FLUKE Reliability

Best Practices – Expected Failure Modes

Speaker:
John Bernet, CMRP, Application and Product Specialist

Meet the Speakers

John Bernet, CMRP

- Mechanical Reliability Application Specialist at Fluke Corp. (10 years)
- Previously worked at Azima DLI for 18 years
- Served 12 years in U.S. Navy on cruiser & aircraft carrier as electrical technician
- Has 30+ years of experience in preventive and predictive maintenance
- Written many technical articles for global trade publications and a 240-page vibration training program

Certified Maintenance & Reliability Professional (CMRP)

Thermal/Infrared Thermography Level I certified

Vibration Analysis Level 2 certified

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Agenda

1. Root Cause Analysis – fix it once, not again and again
2. Expected Failure Modes – what tools/technologies do I start with? It depends . . .
3. Asset criticality – what tools/technologies do I start with? It depends . . .
   Why many teams use predictive tools in a troubleshooting mode?
4. What are the simple steps of Total Condition Maintenance and how
   can Vibration Analysis find the most common mechanical faults?
5. Why many teams struggle to start a Reliability program and how
   can we learn from the few teams that have succeeded?

Root Cause Analysis

Why do teams keep replacing the same bearings and seals?

Need to find root cause of the problem – fix the root cause don't just fix the symptom

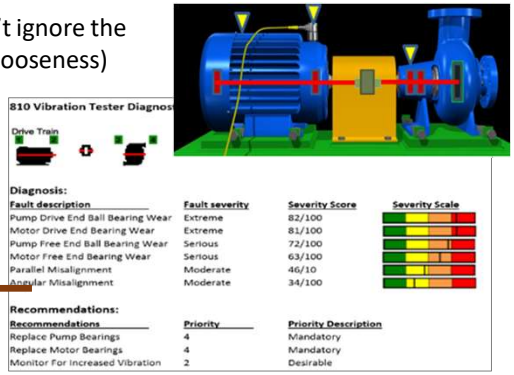
50% of rotating machine damage is directly related to misalignment

Flexible couplings just transfer forces to bearings and seals

Most teams just replace bearings and seals because alignment takes too much time

Diagnose the root cause

Diagnostic tester reports all faults – don't ignore the root cause (misalignment, imbalance, looseness)



Correct the root cause on most machines

Step-by-step alignment tools provide quick, easy precision alignment to fix root cause on most machines in the plant (not just a few)

"We electricians would replace the motor bearings and mechanics would replace the pump bearings and seals, and we'd slap it all back together. In a few months we would do it all over again. Then we learned to perform precision shaft alignments, and the bearings would last for years and years."
Maintenance Supervisor from US Navy

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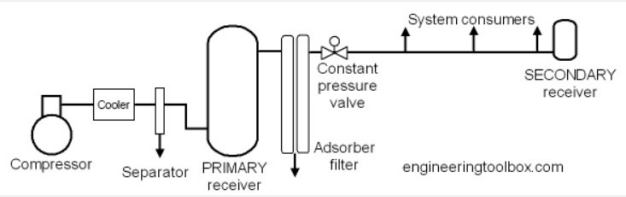
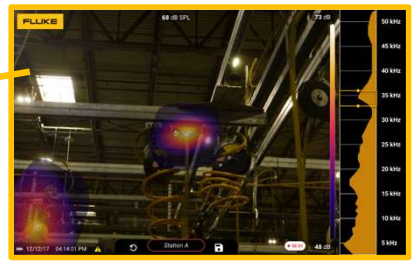
Example: Why do teams keep worrying about air compressors?

Need to find root cause of the problem – fix the root cause don't just fix the symptom

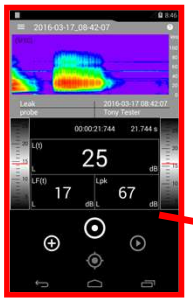
- Keeping air compressors running for important systems is critical to production
- Maintenance teams spend far too much time working and worrying about air systems
- Most teams just repair the compressors because finding leaks takes too much time
- Compressed air is expensive – largest source of energy waste in manufacturing



Scan large area for leaks



Route inspections – 5 tools in 1



"A 96kW compressor runs 24/7 to compensate for leaks. That's $100K/year"
Maintenance Manager from Machinery manufacturer, WA,USA

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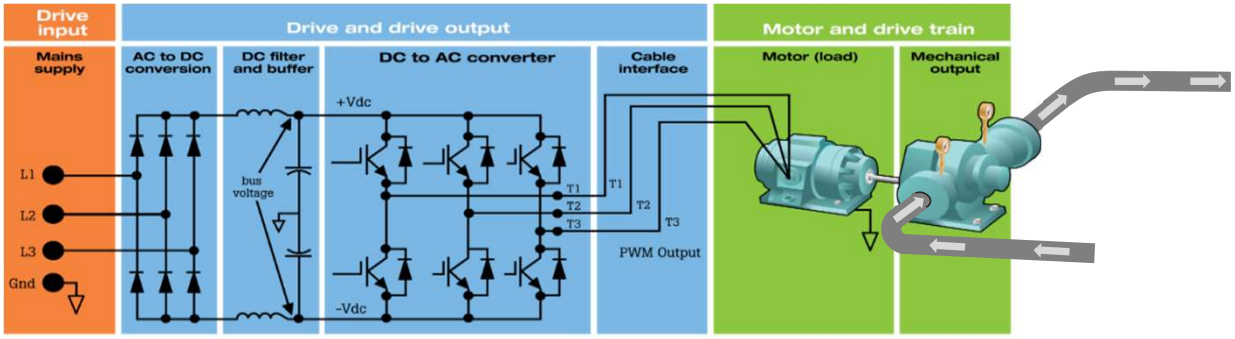
Failure Modes

Using failure modes to drive inspection method

First need to determine expected failure modes before selecting tools



Input Power Quality → **Drive & Drive Output Signals** → **Motor load / windings** → **Motor testing / insulation** → **Mechanical vibration & alignment**

Electrical (scopes, DMM)

Scope Meter and Power Quality

Use to troubleshoot problems in drive and drive output, power distribution, to uncover energy losses and improve efficiency.

