The DLI Vibration System

- The DLI ExpertAlert Vibration System utilized by Hannon Electric is the only automated diagnostic system on the market today that is being utilized by its customer base.
- It has been tested and shown to be 87% to 95% accurate in its diagnoses for machine faults and severity, when mature.
- This presentation shows a slice of the system set-up and capabilities.
Vibration Analysis

The investment in this equipment provides for more thorough analysis and trending of rotating equipment through the use of automated diagnostics combined with analysis tools that quickly and accurately confirm problems.
The Expert Report

The alarm base is set from initial machine measurements or measurements from a like machine. The expert system runs diagnostic templates from the machine design to diagnose the faults.
The Expert Report

**COLOR 1 - ASH HOUSE 2**
Report generated on: 9/7/2007 09:48 AM
Acquired: 9/6/2007 11:43 PM  1xM = 1669 RPM  1xF = 621 RPM  
Averages: 0

Figure of Merit = 21.
WARNING: SIGNIFICANT MAX LEVEL MAY INDICATE A PROBLEM

| Maximum level   | 0.76 (0.0%) in/s at 1.02x on 2V |

**RECOMMENDATIONS:**

**DESIRABLE:** CHECK DRIVE SHEAVE FOR RUNOUT AND ECCENTRICITY

**DIAGNOSTICS:**

**MODERATE DRIVE SHEAVE PROBLEM**

| 0.76 (607%) in/s at 1.00xM on 2V in low range |
| 0.40 (320%) in/s at 1.00xM on 2A in low range |
| 0.20 (162%) in/s at 1.00xM on 2H in low range |

**POSITION LEGEND:**

| POSITION 2 IS: MOTOR, BEARING 2 |
| POSITION 3 IS: FAN, BEARING 3 |
| POSITION 4 IS: FAN, BEARING 4 |
The Expert Report

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POSITION LEGEND:
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The report automatically provides the supporting diagnostics for confirmation.
Figure of Merit = 21.
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Diagnostic details are also included for review and confirmation of the faults identified.
The Expert System

The alarms are based upon average 800 line spectrum alarms.

Green is the alarm base.

Blue is the machine spectrum.
Fault Trending

The faults are automatically trended for severity with the legend showing the problems identified. This assists in prioritizing repairs and corrective actions based upon the problem identified, the severity and the trend of machine.
Expert View (Fault Trending)
Analysis

- Multiple views of the vibration spectrum allow problems to be confirmed and/or identified.
Spectrum Views (Triax)
Spectrum Views (Triax High)
Spectrum Views (Triax High/Low)
Spectrum Views (Waterfall)
Spectrum Analysis & Tools

A full range of tools are provided to confirm the diagnosis and perform manual analysis.
Analysis Tools (Harmonics)
Analysis Tools (Side Band)
Summary

- The system does not eliminate the need for training and developing vibration expertise.
- What it does is automatically identify issues with the machine and trends the problem and provides information to the analysis where to look to confirm the analysis.
- The analysts job is to confirm the problem and severity and make a judgment on the action to be taken.
- The speed and quality of analysis is improved along with improving the learning curve of someone new to vibration analysis.
Set-up

- To set up
  - Create Plant
  - Create Areas
  - Then Create MID’s
  - Then Create Machines
Creating MID

The MID is the machine design.

The single MID may be used for setting up multiple like machines.

It is simple and wizard driven just click the appropriate box and hit next.

No bearing size data is required. It is fast easy and comprehensive.
MID Set-up

The MID setup develops all of the forcing frequency data and sets up the machines for the automated diagnostic system.

Here is an example of a blower.
Machine Listing

The machine list provides instant information on the machine condition by color coding the status and showing a clock if the machine is past due.

All locations are automatically identified in the machine set up.
Vibration Analysis

The most widely used CM technology. Trending and analysis of vibration signatures are used to rate equipment condition and allow for corrective actions prior to breakdown. Primary diagnosis's include; misalignment, imbalance, and bearing problems.
Vibration Analysis

Positives

- Identifies many problems early
- Trends condition and severity
- Can ID the component failing
- Applicable on virtually all rotating components.
Vibration Analysis (Traditional)

Drawbacks

- Requires a CM philosophy
- Requires management and labor support
- Investment in manpower and equipment
- Long start-up time
- Requires expertise and experience
- Dependent on sustainable expertise
Vibration Analysis (New)

Drawbacks

- Requires a CM philosophy
- Requires management and labor support
- Investment in manpower and equipment
What is Vibration Analysis?

- The measurement and trending of vibration amplitudes broken down by frequency to assess changes to the mechanical and electrical health of rotating equipment.
Common Problems Identified

- Imbalance
- Misalignment
- Ball Bearings
- Looseness
- Bent shaft
- Journal Bearings
- Gear Problems
- Impeller Blade Problems
- Motor Problems
- 650 more
How are Vibration Diagnostics Performed?

