METS III
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Unstable Reading of Accelerometers in Cryogenic Service

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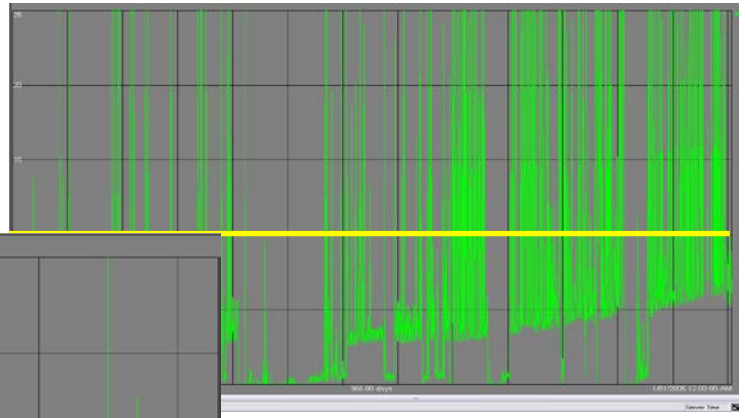
Problem description

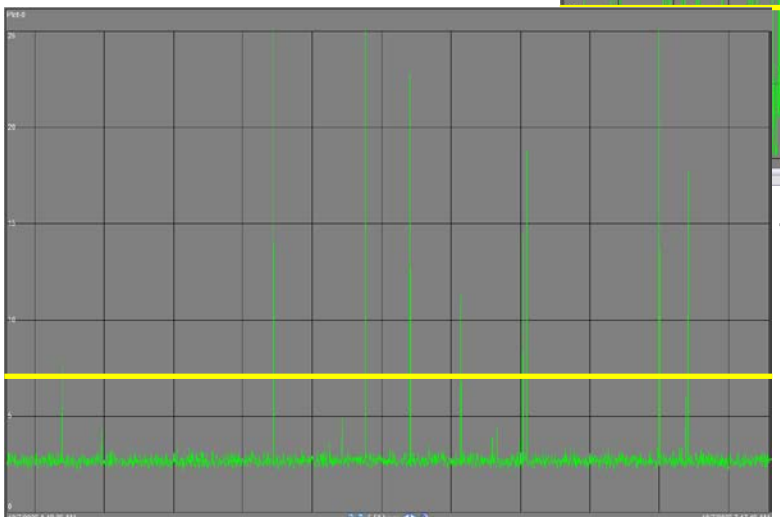
- RasGas operates over 100 pieces of cryogenic submersible equipment. Approximately 80 % are on pumping service and the rest on expansion service.
- These units use two vibration transducers to provide protection and diagnostic capability. The signal from the accelerometer is conveyed to the external signal conditioner (inside field junction box) them to a monitoring system
- Since commissioning vibration signals tend to be spiky (that is, random in nature) they may OEM recommended alert limits. This may mask potential real problems to the machine.

Problem description cont

- Three modes of sensor response were identified during operation:
  - Spiky signal response without sensor failure after time in service
  - Spikey signal response with sensor failure.
  - Sensor failure immediately after unit put in service



