



**43rd Turbomachinery
30th Pump SYMPOSIA**

GEORGE R. BROWN CONVENTION CENTER
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REMOTE MONITORING & DIAGNOSTICS AS APPLIED TO A RECIPROCATING COMPRESSOR HEAD

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Bruce McCain Bio

Bruce McCain is an Engineering Consultant at Oxy Oil and Gas Corporation. He has 25 years experience as an end user, primarily in the upstream sector, providing technical support for rotating, reciprocating, and stationary equipment including design, installation, operation, maintenance, repair, and inspection. He has contributed to various trade publications and industry conferences. Bruce is a licensed Professional Engineer in Texas, a Certified API 510 Pressure Vessel Inspector, and is on the API Std 688 (Pulsation and Vibration Control in Positive Displacement Machinery Systems) Taskforce. He has a BSME from Texas Tech University.

Preface

- It must be noted that every situation is different and individual risks must be evaluated and in all cases, good engineering judgment must prevail
- Care must be taken when analyzing data to not take that data out of context and to understand basis of comparison. In other words, does data indicate something bad or just something not understood or different?

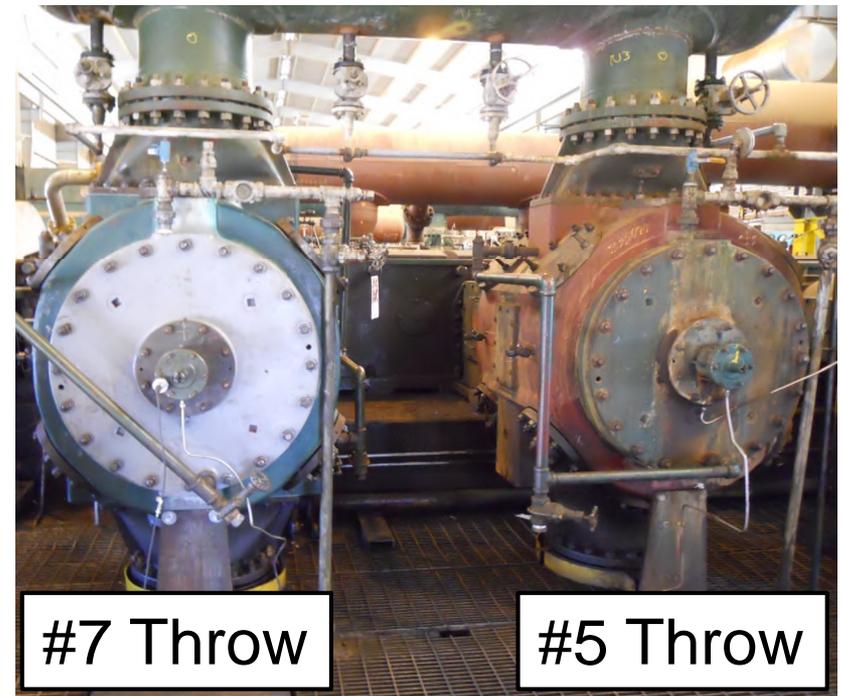
Problem Statement

- High stretch direction vibration (differential displacement) on a reciprocating compressor cylinder head indicated possible crack
- Facility requested path forward options until replacement head arrived (3 months)
- This presentation will demonstrate techniques used to quantify the component condition while providing continuous surveillance and immediate notification of any degradation

Service and Machine Information

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- 8 Throw, 4 Stage, 6500 hp, 327 rpm, 15" stroke
- Water saturated CO₂
- Ps = 45 psig, Pd = 155 psig, Ts = 100 deg F
- Jacket water (JW) pressure ~ 50 psig
- Two 29", 2nd stage cylinders, connected by common bottles
- #7 was a repaired head



