SPE-224562-MS

Transforming Coiled Tubing Operations Utilizing Remote Monitoring and Data Transmission for Optimized Decision-Making

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This paper was prepared for presentation at the GOTECH Conference held in Dubai, UAE, 21 - 23 April, 2025.

Abstract

The integration of real-time data analytics into coiled tubing (CT) operations represents a paradigm shift in improving efficiency, safety, and cost-effectiveness in oil and gas interventions. This paper explores how real-time data acquisition and analysis can address key challenges, including the difficulty of monitoring downhole conditions, managing operational risks such as equipment failure and stuck pipe incidents, and reducing the high logistical and operational costs of deploying personnel in hazardous environments. Case studies illustrate how real-time monitoring of pressure, CT weight, and flow rates and different critical CT parameters enhances operational predictability and minimizes inefficiencies. By integrating remote monitoring and data transmission into web-based platform significant cost savings and operational efficiencies can be realized.

The results indicate that integrating real-time technology significantly reduces reaction time to deviations or unexpected events during CT operations, thereby minimizing non-productive time (NPT) and operational risks. In extended-reach CT operation, real-time data enabled the technical support team to provide immediate feedback on set-down weight adjustments relative to CT speed, optimizing the operation and preventing early lockup. Additionally, in prior experiences, real-time monitoring proved highly effective in swiftly troubleshooting issues with a data acquisition system setup, eliminating the need for an information technology (IT) specialist to mobilize to the site and minimizing operational delays. A third example discusses how the absence of real-time data led to a delay in decision-making, underlining the critical need for immediate data access to prevent extended NPT and associated risks. These observations demonstrate that real-time data availability is a key enabler in reducing operational uncertainties and enhancing CT efficiency.

This paper concludes by discussing the technological innovations and strategic recommendations necessary for the effective implementation of real-time data systems, emphasizing their potential to revolutionize CT operations and establish new standards for performance and safety. Additionally, the paper aims to provide a foundation for the adoption of automated event detection systems, designed to improve risk mitigation by proactively addressing equipment fatigue and preventing potential failures.

Introduction

Real-time monitoring has emerged as a cornerstone of innovation in CT operations, fundamentally transforming efficiency, safety, and cost-effectiveness in oil and gas interventions. Operational complexities such as insufficient training, poor communication, and underutilization of available data have contributed to NPT, delayed decision-making, and potential HSE incidents. Addressing these inefficiencies requires a robust framework for real-time data utilization.

Initially, remote monitoring systems were introduced in drilling operations to centralize decision-making and optimize processes (Thorsen et al., 2012). Over time, this approach expanded to include pressure pumping, reservoir navigation, and well stimulation, reflecting the industry's broader digital transformation. For example, remote operation centers demonstrated how integrating real-time analysis with centralized expertise can enhance operational outcomes across multiple disciplines, reducing health and safety risks and significantly lowering costs.

The evolution of real-time data systems for pressure pumping services further highlights the value of standardized data protocols and interoperability. As outlined by Svensson et al. (2014), innovations such as well-site information transfer standard markup language (WITSML) have revolutionized data transfer and analysis, enabling seamless integration of rig site data into centralized monitoring centers. This approach has been especially transformative in applications like fracturing, CT interventions, and gravel packing, where real-time monitoring enhances decision-making and operational reliability. By aggregating, visualizing, and analyzing real-time data, these systems provide a solid foundation for predictive analytics and advanced digital oilfield strategies.

For CT operations specifically, real-time data analytics address critical challenges, including downhole condition monitoring, risk mitigation for equipment failure and stuck pipe incidents, and the reduction of logistical costs in hazardous and remote environments. Capturing key parameters—such as pressure, CT weight, flow rates, and downhole telemetry data—enables immediate, data-driven decisions in a lower stress environment. These capabilities have proven instrumental in optimizing set-down weight adjustments during extended-reach operations, troubleshooting data acquisition systems remotely, and preventing delays caused by the absence of immediate data access.

Case studies underscore the profound impact of real-time monitoring. Successful implementations have facilitated swift anomaly detection, streamlined workflows, and reduced operational risks. Conversely, failures to effectively utilize real-time systems have led to inefficiencies, increased risks, and delays. Incidents involving improper tool settings or pipe parting due to inadequate parameter tracking highlight the importance of reliable communication infrastructure, skilled personnel, and adaptive problem-solving approaches. Remote monitoring offers a significant opportunity to mitigate NPT associated with competency gaps and operational challenges by enabling timely decision-making and expert intervention. In the analyzed incidents for one of the regions (Fig. 1), 14% were linked to competency issues and 12% to operational challenges (such as stuck pipe, well condition dynamics)—both of which can be directly addressed through real-time oversight, data-driven guidance, and remote support. Additionally, while equipment failure (31%) and string management issues (6%) contribute to NPT, remote monitoring can aid in early fault detection, troubleshooting, and ensuring adherence to best practices, reducing downtime and operational disruptions.

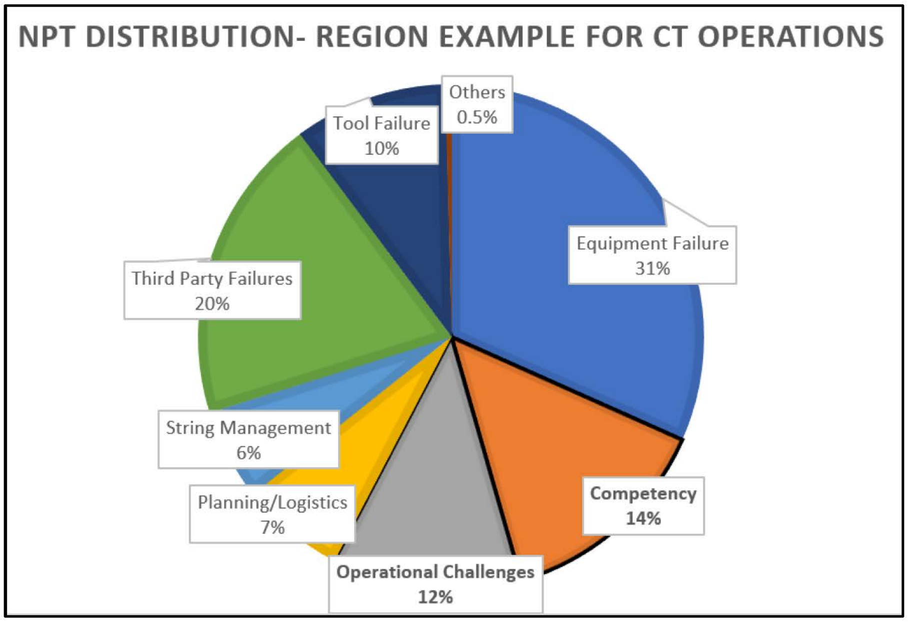

Figure 1—Distribution of NPT for CT operations in 2024 for a middle east region

This paper explores the technological innovations, case studies for CT operations, and strategic recommendations necessary for the effective implementation of real-time data systems in CT operations. By integrating advanced remote monitoring solutions, web-based data platforms, and automated event detection systems, the oil and gas industry can establish new benchmarks for performance and safety. These advancements hold the potential to revolutionize CT operations, ensuring better risk mitigation, minimized uncertainties, and reduced NPT to improve service quality.

