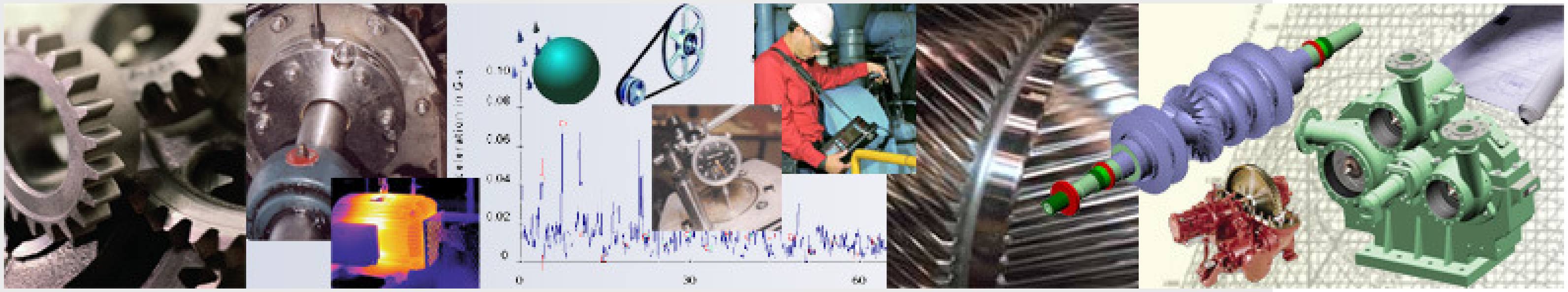
Correction of Chronic Thrust Bearing Failures on a Refrigeration Compressor

September 15, 2011



Presenters: Matthew D. Moll
Rotating Machinery Consultant
DuPont Rotating Machinery Group

Julia Postill
Turbo Components and Engineering

Outline

- Project Commissioning
- Operating Difficulties
- Use of PPM Technologies
- Corrective Action
- Present Condition
- Conclusion

Project Commissioning

Compressor

- 2250 HP (1678 kW) Centrifugal – 4 Stage 7100 RPM
- Service is closed loop refrigeration, Freon ® 22
- Equipped with Proximity Probes, and bearing exit oil temperature RTD’s

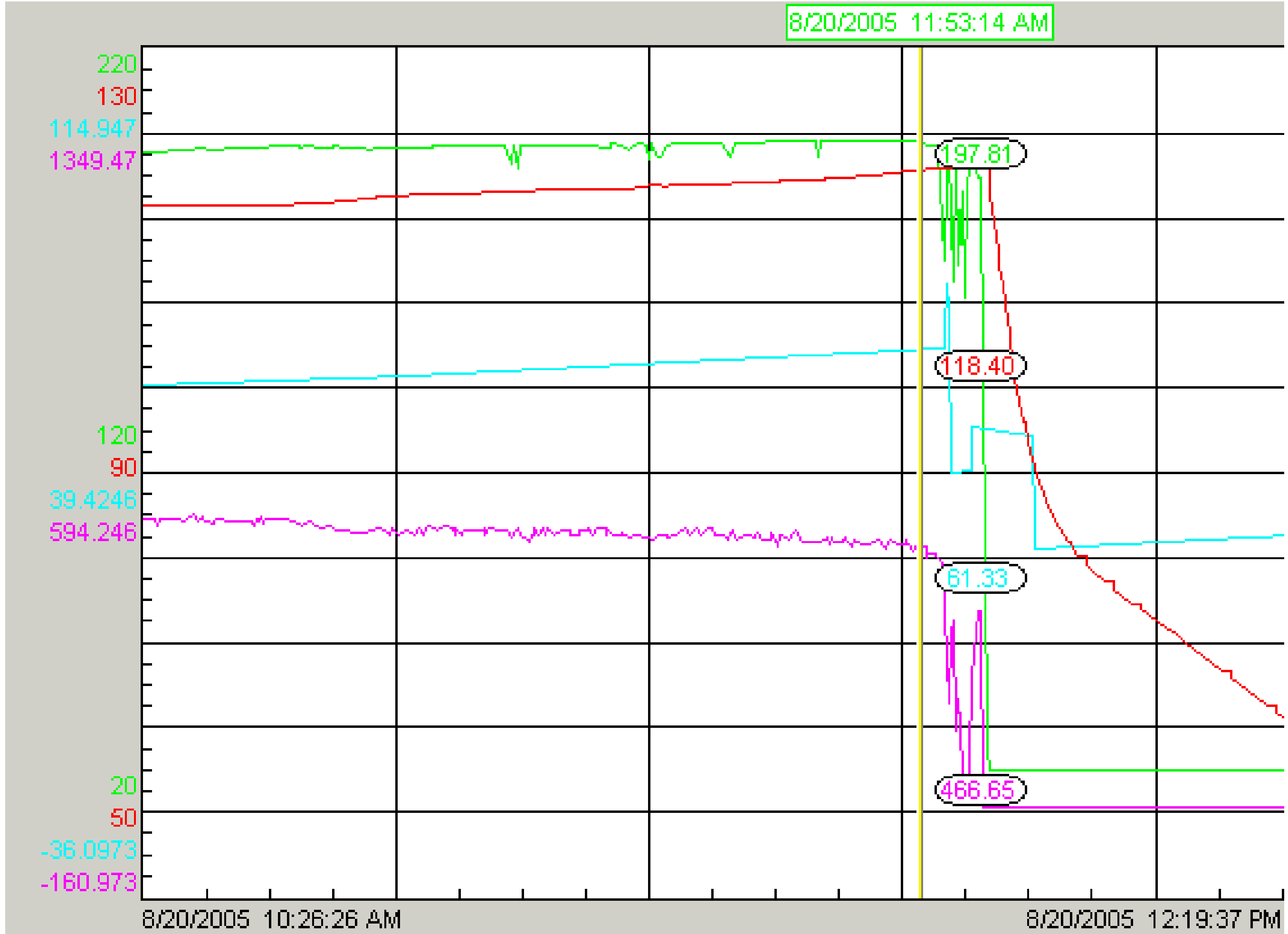
Commissioning Difficulties – startup 1994

