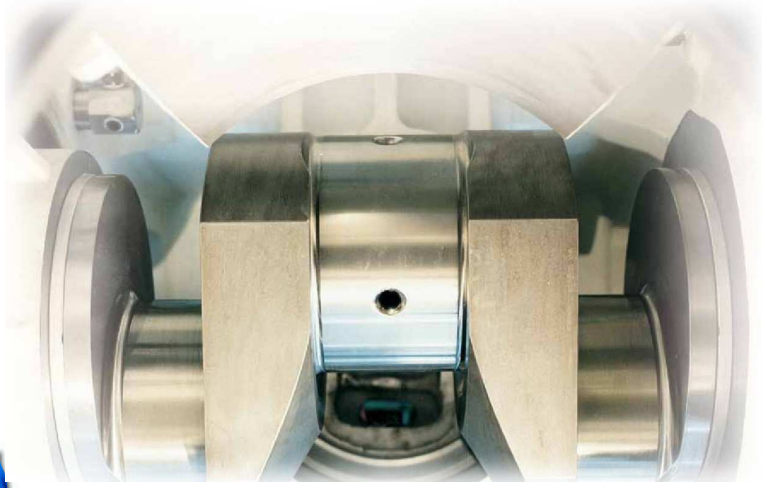
EFRC Training Workshop
Design and operation of reciprocating compressors

Compressor types and typical applications

Ron van den Handel – MACH10

Reciprocating Compressors



Compressor types

- POSITIVE DISPLACEMENT
  - RECIPROCATING
    - Single-acting
    - Double-acting
    - Diaphragm
  - ROTARY
    - Lobe
    - Screw
    - Vane
    - Liquid ring
    - Scroll
- DYNAMIC
  - CENTRIFUGAL
    - Horizontally split
    - Barrel
    - U-casing pipeline compressor
    - Integrally geared
    - Seal-less
  - AXIAL

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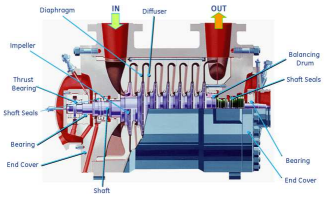
Centrifugal compressors



Courtesy of GE

Centrifugal compressor types

- **SINGLE / MULTISTAGE**
- **BETWEEN BEARINGS / OVERHUNG**
- **INTERCOOLED**
- **SIDE LOADED**
- **HORIZONTAL / VERTICALLY SPLIT / BARREL**

Courtesy of GE

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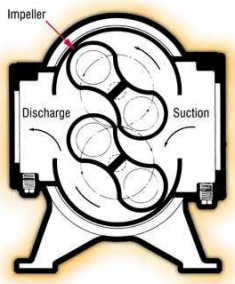
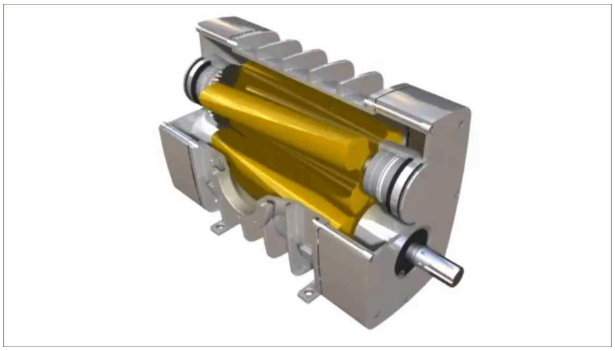
Rotary displacement compressors



LOBE COMPRESSOR (ROOTS BLOWER)



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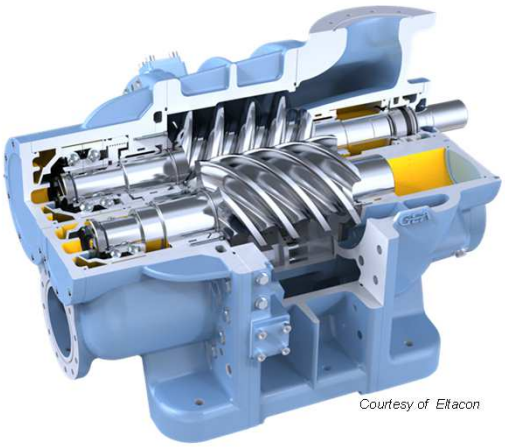
Rotary displacement compressors

