Condition-based Monitoring Infrastructure Upgrades at the NCNR

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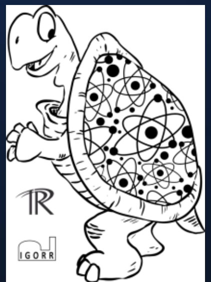

Introduction: NCNR & NBSR

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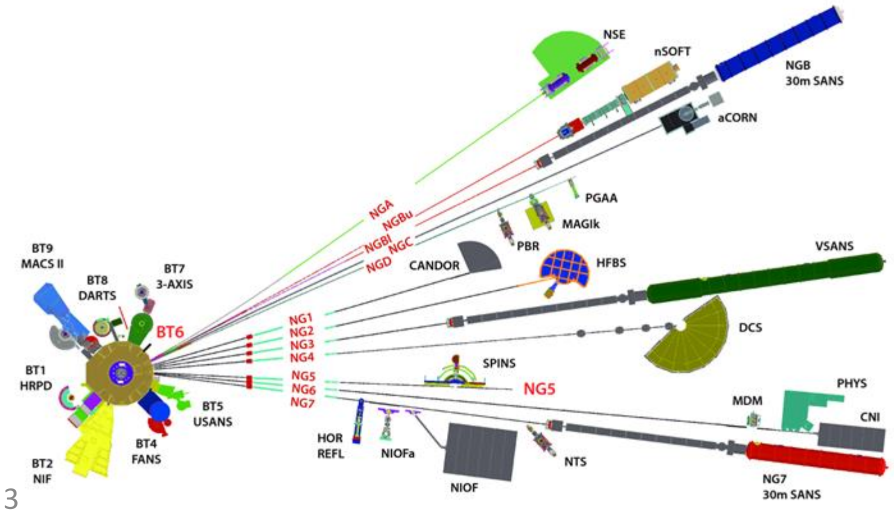
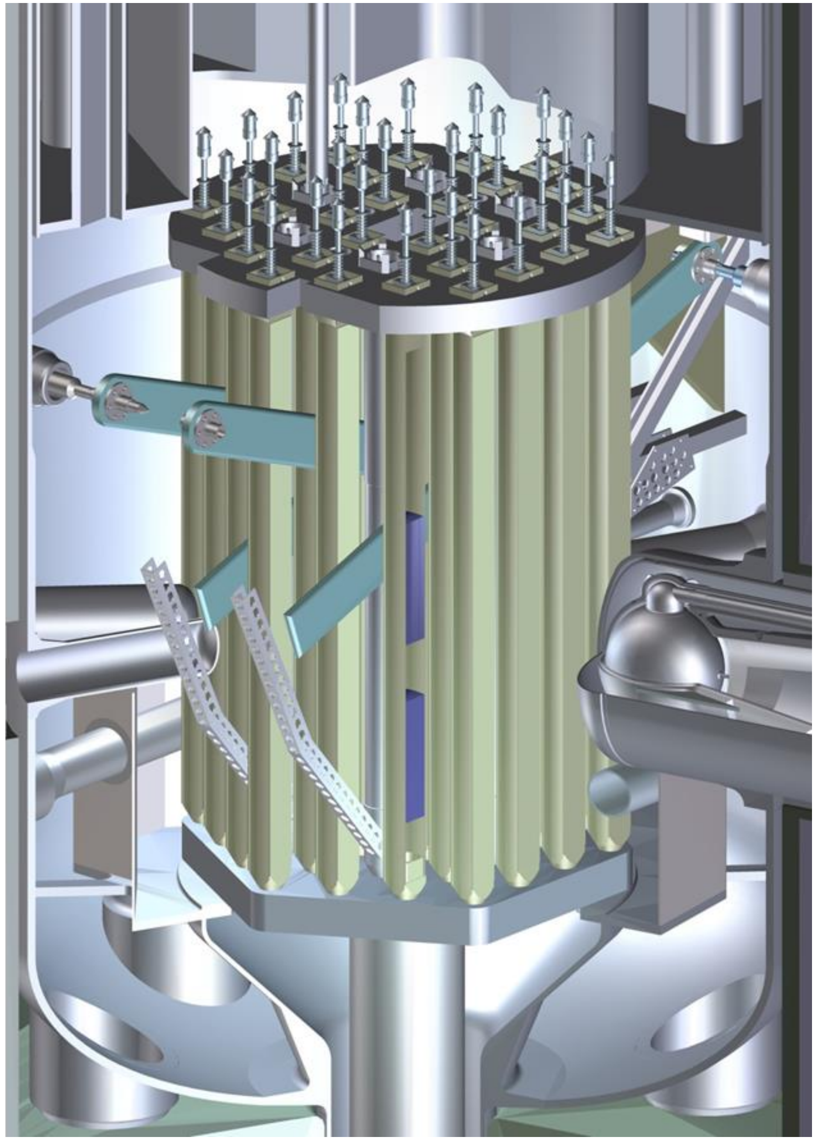
- NCNR is one of the USA’s primary resources for neutron research
- NBSR history of successful operation since 1967
- Recently recovered (partially) from the Feb. 3rd, 2021 incident
- Currently undergoing low-power testing & facility upgrades
- NBSR license to expire in 2029





