EFRC Training Workshop
Basic training

Wearing parts

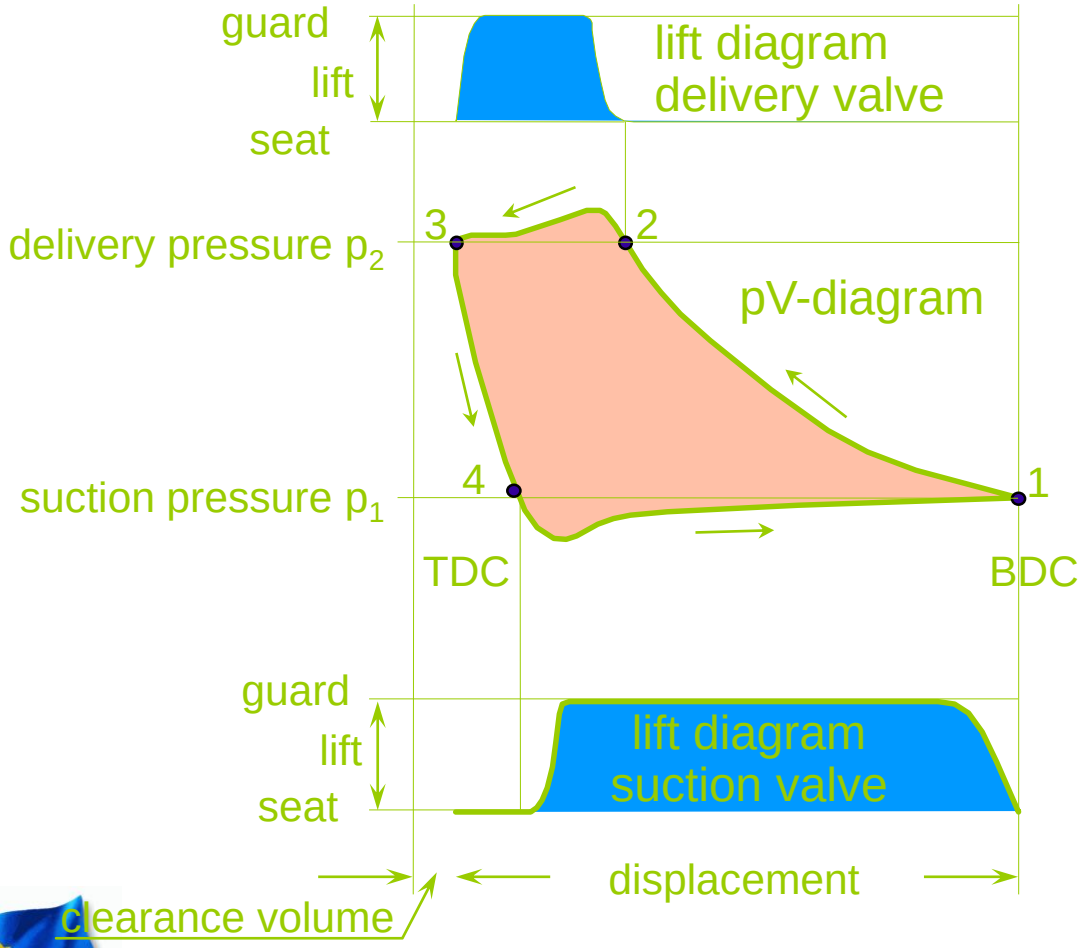
Christian Hold – HOERBIGER

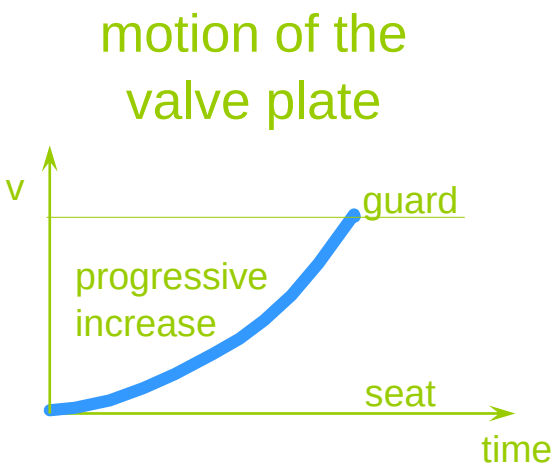
Contents

- Compressor valves
  - Fundamental operating principle & design criteria
  - Overview different valve designs
  - The best valve choice for the application
- Flow control
  - On / Off, variable volume clearance pockets
  - Stepless reverse flow control
- Rings & Packings
  - Fundamental operating principle & design criteria
  - Material selection, lube and non-lube operation

Valves for piston compressors

pV-Diagram and Lift Diagram





Valve Designs

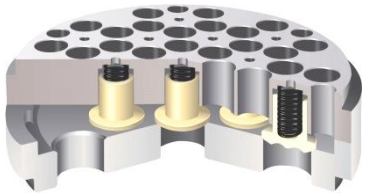
Valves with different types of sealing elements

Steel plates

Poppet valves

Plastic plates

Plastic profiled rings

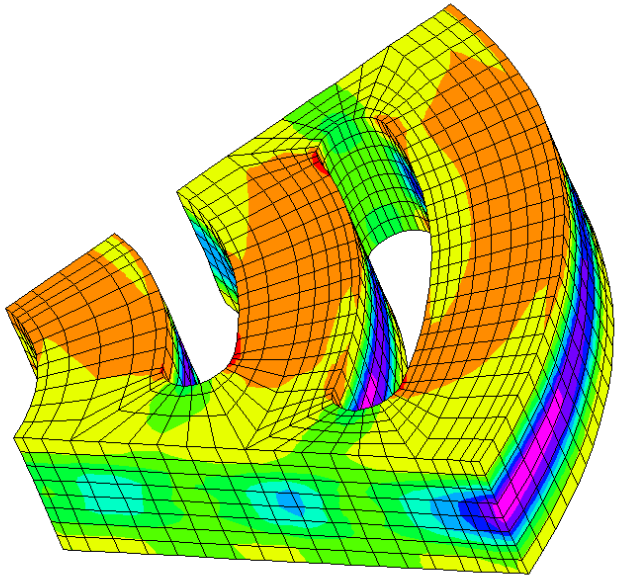


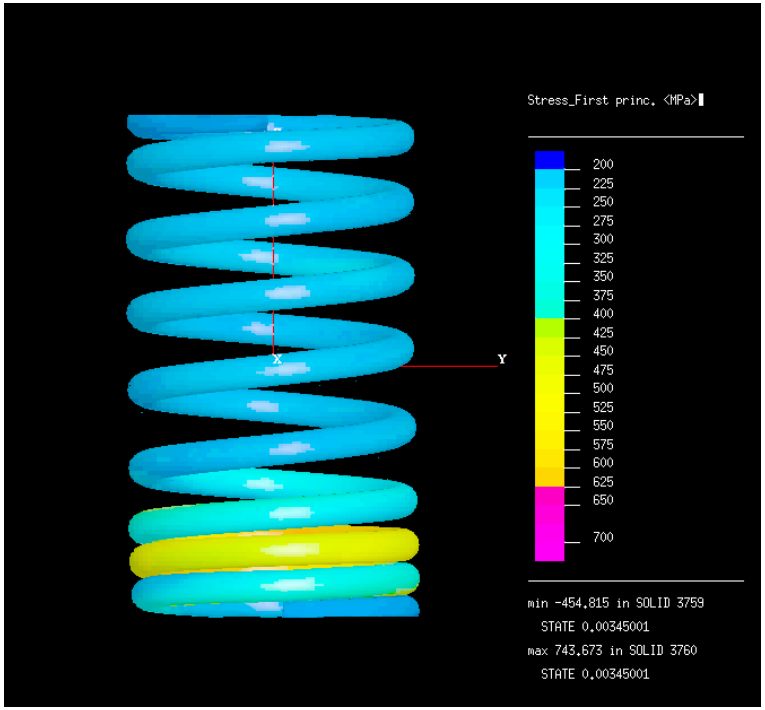
Valve Design

The impact velocity of the sealing element against the guard / seat is the most important design criteria for a compressor valve!

Stresses in the

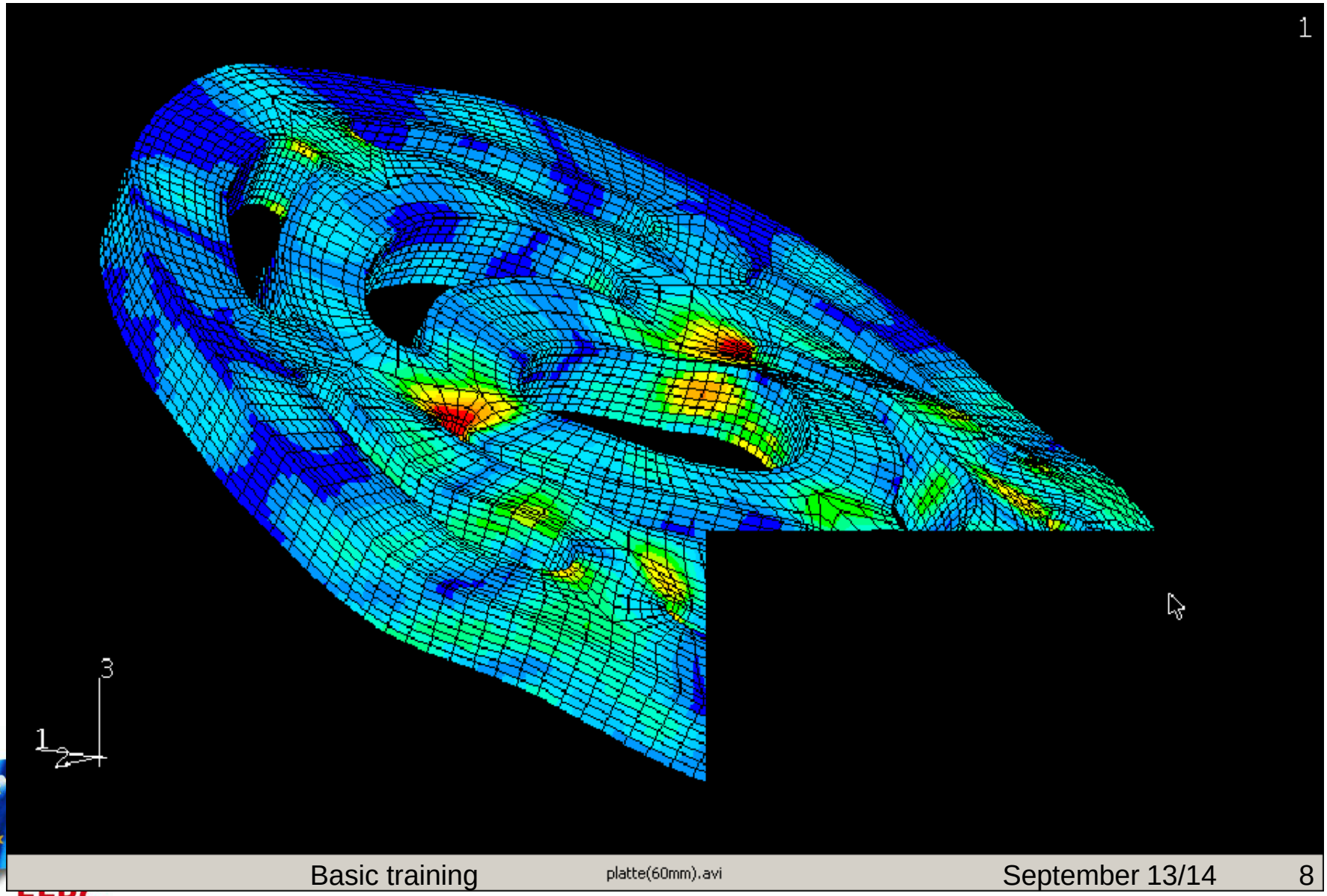
-Sealing Element and
-Closing Springs





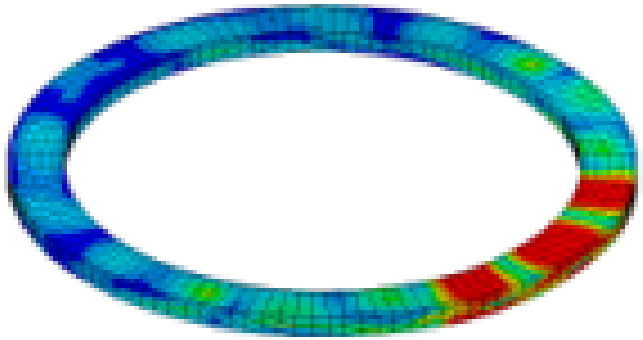
are directly proportional to the impact speeds!

