EFRC Workshop Pulsations

Monitoring & Diagnostic

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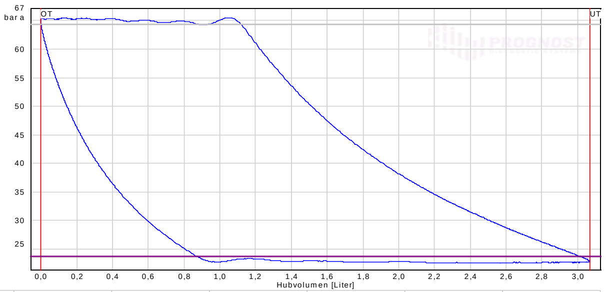
Typical example of a pulsation measuring loop

Data Acquisition

Sampling frequency min. 500Hz

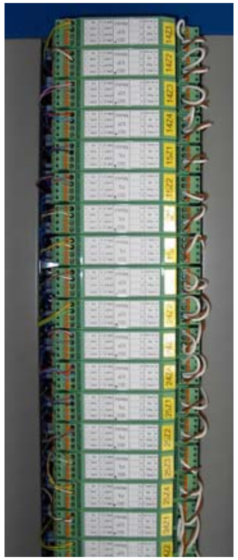
User interface



	Maschine	Messpunkt	Bezeichnung	TAG-Name	Messwert	Einheit
	GB-051	St.1, Zyl.1 DS	p-V-Diagramm			bar a
	GB-051	P SD St1 DS	Saugdruck, Deckelseite	PIAL-054	23,6	bar a
	GB-051	P ED St1 DS	Enddruck, Deckelseite	PI-084	64,2	bar a

GB-051 Online 21.11.2003 16:12:28, p-V-Diagramm Stufe 1, Zyl.1, DS , 443,7 U/min PROGNOST Systems GmbH

Filters



Low-pass to eliminate interferences and channel resonance

Galvanic Isolators

Separation of hazardous area and safe area

Dynamic pressure sensor

Response time < 1 *ms*

Reproducibility $\leq 0.05\%$ *of span*

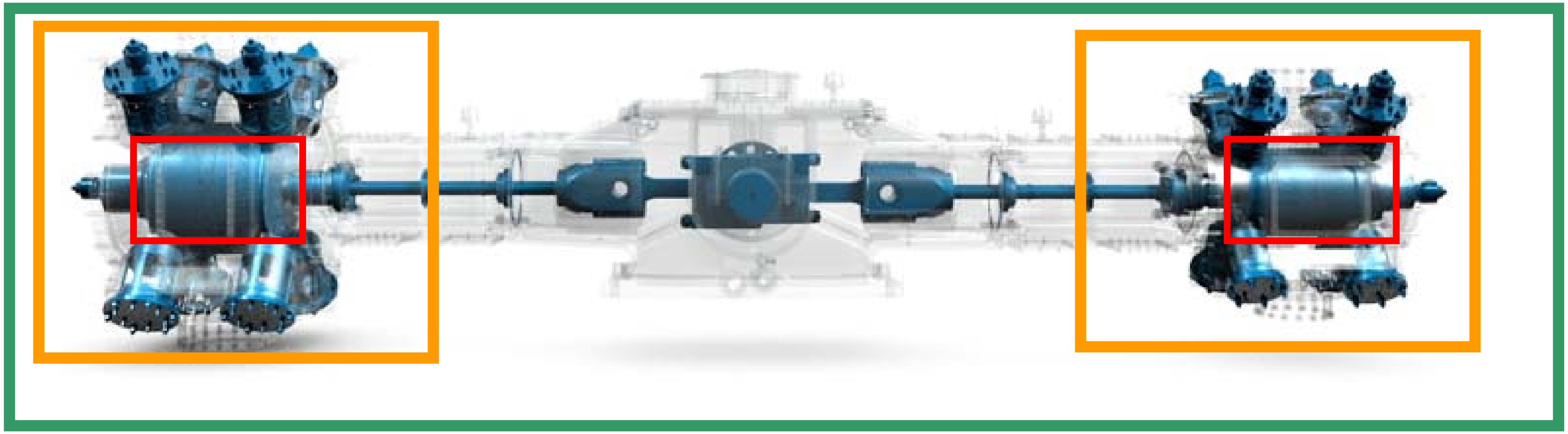
1 year stability $\leq 0.02\%$ *of span*

Typical ATEX Ex-Zones on reciprocating compressors

Zone 0 : Area where an explosive atmosphere exists permanently, for a long period or frequently

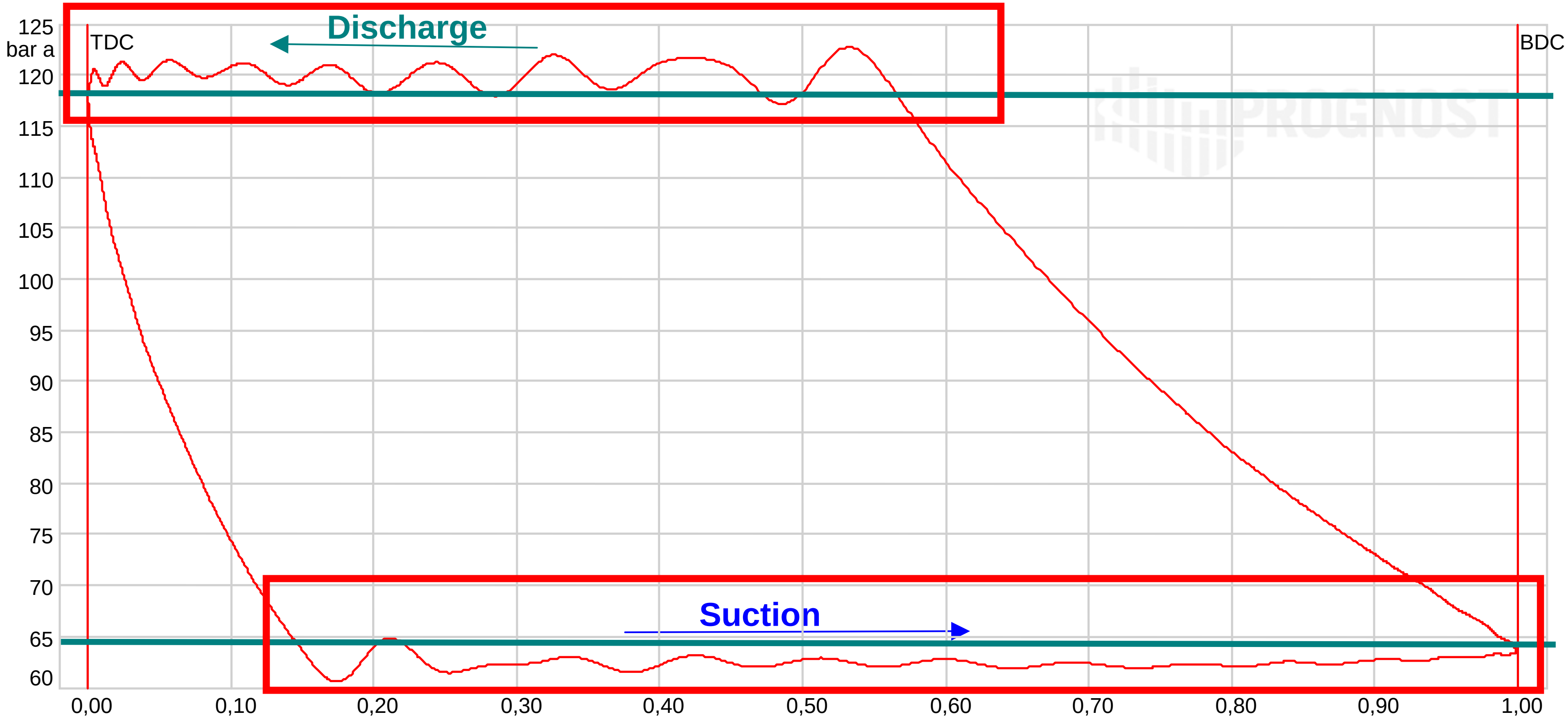
Zone 1 : Area where an explosive atmosphere exists periodically

Zone 2 : Area where an explosive atmosphere exists never or only short term



Based on the above guidelines the ATEX Ex-Zones have to be defined by each operating company for itself.

P-V diagram – pulsation monitoring as side effect



The pulsations in the suction and discharge piping can be monitored by the dynamic pressure measurement e.g. as a p-V diagram during the suction and discharge phase. However, this is only an indirect measurement and does not represent the real magnitude of pulsations in the piping.

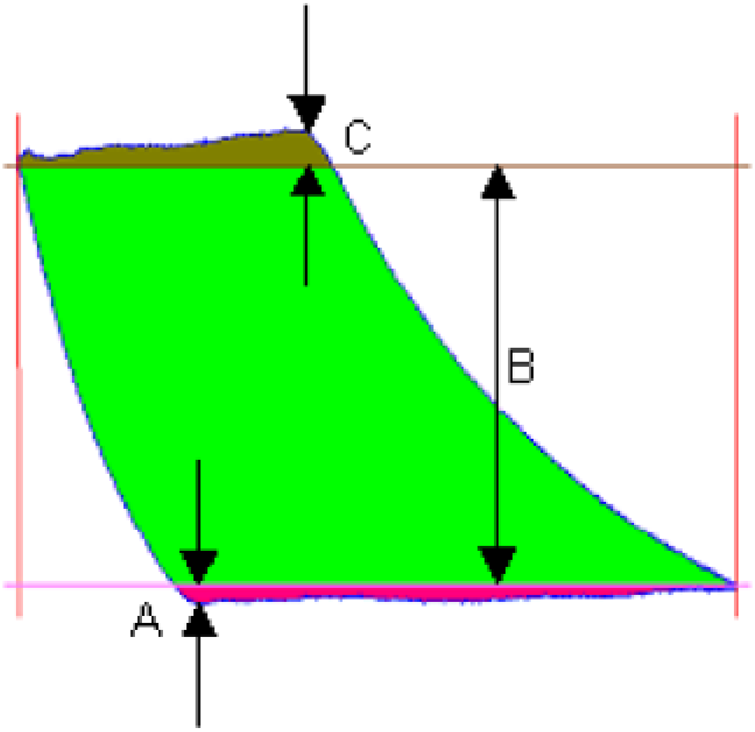
Parameters to monitor pulsations – discharge/suction loss

Discharge loss

Suction loss

In order to automatically monitor pulsations effectively through a p-V díagram certain characteristic values are needed to be continuously calculated. For example the suction and discharge loss is increased by rising pulsations.

