
Digital Transformation for
SRP Operated Wells

Outline

- Introduction
- IoT System
  - Hardware
  - Software - AI / ML Algorithms
- Conventional vs IoT approach
- Benefits
- Case Studies
- Summary

IoT Technology Applications

- Monitoring and diagnosis of producing oil well using SRP

- **Monitoring, analysis and decision-support** systems are historically multi-layered and siloed or non-exist
- **Data does not lead to insight**: volume of information provided by current solutions is overwhelming and delivered in a format that requires significant follow-up processing for the operator to draw an actionable conclusion
- **Insight to action is human intensive**

Noven Technology

- Noven was launched as a start up in April 2018 to create a unique Internet of Things (IoT) / Artificial Intelligence (AI) technology platform allowing never-achieved ease and cost of monitoring and diagnosing industrial systems
- Team highly experienced in metrology and Artificial Intelligence, with demonstrated game-changing innovations involving:
    - High performance and cost-effective sensors (MEMS)
    - Wireless communications
    - Computing power available at the Edge
    - Artificial intelligence
- Over its first three years of history, the IoT/AI platform enabling sensors to communicate and being processed at the edge has been developed, tested and subsequently proven in a harsh environment.

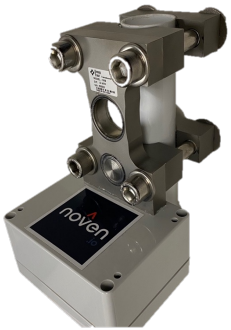
Generated US Patents

#	Application Title	Application Number	Publication Number
1	Polished Rod Load Cell	16/897,566	2020/0393309
2	Two-Point Polished Rod Load-Sensing System	16/897,639	2020/0392832
3	System and Method for Determining Load and Displacement of a Polished Rod	16/898,050	2020/0392822
4	Well Pump Diagnostics Using Multi-Physics Sensor Data	16/898,639	2020/0392834
5	Automated Beam Pump Diagnostics Using Surface Dynacard	16/898,019	2020/0392833

IoT Sensors and Gateway

Wireless

Inclinometer



Wireless

Polished Rod Load Cell

Wireless

Pressure Gauge

Acoustic

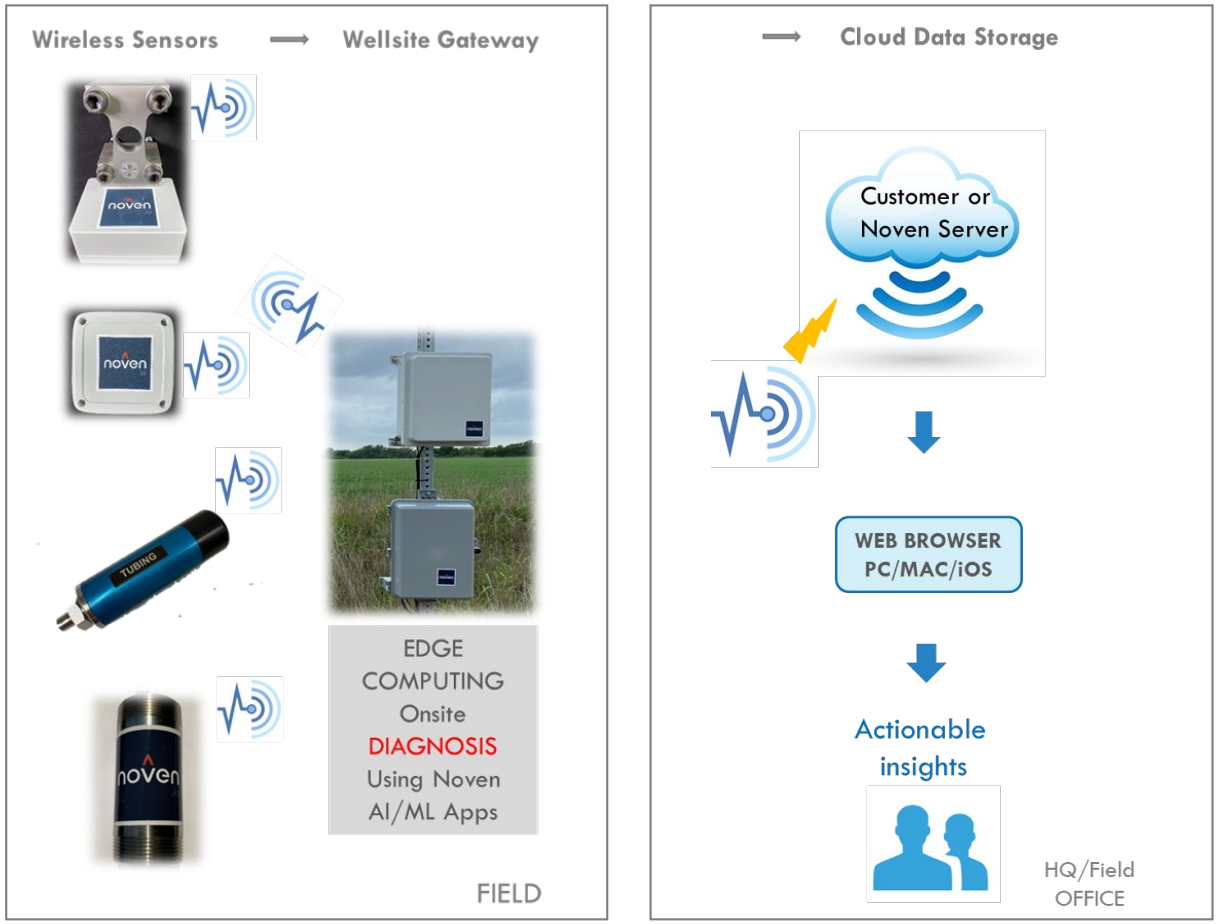
Tank Level Sensor

Wireless

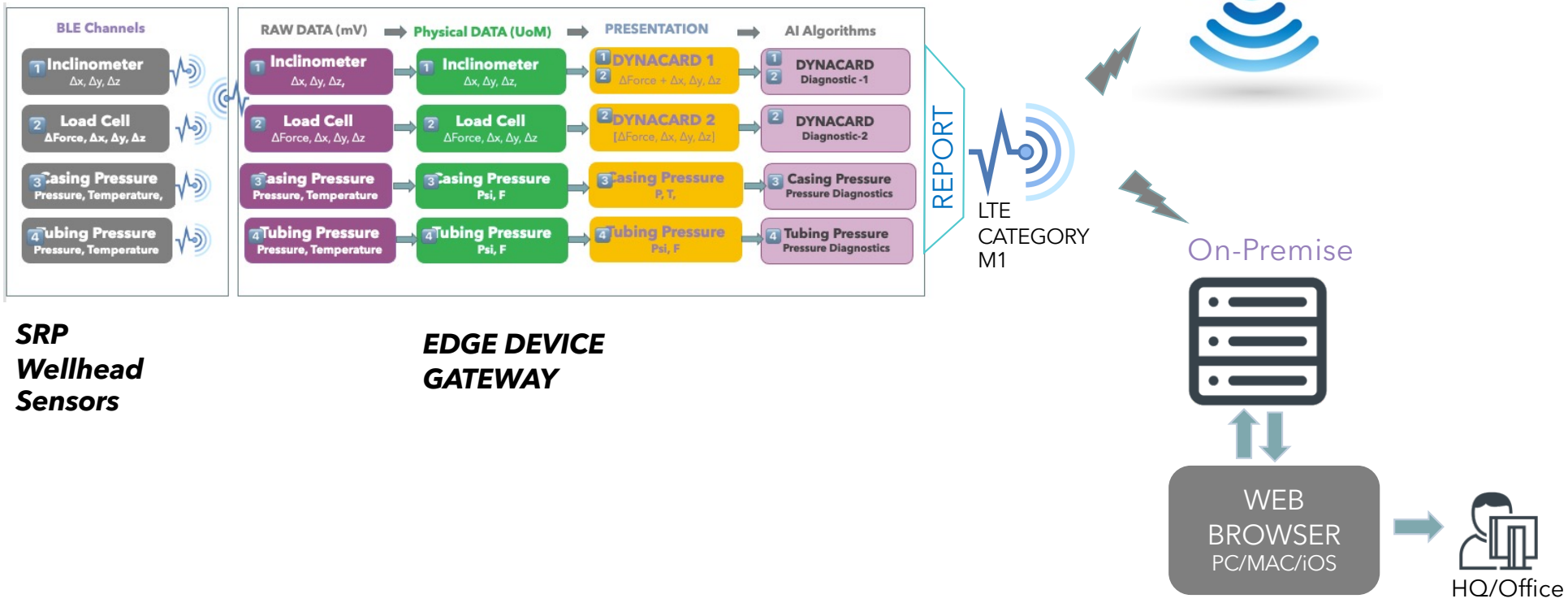
Gateway

Automated data capture, processing and diagnostics using proprietary AI/ML algorithms

