Condition Monitoring and Diagnostics of Compressor Valves

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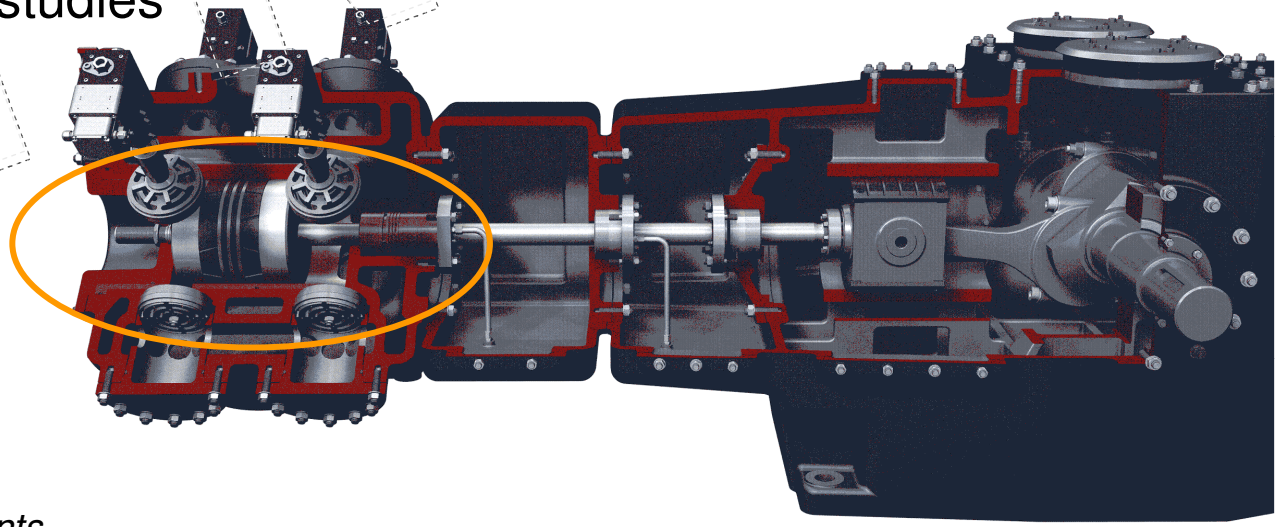
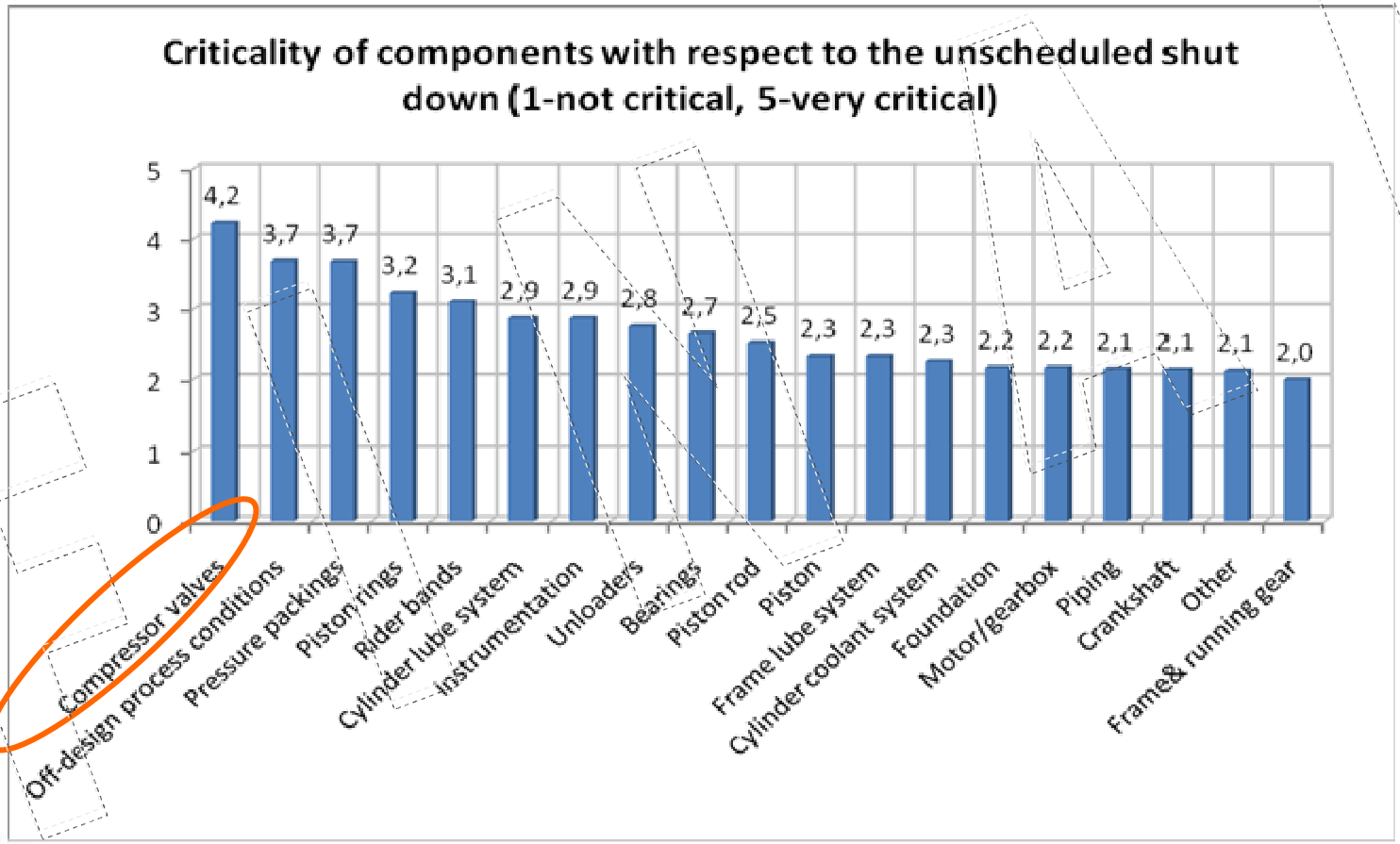
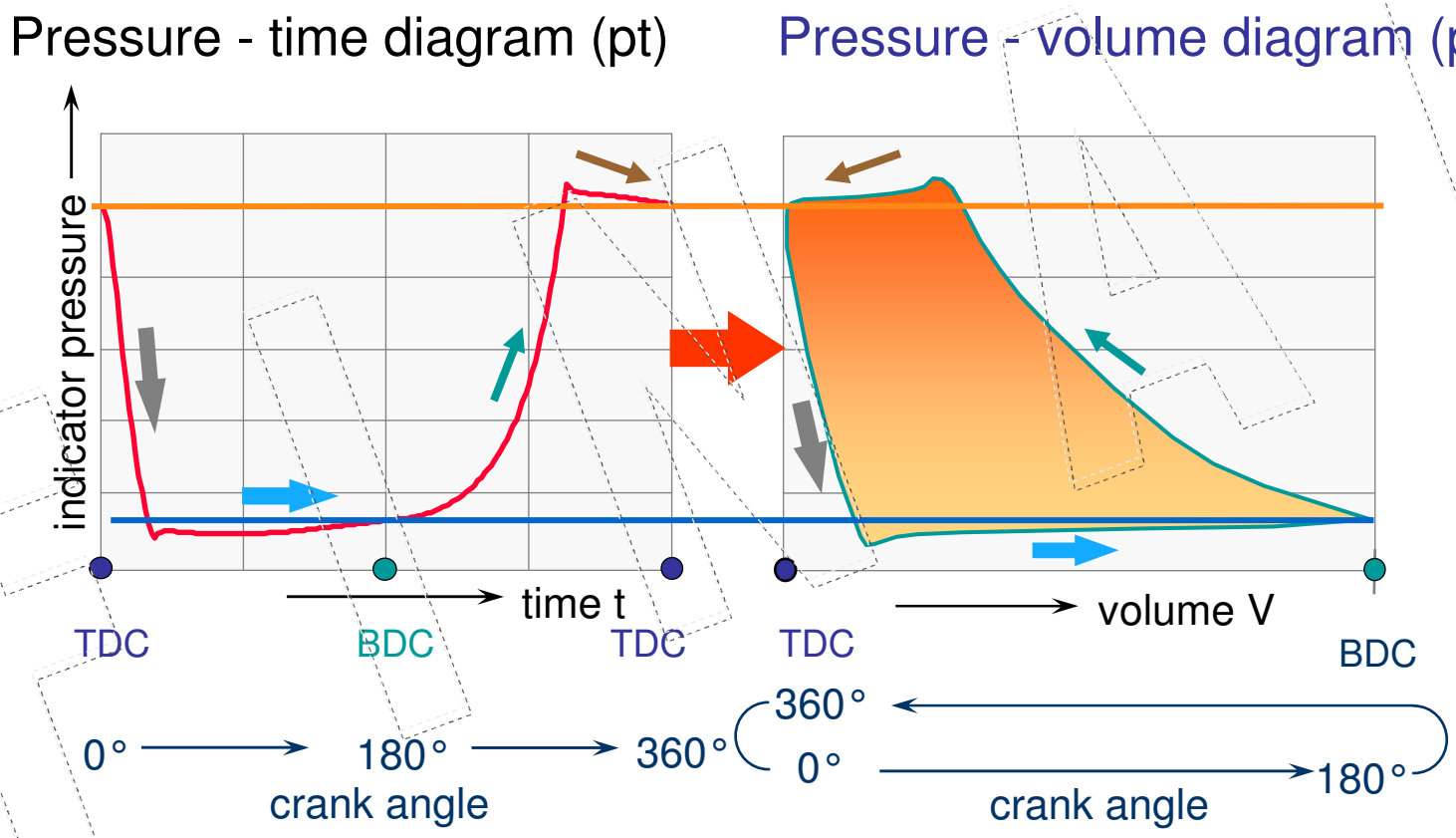


