EFRC Training Workshop
Lubrication and Wear

Cylinder lubrication,

Effect on wear of pistons and rider rings

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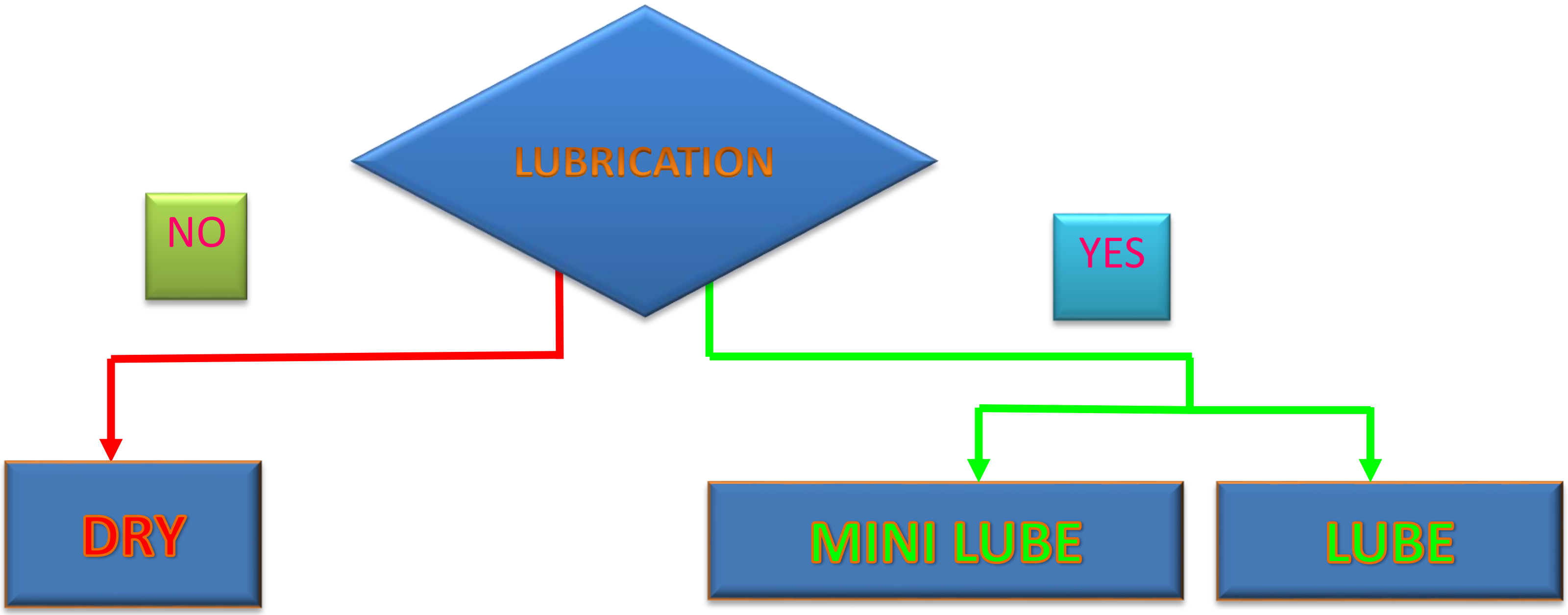
CONTENT:

1. Cylinder lubrication
2. Wear
3. Field experience

CONTENT:

1. Cylinder lubrication
   - Options
   - Purposes
   - Oils
   - Quills
   - Lubrication systems
2. Wear
3. Field experience

CYLINDER LUBRICATION: OPTIONS



Depending on:
- ✓ Lubrication tolerability
- ✓ Economic evaluation
- ✓ Requested reliability
- ✓ Discharge pressure

CYLINDER LUBRICATION: PURPOSES

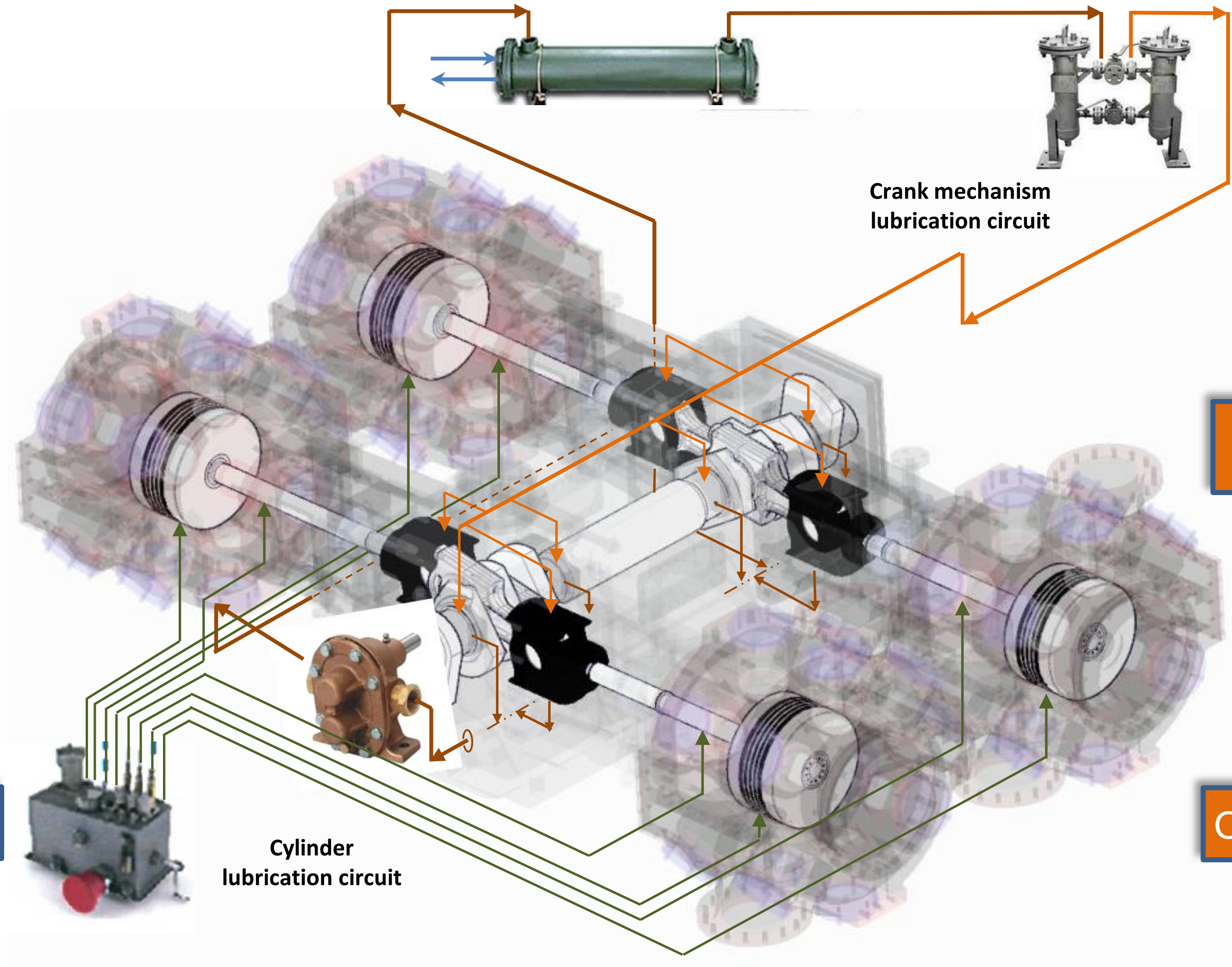
Purposes

- ✓ Minimize wear
- ✓ Dissipate frictional heat
- ✓ Remove impurities
- ✓ Protect metal parts from corrosion

