

On site vibration diagnosis – Practical approach guidelines

by Harry Lankenau



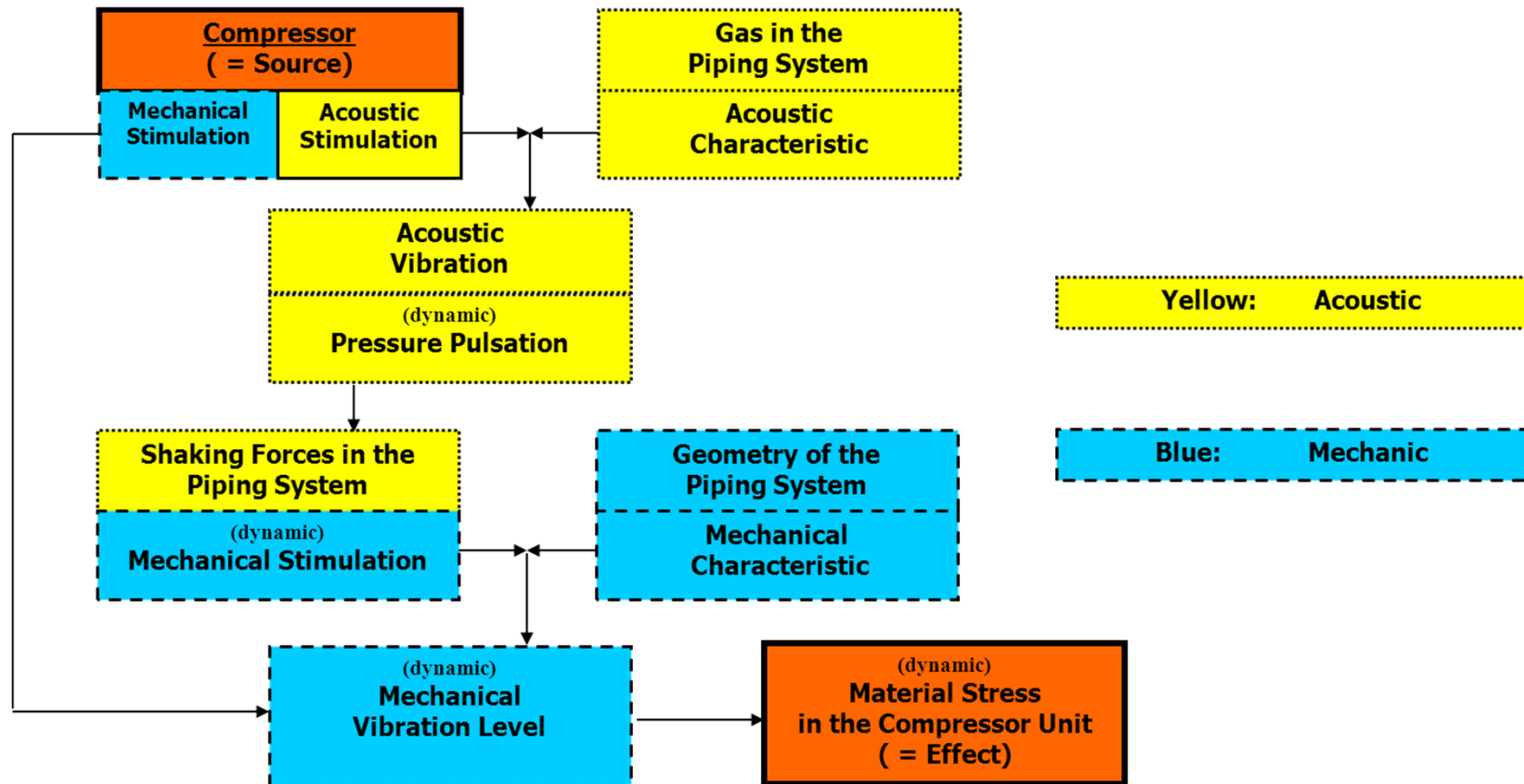
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“Source and Effect Chart” showing the path from the compressor vibration “*Source*” through acoustics and mechanics to the final material stress as “*Effect*”

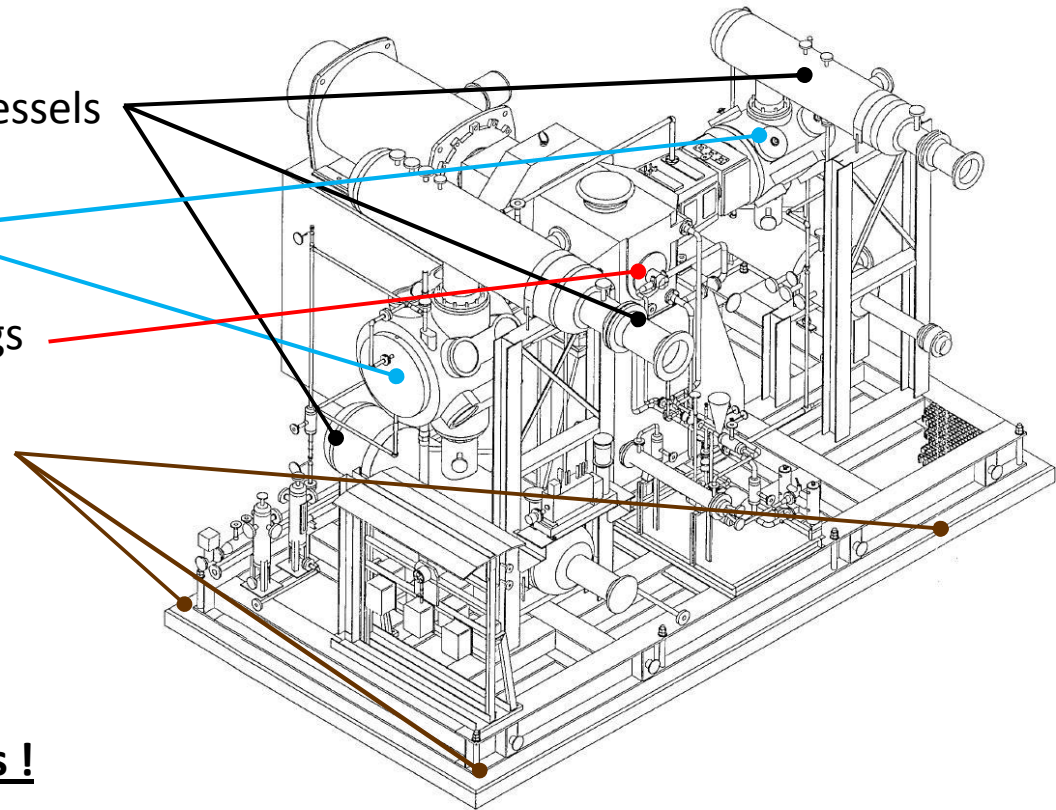


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“What people typically have in mind”:

- 28 mm/s rms for piping and vessels
- 11 mm/s rms for cylinders
- 4 mm/s near the main bearings
- 2 mm/s rms at the foundation