Parameters to monitor pulsations – valve inertia

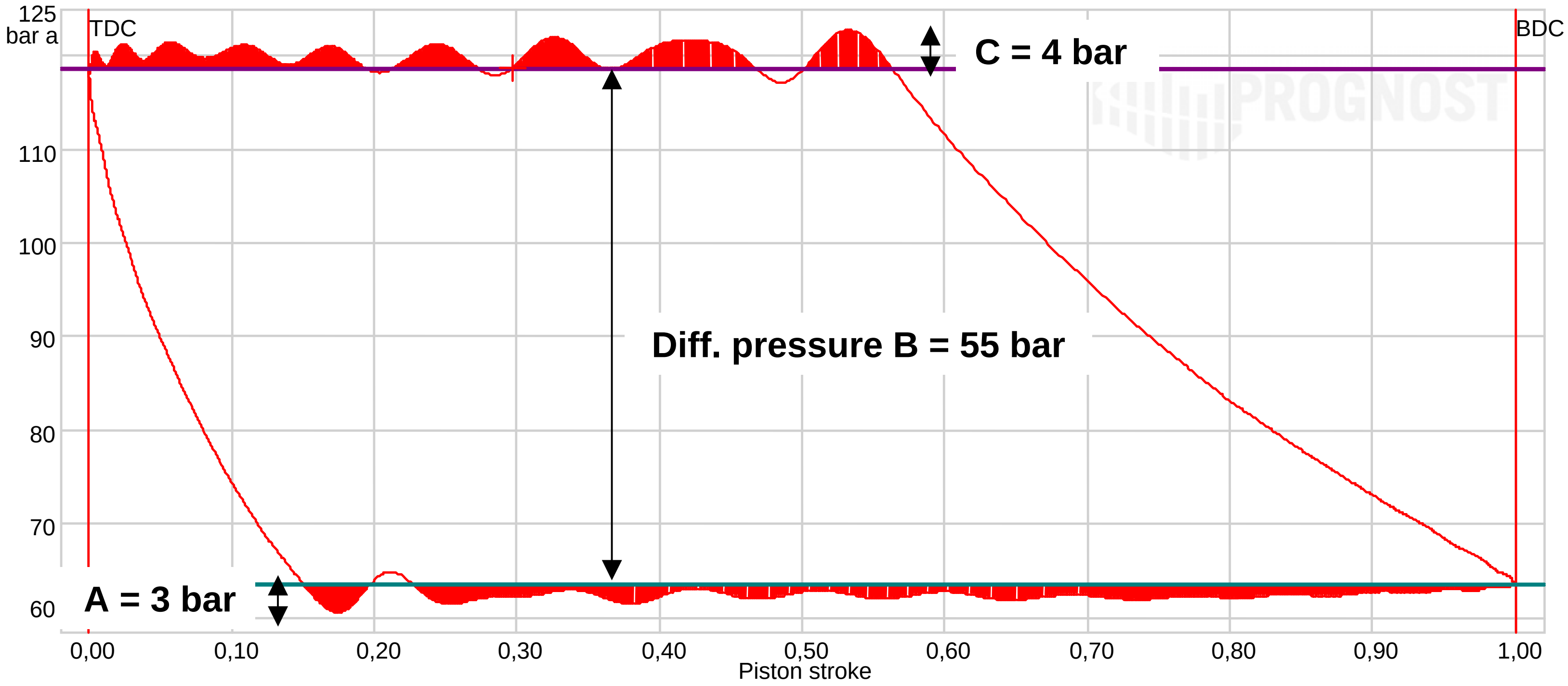


The valve inertia is a parameter that reflects the ratio of maximum pressure over- / undershoot of the dynamic pressure to the discharge/suction pressure (A or C) with regard to the pressure ratio (B). An increasing valve inertia indicates a rising pulsation or delayed opening of the suction/discharge valve.

Inertia suction = A / B

Inertia discharge = C / B

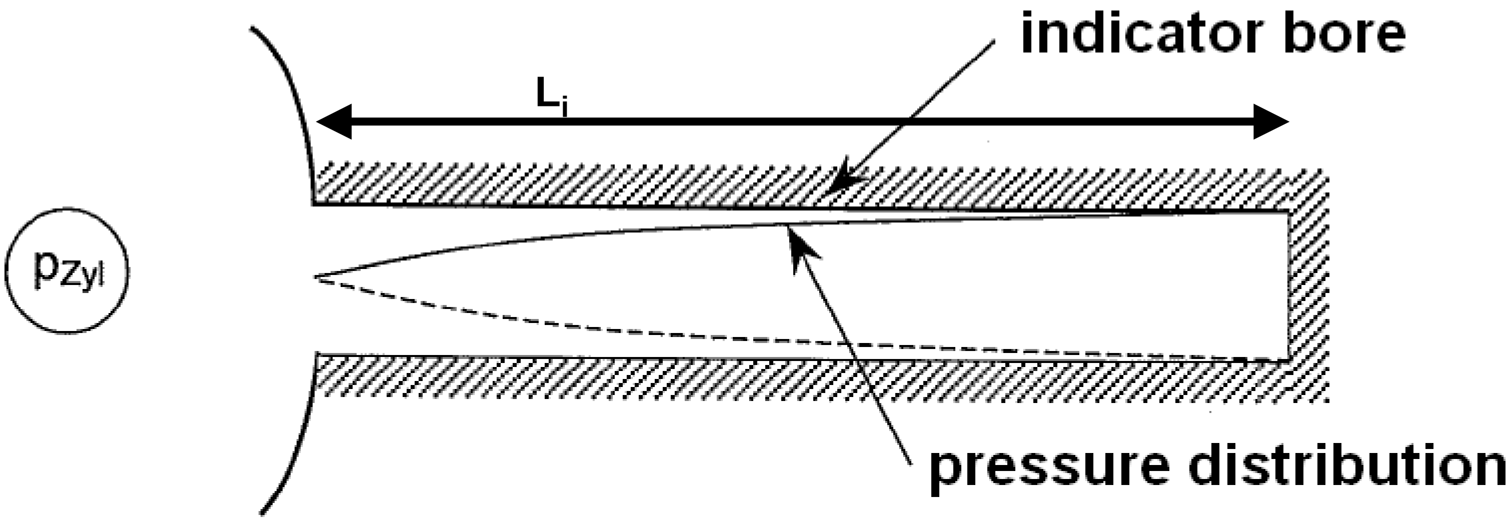
Parameters to monitor pulsations – Example valve inertia



Inertia discharge = C / B = 4 bar / 55 bar = 0,073

Inertia suction = A / B = 3 bar / 55 bar = 0,055

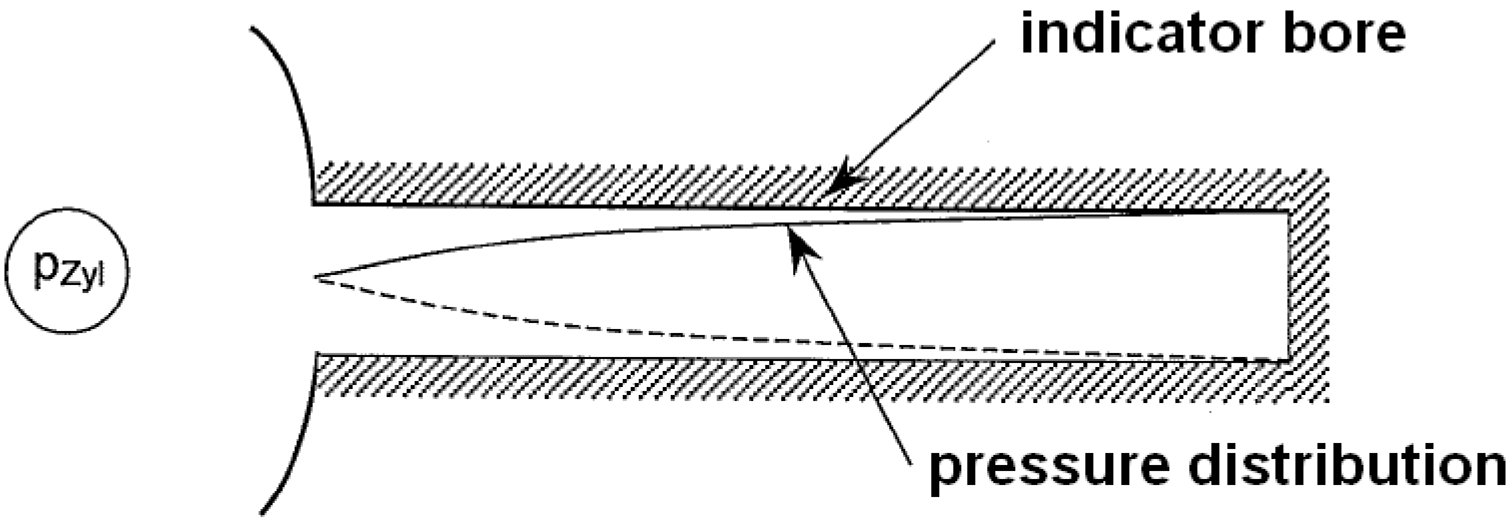
Channel resonance



The channel resonance is an **acoustic effect** that results from the **length of the indicator tap** and the **speed of sound**. It causes a **pressure pulsation** on the dynamic pressure signal that might be **mistakenly** considered a pressure pulsation. It has to be **eliminated** from the signal by an appropriate **low-pass filter**.

$$f_{channel} = \frac{c_S}{\lambda} = \frac{c_S}{4 \cdot L_I}$$

Channel resonance



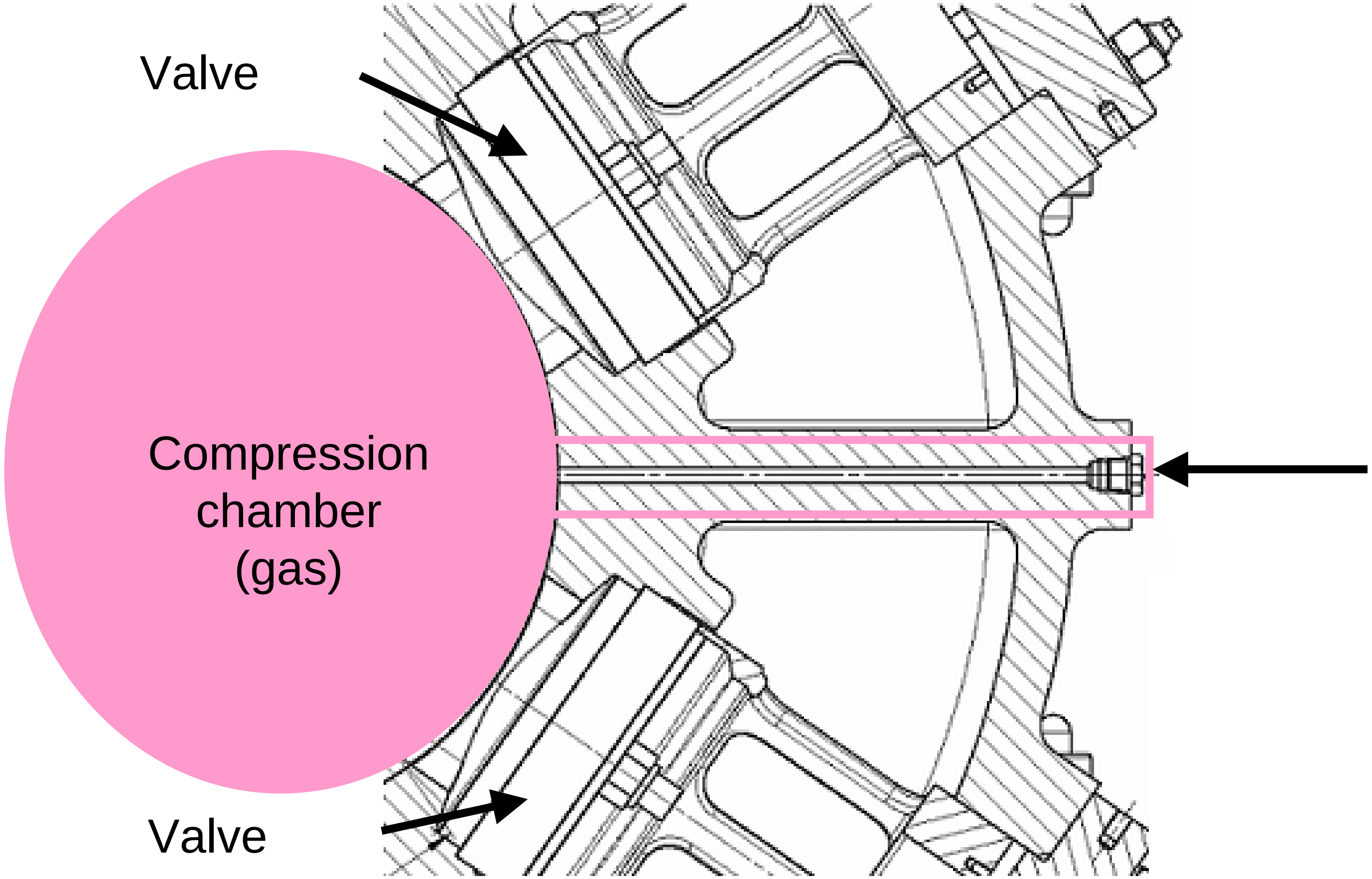
Examples : Calculated channel resonance for indicator tap length 450 mm at 20 °C

