Physical Components of Secondary Pump Condition-based Monitoring System

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Physical Portion

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Digital Portion

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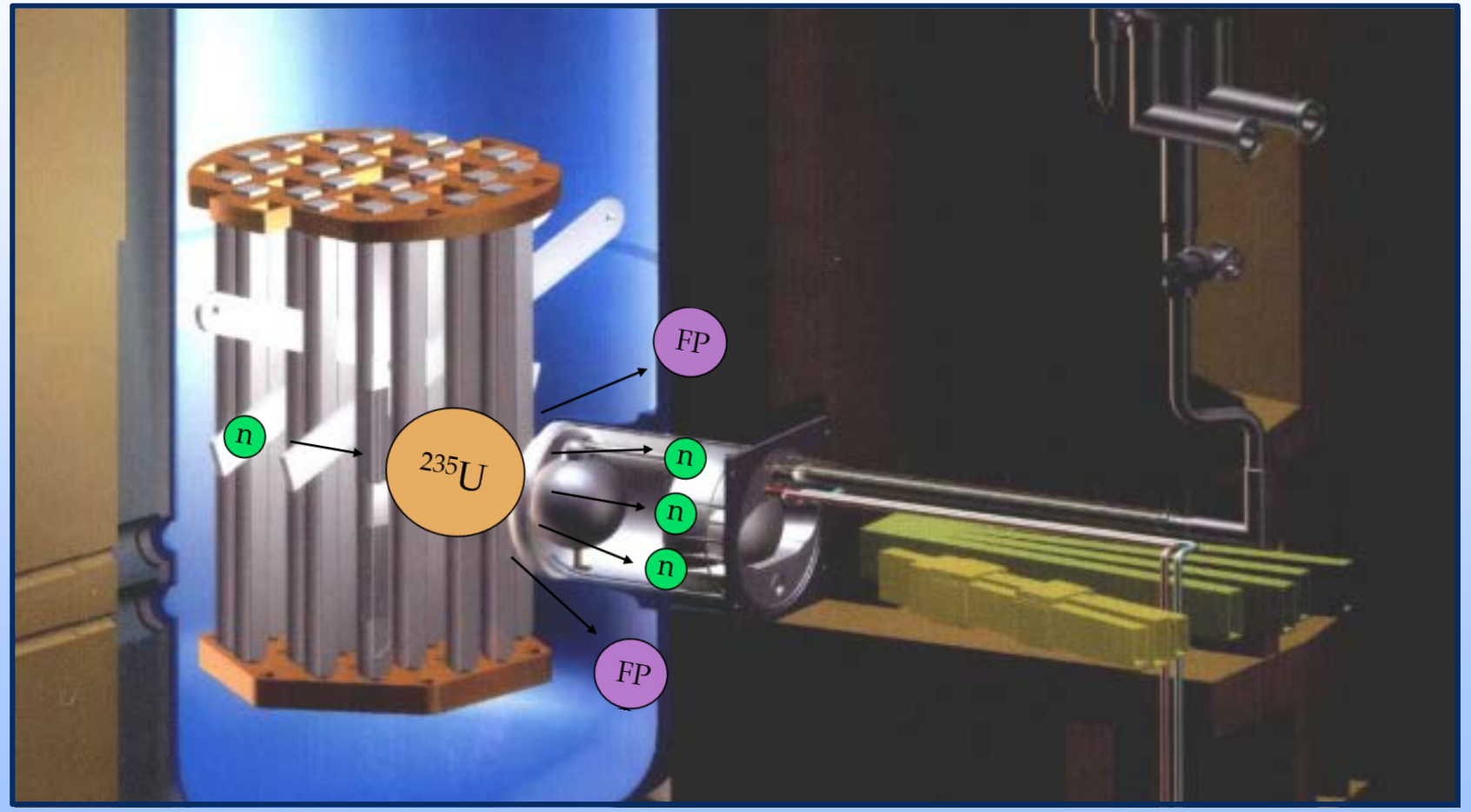
Outline

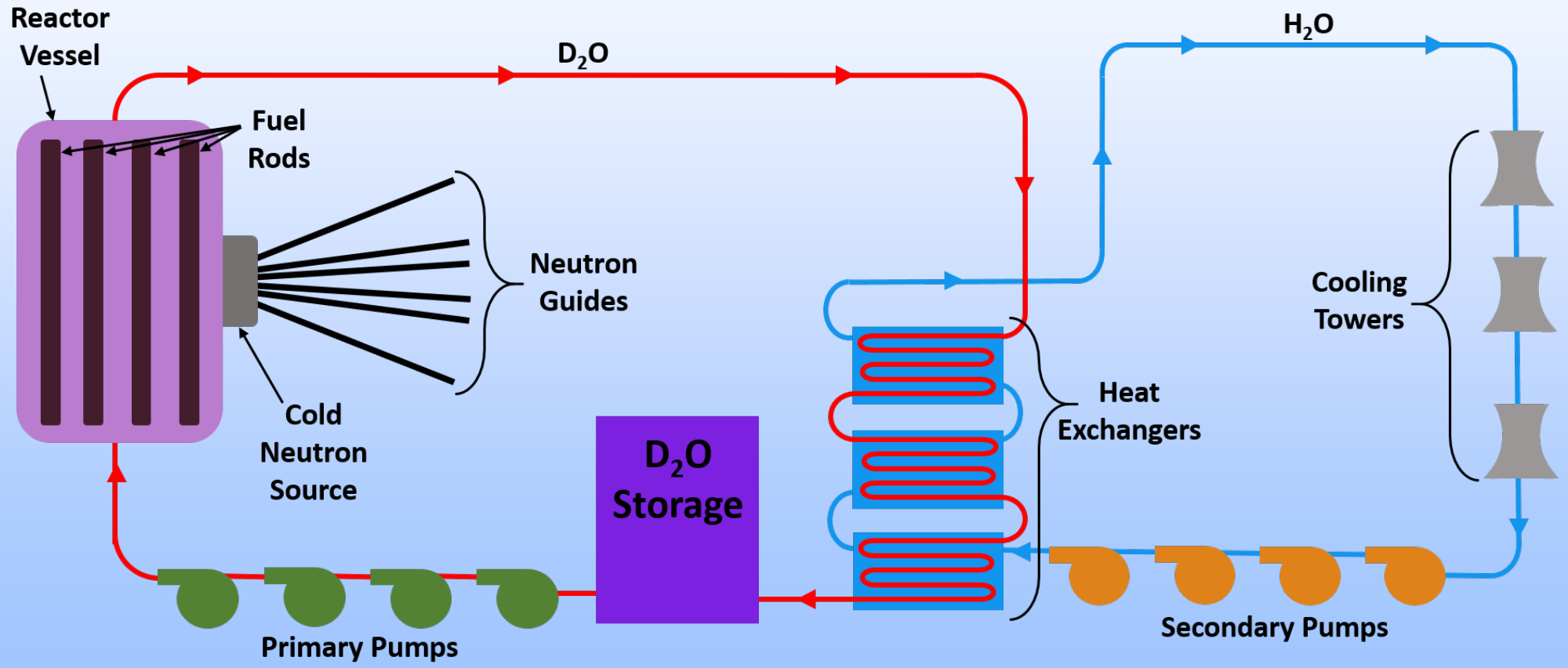
- Setting the Stage
- Techniques Used
  - Vibration Analysis
  - Temperature Analysis
- Conclusions
- Future Work/
  Additional Applications

The National Bureau of Standards Reactor (NBSR) is a heavy water reactor used for creating neutrons needed for research.



[https://www.ncnr.nist.gov/summerschool/ss07/bob_williams.pdf]

Secondary pumps circulate regular water that cools the heavy water leaving the reactor via external cooling towers.



Condition-based Monitoring (CBM) is a type of predictive maintenance that looks at the pump's current status.

The designed CBM system consists of two techniques: vibration and temperature analysis.

Vibration Analysis

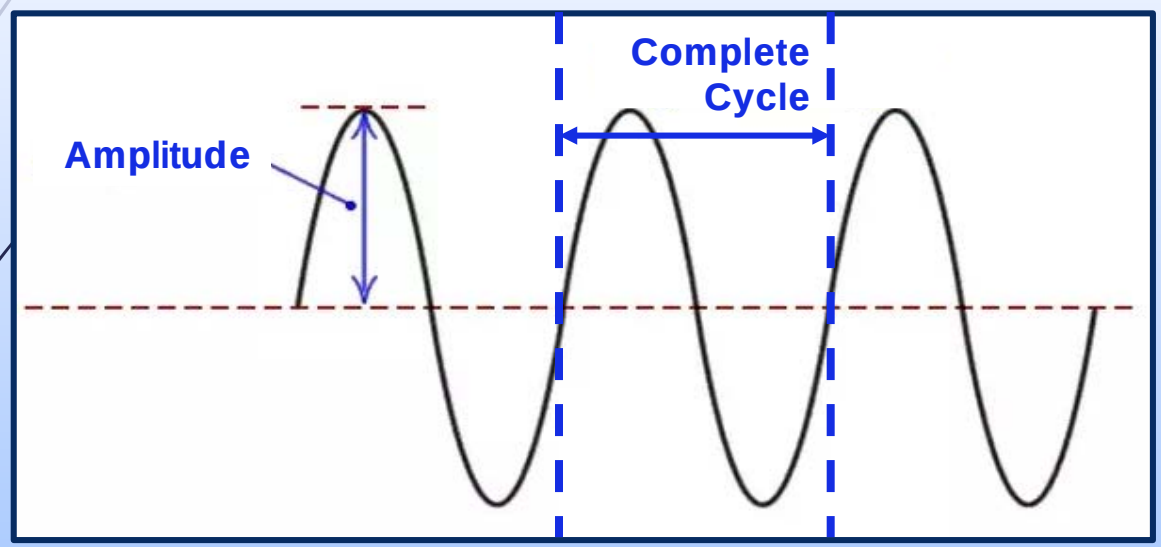
Temperature Analysis

[http://www.go4b.com/usa/datasheets/milli-temp-bearing-temperature-sensor.pdf]

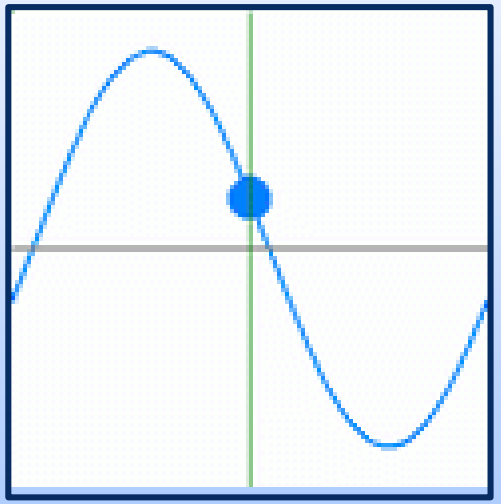
Vibration Analysis Explanation

How it works

Vibration analysis data is recorded in the form of sine waves; these waves are defined using *amplitude* and *frequency*.