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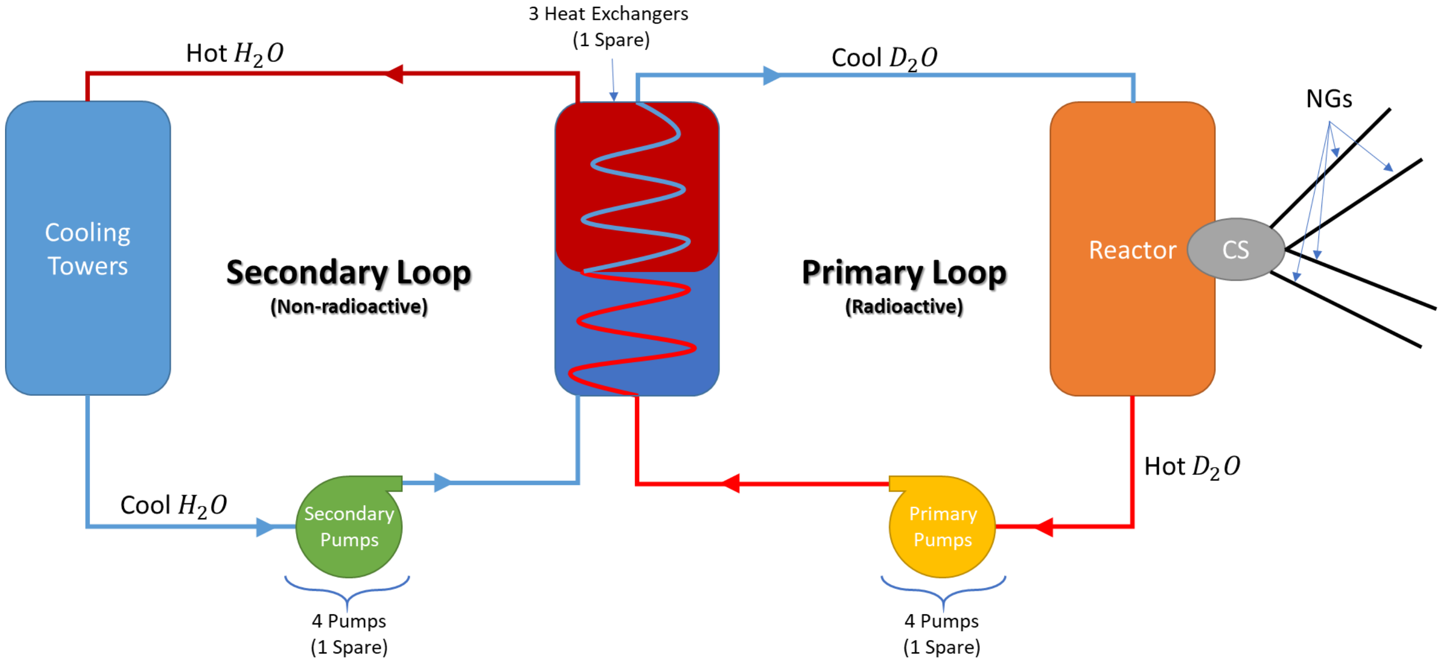
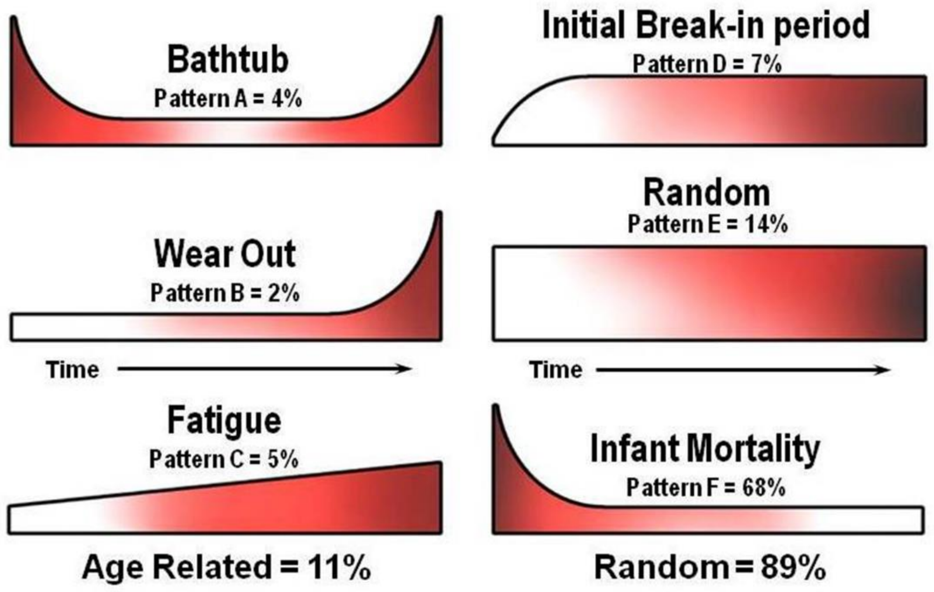
Introduction: Facility Overview

- NBSR operates with two cooling loops
  - Primary Loop = D_2O
  - Secondary Loop = H_2O
- Other systems include
  - Helium recovery system
  - Auxiliary cooling systems
- A total of XXX rotary equipment
- Advanced monitoring programs are desirable to keep-up with the ageing equipment

