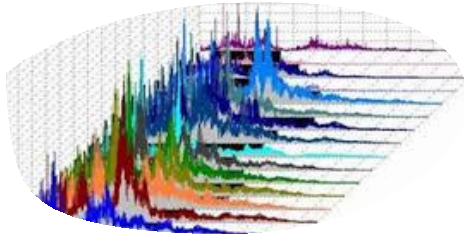



The Most Effective Chiller Diagnostics Today




Alan Garbers
Johnson Controls
<http://www.johnsoncontrols.com/buildings/services-and-support>



Agenda

- Predictive Diagnostics -- Overview
- Focus: Diagnostics & Chillers
- Online Connected Diagnostics for Chillers
- Questions
- Wrap-up



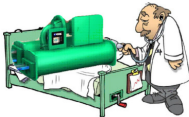
Predictive Diagnostics What is it?

Non-invasive Testing to provide Definitive Information About a Machine


*The Heart of **Condition-Based Maintenance***

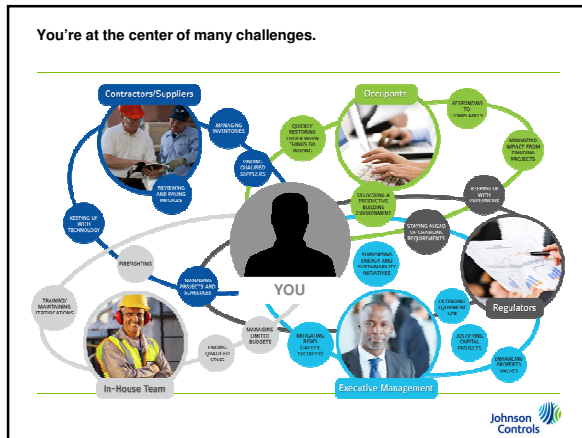
Car Example: Change Oil Based On Analysis

- What is the **Current** Health?
- Is Health **Changing** Over Time?
- Predict **Failures** Ahead of Time

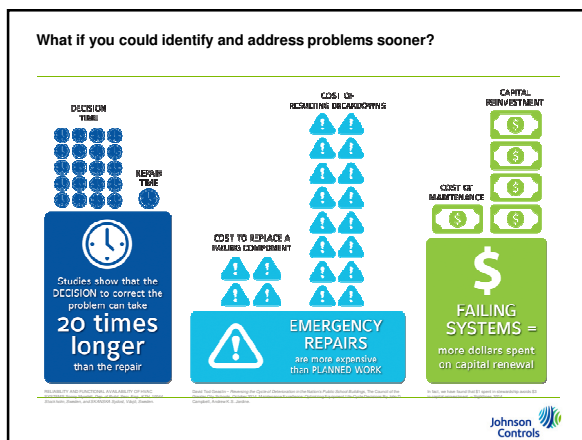


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But you're doing inspections... so why does this happen?

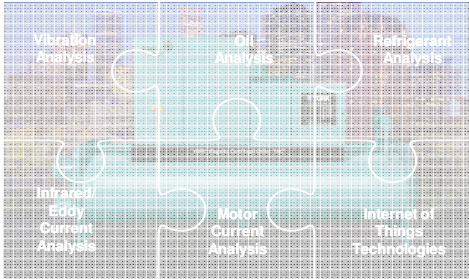


89% of equipment failures are random


Source: Lifecycle Engineering Research



Predictive technologies provides a complete picture of chiller health & performance that helps avoid random failures




Let's look at each of these in more detail...




Predictive Diagnostics Benefits

Keeps a Molehill from Becoming a Mountain.

- Lowers Operational Costs
- Increases Maintenance Program Efficiency
- Lowers Life Cycle Costs



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Predictive Diagnostics **Why Do It?**

Better Information


- *Definitive Data*

Better Decisions

- *Do I Have All Information Needed to Make a Calculated Decision?*

Better Outcomes


- *Fix Root Cause to Prevent a Repeat Failure*

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Predictive Diagnostics **Why Do It?**

Better Decisions

| | | |
|--|----|---|
| <p>Common Practice</p> <p>Problem</p> <ul style="list-style-type: none">• "Bearings are Bad" <p>Solution</p> <ul style="list-style-type: none">• Replace Bearings | Vs | <p>Best Practice <i>Root Cause Analysis</i></p> <p>Problem</p> <ul style="list-style-type: none">• Shaft Imbalance Causing Premature Bearing Failure <p>Solution</p> <ul style="list-style-type: none">• Replace Bearings and <u>Balance Rotor</u> |
|--|----|---|

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Our Focus Today:
Diagnostics & Chillers



The P-F interval

- At the heart of condition based maintenance is the P-F interval
 - P: Potential failure (detectable, some risk of failure)
 - F: Functional failure (can no longer perform function)

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We need to avoid the P-F interval!

