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Why Proper Low Pass Filter Settings on Crosshead Vibration Signals are Crucial to Minimize Risk of Missed Detects

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bp

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Presenter/Author bios

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Oliver graduated from the University of Paderborn in 2000 with a diploma in Chemical engineering.

Presenter/Author bios

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is a Machinery Advisor at BP Refining Technology and Engineering in Houston, Texas. He provides technical advice to the BP global refining portfolio to support business delivery, company strategy, industry direction, and technical assurance to support business decisions. He also promotes technology solutions and development and implementation of best practices across the BP refineries. He is currently the API SOME Chairman, API 618 Chairman, API 692 Chairman and serves as a SME for BP's Engineering Technical Practices. Bob has over 20 years of experience in the industry. Bob graduated from Texas A&M University at Galveston in 1992 with a B.S. in Marine Engineering. He joined the TAC September, 2012.

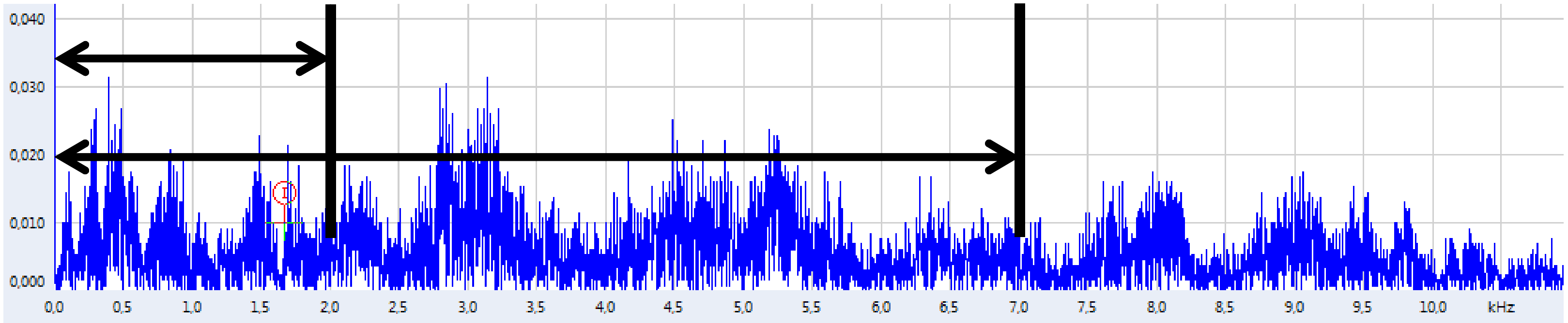
Abstract for show guide only

Crosshead guide acceleration measurements have gained mainstream acceptance by operators of API 618 recips and now joins frame velocity as a recommended shutdown parameter in the 5th edition of the API 670 Machinery Protection Standard.

Knowledge surrounding proper low pass filter settings for acquisition systems performing critical shutdown function is very limited and often misapplied. This case study illustrates why the common practice of setting low pass signal filters at 2 kHz introduces risk that serious failure modes go undetected compromising plant safety, health and the environment.

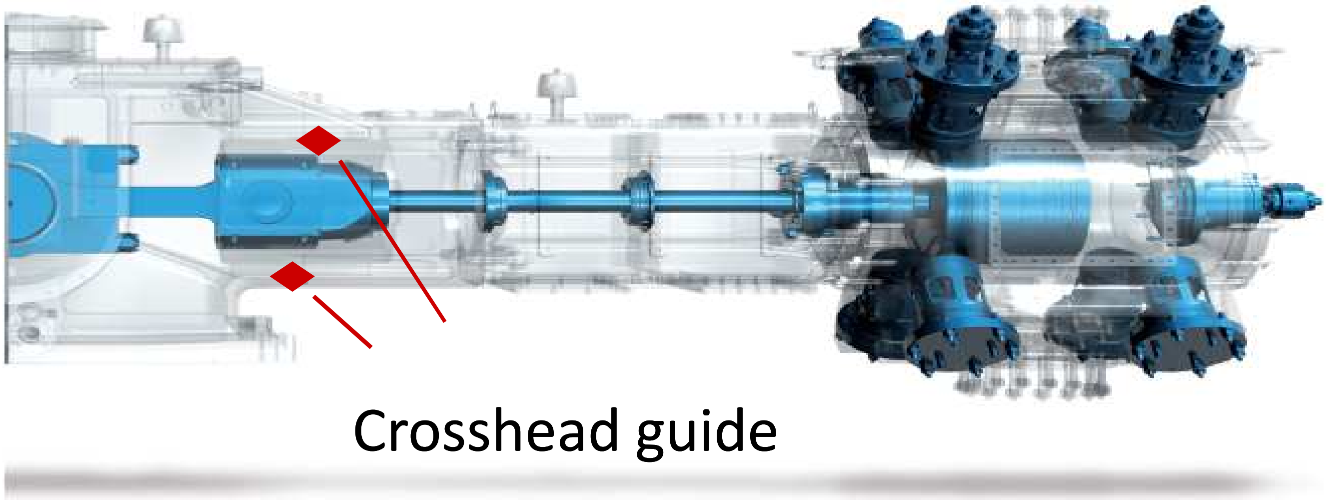
Problem Statement:
"The Filter Setting Challenge"