IoT Platform for Oil & Gas well Monitoring and Diagnostics



Data Flow Diagram

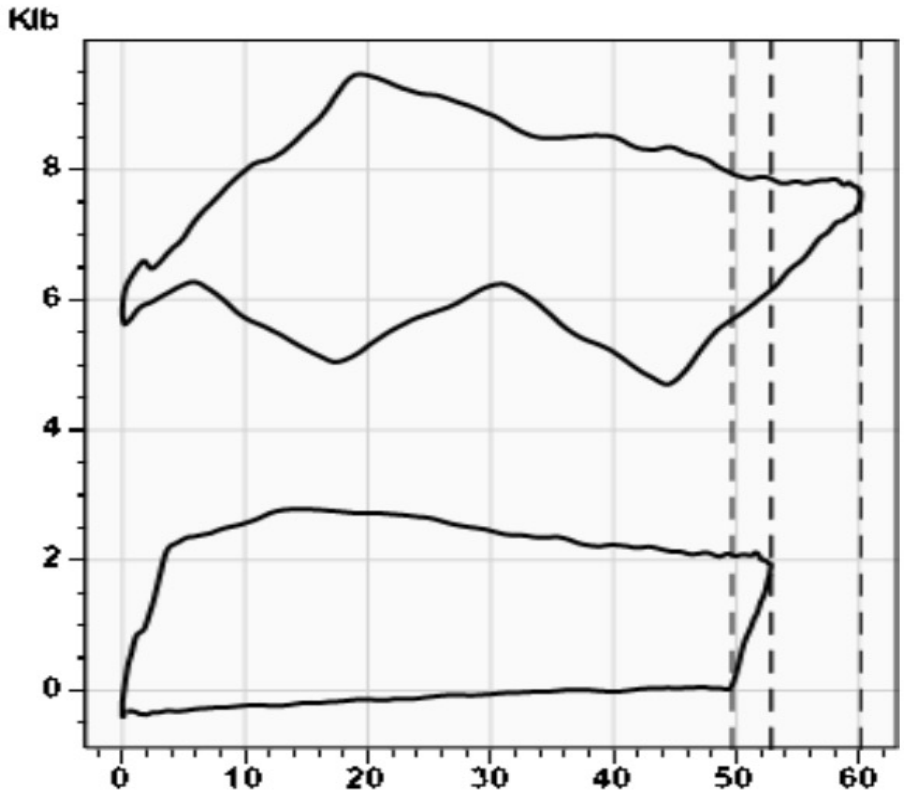


SRP Wellhead Sensors

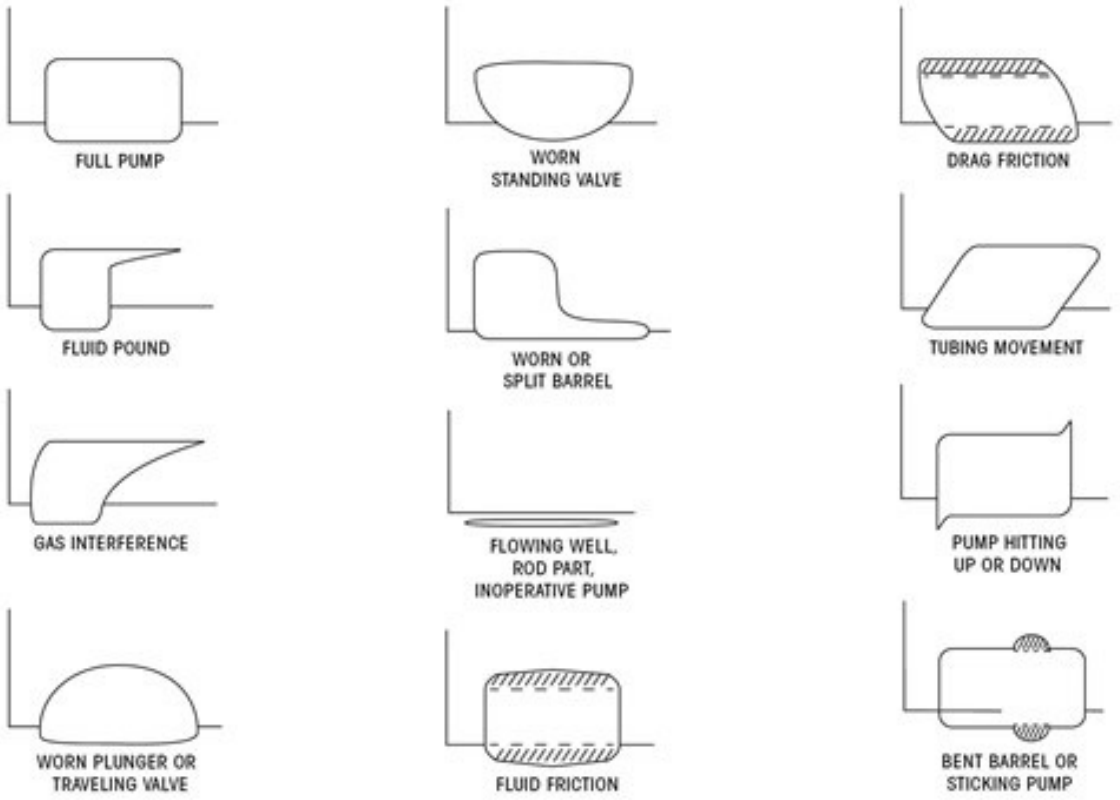
EDGE DEVICE GATEWAY

Conventional vs.
Data Driven IoT Approach

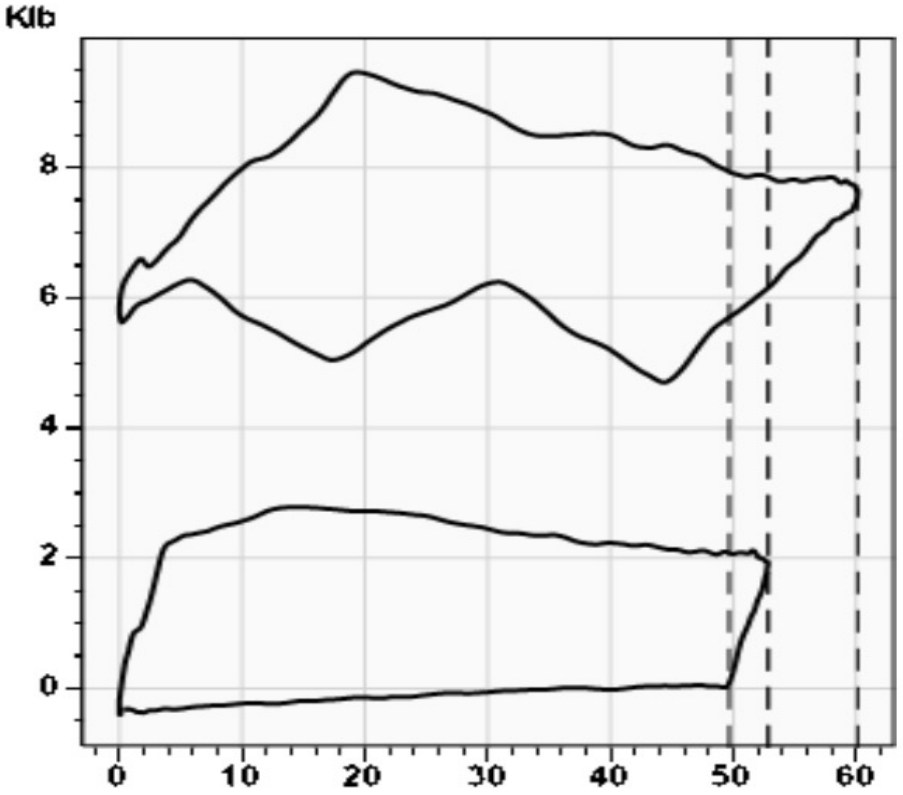
Surface Dyna-Card and Pump Card

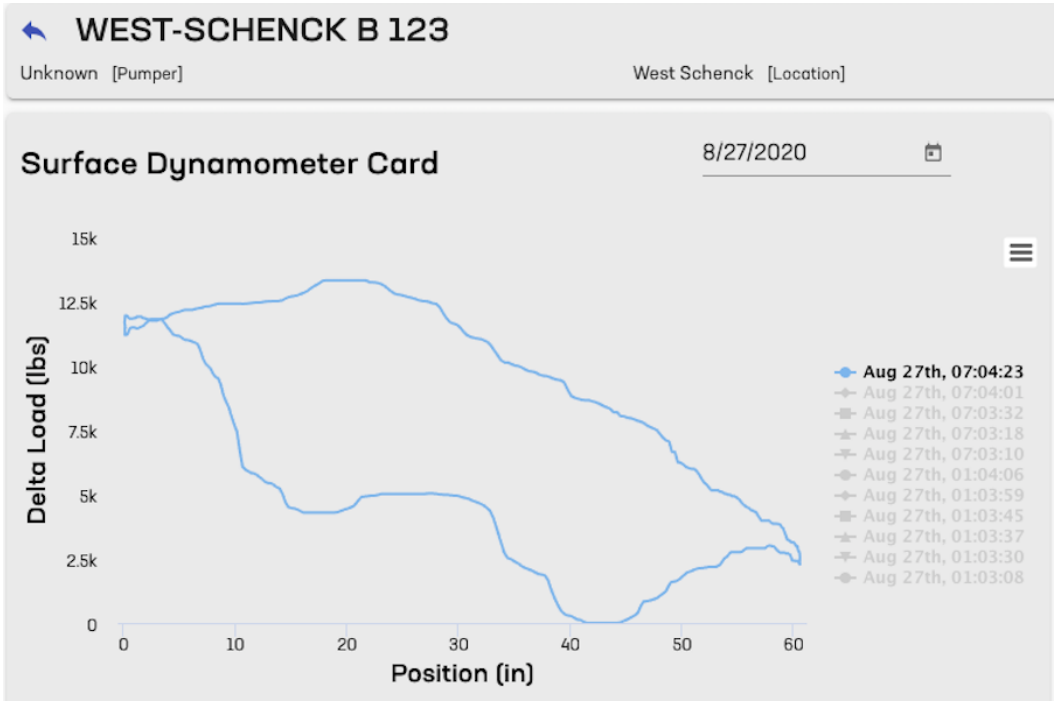


Conventional Pump Cards

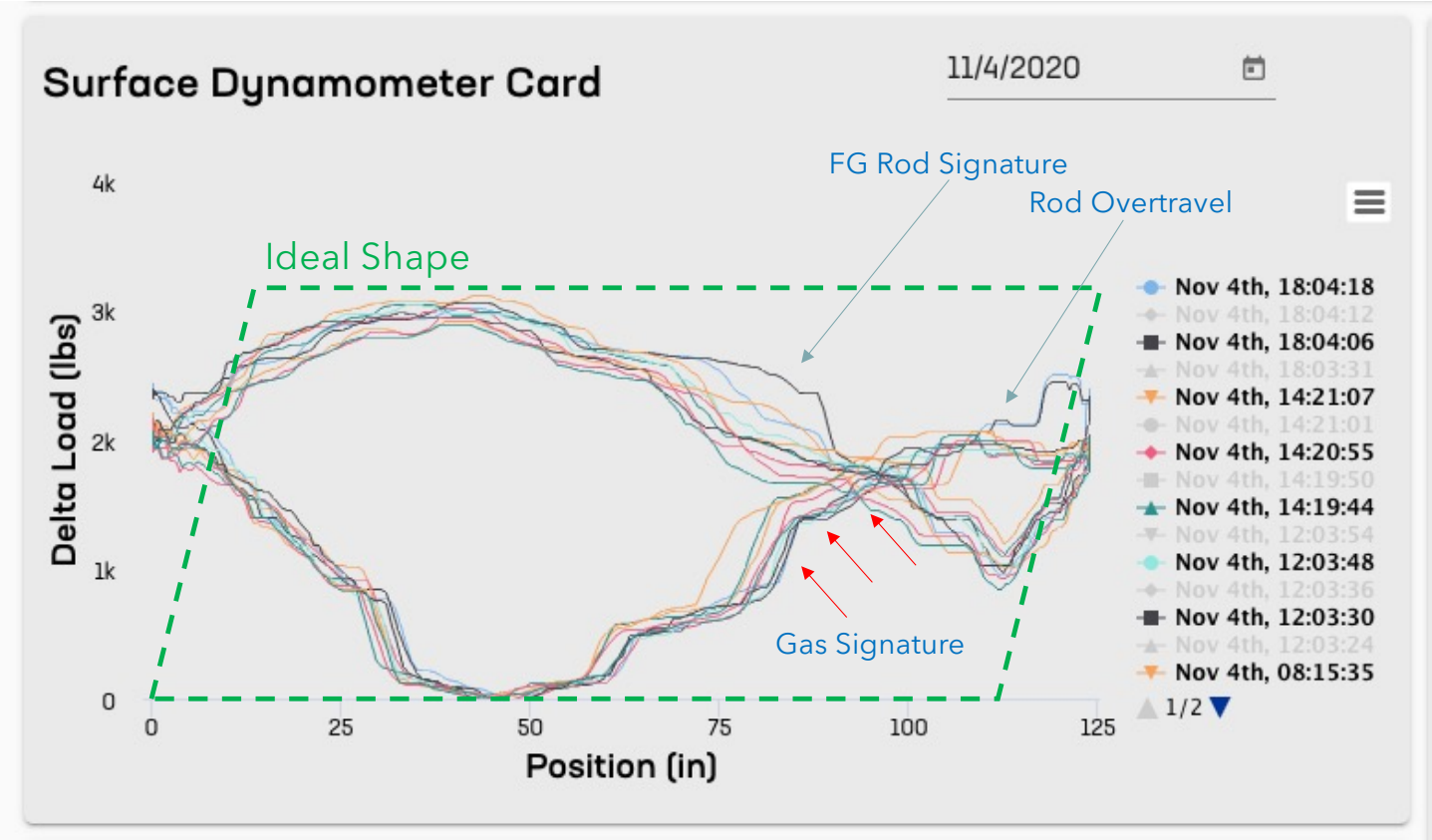


Conventional vs Noven Dyna-Cards





Direct Diagnosis using Surface Dyna-Card



Diagnostics: Working

Proprietary AI Algorithms

- Surface Dynamometer Card Interpretation – I
- Surface Dynamometer Card Interpretation – 2
- Pressure Analytics for oil producer w/ production packer
- Pressure Analytics for oil Producer w/o packer
- Pressure Analytics for Injection well
- Pressure Analytics for Surface flowline + manifolds