Lessons Learned from Various CT Incidents

Operational incidents in remote locations often stem from insufficient personnel competency and a lack of effective communication with technical support and operations teams. This text outlines three incidents that occurred in either offshore or remote areas with limited network connectivity, highlighting significant service delivery challenges. In critical situations, such as over-pull scenarios, improper plug setting, or CT becoming stuck, real-time monitoring and timely technical support can alleviate decision-making burdens, ensuring safer and more efficient operations.

CT Over-Pull and Pipe Parting Incident

During an offshore CT acid stimulation operation, a 1.75-inch tapered CT encountered an obstruction at 15,177 ft while running in hole (RIH). Excessive drag was observed as the CT operator began pulling out of hole (POOH). Under instruction from CT supervisor and engineer, the CT operator continued to POOH reaching a maximum force of 55k lbs (100% yield), exceeding the calculated 80% yield limit of #45k lbs. This led to the CT parting and the loss of #13,000 ft of pipe in the well. Fig. 1a shows a plot of CT parameters with depth on the x-axis.

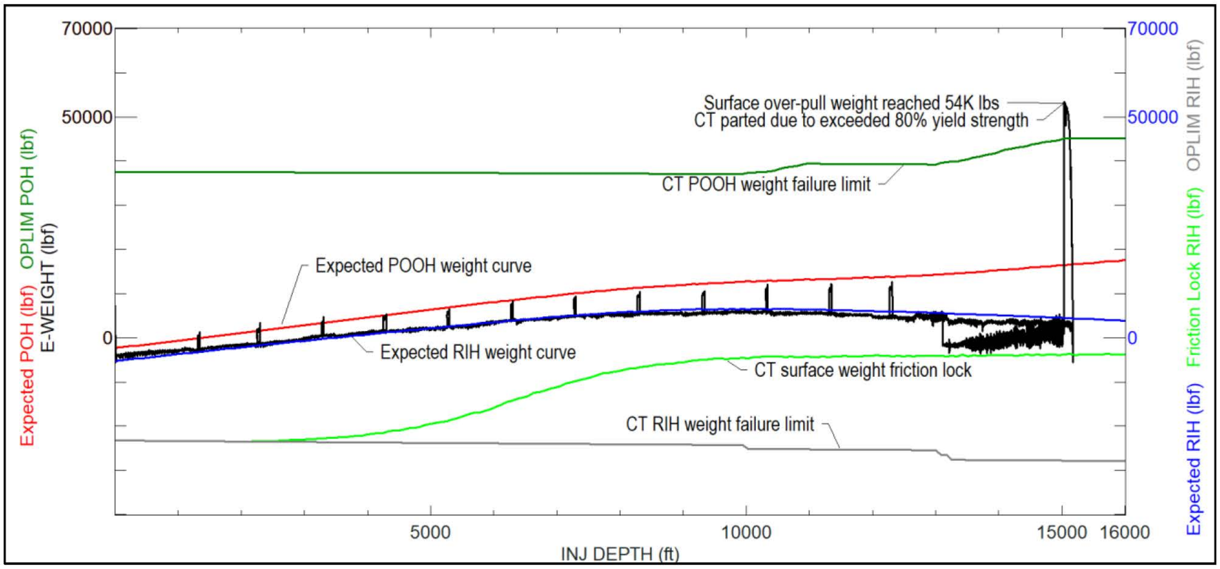

Figure 1a—CT over-pull exceeded yield strength and CT was parted

Following pipe recovery efforts, data analysis revealed that the crew lacked proper weight matching from predictive software, leaving them unaware of failure thresholds during the operation. Additionally, the Intelligent Injector Control (IIC) System configuration was tampered with wrong input resulting in incorrect failure limits to be applied. Aitken et al. (2017) explains the process of bringing together the pre-job simulation with well intervention operating limits with the help of IIC System. However, as with any system, IIC system's benefits are contingent upon proper usage; if not used correctly, it can become more of a challenge than an advantage.

This case underscores the critical need for:

- Accurate weight monitoring and adherence to operational limits.
- Proactive use of real time simulation tools to predict operational thresholds.
- Enhanced training and vigilance in software setup (IIC System) and safety protocols.

Furthermore, limited communication infrastructure further delayed root-cause analysis, as poor connectivity hindered technical support access and timely raw data evaluation. Real-time monitoring systems could have provided immediate alerts about yield limit exceedance, gaps in IIC System setup, and more vigilance on the operations thus enabling corrective actions to prevent the failure.

Plug Setting Failure

A CT operation to set an isolation plug faced delays and inefficiencies due to field crew inexperience and night-shift communication gaps. Though equipped with real-time monitoring, the system was underutilized, leading to improper interpretation of critical parameters such as weight-on-BHA (WOB) and pressure trends. Misinterpretation of a pressure drop during a ball drop event caused the crew to mistakenly confirm plug setting, only for the plug to shift unexpectedly during POOH to surface. Ultimately, this error resulted in #40 hours of NPT.

Fig. 2 shows the sequence of events and the failure to set up the plug. Upon reaching the target depth, the crew onsite struggled to interpret critical parameters such as pressure and WOB necessary for proper plug setting. The real-time monitoring system was not utilized during night shift activities, limiting its effectiveness in identifying anomalies in the plug setting event. During the ball drop and subsequent pumping, the crew observed a pressure drop of approximately 800 psi, which was mistakenly interpreted as confirmation of plug setting by the tool specialist. The tool specialist confirmed that the plug is set and requested to POOH. Instructions were accepted by all parties without challenging the facts or deviation in observation. Later, during POOH, a pressure increases of 1,000 psi went unanalyzed and ultimately the plug was set inside the surface riser. If there was active remote monitoring, then these deviations from the program could have been highlighted and corrective actions taken to guarantee the successful outcome of the operation.

This case highlights the importance of:

- Proper utilization of real-time monitoring systems to improve any gaps in field attentiveness or lack of knowledge especially when running third-party tools.
- Robust communication protocols to mitigate knowledge gaps during night operations.