See examples of 2kHz and 7kHz low pass filters:



At which frequency would you best set the low pass filter for crosshead guide acceleration performing an interlock function?

Relevant sensor position



Crosshead guide

acceleration

(top <u>or</u> bottom)

API 670 5th Edition

API 670 5th edition recommends crosshead guide vibration sensors to detect mechanical or process induced impacts.

Annex P.4.3.4.4:

"These acceleration sensors are typically mounted in the vertical direction on the top or bottom of the crosshead guide.

The selected frequency range may need to be configured to accept higher frequencies (up to 7kHz with a 2kHz minimum) to detect mechanical impacts depending on machine characteristics."

End User Case Study 1

<u>Recip Compressor Info :</u>

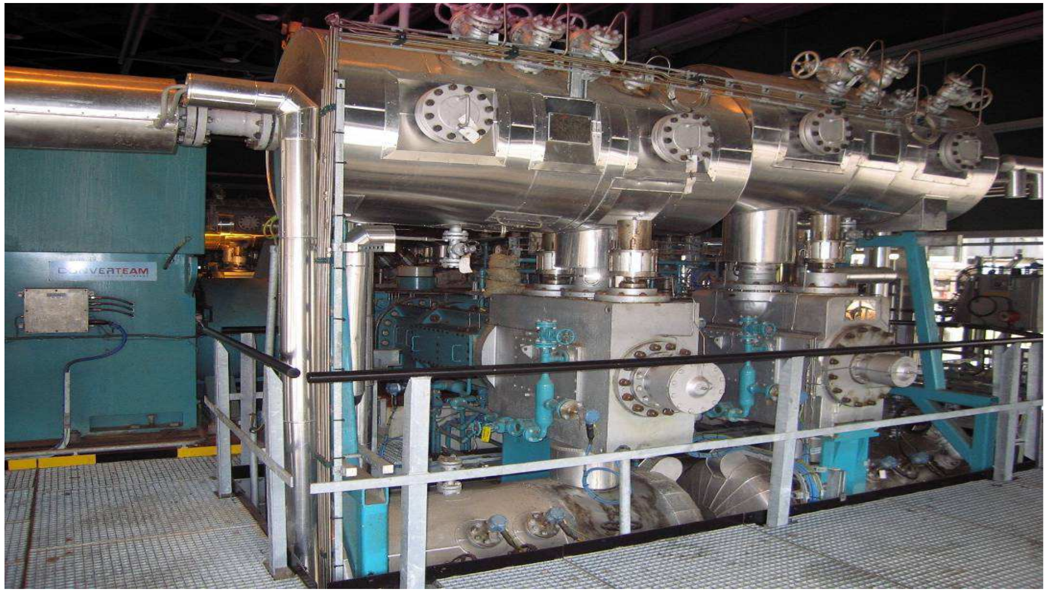
- 4 throw – 3 cylinders – 3 stages
  (1 balance dummy throw)
- Hydrogen service
- Suction 3.3 barg (47.5 psig)
  Discharge 34 barg (495 psig)
- 1,400 kW (1,875 hp)

New compressor at commissioning

End User Case Study 1

<u>Monitoring scope follows API 670 Annex P:</u>

- Crosshead guide, frame and cylinder vibration
- Piston rod position (Y-axis)
- Internal cylinder pressure (pV)
- Motor bearing displacement