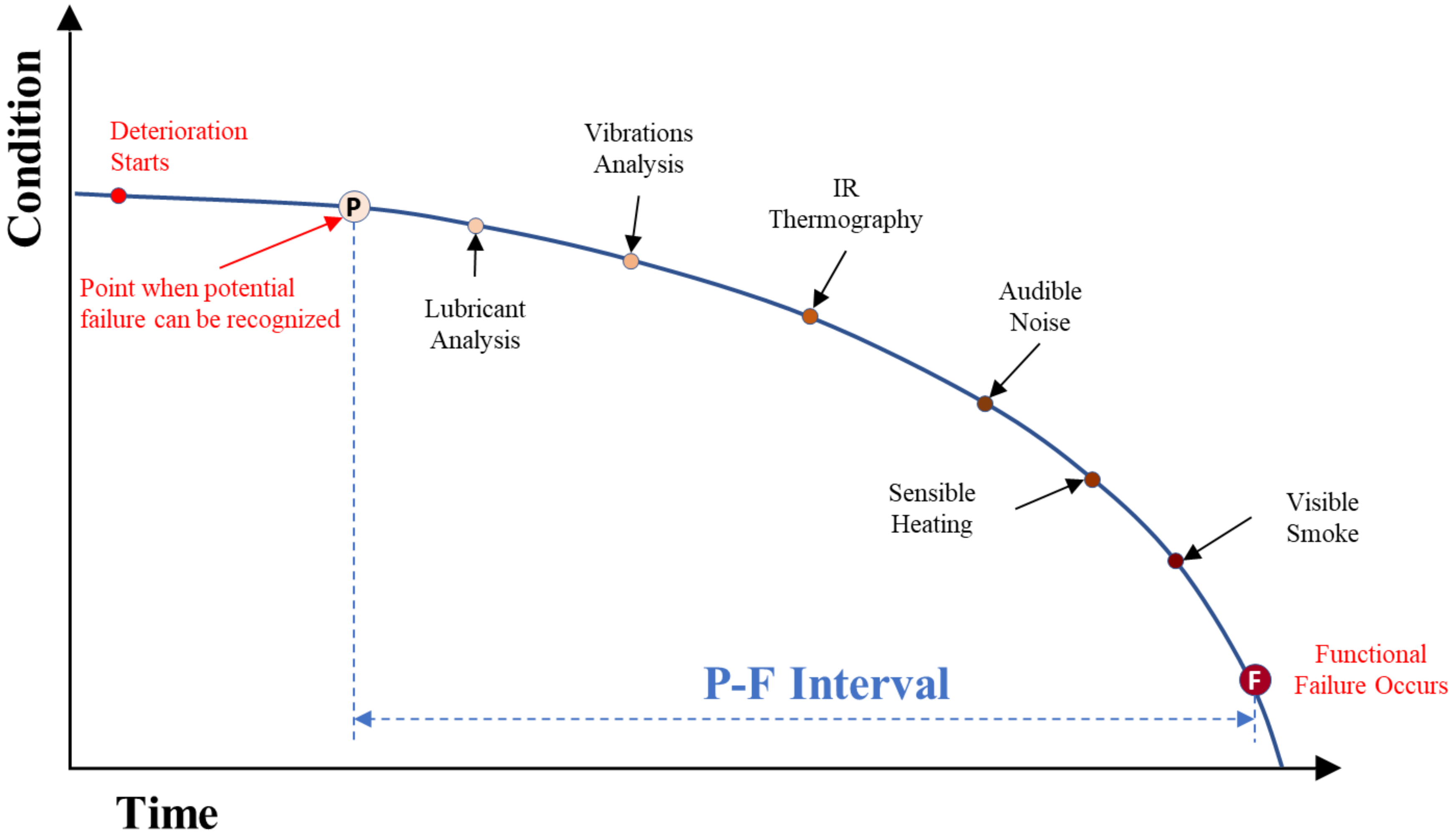


Time-based Maintenance

- Reliable for failure modes that fit patterns A, B, or C
  - Requires deep understanding of failure mode of each machine
  - Each machine is unique
  - Massive amounts of data are needed
- Note that only 11% of failures fit A, B, or C
- Majority of failures fit patterns E and F
  - For pattern F: no need for maintenance as it implies failure during installation and initial run
- For a facility with a transitioning workforce, knowledge can be lost, which makes time-based maintenance significantly less reliable.



Condition-based Maintenance



Condition-based Maintenance

<u>In-house Program</u>

- Internal personnel perform data collection & analysis
- Facility purchases both equipment & software

<u>Contracted Program</u>

- A contractor performs both data collection & analysis
- Facility (typically) doesn't own equipment or software

<u>Remote Program</u>

- Hybrid
- Internal personnel perform data collection
- Outside contractor performs analysis
- Facility would own some equipment, but no software

As facility ages, more CBM needs arise, which would drive up contracting costs.

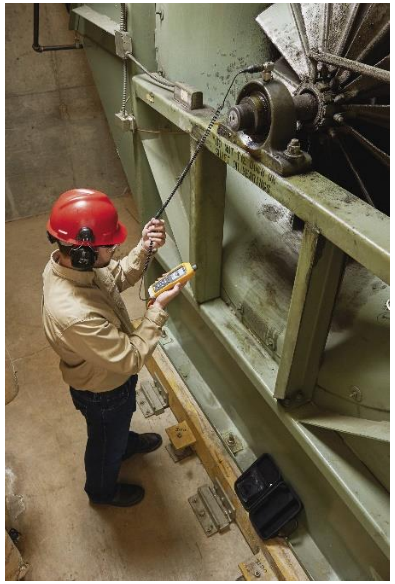
Although continuous personnel training is costly, for an ageing facility with a low number of assets (<200) and high CBM needs, an in-house program makes more sense financially and functionally.

