April 27 - April 29, 2022

# Pumps and Motors: Condition, Optimization, and Reliability Evaluation

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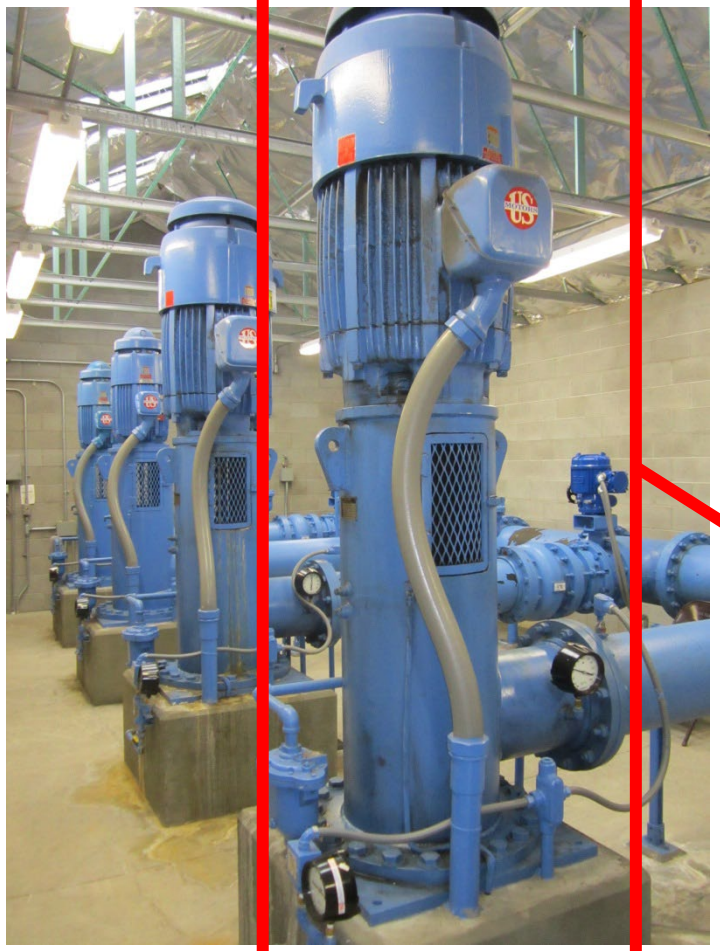
# Introduction

- How can we determine a pump's condition?
  - A pump is the 'beating heart' of a system
  - A pump test is a 'doctor's appointment
- How do you prioritize the overhaul and repairs of your pumps/motors?
  - Run them until they fail
  - Replace the oldest equipment first
    - "It's not the years on the machine, but the number of hours"
  - Replace the weakest link in the chain

# Available Pump Testing Capabilities



Testing is performed on-site without disassembly or damage to equipment

- Non-invasive and non-destructive testing

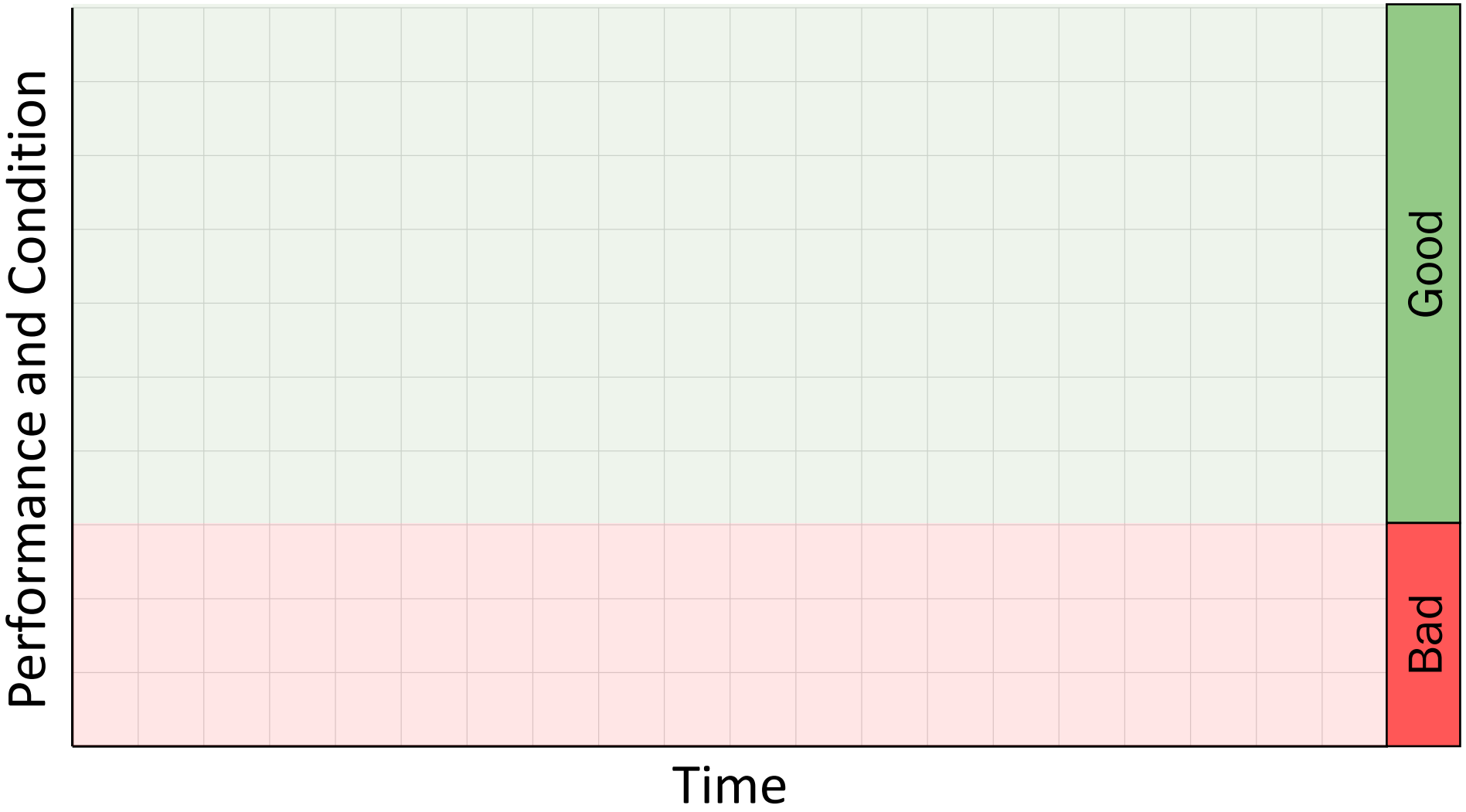
Conducted Tests:

1. Vibration Analysis
2. Energy Signature Analysis
3. Thermography

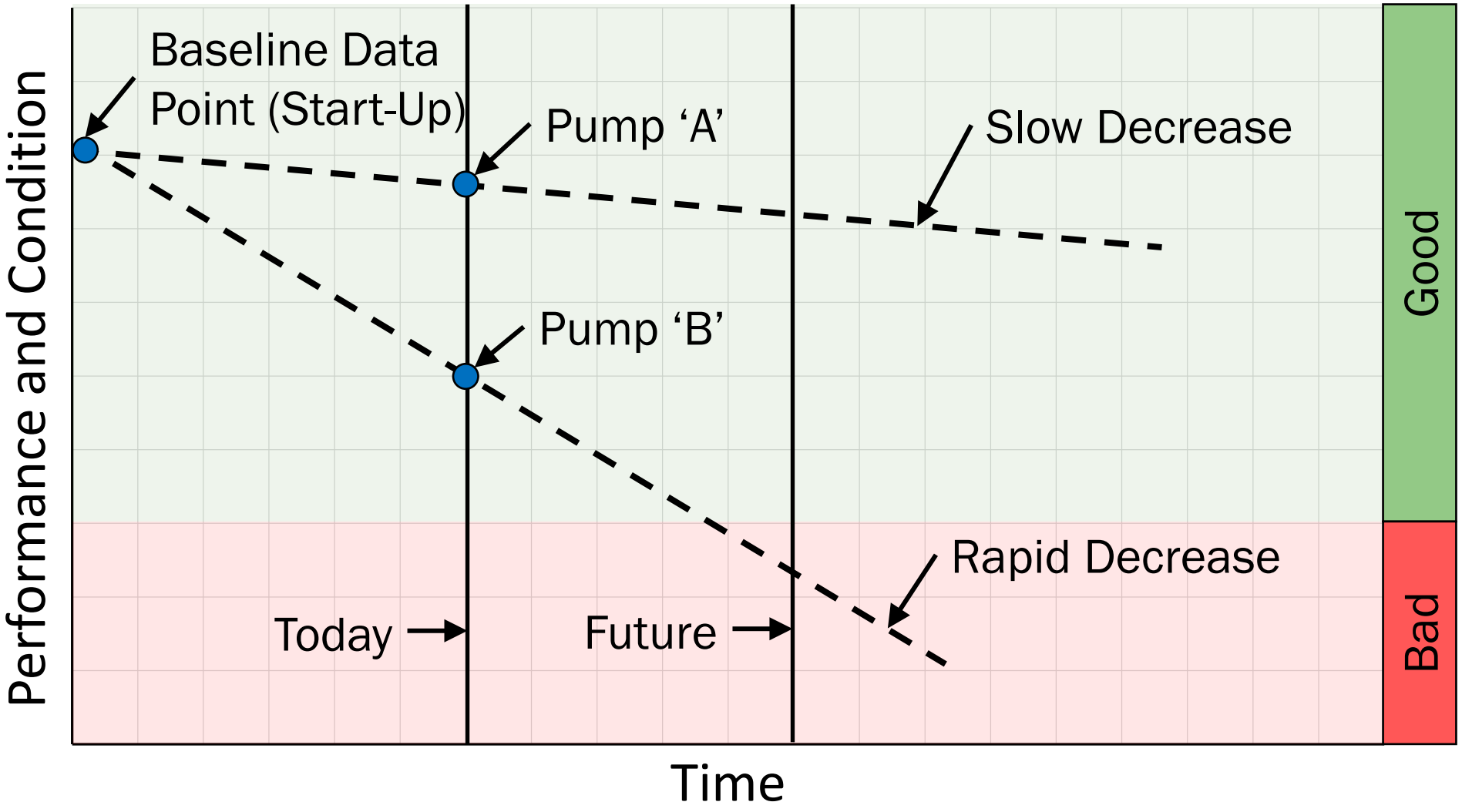
# Testing and Analysis

- Non-invasive and non-destructive procedures for condition assessment.
- Defect or faults create wasted energy and cause unnecessary wear and damage on equipment.
- Analysis helps with data driven repair and replacement schedules. Other benefits include:
  - Optimized energy usage
  - Reduced maintenance costs
  - Maximized useful life of equipment
  - Avoid costs due to catastrophic failure or unplanned repairs

# Trends in Collected Data



# Trends in Collected Data



# Vibration Testing and Analysis

# What is Vibration Analysis?

- Vibrations are generated by all machines during operation
  - These vibrations have patterns that can be identified or calculated
- Vibration Analysis: The process for measuring the vibration levels and frequencies of machinery and using that information to analyze how "healthy" the machines and their components are
- Types of Vibration Issues:
  - Imbalance
  - Bearing Failures
  - Mechanical Looseness
  - Resonance and Natural Frequencies
  - Electrical Motor Failures
  - Bent Shafts
  - Gearbox Failures
  - Cavitation in Pumps
  - Critical Speeds

# Types of Vibration Data Collectors


"Nickle Test"

