High Pressure Compression and Design

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Burckhardt Compression

EFRC

EFRC training on challenging conditions

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Challenges in high-pressure compression

- High gas force → small piston area required
- Reduced compressibility of gas under high pressure → high forces on valves
- Sensitive gas properties close to the critical point
- High static pressure over cylinder packing
- Lubrication problem due to reduced oil viscosity

Challenges in supercritical compression

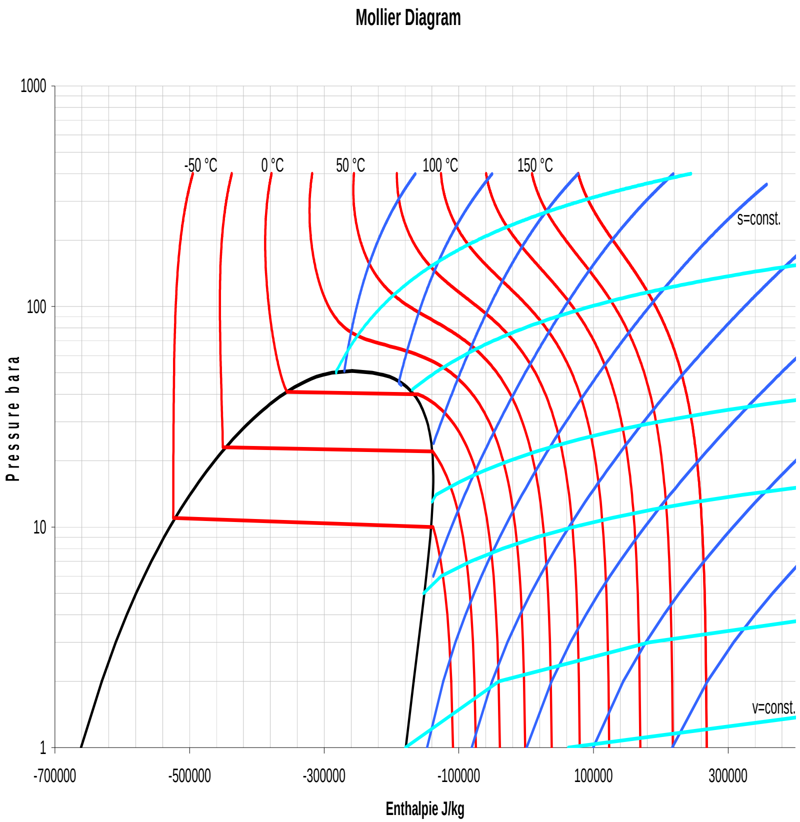
- Large change in temperature after isenthalpic expansion
- Density is very sensitive to temperature
  - Example:

    2-stage compression from 70 to 300 bar:

    $Ts_{1/2}$=40 °C → interstage pressure (Pd1)= 195 bar

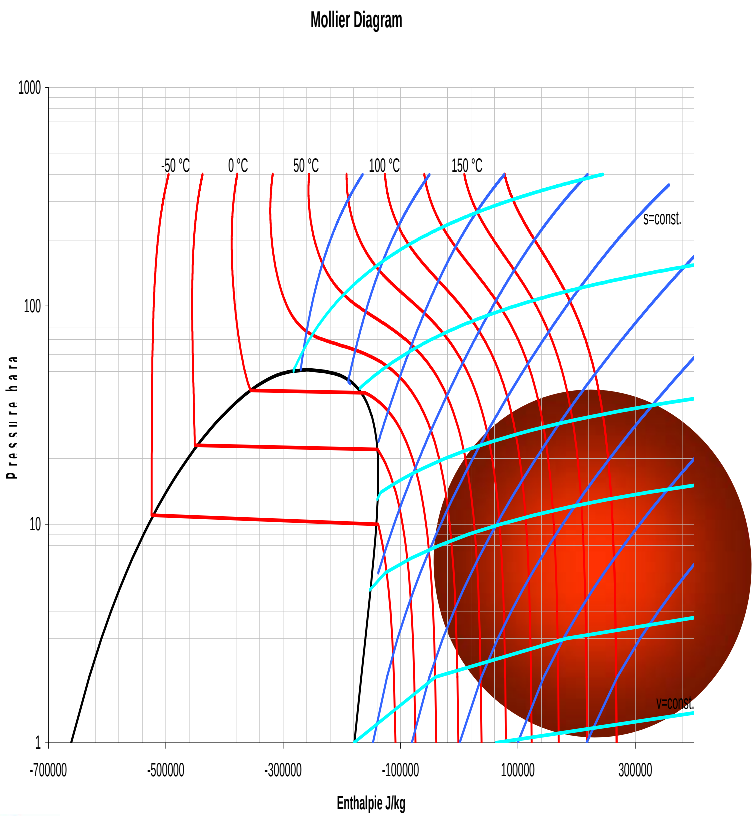
    Ts_1 changes to 35 °C → Pd1 = 260 bar