1. Electric harmonics
2. Distortion
3. Load studies

Motor and insulation tester

Assures safe operation, prolongs life of electrical systems and motors.

1. Motor speed, torque, power and efficiency
2. Motor insulation degradation

Thermal (imagers)

Infrared Imagers

Best technology for finding electrical hot spots in switchgear and motor controllers, and screening process and mechanical assets.

1. Fault connections
2. Overheated bearings
3. Tank levels

Mechanical (vibration)

Vibration and alignment

Best technology for diagnosing mechanical faults in rotating machines. Correct shaft alignment.

1. Imbalance
2. Looseness
3. Misalignment
4. Bearings

Expected failure modes

A

Write down some of the failure modes that you typically run into at your facility

B

Write down which technologies can help to identify these failure modes

C

Write down what are the corrective actions for each of these failure modes

Some typical failure modes found by others in the industry:

Expected failure modes

	Asset type	Failure Modes	Technology suggested					Correction
			Oil Analysis	Ultrasound	Vibration	Motor testing	Thermography	
Mechanical	Rotating machines motors, pumps, fans, compressors, blowers, gearboxes, belts turbines, engines, generators, paper rolls, machine tools, mills, hammers, planetary gears, etc.	Bearing early warning		Lubrication	*High frequencies*			Grease bearings
		Bearing wearing (1-3)			Mid-high frequencies			Wait / schedule
		Bearing late stage (4)			Low frequencies		*Thermal supports vibe*	Replace bearings
		Shaft imbalance			Low frequencies		*Thermal supports vibe*	Balance / ovehaul
		Misalignment - shaft/belt			Low frequencies		*Thermal supports vibe*	Alignment tools
		Looseness - rotating/non-rotating			Low-mid frequencies		*Thermal supports vibe*	Overhaul unit
		Belt wear problems			Low-high frequencies		*Thermal supports vibe*	Replace belt(s)
		Pump/fan/compressor faults			Low-mid frequencies		*Thermal supports vibe*	Troubleshoot/repair
		Gear/foundation faults			Low-mid frequencies		*Thermal supports vibe*	Troubleshoot/repair
		Cavitation/turbulence/process			Low-mid frequencies		*Thermal supports vibe*	Troubleshoot/repair
		Resonance/structure problems			Low-mid frequencies		*Thermal supports vibe*	Troubleshoot/repair
		Low speed shaft problems		Mechanical	*Low frequencies*		*Thermal supports vibe*	Troubleshoot/repair
	Oil cooled / lubricated	Lubrication problem	Oil lab tests	*Mechanical*				Replace oil
		Contaminants in oil	Oil lab tests					Replace oil
		Condition Monitoring	Wear Particle Analysis					Repair machine
Process	Air systems	Air / gas leaks		Leaks			*Temperature change*	Correct leak
	Steam traps	Stuck / faulty traps		Steam			*Temperature change*	Overhaul trap
	Valves	Valve actuator problems		Valves			*Temperature change*	Troubleshoot/repair
	Tanks	Tank levels - blockage, sludge		Tightess			Thermal - tank levels	Troubleshoot/repair
Electrical	Power lines, drives, switchgear, controllers	Electrical safety hazards		Electrical - warning			Thermal - warning	De-energize first
	Electric motors	Power Quality				Motor testing - PQ		Correct problem
		Power Circuit				Cicuit faults	Thermal - electrical	Repair fault
		Insulation				Insulation breakdown		Repair motor
		Rotor			*Rotor bar - MCA*	Rotor faults		Repair motor
		Stator				Stator faults	*Temperature change*	Repair motor
		Air gap				Air gap faults		Repair motor

Match technology:
- **Bold = Best practice**
- *Unbold = Supports other*

Fluke Reliability experts can help you create a list of the Expected Failure Modes found in your facility

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Expected failure modes – Best Practices for each technology

Summary

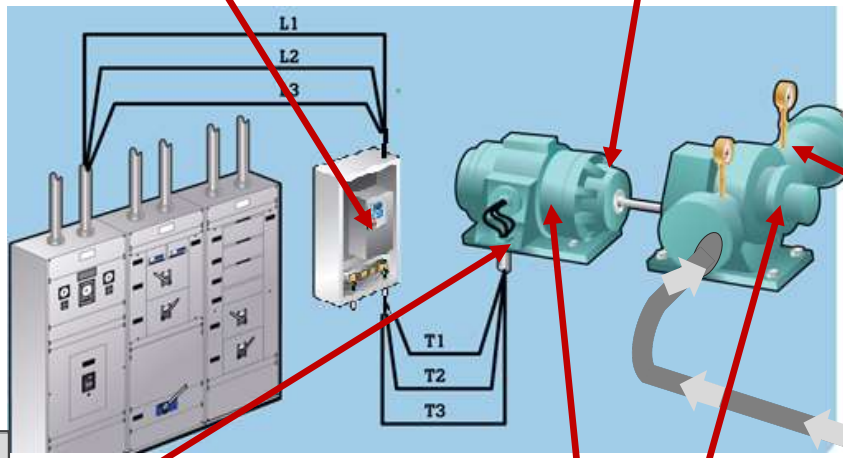
- **Match the best tool / technology to the expected failure mode**
- **Think about your assets holistically - power in and work out**
- **Combine technologies to protect each link in the chain**

Thermography – high temp

- Find electrical hot spots
- Process / operations issues
- Support serious mech faults

Ultrasound – air leaks, lubrication

- Find leaks
- Valve actuator problems
- Bearings need lubrication
- Stem trap problems
- Tank tightness
- Electrical safety hazards



Oil: oil-cooled components

- Lubrication breakdown
- Component wear
- Overheating
- Wear particles

Motor testing: motor problems

Energized:

- Current testing / MCSA /
- PF and Harmonic Distortion

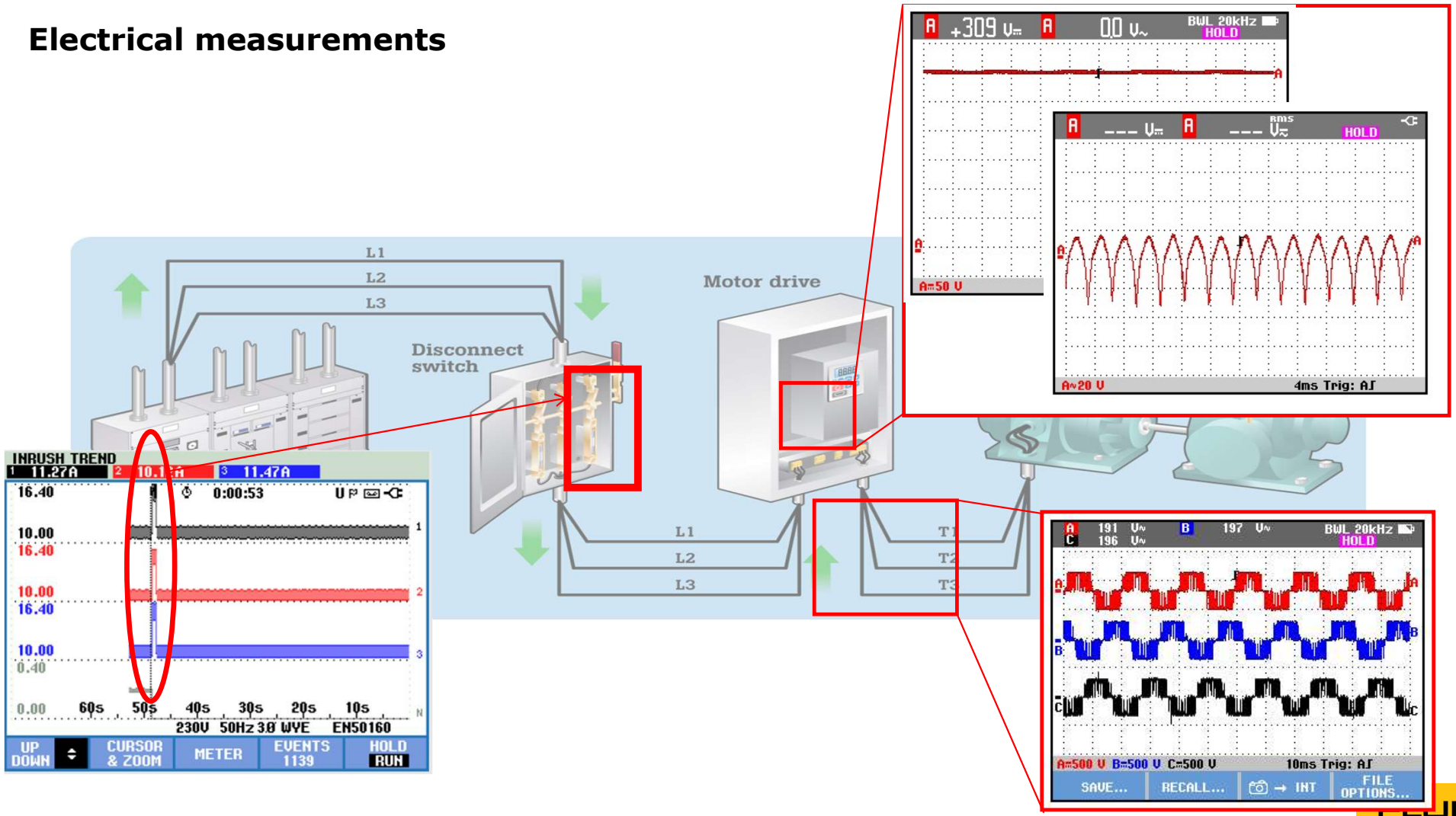
De-energized:

- Motor insulation degradation
- Hi Pot, Surge, Megohmmeter

Vibration: best for mechanical faults on rotating machines

- Misalignment
- Resonance/structure
- Component faults
- Gear / belt faults
- Shaft imbalance
- Cavitation / turbulence
- Looseness
- Balancer
- Bad bearings
- Laser shaft alignment
- Laser belt alignment
- Speed / timing issues

