A NON-PROFIT ORGANIZATION

RATS - ROTATING & TURBOMACHINERY SOCIETY

WWW.ROTATINGSPECIALIST.ORG

MRO 2023

MAINTENANCE
RELIABILITY
OPERATIONS

TECHNICAL CONFERENCE & WORKSHOPS

Asset Health Monitoring
An End User Perspective

Chris Hobbs, Pembina Pipeline

PEMBINA

Wednesday October 25, 2023

DOW Centennial Centre - Fort Saskatchewan

Dashboarding & Issue resolution

- Pembina has recently undertaken an initiative to maximize the value of it's (rotating equipment) operating installed base (> 1200 pipeline pumps).
- This presentation will highlight the methodology, intended benefits, and examples of the different types of optimization opportunities and deficiencies observed through this journey.
- The outcome enables a complete and proactive assessment of asset health, while visually simplifying and spotlighting continuous improvement opportunities with asset performance modelling and Key Performance Indicator (KPI) dashboarding.
- To facilitate quick adoption and roll out, Original Equipment Manufacturer (OEM) pump curves were digitized for critical assets. This exercise also yielded immediate benefits:
  - Highlighting assets currently not meeting their functional performance standards
  - Identification of the onset of equipment degradation
  - Masked legacy issues (design, construction and commissioning)
  - Reprioritized maintenance overhauls from one asset to another
  - Improved diagnostics to mitigate unplanned outages

What's the value?

1. Quantifiable power optimization – through data driven decisions based on condition-based monitoring
   - **Operational optimization opportunities**
     - # online pumps
     - # online pump stations
     - Inefficiency induced by operation against pinched Pressure Control Valve (PCV)
     - Drag Reducing Agent (DRA) injection rates – compromised between power optimization, asset reliability and product throughput.
   - **Rotating equipment wear identification**
     - Correlated inefficiency (wear) to power loss and quantified the Return On Investment (ROI) based on rebuild $
       - For Variable Frequency Drive (VFD) driven assets: actual vs. expected speed
       - For constant speed applications: actual vs. expected Total Developed Head (TDH)
       - Enabled development of performance thresholds

Additional Benefits

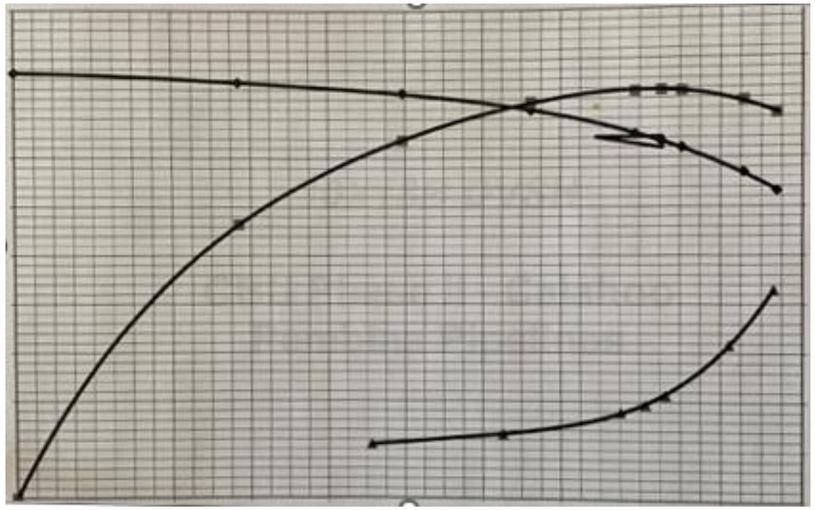
2. Accurate scope of repairs
3. Enabled a holistic maintenance program, combining access to and correlation between:
   - typical predictive technologies (vibration, oil analysis, etc.),
   - traditional maintenance practices (time directed [calendar or service based], visual inspections, etc.) and
   - previously unavailable real time continuous pump performance monitoring and data trending for a pipeline system building towards a fleet of >1200 pumps.
4. Long term pump-specific forecast of refurbishment for development of annual budgets. Allows for improved confidence and a condition-based assessment rather than time-based.
   - “That pump must be ready for a rebuild by now – hasn’t been out in 15 yrs???”
   - OEM recommended maintenance
   - Generic maintenance intervals

Wait??? Still more benefits?

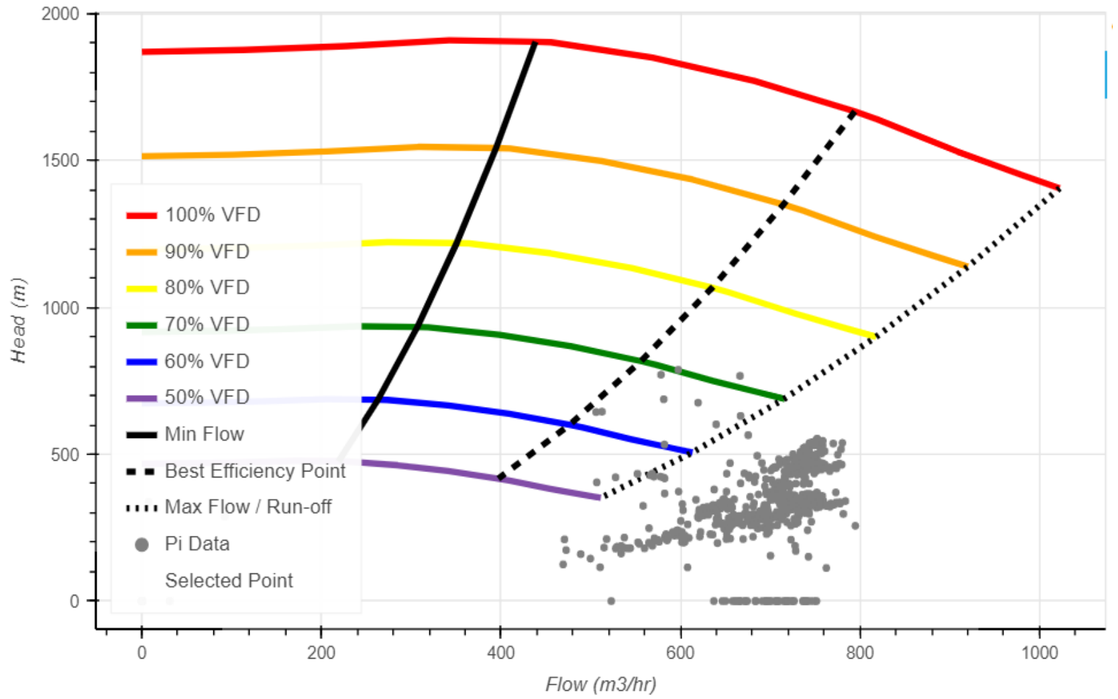
5. Enables advanced analytics (e.g. machine learning, AI, etc.)
6. Balanced assessment of throughput, power consumption, maintenance costs and Environmental, Social, and Governance (ESG) considerations
7. Provides detailed technical information and context to aid in troubleshooting and identifying root causes, both internally and working with OEM.

