WORLD-CLASS OUTSTANDING INTERNATIONAL

PROGRAM | EXHIBITION | NETWORKING

HOW AN ON-LINE MONITORING SYSTEM SUCCESSFULLY TRIPPED A 4-THROW RECIPROCATING COMPRESSOR ON THREE SEPARATE EVENTS PREVENTING MAJOR EQUIPMENT DAMAGE AND DOWNTIME

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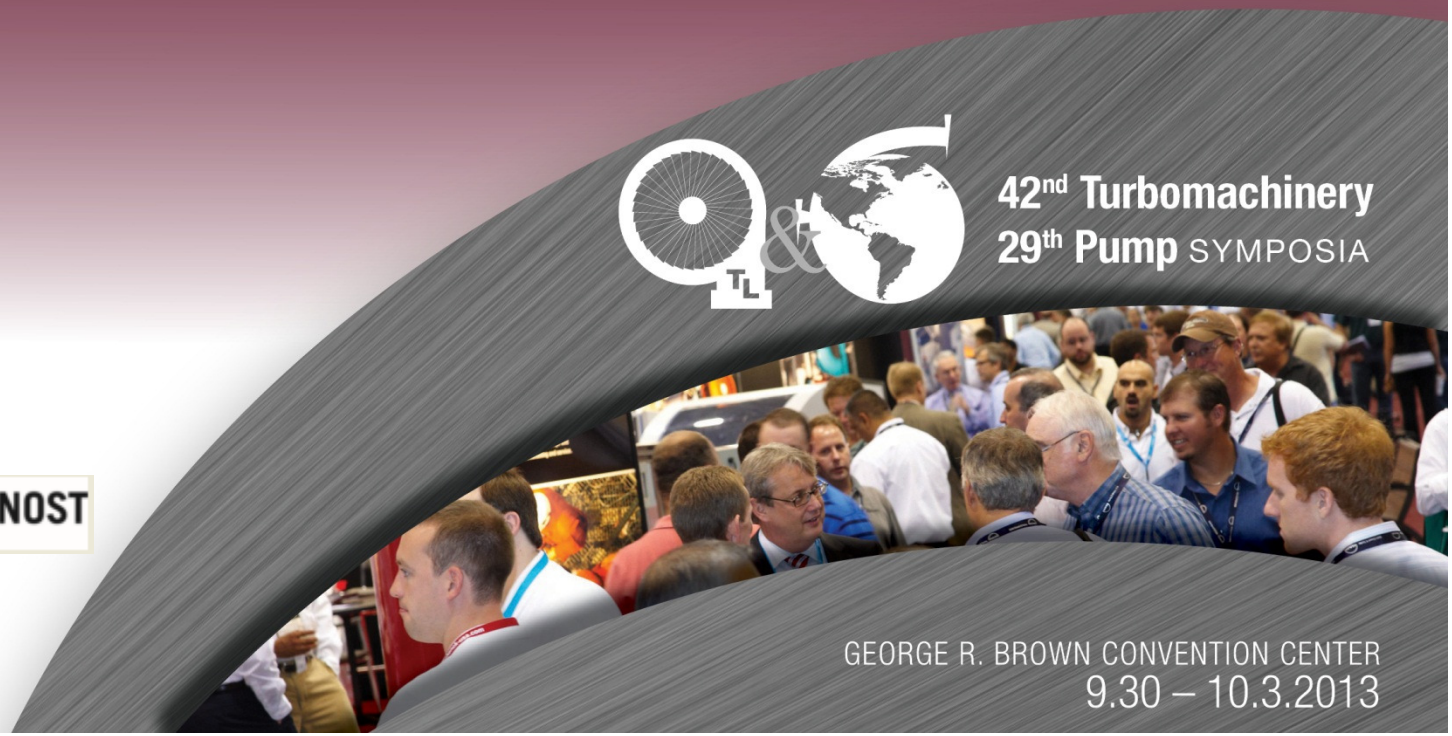

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TEXAS A&M ENGINEERING TEES TURBOMACHINERY LABORATORY

ATM

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25 Years with DuPont in LDPE business

20 Years experience on reciprocating compressors including Hyper Compressors

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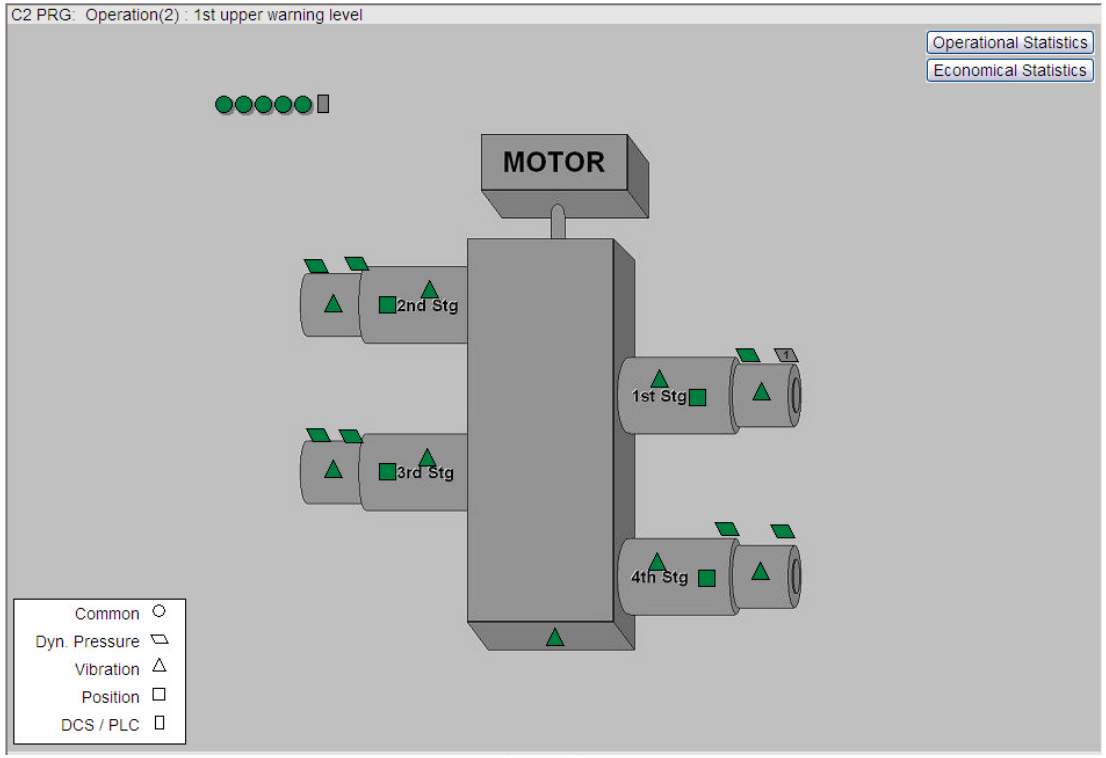
Task Force Member - API-670 5th Edition

Compressor Description

- 514 RPM - 1000 Hp Synchronous motor
- 9.5” stroke
- 4 Stages
- Ethylene Gas
- Suction Press – 2 psig
- Discharge Press – 600 psig
- Interstage cooling, separators and suction snubbers with blowdowns

Compressor On-Line Monitoring Installation



Sensors Installed

- CHS Vibration
- CYL Vibration
- Rod Position **
- CE/HE Pressure
- Roving/Crankcase Vibration