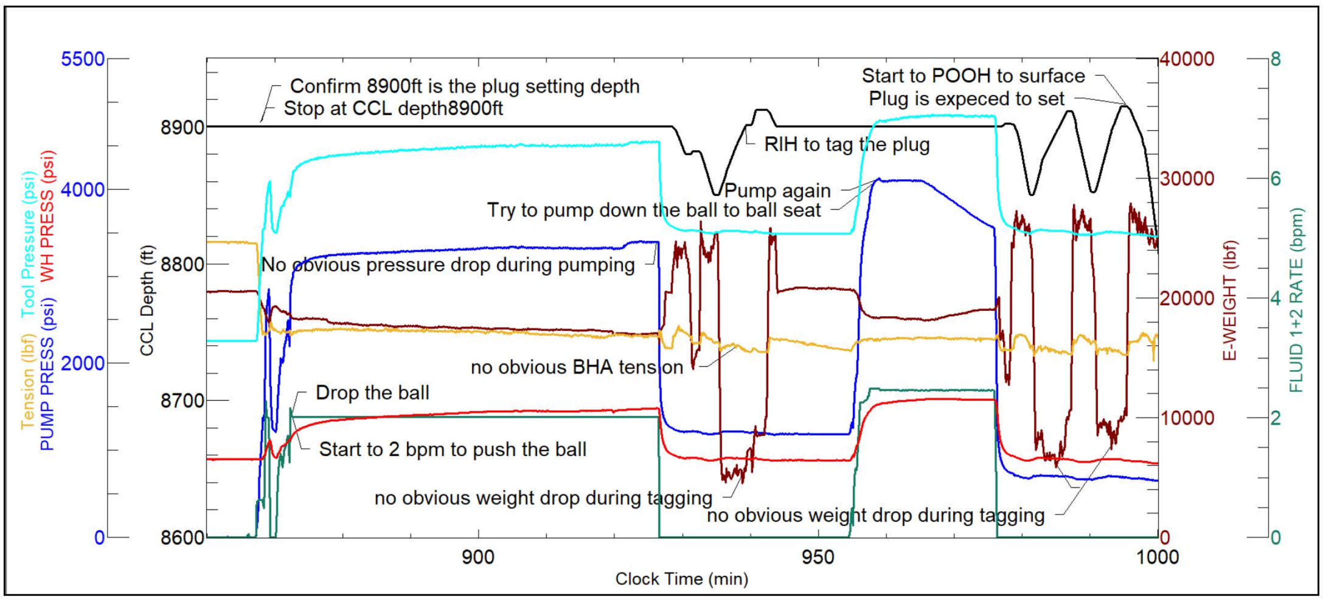

Figure 2—Failure on set up the plug and corresponding parameter behaviors

CT Stuck- Delay in Data Sharing

A milling operation was performed using 2.375-in. CT. Initially, the CT tagged 20 ft. above the anticipated plug depth. Nitrified fluids were pumped at a rate of 2.5 bpm and 350 scf/min to commence milling, maintaining a wellhead pressure (WHP) of around 450 psi. During the RIH, an increase in CT pressure was noted approximately 18 ft below the initial tagging depth, followed by a sudden drop in WHP to zero and a loss of returns. Attempts at POOH resulted in overpull, whereas further RIH led to slack, indicating the CT was stuck. At this juncture, the choke was fully opened, and the pumping rate was adjusted to reestablish returns, but this was unsuccessful.

Subsequent investigation revealed that the initial tag depth was approximately 20 ft shallower than the actual milling depth, likely due to the presence of soft debris. No bottoms-up circulation was performed as mentioned in the program to clear debris or establish clean returns before engaging the mill with the plug. Additionally, the pressure applied above the plug was higher than below, causing solids to fall back into the annulus once plug integrity was compromised and communication was established below the plug. This overbalance condition led to the loss of returns and debris accumulation, which obstructed the annular passage. There was a significant delay in sharing the job files with the office engineer to troubleshoot downhole conditions. Additionally, during the stuck situation, free point calculations had to be repeated twice as the initial data shared was insufficient. More experienced personnel had to be deployed with special night driving approval to the well-site for additional support and investigation.

The above incidents illustrate the operational risks associated with insufficient real-time monitoring and communication infrastructure. By implementing robust remote monitoring systems and enhancing personnel training, the CT industry can improve decision-making during critical operations; reduce NPT and associated costs; and ensure operational safety and service quality through proactive risk mitigation.

Real-time monitoring systems serve as practical communication channels, enabling field teams to identify and address abnormalities promptly. This capability significantly enhances overall operational reliability, particularly in remote or high-risk environments.

Remote Monitoring Transition: Enhancing CT Operations

Remote Operations Services provide a framework for efficient management and support for field operations. These services integrate regional and local technical support, remote operations solutions, and integrated services to ensure operational efficiency, cost reduction, and risk minimization. By incorporating remote monitoring into CT operations, operators can enhance efficiency, reduce costs, and improve safety.

Saeverhagen et al. (2013) discuss the evolution and importance of Remote Operations Centers (ROCs) in addressing the critical challenges facing the oil and gas industry, including workforce shortages and operational efficiency demands. Fig. 3 shows an example of ROC. Over the last decade, ROCs have been implemented to centralize operations previously carried out at the rig site, leveraging real-time data, automation, and remote monitoring to improve efficiency, reduce costs, and enhance safety. This transition significantly reduces the number of personnel onboard while maintaining or even improving service quality and operational reliability.

Figure 3—Remote Operation Center

Remote Operations Services

Remote Operations (RO) Services (Fig. 4) are categorized into:

- **RO Level 1:** On-demand Subject Matter Expert (SME) support for immediate technical challenges.
- **RO Level 2:** Continuous 24-hour monitoring with operational directives provided by on-site personnel including pre-job planning assistance, simulations, and job design to ensure operational readiness.
- **RO Level 3:** Remote personnel assisting in directing operations with full personnel available on location.
- **RO Level 4:** Remote personnel fully control operations, reducing the number of wellsite personnel requirement

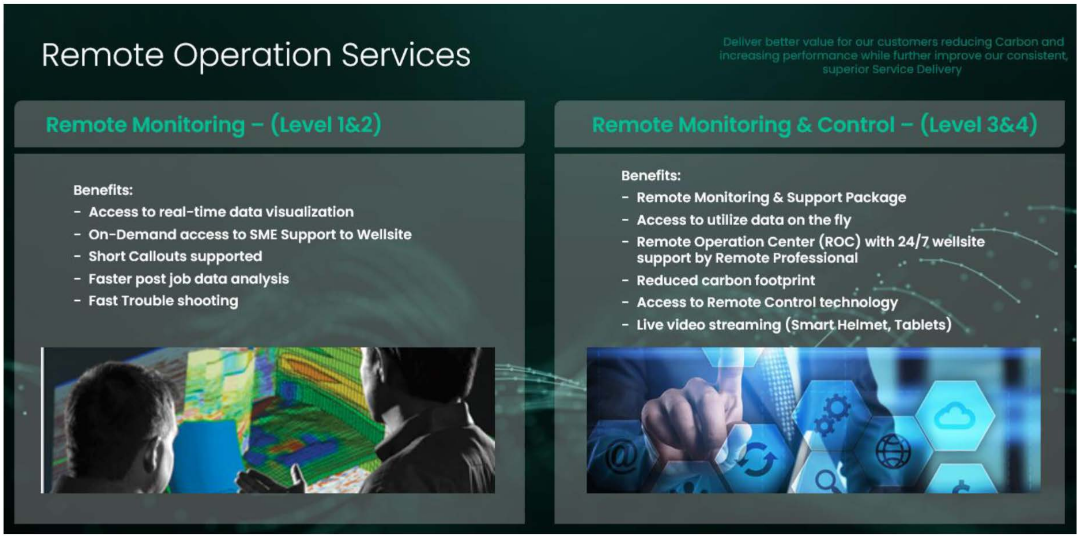

Figure 4—Remote Operation Services Category

The function of this RO is to offer remote coordination to facilitate the seamless management of operations and support decision-making processes through real-time data transmission and communication. For CT operations, the RO Level 1 and Level 2 ensures that subject matter experts can remotely assist with job design, equipment troubleshooting, and operational adjustments. Access to real-time data visualization enables rapid diagnostics and decision-making, minimizing downtime and increasing success rates in complex CT interventions such as extended reach acidizing, cleanouts and milling operations.

By leveraging RO Level 3 and RO Level 4 capabilities, CT operations can be managed remotely, reducing the need for large offshore/ remote land crews. For example, real-time control of critical downhole parameters such as pressure, temperature, and flow rates are achieved through telemetry, and surface sensors systems connected to the VSAT network, enabling precise operational adjustments. Fig. 5 explains the various Remote Operation Services models and their components.