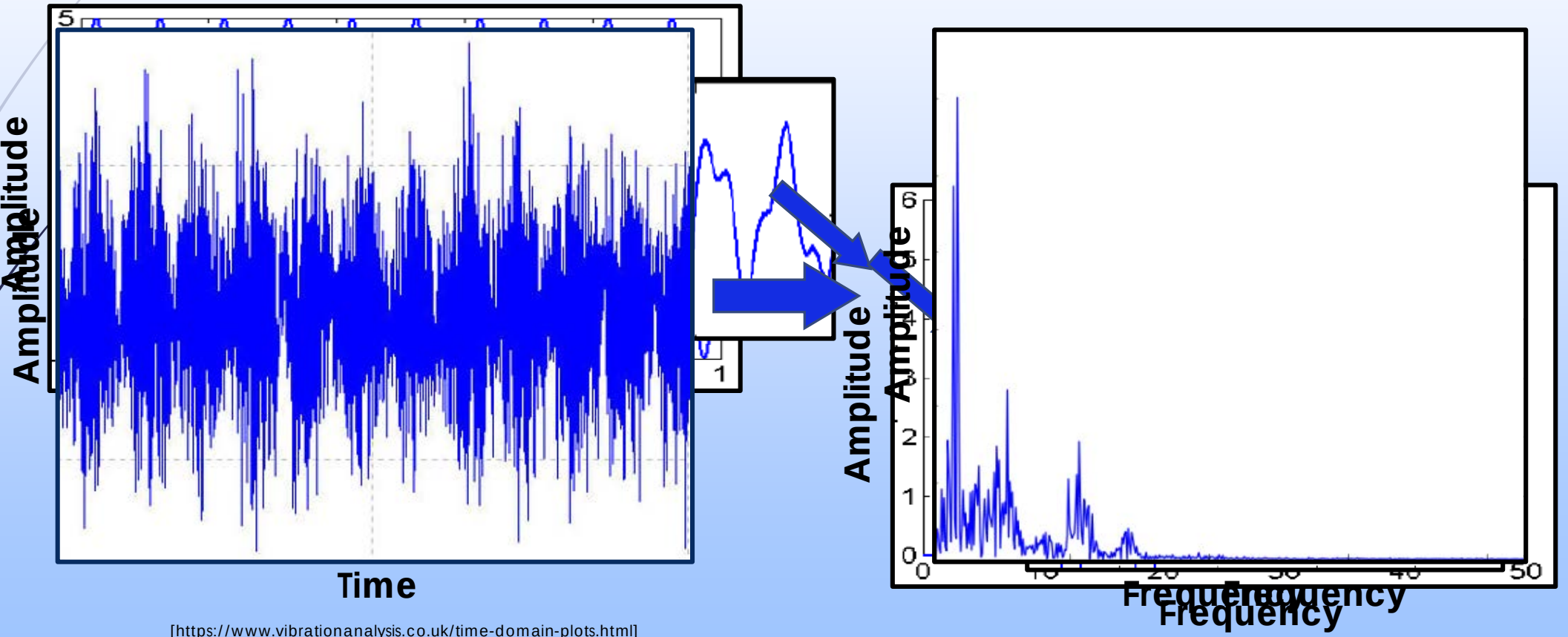


[https://www.quora.com/What-is-the-amplitude-of-a-light-wave]



[https://commons.wikimedia.org/w/index.php?curid=14994157]

The recorded data is graphed on a frequency plot, instead of a time plot, because it is filtered using *Fast Fourier Transform* (FFT).

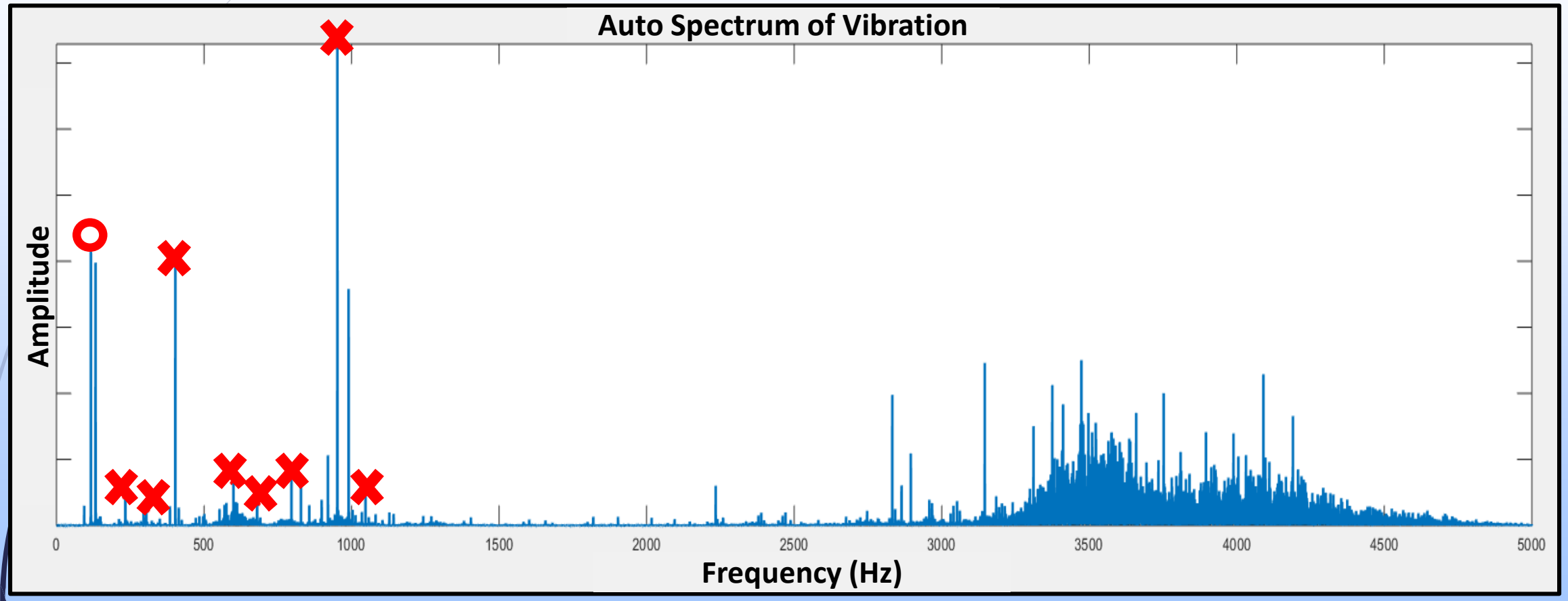


[https://www.vibrationanalysis.co.uk/time-domain-plots.html]

[https://ham.stackexchange.com/questions/5052/losing-low-frequencies-in-am-transmission]

[http://www.hds.bme.hu/~fhegedus/VibrationMonitoring/Literature/Pump_Condition_Monitoring_Through_Vibration_Analysis_Cornelius_Scheffer_2008.pdf]

The filtered data must be analyzed for it to be useful: this is done by picking peaks at important frequencies.



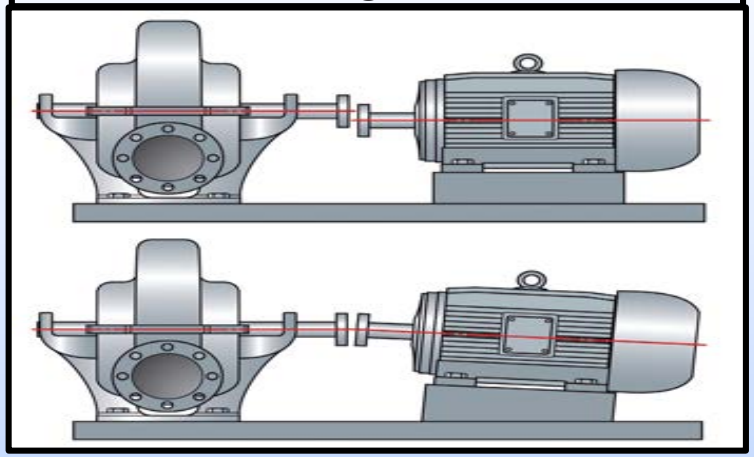
= VPF

= Multiples

$$VPF = (Operating\ Speed) \times (Number\ of\ Vanes)$$

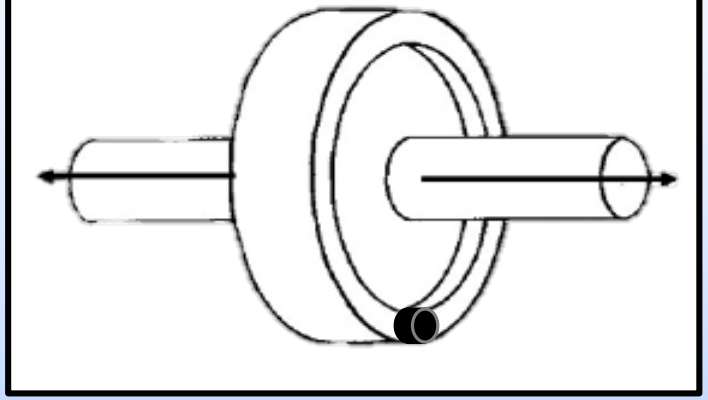
The important peak(s) correspond to different faults that could be affecting the pumps.