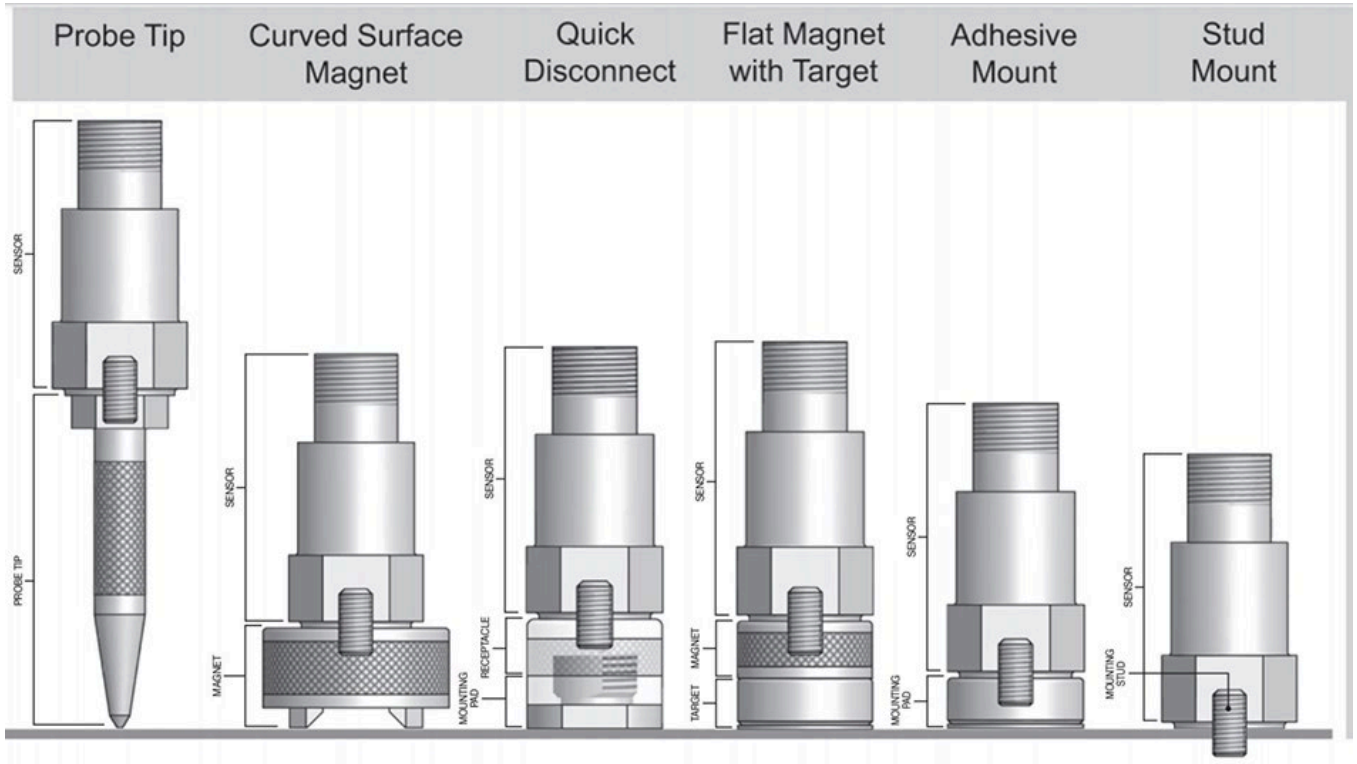

Vibration Meters


Dynamic Vibration Data Collectors

# Types of Accelerometers

- Piezoelectric Accelerometers
  - Most popular and widely used
- Variable Capacitance MEMS
  - Micro-electro-mechanical systems
  - Smallest and least expensive
- Piezoresistive Accelerometers
  - Best for shock testing

# Type of Accelerometer Probes



# Good Data vs. Bad Data

- Anyone can collect data, but collecting good data is critical
- Consistency (or precision)
  - Ensure repeatability and follow your established system
  - Trending data is invaluable → first indicator there may be an issue
  - Avoid changes in testing intervals, conditions, or other variables
- Accuracy
  - Using accurate and calibrated equipment is crucial
  - Ensure measurements are performed during normal operation
- Avoid common Mistake:
  - Collecting data on incorrect equipment
  - Collecting data in the wrong location
  - Slapping accelerometer onto equipment (introduces resonance)

