Advantages and disadvantages with different types of transducers measuring valve vibration

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QRING

We were issued to look on vibrations on big valves and pipes.

Pipes/valves rarely has sinusoidal vibrations they are stochastic

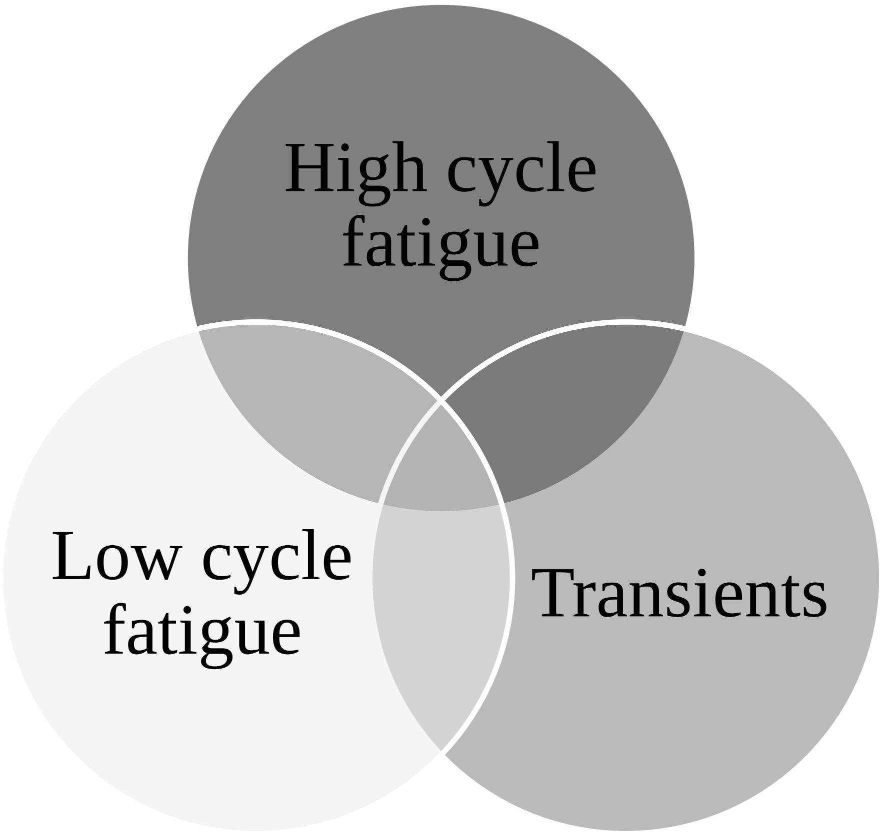
Forced sinusoidal vibrations can come from rotating machinery in the system

Big pipes can give infra sound witch gives low frequency vibrations

Flow turbulence can induce high frequency vibrations

What phenomena is causing the damage?

What stress factors or stress situations cause damage?


High cycle fatigue
Low cycle fatigue
Transients

Transducer choice

- Transducer choice
  - The usual one, i.e. .
  - A planned one
  - A choise based on a discussion with other specialist.
  - A choise based on the damage seen on site

An example

Tests done on big high pressure valves

The electric-hydralic control valve has broken.

There have been more than one failure

Consequencies for production; several days reduced effect

One of the possible causes was vibrations. Another was pulsations

How did we face the problem?

The damage seems to be of transient behaviour

1st Step

- Fast - improvisation;
  - Use equipment present on-site
    - 4x 10 mV/g PCB 356B21 Triaxial accelerometers
      - These had been used on another system the past year.
      - Mini 4-pole contacts on these accelerometers with limited life.
  - High ambient radiation
    - Allowed mounting time to be < 15 min.
    - 4x accelerometers and ~50 m cabling.
- Produced data with strange spikes in it.
  - Cabling glitches were suspected.
  - [Transducers and cabling later checked out OK on calibration table.]

The Qring Way

2015-09-02_085706	2015-09-18 08:56	Filmapp
2015-09-02_090208	2015-09-18 08:56	Filmapp
2015-09-02_100207	2015-09-18 08:57	Filmapp
2015-09-02_110208	2015-09-18 08:57	Filmapp
2015-09-02_120207	2015-09-18 08:57	Filmapp
2015-09-02_130207	2015-09-18 08:57	Filmapp
2015-09-02_140207	2015-09-18 08:57	Filmapp
2015-09-02_150208	2015-09-18 08:57	Filmapp
2015-09-02_160208	2015-09-18 08:57	Filmapp
2015-09-02_170207	2015-09-18 08:57	Filmapp
2015-09-02_180207	2015-09-18 08:58	Filmapp
2015-09-02_190208	2015-09-18 08:58	Filmapp
2015-09-02_200208	2015-09-18 08:58	Filmapp
2015-09-02_210207	2015-09-18 08:58	Filmapp
2015-09-02_220207	2015-09-18 08:58	Filmapp
2015-09-02_230208	2015-09-18 08:58	Filmapp
2015-09-03_000208	2015-09-18 08:58	Filmapp
2015-09-03_010207	2015-09-18 08:58	Filmapp
2015-09-03_020207	2015-09-18 08:59	Filmapp
2015-09-03_030208	2015-09-18 08:59	Filmapp
2015-09-03_040207	2015-09-18 08:59	Filmapp
2015-09-03_050207	2015-09-18 08:59	Filmapp
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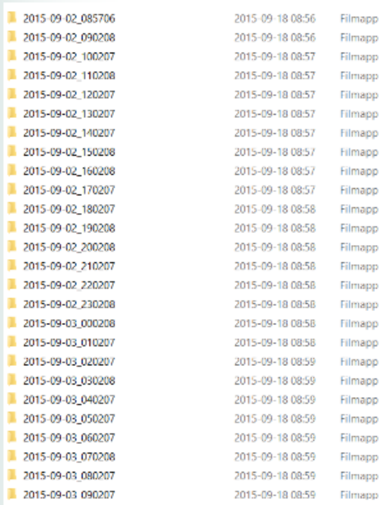
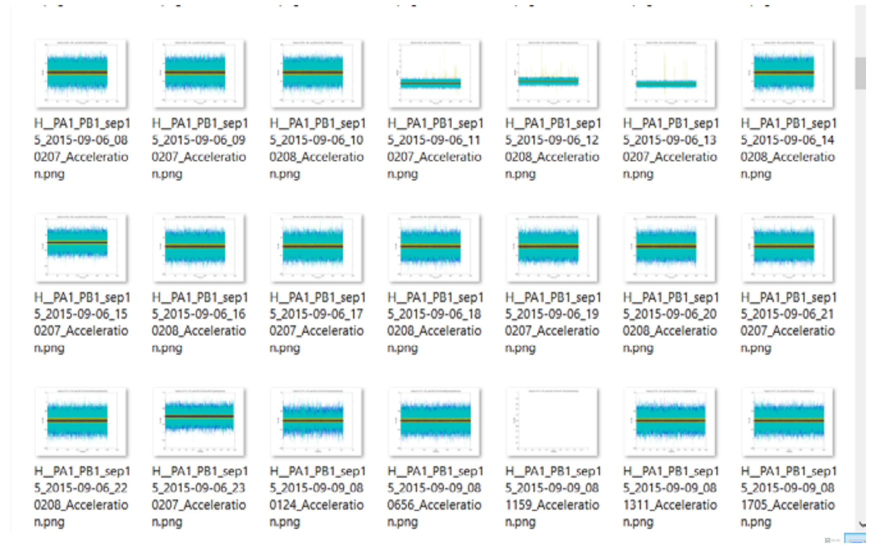
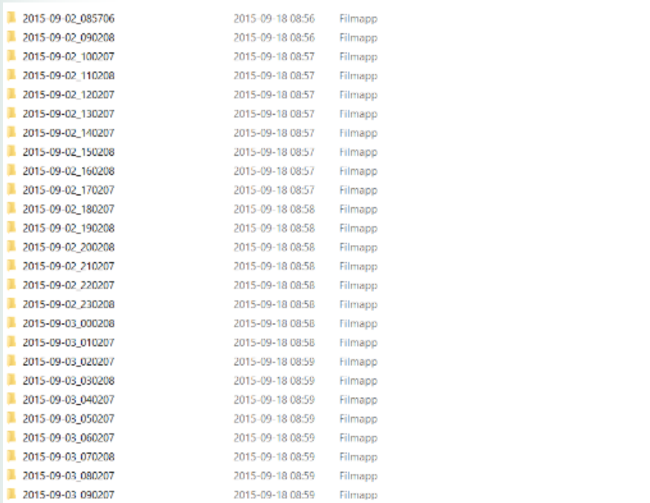
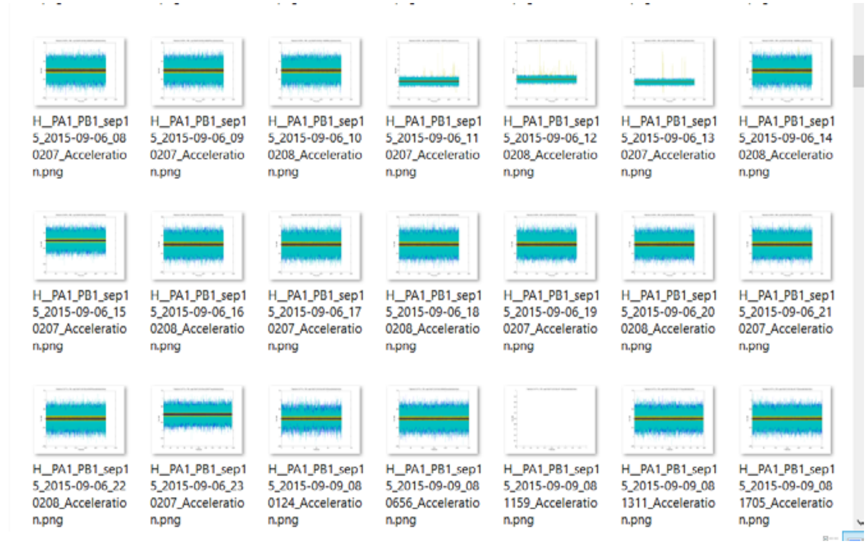
The Qring Way