Real Gas Properties: Mollier (log*p*/enthalpy) Diagram



- Common representation of gas properties in liquid-/mixed-/gas-phase
- Plotted are lines of equal temperature, equal specific volume and equal entropy
  - Isentropic change of conditions represents an idealized change in volume with constant entropy → ideal compression / expansion

Real Gas Properties



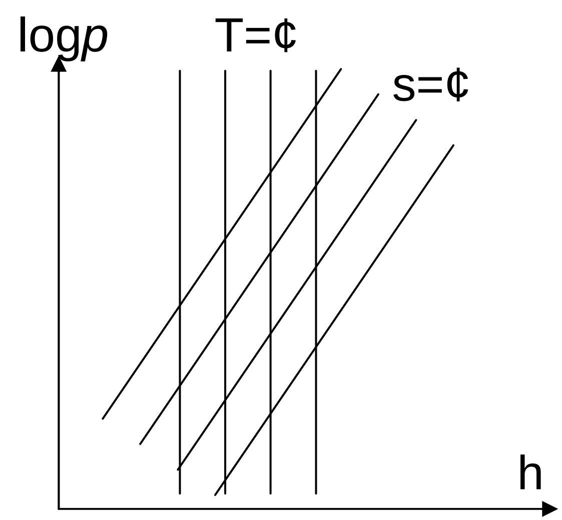
Ideal gas region:

$$pV = mRT$$

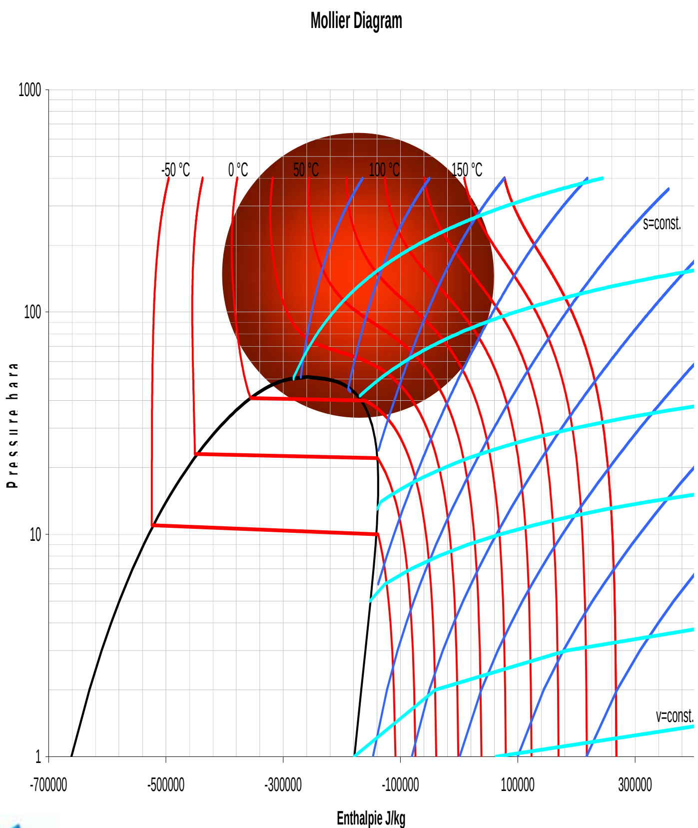
$$h \approx T$$

$$\kappa = \frac{c_p}{c_V} = 1.1 - 1.7$$

$$p_2 = p_1 \left(\frac{V_1}{V_2} \right)^{\kappa} ;\ if\ V_2 = \tfrac{1}{2} V_1 \rightarrow p_2 = 2.14\, p_1 - 3.24\, p_1$$



