EFRC Training Workshop

Basic Training of Reciprocating Compressor Systems

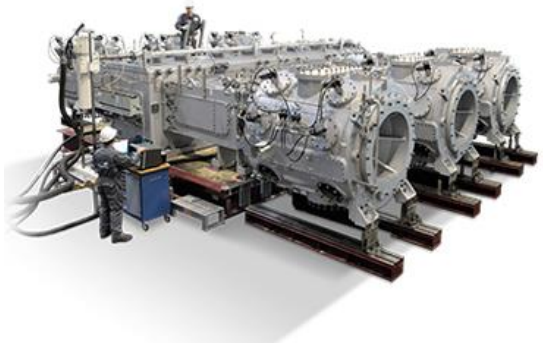
Design and Construction

Niek Albers

Howden Thomassen Compressors B.V.

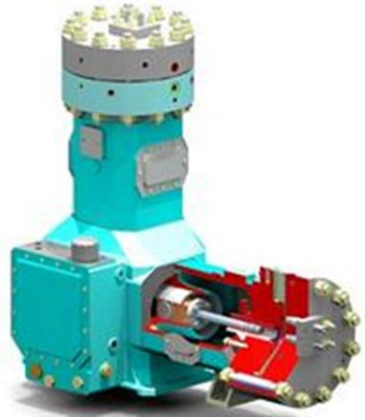
Compressor configurations

Horizontal

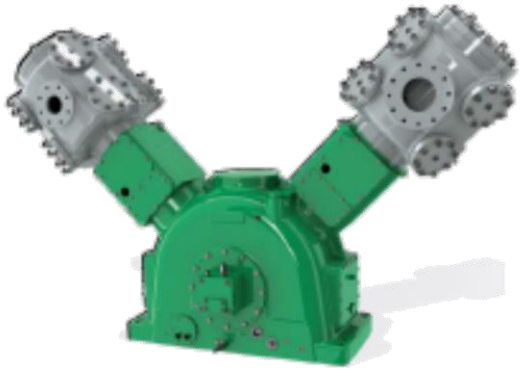


Vertical

L-type



V-type



W-type

Image source: Howden, SIAD MI (V), GEA Grasso (W)

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Configuration?

	Horizontal	Vertical	L-type	V-type
Footprint	--	++	+	+
Maintenance	+	-	-	-
Scalability	++	+	-	-
Capacity	++	+	-	-

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Small or large?

	Small	Large
CAPEX	-	+
Maintenance	-	+
Footprint	-	+
Redundancy	+	-

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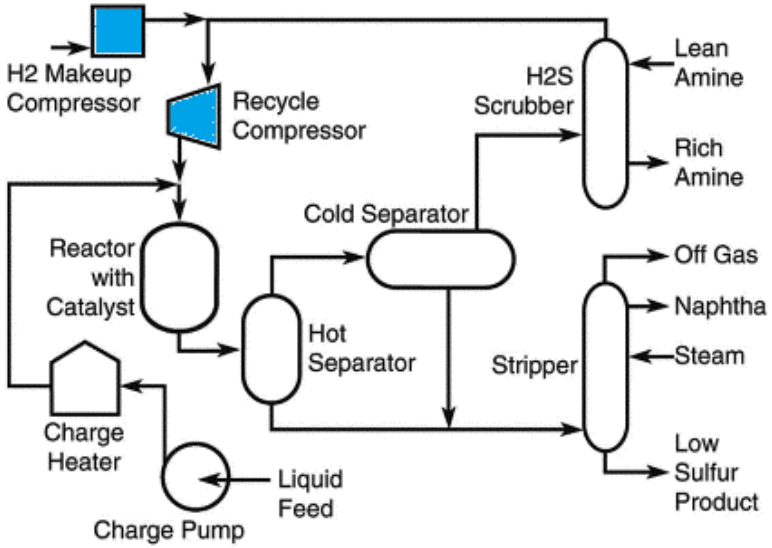
Separate units or multiservice?



	Separate	Multiservice
CAPEX	-	+
OPEX	+	-
Footprint	-	+
Capacity	+	-
Availability	+	-

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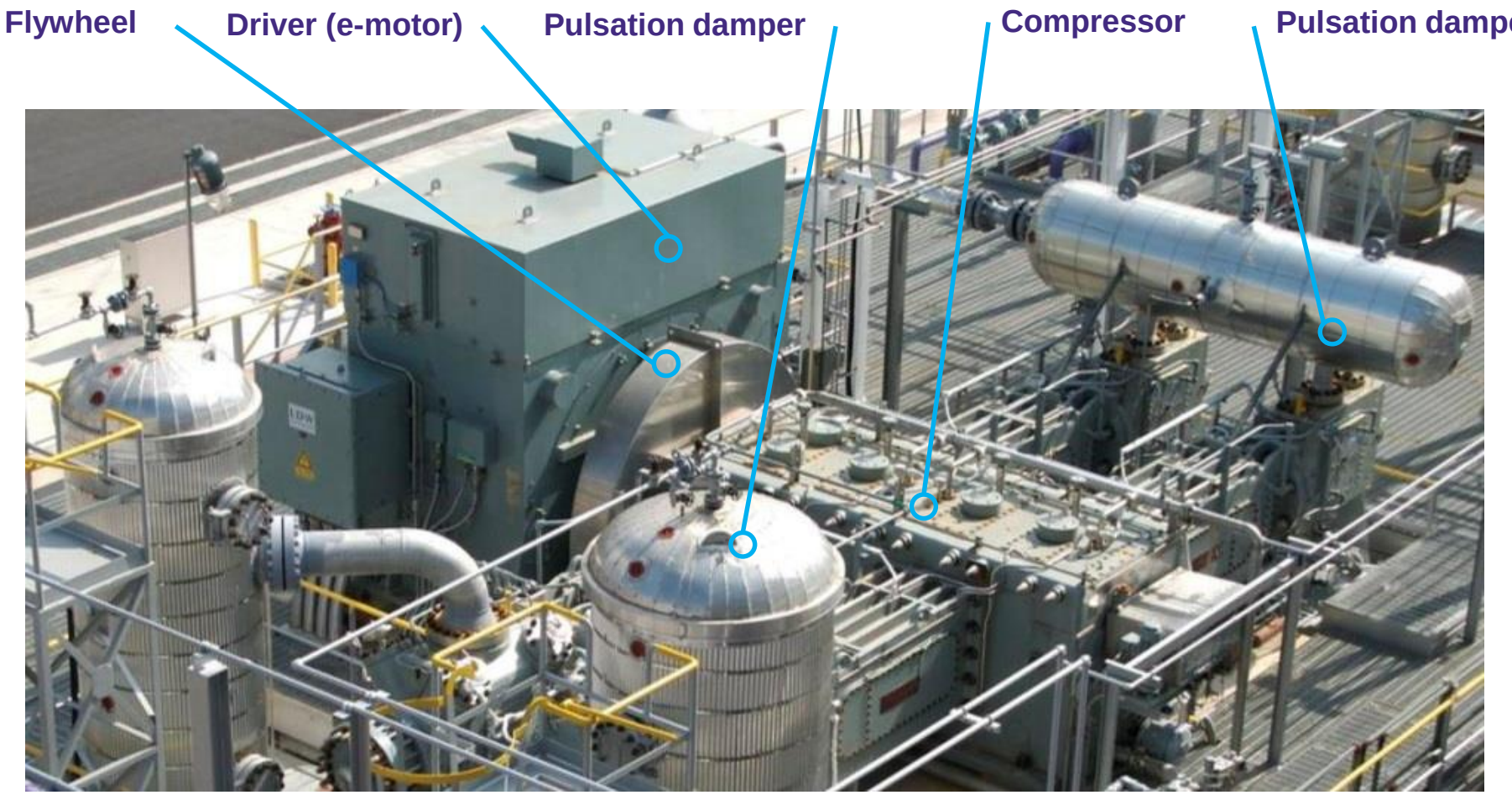
Main components



