

Unique Short Term and Subsequent Long Term Solution to Rotordynamic Stability Problem

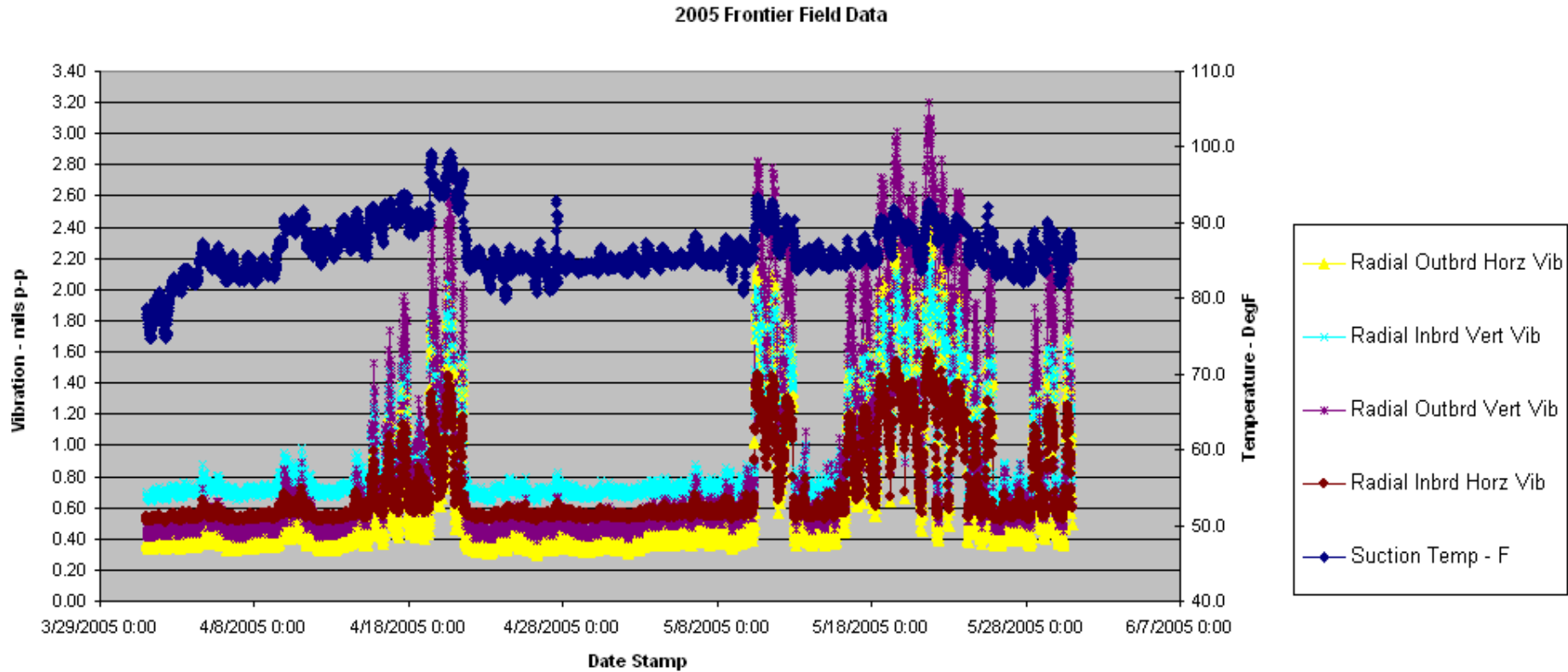
Tom Scott: Sr. Reliability Engineer
Frontier Refining

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GE Oil & Gas - CONMEC

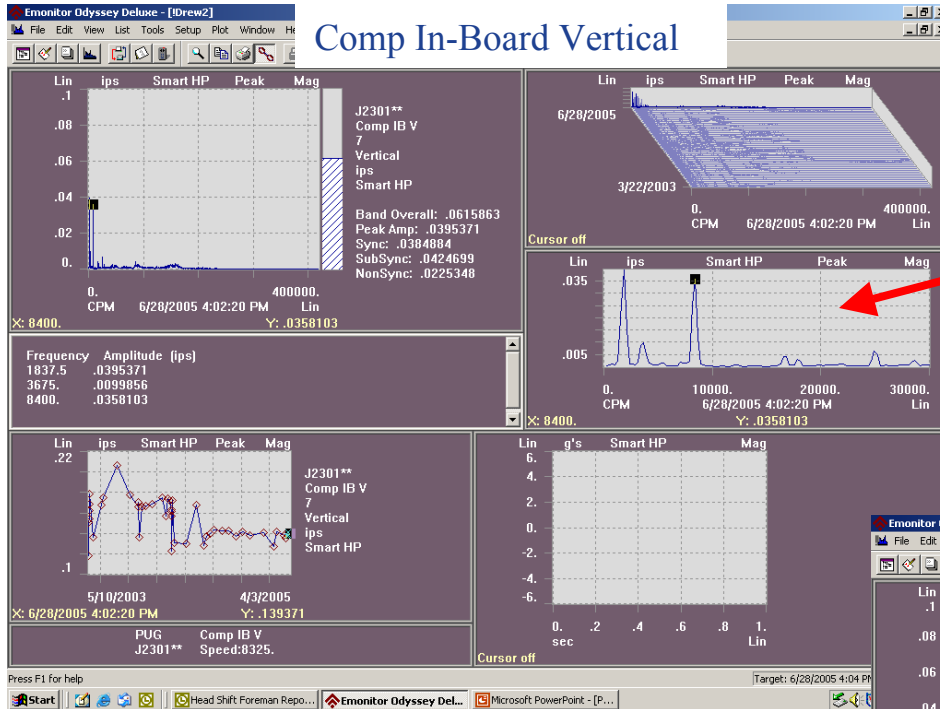
Problem Statement & Background

- **High vibration levels occurring during periods of operation when suction gas temperatures exceeded 90F on a H2 Recycle Compressor installed at Frontier Refinery's El Dorado, KS refinery.**
 - > **Vibration was observed to be sub synchronous in nature ~ .47x**
 - > **Overall vibration levels approached 3.0 mils p-p during these time**
 - > **Problem became readily apparent approximately 2 years after initial start up of new compressor internals**