- We need to stay in the mode where the machine is defect free!
- We therefore need to focus on what happens *before* failure is initiated!

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Diagnostic Analysis Expertise


WARNING:
NOT All Analysis is Equal

It's not the tools.
It's the experience of the engineer looking at the data.

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What should you look for in a predictive testing provider?

- Experience on HVAC Equipment**
 - Is this what they do all the time?
- Centralized approach**
 - Who is doing the analysis?
 - What volume of equipment do they see?
- Statistical approach to analysis**
 - What algorithms or other methods do they have to analyze the data?



Diagnostic Analysis Lifecycle

Commissioning (Baseline)

- Ensure Machine Manufactured & Installed per Specifications
- Start Trend to Compare Against Going Forward

Re-baseline (After Repairs)

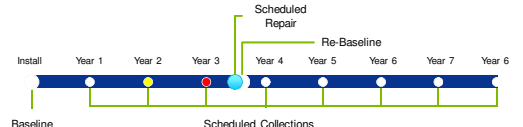

- Ensure Repairs Correct the Problem
- Make Sure No Other Problems Exist

Regularly Scheduled

- Proactively Identify Problems Before Failure
- Allows Time to Schedule Repairs

Spot Check (Unusual Observation)

- Identify & Confirm Possible Abnormal Mechanical Condition Identified During Normal Rounds


Diagnostic Analysis Recommended Collection Frequency

HOW OFTEN DOES IT RUN?
HOW CRITICAL IS THE EQUIPMENT?

Process cooling? (MRI and Surgery)
Comfort cooling? (Offices)

| Machine Operation | Machine Criticality | | |
|--------------------------|---------------------|-------------|------------|
| | Comfort Cooling | Environment | Production |
| 6 Months per Year | 1 / Year | 2 / Year | 4 / Year |
| Year Round (12 hrs/ day) | 2 / Year | 4 / Year | 12 / Year |
| 24/7 - 365 | 4 / Year | 4 / Year | 12 / Year |

The scheduled collection frequency should be based on how often the machine operates and the criticality of the system it supports, not on the cost of the equipment.



Avoiding Defects 3 KEY TAKEAWAYS

(1) Proper Alignment
 Misalignment
 Unbalance
 Looseness
 Piping Alignment at Commissioning (avoid binding)

Avoid Contamination
 (2) Proper Oil
 (3) Proper Grease vs. Blend or Mixture

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Diagnostic Area Vibration Analysis

Types of Analysis
 • Snapshot
 • Continuous Vibration Monitoring

Use to...
 Condition of rotating components:

- Bearings
- Shafts (Motor, Compressor, Fan, etc.)
- Gears
- Impellers
- Sheaves
- Belts
- Couplings
- Alignment
- Imbalance

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Diagnostic Area Vibration Analysis

Why?
 • Trend Data -- Flags Issues with a Comparative Database

How is the data changing as the equipment ages?

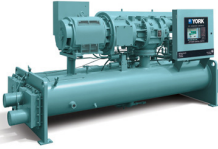
VIBRATION TREND RESULTS
 Electrical

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Diagnostic Area Vibration Analysis

What Equipment?
Any equipment where the risks outweigh the cost of monitoring.

Yes



No




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Diagnostic Area Oil Analysis

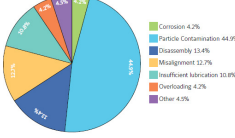
Poor Oil Analysis: "Is the Oil Slippery?"

Why?

- Oil is the "Sponge" of the Machine.
- Contaminants?** Finds Parts Per Million, not a color change.
- Component Wear?** ("Markers" in Oil, i.e., acid, copper, iron...)
- Useable Life?**
Change Oil Only When it Needs to be Changed




CAUSES OF BEARING FAILURES



Lubrication issues account for over half of all bearing failures.

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Diagnostic Area Refrigerant Analysis



Types of Analysis

- Acid
- Moisture
- HBR (High Boiling Residue)
- Purity – Break down or cross refrigerant contamination - Blends
- Particulate – Dirt/other contaminants in refrigerant

Use to...

- Identify issues with Chiller Efficiency (Non-condensable, HBR)
- Identify leaks in low pressure machines
- Identify Internal Contamination

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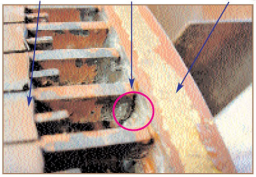
Diagnostic Area Motor Current Analysis

What?

- Analyze Motor Current

Why?

