

aramco



Abdullah Algady

**Predicting Centrifugal Gas Compressor Failures
at Aging Oil and Gas Facilities with Seeq**

Seeq[®] connect



Predicting Centrifugal Gas Compressor Failures at Aging Oil and Gas Facilities with Advanced Analytics

Abdullah K. Algady



Aramco Overview

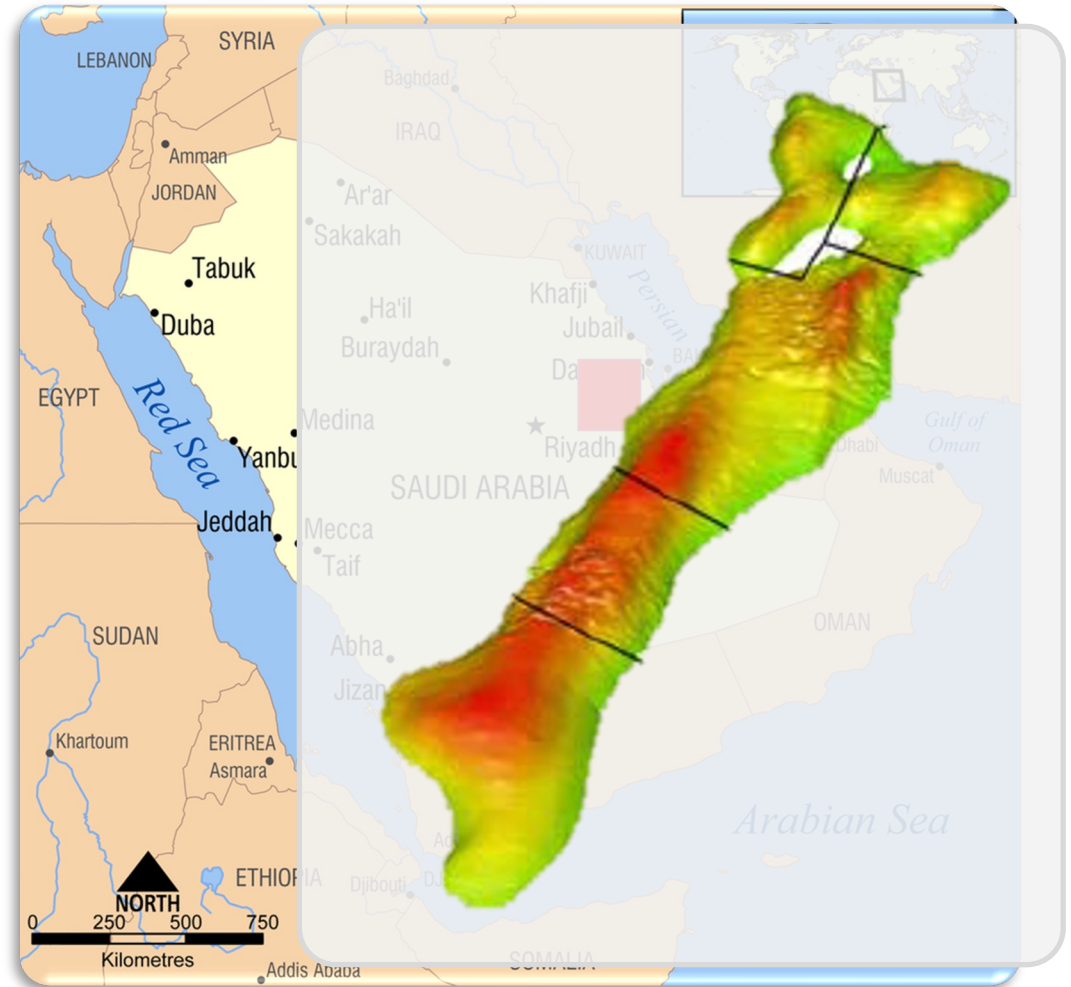
Aramco is one of the world's largest integrated energy and chemicals companies, creating value across the hydrocarbon chain, and delivering societal and economic benefits to people and communities around the globe who rely on the vital energy we supply.



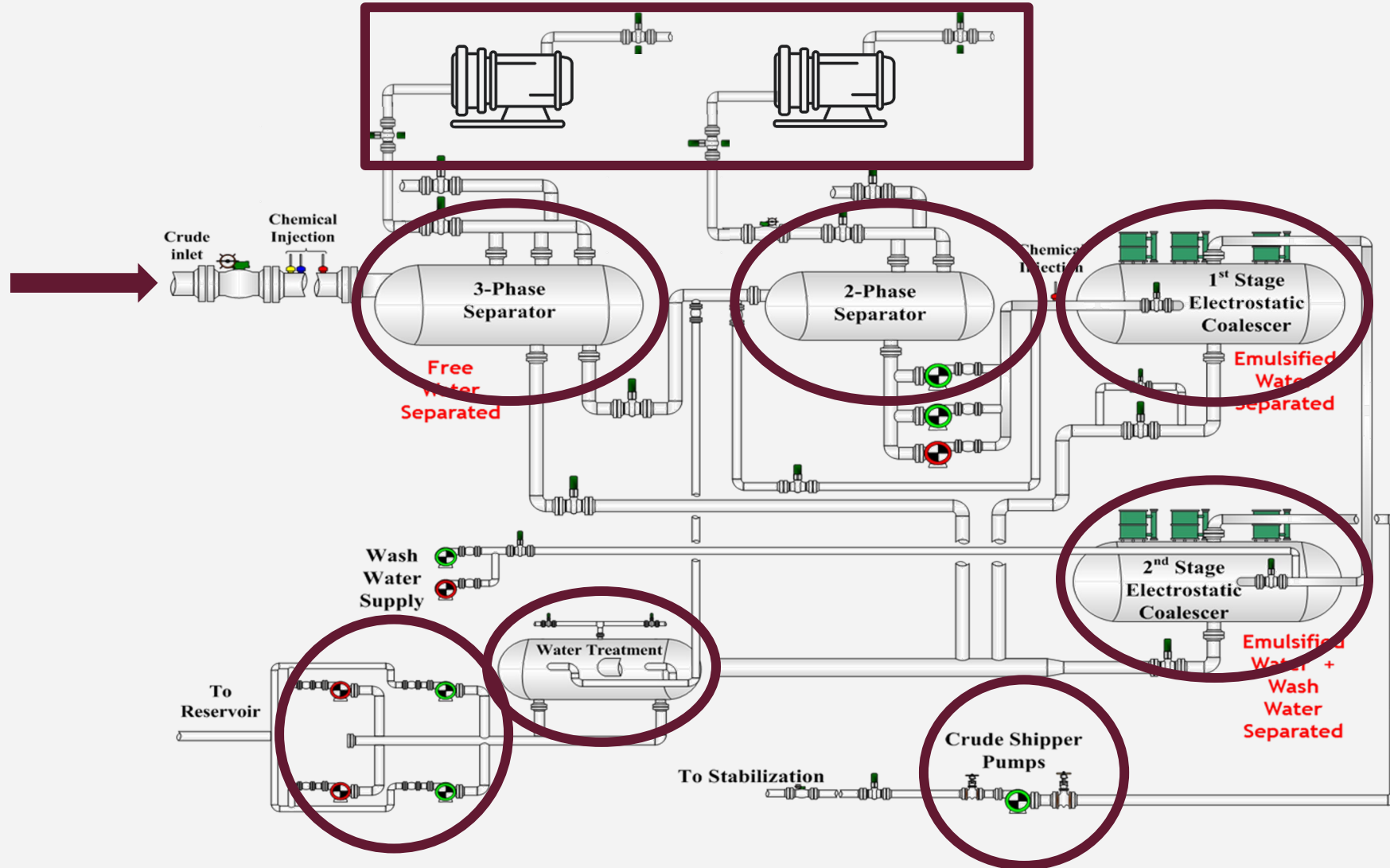
North Ghawar Producing Department - NGPD

