OPTIMIZING ROD LIFT OPERATIONS WITH EDGE COMPUTING

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ABSTRACT

Rod pump operations often suffer from high manual workload, limited diagnostics and dynamic well conditions. For wells fitted with controllers and variable speed drives, challenges remain around data gathering and evaluation, bringing well specific insights to action and a continuous need of physical supervision to ensure well uptime. Edge computing and Internet of things (IoT) technologies offer high frequency data gathering, real-time evaluation and a tool to enable operators of oil and gas wells to help optimize production and automate some redundant tasks. During my time at Oasis Petroleum and Agora Edge Solutions have developed a rod pump management platform to ensure best operating conditions, autonomous dynacard evaluation and interventions and a proactive approach to help operators manage anomalous conditions in some high failure wells.

INTRODUCTION

Sucker rod pumps remain one of the oldest and most common methods of artificial lift in the oilfield today. In the Bakken specifically, they continue to be a mainstay for production teams. Modern production operations rely on pump off controllers, variable speed drives, and surveillance software to maximize production and optimize well reliability. The automation technology deployed today uses logic based around fluid level, flow, vibration, and rod loading to effectively manage rod pump operations. Setpoints are managed locally or remotely by operators who can change upwards of 150 unique parameters on an individual well. Many operators manage hundreds of wells individually, and it can be challenging to troubleshoot well problems and update well setpoints given the large volume of data that must be observed prior to making changes.

The primary diagnostic tool for rod pump performance is the dynamometer card [image]. This is a graphical relationship between the rod position and rod loading. There is a surface and bottomhole dynamometer card and operators use the shape of these cards to determine normal or abnormal downhole conditions. An experienced production operator will classify the cards they see and take actions on the rod pump's setpoints to mitigate abnormal behavior. However, it is difficult to do this in real-time and operating under abnormal conditions such as tagging can lead to high rates of downhole failure. Tagging is when the weight of the rod string makes contact with the top of the pump and the impact from even a few tagging events can result severe damage or failure (Fig. 1).

High performance edge computers present an opportunity to address abnormal well conditions in real-time. Machine learning algorithms to classify each individual dynamometer card can be run locally at each pump and capture abnormal conditions as they occur. Unlike pump off controllers, edge computers look beyond individual setpoints and operating parameters to optimize pump performance. This enables the edge device to adapt to the pump's previous and current behavior to optimize future setpoints with the goal being to reduce the dependence on manual surveillance, improve pump reliability, and optimize well production.

This paper will focus on the use of edge computing to reduce failures in rod pump wells through use of intelligent workflows at the edge. First, we will review current methods of data capture and the opportunities edge computing creates with higher fidelity data. Next, we go through the advantages of deploying these models at the edge and the variety of models being deployed to address the initial challenge. Finally, we will attempt to demonstrate the value of the solution to reduce failures by looking at a 74-well pilot spanning 8 months.

SCADA AND EDGE COMPUTING

Many operators utilize a SCADA system to monitor the data remotely, sometimes from a control room. A SCADA system does its job very well in raising any threshold breaches or avoiding sudden failures while providing data access. However, many challenges remain in the current oilfield environment. With limited device integration and scalability, lack of contextual data and its assessment, SCADA systems alone are not capable to drive integration and innovation in the field. This is where Industrial Internet Of Things (IIoT) and edge computing can complement existing infrastructure (Fig. 2).

Operators have realized that to reduce their cost per barrel, they cannot have an isolated view for different components of oilfield operations. To gain efficiency, operators must minimize the bottlenecks in the system from reservoir to surface to facilities. IIoT has allowed operators to enable intelligence at the well or facility to minimize manual intervention and collect the data in a centralized location. An IIoT platform should be capable of delivering dynamic intelligence to the field through edge computing combined with domain expertise and operational experience.

The edge computing platform, designed specifically for the oil and gas industry, must have the following capabilities:

1) Openness: Openness refers to the ability to work with field equipment from any manufacturer. Additionally, data generated from field equipment can be transmitted to open, public or proprietary data ecosystems. Within this context, openness also refers to open innovation. A collaborative approach necessitates use of an open and fully adaptable software development kit that can be used by any company looking to bring innovative edge computing and IIoT solutions to the oilfield. It would benefit from a partnership ecosystem, to bring digital innovation from both inside and outside the oil and gas industry.
2) Security: Ensuring edge computing and IIoT solutions are secure is paramount. These solutions must be secure by design and in operation—from the edge to the cloud to the enterprise—covering data security and asset integrity.
3) Scalability: Due to the complex nature of the industry, scalability is critical. An edge computing and IIoT platform for oil and gas must be agile, with the ability to independently manage multiple operational use cases, while also enabling edge device management through remote tools and over-the-air updates.