Low Consistency
Low Accuracy

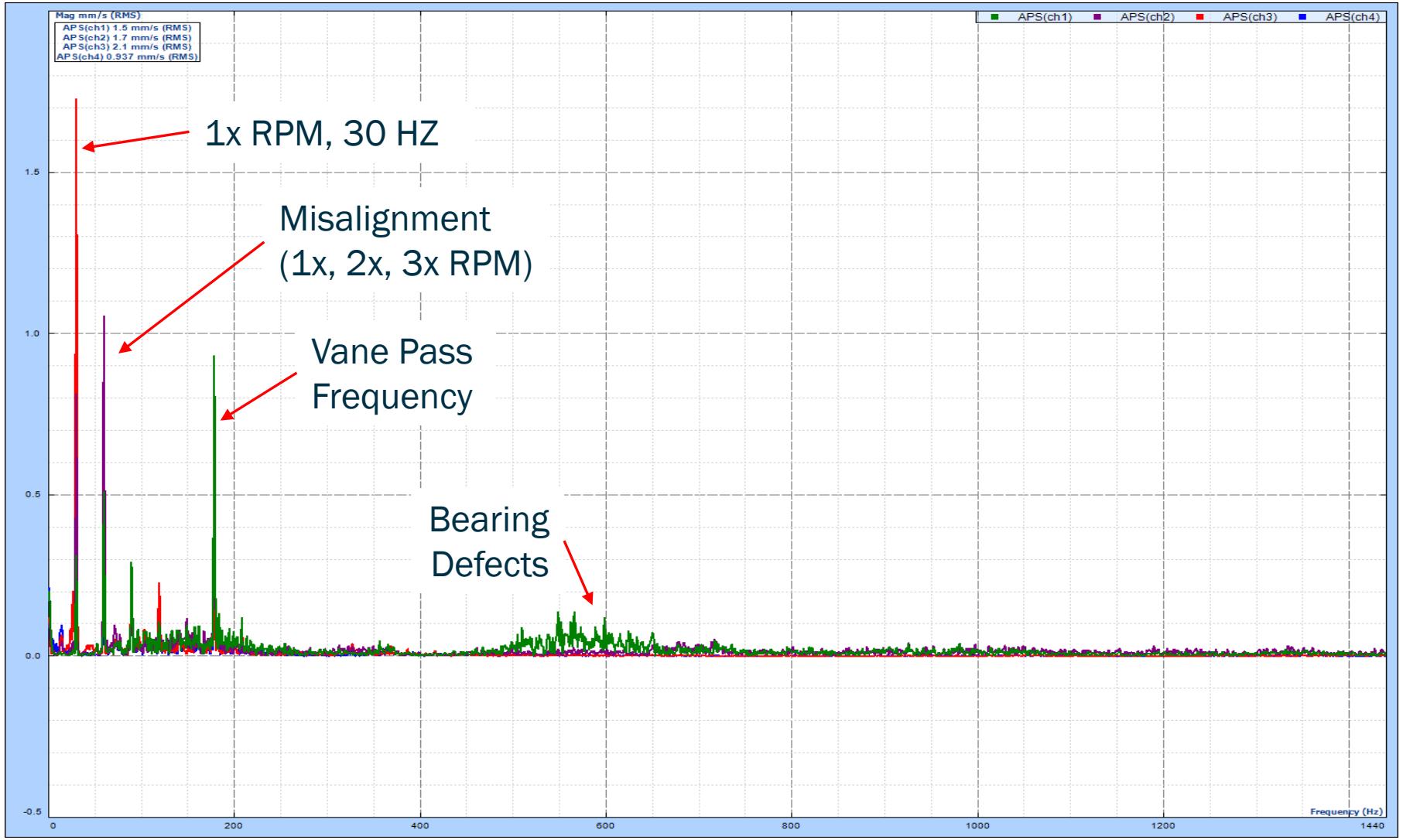
High Consistency
Low Accuracy

Low Consistency
High Accuracy

High Consistency
High Accuracy

# Vibration Data Collection

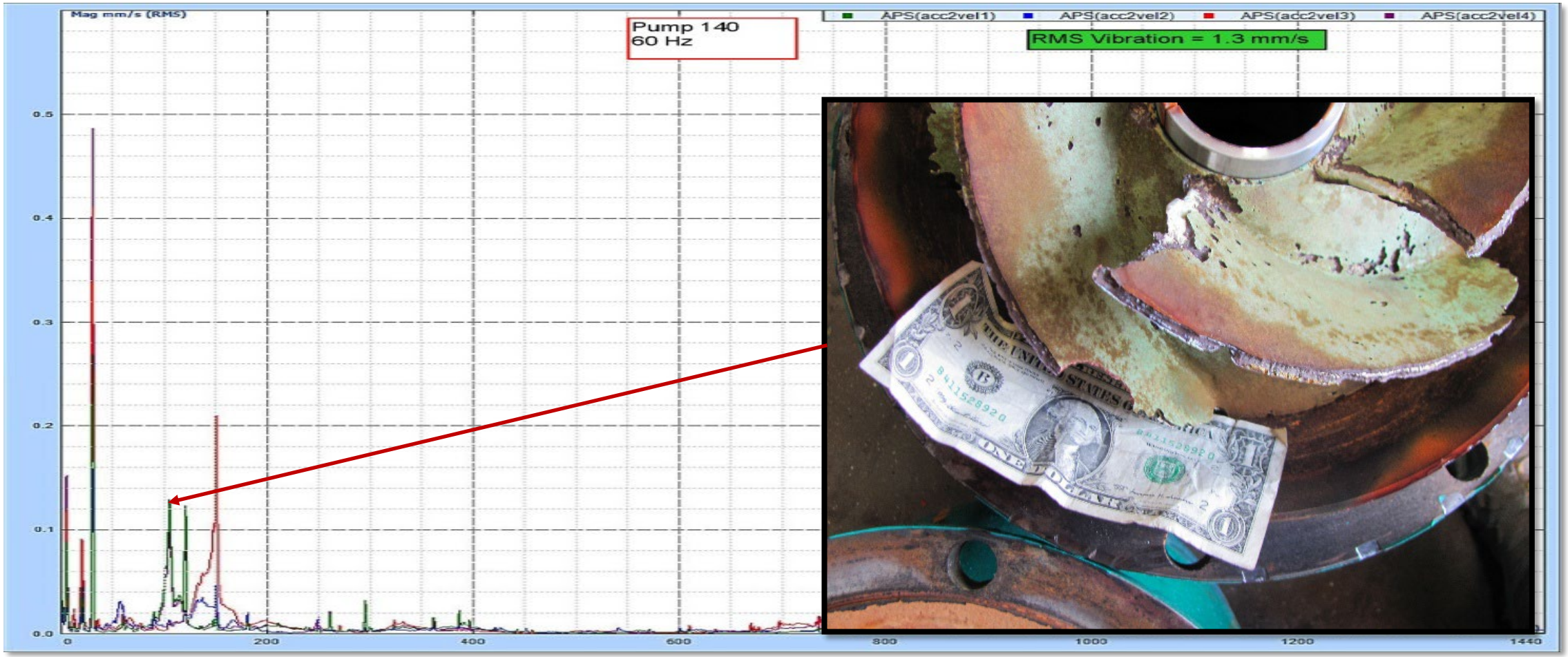
# Vibration Spectrums



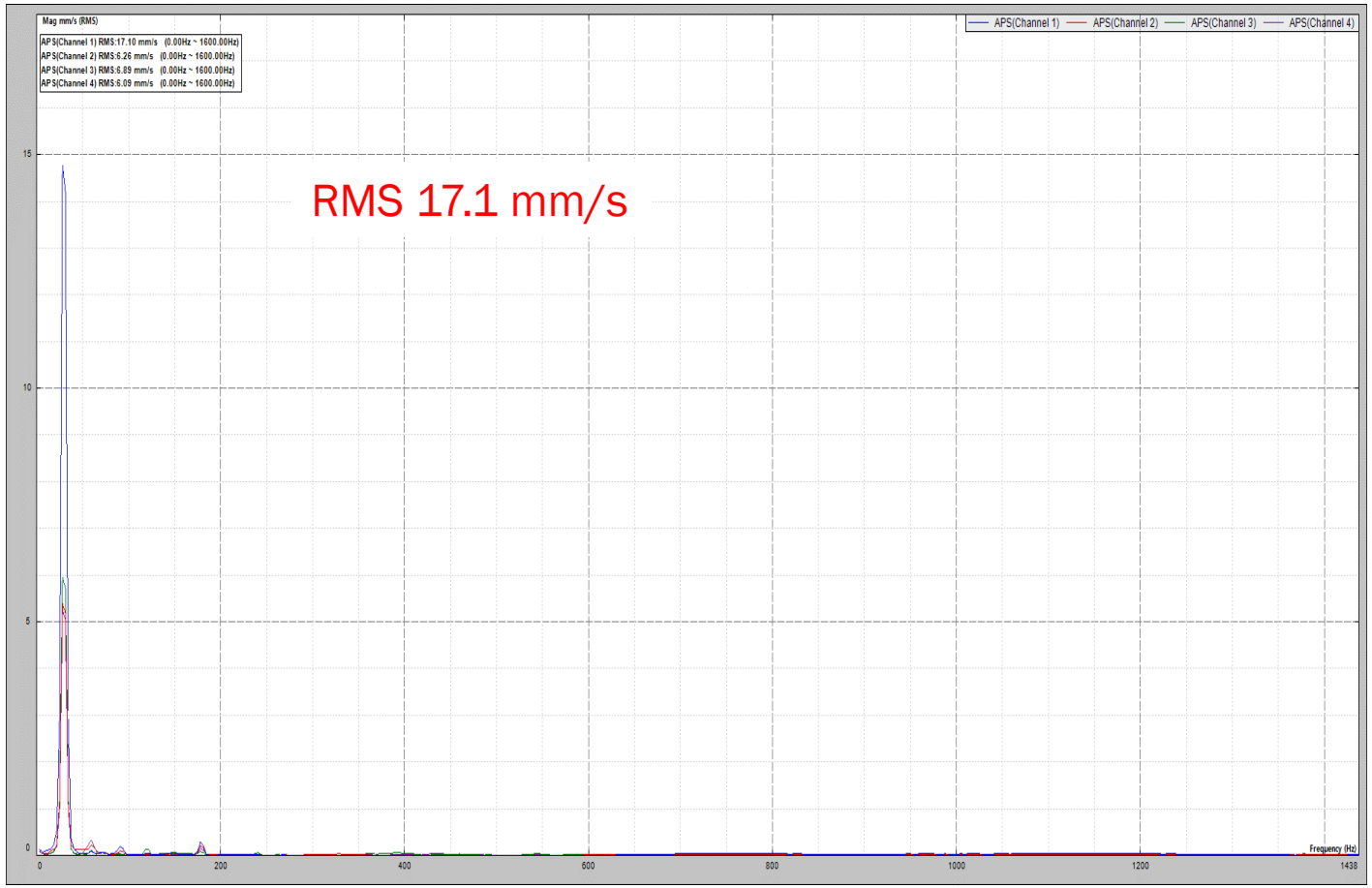
# International Standards Organization (ISO)

| Table 1<br>ISO 10816 | | Machinery<br>Groups 2 and 4 | | Machinery<br>Groups 1 and 3 | |
|---|---|---|---|---|---|
| | | Rated Power | | | |
| Vibration Velocity<br>less than or equal too | | Group 2: 20 HP - 400 HP<br>motors (15 kW-300 kW)<br>6.2" <= H <=12" | | Group 1: 400 HP - 67,000 HP<br>motors (300 kW-50 MW<br>12" <= H | |
| in/sec<br>peak | mm/sec<br>RMS | Group 4: Pumps >= 20 HP (15 kW)<br>Integrated driver | | Group 3: Pumps >= 20 HP (15 kW)<br>External driver | |
| 0.61 | 11 | Damage Occurs | | | |
| 0.39 | 7.1 | | | | |
| 0.25 | 4.5 | Restricted Operation | | | |
| 0.19 | 3.5 | | Unrestricted Operation | | |
| 0.16 | 2.8 | | | | |
| 0.13 | 2.3 | | | | |
| 0.08 | 1.4 | | | Newly Commissioned Machinery | |
| 0.04 | 0.7 | | | | |
| 0.00 | 0.0 | | | | |
| Foundation | | Rigid | Flexible | Rigid | Flexible |