Risk Review

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- Full participation by Operations, Maintenance, Engineering
- Machine has experienced head cracking in the past attributed to liquid carryover
- Have repaired heads in the past with mixed success
- Bubbles in jacket water outlet (seen in sight glass) have indicated past cracked heads, though none in this case
- High jacket water pressure and change in jacket water level have indicated past cracked heads, though none in this case
- Jacket water intrusion into cylinder has indicated past cracked heads, though none in this case

Risk Review Outcome

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- Operations personnel to monitor scrubber for liquid dump operation
- 2nd stage JW sight glass observation part of normal rounds
- Line of fire at end of cylinder roped off
- JW level and pressure alarms verified in working order
- RM&D system to generate email and text alerts when differential vibration exceeds established amplitude, along with daily monitoring of trends with cc to Operations, Maintenance, and Engineering
- Full agreement by all to not push the differential limit

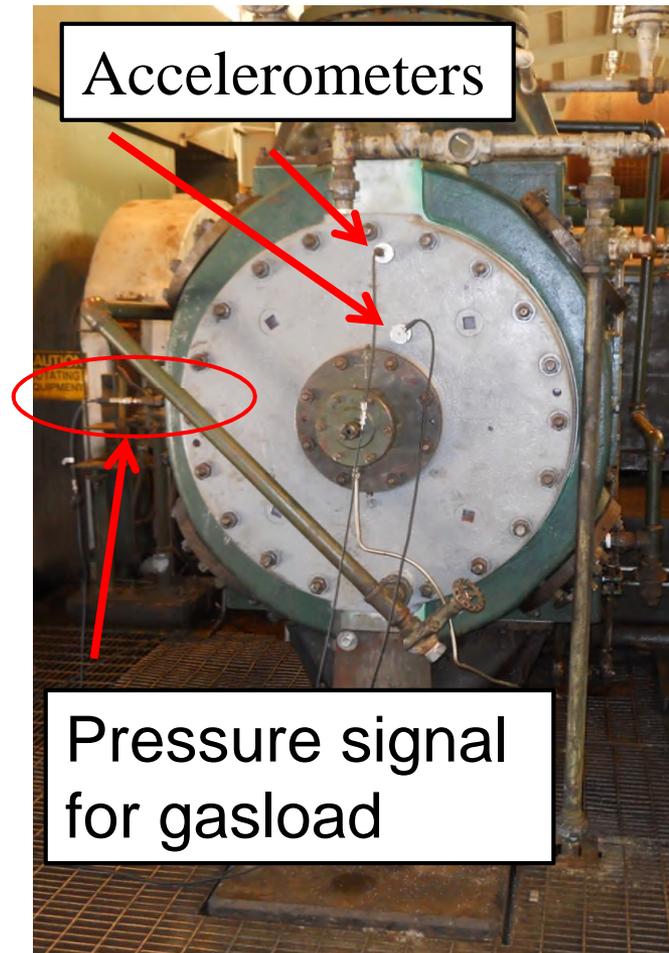
Evaluation Scope

- Installed pressure transducers on head and crank end cylinder connections for both key phase signal and gasload trending
- Performed ODS on a good and bad cylinder heads
- Placed accelerometers on head face at bolt circle and near center, filtered all but 1x and subtracted to get differential displacement across head face
- Placed strain gages on problematic head to measure differential strain but results were inconclusive, so not monitored long term

Evaluation Scope

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- Measured differential vibration on all 2nd stage heads (8) to establish a baseline of acceptable operation
- Established a “not to exceed” differential vibration requiring immediate shutdown based on trended amplitude and response to gasload change