Electrical measurements



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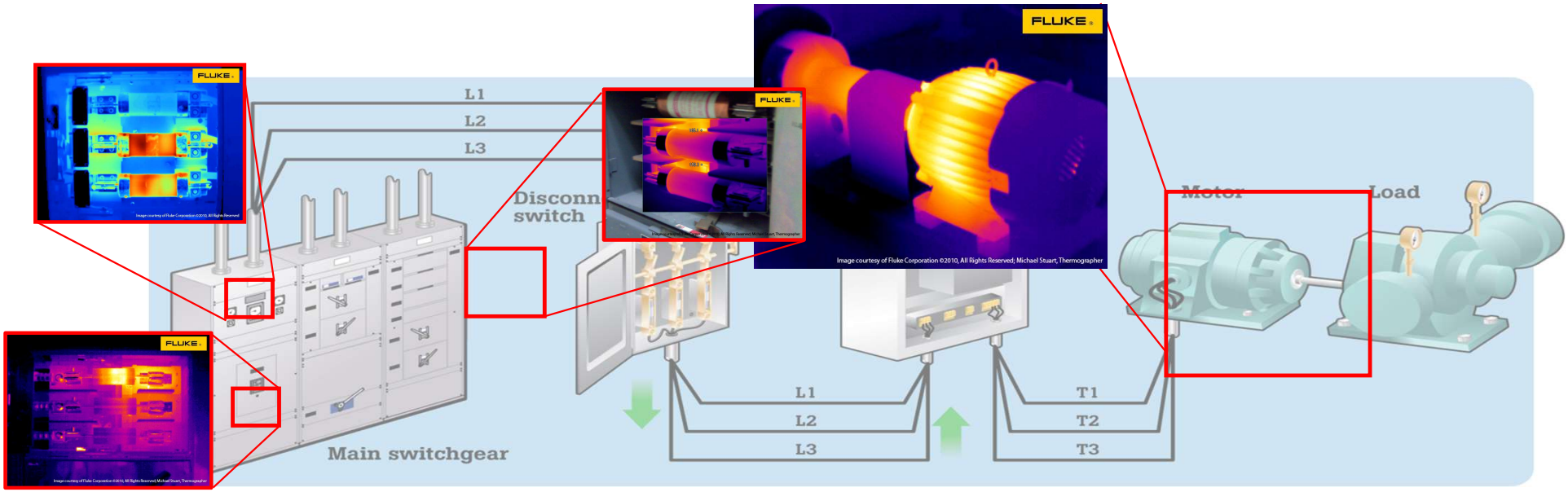
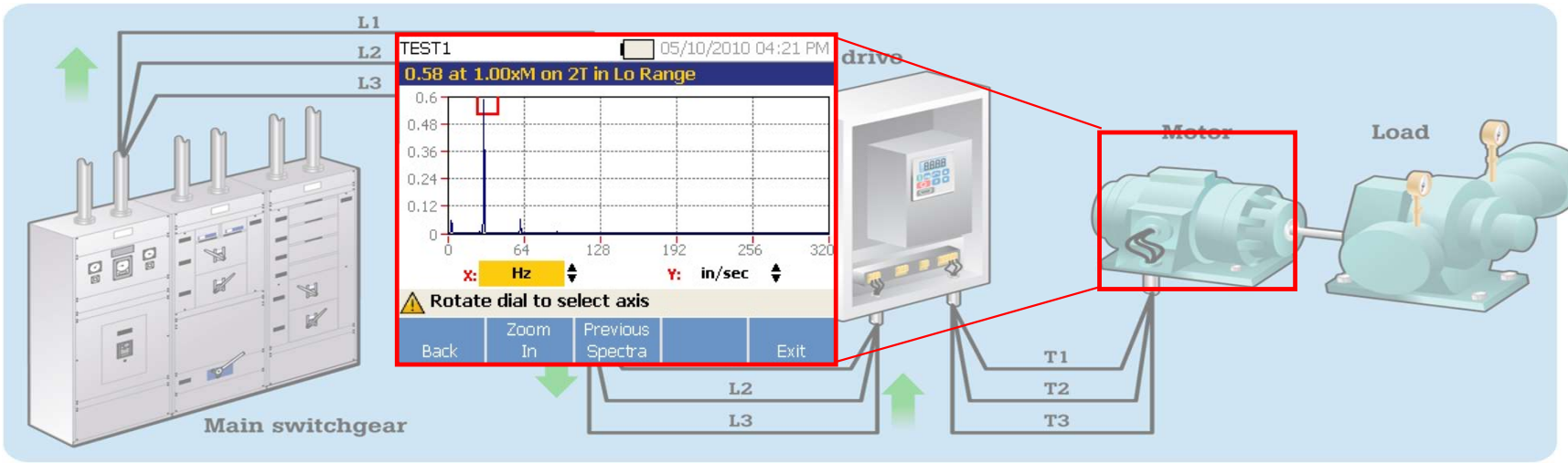
Thermal measurements



- Use a thermal camera to scan the component and look for irregular and non-uniform thermal patterns or anomalies such as:
- **Electrical** - Power quality issues, harmonics, current unbalance, or even high resistance.
- **Mechanical** - Uneven heating/cooling, bearing, coupling, gearbox or even belt or chain drive issues.

Mechanical measurements



- Forces from the Imbalance show up on one shaft only. In this case, the motor shaft.

POLL QUESTION

Which of these measurements do you use to assess machine health at your facility? **(Click all that apply)**

- Thermography
- Vibration
- Oil Analysis
- Ultrasound
- Other

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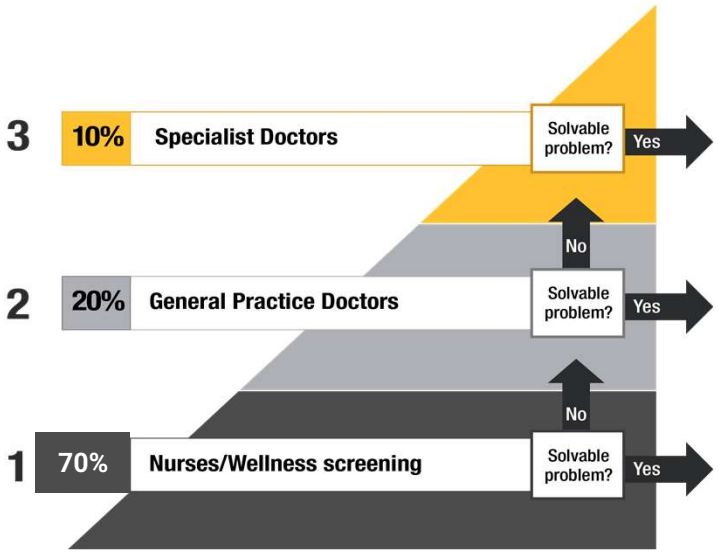
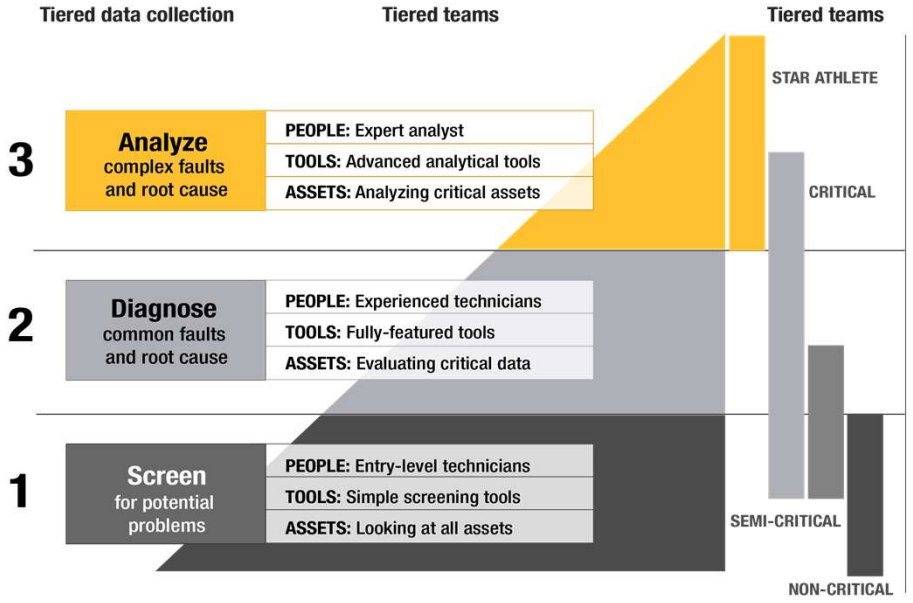
Asset Criticality

The criticality dilemma – a healthcare parallel

Everyone is **EQUALLY** important **AND** resources are limited. What to do?