ROTARY DISPLACEMENT SCREW COMPRESSOR



Courtesy of Eltacon

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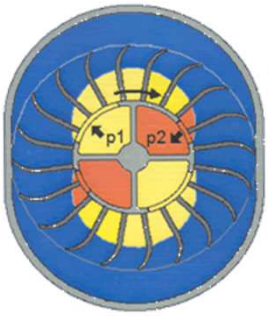
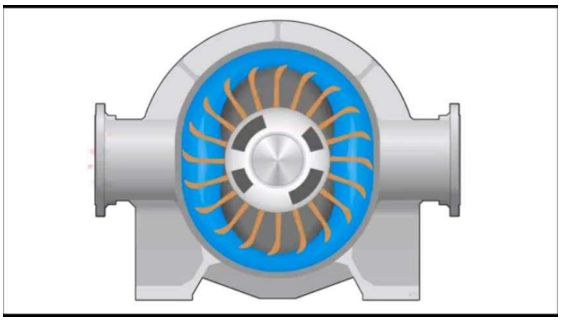
Rotary displacement compressors

LIQUID RING COMPRESSOR / PUMP





Courtesy of Nash

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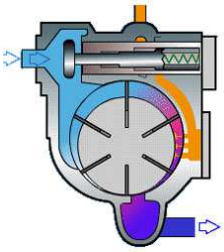
Rotary displacement compressors

ROTARY VANE COMPRESSOR



Courtesy of Air Link Compressors

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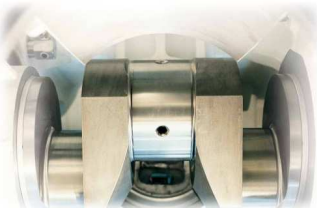
Classification



RECIPROCATING COMPRESSOR TYPES

- **HORIZONTAL**
  Traditional(*) / Free floating
- **VERTICAL**
  Traditional(*) / Labyrinth Ring
- **HIGH SPEED**
  Traditional(*)
- **INTEGRAL** with Gas Engine
- **V-TYPE**
  Utilities, Nitrogen, Air

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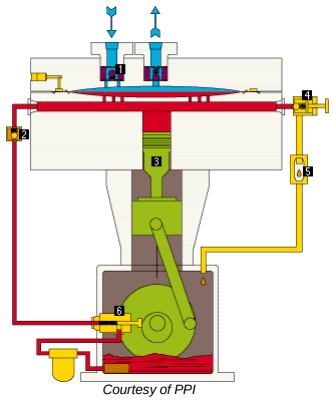
(*) Traditional means with rider and piston ring

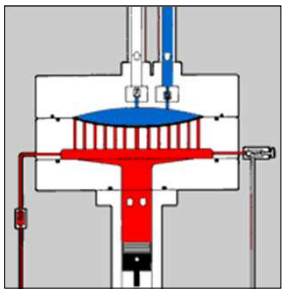
Classification

DIAFRAGM COMPRESSOR

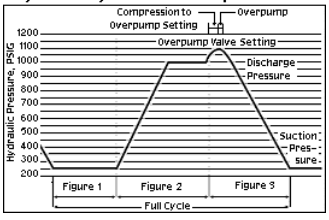


Courtesy of PPI

- 1) Check valves
  2) Hydraulic inlet check valve
  3) Hydraulic pistons
  4) Hydraulic overpump valves
  5) Overpump sight glass
  6) Hydraulic injection pump



Hydraulic System Oscilloscope Scan



Courtesy of PPI

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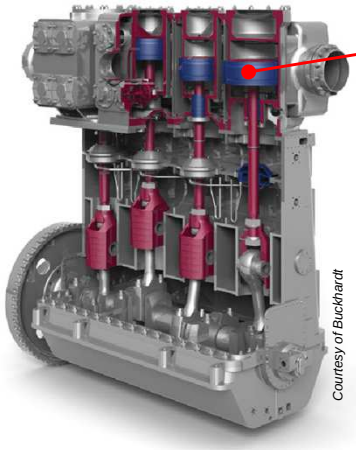
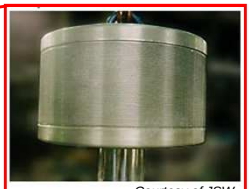
Classification