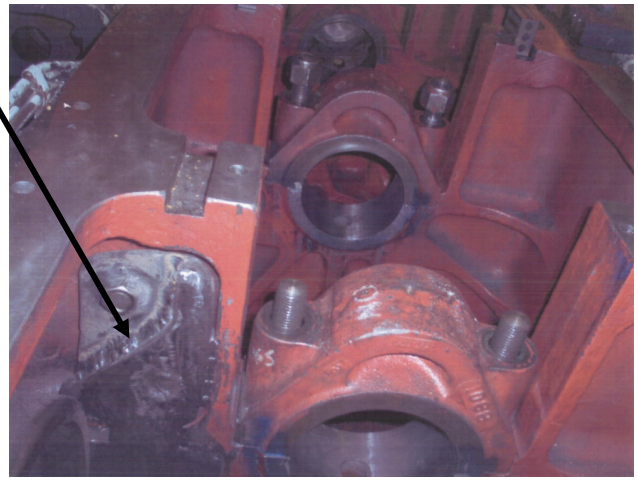
** 1st/2nd Stg RP added Feb. 2012

- System installed and commissioned in January 2011
- Interlocks in service July 2011
- Total of 26 Compressors on site with 416 Instrument loops

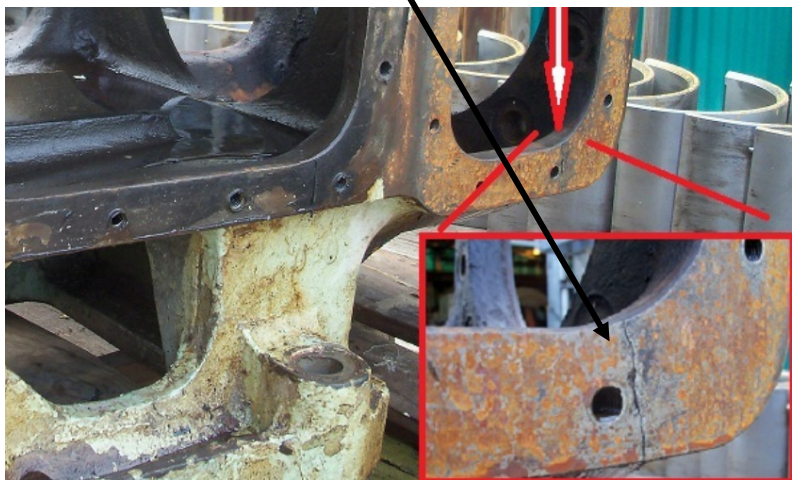
History of failures prior to Monitoring System

- Known as “Trash” Compressor
- Many valve failures due to liquid
- Several significant failures due to liquid
  - Head bolts found loose
  - 1st stage Aluminum piston destroyed
  - Cracks found in crankcase
- Upgrades made to liquid separation system has helped
- When compressor is down, flaring ethylene gas

Metal-Stitch Repairs



Crack in distance piece



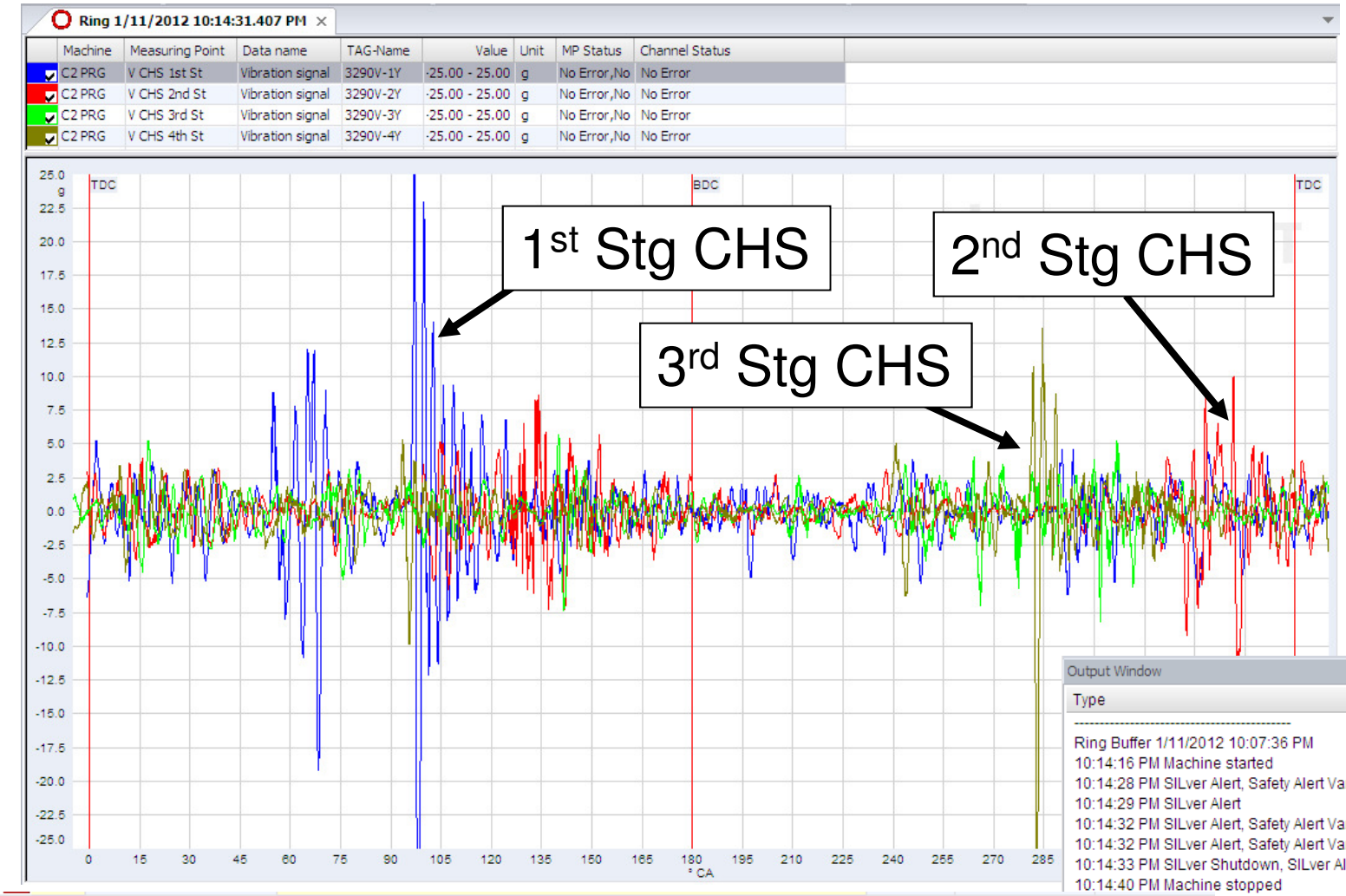
Sequence of Events - Summary

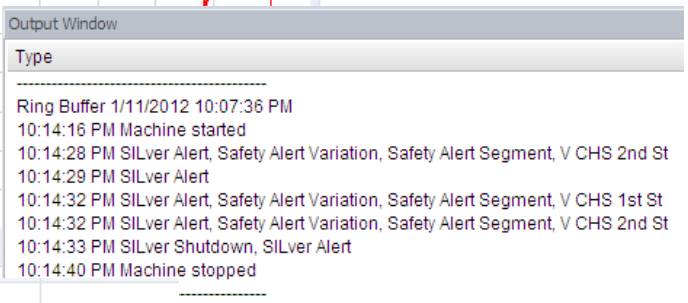
1/11/12	10:14 pm	Interlock due to start-up with compressor full of liquid
2/18/12	6:05 am	Interlock on 2nd Stg CHS RMS Vibration due to loose piston (from prior event)
2/22/12	12:52 pm	Interlock on 2nd Stg CHS RMS Vibration due to incorrect crosshead to pin clearance

