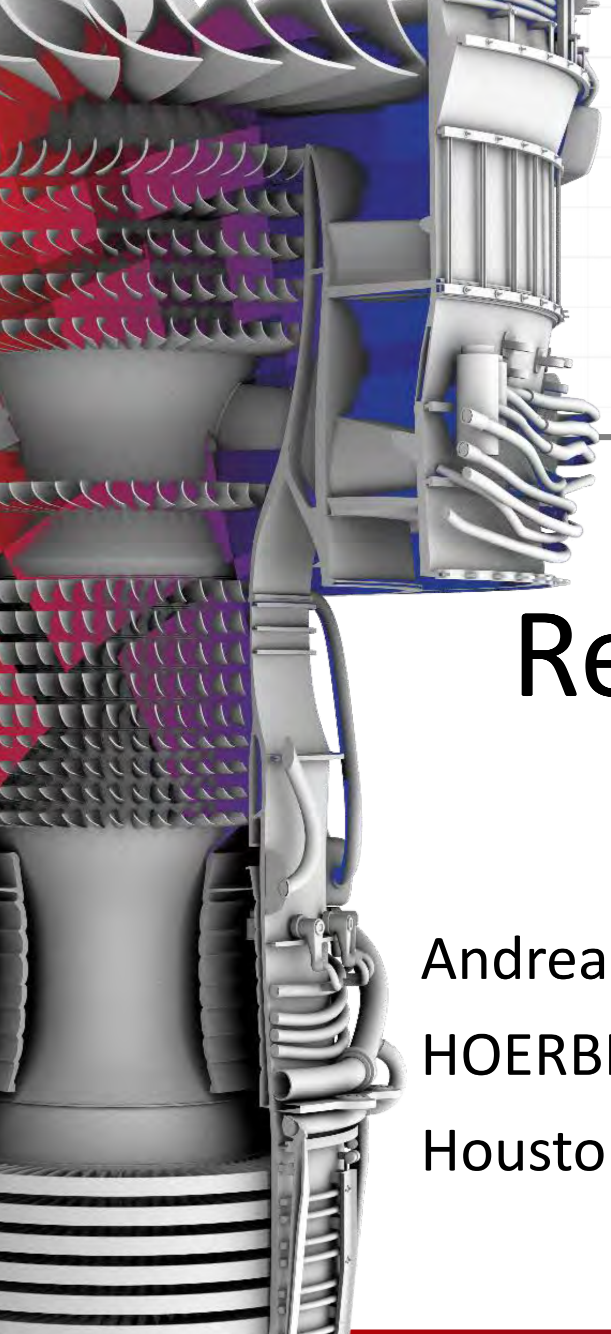

TURBOMACHINERY & PUMP SYMPOSIA

High Reliability Pistons for Reciprocating Compressors in High Wear Situations.

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Authors

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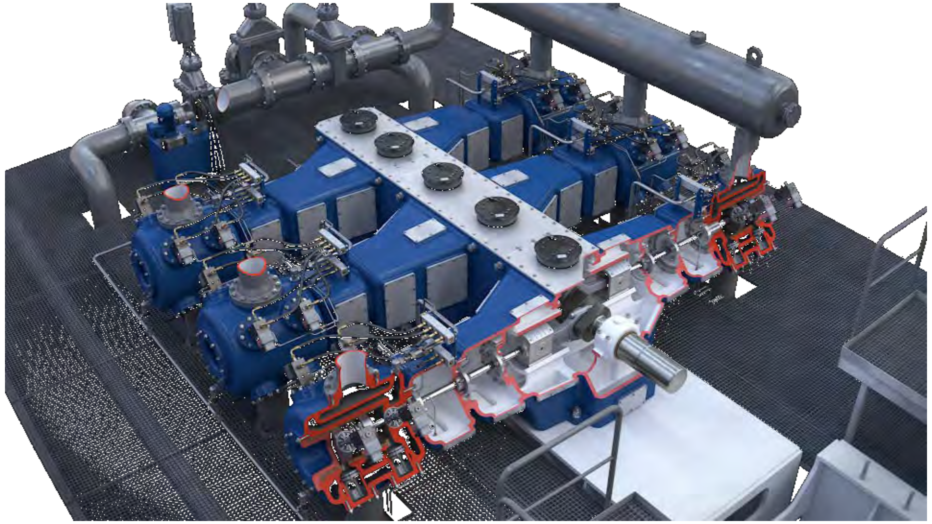
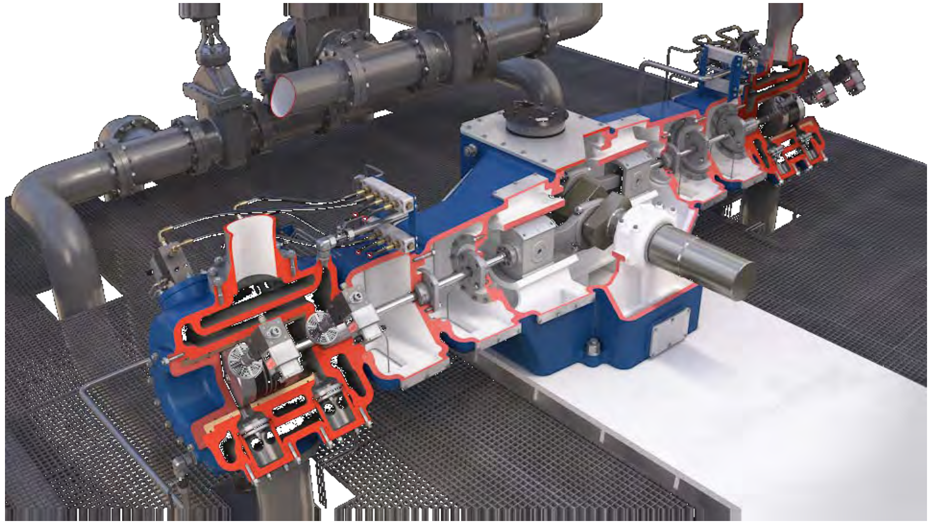
John Ladd *is a Solutions REE Engineer and Compressor Analyst at HOERBIGER Service Inc. in Houston, TX. His primary role is conducting comprehensive technical evaluations of reciprocating compressors to identify and quantify unit improvements in reliability, efficiency, and environmental soundness. Prior to his current role John earned his Master's in mechanical engineering at Colorado State University with a focus on legacy integral pipeline compressors.*