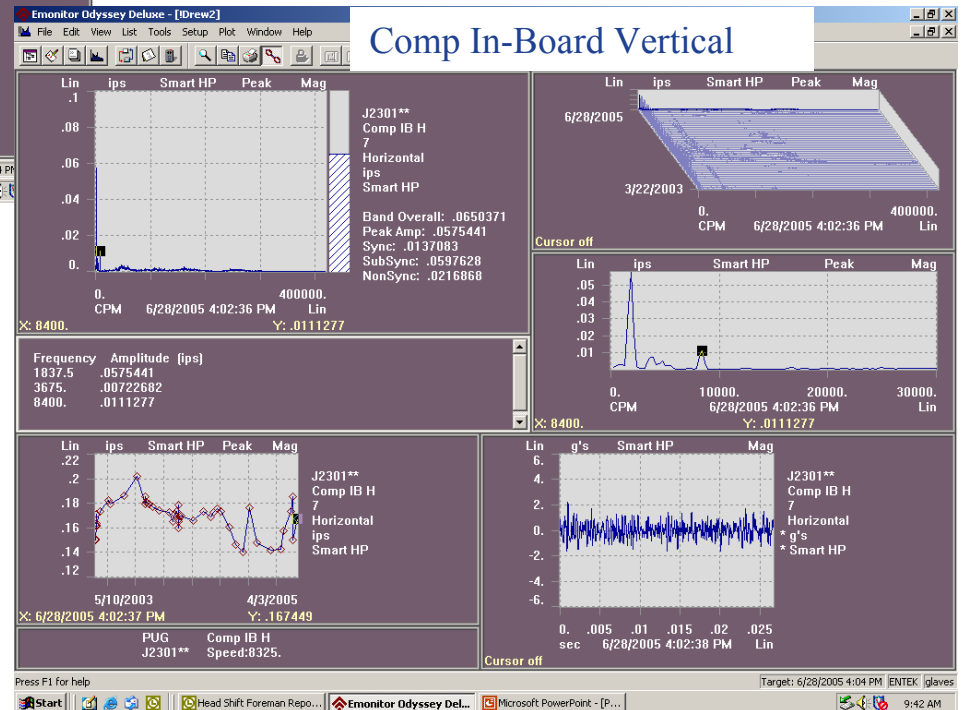
Data Trending



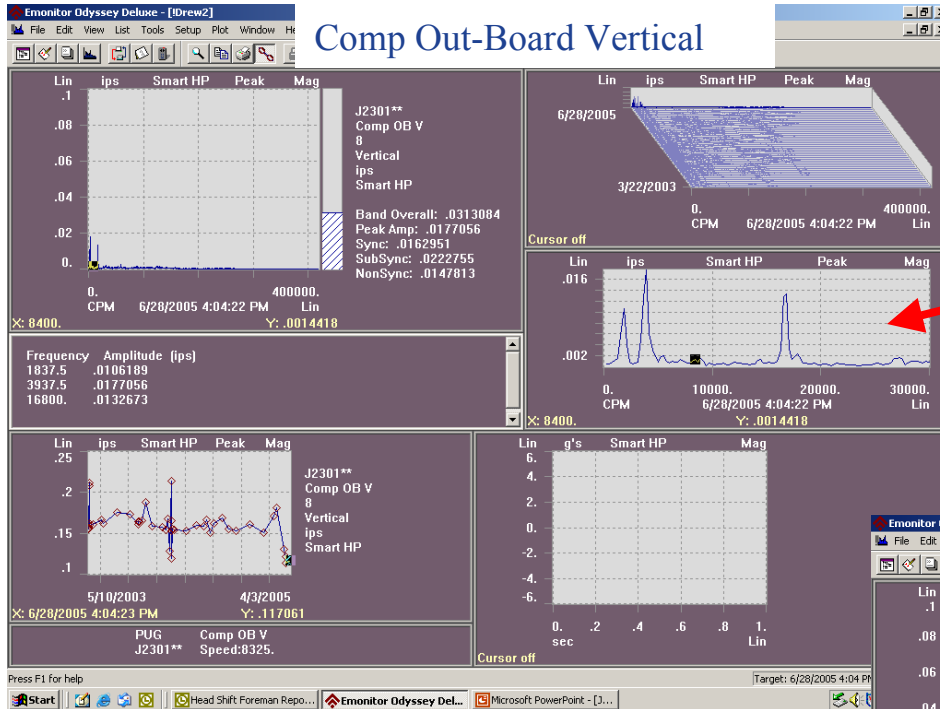
Data Trending



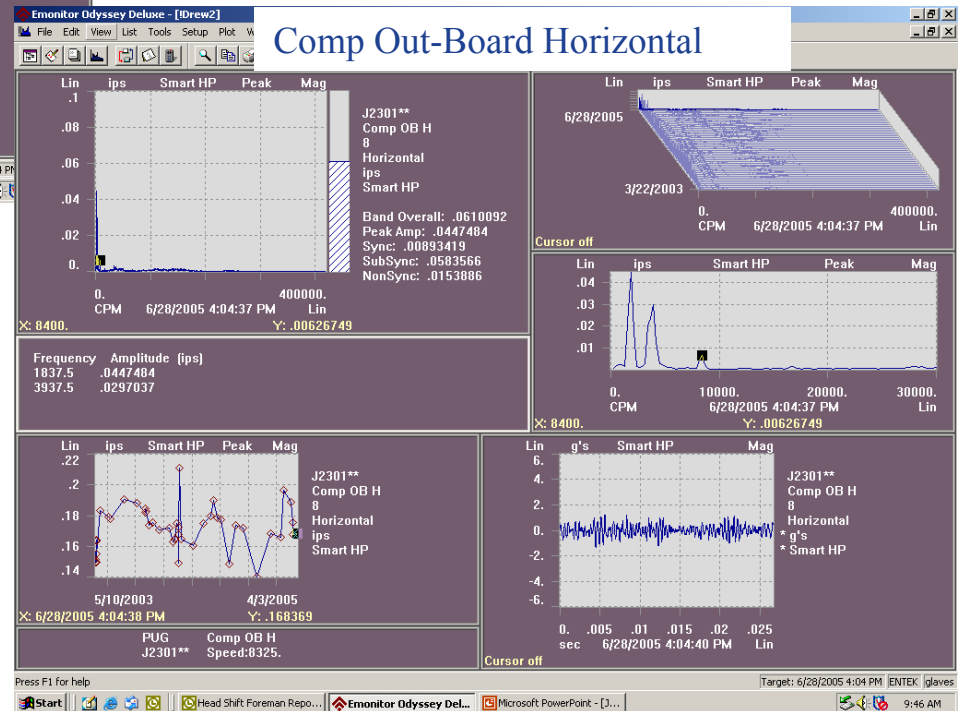
Note High 1800 RPM Amplitude & Sub-Synchronous Presence. Cursor on 1X