ADVANTAGES OF IIOT SOLUTIONS:

An IIoT-enabled solution brings intelligent ways to approach various operational and data management challenges (Fig. 3). Below are some of these benefits:

1) Fast track asset digitization:
   To achieve operational efficiency, operators are moving to digital transformation. In turn, there is a requirement to bring more assets online and collaborate on a common platform to achieve a holistic understanding of gaps and potentials across the field. Edge IIoT solutions expedite the digitization process at much lower cost while connecting assets and bringing data in a contextual collaborative format to maximize productivity in field operations.

2) Dynamic intelligence with edge computing:
   Edge computing allows the operator to test multiple workflows on the streaming data and capture relevant insights. The computations done on the edge can help track and control assets in a fast loop manner while pushing only relevant data to the central cloud computing platform thereby achieving high efficiency.

3) Automation of manual tasks:
   Traditionally, operators spend a great deal of their time in collecting and analyzing data manually. An IIoT platform captures data in high frequency while the edge computations allow real-time

analysis and feedback. Also, it empowers the field operator to capture and write data directly onto the platform thereby breaking the data silos. With this approach, operators and engineers get more time to focus on critical operational issues and improved productivity.

4) Proactive asset management:
With suitable instrumentation and high frequency data, an IIoT edge solution can track and proactively monitor any equipment or asset in the field with smart alerts to the user on the condition and equipment prognostics.

5) Reduce HSE risk and environmental footprint:
Many E&P operators worldwide are identifying ways to minimize operational and HSE risks and reduce carbon emissions due to some manual tasks requiring on-site visits. With remote operations and edge computing workflows enabled by an IIoT solution, allowing some operations to be conducted remotely or even autonomously.

CASE STUDY

The pilot was performed on Oasis Petroleum wells in Bakken Shale, North Dakota. Currently, the Oasis operators manage over 1500 rod pump wells in the Williston basin. The rod pump controller data is transmitted over SCADA. The goals of the pilot were:

1) Identify and mitigate tagging. Tagging is thought to be a contributing factor to failures and if the number of tagging events was reduced or eliminate then failures should be reduced. Edge devices enable cards to be gathered and evaluated from every stroke as opposed to a handful which are seen with SCADA.

2) Increased surveillance of high failure wells: Dynamic conditions seen in some wells would benefit from frequent set point changes. Performing those changes utilizing SCADA frequency data is very difficult but with the addition of edge devices, these conditions can be immediately identified and action can be taken autonomously to better match set points to current operating conditions.

3) Production Optimization: Unconventional operation present challenges associated with handling gas. Long laterals which load up with fluid and then unload rapidly create conditions which go from full fluid in the pump to gas interference and finally to pumped off conditions. Edge computing enables every stroke and pump card to be gathered and evaluated and appropriately responded to. A big advantage of the edge solution is the ability to have multiple secondary pump fillage setpoints depending on the card shape. If cards are experiencing gas interference and the operator is comfortable with lower set points to be able to work through gas, then that can be accomplished. When a lateral loads up, fluid entry is minimal and cards are pumped off, a higher pump fillage set point can be employed. This has the advantage of being able to maximize production by not shutting down operations if conditions are just gassy, but identifying and mitigating fluid pound conditions to prevent damage to equipment.

4) Gain in operator efficiency: Most companies are looking for ways to become more efficient in every aspect of operations and edge computing presents a way to achieve that goal. Edge devices are able to instantly identify conditions where downhole pump are no longer pumping and notify the operator that action needs to be taken thereby reducing downtime. The devices can identify conditions where wells are pumping at maximum stroke per minute with high pump fillage and notify the operator that there is possibly an opportunity for increased production. The devices can autonomously optimize idle time for rod pumps by trialing different idle time settings on a scheduled timeline.

These are common problems for many exploration and production companies where the number of wells has grown exponentially over the past few years. It is becoming increasingly difficult to effectively evaluate data from every well on a daily basis.