Misalignment



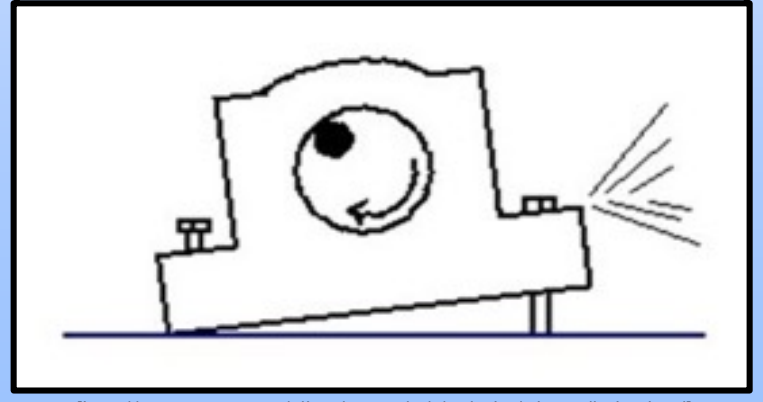
[https://www.flowcontrolnetwork.com/the-importance-of-shaft-alignment/]

Unbalance



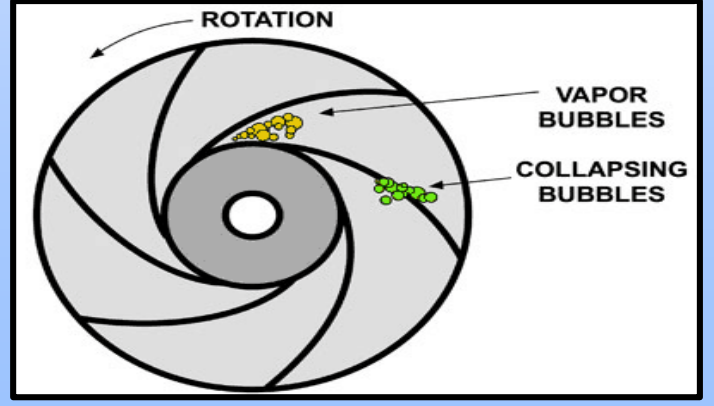
[https://www.pumpsandsystems.com/topics/pumps/centrifugal-pumps/]

Looseness



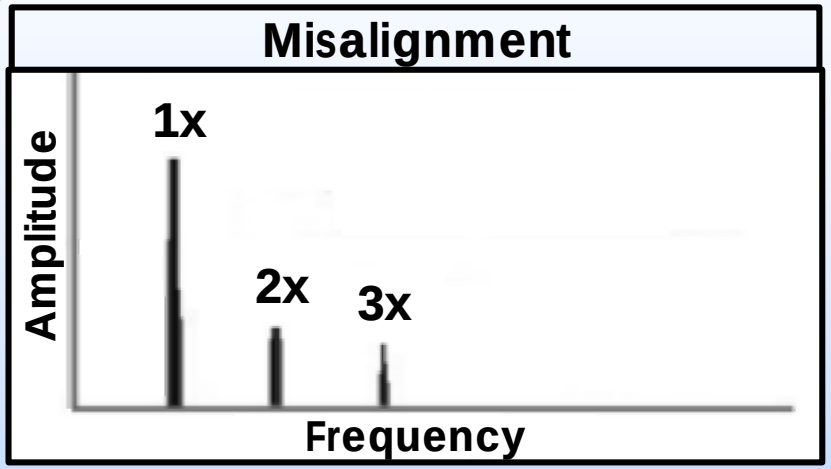
[http://www.rotor.zone/vibrationanalysis/styled-7/photos/index.html]

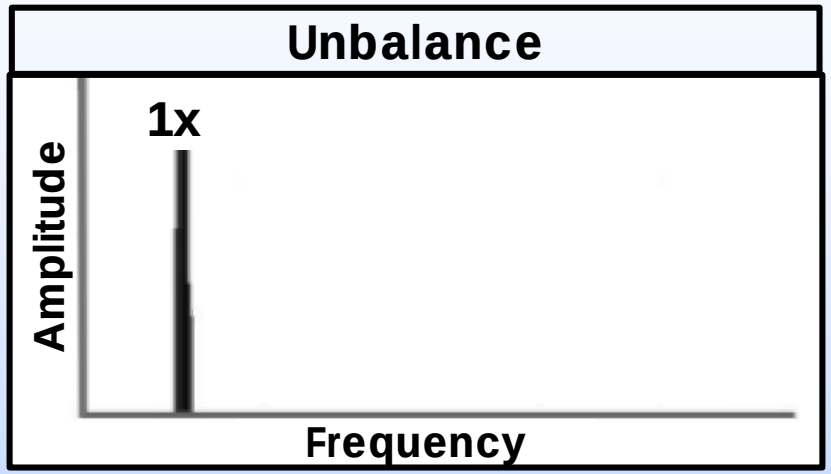
Cavitation

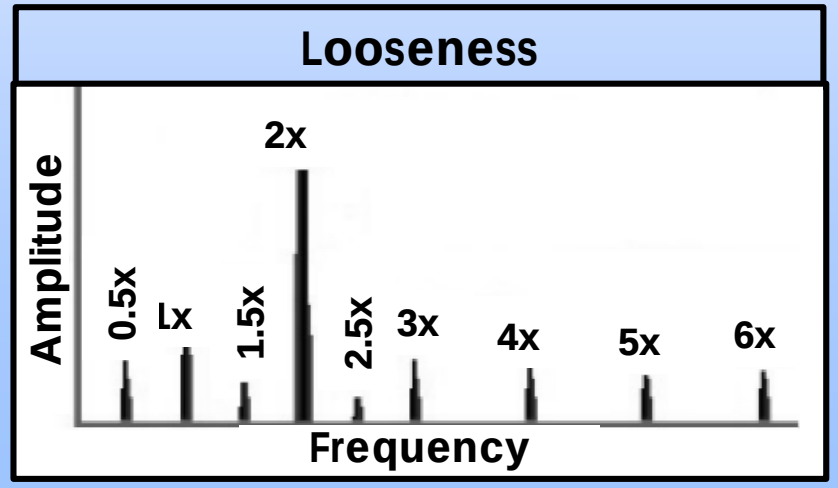


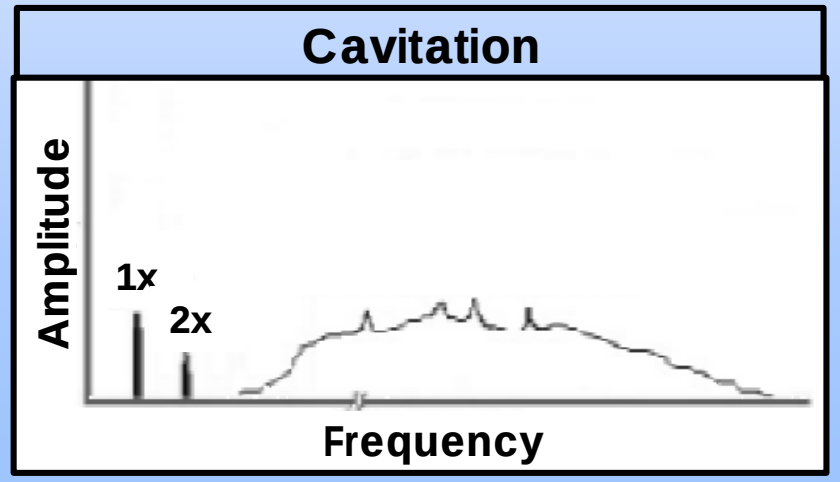
[https://www.nuclear-power.net/nuclear-engineering/fluid-dynamics/centrifugal-pumps/cavitation/suction-cavitation/]

The faults are identified by their spectra that consist of a specific combination of peaks at certain frequencies.



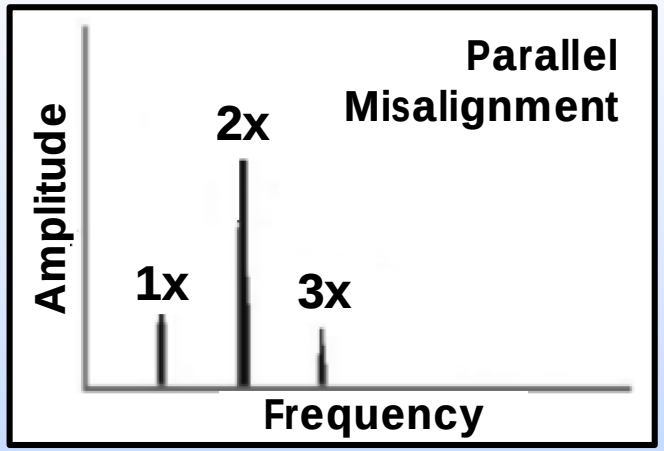


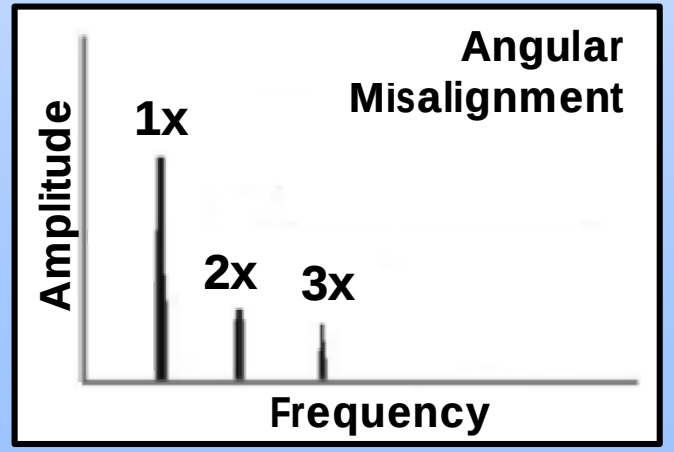


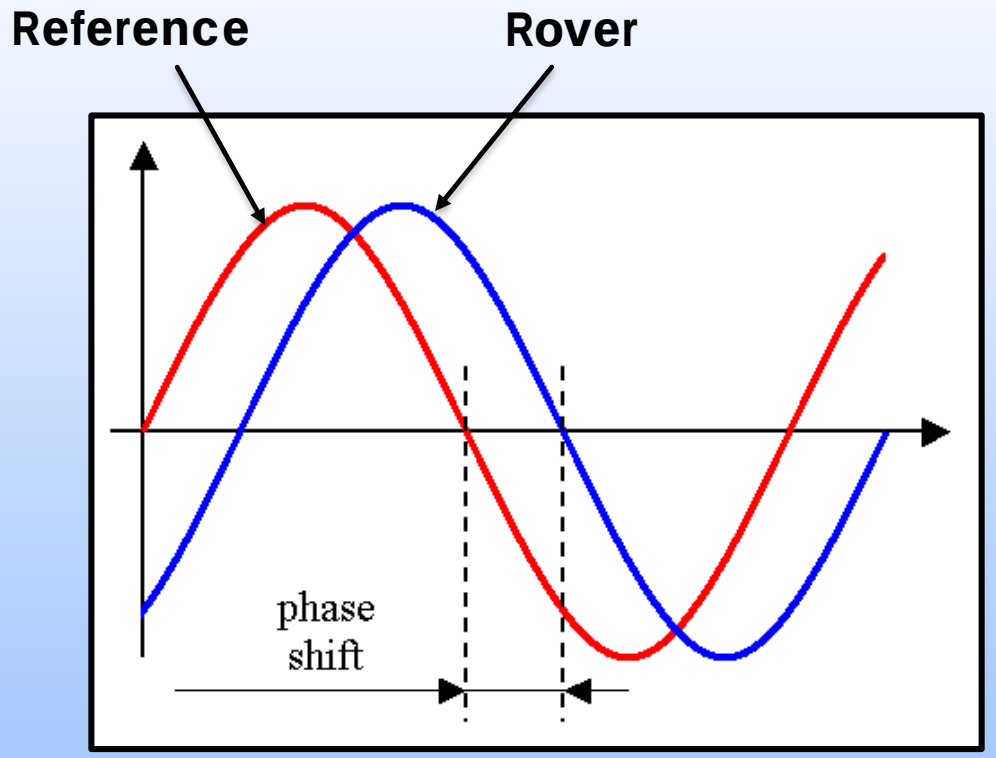


[http://www.hds.bme.hu/~fhegedus/VibrationMonitoring/Literature/Pump_Condition_Monitoring_Through_Vibration_Analysis_Cornelius_Scheffer_2008.pdf]

The graphs of some faults look similar, so *phase analysis* is employed to confirm the pump's diagnosis.



