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Lessons from 2,500+ Production Casing Runs in Unconventional Plays and Best Practices for Extended Laterals

A. Ichim, L. Pereira, and C. Blanc, Tenaris, Houston, TX, USA

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Abstract

As lateral lengths in unconventional wells continue to increase, operators face growing challenges in running production casing to bottom without incurring non-productive time (NPT) or compromising well accessibility and/or integrity. This paper shares key lessons learned from over 2,500 production casing runs across major U.S. shale basins. We examine how evolving drilling practices and lateral designs impact casing installation, and how real-time monitoring tools help mitigate risks and improve operational outcomes.

We begin by analyzing trends in lateral length extension and drilling practices over the past years. We then review the fundamentals of torque-drag and fatigue, and their application to casing installation in high-friction, long lateral, tortuous wellbores. As part of this analysis, we also review drilling best practices such as trajectory smoothing, hole cleaning, and fluid management, that contribute to successful casing runs. The paper introduces a cloud-based real-time monitoring system that tracks surface parameters, compares them to modeled expectations, and alerts field and remote monitoring crews to deviations in real time. Case studies from multiple basins illustrate how the system reduced the risk of downhole restrictions, optimized casing running speeds, and prevented stuck pipe incidents.

The implementation of real-time monitoring significantly enhanced casing running operations by enabling crews to make informed, data-driven decisions during execution. These efforts led to the development of improved standard operating practices, fostering more consistent performance across wells and crews. The visibility provided by real-time torque and drag data encouraged clearer communication among rig personnel, engineers, and service providers, aligning expectations and reducing uncertainty during critical operations. Notably, the system helped overcome historical reluctance to rotate production casing strings by providing confidence in downhole conditions and mechanical limits. As a result, teams executed casing runs with greater consistency, minimized non-productive time, and reduced the frequency of downhole issues through proactive adjustments and better planning, reducing casing installation time by up to 50%. In several cases, the system detected abnormal drag trends early enough to allow corrective action before encountering critical issues.

Introduction

Horizontal drilling and multi-stage fracturing have unlocked vast resources in unconventional shale formations over the past decade. As operators drill longer laterals to maximize reservoir contact, some wells now extend 3 or more miles in measured depth, with lateral reach ratios (horizontal length to vertical depth) exceeding 3:1 in extreme cases. These extended-reach wells, while improving recovery per well, have introduced new operational challenges in well construction. Installing (or running) the production casing, a once-routine step, has become increasingly difficult and can turn into a critical path operation for long horizontals. High frictional drag, helical buckling of the casing string, and torque limits of connections are more frequently encountered as lateral lengths increase (Pereira et al., Benedetto et al., 2020). If not managed properly, these issues can generate accessibility issues or prevent the casing string from reaching total drilled depth, leading to lost production, costly mitigation, or even well abandonment.

Figures 1 – 3 below illustrate the trend of increasing lateral lengths over time across US onshore basins, alongside a reduction in drilling times to total depth. While these data reflect notable gains in operational efficiency, they also raise concerns regarding wellbore quality. Specifically, improvements in drilling speed may not consistently translate into better wellbore conditions for production casing installation. Instead, persistent challenges remain, such as abrupt directional changes resulting in high dogleg severities, the occurrence of micro-doglegs, elevated overall wellbore tortuosity, and the potential accumulation of cuttings left behind during the drilling phase due to less favorable wellbore cleanup practices and shortened circulation times at total depth (TD). These factors collectively continue to impact casing installation operations, potentially increasing the risk of non-productive time, stuck pipe, and complicating well accessibility and integrity in completions and production operations.