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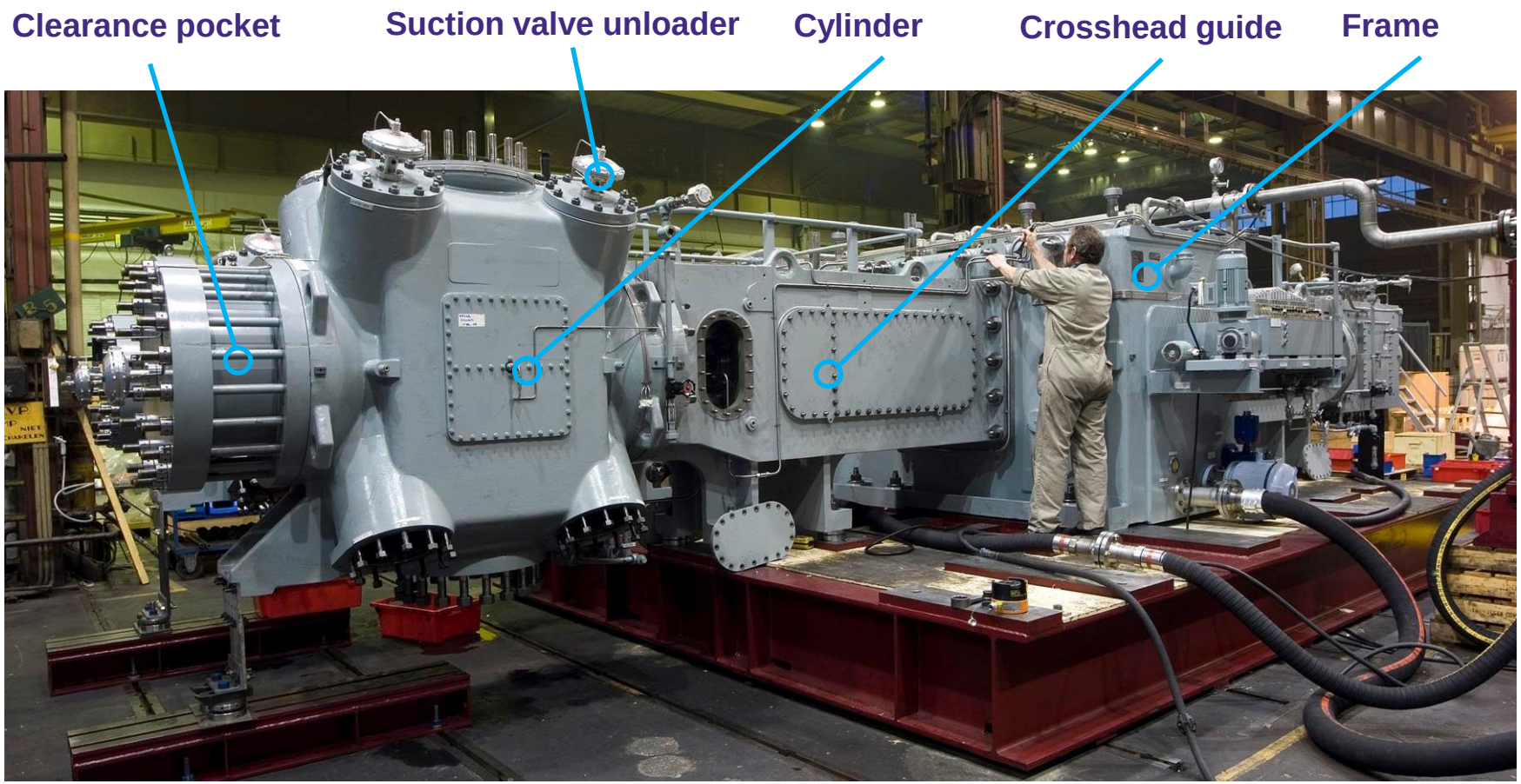
Main components



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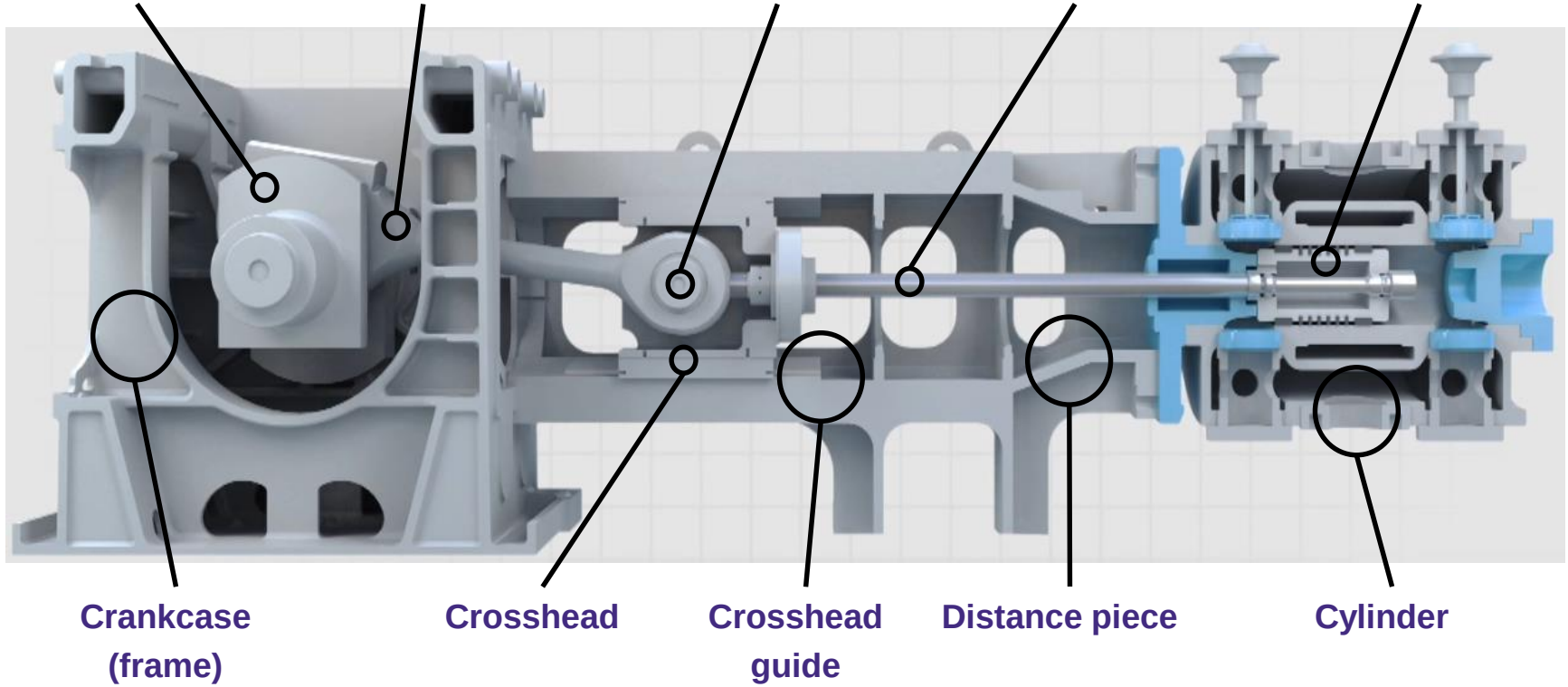
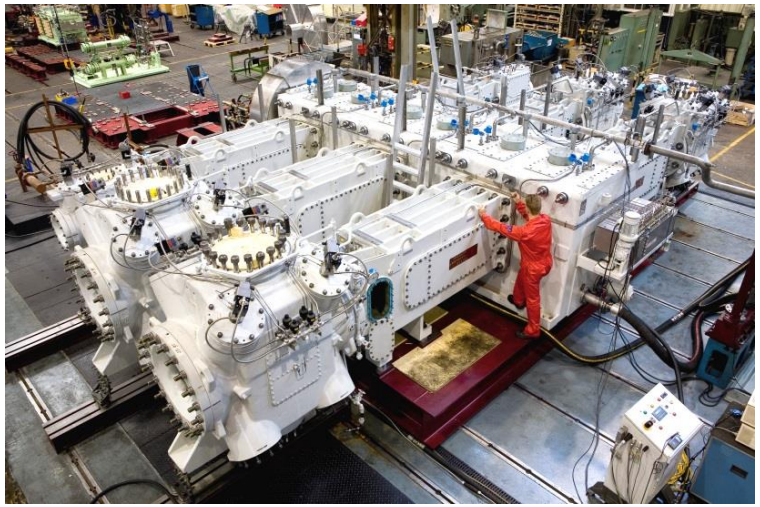
Construction