# Vibration Results Compared with Reality

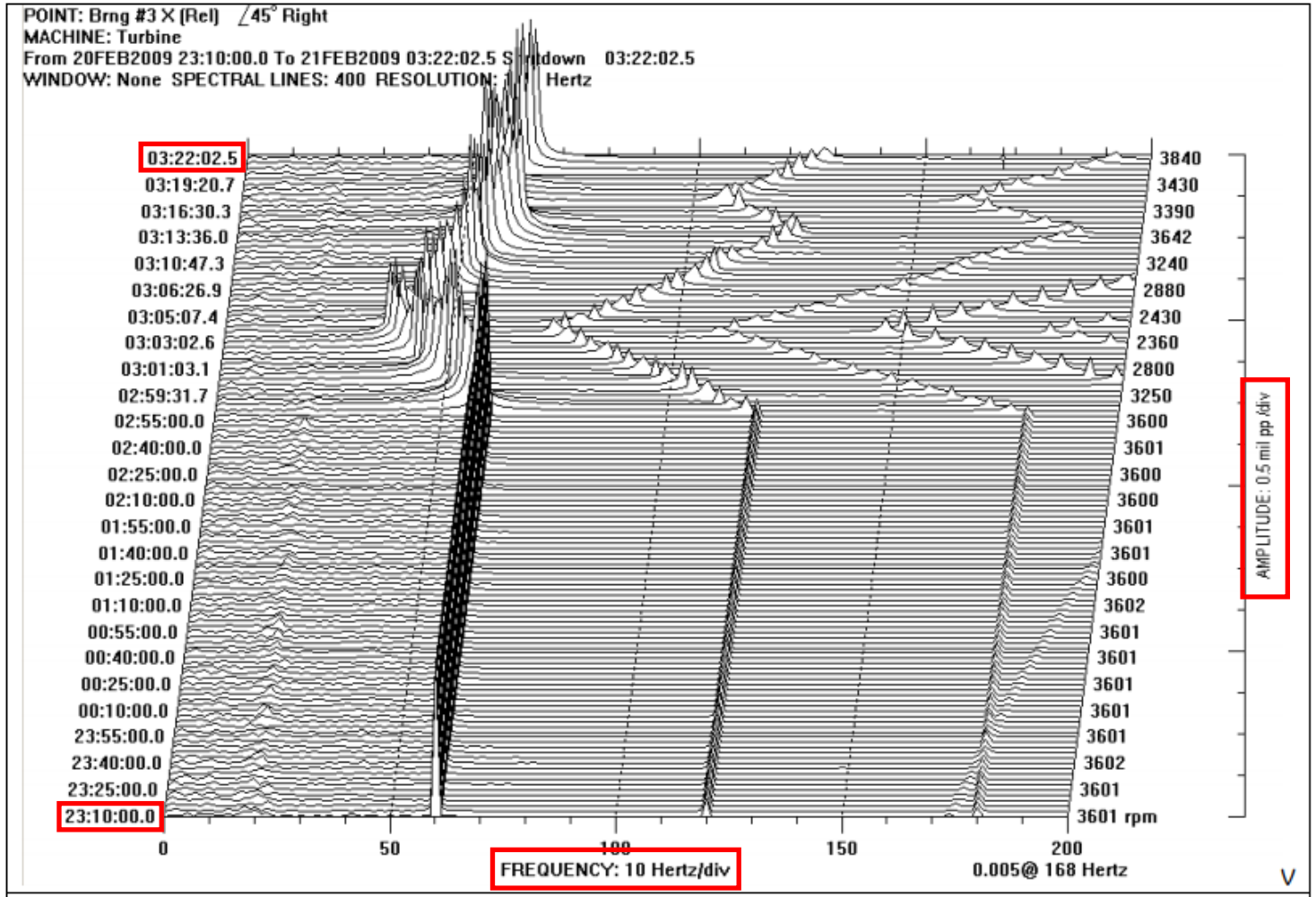


# Vibration Results Compared with Reality




1785 RPM, 125 HP Motor

# Waterfall Plots




Waterfall. Includes some steady speed data and an overspeed test. Note spectrums vs. time but RPM is available on the right axis