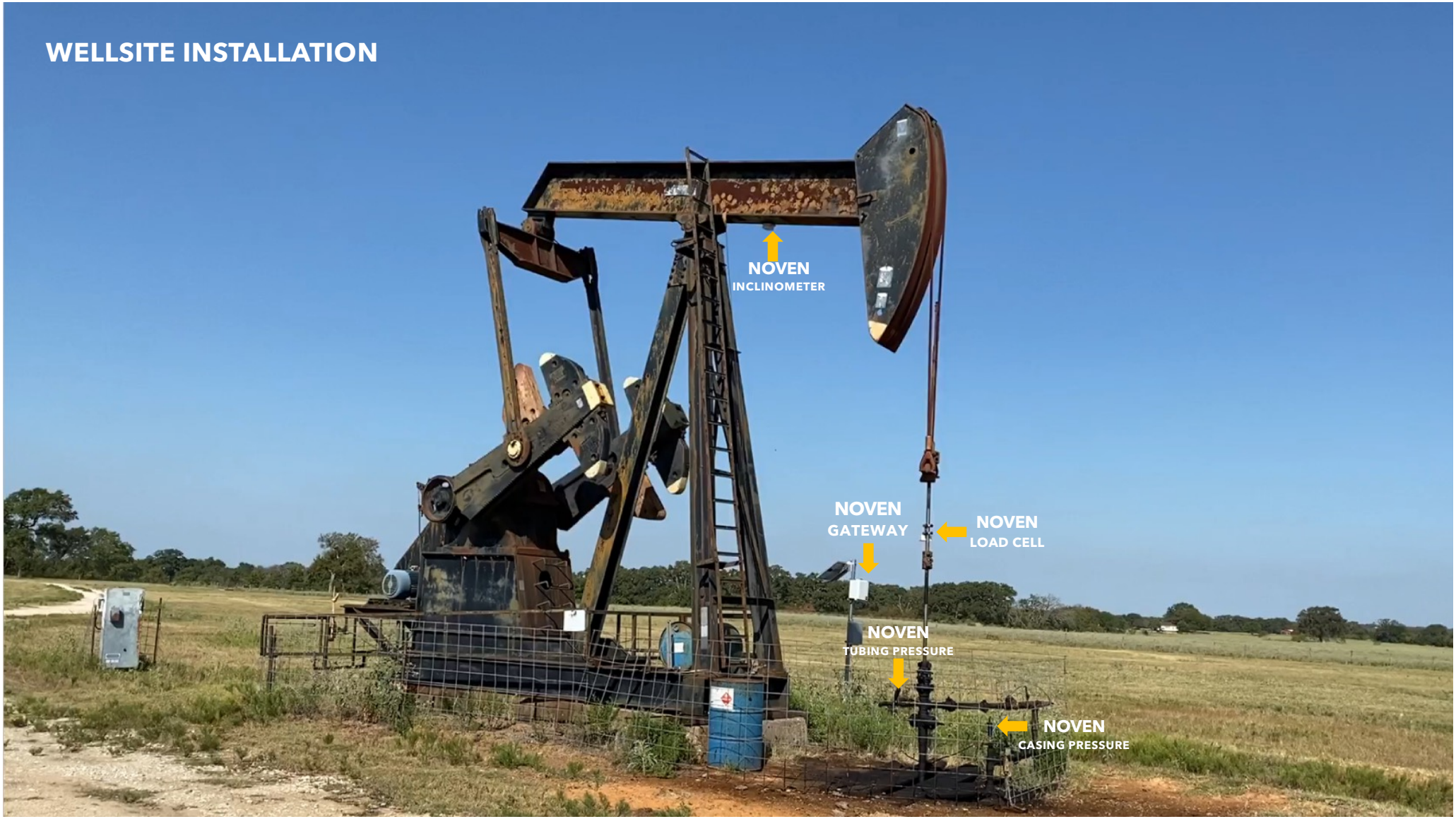
Sucker Rod Pump Diagnostics

Pump Diagnostic	Description	Value of Diagnosis	Action
W	The pump is working, OK	Fair	Keep monitoring
G	The pump is working with gas interference	Moderate	Check gas separator efficiency, production trend, choke setting
P	The pump is working with pumping problems	High	Review pump performance and schedule for intervention
I	Pump is working with mechanical integrity issues	Higher	Review installation, operating conditions, schedule for repair
F	Completion / pump failure	Highest	Review well performance and schedule for workover

Pressure Analytics Diagnostics

Pressure Diagnostic	Description	Value	Action
1	Well pressure trends stable	Fair	Keep monitoring
2	Sudden increase in THP	Moderate	Well Issue (oil/ water) Gas/Water breakthrough
3	Sudden increase in CHP	High	Potential Integrity Issue
4	Gradual Decline in WHP	Higher	Reservoir pressure decline, Well review for stimulation, AL
5	Sudden decline in WHP	Highest	Sanding, plugged pump intake schedule for repair / workover

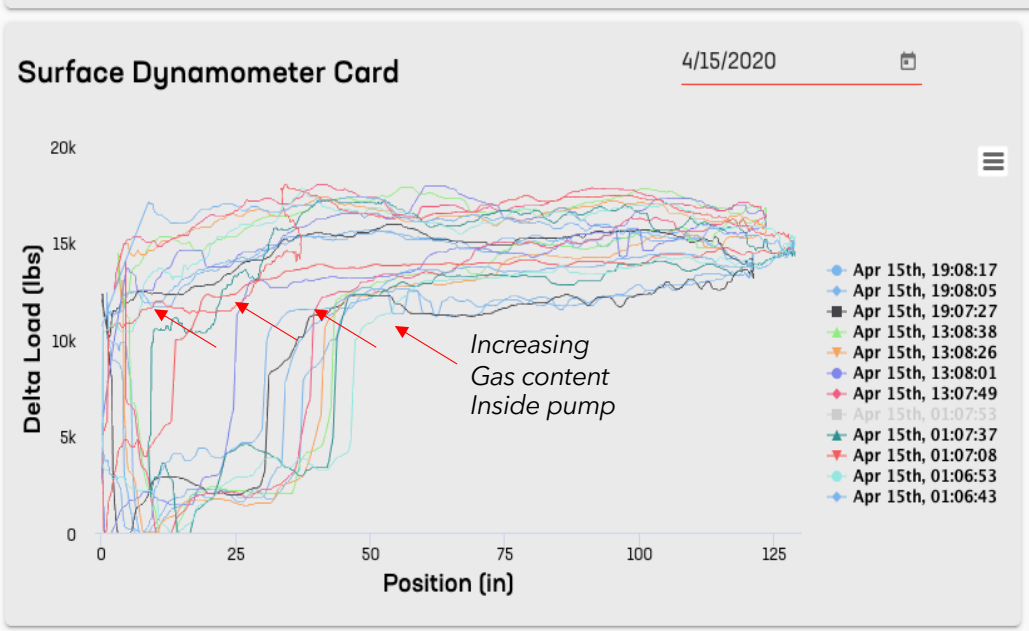
WELLSITE INSTALLATION

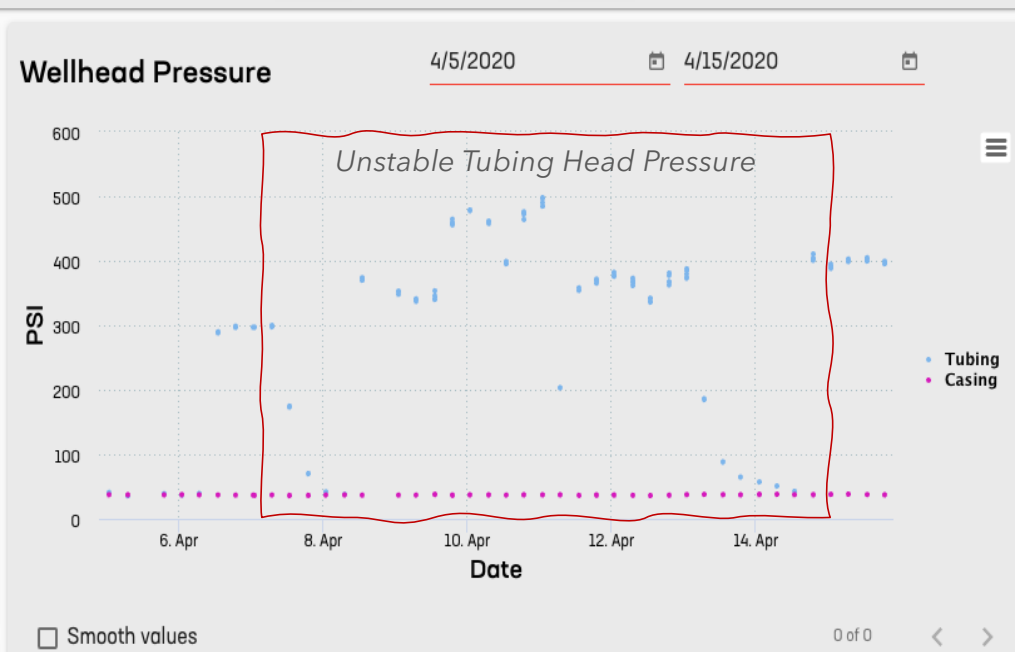


Issues diagnosed from test wells

- Gas Interference
- Hole in the tubing
- Deep Parted Rod
- Productivity decline
- Undersized pump design
- Surface Separation Issue
- Downhole pump issue
- Mechanical Integrity
- Flow line issue
- Well SI