NGPD Operates 9 Gas Oil Separation Plants (GOSP) at Ghawar Field.

- +40 Pressure Vessels
- +10 Gas Compressors
- +25 Salt Water Injection Pumps
- +20 Oil Charge/Shipper Pumps



NGPD Process Overview



Business Challenges Overview

➤ Gas Compressors Failure History 2013-2022



- Instrumentation (vibration, temperature and process)
- Process Abnormality
- Lube and Seal oil systems



Flaring Emission

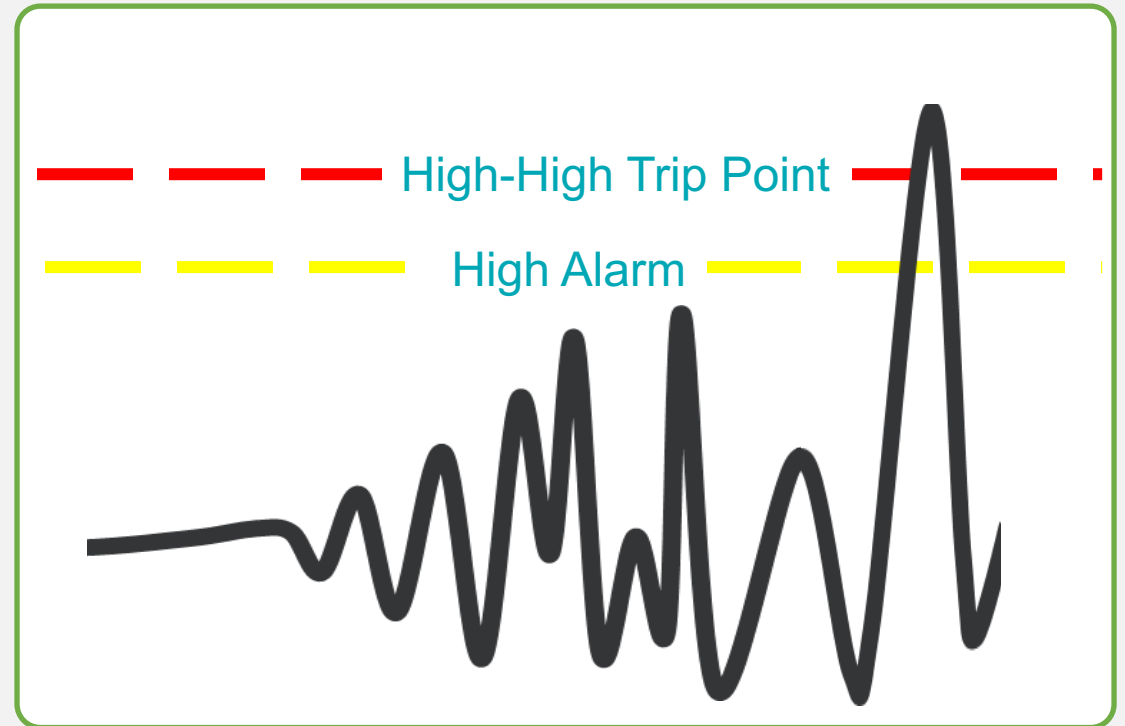
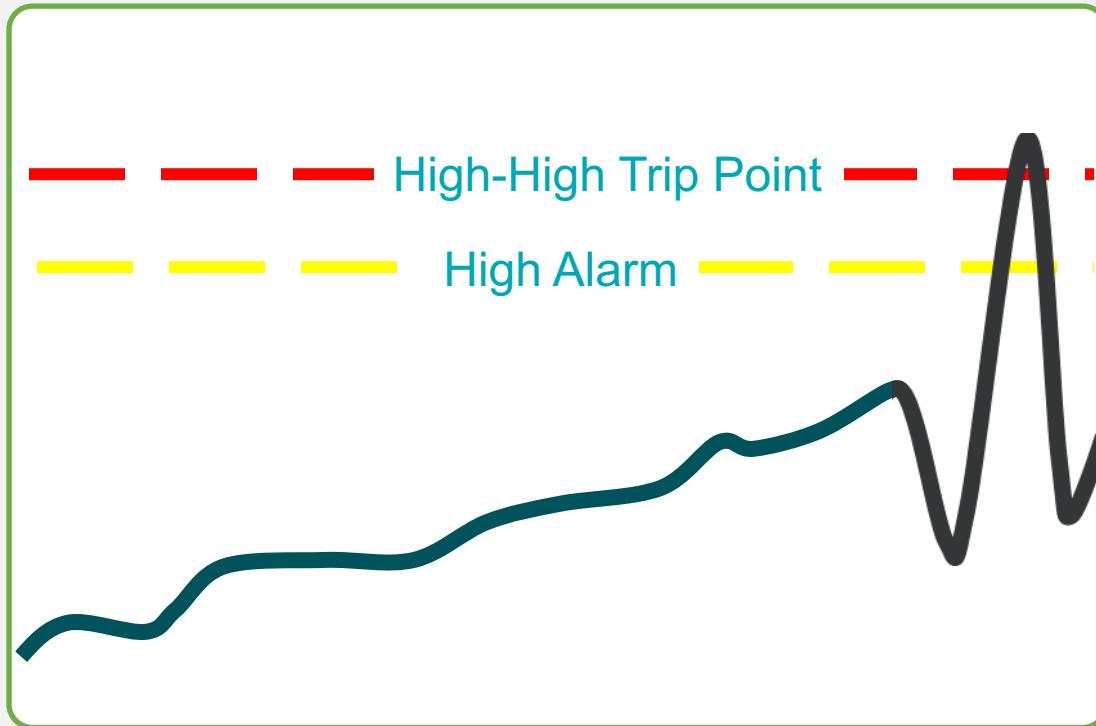