Why is monitoring of valves important?

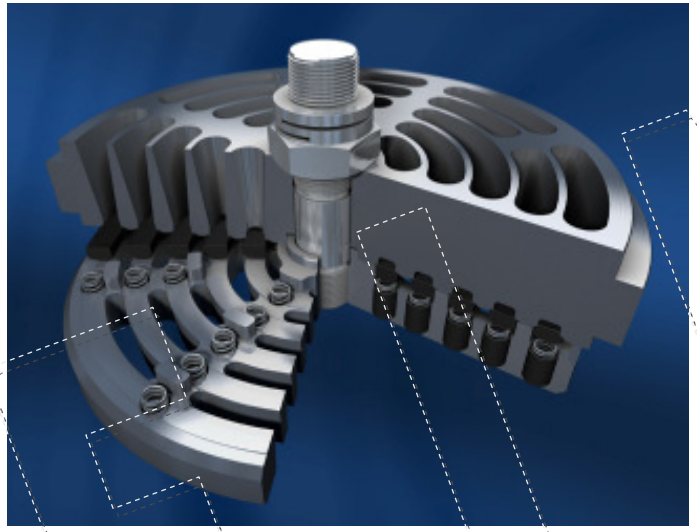


Compressor reliability survey" -2010
André Eijk – Leonard van Lier from TNO Industrie, Delft

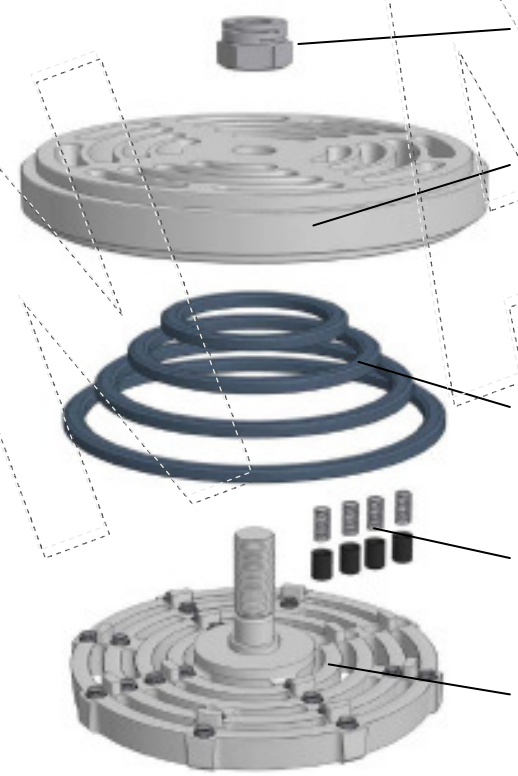
Indicator diagram



Components of valves



Example:
Ring-type suction valve for process gas applications



Selflocking nut

Valve seat

Non-metallic, high performance sealing elements

Closing springs

Valve guard unit

Requirements / Impacts on Reliability

Requirements for valves

- Long lifetime
- Maximum reliability
- High efficiency
- Minimum clearance volume
- High robustness
- Excellent chemical resistance
- Low lifecycle costs

Process impacts on Reliabilty

- Operation outside design envelop
- Liquid/condensation
- Debris and/or polymerisation
- Excessive lubrication

Incorrect maintenance practices

- Incorrect re-machining
- Assembly failures
- Improper sealing element and spring replacements

Process impacts (1)

Presence of liquid / condensate

- Gas in saturated condition
- Condensation due to low gas suction temperatures and/or low water cooling temperatures
- Insufficient drain system
- Liquid tends to be entrained in slugs

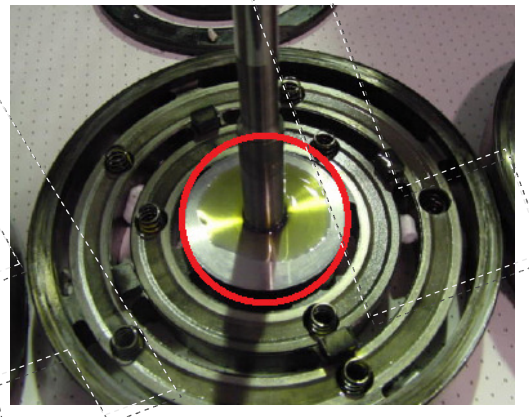
Presence of debris or polymerisate

- Gas impurities
- Catalyst wear
- Debris from piping system

Process impacts (2)

Excessive cylinder lubrication

- Excessive lube rates particularly during initial start of compressor
- Accumulation of lube oil during unloading



Operating conditions

- Variable conditions
  Example: Refining - SOR to EOR
  Natural gas: storage
- Reactor catalyst condition, changing gas mol weight, dirty gas
- Unstable process conditions especially during SOR

Process related failure modes (1)

Liquid carry over / excessive lubr.

Sealing elements

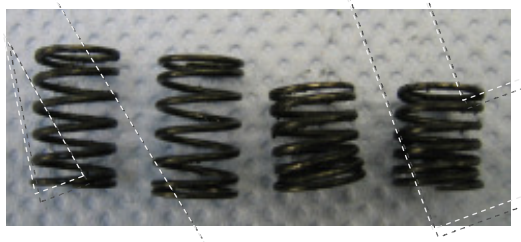
- Pitting or delamination due to excessive opening or closing impact caused by oil sticktion
- Forced rupture of sealing elements
- Breakage of valve plate webs due to local loading of liquid slugs
- Breakage of guards

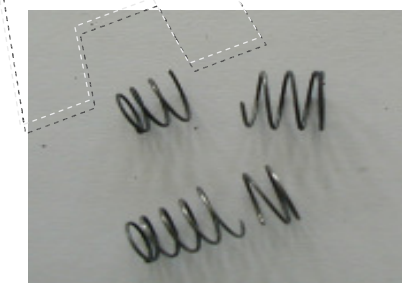
Process related failure modes (2)

Liquid carry over / excessive lubr.

