FLUKE®
Reliability

Understanding the Basics of Automated Diagnostic System

Meet the Speaker

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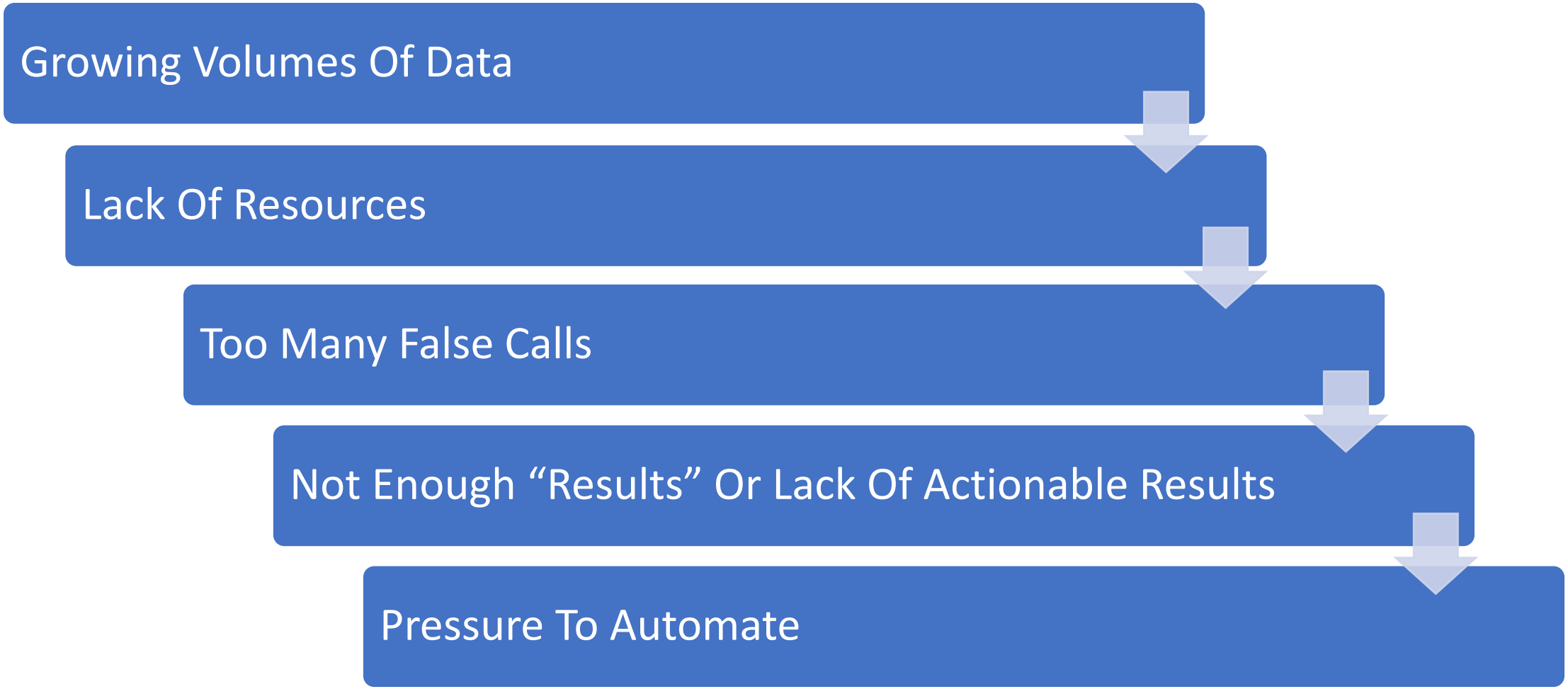
Senior Solutions Services Subject Matter Expert

- Roles:
  - SME-Operations Group
  - Technical Sales Engineer
  - Program Manager
  - Senior Analyst
- Level 3 Vibration Analyst / 20+ years

Why is Automation so Important?

Challenges Customers are Facing



Requirements For A Reliable Automated System

- Repeatable Data
- Accurate Alarming
- Consistent and Reliable Rule Base
- Diagnostic Results with Usable Action Items

Introduction to Azima's Condition Monitoring Solution

CM Hardware

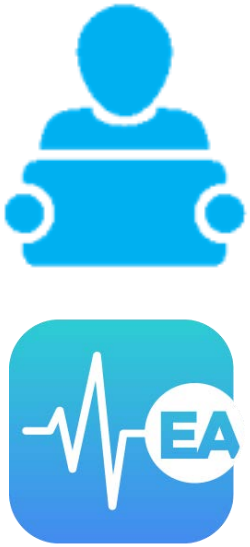
Online

Portable

Wireless

CM Software and Services

AI Backed CM Analysis

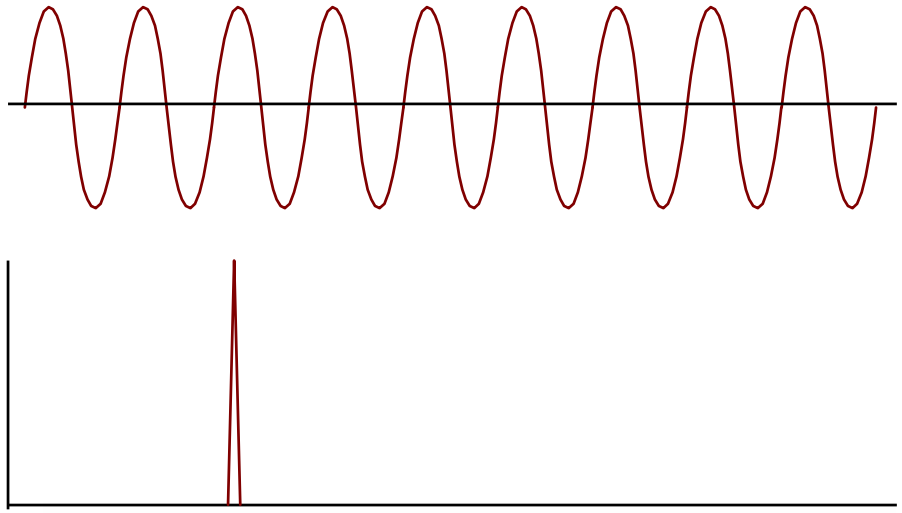


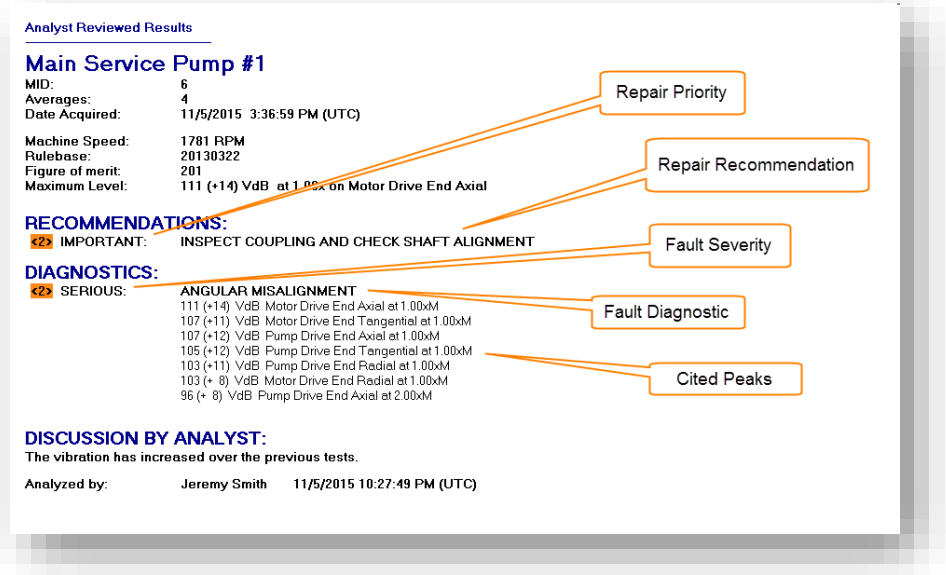
Reporting Software

FLUKE Reliability

What it IS!