Trip Index KPI



Equipment Reliability

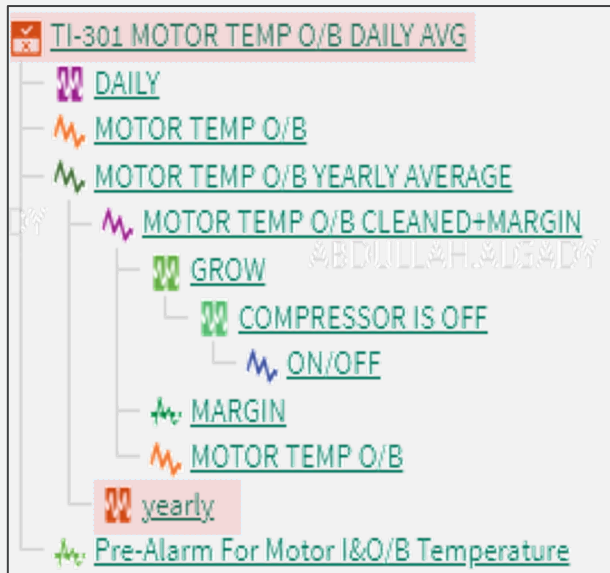
Business Challenges Overview



Seeq Advanced Analytical Tool Overview

➤ 14 Trips Due to The Mechanical Parts Temperature and Vibration Elements During 2018-2022

Q Calculation Hierarchy for Each Tag



```

1 $y=condition(1y, capsule(now()-1y, now()))
2   $y1=$y.move(-1y)
3   $y2=$y.move(-2y)
4   $y3=$y.move(-3y)
5   $y4=$y.move(-4y)
6   $y5=$y.move(-5y)
7   $y6=$y.move(-6y)
8   $y7=$y.move(-7y)
9   $y8=$y.move(-8y)
10  $y9=$y.move(-9y)
11  $y10=$y.move(-10y)
12  $y.combineWith($y1,$y2,$y3,$y4,$y5,$y6,$y7,$y8,$y9,$y10).
  
```

	The daily average is <u>below</u> the yearly average. (normal)
	The daily average is equal to or <u>above</u> the yearly average. (OME to investigate)
	The daily average is equal to or above the <u>pre-alarm</u> settings. (OME to investigate)

Seeq Advanced Analytical Tool Overview

➤ Results and Analysis

NGPD Predictive Tool Navigation

HP Gas Compressors

ABGOSP-2 IPPT

IP GAS COMPRESSOR K-001	RUNNING PERCENTAGE	XV1-504-4A	XV1-504-4B	XV1-504-4C	XV1-504-4D	XV1-504-4E	XV1-504-4F	XV1-504-4G	XV1-504-4H	XV1-504-4I	XV1-504-4J	XV1-504-4K	XV1-504-4L	XV1-504-4M	XV1-504-4N	XV1-504-4O	XV1-504-4P	XV1-504-4Q	XV1-504-4R	XV1-504-4S	XV1-504-4T	XV1-504-4U	XV1-504-4V	XV1-504-4W	XV1-504-4X	XV1-504-4Y	XV1-504-4Z
May 31, 2023	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Jun 1, 2023	12.434%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

ABGOSP-3

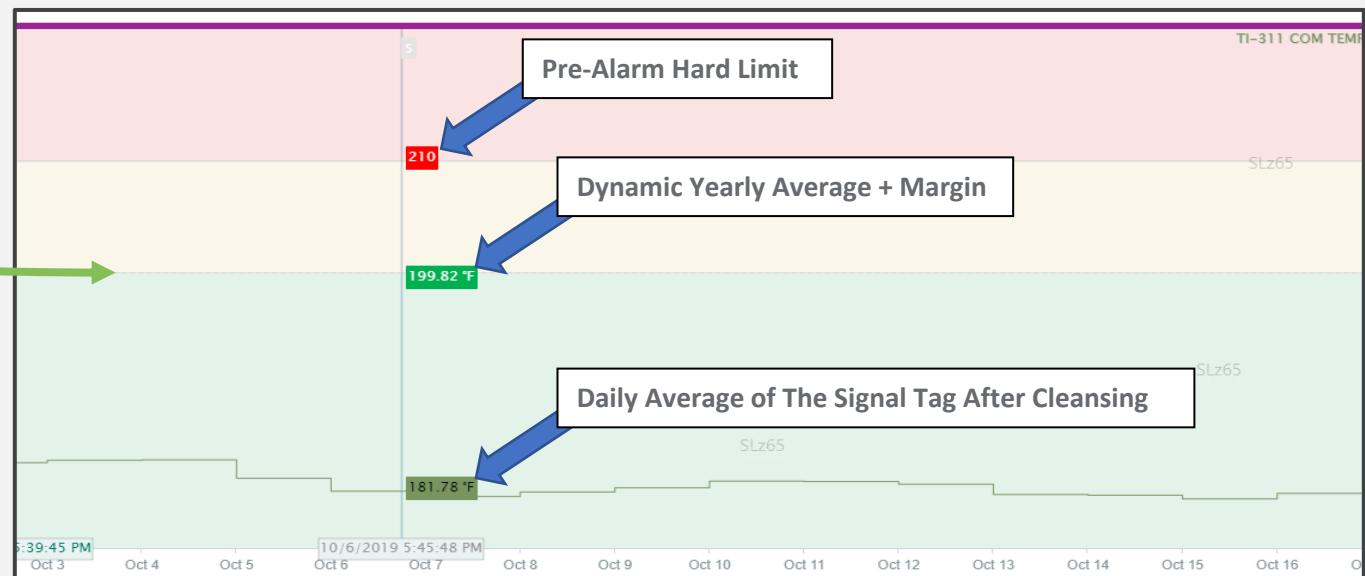
IP GAS COMPRESSOR K-002	RUNNING PERCENTAGE	XV1-504-4A	XV1-504-4B	XV1-504-4C	XV1-504-4D	XV1-504-4E	XV1-504-4F	XV1-504-4G	XV1-504-4H	XV1-504-4I	XV1-504-4J	XV1-504-4K	XV1-504-4L	XV1-504-4M	XV1-504-4N	XV1-504-4O	XV1-504-4P	XV1-504-4Q	XV1-504-4R	XV1-504-4S	XV1-504-4T	XV1-504-4U	XV1-504-4V	XV1-504-4W	XV1-504-4X	XV1-504-4Y	XV1-504-4Z
May 31, 2023	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Jun 1, 2023	12.438%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