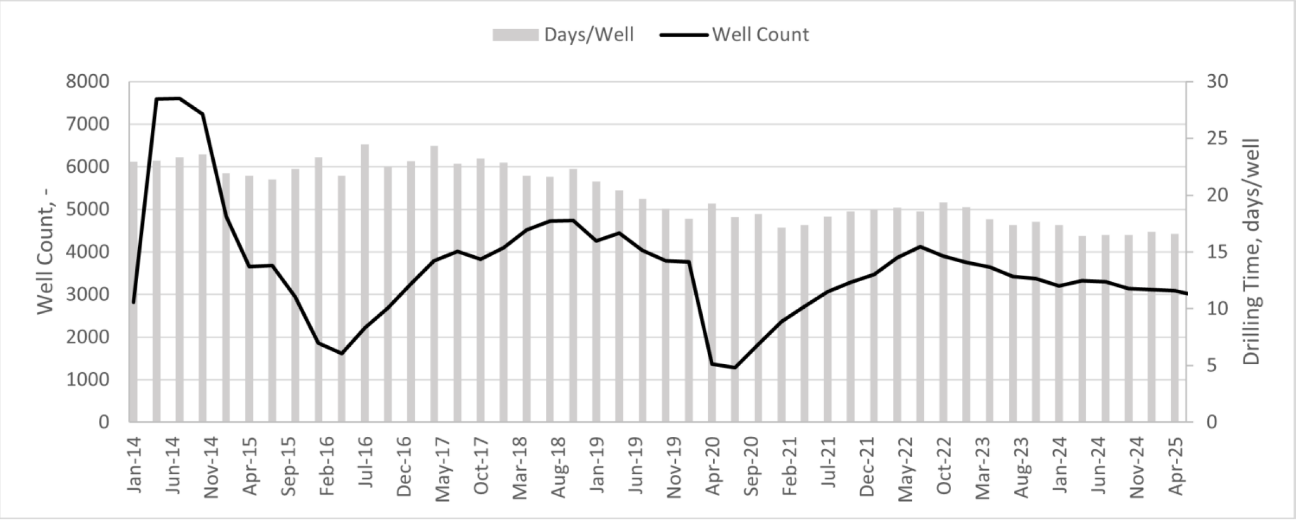

Figure 1—US Lower 48 Quarterly well count and average drilling time (Enverus, Tenaris, 2025)

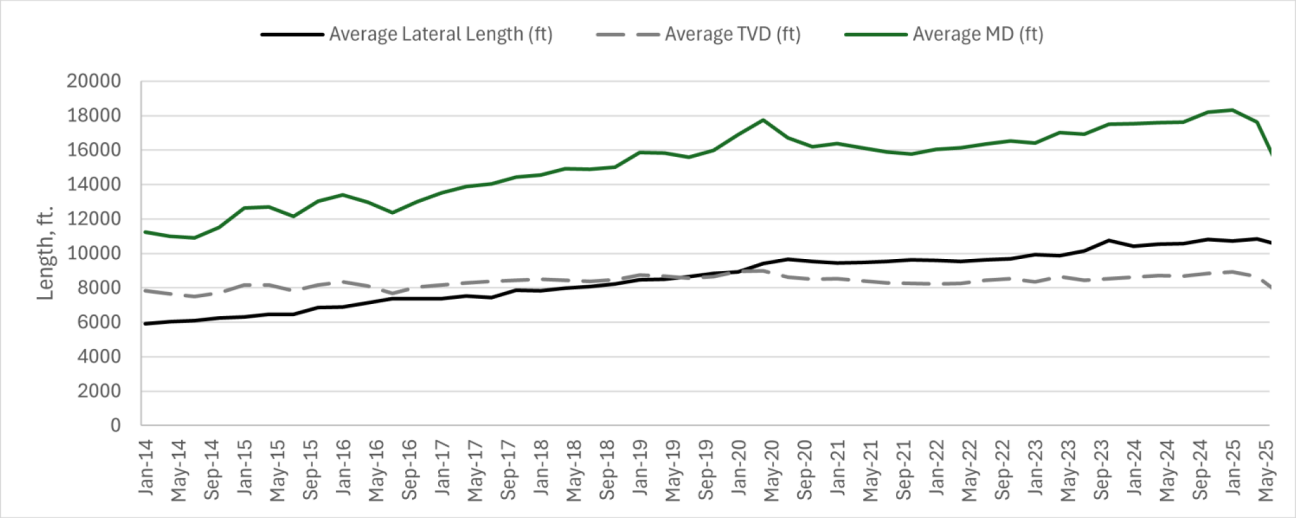

Figure 2—US Lower 48 Quarterly average lateral length, true vertical depth (TVD) and measured depth (MD) evolution (Enverus, Tenaris, 2025)