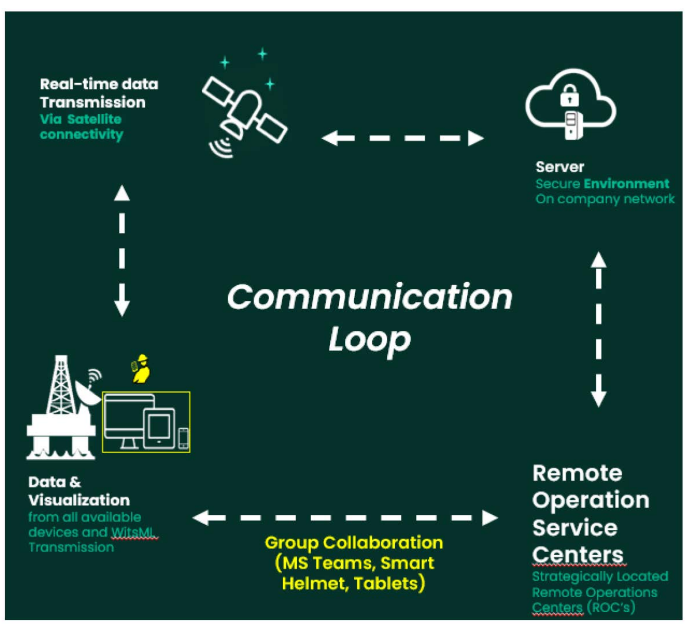

Figure 5—Communication Model for pressure pumping RO

Adopting remote operation services in CT has cost implications. While initial setup costs for satellite communication systems and remote monitoring tools can be high, the long-term savings in personnel costs, reduced downtime, and improved operational efficiency justify the investment. Future advancements, such as Neural Network analytics, and artificial intelligence promise to further optimize remote CT operations, reducing costs and improving safety.

VSAT System Details

The integration of Very Small Aperture Terminal (VSAT) technologies into offshore CT operations represents a significant advancement in remote operational capabilities. VSAT enables high-speed satellite communication, critical for real-time data transmission and operational oversight in remote environments. A VSAT is a small-sized earth station used in the transmit/receive of data, voice and video signals over a satellite communication network, excluding broadcast television. For CT RO, all the CT real-time data will be transmitted by VSAT to the ROC.

Fig. 6 illustrates the system workflow of the RO system. The unit laptop records job data and connects to an indoor rack comprising an Antenna Control Unit (ACU), modem, router, and Uninterruptible Power Supply (UPS). The rack connects to an antenna, which establishes satellite communication. The ROC accesses the unit laptop for remote control, file transfer, and real-time communication. There is also an important third party data hub used for server daily maintenance and connection check for all the VSAT. The ROC will access the remote unit laptop by software achieve the following functions:

- Full control the remote unit laptop
- View only the remote unit laptop
- File transfer with double directions
- Chat, voice chat and send message

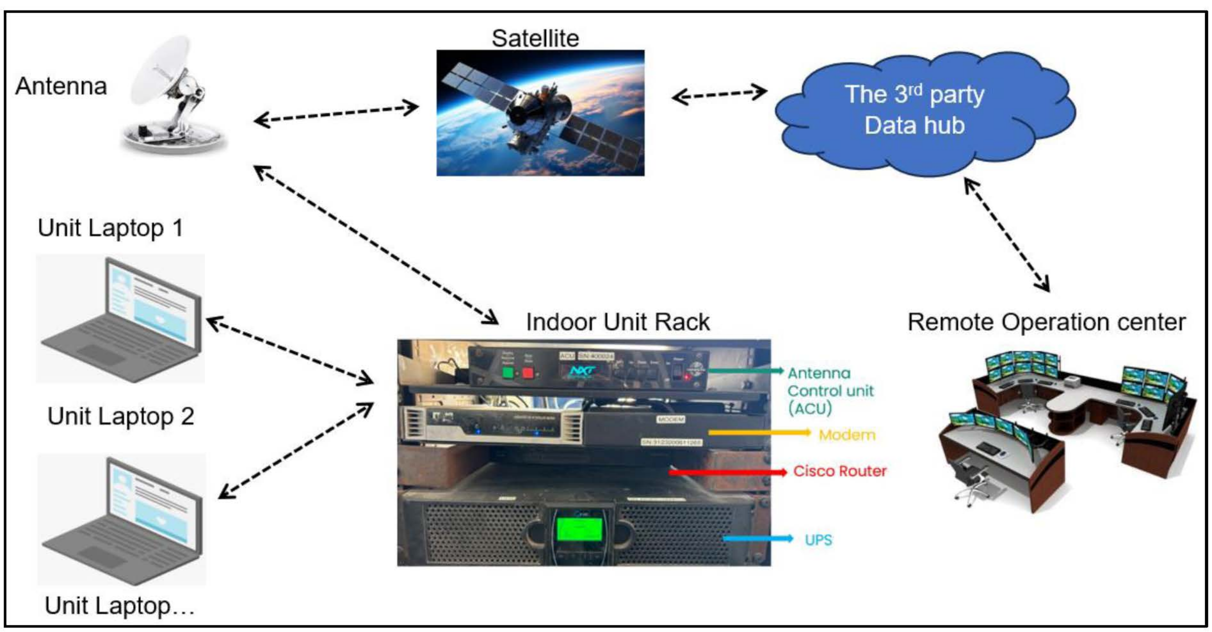

Figure 6—VSAT fundamental system workflow

RO advantages are summarized as below:

- Allow immediate and better decision making with rapid data explanation and remote professionals support.
- At any time, the job data could be transferred to ROC without interrupting the operation of remote laptop, the ROC could also send files to the remote laptop as well.
- Reduces the need to deploy on-site technical support (such as mechanics, electricians and engineers), saving costs on transportation and accommodation.
- Avoid NPT due to the incompetency of personnel in the location by remotely controlling and setting up the unit laptop properly.

Typical hardware footprint is not massive, especially for land operations (Fig. 7). This capability proves particularly advantageous for intricate interventions, including extended reach open hole matrix acidizing, lengthy cleanouts, complex milling operations and mechanical applications where rapid and informed decision-making is critical. Furthermore, VSAT facilitates remote equipment health monitoring, supporting predictive maintenance and minimizing the risk of unexpected failures.