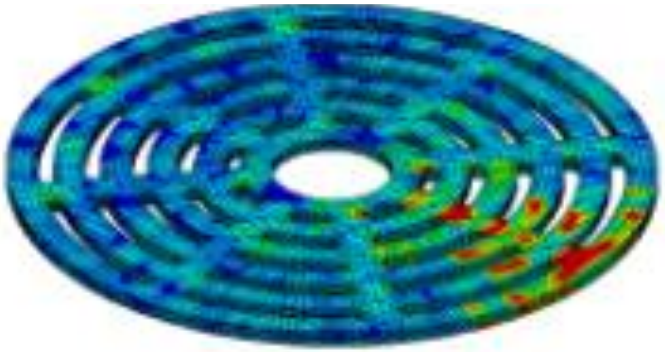
Impact at an angle – stresses in the sealing element



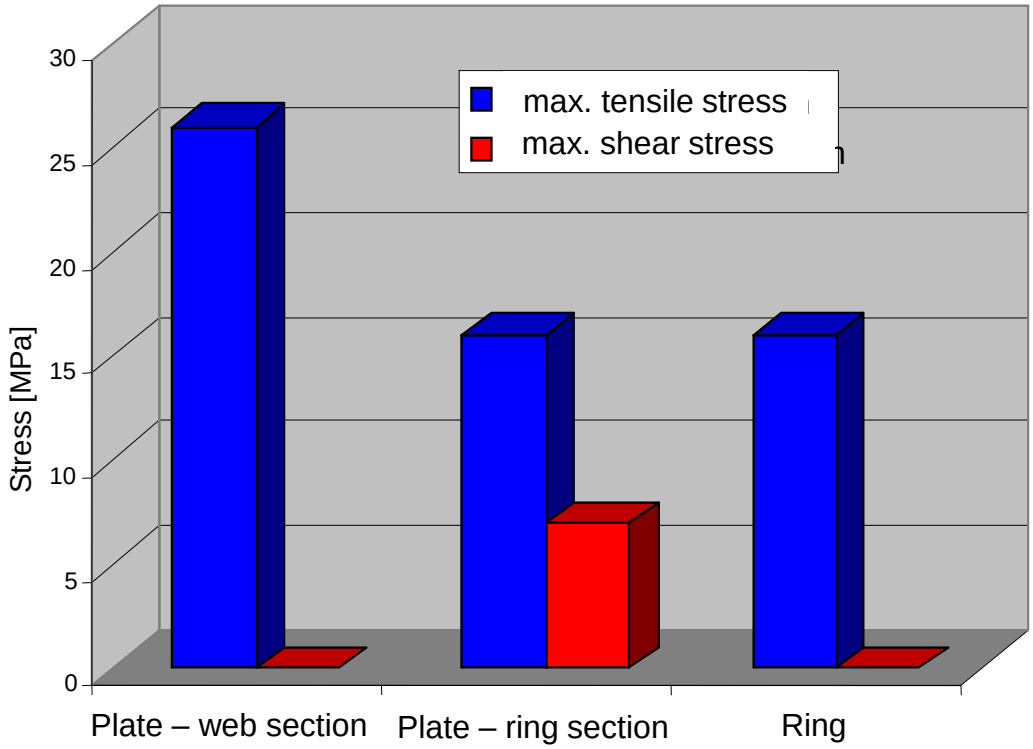
Advantages of ring valves

No stress concentration effects!





Stresses in plates and rings



What can be done – valve design

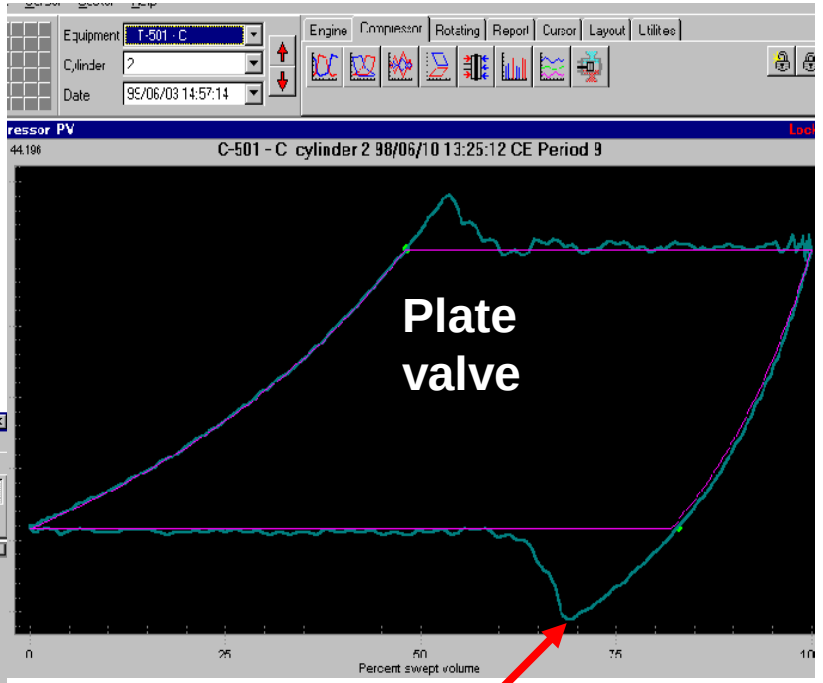
Hydrogen Compressor

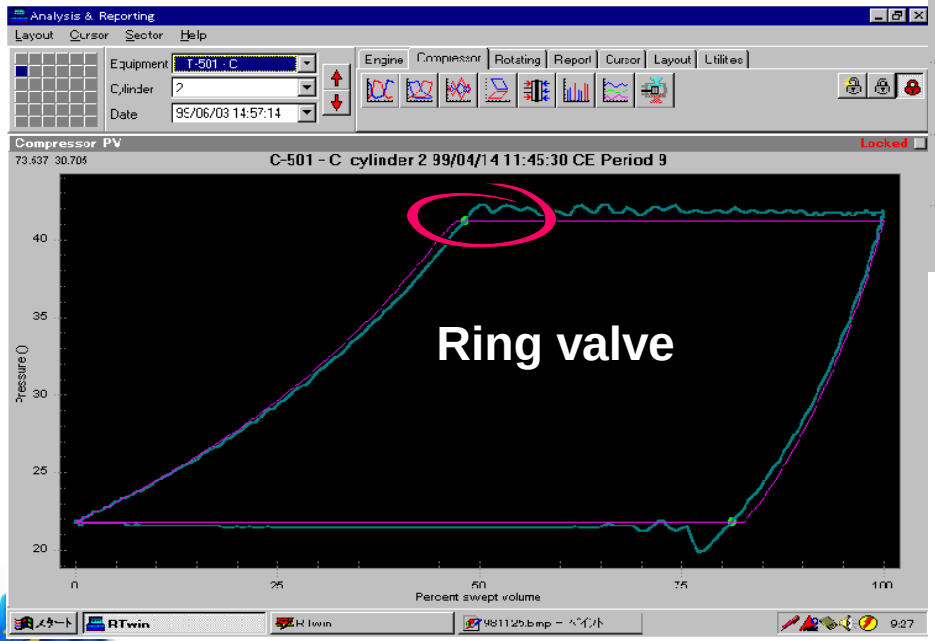
The problem:

Plate valve failing after short amount of time – pV reading revealed sticktion effects

The Solution:

Changed to ring valve -
lifetime now 16.000 h





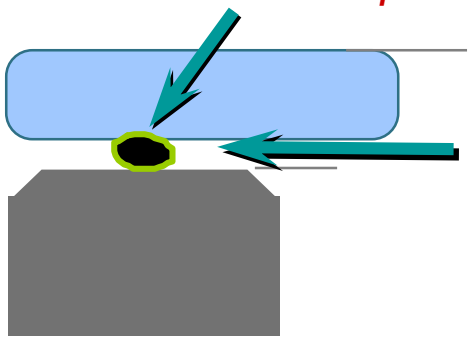
Sticktion effect:
huge pressure overshoot due to delayed opening of sealing element

The profiled geometry of ringvalves (line contact) leads to less sticktion

What can be done – valve materials

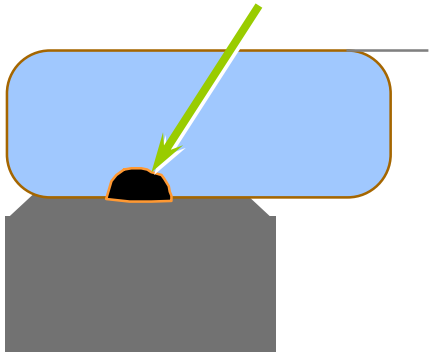
Resistance to dirt particles – e.g. polypropylene

the steel valve plate is hard - danger of breakage



the valve seal is not tight

The plastic valve plate can deform,
the particle is embedded



Plastic valve plate with embedded particles

What can be done – valve design

Operating Company

Site	Map Ta Phut, Thailand
Service	CCR Net Gas Booster

Compressor

lubricated

Operating conditions

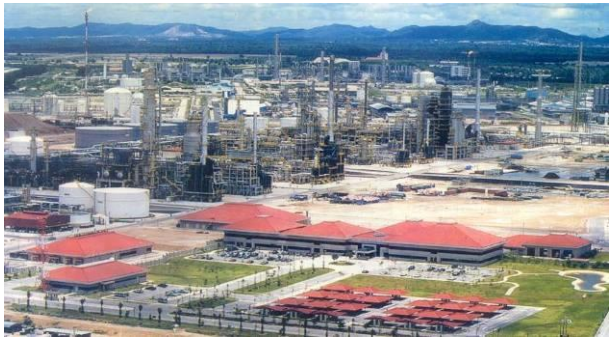
Gas	Hydrogen Rich Gas (MW 8)
Suction Pressure	5,6 bara
Final Pressure	47,5 bara