Characteristics

- ✓ High pressure working conditions
- ✓ Low (*drops/min*), measured and constant flow rate required
  - as lube oil is a contaminant for the process gas
  - to guarantee controlled flow for each injection point
- ✓ The lube oil cannot be recovered
- ✓ Heat dissipation

CYLINDER AND CRANK MECHANISM LUBE CIRCUITS



Cylinders

Open circuit

Crank mechanism

Closed circuit

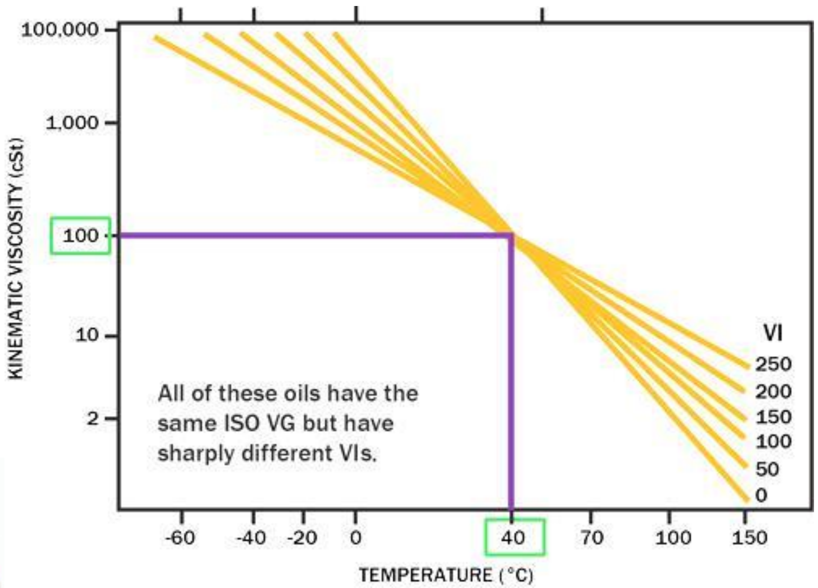
TYPICAL LUBRICATION OILS FOR CYLINDERS

Compressor oil viscosity generally used for cylinders: ISO VG 220 / ISO VG 320 (ISO3448)

Necessary to know how the viscosity changes in relation to a temperature change

ISO viscosity grade only refers to the viscosity at the temperature of 40 °C

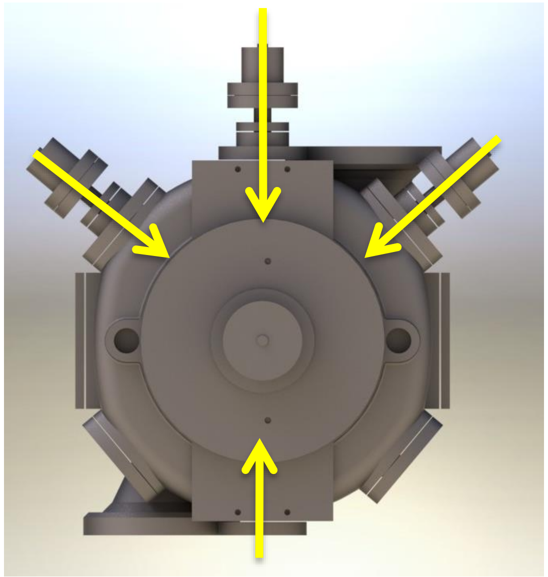
Viscosity Index (**VI**) = variation of viscosity with temperature



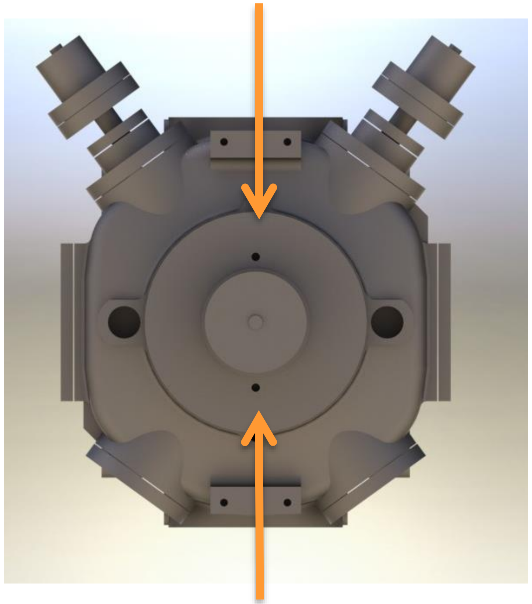
The higher is the V.I., the lower is the change of viscosity at the same Δ temp.

CYLINDER LUBRICATION INJECTION POINTS

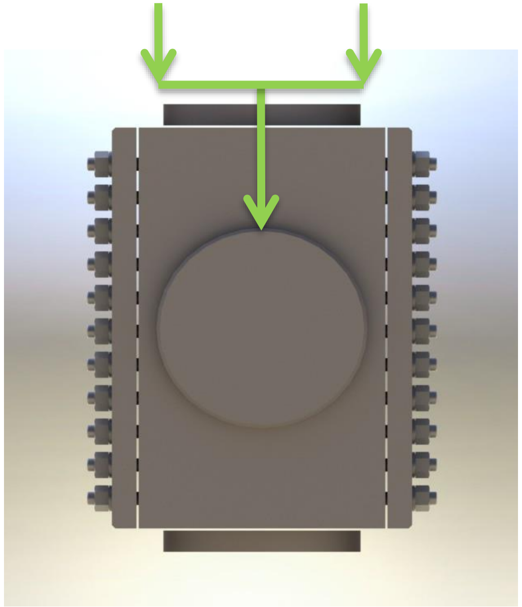
The oil must be distributed in all the area swept by the piston



