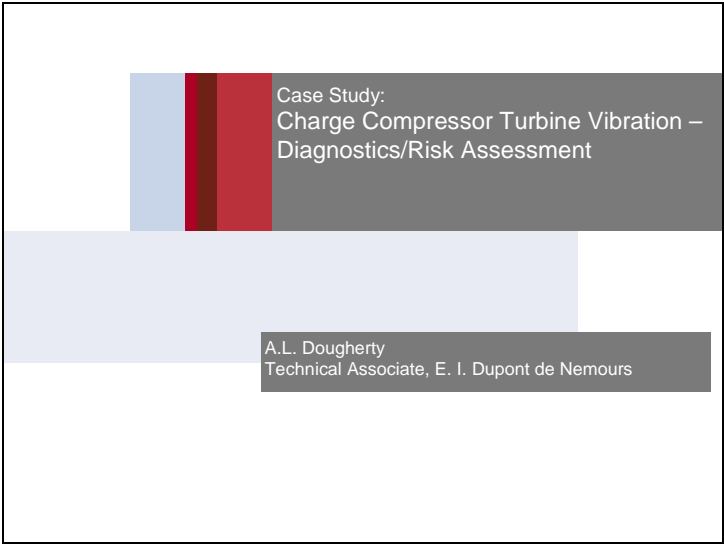


**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

Slide 1



**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

Slide 2

2

**Charge Compressor Turbine Vibration –
Diagnostics/Risk Assessment**


- **Event Summary**
- **Diagnostics/Machine Assessment**
- **Risk Management**
 - Machine Surveillance/Checks
 - Changes/restrictions to Operating Conditions
- **Machine Inspection**
- **Current Status/Follow-up**

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- This Case Study presents the diagnostic, machine assessment, and risk management methods performed following a sudden change in vibration condition to a 36MHP steam turbine. The turbine is the driver for the ethylene plant's 4-stage charge compressor that is the heart of the plant's process.
- The triggering event—an increase in vibration from less than a mil to 4.5 mils—occurred at a time when the Gulf Coast region was recovering from the impact of Hurricane Rita. Ethylene supplies were short as plant's struggled to return to operation, and businesses were concerned with the impact to downstream customers.
- The methodology described allowed continued safe operation of the plant for (8) months, until the opportunity to perform corrective maintenance became available.

**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

Slide 3



3

Case Study Abstract

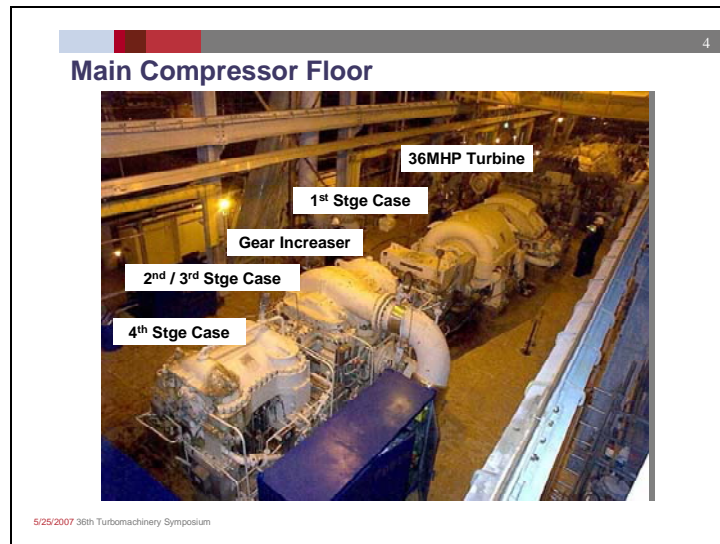
Reducing downtime and sustaining high production rates are essential for companies to remain competitive. A 36MHP steam turbine experienced sudden high vibration. Through use of vibration analysis, selective external case cooling, and altering of specific operating conditions, continued safe production was provided for eight months until an overhaul opportunity became available.

The analysis of machine vibration data, operating conditions and interlock changes, use of external case cooling will be discussed. Subsequent machine inspection findings and failure analysis will also be provided.

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**Case Study:
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- This is a view of the main charge gas compressor deck showing the steam turbine and the 3-case, 4-stage layout of the machine train.