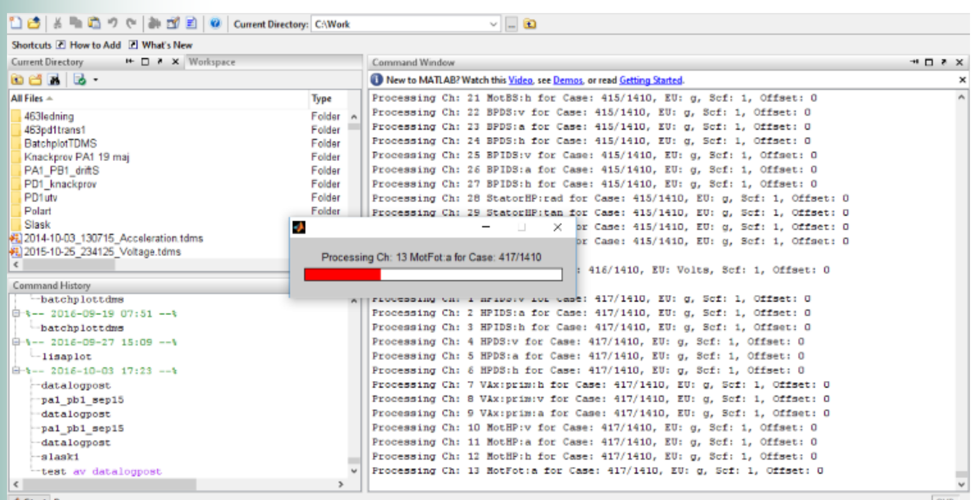




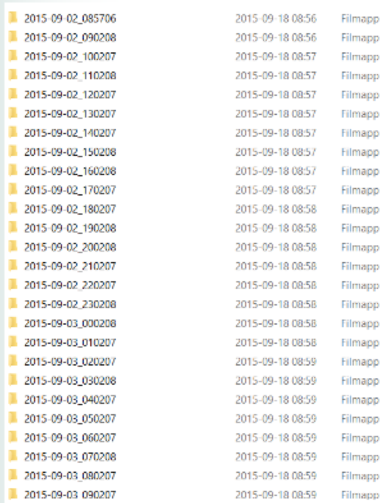
The Qring Way

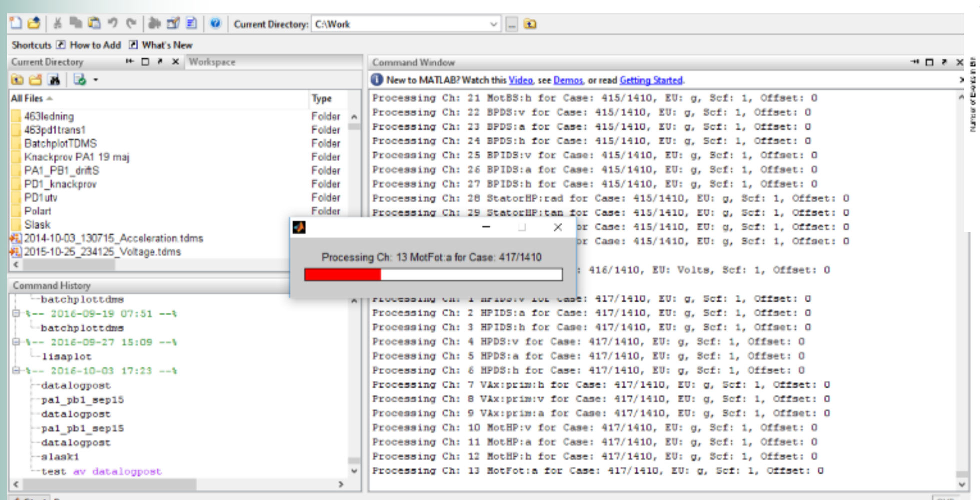


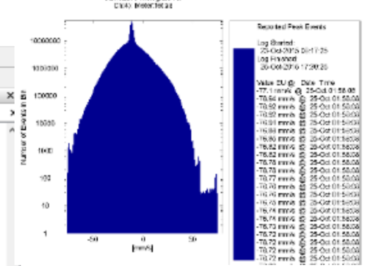


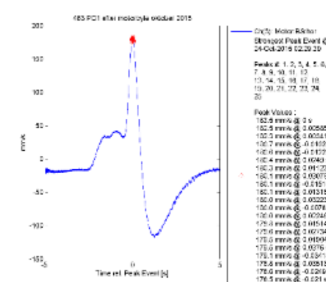


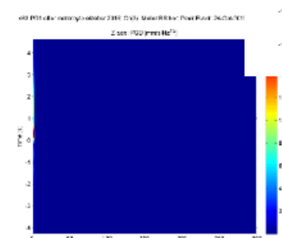
The Qring Way



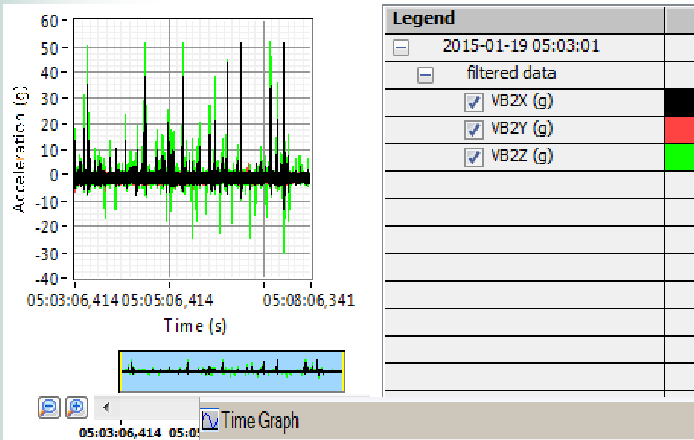




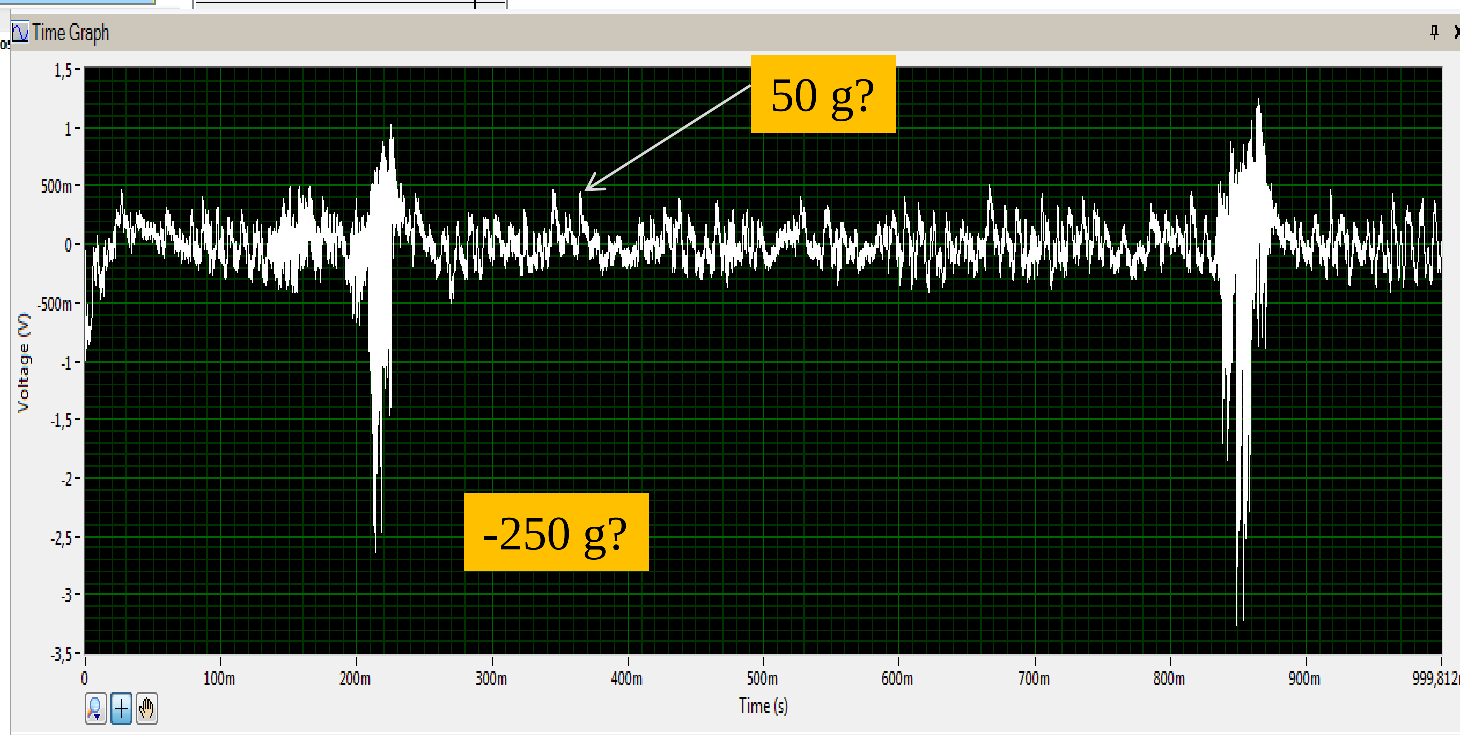




Example Time Signal



10 mV/g



An example

Tests done on big high pressure valves

The electric-hydralic control valve has broken.

There have been more than one failure

Consequencies for production; several days reduced effect

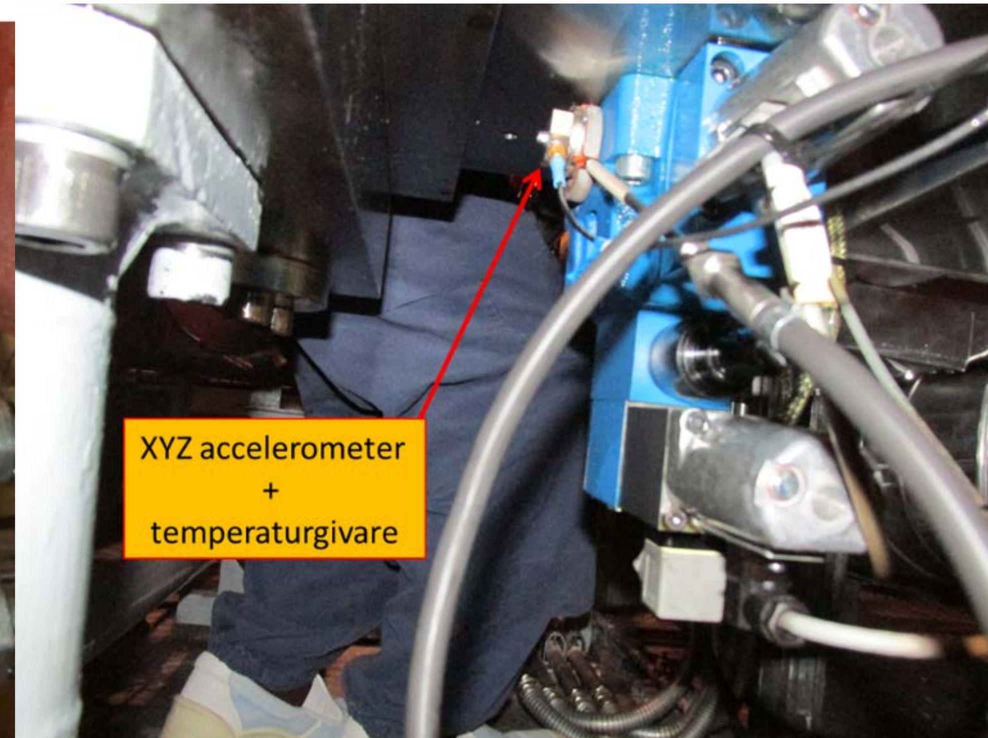
One of the possible causes was vibrations. Another was pulsations

2nd Step

- Change transducers & place in optimal positions
  - Accelerometers
    - Brand new 100 mV/g industrial 3143D Dytran transducers with brand new cabling.
    - +/- 50 g, 0.5 – 3 000 Hz frequency range (±5%) & isolated chassis.
    - Intended for general purpose use
    - 25 kHz > internal resonance frequency
  - Pulsation measured using Piezocable
  - Temperature measured using PT100