Time Series Data
Spectrum Data
High Resolution
(Avg 100,000 Lines/Machine Test)
Diagnostic
Actionable





How Do We Do It

Pre-Data

Understand The Machine

Identify “Forced” Frequencies

Post Data

Analyze Data

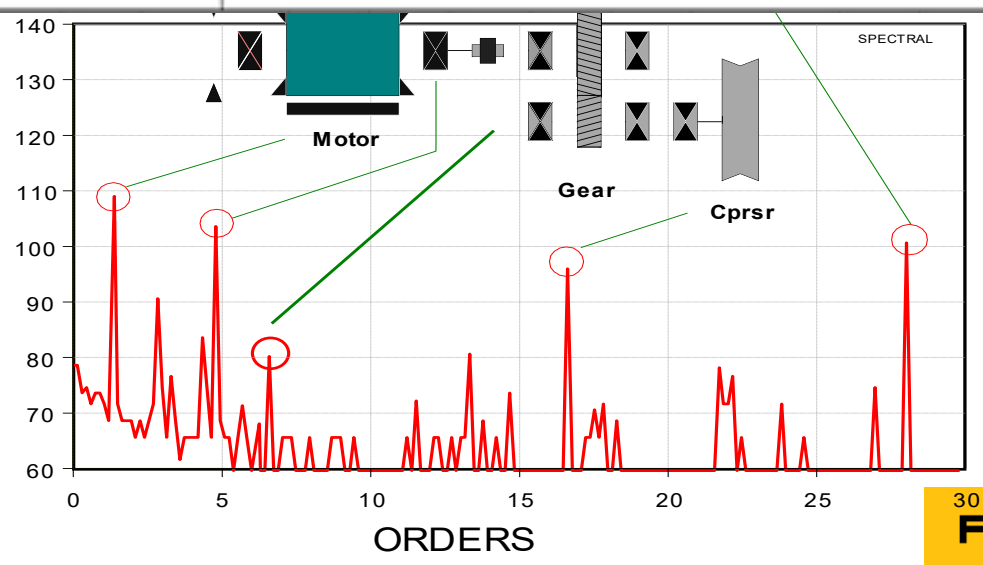
Determine Exceedances

Identify “Fault” Frequencies

Determine Severity

Recommend Action

Plant / Area				Machine Name								Asset ID			Photo ID
Plant 1 / Crush / Extraction				Recycle Pump #1								P-031231			
HORIZ	OVERHUNG	M NDE	M DE	CPL	Machine Type:		Pump	Fan	Comp: Cent	Screw	Recip	Blower	Refiner	Agit	Other
VERT	Y N	1	2	Rigid	3	4	5	6	7	8	Rigid	9	10	11	12
MANUF.	Toshbia			Flex							Flex				
HP	25		VAH	None	VAH						None				
DRIVER				Chain							Chain				
RPM	3575			Belt							Belt				
DR Mod#				Frame: 256T			Brgs: 6310 / 6309							Photo ID	
DVN Make: Durco				Type: Centrifugal			Model: Group 1							Photo ID	
RATIO:															
NOTES				2 3											



Attachment Pads – Epoxy or Stud Mount

NO MAGNETS!!!

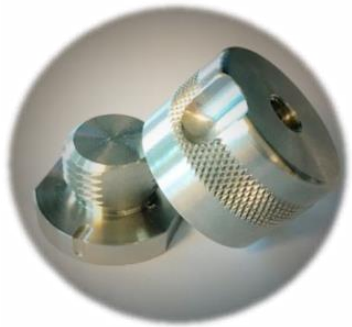
Superior Frequency Response

- Ensures consistent, precise location of accelerometer/sensor for each testing period
- Eliminates variations in measurements from magnets

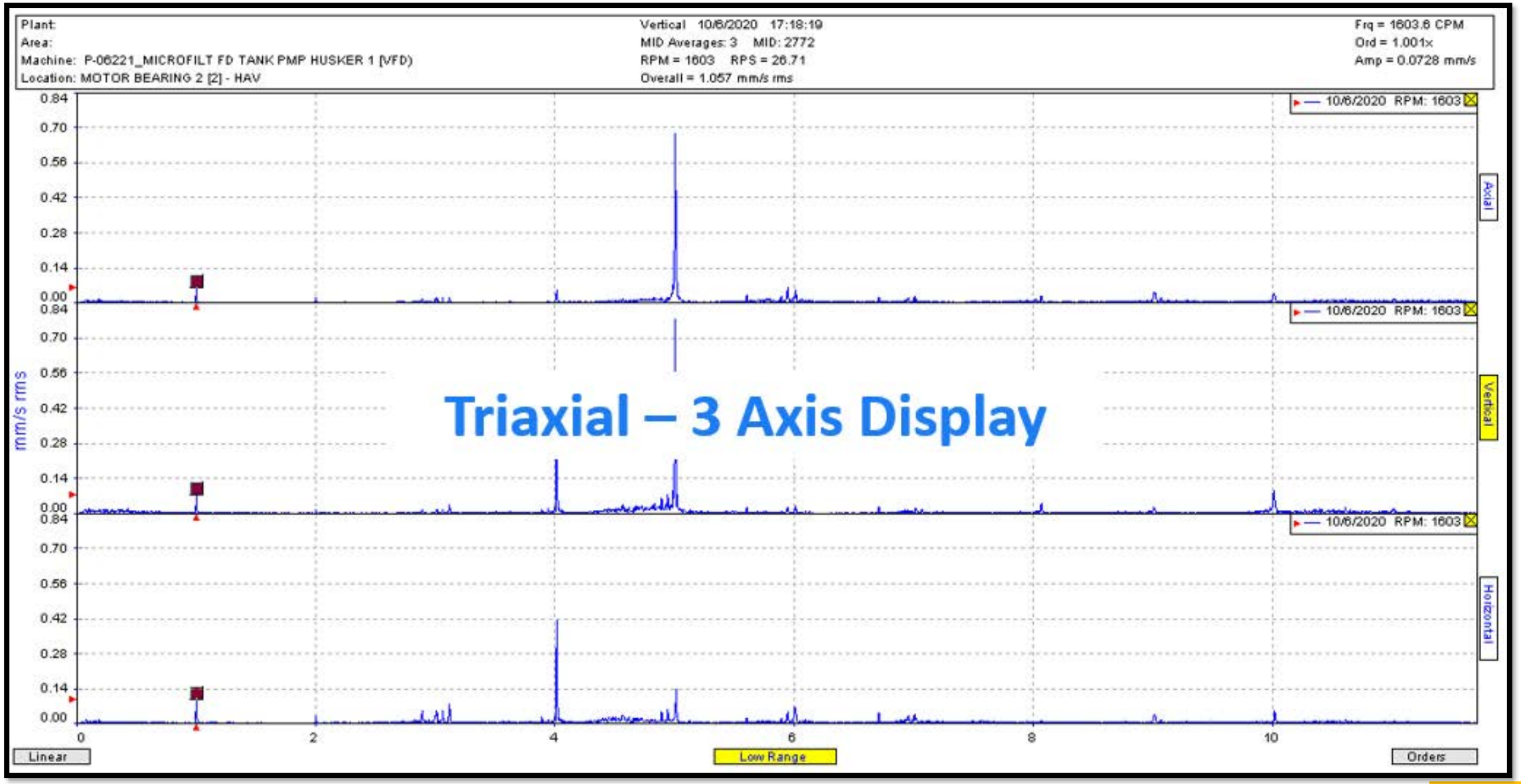
Triax Data - Proven Methodology

- Simultaneous collection of data on three axis
- Fewer measurement points for faster collection of data
- Ensures common speed and load for all three axis