Typical vibration signal spiky response

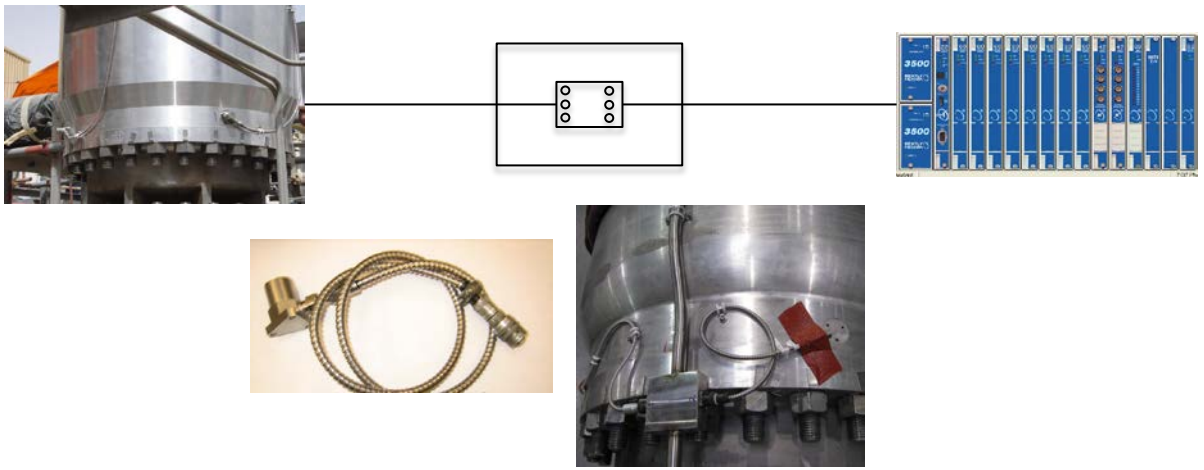


Time zoomed signal

Findings

- A multidisciplinary team, was formed to investigate root cause and possible mitigation actions, including OEM of system involved; Turbine, Transducer, monitoring system

- More than 20 tests on different component were performed to isolate the source of unstable vibration readings that can be summarized as follows:
    - Monitoring System
    - Signal Cable (from JB to Monitoring System)
    - Input Module (field junction box)
    - Transducer and/or Transducer cable (submerge unit)



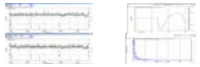
Monitoring System Signal Cable/ Input module in field Findings

–Data collector was used to record raw acceleration signal at the buffered output of the vibration monitor at the instrument housing and at the Accelerometer Input Module (AIM) located on the unit platform.

–Data confirmed the presence of low frequency components in the vibration signal which is being amplified by the integrating circuitry.

–No significant difference between data collected at Monitoring System and the AIM

–Test confirmed Signal cable monitoring system (I/O, Safety barriers) are not inducing errors in the signal.



Accelerometer, extension cable, AIM,

Findings

–Accelerometers and cable tested by OEM.
- Leak test confirmed no leaks found when used as recommended
- Shock data did not show significant changes in Accelerometer response

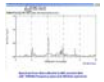
–Five (5) accelerometers sent to manufacturer to perform failure analysis:
- 3 Accelerometers stopped working (no signal at all)
- 2 Accelerometers still working with spike signals
- Frequency response and scale factor confirmed to comply with OEM specification and no significant degradation of probe performance compare to a new probe.

–Third party study suggested that “data during the spurious events is in many way similar to what was re-created by intentionally saturating the accelerometers”.