2nd Installation

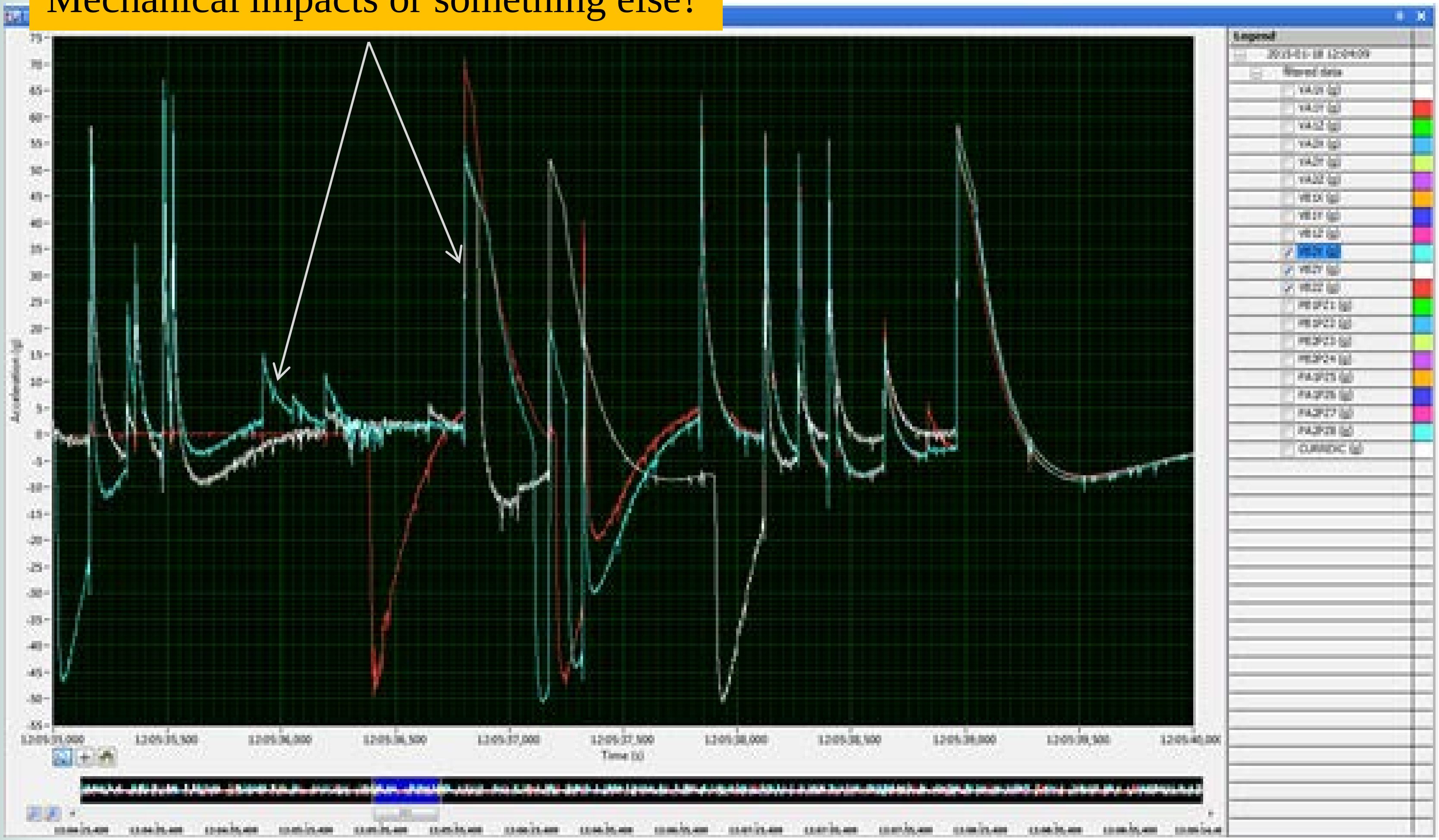
Figur 2 Installation av piezoelektrisk tråd.



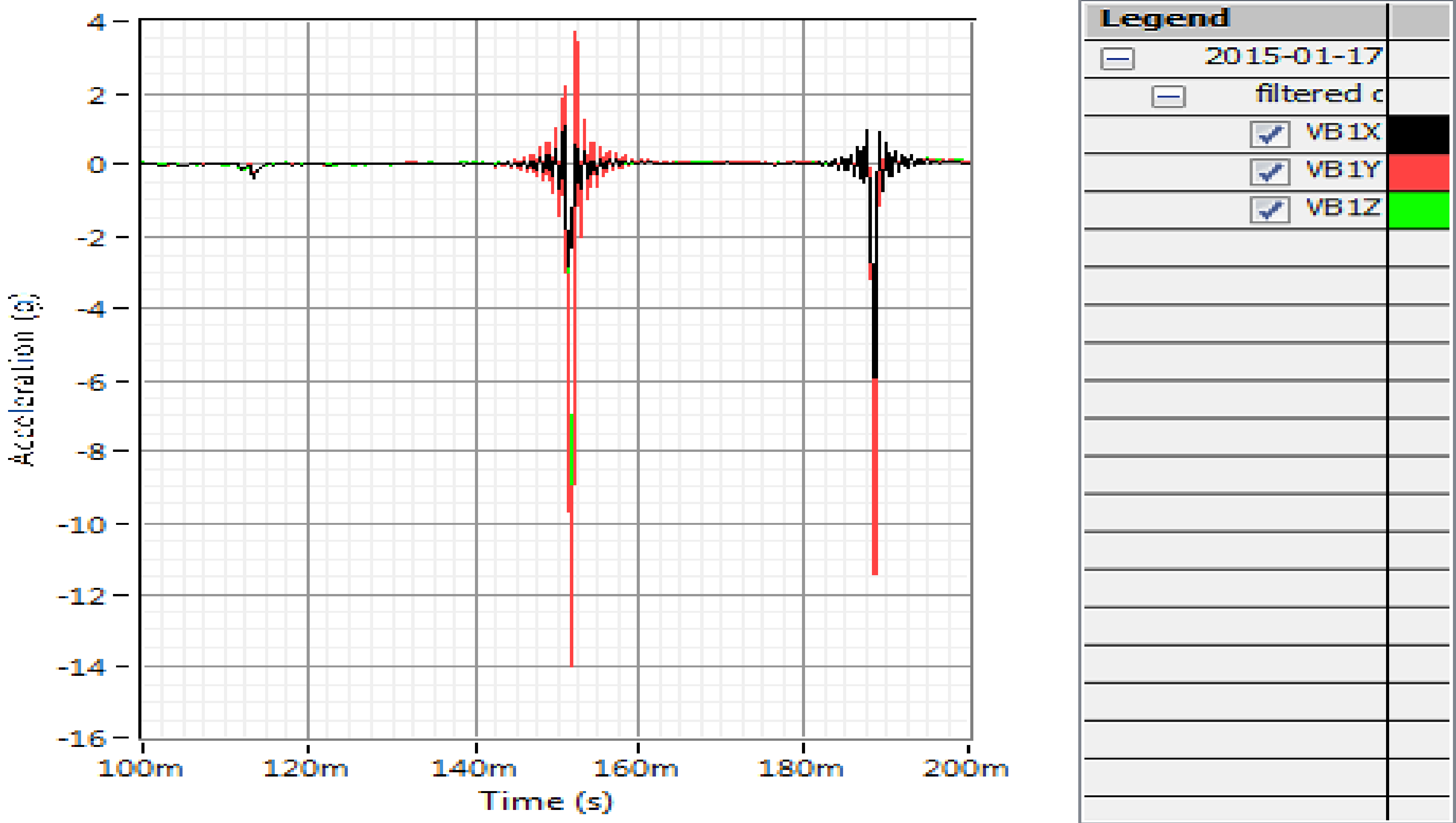
Pulsation & temperature were excluded as culprits

Example Time Signals

Mechanical impacts or something else?



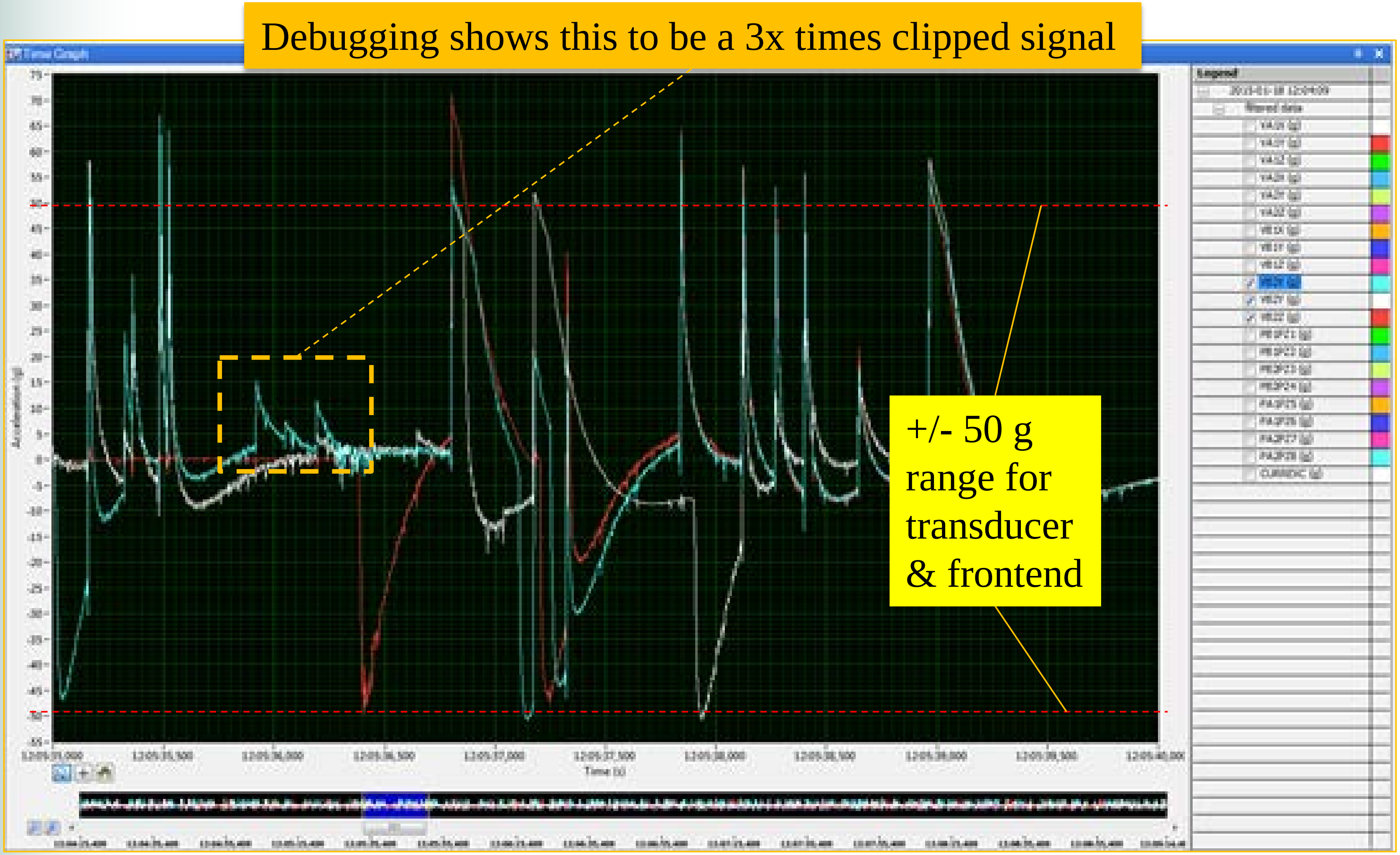
Zoom in on Spikes well within the 50 g range



Debugging showed

- DC-offset
  - The measurement frontend was placed on metal bench that was in contact with (not connected) cable shield.
  - This was found to cause DC offset on input amplifier which could explain why a 50g accelerometer clips at 20g.
  - DC offset comes and goes without 50 Hz hum
- Spikes
  - There were still strange spikes present in the signal that sometimes clipped and sometimes did not clip.