Edge devices are a tool to help operators, technicians and engineers become more efficient and be able to more effectively manage their wells.To solve the above challenges at minimal cost and bring maximum productivity, edge gateways were deployed to connect to the rod pump-off controllers. Real-time high-frequency data was analyzed and calculated at the edge to capture the rod pump behavior. The wells data was securely transmitted and can be accessed anywhere from a mobile device or computer with the ability to remotely control the rod pumps. The solution provided immediate value in:

- Data accessibility and real-time monitoring
- Edge calculations to derive pump fillage and dynacard diagnostics
- Smart alerts to the user to assess current conditions and act proactively
- Optimize pump performance and personnel management

Edge-enabled real-time dynacard analysis

Dynacard analysis is a critical piece of sucker rod pump diagnostics. A dynacard is a plot between rod load and displacement over a pump cycle. The subject matter experts refer to dynacards for a quick snapshot analysis of the pump performance. The shape of the dynacards reflects the phenomenon happening in the well and requires a trained eye with oilfield experience to distinguish between different pumping situations and issues. Often, pump dynacards are overlaid to find any anomalies in the pump behavior.

Since every pump stroke generates a dynacard, there are thousands of cards generated in a few days, and it is not humanly possible to go over each and every card. Typically, rod pump software collects 5-20 dynacards per day for a well which are analyzed to assess the pump behavior. The edge device performs automated classification using computer driven pattern recognition techniques. This approach was taken to solve the challenges on identifying a critical pump signature as soon as it happened by deploying a pattern recognition model on the edge gateway. This module used machine learning libraries on the edge and analyzed data from every stroke to return a dynacard classification in real time. Smart logics were put to ascertain a pump issue and then provide email notifications to the operator so that wells could be prioritized for immediate action.

To keep the model in an evergreen high-confidence prediction state, inputs from domain experts are often required. Traditionally, this is a big challenge because the data interpretation usually happens outside the application and its very difficult to combine the feedback to enhance the existing models. The rod lift solution deployed with the IIoT platform allows continuous feedback and model update in the same application so that the model truly leverages the domain inputs and feedback and always remain highly reliable. This workflow has resulted in better collaboration among the engineers and pumpers while providing a single source of truth in their operations.

Closed loop autonomous control

The edge algorithms which run on the gateway provide real-time management of rod pump wells. First, these algorithms continuously monitor the trending pump parameters and dynacard behavior with the production performance. These snapshots taken in real-time guide the data-driven model to identify anomalies and take autonomous action e.g., changing VFD settings to manage SPM or pump downtime. Second, the algorithms capture the data patterns and determines whether a production optimization opportunity is available. The VFD settings are then changed to reflect the new settings for the pump. These algorithms run continuously learning from the data and together with constraints such as run time, number of pump cycles etc., work to ensure an optimal setting at all times.

RESULTS

The pilot wells were in the Bakken and Three Forks formation. The wells are 10,000’ – 12,000’ deep horizontal wells completed using modern multi-stage hydraulic fracturing techniques. A total of 74 wells were selected for the pilot. The evaluation took place over 8-months with the objective being to reduce the 12-month failure rate and maintain or improve base production.

Prior to the installation of the edge devices, the average of the previous two-months of production were used as the baseline for the well's performance. A two-year history of failure data was compiled for the 74-wells in the pilot. At the start of the trial, the average failure rate of the wells was ~1.5 and steadily decrease to the current rate of ~1.00.

The algorithms deployed on the edge device primarily focus on adjustments to the number of cycles and strokes per minute. Cycles are the number of times the pump shuts off when the pump fillage threshold is too low. The pump shutdowns for a pre-defined amount of downtime before restarting operation. This process is controlled automatically by the pump off controller. One hypothesis from this project was that excessive cycles led to inscreased wear on the downhole equipment, therefore a reduction in cycles should lead to lower failures. Figure 5 demonstrates the effectiveness of our algorithms in reducing the number of cycles on these wells.

When it comes to reducing failures, reducing the strokes per minute, is the most obvious way to reduce wear related failures. The challenge becomes reducing failures without sacrificing production. As you can see in Figure 6 and 7, the edge-based algorithms work to improve pump fillage and run time by more than 8% over the trial period.

The strokes per minute were reduced by 7% (Figure 8), cycles were reduced by 36%, pump run time increased 7.8%, and pump fillage increased by 3%. Figure 9 shows the 33% reduction in failures versus the 12-month moving average.