Accelerometer, extension cable, AIM,

Findings

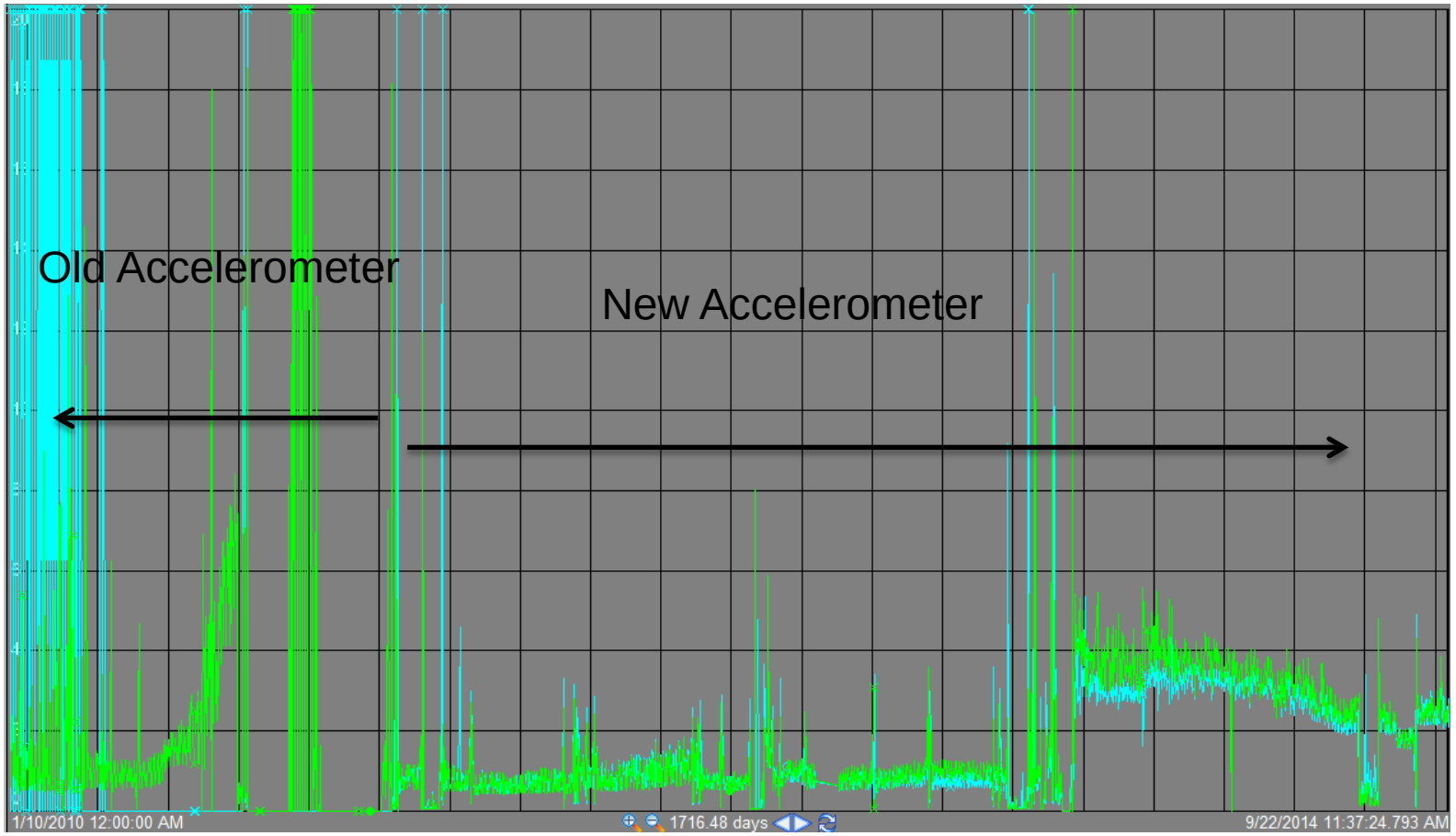
- Data collected with a 10 KHz frequency span (FS) shows that most of the energy its generated at higher frequencies.
- New set of data was collected, using a 40 KHz FS, confirmed that most of the vibration energy is being generated around 15KHz. This frequency is very close to the specified accelerometer mounting frequency (≥12KHz).
- The vibration excursion is caused by the system being overloaded when the natural frequency of the accelerometer is being excited
- With this information a prototype accelerometer was developed between OEMS and RasGas.



Accelerometer Comparison

Performance Specifications	(older model)	(new model) Prototype
Sensitivity	100mV/g	30mV/g
Measurement Range	15 g pk	170 g pk
Frequency Range +/- 3db	.35–4000 Hz	4–1500 Hz
Filter	none	Low pass with 1.8kHz corner frequency
Temperature Range	-350 to +250 F (-212 to + 121 C)	-350 to +250 F (-212 to + 121 C)
Hazardous Area Approval	ATEX, CSA, IECEx	ATEX, CSA, IECEx
Resonant Frequency	16–18 kHz	> 20kHz

- A larger measurement range was implemented to keep the transducer from being overloaded (saturated) by a high frequency event.
- A low pass filter was applied to remove unwanted high frequencies that influence overall measurement levels. Machine speed is 66Hz max so there is no concern of signal aliasing.
- New transducer mounting configuration was maintained to be adaptable to RasGas fleet.