Not so Easy to Interpret



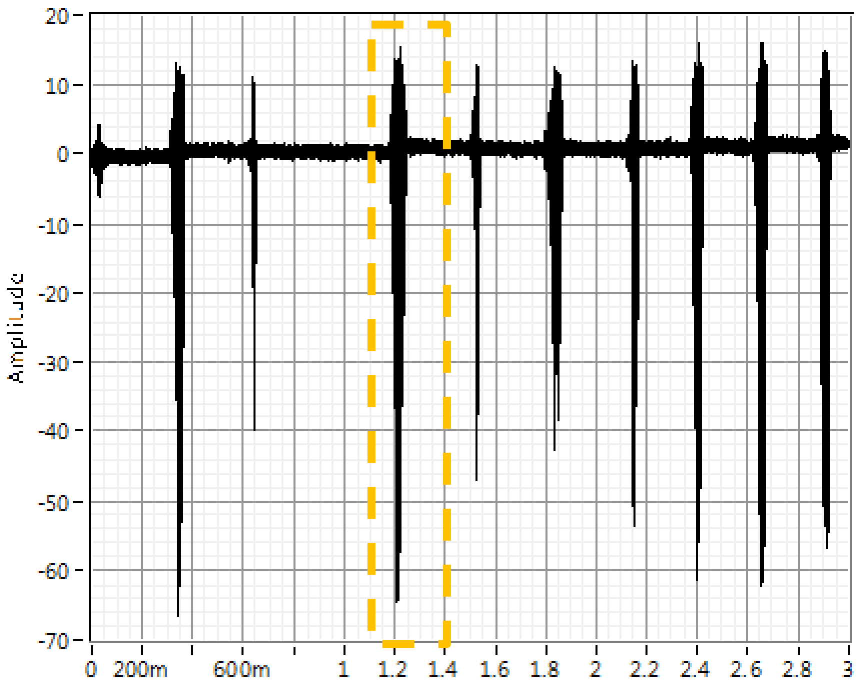
Why would a transducer clip at 10% of its amplitude range?

- Short duration mechanical shocks can excite up to very high frequency, i.e 100+ kHz?
- Overloaded piezosensors are shocked with a DC shift that remains for a long time (many minutes)
- Literature shows that shock accelerometers have
  - 80+ kHz resonance frequency & built in mechanical filters to avoid saturating accelerometer amplifier when driving sensor at resonance.
- Such excitation only exists <u>very</u> close to the mechanical impact.
  - (Not explained by valve closing)

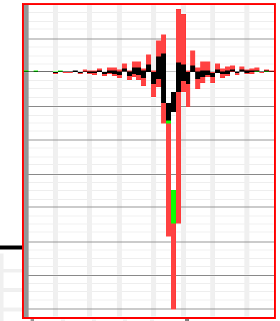
Extra Measurement

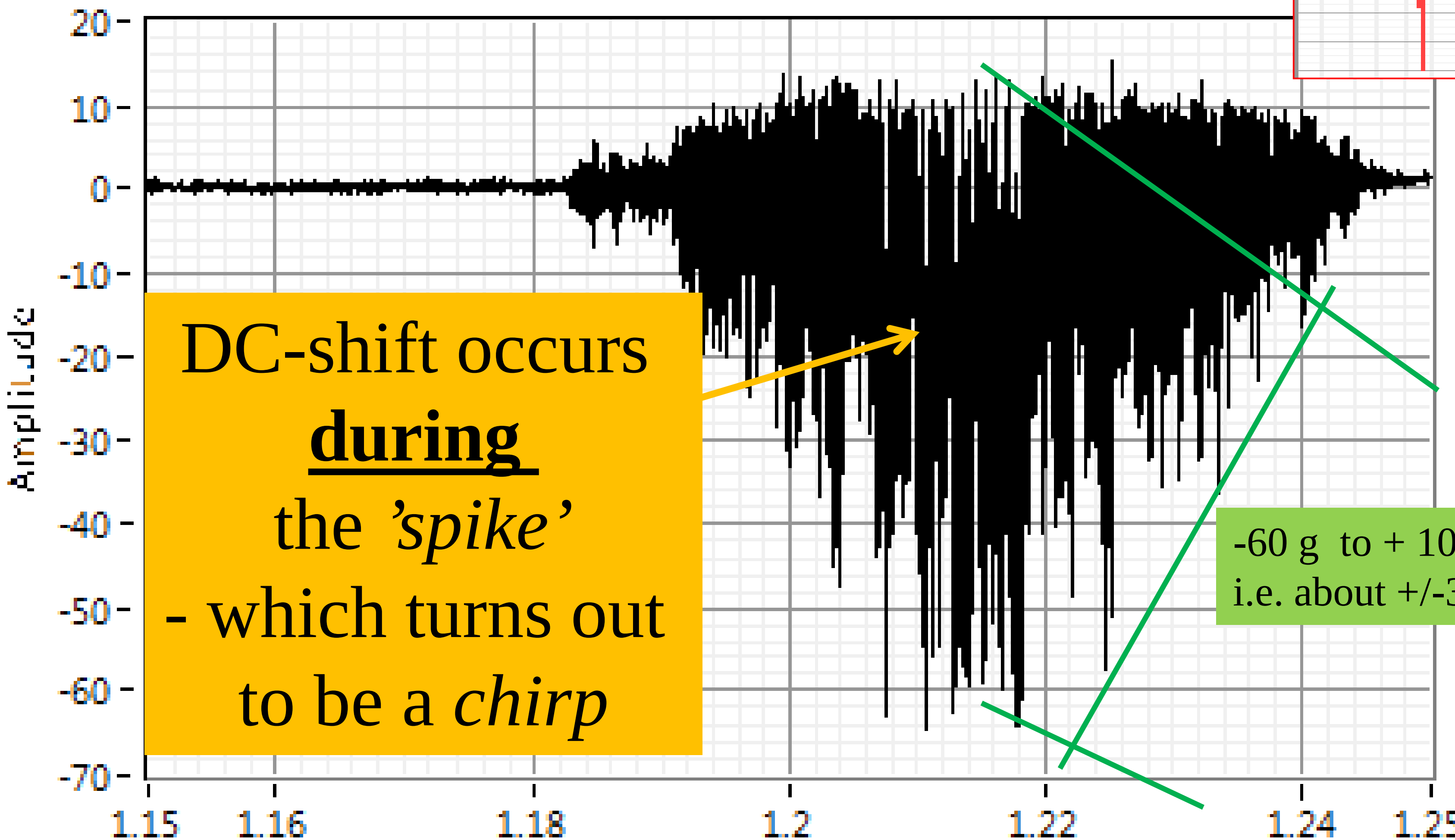
- 1 MS/s (390 kHz) frontend
- 10 V input range
- Battery operated ICP amplifier
- Measurement PC operated from battery
- 1ch at a time

Why are spikes assymmetric ?



Zoom In on Single '*Spike*' sampled at 1 MS/s





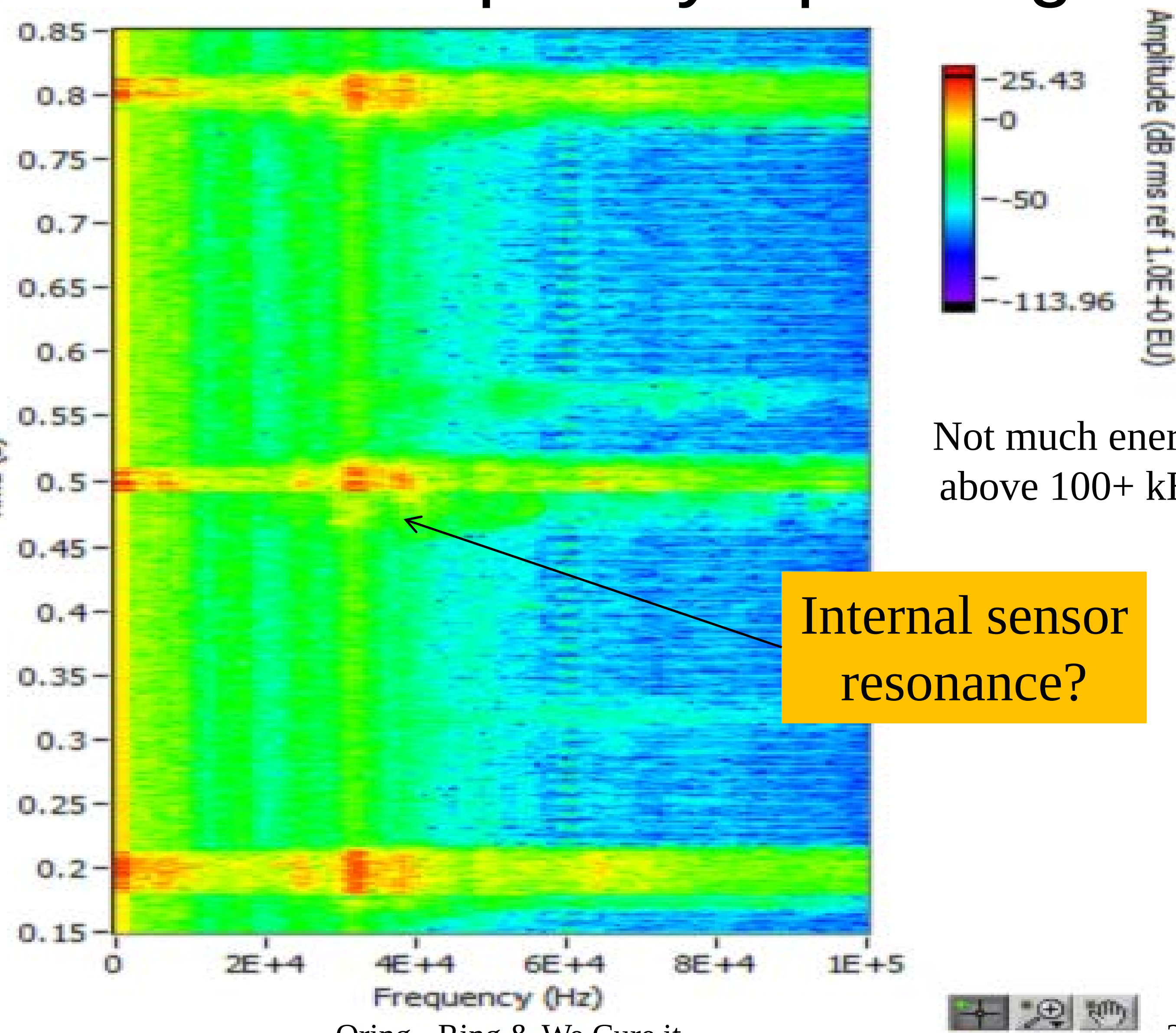
DC-shift occurs **during** the '*spike*' - which turns out to be a *chirp*

-60 g to + 10g
i.e. about +/-35 g

Time-Frequency Spectrogram

0.3 s

0.3 s



Not much energy above 100+ kHz

Internal sensor resonance?

Observations

- DC shift in sensor electronics when sensor is loaded at 25+ kHz resonance.
- Not *’Spikes’* - *Chirps*
  - *Transmission* of chirps may be explained by things like
    - Compression modes in mechanical components, e.g. a compression wave propagates at 5000 m/s in steel, a length of 2 m => $\lambda/2$ @ 1250 Hz.
    - The compression/shear wavelength at 25 kHz is 0.2 m/0.1 m which is small enough for resonance in the breast plate height direction, etc.
  - What is driving these chirps?
  - Is it a problem for the EHS?

A second opinion was called in

In this case there were 2 measurement systems on the same transducers

3rd Step.
Investigations why we got different & these strange results?