Developing the Solution: Digitization of Pump Curves

- Pembina converted OEM pump curves to a digitized format that can incorporate available information from Supervisory Control And Data Acquisition (SCADA) / PI systems and import them onto a plot in real time.
- **This enables trending of large volumes of data and calculations across a large fleet of pumps over an extended period of time:**
- **Operating deficiencies (time spent outside allowable operating region [AOR] or preferred operating region [POR])**
- **Power consumption optimization opportunities**
- **Pump inefficiencies**



Before: Paper copy (or worse yet picture of paper copy) pump curve supplied by equipment manufacturer



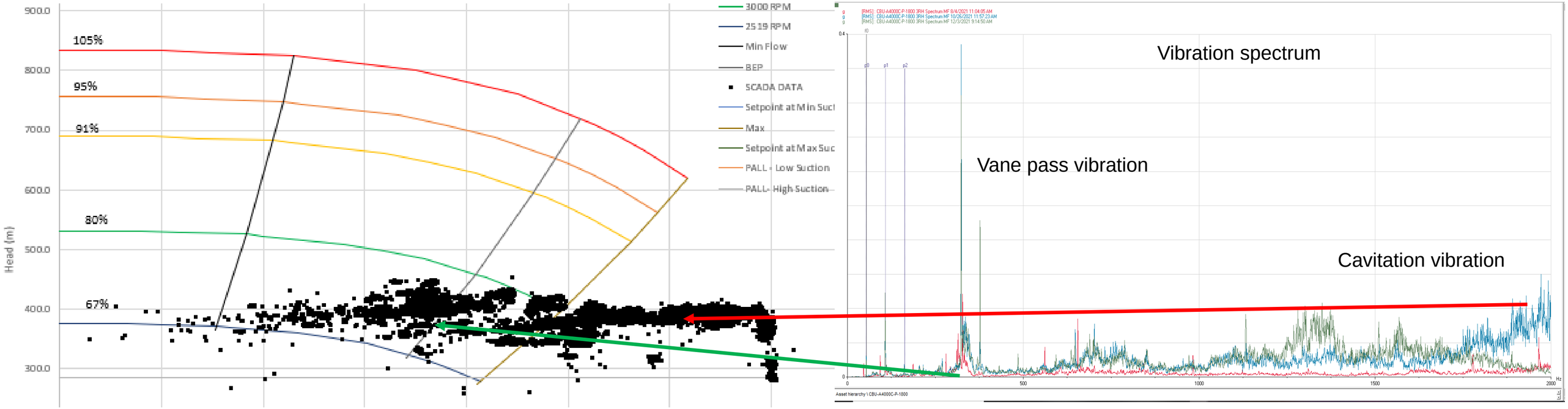
After: Digital pump curve enabling overlay of field instrument data

Transition from reactive failure modes to condition based failure modes

- Typically, based on a combination of fleet size and available resources, hydraulic performance issues and operating / control issues were dealt with reactively.
- Heavier reliance placed on more traditional condition monitoring technologies such as vibration and used oil analysis to provide a predictive approach to maintenance.
- Live plots of process data on pump curves enable quick and easy assessment of pump operation inside or outside of the allowable operating region.
- Automation of large volumes of data and trending over long periods of time combined with dashboarding results in improved visibility of fleet health / performance.
- Transitions from “squeaky wheel”, “break / fix” and OEM time-based maintenance models to a more data-driven informed model allowing prioritization of work and focused efforts.

Here’s what we’ve found (so far)…

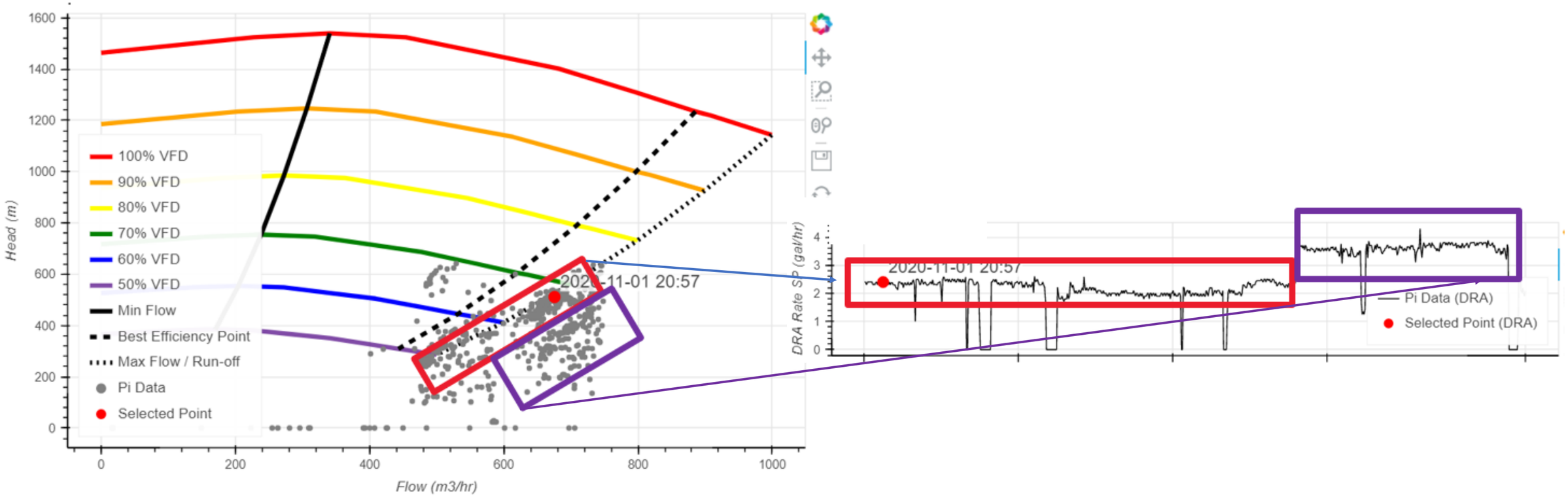
Operating optimization opportunities - # pumps online