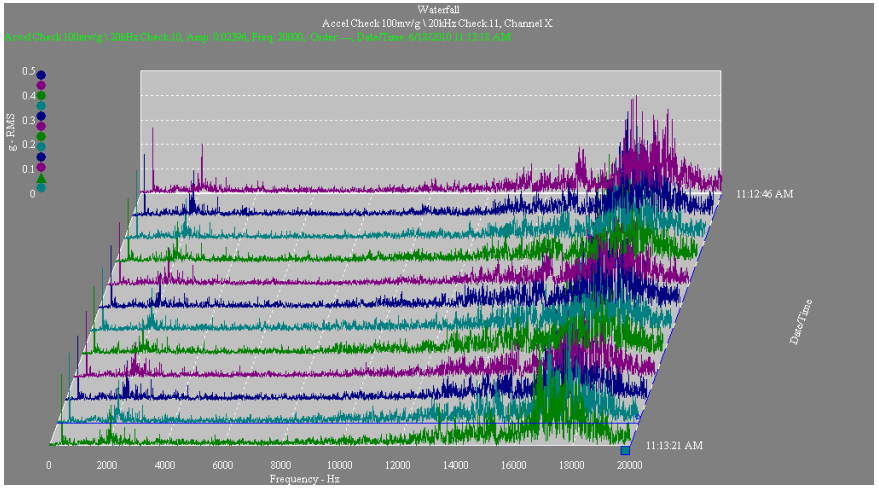


Accelerometer long trend

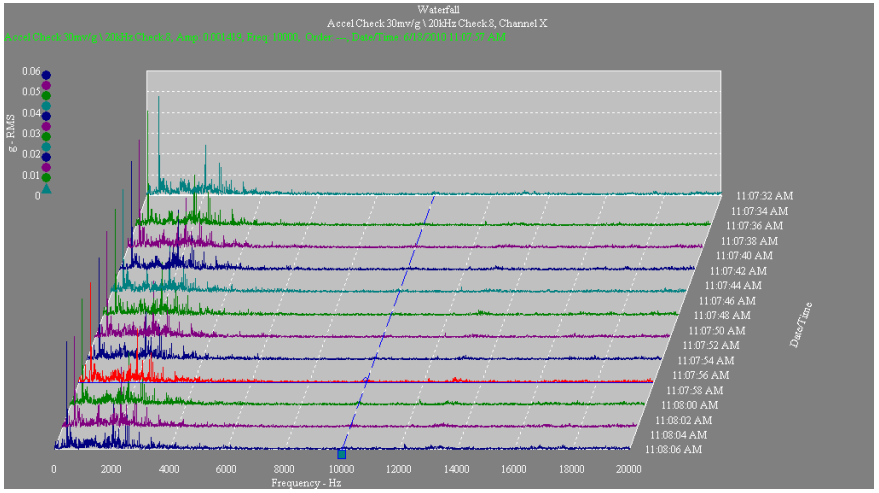
Testing of New Transducer

- New transducer was installed with old transducer side by side on a 2500Hp (1864kW) submerged motor vaporizer feed pump operating in LNG at OEM test facility.
- OEM test facility capable of high frequency monitoring of transducers to mimic testing performed at RasGas site for results comparison.
- Pump simulated well the problem experienced at RasGas as can been seen on subsequent plots of the high frequency excitation of the old transducer. Excitation was enough to see the phenomena without taking transducer to complete saturation.
- New transducer shows no sign of high frequency events to 20kHz and with no signal loss at low frequencies.

Side by side accelerometer test at OEM cryogenic test facility



Old accelerometer with high frequency 18KHz excitation



New accelerometer without high frequency excitation

Conclusions

- Accelerometer mounting resonance being excited at running speed which lead to transducer saturation and unstable signal quality.

- Historical acceleration data can still be used for trending purposes but not for machinery health protection or reliable frequency analysis.

- New accelerometer installed in hydraulic turbines and LNG pumps have no indication of “spiky” (saturated) signal.

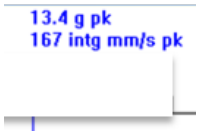
- New accelerometer can be use for machinery protection and advanced frequency analysis to determine machinery health.