CONCLUSION

Digital transformation is a tool which can potentially help lower operating expenses and improve profit margins. In today's marketplace, it is imperative that companies leverage digital innovation to improve efficiencies and achieve higher performance levels. The industry has been challenged with developing innovative technologies to reduce total operating costs and enhancing the productivity of both people and oilfield equipment, all while minimizing HSE exposure and environmental footprint. Given the data silos in existing infrastructure, the variation in equipment communication protocols and the lack of standardization in data storage structures; it may become infeasible to align data and processes together to operate in a holistic manner. As digitalization process of field assets starts maturing, more operators could start seeing and leveraging the benefits of IIoT solutions by smartly instrumenting and enabling scalable workflows for a full-field optimization. By driving dynamic intelligence through an open, secure computing and IIoT platform, oil and gas operators can potentially achieve a step change in performance. Using a digitally empowered environment and domain-specific workflows and algorithms, companies may be able to enhance operational efficiency and productivity.

ACKNOWLEDGEMENTS

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FIGURES

Fig. 1: Sucker Rod Pump Damage

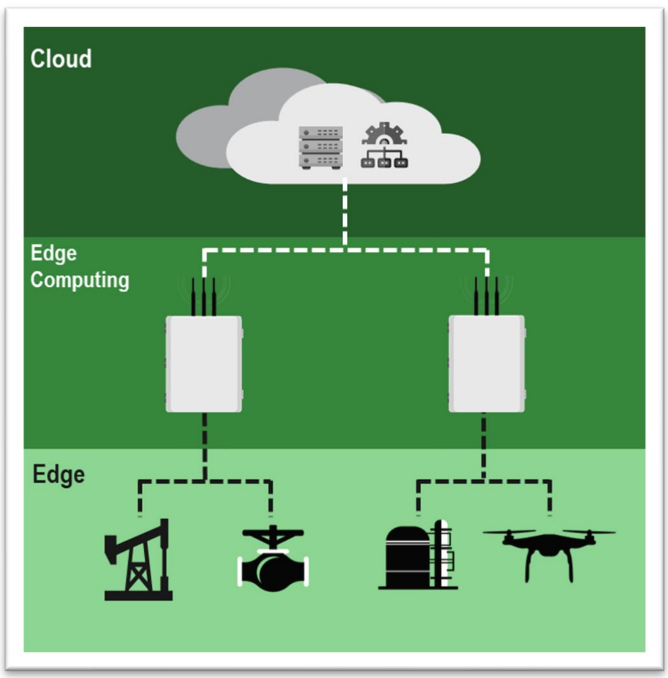

Fig. 2: Cloud and Edge computing

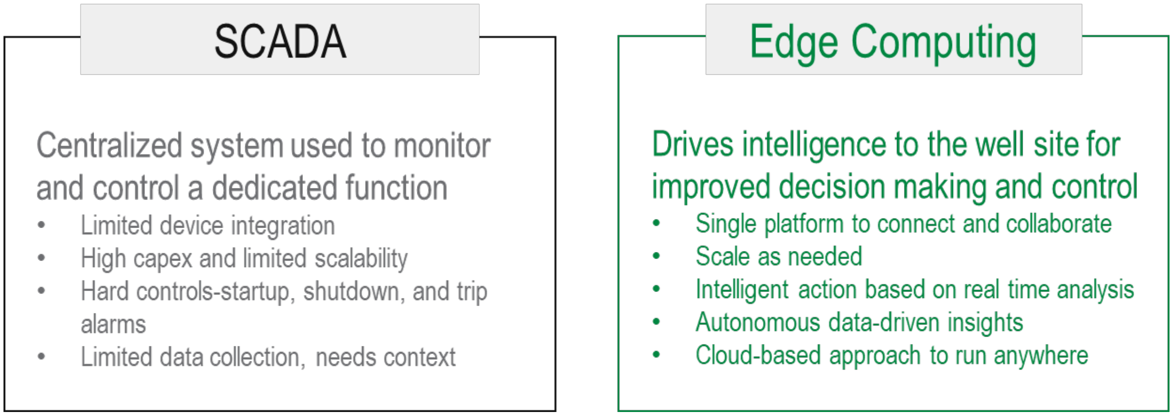

Fig. 3: Edge computing fills the gaps of a SCADA system.