SHGOSP-2

ARDULLAH ALTAJY

K-001A

IP GAS COMPRESSOR K-001A	RUNNING PERCENTAGE	XV1-504-4A	XV1-504-4B	XV1-504-4C	XV1-504-4D	XV1-504-4E	XV1-504-4F	XV1-504-4G	XV1-504-4H	XV1-504-4I	XV1-504-4J	XV1-504-4K	XV1-504-4L	XV1-504-4M	XV1-504-4N	XV1-504-4O	XV1-504-4P	XV1-504-4Q	XV1-504-4R	XV1-504-4S	XV1-504-4T	XV1-504-4U	XV1-504-4V	XV1-504-4W	XV1-504-4X	XV1-504-4Y	XV1-504-4Z
May 31, 2023	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Jun 1, 2023	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%



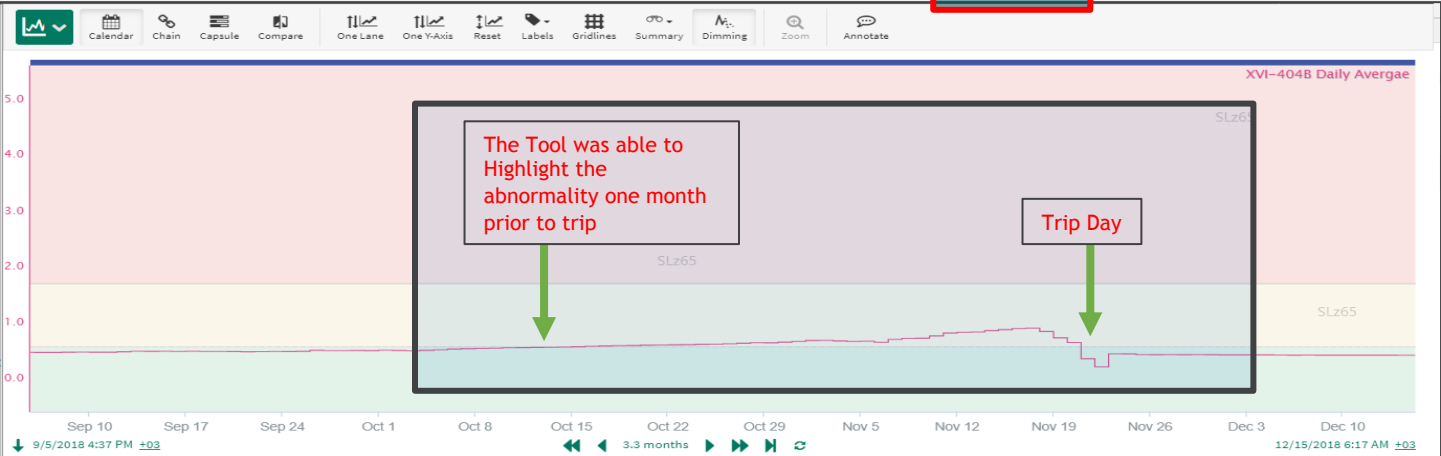
First Failure Prediction Example

➤ Results and Analysis

Q Vibration Examples of Previous Gas Compressor Trips Could Have Been Avoided



HP GAS COMPRESSOR K-001	RUNNING PERCENTAGE	XDI-409A Daily Average	XDI-409B Daily Average	XVI-407A Daily Average	XVI-407B Daily Average	XVI-408A Daily Average	XVI-408B Daily Average	XDI-403 Daily Average	XDI-406 Daily Average	XVI-404A Daily Average	XVI-404B Daily Average	XVI-405A Daily Average	XVI-405B Daily Average	XVI-401A Daily Average	XVI-401B Daily Average	XVI-402A Daily Average
Oct 6, 2018	100 %	-3.483 mil	-3.356 mil	0.9487 mil	0.9913 mil	0.4872 mil	0.4367 mil	-5.417 mil	-3.06 mil	0.5191 mil	0.5301 mil	1.2275 mil	1.2147 mil	1.071 mil	1.2867 mil	1.635 mil
ABDI Oct 7, 2018	100 %	-3.514 mil	-3.42 mil	0.9391 mil	0.9758 mil	0.483 mil	0.4309 mil	-5.396 mil	-3.138 mil	0.5249 mil	0.537 mil	1.2072 mil	1.1995 mil	1.0617 mil	1.2577 mil	1.5929 mil
Oct 8, 2018	100 %	-3.934 mil	-3.832 mil	0.9426 mil	0.9825 mil	0.4851 mil	0.4346 mil	-5.403 mil	-3.162 mil	0.533 mil	0.5432 mil	1.2252 mil	1.223 mil	1.0795 mil	1.2858 mil	1.6032 mil
Oct 9, 2018	100 %	-3.82 mil	-3.708 mil	0.944 mil	0.985 mil	0.4867 mil	0.4353 mil	-5.367 mil	-3.155 mil	0.5385 mil	0.5487 mil	1.2371 mil	1.2307 mil	1.082 mil	1.294 mil	1.6127 mil
Oct 10, 2018	100 %	-3.883 mil	-3.796 mil	0.9442 mil	0.9836 mil	0.4856 mil	0.4314 mil	-5.363 mil	-3.133 mil	0.542 mil	0.5536 mil	1.232 mil	1.2287 mil	1.0844 mil	1.2774 mil	1.6027 mil
Oct 11, 2018	99.728 %	-4.19 mil	-4.173 mil	0.9422 mil	0.9761 mil	0.4859 mil	0.4328 mil	-5.335 mil	-3.159 mil	0.545 mil	0.5562 mil	1.2225 mil	1.227 mil	1.0207 mil	1.1842 mil	1.4881 mil
Oct 12, 2018	100 %	-3.958 mil	-3.87 mil	0.9379 mil	0.974 mil	0.4871 mil	0.4366 mil	-5.218 mil	-3.146 mil	0.547 mil	0.56 mil	1.217 mil	1.2152 mil	1.0296 mil	1.2138 mil	1.4898 mil