$$f_{channel} = \frac{c_S}{\lambda} = \frac{c_S}{4 \cdot L_I}$$

Hydrogen : 1314 m/s / 4 * 600 mm = 547,5 Hz

Natural gas : 397 m/s / 4 * 600 mm = 165,4 Hz

Pressure Measurement – indicator tap on cylinder



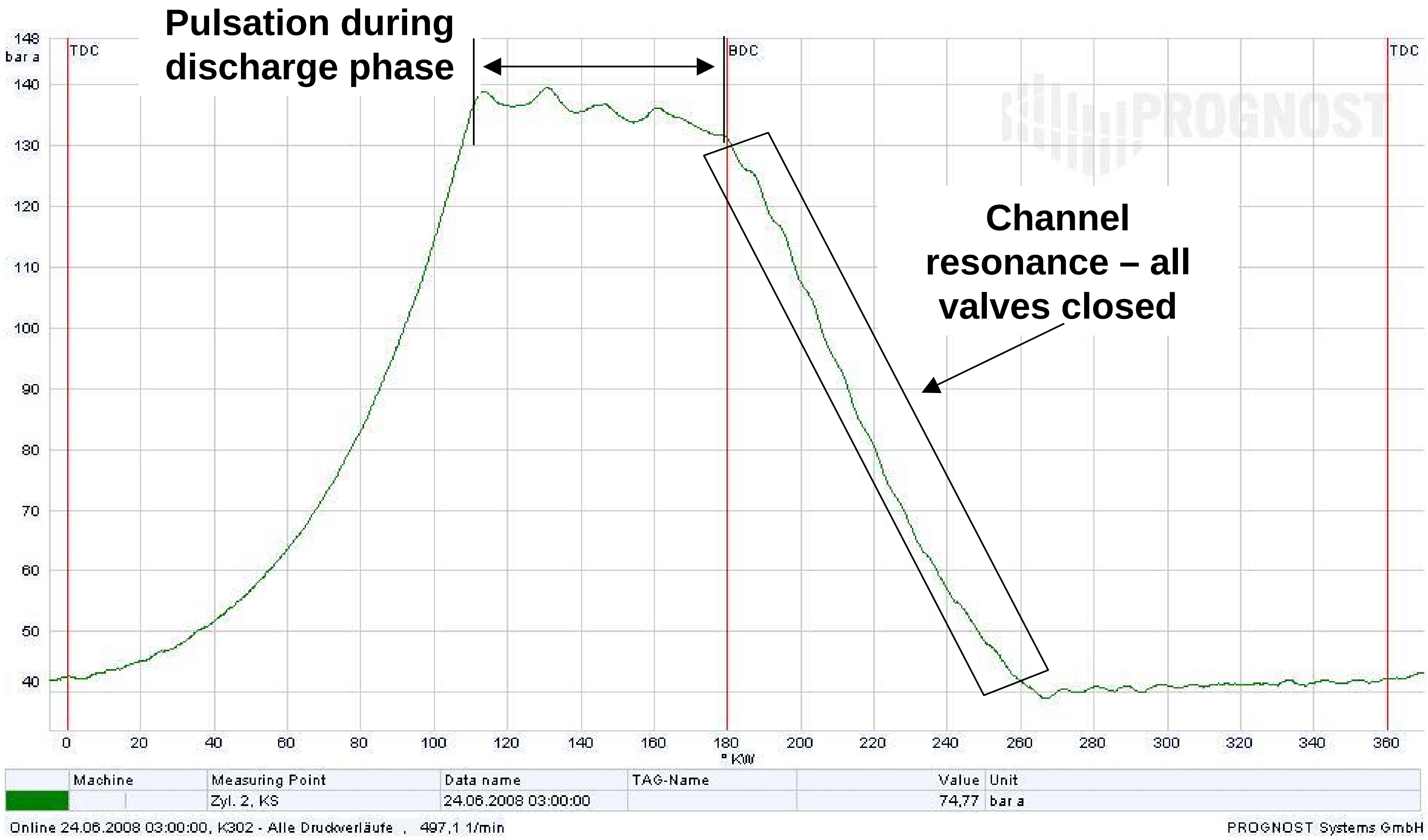
Pressure Measurement

Pressure probe...

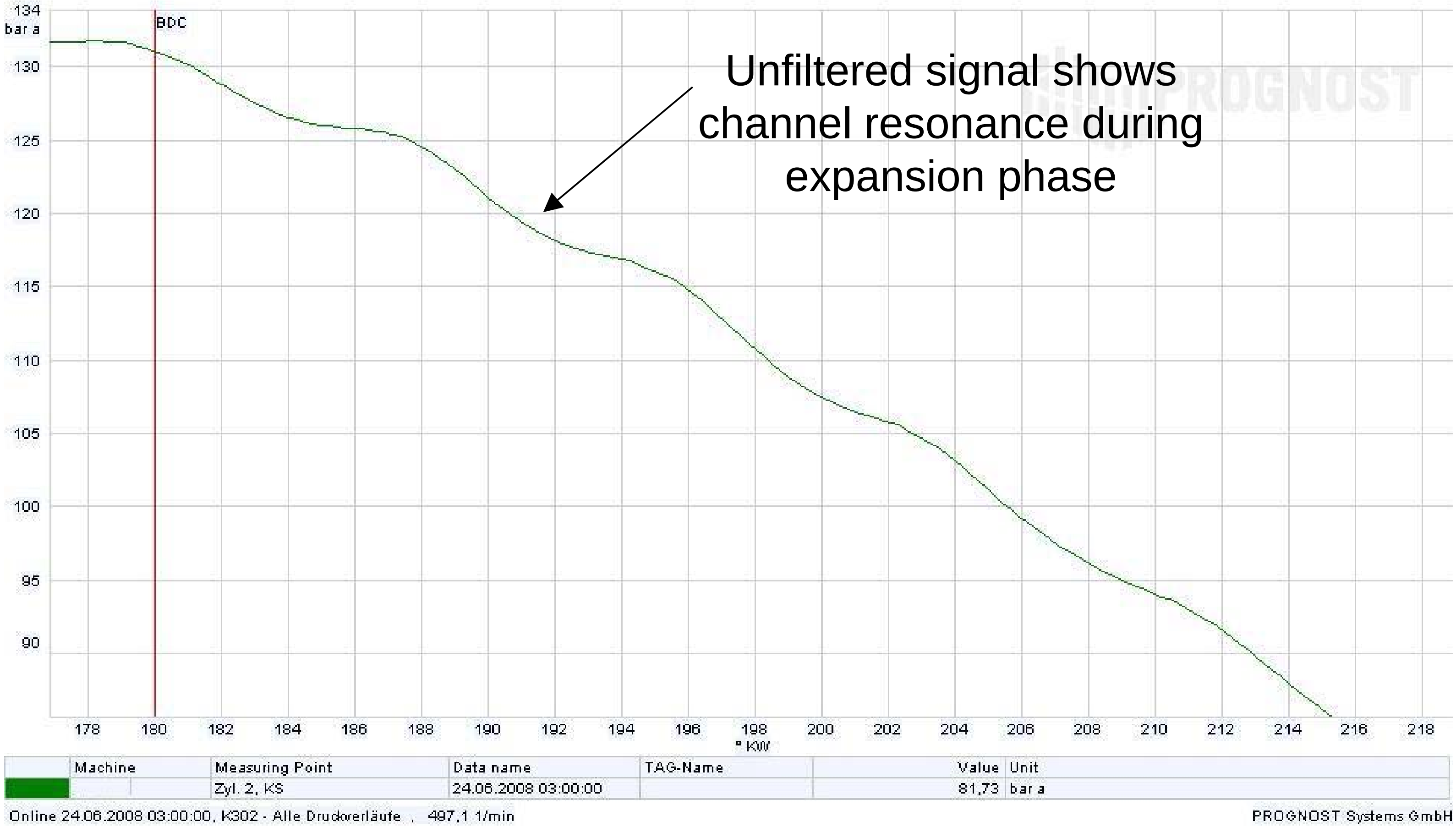
…directly screwed into an indicator tap

... with elbow and indicator valve (ball valve)