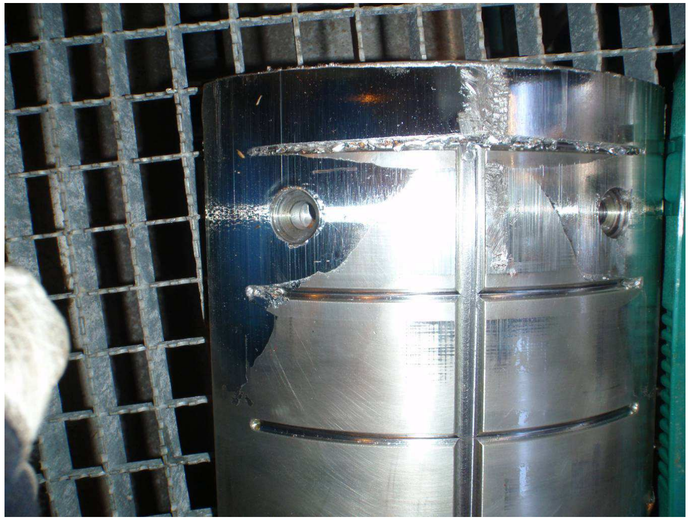


New compressor at commissioning

Failure Photos Case Study 1

Small end of connecting rod

1st stage pin



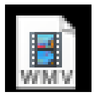
Crosshead slipper

End User Case Study 1

Movie: of seizing wrist pin due to lack of lubrication

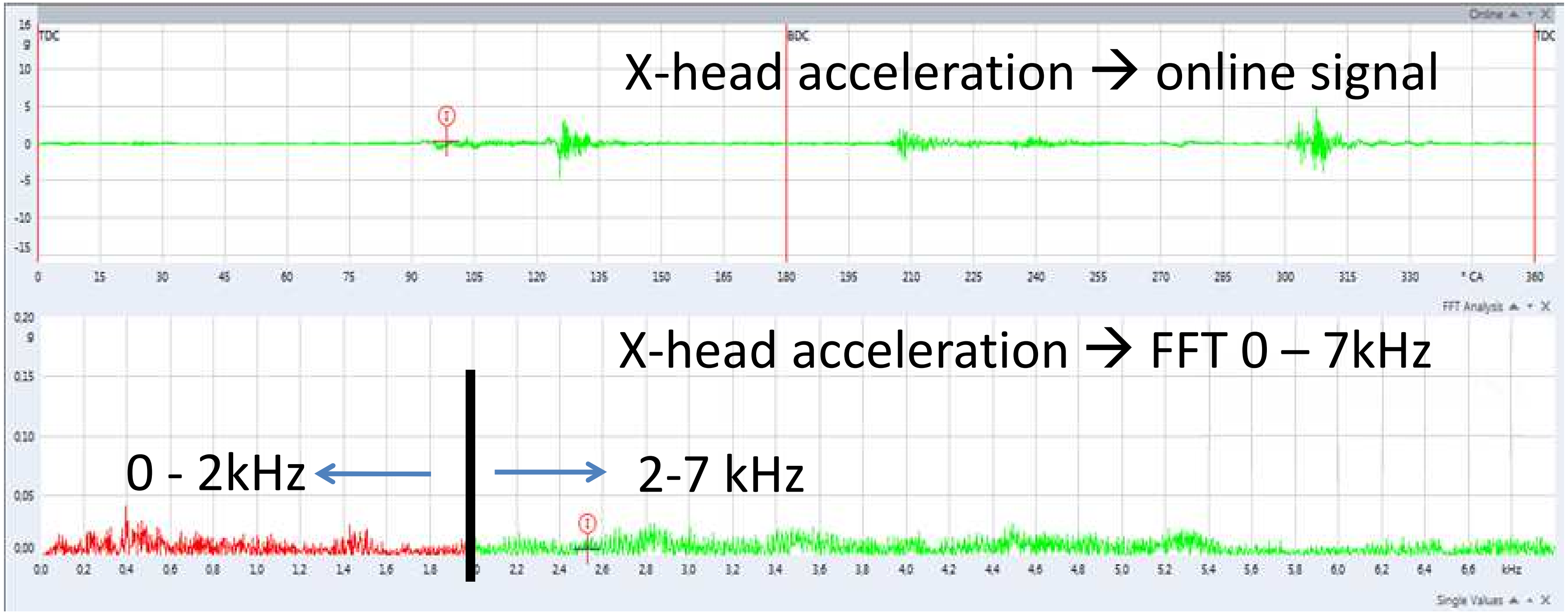
Note: double click on .wmv file when not in show mode. Will be configured as hyper link later.