1) Create a cut-line and only serve the critical people? → *UNACCEPTABLE*
2) Build-up the vast resources needed to give everyone 100% care? → *UNSUSTAINABLE*





- Tiered levels of training and certification
- Tiered levels of workers
- Tiered volume of visits / inspections
- Tiered amount of time spent on each person

Condition-based <u>screening</u> helps relieve workload at each level of care

Common tools and strategies (reactive, troubleshooting, proactive, etc.)

Different assets require a different mix of technologies - Mechanical / Electrical / Thermal

***Screening* tools** - thermal imagers, vibration meters, vibration sensors

Trend graphs / scan images – look for change of potential problems

***Troubleshooting* tools** - electrical scopes, digital multi-meters, insulation testers

Analyze data – look for changes / troubleshoot of potential causes

***Predictive* tools** - vibration tester, vibration analyzer, corrective tools, vibration sensors

Analyze results – evaluate faults and severity, recommend repair actions

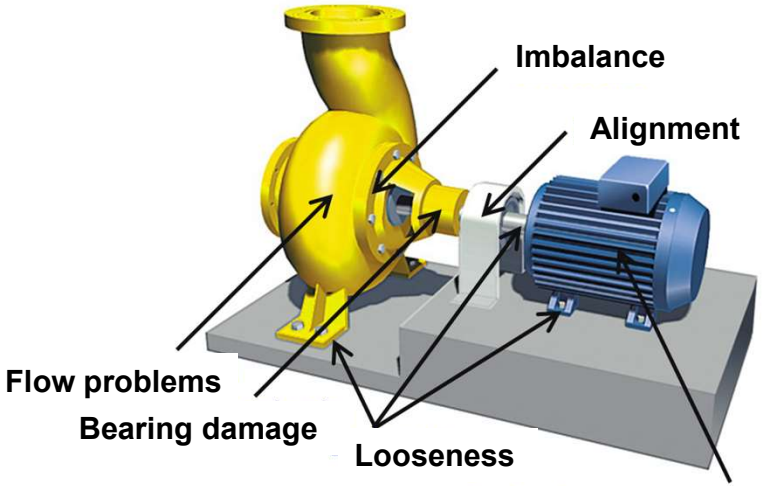
Why do many teams often revert back to using predictive tools in a troubleshooting mode?

Common problem: a lack of resources and time

Why start with vibration?




- Thermography (IR)
- Ultrasonic
- Electrical / Current Analysis
- Oil Analysis
- **Vibration Measurements**



NOTE: Vibration faults have directionality

(80% of all machine faults can be detected with vibration analysis)

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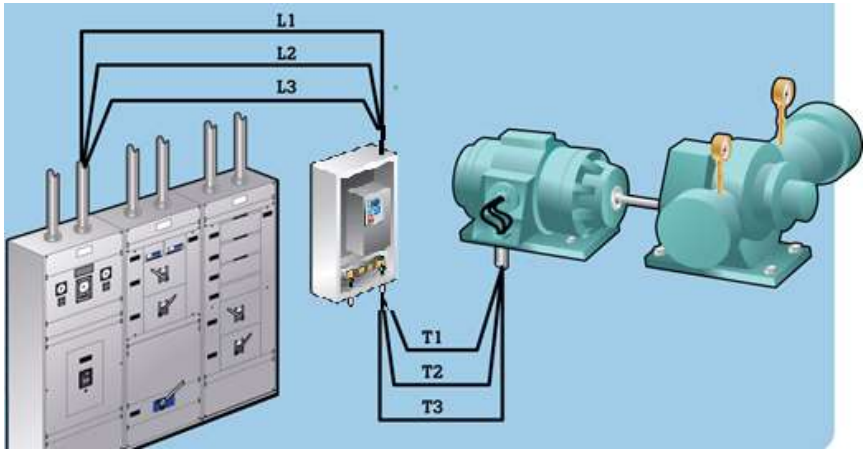
Motor fundamentals – both electrical and mechanical faults

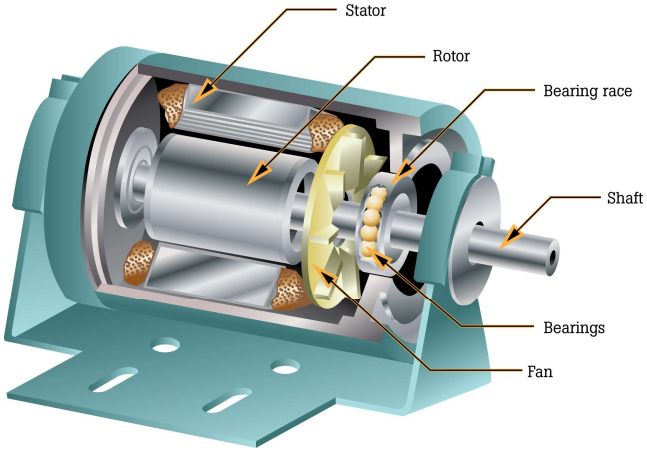


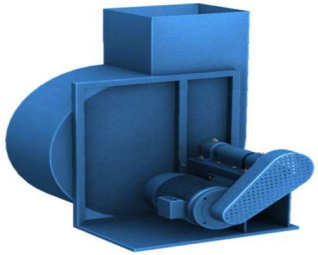
Drive trains

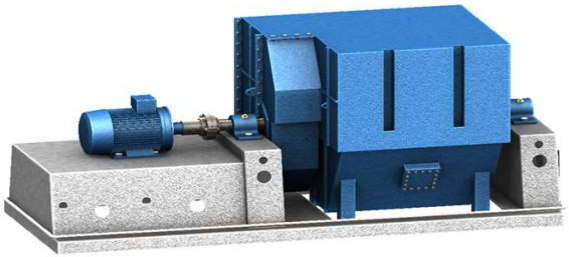
- Direct drive
- Coupled
- Belt drive
- Gear drive