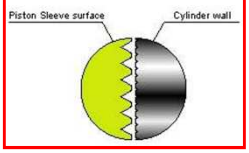
VERTICAL LABYRINTH COMPRESSOR



Courtesy of Buckhardt



Courtesy of JSW



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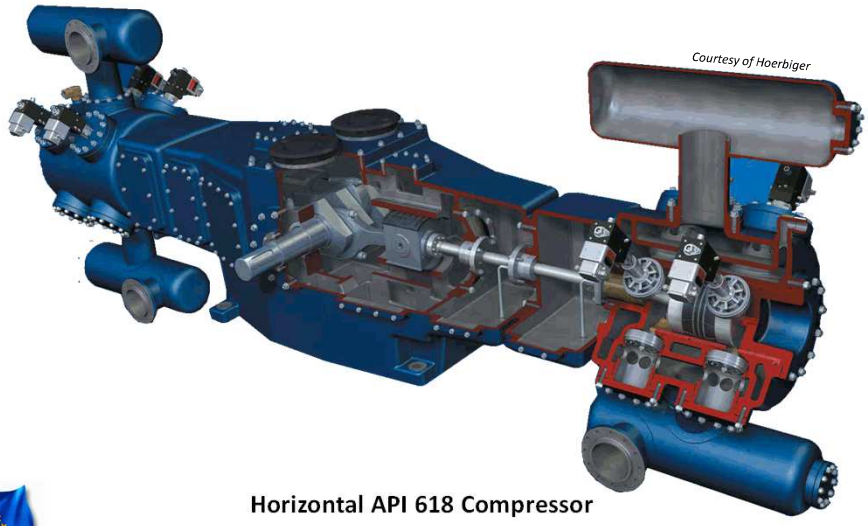
Oil-free sealing, suitable in non-lube applications (i.e. boil-off gas, air, nitrogen compression).

Classification



Courtesy of Hoerbiger

Horizontal API 618 Compressor

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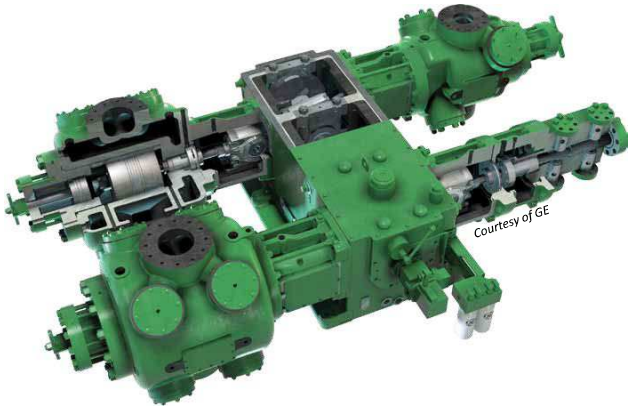
Classification



High-speed API 11P compressor

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Compressors

COMPRESSOR TYPES

Factors influencing selection:

- Capacity
- Compression ratio
- Pressure, Temperature
- type of gas (M , k)
- Presence of solids
- Presence of liquids
- Corrosiveness of gas components
- Cost

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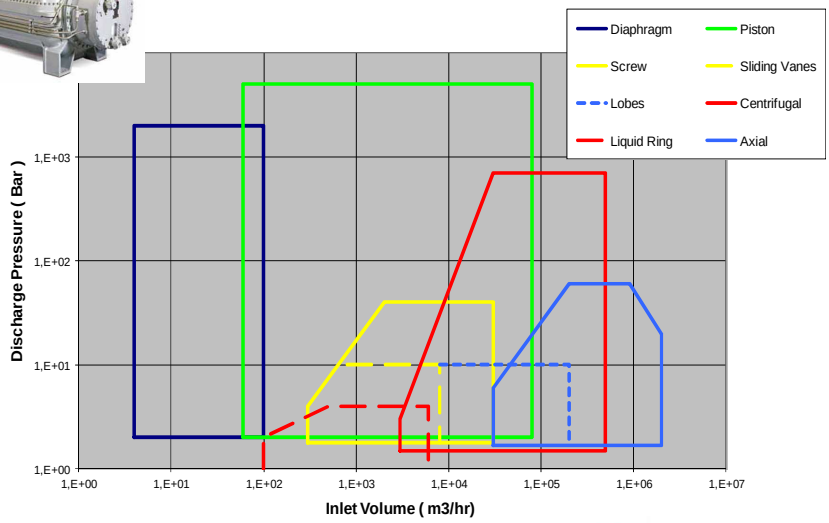