- Performance did not achieve contract performance obligations at high head conditions
- Rotor was redesigned and installed to increase compressor output

Operating Difficulties

Operation 1996 - 2004

- New rotor improved performance, however not over entire operating range
- High head conditions resulted in excessive discharge temperature and sometimes compressor surge



Name	Description	Value	Plot Min	Plot Max	Units
4308PG	REF #3 COND PG	192.40	20	220	PSIA
4277TG	REF #3 COMP EX T	114.07	50	130	DEG C
4270TV	#3 REF 4270TV CONTROL OUTPUT	20.02	-8.04867	67.4733:	%
4253TC.OP	REF #3 (LOAD) EX BRINE T CO	31.95	-36.0973	114.946l	%
4367WG-1	REF #3 COMP TE J-BRG Z VIB	***	-38.048E	37.4733:	MILLS
4280WG	#3 REF LOAD - IN TONS	245.05	-160.973	1349.46l	TONS
4253XG	REF #3 COMP MTR AMPS	207.00	102.927	216.21	AMPS

Operating Difficulties (Cont.)

Operation 1996 - 2004

- During this time period the compressor experiences two thrust bearing failures. Compressor was operated until internal thrust limit interlock switch was tripped.
- Surging was original suspect of root cause of thrust bearing failure

Use of PPM Technology

Routine Oil Analysis

- Samples collected from pressurized lubrication system
- Samples subject to Spectrochemical and Physical Analysis

Vibration Monitoring

- Equipped with Thrust and Radial Probes to a rack system – recording peak output only.
- Periodic data collection on casing of compressor, as well as proximity signals.