Data Trending

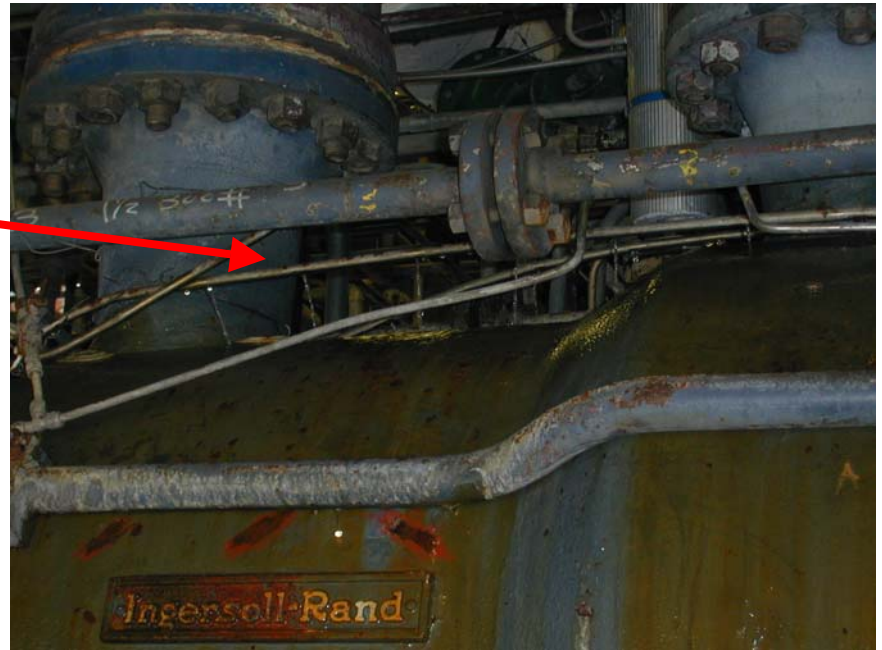


Note High 1800 RPM Amplitude & Sub-Synchronous Dominance and 2X. Cursor on 1X



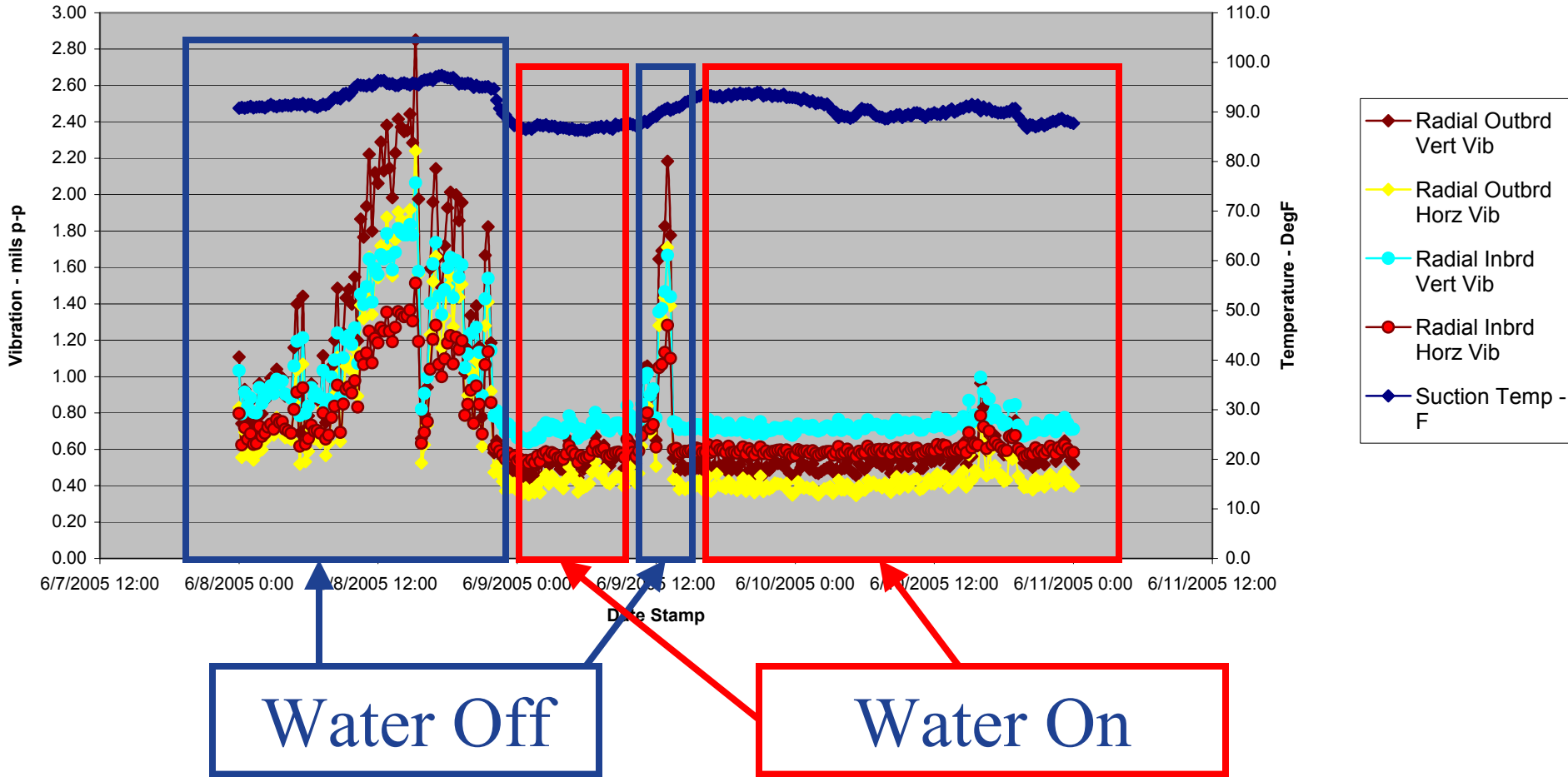
Short Term Solution

**Water Delivery
System**



Data Trending

2005 Frontier Field Data - Water on Casing

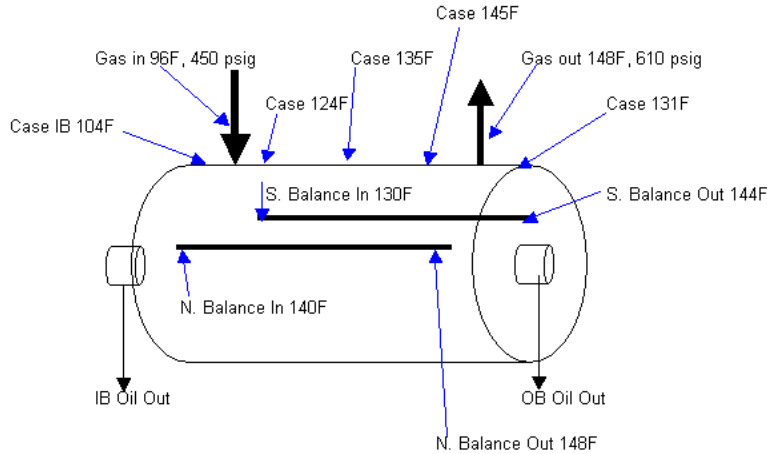


Data Trending

J2301 6/28/05 Water Off Case, Bentley and Case Readings Taken

Temperatures at 3:40 PM 6/28/05

Lube Oil Inlet	108F
IB Bearing Housing	119F
IB Bearing Outlet	119F
OB Bearing Housing	116F
Thrust Bearing	120F
OB Bearing Outlet	120F
Gearbox HS Bearing	168F
Coupling Guard	208F
Seal Oil Inlet	114F
Seal Oil Outlet	153F
Motor amps	680
Lube Oil Pressure	22 psig