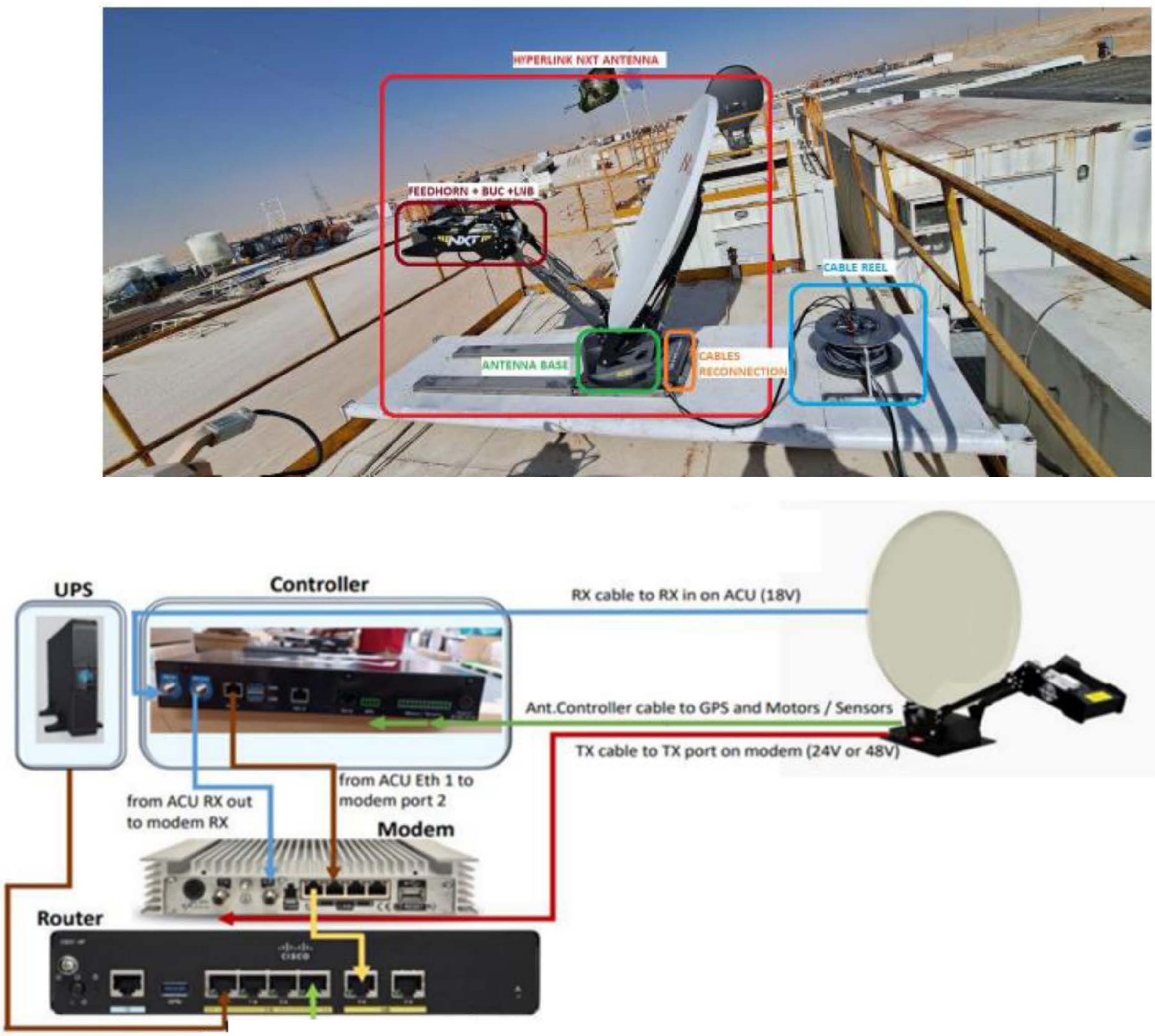

Figure 7—Typical hardware setup at the CT wellsite

Nevertheless, challenges such as communication barriers, resistance to adopting new workflows, and concerns over job displacement highlight the necessity for comprehensive training and organizational adaptation. The benefits of real-time monitoring extend beyond operational efficiency, providing actionable insights for accelerated decision-making, substantial cost reductions by minimizing on-site personnel, and proactive risk mitigation by identifying potential equipment or operational failures before escalation. These advancements underscore the transformative impact of real-time monitoring in enhancing efficiency and safety within the CT industry.

Field and Remote Professional Training and Competency

Ensuring that field and remote operations personnel possess adequate training and competency is crucial for the success of remote monitoring and operations in industrial sectors, advancement of remote operations technologies requires a workforce that is skilled in both fieldwork and remote service coordination. Developing and maintaining these competencies is vital to achieving operational efficiency and safety. This includes structured training programs, competency-based assessments, and ongoing professional development in technical and non-technical skills.

According to Dixit et al. (2024), the Integrated Operations (IO) model focuses on reducing reliance on specialized personnel at well sites by developing new roles and comprehensive competency structures. Multi-skilled Field Professionals (FPRO) are pivotal to this strategy. These professionals are trained to perform a wide variety of well site-based tasks such as surface equipment handling, tool preparation, fluid mixing, and pressure testing, Data acquisition systems, Telemetry communication tools, VSAT equipment set up, which decreases the need for multiple specialists on-site. This multi-skilled approach contributes to optimizing personnel-on-board (POB) while minimizing operational risks. FPROs undergo structured training programs that include task-specific competency assignments, job shadowing, on-the-job training, and web-based learning modules. These programs ensure that personnel remain capable of performing evolving tasks efficiently and safely.

Competency development is managed through a Competency Management System (CMS), which maps tasks to qualification criteria and performance standards. This system involves collaboration between service companies, product experts, and curriculum designers to maintain up-to-date training aligned with global best practices. With the CMS, both field-based and remote professionals can develop and demonstrate the qualifications necessary to perform critical operations. This framework not only supports skill enhancement but also facilitates the seamless transition of tasks from on-site to remote operations.

Successful Case Histories of Remote Monitoring in CT Applications

Case 1: CT Acid Stimulation of Well A

The primary objective of the operations was to enhance productivity through acid stimulation treatments using 15% HCl and emulsified acid in open-hole conditions. Over four runs, the operations encountered significant challenges, including high drag, CT lock-up events, ruptured burst disks (BDs), and weight loss during critical stages.

- The first run in well L-1 encountered CT lock-up at 14,261 ft. and a ruptured BD, necessitating tool inspection and adjustments.
- During the second run, despite surpassing the previous maximum depth and successfully delivering acid treatment, CT locked up again at 13,552 ft during post-flush operations.
- The third run in well L-0 was impacted by a sudden drop in pressure and weight at 12,868 ft due to a ruptured BD, necessitating tool replacement and modifications.
- Eventually, the fourth run in L-0 reached a total depth of 17,831 ft, overcoming challenges such as high drag and weight loss, successfully completing the acid stimulation as per the operational schedule.

These events highlight the importance of real-time monitoring and adaptive problem-solving to address the operational complexities inherent in CT acid stimulation treatments.

First Run. During the CT intervention in Well L-1, with pre-flush fluid positioned at the nozzle, the pumping rate was increased to 3 bpm, and the choke was closed to optimize operations. As illustrated in Fig. 8, CT drag was encountered at 12,200 ft. In response, the choke was partially opened to maintain wellhead pressure (WHP) below 500 psi, while the RIH speed was reduced to 3–5 ft/min to recover CT weight. At 14,261 ft, the CT experienced lock-up. Prior to this, weight oscillations were observed at a constant pumping rate. When the weight trend became static with no recovery, the remotely monitoring technical support team identified anomalies. CT was picked up by 600 ft and re-run at a slower speed of 1–2 ft/min. At 13,862 ft, the decision was made to pull out of the hole (POOH) for surface inspection of the tool. Inspection revealed a ruptured BD, explaining a 500 psi CT pressure drop observed earlier. Additionally, the extended reach tool was found to be non-functional.