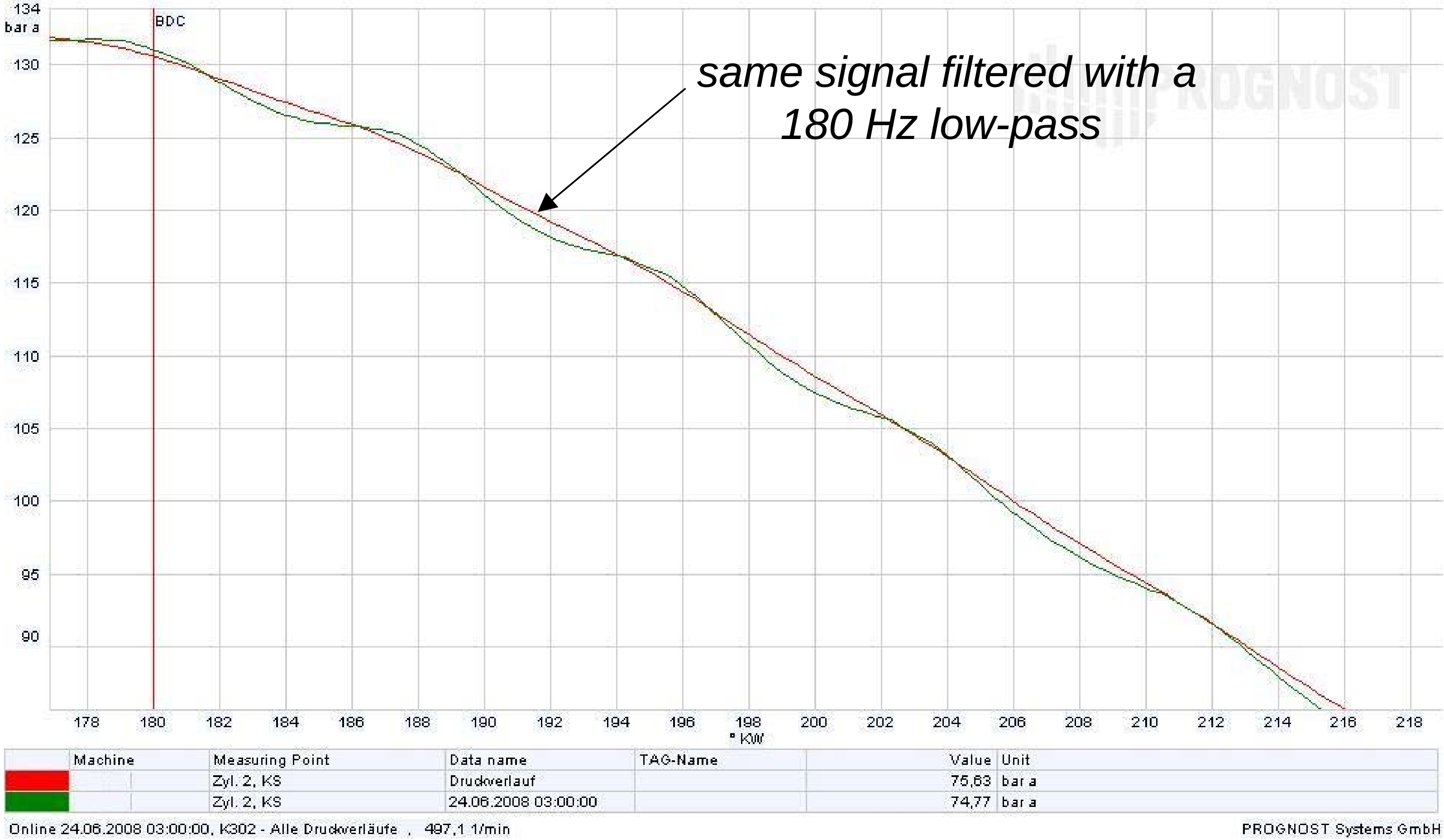
Channel resonance



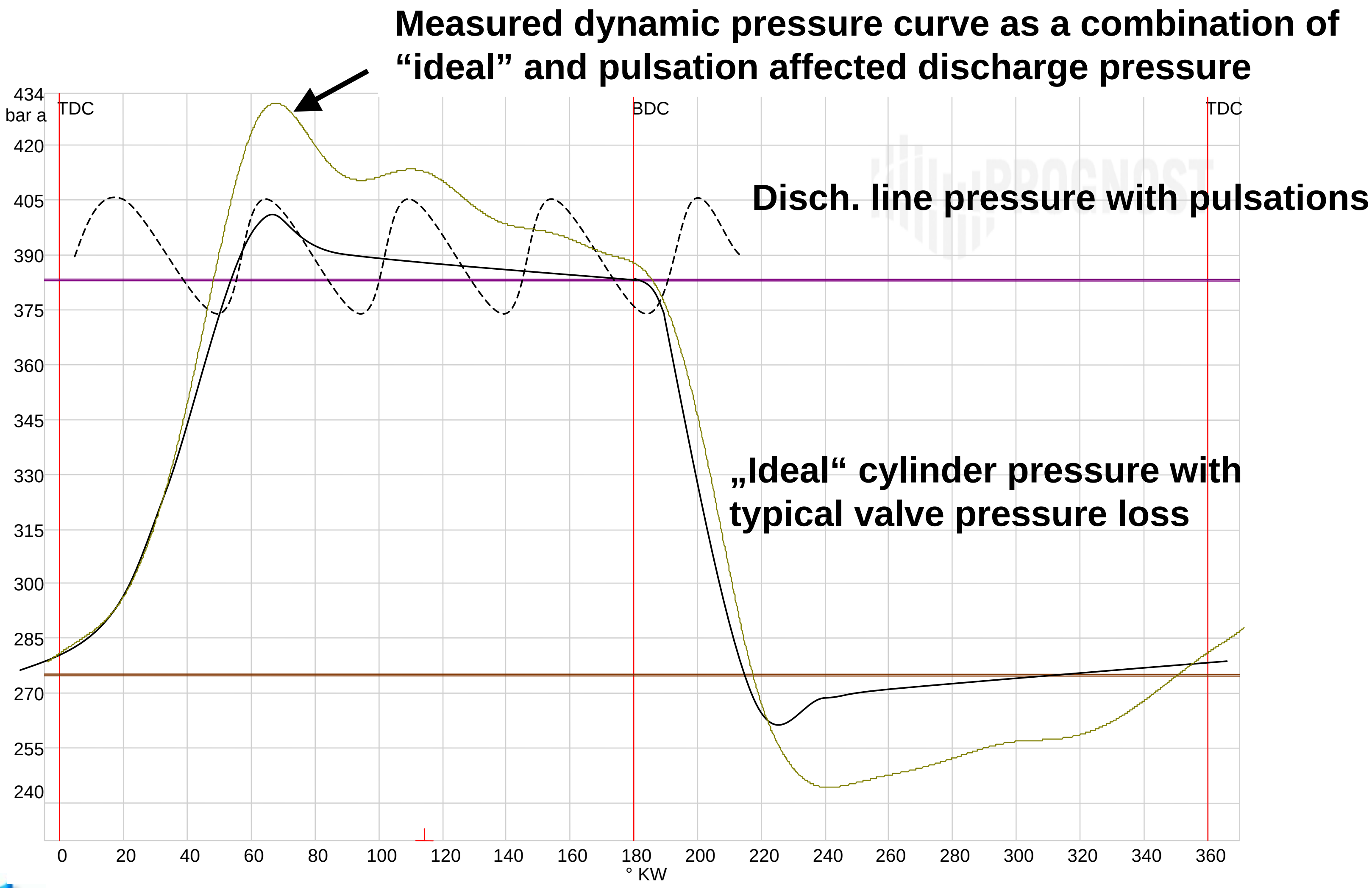
Channel resonance



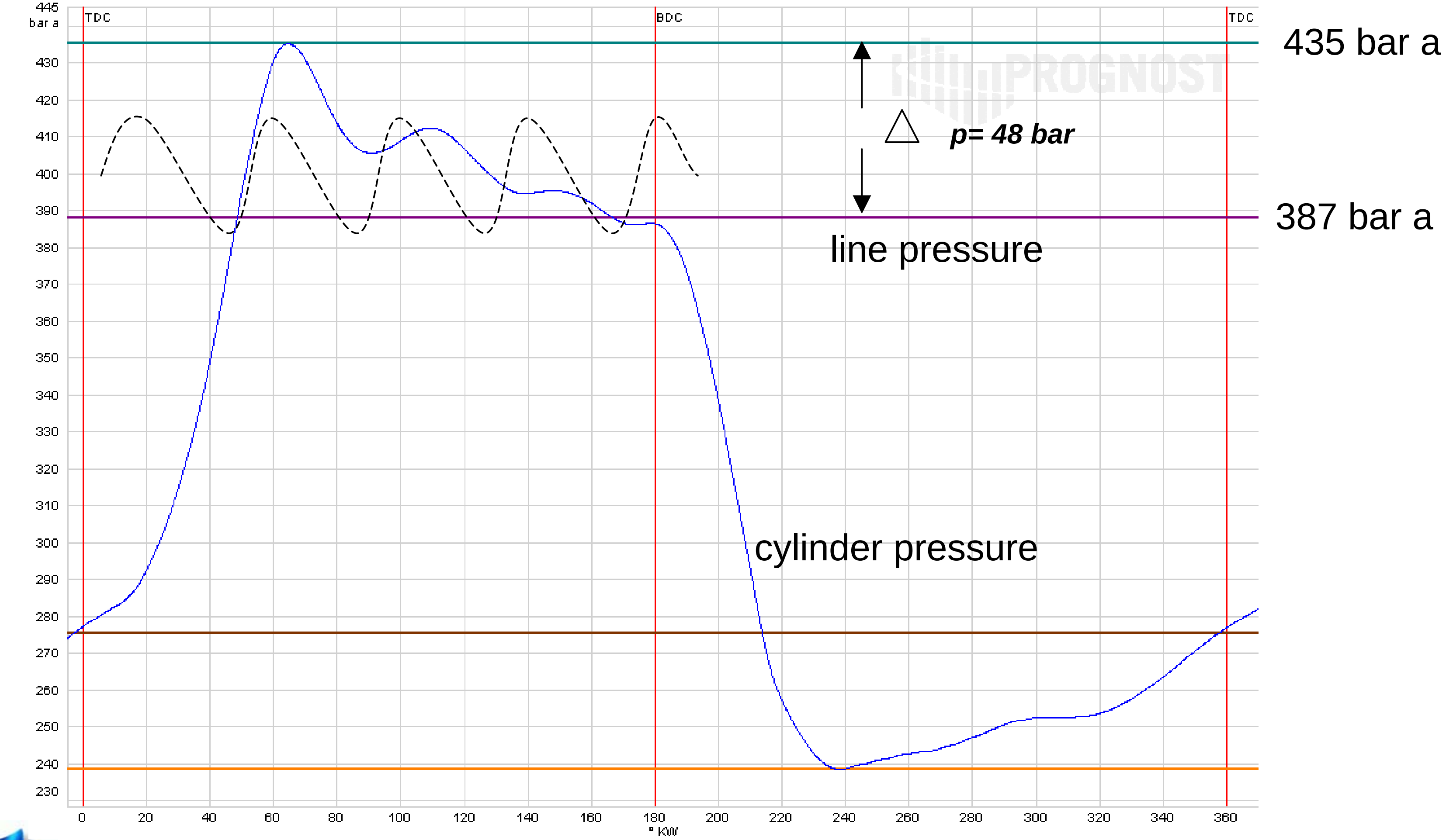
Channel resonance



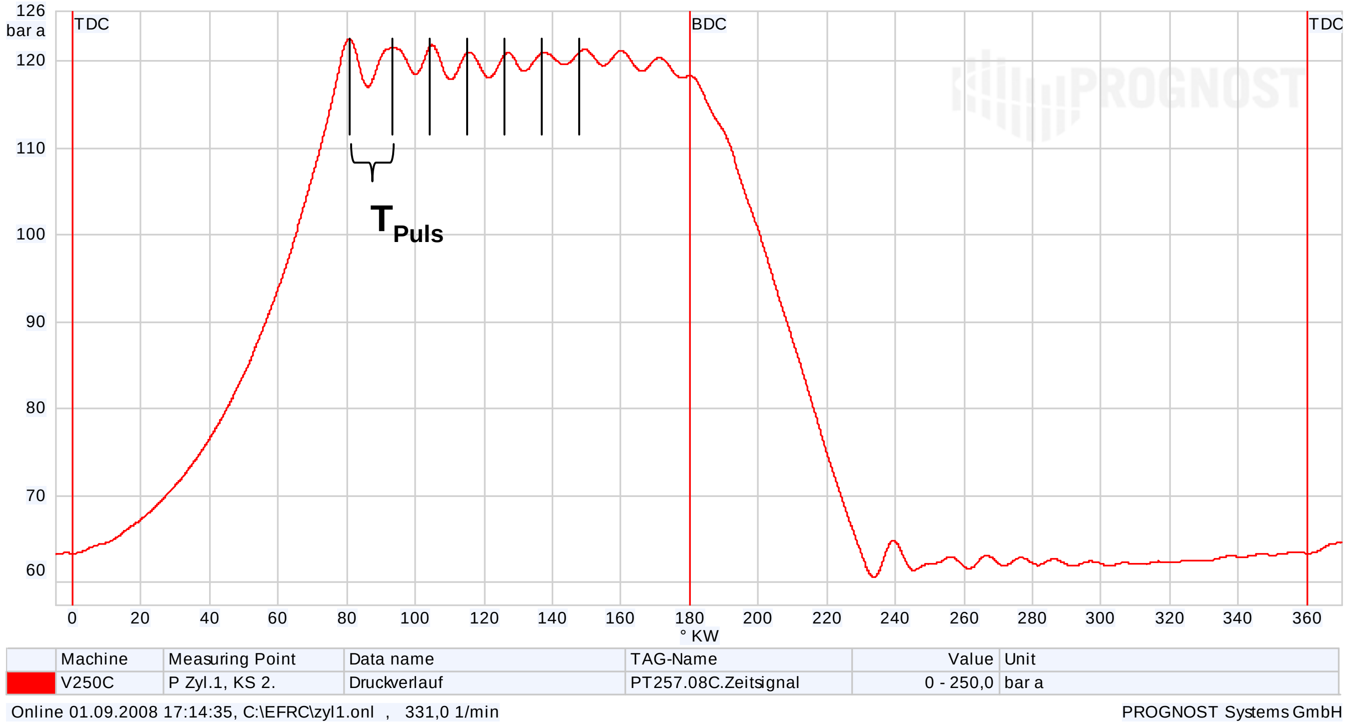
Superimposing pulsations and valve pressures



Superimposing pulsations and valve pressures

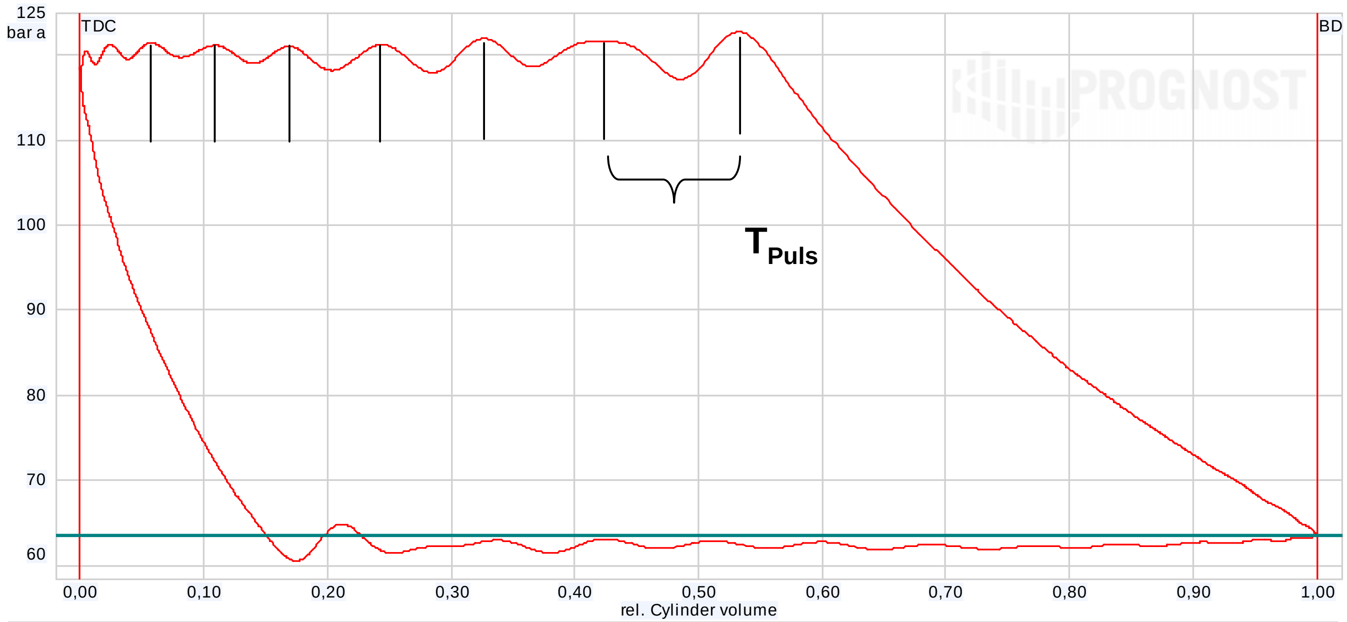


Time domain vs. volume domain



Pulsations can best be viewed in time related dimensions that illustrate the stable frequency of pulsations. Often