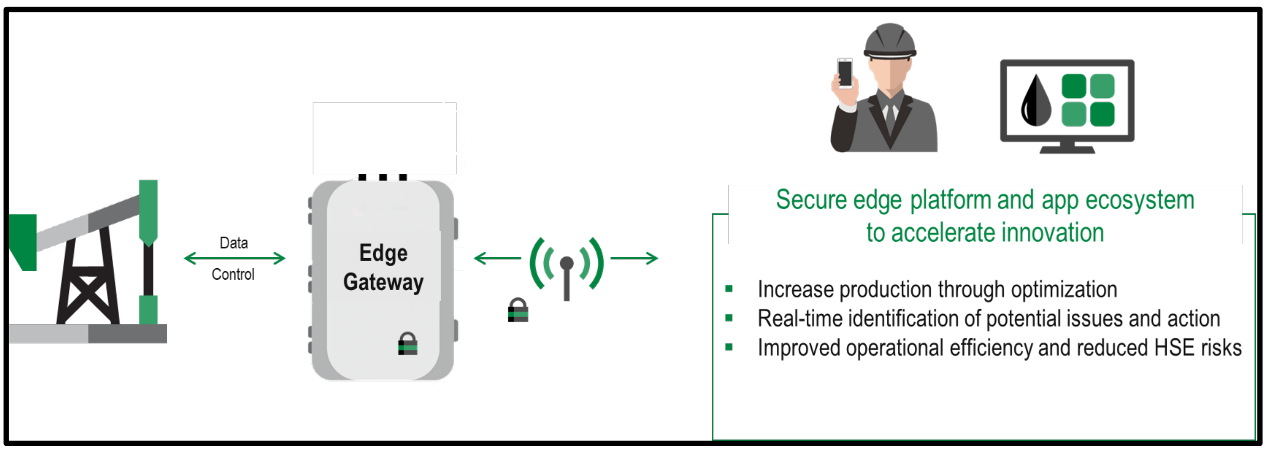

Fig. 4: The edge gateway acts as the brain in the edge-computing workflow.