1. Incoming Spectra
2. What machine is this & what are its vibration sources?
3. How does this spectra compare to that of a healthy machine?
Vibration
Vibration
Vibration Measurement

• For trending and monitoring
  • Data needs to be taken on the correct machine and location.
  • At the same spot
  • At the same angle
  • At the same pressure
  • At approx. the same location
Waveform to Spectrum
Forcing Frequencies

- Five-Bladed Fan

Fly swatter against the blades
Causes five hits for each rotation (1X) or 5x frequency
Spectral Data
Machinery Diagnostics
Vibration Analysis Terms

- Normalization
  - CPM vs RPM vs HZ vs Orders
- Forcing Frequencies
- Harmonics
- Sidebands
Common Machine Faults

- Imbalance
- Misalignment
- Bearing Problems
- Looseness
Imbalance

- At the **Rotational Rate** in the **Radial** directions Equal excitation in all radial directions
**Misalignment**

- At **Twice** Rotational Rate in the **Radial Directions** (parallel)
- At the **Rotational Rate** in the **Axial direction** (angular)
Angular Misalignment

180 degree phase shift across coupling
Parallel Misalignment

180 degree phase shift across coupling
Mechanical Looseness
Rolling Contact Bearing

- Non-integer fundamental peaks in ANY direction
- Harmonics of the fundamental frequency
- Sidebands at the 1X rotational rate
Rolling Element Bearings

For each shaft revolution:

- 4.6 balls will pass an outer race defect
- The ball will make 2.02 revolutions
- 7.4 balls will pass an inner race defect
- The cage will make 0.38 revolutions
Simplified Bearing Tones

- Non-Synchronous Components
  - BPFO = Rollers x rpm x 0.4
  - BPFI = Rollers x rpm x 0.6
  - FTF = rpm x 0.4

- Sidebands
  - Usually 1X Around BPFI
  - May be FTF Around Bearing Tones
Bearing Tones in Spectrum

Non-Synchronous Frequencies

VdB

ORDERS

VdB

ORDERS

0 1 2 3 4 5 6

60 70 80 90 100 110 120
Progression of Bearing Faults

- Slight Bearing Tones at 3.1X
**Progression of Bearing Faults**

- As defect worsens - 2nd harmonic rises
Progression of Bearing Faults

- Increased machine looseness - 1X harmonics increase
Progression of Bearing Faults

- 1X Sidebands around the Bearing Tone
Progression of Bearing Faults

- “Haystack” in Noise Floor appears as Wear Progresses
**Progression of Bearing Faults**

- Entire Noise Floor rises in advanced stages
Progression of Bearing Faults

- Machine Failure
Level 2 - Trends

- Increased Frequency of Data Collection
- Greased Bearing
- Replaced Bearing

◆ = Motor Bearing Wear
Spectral Data

800 Alarm Levels

OVERALL VIBRATION LEVEL

NARROW BAND ALARM LEVEL

AMPLITUDE

ORDERS

AVERAGE + 1 SIGMA ALARM LEVEL
Machine Set-up
For Forcing Frequencies High Speed Centrifugal Compressor

Motor - 1800 RPM

A (Input Shaft)
B (Drive Gear)
C (Compressor Shaft)
D (Impeller)
E (Pre-Rotation Vanes)
Forcing Frequencies

Centrifugal Compressor

Motor = 1800 rpm (Input Shaft)
Gearbox = 1:3.1875 (Helical Gear)*
  Drive Gear = 51 teeth
  Driven Gear = 16 teeth
Compressor = 5742 rpm (Output Shaft)
Compressor impeller = 14 vanes
Compressor pre-rotation = 9 vanes

* ratio rounded to 3.19
Spectral Data

800 Alarm Levels

OVERALL VIBRATION LEVEL

AMPLITUDE

1X  2X  3X  4X  5X  6X

ORDERS

AVERAGE + 1 SIGMA ALARM LEVEL
Vibration Severity

10-1000 Hz

mm/s or in/sec RMS

Limits | Class II | Class III | Class IV | Class V | mm/s RMS
---|---|---|---|---|---
28 | | | | | 20
18 | | | | | 10
11 | | | | | 5
7.1 | | | | | 2
4.5 | | | | | 1
2.8 | | | | | 
1.8 | | | | | 
1.1 | | | | | 

10-1000 Hz
Answers, Not Just Data.

Incoming Spectra

What machine is this & what are its vibration sources?

How does this spectra compare to that of a healthy machine?

What, if anything, is wrong with this machine and how bad is it?

Machinery Fault Report

How does the Diagnostic System work?

We’ve automated the same steps a human analyst follows.

Maintenance Planning
Reliable and Complete Data

- Triaxial Sensor
  - All 3 axes - more complete analysis
  - Improves accuracy of diagnosis
- Permanently Mounted Stud
  - Excellent frequency response
  - Repeatability = accurate trending
- Barcoding
  - Faster and more accurate
  - Prevents human error
Processing Vibration Data

Level I Reports

Level II Trends

Level III Signatures
Level 1 - Reports

- Diagnostic report 90% + Accurate
  - 93% of erroneous analysis was in stating the severity level
  - 67% of missed faults were where there was more than one fault, (missed multiple fault diagnosis)
  - Tended to identify the obvious fault only

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Main Condenser Circulating Water Pump #3
Acquired: 11/17/97 - 13:10:33
FOM: 304

Priority IMPORTANT: REPLACE PUMP THRUST BEARING AND ALIGN UNIT.