Large cylinder

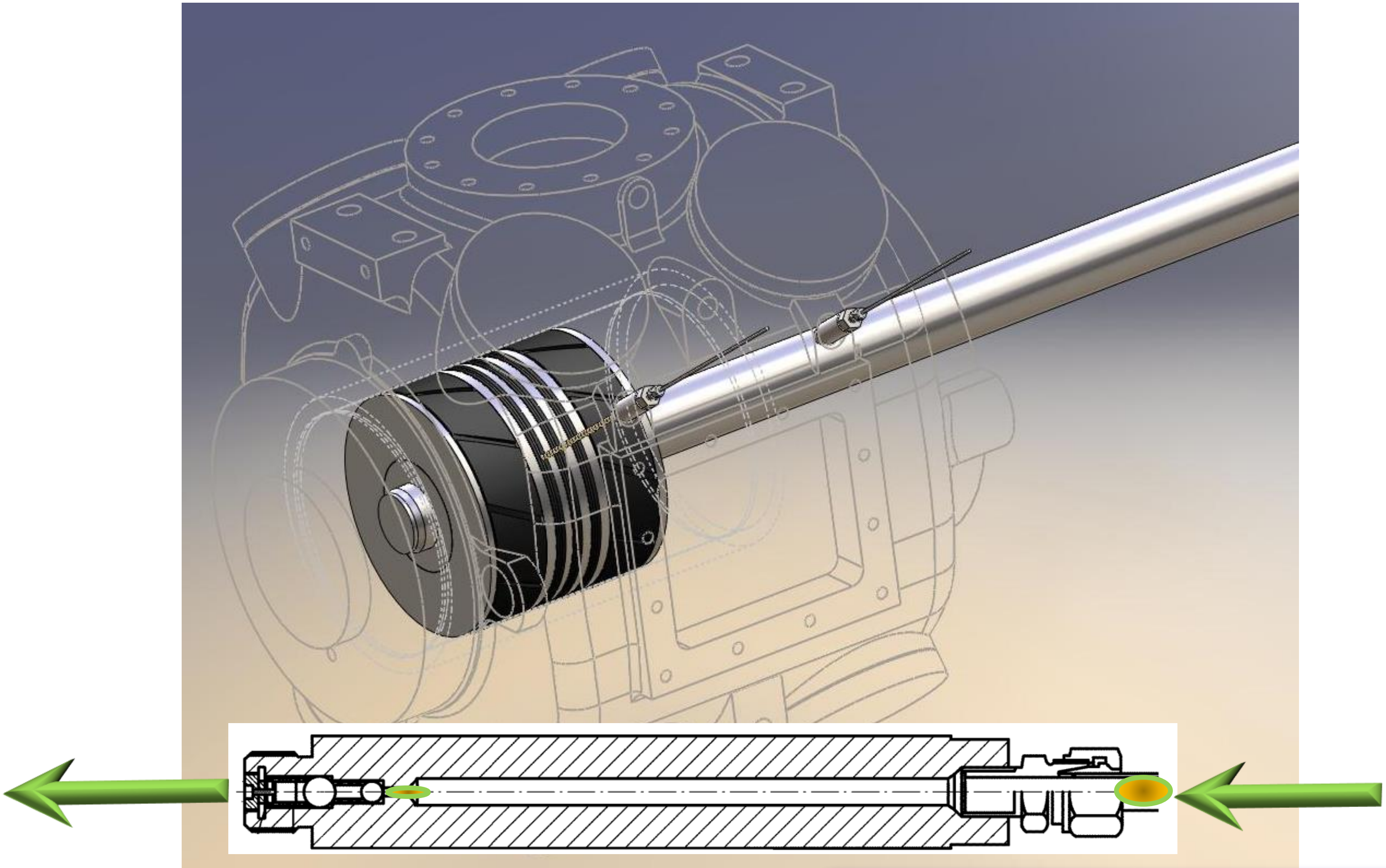


Small cylinder



Forged small cylinder

LUBRICATION QUILLS



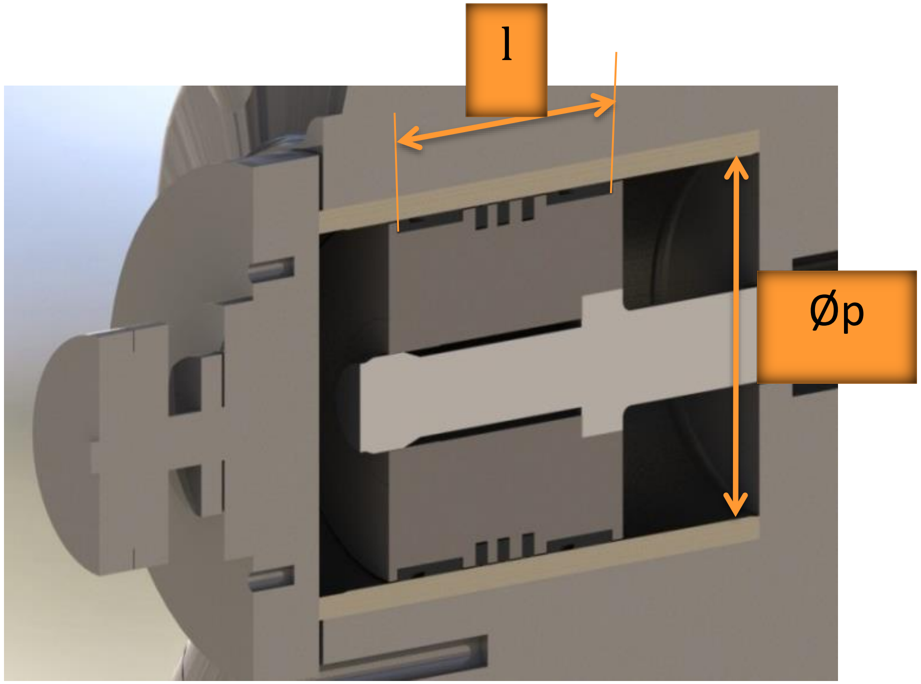
DOUBLE CHECK VALVE

OIL TUBING CONNECTION

OIL CONSUMPTION

Cylinder theoretical consumption = $Cx \cdot SS_P$

- Cx = constant specific consumption, depending on the Mfr experience
- $SS_{P\,=}$ piston Swept Surface



The API618 requires a lubrication system capable of providing oil flow rates between 75% and 200% of the nominal flow