The Problem:

originally fitted with non-metallic plate valves
Discharge valve failures after
1 day to 2 months operation due to severe liquid carryover

The solution:

Ringvalves fitted
Valve run time improved to 26000 h

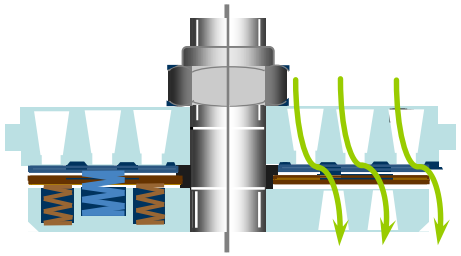


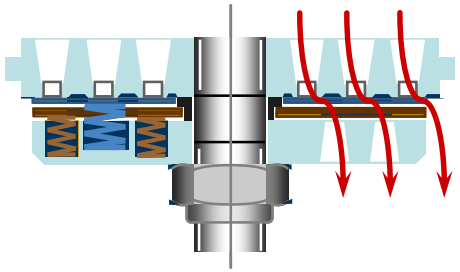
In ringvalves each ring can move independent from the others, making it easier to cope with liquid slugs

Valve losses

Valve losses are losses incurred in the valves

suction valve = intake

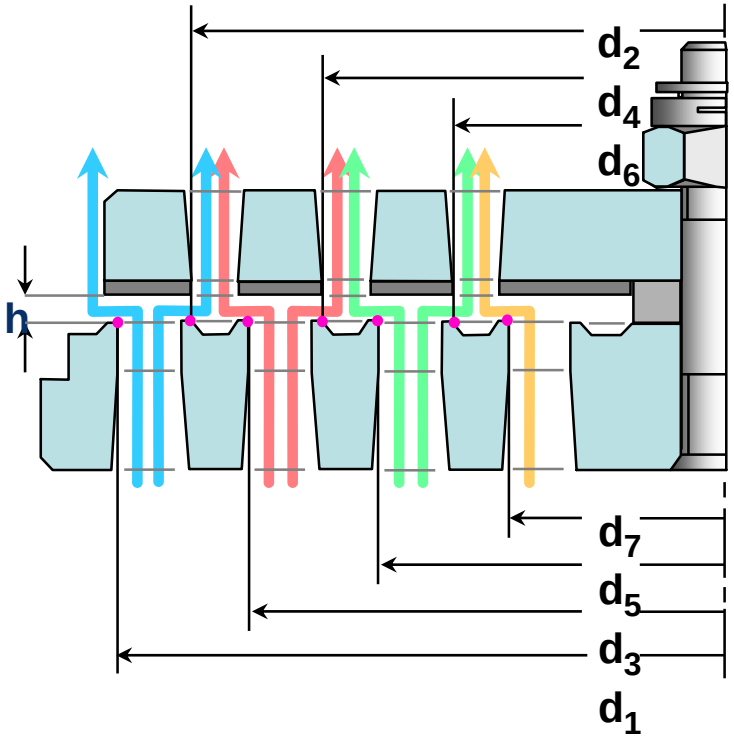




delivery valve = outlet

The passage area f_e is the smallest geometric opening in the valve

$f_e = (d1 + d2 + d3 + d4 + d5 + d6 + d7). \pi . h$



$d_1 \ldots d_7$ seating ledge diameter

h ..... valve lift

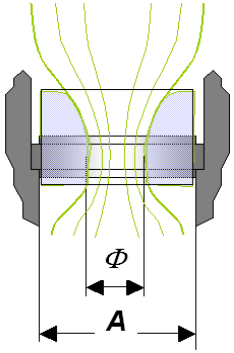
π 3,14159

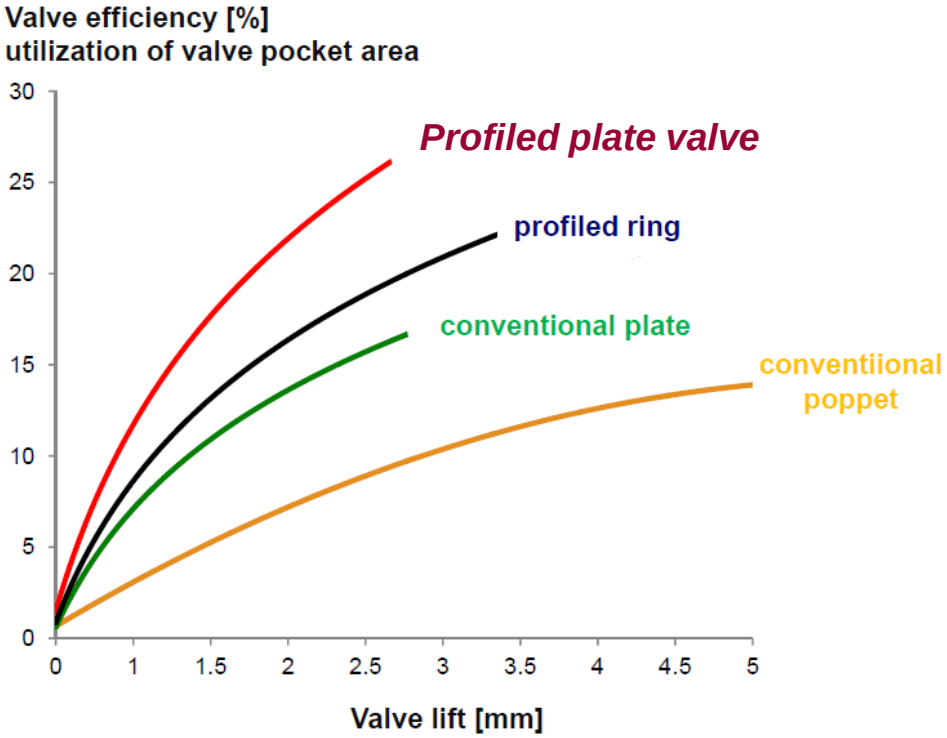
Efficiency – today's valve portfolio

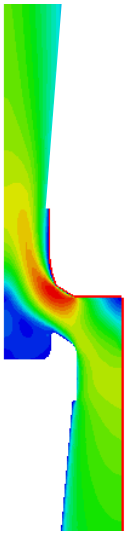
Latest generation profiled plate & ring valves reach the 25% efficiency level

$\Phi = \alpha_\Phi * A$

α_Φ .. Valve efficiency

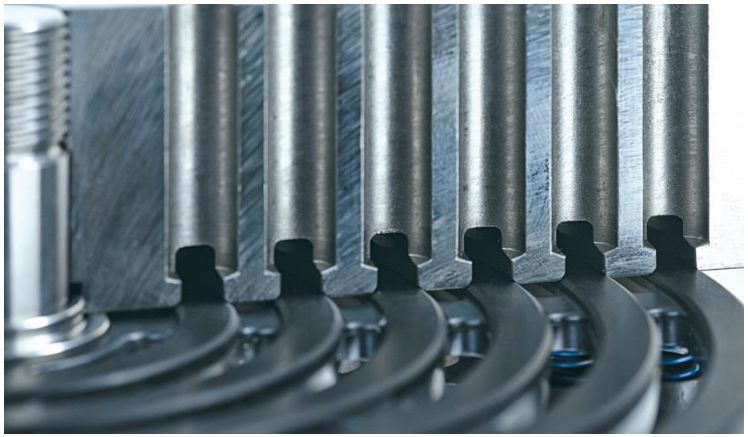


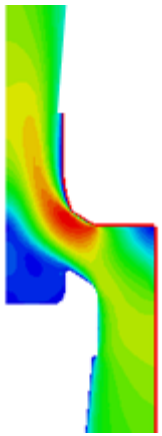




Profiled Valve Plate

Profiled valve plates combine the advantages of a polymer plate and the profiled ring geometry!





Characteristics of plastic materials

"One-dimensional theory" of elastic impact

According to the one-dimensional theory of the elastic impact of a bar with velocity **v** against a hard surface, the forces in the bar produce a stress **σ** given by the formula

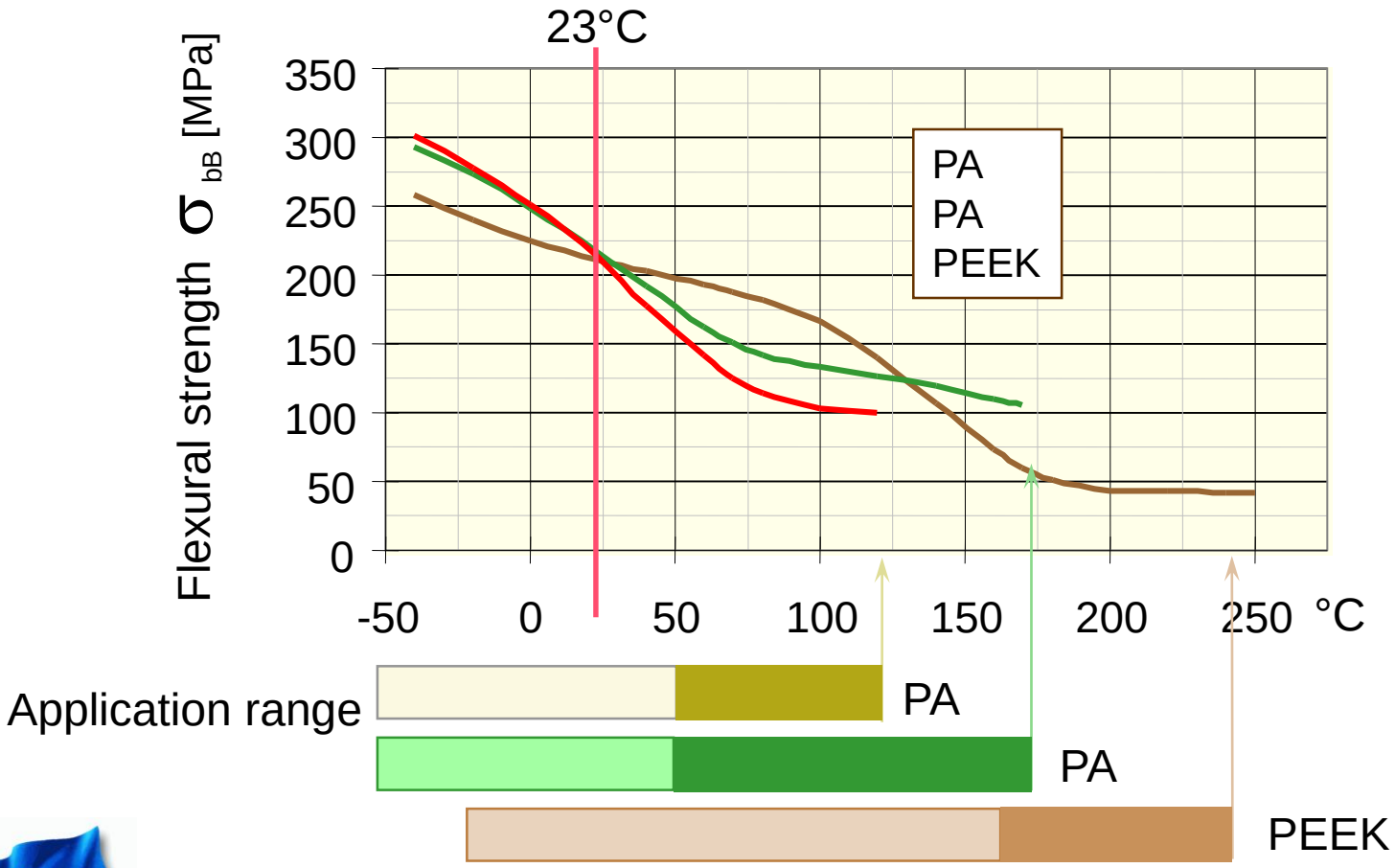
$$\sigma = v*\sqrt{E*\rho} \quad \text{respectively} \quad v = \sigma / \sqrt{E*\rho}$$