**These are NOT limits as per valid
guidelines or actual standards !**

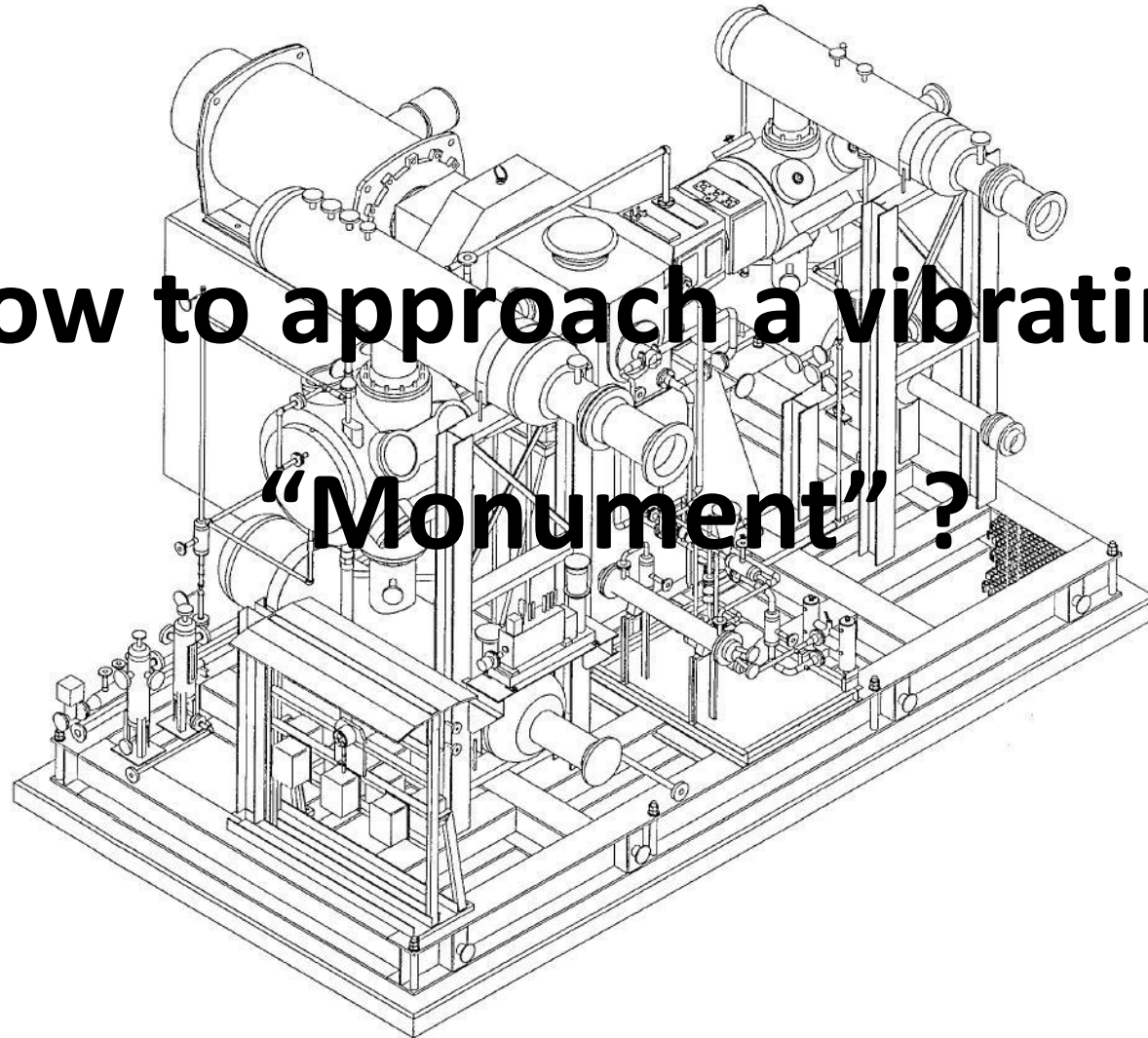
These limits are a kind of “Common Sense”.



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How to approach a vibrating “Monument” ?

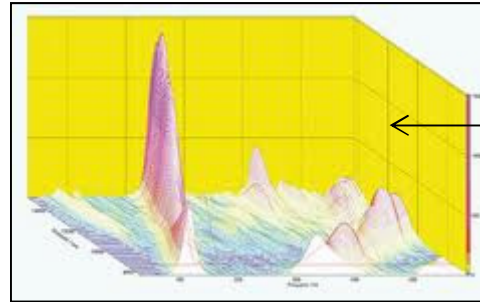


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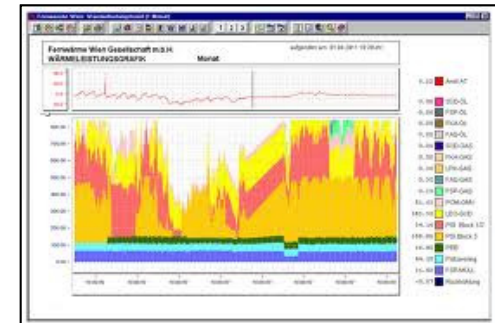


➤ Review machine operating history and vibration data

- When have vibrations become obvious?
- How did they develop?
- Utilize the DCS trends!
- Have machine process and/or load conditions changed?
- Any modifications of the pipelines and/or vessels - which may be linked to vibration occurrences?



Waterfall
Diagramme



Process Trends

Piping Change?