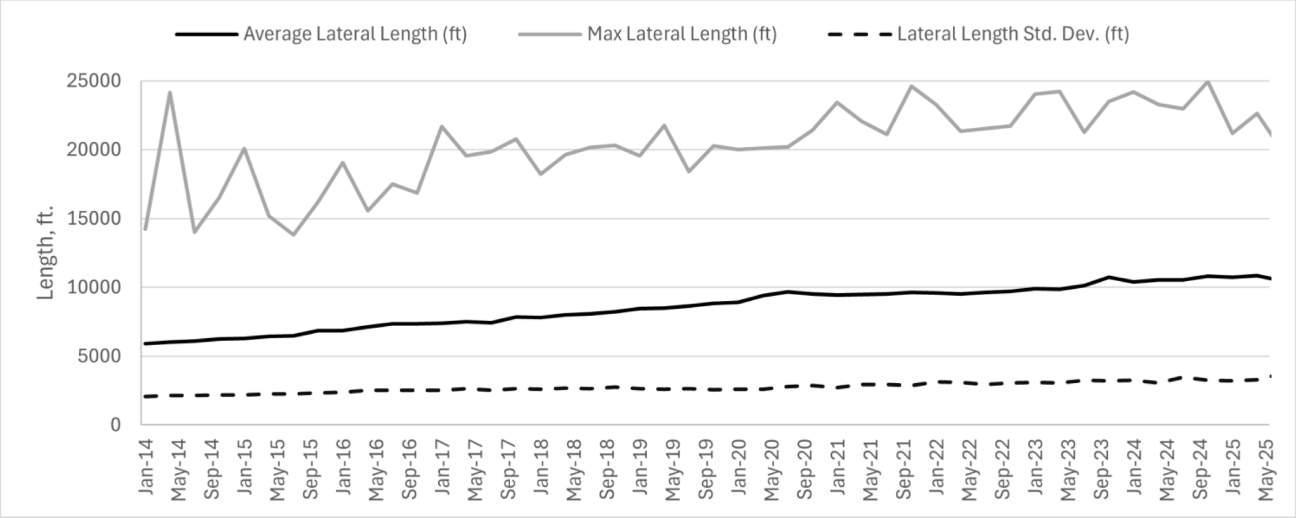

Figure 3—USA Lower 48 quarterly maximum and average lateral length together with its standard deviation (Enverus, Tenaris, 2025)

Furthermore, robust casing installation practices are foundational for completions and production operations because they preserve well accessibility and integrity, the prerequisites for getting frac plugs, perforating guns, and stimulation fluids to target depth without issues. Across recent literature, casing deformation in unconventional wells emerges as a multi-factor phenomenon driven by both geomechanical stresses and operational choices. In tectonically influenced plays with strong strike-slip/reverse-fault stress regimes, hydraulic fracturing operations more frequently trigger layer-interface slippage and fault reactivation, leading to severe casing failures or restrictions that complicate completions execution and subsequent well access (Casero & Rylance, 2020). Complementing these mechanisms, a multi-basin study compiling more than 150 verified failure cases shows casing installation as one of the main causes of loss-of-access events (Perello et al., 2020). Most recently, a comprehensive 2024 review synthesizes field experience and case histories to highlight early identification/diagnostics, continuous surveillance, and integrated geologic, geomechanical, and engineering controls as the backbone of mitigation and recovery; it also cautions that true deformation incidence is likely underreported, underscoring the need for broader sharing of best practices and standardized monitoring (Uribe-Patino et al., 2024). The same best practices also help ensure production systems (i.e. artificial lift) can be installed without issues and utilized for the designed lifetime. In extended laterals, the mechanics of the installation (high frictional drag, connection fatigue, and the onset of sinusoidal/helical buckling) can seed the problems that later surface during completion if they are not proactively managed. As well complexity and subsurface heterogeneity increase, these practices lower the risk of casing deformation and internal diameter restrictions encountered during completions. For example, avoiding production casing internal diameter restrictions during completions through avoiding over-torqued connections or buckled casing strings.

This paper presents knowledge gathered from production casing installations in unconventional horizontal wells, spanning multiple shale basins. The analysis aims to discuss key factors affecting installation success and to extract best practices that enable running casing to planned depth reliably in extended laterals. We provide the technical background for the problem and operational practices known to improve casing installation outcomes. The development and deployment of a real-time casing installation monitoring system to address these challenges in the field is also documented.

Background and Methodology

Multi-fractured horizontal wells (MFHW) pose distinct challenges for oil country tubular goods (OCTG), particularly the production casing string, as each phase of well development imposes unique demands on the connection, such as tension, compression, bending, fatigue, torque, burst resistance, and sealability. These must be evaluated together due to their combined effects (Blanc et al., 2021).