Sequence of Events

1/11/12	10:14 pm	Interlock 17 seconds after started compressor due to being full of liquid
1/12/12 – 1/17/12		Repairs made – New valves on all stages, pushed pin on 1st and 2nd stage – no wear and clearances OK. Drained liquid from low points.
1/17/12	11:30 pm	Machine started after repairs
2/3/12	10:28 pm	Alert on 2nd Stg CHS RMS Vibration – Segment 34

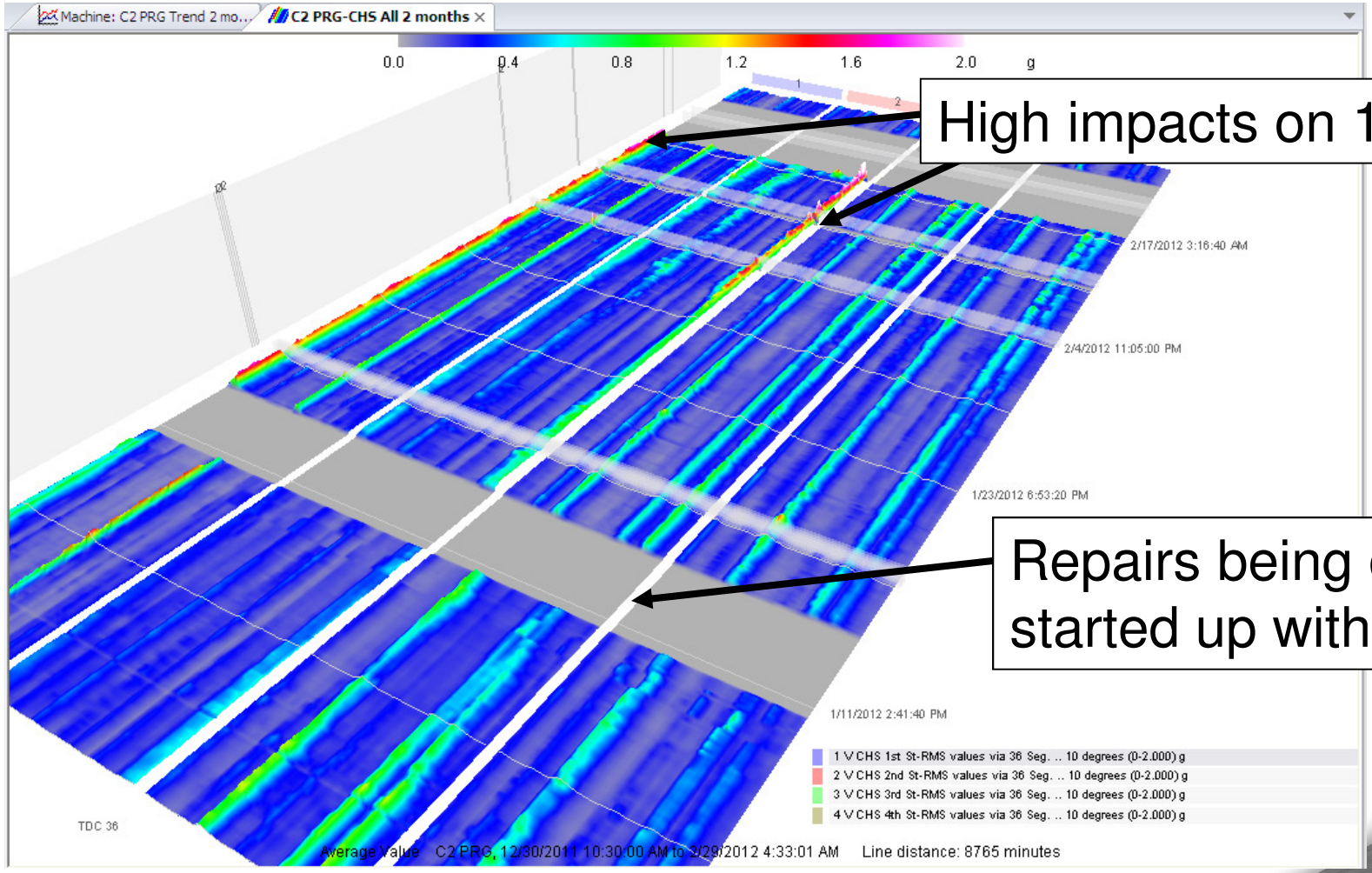
Interlock 17 seconds after started due to liquid





IMP...	1/11/2012 9:14:35 PM	SILver Shutdown, SILver Alert	C2 PRG			
IMP...	1/11/2012 9:14:35 PM	SILver Alert, Safety Alert Variation, Safety Alert Segment	C2 PRG	Cylinder 2nd	V CHS 2nd St	
IMP...	1/11/2012 9:14:35 PM	SILver Alert, Safety Alert Variation, Safety Alert Segment	C2 PRG	Cylinder 1st	V CHS 1st St	

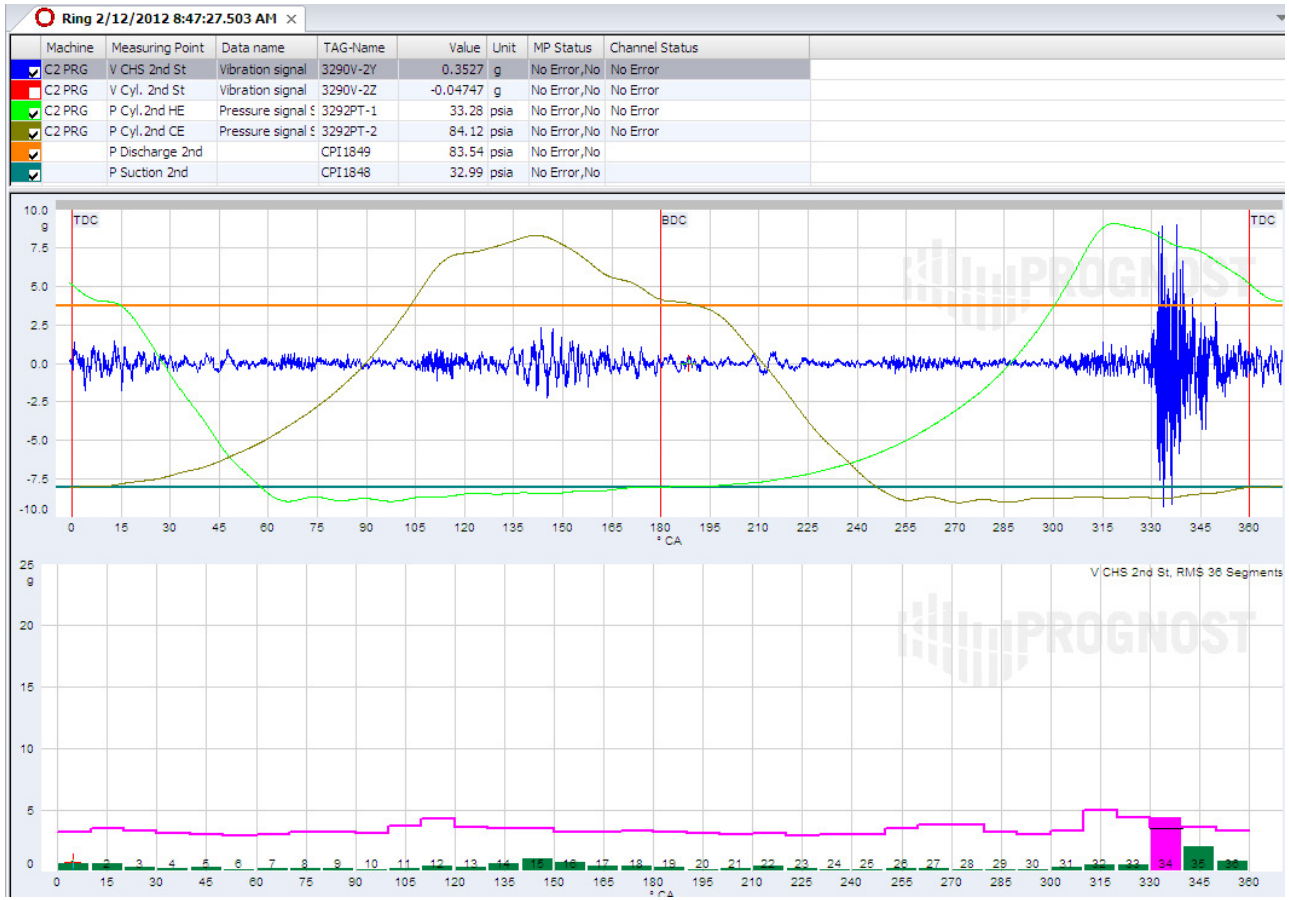
Suspected problems with 1st & 2nd Stages