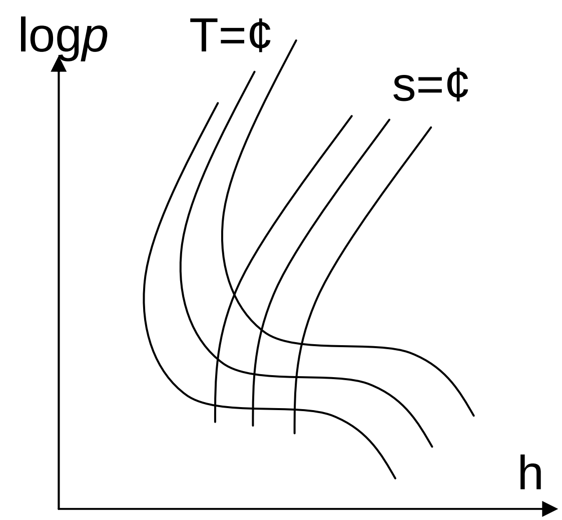
Real Gas Properties



Supercritical region:

$\kappa \; up \; to \; 7.5$

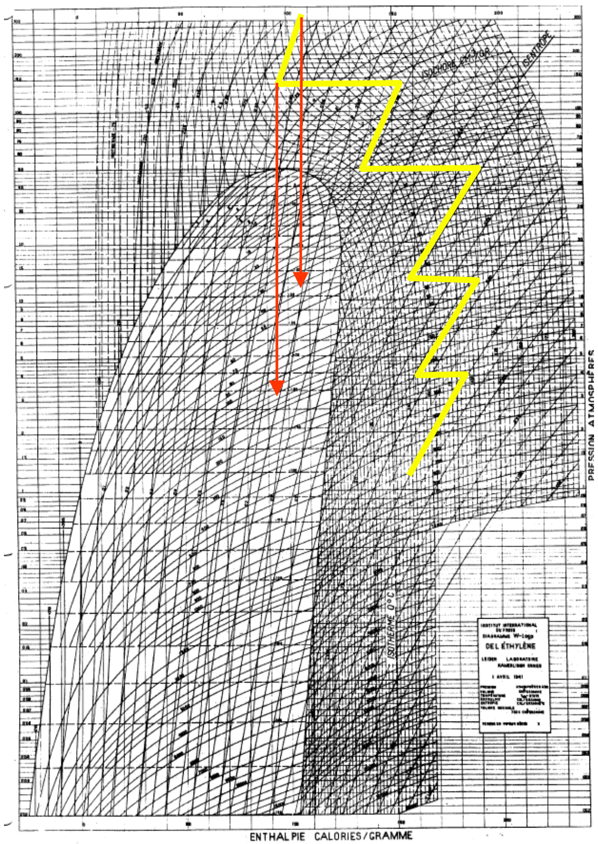
$$p_2 = p_1 \left(\frac{V_1}{V_2} \right)^{\kappa} ; \; if \; V_2 = 0.9 V_1 \rightarrow p_2 = 2.2 p_1$$