	symbol	steel	plastic
modulus of elasticity	**E**	**$2{,}1\times10^{11}$ N/m²**	**$1{,}3\times10^{9}$ N/m²**
density of material	**ρ**	**$7{,}85\times10^{3}$ kg/m³**	**$1{,}5\times10^{3}$ kg/m³**
tensile strength	**$\sigma_{or}.\sigma_{adm}$**	**$3{,}0\times10^{8}$ N/m²**	**$2{,}0\times10^{7}$ N/m²**
impact velocity	**$v_{or}.v_{adm}$**	**7,93 m/s**	**14,32 m/s**

Plastic materials can impact with double the velocity of steel!

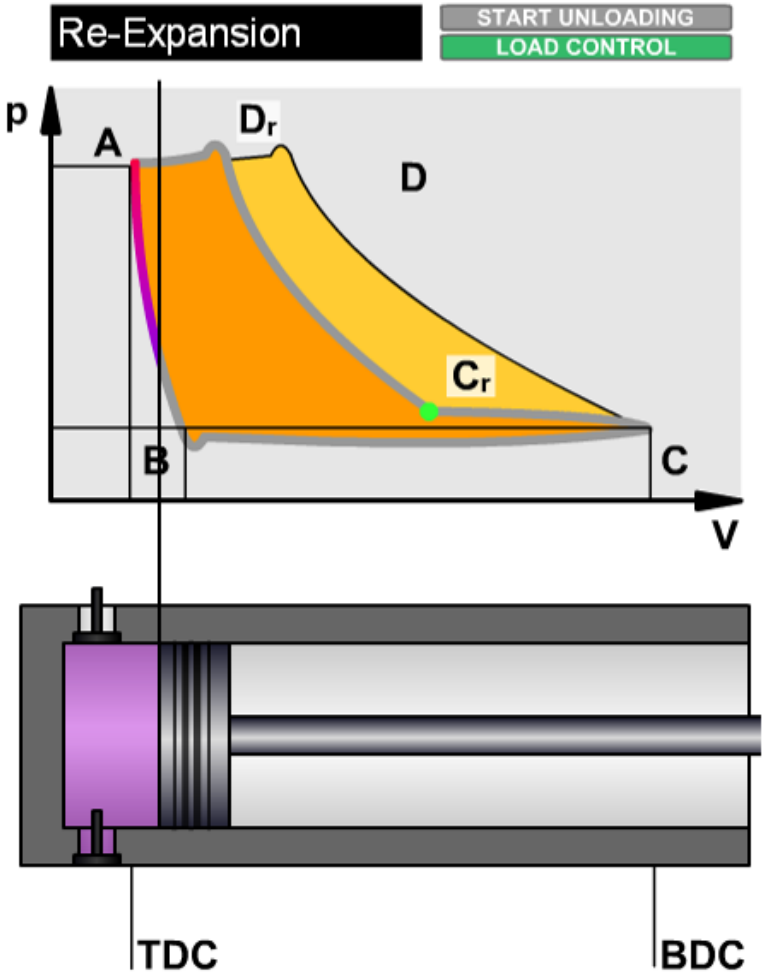
Characteristics of plastic materials

Flexural strength in dependence of temperature



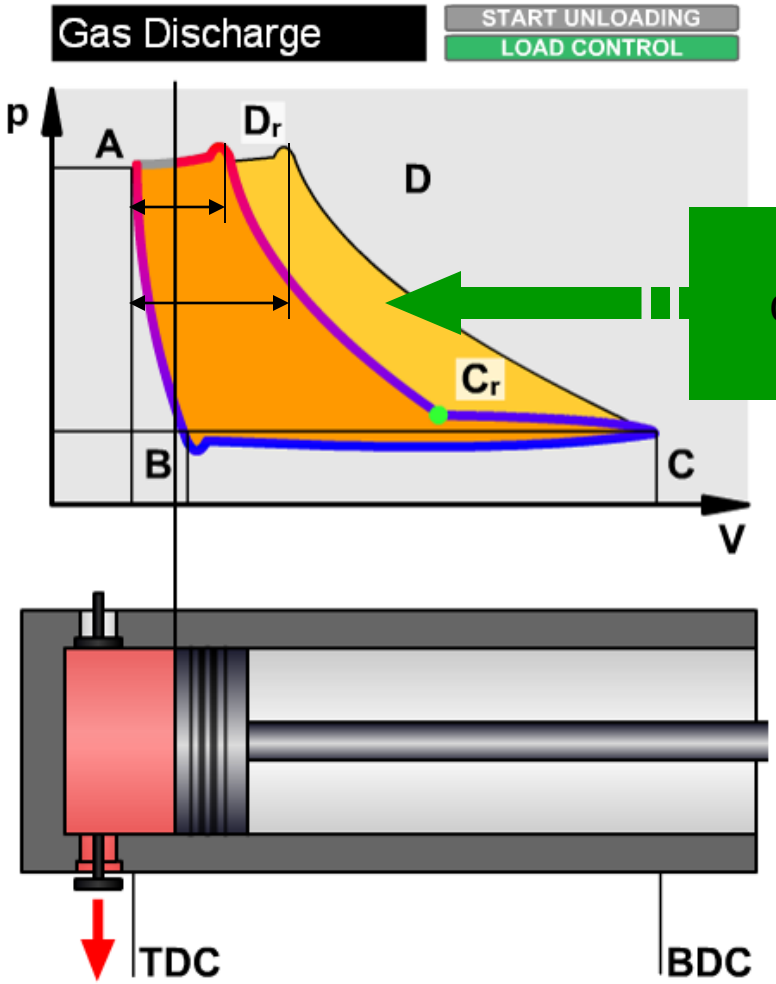
PA…Polyamid
PEEK…Polyetheretherketon

Working principle – Stepless control



Animation

Working principle – Stepless control



Area enclosed by pV graph is equivalent to the energy consumed

Energy savings compared to recycle valve control

Stepless control saves energy

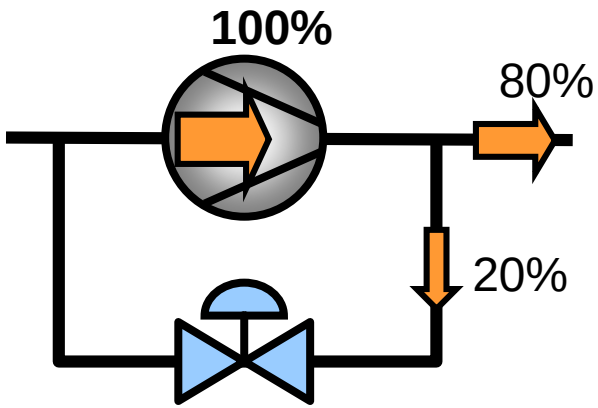
Only the gas flow required by the process is compressed (no recycling)

Typical application:

1,300kW compressor

80% average load

Energy costs €0.06 per kWh



Recycling is waste of energy:

Power loss: 1,300 x 0.2 = 260 kW

Losses: 2,080,000 kWh / year

Recycle valve is waste of money:

With stepless reverse flow control:

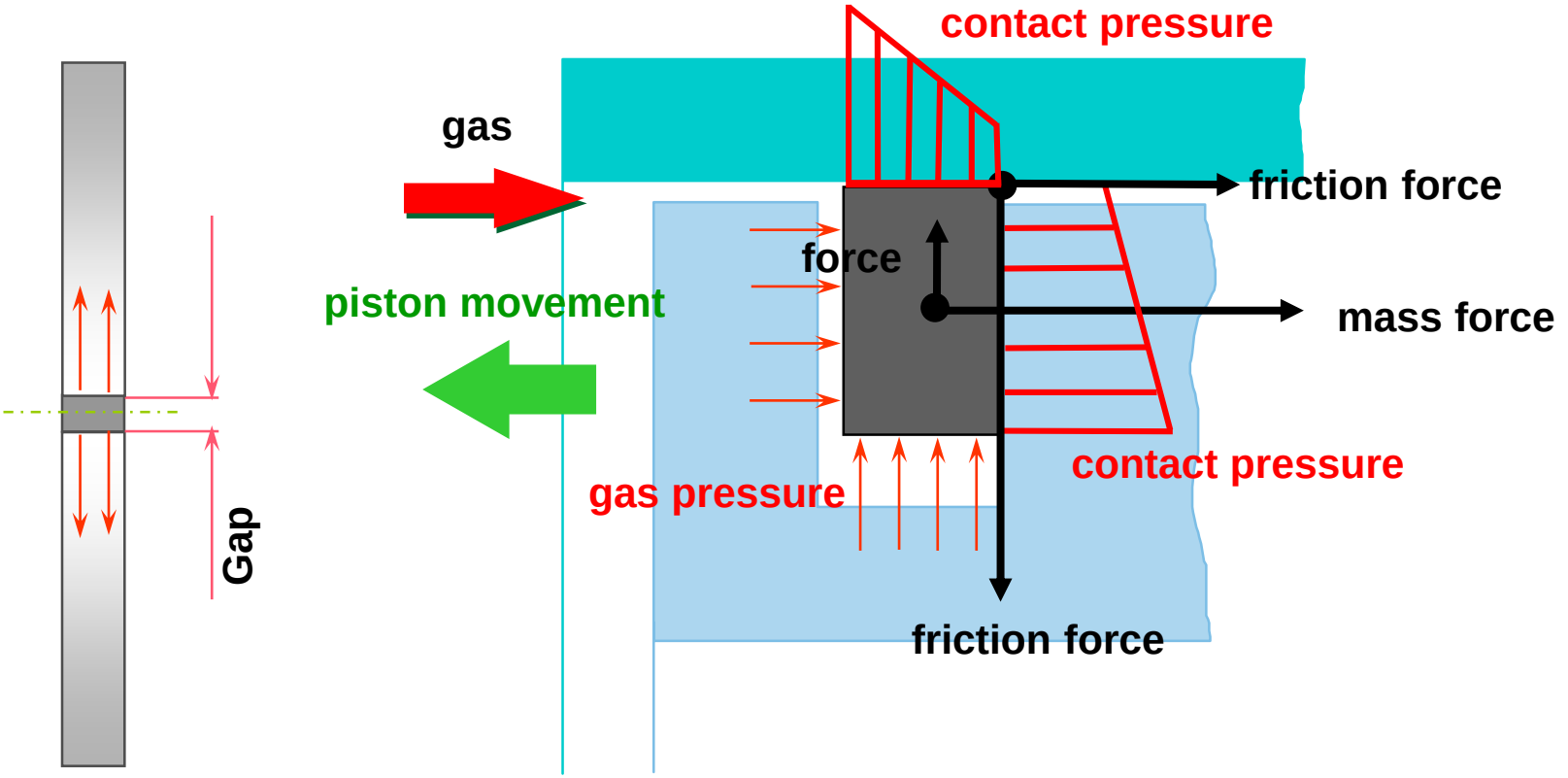
€ 124,800 energy savings / year

Plus savings in CO_2-emissions

Rings & Packings Products

Piston Ring - Basics

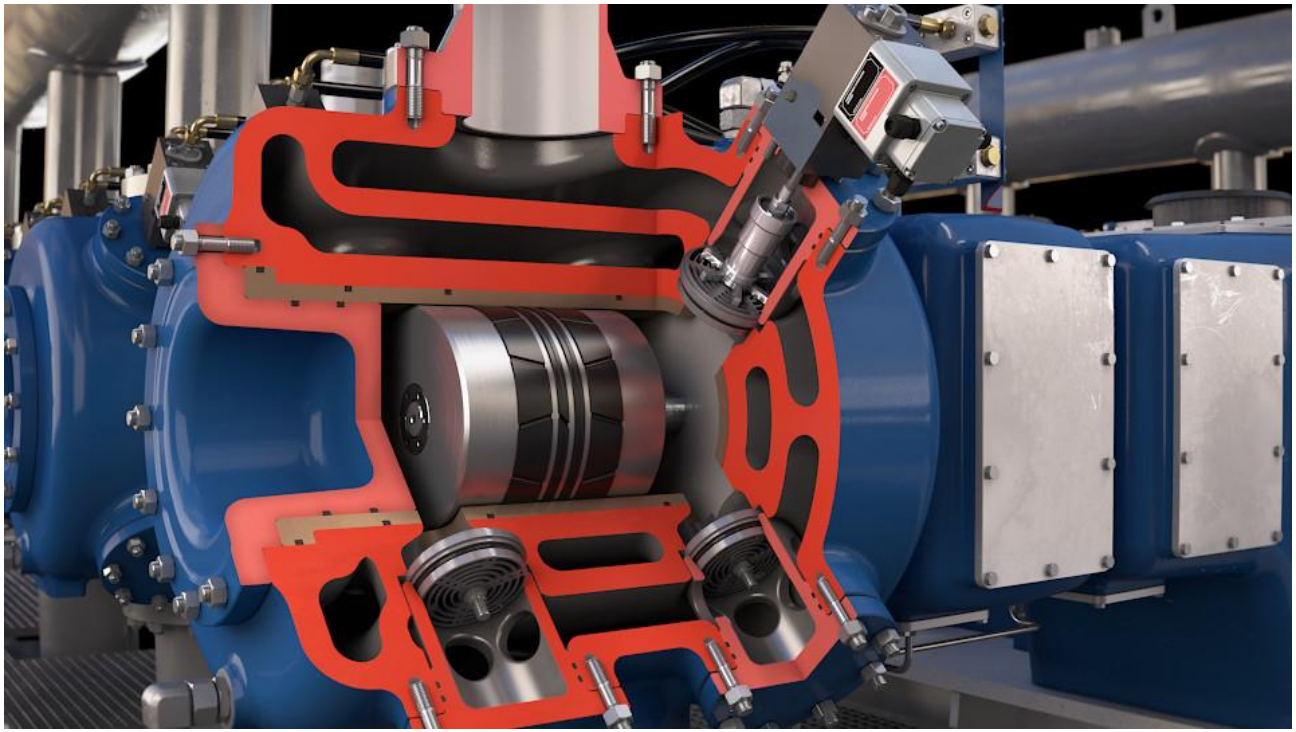
Purpose of the piston ring is to seal the compression space.



Rider Ring - Basics

Purpose of the Rider Rings is to bear the piston and prevent it from contacting the liner.

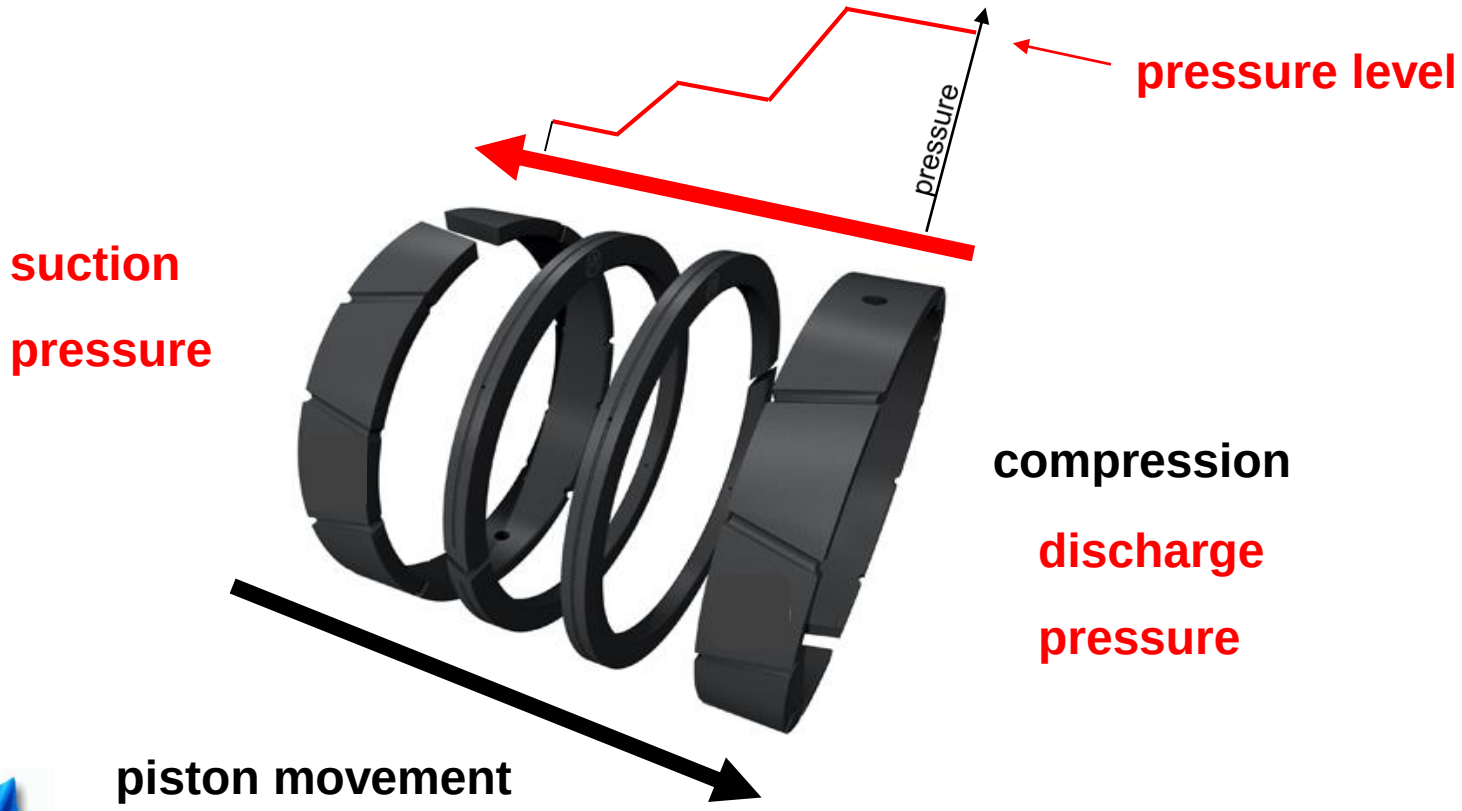
The Rider Ring should not seal the gas !