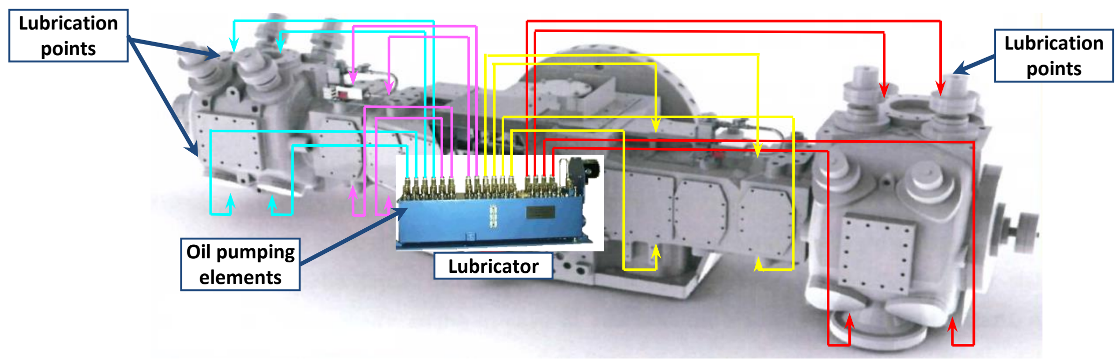
OIL CLASSIFICATION

APPLICATION	TYPE	MAIN CHARACTERISTICS
• Low pressure gas	Mineral or synthetic	Low tendency to foam formation
• High humidity gas	Mineral or synthetic	Antioxidant properties, washing resistance
• Solvents or condensable gases	Mineral or synthetic	low emulsion time, film strength
• Low inlet temperature	Mineral or synthetic	Low pour point
• Air	Mineral or synthetic	Low emulsion time
• Ethylene (LDPE)	Synthetic	Antioxidant, corrosion-protecting qualities, usable for packaging food, low viscosity index

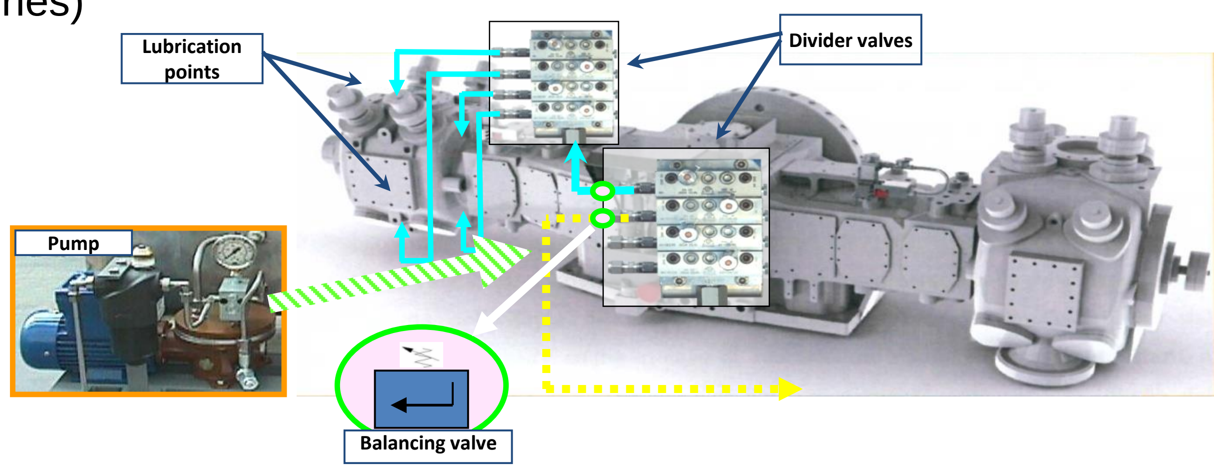
Lube oil selection shall be a compromise between lubricating properties and process

CYLINDER LUBRICATION SYSTEMS

- ✓ **PtP** System (Pump-to-Point) ⇒ A single pumping element for each lubrication point