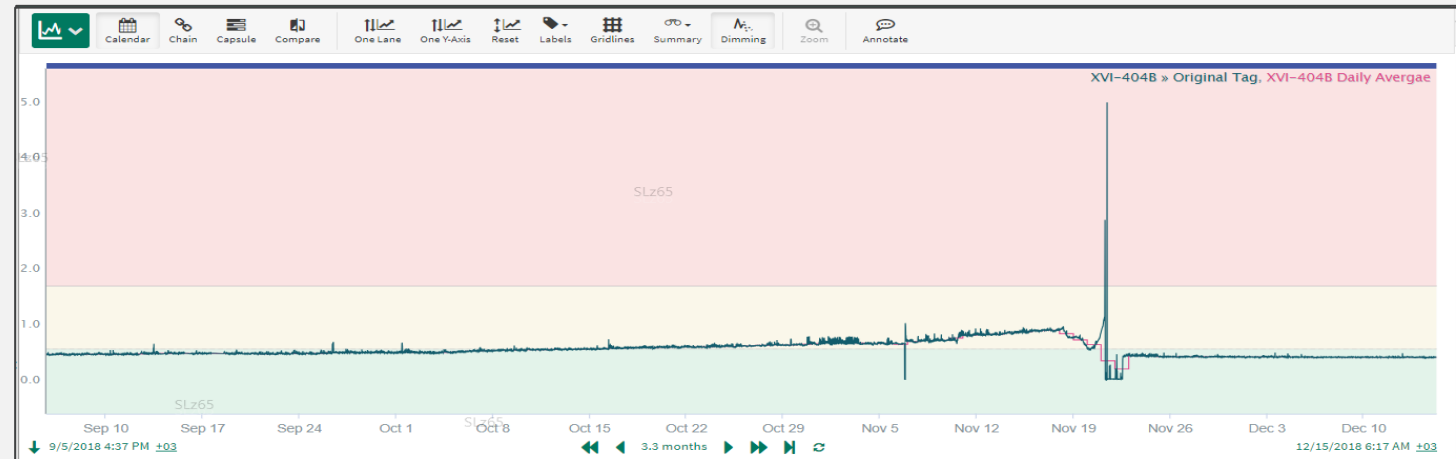
First Failure Prediction Example

➤ Results and Analysis

Q Vibration Examples of Previous Gas Compressor Trips Could Have Been Avoided



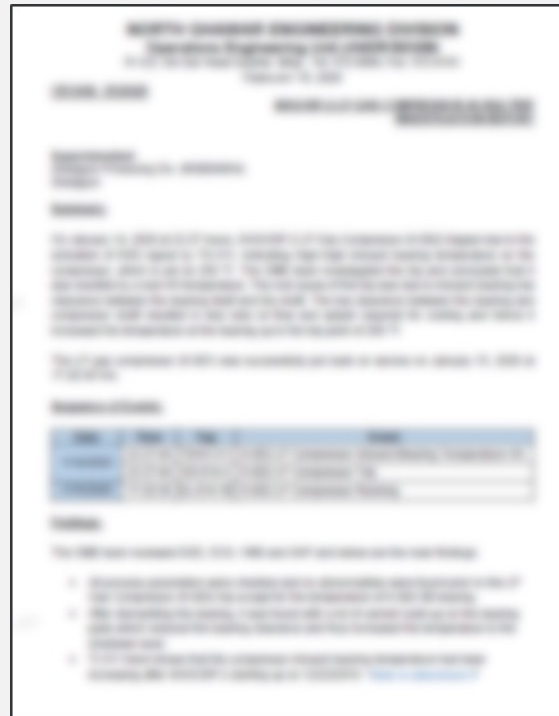
HP GAS COMPRESSOR K-001	RUNNING PERCENTAGE	XDI-409A Daily Average	XDI-409B Daily Average	XVI-407A Daily Average	XVI-407B Daily Average	XVI-408A Daily Average	XVI-408B Daily Average	XDI-403 Daily Average	XDI-406 Daily Average	XVI-404A Daily Average	XVI-404B Daily Average	XVI-405A Daily Average	XVI-405B Daily Average	XVI-401A Daily Average	XVI-401B Daily Average	XVI-402A Daily Average
Oct 6, 2018	100 %	-3.485 mil	-3.356 mil	0.9487 mil	0.9913 mil	0.4872 mil	0.4367 mil	-5.417 mil	-3.06 mil	0.5191 mil	0.5301 mil	1.2275 mil	1.2147 mil	1.071 mil	1.2867 mil	1.635 mil
ABDI Oct 7, 2018	100 %	-3.514 mil	-3.42 mil	0.9391 mil	0.9758 mil	0.483 mil	0.4309 mil	-5.396 mil	-3.138 mil	0.5249 mil	0.537 mil	1.2072 mil	1.1995 mil	1.0617 mil	1.2577 mil	1.5929 mil
Oct 8, 2018	100 %	-3.934 mil	-3.632 mil	0.9426 mil	0.9825 mil	0.4951 mil	0.4346 mil	-5.403 mil	-3.162 mil	0.533 mil	0.5432 mil	1.2252 mil	1.223 mil	1.0795 mil	1.2858 mil	1.6032 mil
Oct 9, 2018	100 %	-3.82 mil	-3.708 mil	0.944 mil	0.985 mil	0.4867 mil	0.4353 mil	-5.367 mil	-3.155 mil	0.5385 mil	0.5467 mil	1.2371 mil	1.2307 mil	1.082 mil	1.294 mil	1.6127 mil
Oct 10, 2018	100 %	-3.883 mil	-3.796 mil	0.9442 mil	0.9836 mil	0.4856 mil	0.4314 mil	-5.363 mil	-3.133 mil	0.5424 mil	0.5538 mil	1.2325 mil	1.2287 mil	1.0844 mil	1.2774 mil	1.6027 mil
Oct 11, 2018	99.728 %	-4.19 mil	-4.173 mil	0.9422 mil	0.9761 mil	0.4859 mil	0.4328 mil	-5.335 mil	-3.159 mil	0.5452 mil	0.5562 mil	1.2225 mil	1.227 mil	1.0207 mil	1.1842 mil	1.4881 mil
Oct 12, 2018	100 %	-3.956 mil	-3.67 mil	0.9379 mil	0.974 mil	0.4871 mil	0.4366 mil	-5.318 mil	-3.146 mil	0.5478 mil	0.56 mil	1.2177 mil	1.2152 mil	1.0296 mil	1.2138 mil	1.4988 mil