The NCNR fits this description

Basic Monitoring Implementations

- Investment in multiple remote systems to measure vibrations and temperature severity
- Enable automated and personnel-driven monitoring of the conditions of machinery

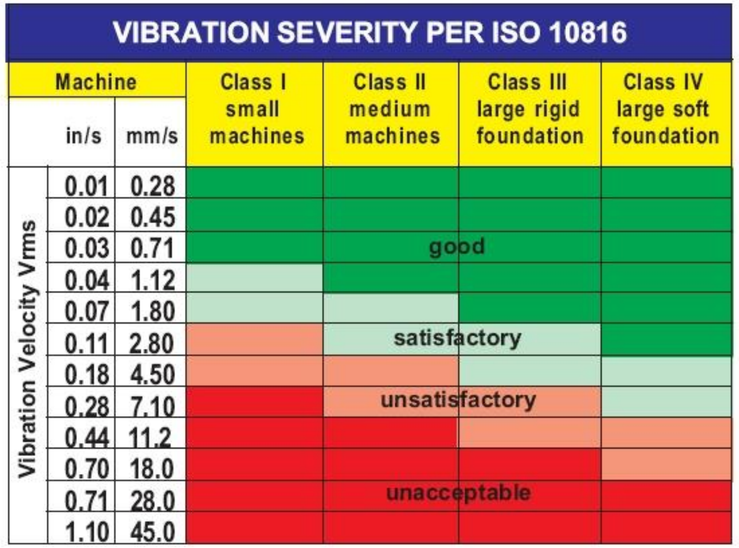
FLIR SV87-KIT

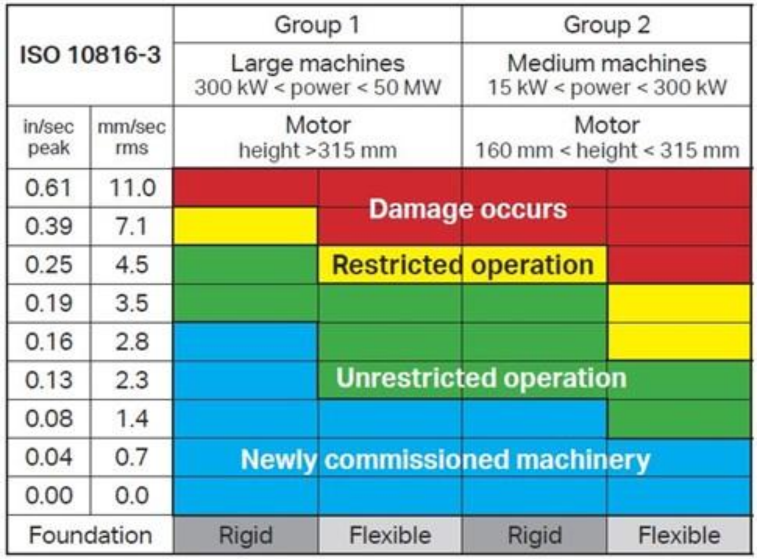


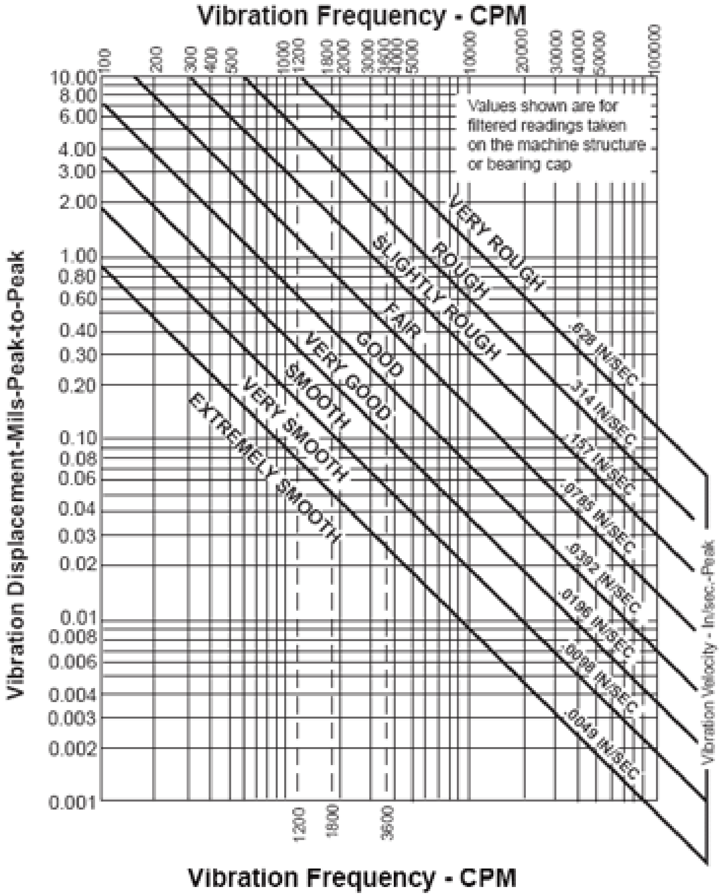
Fluke 805 FC Vibrations Meter

Basic Monitoring Implementations

- In-house training and primer is being developed for personnel
  - Training is informed by appropriate standards & literature
- Help interpret readings from the basic monitoring equipment