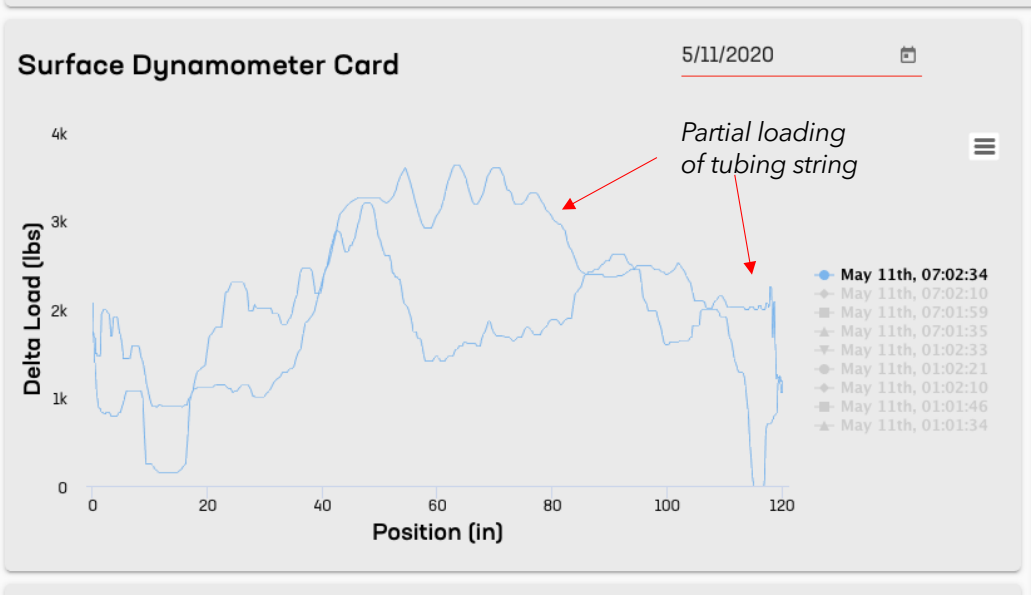
Gas Interference

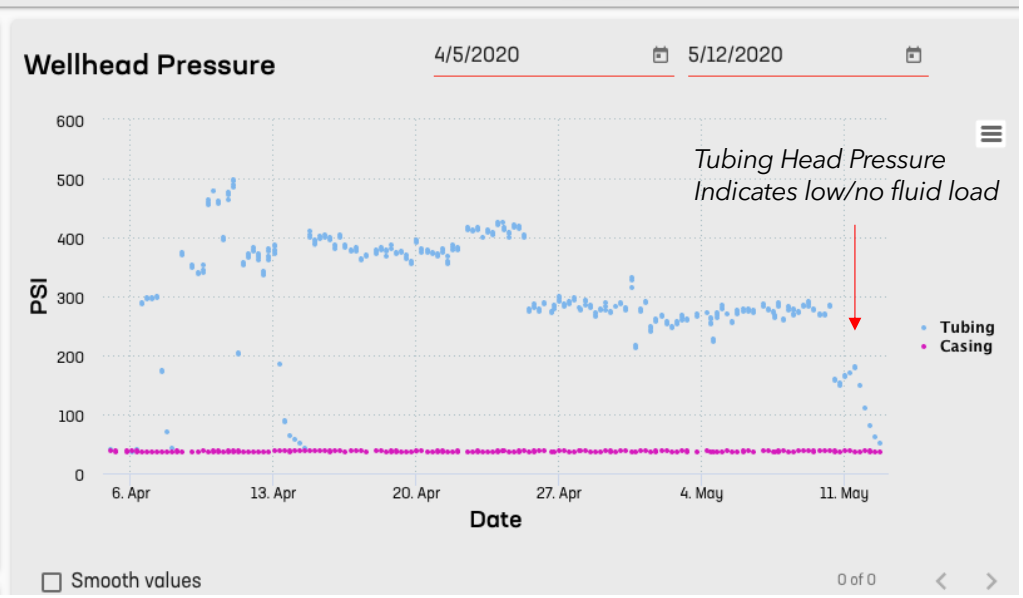




Dyna-card Progressing gas interference
Pressure Unstable THP indicates multi-phase flow with increasing gas content
Impact 70% increase in gas production, losing 250bbls. oil production in a month <40%>

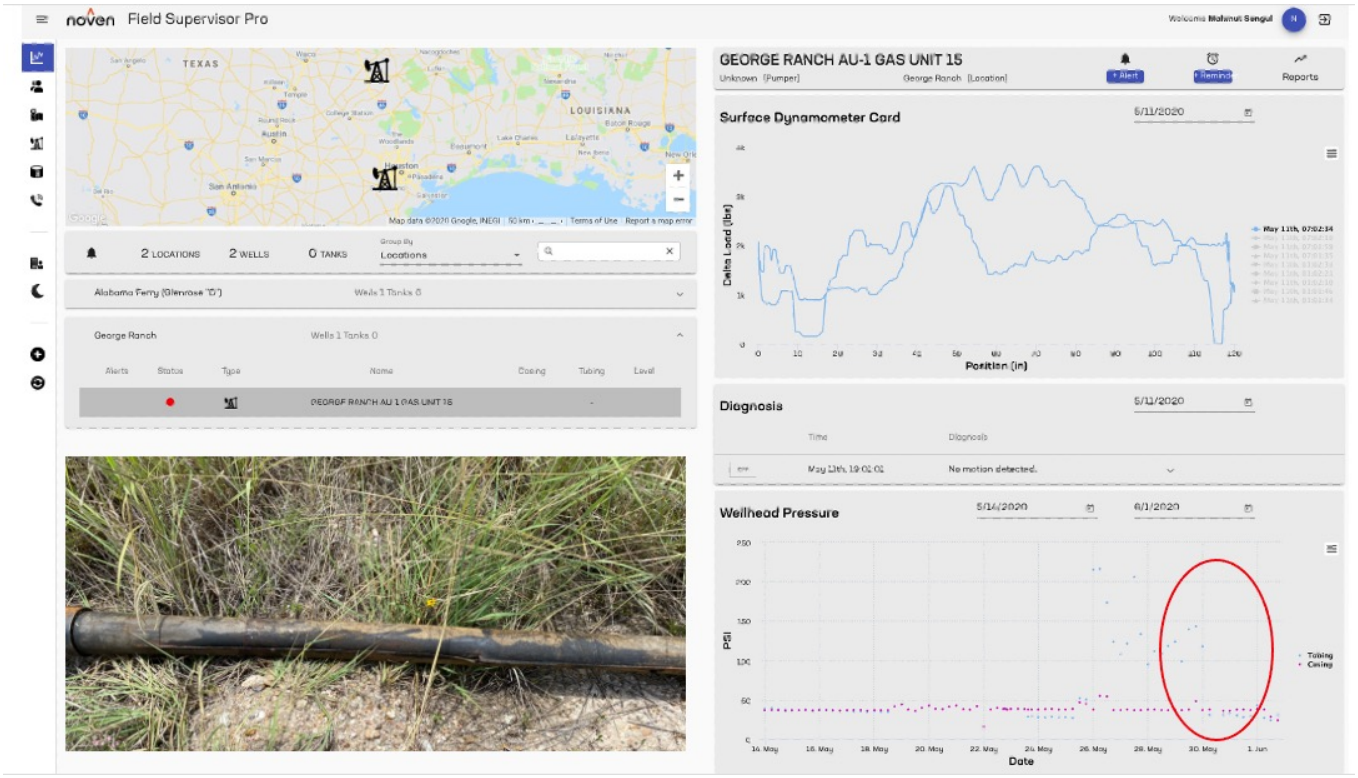
Hole in Tubing





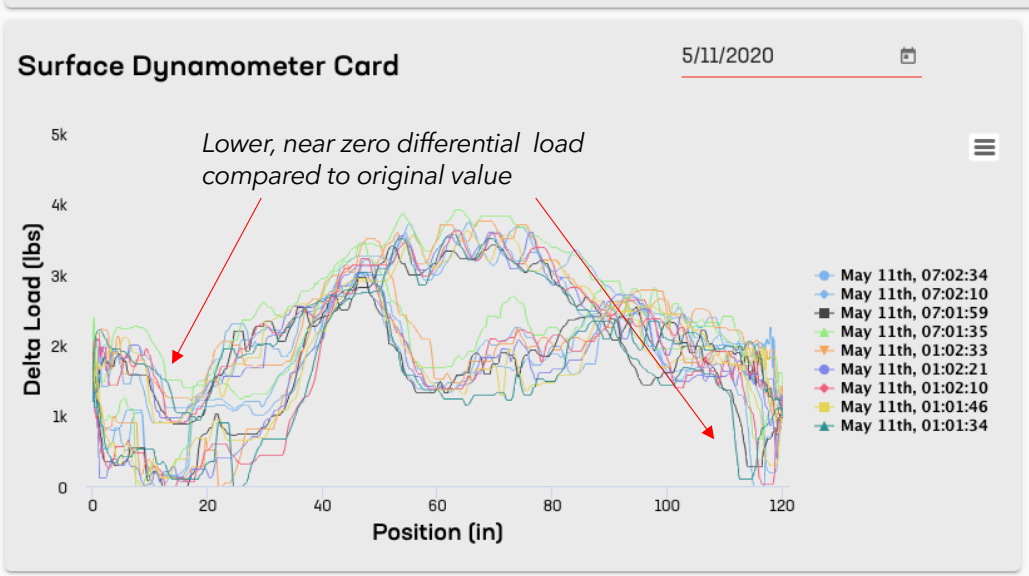
Dyna-card Partial loading of the tubing capacity
Pressure Drop in THP pressure indicates a lower or no fluid load
Impact Losing 300bbls. oil production in a month <80%>