„BP_wristpi“

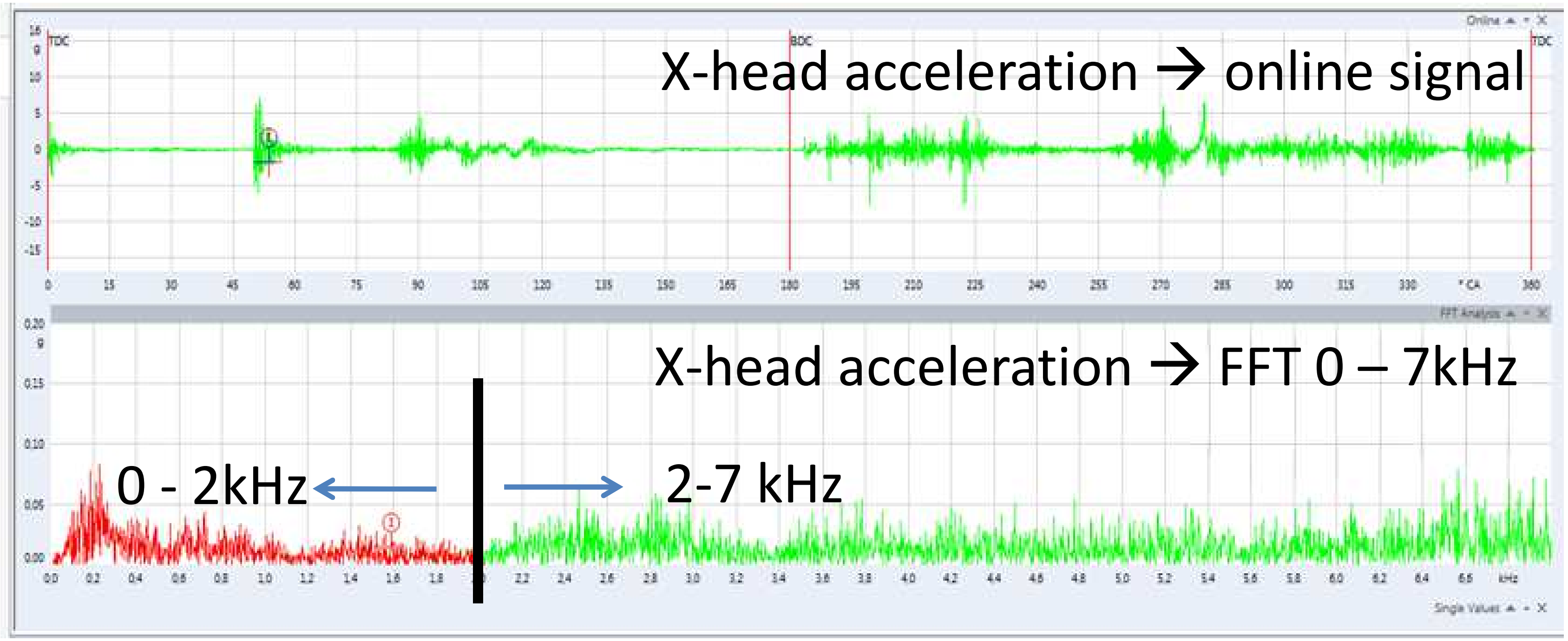


BP_wristpi.wmv

Case Study 1 (good condition)



Case Study 1 (bad condition)