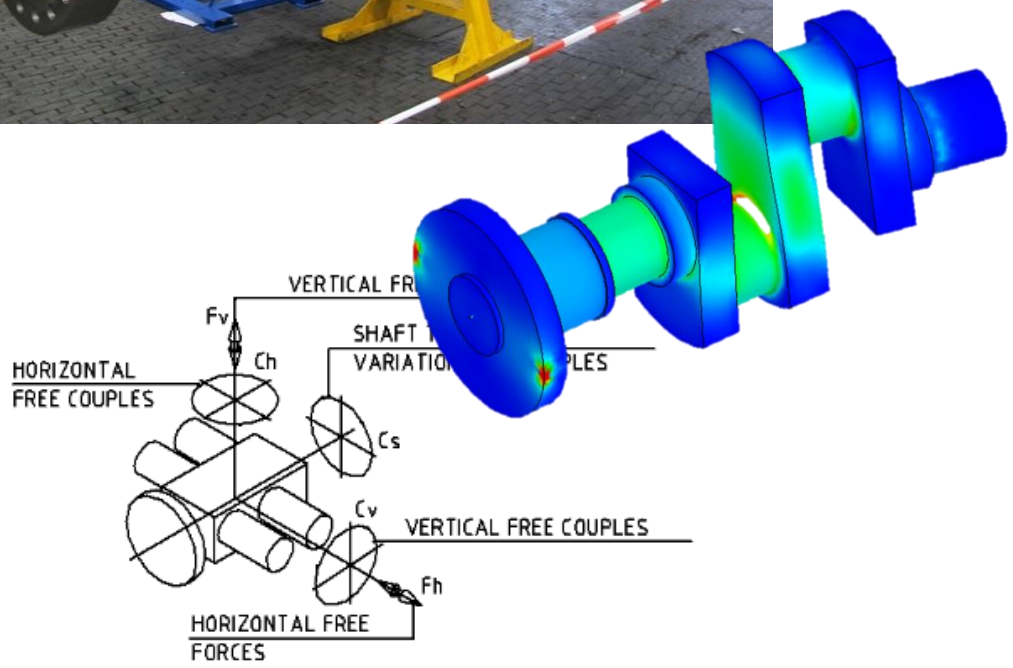
Crankcase

- Function
  - Contain and support parts
  - Transfer forces and moments to foundation
  - Oil reservoir
- Design
  - Cast iron
  - Ribbed construction for force transfer



Crankshaft

- Function
  - Transfer rotating motion from driver to connecting rod big end bearing
- Design
  - Forged steel
  - Drilled passages for lube oil distribution to connecting rod
  - Flanged or shaft end



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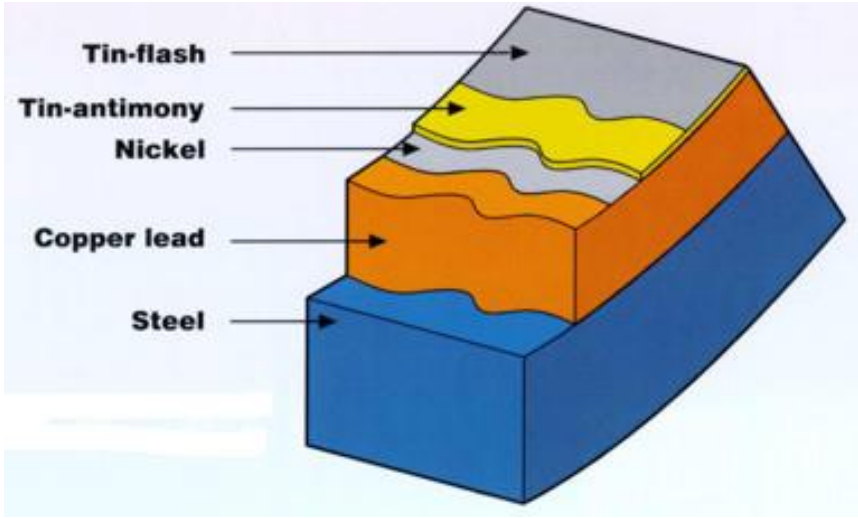
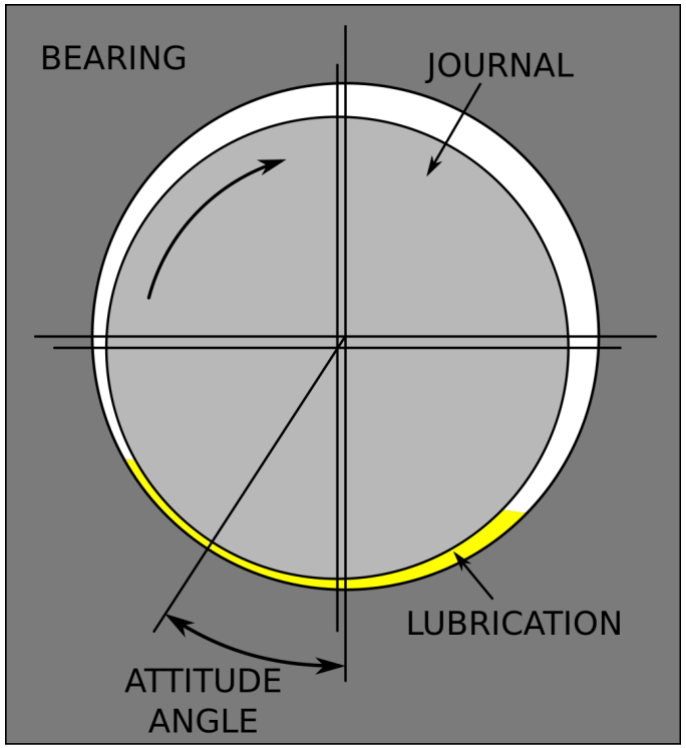
Bearings

- Hydrodynamic lubrication
- Tri-metal bearings
  - High fatigue strength
  - Good anti-friction properties
- Tin flash
  - Corrosion protection
- Running layer
  - Load bearing
  - Soft, thin layer
- Nickel dam
  - Prevents diffusion of tin
- Intermediate layer
  - Cu Pb lead bronze layer
- Steel backing