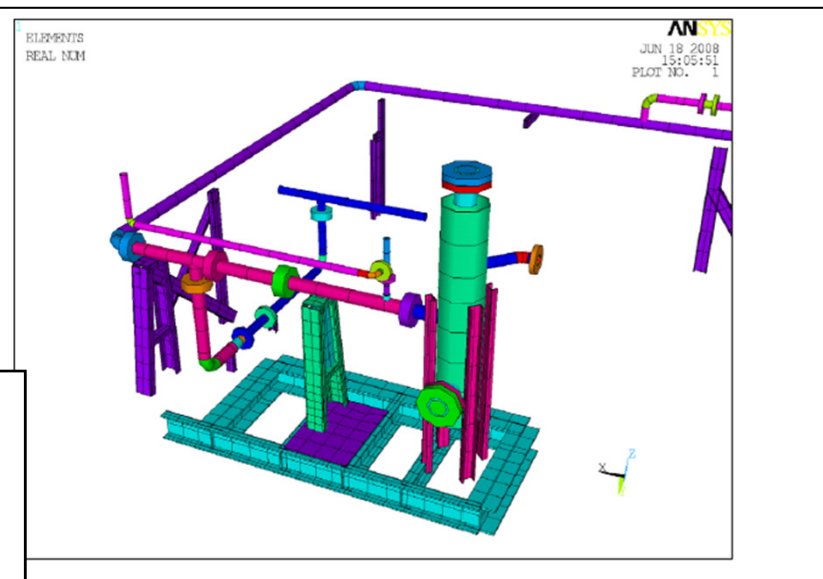
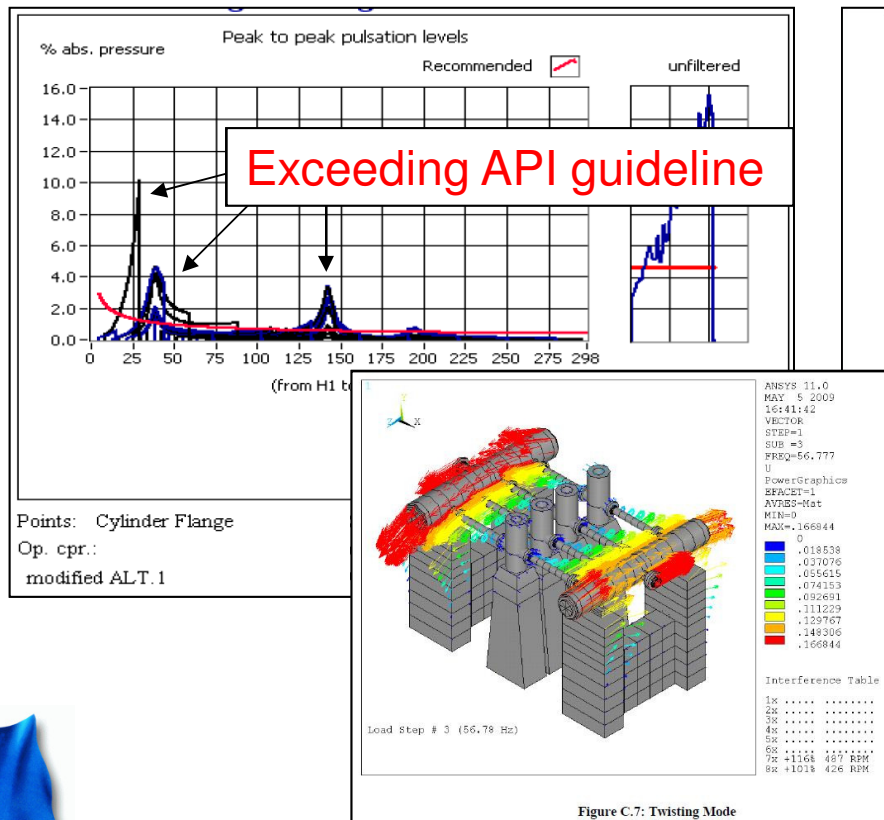
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- Check relevant design documents; if a pulsation study had been performed that may indicate critical conditions for particular process and/or load conditions



Pulsation Study Model – trouble free results and as-built?



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➤ Conduct an initial “Walk down” survey of the compressor and the piping to identify locations of abnormal vibrations - watch out for the following:

- High vibration amplitudes (in terms of displacement).
- High vibration frequencies

Both should be done by “feeling” with the hands (being protected by gloves where necessary and if required).



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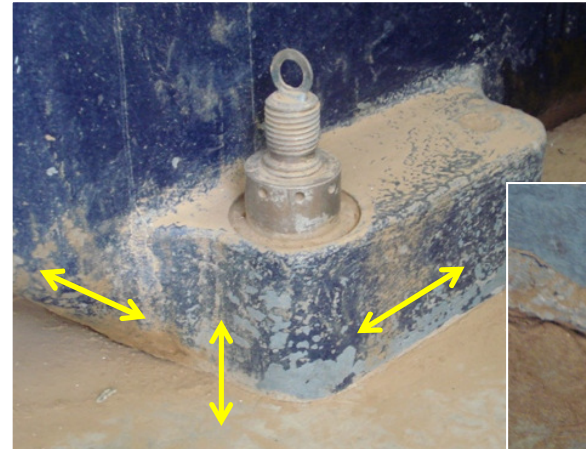
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- Conduct an initial “Walk down” survey of the compressor and the piping to identify locations of abnormal vibrations - watch out for the following:

- Particularly the compressor frame shall be checked for relative movement between:
 - Frame bottom base and foundation or grouting.
 - Mating surfaces (such as cylinder-to-distance piece or cylinder-to-frame).



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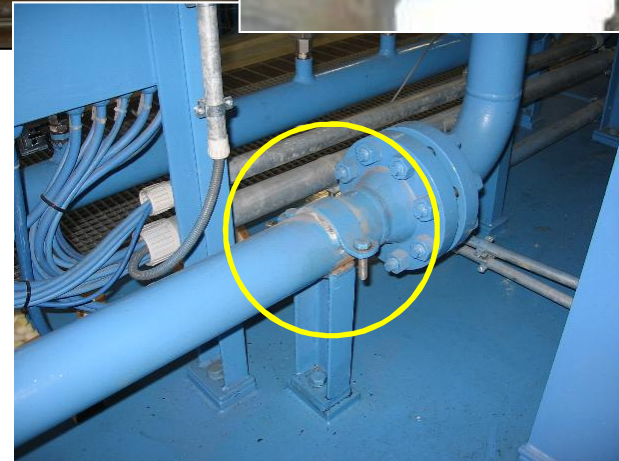
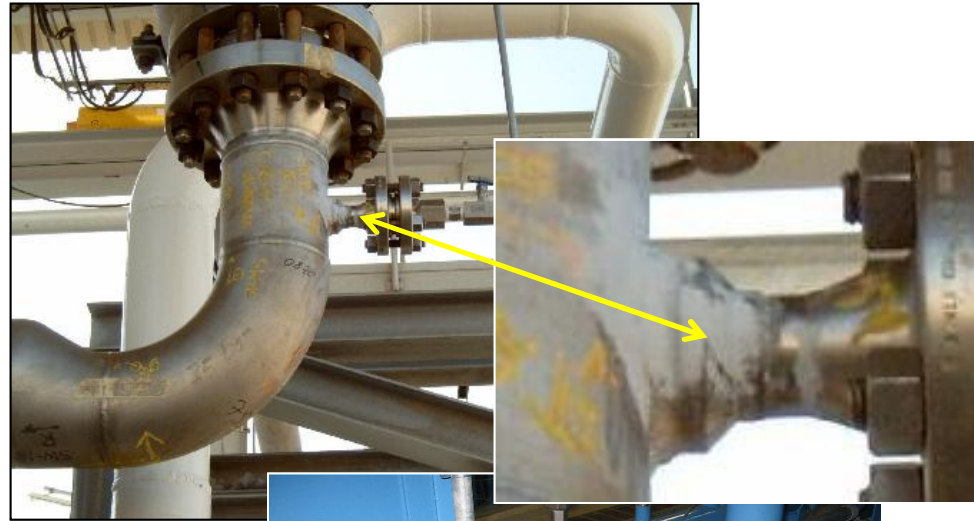
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- Conduct an initial “Walk down” survey of the compressor and the piping to identify locations of abnormal vibrations - watch out for the following:

- Failed piping (which had earlier been repaired); particularly small bore nozzles of vessels and branch-off lines.
- Support structure showing cracks, signs of damage or which have come loose; typically missing or broken clamps.