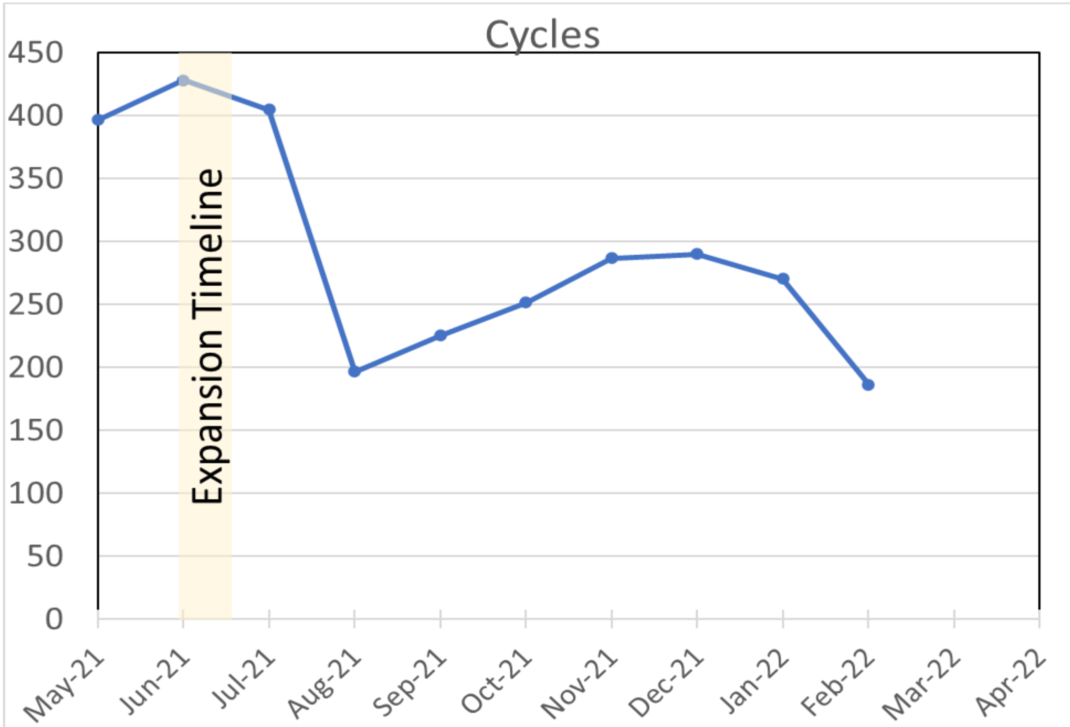

Fig. 5: Cycle Count for 74 Wells

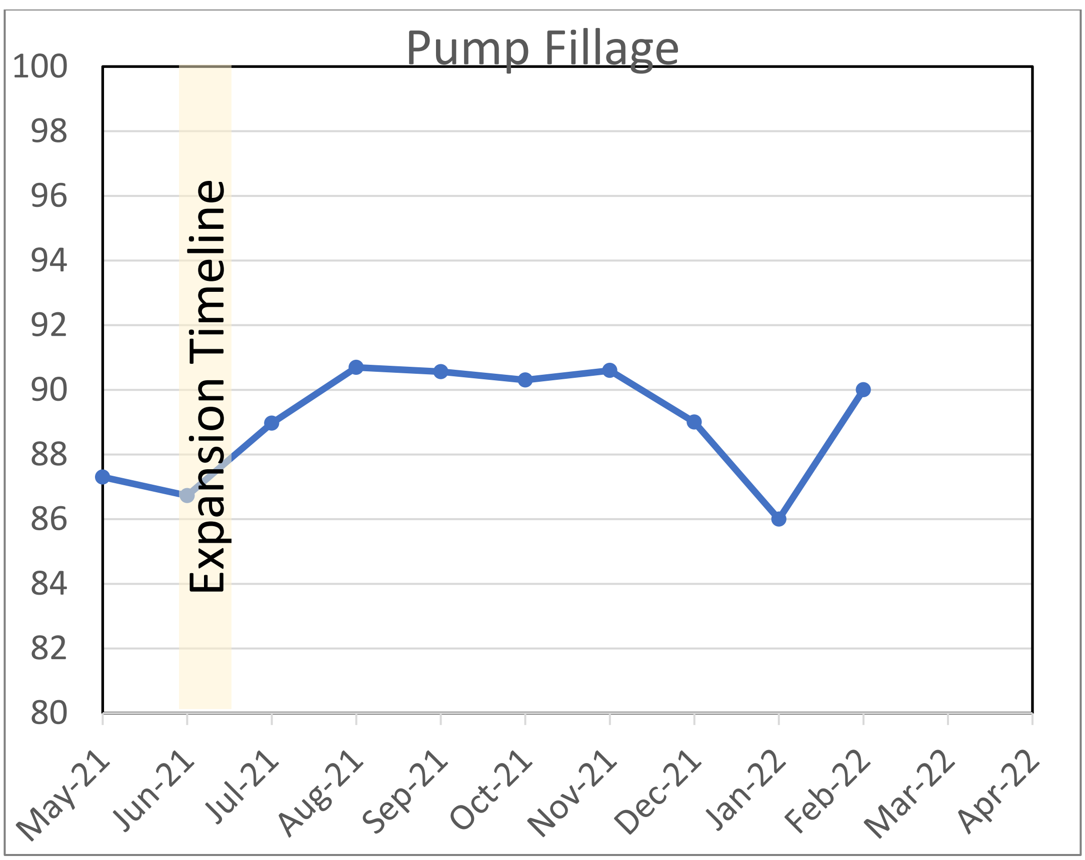

Fig. 6: Pump Fillage on 74 Wells

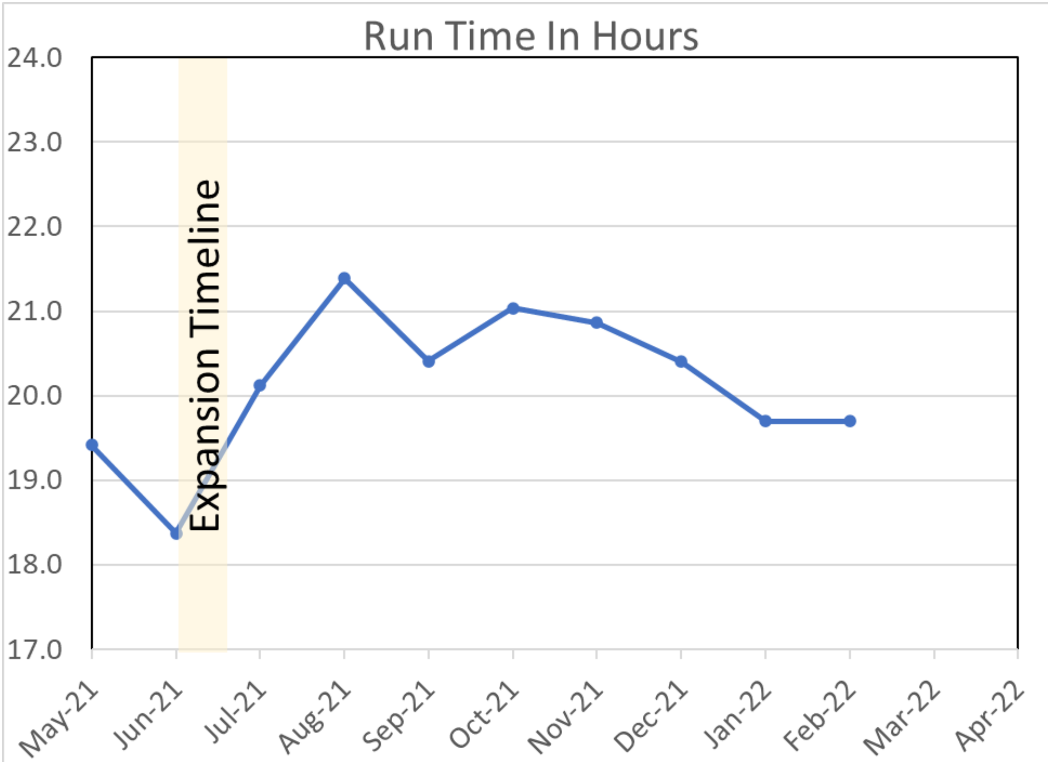

Fig. 7: Run Time in Hours on 74 Wells

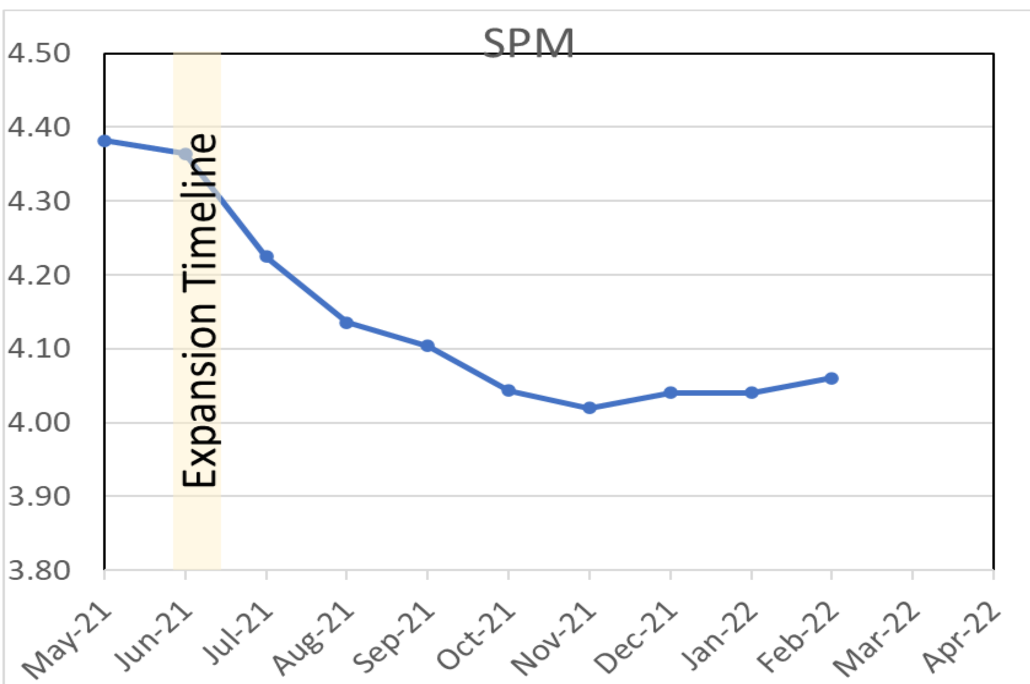