**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

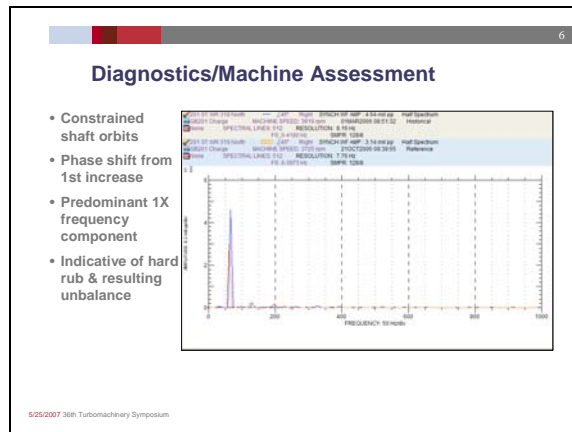
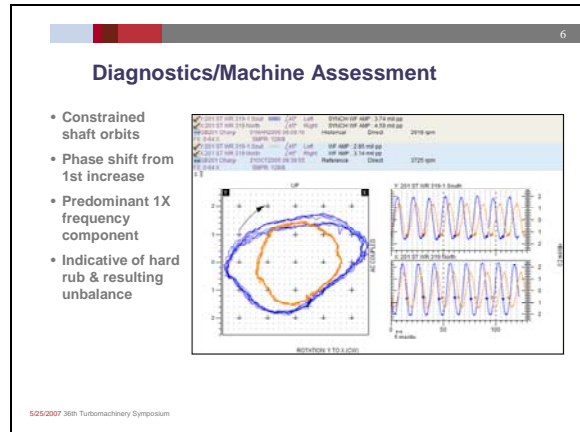
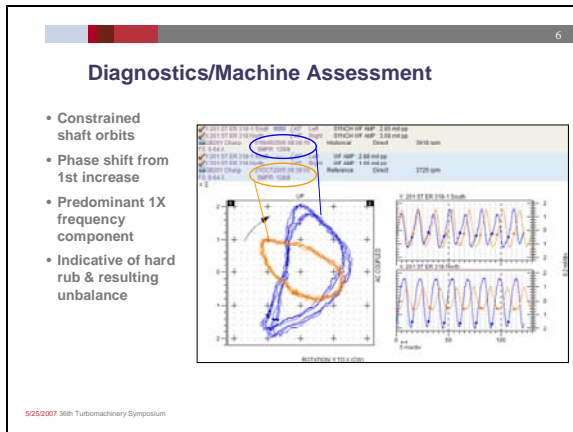
Slide 5



- Overall sequence of events...
- Plant startup was completed the second week in October following Hurricane Rita, within a week after startup, the charge compressor turbine experienced a sudden increase in vibration, the highest amplitude observed at the OB bearing/exhaust end of turbine.
- Speed was decreased on the machine, and a review of the available vibration data was performed, as well as a determination of the machine's sensitivity to speed changes, e.g. imbalance, rub, and change in vibration levels.

**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

Slide 6



- Review of the Bentley System 1[®] vibration data produced the following observations:
- Constrained orbits (both ends of machine)
- Higher amplitudes at exhaust end of rotor
- Predominantly 1X component
- Most likely a mechanical issue, broken component (shroud band, etc.) and possibly lodged, creating a rub and thermal bow in shaft

**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

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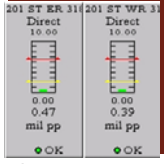
7

Risk Management - Changes/restrictions to Operating Conditions

- Compressor Interlock - Need (2) on any bearing
 - (1) probe in Alert, (1) probe in Danger = Compressor Interlock
- Normal Settings

Danger	Alert
6.5 mils	2.0 mils
- Temporary Settings

Danger	Alert
10.0 mils	2.0 mils
- Operate Machine on Speed Control (constant speed, let suction pressure vary)



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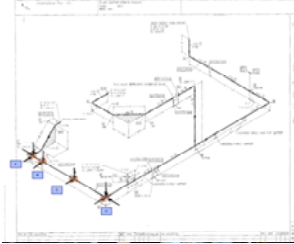
- Rotor showed 4.5 mils direct amplitude
- Interlock scheme set at 2 for alert (1 vote in), danger at 6.5; 1 alert vote + 1 danger vote on same bearing needed for interlock
- Considered potential failure modes of system and hazards associated with possible failures:
- Turbine protected from excessive damage by interlock; moved danger from 6.5-10 mils (based on severity chart); 10 mils within bearing clearances, provide margin for potential spike.
- Concerned with peripheral systems and potential hazards; governor oil/fire, stainless instrument tubing failure, etc.
- Decided to operate machine on speed control--typically operated on suction pressure control—to reduce likelihood of “moving/shifting” the rub, possibly worsening or interlocking the machine and not being able to bring back up through criticals.