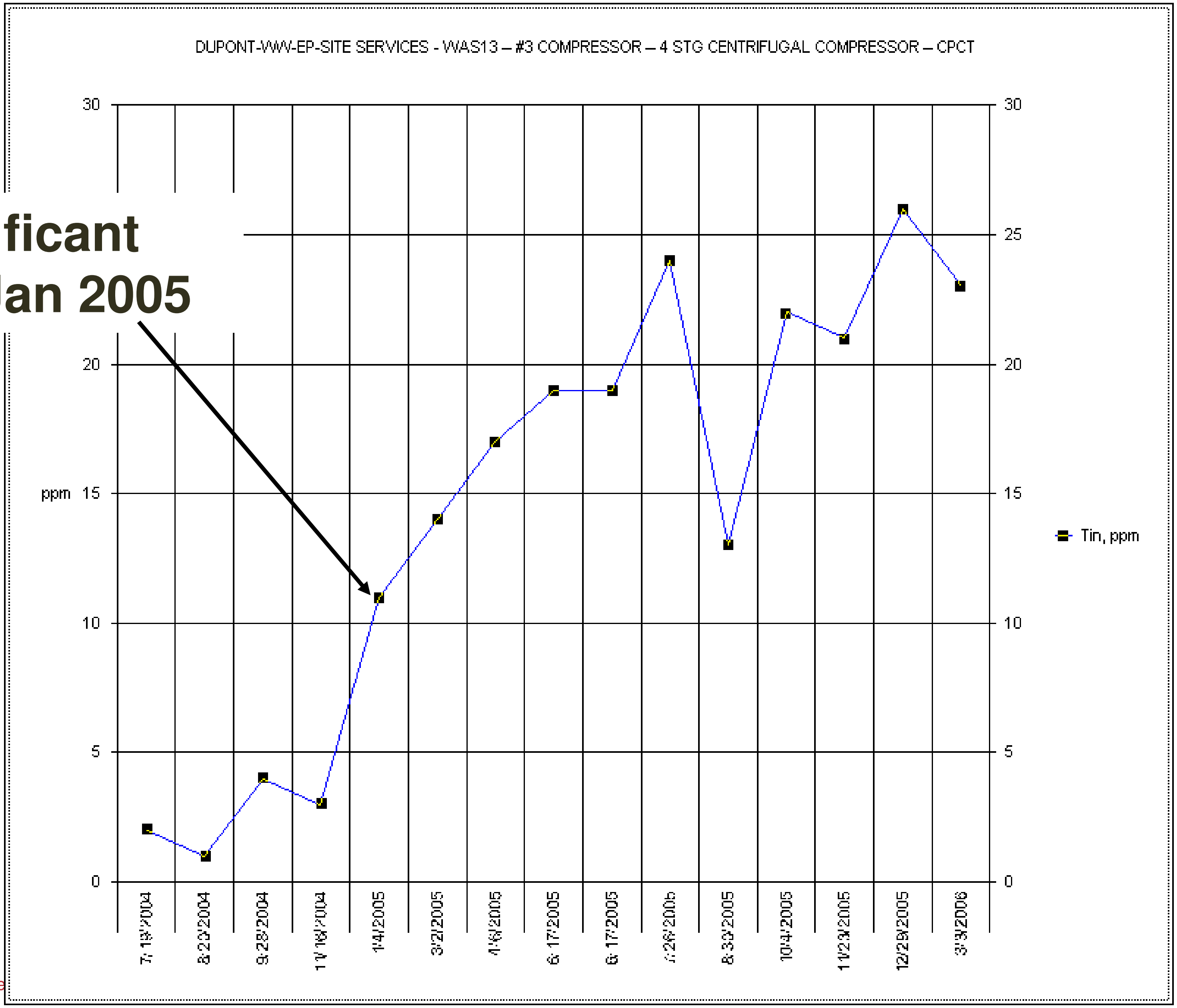
Temperature Monitoring

- Oil Supply Temperature
- Thrust bearing drain temperature
- Radial bearing contact RTDs.

Use of PPM Technology (Cont.)

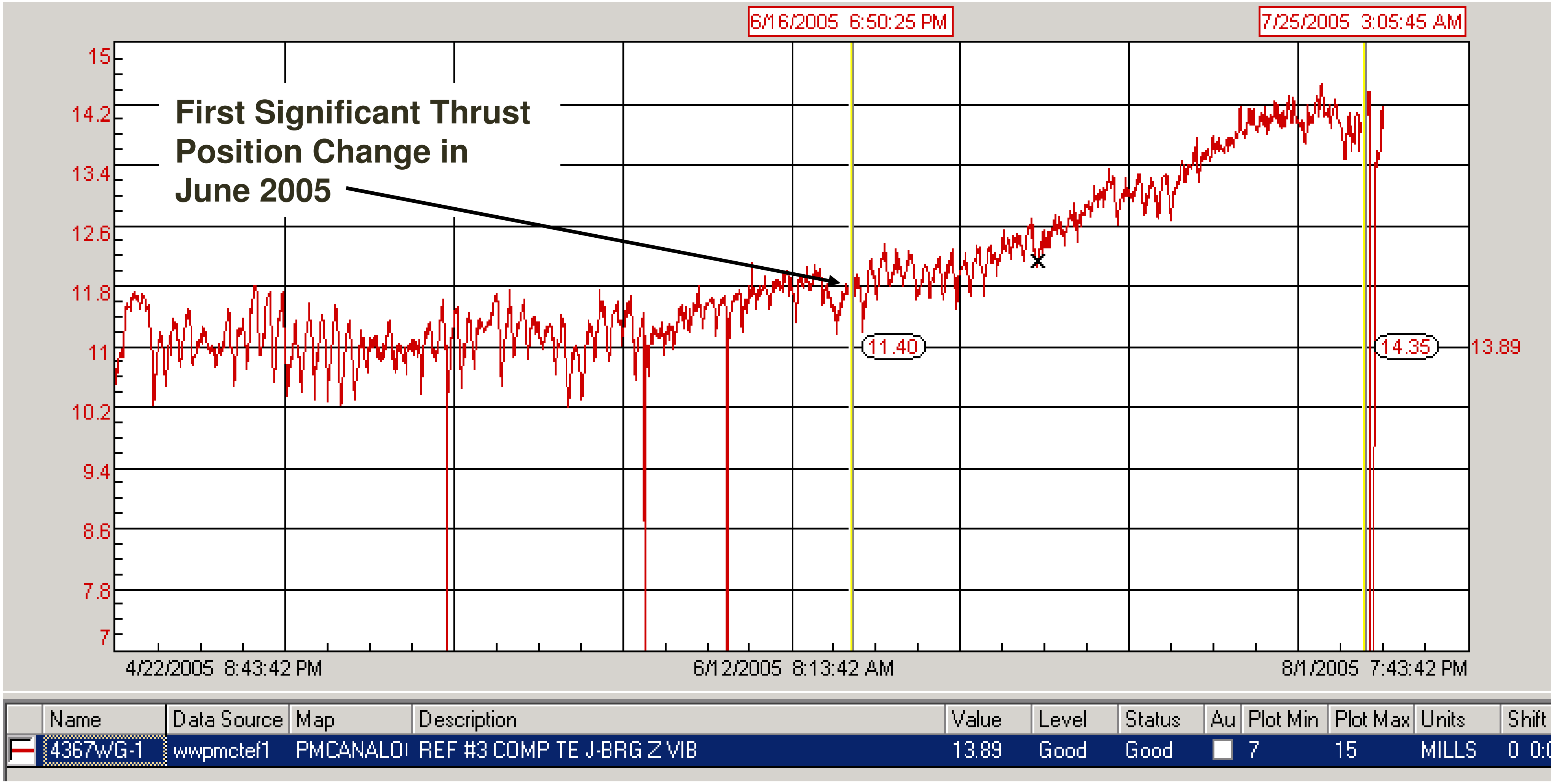
Thrust bearing distress was first detected by routine oil analysis