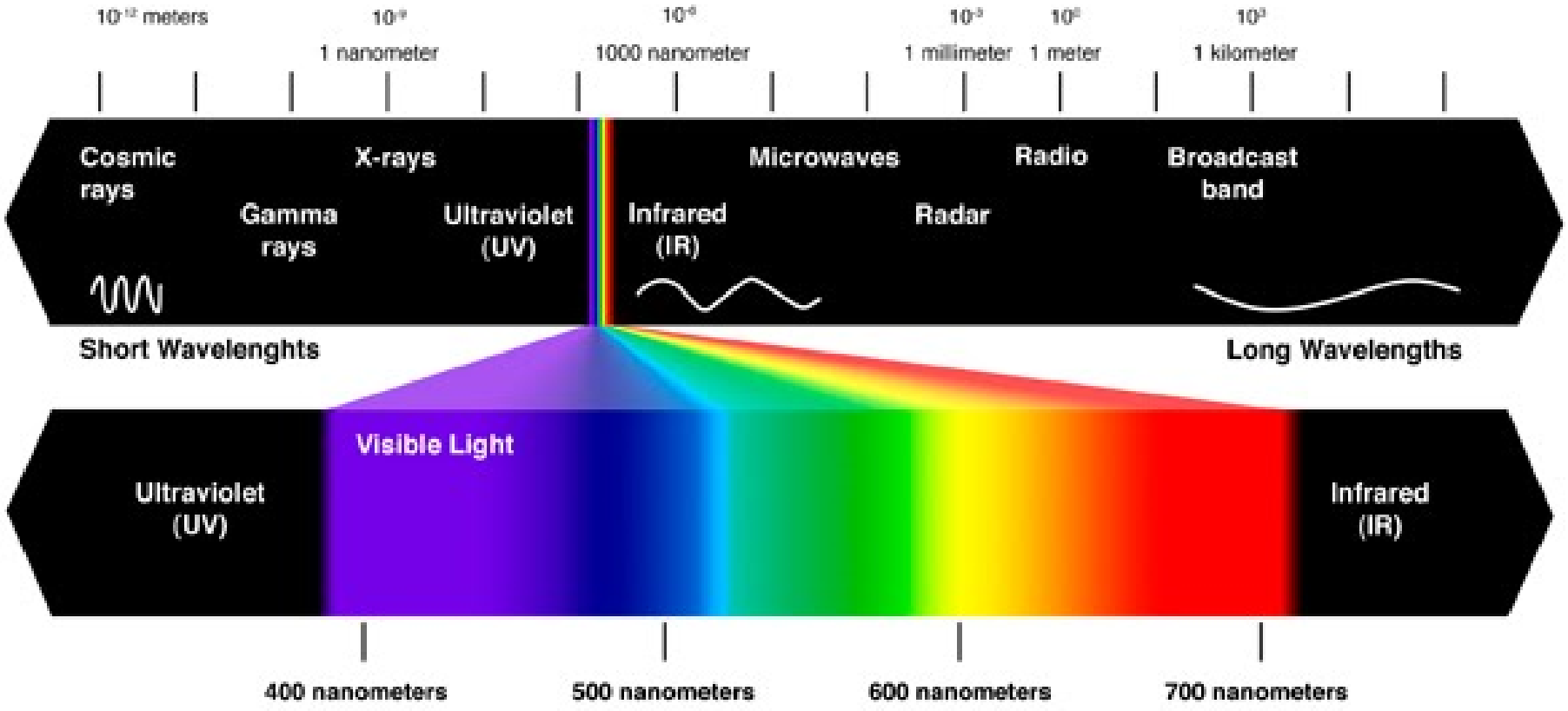
# Establishing a Process

- Established Process = increases accuracy and repeatability

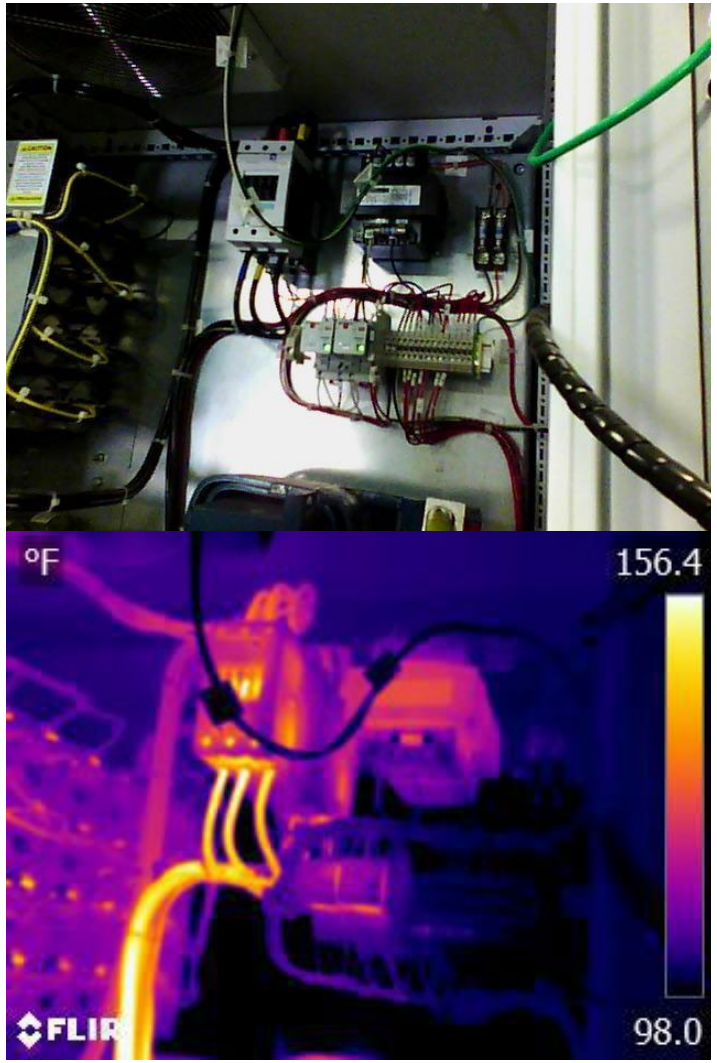
1. Measure the Vibration
2. Establish a Acceptable Vibration Levels
    - Determine normal/acceptable level of vibration
3. Generate Signal Models or Spectrums
4. Analyze your Data
    - Identify harmonics, synchronous peaks, and abnormalities
    - Track changes and variations within the model or spectrum

# Thermography (Thermal Imaging)

# Thermography Concepts

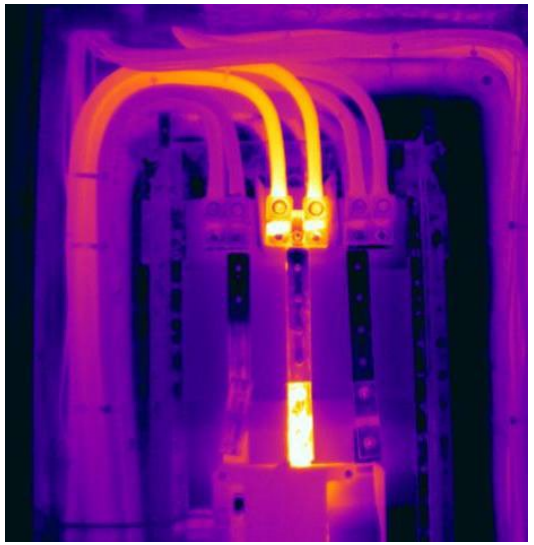


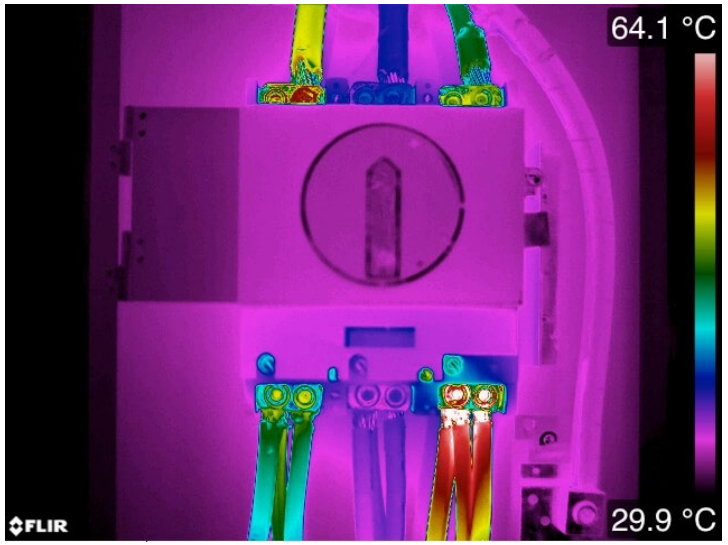
# Thermography Data Collection




- Thermography
  - Non-invasive procedure
  - Aids in data driven repair and replacement schedules
  - Identifying areas of excessive heat generation (wasted energy)
- Thermography is a fast way of identifying areas of excessive heat generation
  - Excessive heat generation = Wasted Energy
  - Wasted energy leads to damage in equipment