Agenda

Introduction – Compressor Cylinder



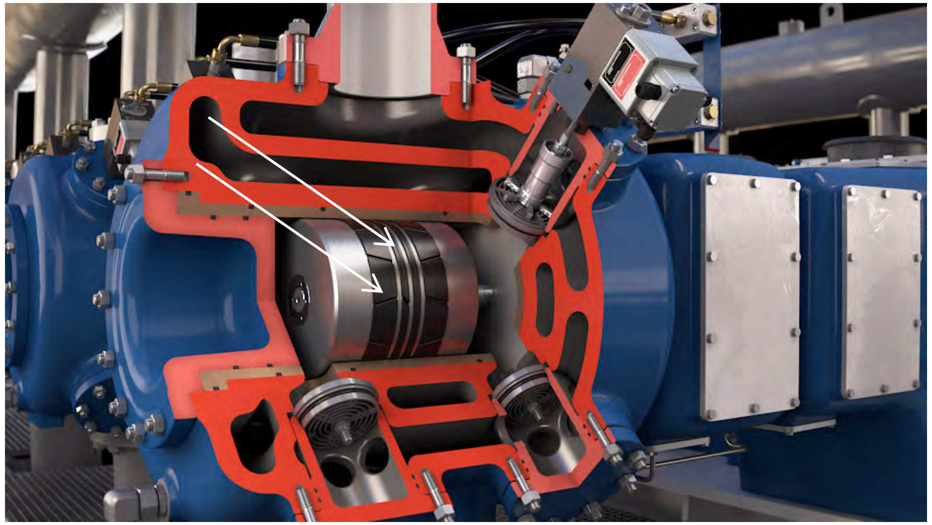


Cut through a two-throw compressor

Six throw compressor

Piston rings: Sealing

Rider bands: Weight

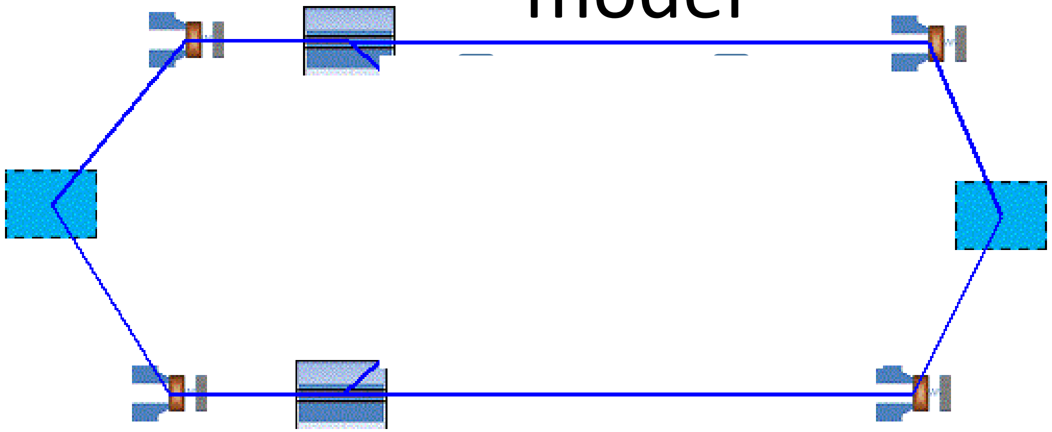


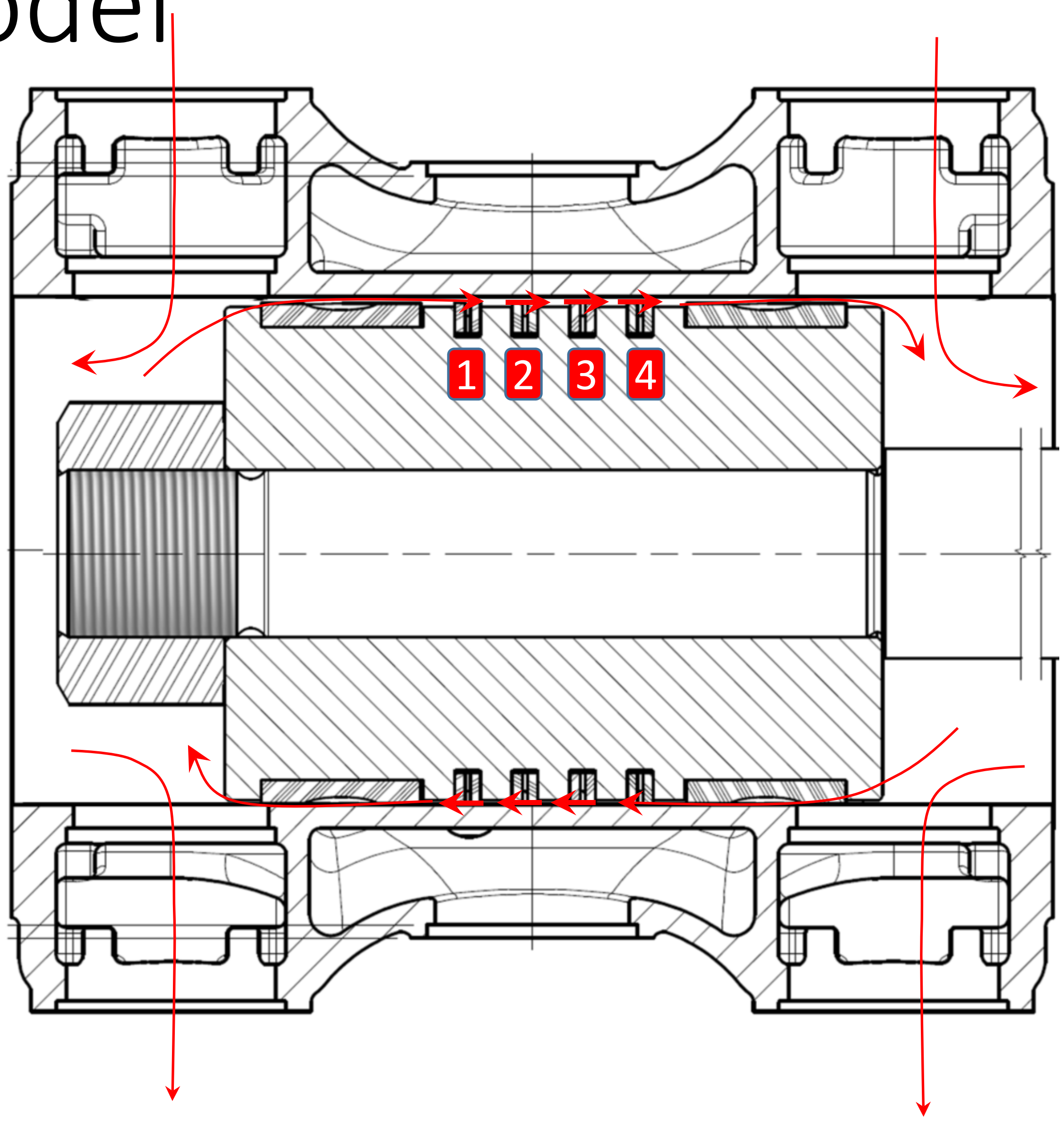
Cut through compressor cylinder

Piston ring leakage model

Piston with slippage path