First Significant Increase Jan 2005



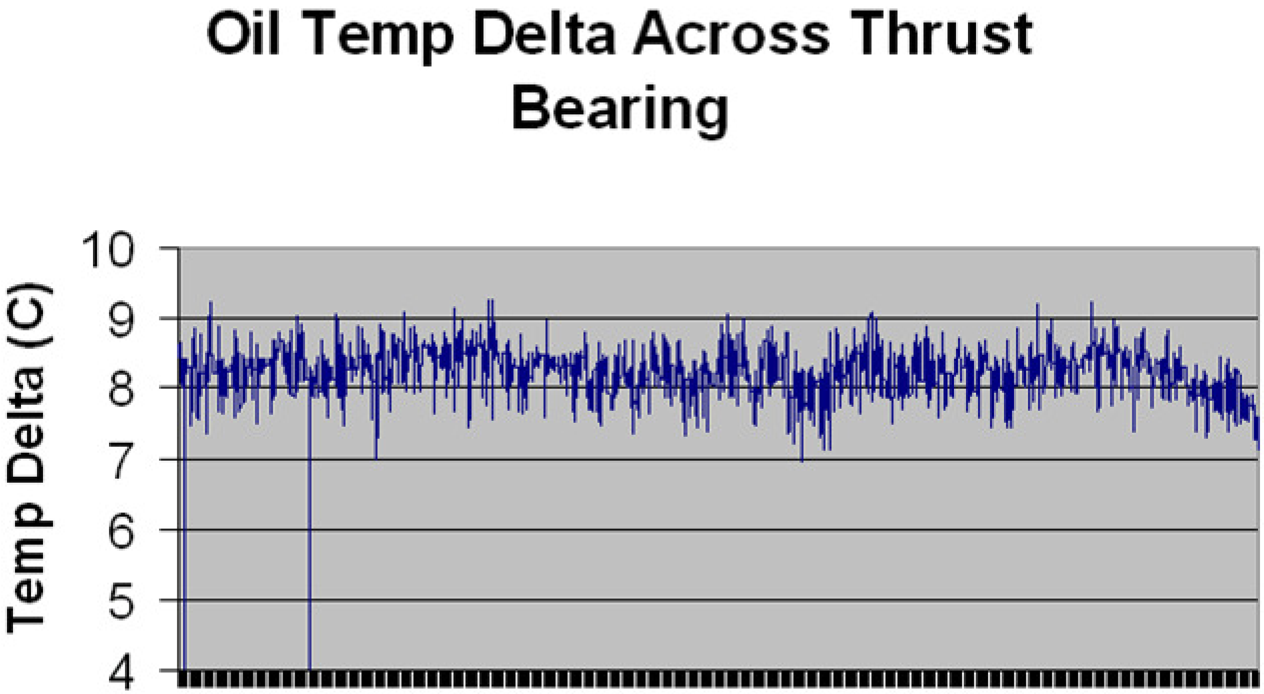
Use of PPM Technology (Cont.)