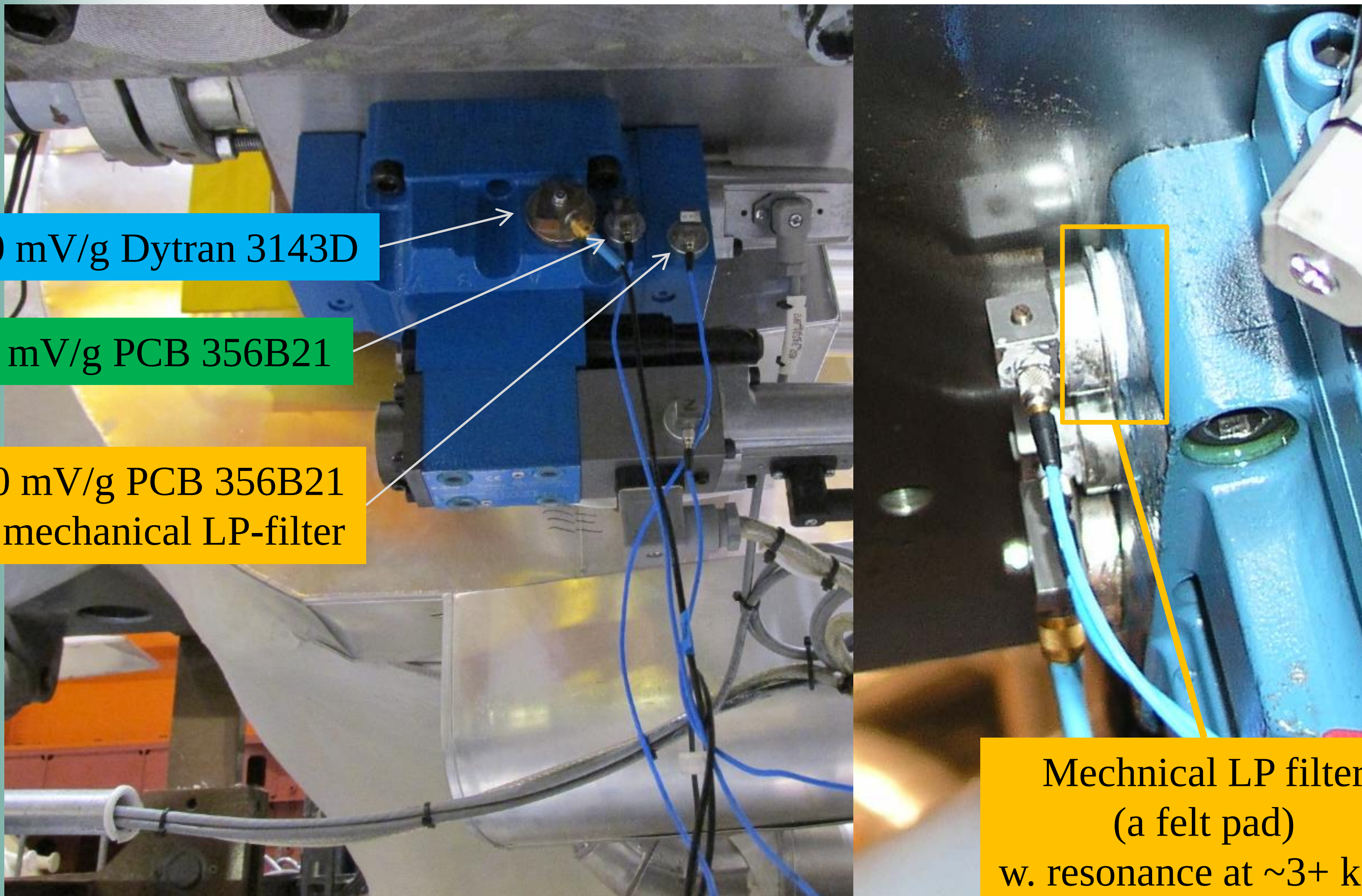
Goals were to

- Figure out what is the correct vibration level?
- Why do we get these strange spikes?
- Are they harmful?

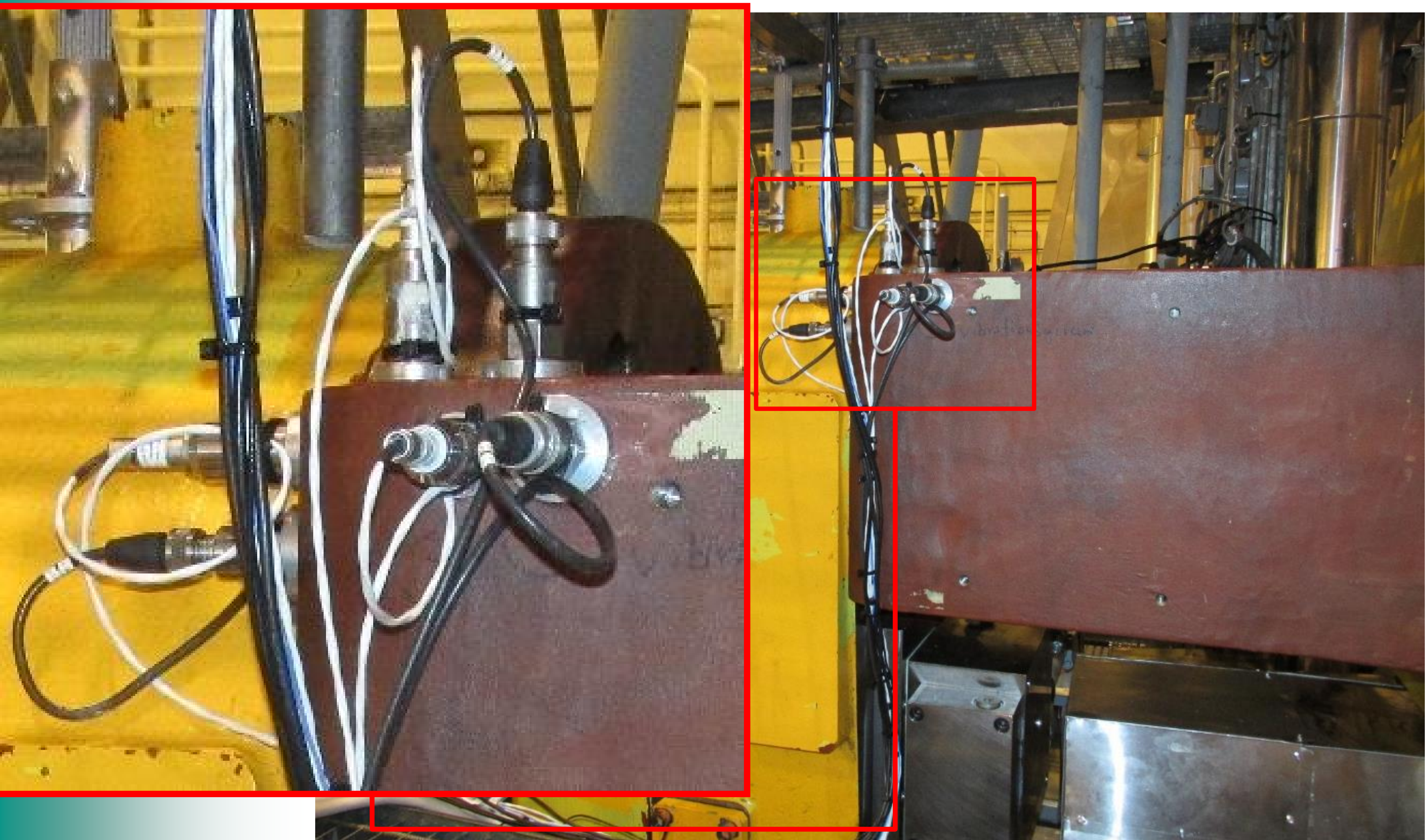
4th setup

- Vibration transducers of varying type, and make
  - Dytran 3143D, 100 mV/g
  - Wilcoxon 100 mV/g compression type
  - PCB 356B21 10mV/g
  - B&K 4381V/4382V with charge amplifers 1 mV/pc to 0.01 mV/pC
  - Velocity transducer VT1613 with linearization amplifier
- Piezostrain gauges on linkage to estimate valve loads.
- NI cDaq frontend switched to VXI frontend
  - 20 V input range
  - 30V ICP feed to maximize transducer range.
  - OKG Multicabling & dSUB25 based cabling.

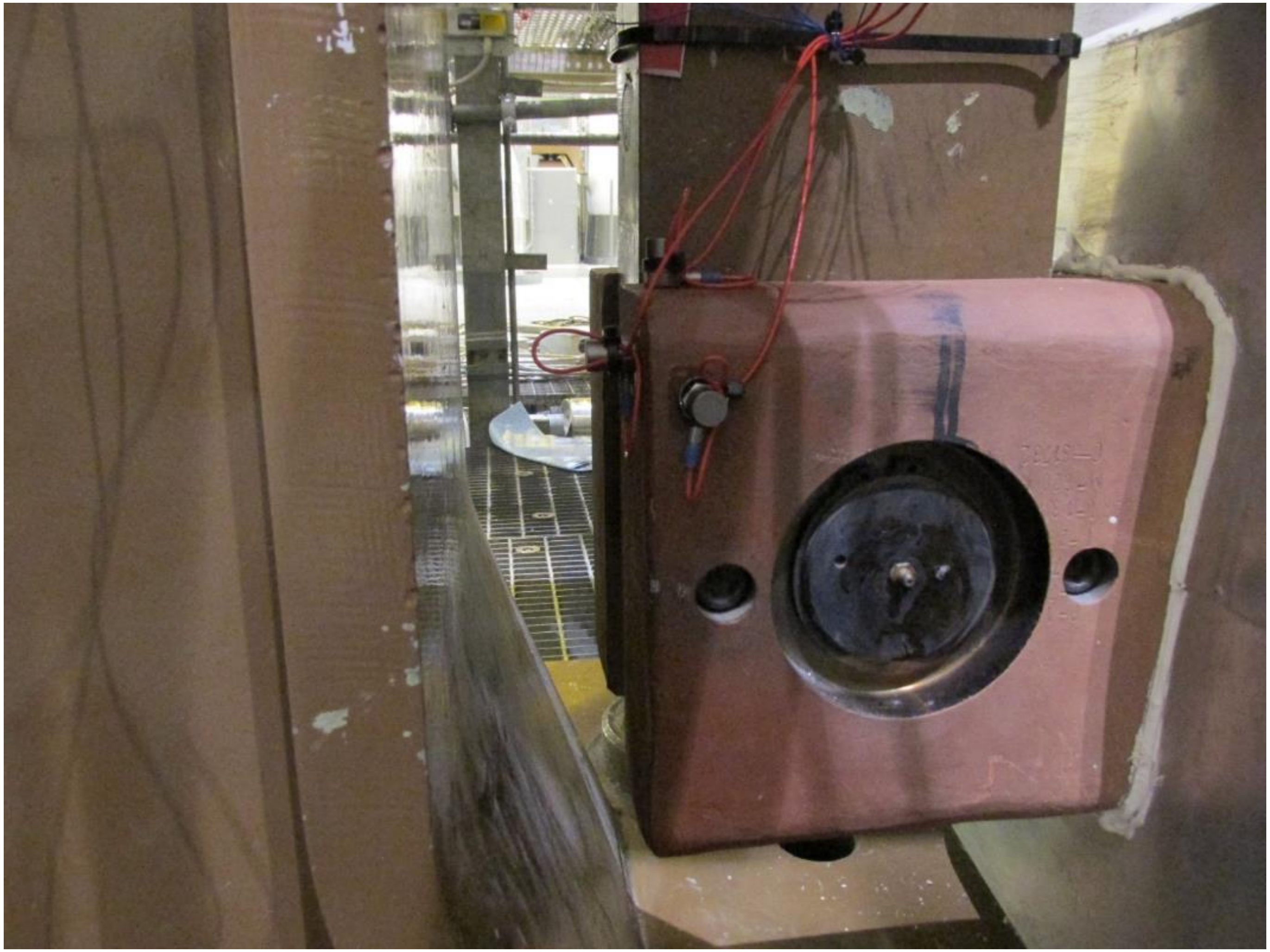
We added more transducers to figure out what was the problem