SERIOUS PUMP THRUST BEARING PROBLEM
- is indicated by 0.117 (+0.101) IPS [4A] at 4.17xP
- 0.139 (+0.097) IPS [4V] at 4.17xP
- 0.099 (+0.083) IPS [4A] at 5.17xP

SERIOUS ANGULAR MISALIGNMENT
- is indicated by 0.241 (+.147) IPS [2A] at 1.00xM
- 0.203 (+.131) IPS [4A] at 1.00xP
Maintenance Planning

- Schedule immediate repairs (Extreme Faults)
  - Avoid catastrophic failure or secondary damage
- Schedule normal repairs (Serious Faults)
  - Planned outage or maintenance period
- Review parts availability (Moderate Faults)
  - Stock long-lead-time parts for critical equipment
  - Order parts in advance for planned shut downs
- Retest following maintenance or replacement
  - Reset baseline & reference information
  - Verify maintenance was performed correctly
Incoming Spectra

What machine is this & what are its vibration sources?

How does this spectra compare to that of a healthy machine?

What, if anything, is wrong with this machine and how bad is it?

Machinery Fault Report

Maintenance Planning

How does the Diagnostic System work?

We’ve automated the same steps a human analyst follows.
Alarm Issues for Bearings
Trend
Keys to a successful program...

- Ensure **reliable** and **complete** data collected
- Ensure you get **answers**, not just data
- Ensure you get First Rate **support** and **training**
- Use the **right** technology for the **right** application
- Distribute the **information everywhere** it is needed for planning of repairs
Setups are easy with setup Wizards
Vibration Data Collected

Tri-axial Display

Single Axes Display
**MACHINE:** MAIN CONDENSATE PUMP (TD)
**SHIP APPLICABILITY:** 61,62,63,64
**CVN63 UNITS:** 1B,2B,3B,4B

<table>
<thead>
<tr>
<th>DRIVER</th>
<th>INTERMEDIATE</th>
<th>DRIVEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>CID# 05790037</td>
<td>CID# 05790037</td>
<td>CID# 01600034</td>
</tr>
<tr>
<td>MFR: WHITON</td>
<td>MFR: WHITON</td>
<td>MFR: ALLIS CHALMERS</td>
</tr>
<tr>
<td>MFR DWG#: 347-2918</td>
<td>TECH MANUAL: 347-2918</td>
<td>TECH MANUAL: 347-2918</td>
</tr>
<tr>
<td>HP: 40</td>
<td>RPM (INPUT/OUTPUT): 6410/1170</td>
<td>RPM: 1160</td>
</tr>
<tr>
<td>STEAM CONDITIONS: Chest: 575 PSIG, Exhaust: 15 PSIG</td>
<td>TYPE: SINGLE DOUBLE REDUCTION</td>
<td>TYPE: DOUBLE STAGE, SINGLE SUCTION, VOLUTE</td>
</tr>
<tr>
<td>RPM: 6410</td>
<td>TYPE: HELICAL FLOW,</td>
<td></td>
</tr>
</tbody>
</table>

**TEST RPM's AND OPERATING CONDITIONS**
TURBINE: 6400, PUMP: 1168

**ANALYSIS RANGES**
REF RPM: 1 X TURBINE
ORDERS: 2, 100
FREQ HZ: 220, 11000

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**Date:** DECEMBER 1992

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**What machine is this?**

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**Data Compared to Knowledge Base**

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**Incoming Spectra**

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**Machinery Knowledge Base**
Peaks Compared to Average Data

Incoming Spectra

What machine is this & what are its vibration sources?

How does this spectra compare to that of a healthy machine?

Average Spectra Data Base
Baseline Data
Of a healthy machine - Average + 1 Sigma Alarm Level

OVERALL VIBRATION LEVEL

800 Alarm Levels

AVERAGE + 1 SIGMA ALARM LEVEL
Diagnostics Automated

Incoming Spectra

What machine is this & what are its vibration sources?

How does this spectra compare to that of a healthy machine?

What, if anything, is wrong with this machine and how bad is it?

Spectral Analysis Rule Base
Diagnosis Rule Applied

Misalignment (Parallel)

1. 2X Vertical or Horizontal > .03 IPS
   
   and

   > 20% above Baseline on both sides of the coupling

2. 2X Vertical > 1X Vertical
   
   or

   2x Horizontal > 1X Horizontal for one side of coupling

3. The Maximum 2X > .06 IPS
   
   or

   The sum (V & H) of 2X exceedances > 10 times the 1X (V & H) for at least one side of the coupling
Answers, Not Just Data.

1. **Incoming Spectra**
   - What machine is this & what are its vibration sources?

2. **How does this spectra compare to that of a healthy machine?**

3. **What, if anything, is wrong with this machine and how bad is it?**

**Machinery Fault Report**

**Maintenance Planning**

---

**How does the Diagnostic System work?**

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