High impacts on 1st & 2nd Stg

Repairs being done after started up with liquid

2nd Stg CHS ALERT (2/3/12 until 2/18/12)

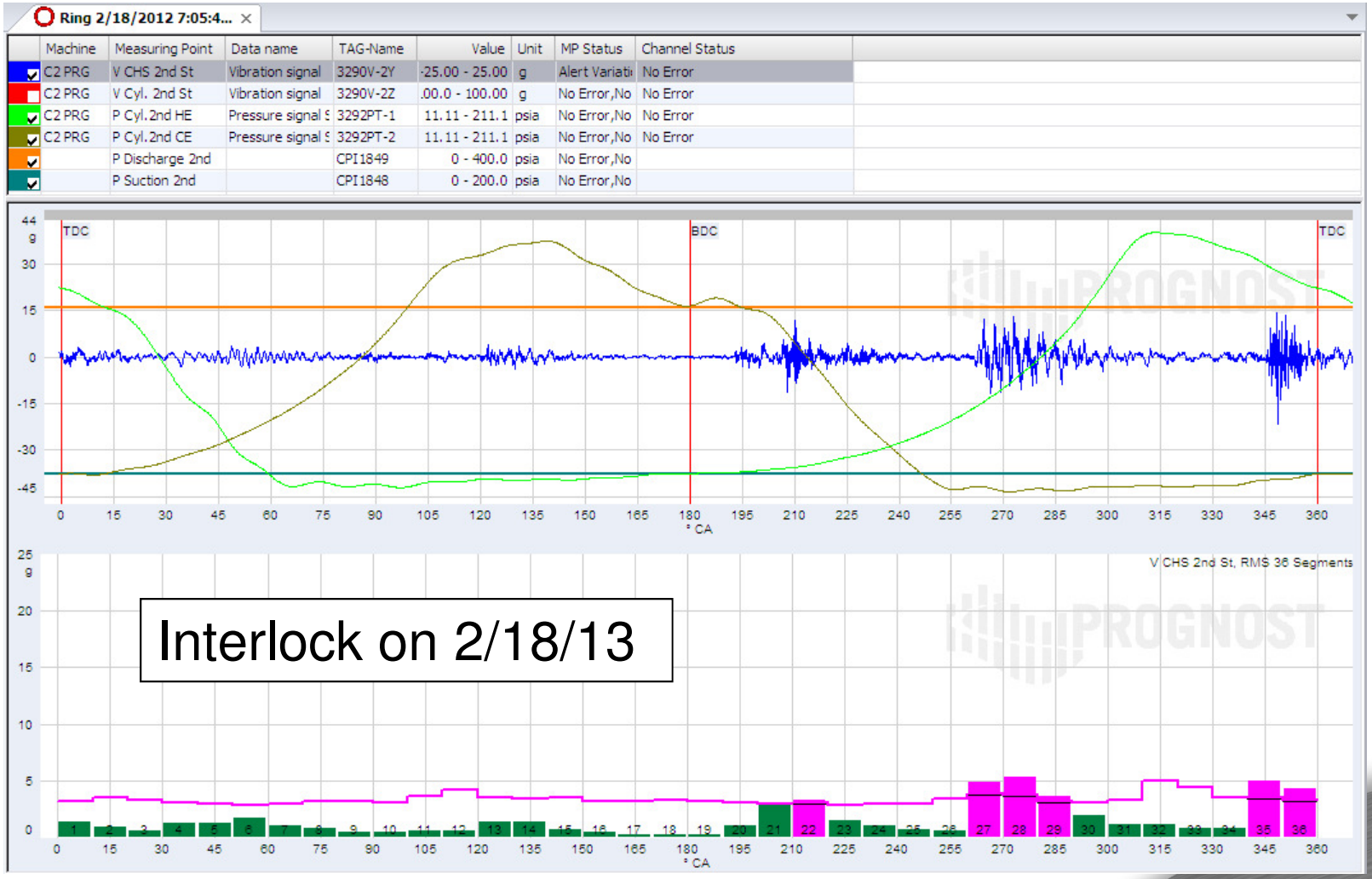


IMP...	2/3/2012 10:34:16 PM	Alert for safety limit segment canceled	C2 PRG	Cyl...	V CHS 2nd St
IMP...	2/3/2012 10:34:13 PM	SILver Alert	C2 PRG		
IMP...	2/3/2012 10:34:13 PM	SILver Alert, Safety Alert Variation, Safety Alert Segment	C2 PRG	Cyl...	V CHS 2nd St
IMP...	2/3/2012 10:28:50 PM	Alert for safety limit segment canceled	C2 PRG	Cyl...	V CHS 2nd St
IMP...	2/3/2012 10:28:47 PM	SILver Alert	C2 PRG		
IMP...	2/3/2012 10:28:47 PM	SILver Alert, Safety Alert Variation, Safety Alert Segment	C2 PRG	Cyl...	V CHS 2nd St
IMP...	1/14/2012 11:37:06 AM	UNSAFE for 'C2 PRG' activated !!!	C2 PRG		