Compressor rotor running position would suddenly change after about six months to two years stable operation to + 1.5 mil (0.038 mm) per month in active direction. This rate of change would suddenly plateau for a month or more then reinitiate the climb



Use of PPM Technology (Cont.)

Lube Oil Temperature – not an effective indicator of bearing distress dT 8 deg C (14.4 deg F)

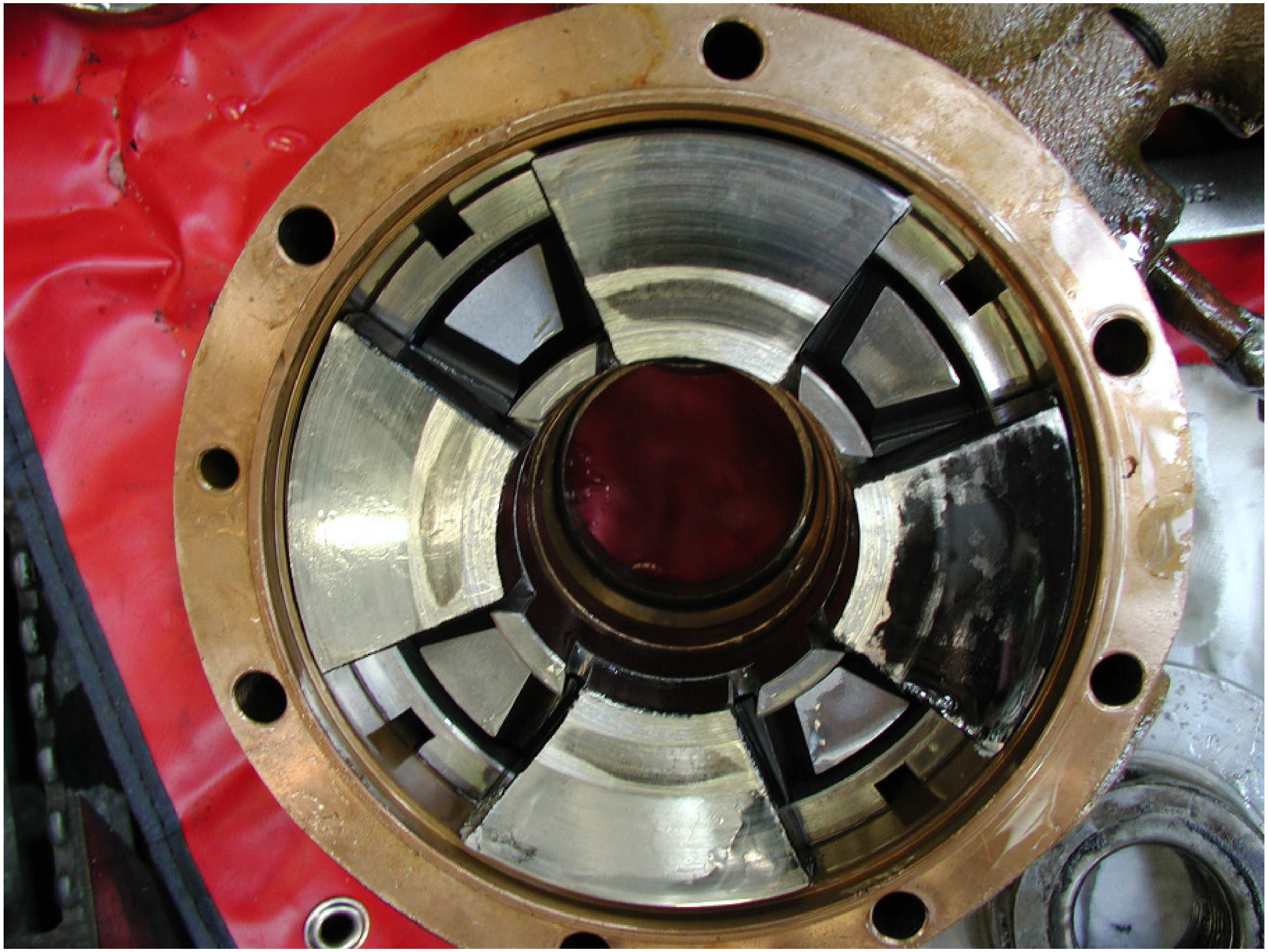


June 1st to Aug 1st 2005

Use of PPM Technology (Cont.)

Thrust bearing removed from service February 2006

(Third Bearing)



Corrective Action

OEM involved with failure investigation

- OEM Reviewed thrust bearing sizing calculations from 1995. In the original calculations the compressor balance piston was sized for 170 psi (1172 kPa) load on the thrust bearing.
- OEM utilized a new design routine (2006), this calculation indicated that with the installed balance piston, the load on the thrust bearing was 360 psi (2482 kPa)
- OEM recommendation was to increase balance piston sizing. There was no cost for the analysis, however the cost associated with refitting the compressor with a larger balance piston was not offered with the solution.