mistakes are made when pulsations are judged by watching p-V diagrams that are using a volume dimension on the horizontal axis.

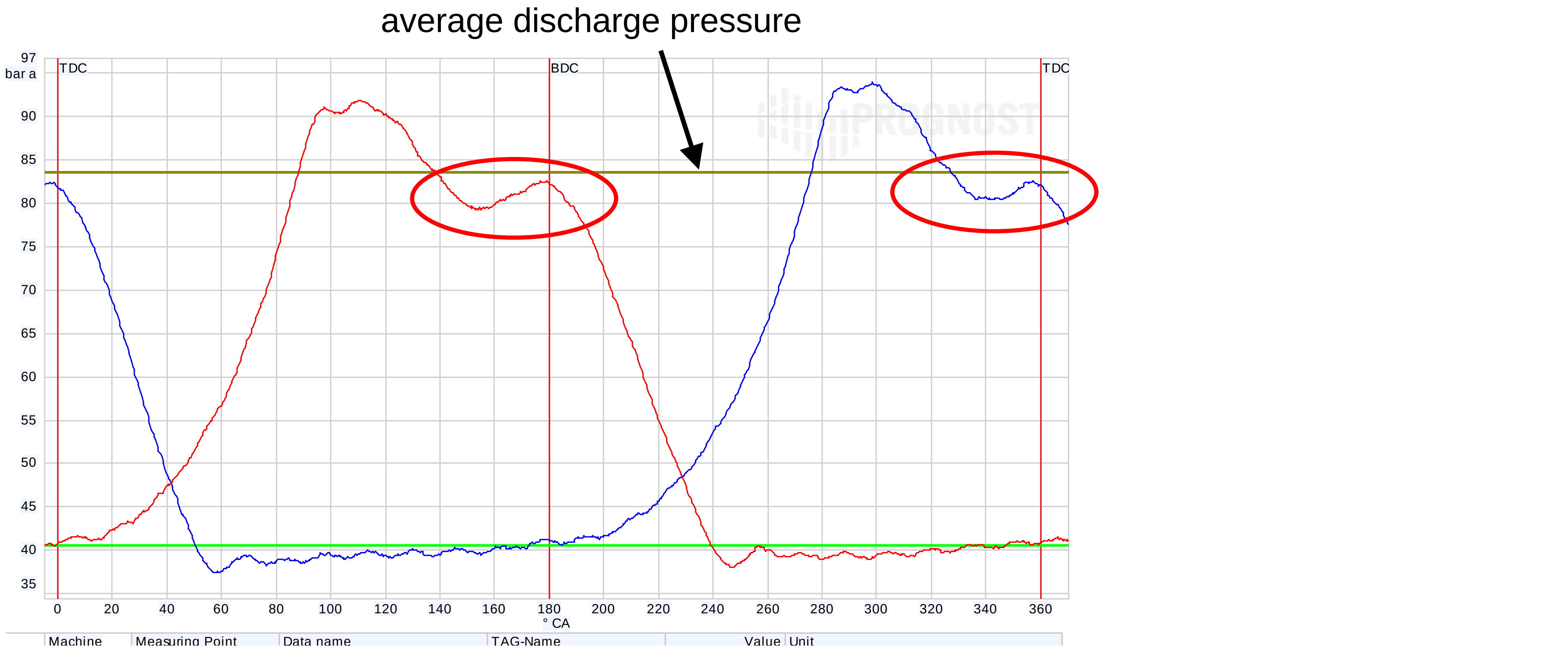
Time domain vs. volume domain



	Machine	Measuring Point	Data name	TAG-Name	Value	Unit
	V250C	P Zyl.1, KS 2.	p-V-Diagramm	PT257.08C	0 - 250,0	bar a

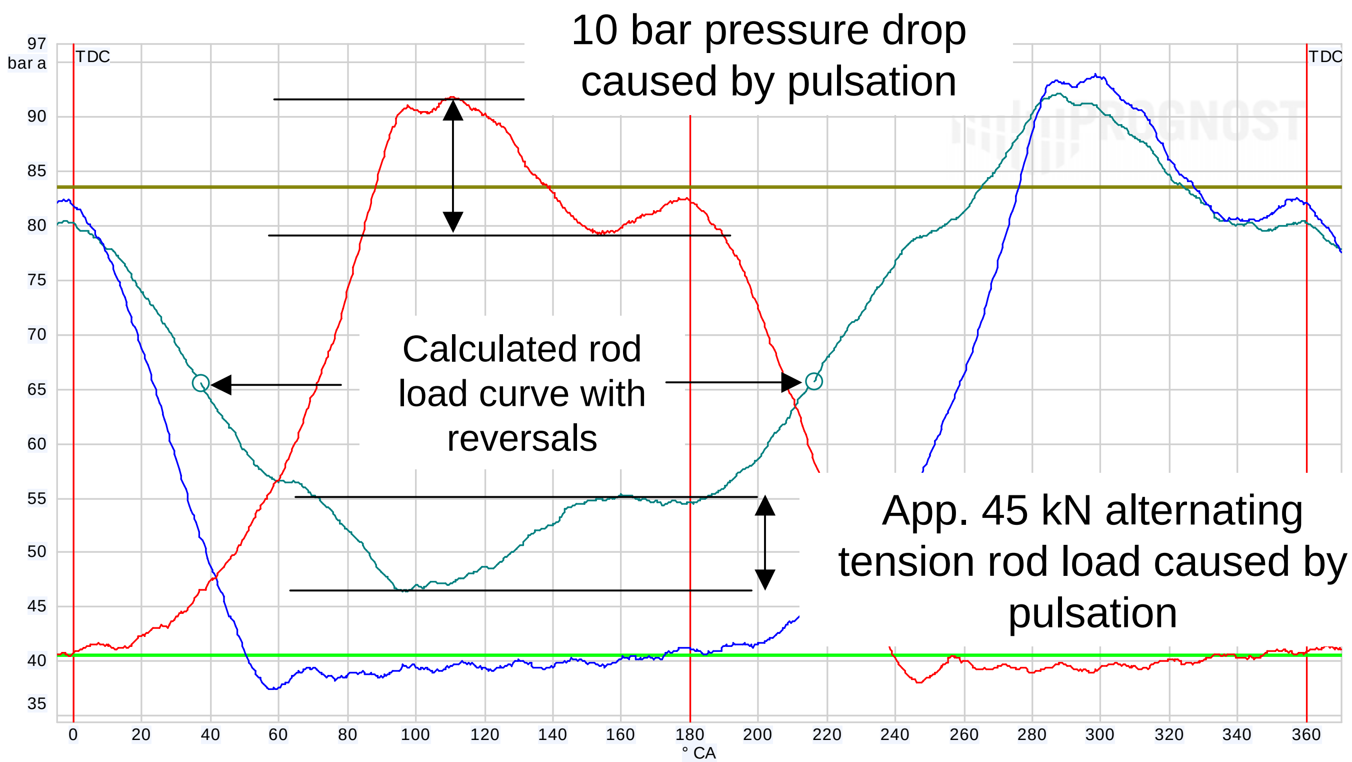
When displayed in a p-V diagram the same pressure pulsations often are not recognized as pipe pulsations, because they appear to have changing frequency.