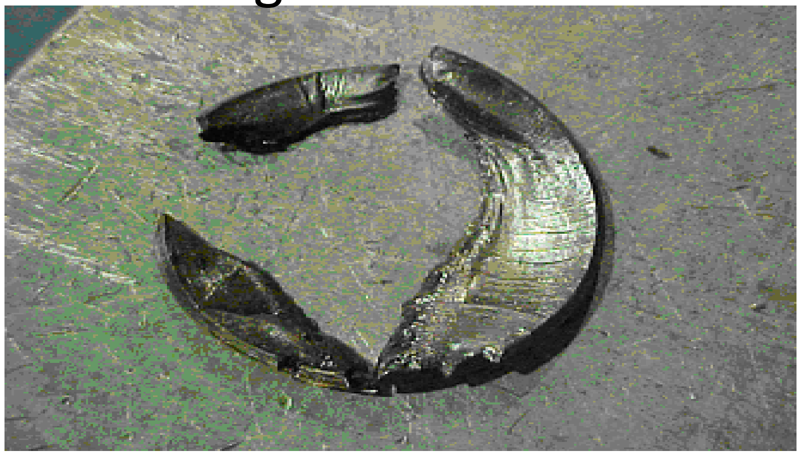


Case Study 1

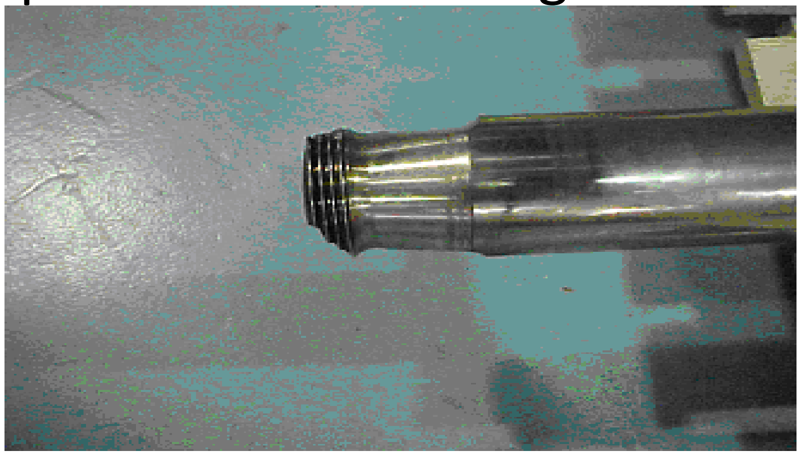
- Majority of failure related energy has higher frequency content above 2kHz
- Critical wrist pin seizures do not involve impacts typical of loose components (showing lower frequency content below 2 kHz)

Case study 2: Failed piston rod

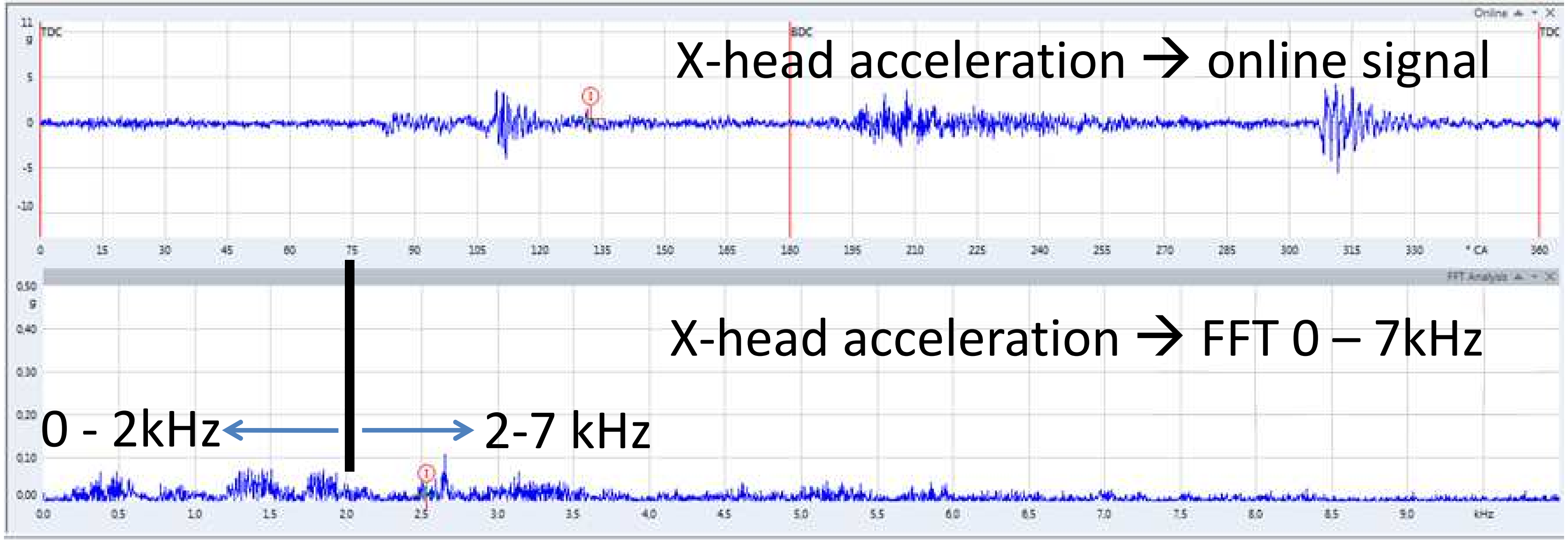
Fragments of the piston rod thread region



