie NL

Thank You for Your Attention!

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