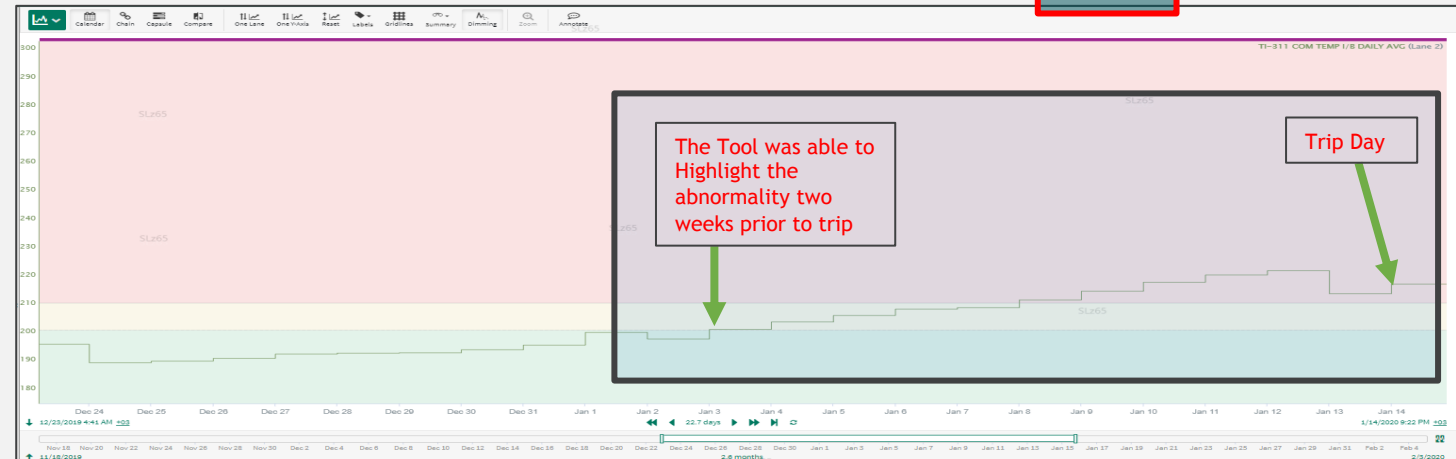
Second Failure Prediction Example

➤ Results and Analysis

Q Temperature Examples of Previous Gas Compressor Trips Could Have Been Avoided



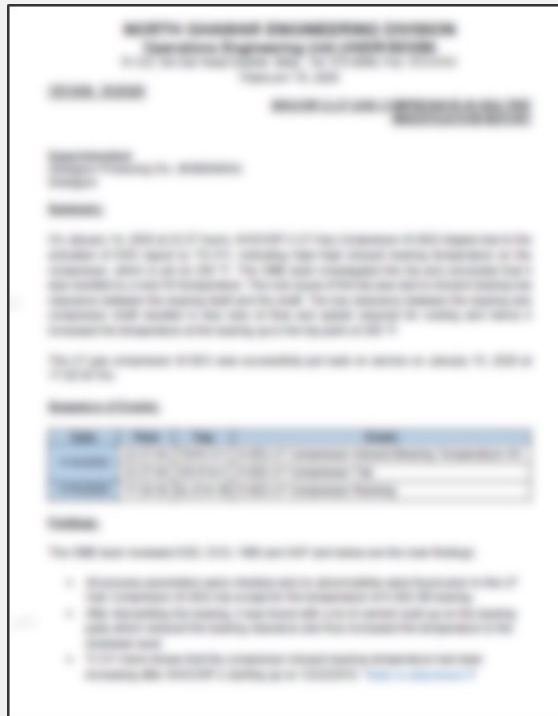
LP GAS COMPRESSOR R-002	RUNNING PERCENTAGE	TI-301 MOTOR TEMP O/B DAILY AVG	TI-302 MOTOR TEMP O/B DAILY AVG	TI-303 GB TEMP MS O/B DAILY AVG	TI-304 GB TEMP CS O/B DAILY AVG	TI-305 GB TEMP CS O/B DAILY AVG	TI-306 GB TEMP MS O/B DAILY AVG	TI-309 GB TEMP MS O/B DAILY AVG	TI-310 GB TEMP CS O/B DAILY AVG	TI-311 COM TEMP O/B DAILY AVG	TI-312 COM TEMP O/B DAILY AVG	TI-313 COM TEMP ACTIVE THRUST B DAILY AVG	TI-314 COM TEMP INACTIVE THRUST B DAILY AVG
Dec 30, 2019	100 %	156.13 °F	156.33 °F	159.91 °F	156.62 °F	160.66 °F	156.3 °F	164.42 °F	176.52 °F	166 °F	156 °F	156.58 °F	172.21 °F
Dec 31, 2019	100 %	156.21 °F	160.14 °F	160.69 °F	157.69 °F	161.67 °F	157.5 °F	165 °F	176.12 °F	166.13 °F	156 °F	157.61 °F	164.84 °F
Jan 1, 2020	100 %	156.43 °F	156.2 °F	156.24 °F	155.04 °F	156.81 °F	156.84 °F	160.13 °F	176.81 °F	166.84 °F	156 °F	154.52 °F	156.84 °F
Jan 2, 2020	100 %	155.7 °F	156.66 °F	156.22 °F	156.91 °F	156.2 °F	160.2 °F	161.46 °F	176.32 °F	167.3 °F	157 °F	156.44 °F	156.42 °F
Jan 3, 2020	100 %	155.3 °F	156.24 °F	156.1 °F	155.79 °F	156.5 °F	155.23 °F	163.73 °F	176.16 °F	166.66 °F	156 °F	156.24 °F	156.56 °F
Jan 4, 2020	100 %	155.09 °F	156.42 °F	156.12 °F	156.11 °F	156.26 °F	162.9 °F	162.9 °F	177.8 °F	163.34 °F	156 °F	156.73 °F	156.77 °F
Jan 5, 2020	100 %	155.15 °F	155.6 °F	156.04 °F	154.82 °F	157.2 °F	155.13 °F	176.13 °F	176.01 °F	165.6 °F	156 °F	155.43 °F	155.53 °F
Jan 6, 2020	99.06 %	155.19 °F	155.76 °F	157.43 °F	157.61 °F	156.96 °F	176.81 °F	176.35 °F	176.35 °F	167.66 °F	156 °F	155.6 °F	155.81 °F
Jan 7, 2020	100 %	155.51 °F	157.56 °F	156.6 °F	156.12 °F	156 °F	156.23 °F	162.12 °F	177.76 °F	168.39 °F	156 °F	154.97 °F	154.81 °F
Jan 8, 2020	100 %	155.48 °F	157.61 °F	156.5 °F	156 °F	156.67 °F	156.76 °F	163.41 °F	176.26 °F	171.09 °F	156 °F	154.62 °F	156.16 °F
Jan 9, 2020	100 %	155.52 °F	157.32 °F	157.56 °F	155.93 °F	157.08 °F	155.96 °F	162.93 °F	177.87 °F	164.13 °F	156 °F	154.34 °F	155.56 °F
Jan 10, 2020	100 %	155.61 °F	156.08 °F	156 °F	157.14 °F	156.53 °F	163.16 °F	176.67 °F	176.67 °F	172.09 °F	156 °F	156.36 °F	156.17 °F
Jan 11, 2020	100 %	155.55 °F	156.24 °F	156.3 °F	151.51 °F	151.61 °F	156.96 °F	173.34 °F	172.63 °F	170.02 °F	156 °F	157.67 °F	156.44 °F
Jan 12, 2020	100 %	155.29 °F	156.65 °F	156.12 °F	156.67 °F	156.16 °F	156.34 °F	171.23 °F	171.76 °F	171.42 °F	156 °F	156.12 °F	156.66 °F
Jan 13, 2020	100 %	156.44 °F	156.25 °F	156.46 °F	156.65 °F	156.17 °F	160.13 °F	176.36 °F	176.36 °F	161.3 °F	156 °F	151.36 °F	156.13 °F
Jan 14, 2020	93.628 %	155.36 °F	146.53 °F	150.99 °F	149.31 °F	159.99 °F	145.33 °F	166.2 °F	166.76 °F	161.69 °F	156 °F	155.66 °F	156.66 °F
Jan 15, 2020	27.413 %	161.666 °F	166.205 °F	164.448 °F	157.345 °F	160.642 °F	162.255 °F	166.535 °F	166.664 °F	163.907 °F	156 °F	167.09 °F	163.367 °F