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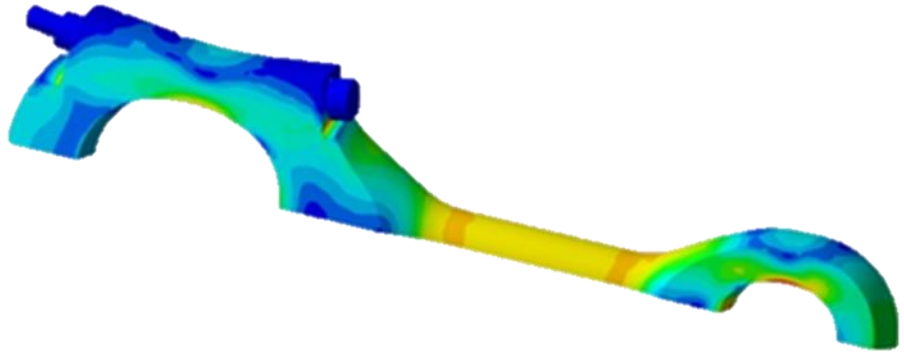
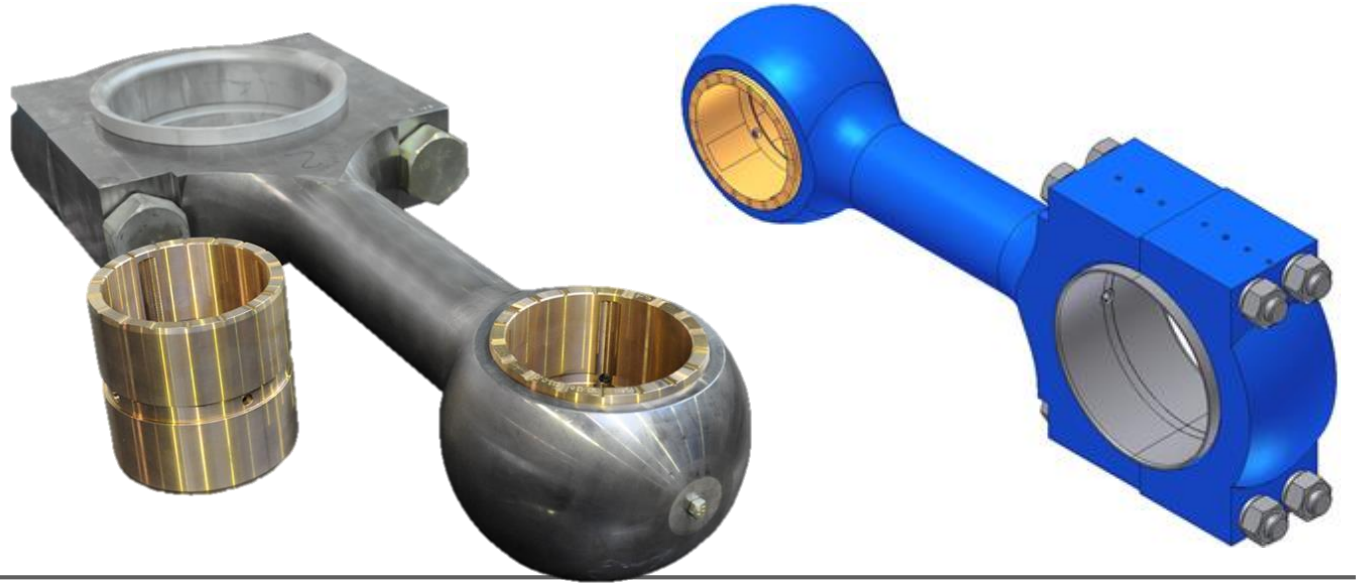
Connecting Rod

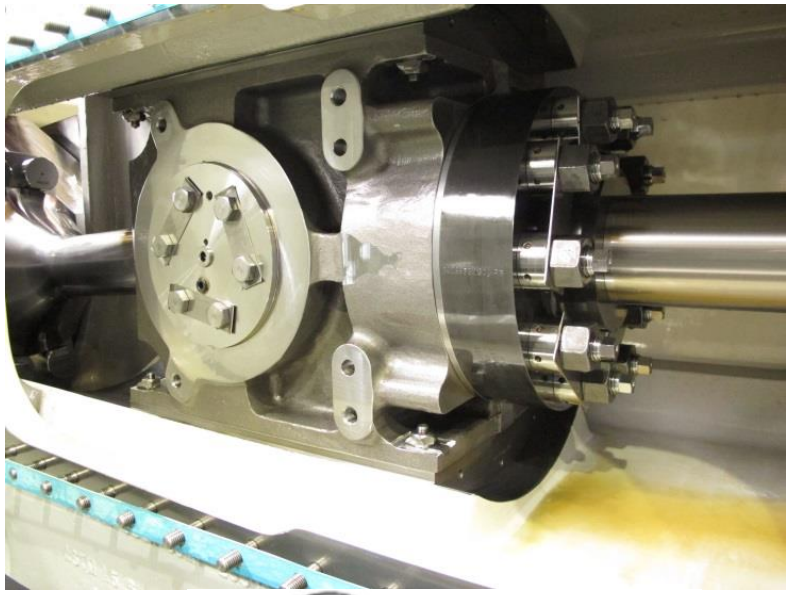
- Function
  - Connect crankshaft to crosshead
  - Transfer rotating to reciprocating motion
- Design
  - Forged steel
  - Big end bearing cap
  - Houses big and small end bearings

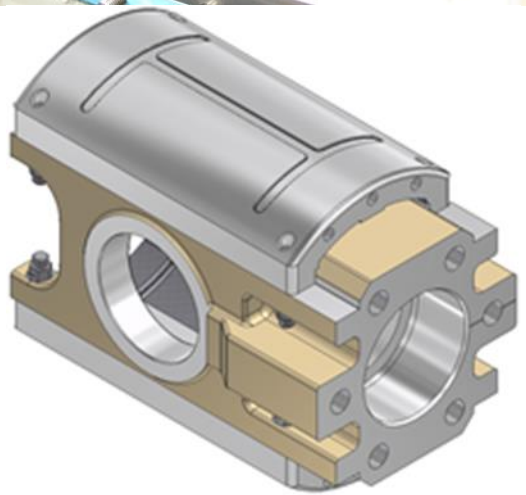




Crosshead

- Function
  - Connect piston rod to connecting rod
- Design
  - Cast steel
  - Replacable shoes
  - Floating or fixed crosshead pin
  - Crosshead pin bushings