After assembling the connection, the casing string is installed in wells with long horizontal sections and steep inclinations. Installation methods include tripping in on elevators, rotation to overcome axial drag (also referred to as reaming in), and casing flotation to reduce effective weight. Challenges such as excessive drag or wellbore instability may require simultaneous application of pick up, slack off, and torque to free stuck pipe, and rotation can improve cement placement. Key connection requirements for production casing during installation are tension, compression, bending, fatigue resistance, torque capacity, and runability. After cementing, hydraulic stimulation subjects the production casing to high differential pressures and temperature changes, demanding bending, burst, tensile capacity, and sealability. In the production phase, connections must maintain sealability under reservoir conditions after exposure to tension, compression, internal pressure, and bending. Figure 4 illustrates common challenges for tubulars in MFHW during the well lifecycle.

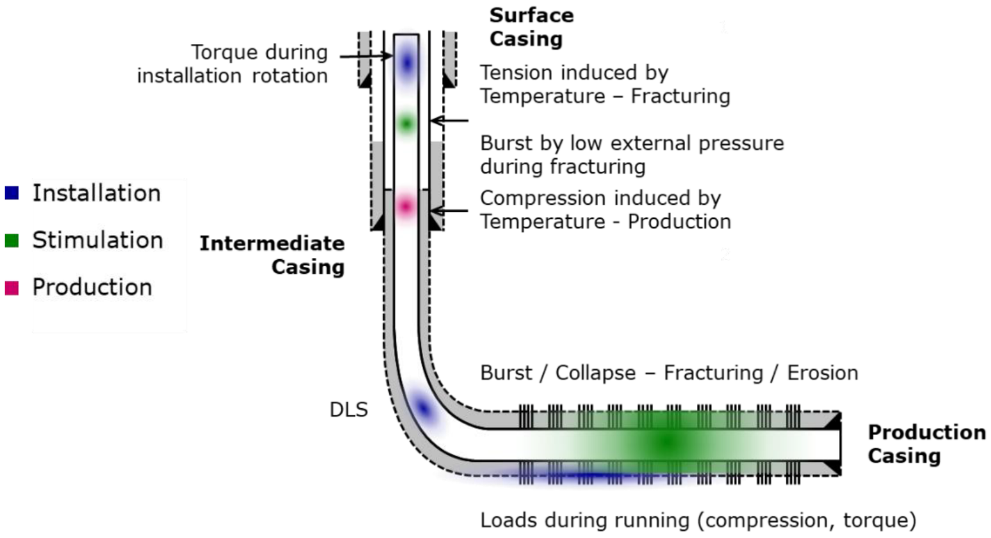

Figure 4—MFHW Challenges during different stages

Running production casing to total depth in a horizontal well requires overcoming frictional forces that resist the pipe's mo vement. In the conventional soft-string torque and drag model (Johancsik et al. 1984), the drilling or casing string is modeled as a flexible line in contact with the wellbore. As the string is run in, frictional drag acts opposite to the direction of motion. The drag force Fd at any contact point is proportional to the normal contact force N (determined by the pipe's weight and wellbore curvature) times a friction coefficient μ. In mathematical terms, $Fd = \mu \cdot N$ (Coulomb friction). In inclined and horizontal sections, much of the pipe's weight is supported by the low side of the hole, increasing normal force and thus drag. The result is that hook load (the weight recorded at surface including the rig block weight) continuously decreases as more pipe enters a horizontal section. In very long laterals, the hook load can approach the block weight if drag forces balance out the buoyant string weight, at which point the pipe can no longer be run deeper by lowering it on elevators only - a condition often called lock-up.

To mitigate lock-up, operators can use a flotation device to reduce the effective weight of the casing string in the lateral, and/or rotate the casing string, converting some axial drag into torque. In its most basic form, the torque required to rotate the string can be expressed as $T = \mu \cdot N \cdot r$, where r is the outer radius of the tube, or $OD/2$. However, rotation introduces cyclic stresses. As the casing rotates through curved sections (doglegs), it experiences bending, which leads to alternating tension-compression cycles that induce fatigue (Rodriguez-Jordan et al., 2014). Fatigue, primarily at connections, is a concern for casing installation when:

- The connection has a low fatigue life
- The casing string is rotated in one spot for extended time intervals
- The trajectory exhibits high dog leg severity
- The trajectory has micro-doglegs that are not properly recorded by available surveying methods
- The string experiences additional dynamic loads or thermal loads
- Rotation while cementing is expected, but may be excessive due to the level of cumulative fatigue generated from rotation and a combination of the preceding points.