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- Conduct an initial “Walk down” survey of the compressor and the piping to identify locations of abnormal vibrations - watch out for the following:
 - Abnormal noise such as metallic rattling, knocking or hammering indicating abnormal and unhealthy impact load.
 - A screwdriver can be utilized to make noise e. g. from the compressor or pipe/vessel internals audible.



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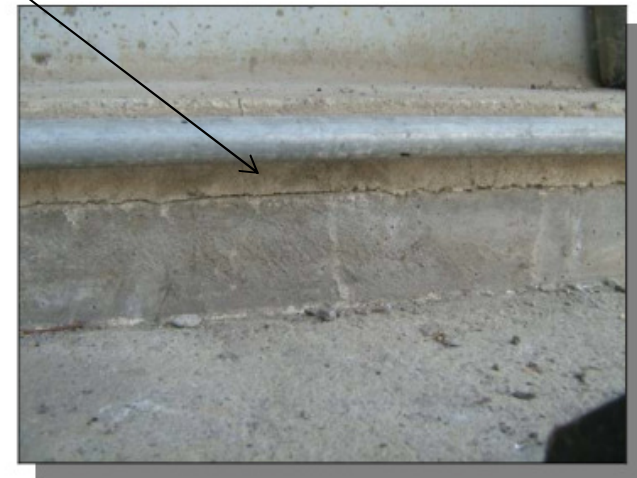
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- Conduct an initial “Walk down” survey of the compressor and the piping to identify locations of abnormal vibrations - watch out for the following:

- Grouting and foundation defects:



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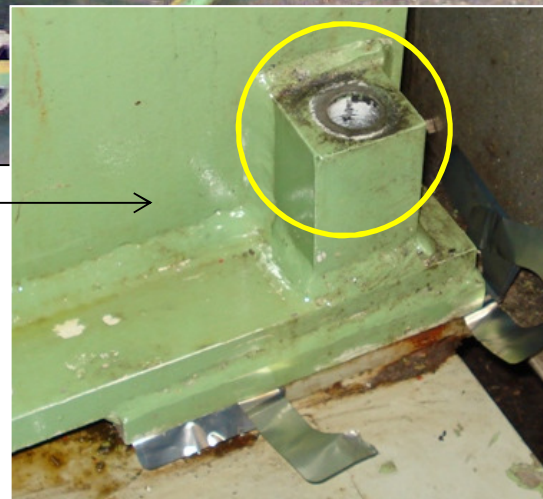


- Conduct an initial “Walk down” survey of the compressor and the piping to identify locations of abnormal vibrations - watch out for the following:

- Loose support fixation:



- Broken and missing anchor bolt(s):

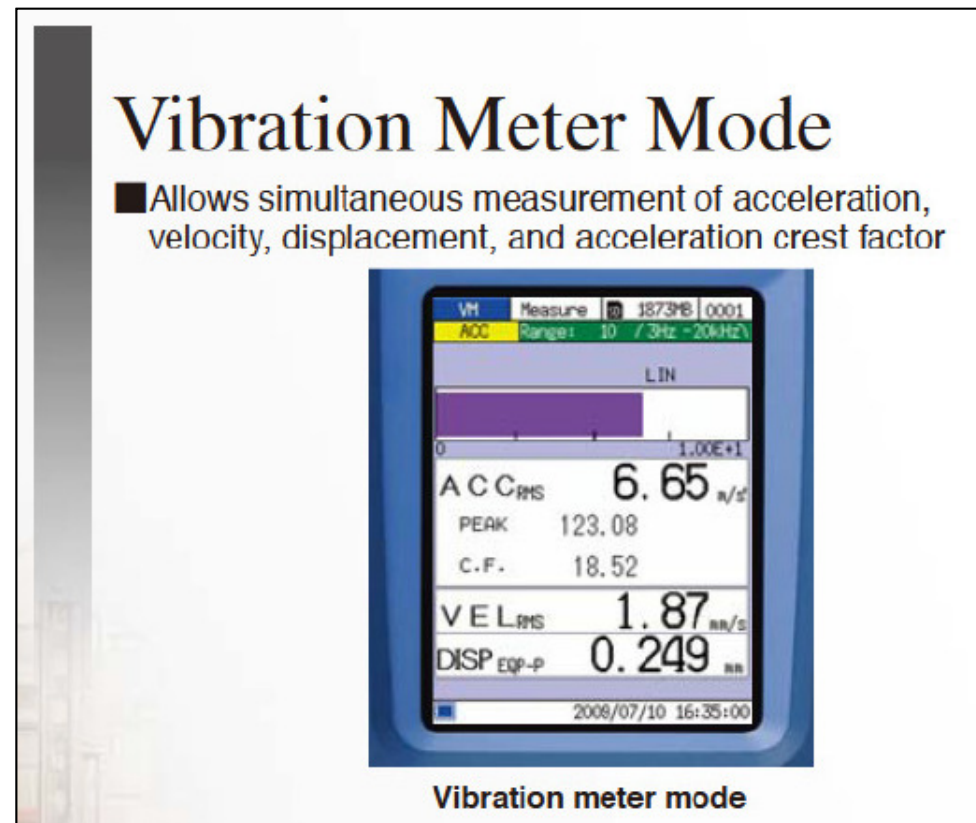


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➤ Measure vibrations at particular points of interest found during the “Walk down” survey:

- At first only the vibration values are required to obtain an overview of the vibration situation:
 - Acceleration
 - **Velocity**
 - Displacement
 - Crest factor(optional)



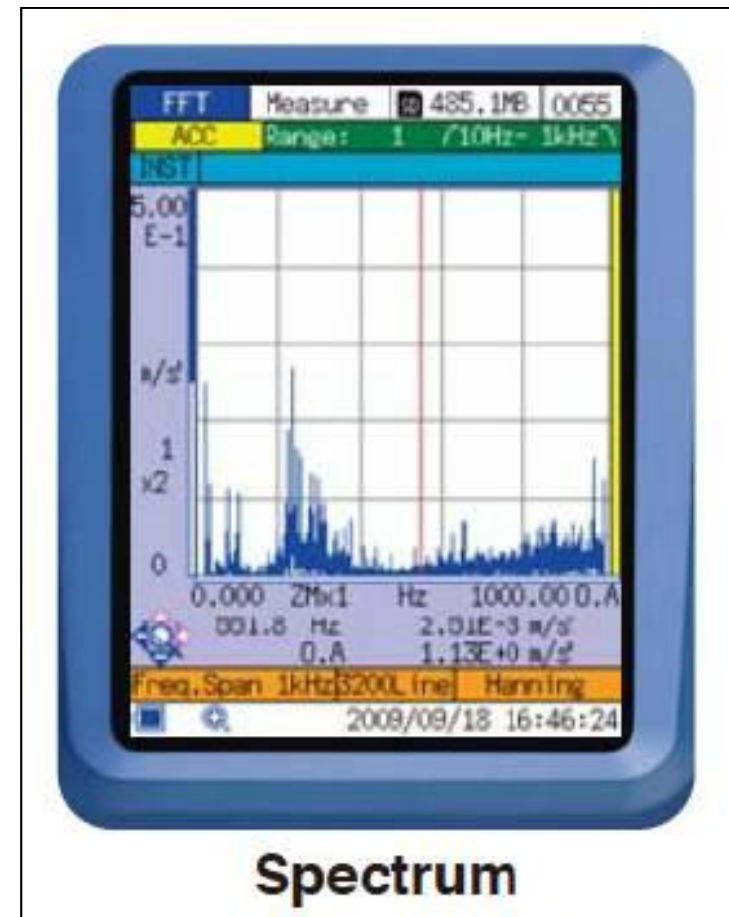
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➤ Measure vibrations at particular points of interest found during the “Walk down” survey:

- The **Frequency Spectrum** shall be recorded at those locations
 - Where vibrations are abnormally high in amplitude and/or frequency
 - At locations where any kind of damage was encountered

The frequency spectrum allows to draw conclusions about the source of the driving forces.

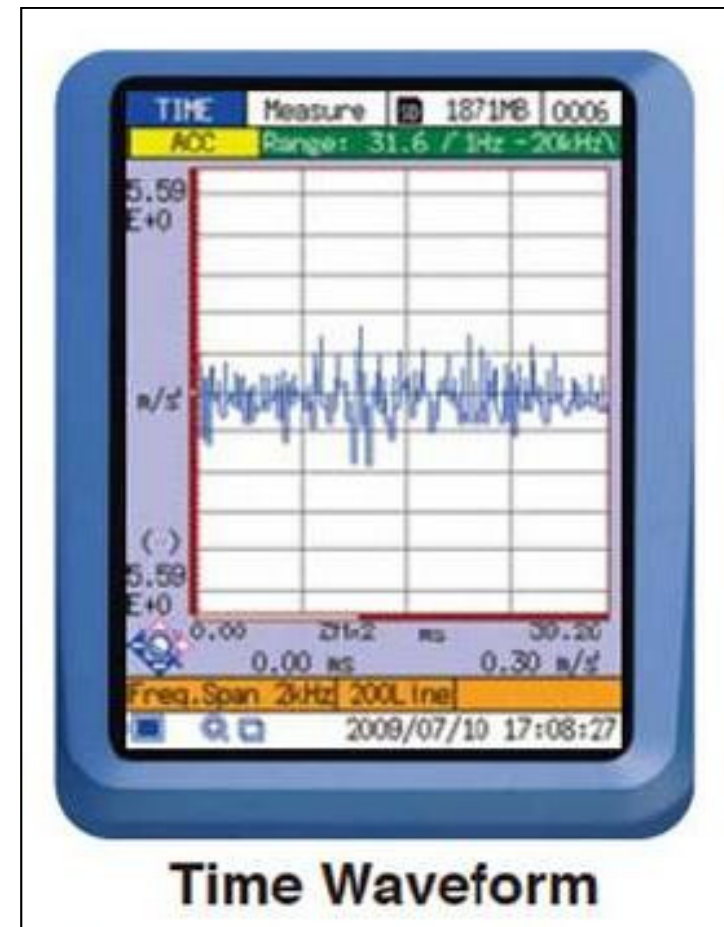


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➤ Measure vibrations at particular points of interest found during the “Walk down” survey:

- The **Time Waveform** may be useful to identify the character of the vibration:
 - If pure harmonic
 - If impacts are involved

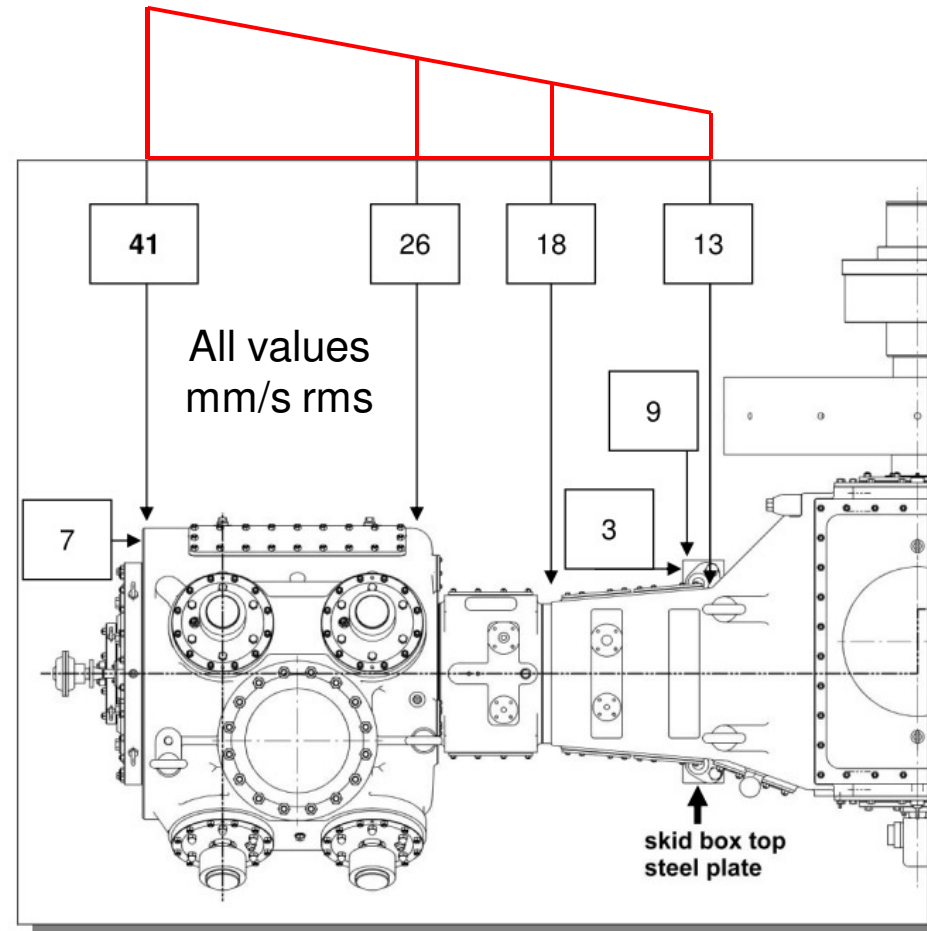


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➤ Measure vibrations at particular points of interest found during the “Walk down” survey:

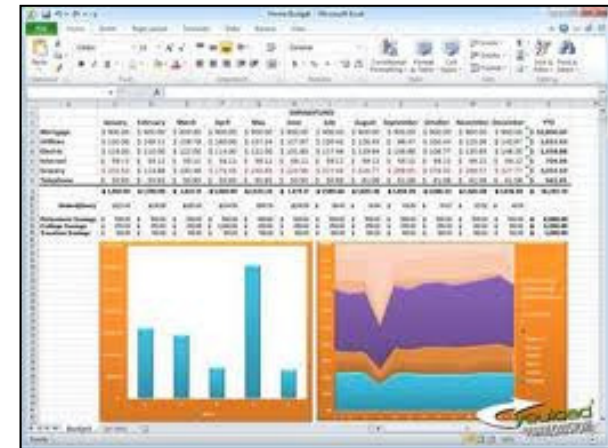
- The vibration mode shape shall be investigated to detect potential high stress concentration (e. g. if vibrations vary significantly along a short distance) and to identify potential mechanical weakness at points of expected high stiffness.