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Applications

Plant	Application	Processed Gas
Refinery	Reforming	H_2 + HC
	LDP – Ultra high pressure	propylene
	Lubricants production	Propane
	Olefines GTL	Natural gas, ethylene, propylene H_2
Petrochemical plants	Ammonia	CH_4, air, H_2+N_2, NH_3
	Methanol	CO, CO_2, H_2, CH_4
	Urea	CO_2
	Ethylene	Charge gas
Natural gas compression	Re-injection	Natural gas
	Pipeline boosting	Natural gas
	LNG	Natural gas
	LPG	Propane
Shipping/ storage	Boil off compression	LNG
Steel mill	Oxygen compression	O_2, N_2

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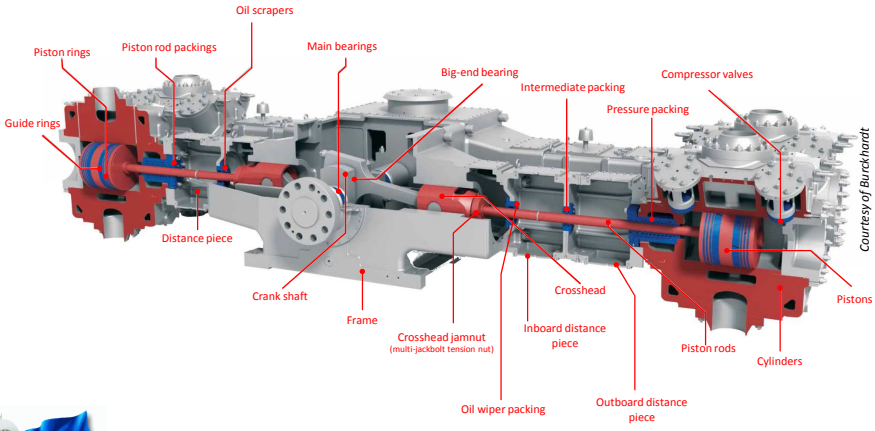
Compressor anatomy



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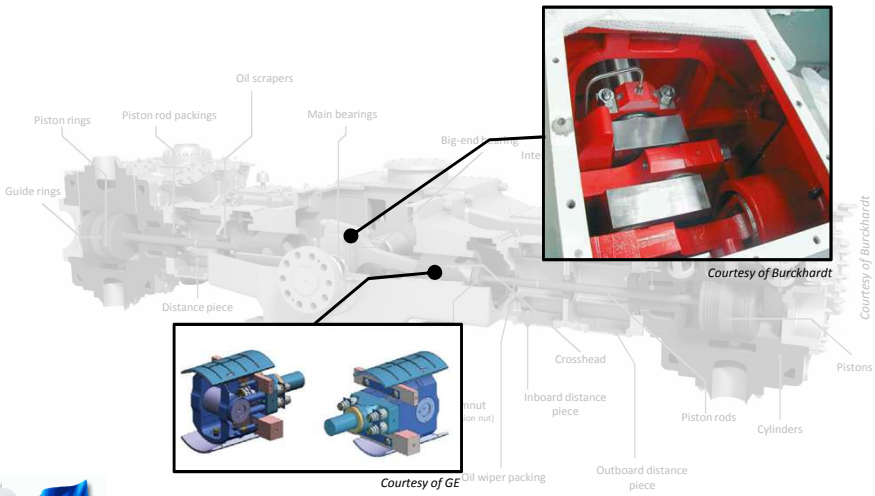
Compressor anatomy