Sequence of Events

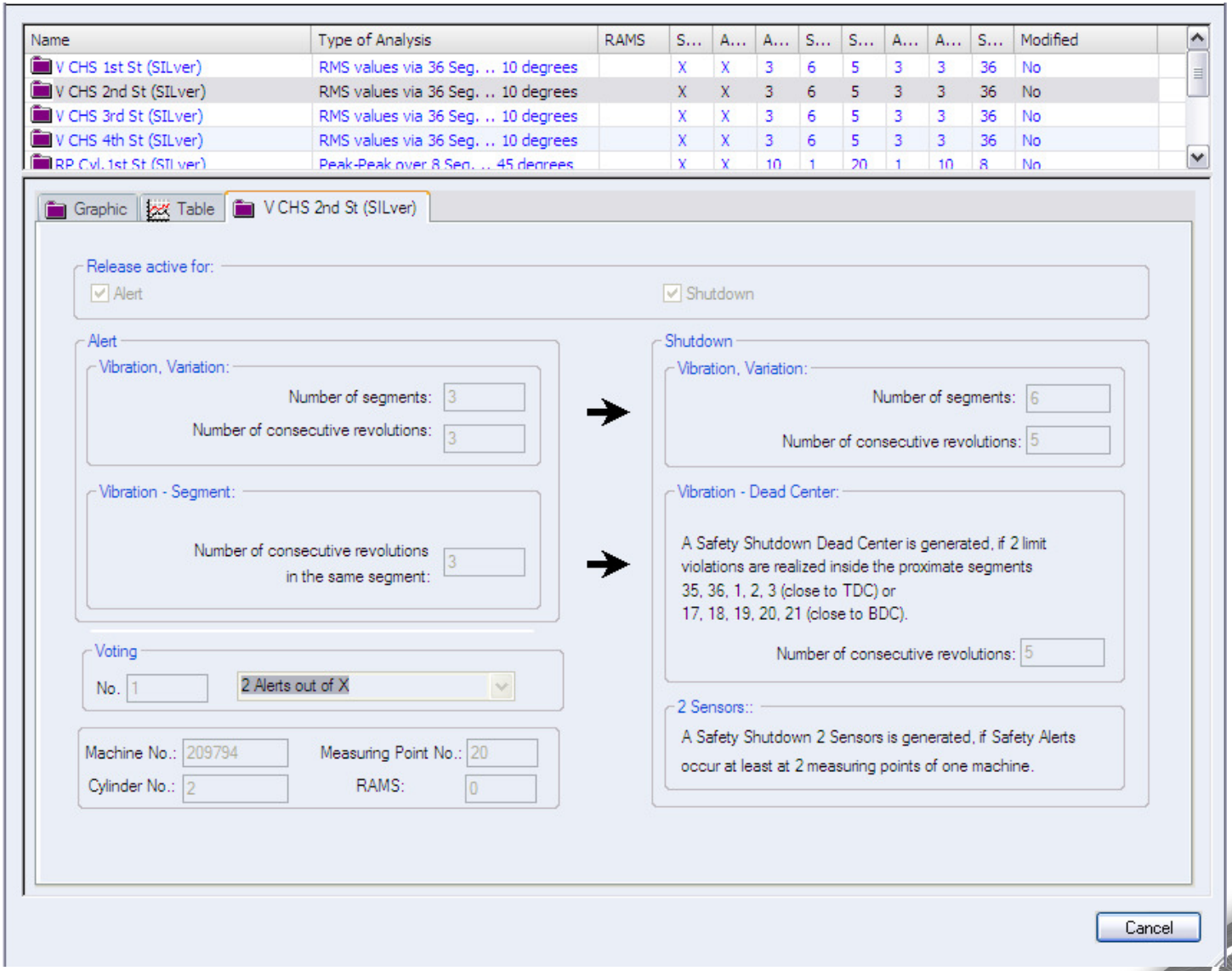
2/18/12	6:05 am	Interlock on 2nd Stg CHS RMS Vibration
2/18/12	6:14 am	Started 9 minutes after Interlock (Ooops!) Interlock on 2nd Stg CHS RMS Vibration (ran 8 minutes with many segment violations)
2/18/12 – 2/22/12		Repairs made – Found loose 2nd stage piston nut. Changed 1st and 2nd stage pistons/rods, changed 2nd stage connecting rod and installed the RP sensors on 1st and 2nd stages

2nd Stg CHS – Found loose piston nut



Interlock on 2/18/13

2nd Stg CHS – Interlock Criteria



Interlock Criteria - Any 6 segments above Alert limit for 5 consecutive revolutions

Sequence of Events (Cont'd)

2/22/12	10:14 am	Machine started after repairs. Interlock 82 seconds after machine started due to 2nd Stg Pk-Pk Variation Rod Run Out over 8 segments (suspected liquid)
2/22/12	10:41 am	Machine started a 2nd time after blowing down snubbers. Interlock 63 seconds after machine started due to 2nd Stg Pk-Pk Variation Rod Run Out over 8 Segments

Start-up after new 2nd Stg Rod installed

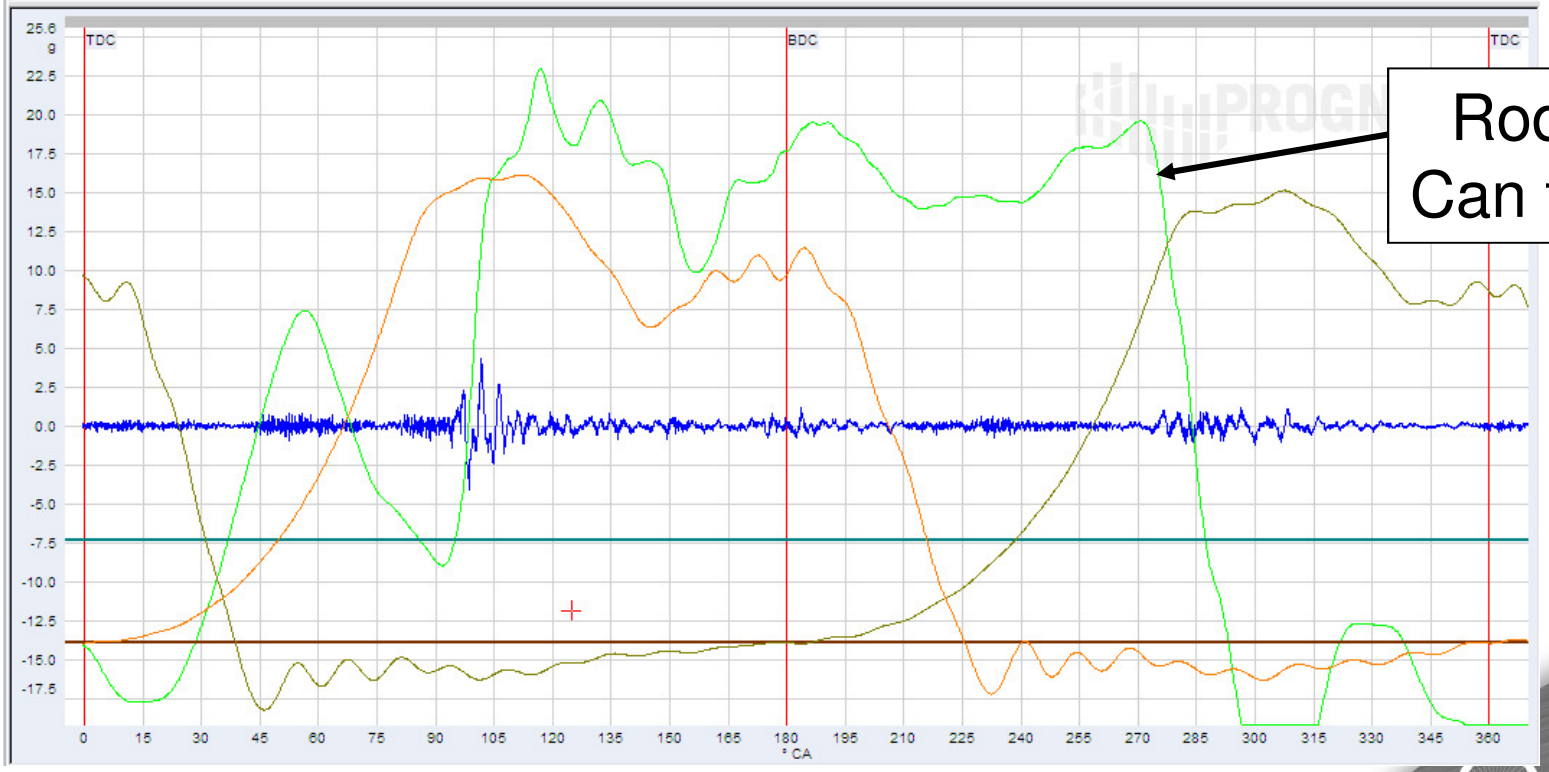
Output Window

Type

Ring Buffer 2/22/2012 10:09:26 AM
10:16:34 AM SILver Alert, Safety Alert var. Piston rod Peak-Peak, RP Cyl.2nd St
10:16:22 AM SILver Alert, Safety Alert var. Piston rod Peak-Peak, RP Cyl.2nd St
10:16:21 AM SILver Alert
10:16:23 AM SILver Shutdown, Safety Shutdown var. Piston rod Peak-Peak, SILver Alert, Safety Alert var. Piston rod Peak-Peak, RP Cyl.2nd St
10:16:23 AM SILver Shutdown
10:16:24 AM SILver Shutdown, Safety Shutdown var. Piston rod Peak-Peak, SILver Alert, Safety Alert var. Piston rod Peak-Peak, RP Cyl.2nd St
10:16:25 AM SILver Shutdown, Safety Shutdown var. Piston rod Peak-Peak, SILver Alert, Safety Alert var. Piston rod Peak-Peak, RP Cyl.2nd St
10:16:29 AM Machine stopped