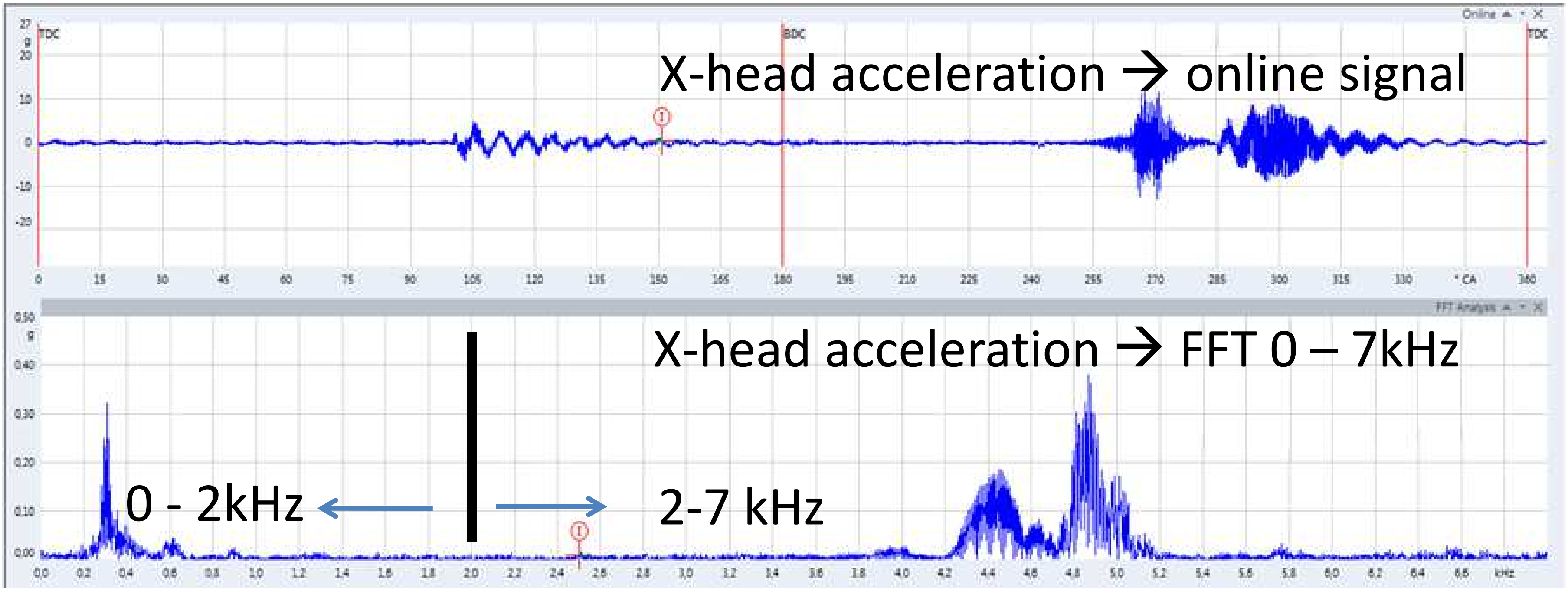
Top view of the failed piston rod thread region