Industrial Accelerometer 100 mV/g & Velocity transducer



B&K 4381V/4382V 35 pC/g HighTemperature Accelerometer on Steam Valve



Piezo electric strain transducers showed low vibration

Comparison

Dytran
3143D
100 mV/g

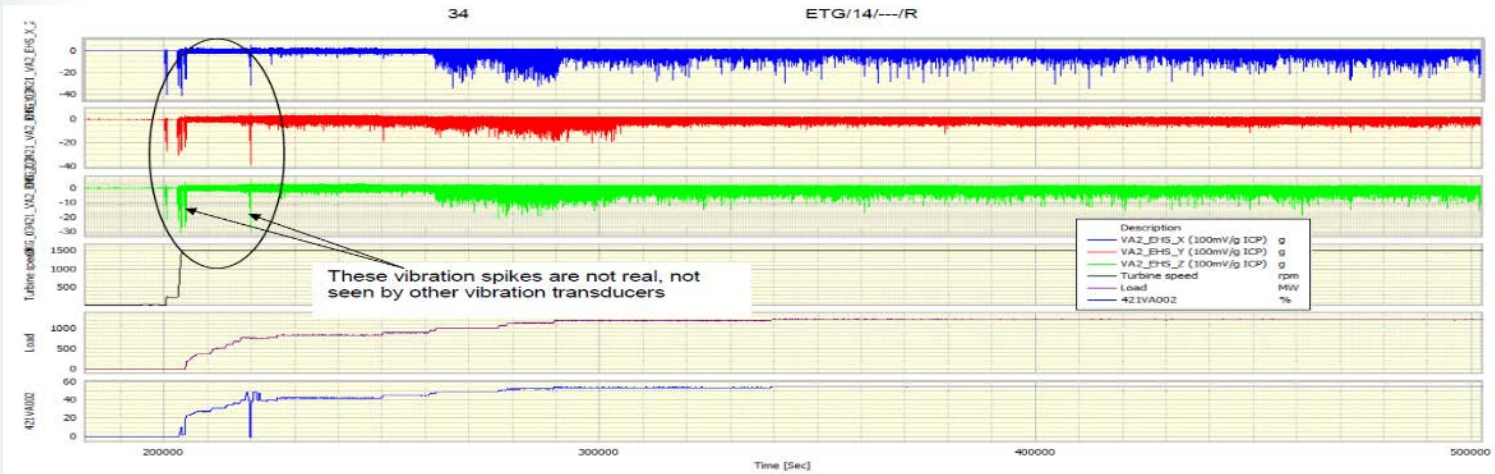


Figure 32 OKG 03: VA2: EHS Dytran 314D1 triaxial accelerometer (100 mV/g) vibration transducers X, Y, Z: Trend plot during load-up to 1200 MW 29th June 2015 to 2nd July 2015

PCB
356B21
10 mV/g
glued

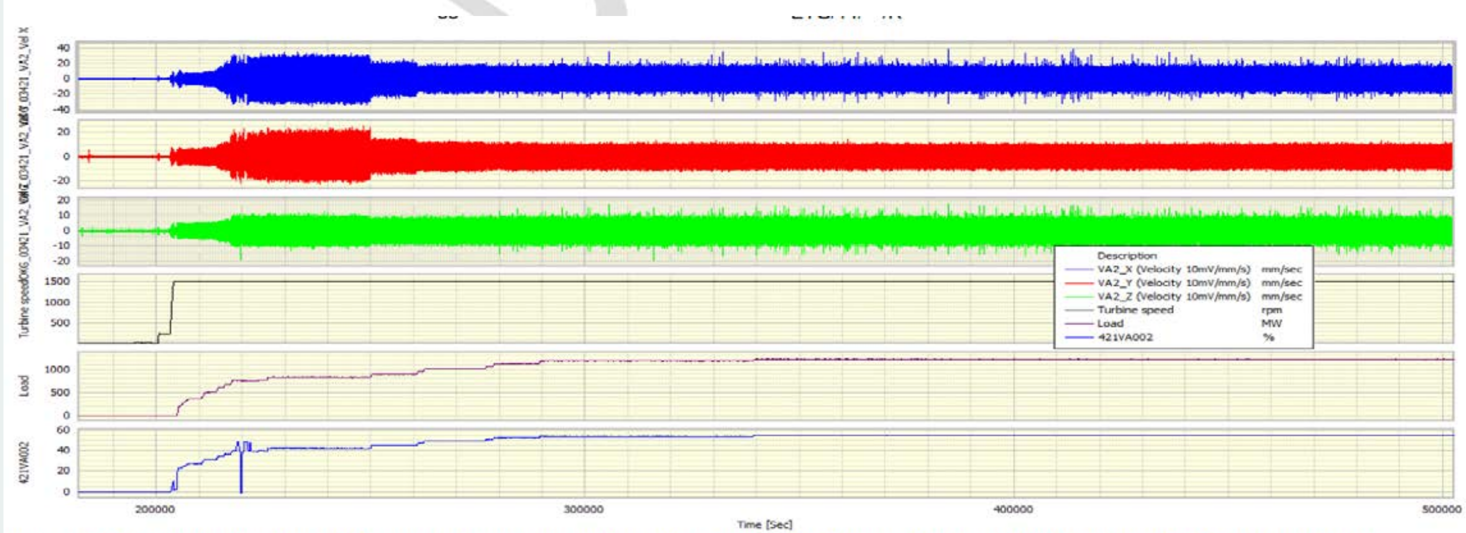
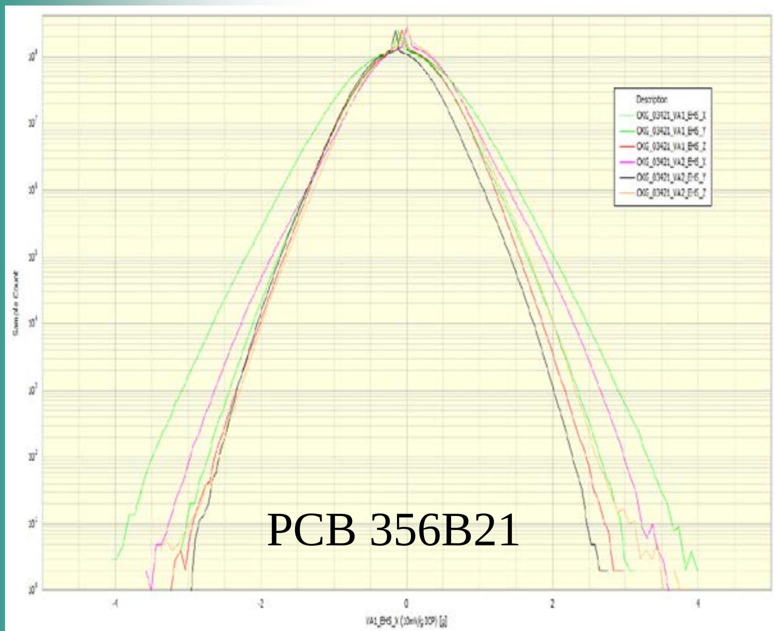
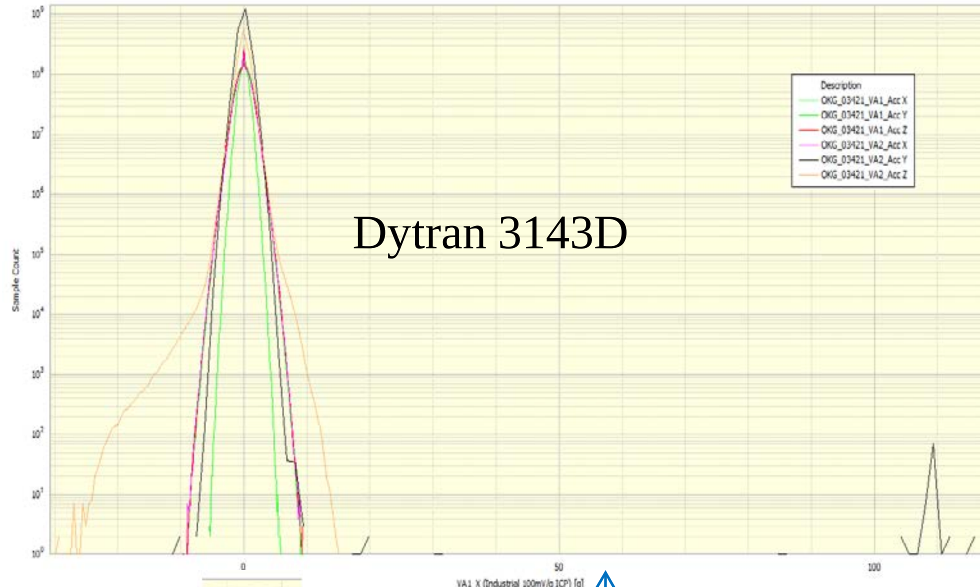


Figure 31 OKG 03: VA2: Velocity 10mV/mm/s vibration transducers X, Y, Z: Trend plot during load-up to 1200 MW 29th June 2015 to 2nd July 2015