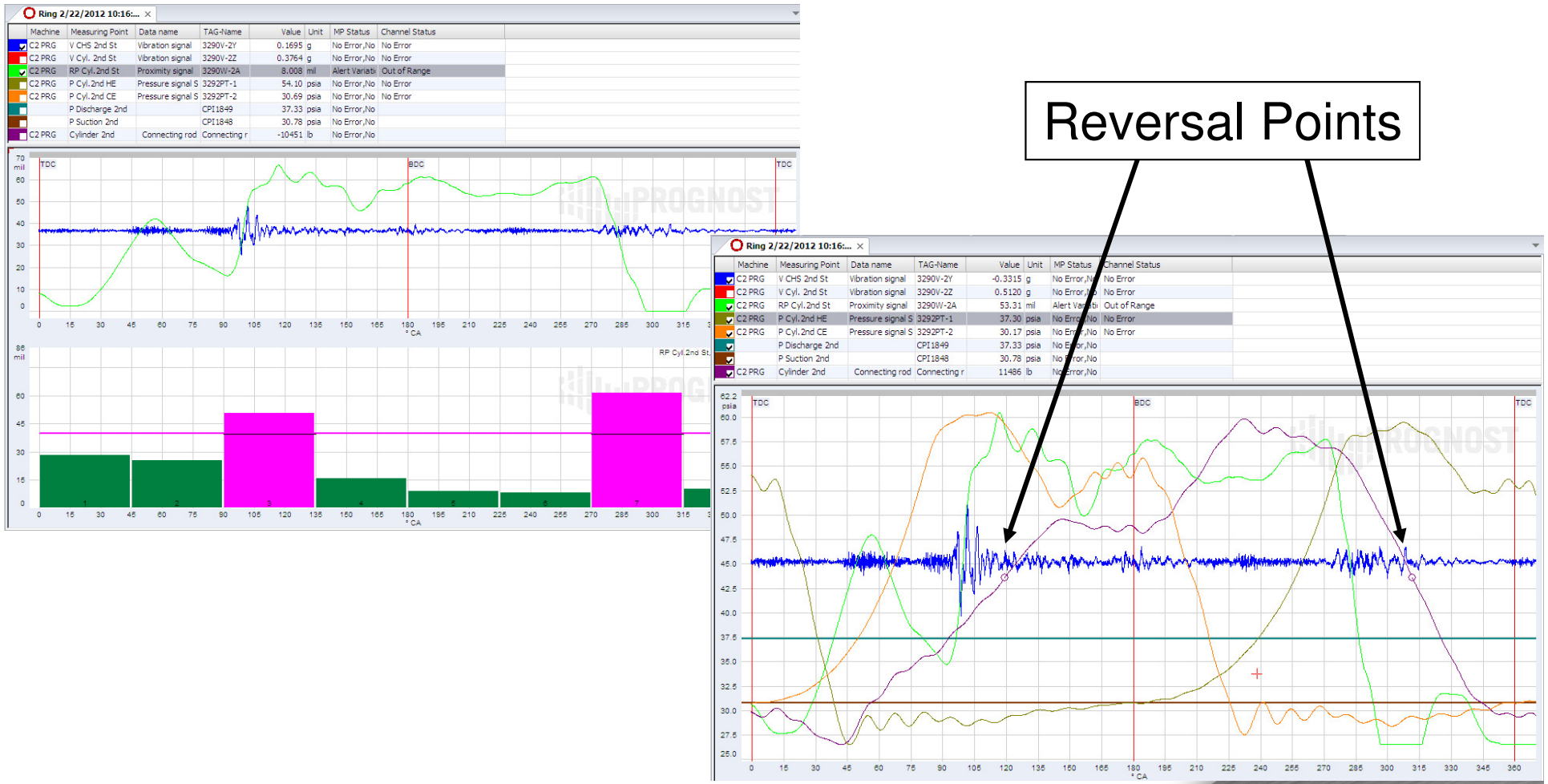
Ring 2/22/2012 10:16:...

Machine	Measuring Point	Data name	TAG-Name	Value	Unit
C2 PRG	V CHS 2nd St	Vibration signal	3290V-2Y	0.1755	g
C2 PRG	V Cyl. 2nd St	Vibration signal	3290V-2Z	-0.3221	g
C2 PRG	RP Cyl.2nd St	Proximity signal	3290W-2A	64.56	mil
C2 PRG	P Cyl.2nd HE	Pressure signal S	3292PT-1	29.16	psia
C2 PRG	P Cyl.2nd CE	Pressure signal S	3292PT-2	59.45	psia
	P Discharge 2nd		CPI1849	37.33	psia
	P Suction 2nd		CPI1848	30.78	psia



Rod Position - Can this be real?

2nd Stage Reversal points



Sequence of Events (Cont'd)

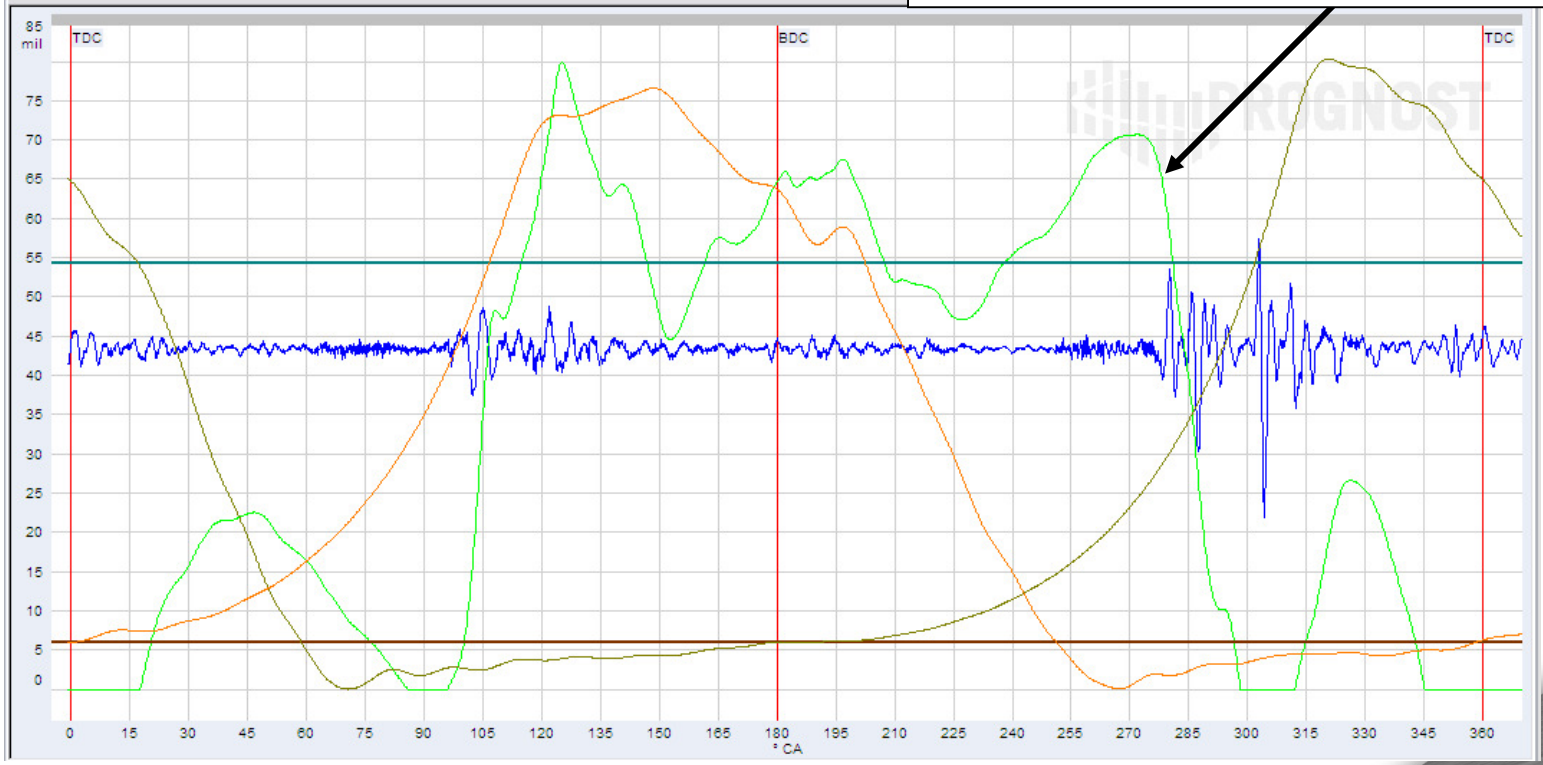
2/22/12	11:00 am	Raised Pk-Pk Rod Run Out Interlock level from 40 mils to 80 mils
2/22/12	12:52 pm	Machine started but had interlock 25 seconds later due to 2nd Stg CHS RMS Vibration
2/22/12 – 2/26/12		Found crosshead pin to crosshead bushing had almost zero clearance. Changed connecting rod, crosshead, crosshead slippers, pin and bushing.
2/26/12	9:32 am	Machine started and has been running well since