Bolted connections

$F_i = bolt\ pretension$

$P = external\ load$

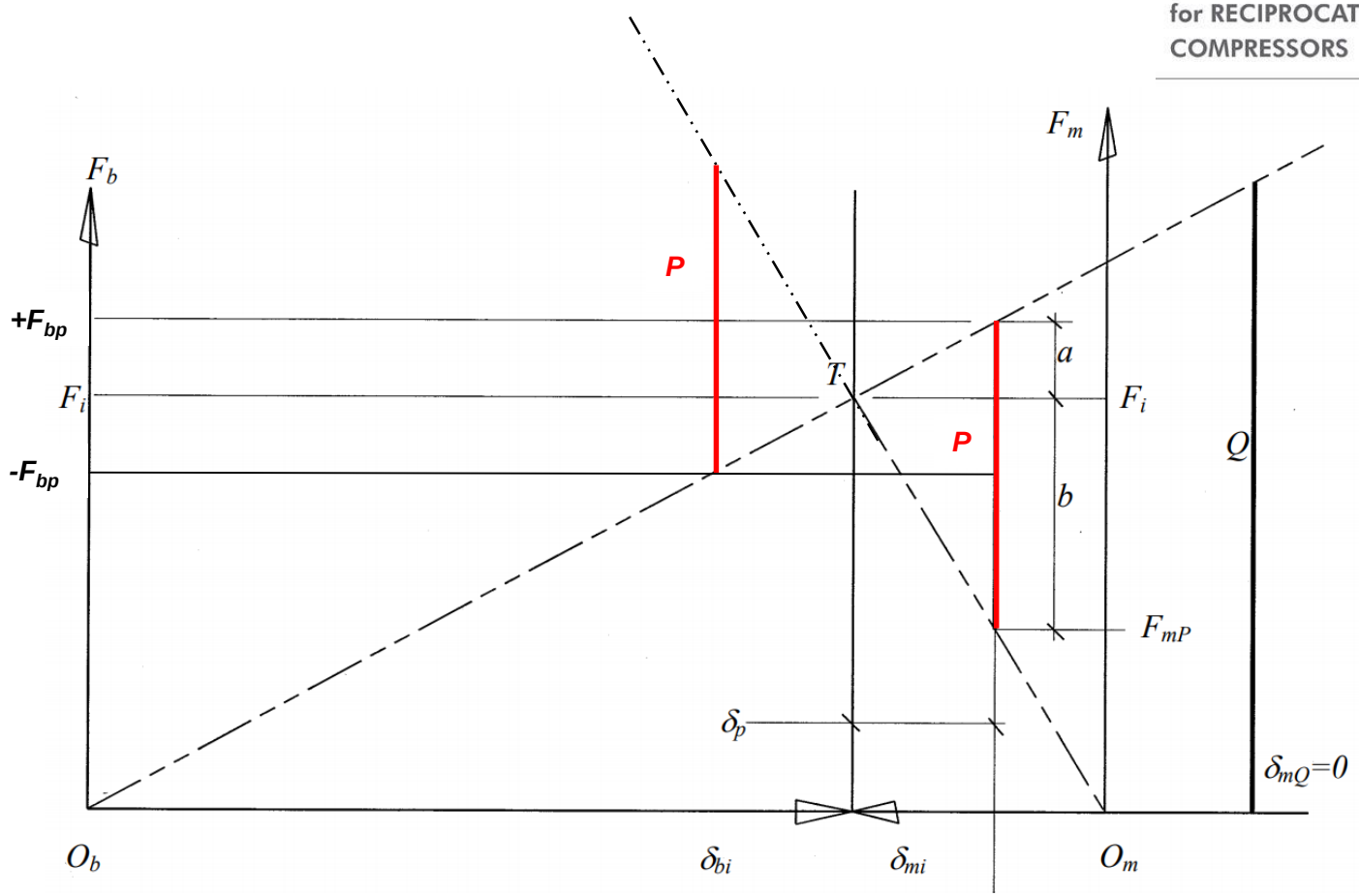
$$k_b = \frac{F_i}{\delta_{bi}}$$

$$k_m = \frac{F_i}{\delta_{mi}}$$

$$\pm F_{bp} = \frac{k_b}{k_b + k_m} P$$

$$k_m \gg k_b$$

$$F_{bp} \ll P$$



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Pin load and reversal

- Combined rod load/pin load is the sum of gas load and inertia forces on the crosshead pin
- Load shall fully reverse between pin and bushing
- Duration (°) and magnitude (%) shall be sufficient to maintain proper lubrication

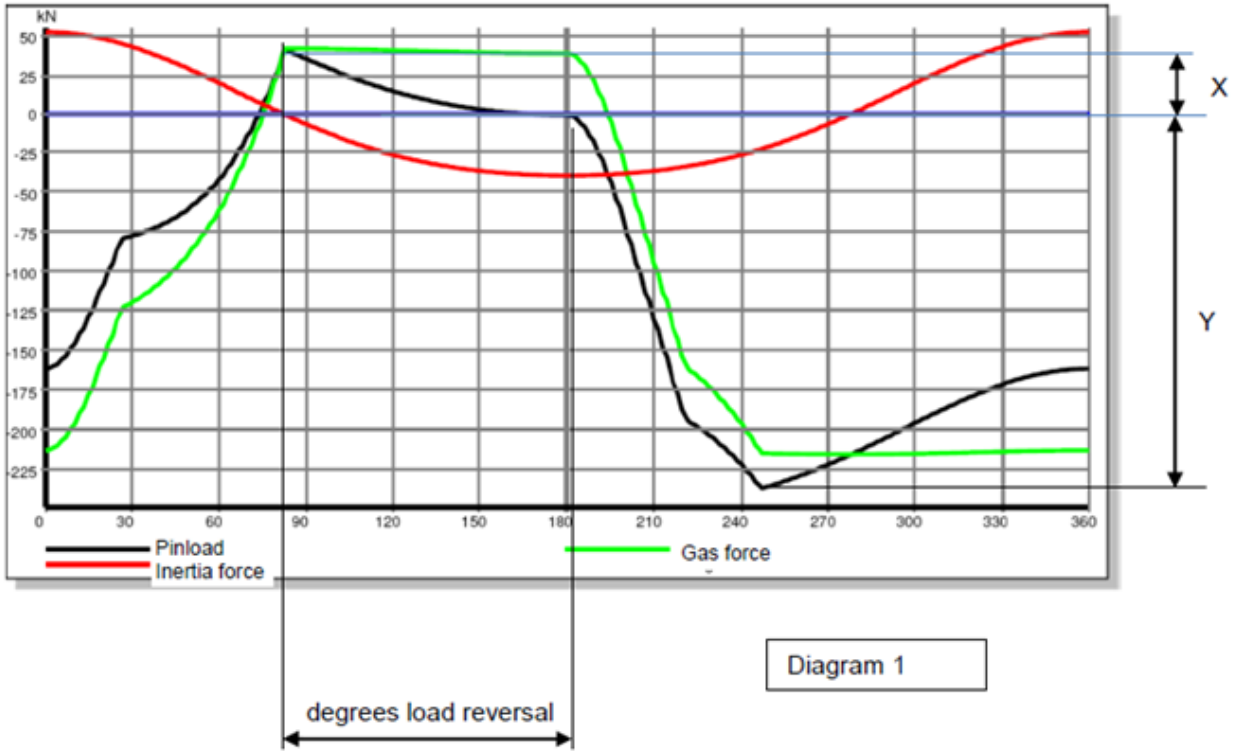
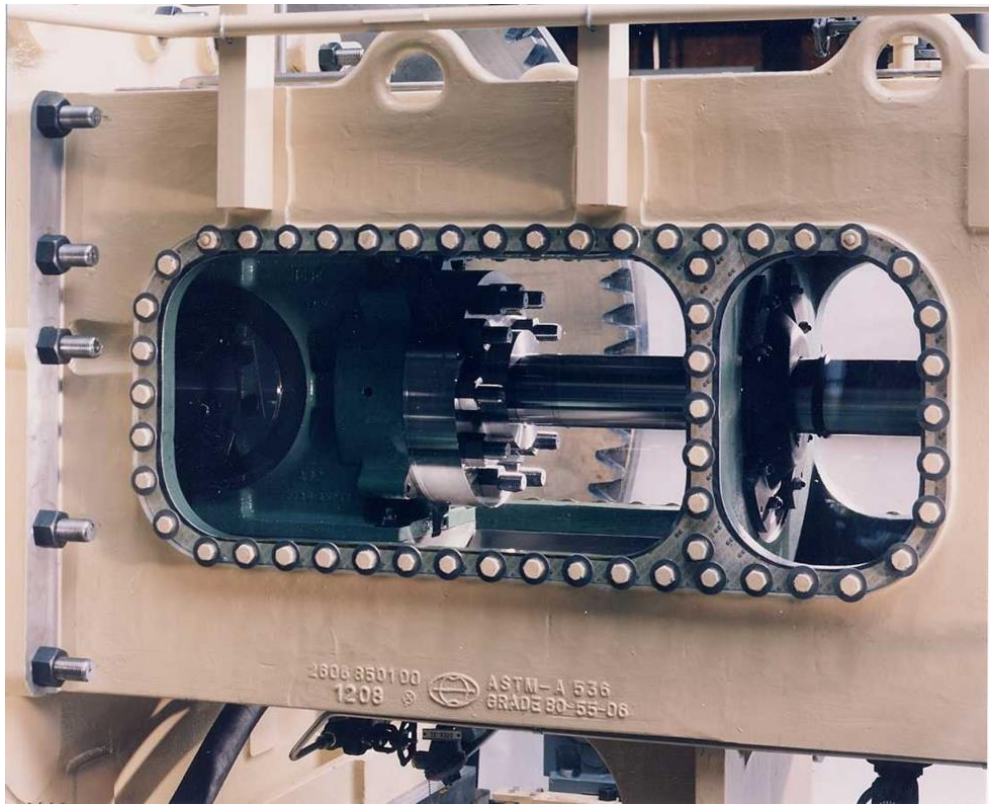