Trio



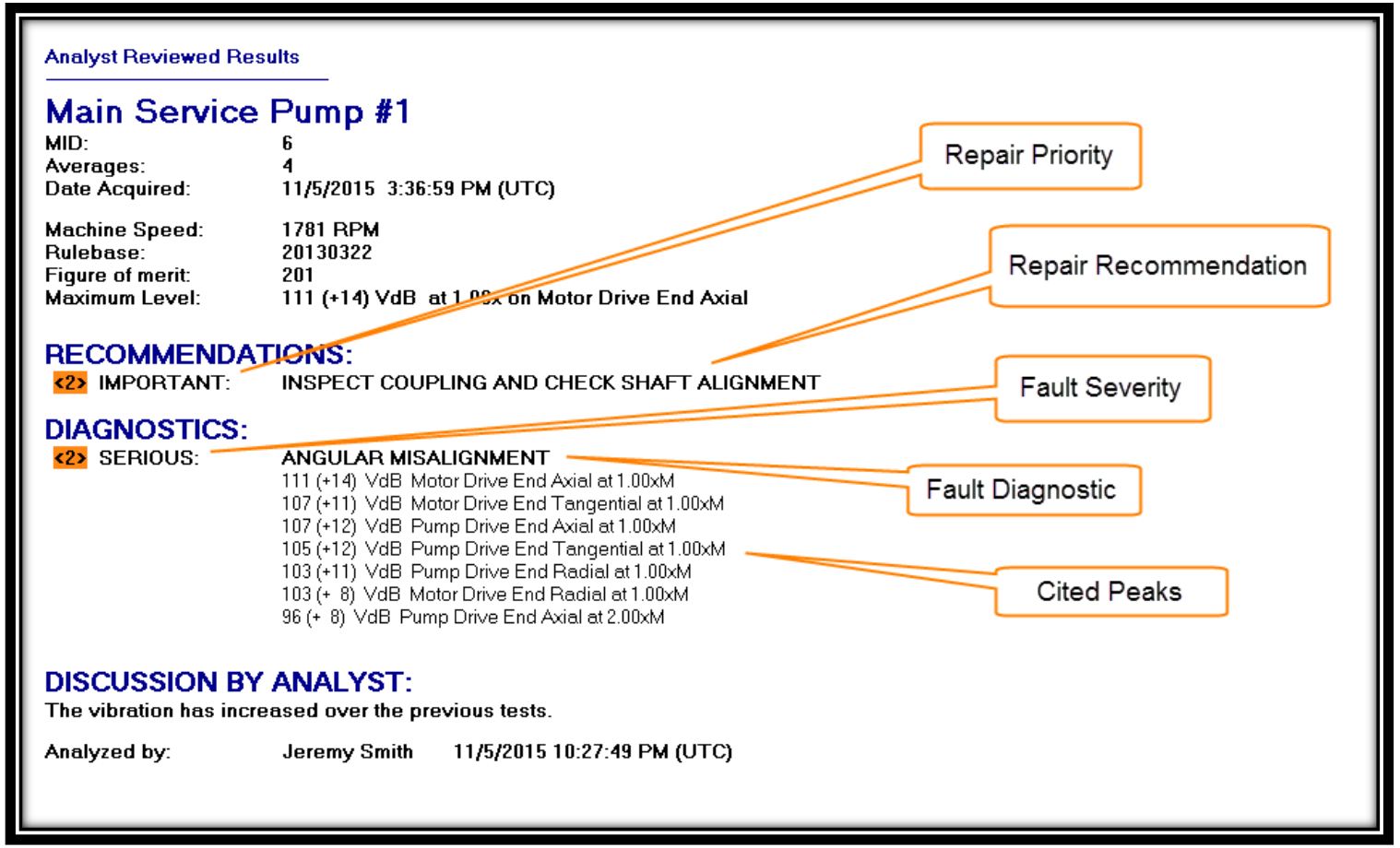
Wireless



FLUKE Reliability

Consistent Results

- 6000+ Diagnostic Rules
- 1200+ Fault Conditions
- 40+ Machine Components



Understanding the Expert Alert Diagnostic System (EADS)

Introduction

- The Expert Automated Diagnostic System (EADS) is designed to assist the vibration analyst.
- The EADS methodology is modeled using well documented principals of narrow band vibration analysis.
- The primary advantage of using the Expert System is to assist the analyst with the routine part of the screening lots of data which includes feature extraction and consistent application of logical rules.

ExpertALERT Diagnostic System (EADS)

- A Basic Understanding-
  - The EADS cites specific machine faults.
  - Software algorithms identify the nature and severity of the faults by applying logical rules.
  - These rules are specific to the component codes supplied by the user.
- Assists Analyst With:
  - Screening.
  - Feature extraction.
  - Consistent application of logical rules.
- These Faults And Rules Derive From The Machine Internal Design (MID)

A Machine Train is the Sum of its Components

- When performing manual analysis on a machine, a vibration analyst must consider the interaction between all components in the machine train.
  - For example, an analyst cannot diagnose motor bearing wear without first checking to see if the indications of bearing wear are stronger on the pump.
- The Expert System requires at least one measurement location on each major component in the machine train.
- When diagnosing a fault on a given component, the Expert System considers that the indications could be coming from an adjacent component.

Triaxial Vibration Data

- Repeatability of vibration measurements is a fundamental principal when doing vibration analysis where the data today is compared to what it was in the past.

- For maximum accuracy, the Expert System uses three axes of vibration data collected at the same locations every time.

- A triaxial accelerometer that is stud mounted or epoxied to the machine provides excellent repeatability and quality of data.
  - History has shown that collecting vibration in all three axes gives the analyst an adequate picture of how the machine is vibrating.

- Mounting pads or sensors permanently fixed to the machine define the measurement locations.

Two Frequency Ranges of High-Resolution Spectra

- Two frequency ranges allow the analyst to diagnose the most common faults that can be seen in the vibration data.
- The low frequency range data typically has a frequency span of zero to 10X the shaft rotation rate while the high range data has a span of zero to 100X shaft rotation rate.
- The faults diagnosed by the Expert System use cited peaks from either one or both frequency ranges.

Test Operating Condition Guidelines

Three assumptions made by the Expert System:

1. The machine is operating in a steady state mode at its predefined standard operating condition.

2. The pads/sensors are in the proper location and are orientated according to how they are setup in the database.

3. The configuration and nameplate data of the machine has not changed since the database was built. It is OK to have an overhauled machine if its configuration and nameplate data are as original.

Standard Test Operating Conditions

- Along with the requirements of the sensor mounting method discussed, the Expert System requires repeatable steady state operating conditions while vibration measurements are made.

- The optimum test condition is to have the machine operating at steady speed with at least 80% rated load.
  - If this is not possible then any test condition that can repeatedly excite the forcing frequencies is adequate.

- VFD Machines – the EADS System works well with variable speed machines if:
  - Speed is constant during data collection
  - Variations are with in +/- 25% of average set speed

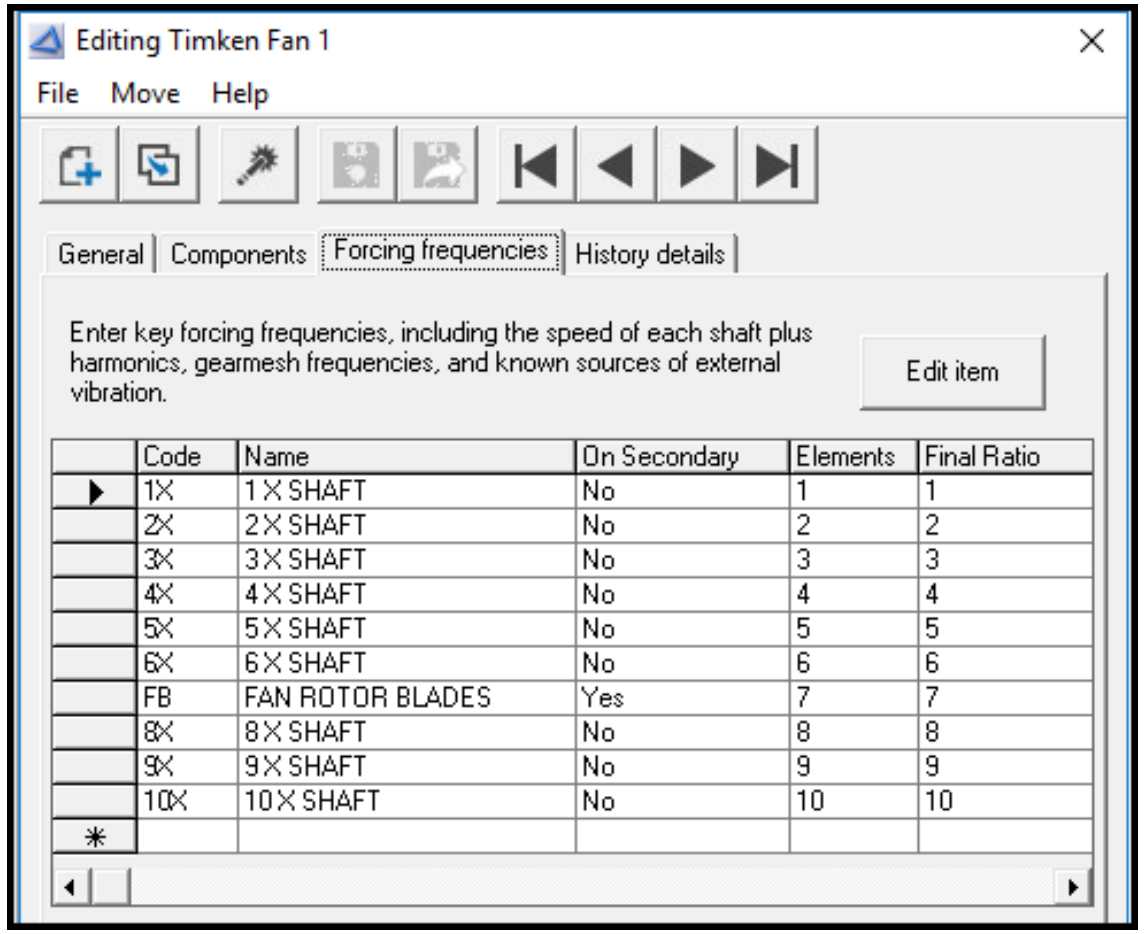
Machine Internal Design (MID)