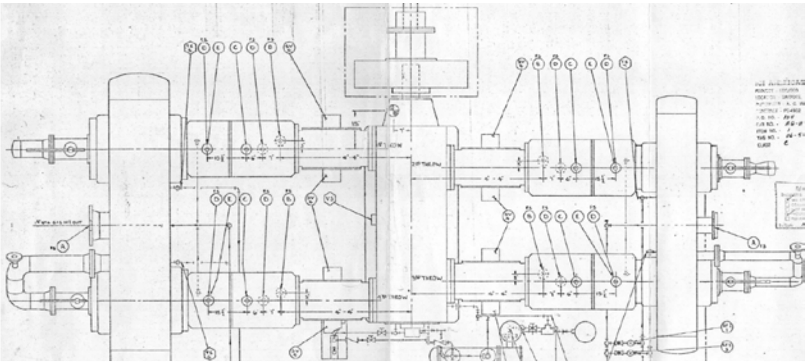
Simulation model





Agenda

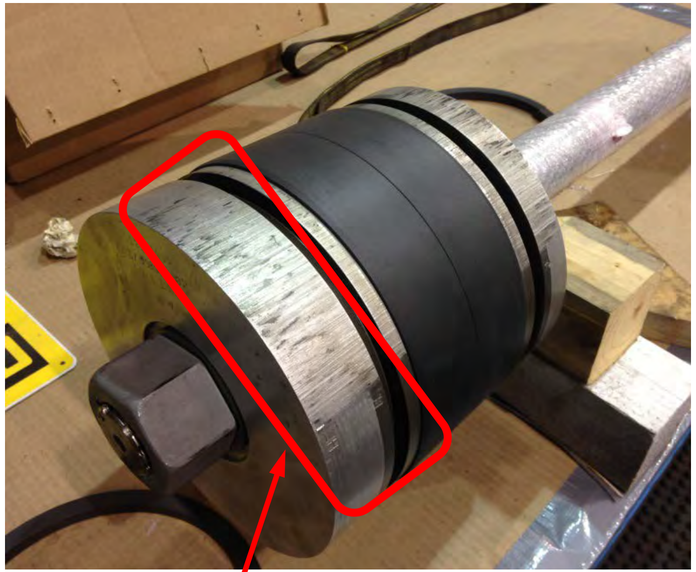
Non-Lube Ethylene: Only 6 months run time



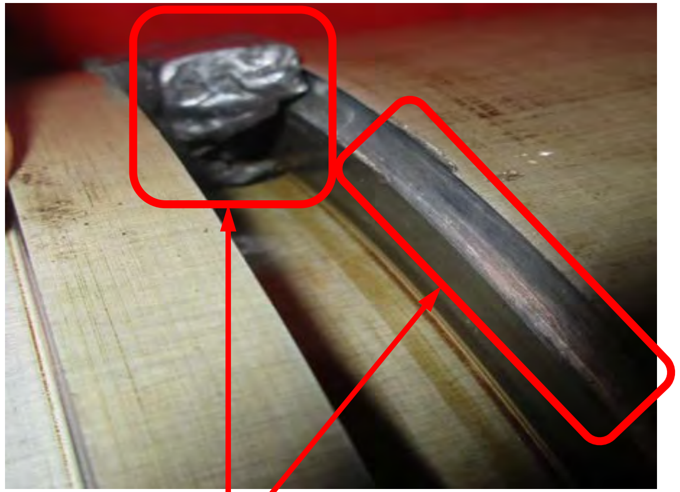
Gas Composition	mol %
Ethylene+Acetylene	45.334
Methane	23.306
CO2	21.191
Oxygen	8.761
Nitrogen	1.293
Molecular Mass [kg/mol]	25.8
Isentropic Exponent []	1.25

Compressor Data (Non-Lube)	Stage 1