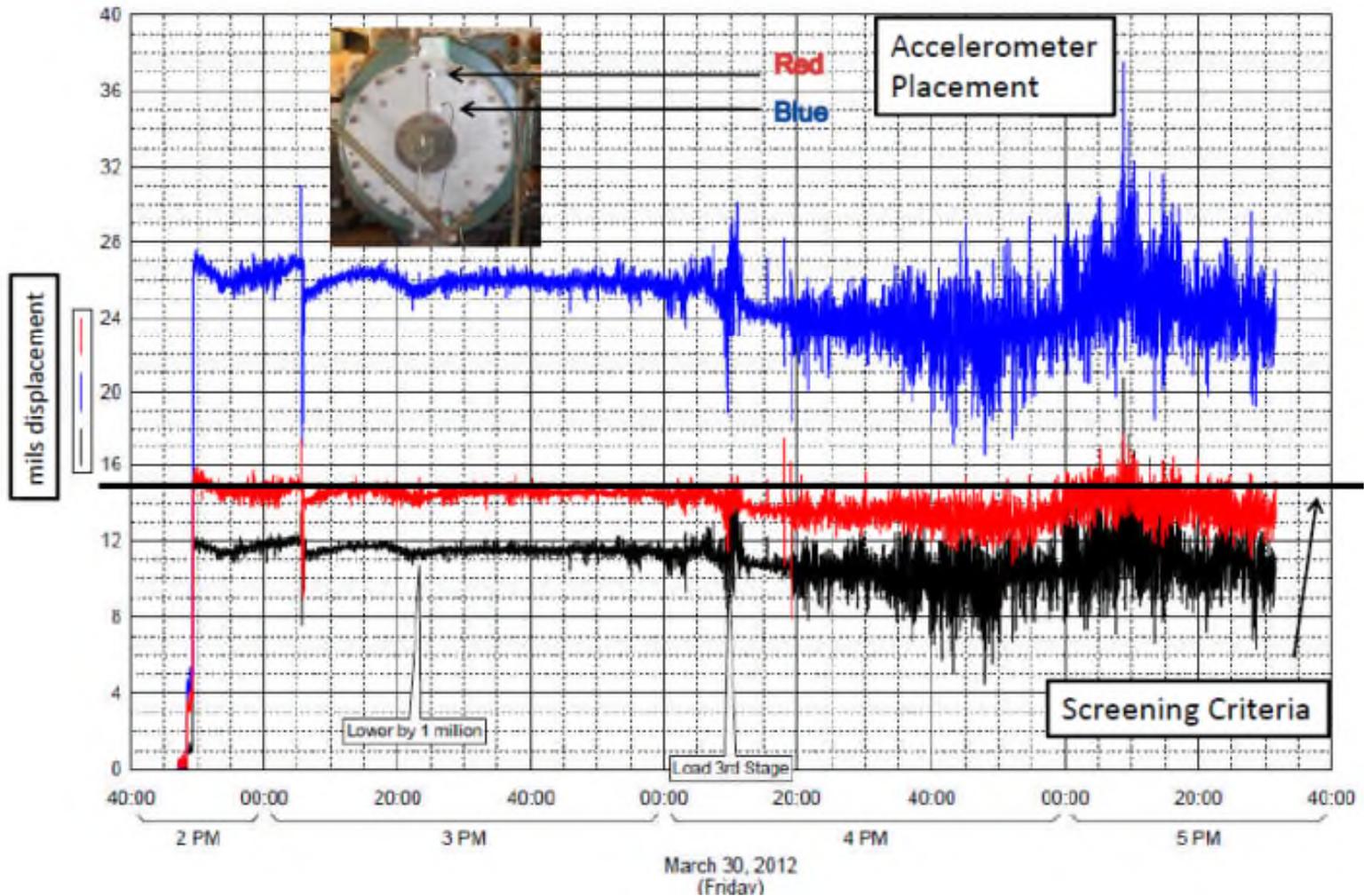
Operational Adjustments

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- Closed 4th stage recycle and adjusted process parameters to reduce 3rd stage discharge pressure
- Subsequently shifted some compression ratio from 2nd stage to 3rd with unloader operation to reduce 2nd stage gasload
- Unloaded problematic 2nd stage on subject compressor while loading 2nd stage on other machines (incremental reduction in gasload and differential displacement)