Diagram 1

Amount of crosshead pin load reversal is "X"/"Y"

Crosshead Guide

- Function
  - Guide reciprocating motion of crosshead
  - Enable lubrication of the sliding surfaces
- Design
  - Cast iron
  - Integral part of frame or integrated with distance piece

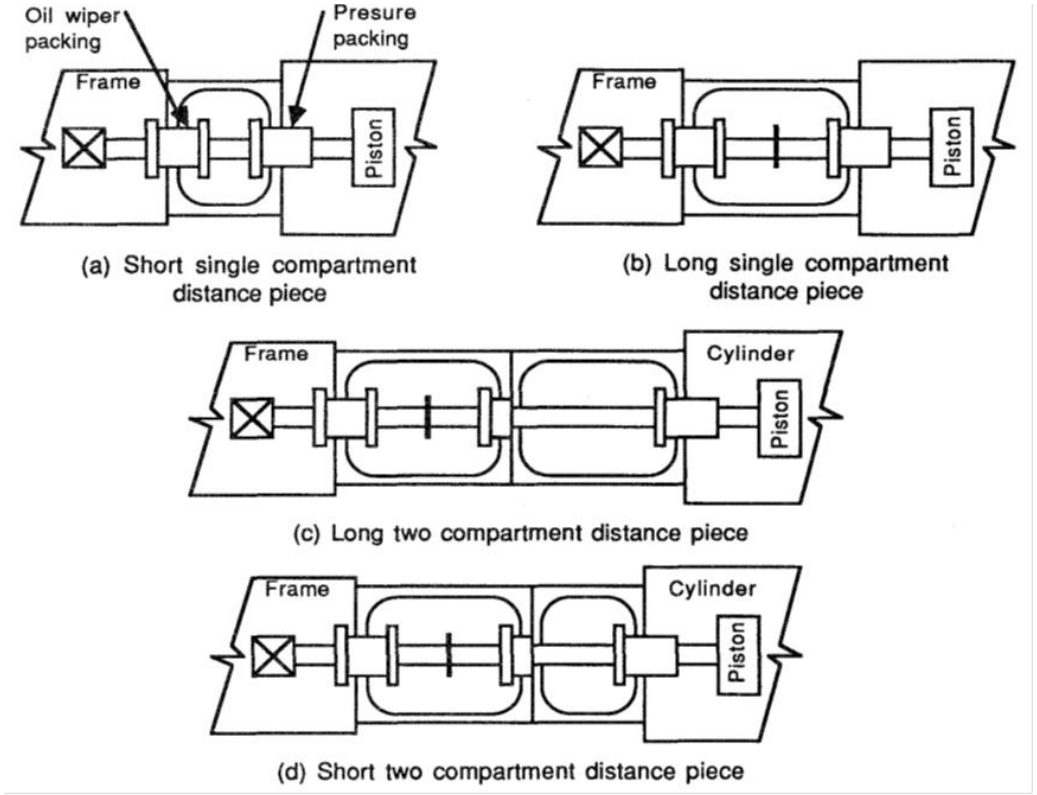


Distance Piece

- Function
  - Connect cylinder to crankcase
  - Provide barrier for process gas between cylinder and crankcase
- Design
  - Cast iron
  - Single or double compartment

Distance Piece

- Type A
  - Single compartment, short
  - Non-flammable, non-hazardous gas
  - Oil carry-over acceptable
- Type B
  - Single compartment, long
  - Non-lube or oil carry-over not acceptable
- Type C
  - Double compartment, long/long
  - Only for special service, e.g. oxygen
  - Normally not used on process gas compressors
- Type D
  - Double compartment, long/short
  - For flammable, hazardous or toxic gases



Source: API 618, 5th edition

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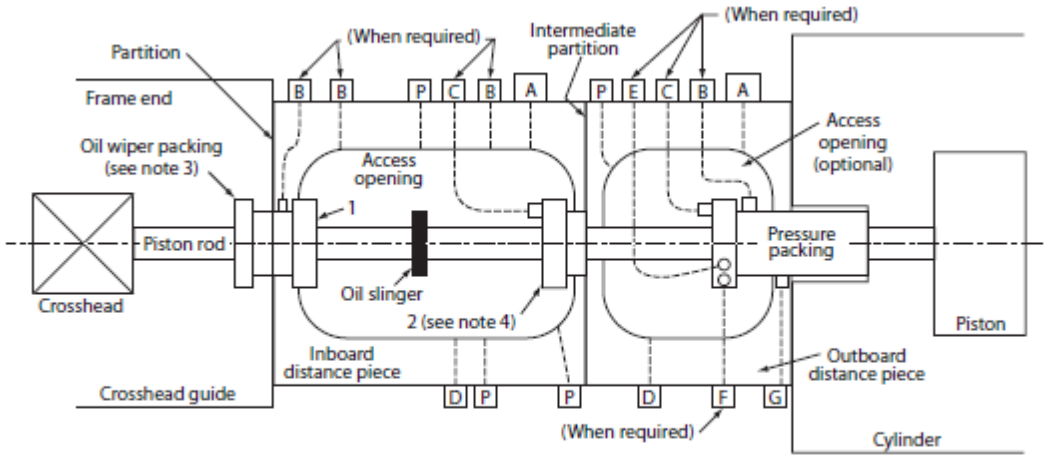
Distance Piece

- Vent
  - Process gas from piston rod packing (combined vent/drain)
  - Process gas from outboard compartment
- Drain
  - Liquids from piston rod packing (combined vent/drain)
  - Liquids from outboard compartment (normally open)
  - Liquids from inboard compartment (normally closed)
- Buffer
  - Inert gas
  - On piston rod packing
  - On inboard compartment or on compartment seals