2 x Stage 1 dia [in]	16.5
2 x Stage 2 dia [in]	10
Stroke [in]	9
Piston Rod dia [in]	2.5
Speed [rpm]	440
Driver Power [hp]	500
Suction Pressure Stg 1 [psig]	14
Disch. Pressure Stg 1 [psig]	65
Suction Pressure Stg 2 [psig]	62
Disch. Pressure Stg 2 [psig]	255
Avg Piston Speed [ft/min]	660

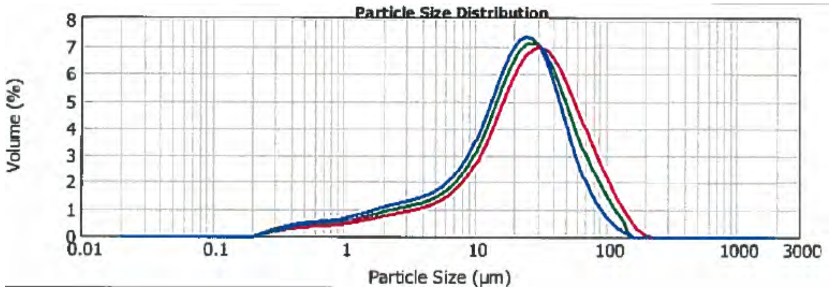
Shut down due to rider band wear every 6 months.