Fig. 8: Strokes Per Minutes on 74 Wells

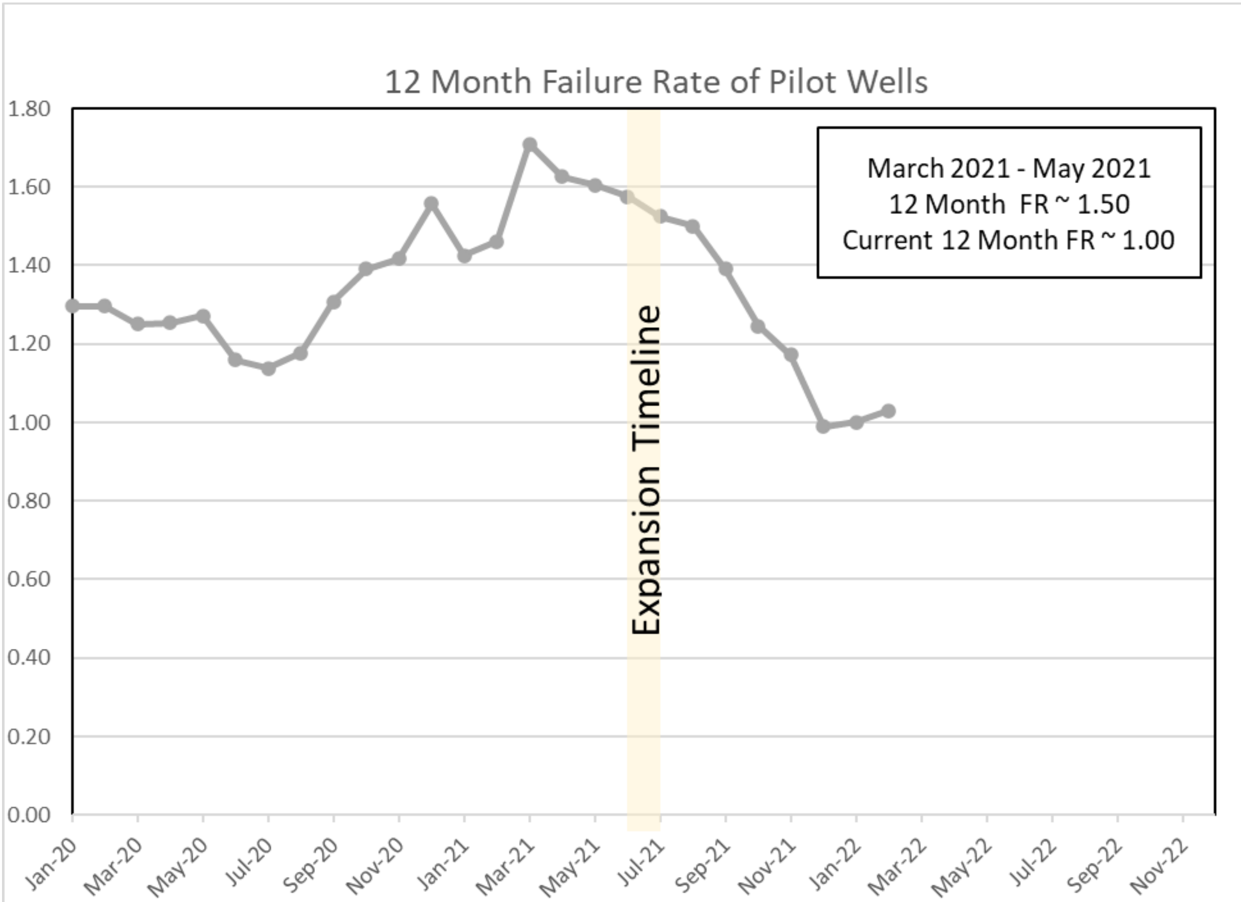

Fig. 9: 12-Month Failure Rate on 74 Pilot Wells

BIBLIOGRAPHY

Sujit Kumar, Agora Schlumberger. Dynamic Edge Intelligence, E&P Magazine – Hart Energy, February 2020.

Sujit Kumar, Agora Schlumberger. On the edge, the next wave of digital transformation, World Oil®, March 2020 p. 35-37.

Camilleri, L.; MacDonald, J., Schlumberger. How 24/7 Real-Time Surveillance Increases ESP Run Life and Uptime. SPE paper 134702 presented at Annual Technical Conference and Exhibition, Florence, Italy, 19-22 September 2010.