Opportunity for optimized control configuration for 2 pump parallel operation

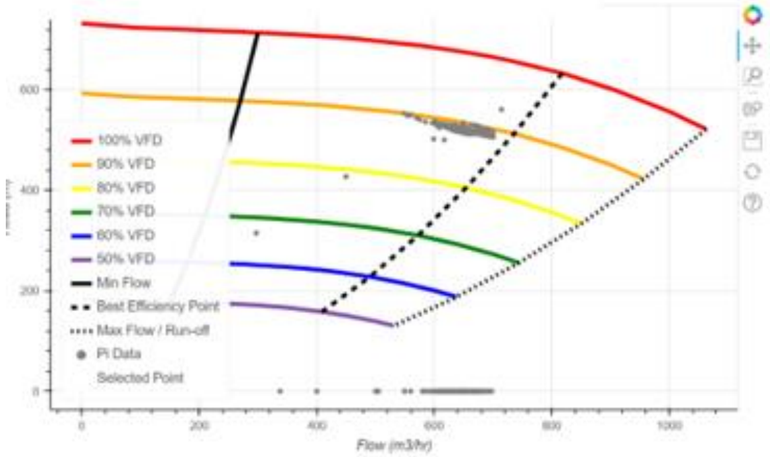
Unacceptable vibration when operating at runoff caused by cavitation and vane pass excitation

Operating optimization opportunities - DRA injection rates

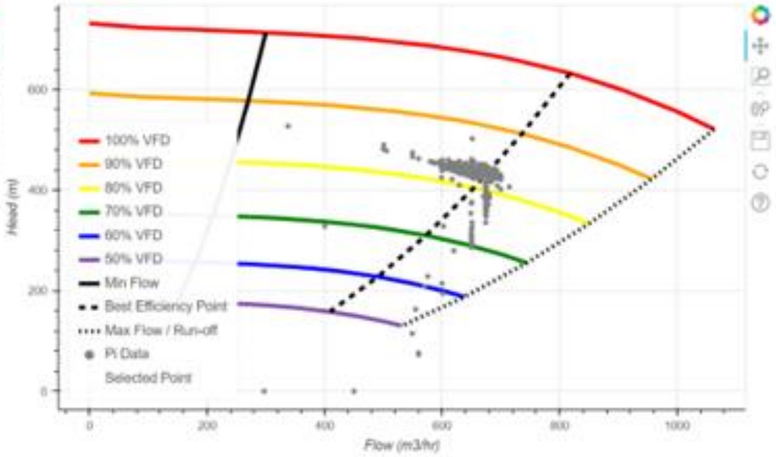


- Opportunity to manage pump operation within AOR at various DRA injection rates
- Compromise between power optimization, asset reliability and product throughput

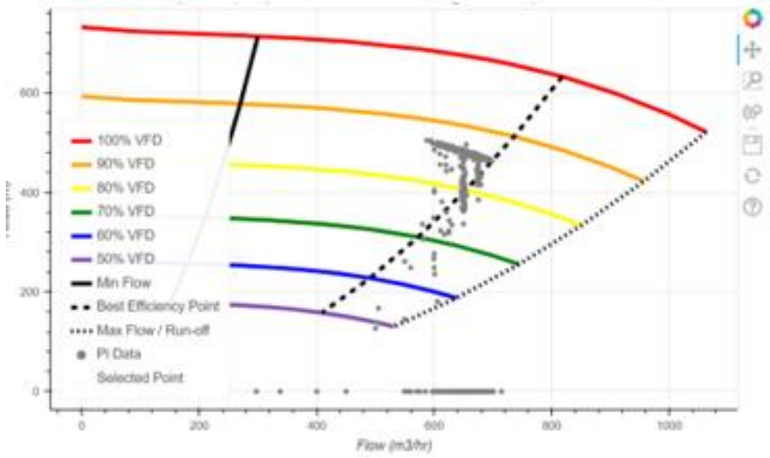
Pump Wear Identification and Inefficiency



Pump 1



Pump 2



Pump 3

3 pumps in series:

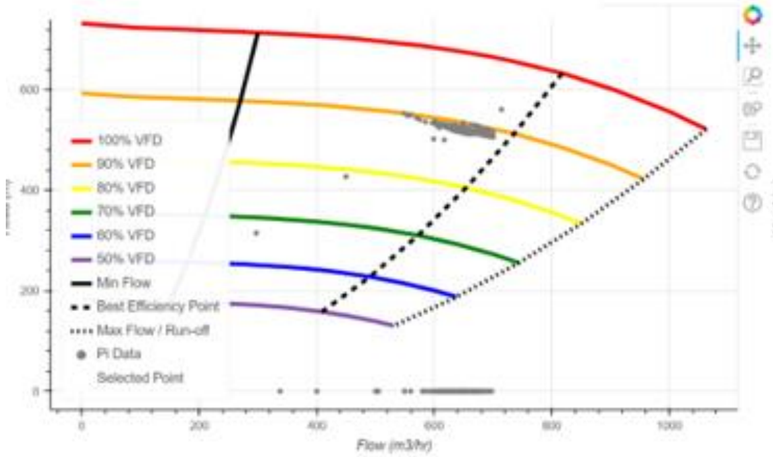
First glance – nothing wrong

Why would ops be complaining about being rate limited?