Spring failures

- Setting of springs
- Breakage caused by high opening impact and consequential dynamic overload of springs
- Spring wear due to dynamic contact of spring coils





Process related failure modes (3)

Debris, catalyst dust, polymerisate

Sealing elements

- Increased wear of sealing elements and springs
- Wear on seat sealing faces

Clogging of flow channels

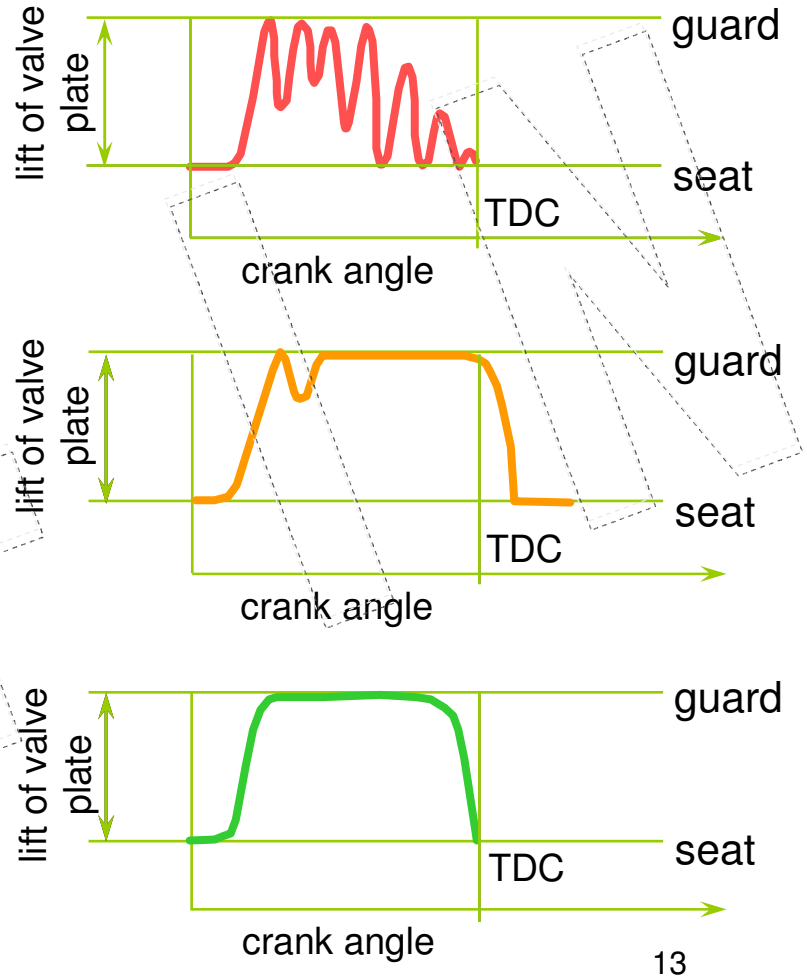
- Sticky constituents or debris block flow channels
- Light gases exhibit almost no drag force to maintain self cleaning action

Maintenance related failure modes (1)

- Valve lift after machining deviates from specification
- Springs replaced with springs made of different material / characteristics
- Use of sealing element material with mechanical properties deviating from original supply
- Incorrect assembly of valve (wrong positioning of seat and guard)
- Valve cage jack bolts not correctly tightened

Maintenance related failure modes (2)

Same valve type but different dynamics due to various lift/spring combinations or off-design operating conditions:



Valve flutter
=> Reduced lifetime

Delayed closing
=> Heavily reduced lifetime

Ideal motion
=> Optimum lifetime

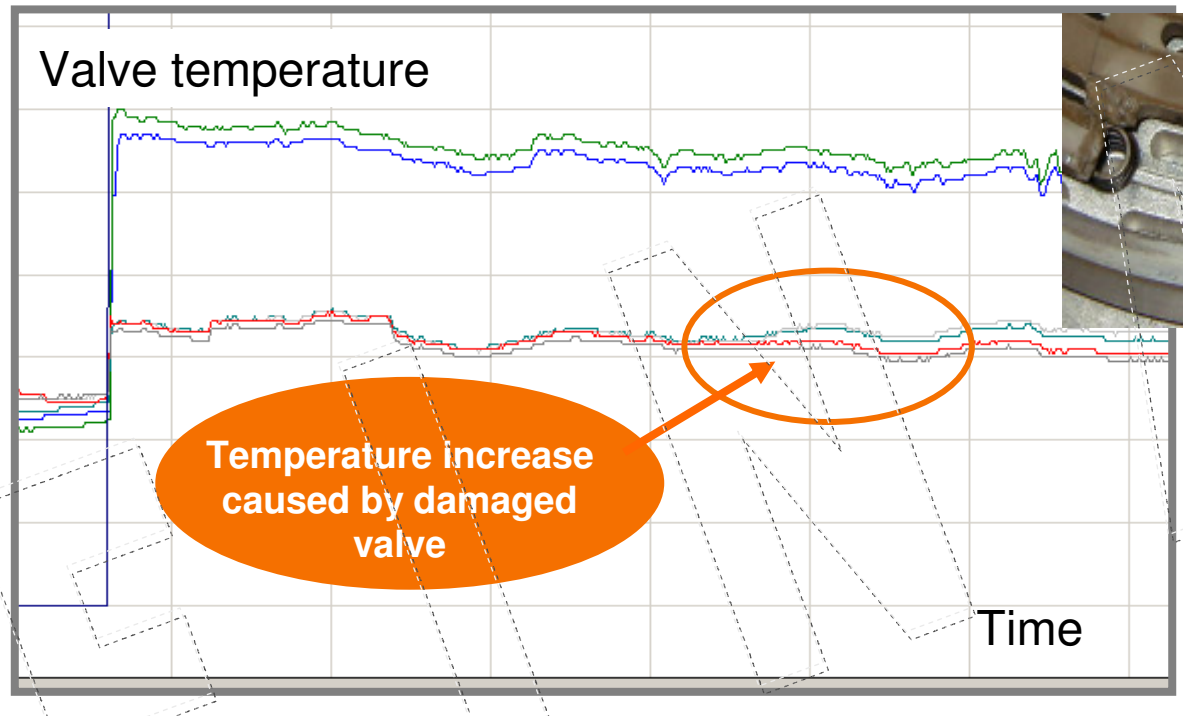
Available monitoring techniques (1)

	Snap-Shot (in intervals)	**On-line** (continuous)
Slow signals ▪ Valve gas temps. ▪ Interstage pressures ▪ Gas flow / motor current ▪ Control signals	▪ Temperature meter (e.g. infrared) ▪ Vibration meter ▪ Local indicators	▪ Process control system (DCS) ▪ Programmable logic controller (PLC) ▪ SCADA
Dynamic signals ▪ Indicator pressure ▪ Vibration (acc.) ▪ Acoustic emissions	▪ Handheld portable data collectors purpose designed for recips ▪ High frequency signal sampling ▪ Measurements related to position of crank shaft	▪ Systems purpose designed for recips ▪ Analyzing each revolution ▪ High frequency signal sampling ▪ Measurements related to position of crank shaft

Available monitoring techniques (2)

Features and benefits	Snap-Shot (in intervals)	On-line (continuous)
Slow signals ▪ Valve gas temp. ▪ Interstage pressures ▪ Gas flow / motor current ▪ Control signals	▪ Detect anomalies ▪ Pin point defective valve in most cases	In addition to snap shot ▪ Earlier detection of anomalies, avoids unplanned shut ▪ Supports automation
Dynamic signals ▪ Indicator pressure ▪ Vibration (accel.) ▪ Acoustic emissions	In addition to above ▪ Identify the root cause for anomaly ▪ Information to improve operation or components ▪ Performance monitoring (pV)	In addition to above and snap shot ▪ Detect even rare process impacts ▪ Prevent larger damage (asset protection) ▪ Reduce down time ▪ Comprehensive root-cause analysis ▪ Increase plant safety