Piston wear marks indicate that rider band wear is a re-occurring problem



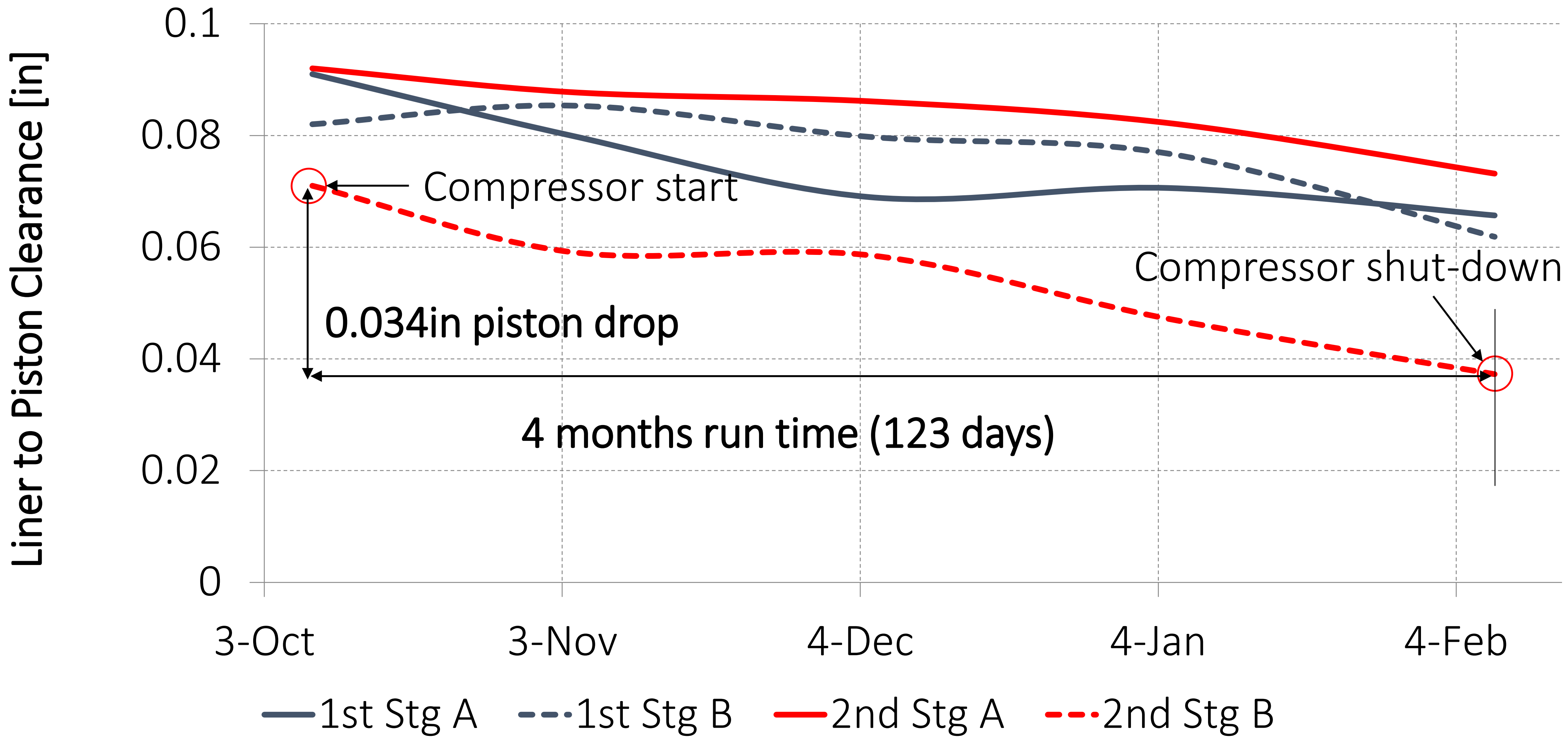
Broken piston rings and worn piston ring groove



Particle size distribution

Worn piston rings, particles embedded in rings

Max run time: 6 months



Agenda

1	Introduction
2	Problem Statement
3	**Failure Analysis**
4	Recommended Changes
5	Summary

Bottle neck analysis

- 2.8psi contact loading (Stage 2 rider)
- Wear rate: 0.01in per month
- Average piston velocity: 660ft/min
- Wear coefficient: 0.528 [1e-6m/(bar m/s hr)]

Order of magnitude higher than what it should be

Explains the broken or even missing rings

	Contact pressure [psi]	Available wear thickness [in]	Wear Progress
Stage 1 Rider	2.6	0.083	30%
Stage 2 Rider	2.8	0.074	36%
Stage 1 Ring	9	0.416[1)]	21%
Stage 2 Ring	35.2	0.339[1)]	100%

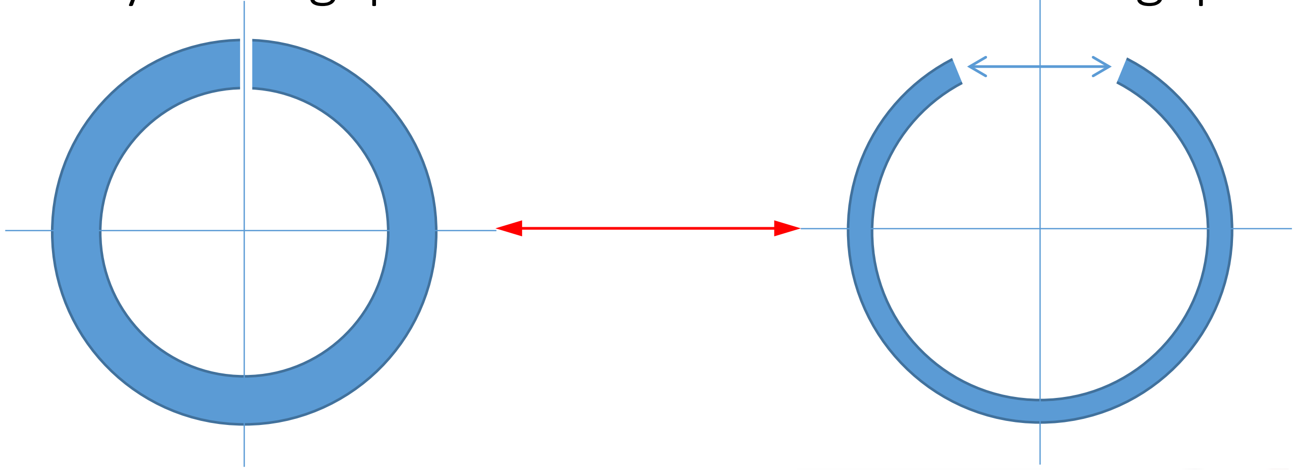
[1)] Min radial ring thickness is 2 x liner to piston gap