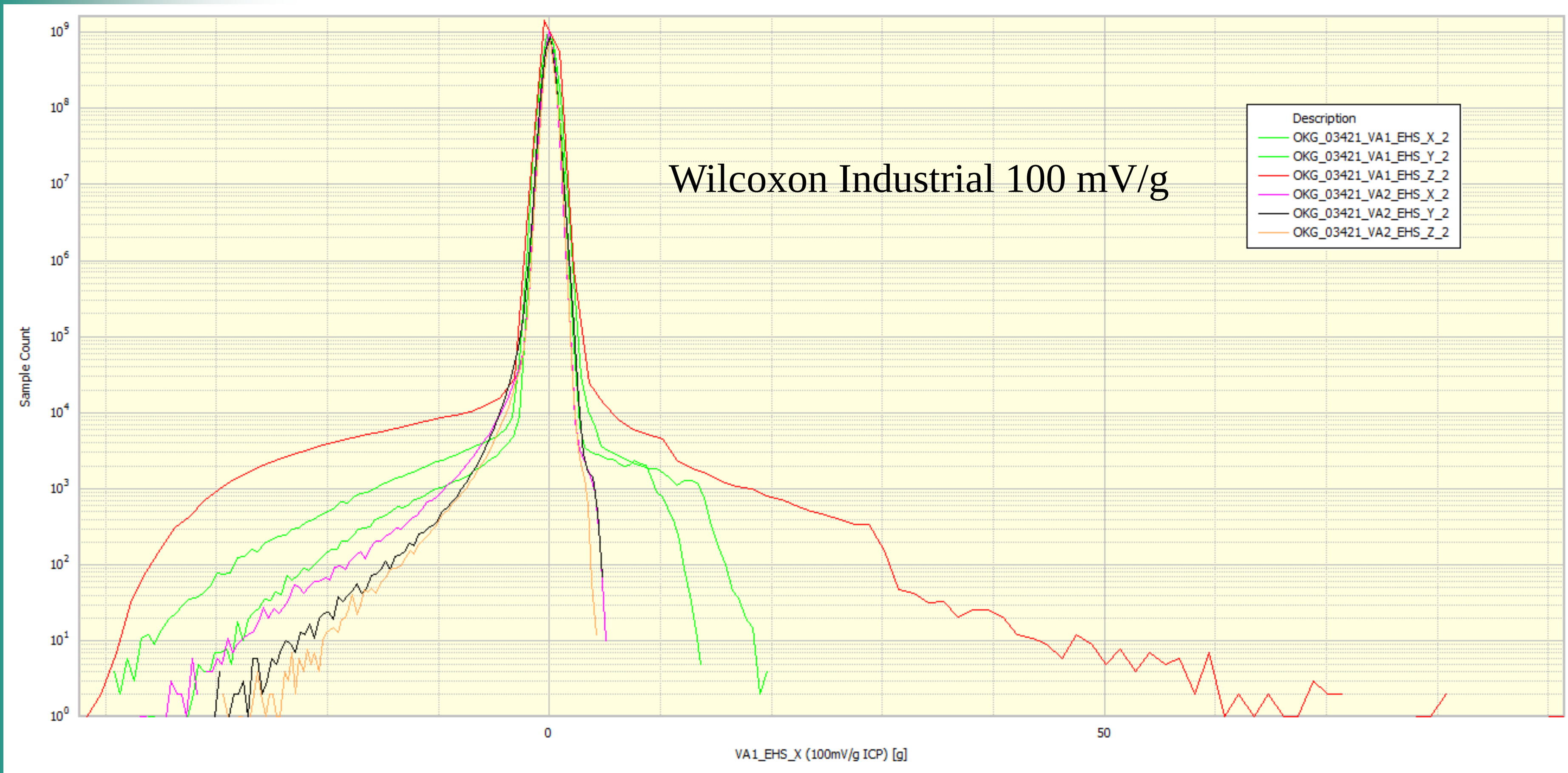
Comparison: Amplitude Histograms



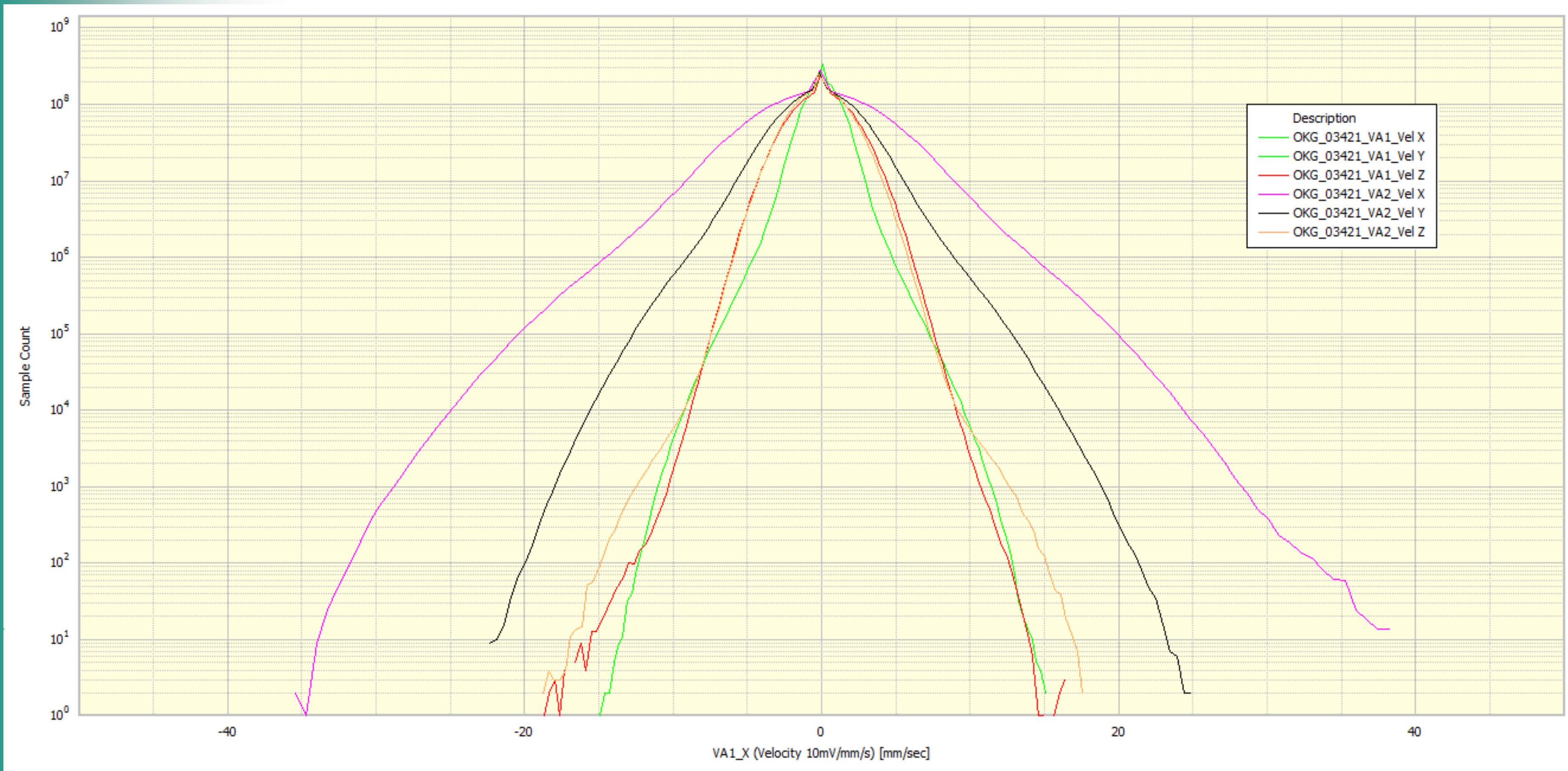


Similar scaling

Other Transducers: Industrial 100 mV/g



Velocity transducer VT1613



Observations

- Dytran & Wilcoxon general purpose 100 mV/g industrial accelerometers did not provide usable signals.
- Velocity transducer VT1613 provides slightly asymmetric histogram.
- 356B21 (glued) 10 mV/g shows symmetric histogram.
- 356B21 w. mech. Filter not measured by 3rd party
- Data up to 60% load.

Project Stopped

- Root cause for EHS problem was identified not to relate to vibration at all.

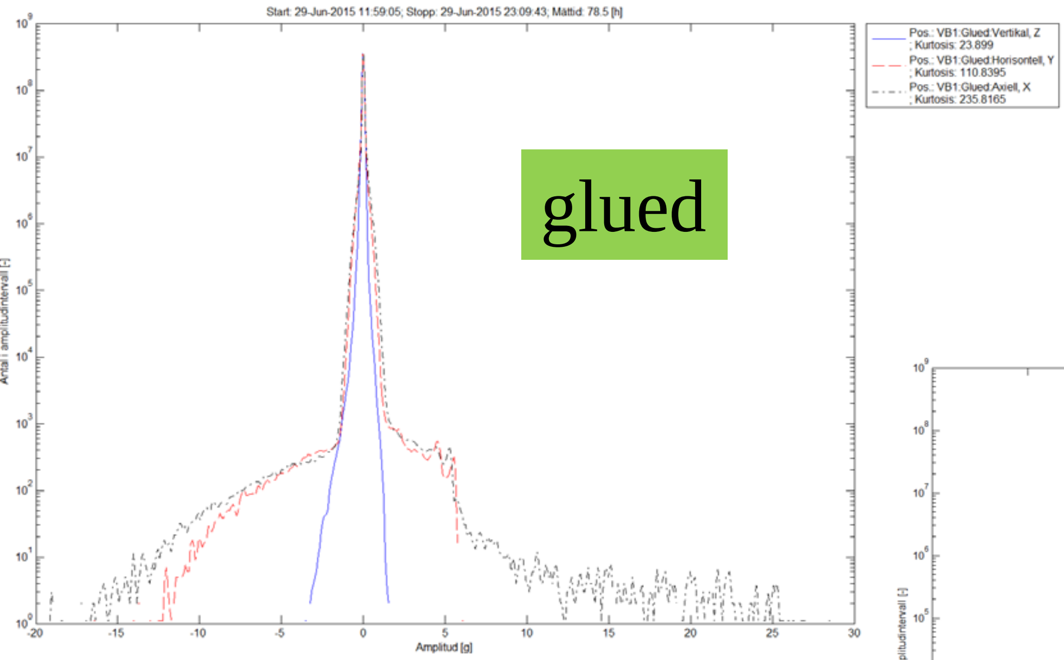
Comparation to 3rd part

- He had 24 channels – we had 96 channels.
- He measured to 60% load – we measured 5 month continous.
- He could not take transducers of every configuration

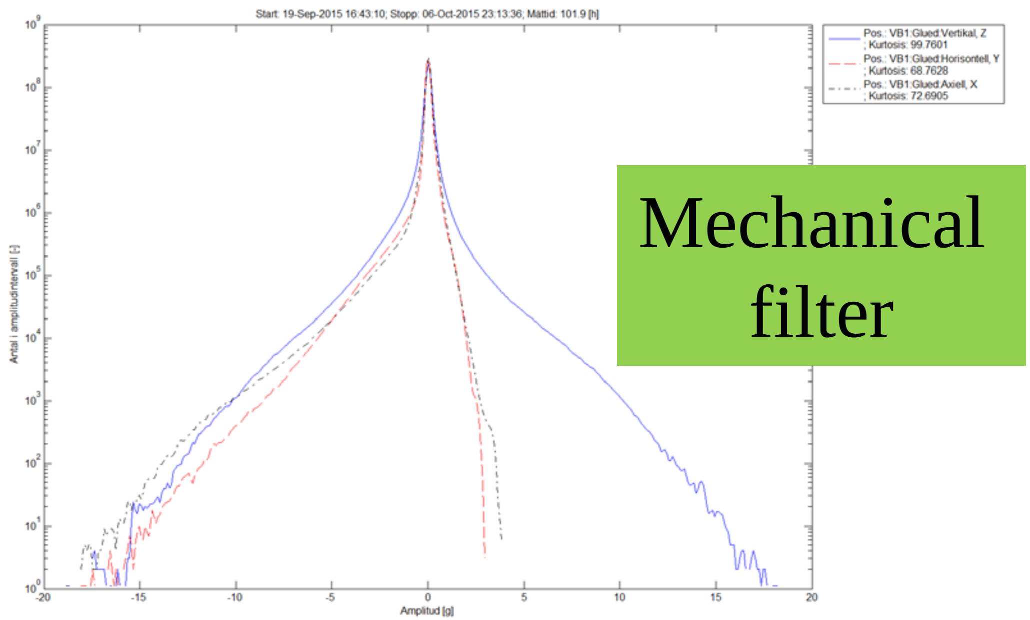
Was 4th round measurement data used?

- Yes, we used it for accelerated testing of the new EHS.
- The transducer evaluation had to continue to do this.