Another challenge common in long laterals is buckling of the casing string. As the string installation progresses towards its setting depth and drag forces increase from cumulative friction, compressive forces commonly build up in the lateral section, build section, and just above the vertical to the curve build transition point (kick off point). When a segment of the string develops a compressive force exceeding the critical buckling load, the string can buckle into a sinusoidal shape, followed by a helical shape, which then increases drag (Haduch et al. 1994). Critical buckling forces for sinusoidal (or lateral) and helical buckling can be calculated as $Fc = k\sqrt{4EIw_c/r_c}$, with k varying from 1 to 5.65 (Mitchell, 2008, Menand and Farrag, 2019). Here, EI is the bending stiffness, w_c is the contact force between pipe and wellbore, and r_c is the radial clearance. In unconventional horizontal wells, helical buckling tends to appear on top of the build section, where the cumulative axial compressive forces are greatest and expected to continue to increase as the installation progresses without rotation. Once buckled, even rotating the string yields diminishing returns because the pipe continuously presses against the borehole wall, while at the same time requiring a higher level of torque to achieve rotation. Thus, the best strategy is often to begin rotating before severe buckling occurs, rather than waiting until the string locks up, and to ensure that the string is not buckled when rotating. A calibrated torque and drag model can predict the depth at which helical buckling is likely to initiate, helping to inform the decision of when to start rotation.

Table 1 summarizes our internal dataset of casing runs by lateral length. From a dataset of 2869 wells, the average lateral length is 11,200 ft and average run time is 21.1 hours. 79% of these were floated, and 31% of the production casing runs from the dataset needed rotation. As expected, shorter laterals (less than 2 miles) rarely required any special measures to reach bottom; normal slacking-off was sufficient in most cases.

In medium-length laterals (2 to 2.5 miles), frictional drag was more significant and rotation was used in roughly a third of these runs. For the longest laterals (longer than 2.5 miles), conventional running practices (no rotation) were less successful. In our data, practically all wells in this category required either rotation while running, the use of a flotation sub, or a combination of both. In a small number of wells, the operator needed to circulate prior to installing the flotation sub, which led to a hybrid approach of a partially filled air chamber. This aligns with previously published observations in other basins - e.g., one study noted that 93% of the laterals between 6,500 ft and 8,200 ft in the Vaca Muerta (a complex play) needed rotation to reach TD (Benedetto et al. 2020). It is also consistent with the industry's general move toward imperfection-tolerant strategies for casing installation in ERD wells (Dall'Acqua et al., 2022).

Table 1—Casing run outcomes for different lateral length ranges

Lateral Length (mile)	Typical Outcome and Challenges	Rotation Utilized (% of runs)	Flotation Utilized (% of runs)
< 2	Low drag; casing runs to bottom with standard practices. Minor doglegs easily overcome.	25.0	71.5
2 – 2.5	Noticeable drag; some tendency for buckling above KOP. Requires close monitoring; may need rotation in tighter spots or higher friction laterals.	32.8	84.8
2.5 – 3	High drag; approaching lock-up without mitigation. Likely need flotation and/or rotation. Tight curvature and tortuosity exacerbate drag and risk of lock-up	43.7	90.8
> 3		44.1	100

Actual outcomes can vary with formation, hole condition/wellbore quality, and equipment, e.g., an 8,500ft lateral that was extremely tortuous might behave more like a "long" lateral in terms of casing installation difficulty.

Given these challenges, our methodology to improve casing running success comprises several elements: engineering planning, realtime monitoring, adaptive operational procedures, and post-job analysis (either for a particular well or a group of wells). In the planning stage, each well's survey data and drilling plan were used to perform a torque & drag simulation. Hook load and surface torque were predicted under plausible friction factor values (usually examining a range from $\mu = 0.2$ *to* 0.5 to bound the "best" and "worst case" scenarios). From this, we identified if flotation would be needed (a flotation sub was recommended if the model predicted insufficient weight at surface when tripping in without flotation) and what the likely "trigger point" for rotation would be (e.g., model might suggest that at ~10,000 ft casing shoe depth, hook load will approach block weight unless rotating).