After increasing RP Intlk to 80 mils

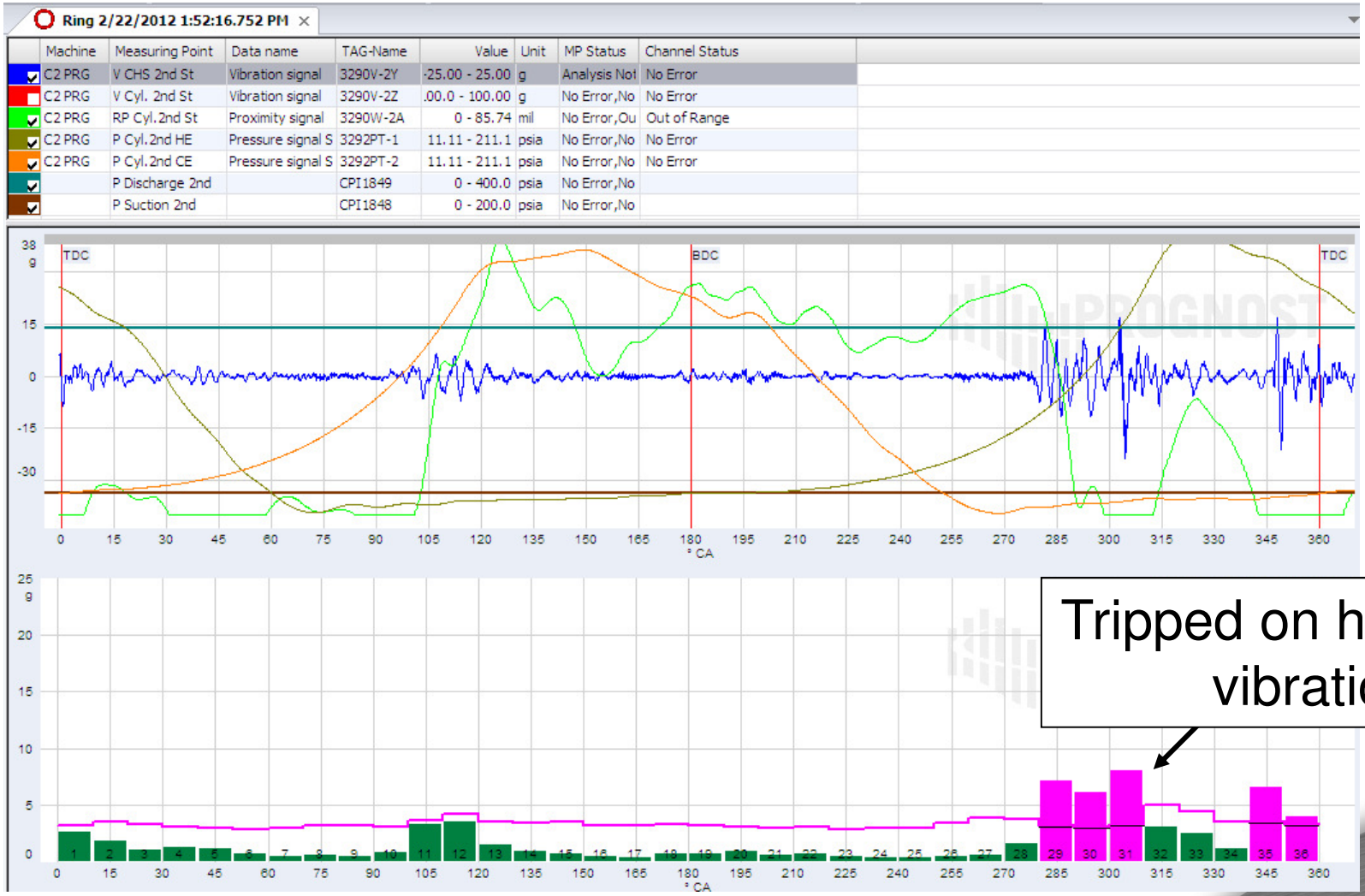
Ring 2/22/2012 1:51:57.154 PM

Machine	Measuring Point	Data name	TAG-Name	Value	Unit	MP Status	Channel Status
C2 PRG	V CHS 2nd St	Vibration signal	3290V-2Y	-25.00 - 25.00	g	Analysis Not	No Error
C2 PRG	V Cyl. 2nd St	Vibration signal	3290V-2Z	-00.0 - 100.00	g	No Error,No	No Error
C2 PRG	RP Cyl.2nd St	Proximity signal	3290W-2A	0 - 85.74	mil	No Error,Ou	Out of Range
C2 PRG	P Cyl.2nd HE	Pressure signal S	3292PT-1	11.11 - 211.1	psia	No Error,No	No Error
C2 PRG	P Cyl.2nd CE	Pressure signal S	3292PT-2	11.11 - 211.1	psia	No Error,No	No Error
	P Discharge 2nd		CPI1849	0 - 400.0	psia	No Error,No	
	P Suction 2nd		CPI1848	0 - 200.0	psia	No Error,No	

Almost 80 mils displacement – Would have interlocked if left At 40 mils Interlock level