Slow signals



Suction valve fatigue failure

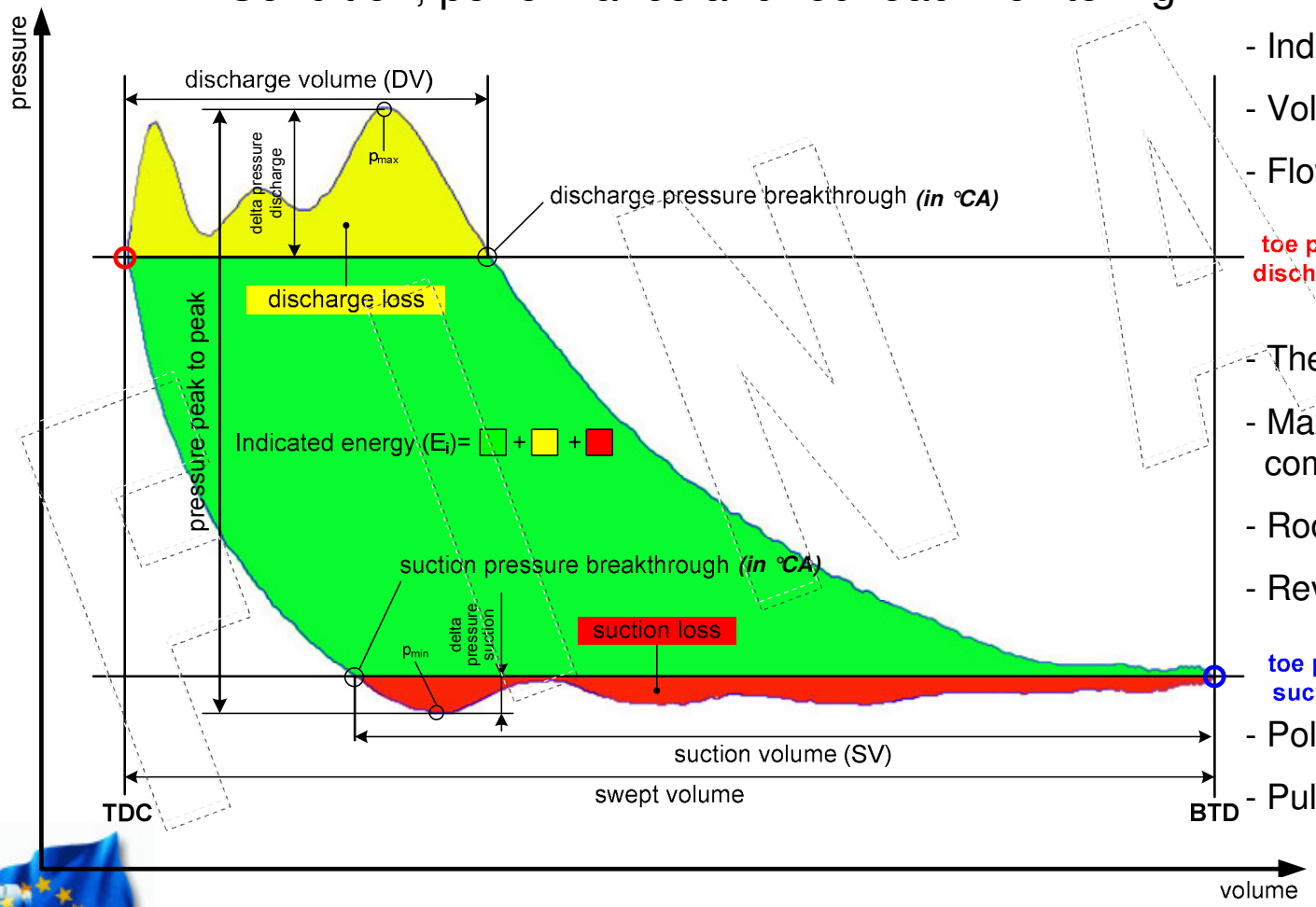
Suction and discharge valve temperature measurements are good indicators for valve condition.

Shifts of interstage pressures, variations of the control signal (to spill back valves, stepless control system) and gas flow measurements provide additional valuable information.

EFRC

Indicator pressure - analysis

Condition, performance and rod-load monitoring



- Suction and discharge losses
- Indicated power
- Vol. efficiency
- Flow

toe pressure discharge (p_D)

- Theor. pV / discharge temp.
- Max. rod load (tension, compr.)
- Rod load ratio
- Reversal period

toe pressure suction (p_S)