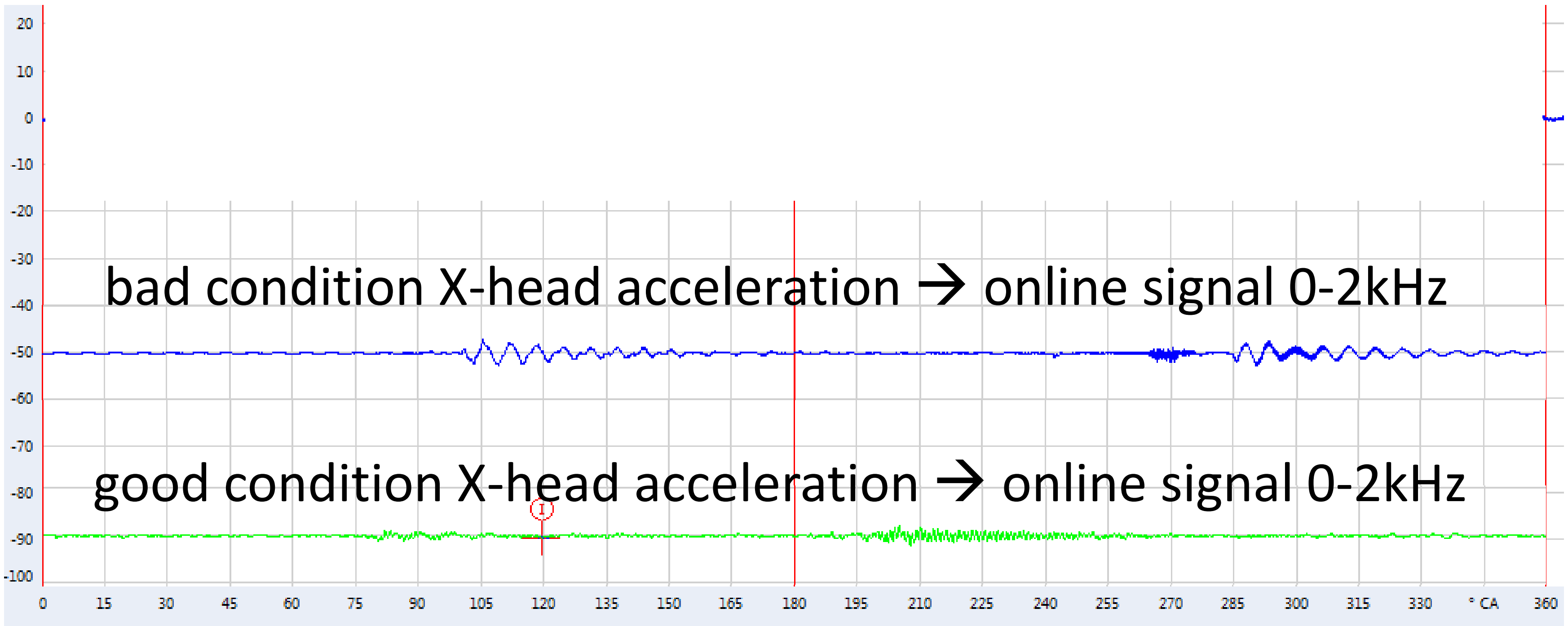
Failed Piston Rod (good)



Failed Piston Rod (bad)