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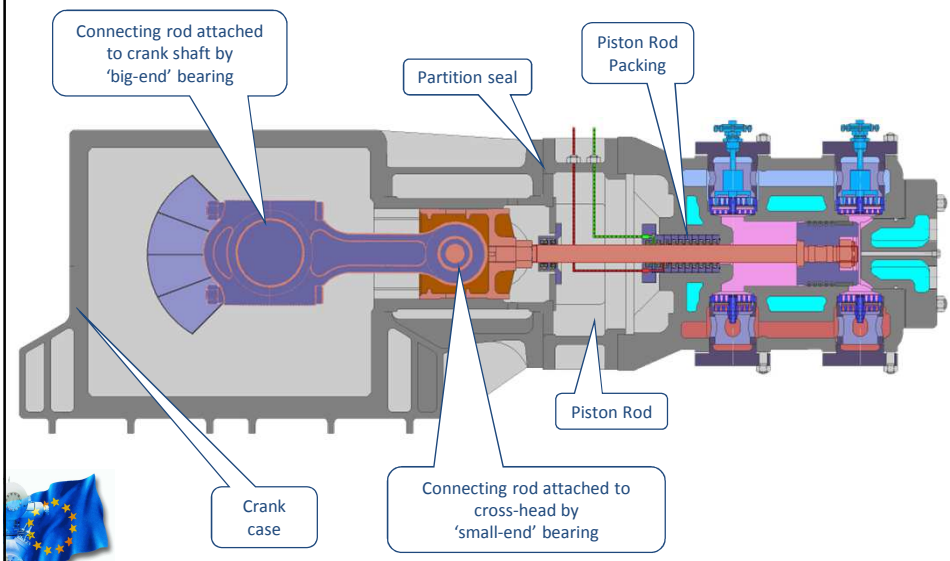
Principles of operation



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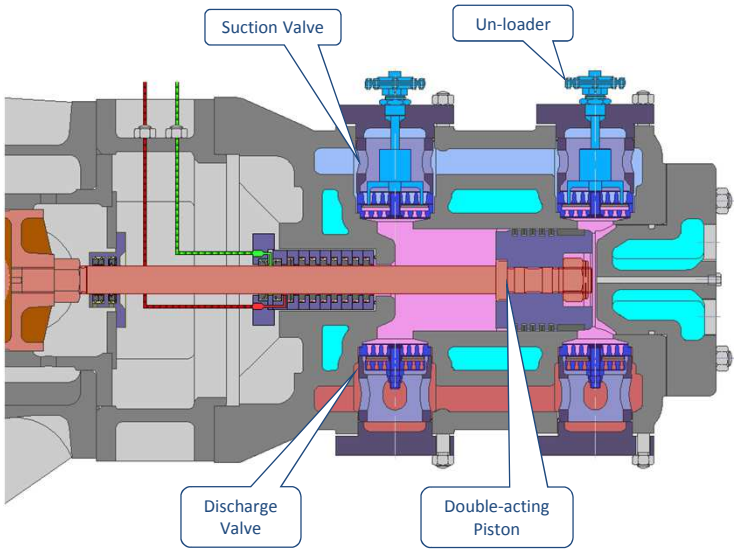
Principles of operation



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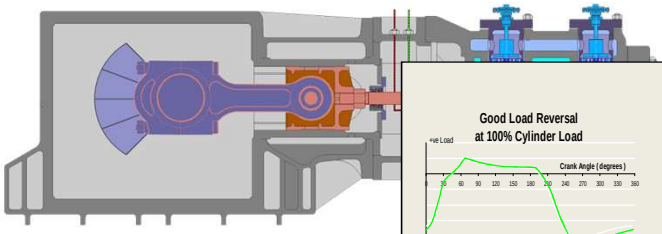
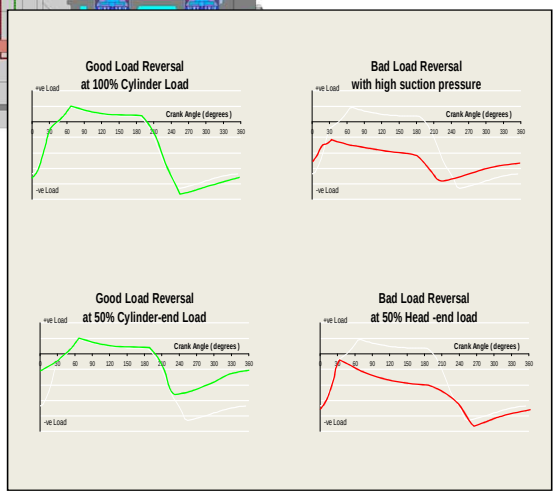
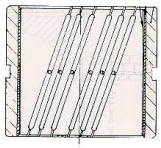
Small-end bearing load reversals