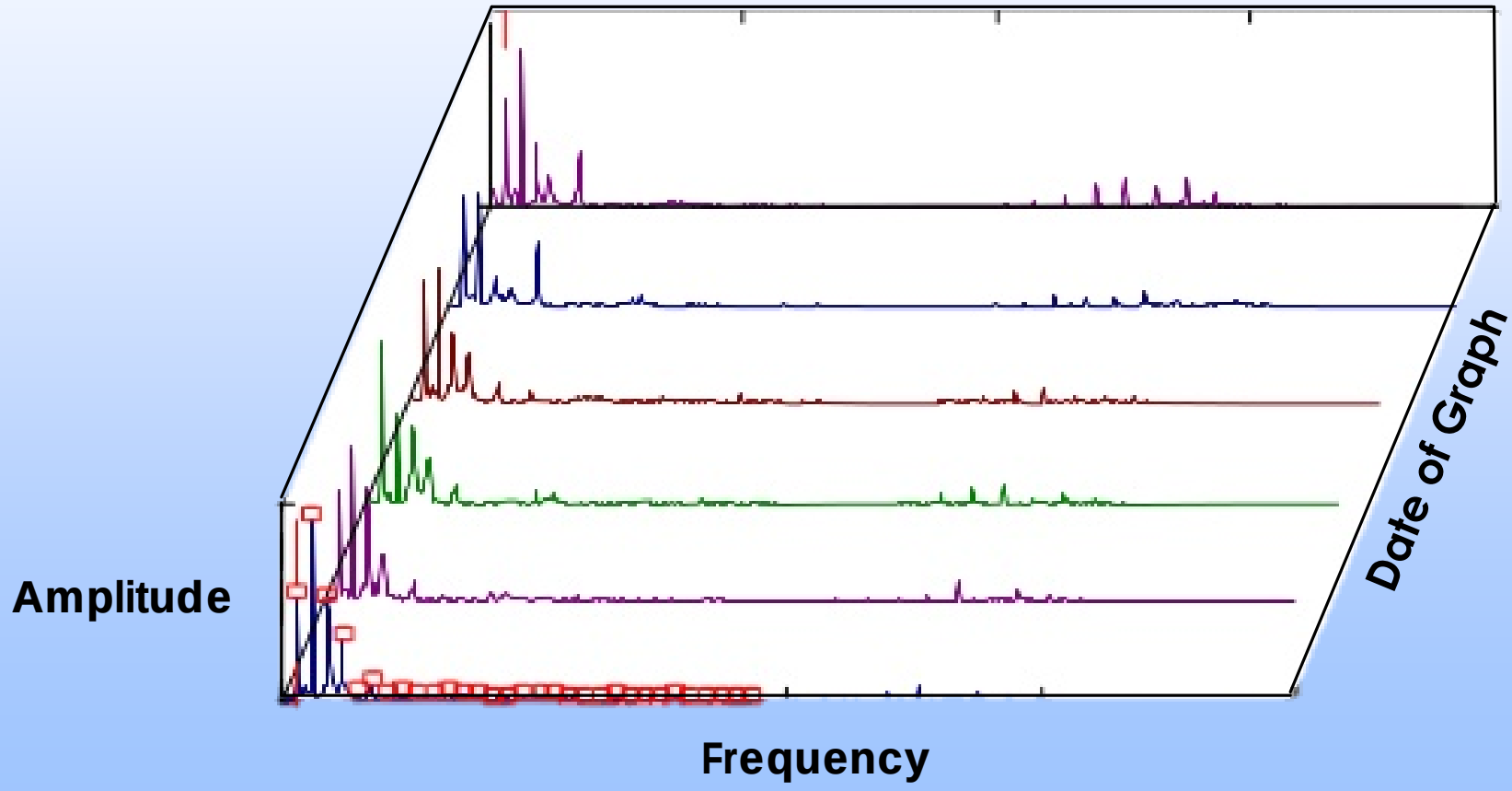




[https://commons.wikimedia.org/wiki/File:Phase_shift.png]

[http://www.hds.bme.hu/~fhegedus/VibrationMonitoring/Literature/Pump_Condition_Monitoring_Through_Vibration_Analysis_Cornelius_Scheffer_2008.pdf]

Once possible faults are identified readings are taken, over time, and compared to the machine's known vibration signature.



[https://www.slideshare.net/makarandnikume/rt-2008-principles-and-practices-of-vibrational-analysis-keefer]

Vibration Analysis Equipment

Physical Sensors

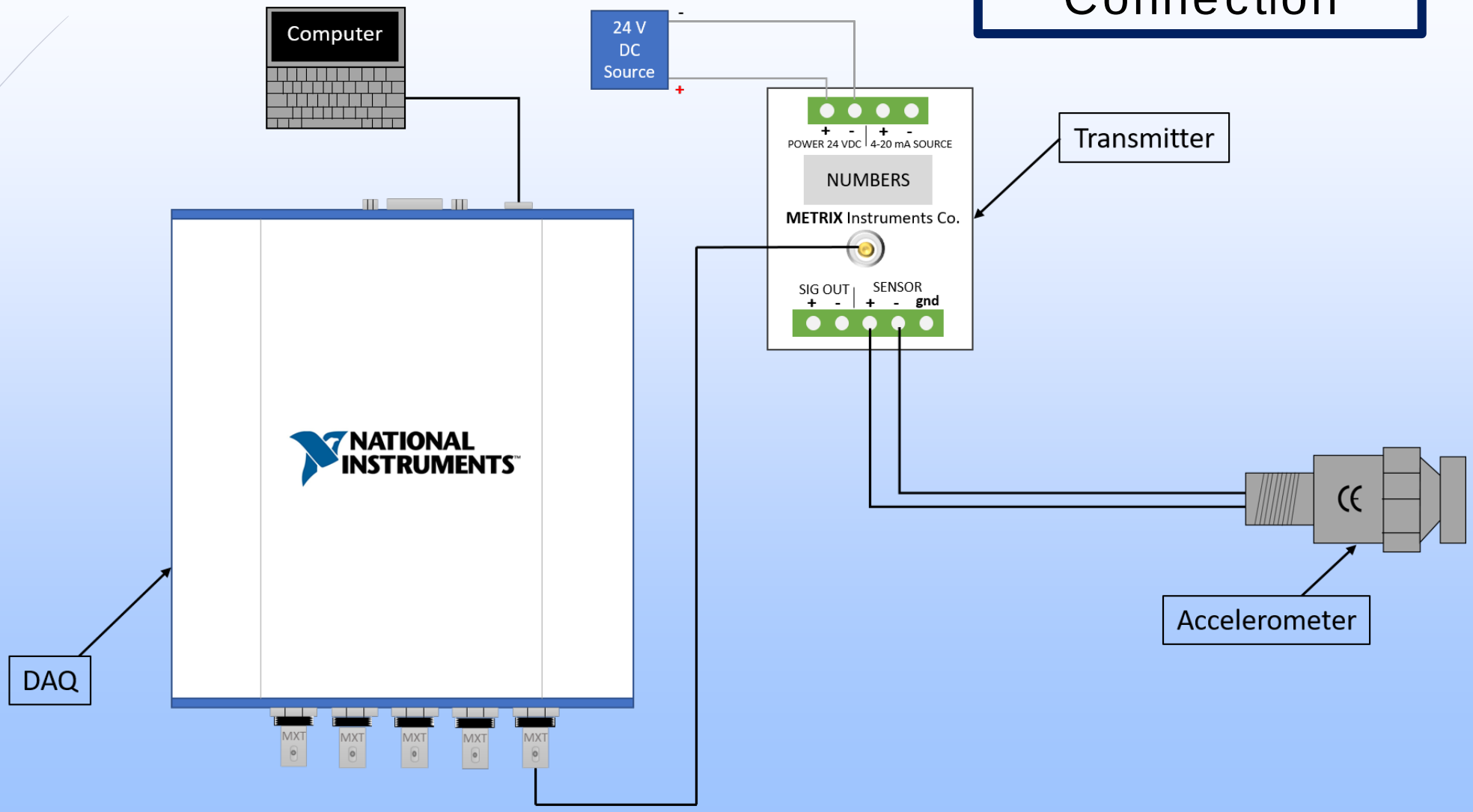
The vibration analysis system consists of accelerometers, transmitter, and a Data Acquisition Device (DAQ).