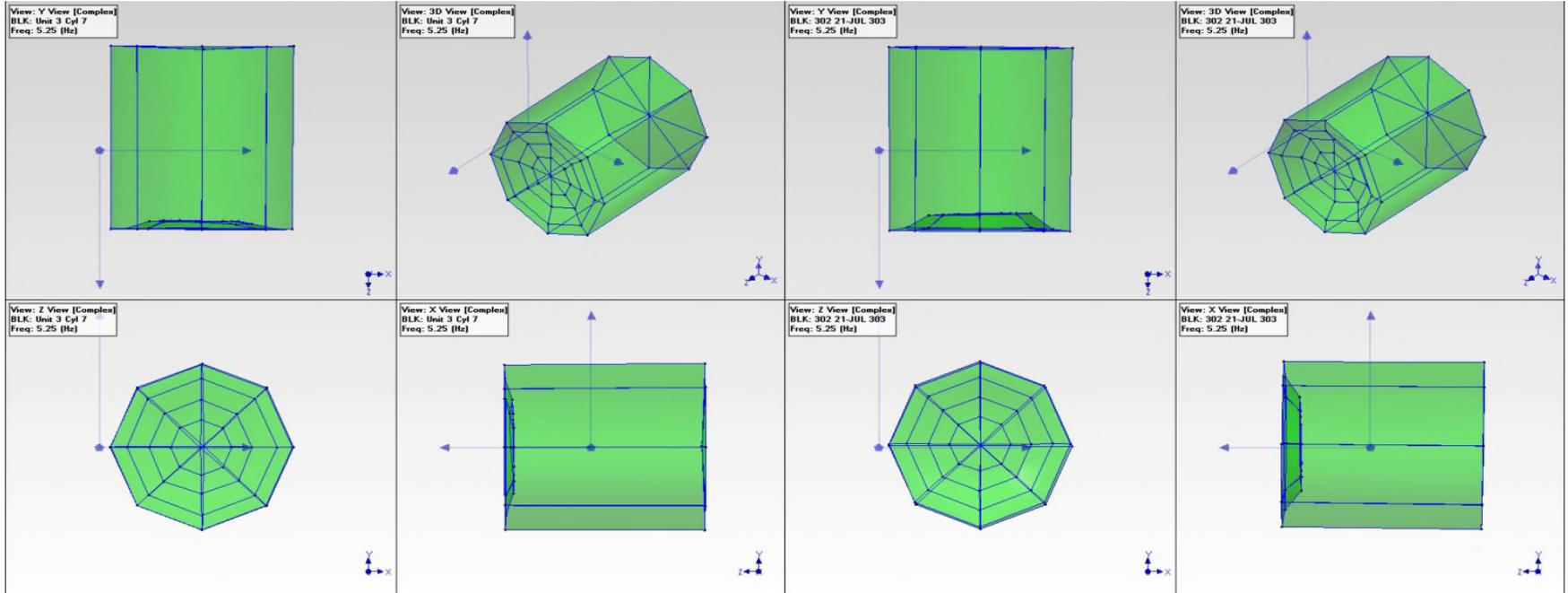
Initial Differential Vibration

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Operating Deflection Shape (ODS)