Small end bearing designed for zero load reversals



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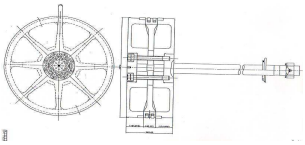
Piston and rings



PISTONS

MATERIALS OF CONSTRUCTION

- Aluminum (Air Service)
- Cast Iron
- Steel

TYPES

- Single Piece for piston rings only
- Segmented for Ryder band Applications (high weights)
- Hollow used to reduce weights

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Piston and rings

PISTON RINGS

Piston rings are designed to seal the gas between the stroke translation.

- Leakage does occur depending on the piston ring design
  - Single piece – tangential cut
  - Segmented (2,3,4) – tangential cut or "S" cut
- Materials depend on process gas and lube requirements
  - PEEK
  - Carbon filled Teflon
  - Glass filled Teflon
  - Bronze
- Piston Ring Design (many references (Kaydon ring Design Handbook)

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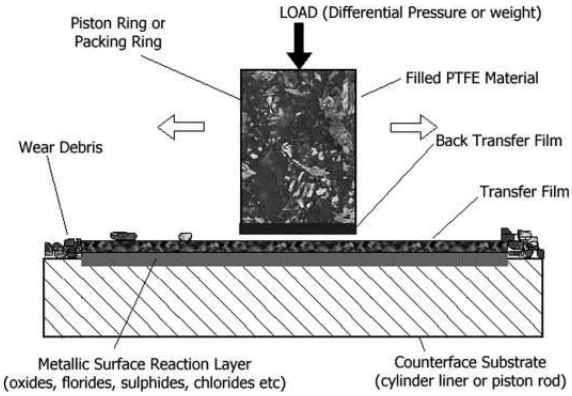
Piston and rings



RUNNING-IN WEAR MECHANISM

Transfer process of non-metallic rings

Cylinder / rod roughness critical

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Piston rods

PISTON RODS DESIGN

DESIGN CONSIDERATIONS (2)

- Surface Finish
- Tolerance of rod (within 0.001 TIR full length)
- Rolled thread

MATERIALS

- 13% Cr.
- AISI 4140
- Surface hardness at least 50 Rc
- Repair

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Piston rods

FACTORS AFFECTING WEAR MECHANISM

- Working pressures and temperatures
- Counter-surface materials (chemistry)
- Counter-surface finish (e.g. too rough or too polished)
- Gas type, dryness and oxygen content
- Gas cleanliness : solids / liquids
- Speed and stroke
- Cooling efficiency

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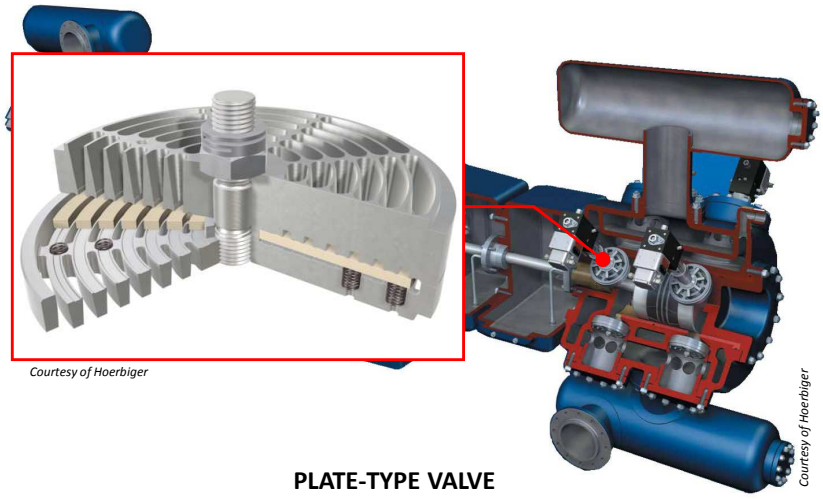
Valves