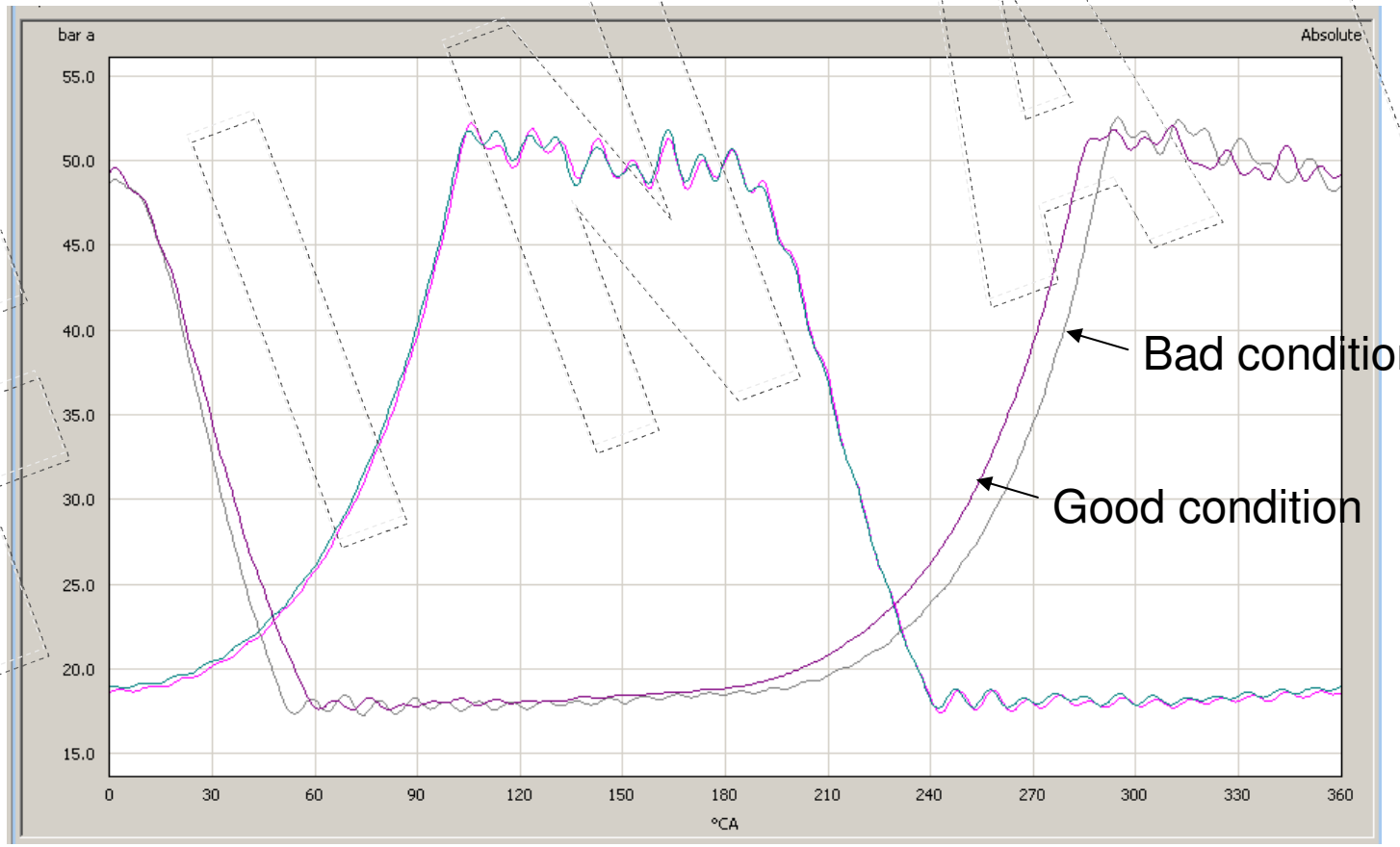
- Polytropic coefficients
- Pulsations

Indicator pressure – leakage detection

Example: Suction valve leakage

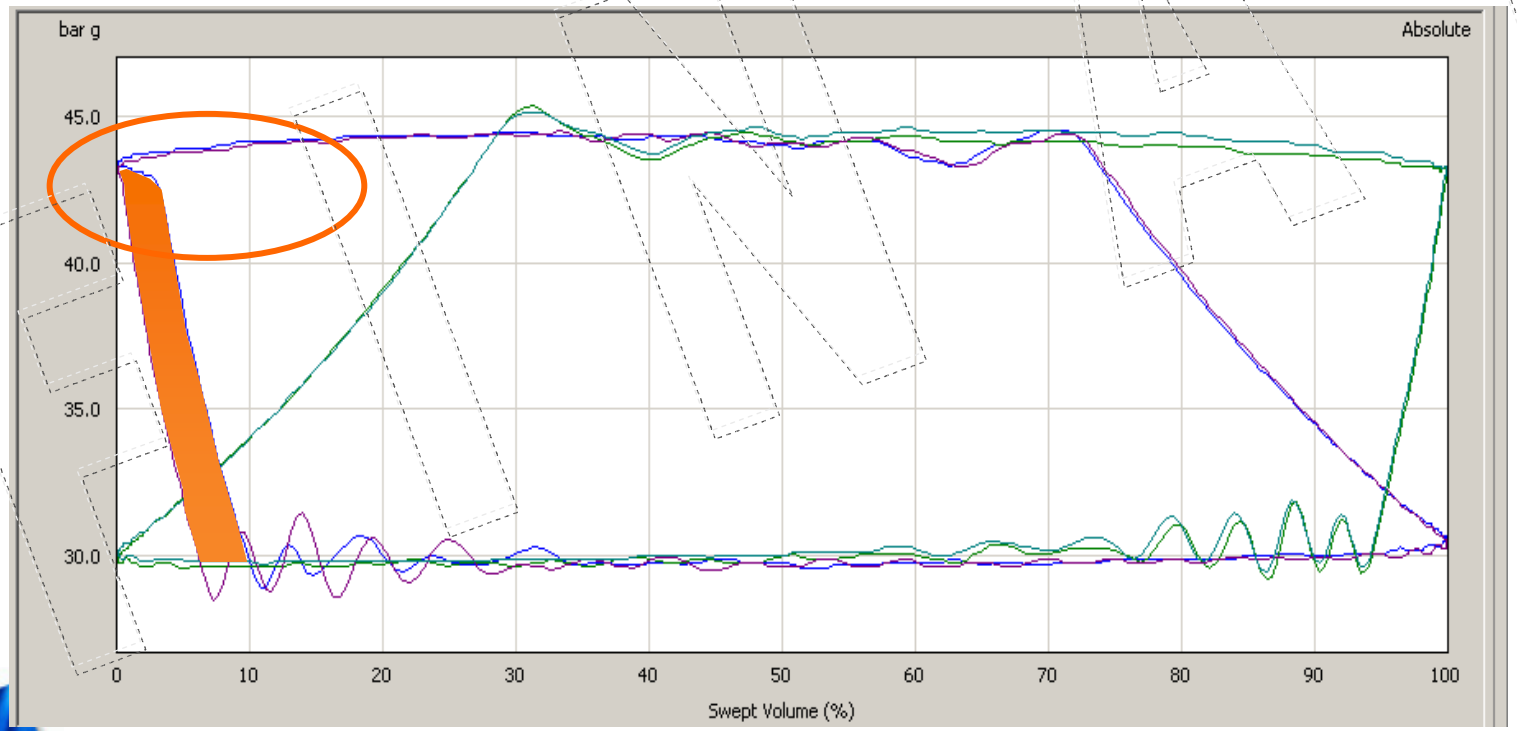
During compression stroke gas leaks through valve into suction plenum, therefore slower compression and loss in capacity.

Faster pressure reduction in the cylinder during re-expansion.



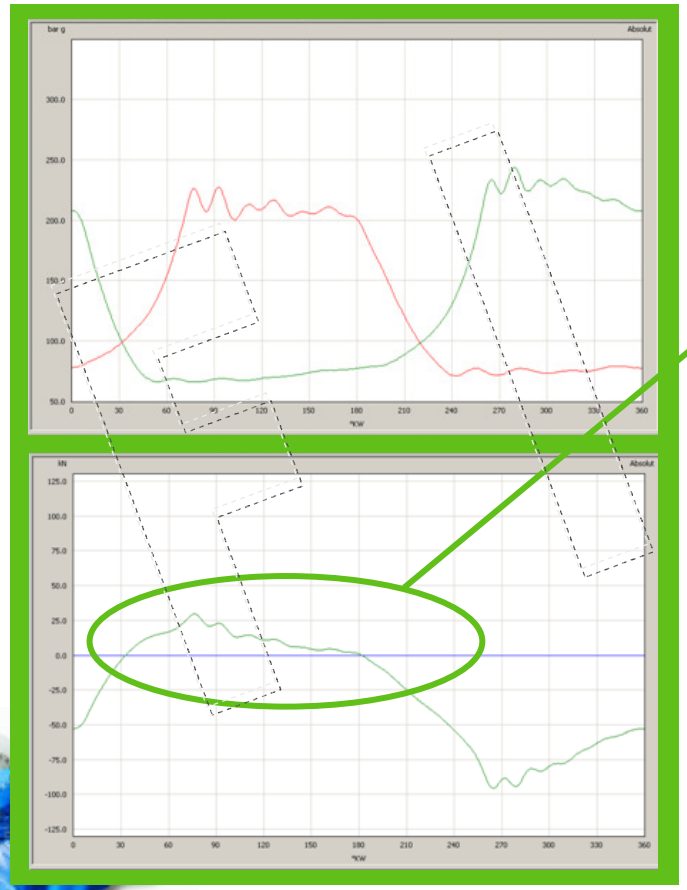
Indicator pressure – late closing

If the compressor valves close too late (e.g. off-design operating condition, incorrect springing, over lubrication) capacity is lost and lifetime drastically reduced.



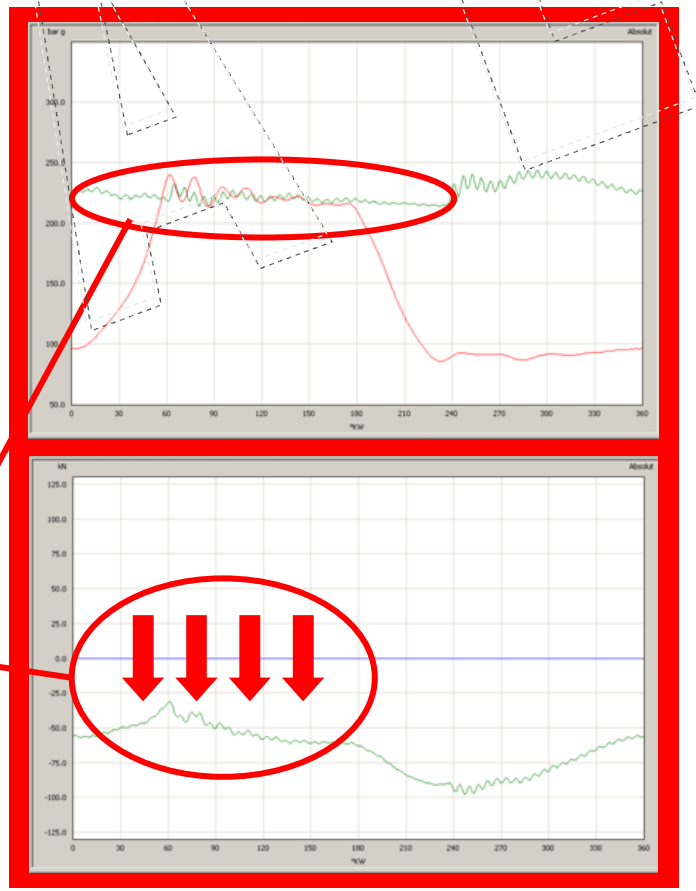
Indicator pressure – rod load reversal

Incorrect valve unloading, off-design operating conditions or major valve failures can lead to excessive rod-load and insufficient rod load reversal .



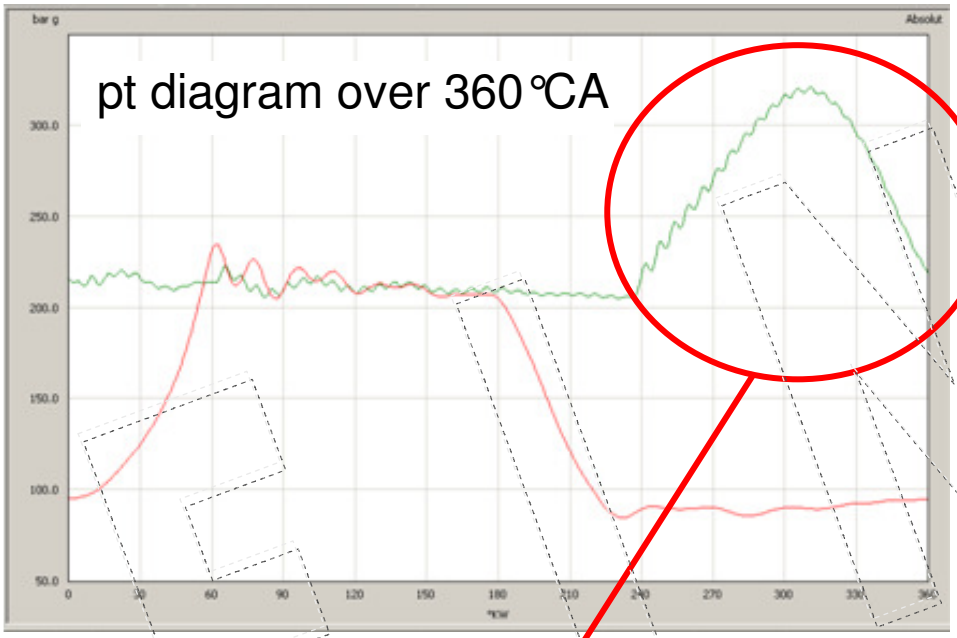
Normal indicator pressure plots for head and crank end cylinder side.