Pulsation and rod load



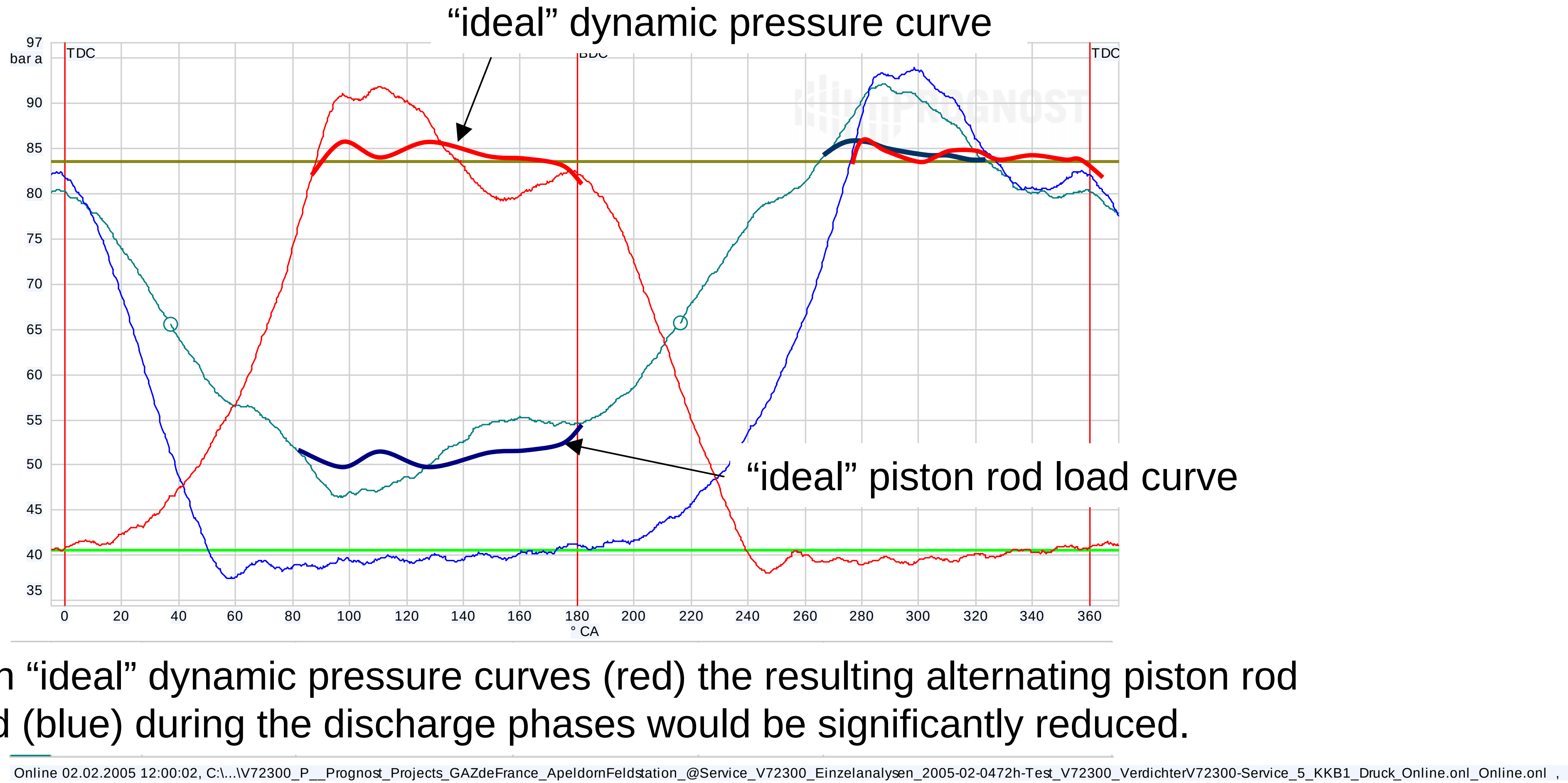
In the above example the pulsation in the discharge piping is causing the pressure in the cylinder even to drop below the average discharge pressure. This causes a significant change to the rod load as compared to ideal pressure curves.

Pulsation and rod load



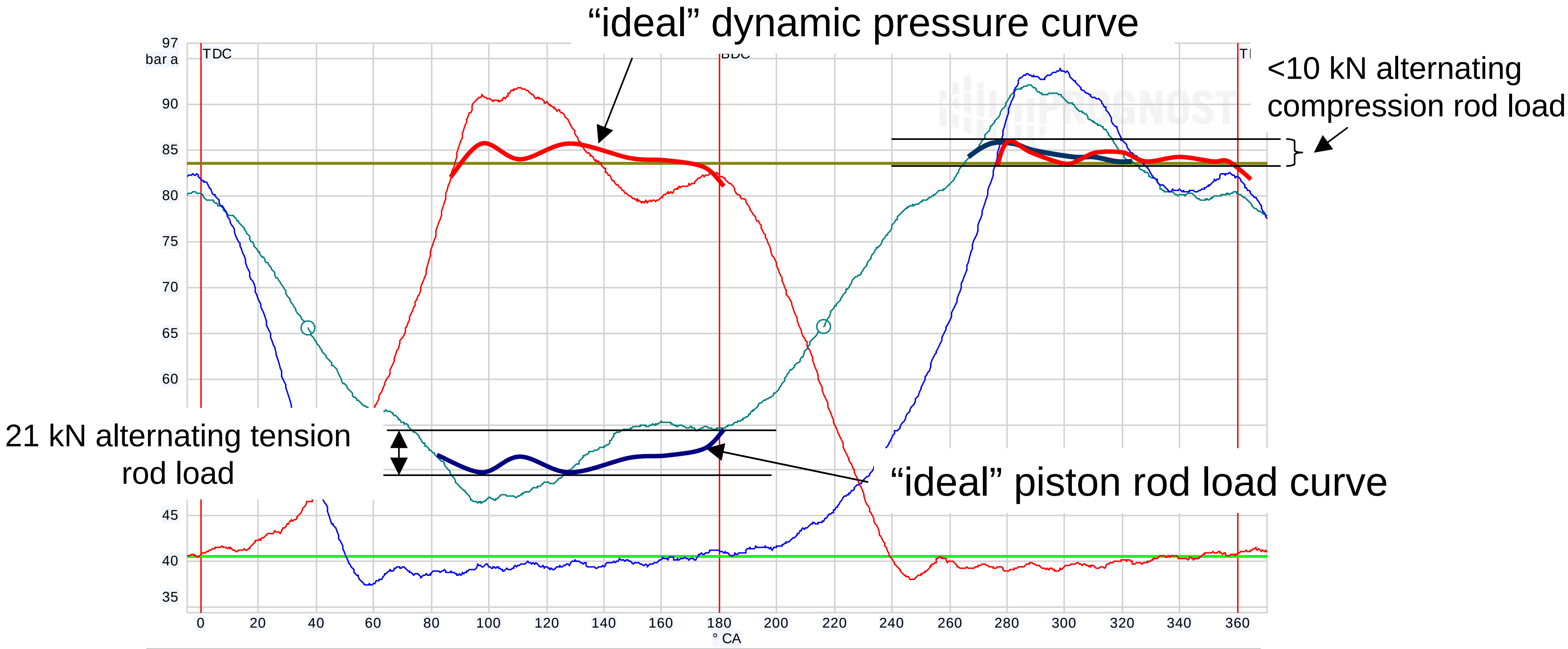
The pulsation in the discharge piping is causing a pressure drop of more than 10 bar during the discharge phase of the head and crank end compression chamber. This causes an alternating tension rod load of app. 45 kN, equivalent to app. 50% of the total tension rod load.

Pulsation and rod load



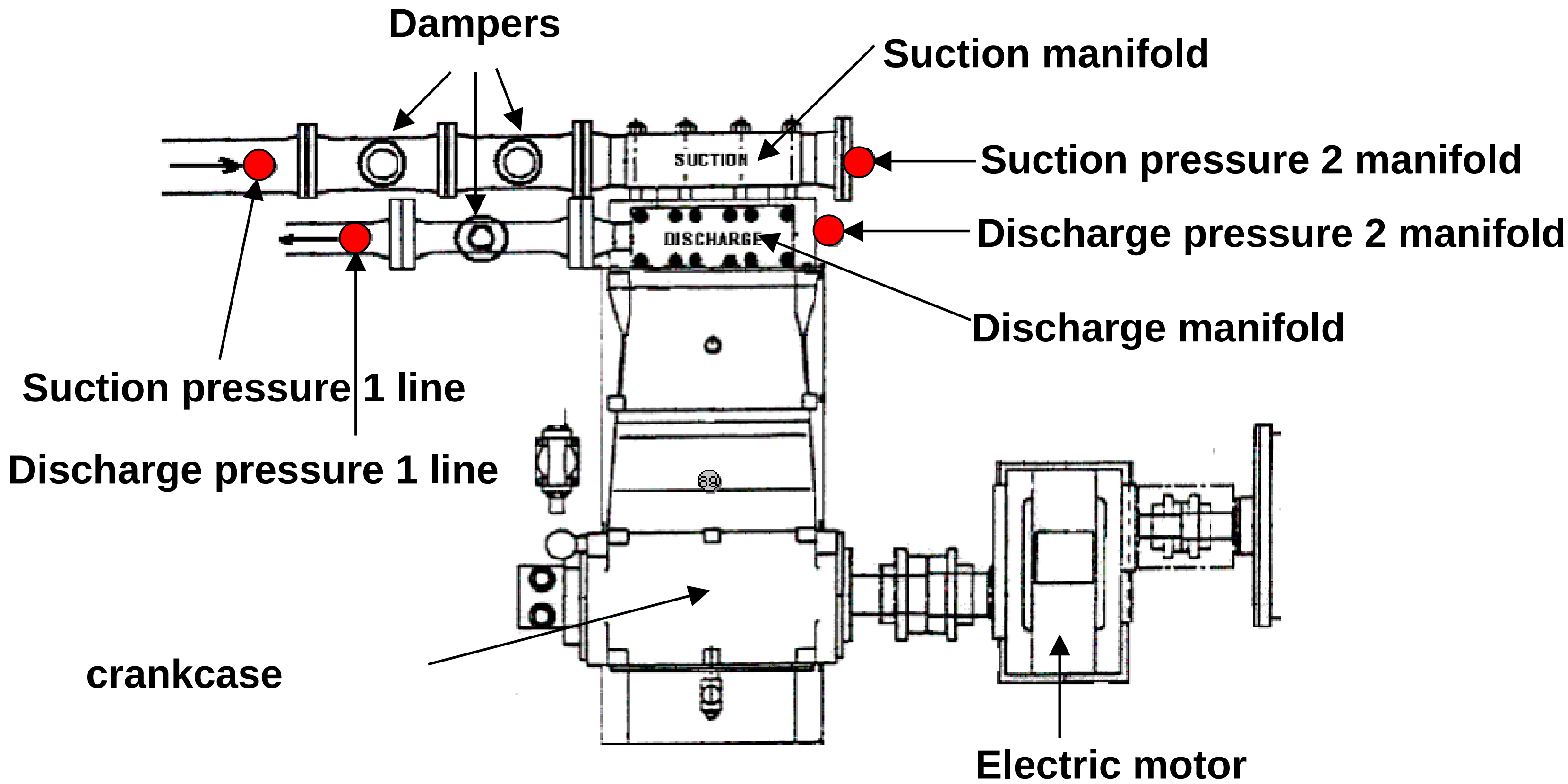
With "ideal" dynamic pressure curves (red) the resulting alternating piston rod load (blue) during the discharge phases would be significantly reduced.