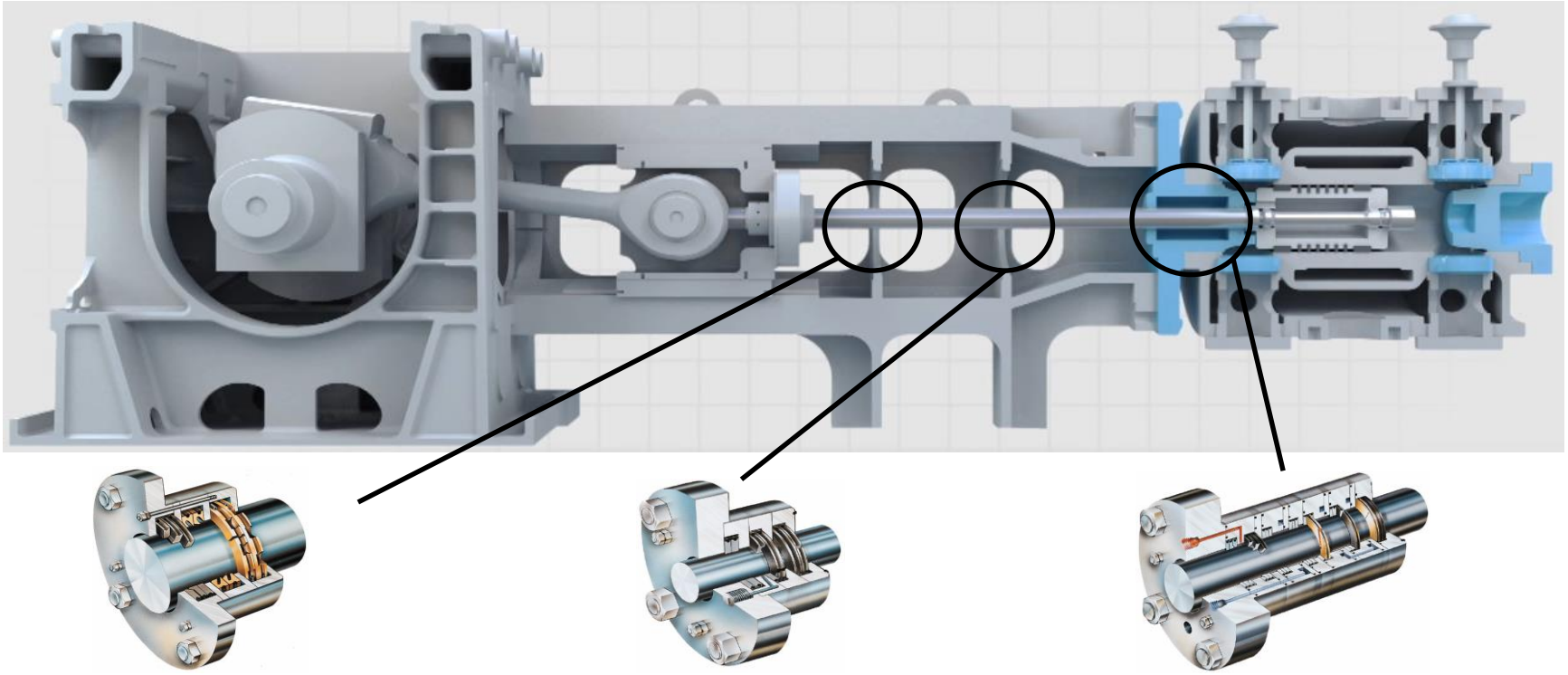
TYPE D
SHORT TWO-COMPARTMENT OR DOUBLE DISTANCE PIECE ARRANGEMENT
(INBOARD DISTANCE PIECE OF SUFFICIENT LENGTH FOR OIL SLINGER TRAVEL)

Legend:
1. Seal or buffer packing, distance piece
2. Intermediate seal or buffer packing, distance piece (solid access covers required)

Connections (see 6.12.2 for sizes):
A Vent, distance piece
B Purge, buffer, or pressure, packing or distance piece
C Lube, pressure packing
D Drain, distance piece
E Coolant out, pressure packing
F Coolant in, pressure packing
G Common vent and drain, pressure packing
P Plugged connection

Source: API 618, 5th edition

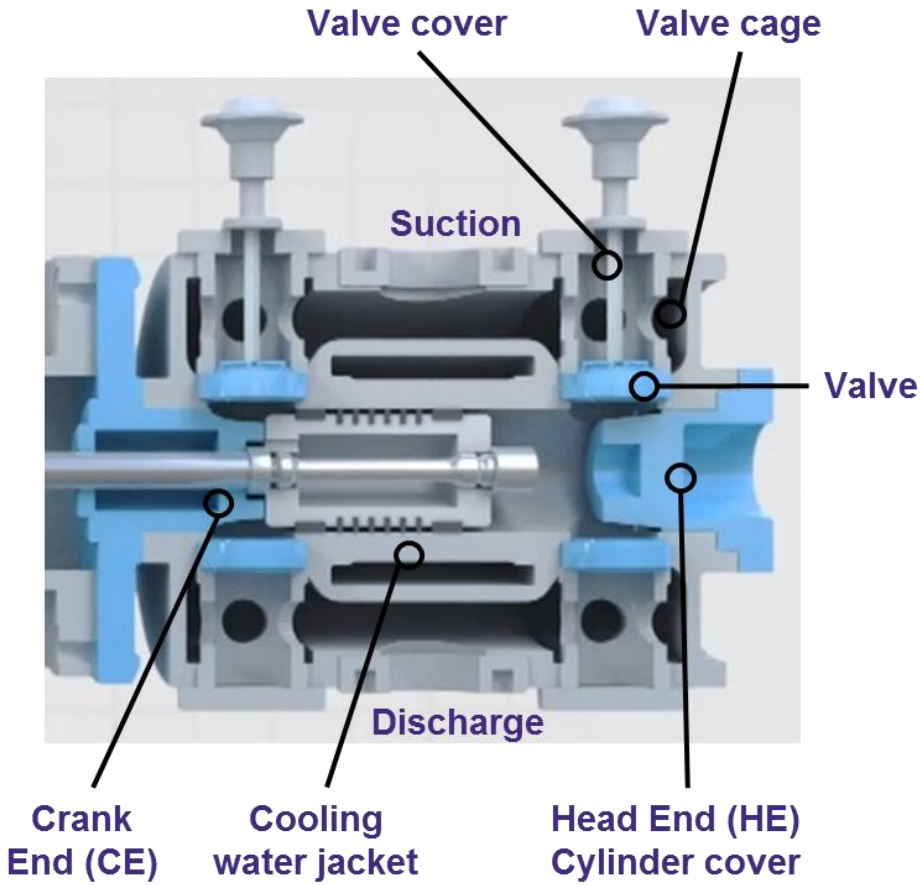
Piston rod sealing



Oil wiper packing	Intermediate packing	Stuffing box
Wipes of the motion work lubrication oil from the piston rod. Seals crankcase from inboard compartment.	Seals the inboard compartment from the outboard compartment	Main pressure seal. Seal between compression chamber and compartment.