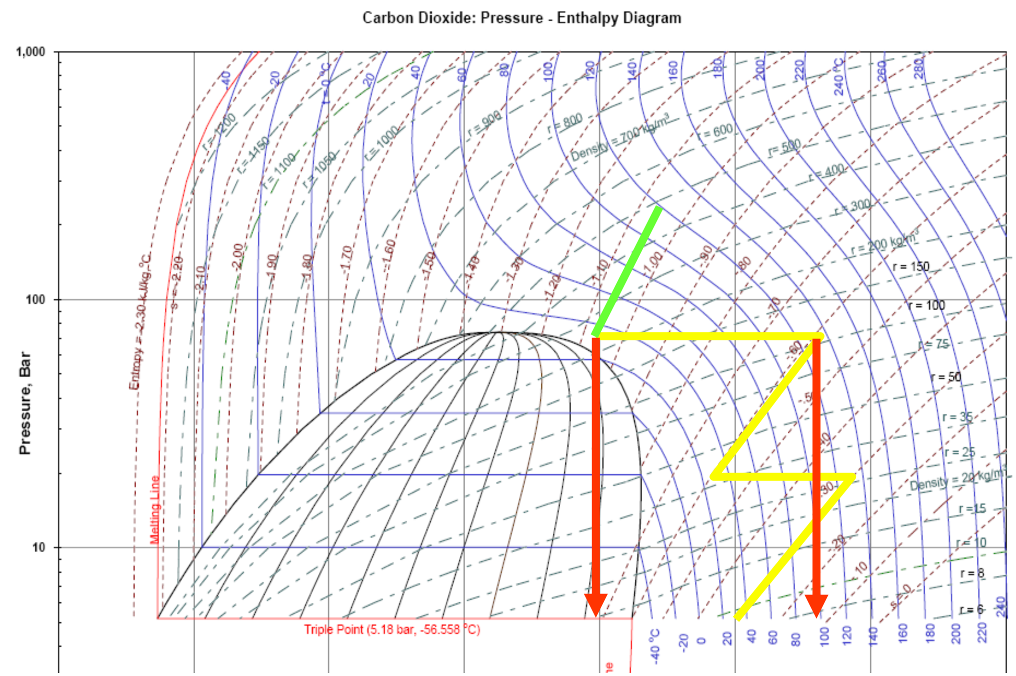
Supercritical compression

- Common examples

Ethylene:



Carbon dioxide:



Impact on Compressor Parts

Sealing System: Condensation in packing

→ Design requirement:

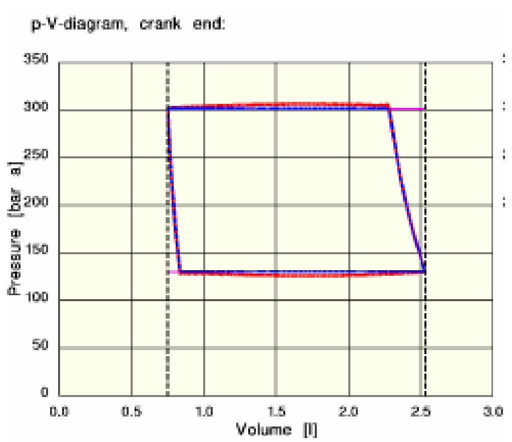
- Heated packing
- Increased suction temperature