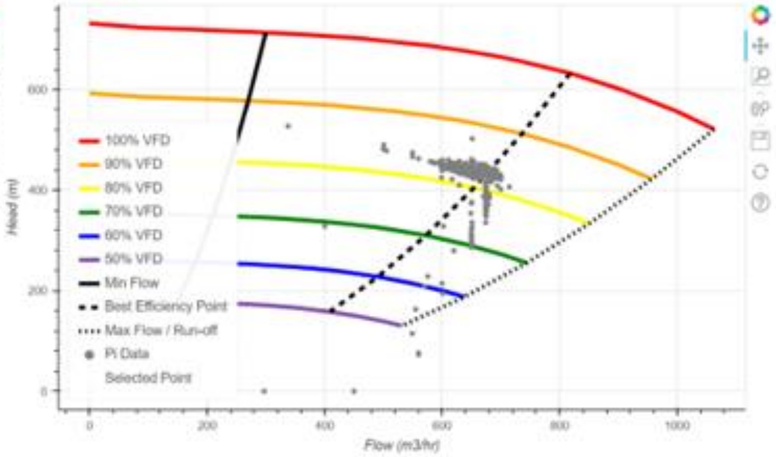
What options are available?

How can we apply learnings, so we're not left in this scenario in future?

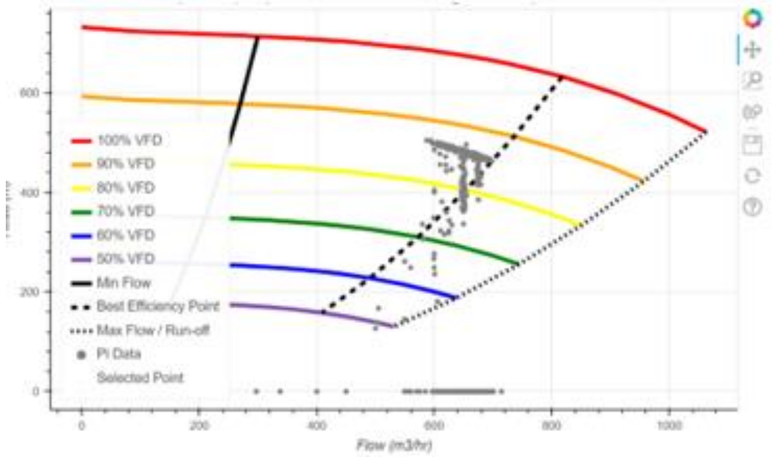
Pump Wear Identification and Inefficiency



Pump 1



Pump 2



Pump 3

All pumps restricted to 90% VFD Speed maximum - orange line as high as we could go

Pumps 2 & 3 are both actually operating at 90% speed – but outputting TDH equivalent to 82 & 86% respectively

Operate pumps 1 & 3 together in short term to get highest TDH / flow.

Repair pump 2 ASAP.

Schedule 3rd pump for rebuild shortly after return of pump 2.

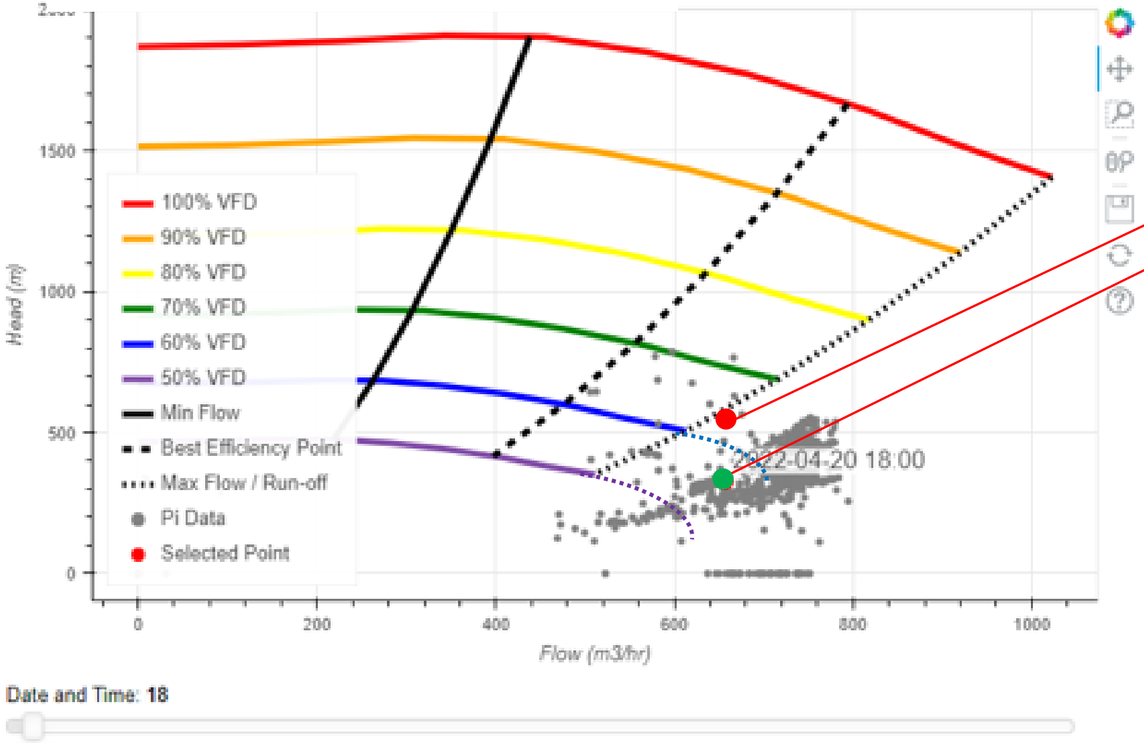
And a case study that really shaped the direction of the initiative and illustrated the potential possibilities