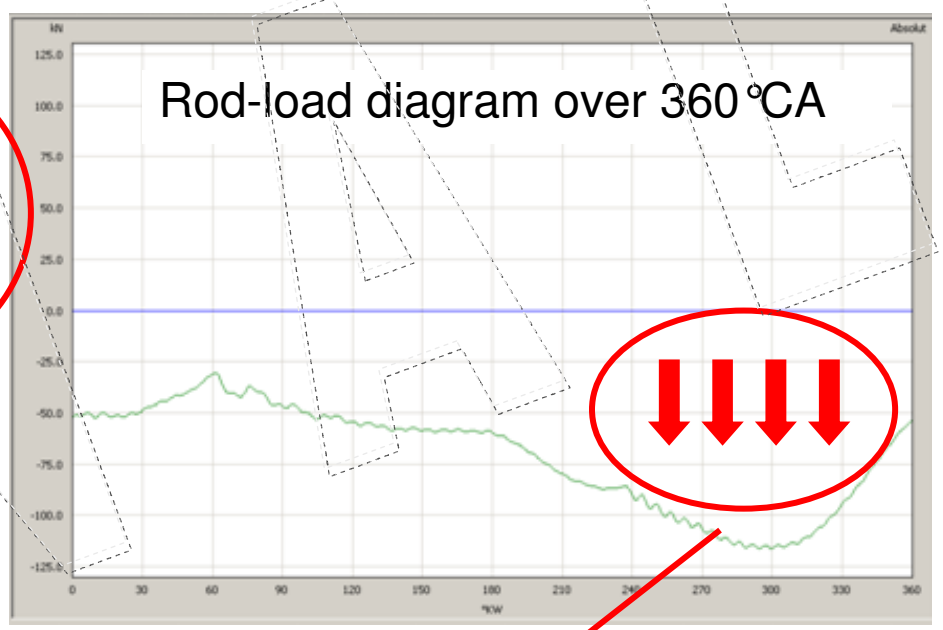
Proper rod load reversal



Damaged discharge valve on HE impedes rod load reversal.

Indicator pressure – rod load/max. pressure

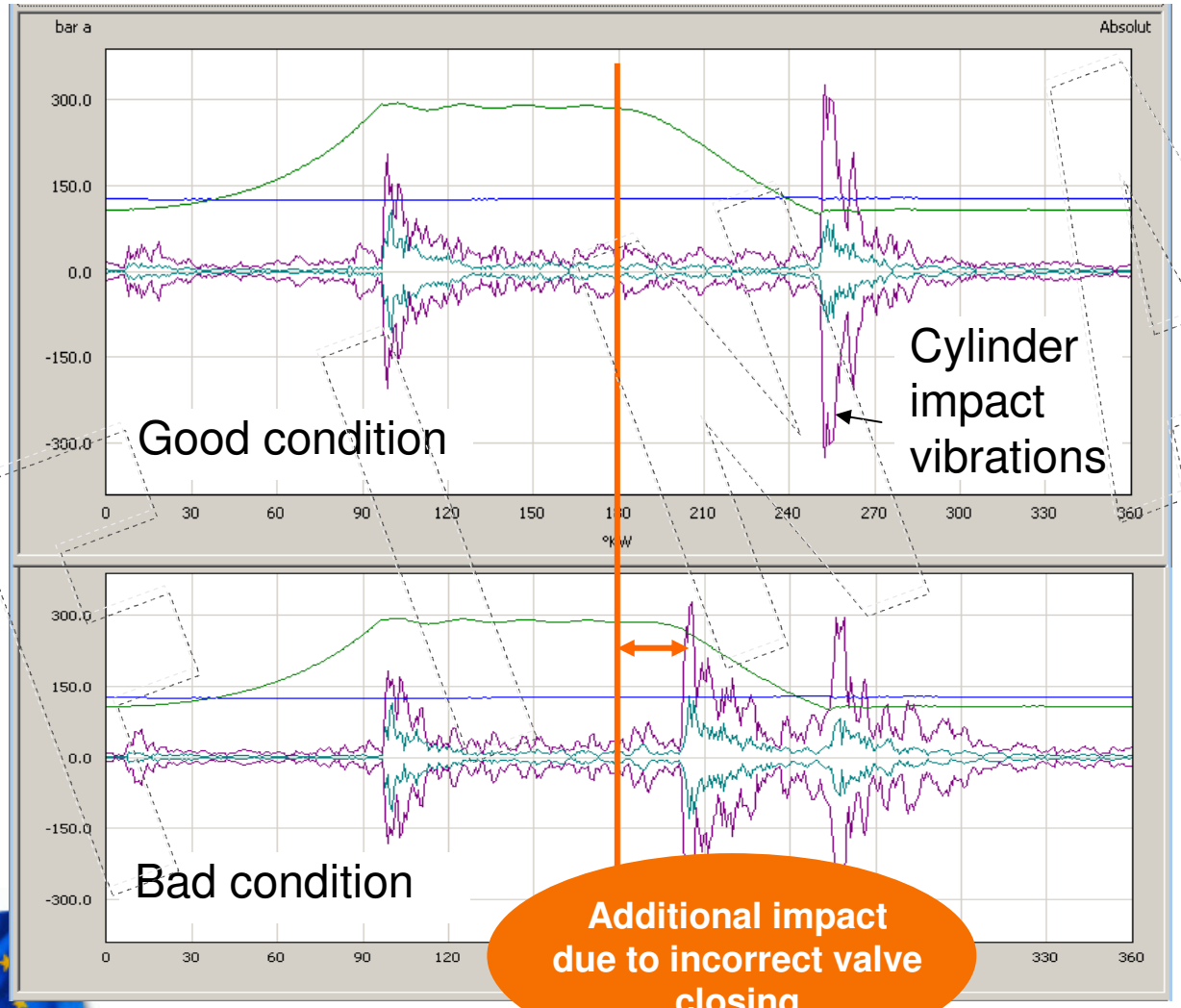




After maintenance incorrectly assembled discharge valve leads to overshoot of cylinder pressure.

Maximum rod load is exceeded.

Vibration – valve stress factor detection



Impact vibration monitoring combined with indicator pressure analysis allow for event analysis and detection of:

- Liquid carry over
- Late closing
- Excessive closing/opening impacts of valve sealing element
- Loose valve assemblies