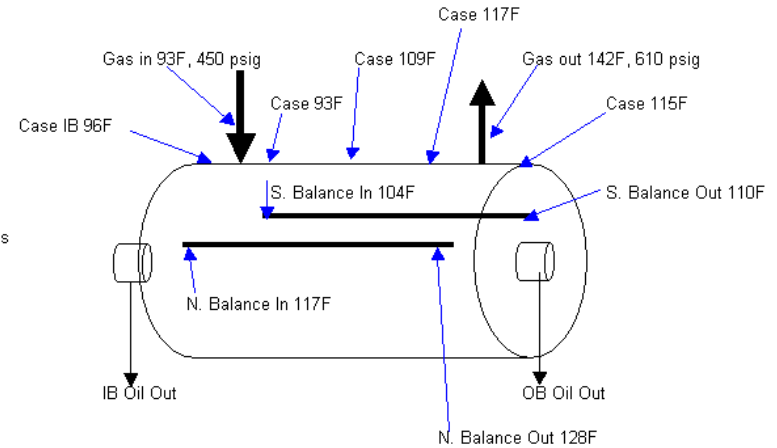


20 to 30 deg F change
in casing temperature

J2301 6/29/05 Water On Case, Bentley and Case Readings Taken

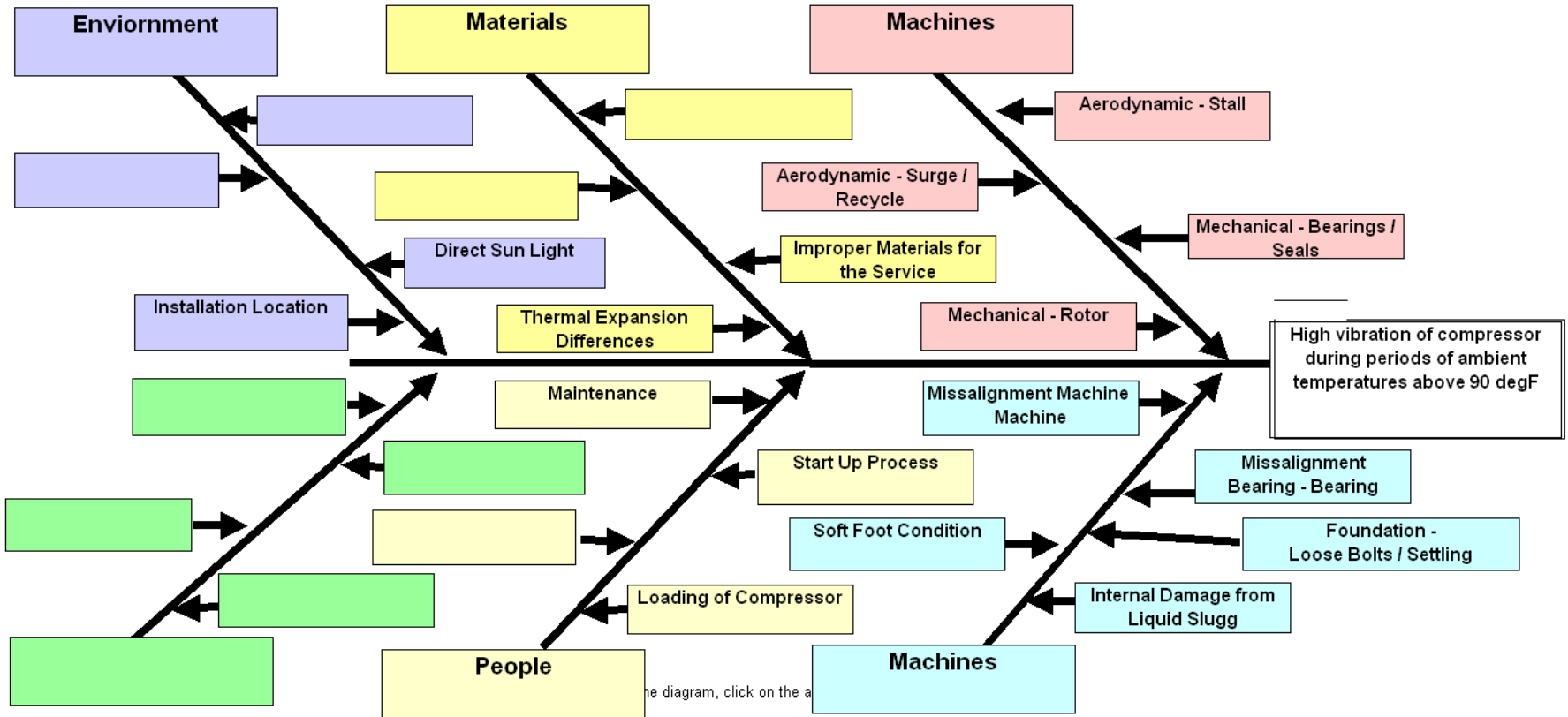
Temperatures at 1:40 PM 6/29/05

Lube Oil Inlet	116F
IB Bearing Housing	116F
IB Bearing Outlet	120F
OB Bearing Housing	116F
OB Bearing Outlet	118F
Thrust Bearing	118F
Gearbox HS Bearing	165F
Coupling Guard	192F
Seal Oil Inlet	110F
Seal Oil Outlet	142F
Motor amps	676 amps
Lube Oil Pressure	22 psi



Analysis

Fishbone Diagram

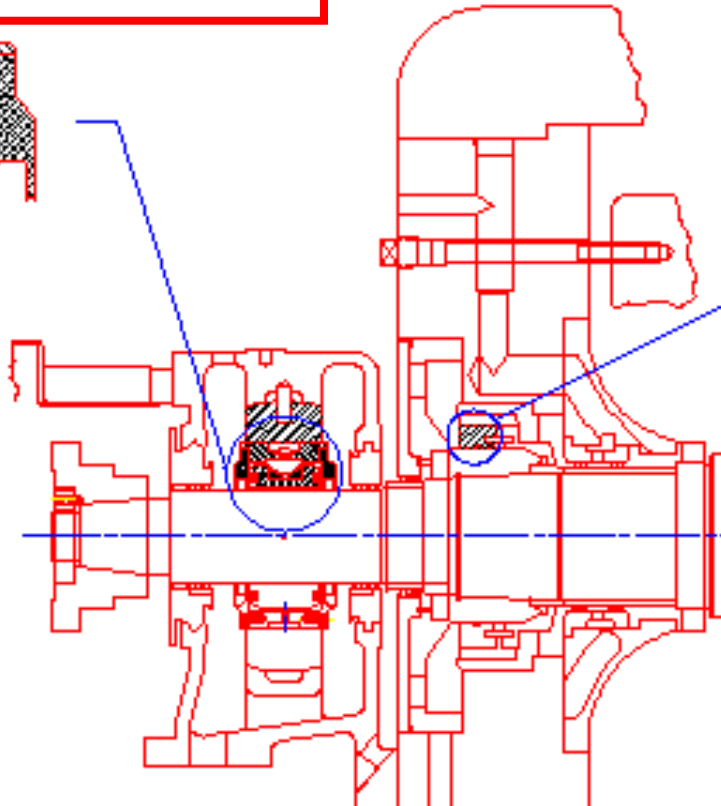


Remaining Potentials:

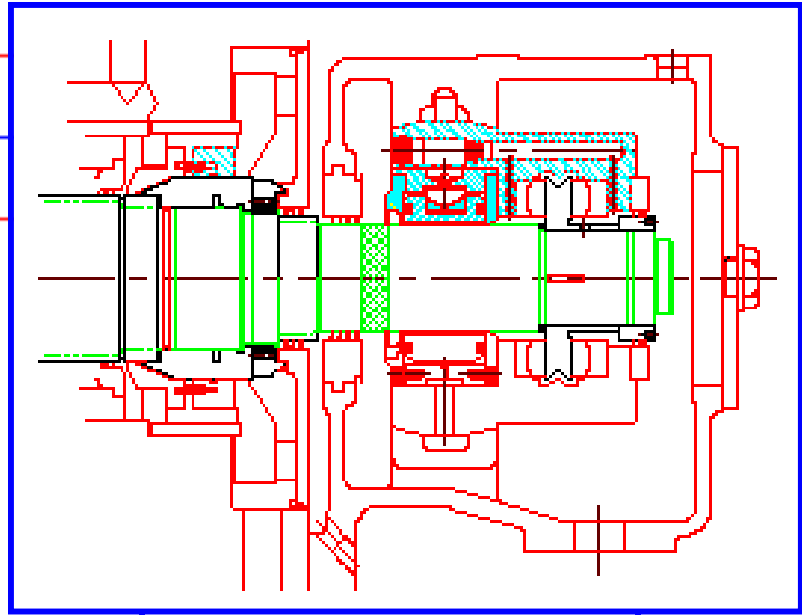
Bearing – Seals / Alignment (Soft foot – Foundation Factors)