Corrective Action (Cont)

Creative solution desired

- OEM calculations combined with operating experience converged on a overloaded thrust bearing as being the root cause of the failures.
- Those familiar with compressor design understand that resizing the balance piston is the most elegant solution to solve this problem.
- Those familiar with compressor fabrication and maintenance understand that resizing the balance piston is an expensive procedure.
- Site management did not desire to absorb the cost associated with taking the compressor out of service to retrofit or the lost production.

Corrective Action (Cont)

Creative solution desired

- The preferred solution was to redesign the thrust bearing with increased load carrying capacity to reduce the risk of failure.
- To keep a low cost modification, the thrust bearing had to be used in the same envelope as the original OEM bearing, with no modification to the bearing housing.

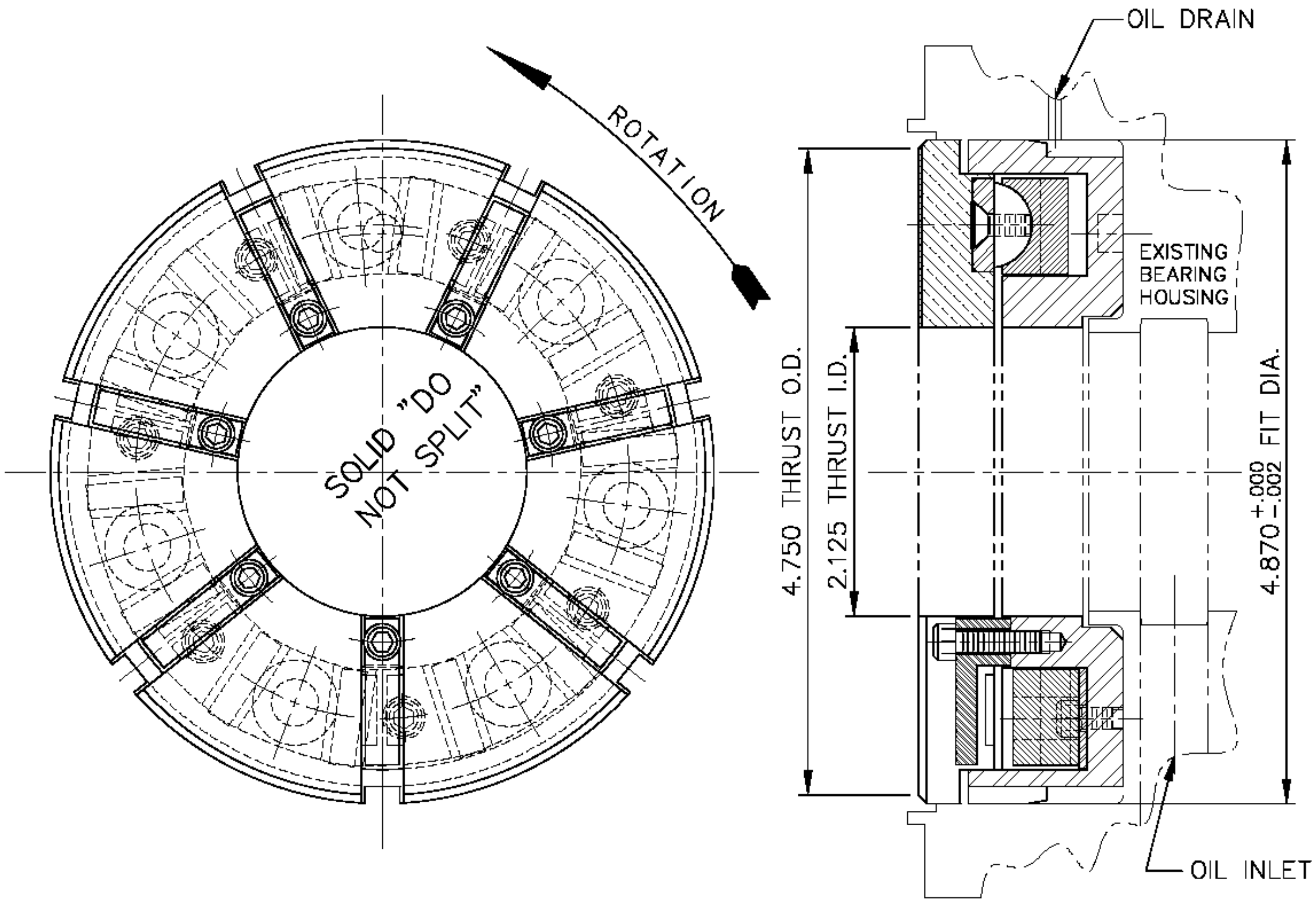
Corrective Action (Cont)