Valves: The poor compressibility leads to

– Short reaction time

– High impact velocities

– High gas velocity

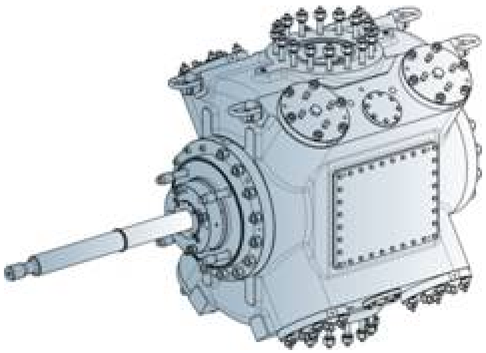


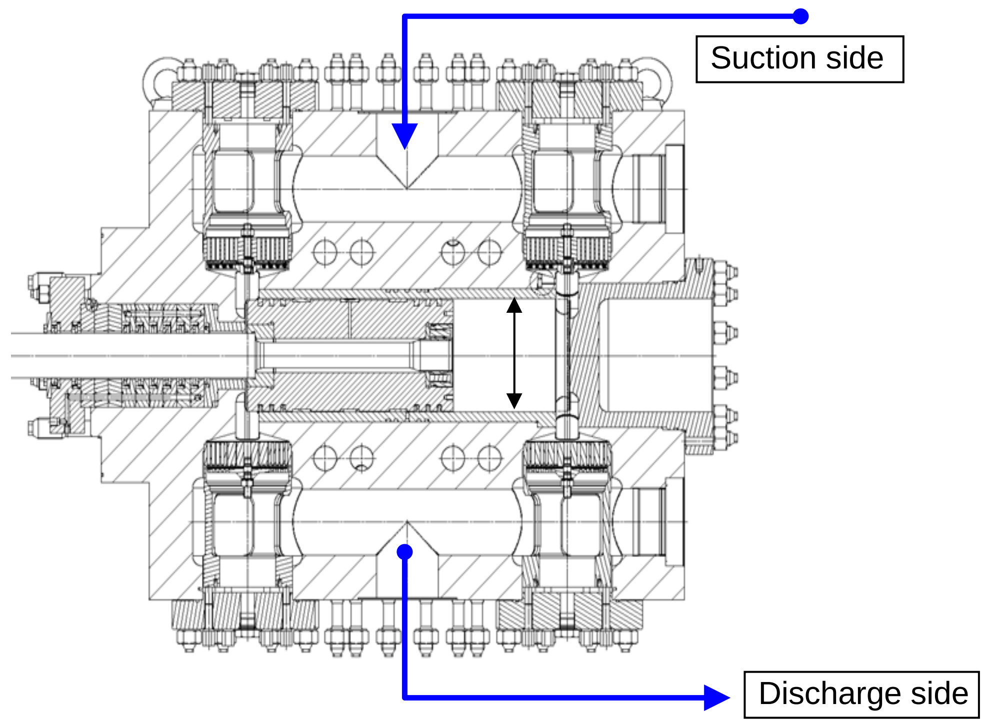
High pressure cylinder

- Reasons for special design:
  - – Exceeded allowable rod load
  - – Over critical compression
    - Leakage problem
  - – High pressure on packing
  - – Insufficient rod reversal

High pressure cylinder

- Double acting piston

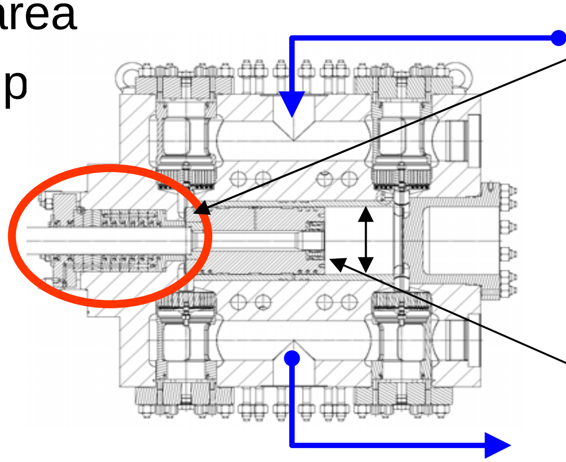




High pressure cylinder

- Problems with double acting pistons in high pressure applications:
  - Lubrication problems at the crosshead pin due to insufficient rod reversal
  - Very high loading due to unequal piston area
  - High differential p packing

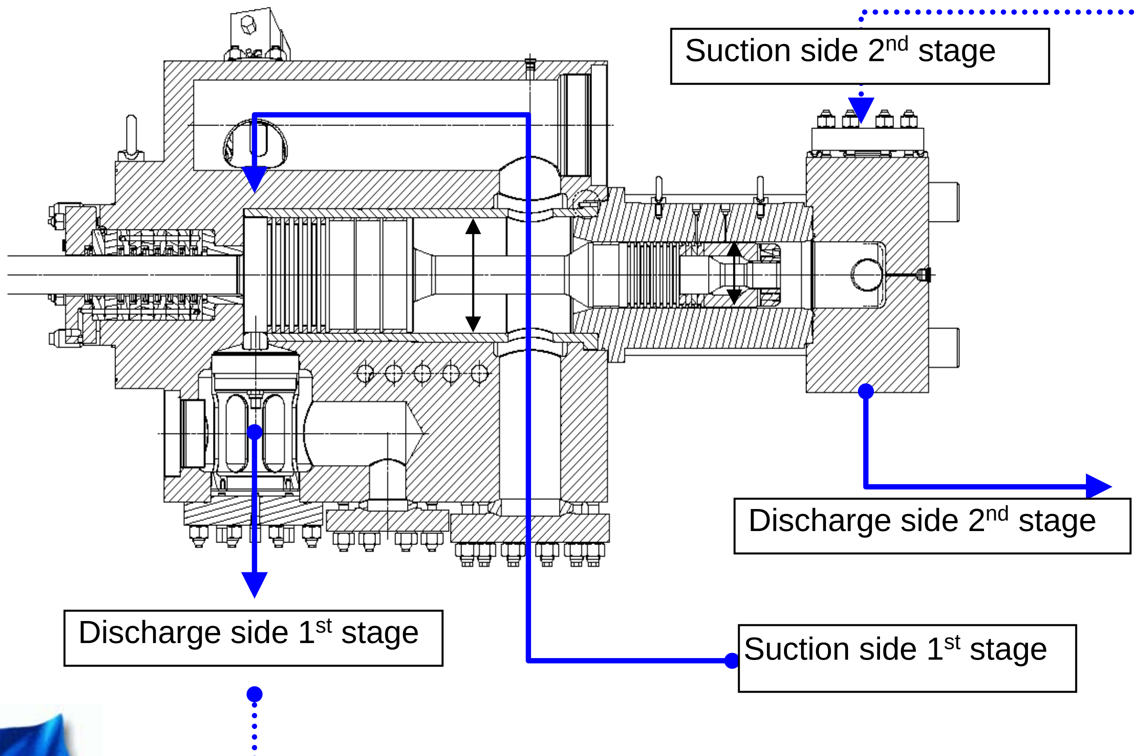
$$A_2 = \frac{D^2\pi}{4} - \frac{D_{rod}{}^2\pi}{4}$$