Accelerometer

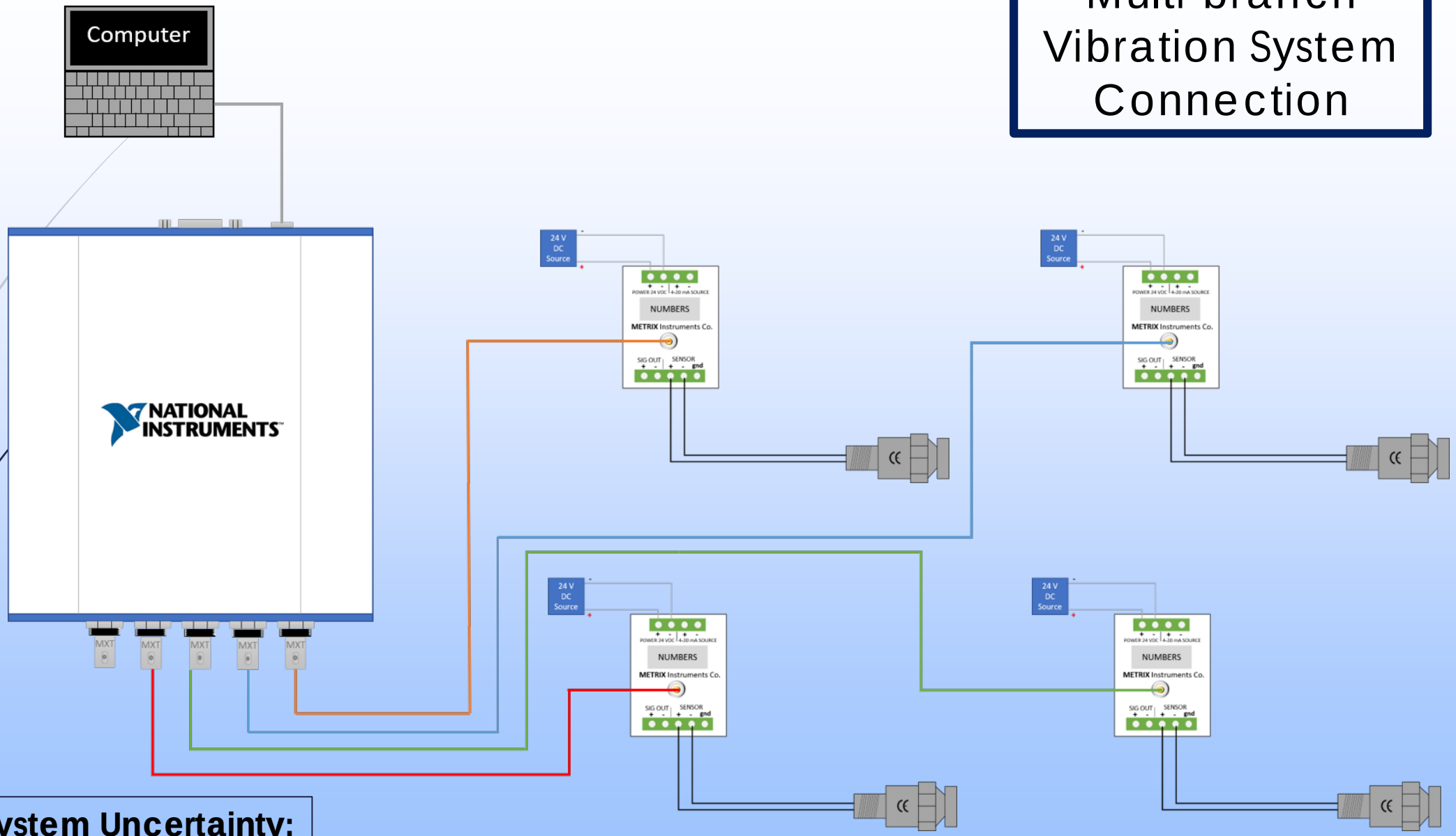
Transmitter

Data Acquisition Device

Single Branch Vibration System Connection



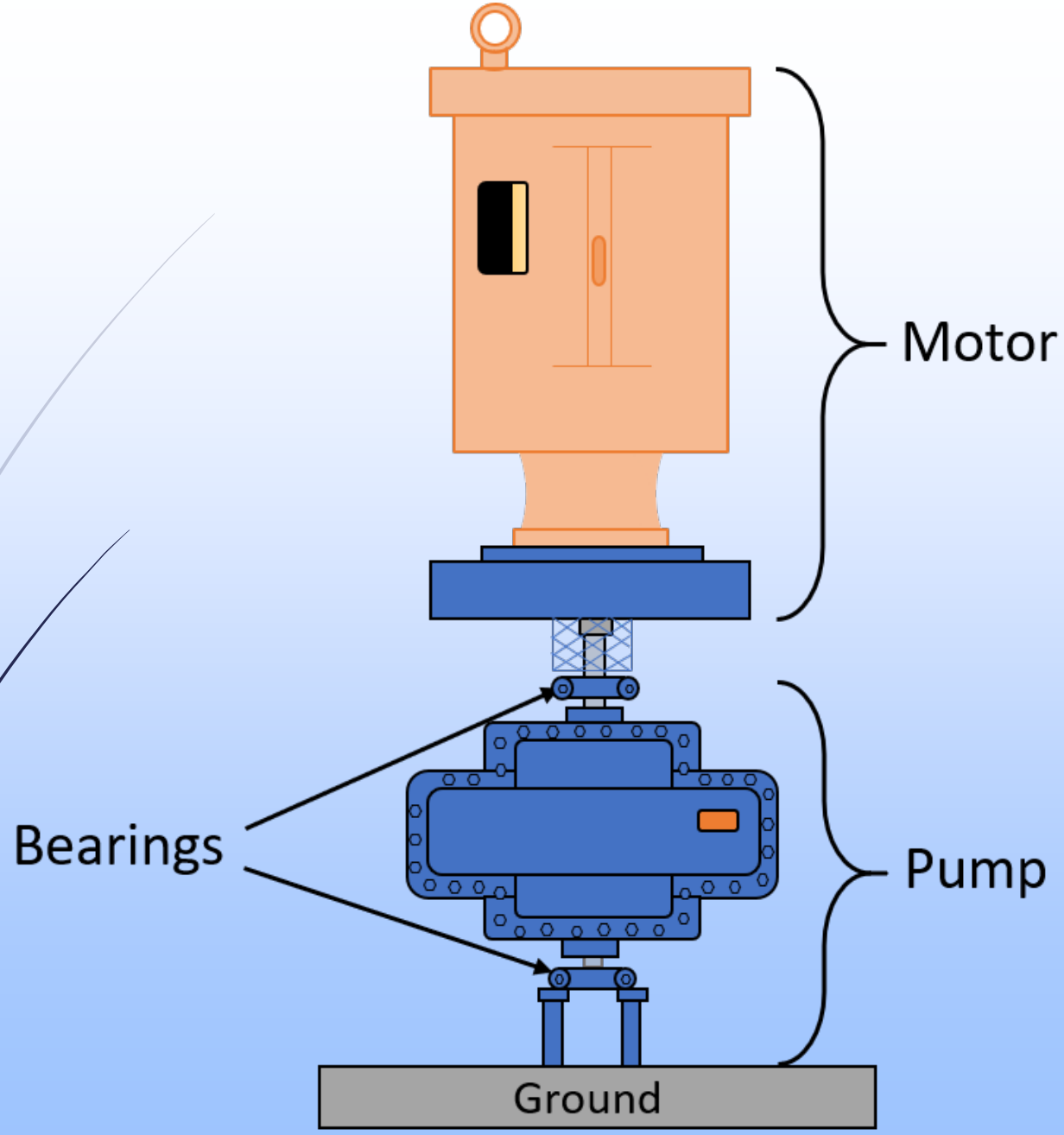
Multi-branch Vibration System Connection



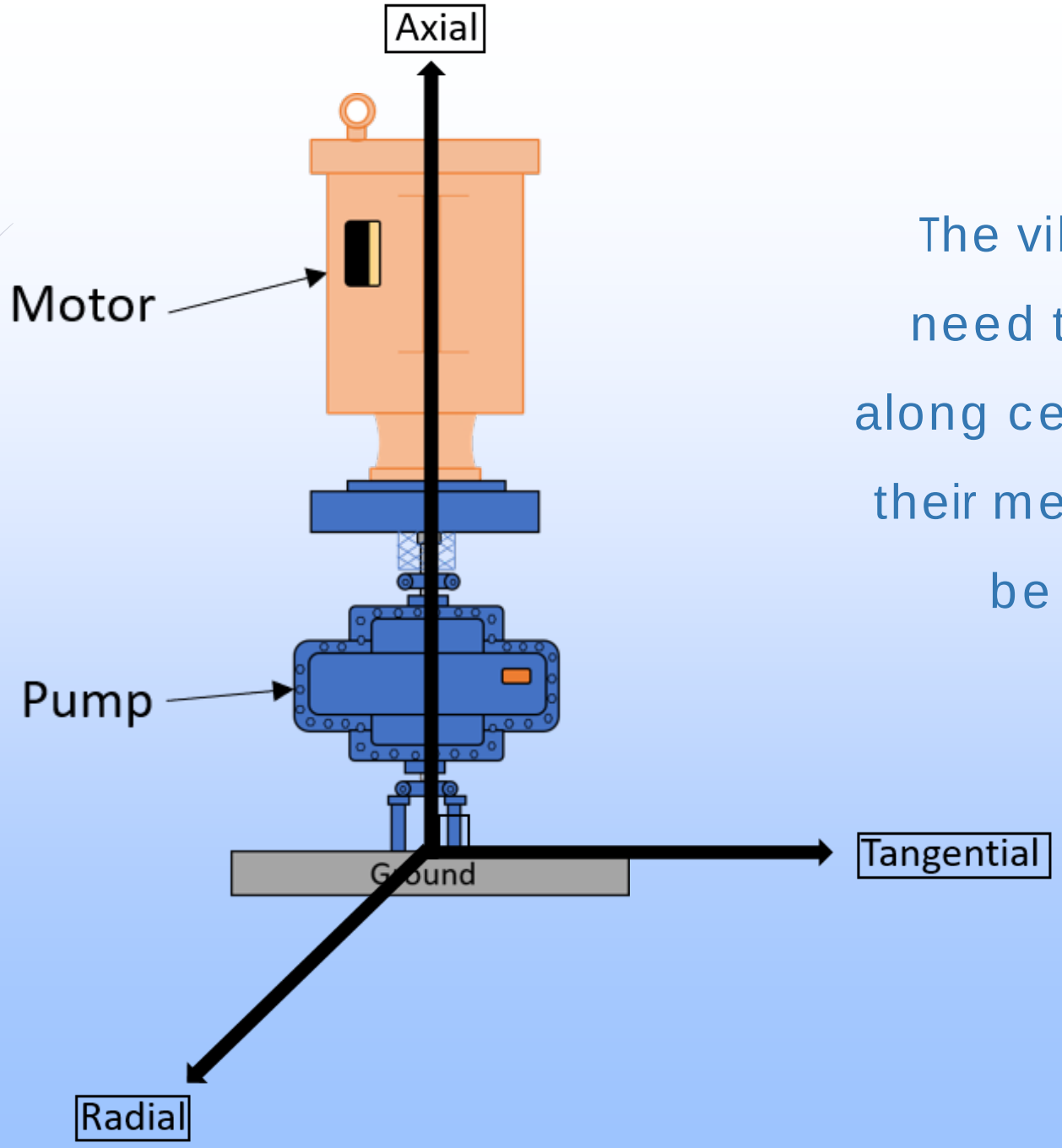
System Uncertainty: 6.4236%

Vibration Analysis Application

Mounting the sensors & recording data



All of the sensors used get mounted onto a secondary pump, which is part of a pump-motor setup.



The vibration sensors need to be mounted along certain axes so that their measurements can be compared.

Specific locations to mount the sensors onto must be carefully chosen to follow strict criteria.