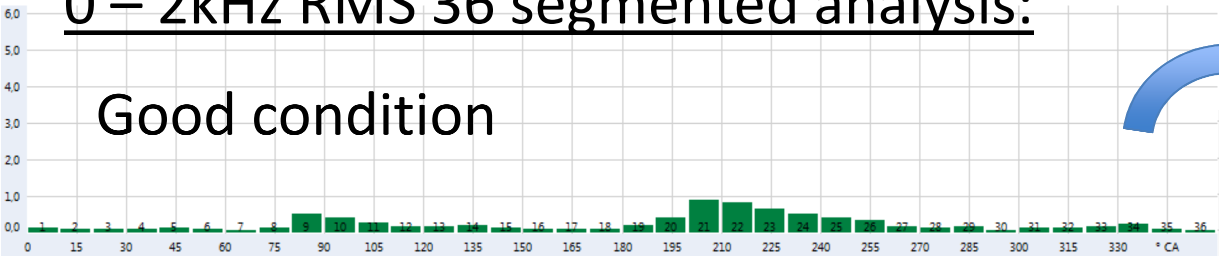
Failed Piston Rod – Online Signals



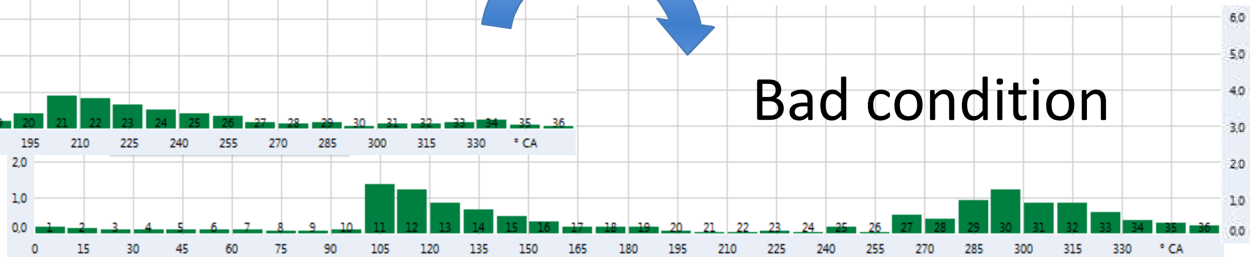
Crosshead Guide – Safety Analysis

<u>0 – 2kHz RMS 36 segmented analysis:</u>

Good condition

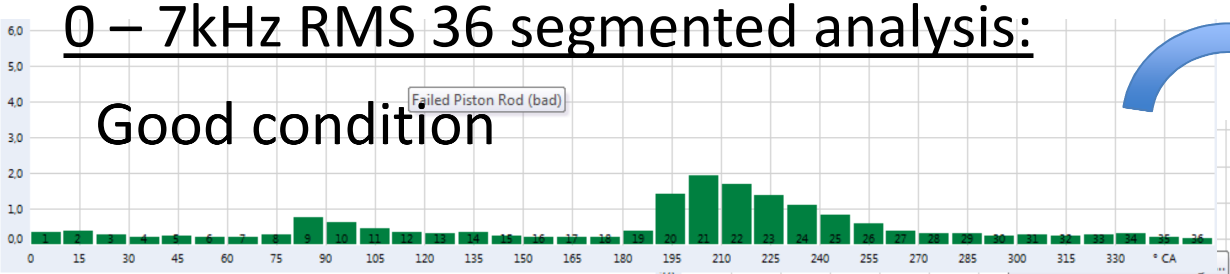


Bad condition

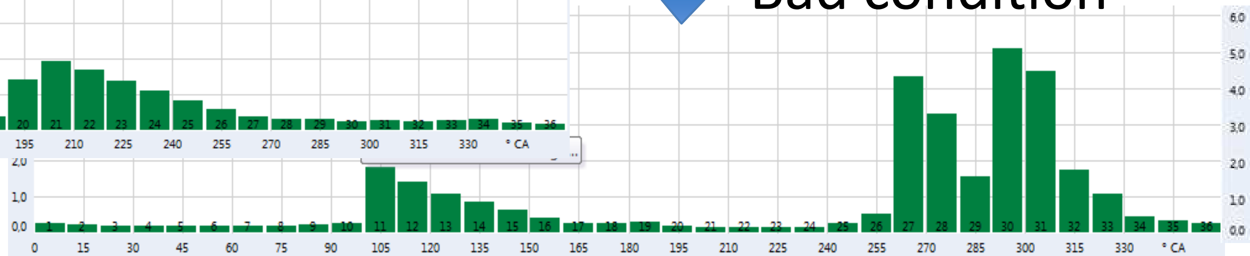


<u>0 – 7kHz RMS 36 segmented analysis:</u>

Good condition



Bad condition



Signal Analysis Considerations

- The RMS value for a number of *n* data samples is the square root of the arithmetic mean of the squares of the n values.

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{n}\left(x_1^2 + x_2^2 + \cdots + x_n^2\right)}$$

- <u>Upside:</u> RMS values are best to describe the energy within a given signal
- <u>Downside:</u> Individual, high X_Y^2 data samples get lost in the average if n = number of samples is high.
  (e.g. RMS over one entire revolution or one second)

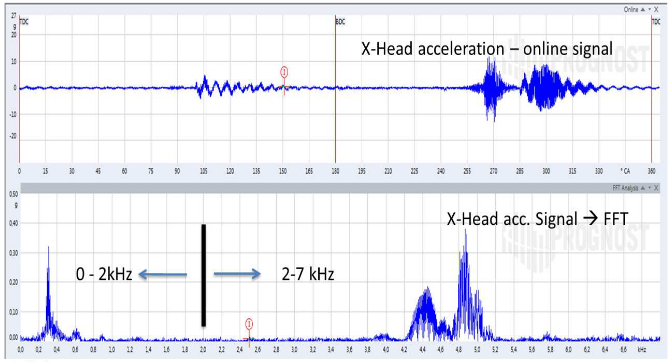
Signal Analysis Considerations

1. To not miss individual impacts, some users apply Peak over RMS
2. Unfiltered peak analysis leaves users vulnerable for nuisance alarms e.g. caused by isolated, high frequency events, signal spikes or sensor glitches
3. In order to eliminate these nuisance alarms some users apply a low pass filter (e.g. 2 kHz)

Above strategy (1-3) reduces nuisance alarms but eliminates capability to detect those critical failure modes with majority of energy in higher frequency ranges as demonstrated before.

Conclusions

Breaking Piston Rod (bad)



- Certain failure modes show majority of energy at higher frequencies (e.g. 4 - 7 kHz)
- We suggest to follow API 670 and employ full signal bandwidth 0 - 7kHz
- Best to combine 0-7kHz with RMS (segmented) analysis - so:
  - repetitive impacts are not missed at critical stage
  - RMS based segments represent a solid (e.g. 10°CA) weighted average, so single isolated signal spikes do not lead to nuisance alarms