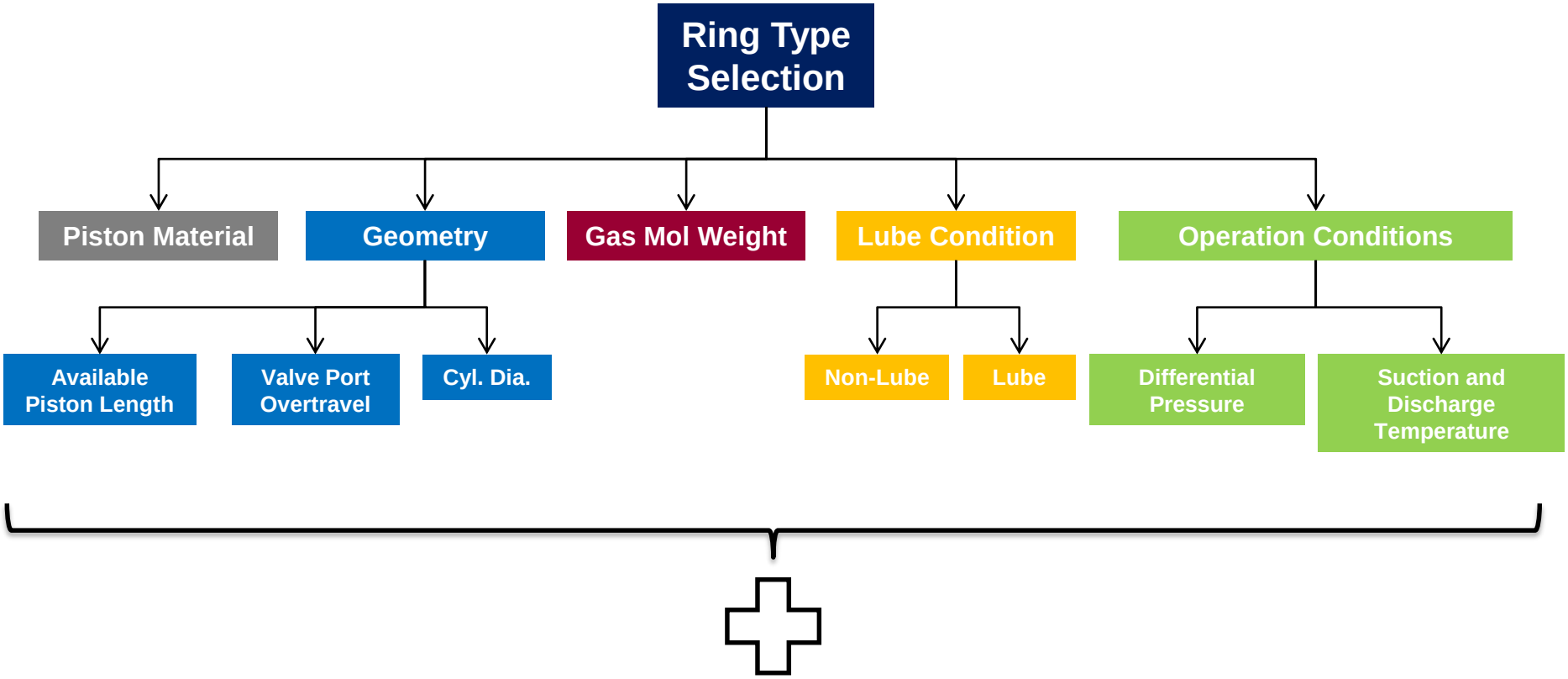
Piston Arrangement - Design

Main criterion for evaluation of number of rings is

Pressure difference = Discharge pressure - Suction pressure

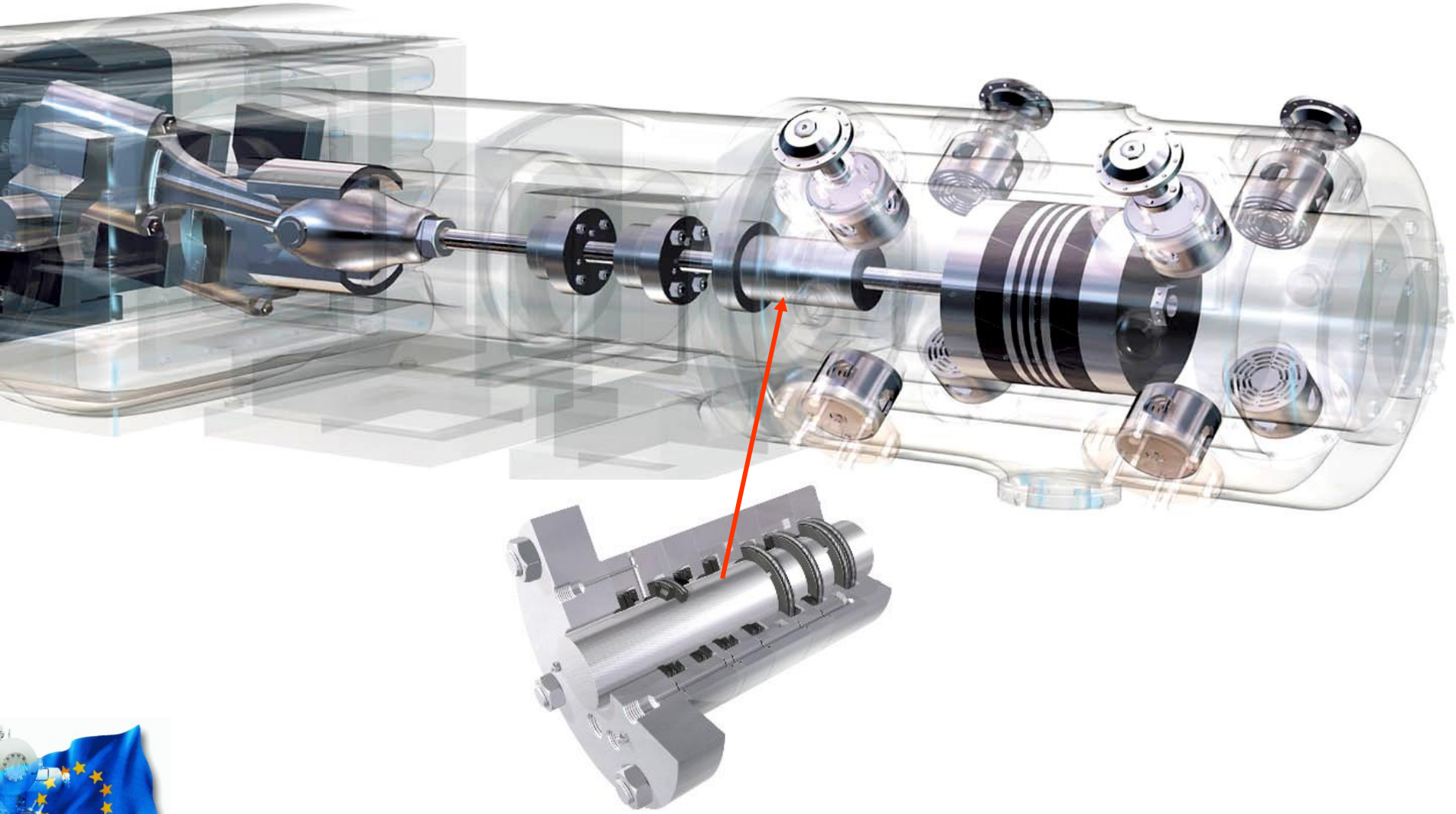


Cylinder Ring Design Criteria



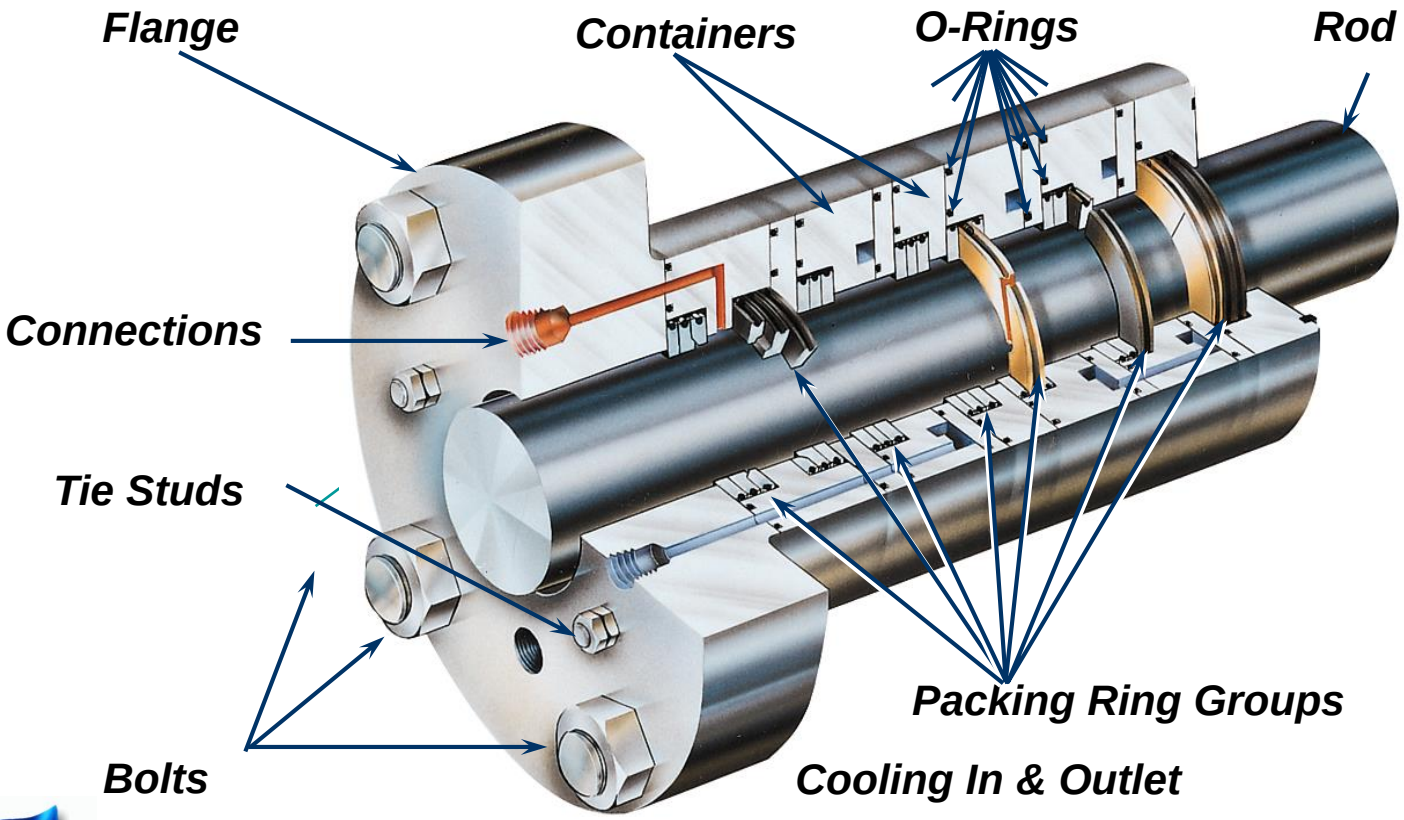
Application Specific Solutions for individual Processes and Problems

Pressure Packing

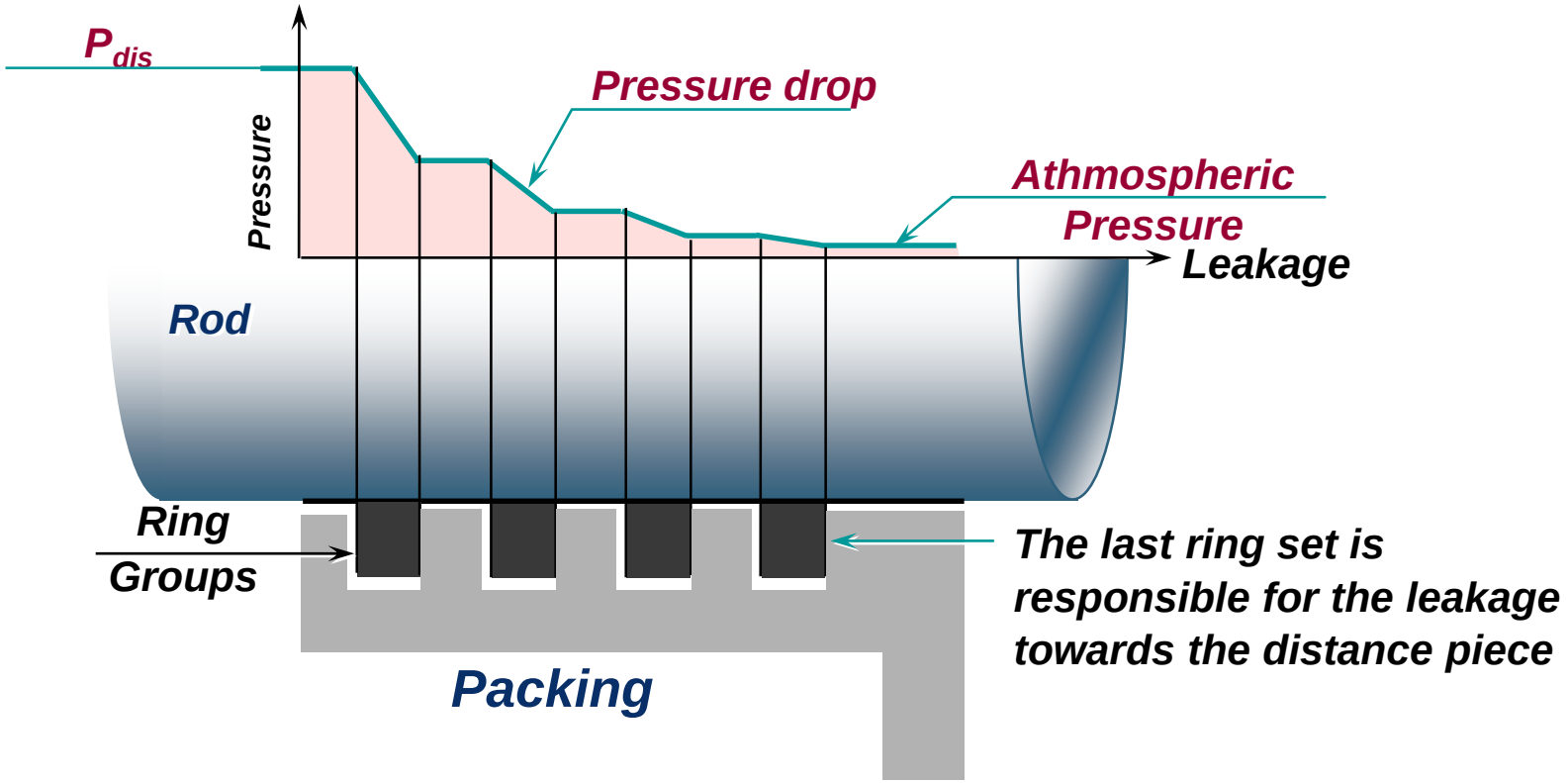


Pressure Packing - Basics

Function: Seal the compression chamber against the intermediate piece.