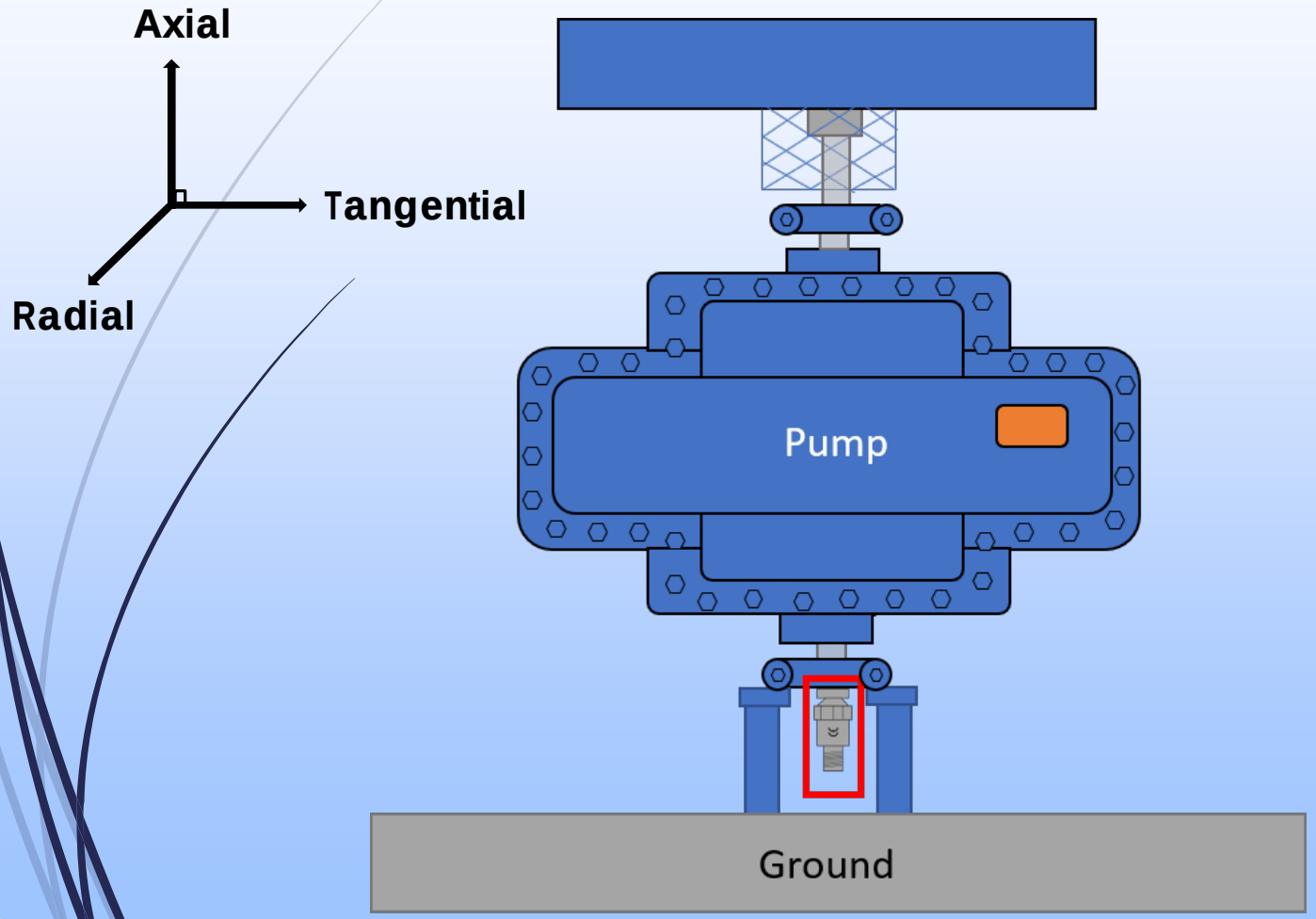
Position Criteria

- [x] Close to the vibration source

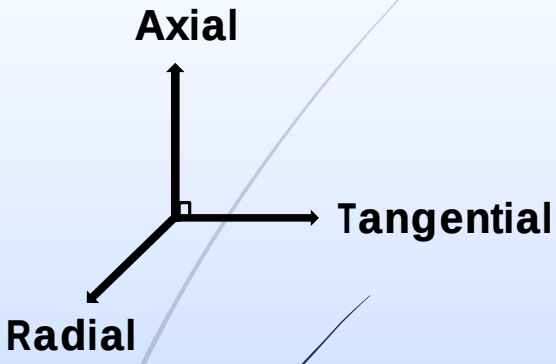
Surface Criteria

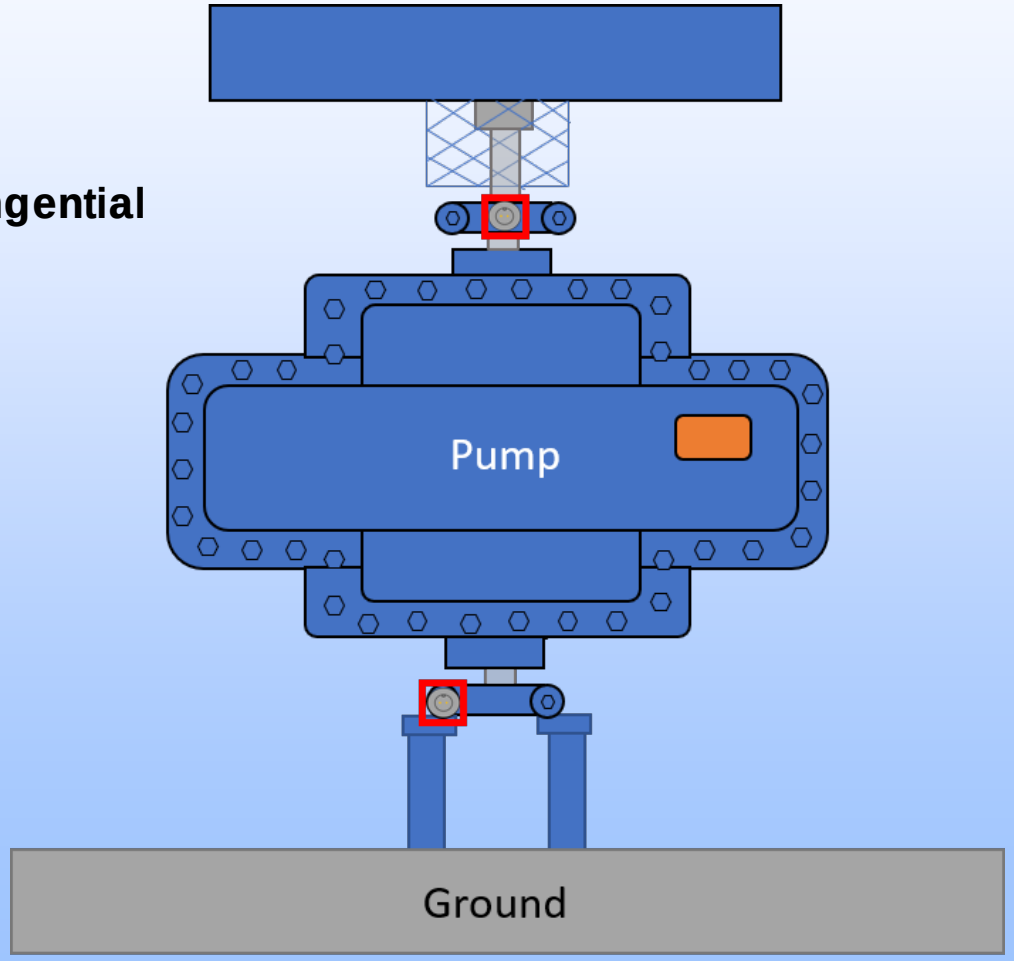
- [x] Clean
- [x] Relatively smooth
- [x] Wider than the sensor
- [x] Flat (for flat magnets)