Second Failure Prediction Example

➤ Results and Analysis

Q Temperature Examples of Previous Gas Compressor Trips Could Have Been Avoided



LP GAS COMPRESSOR R-002	RUNNING PERCENTAGE	TI-301 MOTOR TEMP O/B DAILY AVG	TI-302 MOTOR TEMP I/B DAILY AVG	TI-303 GB TEMP MS O/B DAILY AVG	TI-304 GB TEMP CS O/B DAILY AVG	TI-305 GB TEMP CS I/B DAILY AVG	TI-306 GB TEMP MS I/B DAILY AVG	TI-309 GB TEMP MS O/B DAILY AVG	TI-310 GB TEMP CS I/B DAILY AVG	TI-311 COM TEMP I/B DAILY AVG	TI-312 COM TEMP O/B DAILY AVG	TI-313 COM TEMP ACTING THRUST I/B DAILY AVG	TI-314 COM TEMP INACTIVE THRUST I/B DAILY AVG
Dec 30, 2019	100 %	156.13 °F	156.33 °F	159.91 °F	156.62 °F	150.65 °F	156.3 °F	164.42 °F	176.52 °F	193.52 °F	156.26 °F	156.56 °F	177.21 °F
Dec 31, 2019	100 %	155.21 °F	160.14 °F	160.69 °F	157.69 °F	151.67 °F	157.5 °F	165 °F	176.12 °F	195.19 °F	156.18 °F	157.61 °F	154.84 °F
Jan 1, 2020	100 %	156.45 °F	156.2 °F	155.24 °F	155.04 °F	156.81 °F	155.94 °F	160.13 °F	175.81 °F	199.64 °F	154.52 °F	156.84 °F	156.84 °F
Jan 2, 2020	100 %	155.7 °F	156.66 °F	156.22 °F	156.2 °F	156.81 °F	156.2 °F	161.46 °F	176.32 °F	197.3 °F	155.67 °F	156.44 °F	156.42 °F
Jan 3, 2020	100 %	155.3 °F	156.24 °F	156.1 °F	155.79 °F	156.5 °F	155.23 °F	163.73 °F	176.16 °F	200.86 °F	155.32 °F	156.24 °F	156.56 °F
Jan 4, 2020	100 %	155.09 °F	156.32 °F	156.42 °F	156.12 °F	150.11 °F	156.26 °F	162.6 °F	177.8 °F	203.34 °F	151.08 °F	156.73 °F	156.77 °F
Jan 5, 2020	100 %	155.15 °F	155.6 °F	156.94 °F	154.82 °F	157.2 °F	155.13 °F	170.15 °F	175.01 °F	205.6 °F	155.35 °F	155.43 °F	155.53 °F
Jan 6, 2020	99.06 %	155.19 °F	155.76 °F	157.43 °F	155.14 °F	157.4 °F	156.96 °F	170.81 °F	176.35 °F	207.96 °F	157.73 °F	155.8 °F	155.81 °F
Jan 7, 2020	100 %	151.51 °F	157.56 °F	156.8 °F	156.28 °F	159 °F	156.53 °F	162.13 °F	177.76 °F	208.39 °F	151.06 °F	154.97 °F	154.81 °F
Jan 8, 2020	100 %	152.48 °F	157.61 °F	156.5 °F	156 °F	156.67 °F	154.76 °F	163.41 °F	176.26 °F	211.09 °F	154.07 °F	154.62 °F	156.16 °F
Jan 9, 2020	100 %	152.92 °F	157.32 °F	157.56 °F	155.93 °F	157.08 °F	155.96 °F	162.93 °F	177.87 °F	204.15 °F	154.32 °F	154.34 °F	153.56 °F
Jan 10, 2020	100 %	153.51 °F	159.09 °F	160 °F	157.14 °F	160.53 °F	156.11 °F	165.16 °F	176.67 °F	217.09 °F	156.63 °F	156.36 °F	156.17 °F
Jan 11, 2020	100 %	152.88 °F	150.24 °F	155.3 °F	151.51 °F	151.86 °F	146.96 °F	173.34 °F	172.63 °F	218.82 °F	159.62 °F	157.87 °F	150.44 °F
Jan 12, 2020	100 %	151.26 °F	146.65 °F	150.12 °F	150.67 °F	150.16 °F	145.51 °F	171.23 °F	171.76 °F	221.42 °F	156.06 °F	156.11 °F	156.66 °F
Jan 13, 2020	100 %	150.44 °F	154.25 °F	156.46 °F	154.85 °F	154.77 °F	150.14 °F	176.7 °F	176.36 °F	206.26 °F	151.36 °F	156.12 °F	156.12 °F
Jan 14, 2020	93.628 %	152.36 °F	146.53 °F	150.99 °F	149.31 °F	159.99 °F	145.33 °F	166.2 °F	166.76 °F	216.69 °F	151.26 °F	156.56 °F	156.56 °F
Jan 15, 2020	27.413 %	161.666 °F	166.205 °F	164.438 °F	157.545 °F	160.642 °F	152.255 °F	166.535 °F	166.664 °F	153.907 °F	155.28 °F	157.09 °F	153.367 °F