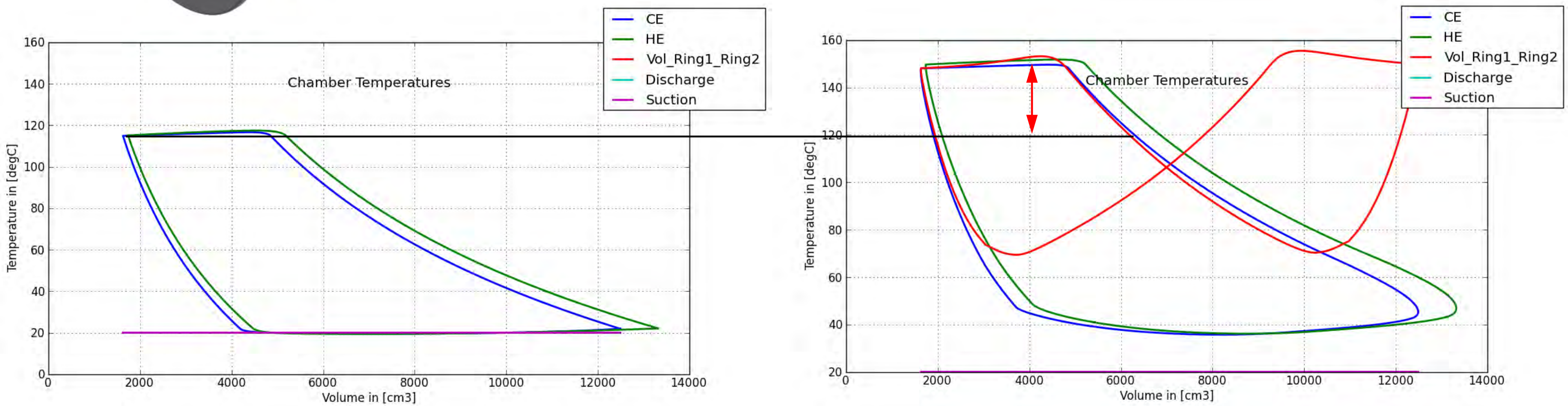
2nd stage blow-by

Blow-by in end gap of piston ring

Initially: Zero gap

End of life: 2in gap width





54°F Temp increase; 20% capacity losses

Summary of findings and recommendations

- Reason for shut-down: Rider band wear (1st and 2nd stage). Monitored via rod drop indicator.
- Ring inspection shows that rider bands and piston rings are wearing heavily.
- The wear coefficient is an order of magnitude higher than what it should be.
- Particles are present and can be found embedded in the rings.
- A blow-by analysis shows that the 2nd stage piston rings are the first ones to reach the wear limit. The impact of the blow-by is not extremely critical.

Problem	Solution
Rider band wear	Reduce contact pressure, increase wear thickness, material
Piston ring wear	Number of piston rings, piston ring design, material
Piston groove wear	Piston material
Particles	Outboard riders with faces grooves

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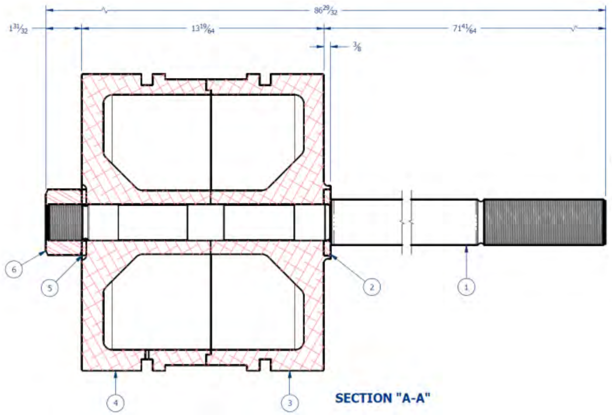
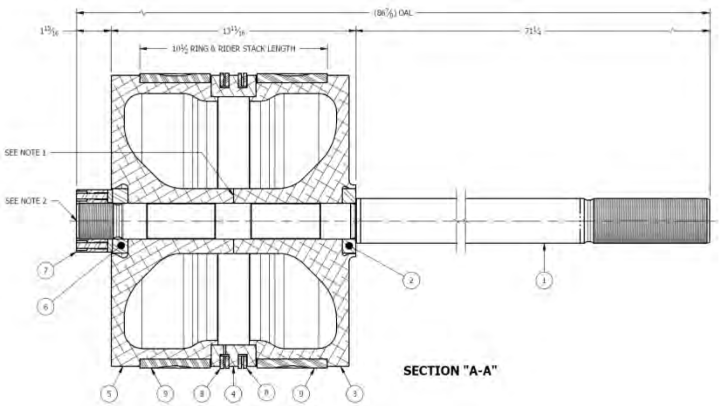
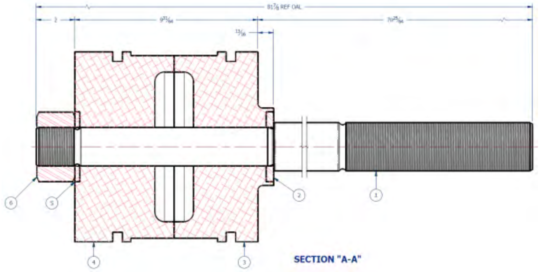
New piston design for optimized run-time