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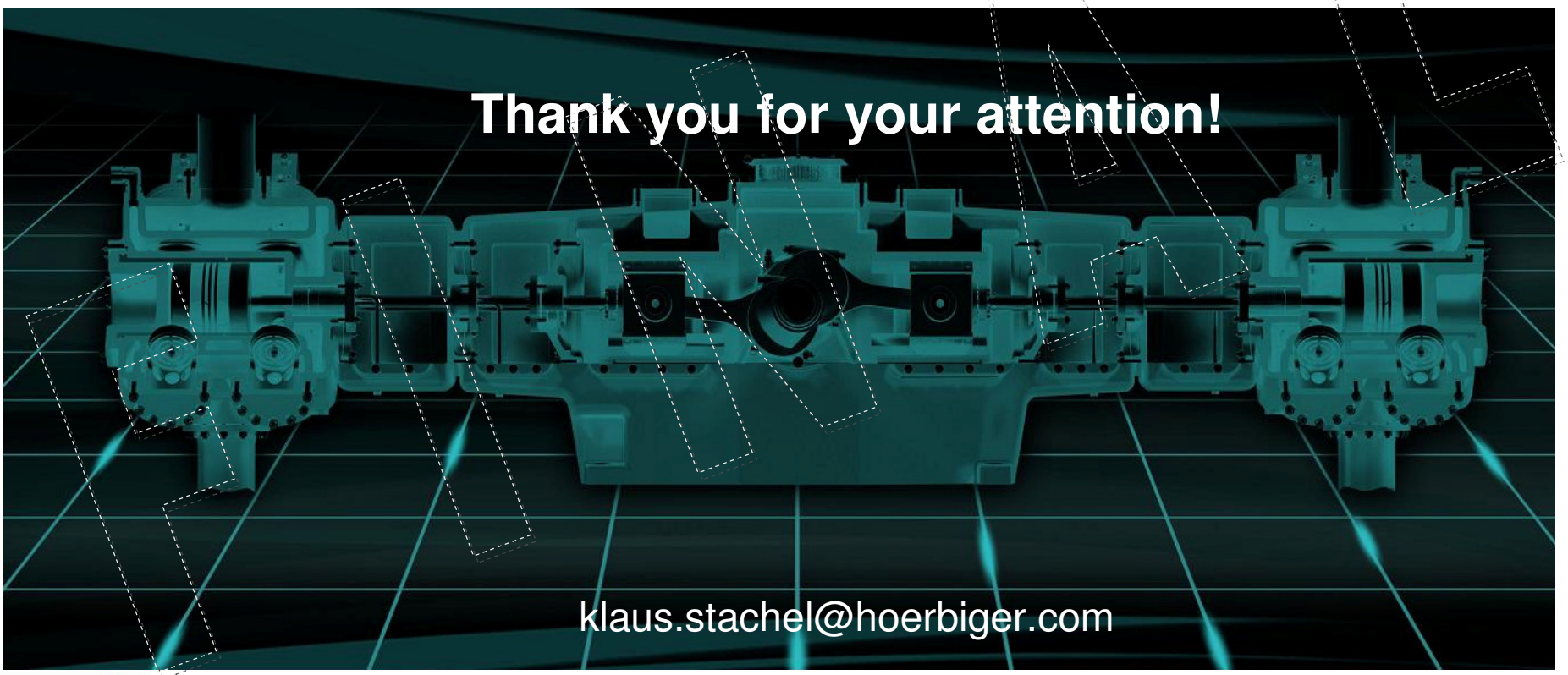
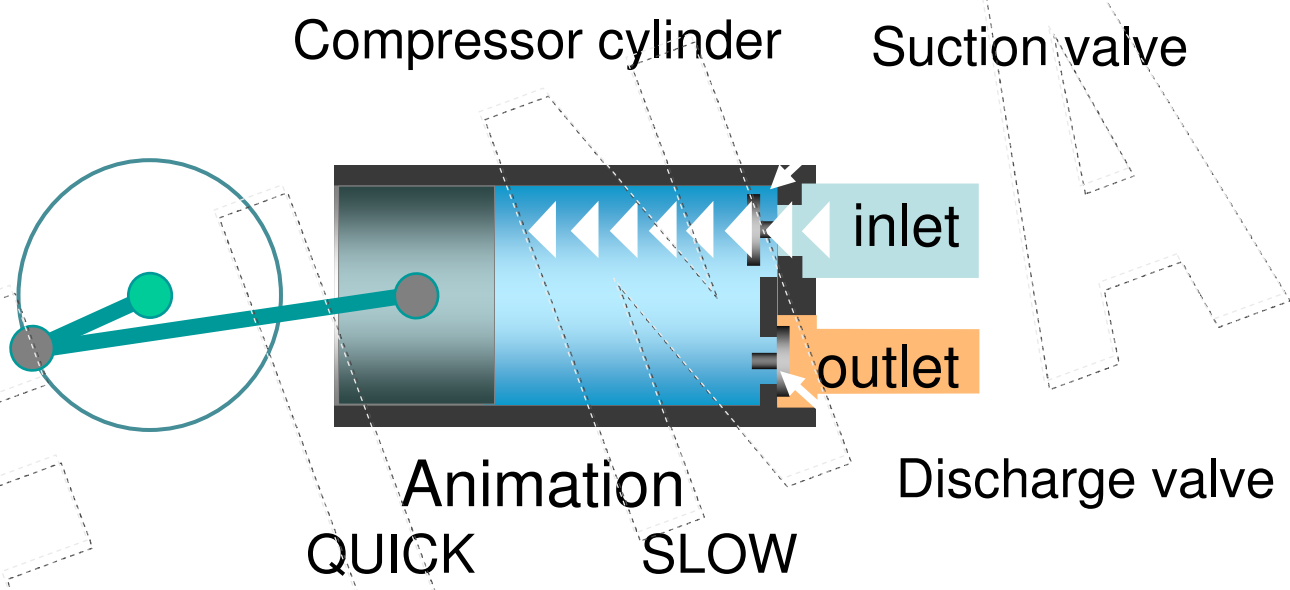
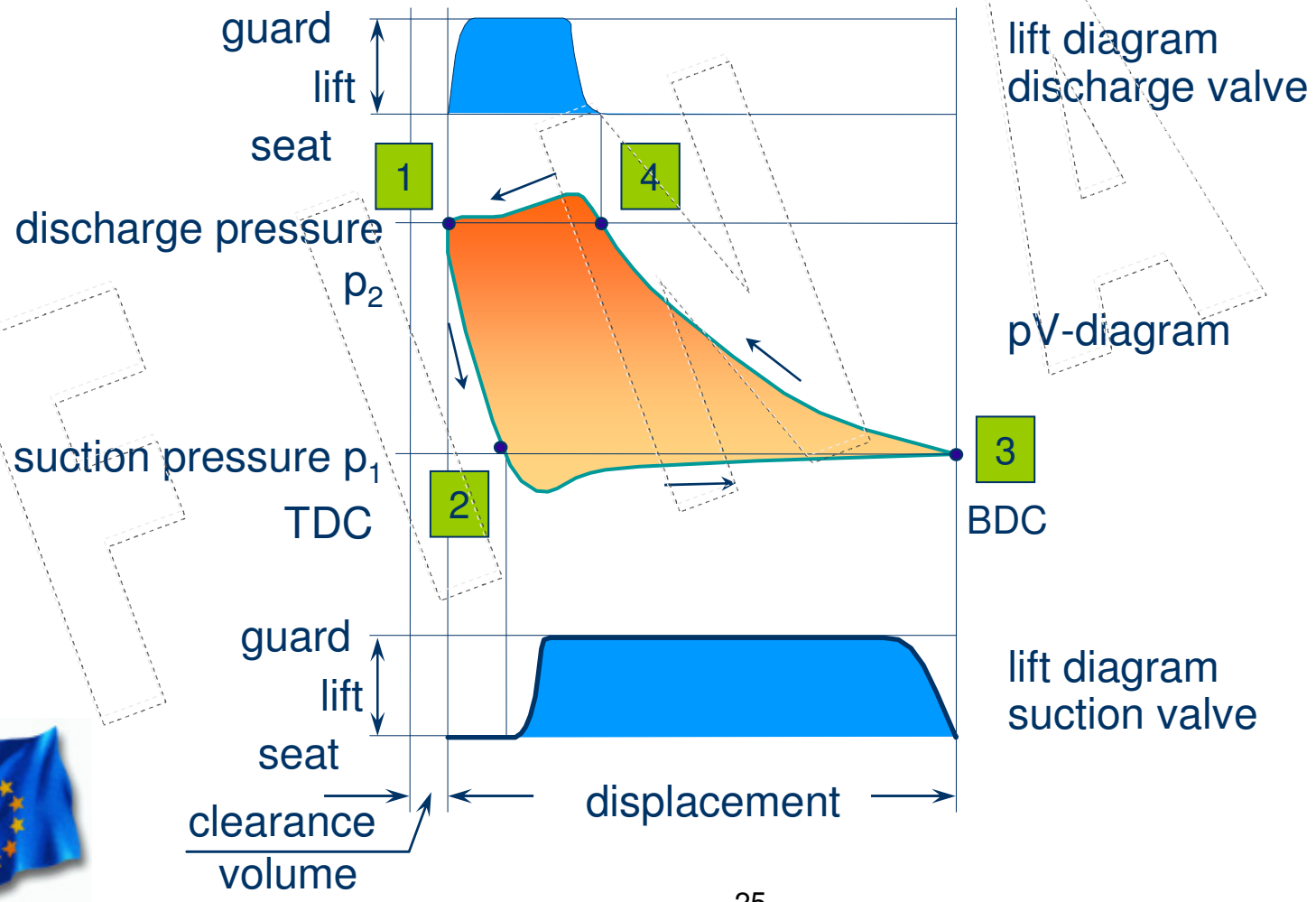