- Lost HP, Increased Power Consumption
- Catastrophic Motor Failure

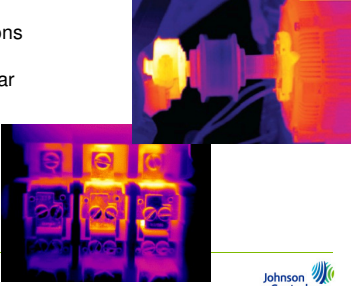


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Diagnostic Area Thermal Imaging

Mechanical and electrical issues >>>

- Coupling wear (Misalignment)
- Bearing wear
- Corroded connections
- Loose connections
- Damaged switchgear
- Imbalanced loads
- Faulty steam traps.



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Diagnostic Area Eddy Current Analysis


What?

- Proactively Monitors for Advancing Chiller Tube Failures

Why?

Avoid Catastrophic Failure because of:

- Broken or cracked tubes
- Corrosion
- Pitting
- Freeze bulge
- Support wear



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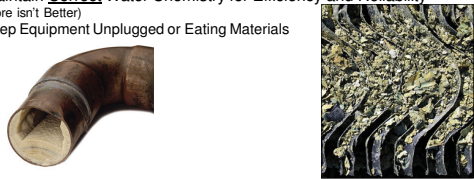
Diagnostic Area Water Treatment Analysis

What?

- Analyzing Water Quality (Both Cooling Tower Water and Chilled Water Systems)
Too aggressive? Not aggressive enough?

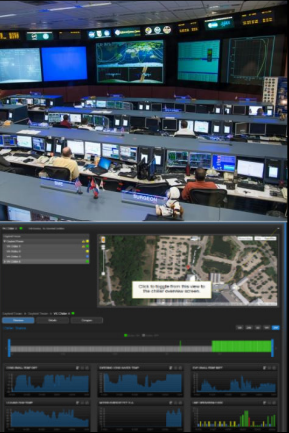
Why?

- Maintain Correct Water Chemistry for Efficiency and Reliability (More isn't Better)
- Keep Equipment Unplugged or Eating Materials

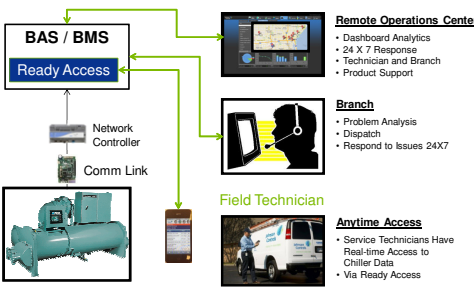


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Smart Chiller Diagnostics: Predictive Maintenance & Beyond



Diagnostic Area Internet of Things Technology



BAS / BMS
Ready Access

Network Controller
Comm Link

Remote Operations Center

- Dashboard Analytics
- 24 X 7 Response
- Technician and Branch
- Product Support

Branch

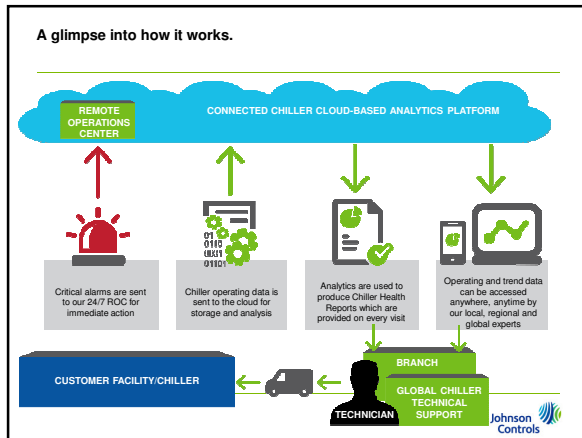
- Problem Analysis
- Dispatch
- Respond to Issues 24X7

Field Technician

Anytime Access

- Service Technicians Have Real-time Access to Chiller Data
- Via Ready Access

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Diagnostic Area *Advanced Online Connected Diagnostics*

The Most Important Step: Use The Data!
Don't store it away like the lost Arc...

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Summary

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What if you took this more strategic approach to Condition Based Maintenance?

What could you expect if you took a more strategic approach to maintenance?

66% Reduction in unplanned/emergency repairs

6% Reduction in mean time to repair

Source: Johnson Controls, Inc. Engineering Analysis

Optimizing Maintenance Costs/Extending Asset Life
Smart Connected Chiller Services

Capital Budget

Repair Budget

Energy Budget

Maintenance Budget

Allows you to:

- Right-size the investment in maintenance
- Minimize negative impacts to other areas of the budget

Summary

- Predictive Diagnostics Overview
- Chilled Water System Diagnostic Applications
- Online Diagnostics AKA: Internet of Things / Smart Devices


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**What Questions
Do You Have?**

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