Improvements to the thrust bearing design:

- larger thrust bearing area to reduce unit load from 360 psi to 242 psi (2482 kPa to 1669 kPa)
- copper backing material for faster heat dissipation;
- offset pivot to further increase the load carrying capacity;
- ball & socket pivot to reduce pivot wear caused by high loads;
- provided option to install instrumentation to monitor the bearing metal temperature during bearing service;

Corrective Action (Cont)

Bearing description: flooded, self-equalizing, ball & socket pivot, seven copper backed pads, 62% offset pivot;



Corrective Action (Cont)

- The new bearing design has a 41% increase in thrust area then the original design; copper backing material for faster heat dissipation;
- This was accomplished by changing the design from four pads to seven pads because there was no room to increase the thrust area by changing the bearing diameters.
- The pivot location was radial and circumferentially offset, to allow a better flow in each thrust pad and to better support a full oil film over each pad.

Corrective Action (Cont)

- Due to this change the mean velocity increased from 107 fps to 112 fps (32.6 m/s to 34.1 m/s);
- The increase in thrust area and the larger pivot diameter resulted in an increase in the horse power loss. The bearing was already getting the adequate amount of oil, so no increase in oil supply was necessary.

Present Condition

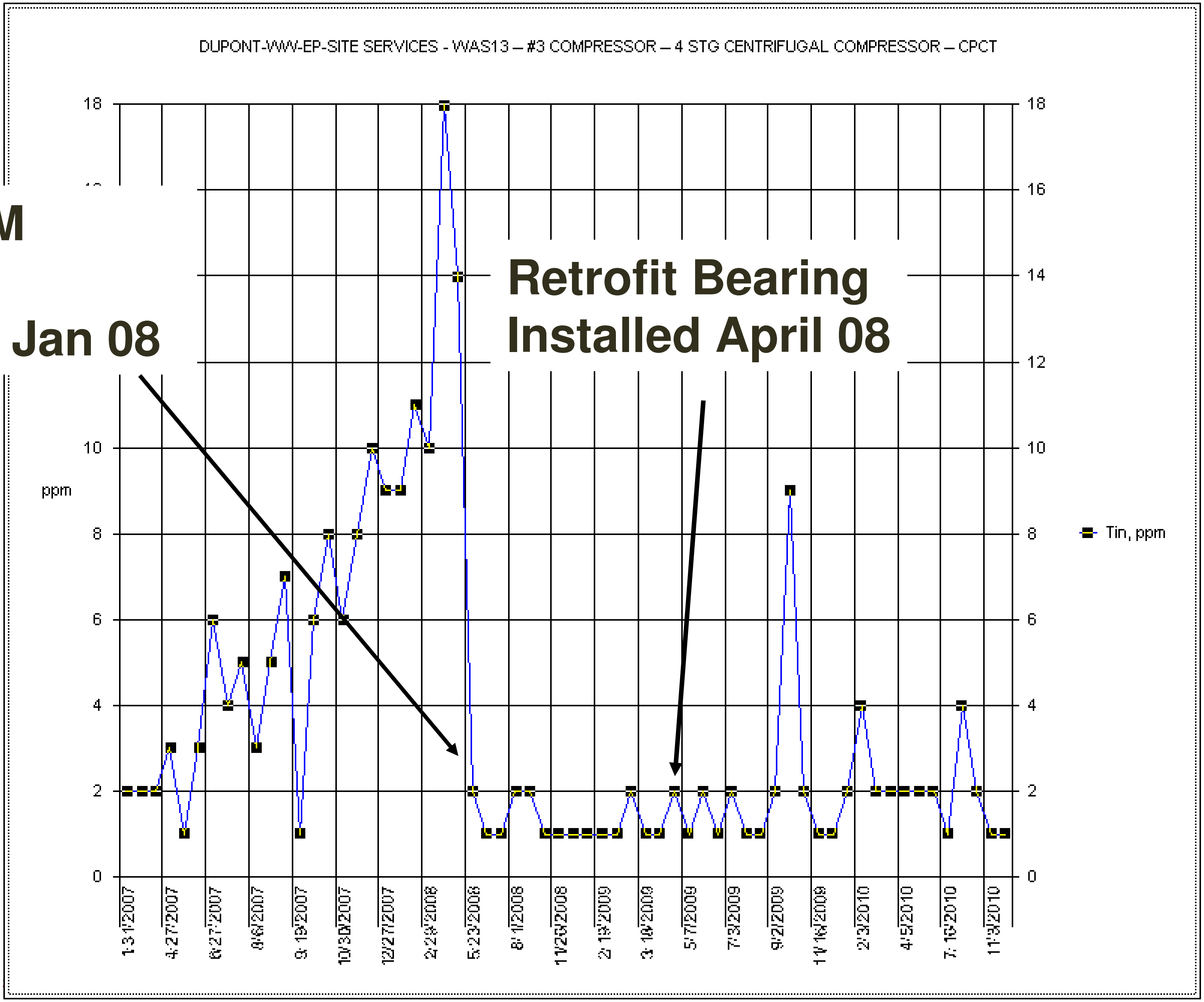
Lower trend line indicates thrust position of rotor from Aug 2008 to March 2010