Driven units

- Pumps
- Fans
- Blowers
- Compressors







Total Condition Maintenance

Total Condition Maintenance - 4 simple steps

820-2 LED Stroboscope

Fully automated tools for common faults on standard machines by techs with no advanced training

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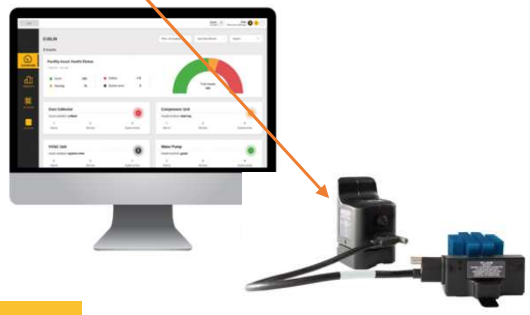
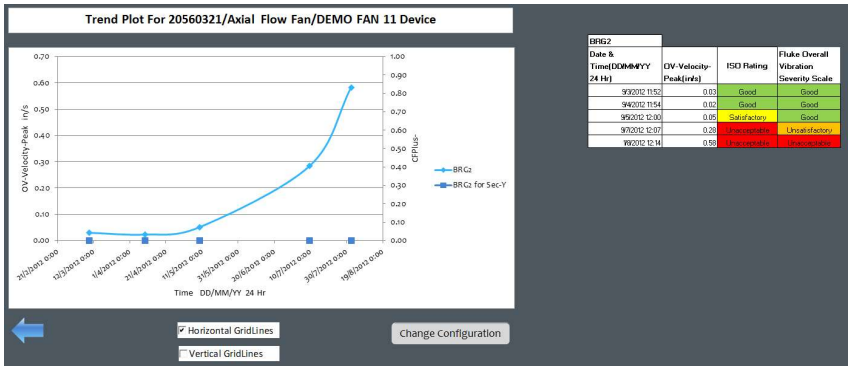
Interpreting screening measurements

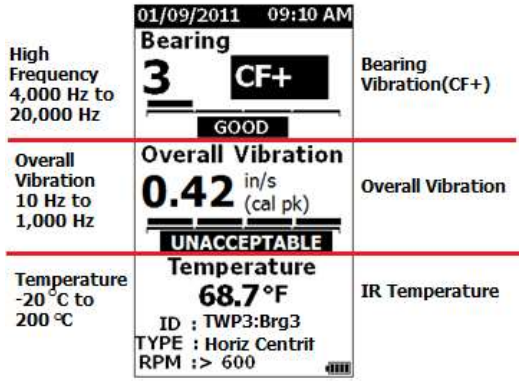
Step 1 - SCREEN

- Portable tools
- Wireless sensors





Date & Time(DD/MM/YY 24 Hr)	OV-Velocity-Peak(in/s)	ISO Rating	Fluke Overall Vibration Severity Scale
9/3/2012 11:52	0.03	Good	Good
9/4/2012 11:54	0.02	Good	Good
9/5/2012 12:00	0.05	Satisfactory	Good
9/7/2012 12:07	0.28	Unacceptable	Unsatisfactory
9/8/2012 12:14	0.58	Unacceptable	Unacceptable



- Trend levels to determine if healthy or not
- Screen machine health using ISO levels based on 4 general size categories or 37 machine specific categories

Send readings wirelessly to your smart phone and the cloud to stay in contact with your entire team without leaving the field. Make decisions faster.

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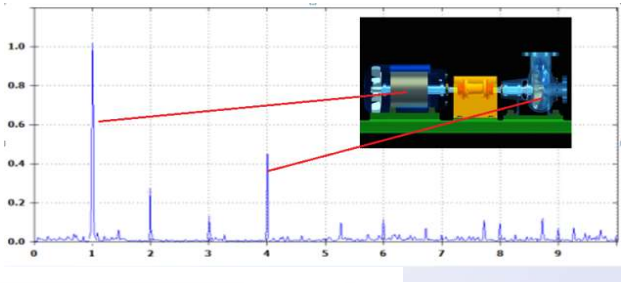
Interpreting vibration measurements

Step 2 - DIAGNOSE

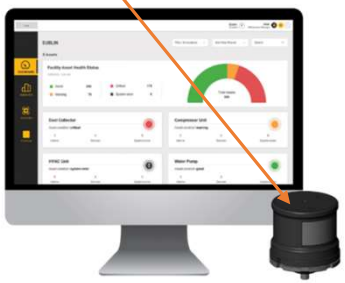
1. **Identify vibration peaks** as they relate to a source component on the machine.
2. **Look for patterns** in the data based on vibration rules.
3. **Measure the amplitude** of the vibration peak to determine the severity of the fault.

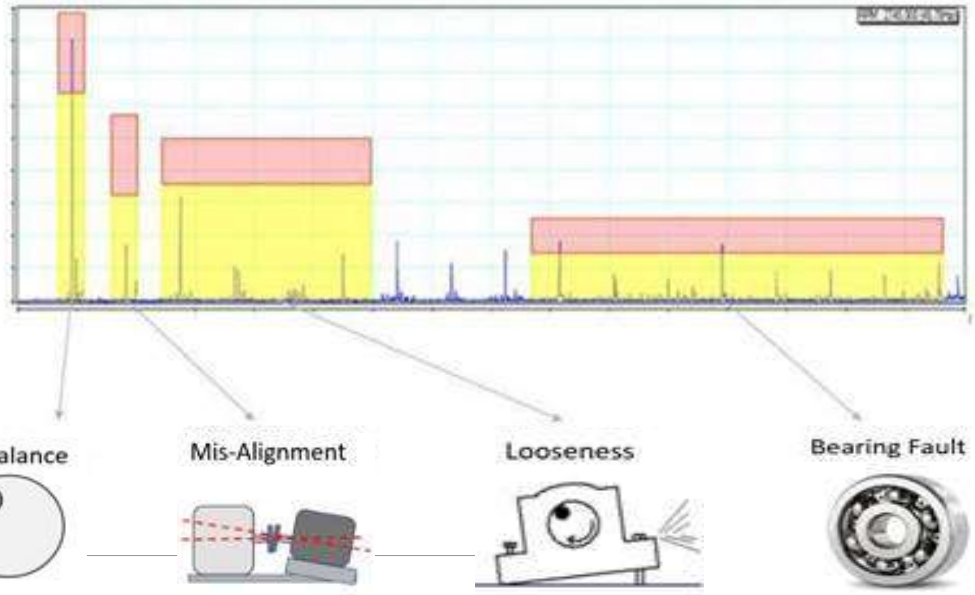
4 most common faults:

1. Imbalance
2. Misalignment
3. Looseness
4. Roller Bearings



- Portable tools
- Wireless sensors





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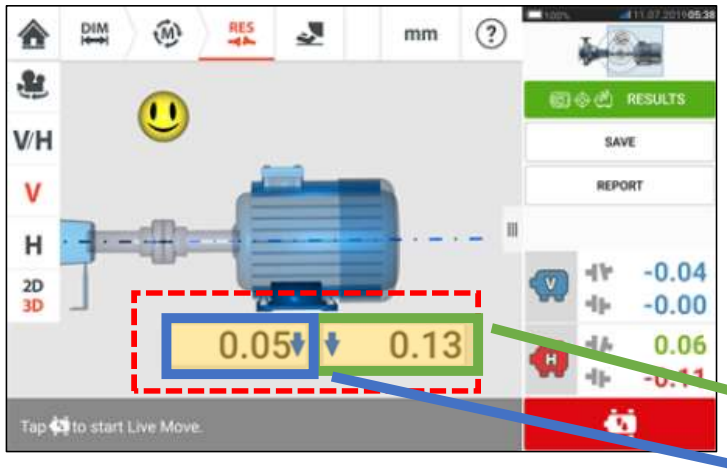
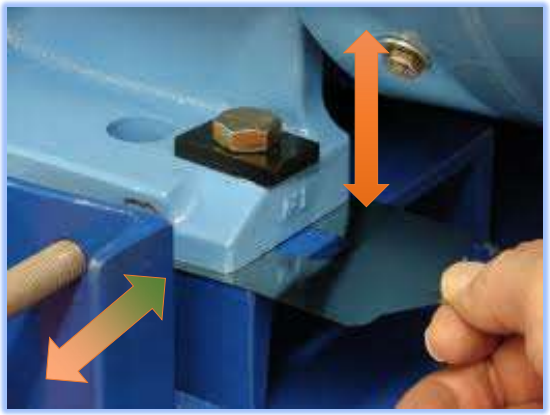
Correcting misalignment

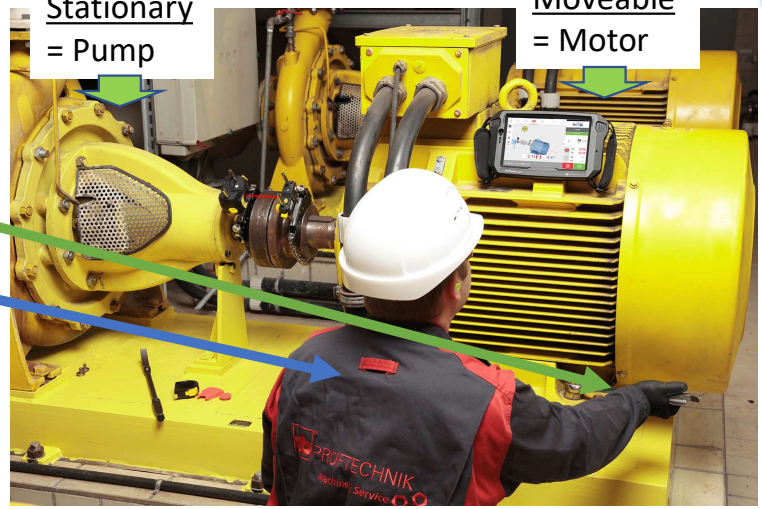
Step 3 - CORRECT



Add/remove shims for vertical

Move left/right for horizontal





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EB1

Questions to consider for which tools are best for you

Which of my machines would be best served with a handheld vibration tool and which would be best with a wired or wireless vibration sensor?

- An asset criticality assessment would help

Does my super critical machine warrant continuous monitoring with high-resolution data for sophisticated analysis of more than routine faults?

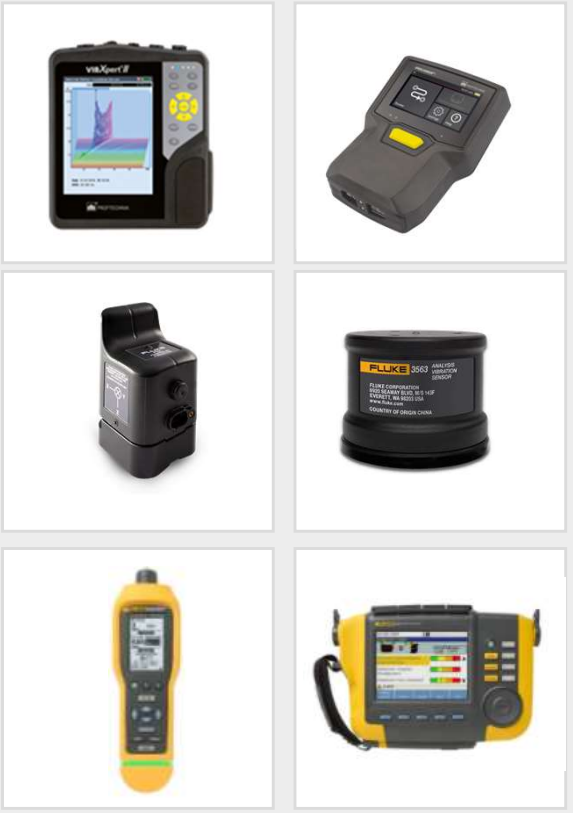
- High performing wired sensors are designed to measure vibration data and can provide high-resolution data

What infrastructure needs to be in place in my facility for the machine to operate?