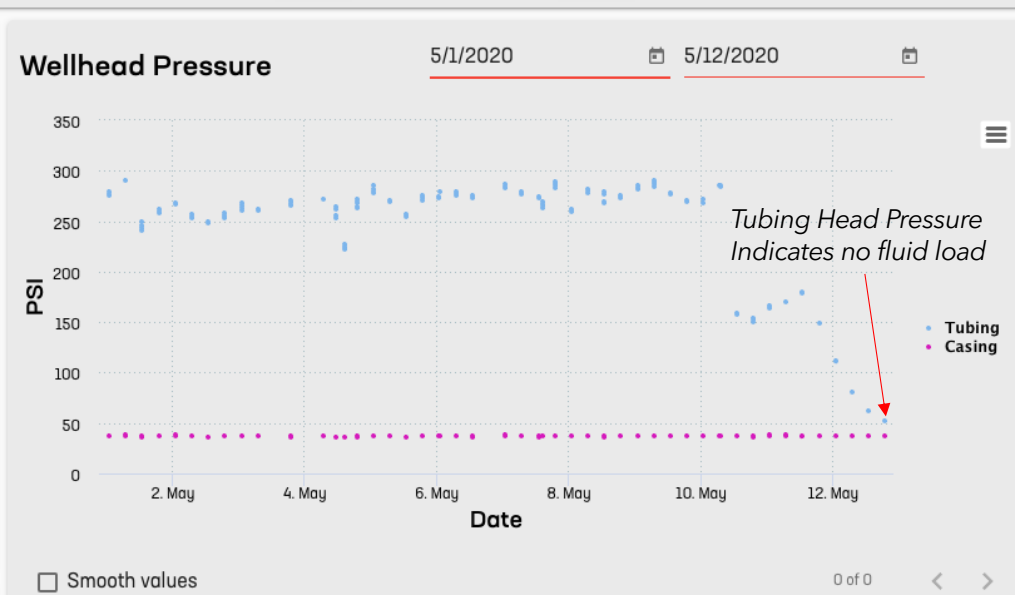
A Hole in the Tubing String



Dyna-card Partial loading of the tubing capacity
Pressure Drop in Tubing Head pressure indicates a lower or no fluid load
Impact Lost 80% of oil production

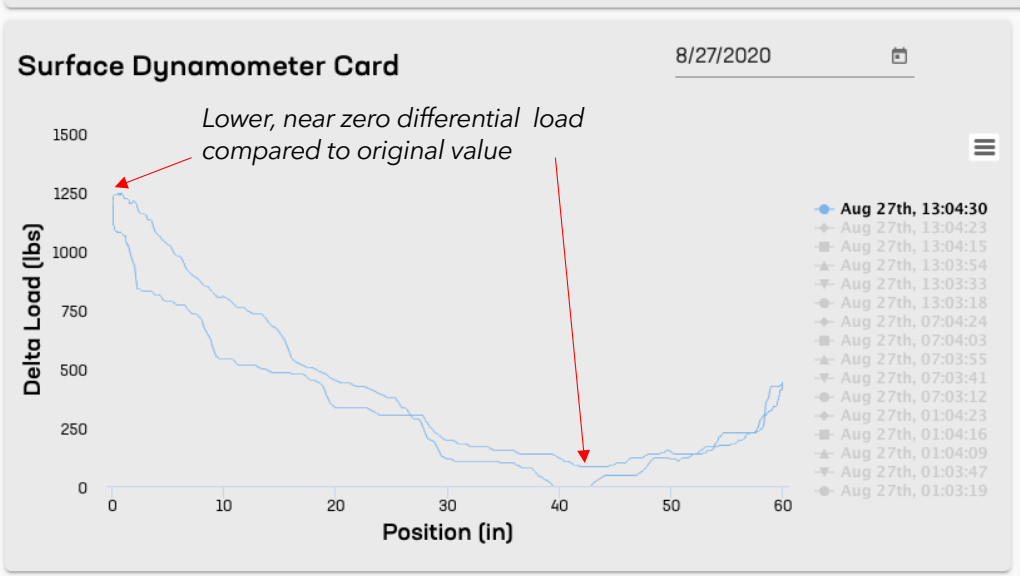
Deep Parted Rod

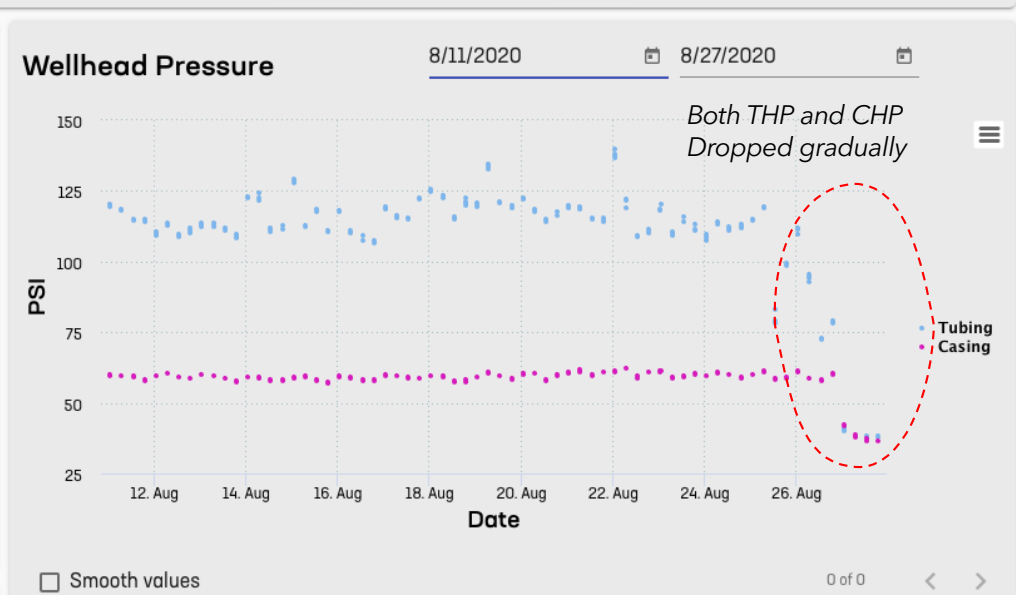




Dyna-card No appreciable load compared to the expected (0-3klb. vs. 15-20klb.)
Pressure Drop in THP pressure indicates a lower or no fluid load
Impact Losing 450bbls. oil production in a month <100%>