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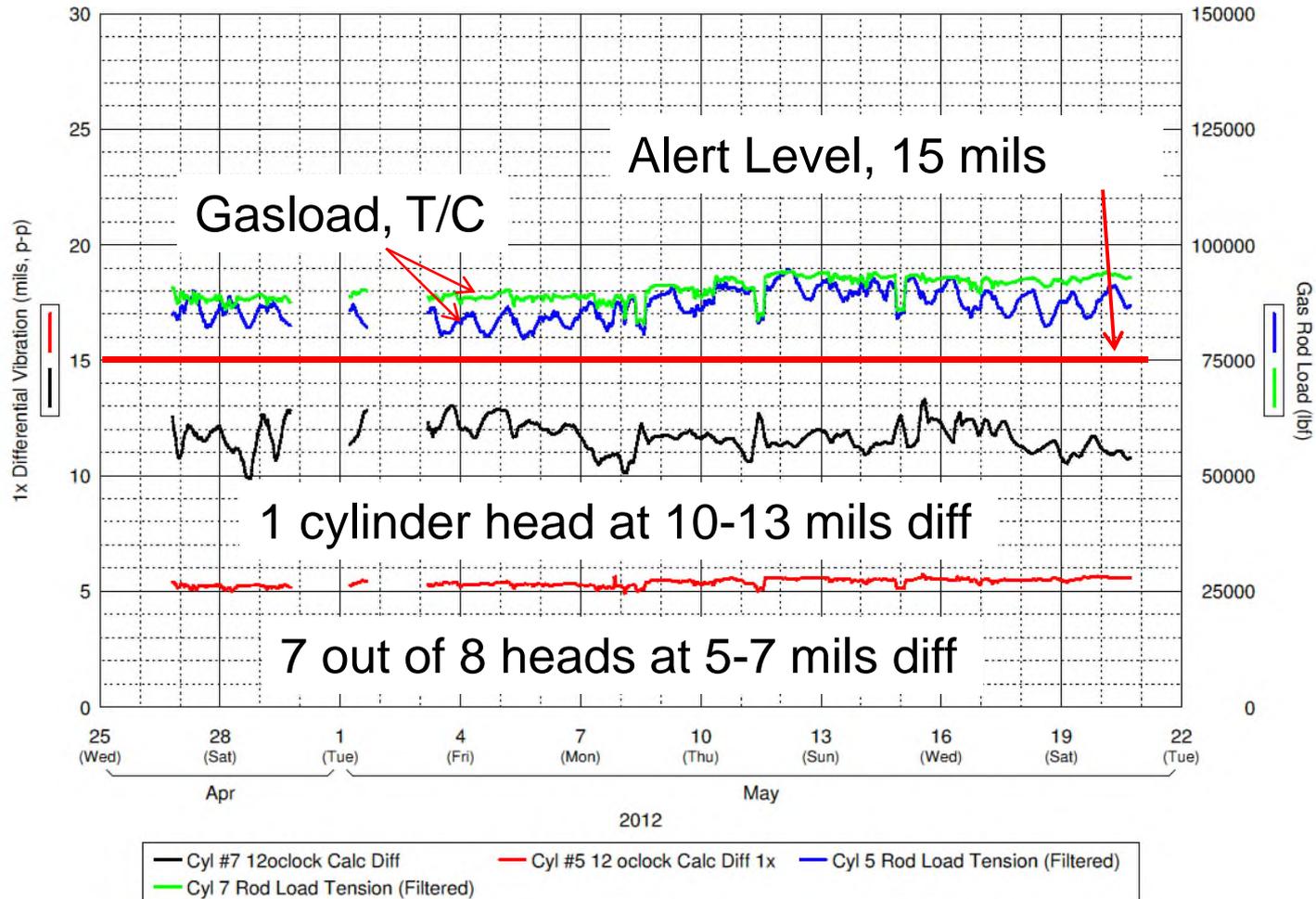