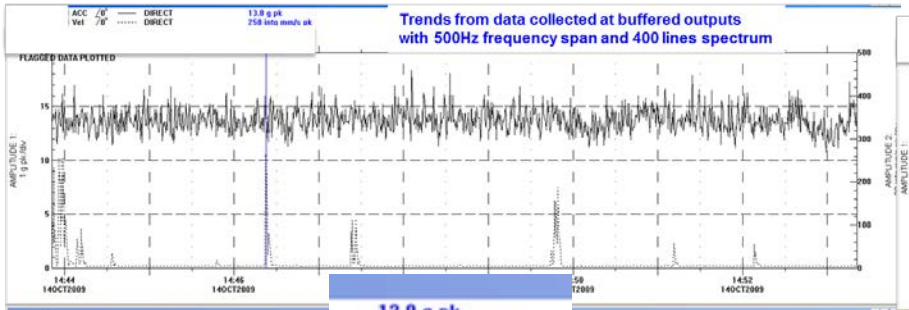
Recommendations

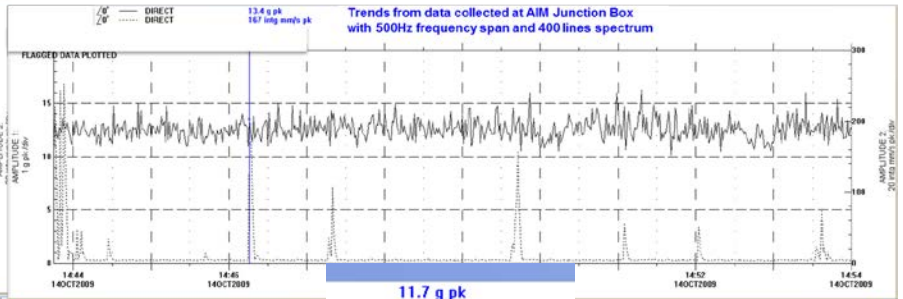
- Install new accelerometers on units removed from service.
- Upgrade Monitoring systems to received new sensors.
- Analyze option to return to condition based maintenance.
- Set new alert and trip levels according to new OEM recommendations.

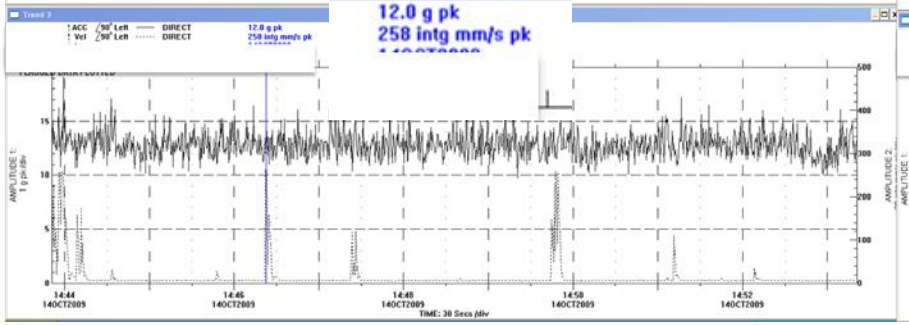
- Back Up

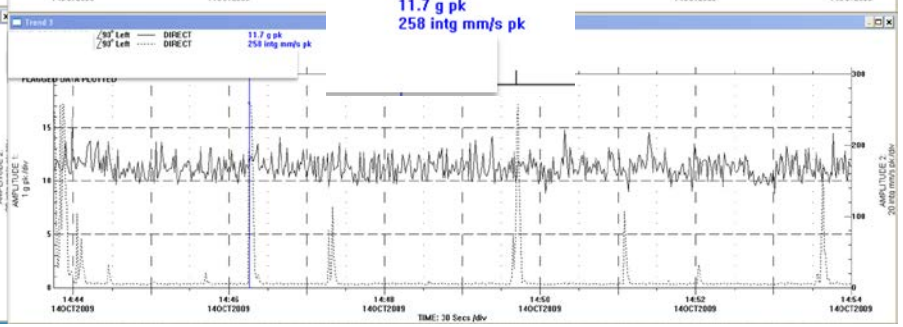
Vibration trend collected at monitoring system and at AIM