- Wireless sensors may require network connections
- Wired sensors may require tethered connection via the ethernet to ensure no loss of data

Where does my data need to integrate with one of our systems to be effective? What data needs to be sent? What actions should be triggered in those systems?

Which machines warrant the cost of individual sensors? Can those machines be monitored with handheld tools when a technician's time could be spent elsewhere?



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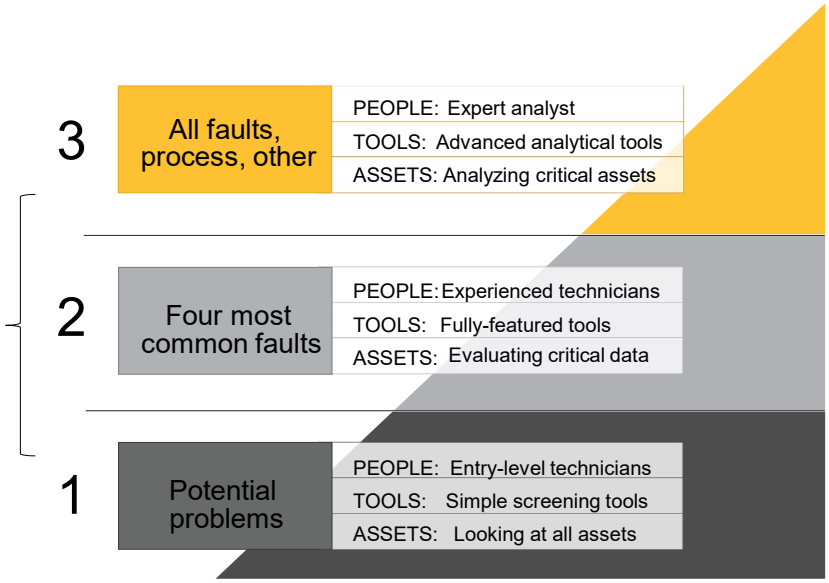
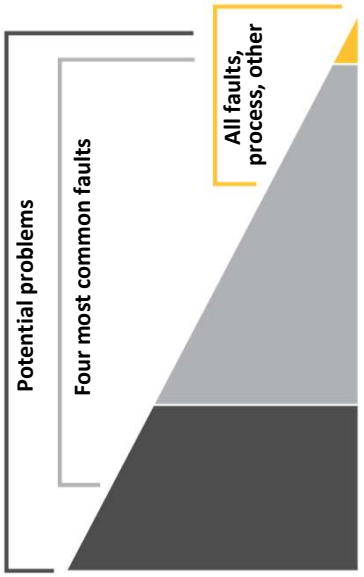
Slide 25

EB1 Add a photo of the wired sensors, to flesh out the message
Ellis, Barbara, 8/12/2021

What are the best tools for your needs

Classifying your rotating equipment into 3 major categories will help to determine asset criticality





Top 10% Production Critical

- Top Tier Machines
- Fewer in Number
- Main Turbine
- Paper Machine
- Machining Tools

Middle 60% Vital/Important

- Middle Tier Machines
- Hundreds/thousands
- Vital motors, pumps, fans, blowers, compressors, etc.

Bottom 30% Less Critical

- Bottom Tier Machines
- Hundreds/thousands
- Non-vital motors, pumps, fans, blowers, compressors, etc.

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Building a Reliability Program

Why many teams struggle?

Predictive equipment vendors have been developing and improving tools / software

So why are most companies (in almost all industries) still mainly using reactive and preventive methods?

- *Today's tools are the most advanced, and training has never been easier, but the problem is always time and resources.*

1 How do we grow a reliability program
… when we are 100% busy?

We have no time to collect/analyze data and generate reports.

2 How do we make the best decisions
… when we have incomplete information?

We don't have time to conduct all the necessary routes, nor can we have access to all machines

3 How do we monitor all critical assets
… with limited resources?

We must allocate/balance resources needed for planned/calendar-based maintenance, repairs, and emergencies, etc.

How a few teams succeed?

Reliability Best Practices—four important cornerstones:

1. Learn from successful customers: start small and grow; select the right tool based on failures; get answers, not just data, and share with others on team
2. Evaluate your plant specifics: asset criticality, failure modes, risks to uptime, needs, etc.
3. Assess your company's resources, goals, success metrics, plan for implementation, etc.
4. Partner with a reliability consultant—get support to transition from goals to results

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EB2

We are Fluke Reliability

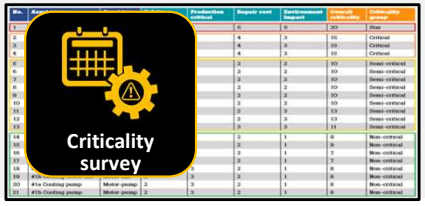
We simplify connected reliability solutions for the people who keep the world up and running

Help guide the customer past the obstacles on their reliability journey from Point A to Point B

- ✓ Successful start-up
- ✓ Successful implementation
- ✓ Successful sustainment

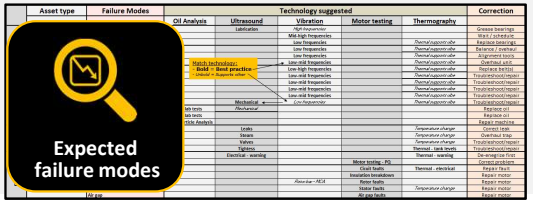
1 New PM program setup

#1 Problem:
start too big → no success → canceled
Solution:
Start small & simple → grow → funding
Fluke Reliability Service / Support:



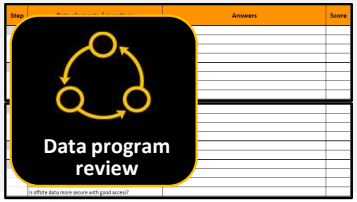
2 Technology selection

#1 Problem:
Use one tool to measure everything
Solution:
Match right tools to likely failure modes
Fluke Reliability Service / Support:



3 Data management

#1 Problem:
Data overload - What to do with data?
Solution:
Need answers from the data!
Fluke Reliability Service / Support:



Slide 29

EB2 split this slide into two, Our chevron grid, and then the 3 pillars.
Ellis, Barbara, 8/12/2021

Questions

QUESTIONS?

Thank you!

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THANK YOU!