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- For the time of the vibration measurement it is vital to record the actual compressor unit condition.
- Print-outs from the control room or monitoring system shall be obtained for the time of the measurement.



Or the process data must be recorded from the local instrumentation and panel.

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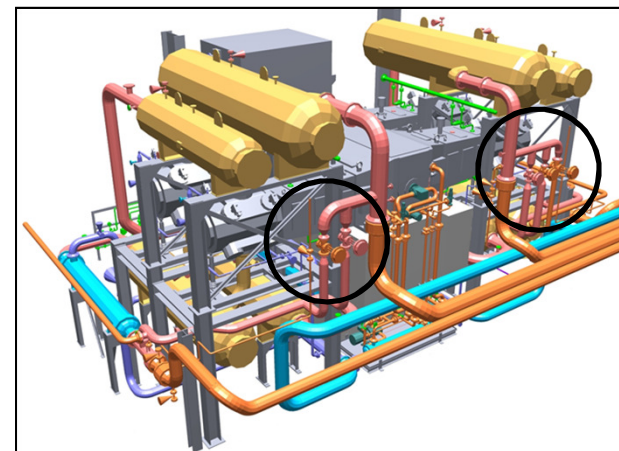
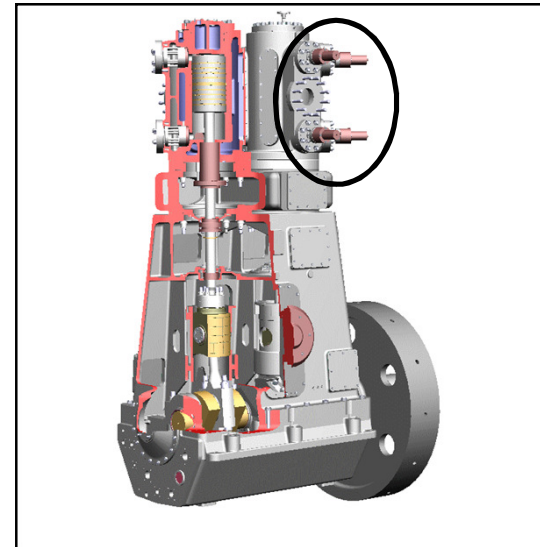
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➤ The compressor load shall be varied – if possible - to identify if the vibrations are related to the load condition:

- No load – e. g. through suction valve lifters (if installed).
- Low load condition – e. g. during start-up - when discharge pressure is equal or close to the suction pressure.
- Mobile temperature measurement equipment shall be applied for abnormal heat detection (e. g. valves).
- Gas recycle mode - bypass valve(s) open.



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➤ The compressor load shall be varied – if possible - to identify if the vibrations are related to the load condition:

- Various suction and discharge pressures (such as typically for natural gas storage compressor units).
- Various speeds – in case of speed control – to see if vibrations are linked to the running frequency and its harmonics.



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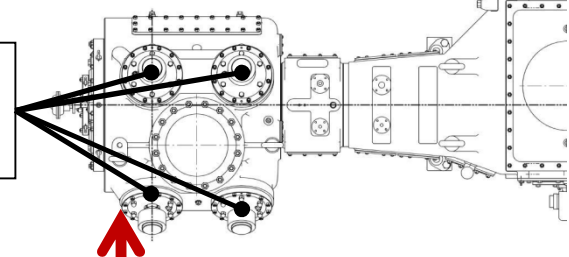


➤ Referring to the “Source-and-Effect-Chart” following conclusions that can be drawn from various load conditions and its effect:

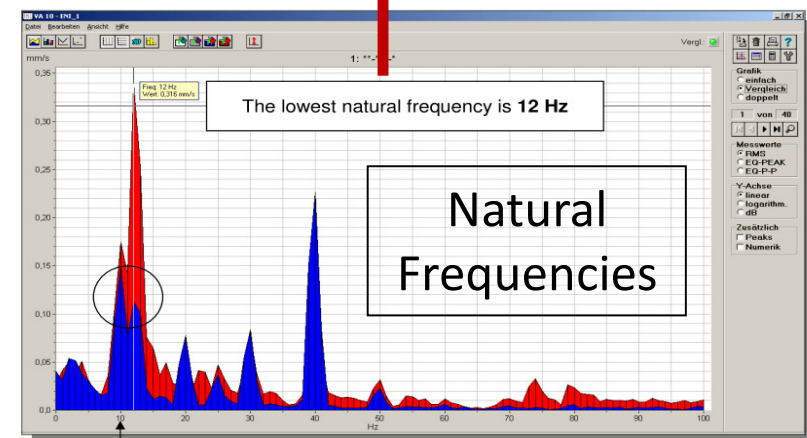
- If vibrations are high during a no-load-condition (e. g. all suction valves lifted) they are likely to be caused from the “Mechanical Characteristic” of the compressor itself or the pipe and vessel system, because a natural mechanical frequency is matched (mechanical resonance condition).

A bump test is then required.

Suction
valve lifters



“No-run-vibrations” (blue) and “bump test” result (red) in axial direction (in the direction of the compressor crankshaft axis; perpendicular to the piston rod axis):



The speed of the compressor is (nearly) 600 rpm = 10 Hz = 1st Harmonic.