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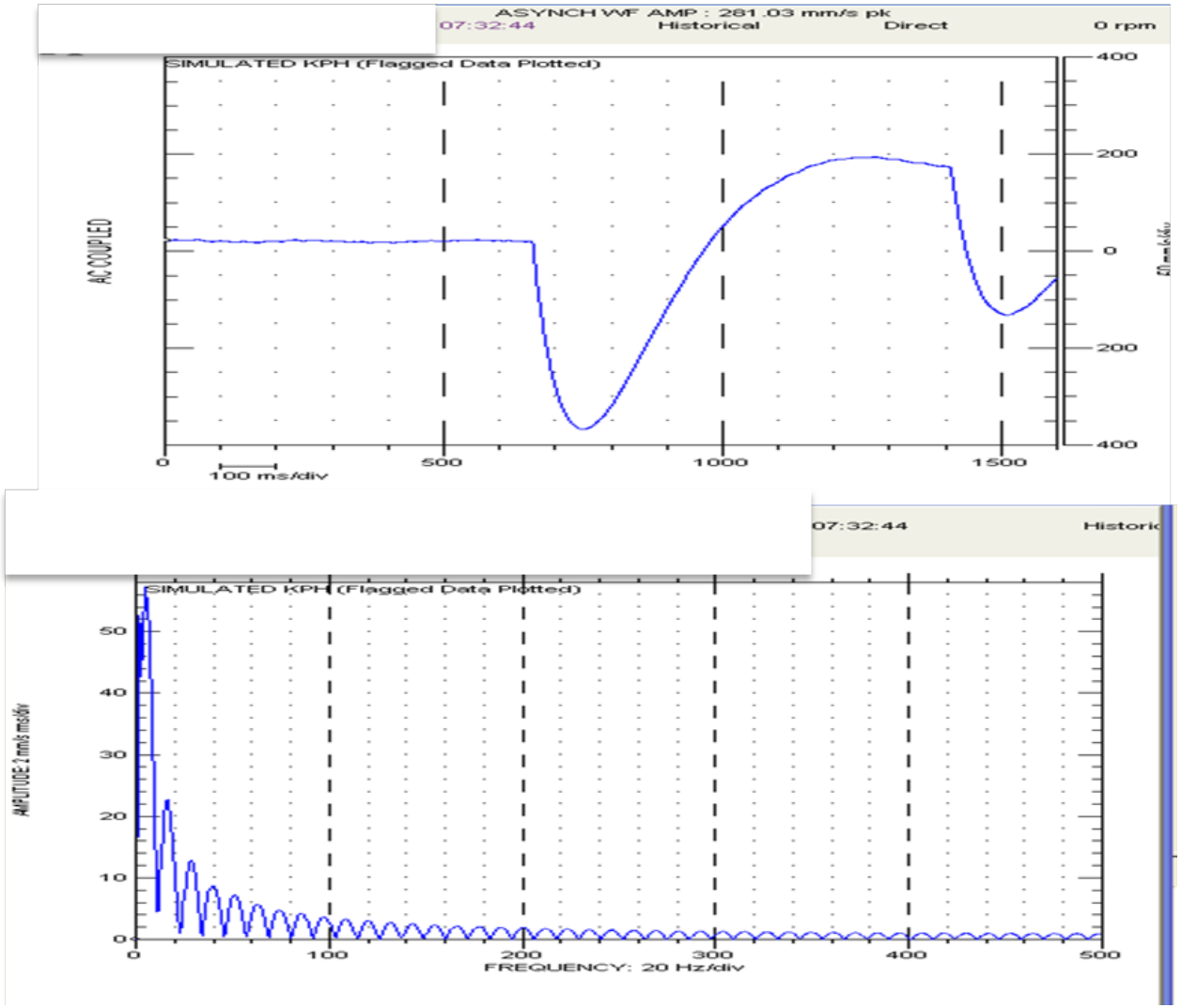
Time base and spectrum of vibration excursion