Courtesy of Hoerbiger

Courtesy of Hoerbiger

PLATE-TYPE VALVE

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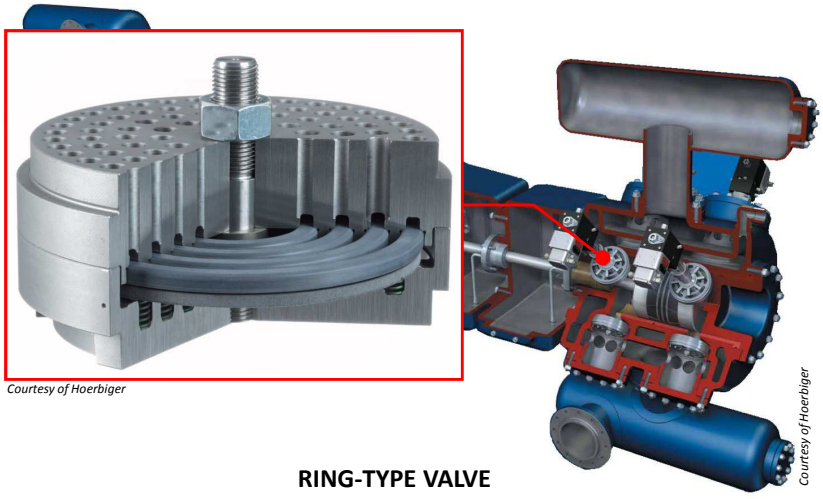
Valves



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RING-TYPE VALVE

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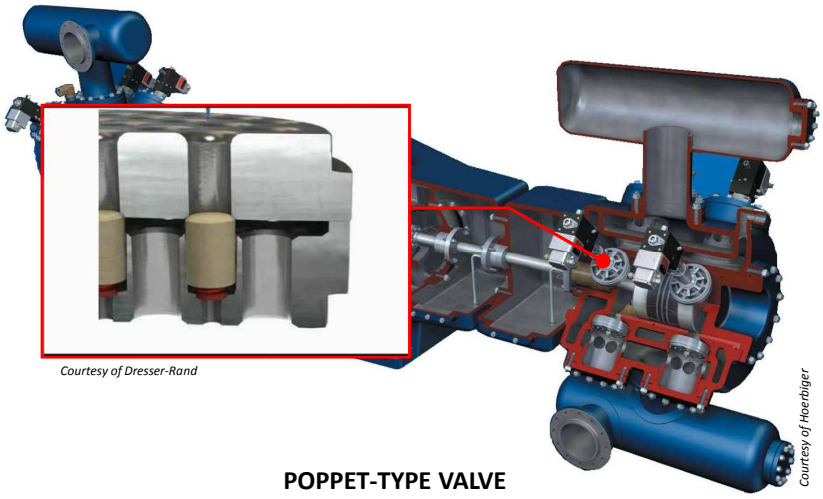
Valves



Courtesy of Dresser-Rand

Courtesy of Hoerbiger

POPPET-TYPE VALVE

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Valves

VALVE TYPE	CLEAN SERVICE	LUBRICATED / DIRTY SERVICE
Plate	Metal	Nylon / PEEK / EP
Ring	Nylon / PEEK	Nylon / PEEK / EP
Poppet	Nylon / PEEK	Nylon / PEEK / EP

VALVE MATERIAL SELECTION

Springs : Hastelloy X750 or Nimonic 90
PEEK = Poly Ether Ethyl Ketone
EP = Engineered Plastic / composite materials

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Valves

FAILURE MECHANISMS

- Plate sticking
  - Due to condensable liquids (Lube Oil)
- Plate fracture
  - Due to bending caused by dirt under plate or sticking
- Spring fracture
  - Due to fatigue / corrosion