Advanced Monitoring Implementations

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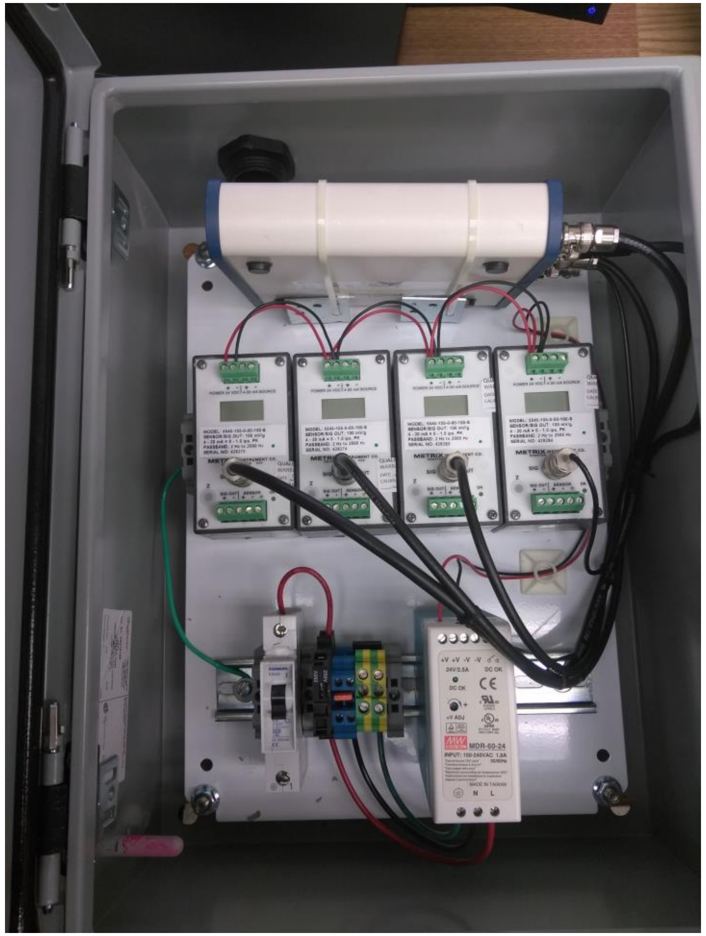
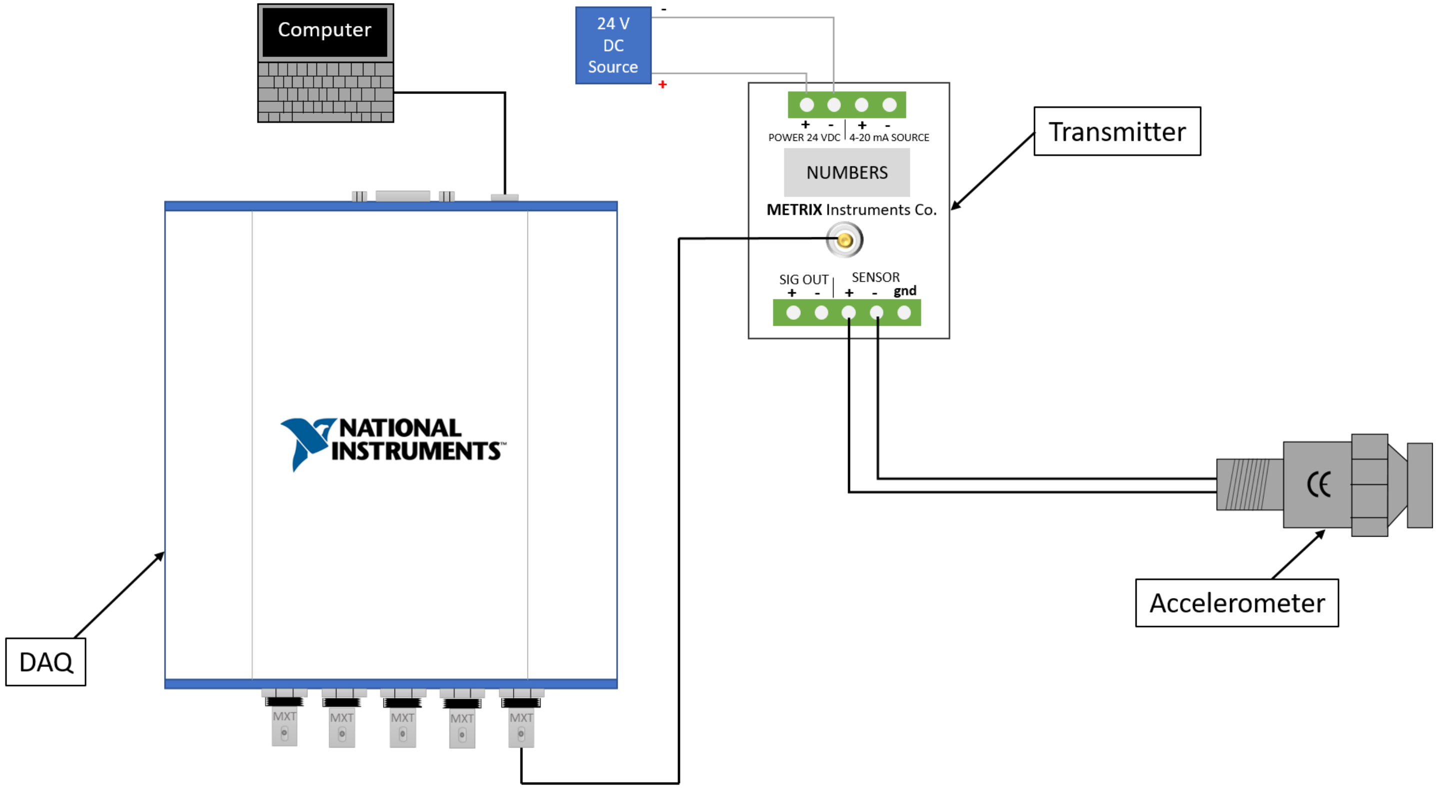
- Infrastructure is available for both primary & secondary pumps