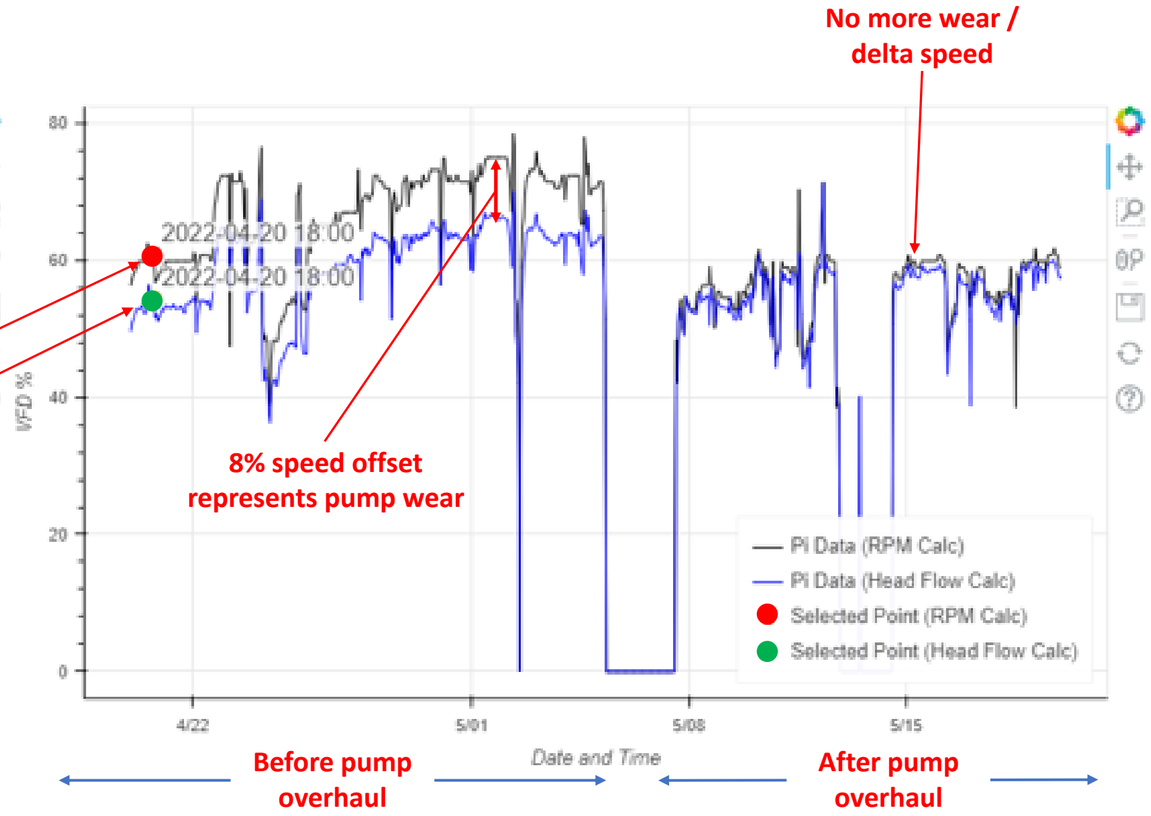
Unlocking the potential

Postmortem assessment of a pump overhaul:

- Validated and quantified condition-based monitoring through physical assessment of component condition
- Power consumption savings calculated and confirmed to be equivalent to $70K per year on a single pump
- “We removed it because of vibration, not power, so where do we look next for power opportunity on the system (or across the business) as a whole??”
- Pursuing “new” business case for ESG and cost of power as considerations in overhaul strategy

The “Speed” Method (dashboarding speed instead of efficiency – more relatable to operations)



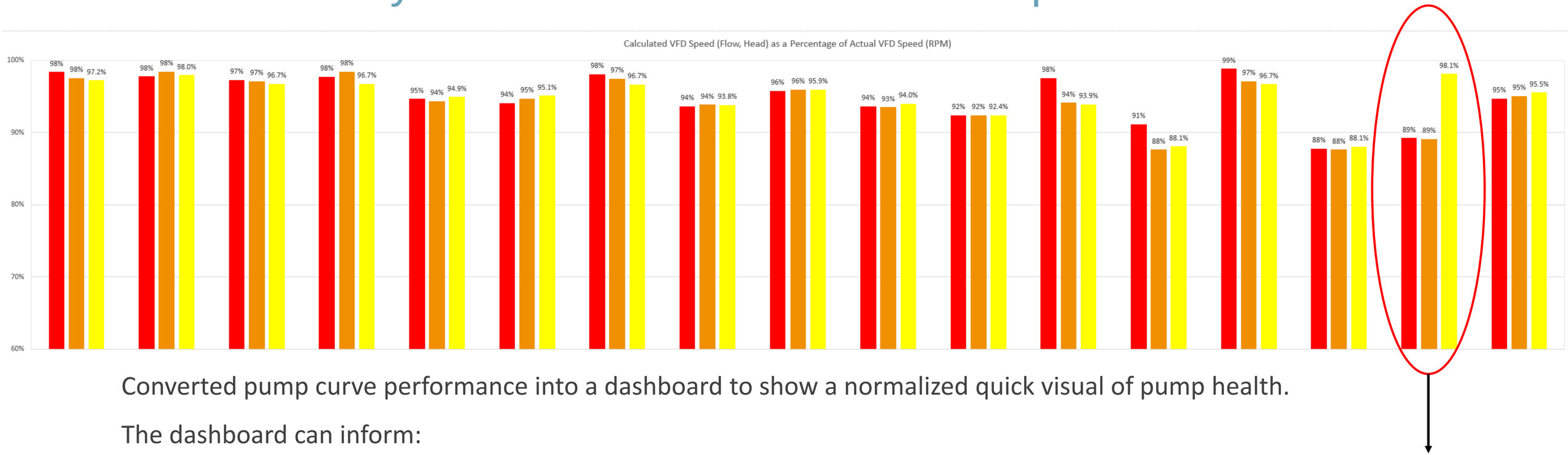


Plotted actual field data on pump curves to compare current performance vs expected performance (red dot is what the expected performance, green dot is the actual performance)

Before replacing the pump, actual speed of variable frequency drive was on average 8% higher than calculated expected speed

After pump replacement, actual pump speed more closely matches calculated speed

Dashboard of Hydraulic Performance across Pipeline



Converted pump curve performance into a dashboard to show a normalized quick visual of pump health.