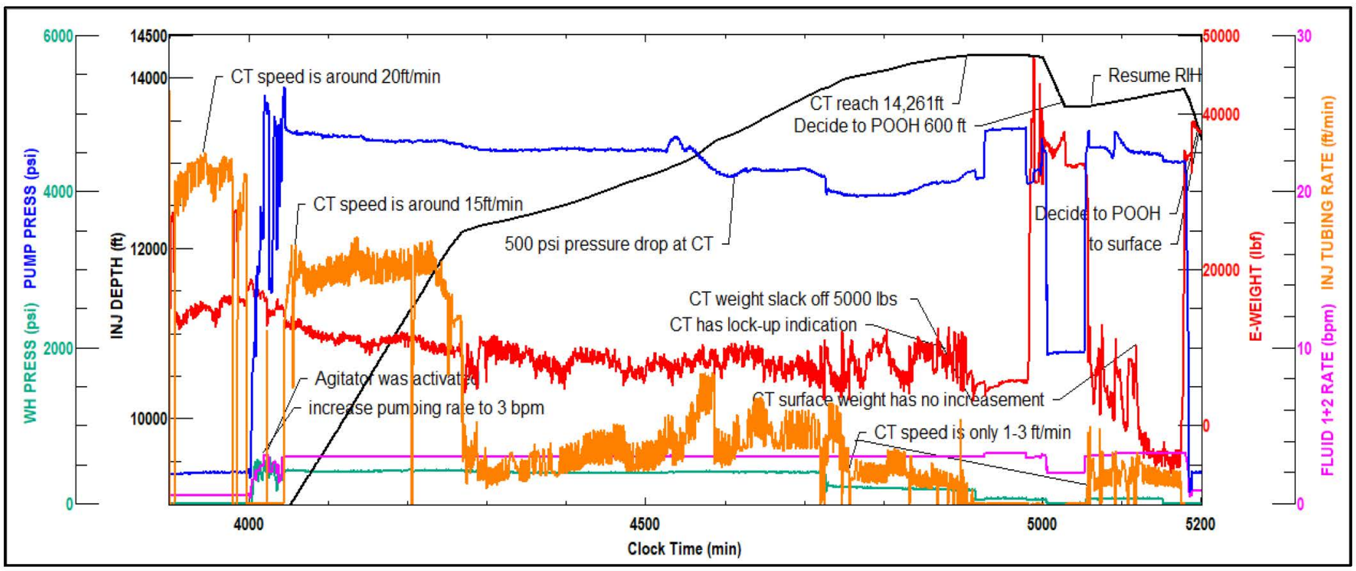

Figure 8—First run acid stimulation for L-1 CT parameter behavior showing extended reach tool was not functioning and POOH to surface

Real-time data interpretation played a pivotal role in identifying tool-related issues, allowing the team to take timely corrective actions, including POOH for tool inspection. These proactive measures minimized NPT and prevented unnecessary wastage of resources, such as treatment fluids, pumping time, and rig operational time.

Third Run in L-0. The CT operation resumed with RIH activities. As depicted in Fig. 9, the CT speed was stabilized at 15 ft/min between 9,000 ft and 11,500 ft. To ensure the effective displacement of pre-flush fluid, the pumping rate was increased to 3 bpm while RIH continued. At 12,868 ft, a sudden and significant drop in pumping pressure and weight was recorded, strongly indicating BD rupture. Despite the anomaly, RIH proceeded to a depth of 12,935 ft, at which point it was decided to POOH for surface inspection. Upon retrieving the CT to the surface, the BD failure was confirmed, allowing for further evaluation and resolution.

Real-time monitoring during this complex CT operation provided a comprehensive understanding of well conditions. By leveraging real-time data, the team made informed decisions to mitigate challenges and adapt to dynamic well conditions, ensuring operational continuity and efficiency.

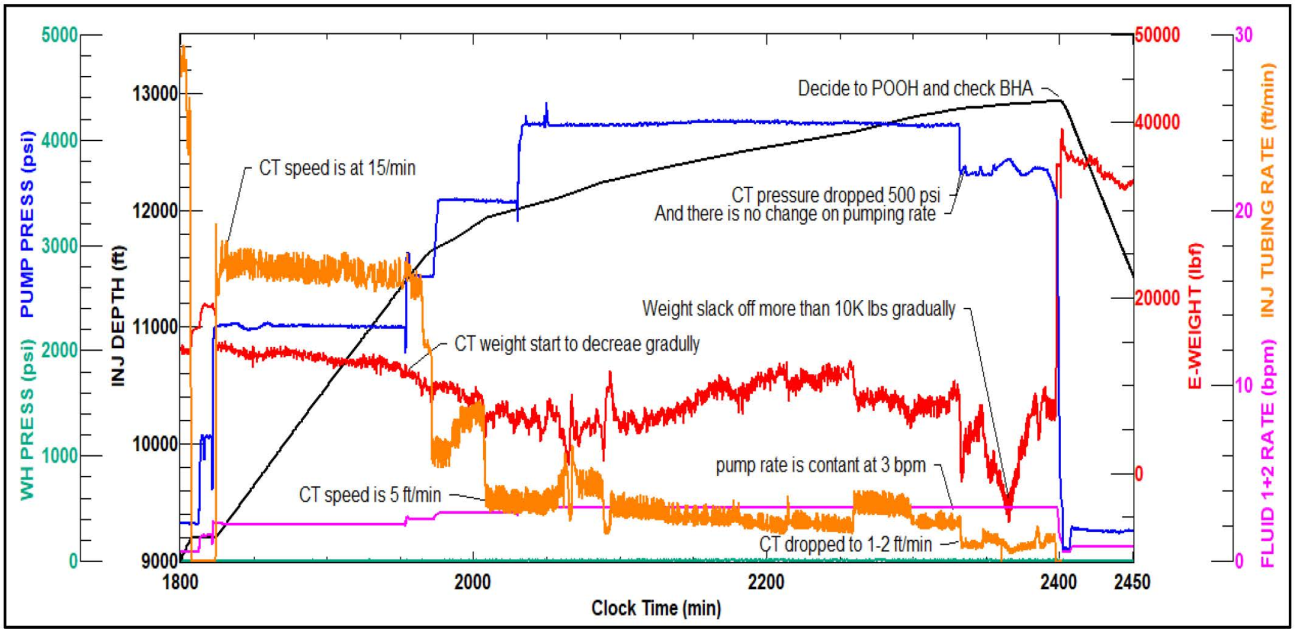

Figure 9—Acid stimulation for L-0 CT parameter behavior showing agitator was not functioning and POOH to surface

Fourth Run in L-0. CT operations proceeded with RIH to 12,935 ft, encountering high drag at 11,540 ft, which required reduced speed. CT reached a total depth of 17,831 ft, completing acid treatment as planned. During RIH for post-flush, weight loss was observed at 11,025 ft, necessitating a further speed reduction. The post-flush volume was successfully pumped, and 850 bbl of brine was later bullheaded through the kill line before POOH and rigging down the CT unit.

Case 2: Managing CT Weight Drag and Adjusting Pumping Sequence During POOH in Well B

During a stimulation job in a power injector well, a rotating tool was deployed for a cleanout run. Overpull was observed during pull-out-of-hole (POOH) operations, as shown in Fig. 10, caused by sticky material accumulation from the initial cleanout pass. Real-time monitoring and remote technical support enabled proactive decision-making to manage potential risks, including CT overloading due to excessive pipe loads. This integration of remote support and real-time data facilitated timely mitigation measures, preserving equipment integrity and optimizing job outcomes.