Advanced Monitoring Implementations

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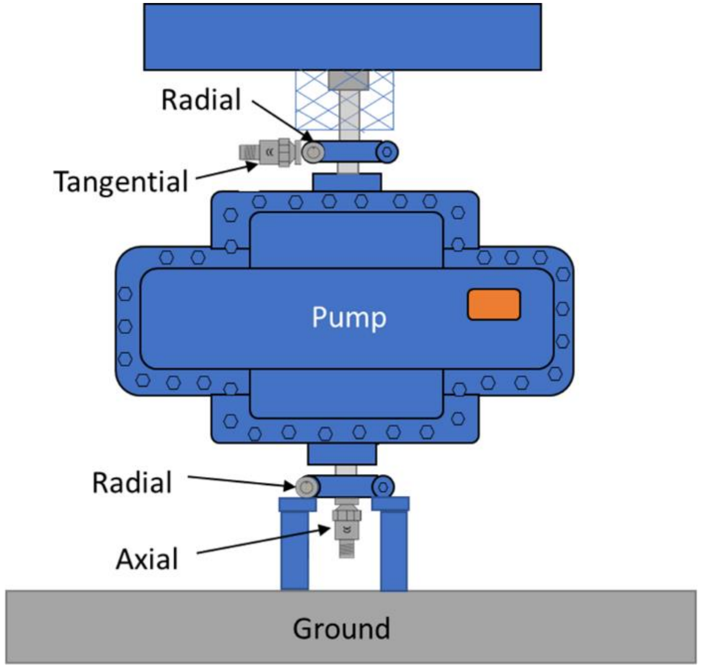
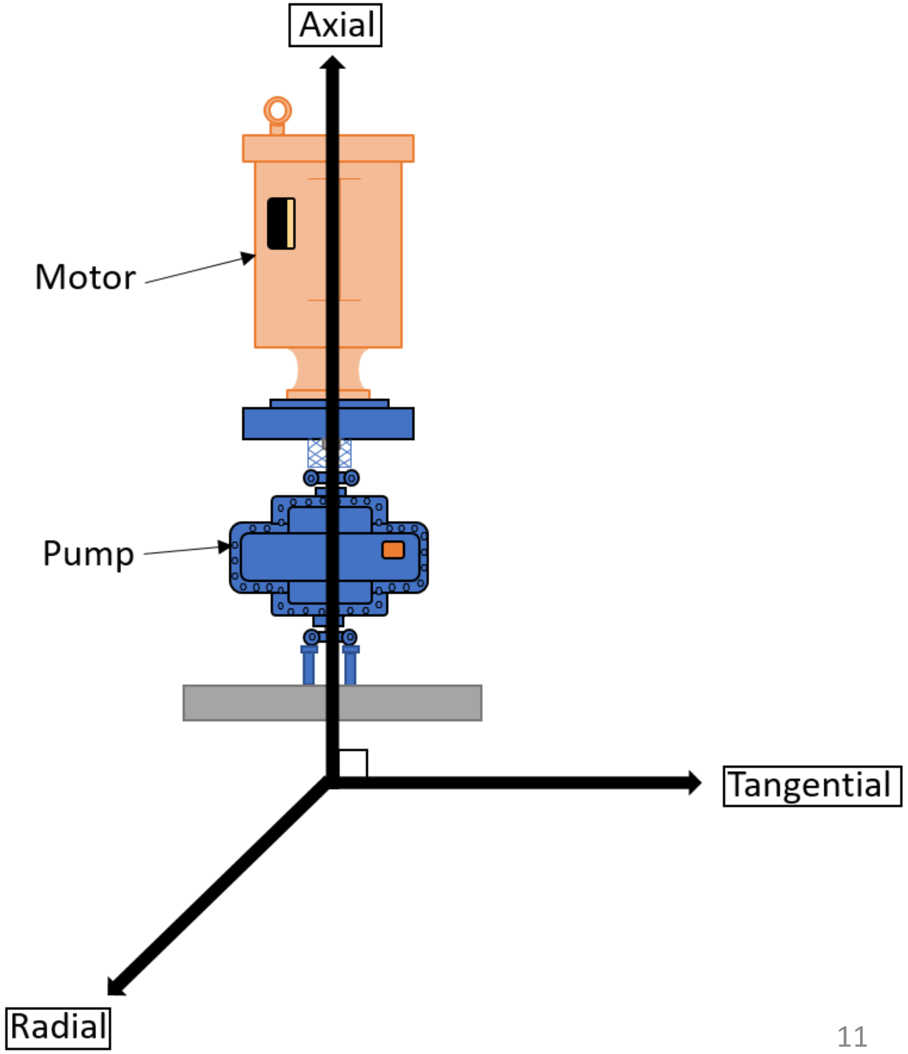
- Accelerometers installed on the following axes
  - Tangential
  - Radial
  - Axial
- Frequency analysis is used to detect faults