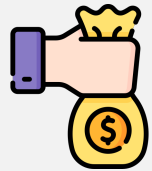


Realized Benefits

➤ Benefits



**Value
Creation**



Third Party
Implementation



**Operational
Efficiency**



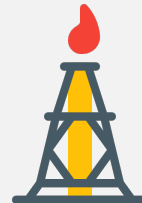
Reliability



Auto.
Analyzes
+600 tags



HSSE



116 MMSCF



**Business
Sustainability**



10/14 Trips



Trip Index

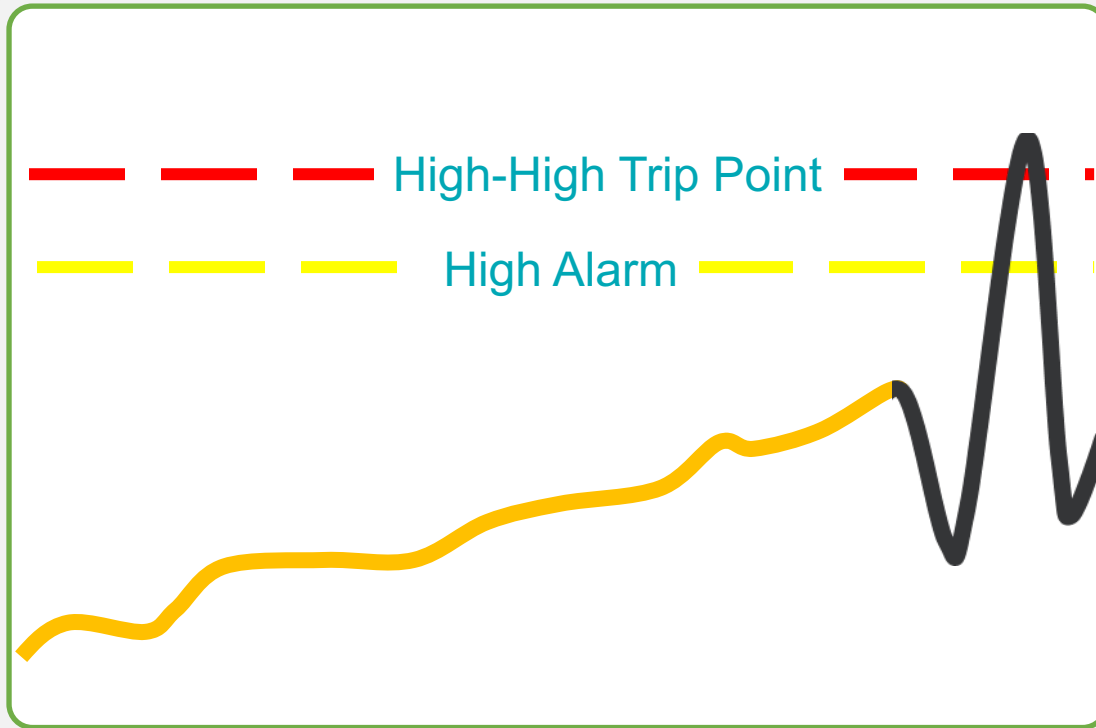
Path Forward

- Incorporated at NGPD Reliability Center



Path Forward

- Incorporated at NGPD Reliability Center




XVI-404A	XVI-404B	XVI-405A	XVI-405B
0.5191 mil	0.5301 mil	1.2275 mil	1.214
0.5249 mil	0.537 mil	1.2072 mil	1.199
0.533 mil	0.5432 mil	1.2252 mil	1.223
0.5385 mil	0.5467 mil	1.2371 mil	1.230
0.5424 mil	0.5538 mil	1.2325 mil	1.228
0.5452 mil	0.5562 mil	1.2225 mil	1.227
0.5478 mil	0.56 mil	1.2177 mil	1.215

XVI-402A
.635 mil
.5929 mil
.6032 mil
.6127 mil
.6027 mil
.4891 mil
.4896 mil

Thank You