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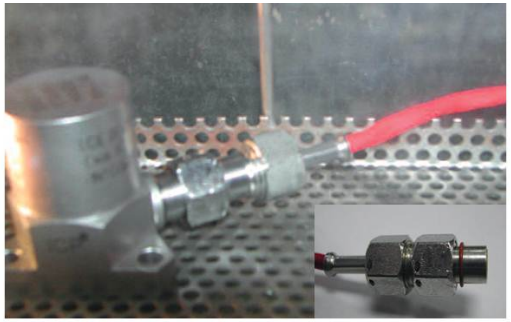
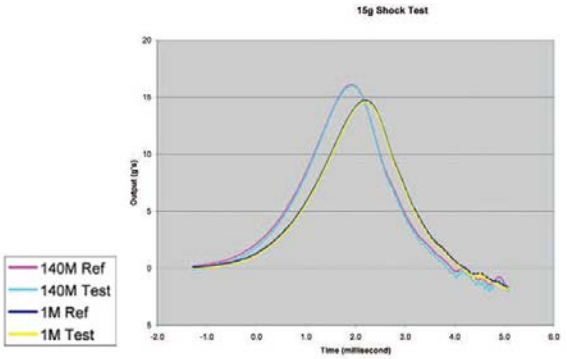
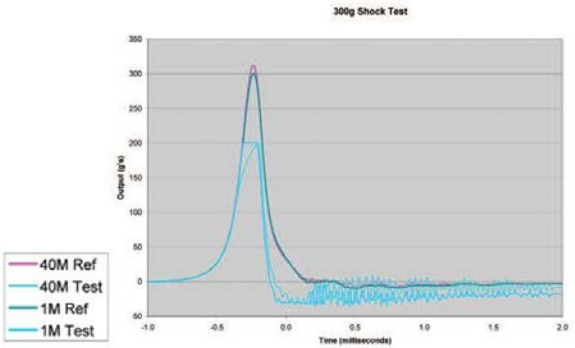


Accel/Cable Submerged in bubble leak detector fluid. No leaks found when using connector with supplied o-ring, unit failed when tested without o-ring in place.