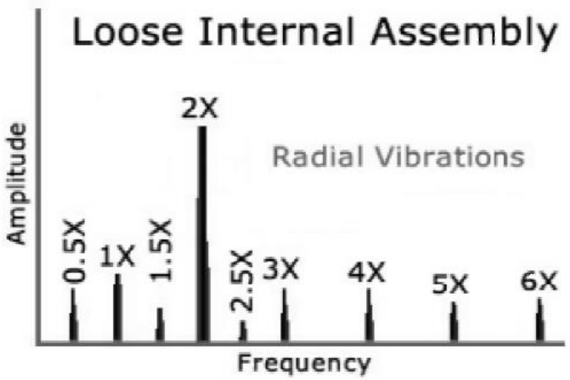


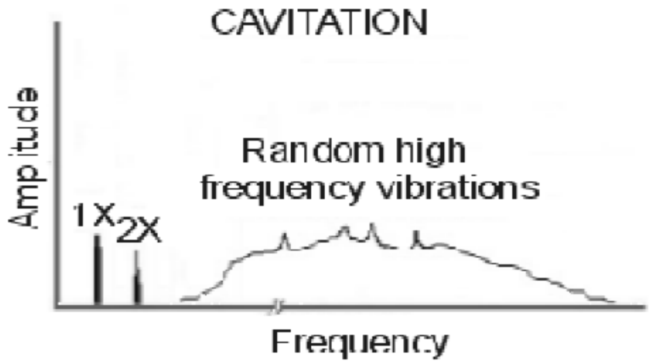
Advanced Monitoring Implementations

- Frequency-domain analysis of vibrations signatures reveal different conditions
- This knowledge is included in the in-house primer and training

Analyses are based on a principal harmonic, which is the vane-pass-frequency (VPF) for pumps.