Pressure Packing - Basics

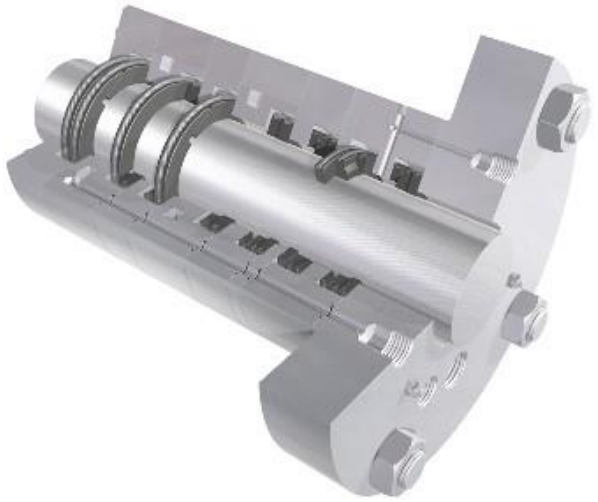


Rule of thumb for the packing:

Each ring set reduces the pressure by half of the prior one. If one ring set has worn down the pressure has to be reduced by the remaining ring pairs.

Pressure Packing - Layouts

Packing Features:



Main features of pressure packings are:

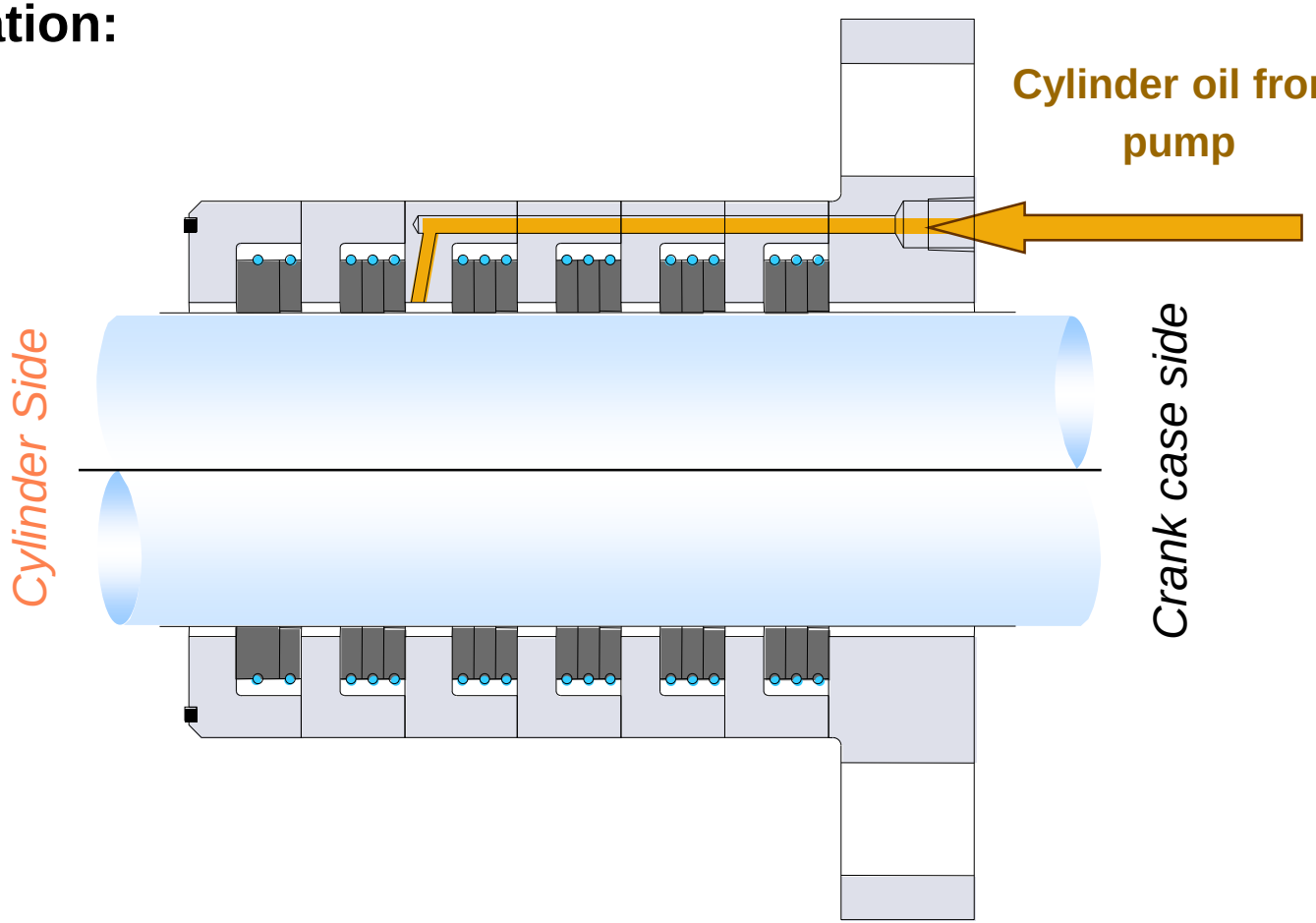
- Lube or non-lube
- With or without cooling
- With or without vent
- With or without purge

Types and numbers of ring groups within a packing are depending

Of the design criterias !

Pressure Packing - Layouts

Lubrication:

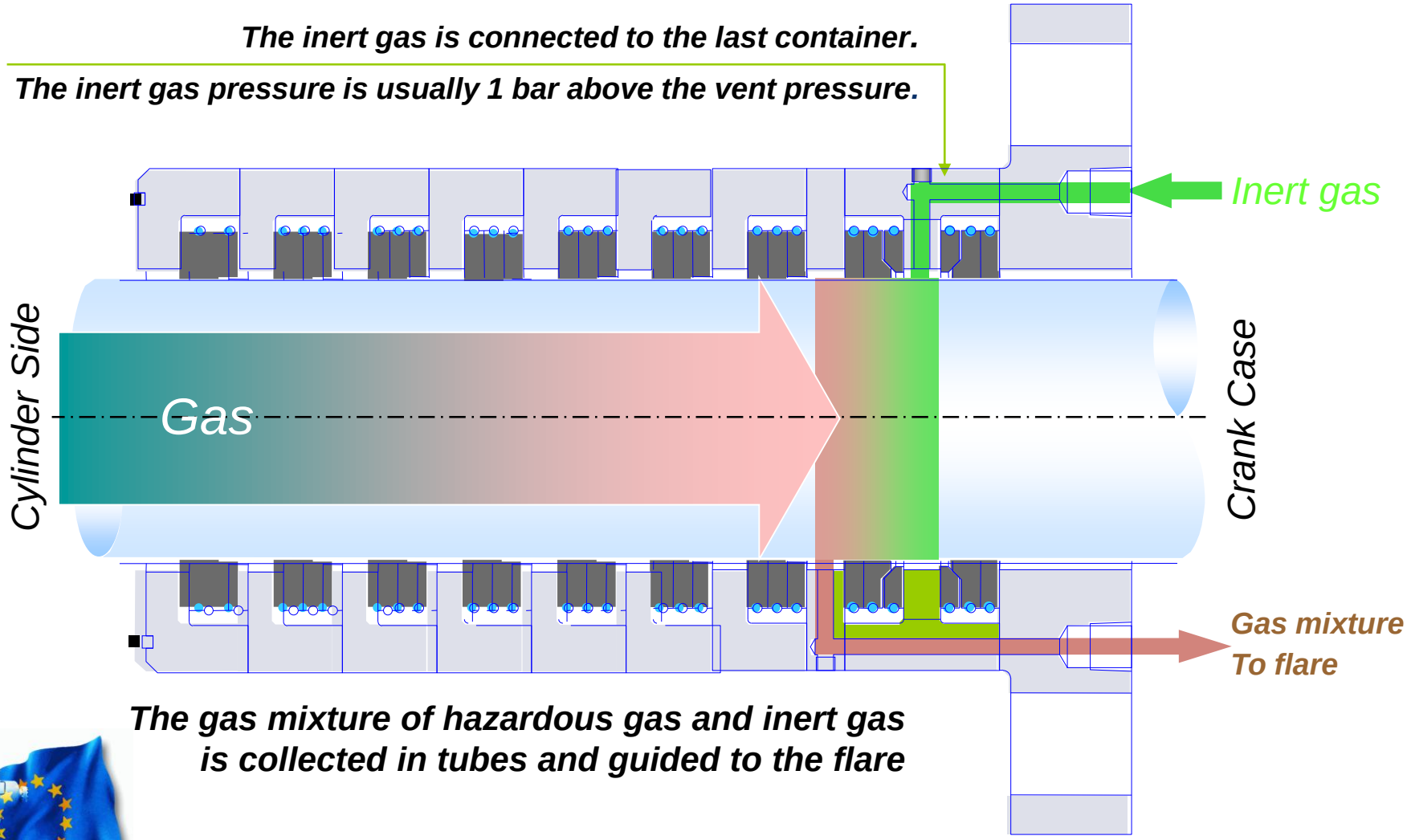


Pressure Packing - Layouts

Purge:

The inert gas is connected to the last container.

The inert gas pressure is usually 1 bar above the vent pressure.