Long Term Solution

New Tilt-Pad Bearing Design
with Spherical Pad Seat



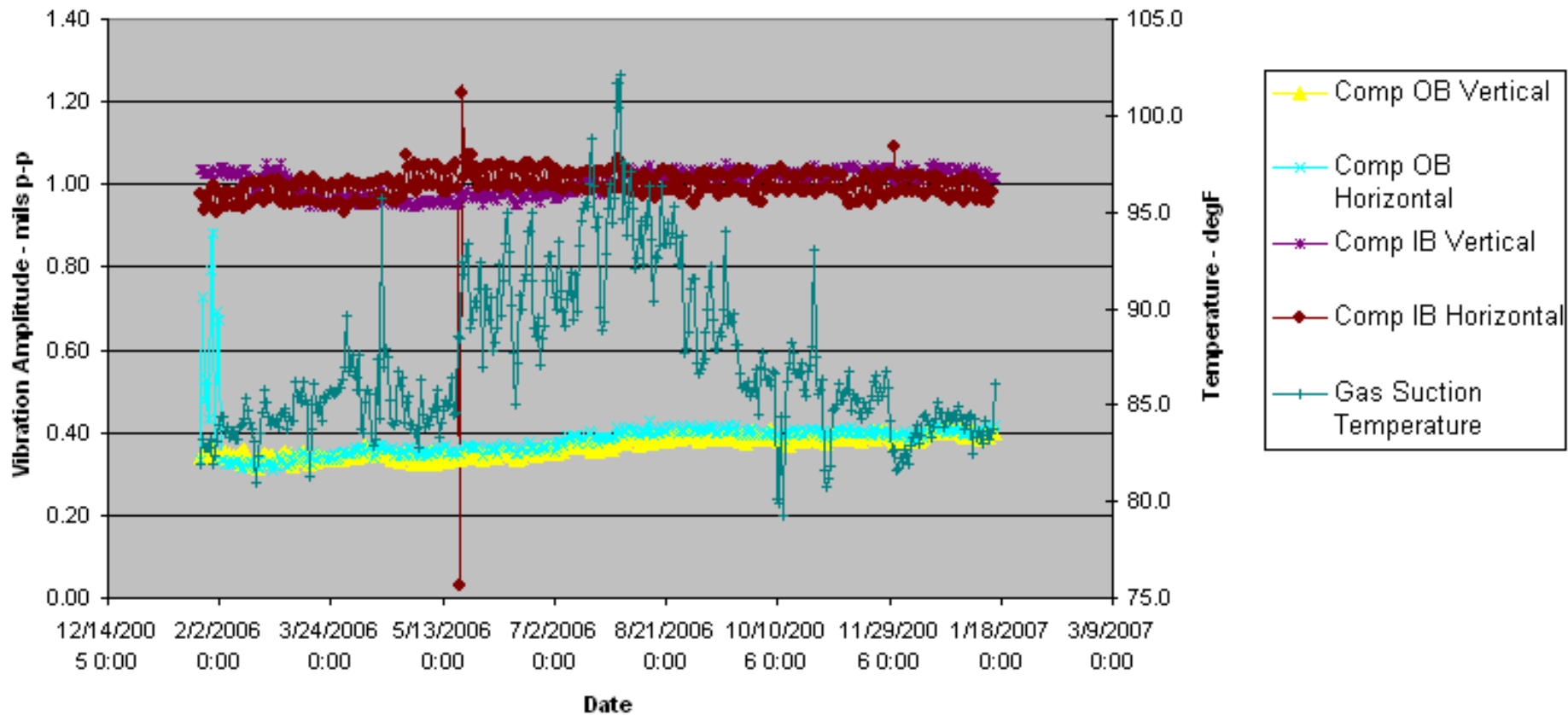
Reworked Floating
Seal Ring to add
Relief Groove



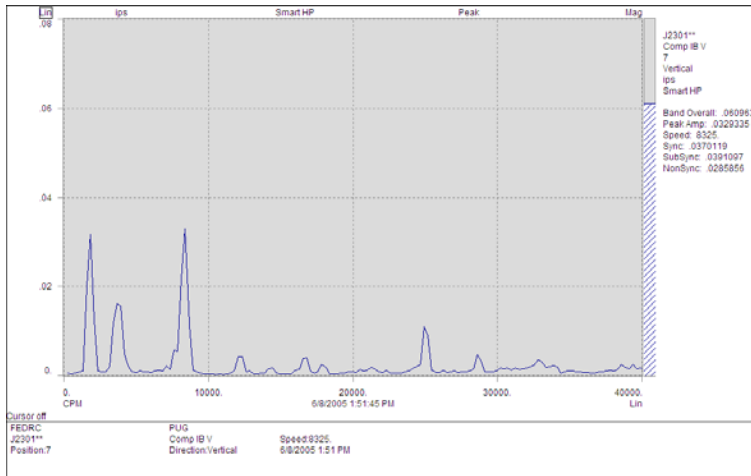
Thrust End

Results

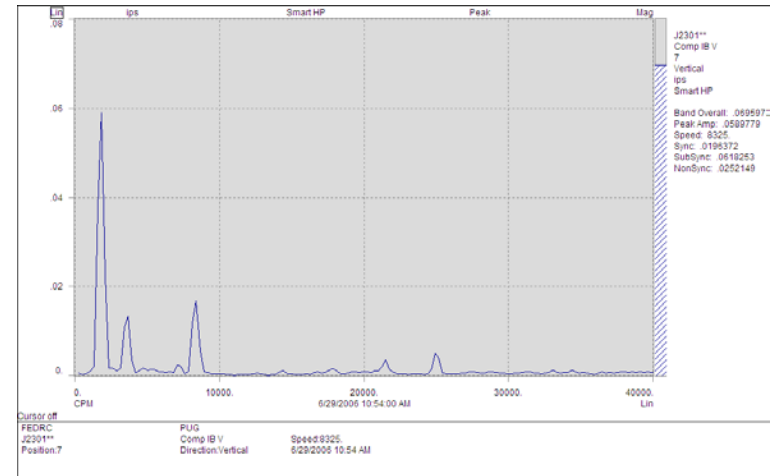
Post Bearing - Seal Redesign
New Designs Installed and Unit Restarted Jan 16, 2006