Case Study: Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment

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Risk Management - Machine Surveillance


- Considered vibration affect to support system piping/tubing; lube oil, gland steam, seal oil
- Completed Assessment / Initiated Weekly patrols
- (1) fatigue crack discovered on governor control oil line



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Risk Management - Machine Surveillance

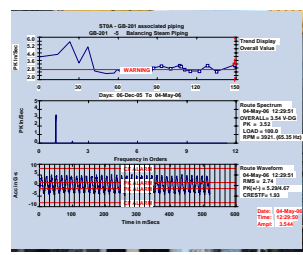
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- An initial round of patrols were completed to identify likely failure candidates based on high-cycle, high amplitude characteristics.
- Performed weekly off route CSI field measurements and visual checks on peripheral components adjacent to machine
- Had fatigue crack in governor oil supply; applied a leak clamp
- Had a crack in the gland seal line at the turbine exhaust end

**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

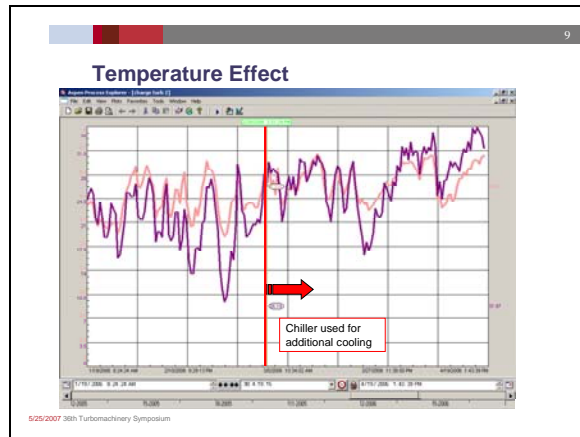
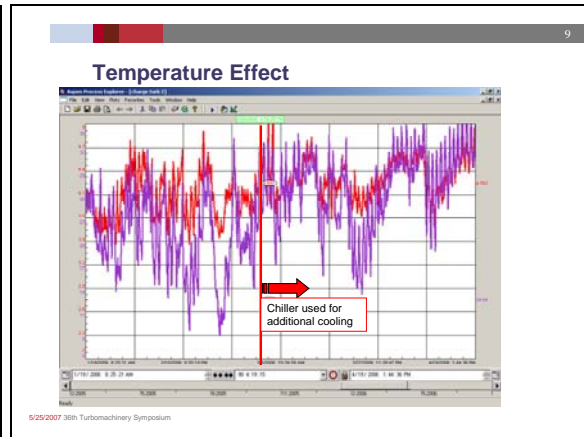
Slide 9

Temperature Effect

- Used refrigerated air to attenuate vibration amplitude
- Air ducts directed at bearing housings
- Reduction of over 1 mil