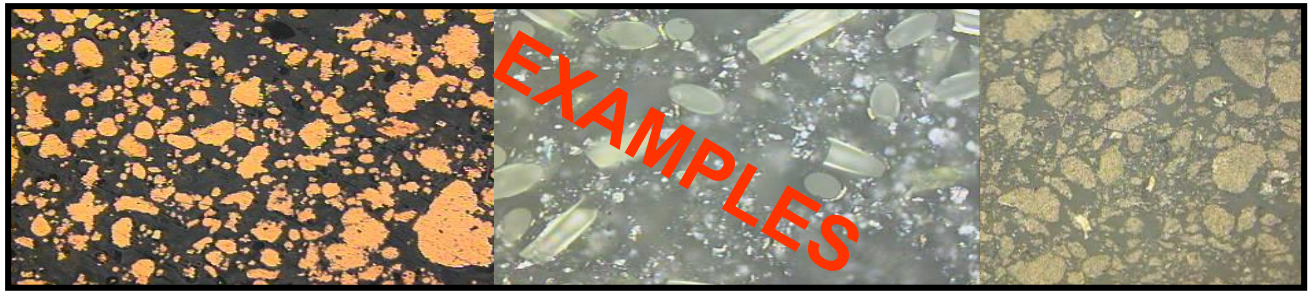
The gas mixture of hazardous gas and inert gas is collected in tubes and guided to the flare

Basics – PTFE Compounds

PTFE Compound:

Pure PTFE => very low coefficient of friction but also a ***quite low wear resistance***. If there‘s no transferfilm present, it ***wears down very fast***.

Fillers are added ***to increase*** the ***wear resistance*** and the mechanical properties. These fillers are (Carbon fibres, graphit dust, glass fibres, ceramic dust, metall dust, polymer dust, MoS2, ...)

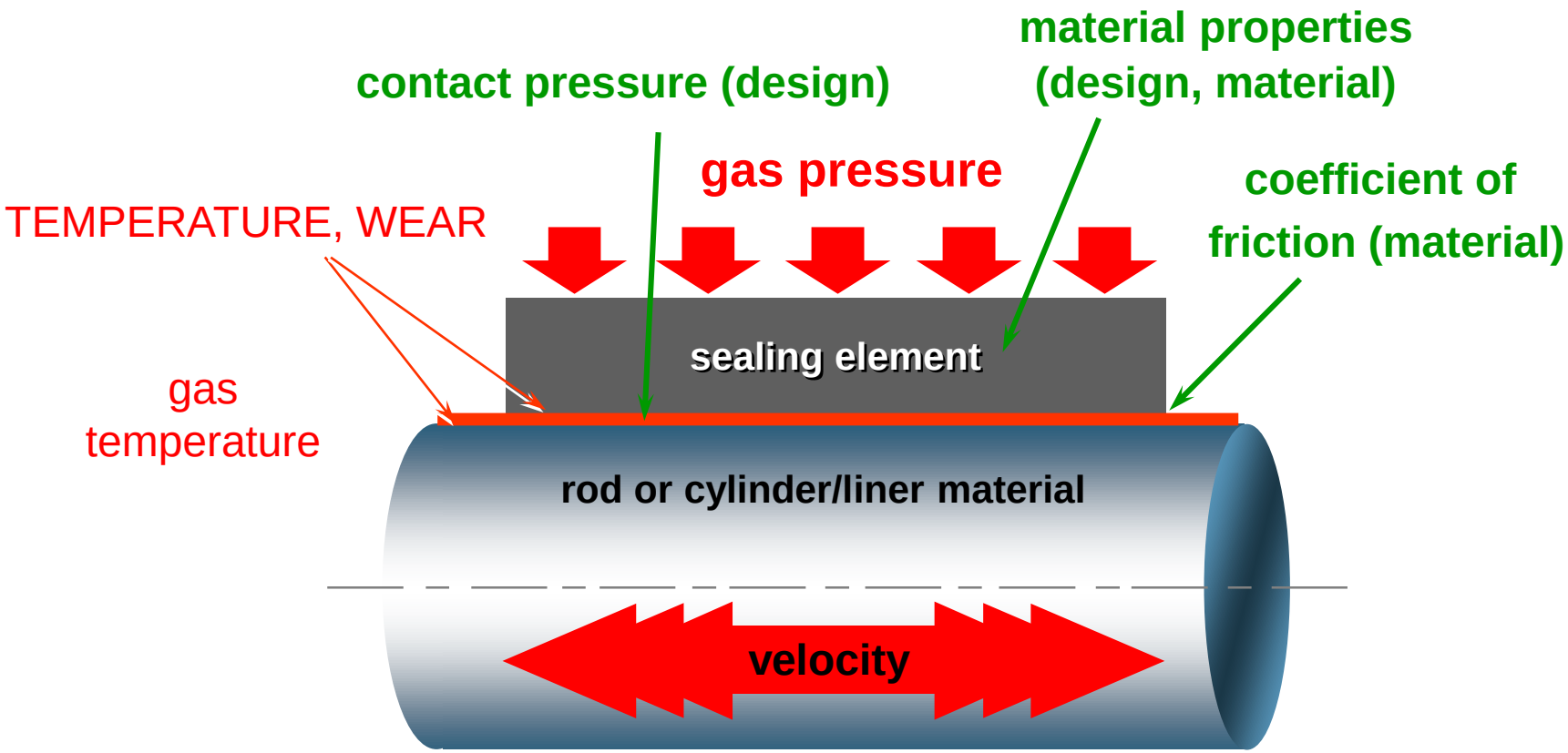


PTFE with bronze

PTFE with glass fibres

PTFE with carbon

Tribology System

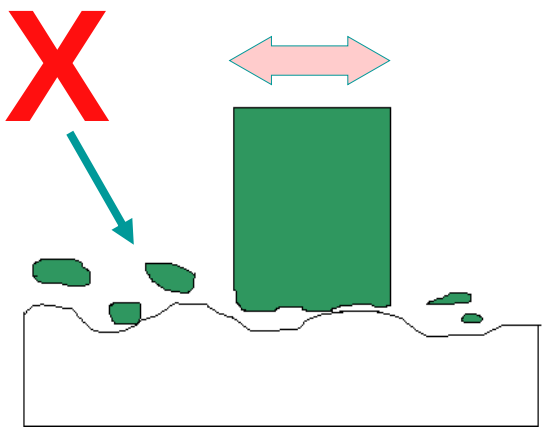


Wear rate proportional to **Pressure** and **Velocity**
(There is also a **temperature** effect in practice)

Non-Lube – The Transfer Film

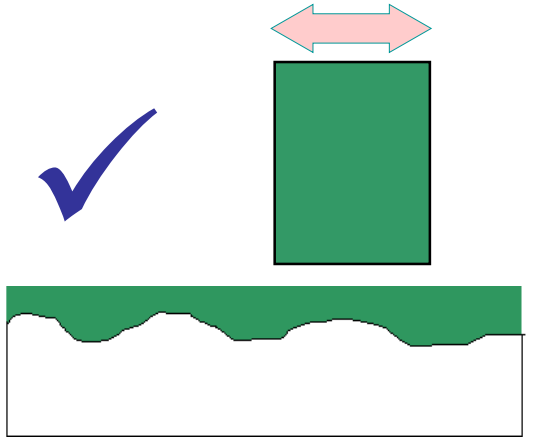
- **High Wear Mode**
  - **Adhesive** wear behaviour
  - Polymer to metal
  - **High friction**

  ➔ **High wear – SHORT LIFE**

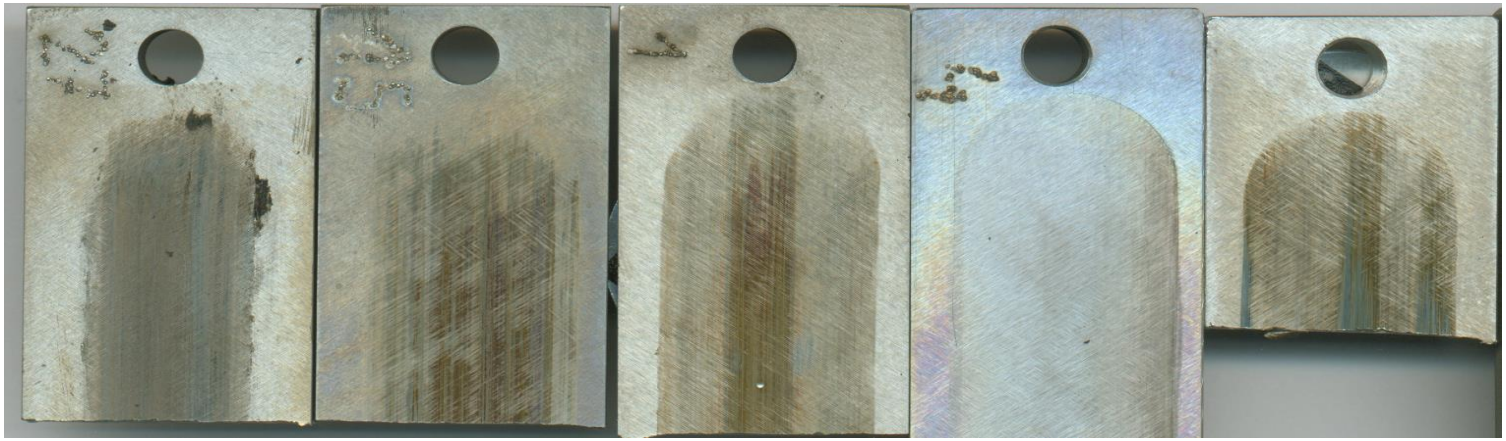


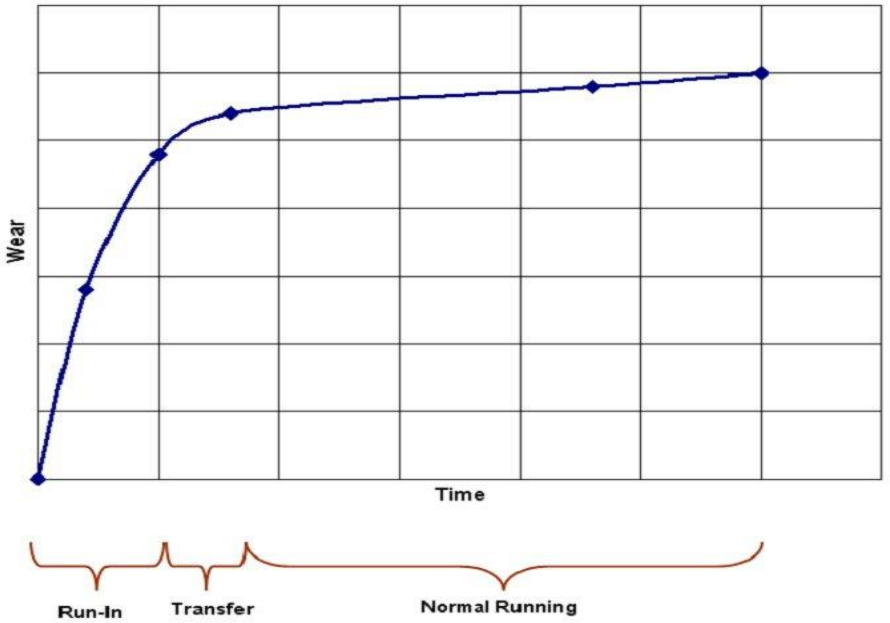
- **Low Wear Mode Transfer Film**
  - Polymer to polymer running
  - **Low friction** which is load independent

  ➔ **Low wear – LONG LIFE**



Non-Lube Operation – Bedding-in





Material Selection Criteria