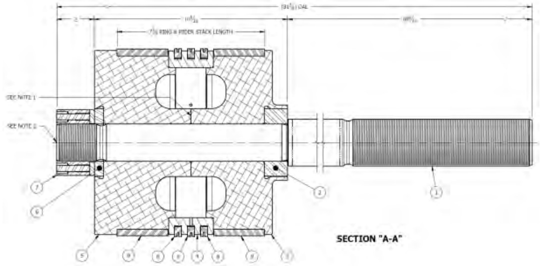
Stage 1 original



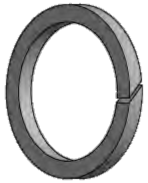
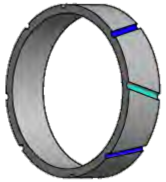
Stage 1 new



Stage 2 original



Stage 2 new

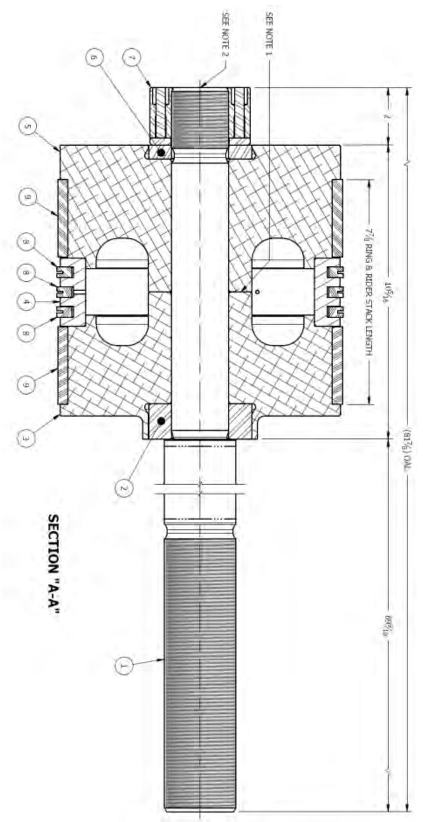
	Piston rings	# of rings	Rider rings	# of riders	Rider Location
Original (1st and 2nd stage)		2		2	Inboard
Upgraded (1st and 2nd stage)		2 (Stg 1) 3 (Stg 2)		2	Outboard