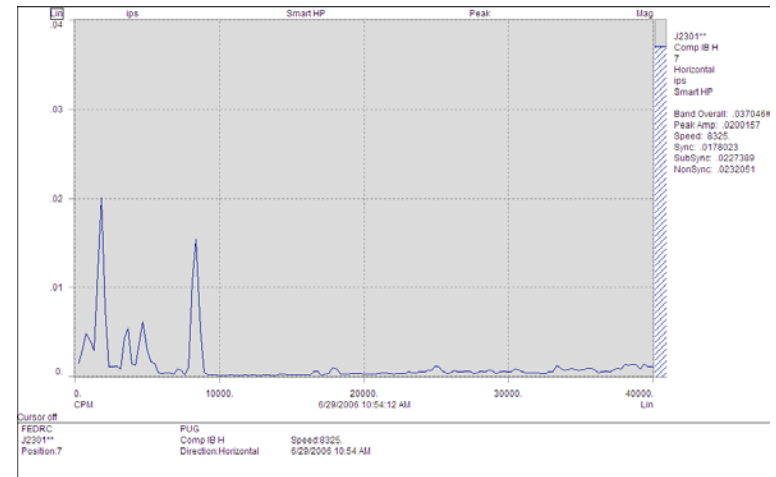
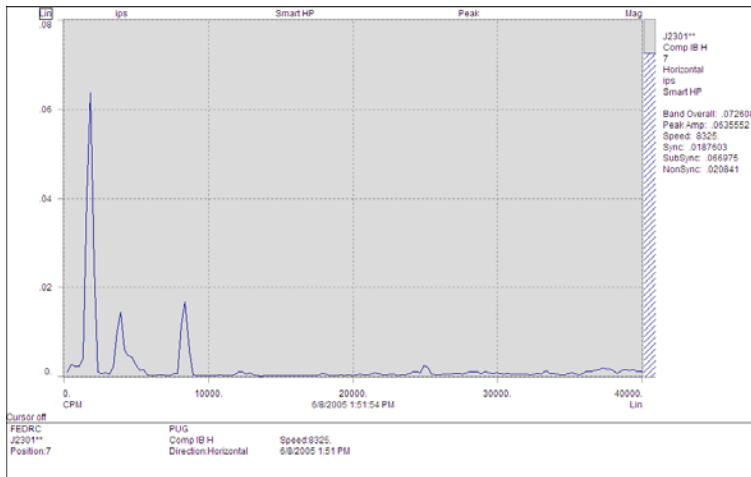
Results – Bearing Cap Readings