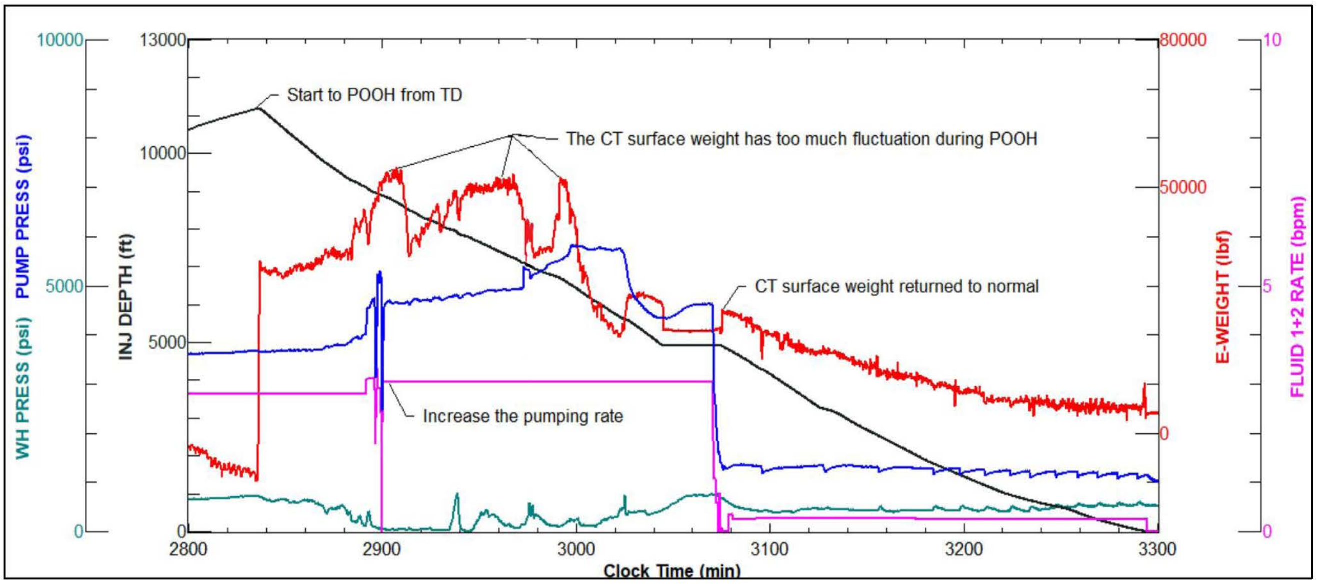

Figure 10—During POOH CT weight fluctuation between 9200ft to 5000ft

At 9,250 ft, the POOH weight reached 50,000 lbs with a choke size of 26/64. As operations progressed to 9,100 ft, the weight increased further to 53,000 lbs. During this time, pumping at 3.1 bpm and introducing nitrogen at 300 scfm helped stabilize the operation.

At 8,500 ft, the weight initially decreased to 37,000 lbs but began to rise again, reaching 50,000 lbs. By 6,370 ft, a significant drop to 35,000 lbs was recorded. At 5,000 ft, the POOH weight returned to normal levels.

The fluctuations in weight were attributed to the presence of sticky material, later confirmed by field personnel. The material was effectively dissolved using a mutual solvent. Technical support promptly adjusted the solvent concentration in the treatment recipe and collaborated with the client to implement the revised plan.

Real-time monitoring and swift technical support adjustments were critical in maintaining operational safety and success. The revised solvent concentration ensured effective dissolution of the sticky material, minimizing risks to equipment and enhancing client satisfaction.

This case highlights the importance of real-time monitoring and adaptive decision-making during CT operations. Real-time tracking of key parameters through IIC system ensured that the CT remained within safe operating limits, reducing the risk of stuck pipe or equipment damage. Continuous collaboration between field personnel and technical support teams contributed to high-quality operational delivery and optimized outcomes.

Case 3: Early Diagnosis of Load Cell Replacement During a 2-7/8-in CT Rig Job

During a 2 7/8" acid stimulation job, remote monitoring enabled early identification of equipment issues, minimizing potential NPT. As shown in Fig. 11, abnormal surface weight behavior was observed during RIH. Weight fluctuations exceeded 12,000 lbs, and during short 50 ft pull tests, weights peaked and then dropped by 8,000 lbs at every 1,000 ft increment. This unsteady behavior persisted until reaching 6,100 ft. After consulting with the ROC and obtaining client approval, the CT was POOH to 3,000 ft and RIH resumed. However, the weight behavior remained erratic. The decision was made to POOH to surface for inspection. During POOH, the IT specialist remotely accessed the data acquisition software to double check and confirm correct setup. This prevented several hours of driving time that would have been required in normal operations. Upon reaching surface, the electronic load cell was replaced.

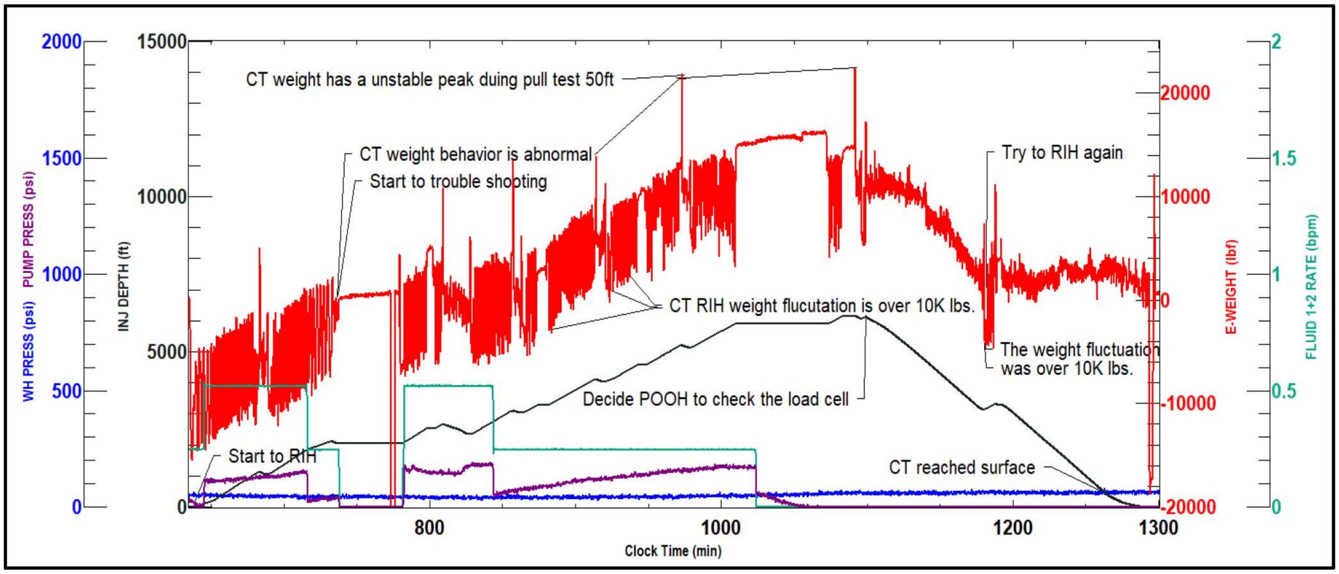

Figure 11—Abnormal weight behavior from RIH to 6150ft then POOH to surface

In the subsequent run, the weight returned to normal, allowing the CT to reach total depth (TD) and complete the acid stimulation job successfully.

This case highlights the importance of real-time monitoring, accurate CT simulation, and proactive communication between field engineers (FE), field specialists (FS), and ROC personnel to diagnose and resolve operational anomalies promptly. For large-diameter CT operations, deviations from simulation results warrant immediate inspection and corrective actions to ensure safe and efficient operations.