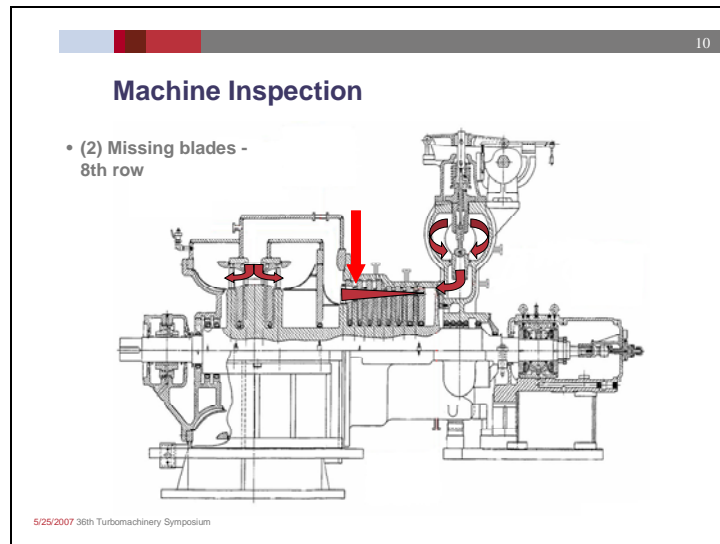


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- Noticed trend relationship of vibration and ambient temperature—lower ambient temperature, lower amplitude.
- Provided Refrigerated air at both bearings at specific locations; result “racked” case/bearing enough to reduce rub contact and thermal bow associated with rub.
- Installed chiller for lower temperatures as summer/hotter temperatures approached.

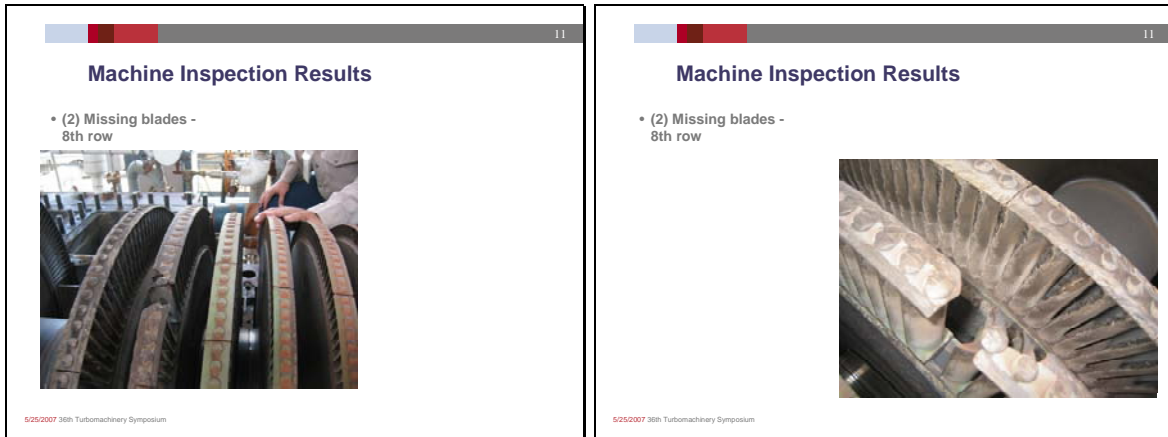
Slide 10



- Discovered (2) blades missing in the 8th row, broken at the root; roughly 40 degrees apart

**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

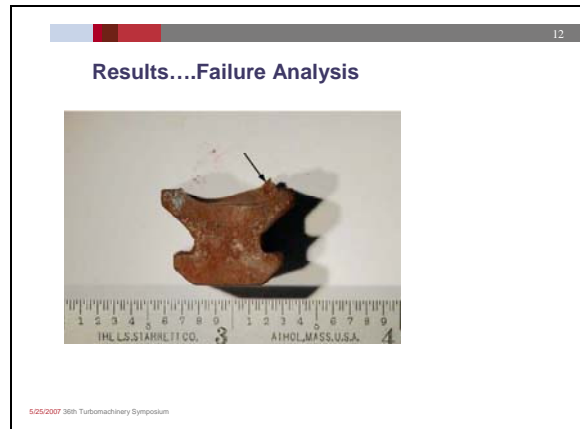
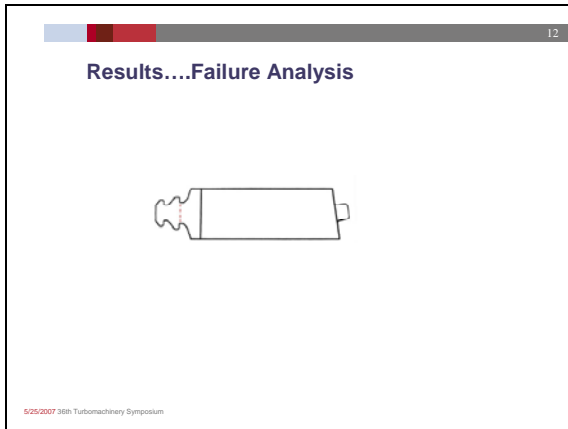
Slide 11



- Heavy rub marks on shroud; damaged tip seal, diaphragms where FOD passed through remaining steam path.
- Largest piece of missing blading discovered (wedged against diaphragm) was roughly the size/volume/shape of a level teaspoon of material.