Sensor Mounting in the Axial Direction

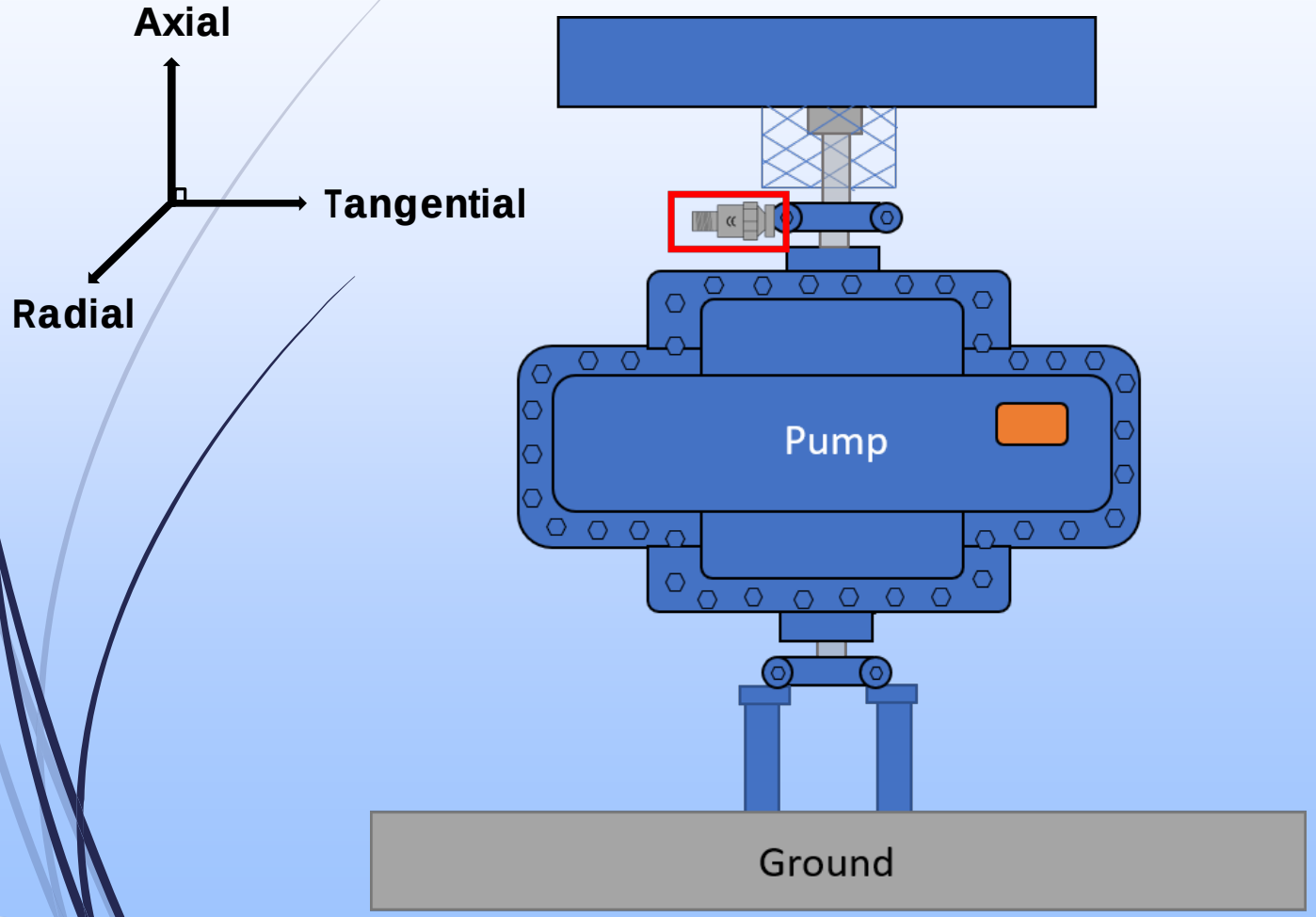


Sensor Mounting in the Radial Direction





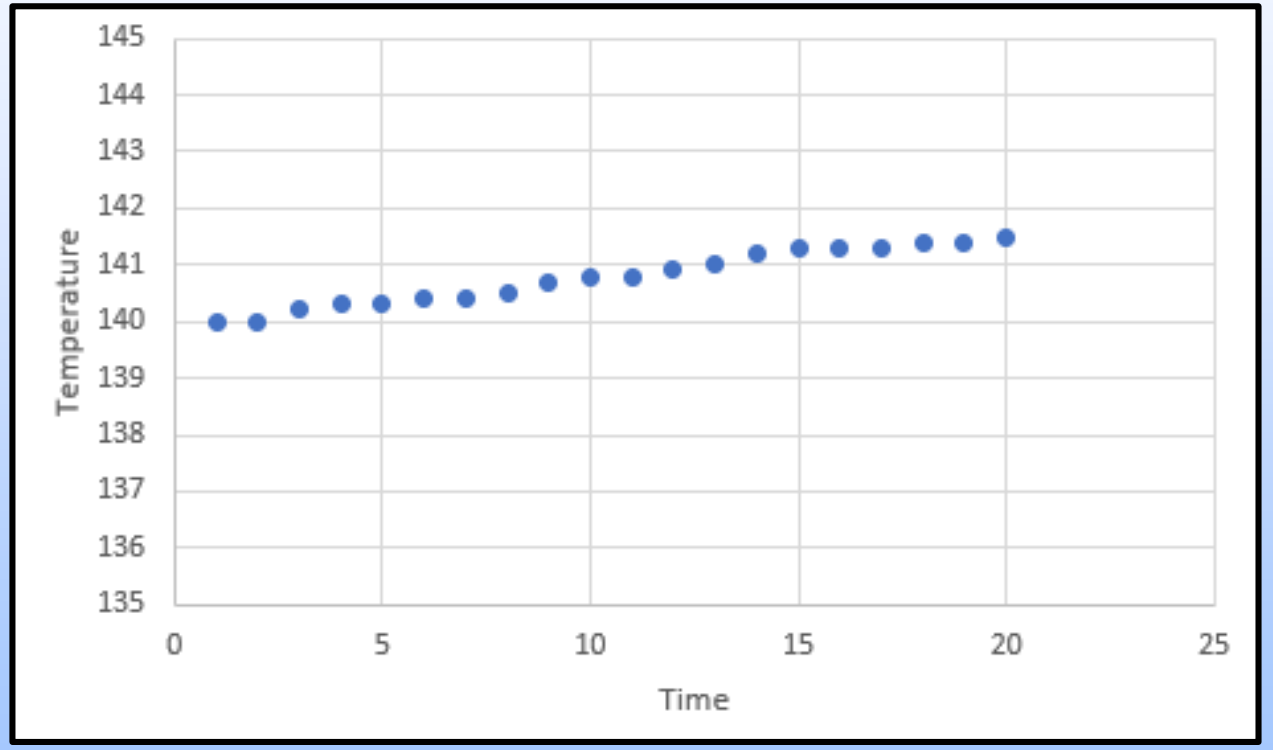
Sensor Mounting in the Tangential Direction



Temperature Analysis

Overview

Temperature analysis records temperature, over a long period of time, to watch for any trends.



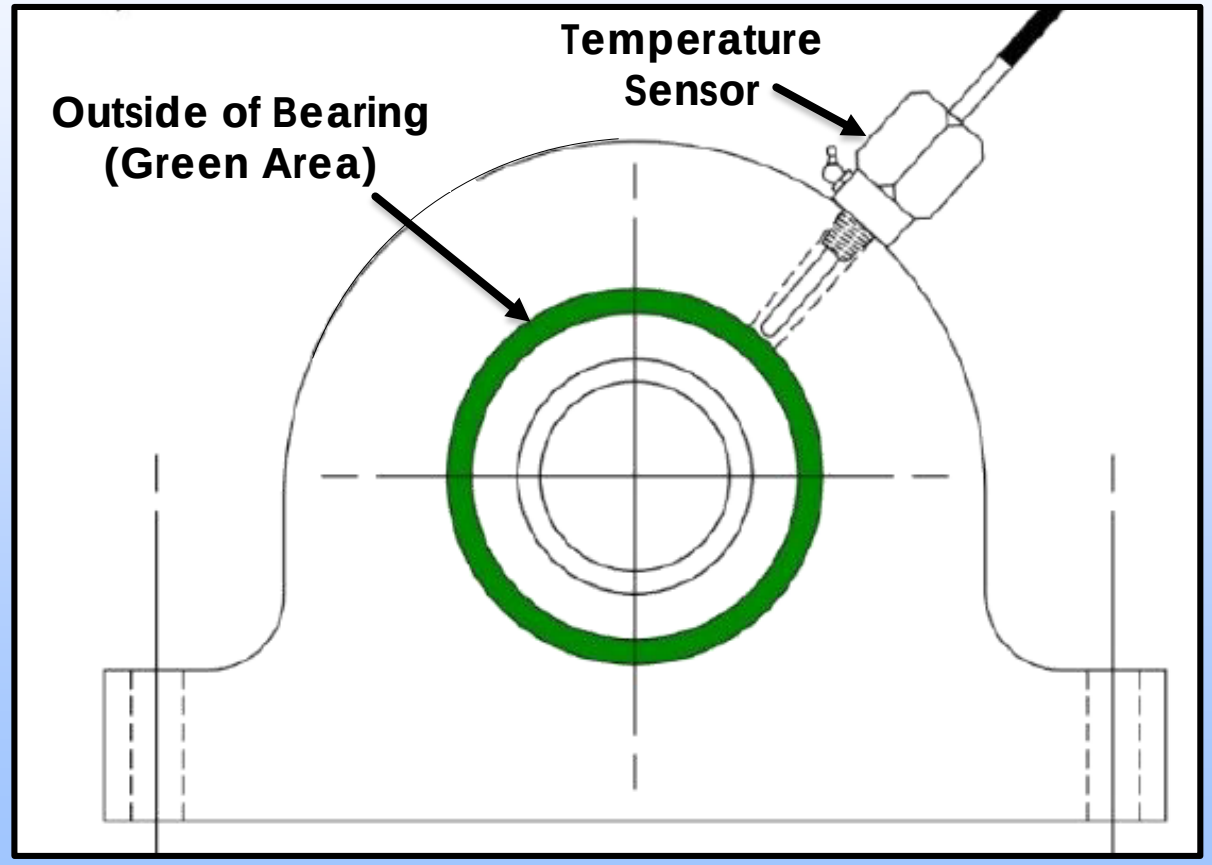
Temperature dependence on time

Temperature inside the bearings is used because bearing oil temperature increases as they wear.

[http://www.go4b.com/usa/datasheets/milli-temp-bearing-temperature-sensor.pdf]

[http://www.go4b.com/usa/datasheets/milli-temp-bearing-temperature-sensor.pdf]

The temperature sensor is inserted into the grease zerk of the bearing to take internal temperature readings.



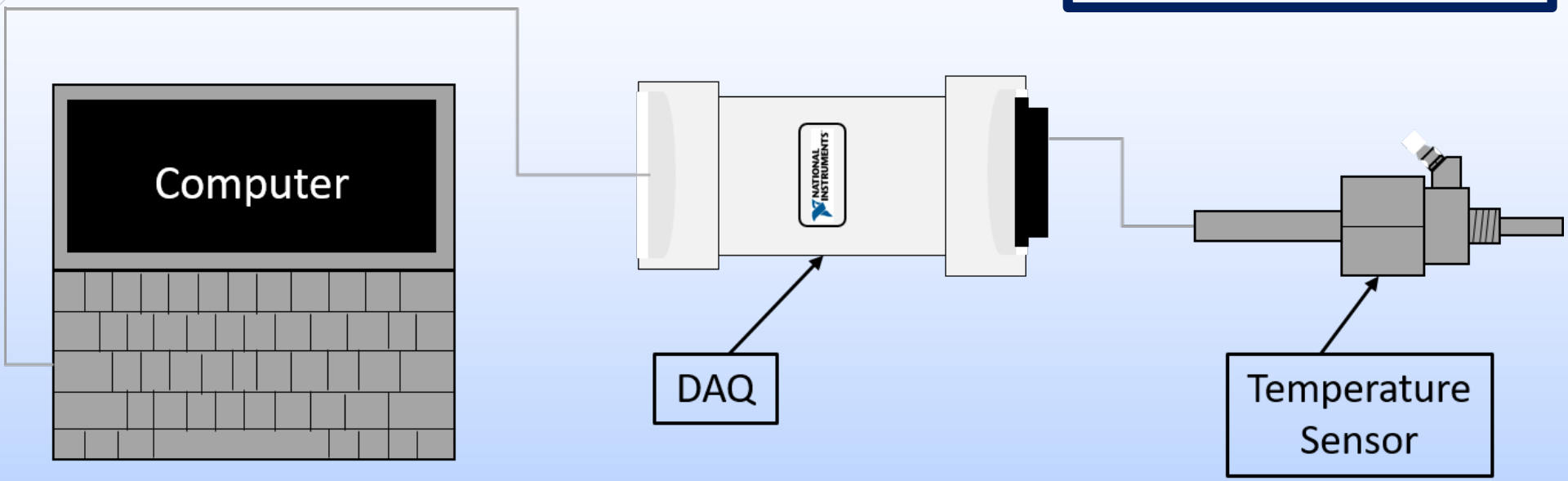
[http://www.go4b.com/usa/datasheets/milli-temp-bearing-temperature-sensor.pdf]

The temperature analysis system consists of a temperature sensor, called a Resistance Temperature Detector (RTD), and a DAQ.