- The MID trains the Expert System about the configuration of the machine so that it can apply the correct rules.
- The MID is built with specific Component Codes for each component on the machine train
  - Each Component Code identifies specific details of the component
    - AC, DC or VFD Motor
    - Bearing type-Roller or Journal
    - Overhung or center hung component
    - Number of test locations
- Each Component Code has a specific set of rules
- An MID can contain one machine or a multitude of identical machines

MID Forcing Functions

- In a rotating machine, moving parts impart vibratory forces into the machine structure, typically these forces occur at specific frequencies determined by the function of machine elements.

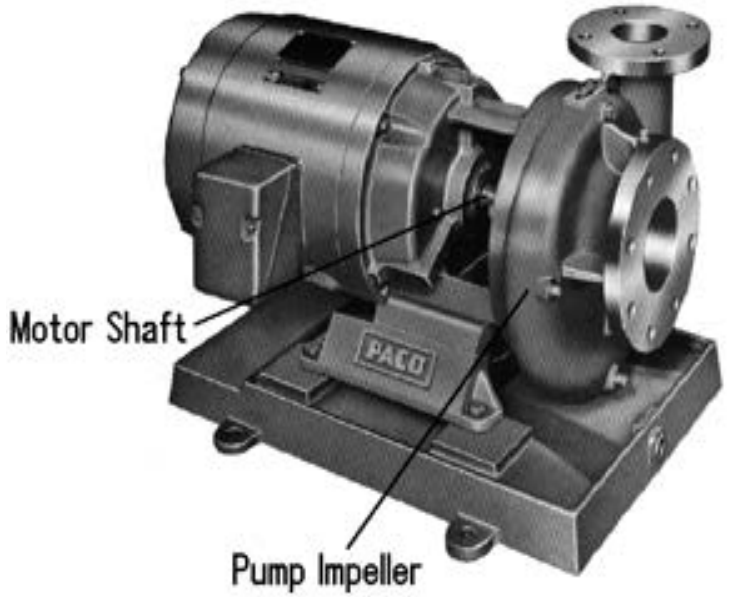
- One of the most important tools for vibration analysis, both manual and automated, is knowing and understanding the functions that create forcing frequencies present in each machine.

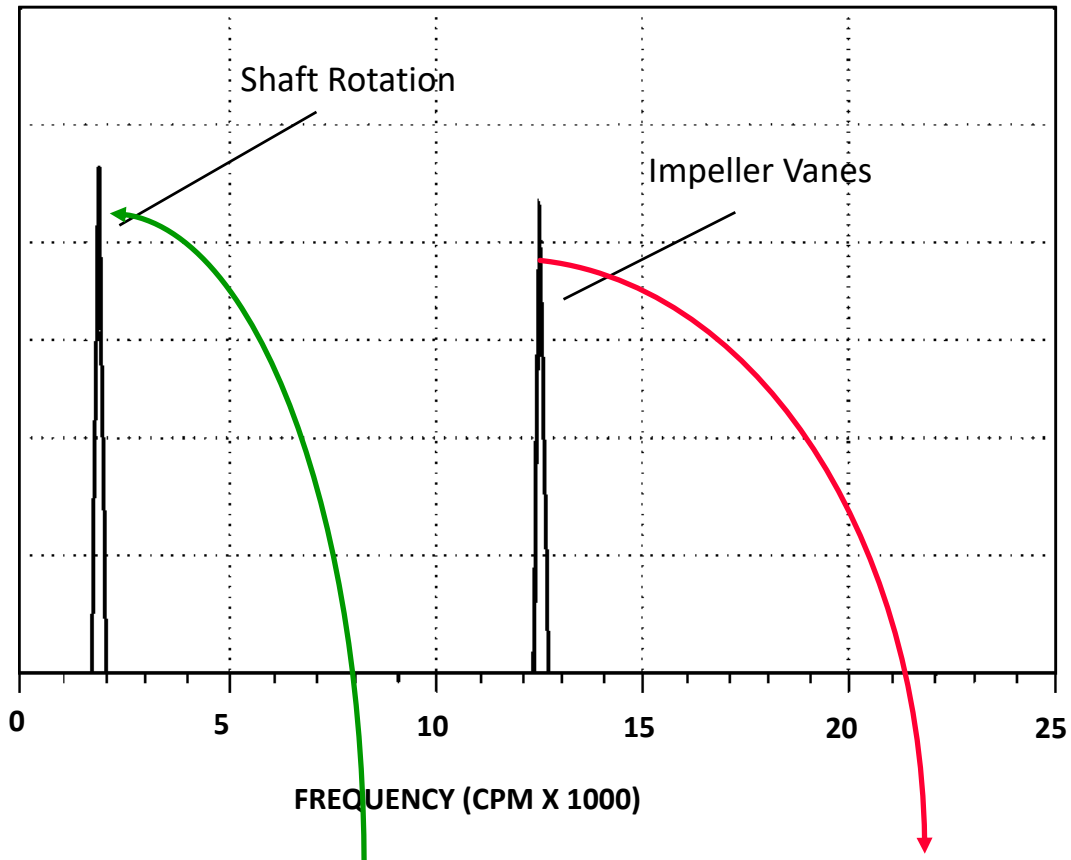


	Code	Name	On Secondary	Elements	Final Ratio
▶	1X	1 X SHAFT	No	1	1
	2X	2 X SHAFT	No	2	2
	3X	3 X SHAFT	No	3	3
	4X	4 X SHAFT	No	4	4
	5X	5 X SHAFT	No	5	5
	6X	6 X SHAFT	No	6	6
	FB	FAN ROTOR BLADES	Yes	7	7
	8X	8 X SHAFT	No	8	8
	9X	9 X SHAFT	No	9	9
	10X	10 X SHAFT	No	10	10
*					