5-7 mil
differential on
“good” outer
head

11-13 mil
differential on
“bad” outer
head

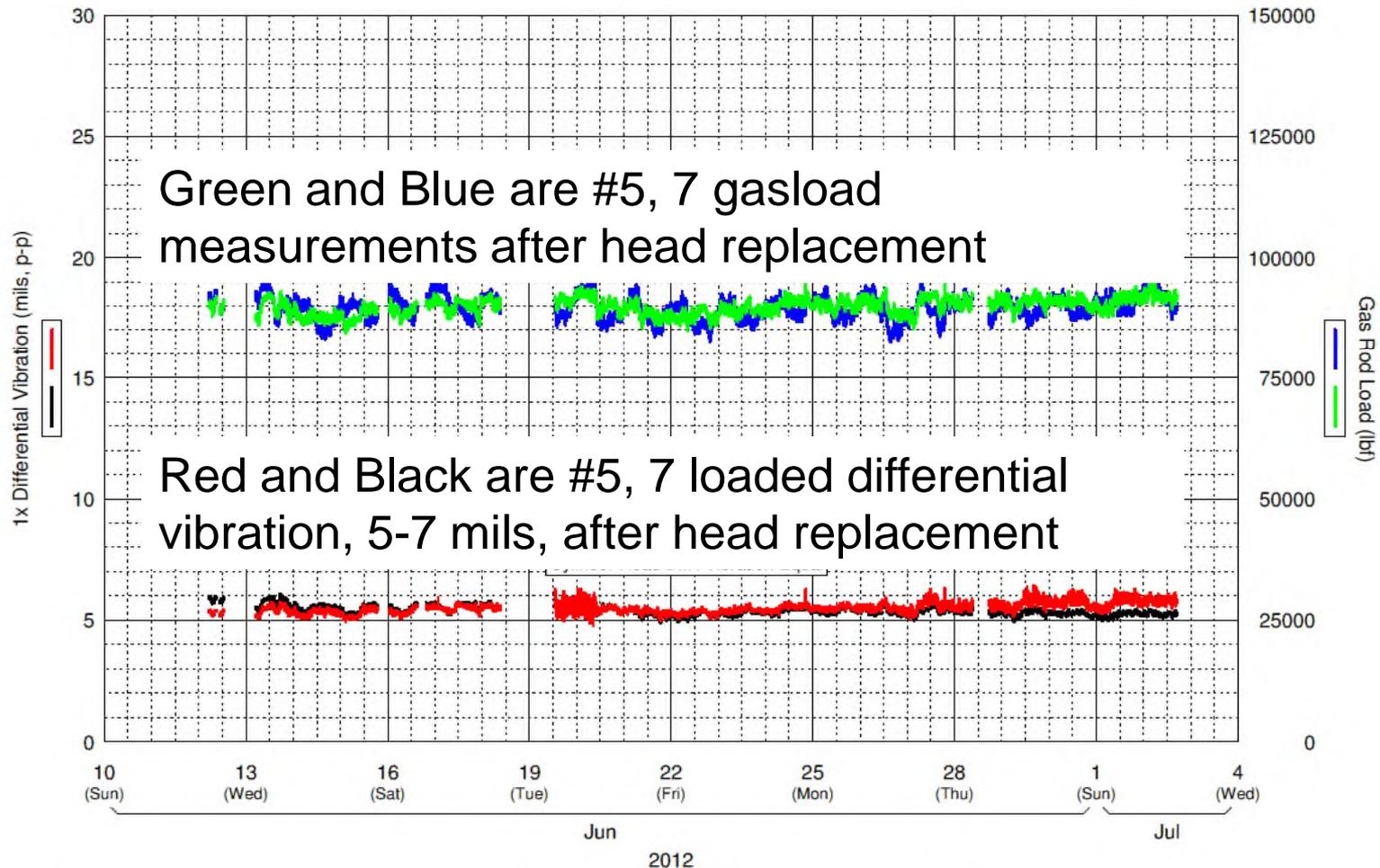
Differential Vibration and Gasload Trends

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Gas Rodload and Differential Vibration After New Head Installed

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Summary and Conclusions

- “Normal” differential vibration across outer head face of 5-7 mils
- One “repaired” cylinder head indicated differential vibration of 10-13 mils
- An alert level was established at 15 mils differential vibration based on consistent trending
- Automated alerts were utilized to provide early warning in the event of crack propagation

Summary and Conclusions (cont)

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- Based on this effort, operation with repaired heads require more extensive evaluation including RM&D and for short duration only
- RM&D technology, coupled with support from Operations, Maintenance, and Engineering staff, allowed for safe and confident, short term operation of a damaged head until a replacement could be sourced
- RM&D is an appropriate surveillance and analysis tool that can help to minimize assumptions while maximizing confidence in identified path forward