$$VPF = \frac{RPM}{60} \times N_{vanes}$$

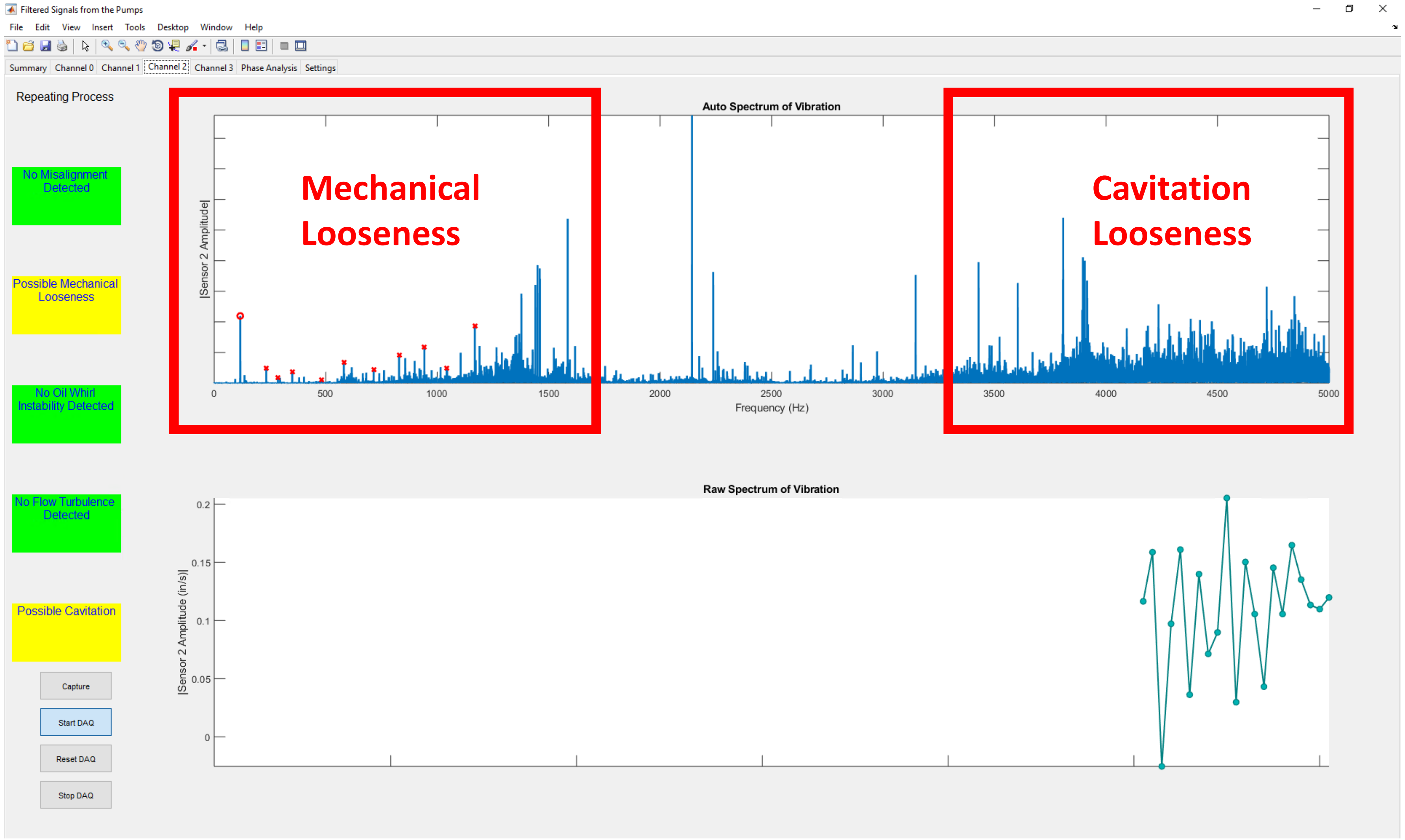




Fault Type	Peak Frequency	Peak Amplitude
Unbalance	1x	(rotational speed)^2
Eccentricity	1x	Varies with load
Bent Shaft	1x, 2x	1x dominates if bend near shaft center 2x dominates if bend near shaft end
Angular Misalignment	1x, 2x, maybe 3x	1x will dominate
Parallel Misalignment	1x, 2x, maybe 3x	2x will dominate
Bearing Misalignment	1x, 2x, 3x	2x will dominate
Looseness	1x, 1.5x, 2x, 2.5x, etc.	2x will dominate
Vane/Blade Pass	1xVPF, 2xVPF, etc.	Will dominate high freq. end of spectrum
Turbulence	Low, random, broad-band	Varies
Cavitation	High, random, broad-band	Varies

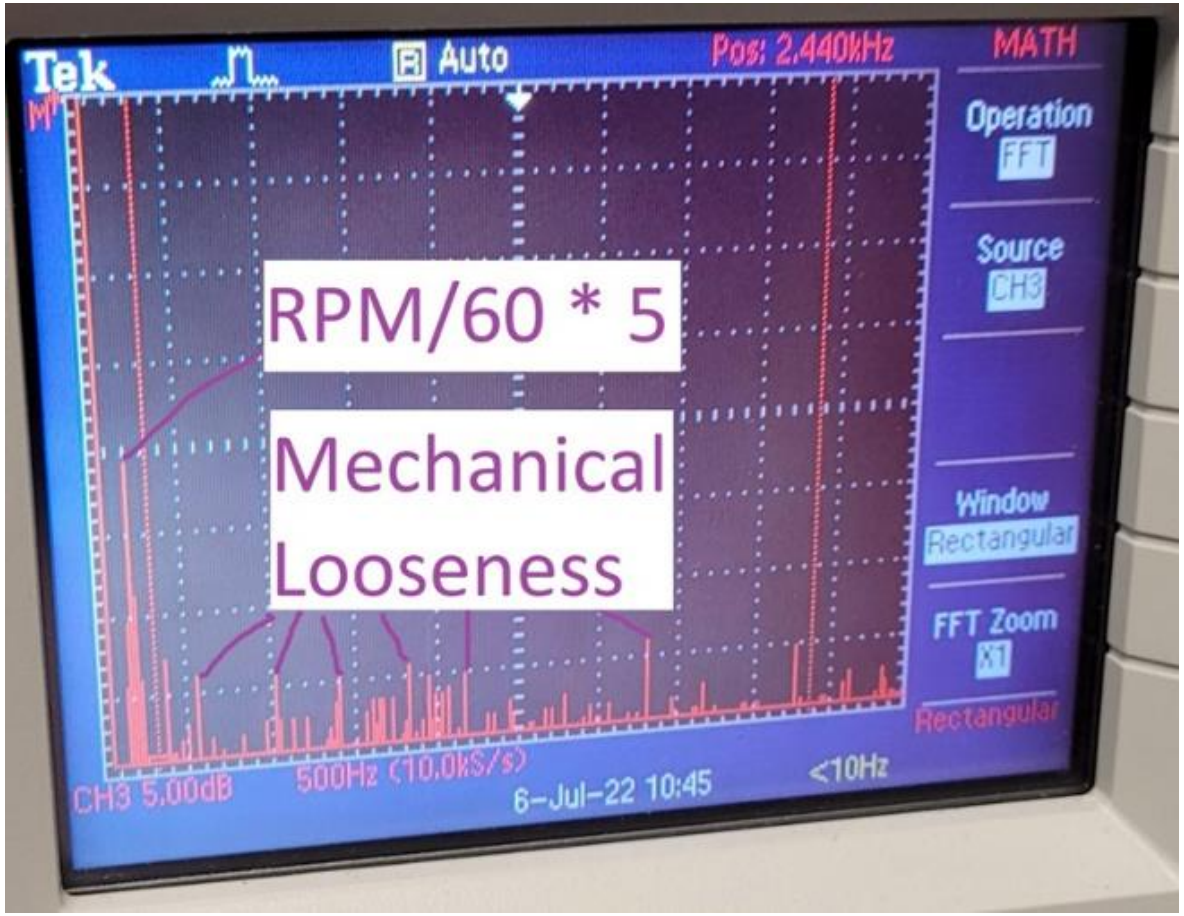
Advanced Monitoring Results

- Secondary pump advanced vibrations analysis framework developed (2018)
  - Quasi-realtime
- Secondary pump failure detected prior to scheduled maintenance (2018)
- Demonstrated effectiveness of CBM at the NCNR



Advanced Monitoring Results

- Primary pump failure detected well before scheduled maintenance (2022)
- Pump has been tagged out
- Incited the development of a more permanent CBM program and infrastructure at NCNR
  - This was essentially what catapulted the current efforts



Summary & Conclusions

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- Efforts began towards the development of a permanent CBM program at the NCNR
- Upgrades are being pursued to the existing infrastructure
  - New equipment purchased
  - Analysis primer/guide has been drafted
  - In-house training is being developed
- In-house capabilities have already demonstrated the effectiveness of CBM for monitoring pumps health
  - Secondary pump in 2018
  - Primary pump in 2022

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Questions??

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