Close-Coupled Pump

Motor: 1800 rpm
Impeller mounted directly on motor shaft
Pump Impeller Vanes: 7



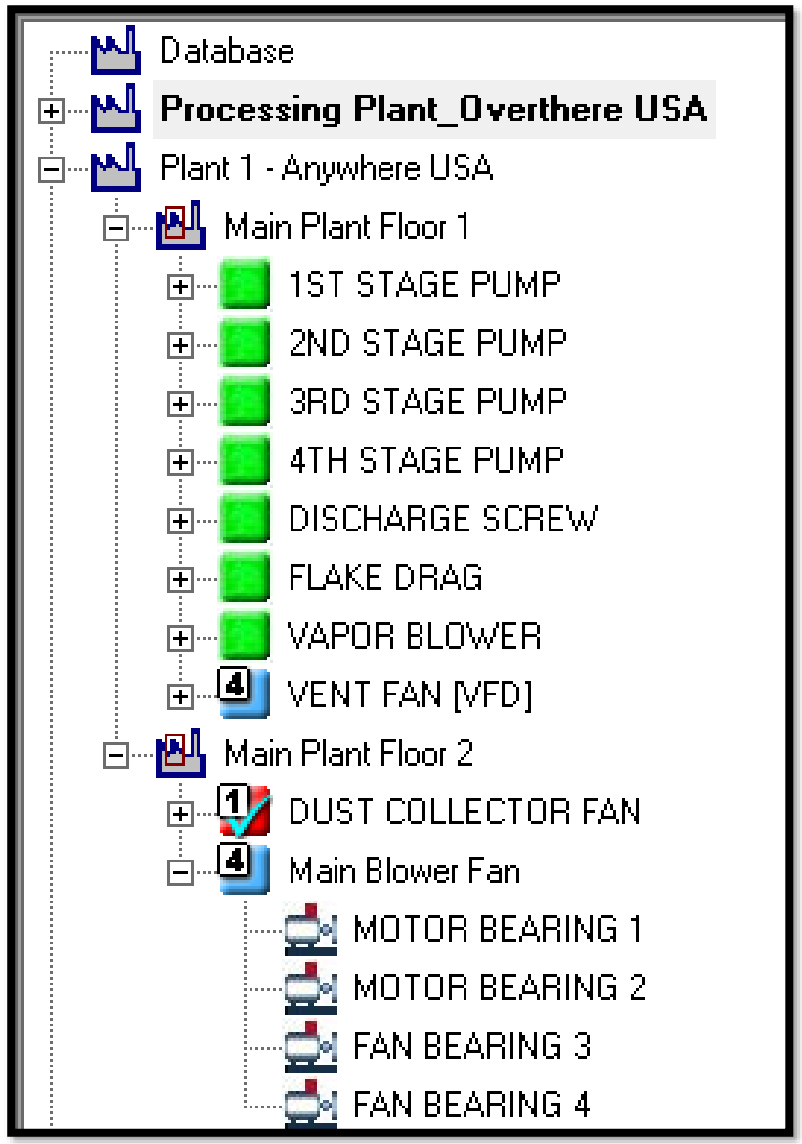


Vane Rate = 1800 cpm x 7 = 12,600 cpm

Building the Database

- Define the hierarchy
- Create the Areas
- Build the Machines
  - Machines can be built from the MID or be built manually.
    - It is recommended to first build the MIDs first and then build the machines from the MID
- Edit as needed

Build EA Database



Database Hierarchy

- Plant
  - Area
    - Machine
      - Locations

- No limit to number of plants or areas

Baseline and Alarming

Fine Tuning – after the first data set

- New data should be reviewed for the proper data collection set up
  - Are low and high range data being captured?
    - Spectra and waveform
  - Do the setups include all frequencies of interest?
    - For gearboxes, 3.5 times higher than the highest gear mesh frequency is recommended
  - Is the resolution high enough to separate all peaks of interest?
  - If averages are already added, verify the average data.

Fine Tuning – after the first data set

- New data should be reviewed to identify any forcing frequencies to add or correct

  - Drive Shaft Speed
  - Driven Shaft Speed
  - Motor Bar
  - Vane/Blade Pass
  - Gear Mesh Frequencies
  - Belt Rate

Baseline and Alarming

- With vibration analysis in general, it is apparent that the frequency of vibration is usually a good indicator of the source of the vibration.
- The source then leads to determining which type of mechanical fault is in evidence.
- In addition, the relative dominance of certain frequencies in one or more of the three axes and at which measurement location(s) are factors in the analysis.
- The debate more often surrounds the question of what amplitudes are considered excessive, and the severity of the indicated faults.
- Many people have sought to establish absolute vibration amplitudes as criteria for general classifications of machinery.

Baseline and Alarming

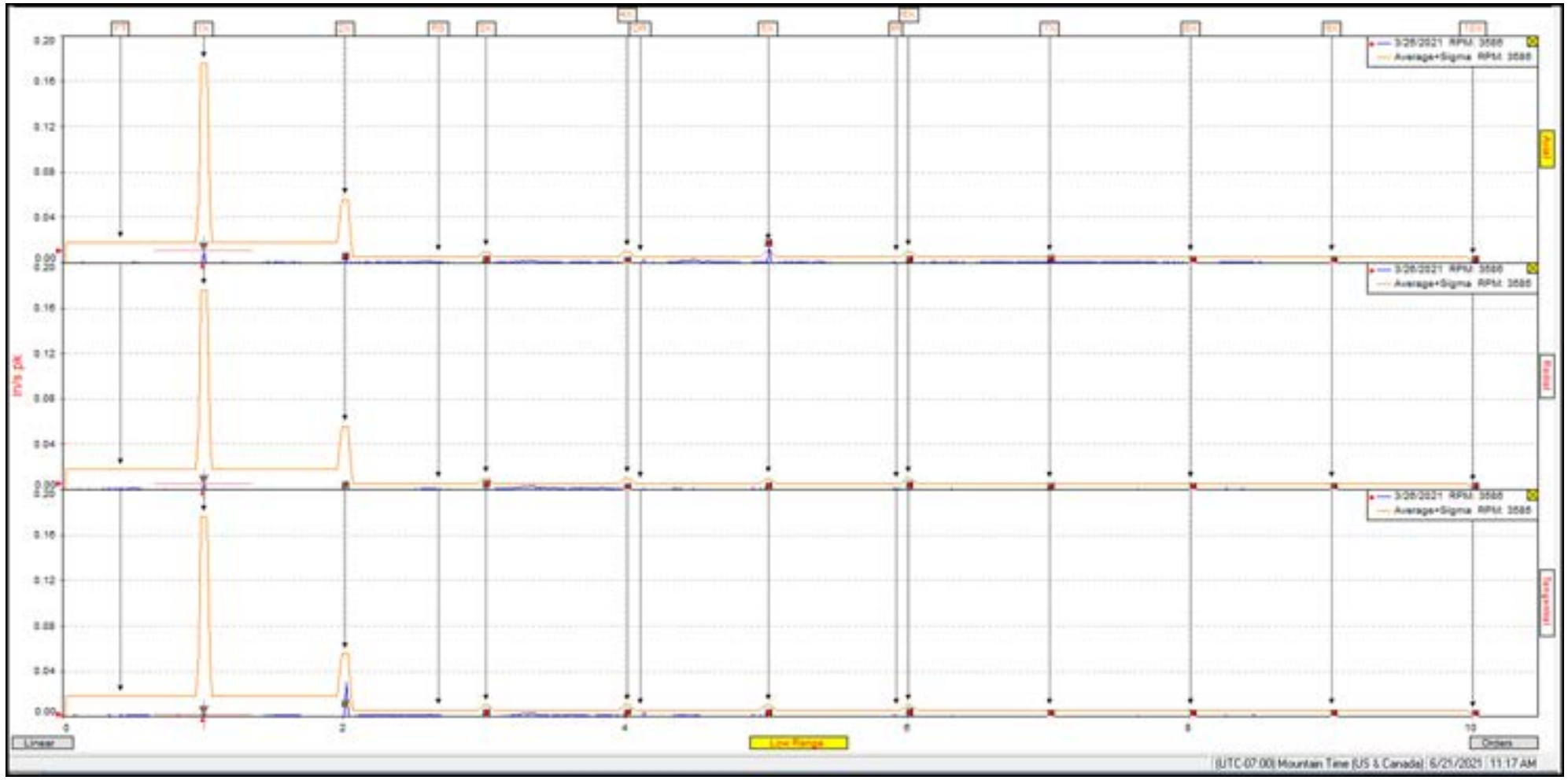
- Experience has shown, however, that certain frequencies or orders of vibration that are very high for one model of machine may be quite normal for a similar machine type.
- When presented with the opportunity to have multiple machines of the same model in a vibration monitoring program, a good basis for comparison already exists.
- By establishing average baseline spectra for a specific machine type, we are allowing the machine itself, and many others identical to it, to determine what amplitudes are allowable.