Rotor Running Position Cycling 2 mils (.051 mm) with changes in head pressure over 18 months

Present Condition (Cont)

New OEM Bearing Installed Jan 08

Retrofit Bearing Installed April 08



Present Condition (Cont)

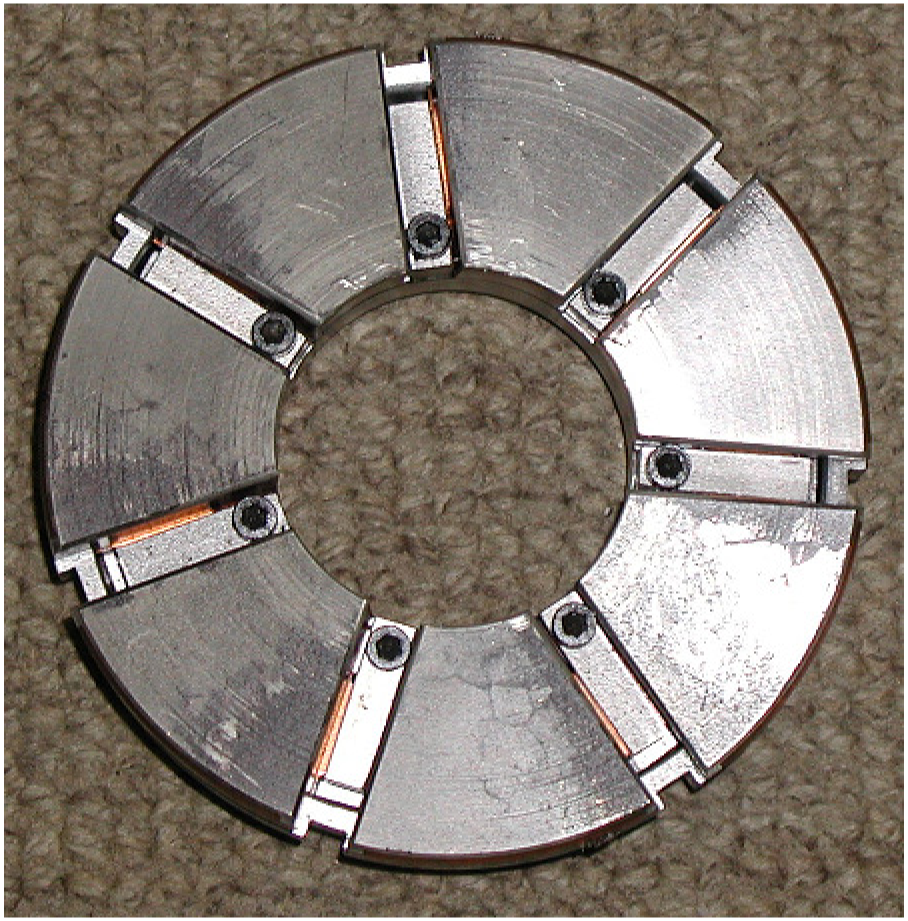
OEM thrust bearing installed between January and April 2008

Present Condition (Cont)

- Retrofit Thrust bearing was installed in April 2008 and demonstrated successful operation for ~24 months, at which time it was replaced
- Replacement bearing is demonstrating similar performance in the same timeframe.
- Oil analysis laboratory results indicate significantly less bearing material circulating in lubricating system.
- The average oil temperature change across the bearing increased from 8.5 deg C to 10.3 deg C (15.3 deg F to 18.54 deg f) with the retrofit, as expected for the additional frictional losses.

Present Condition (Cont)

Retrofit thrust bearing after 24 months of operation



Conclusion

- Use of advanced bearing design practices can be used in the maintenance field to reduce downtime and cost
- In small volume lubricant systems, oil analysis is a leading indicator to vibration and thrust position for bearing faults.
- Bearing discharge oil temperature is not a useful indicator for bearing condition monitoring, further reinforcing the objectives of API 670.

Questions?

A discharge bearing oil temperature interlock that actually tripped!