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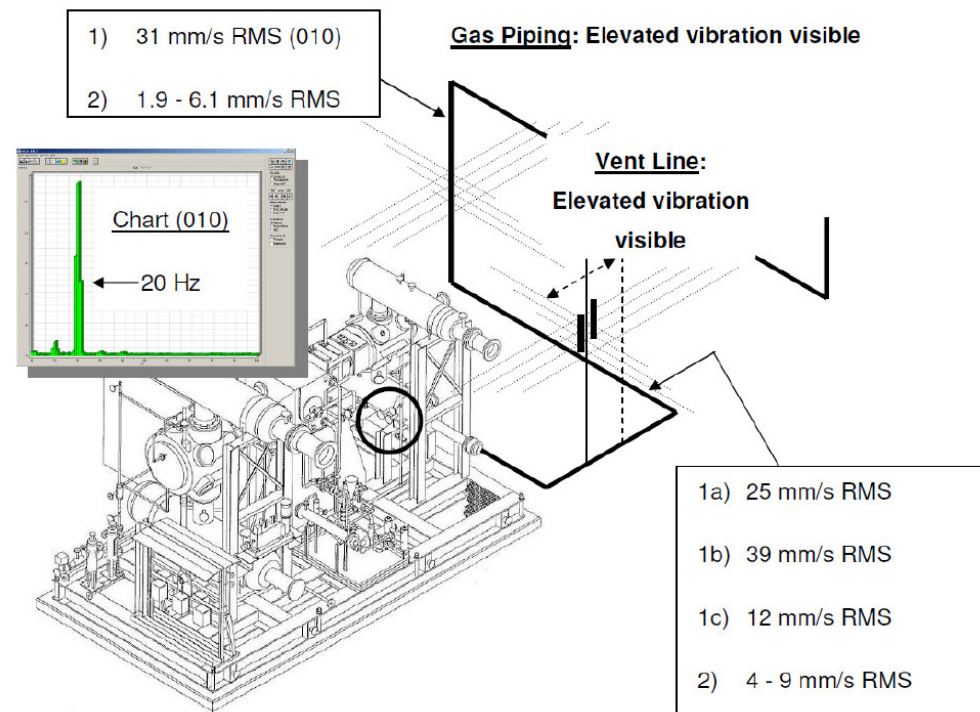
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➤ Referring to the “Source-and-Effect-Chart” following conclusions that can be drawn from various load conditions and its effect:

- If the vibrations vary with load – which means that gas pulsations are likely to be active – it may be a mix of pulsation induced unbalanced shaking forces and the mechanical characteristic that cause the vibrations.
- Further investigations are then required

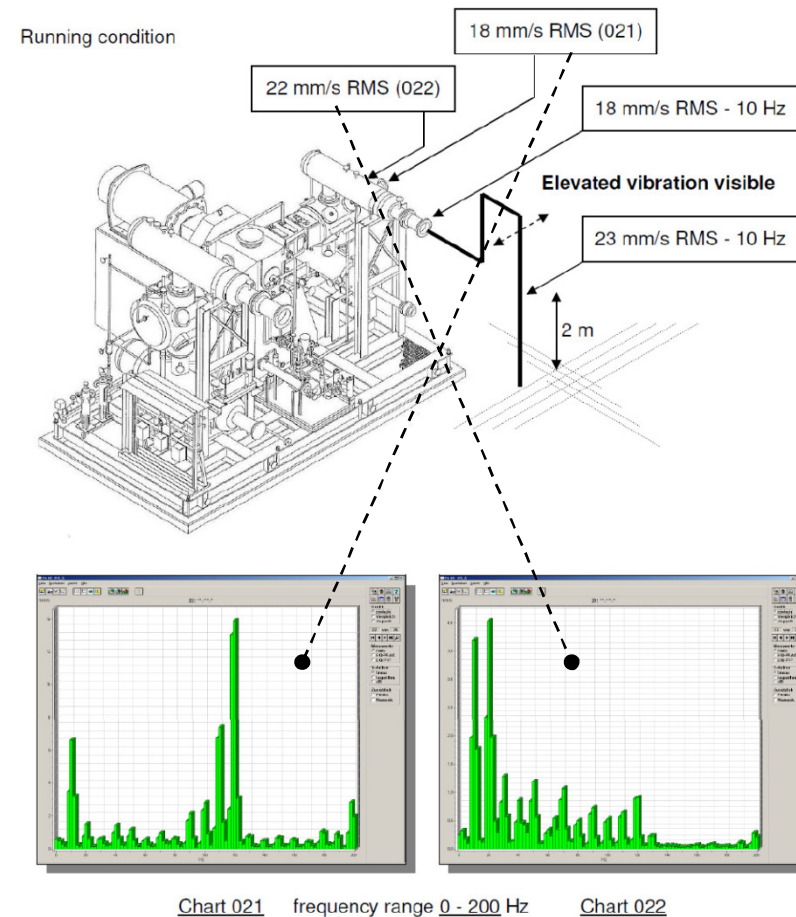


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➤ Referring to the “Source-and-Effect-Chart” following conclusions that can be drawn from various load conditions and its effect:

- If high frequency vibrations are involved (as shown here) the relevant piping may be under mechanical stress and tension.
Comparable to a violin or guitar cord minor excitation can result in significant high frequency vibration.
- Also small bore nozzles tend to vibrate at high frequencies – and may crack off.



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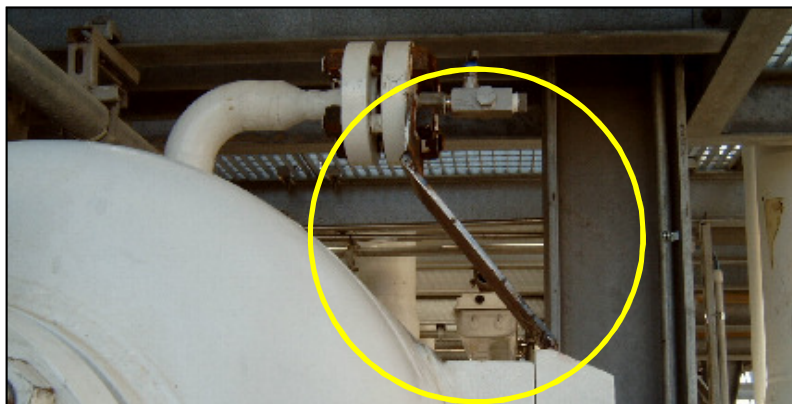
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➤ Referring to the “Source-and-Effect-Chart” following conclusions that can be drawn from various load conditions and its effect:

- If high vibrations can easily be restraint – e. g. through bracing and/or supports they are likely to be related to mechanical resonance.
- If not high shaking forces have to be anticipated which need to be lowered!



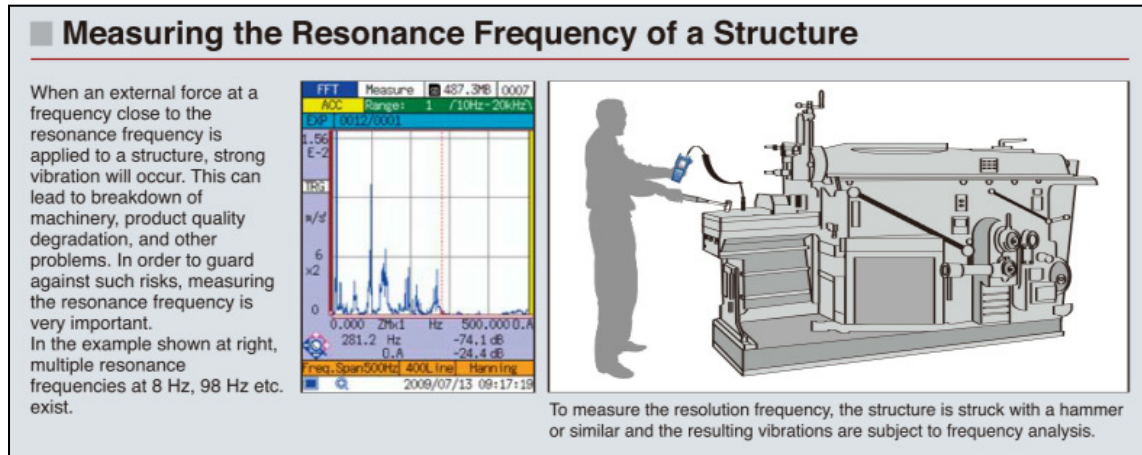
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➤ The “Bump Test” and typical locations