The dashboard can inform:

- Asset performance current status
- Wear rate degradation trends
- Long term forecast of priority rebuilds on a system or in a region
- Correlates lost pump efficiency with power consumption
- Rebuild thresholds to optimize ROI / payback

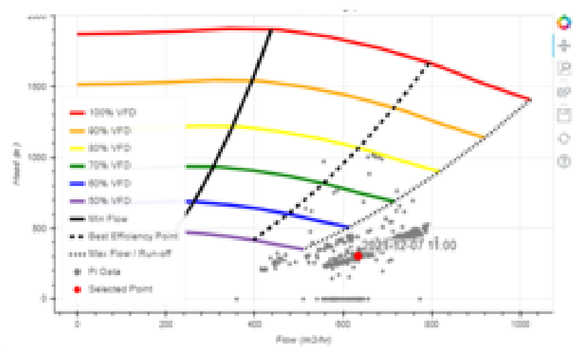
Validation of restored performance / efficiency by trending 2020/21/22 year over year values

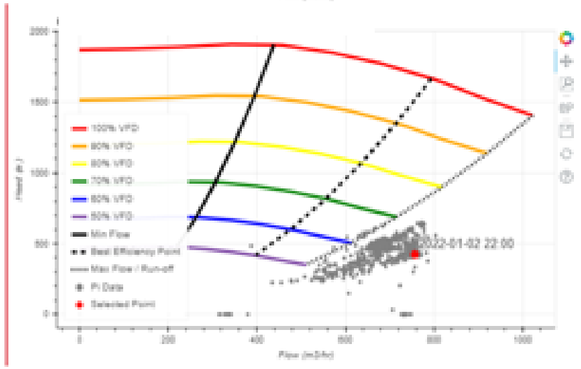
Operation Outside of Alowable Operating Region

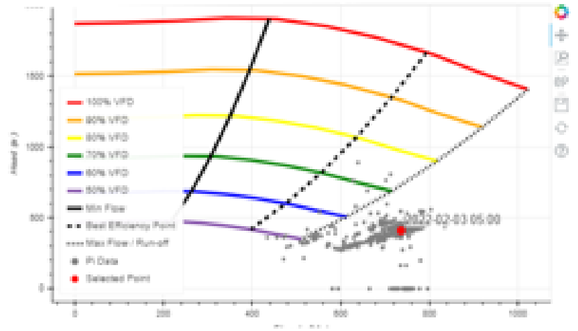
- Impacts:
  - Power consumption
  - Life cycle impacts to impeller vanes, eyes, swirl bars, bearings & mechanical seals

- Solutions:
  - De-staged to better accommodate the hydraulics and restore operation within AOR
  - Justifying DRA injection rate reduction to achieve optimal balance between # of online stations & efficiency / power consumption

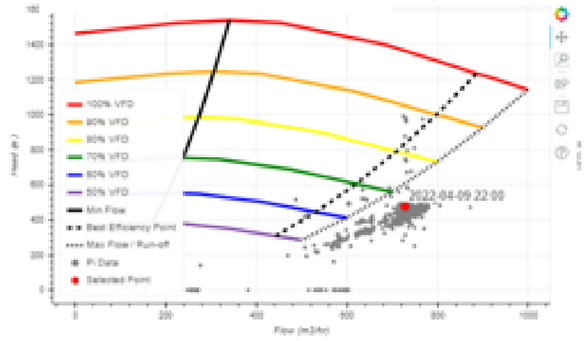
Pre pump replacement:

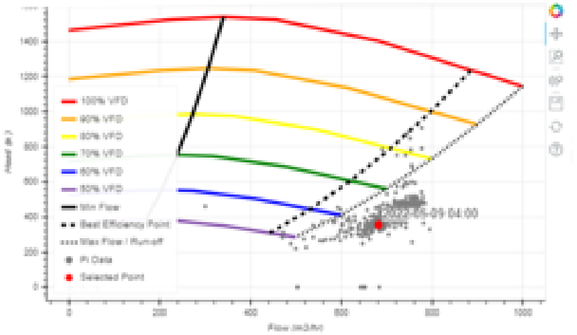


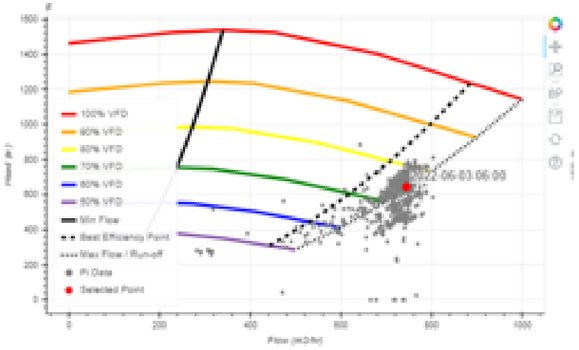




Post pump replacement:

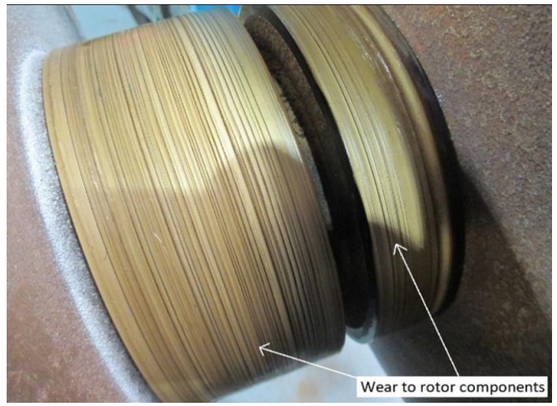


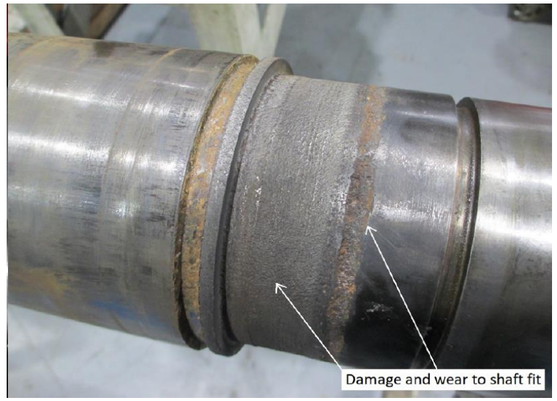


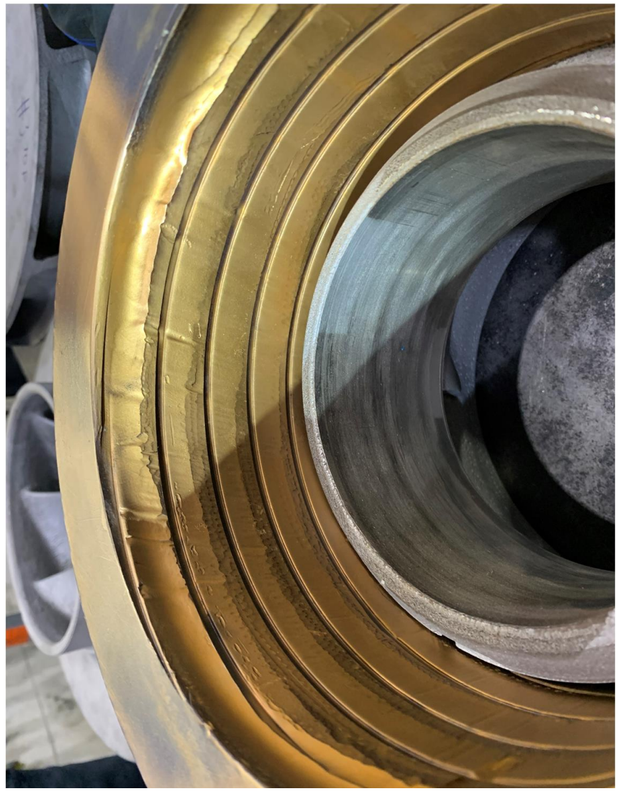


Inferior wearing component material selection

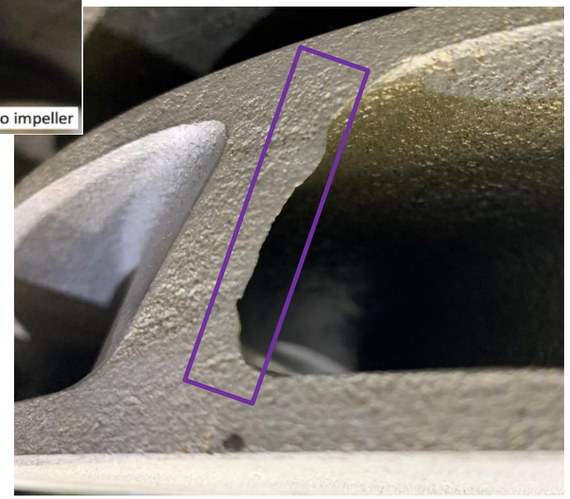
- Impact:
  - Significant clearance due to lack of resistance to erosion
- Solution:
  - Upgraded to more resilient API S5/6 materials