Cylinder

- Function
  - Transfer process gas to/from compression chamber
  - Contain process gas during compression cycle
- Design
  - Double acting (DA) most common
  - Cast iron, cast steel or forged steel



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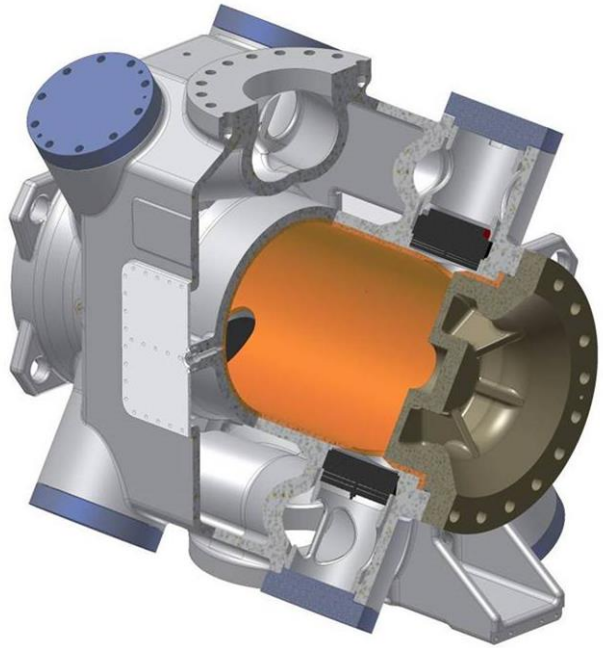
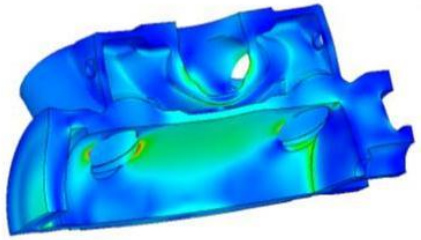
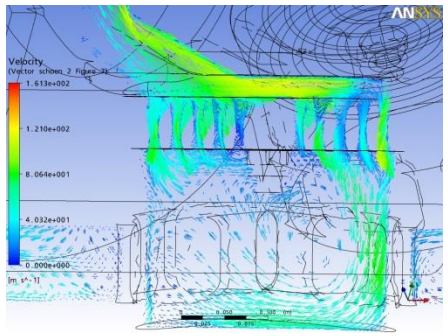
Cylinder

- Design
  - < 100 barg: Cast iron
  - < 180 barg: Cast steel
  - >180 barg: Forged steel
- Cooling water jackets & channels
- Replaceable, dry type liner
- Flanged connections for piping
  - ASME B16.5
  - ASME B16.47A/B
  - Or proprietary design







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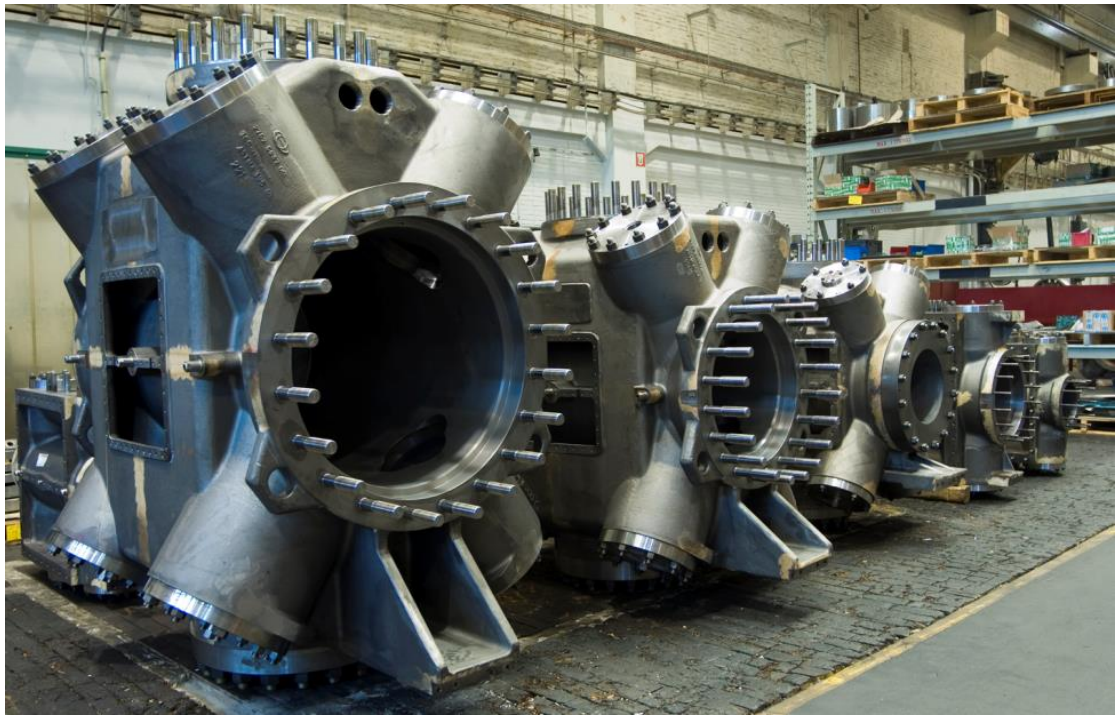
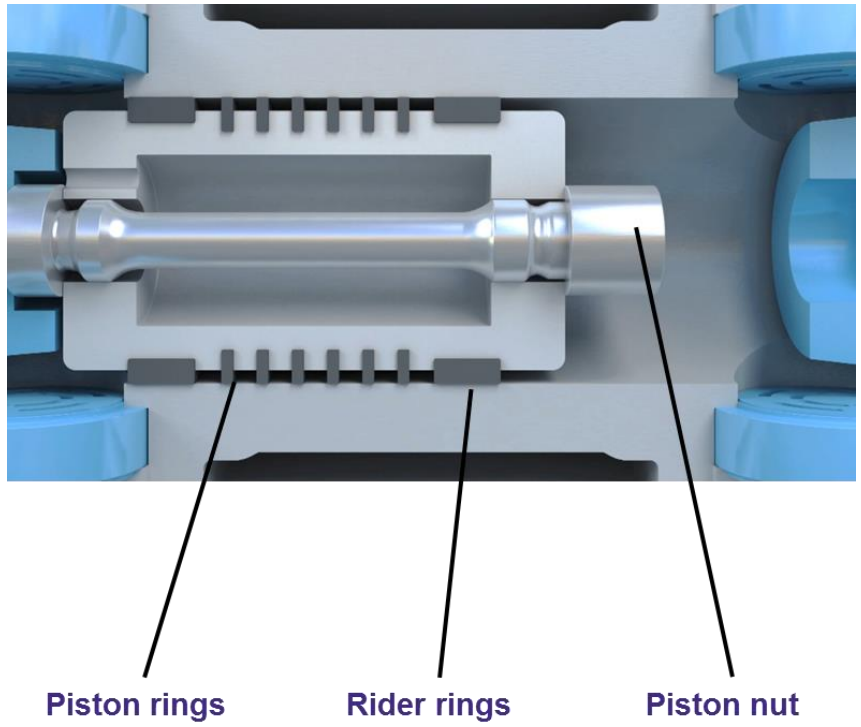
Cylinder

- NDE
  - PT, UT, MT, RT
- Hydrostatic testing
  - Mechanical integrity
  - Using water
  - 1.5 x P_{design}
- Pneumatic testing
  - Leakage test
  - Using inert gas
  - 1 x P_{design}



Piston

- Function
  - Reduce process gas volume
- Design
  - Cast iron, stainless steel or aluminium alloy
  - Solid or hollow
  - Vented if hollow
  - Grooves for piston and rider rings



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Standards

- API
  - 618: Reciprocating Compressors
  - 614: Lubrication, shaft-sealing and control-oil systems and auxiliaries
  - RP 686: Recommended practices for machinery installation and installation design
  - RP 684: Standard paragraphs rotordynamic tutorial
  - RP 688: Pulsation and vibration control in positive displacement machinery systems
- Customer & project specifications

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- API 618 heavy duty reciprocating compressors are rugged, flexible and highly efficient
- State of the art design & analysis tools are applied to optimize equipment safety and reliability