Pulsation and rod load



With "ideal" dynamic pressure curves (red) the resulting alternating piston rod load (blue) during the discharge phases would be significantly reduced by 20% of total tension rod load to app. 21 kN during tension phase and by 25% of total compression rod load to less than 10 kN during compression phase.

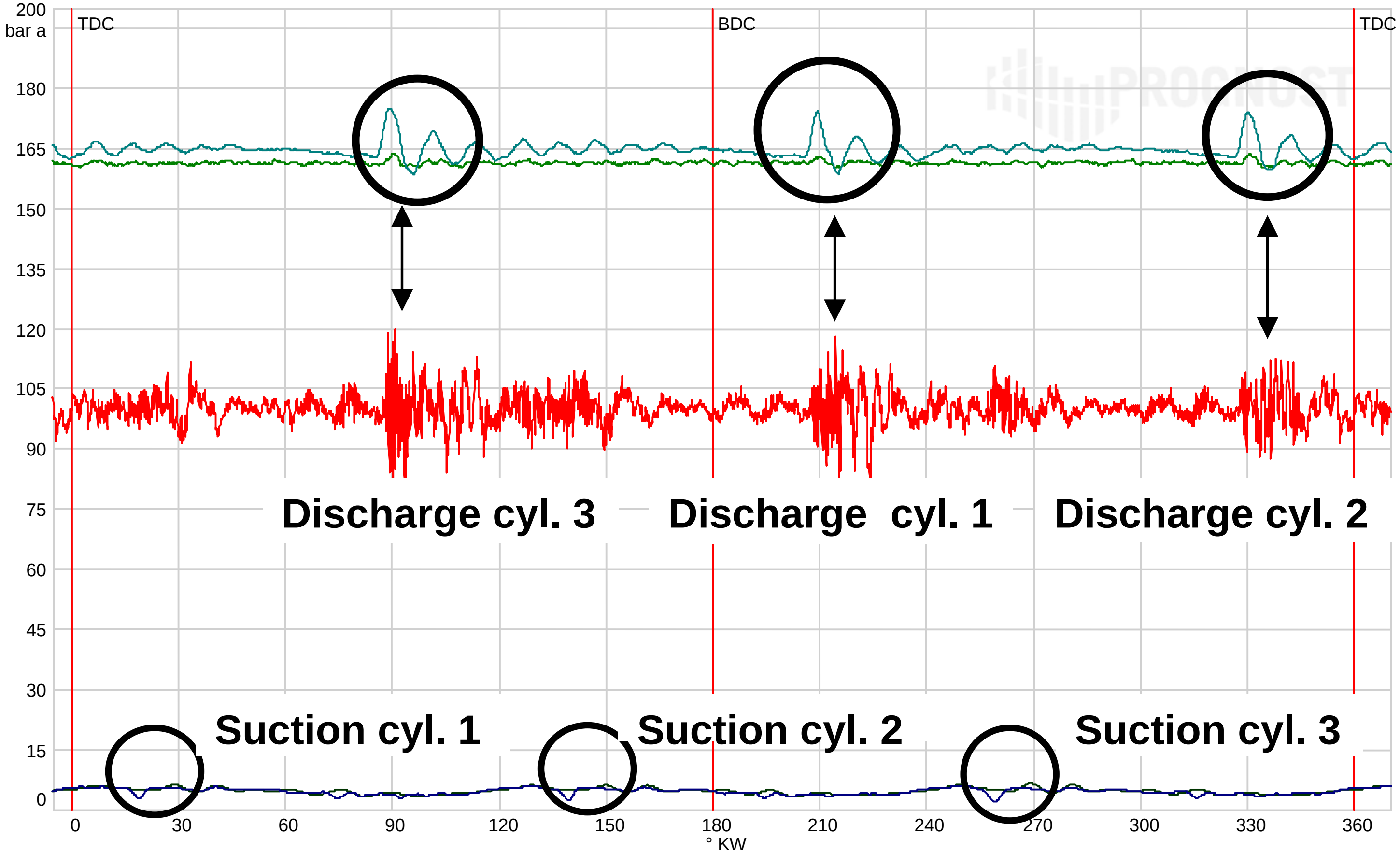
Example : Online monitoring of pulsations



Monitored parameters:

Pulsation level (upstream suction damper, suction manifold, discharge manifold, downstream discharge damper)

Example : Online monitoring of pulsations



	Machine	Measuring Point	Data name	TAG-Name	Value	Unit
	C 302	V CHS Casing	Vibration signal	302VE990.time_signal		m/s²
	C 302	SP1 line	Pressure signal	302PT990.time_signal		bar a
	C 302	SP2 manifold	Pressure signal	302PT991.time_signal		bar a
	C 302	DP1 line	Pressure signal	302PT992.time_signal		bar a
	C 302	DP2 manifold	Pressure signal	302PT993.time_signal		bar a

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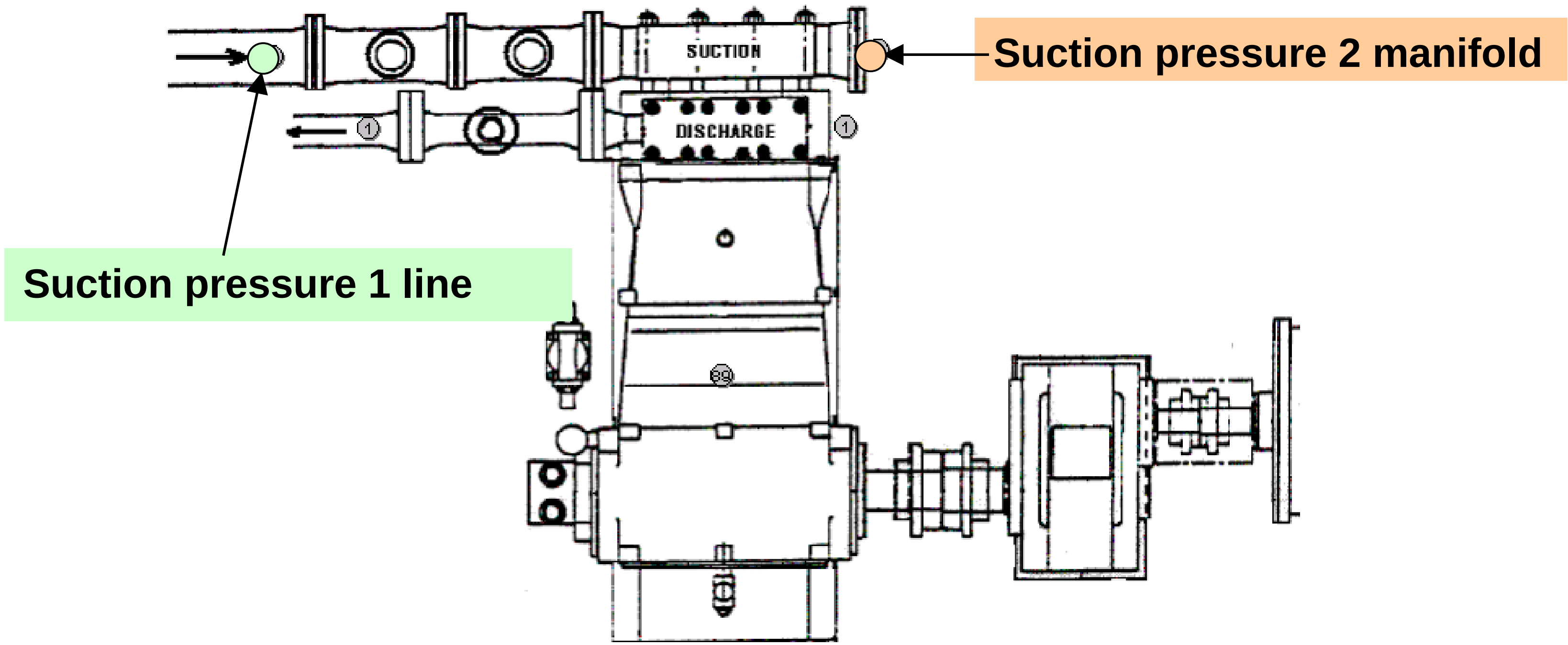
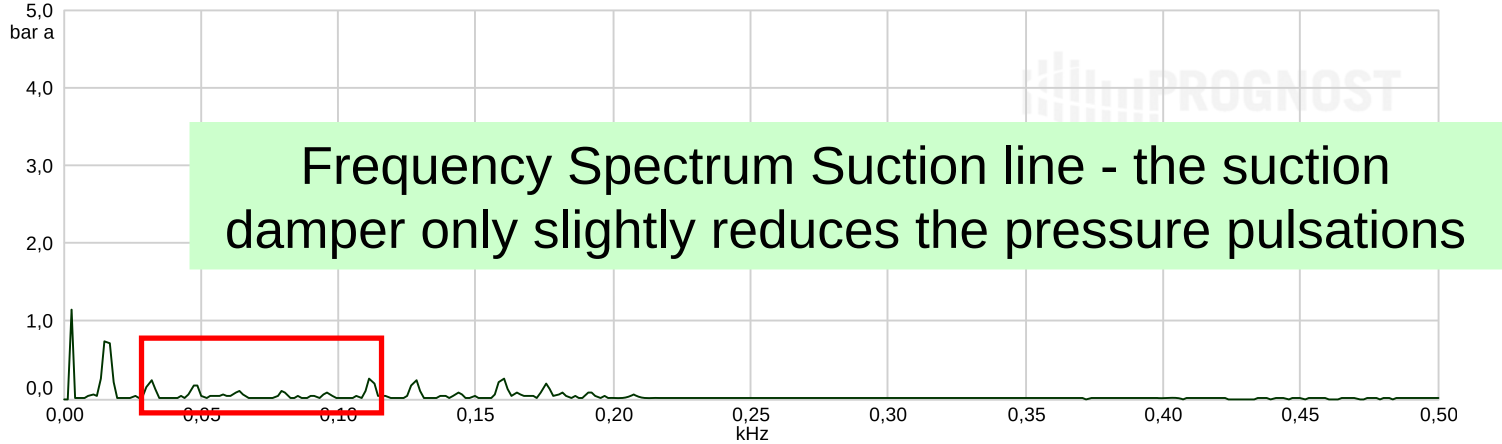
Transient signals of vibration and dynamic pressure for 1 crankshaft revolution