$$A_1 = \frac{D^2\pi}{4}$$

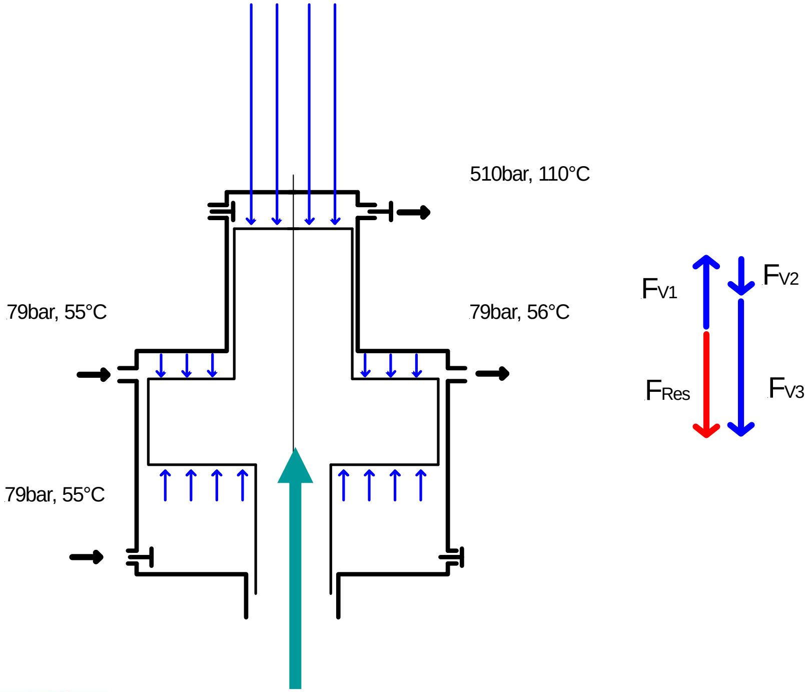
High pressure cylinder

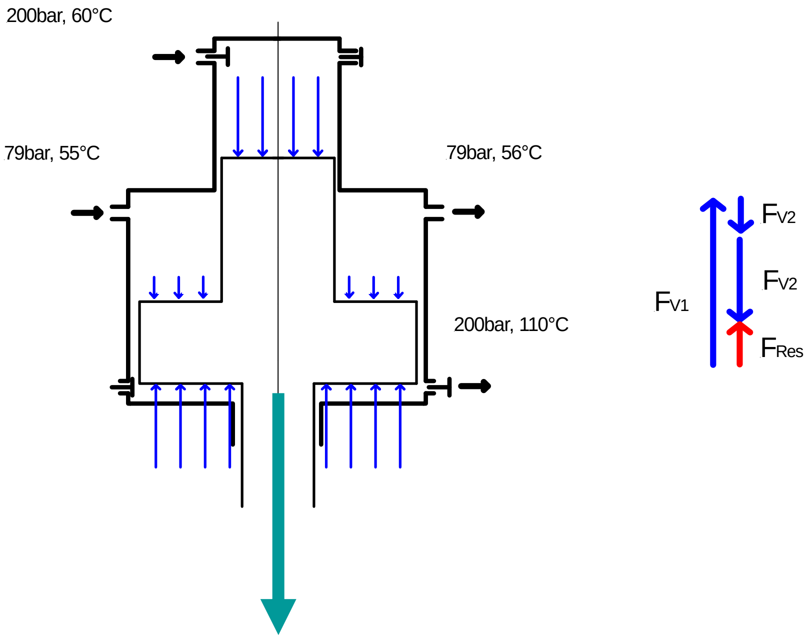
- Step-Piston



High pressure cylinder

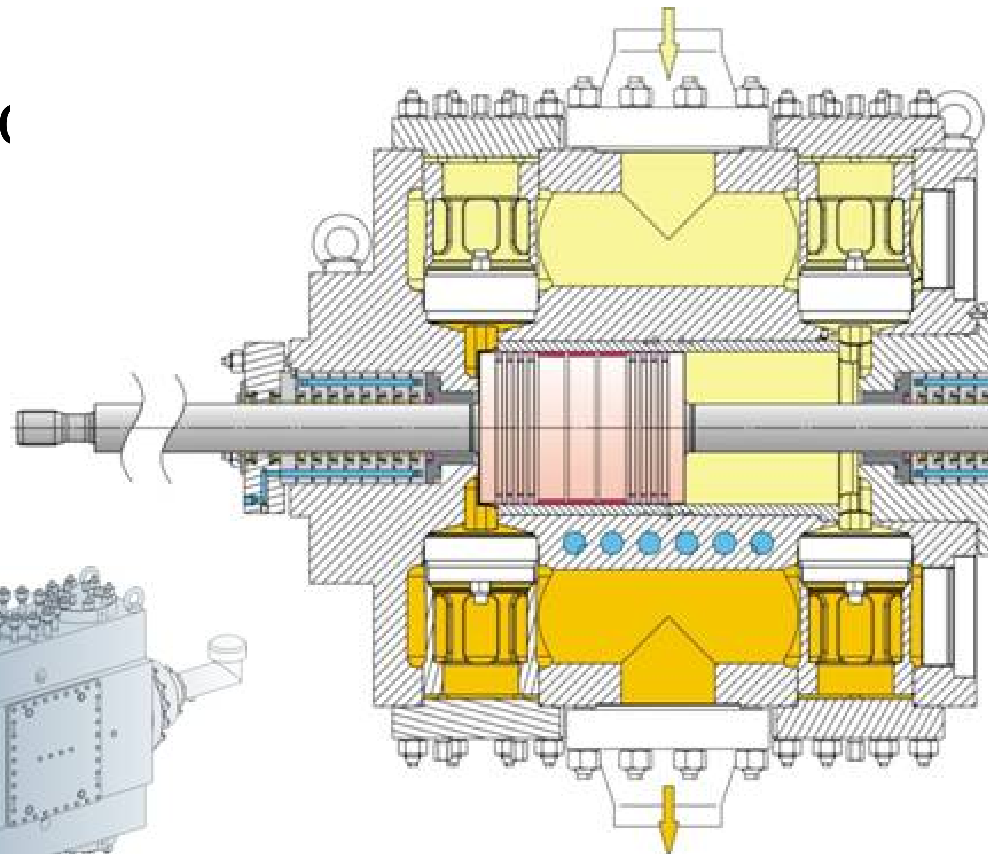
- Step-Piston

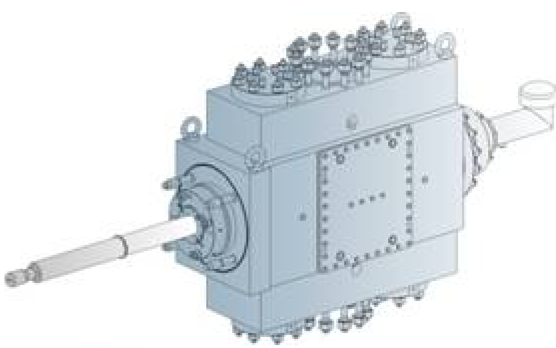


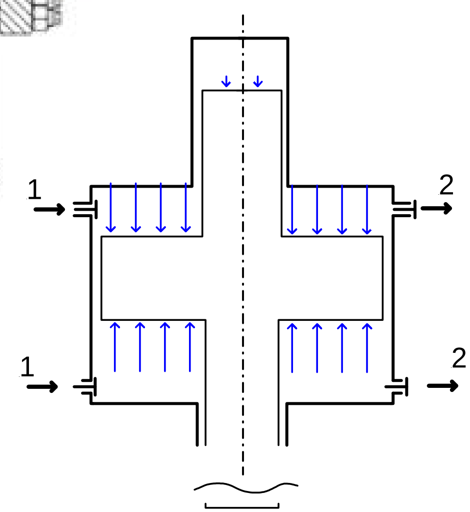


High pressure cylinder

- Tail-Ro

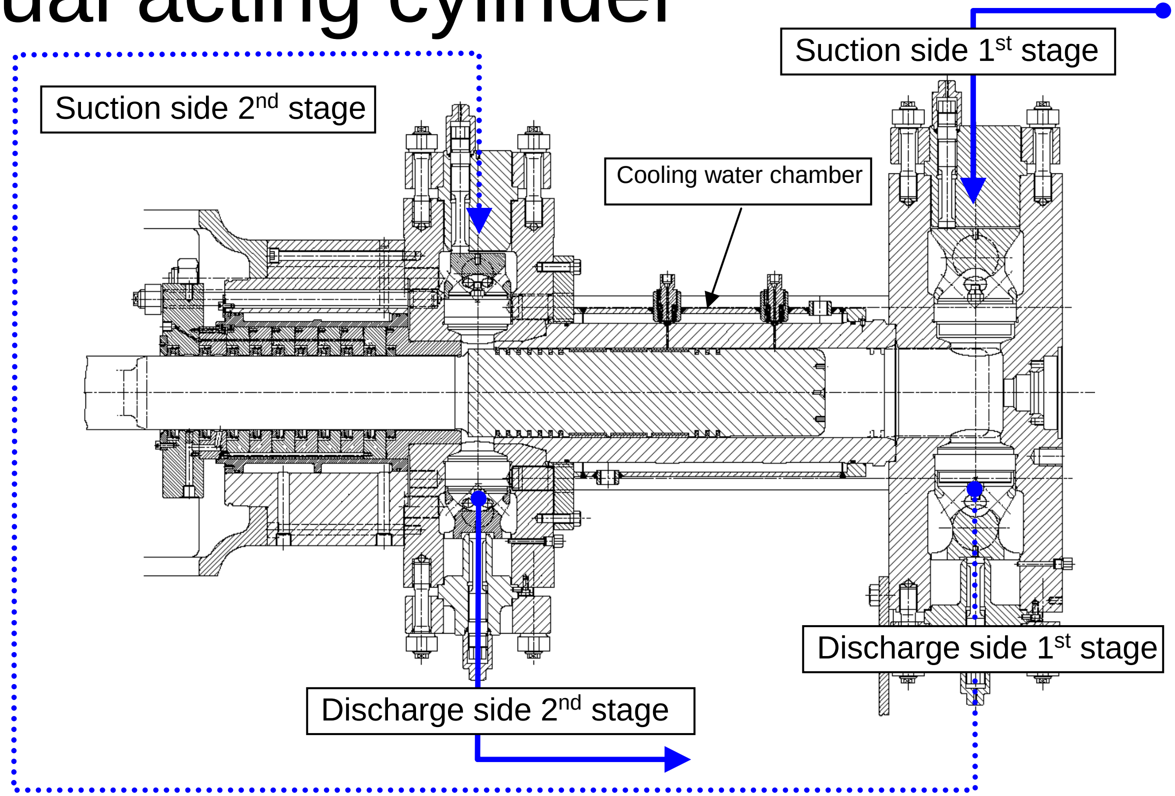






High pressure cylinder

- Dual acting cylinder



High pressure cylinder design - Comparison

	Double acting piston	Step-piston	Tail-Rod	Dual acting piston
Forces	-- Unequal gas forces	+ Gas forces can be equalized	++ Symmetric design	+ Gas forces can be equalized
Reliability	+ Two sealing systems, no static load on piston sealing elements	+ Three sealing systems with reduced pressure difference	- Additional packing, no static load on piston sealing elements	+ Two sealing systems
Flexibility	- Sensitive to pressure variation → rod reversal / rod load	- Sensitive to changes in pressure /compression ratio → rod reversal / rod load	++ Symmetric design → wide range of operation conditions possible	- Sensitive to changes in operation data → rod reversal / rod load

Conclusions

- In supercritical compression applications small variations of the operation conditions may have major impact on the compressor.
- High pressure applications require special cylinder design. The choice should be made with respect to all possible operation conditions.

→ The quality of the compressor selection depends on the quality of the specified operation data.