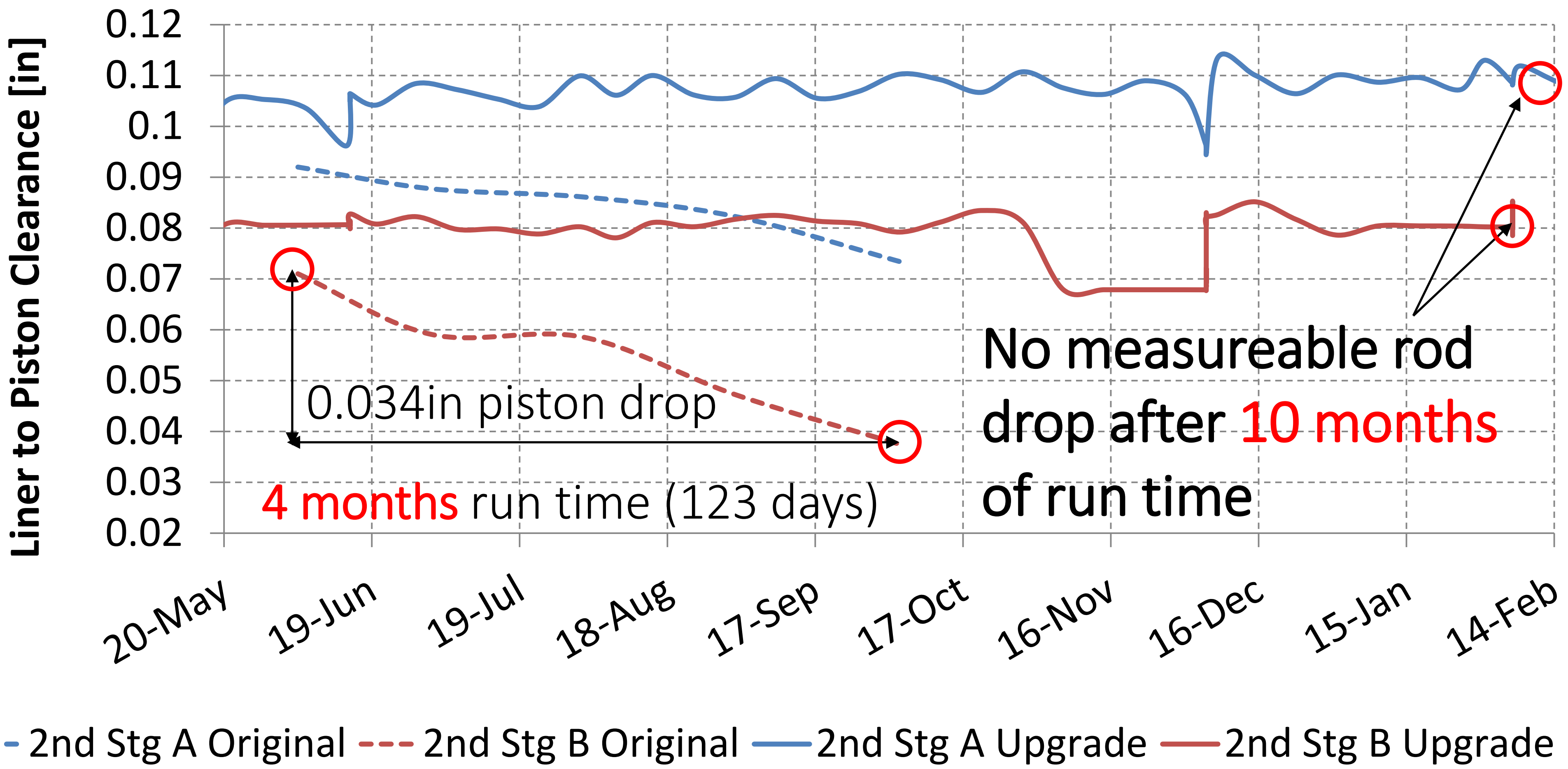
Expected impact of recommended changes

	Contact pressure [psi]	Available wear thickness [in]	Wear Progress Original	Wear Progress Upgraded	Calculated increase of run time
Stage 1 Rider	1.5	0.083	30%	15%	201%
Stage 2 Rider	2.3	0.074	36%	26%	140%
Stage 1 Ring	4.5	0.416	21%	10%	200%
Stage 2 Ring	11.7	0.339	100%	33%	300%

Impact of material change and susceptibility to particles is hard to quantify and is not included in these estimates

Performance of new design





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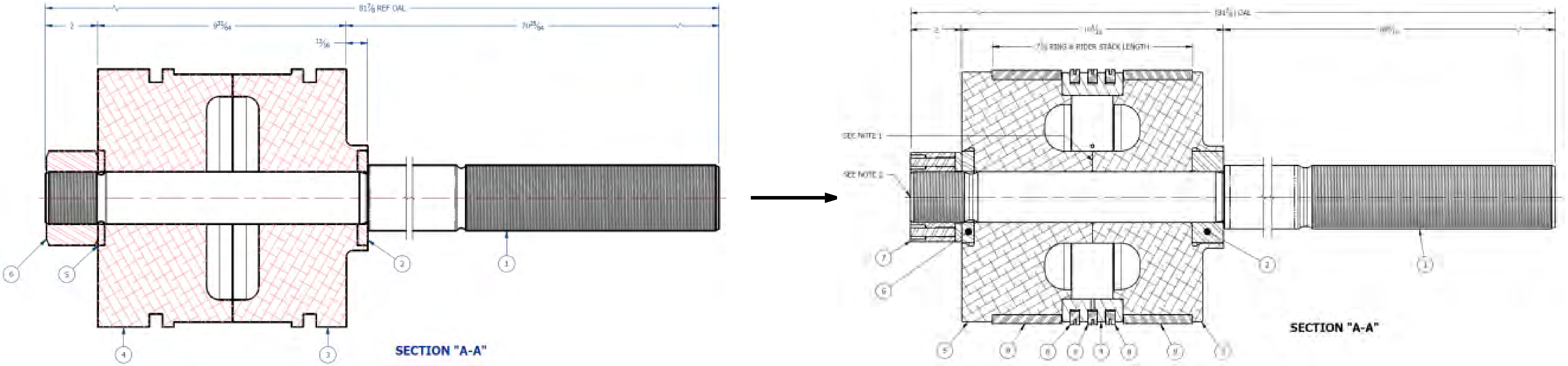
Summary – Application of high performance pistons

- Lifetime can be maximized by optimizing all relevant parameters of pistons / cylinder rings:
  - Contact pressure.
  - Ring design.
  - Available wear thickness.
  - Number of rings.
  - Location of ring.
- Blow-by simulation is required to optimize the design parameters.
- For non-lube machines especially, a design optimization should be considered.
- Lifetime increase of a factor of three has been demonstrated.

Thank you for your attention

"Making pistons more reliable by quantifying blow-by and wear in the engineering phase!"



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