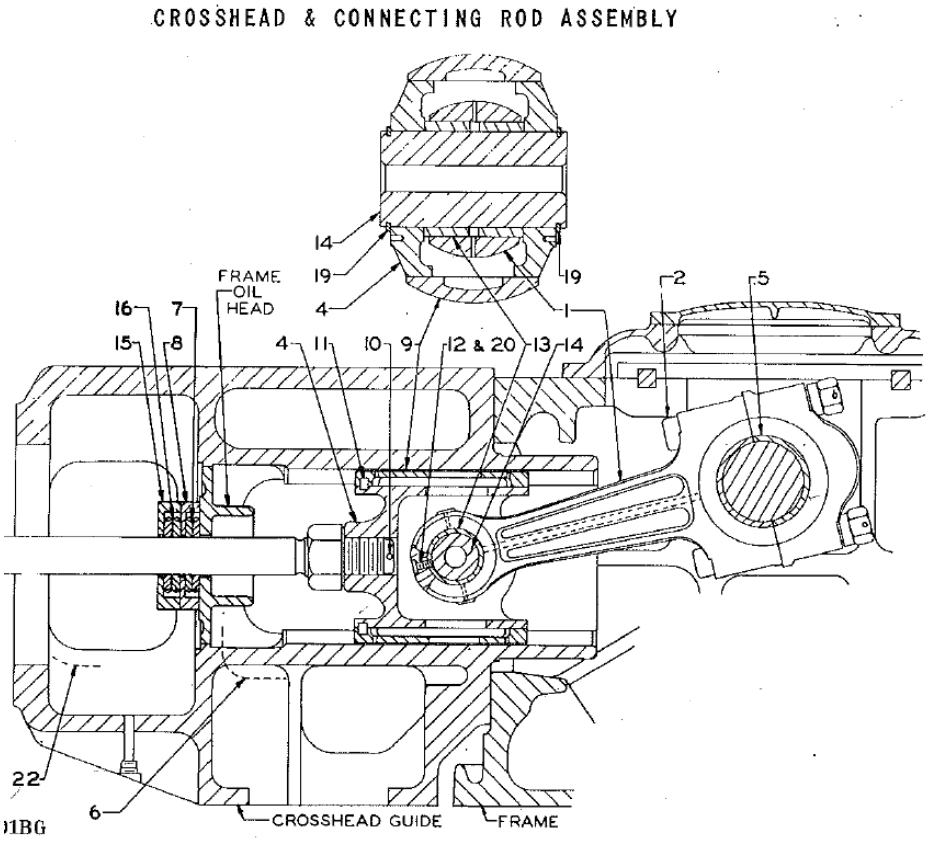


2nd Stg Pin to Bushing clearance inadequate

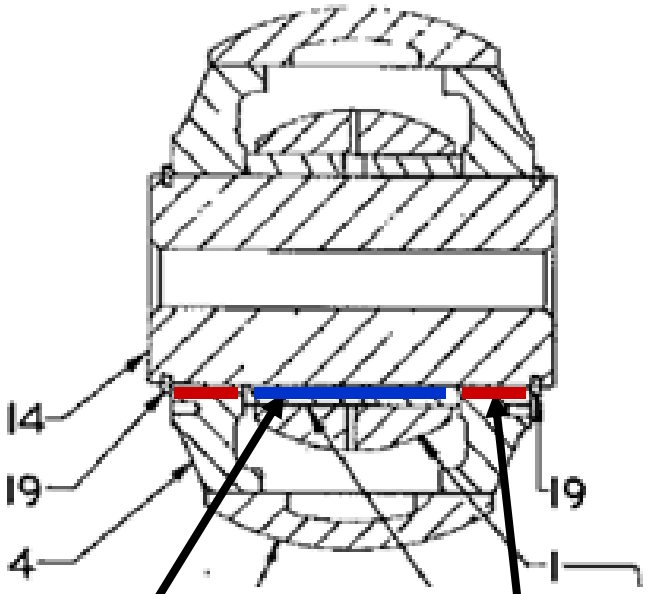


Tripped on high CHS vibration

Crosshead Design



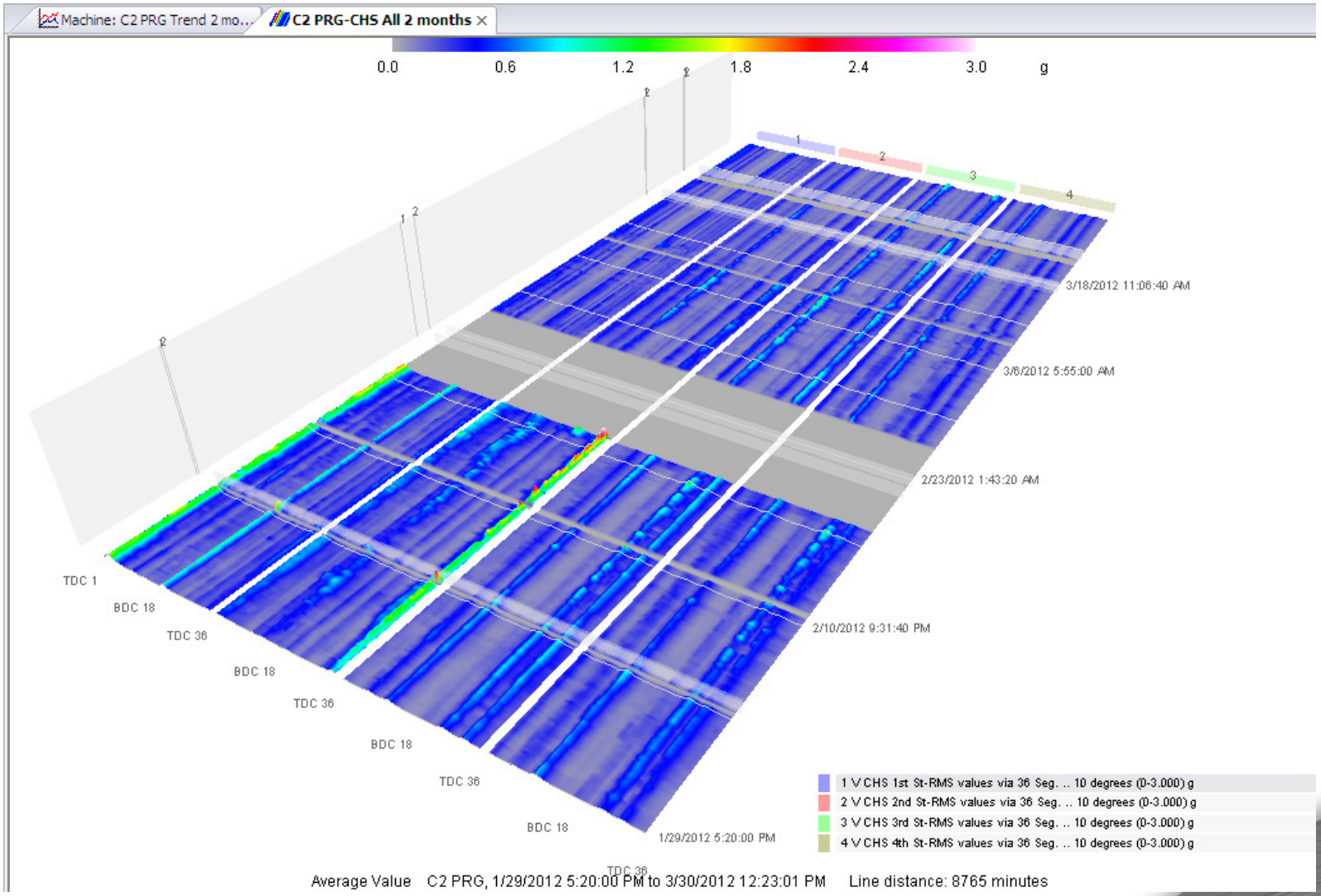
Floating Style Pin



0.0005”-0.002” clearance

0.0015” – 0.0045” clearance

Smooth operation after final repairs



What did we learn…?

- On-Line Compressor Monitoring works
- Believe the data (rod position was real!!)
- Check on a regular basis (ALERTS from 2/3/12 not recognized until 2/12/12)
- Production Protocol when getting ALARMS from System
- Interlock values are set adequately to prevent damage and not have false trips – no significant damage found during any events
- After an event, make sure to do enough checks (liquid at S/U most likely caused the 2nd stage piston to get loose over time)
- Source of water was found to be a corroded indicator nipple on 1st stage cylinder - replaced with SST indicator

Thank you for your attention

Questions?