# Thermography

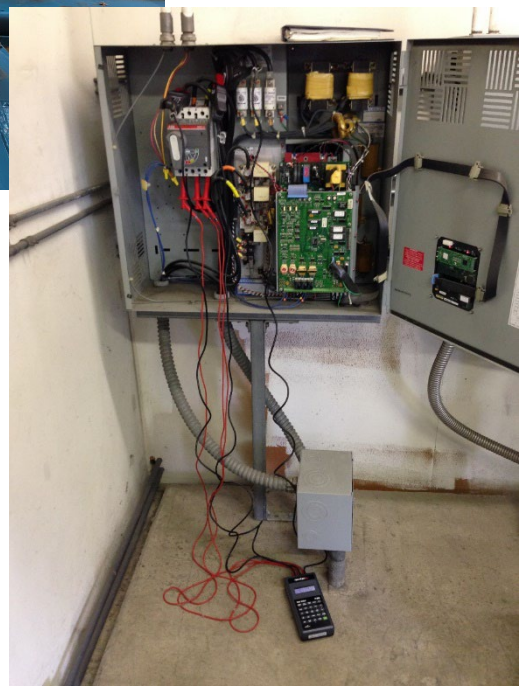




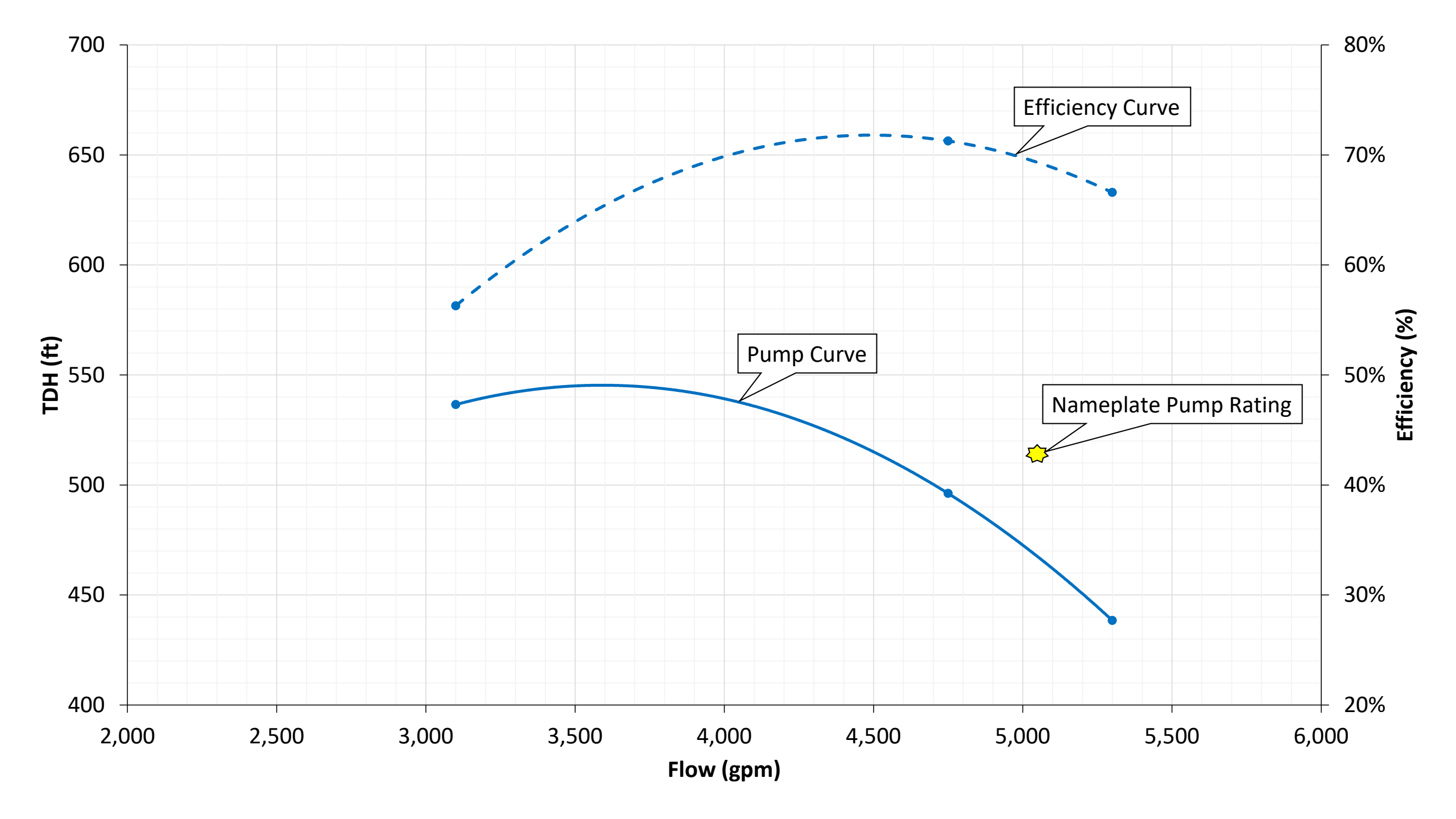

- Causes of wasted energy include:
  - Poor cooling
  - Reduced airflow
  - Lack of lubrication
  - Misalignment
  - Electrical faults