Temperature Sensor

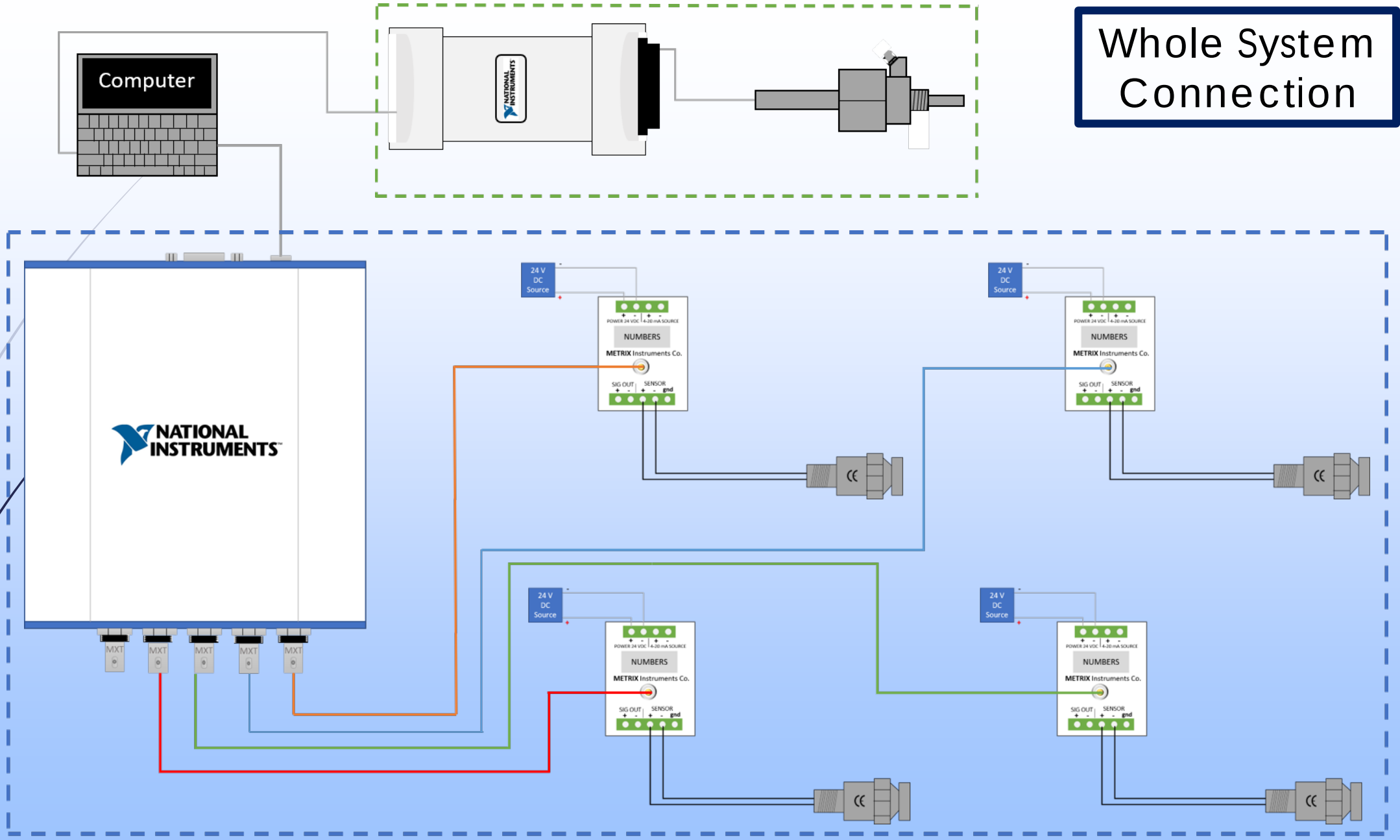
Data Acquisition Device

Temperature System Connection

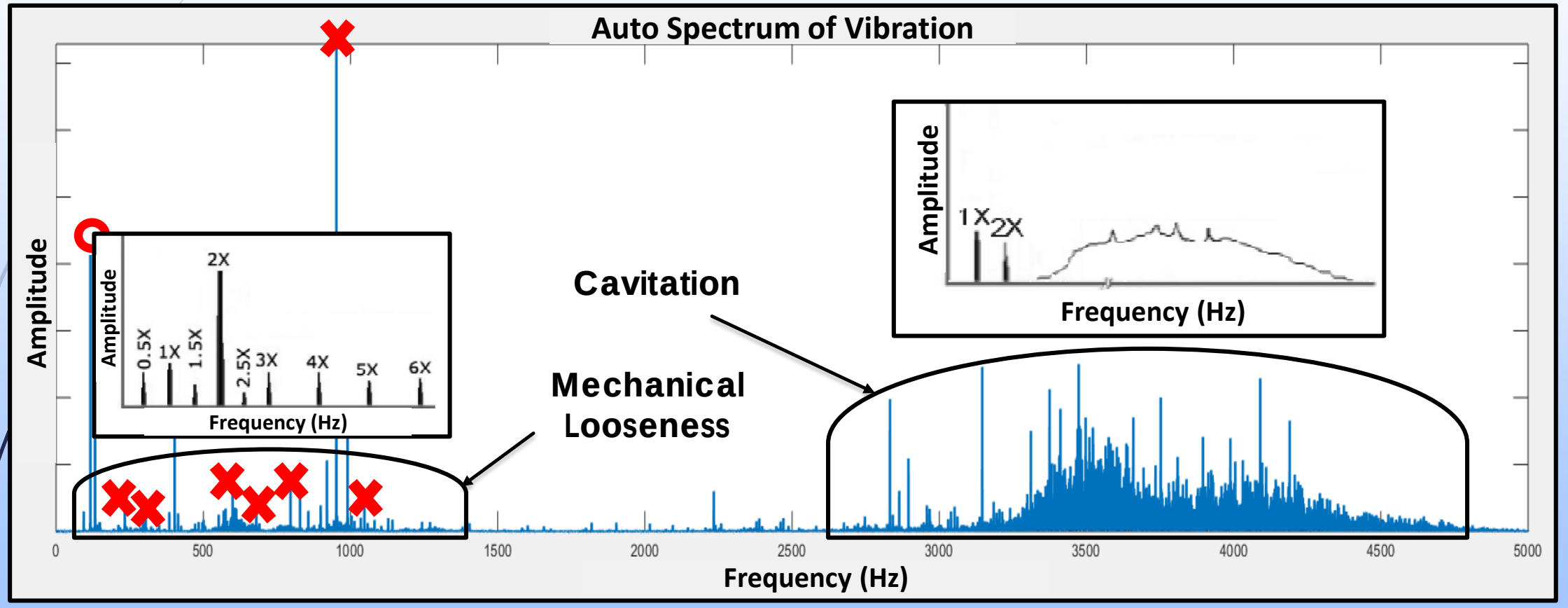


System Uncertainty: 1.3457%

Whole System Connection



Conclusions



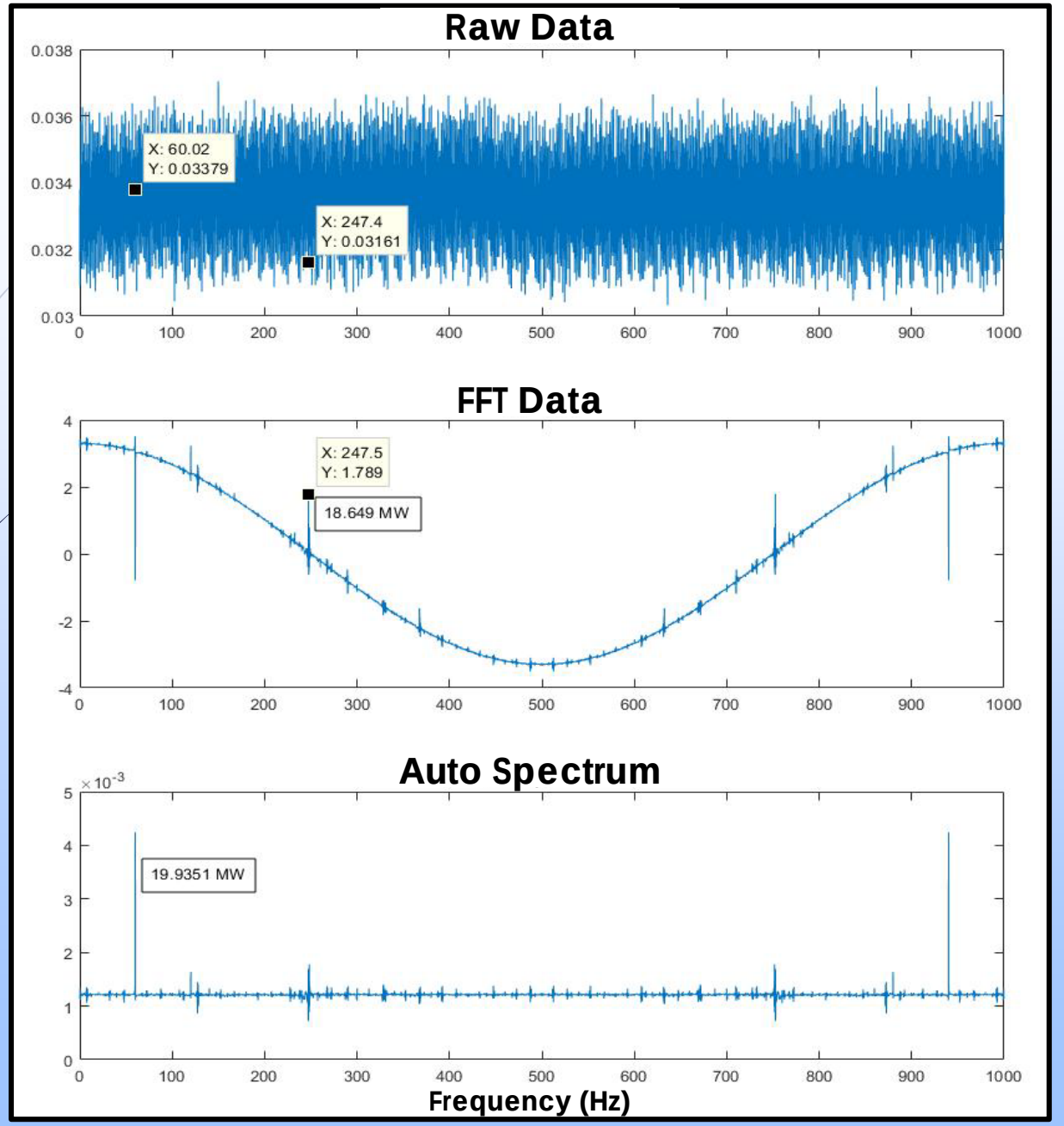
[http://www.hds.bme.hu/~fhegedus/VibrationMonitoring/Literature/Pump_Condition_Monitoring_Through_Vibration_Analysis_Cornelius_Scheffer_2008.pdf]

Future Work/ Additional Applications

Vibration analysis can be used in a variety of other applications, such as crack detection in reactor vessels.

[https://www.indiamart.com/proddetail/reactor-vessel-3093578291.html]

[http://blog.onlinemetals.com/weldability-of-stainless-steel/]



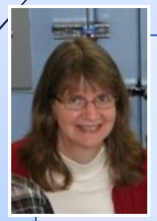
Future work includes using FFT and auto spectrum to filter power data from nuclear channels.

Acknowledgements

Muhammad Afridi, PhD

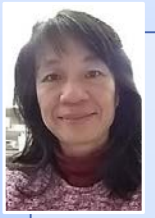
Richard Allen

Scott Arneson



Julie Borchers, PhD

Joseph Dura, PhD



Heather Chen-Mayer, PhD

Sam MacDavid

Mitchell Stansloski, PhD, PE

Danyal Turkoglu, PhD

Acknowledgements

Special Thanks

Dağistan Şahin, PhD

Marcus Schwaderer, MBA, COR II, PM II

Abdullah Weiss, EIT

Questions


NSF
CHRNS
CENTER FOR HIGH RESOLUTION NEUTRON SCATTERING
NIST