**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

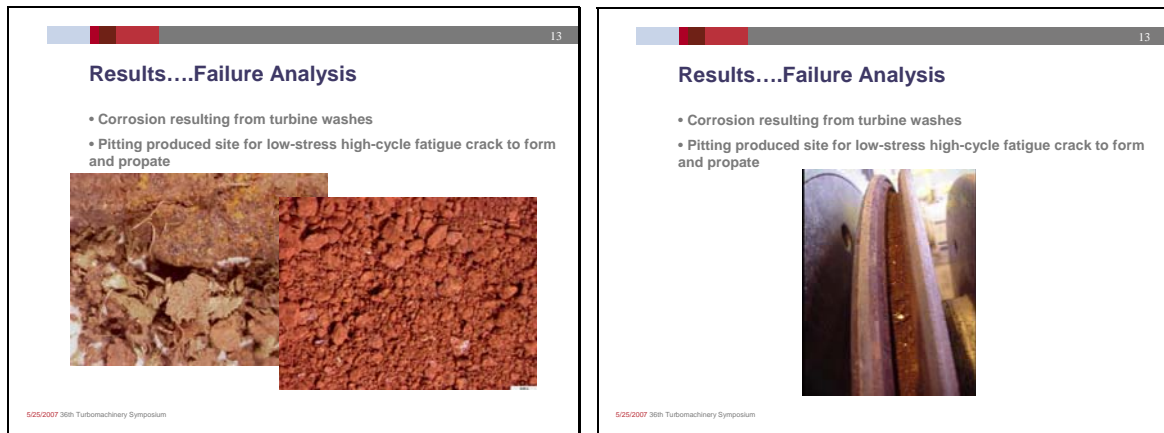
Slide 12



- Photographs from failure analysis report from Dresser showing origin of initiating crack

Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment

Slide 13



- Had performed monthly turbine washes 2/02 thru 5/03 to re-establish efficiency; corrosion/corrosion products the result of these washes. Washes were necessitated by poor water quality caused by excessive condenser leaks. Condenser has been replaced.
- In removing the blading from the 8th and 9th rows, the corrosion deposits were prevalent in the 8th stage.

**Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment**

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Summary

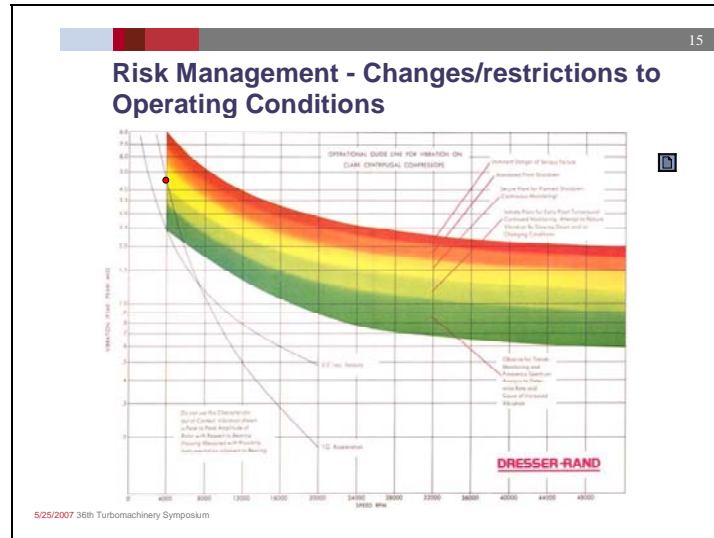
- Event presented opportunity to use diagnostic tools to assess the risk potential
- Controls then implemented to mitigate identified hazards
- Safe operation was continued for (8) months during critical period for customers/business following Hurricane Rita

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- Make use of all available machine condition information to provide detailed risk assessment
- Ran (8) months by managing risk during critical period

Case Study:
Charge Compressor Turbine Vibration – Diagnostics/Risk Assessment

Slide 15 (Supporting Info for Slide 7)



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