Baseline and Alarming

- At the onset of a program, the EADS system uses a SYNTHETIC AVERAGE based on MID configuration
  - It is very important to have correct configuration for EADS to perform well
- Once you have historical data then statistical averages can be applied
  - Averages can “normalize” problem machines
    - Never average data that contains significant faults

Synthetic Average

- This baseline is comprised of 17 values (1x – 9x, 1xFF, 2-3xFF, 4-12xFF and various noise floor ranges) that are unique to each major component group.



Baseline and Alarming

- The average baseline used by the Expert Alert Diagnostic System is a set of frequency spectra drawn from actual data.
- These spectra are created by calculating the average of user selected data at each discrete frequency value.
- The software then computes a standard deviation.
- The average + the standard deviation = the alarm level

Baseline and Alarming

The analyst chooses which data sets are added (manual process)

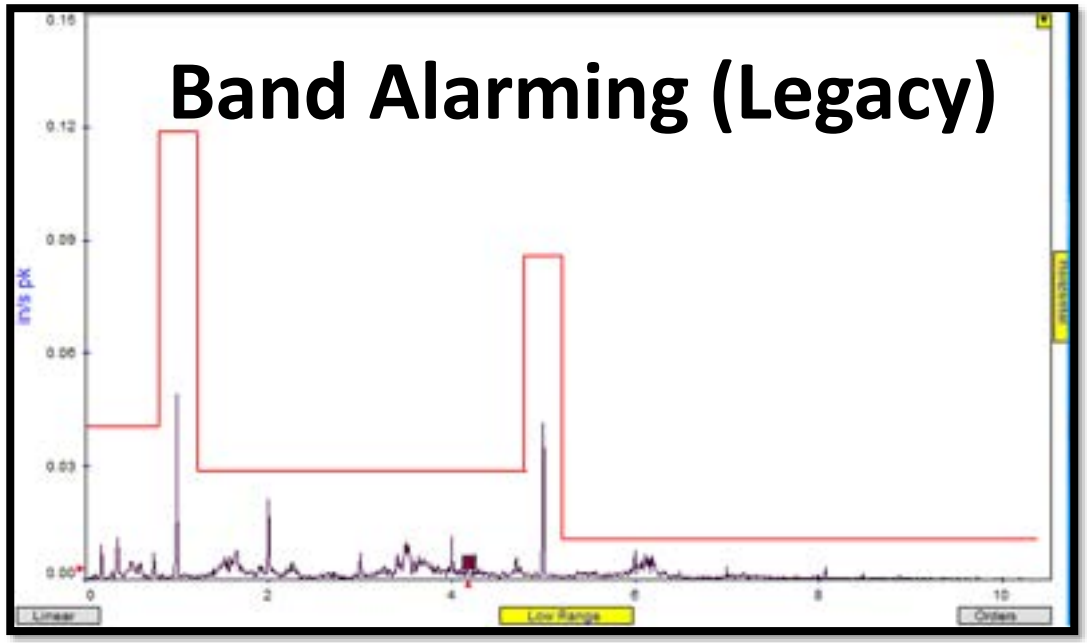
- Data sets that show normal operation should be added.
  - Keep in mind that we are creating and average some variance should be allowed. Elevated running speed, motor bars and other certain forcing frequencies can be elevated.
  - Including data sets with bearing faults is not recommended
    - Averages can “normalize” problem machines

      Never average data that contains significant faults
  - Avoid ski sloped data
  - A minimum of 6 data sets is required for a certified average. 12-20 is ideal.

There are internal tools that allow for automation to assist in creating the averages.

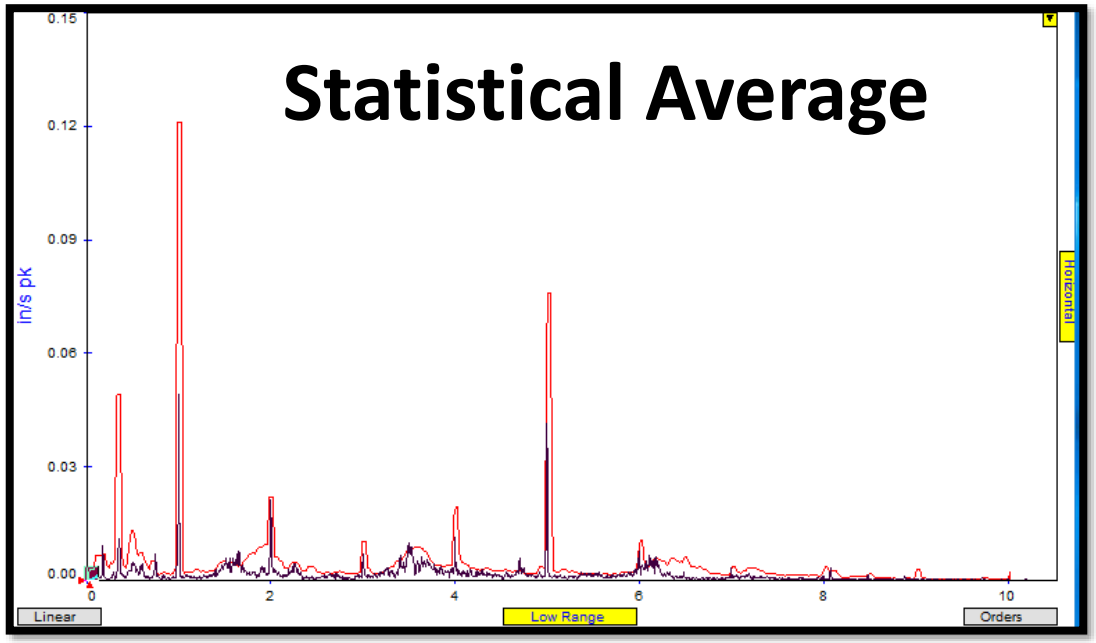
What is a Statistical Average

Others



VS

Azima DLI Screening



8000+ Line - Screening Criterion (per machine)

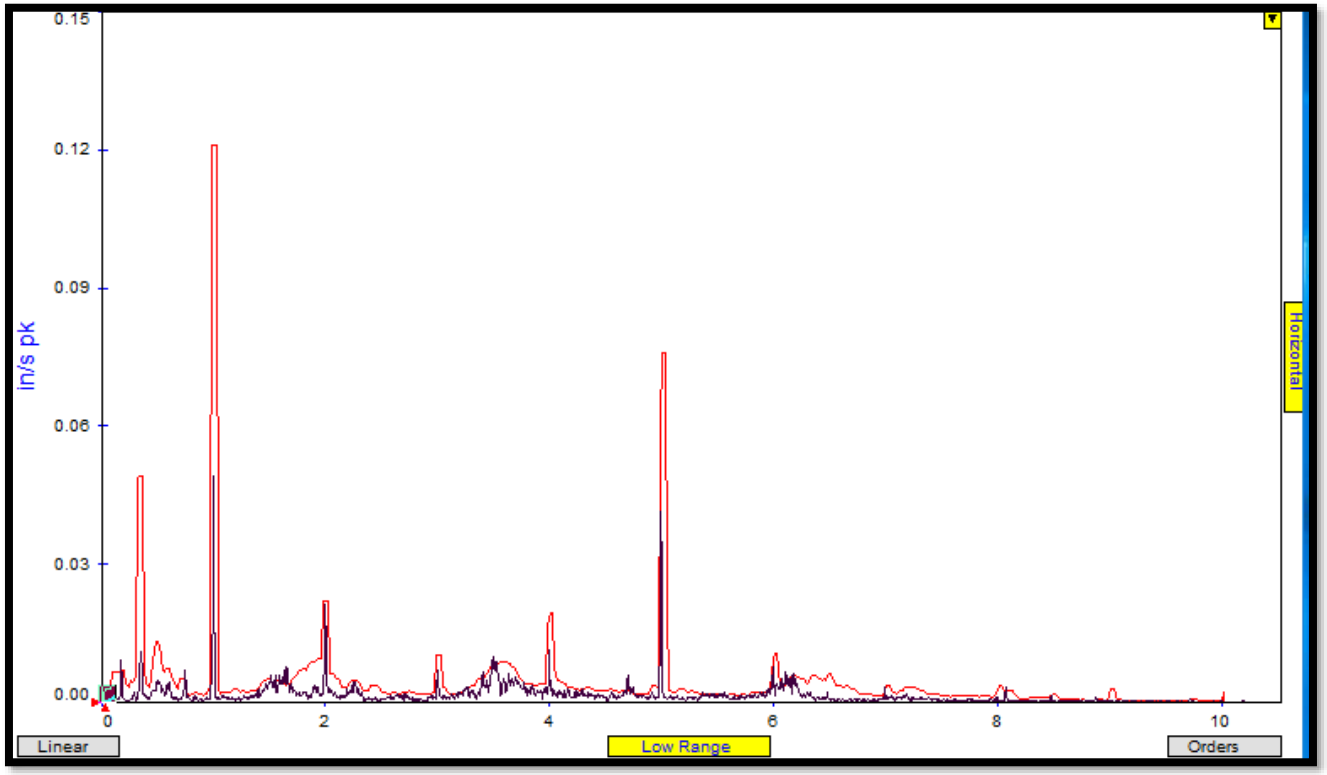
Normalization and Data Processing

Order Normalization in EA

The EADS software contains a complex algorithm that calculates the running speed of the machine using the following:

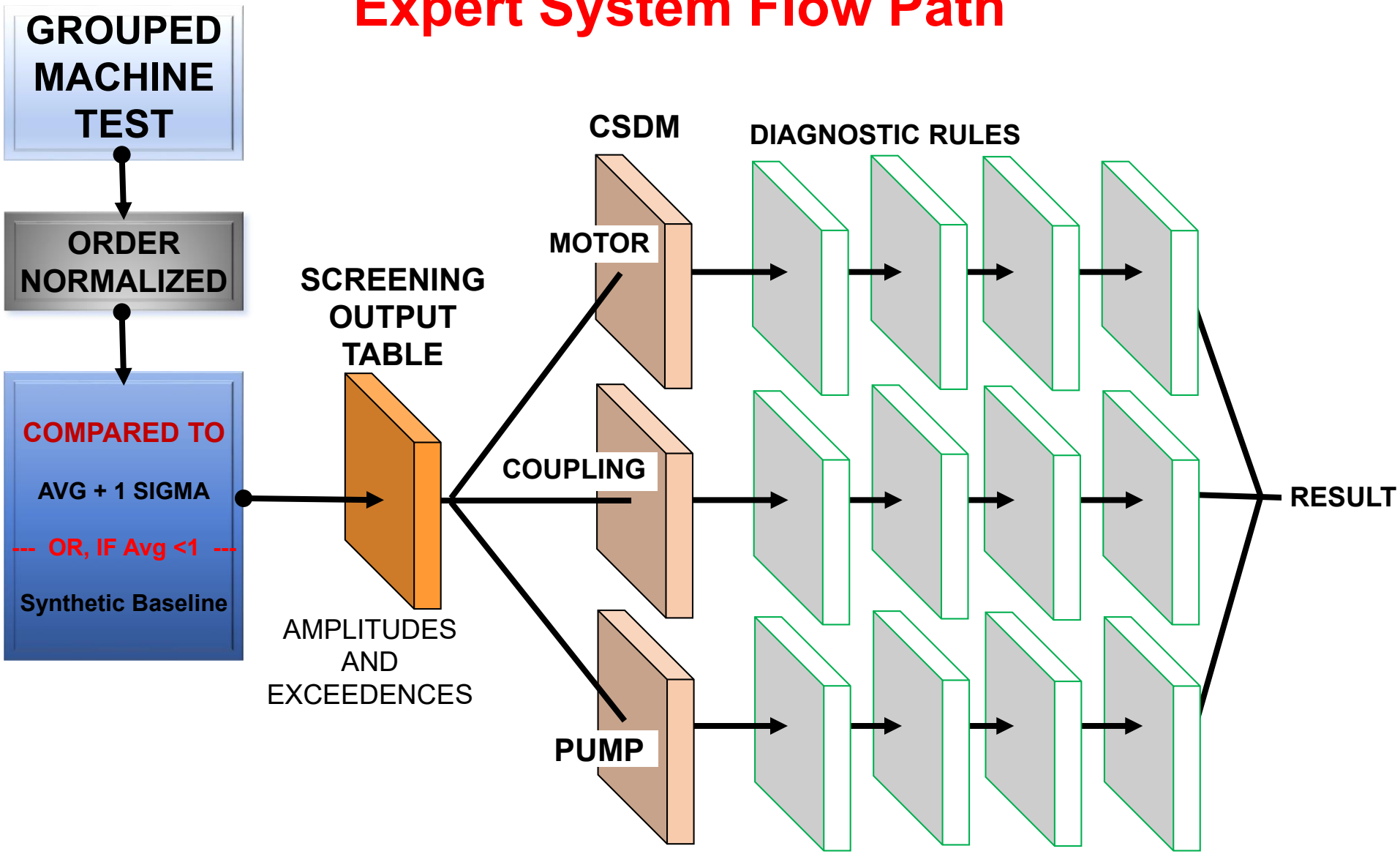
- Assigned Machine Nominal Speed
- Window Variance up to 30% (Especially important for VFD machines)
- Other noted frequencies of interest
  - Secondary shaft speeds
  - Forcing Frequencies

Processing the Data



After the data is order normalized, it is compared to the average data and processed through the Screening Output Table

Expert System Flow Path



(CSDM = COMPONENT SPECIFIC DATA MATRIX)

FLUKE Reliability

Automated Diagnostic Process (Simplified)