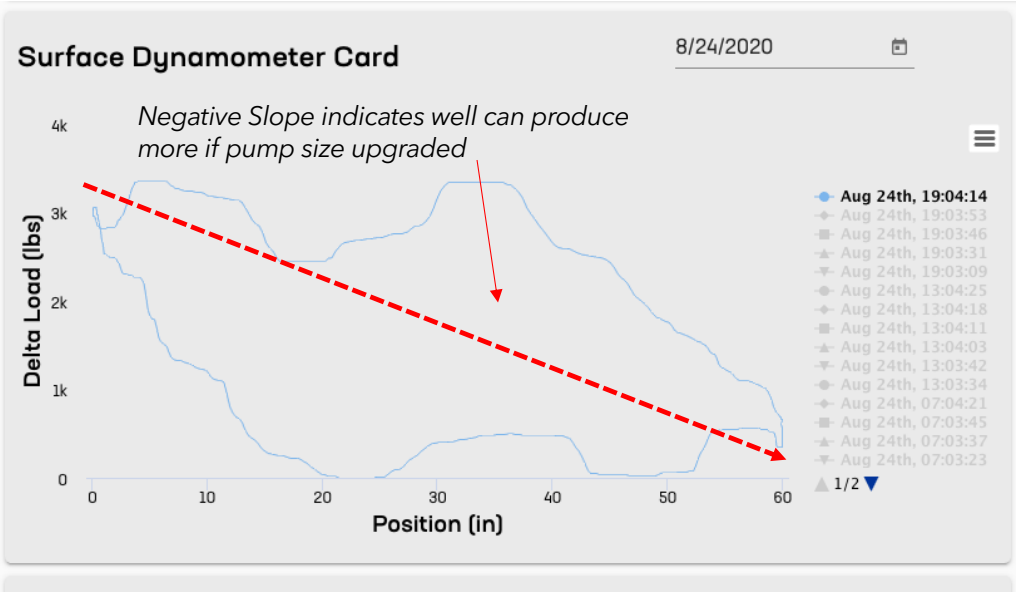
Productivity Decline - Sanding

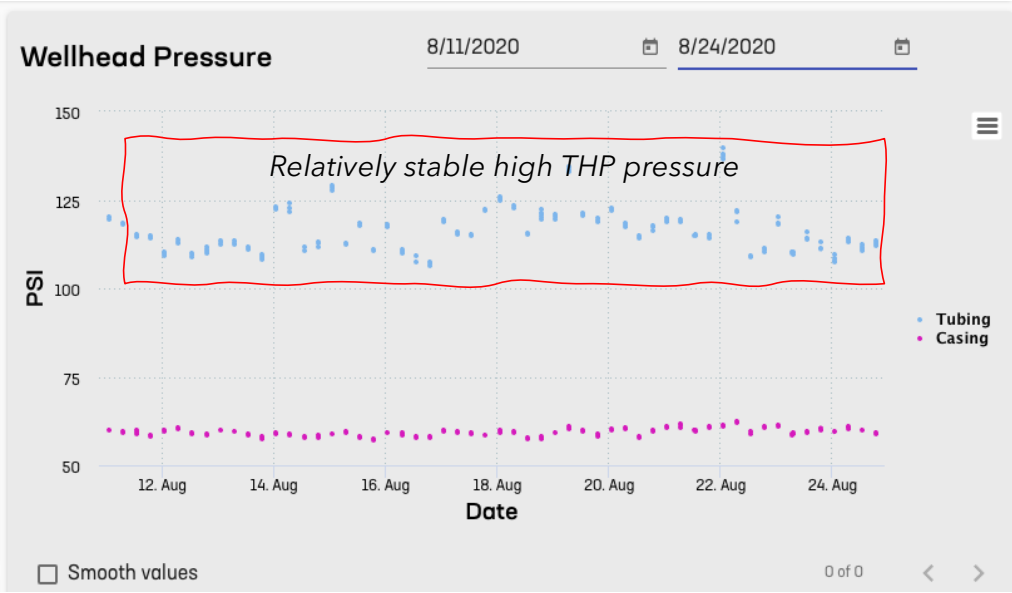




Dyna-card No appreciable delta load compared to the expected (0-1.5klb. vs. 8-12klb.)
Pressure Drop in both Casing and Tubing pressure indicates a limited flow from reservoir
Impact Losing 150bbls. oil production in a month <90%>

Production Optimization Opportunities

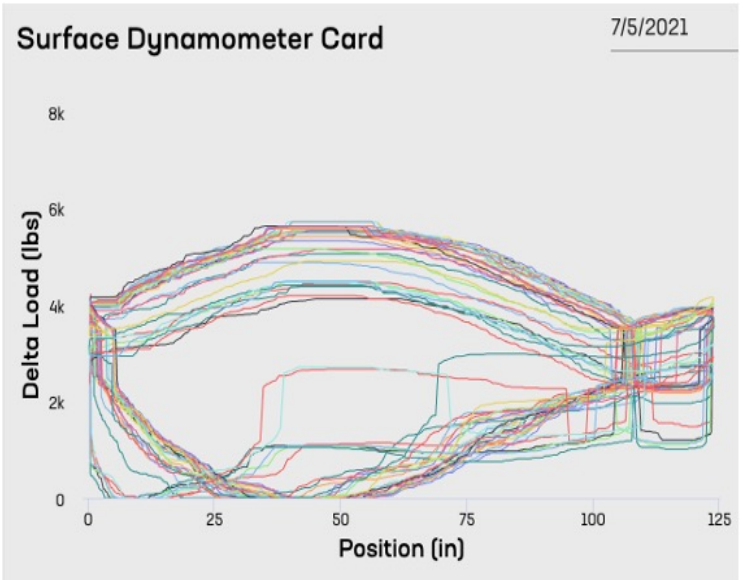




Dyna-card Delta loading indicates tubing is full. However, negative slope shows upside
Pressure Stable high tubing pressure indicates an additional production capacity
Impact 250bbls. Incremental oil production in a month 40%+

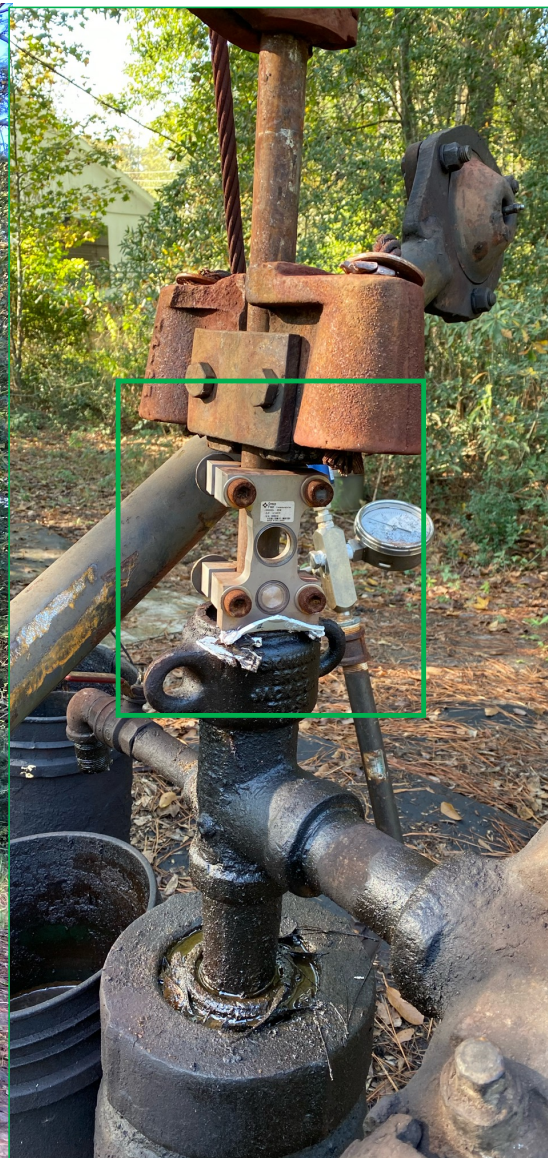
Undersized Pump

Gas Slug Detection in HW



Dyna-card Delta loading indicates unstable fluid gradient
Pressure Tubing pressure fluctuates
Impact Detecting the gas slug in horizontal well is a very instrumental to avoid premature pump, well failures
Operator can immediately act to advert costly workovers
Increased production efficiency translates directly more uptime, more revenue

Structural Integrity Failure



Benefits of IoT System for SRP Wells

- AI/ML powered way of monitoring, managing SRP operated wells
- Cutting edge end to end technology platform
  - Scalable from few to 1,000's of wells
  - Extensible to monitor, automated diagnose of well pads, clusters, remote manifolds, facilities
- Affordable
  - Differentiation by choice of technology
  - Fraction of cost compared to alternatives
  - Deployable at new and existing wells

Cost Benefit Analysis

System Deliverables

- 20+ Dynacard 3 to 4 times a day.
  - Dynacard is the gold standard for Sucker Rod Pump (“SRP”) performance evaluation
  - All of them are automatically interpreted using “Edge Computing AI system”
  - Actionable diagnosis is delivered directly to the “Production Engineer”
- The evolution of casing and tubing pressure is continuously analyzed by Edge computing AI system for detection of well & completion issues (packer, tubing leaks, flow assurance, formation damage) on a:
  - Short time basis
  - Long time basis
- If needed, a qualitative “gas slug” monitoring, detection based on the analysis of the 20+ Dynacard taken out each acquisition
- All Wells are automatically diagnosed (a few times a day)
- System automatically highlights priority issues and proactively direct needed intervention

Cost Benefit Analysis

- A field of 100 wells producing 50 BOPD will deliver 150,000bbls. a month, for a value of 7.5M$ (oil price of 50 $/bbl.).
- A reasonable assumption is that 10% of the wells are experiencing some of these issues
- The early detection of the issue allows to gain on average about 2 weeks on the resolution
- The production gained would have a value of $375K per month. This is not considering any savings from the ability to have much less required human presence in the field, less driving time (on average long travel distances), less safety risk, and measurable lower carbon footprint.
- The monthly cost of the system is order of magnitude cheaper for the entire field compared to existing practice.
- Even if one takes a very conservative assumption of only 5% of the wells having issues, the system has still a high payback

IoT Driven Diagnosis system

Action taken on diagnostic allows to avoid unplanned system downtime

➔ ***more oil production revenue***

➔ ***lower operating cost***

Knowledge of the key components allows to optimizes maintenance schedule

➔ ***more oil production revenue***

➔ ***lower operating cost***

Knowledge of the state of key components allows to eliminate catastrophic incidents

➔ ***more production revenue +***

➔ ***catastrophic risk full mitigation***

Full cash payback of The System in weeks

Summary

- Set of proprietary advanced sensors, *fully wireless*
- Edge-computing
  - AI locally runs, produces automated diagnosis that can be acted upon
  - Reports pushed to cloud or on-premise server a few times a day
- AI/ML Algorithms
  - Surface Dyna-Card → Does not require empiric computation, direct measurement used to estimate state of pump operation
  - Pressure Analytics → time series analysis, provides state of well inflow
  - In progress of combination of both provide state of whole well system
- One production engineer can manage 100's of wells daily
  - Has a daily automated diagnostic of all his wells
  - He /She can concentrate on new issues

IoT for all

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Noven Operating Environment

1. Amazon Web Services (AWS) System deployed on May-13, 2019

   OKLATEX, Claire -1 Test well

2. Noven private Cloud Server installed on Sep-19, 2020

   Tri – City Oil – Pinchback Seawillow, SW-16

3. Noven On-premise server up and running since May-12, 2021

   Viceroy Petroleum, WSB-1876

What Noven System provides?