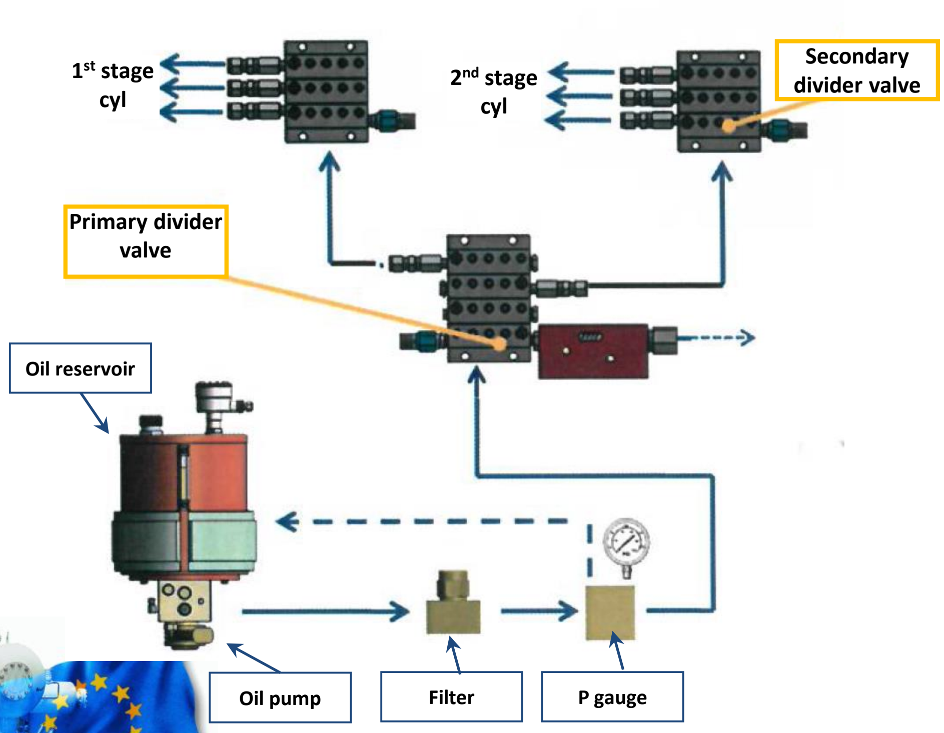


- ✓ **PS** System (Progressive Series) ⇒ A pumping element with Divider Valves

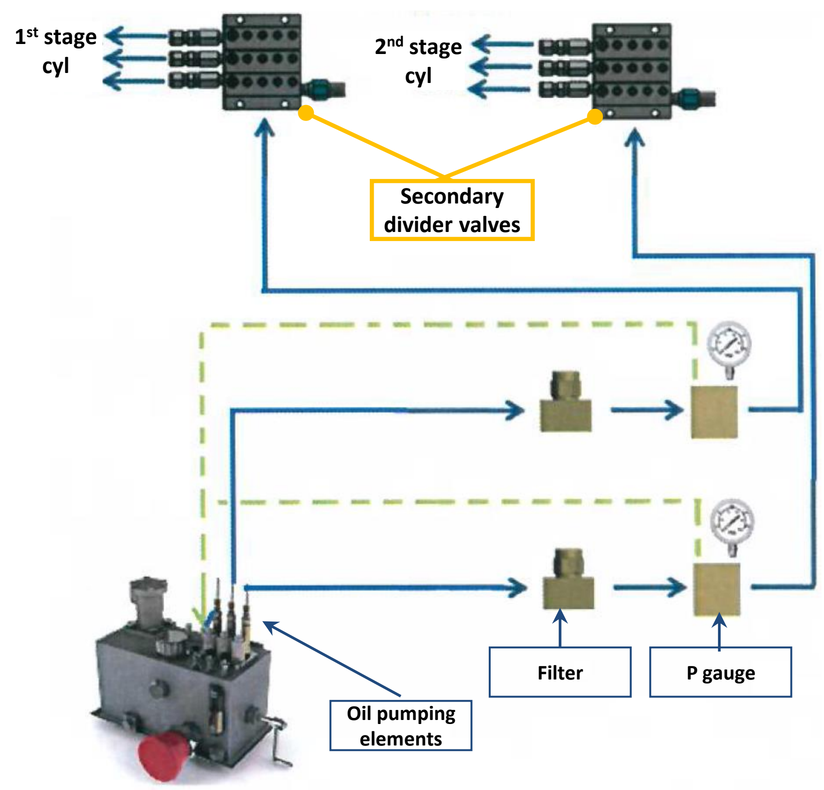


PS lubrication systems

Traditional version
with primary and secondary Divider Valves



Hybrid version
with secondary Divider Valves only



COMPARISON

PtP System	Traditional PS System	Hybrid PS System
PROS:	**PROS:**	**PROS:**
✓ High injection frequency	✓Only one pumping unit	✓Few pumping elements with optimum operating range
✓Flow rate to the single point: • independent from the other points • easily adjustable	✓Oil flow rate matching requirements	✓Each pumping elements feeds the full flow required by one cylinder/stage
✓No additional device downstream of the pumping elements	✓ Easier flow monitoring	✓The flow rate can be easily adjusted to each cylinder /stage
		✓Balancing valves not necessary
		✓Oil consumption minimized
CONS:	**CONS:**	**CONS:**
✓Flow rate higher than necessary • Setting to minimal flow rate • Unstable operating conditions • Oil consumption may result higher than necessary	✓Flow rate to each single point not adjustable	✓In the event of blockage of a line the divider valve makes all the relative cylinders run dry
	✓If a line is blocked, the secondary divider valve stops, stopping also the primary one and making all the cylinders run dry	
	✓Balancing valves required	

CONTENT:

1. Cylinder lubrication
2. Wear
3. Field experience

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1. Cylinder lubrication
2. Wear
   - Definition and possible causes
   - Wear rate
   - API 618 prescription
   - Piston rings and rider rings
   - Materials
3. Field experience

WEAR: DEFINITION AND ORIGIN