Shock acceleration test with and without overload

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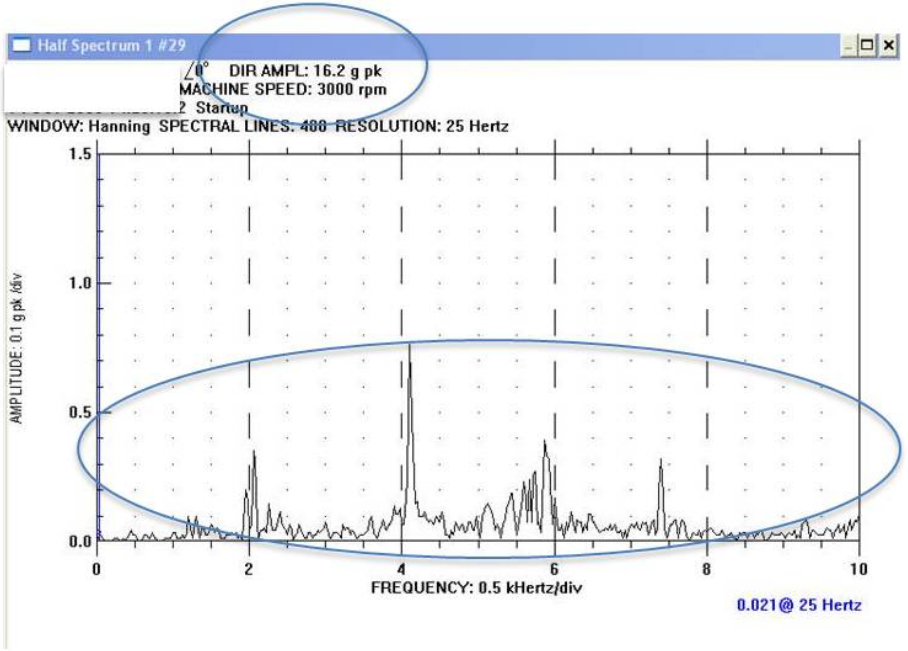
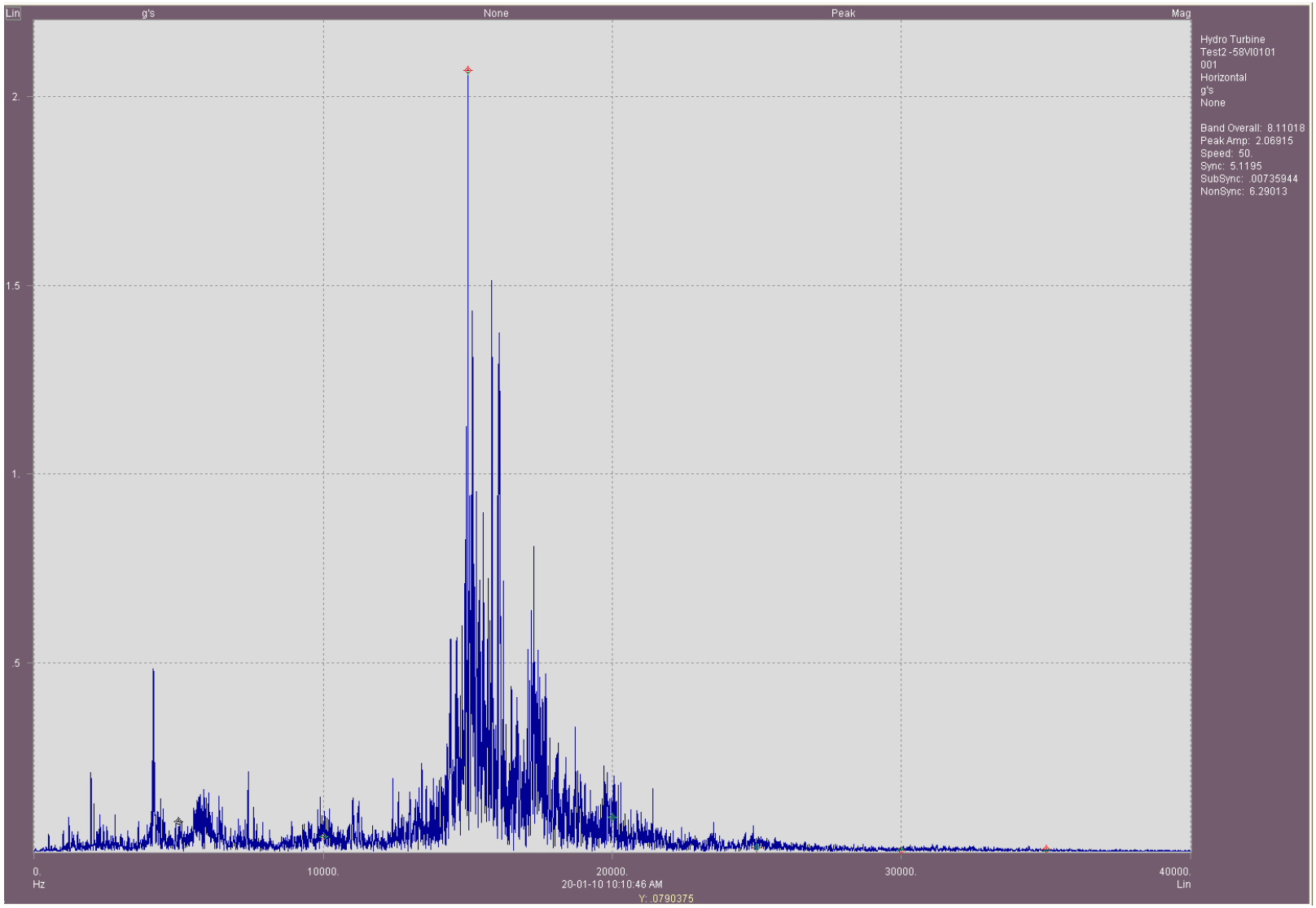
Direct amplitude, overall vibration signal <u>16.2 g Pk</u>

Vibration signal capture at less than 10KHz vibration signal <u>16.2 g Pk</u>



Spectrum from data collected at AIM Junction Box with 10000Hz frequency span and 400 lines spectrum



Spectrum from data collected at AIM (field) with a FS of 40KHz

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