- 20+ Dynacards 3 to 4 times a day.
  - Dynacard is the gold standard for SRP evaluation
  - All of them are automatically interpreted using “Edge Computing AI system”
  - Actionable diagnosis is delivered directly to the “Production Engineer”
- The evolution of casing and tubing pressure is continuously analyzed by Edge computing AI system for detection of well & completion issues - packer, tubing leaks, flow assurance, formation damage, issues - in a
  - Short time basis
  - Long time basis
- No other system delivers automatically that many analysis.
- ”How many Dynacards does an engineer analyze daily today?”
- “How many wells are reviewed by an engineer on a daily basis today?”

Results in a field

Assumption:100 wells with 300BOPD/well

- One single Engineer can manage the whole field with never attained results
- Very early identification of pump integrity (leaking valve, rod, gas issues)
  - If only 5% of the wells get an issue and we detect it 10 days earlier, what is would translate?
  - Oil Company can react to the issue 10 days earlier saving an equivalent of 50 well/days of full production
  - If one assume the issue resulted in 50% loss of pumping efficiency, this represents 7,500bbls oil in a month
- In the same way early detection of flow assurance (casing, tubing, formation damage)
  - 5% of the well with issue and saving again 10 days to react (very conservative)
  - making up for a 50% production loss represents again 7,500bbls/month savings
- The deployment of the Noven System in a 100 wells field
  - will cumulatively save 15,000bbls oil / month production

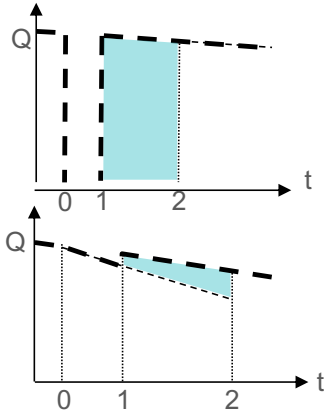
Value Metrics

1. Efficiency

Same activity or decisions with lower OPEX; saved CAPEX or improved Capital Efficiency and well/facility utilization

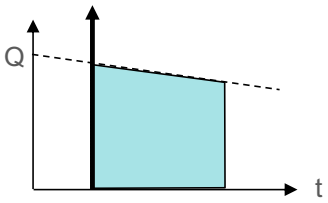
2. Minimize lost or deferred production

Avoid falling below the original production target



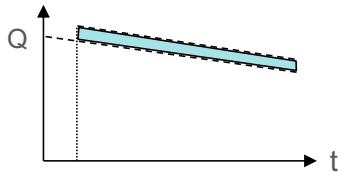
3. Penalty Avoidance

Avoid events with large impulsive cost (e.g., spill, leak, noncompliance, loss of capital equipment)



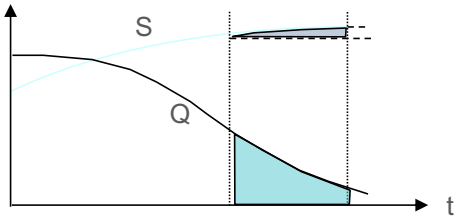
4. Accelerated Production

Exceed the original production target



5. Increased Recovery

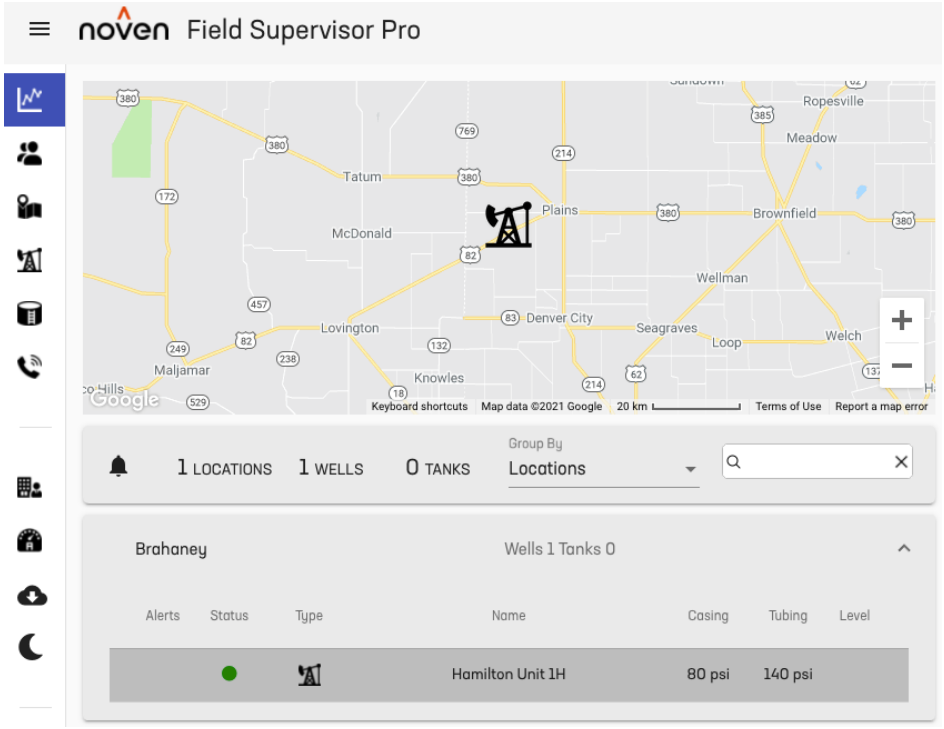
Extend field life by reducing economic limits

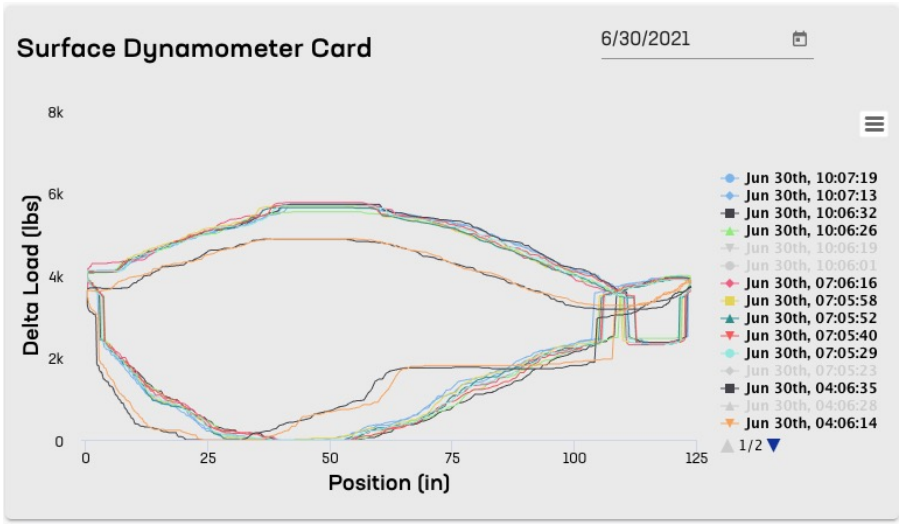


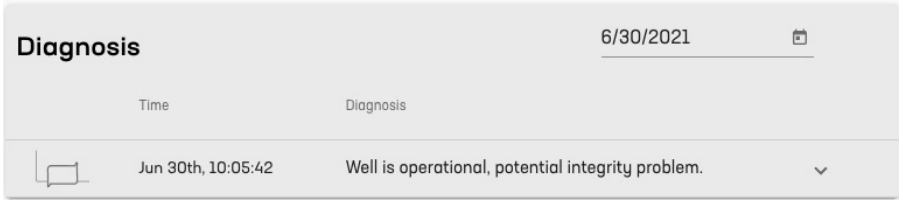
Class Labeling rules and guidelines

- All classification decisions must be supported by visual evidence in surface and subsurface dyna-cards
- No supplementary data (including technician comments, other physical or processed data, weather conditions, etc.) must be taken into account if they yield another class label other than visually demonstrated in a dynacard, unless these data is a part of classification algorithm
- If dynacard demonstrates features from multiple classes, the labeling should be done based on dominant feature. If there is no dominant feature the dynacard should be skipped.
- Dirty data clearly demonstrating sensor malfunctioning should be skipped and not labeled

SRP Well View







Water Injection System Monitoring