Wear: Is the loss of surface material that occurs progressively on the surfaces of bodies in contact when subject to relative movement

Reasons for rapid wear of cylinder seals and counterparts:

- ✓ Inappropriate lubricant oil quality and/or quantity
- ✓ Wrong number /design of sealing elements
- ✓ Too high surface pressure on rider rings
- ✓ Wrong sliding parts material selection
- ✓ Abrasive particles / solvents in the process gas
- ✓ Wrong roughness of sliding surfaces

WEAR RATE

General relationship of wear rate (**W_r**):

$$W_r = kPVT$$

Where: **k** = function of material
P = contact pressure (variable during each piston stroke for seal rings)
V = piston velocity (variable during each piston stroke)
T = time (service life)

Wear rate (W_r) is proportional to friction

API 618 PRESCRIPTION ON RIDER RINGS

From point 6.10.3.2 of API 618 5th Edition:

For non-lubricated horizontal cylinders, the bearing load calculated from Equation 2 on nonmetallic wear bands shall not exceed 0.035 N/mm² (5 lbf/in.²) based on the mass of the entire piston assembly plus half the mass of the rod divided by the projected area of a 120° arc of all wear bands (see Equation 2).

For lubricated horizontal cylinders, the bearing load calculated from Equation 2 on wear bands, if used, shall not exceed 0.07 N/mm² (10.0 lbf/in.²) using the same approach described for nonmetallic wear bands.

$$L_B = \frac{M_{PA} + (M_R/2)}{(0.866 \times D \times W)} \qquad (2)$$

Where:

L_B is the bearing load on wear band in N/mm² (lbf/in.²);

M_{PA} is the weight of piston assembly in N (lbf);

M_R is the weight of piston rod in N (lbf);

D is the cylinder bore diameter in mm (in.);

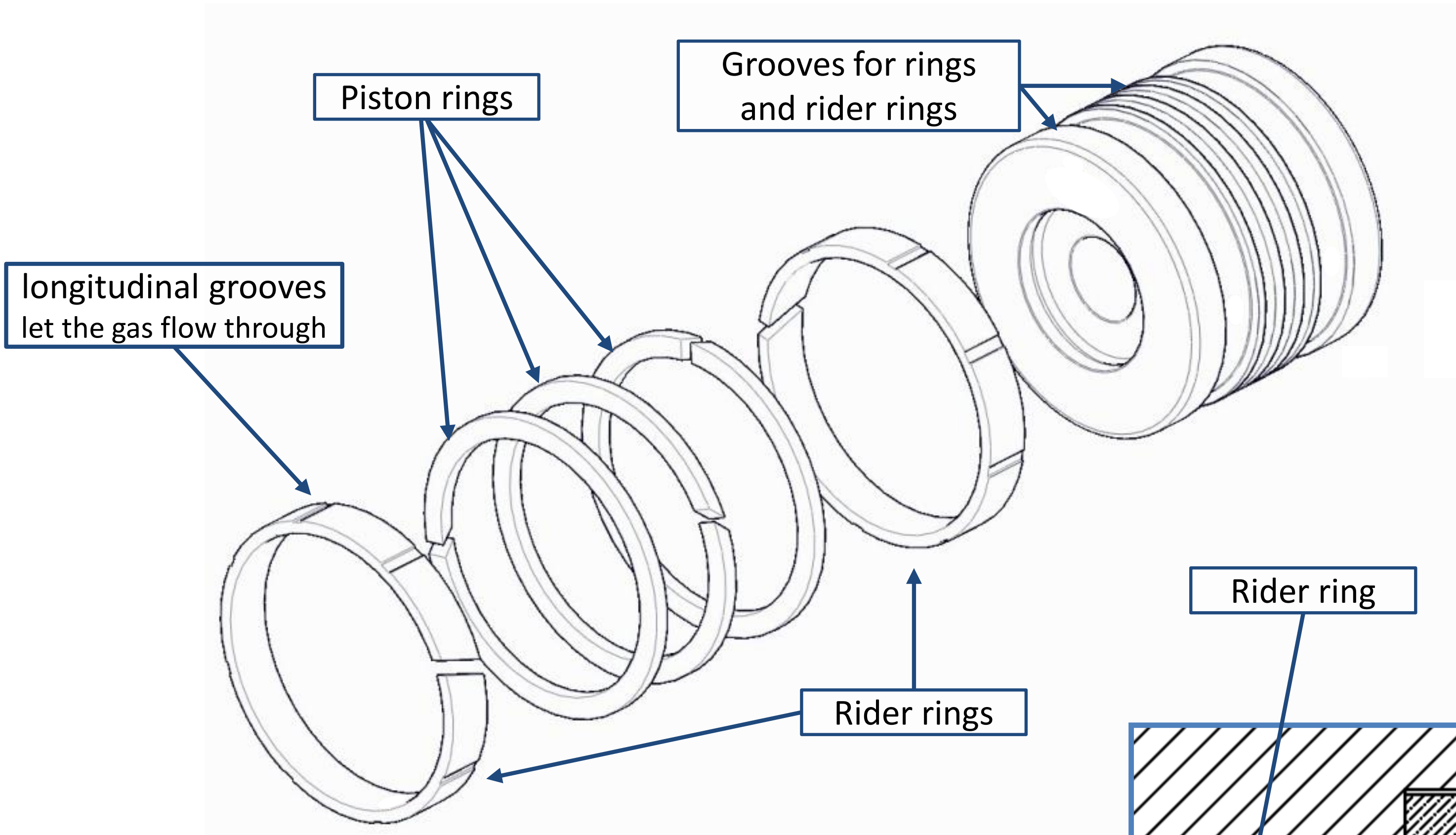
W is the total width of all wear bands in mm (in.).