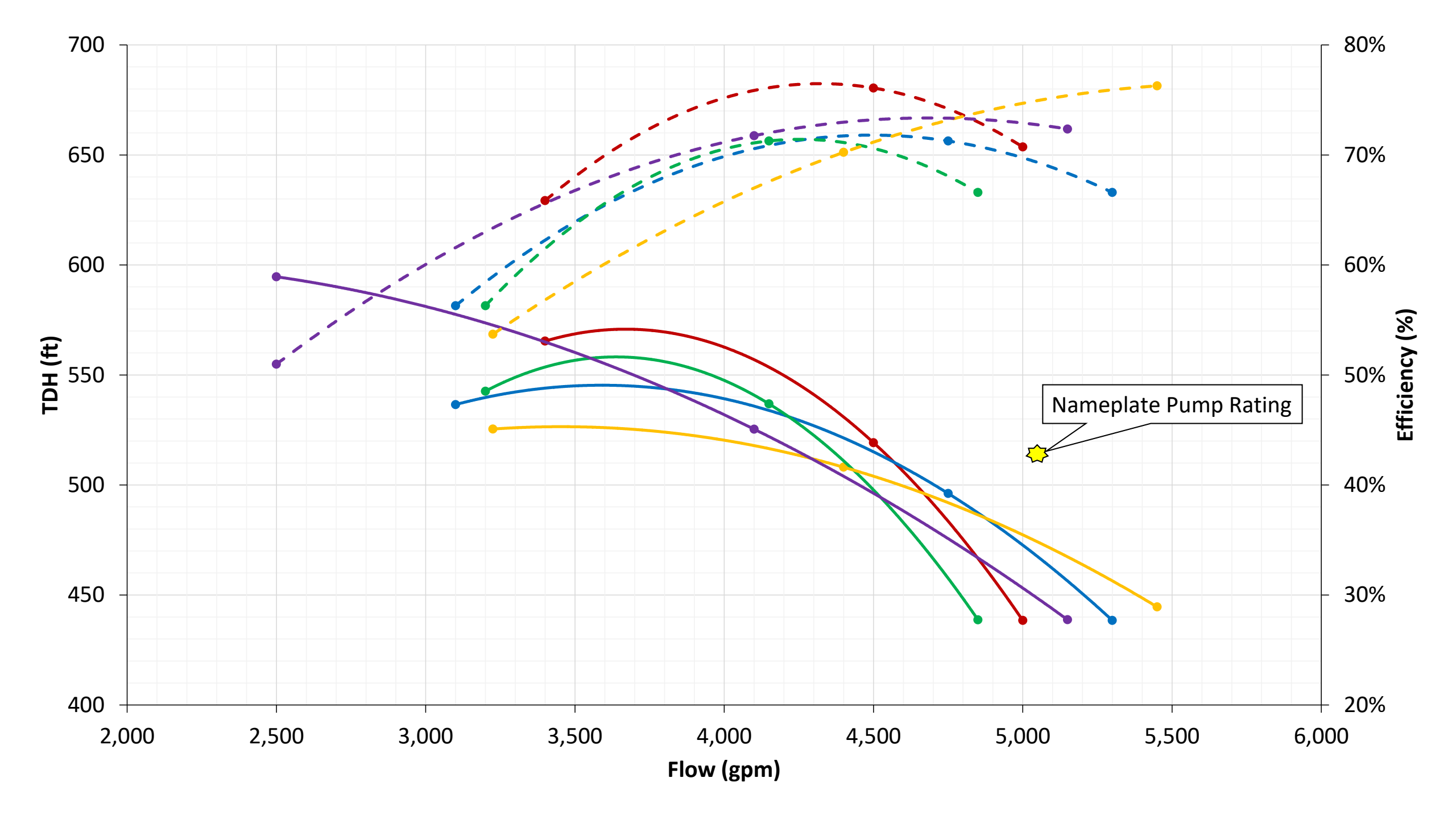
# Energy Signature Analysis

# Hydraulic and Energy Data Collection



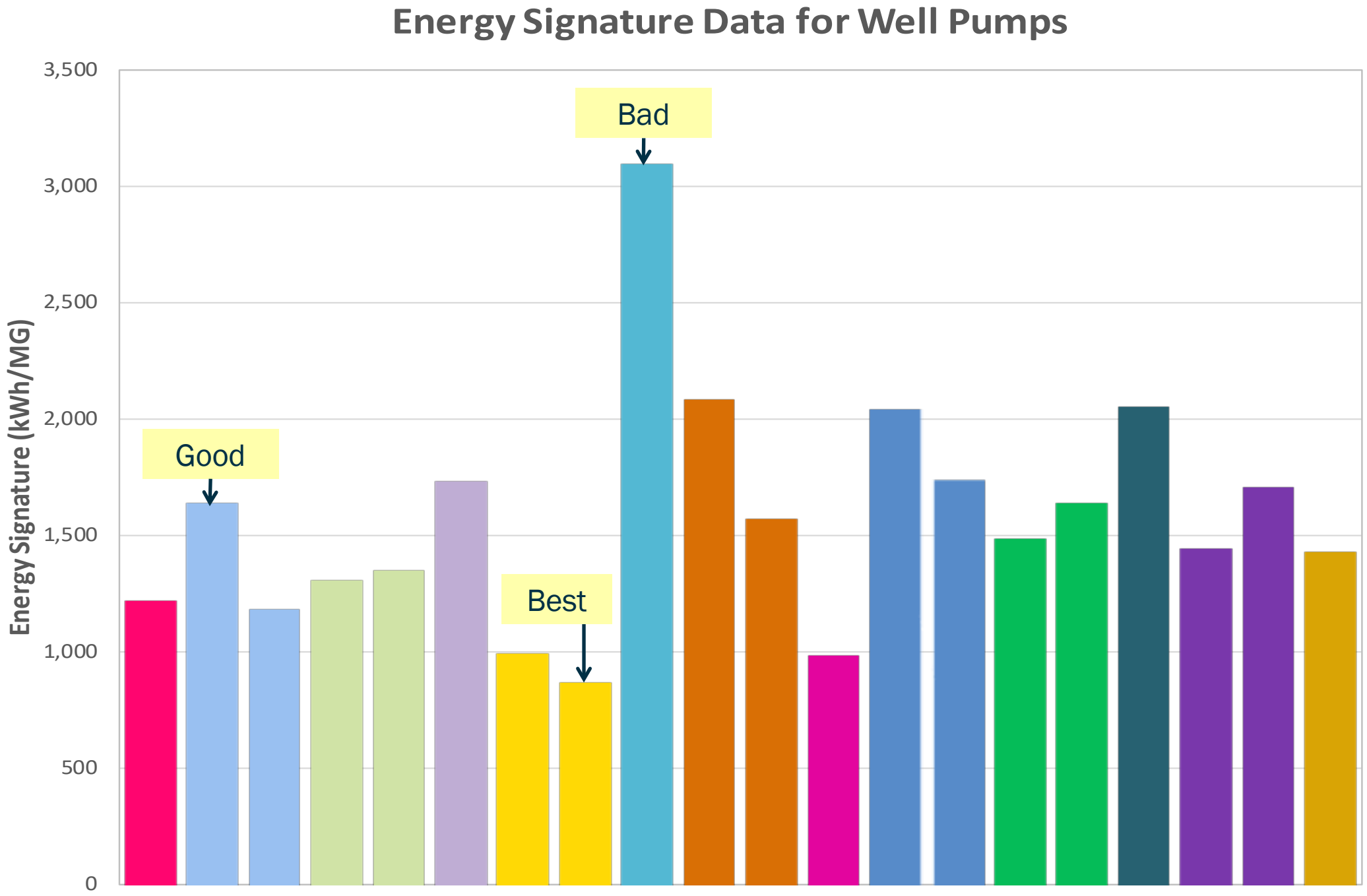
- Hydraulic Data
  - Flow rate and suction/discharge pressure
- Electrical Data
  - Current, voltage, and power quality data
- Multiple-Point Pump Test
  - Normal operating point performance
  - Throttled pump performance
  - VFD settings


700
650
600
550
500
450
400
TDH (ft)
80%
70%
60%
50%
40%
30%
20%
Efficiency (%)
Efficiency Curve
Pump Curve
Nameplate Pump Rating
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
Flow (gpm)


700
650
600
550
500
450
400
TDH (ft)
80%
70%
60%
50%
40%
30%
20%
Efficiency (%)
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
Flow (gpm)
Nameplate Pump Rating

# What is an Energy Signature?

- Metric for measuring pump energy consumption
- Energy required to pump 1 million gallons of water
  - Units = Kilowatt-Hours/Million Gallons [kWh/MG]
- Lower Energy Signature = Better Pump Performance
- Function of:
  - System demand
  - Discharge HGL
  - Suction HGL
  - Mechanical and electrical equipment efficiency


Energy Signature Data for Well Pumps
Energy Signature (kWh/MG)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Bad
Good
Best

# Costs and Benefits

# Benefits of Testing

- Cost Savings
  - Optimize energy use
  - Reduce maintenance costs
  - Maximize useful life of equipment
  - Avoid costs due to catastrophic failure or unplanned repairs
- Factual Support for Decision Making
  - Advise elected officials
  - Explain decisions to stakeholders

# When Should our Equipment be Tested?

- Single Test = Current Condition of Equipment
  - Start-up testing allows you to determine the true condition and performance of equipment before it begins service
- Periodic Testing + Data Trending = Increased Predictability
  - Preventative Maintenance

# How to Get Started?

- Consider Testing Your Pumps
  - Collect baseline measurement
  - Start-up testing
  - Repeated testing across specified intervals
    - 1-, 2-, 3-, or 5-year intervals depending on the age or usage of the facility
  - Establish a route
    - Increases repeatability of data collection and minimizes errors
  - Troubleshooting specific issues

# Questions?