- Vessels and accessories
- Compressor cylinders
- Steel structure
- Piping



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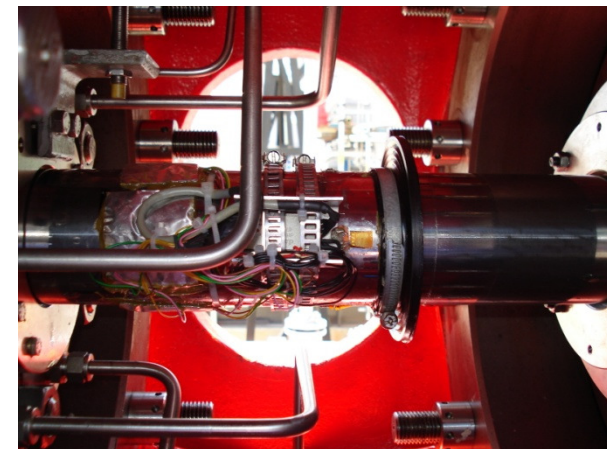
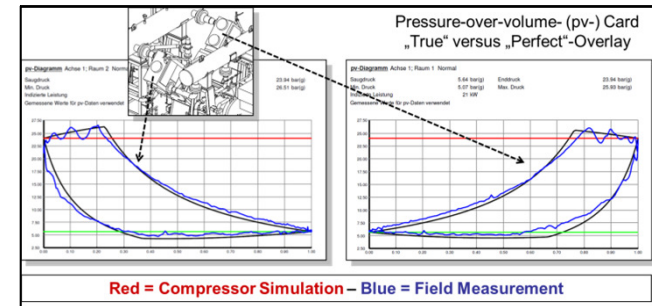
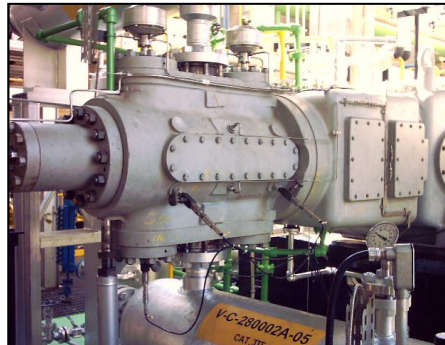
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➤ If first site intervention through basic equipment (hand held vibration meter) does not render results in clear hints towards the vibration root cause further activities are required:

- Conduct pulsation measurement and pv-diagnosis.
- Perform strain gauge measurement to identify the true material stress level.

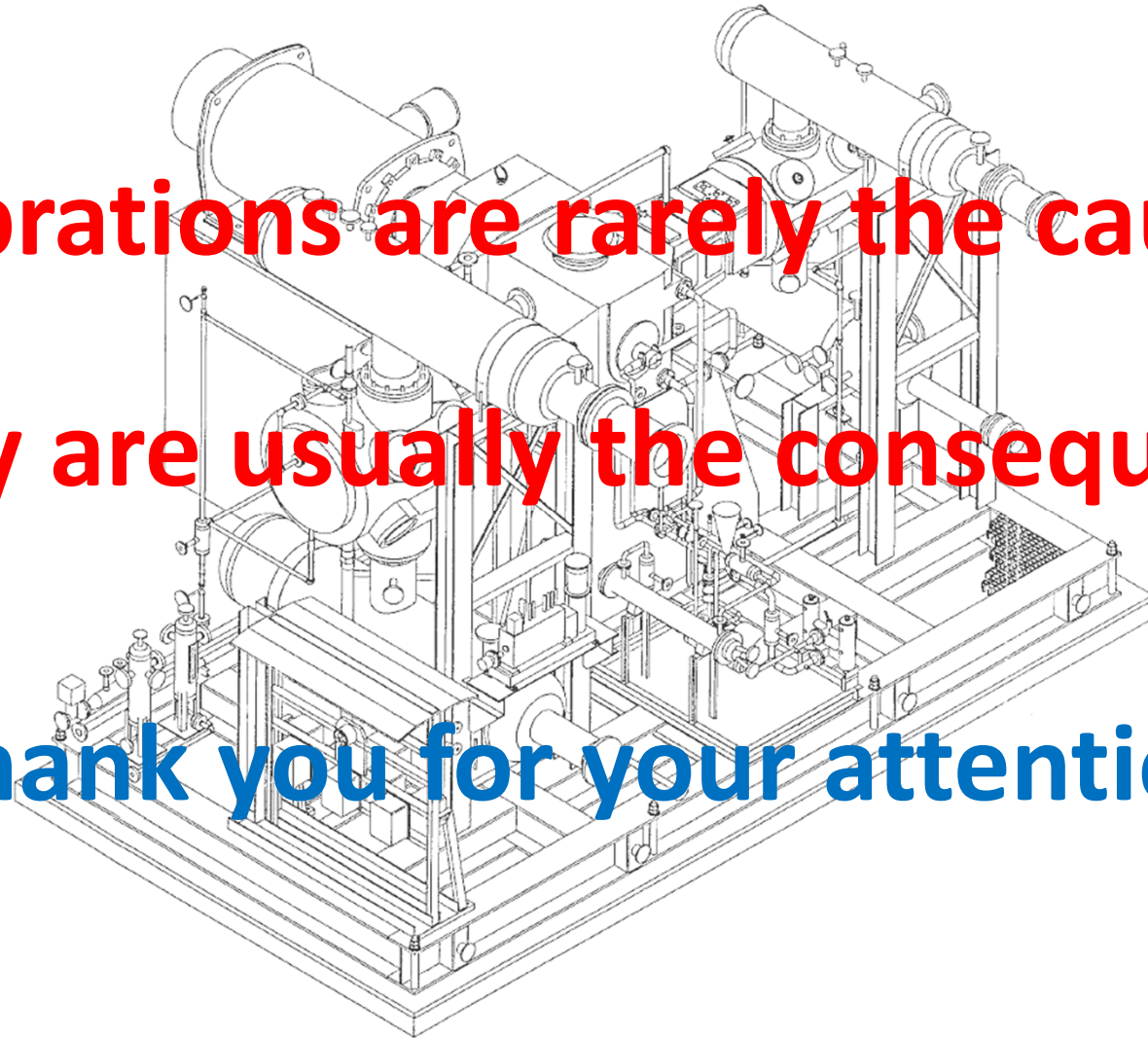


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**Vibrations are rarely the cause
They are usually the consequence**

Thank you for your attention





Reference

VIBRATIONS IN RECIPROCATING MACHINERY AND PIPING SYSTEMS

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