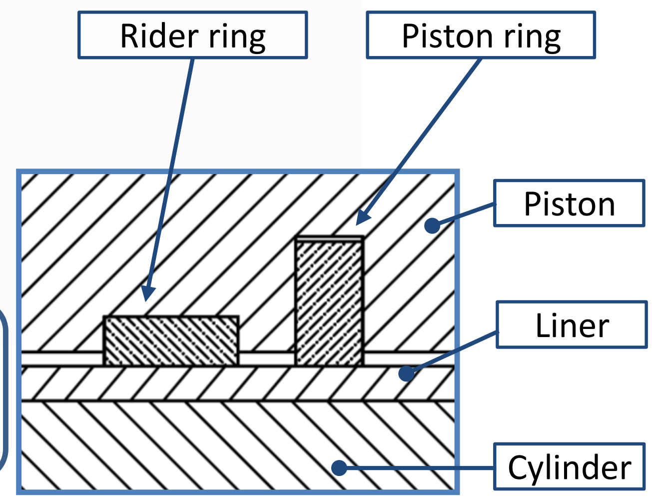
Max specific load:

0.07 N/mm² → **lubricated** service

0.035 N/mm² → **dry** service

PISTON RINGS AND RIDER RINGS

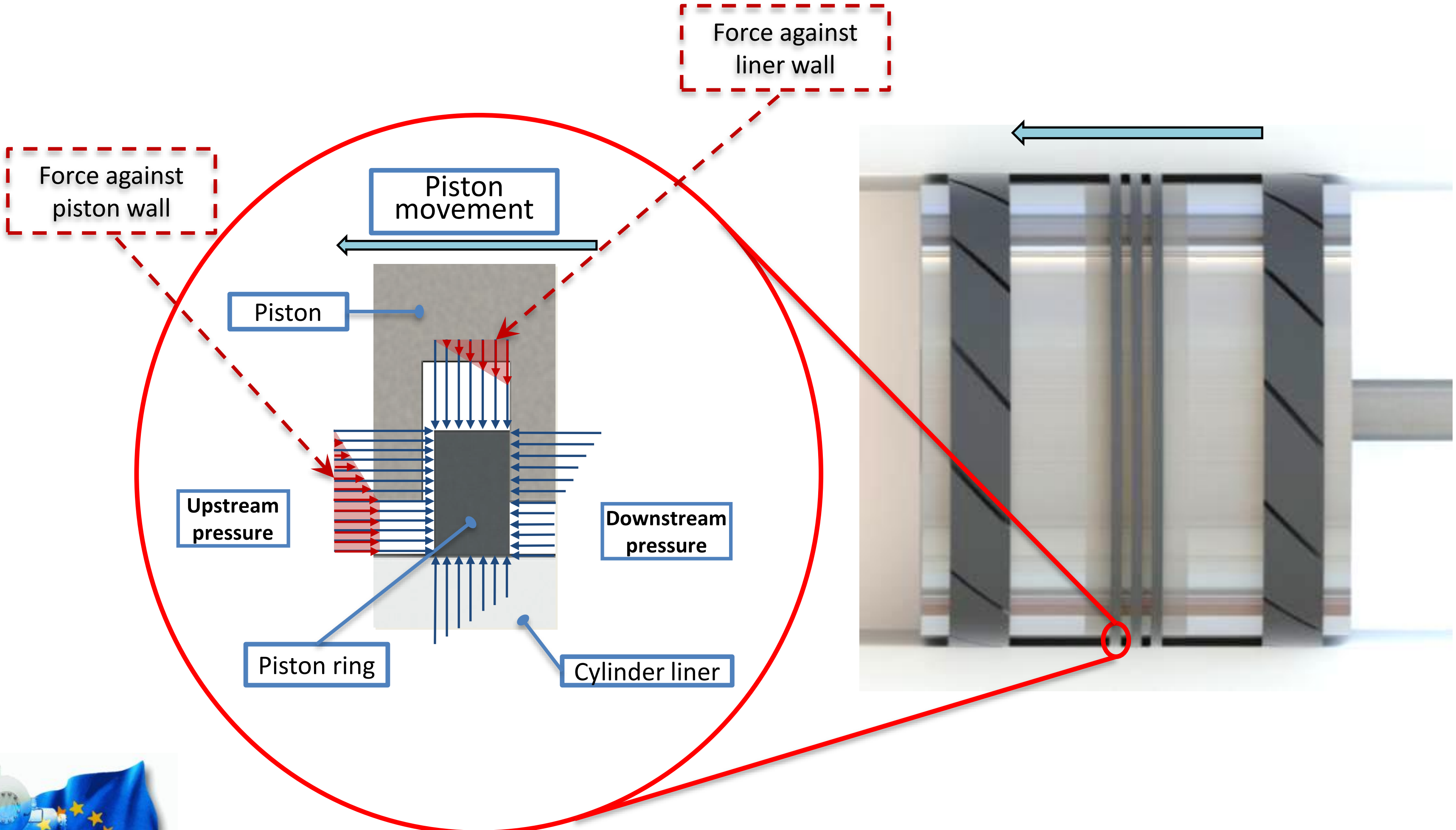




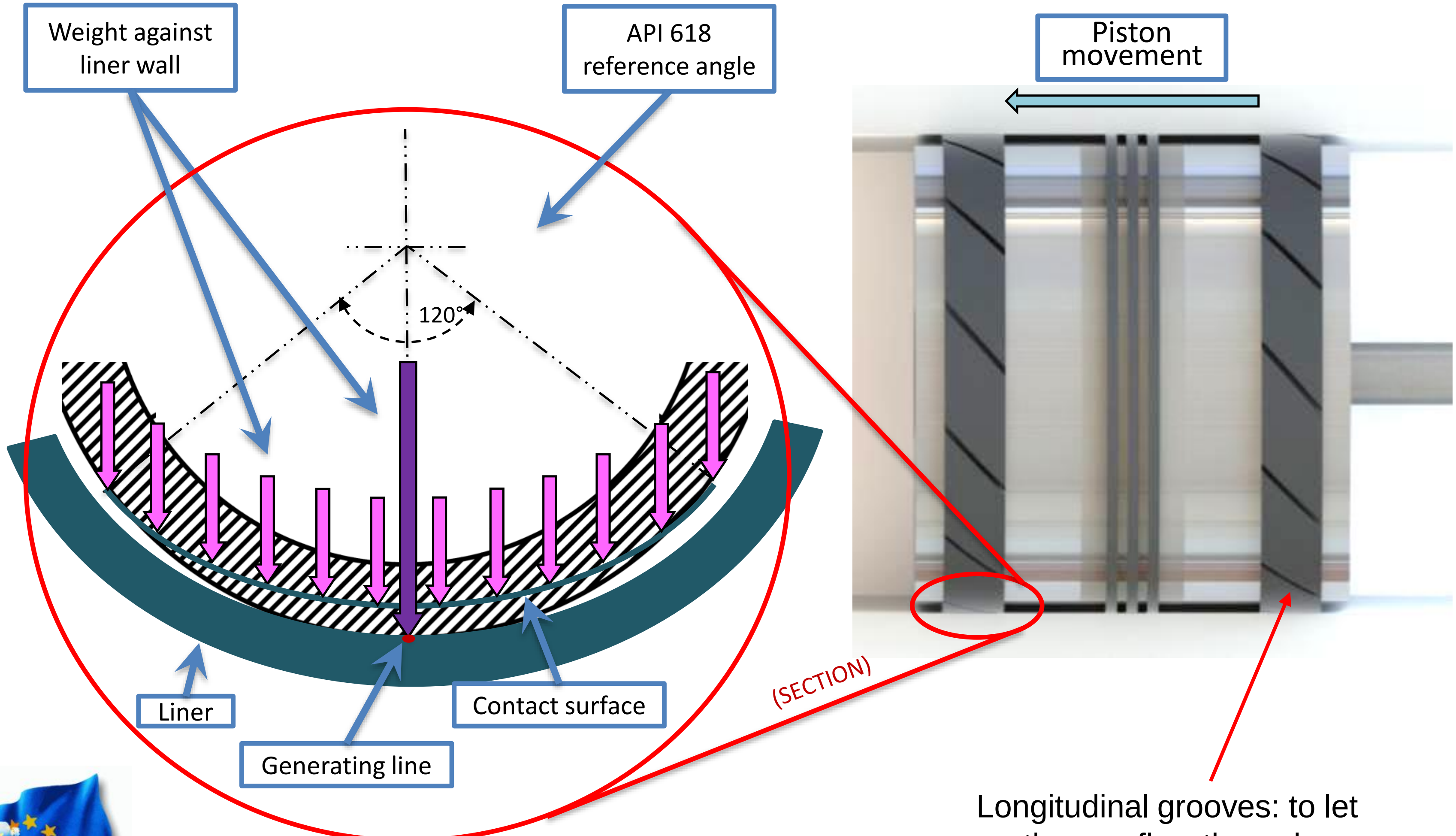
Piston rings ➡ Function of sealing

Rider rings ➡ Function to bear the piston weight

HOW DO PISTON RINGS WORK



HOW DO RIDER RINGS WORK

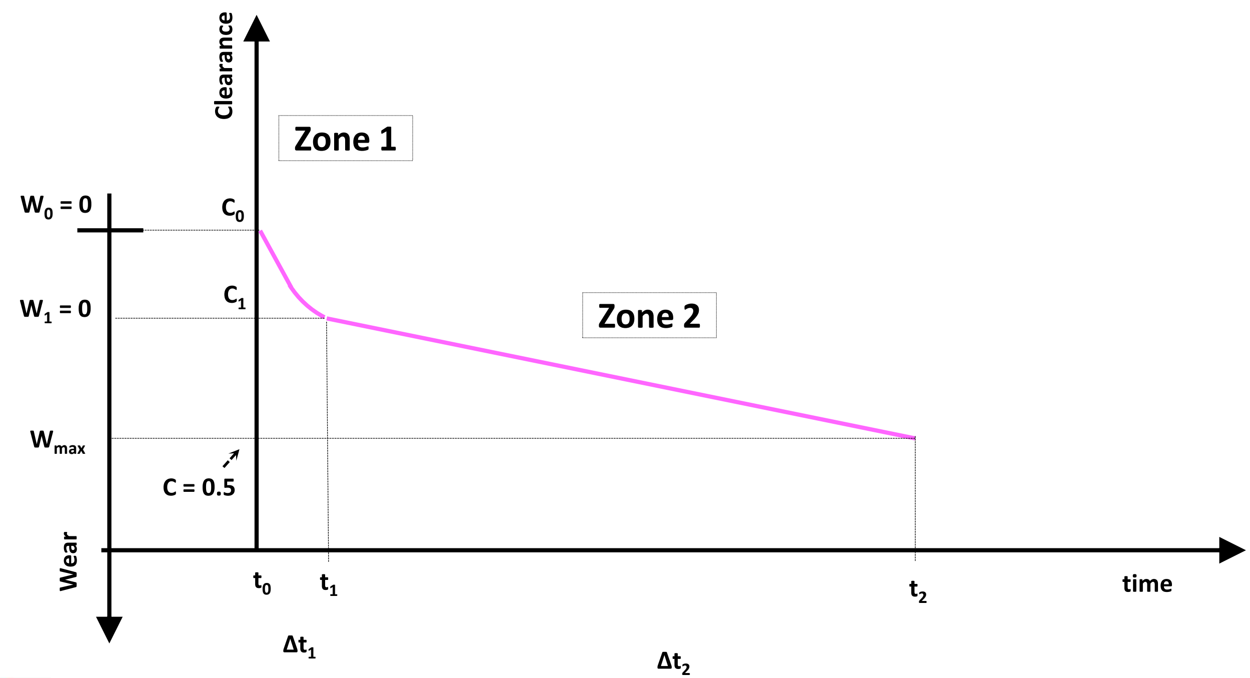


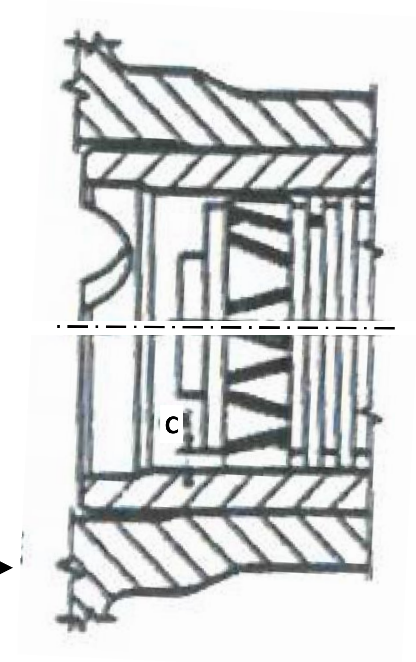
RIDER RINGS WEAR

Typical wear pattern

Zone 1: The contact zone changes from a generatrix to a wider surface ⇒ High wear rate

Zone 2: The wear rate stabilizes to a much lower value ⇒ Stable low wear rate





Clearance C shall be monitored - C_{min} value: ~ 0.5 mm

THERMOPLASTIC MATERIALS

Main features to be achieved

Low coefficient of friction → to limit heating and wear of the counter parts

Good thermal conductivity → to assist dispersion of generated heat

High mechanical resistance → to withstand the ΔP to which the parts are submitted

Main filler goals

- ✓ To increase resistance to wear
- ✓ Increases thermal conductivity
- ✓ Improves of mechanical characteristics

Surface finishing

Balance between too rough and too smooth

Optimal finishing of cylinder liner: 0.3-0.4 µm Ra

After a first period of thermoplastic material transfer,
sliding takes place between two surfaces both having a low coefficient of friction

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FIELD EXPERIENCE

Description of the system

Compressor Type	Reciprocating Compressor
Service	Heavy hydrocarbons (sour gas with H_2S presence)
Compressor design	4 cyl.s, balanced opposed
Nr of cylinders / stages	2 / 2
Lubricated	Yes
Driver	Electric motor
Transmission type	elastic coupling
Nameplate Power	835 kW
Suction /Discharge Pressure	1.0 / 6.0 bara
Piston rings/rider rings mtl	PTFE

Problem

Rapid wear of piston rings and rider rings

(of a 2nd stage cylinder at 2 months by 1st start)

Early action

Rings/wear bands replaced with PTFE differently filled

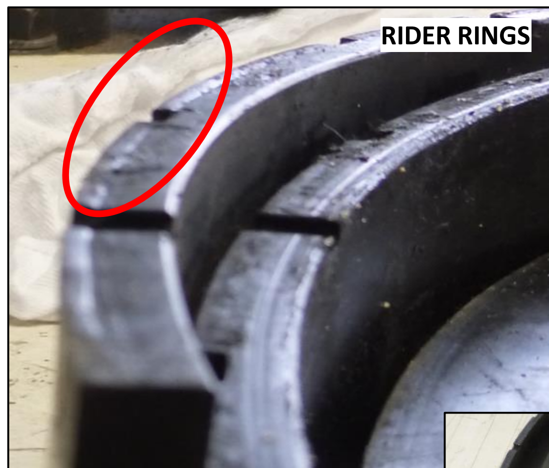
Wear bands with different design

FIELD EXPERIENCE

Description of the problem: sight findings

- ✓ Cylinders found dry;
- ✓ Solid, non metallic particles covered the piston head;

- ✓ Rider rings extruded;



- ✓ Rider rings bent;

FIELD EXPERIENCE