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Valves

FAILURE MECHANISMS

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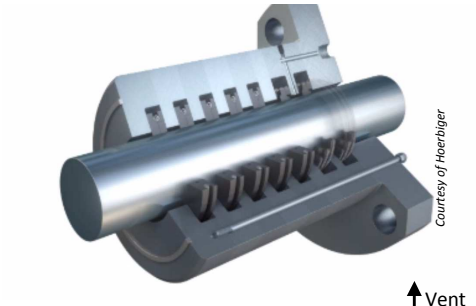
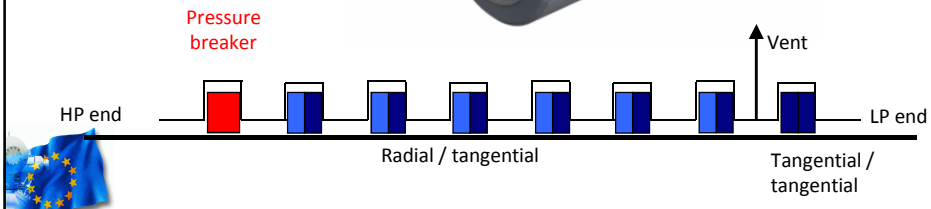
Piston Rod Packing

PRESSURE RING PACKING



Courtesy of Hoerbiger



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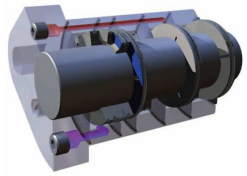
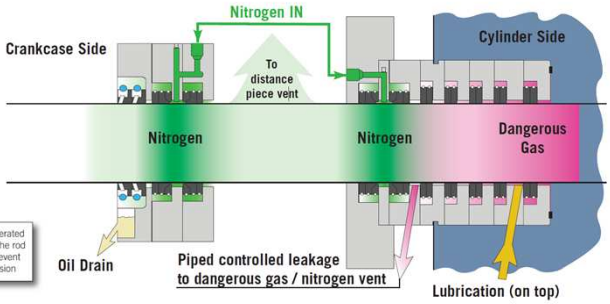
Piston Rod Packing

PURGED PACKING BOX

TOXIC SERVICES





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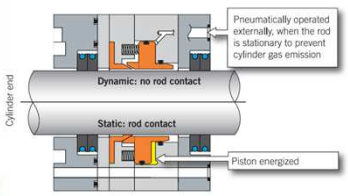

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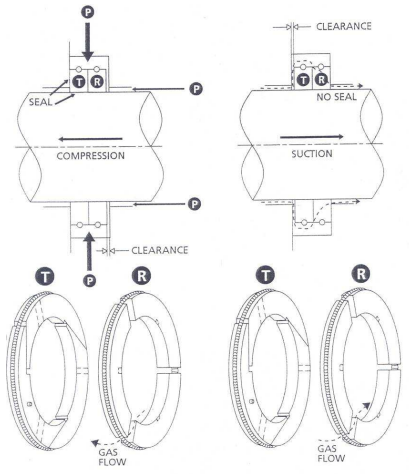
Piston Rod Packing



Courtesy of Kranz

FUNCTIONING OF SEGMENTAL PACKING RINGS

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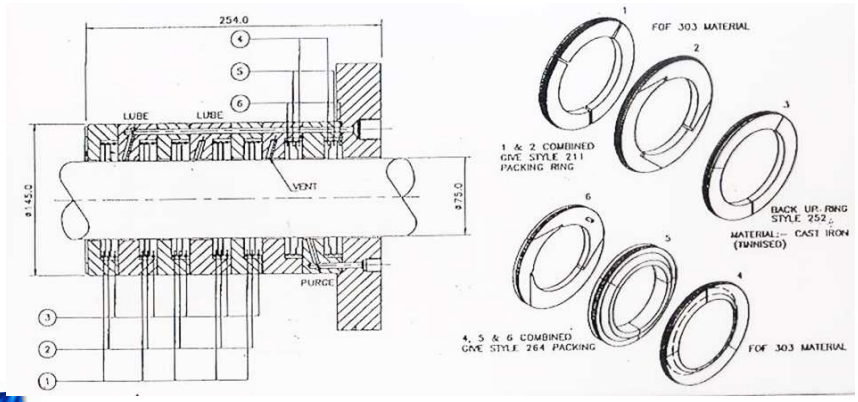
Piston Rod Packing

PURGED PACKING BOX

TOXIC SERVICES



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Field Failure

In case of poor design …

Reliable piece of equipment

In case of adequate design and construction …