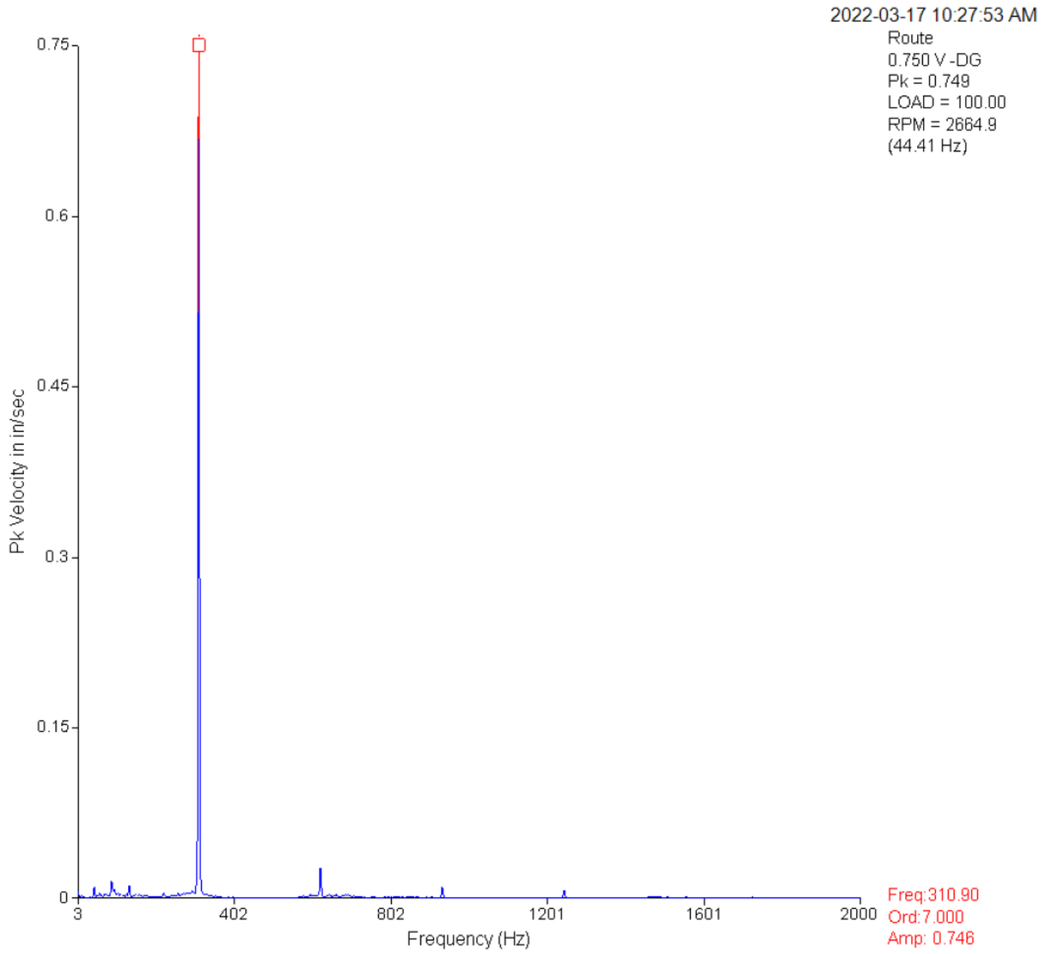


Erosion & Corrosion



Cavitation / recirculation

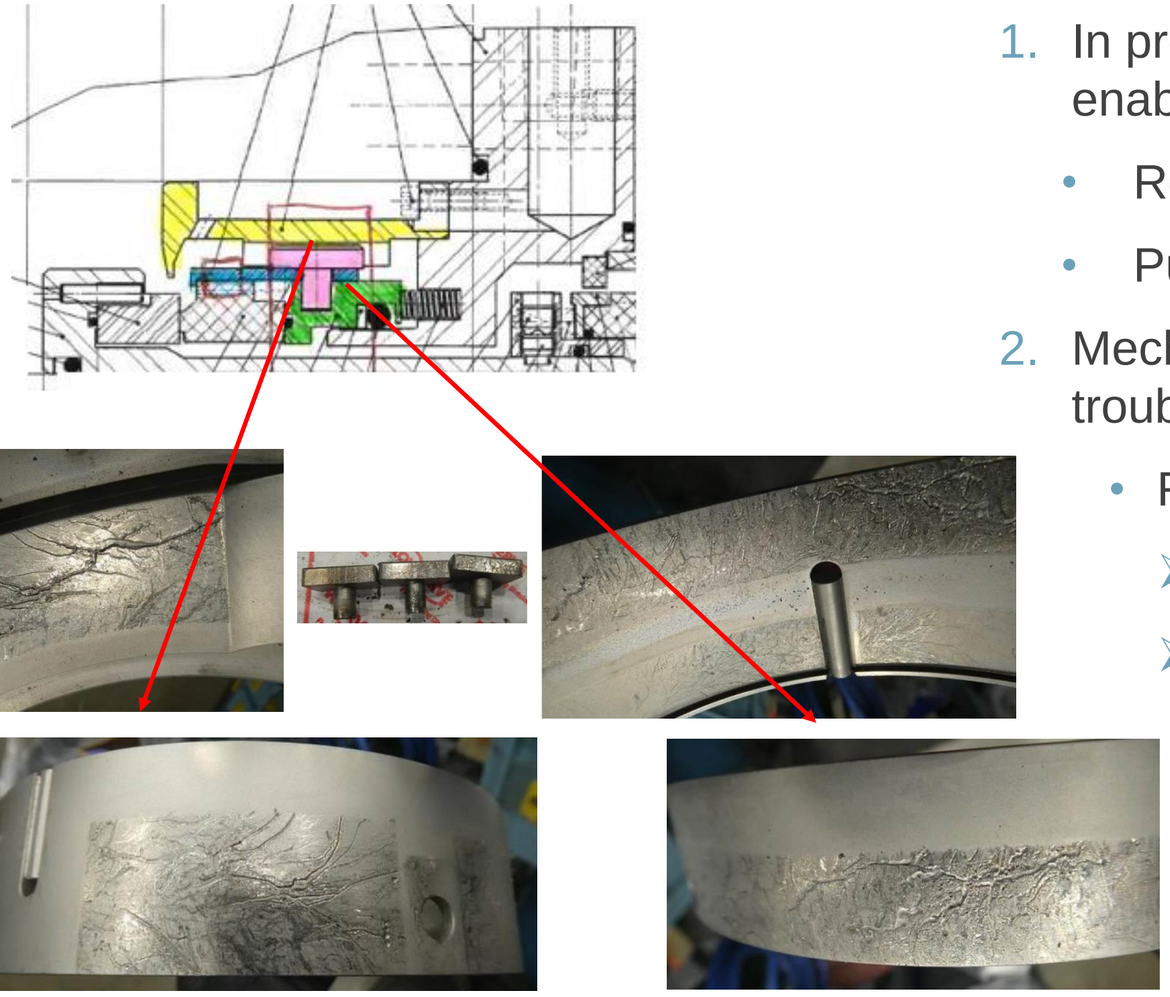
Acoustic Resonance



- Impacts:
  - Elevated vibration levels observed:
    - The cross over line of the pump bundle,
    - Balance line
    - Pump bearing housings
    - small bore piping in the surrounding area

- Solutions:
  - Upgraded balance line stiffness, dampening, wall schedule and geometry
  - Modified impeller vane count on the impeller stage feeding crossover, reducing pulsations generated
  - Profiling vanes and volutes to minimize the significance of the pulsation / interruption of flow
  - Operating away from runoff condition

Observed Problems and yet to be resolved issues



1. In process of resolving residual acoustic resonance to enable full VFD range:
   - Rotor-dynamic modelling
   - Pump inboard bearing housing design modification
2. Mechanical seal ongoing problem definition & troubleshooting:
   - Requires additional information
     - stuffing box parameters (flow / pressure),
     - retention of failed components for further assessment / analysis

That’s a wrap

The initiative successfully delivered:

1. A manageable way of processing and leveraging a massive amount of available data in SCADA against a large asset install base.
2. Fleet monitoring in real time, with quick and easy access to historical trends, simplifying troubleshooting and root cause investigations.
3. Application of a relatable “Speed method”

Thank You To Our Sponsors

RATS is a non-profit organization, run by a volunteer board of directors. The founding premise of RATS is in the social networking and community building of people within the rotating equipment and turbomachinery industries.

RATS

ROTATING AND TURBOMACHINERY SOCIETY

A NON-PROFIT ORGANIZATION

THANK YOU FOR PARTICIPATING IN OUR PRESENTATION

Please fill out the feedback form to help us improve the next event.

All presentations will be available to download from the RATS website.

A portion of MRO proceeds fund scholarships through our partnered institutions:

NAIT

Red Deer Polytechnic

UNIVERSITY OF ALBERTA

RATS is proud to support

VETERANS ASSOCIATION

WINhouse

DOW Centennial Centre - Fort Saskatchewan

2023 MRO Technical Conference & Workshops

MAINTENANCE - RELIABILITY - OPERATIONS

WWW.ROTATINGSPECIALIST.ORG