Description of the problem: measurements carried out

- ✓ Lubrication:

  measured values lower than the nominal values

point of lubrication	*outlets per cyl./packing*	*flow rate per outlet (drops/min)*	
		nominal	*measured*
cylinder 1, 3 (1st stage)	1 / 1	11	6
cylinder 2, 4 (2nd stage)	1 / 1	7	6
packing boxes, cylinder 1, 3	1 / 1	5	3
packing boxes, cylinder 2, 4	1 / 1	5	3

- ✓ Gas and walls temp.s verification:

  lower temperatures on cyl with new rings/rider rings

	gas temp	upper wall temp	lower wall temp
suction	60 °C	---	---
discharge	105 °C		
cyl#4 (new rings)	---	110 °C	120 °C
cyl#2 (original rings)	---	120 °C	130 °C

- ✓ Cylinders dimensions:

  discrepancies between nominal and measured dimensions:

	Nominal dimension [mm]	**Measured dimension [mm]**
1st stg wear band length	49.25	49.40
2nd stg wear band length	68.95	69.40

FIELD EXPERIENCE

Diagnosis:

Suggested solution:

✓ Lubrication system failure:
- very low oil flow;
- intermittent lubrication: not good for PTFE;

→ New lubrication system: progressive type
- increased oil quantity:

	measured:	necessary:
1st stage	**6** drops/min	**50** drops/min
2nd stage	**6** drops/min	**25** drops/min

- More reliable lube system;
- each injection point monitored;

✓ PTFE seals can be penalized by:
- gas condensation (due to heavy hydroc.s)
- presence of particles in the gas

→ Rings changed from PTFE to PEEK as more resistant:
- to condensate;
- to particles;

✓ Rise in wall temperature

→ Rings/wear bands design changed:
- more longitudinal grooves for rider rings;
- lower expansion coefficient

✓ Measured dimensions on rings / wear bands not matching the nominal ones

→ New piston design:
- longer rider rings to reduce the specific pressure
- larger clearances for seals

✓ Rod drop monitoring unreliable

→ Correct monitoring system

CONCLUSION

Wear causes:

- ✓ Mainly**:**
  - Lubrication system (type and quantity)
- ✓ Besides:
  - Materials of ring seals and rider rings
  - Shape of the rider rings
  - Correct dimensioning of rings grooves
  - Heat dissipation
  - Roughness of the sliding surfaces
  - Rod drop monitoring

Notes:

- ✓ Several aspects may con-cause the wear of rings and rider rings
- ✓ When present, **<u>the reliability of the lubrication system is fundamental</u>**
- ✓ The worst running conditions for PTFE seals is **intermittent** lubrication

Questions