Economical and Technical Value of remote monitoring

According to Saeverhagen, (2015). The adoption of remote monitoring strategies in the oil and gas industry delivers substantial technical and economic benefits. By reducing onsite personnel requirements by 30–70%, remote operations can save $500,000 to $1 million annually per person in high-cost regions like the North Sea. Centralized ROC's enhance operational efficiency by supporting multiple rigs simultaneously, minimizing NPT through 24/7 monitoring, real-time intervention, and troubleshooting.

Key benefits include:

- Cost Reduction: Decreased transportation, lodging, and safety expenses.
- Safety Improvement: Reduced health, safety, and environmental (HSE) risks due to fewer personnel at rig sites.
- Scalability: Remote centers could support up to forty-eight concurrent operations, demonstrating their efficiency and scalability.

Successful implementations in the Middle East and Latin America have shown that remote monitoring not only lowers personnel requirements but also maintains high operational performance. To remain competitive in a low oil price environment, the industry must continue to prioritize automation, cross-functional training, and remote operations for improved cost efficiency and service quality.

Conclusions and Key Challenges

Early Detection of tool failures: In an extended-reach acid stimulation operation, real-time monitoring enabled the early detection of a tool failure, allowing for swift corrective action and minimizing NPT. Real-time monitoring systems can recognize parameter variances, such as sudden pressure drops or weight fluctuations, that signal abnormal behavior. Without remote monitoring to detect these anomalies early, the issue could have escalated, leading to significant downtime and operational delay

Enhanced Safety Through Remote Operations: With the integration of RO, CT activities can be executed more securely. RO enables real-time technical support, addressing challenges promptly and reducing operational risks in critical jobs.

Reduced Field Workload and Higher Service Quality: For critical CT jobs, RO relieves the pressure on field personnel by providing continuous technical support. This improves service delivery quality by enabling informed decision-making and proactive issue resolution.

Reduced Personnel on Board (POB): RO effectively minimizes the need for onsite personnel, bridging competency gaps in the field while ensuring safe and efficient operations.

Retention of Expertise and Training the Next Generation: ROC's play a crucial role in addressing the growing shortage of skilled workers. By retaining experienced personnel in these centers, valuable knowledge is preserved, and the next generation of engineers is effectively trained, maintaining high quality service.

Addressing Operational Inefficiencies: Case studies demonstrate that poor utilization of real-time data, insufficient training, and inadequate communication infrastructure can lead to operational inefficiencies. Issues such as CT over-pull failures and improper plug settings highlight the importance of leveraging real-time monitoring and remote technical support.

Transforming CT Operations with Remote Systems: The integration of remote monitoring systems, including VSAT technologies and ROCs, has revolutionized CT operations. These systems enable remote control, real-time data visualization, and proactive support, significantly reducing costs and risks, particularly in challenging environments.

Improved Efficiency and Resource Management: Real-time monitoring enhances operational efficiency by enabling the simultaneous tracking of multiple tasks. This allows for quicker detection of issues, better resource allocation, and improved overall delivery quality.

Proactive Risk Mitigation: Continuous monitoring supports early identification of potential issues, enabling rapid response and corrective measures, thereby preventing failures.

In summary, the adoption of RO and ROCs has significantly improved the safety, efficiency, and cost-effectiveness of CT operations. These advancements address industry challenges, such as skilled workforce shortages and increasing operational complexity, ensuring sustainable and high-quality service delivery especially in a busy district where operations are very intensive with multiple simultaneous CT interventions in challenging environments. Through continuous monitoring, remote experts can detect deviations, such as abnormal weight or pressure fluctuations, and advise on corrective actions to mitigate risks like stuck pipes, potential equipment failures. These measures improve safety, operational efficiency, and reduce non-productive time (NPT).

Acknowledgement

The authors wish to acknowledge Baker Hughes for permission to publish the paper.

Nomenclature

- CT = Coiled Tubing
- RTM = Real Time Monitoring
- RIH = Run In Hole
- WOB = Weight on Bit
- IIC = Intelligent Injector Control
- BD = Burst Disk
- NPT = Non productive time

- POOH = Pull Out Of Hole
- VSAT = Very Small Aperture Terminal
- RO = Remote Operations
- ROC = Remote Operations Centers
- SME = Subject Matter Expert
- OH = Open Hole
- WITSML = Well-site information transfer standard markup language

References

1. Saeverhagen, E., Bouillouta, F., Cranfield, A., & Hall, W. (2015). Economic and Technical Value of Remotely Operated Services in Real Time. SPE-177951-MS, presented at the Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, UAE, November 9–12. https://doi.org/10.2118/177951-MS
2. Antonio, B., Gregory, D., Deepak, K., Ruggieri, G., & Maja, J. 2021. Remote Cementing Enabled with Automation Drives Reliability, Consistency and Efficiency: A Case History from Norwegian Continental Shelf. SPE-207833-MS, presented at the Abu Dhabi International Petroleum Exhibition & Conference to be held in Abu Dhabi, UAE, 15 – 18 November 2021. https://doi.org/10.2118/207833-MS
3. Saeverhagen, E., Kellas, R., Bouillouta, F., & Anis, S. (2013). Remote Operations Centers and Re-engineering Work Processes: Retaining Competent Personnel in an Extremely Competitive Marketplace. SPE/IADC Middle East Drilling Technology Conference and Exhibition, Dubai, UAE. SPE/IADC 166743-MS. https://doi.org/10.2118/166743-MS
4. Saeverhagen, E., Thorsen, A., Dagestad, J., Spanovic, N., Cannon, K., (2013). Remote Real-time Analysis - A Game Changer for Remote Operation Centers. IPTC 16999, presented at the International Petroleum Technology Conference held in Beijing, China, 26–28 March 2013. https://doi.org/10.2118/0913-0160-JPT
5. Aitken, B., Micheli, R., Ramsey, T., and Dobkins, K. 2017. Reducing the Impact of Experience Gap and Increasing Service Delivery by Automating the Coiled Tubing Intervention. Paper presented at the Abu Dhabi International Petroleum Exhibition & Conference, Abu Dhabi, UAE, 13–16 November. SPE-188685-MS. https://doi.org/10.2118/188685-MS.
6. Sæverhagen, E., Thorsen, A. K., Dagestad, J. O., Svensson, I., and Grøvik, L. O. 2012. From Standard Operations via Re-manning and Remote Support to Automated Advisory Systems; a Stepwise Development Program for Remote Operations Over a Decade. Paper presented at the *SPE Intelligent Energy International*, Utrecht, The Netherlands, 27–29 March. SPE-150155-MS. https://doi.org/10.2118/150155-MS.
7. Svensson, I., Sach, M., and MacLeod, A. 2014. Advances in Real-time Data Monitoring for Pressure Pumping. Paper presented at the *SPE Bergen One Day Seminar*, Grieghallen, Bergen, Norway, 2 April. SPE-169197-MS. https://doi.org/10.2118/169197-MS.
8. A. Dixit, R. Gonzalez, & A. Elafifi. 2024. Integrated Operations - The Next Level of Remote Operations for Integrated Solutions. Paper presented at the Offshore Technology Conference, Houston, Texas, USA, 6–9 May. OTC-35479-MS. DOI: https://doi.org/10.4043/35479-MS