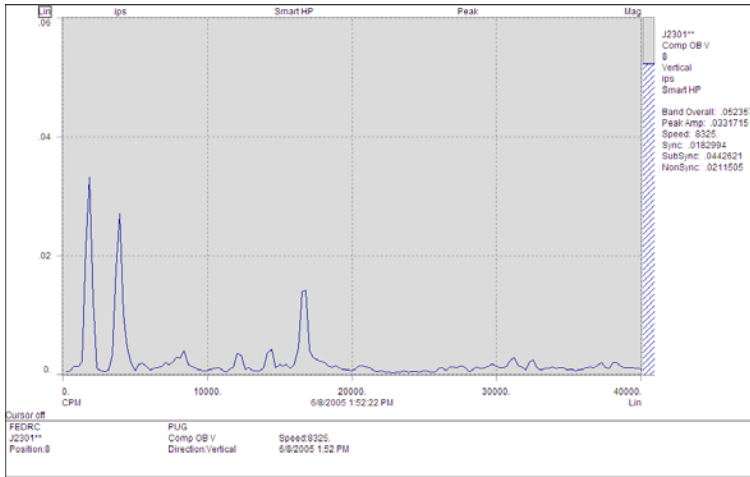
Summer 2005



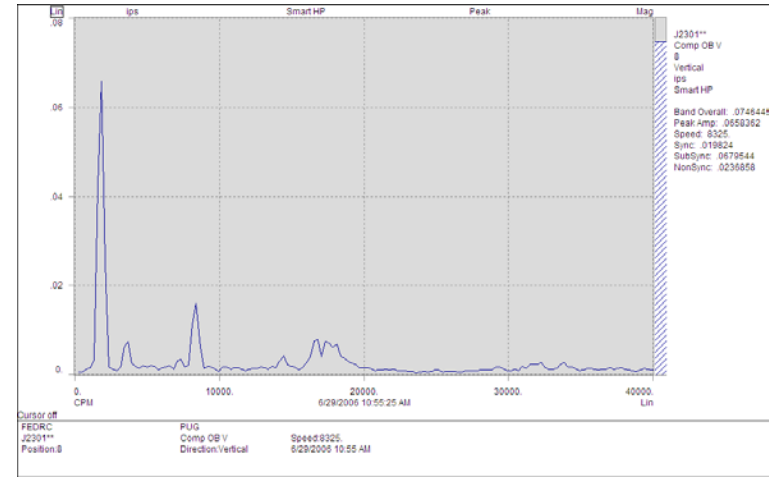
Summer 2006



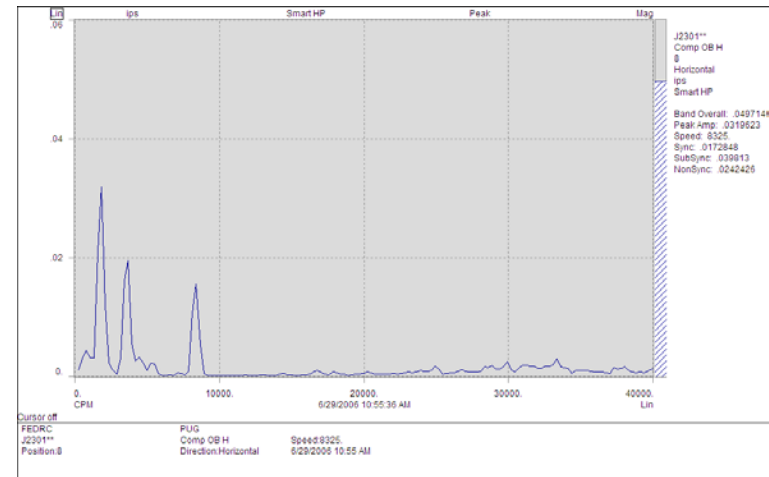
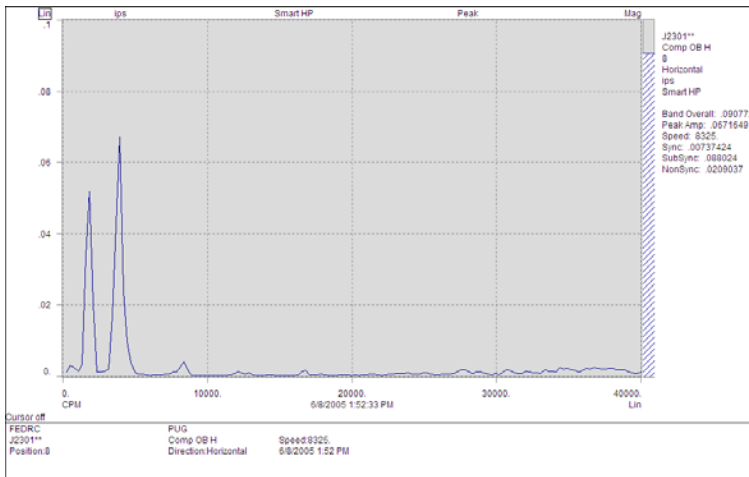
Results – Bearing Cap Readings



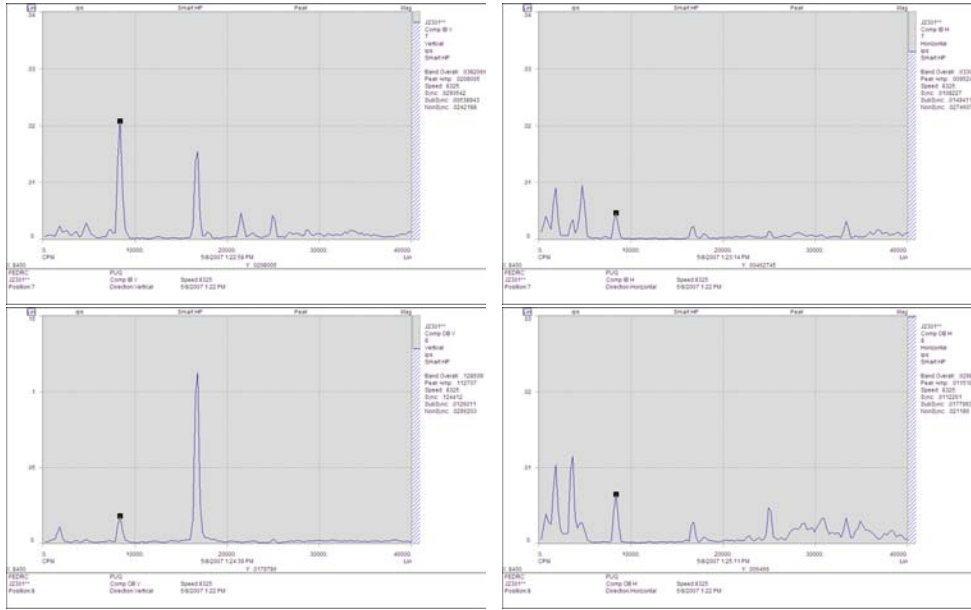
Summer 2005



Summer 2006

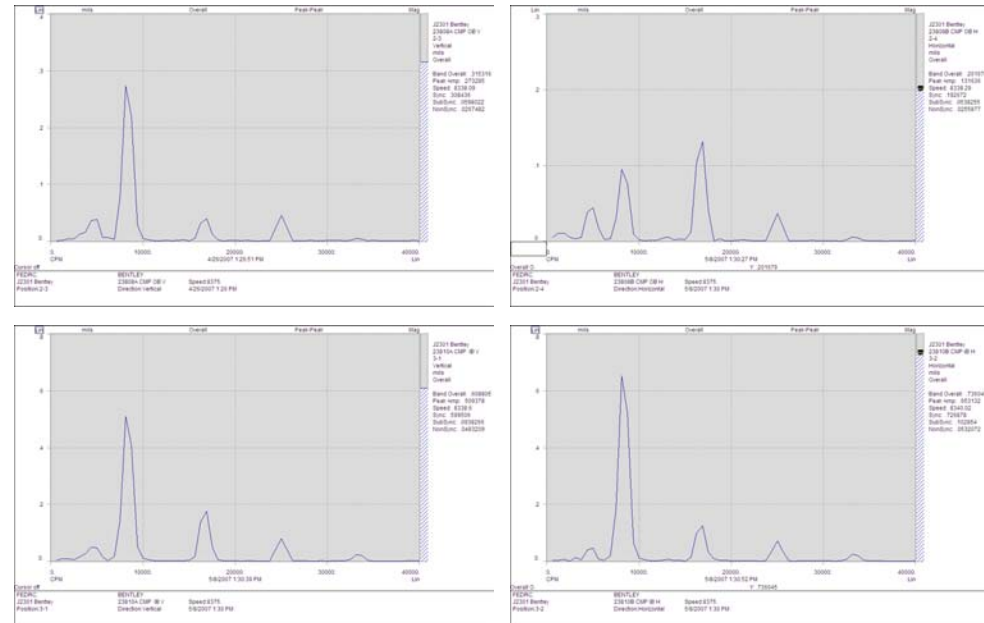


Results – 2007 Motor Change Out



Bearing
Cap
Readings

Shaft
Proximity
Probe
Readings



Conclusions

- **Water Cooling System Controlled Thermal Growth of Compressor Centerline**
 - > **Bearing Dam Bearing effected**
- **Spherical Seated Tilt-Pad Bearing**
 - > **Increased Damping**
 - > **Accommodating to Alignment Impact of High Ambient Temperatures**
- **Grooved Oil Seal Ring**
 - > **Increased Stability via Reduction of Cross Coupling Forces**
- **2006 & 2007 Operation has Low Overall Vibration Levels**
- **Long Term Effects of External Water Cooling not Studied**