Comparison: 356B21 glued/w. mechanical filter



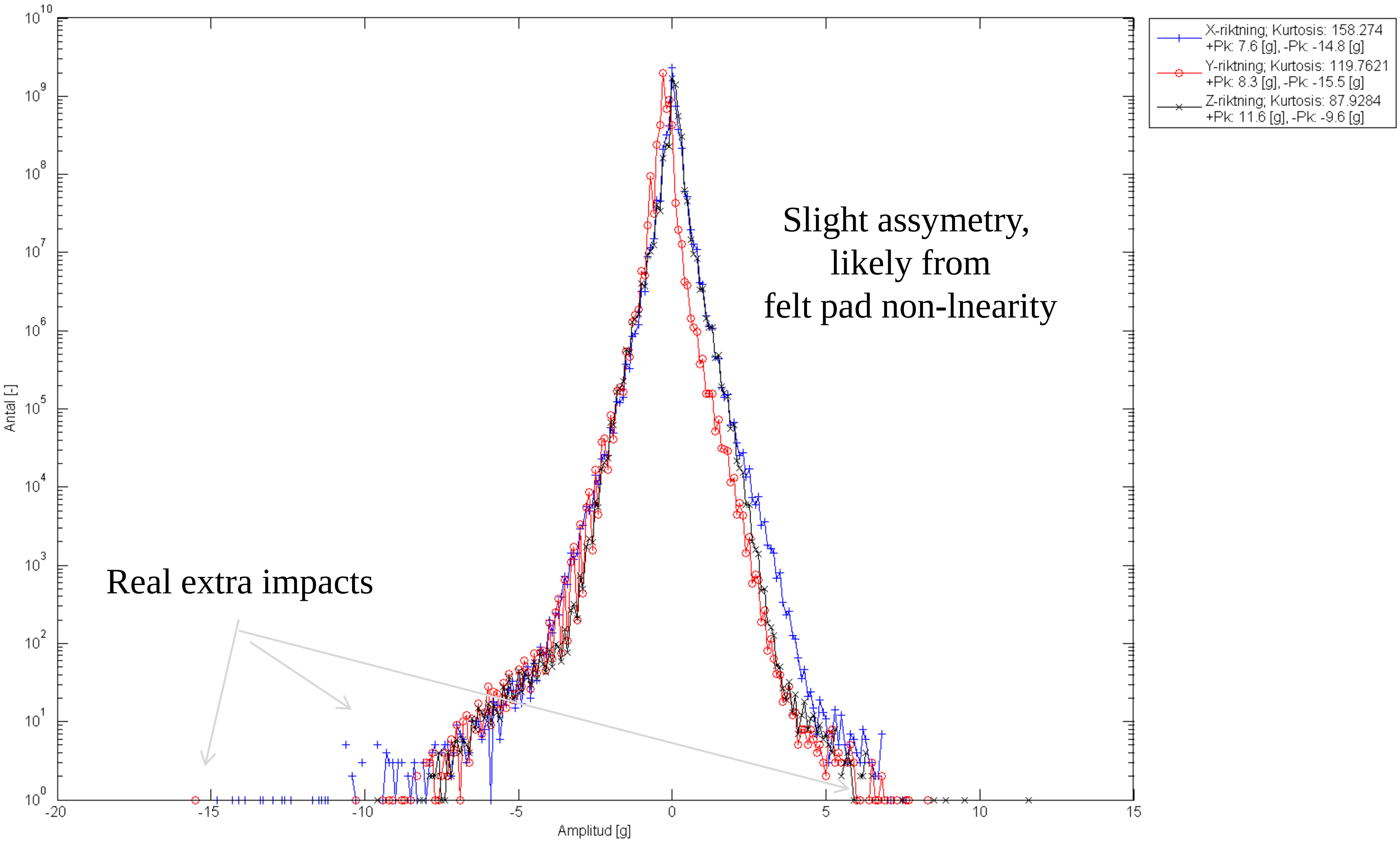
glued



Mechanical filter

Also 356B21 misbehaved when glued

Data used for Accelerated Testing



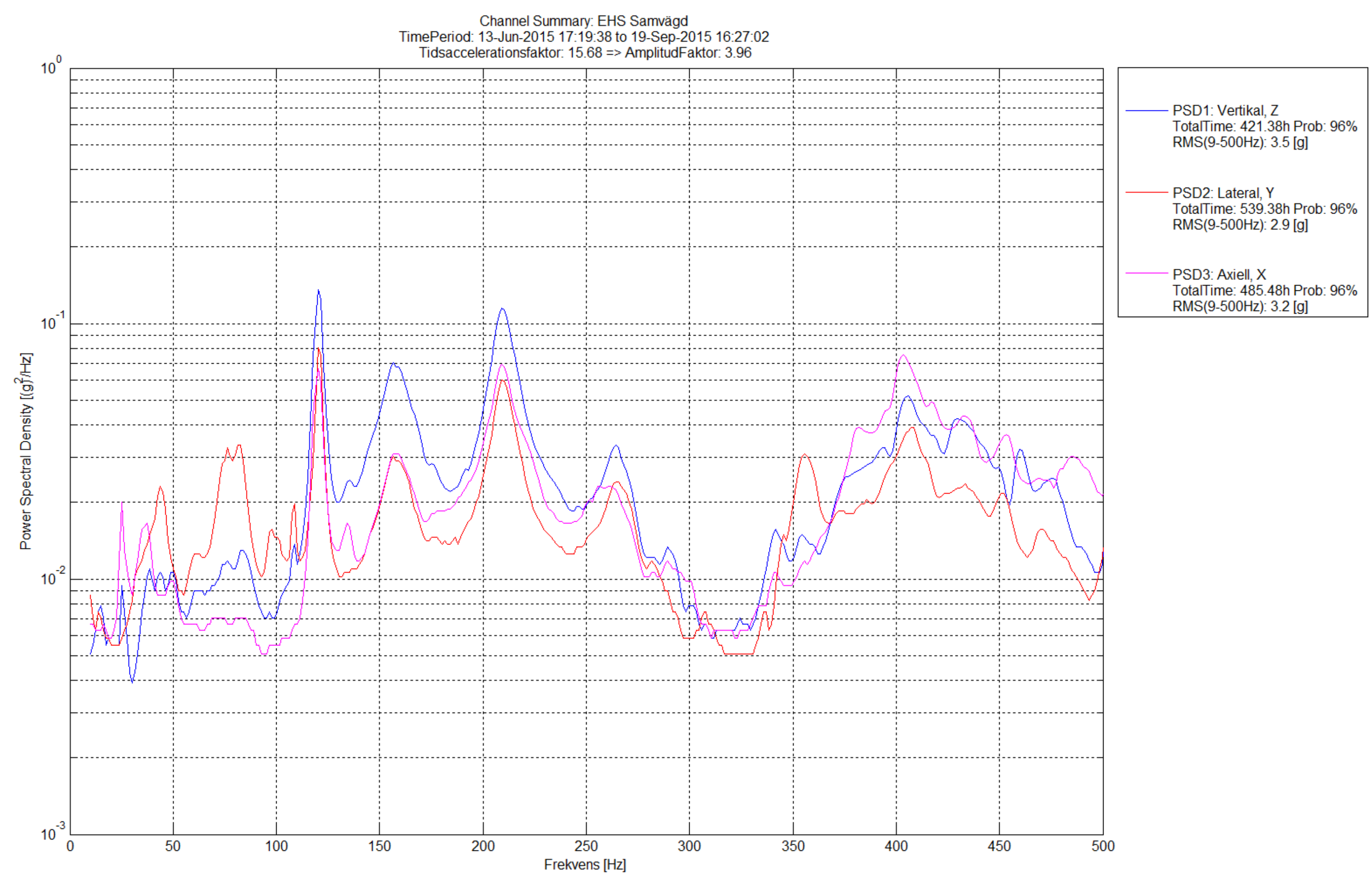
Lesson Learned

- All glued accelerometers were affected by internal sensor resonance and zero shifted because of this.
- Accelerometer with mechnical filter & Velocity transducers worked best because they did not pick up high frequency vibration.
- 4x triaxials with filters were input.
  - 2x fell off after a while
  - 2x worked through the while measurement .

End Results

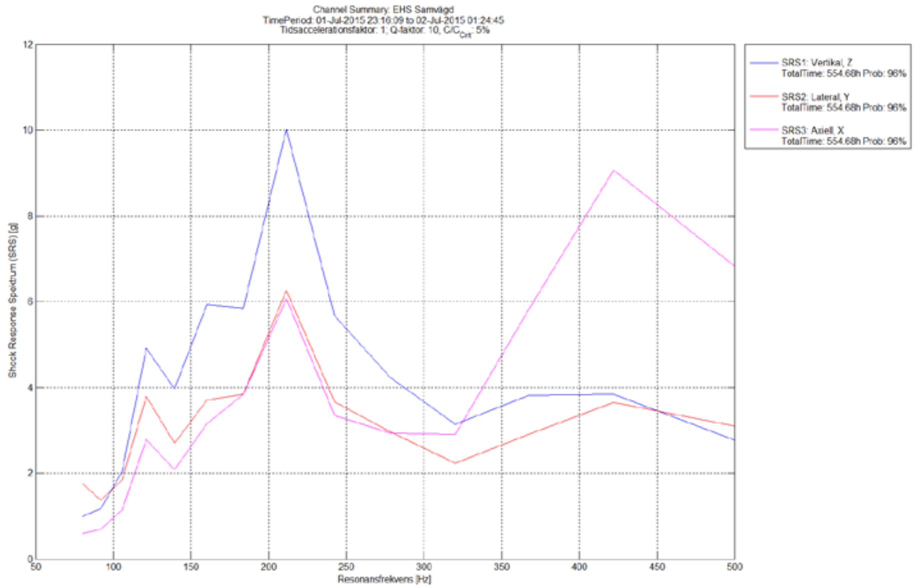
Accelerated Testing

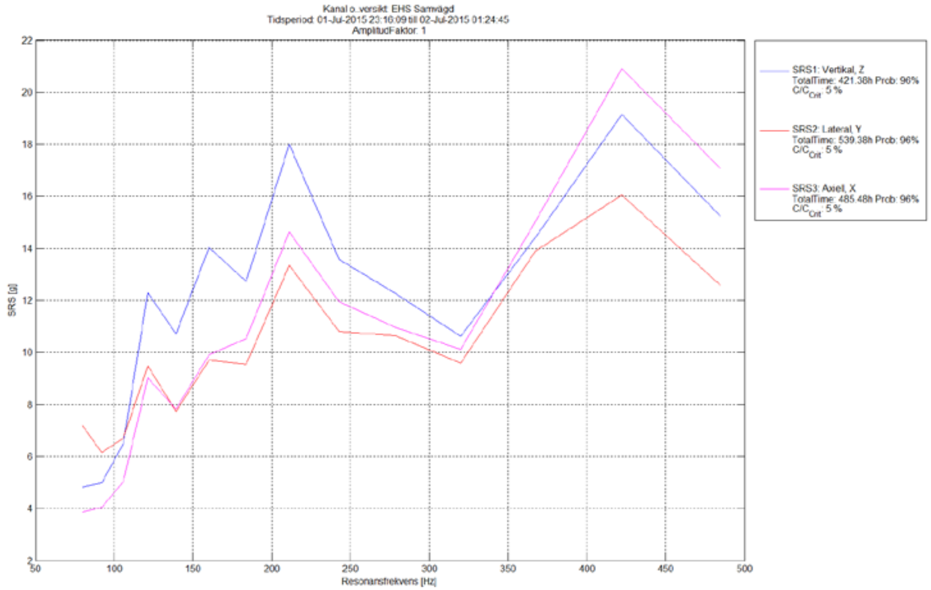
96% Probable PSD



Shock Response Spectrum

Direct (time) & Indirect (spectral)





SRS shows the outlier peaks to be covered
by the noise excitation variability