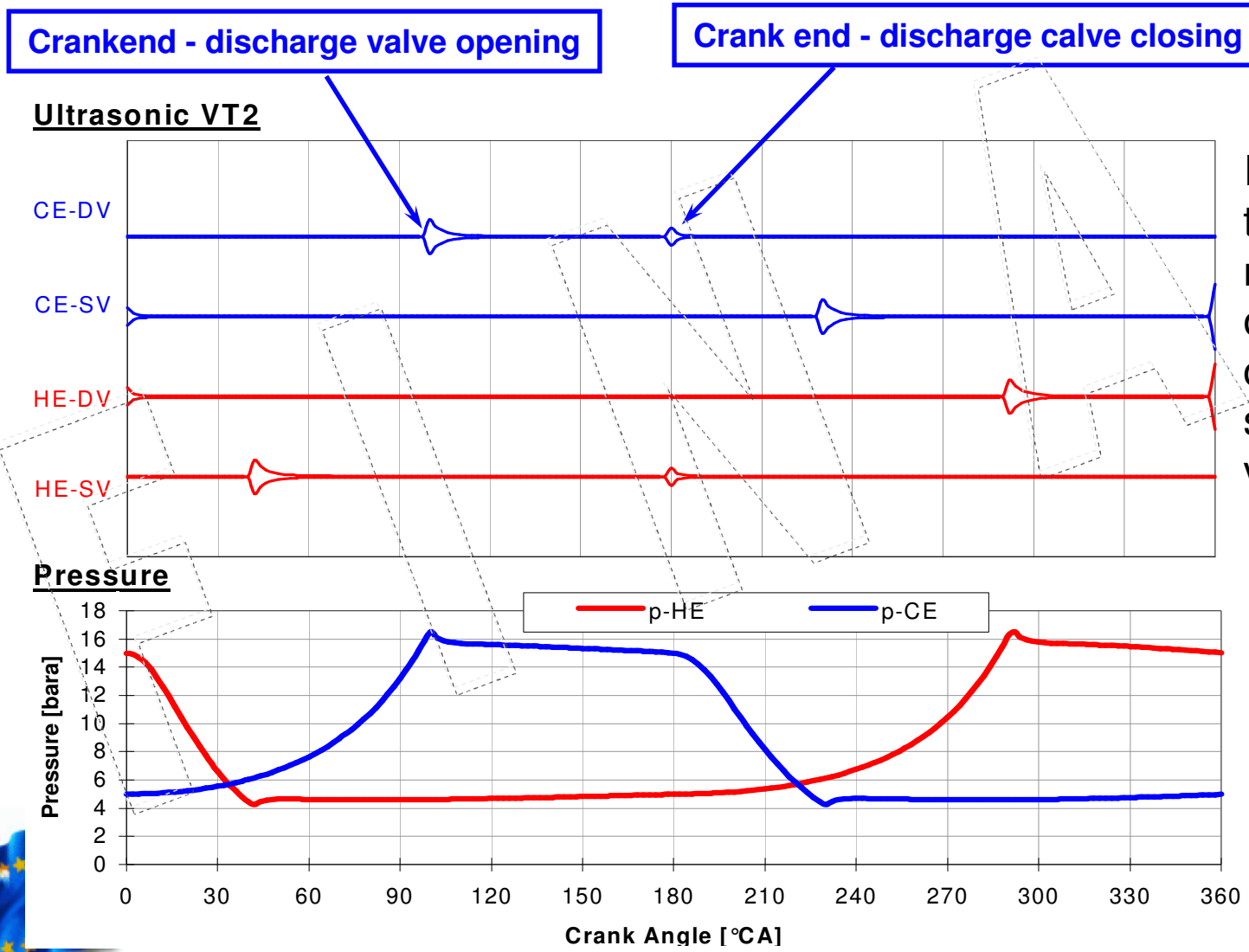
Working principle of valves



Valve lift diagram

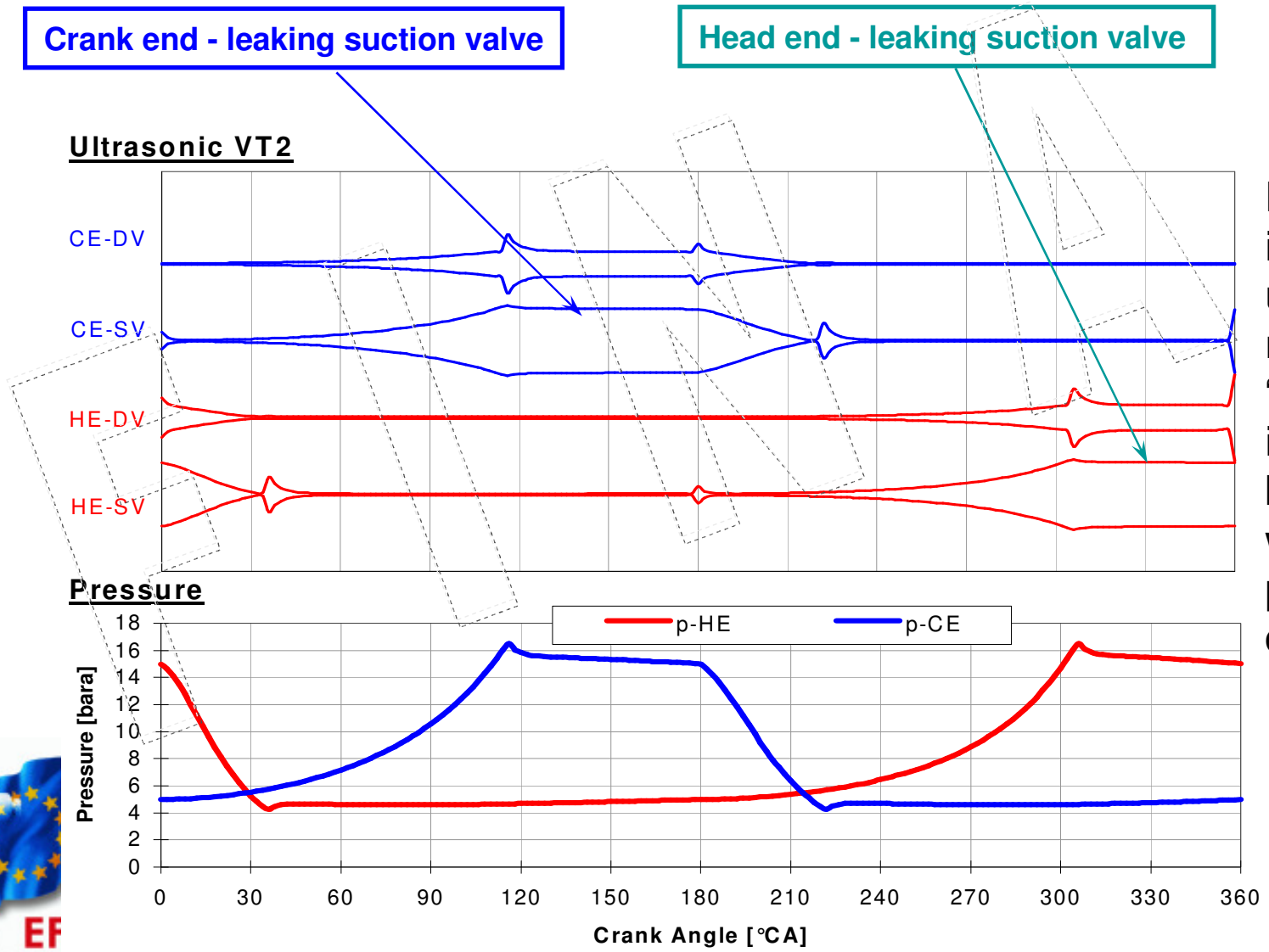


Ultrasonic – ideal condition



In ideal condition the ultrasonic readings show opening and closing events similar to vibration curves.

Ultrasonic – leakage detection



Leakage is identified by ultrasonic readings. The “balloons” indicating gas blows line up with maximum pressure differentials.