Unique Machine Template

MID

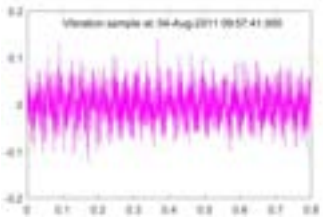
Machine Configuration

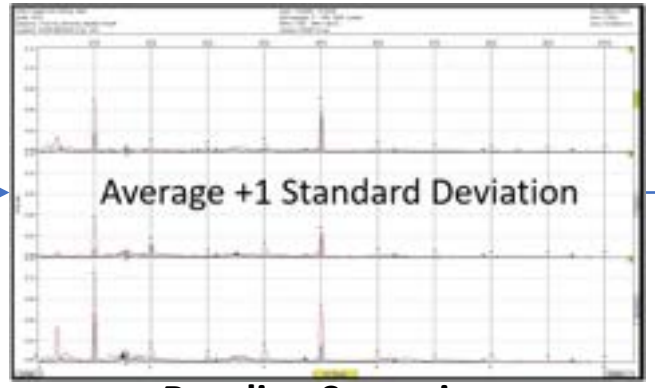
MID – Machine Internal Design

Example

MOTOR	COUPLING	PUMP

Incoming Vibration Data





Baseline Screening

Feature Extraction

Rules Engine

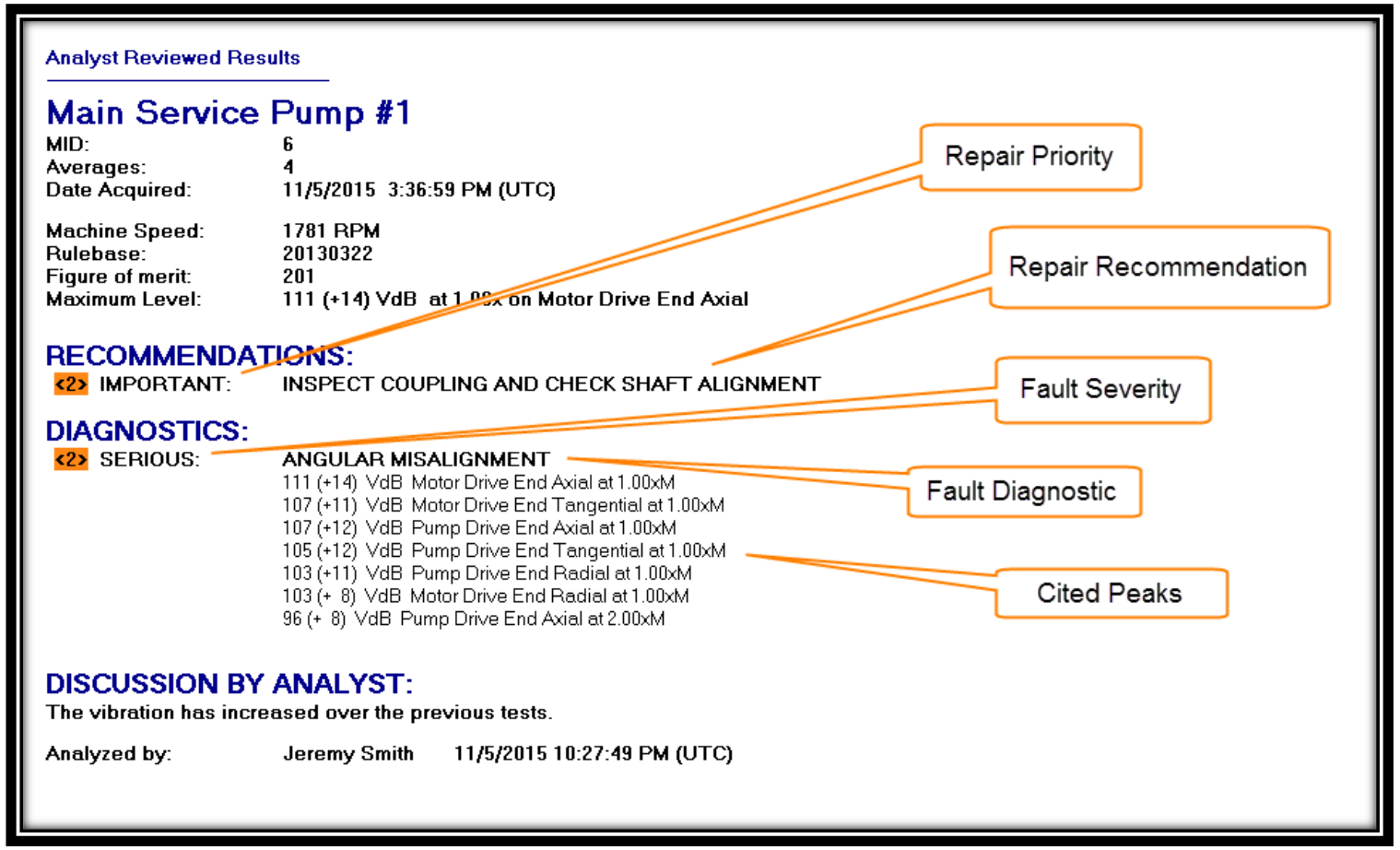
Automated Analysis

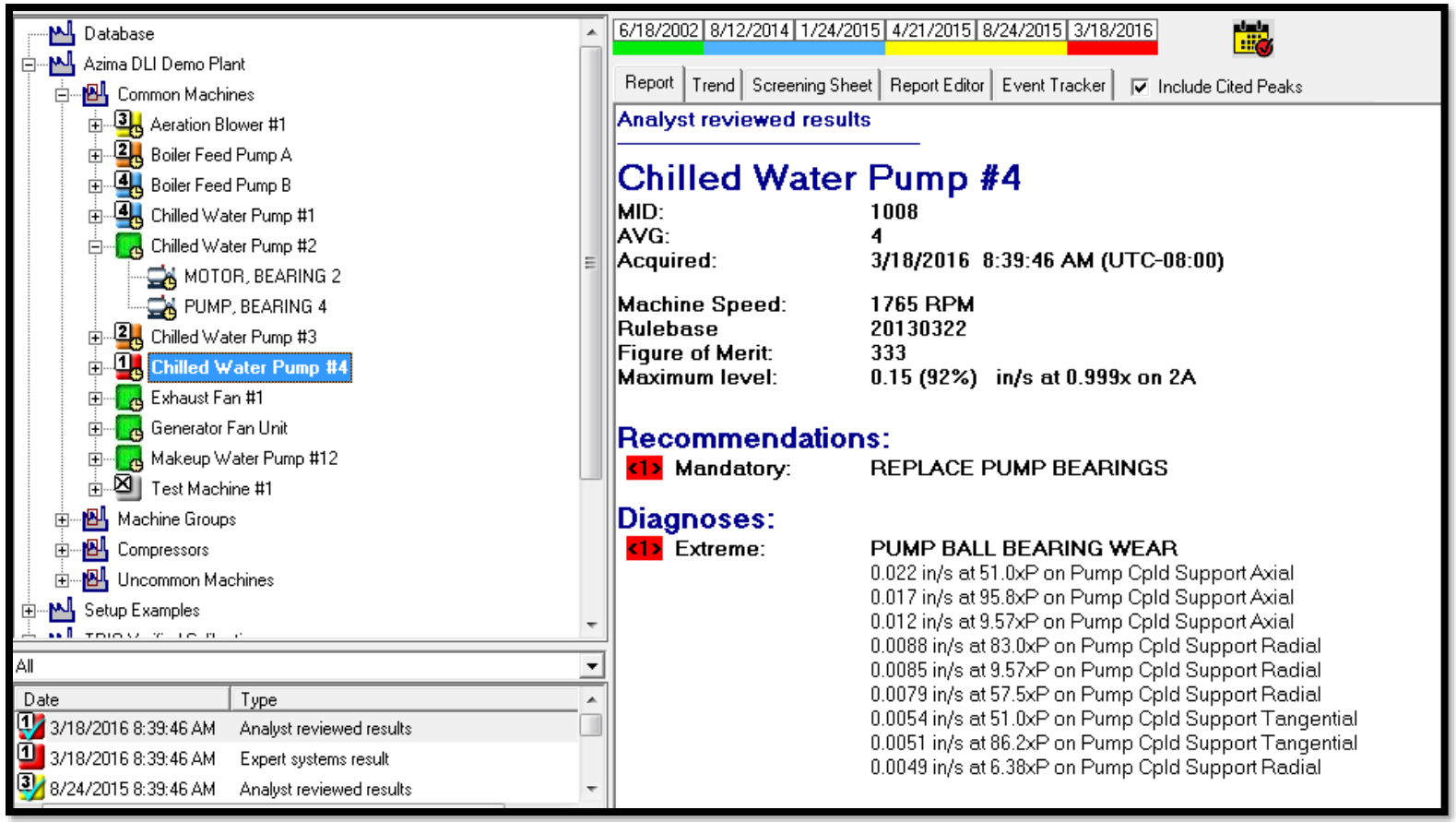
Report Generation

FLUKE Reliability

Expert Automated Diagnostic System Rulebase

- 6000+ Diagnostic Rules
- 1200+ Fault Conditions
- 40+ Machine Components





Extreme Fault Severity
Mandatory Repair Recommendation
Days or hours of Operation

Serious Fault Severity
Important Repair Recommendation
Weeks of Operation

Moderate Fault Severity
Desirable Repair Recommendation
Months of Operation

Slight or No Fault Severity
No Repair Recommendation
Continued Operation

ALERT Process

Material Setup

- System Understanding
- Machine Understanding
- Blocking
- Vibration Test and Analysis Guide

Database Setup

- MIDs
- Data Collection Setups
- Hierarchy - Location Assignment

Initial Data Analysis

- Establish Walking Route
- Watchman Portal and Uploading
- Verify Adequate Data Collection

Fine-tune ExpertALERT

- Establish Machine Baselines
- Adjust MIDs and Individual Machines
- Add Process Points

Azima DLI Milestones

1966 — Founded

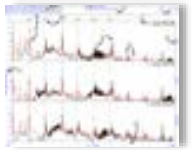
1976 — Development of Automated Diagnostic Software

Computer Controlled Processing

1980 — Aircraft Carrier Contract

1986 — First Online Diagnostic System

1990 — ExpertALERT™ First Expert Automated Software



1995 — 10th Generation ExpertALERT™ Automated Software

2000 — Azima formed

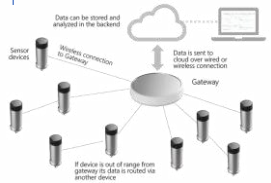
2005 — Azima DLI is formed

2012 — TRIO® First Modular Data Collector

2015 — Strategic Business Level Metrics

2017 — Cloud-enabled complete PdM Program Solution

2019 — Wireless System



2023 — FLUKE Reliability

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QUESTIONS ?

THANK YOU!