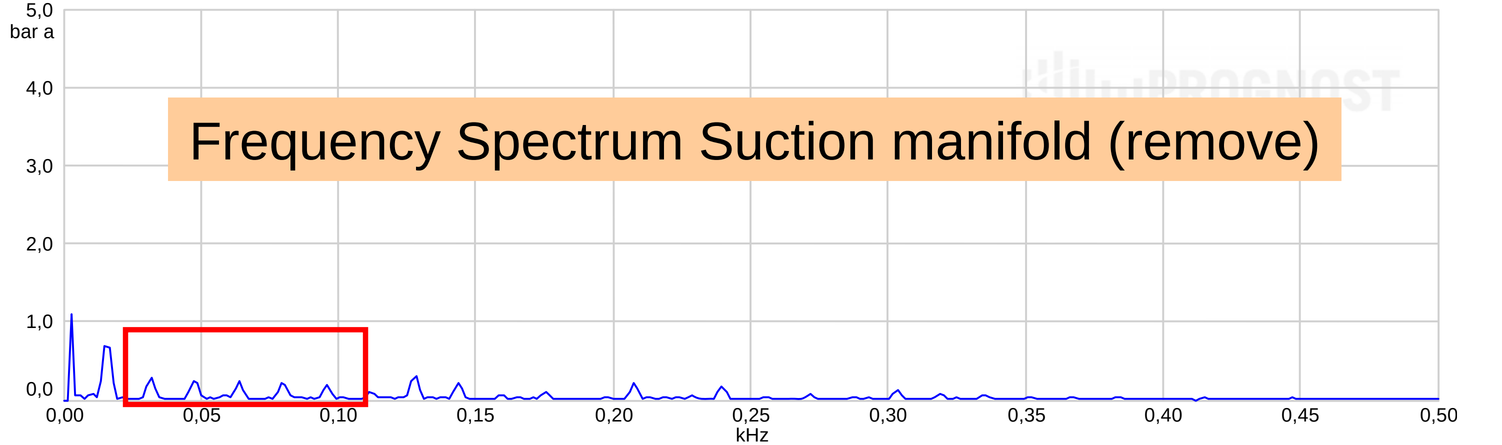
Example : Online monitoring of pulsations – suction side



Example : Online monitoring of pulsations – suction side



	Machine	Measuring Point	Data name	TAG-Name	Value	Unit
	C 302	SP1 line	Amplitude spectrum	302PT990.time_signal		bar a



	Machine	Measuring Point	Data name	TAG-Name	Value	Unit
	C 302	SP2 manifold	Amplitude spectrum	302PT991.time_signal		bar a

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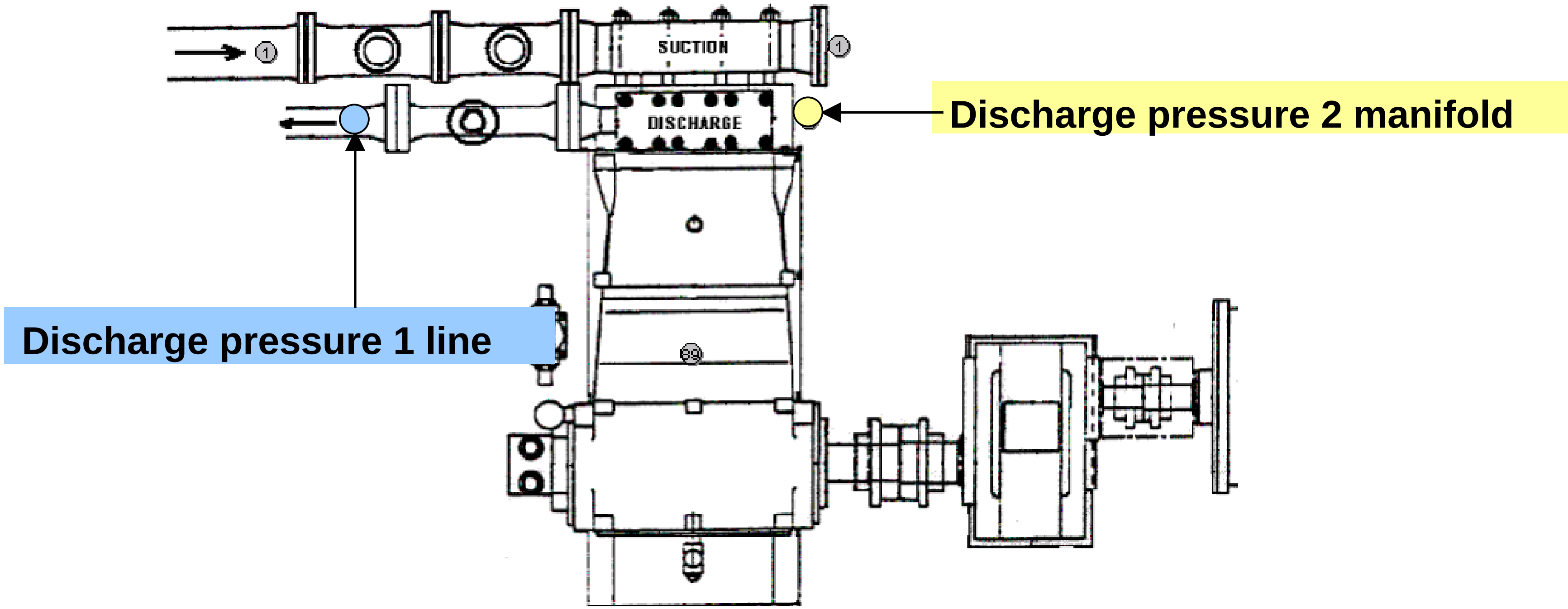
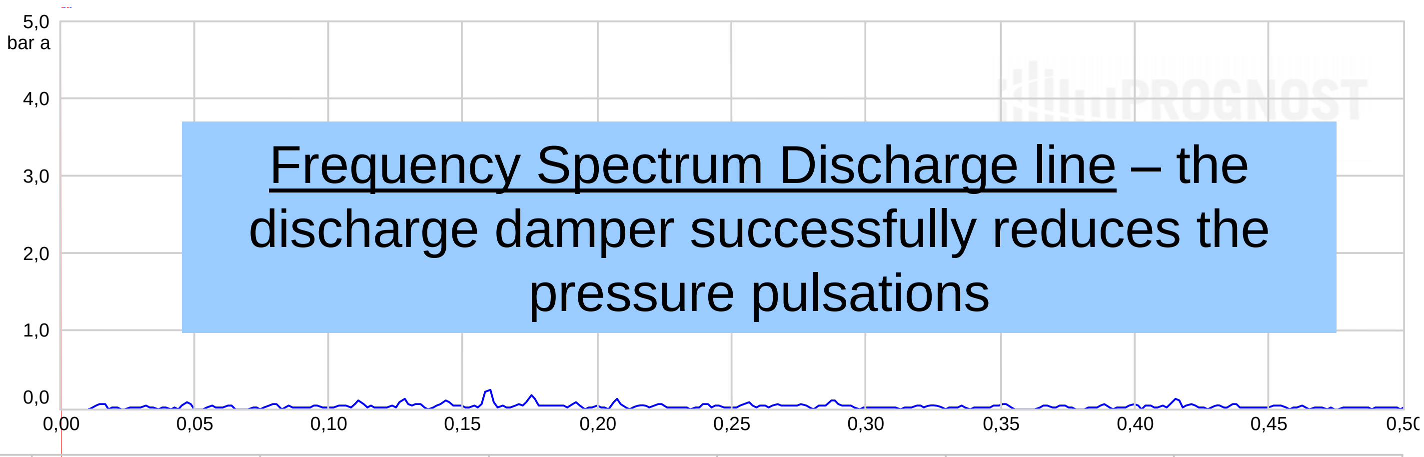
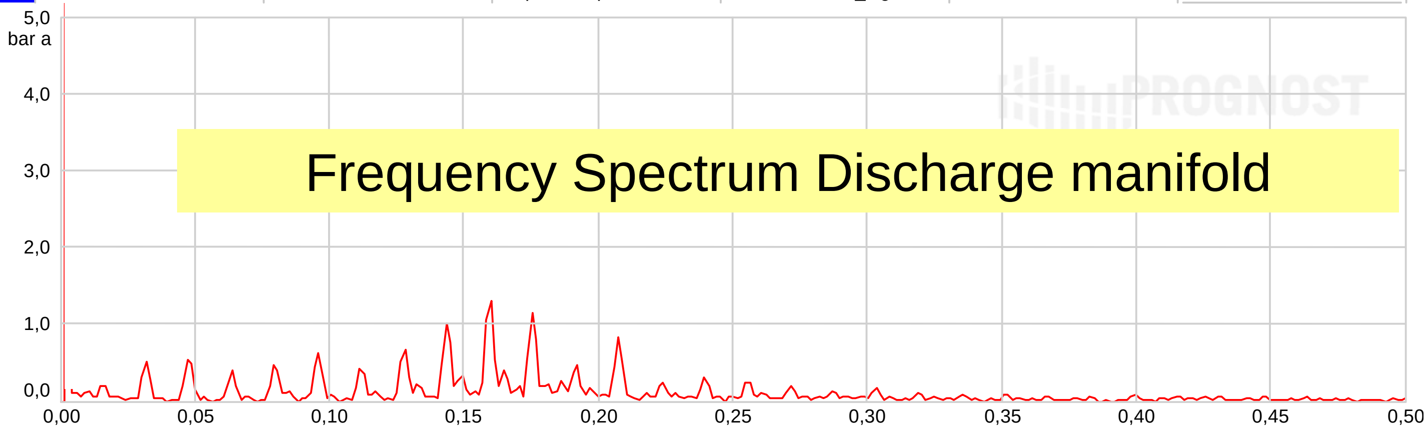
Example : Online monitoring of pulsations – discharge side



Example : Online monitoring of pulsations – discharge side



	Machine	Measuring Point	Data name	TAG-Name	Value	Unit
	C 302	DP1 line	Amplitude spectrum	302PT992.time_signal		bar a



	Machine	Measuring Point	Data name	TAG-Name	Value	Unit
	C 302	DP2 manifold	Amplitude spectrum	302PT993.time_signal		bar a

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Summary

- Pulsations can only be measured when the frequency resolution of the transducer is at least double the expected pulsation frequency.
- Sensors need to be ATEX approved when used in hazardous area.
- The p-V diagram can be monitored for pressure loss and valve ínertia to obtain information on the pulsation level.
- The channel resonance by mistake is often considered a pulsation and need to be eliminated by a low-pass filter.
- Pulsations can cause significant additional piston rod load.
- If pulsations should be monitored directly, dynamic pressure sensors have to be installed in the suction/discharge piping and close to the cylinders
- With above measurement setup pulsations can be effectively monitored and alarmed with respect to maximum pulsation amplitude and frequency.