Communication protocols and crew training were established so that everyone understood the plan and the signs of trouble. The rig crew and engineers were briefed on how to interpret the real-time data: for instance, a hook load significantly lower than expected at a given depth would prompt rotation. Prior to deploying the live monitoring system widely, several trial runs or historical data reviews were conducted to validate its outputs against measurements and to calibrate friction factors.

The real-time monitoring system consists of a cloud application connected to the rig's electronic drilling recorder (EDR) via a WITSML (wellsite information transfer standard markup language) feed. As casing was run, the system utilized a machine-learning based rig state detection algorithm to determine the current rig action, aggregate data at various frequencies (0.1 – 1 Hz) and plot them against the modeled values. Time-series based alerts were configured such that if hook load approached the buckling limit or if surface torque or tension approached a defined threshold (e.g. the connection operating torque or tensile limit, which are referenced from the tubular manufacturer database), notifications are shown in the live dashboards. The system also dynamically tracks cumulative fatigue due to string rotation, providing an on-screen indication of fatigue consumption in each connection based on aggregated EDR data, survey data, and testing data for the particular connection type. Finally, for stuck pipe instances, the system displays full-scale testing or finite element analysis (FEA) generated torque-tension envelopes for various connections, enabling the rig to stay within a low-risk zone when pulling and/or torquing up the string.

Beyond immediate operational parameters, data analytics provided performance benchmarking. The system logs key performance indicators (KPIs) such as average casing joints run per hour, on-slip versus off-slip time, total time to reach TD, and physics inputs needed for the models. By reviewing these KPIs after each well (or even during the run), the engineering teams could identify bottlenecks and inefficiencies. For instance, if one crew was averaging significantly longer make-up times (off-slips time) than others, that could be addressed through training or equipment adjustments. If running speed consistently decreased at a certain depth on multiple neighboring wells, that might indicate a recurring hole condition to improve (such as better hole cleaning in that interval). Overall, capturing this data in real time allowed teams to make informed decisions and maintain better control over the operation, while also feeding a cycle of continuous improvement for future wells.

Results and Discussion

Alongside the real-time monitoring technology, operational best practices were gathered and implemented. Below, we list the main best practices emphasized and the rationale behind each. These were collected from both internal lessons learned and industry references, and they form a checklist for each casing run:

Pre-installation planning

Minimize dogleg severity and tortuosity - A smoother wellpath means less drag and lower risk of the string becoming mechanically stuck from a reduction in contact forces and friction hotspots that would otherwise contribute to the risk of buckling. It also lessens bending stress on the casing, improving running, post-installation casing accessibility, and a preferred casing condition for tools and artificial lift system install.

Ensure adequate hole cleaning - Prevents cuttings beds or debris from accumulating, which can cause tight spots, and gradual or sudden increases in drag. Good hole cleaning (appropriate mud rheology, suitable flow rates, sufficient circulation time and optimized trip out of hole practices) during drilling and once TD is reached reduces the chance of the casing string encountering obstructions while running.

Use casing flotation - Flotation subs allow running of lower sections of casing empty, reducing drag in the lateral while increasing hook load availability as mud fills the vertical section above the floatation sub. Optimized floatation sub placement can result in maximizing hook load availability as TD is approached, or the improvement in hook load availability in combination with rotation when both are required to reach TD.

Select high-torque connections - Enables safe rotation under high torsional loads. Modern production casing connections designed for MFHWs with high torque capacity (e.g., wedge-type thread or buttress modified) and, when needed, metal-to-metal seals, can exceed 30,000 ft-lb torque capacity in a 5.5″ size, allowing rotation without compromising string integrity and/or accessibility (Blanc et al., 2019). This is critical for long laterals that will likely require rotating the casing.

Employ appropriate centralizers - Centralizers aid in casing standoff but may affect running friction. In long laterals, fixed centralizers that rotate with the pipe are recommended if rotation is planned - they prevent the casing from simply spinning inside the centralizer, which was found to limit drag reduction. Low-friction centralizers could be used to minimize additional drag. Understanding optimal centralizer selection and placement for balanced stand-off and running efficiency reduces the risk of challenging running conditions at the cost of prioritized standoff.

Pre-installation torque and drag modeling - Alignment on installation expectations, including expected friction factors, depths at which buckling might initiate, rotation and torque parameters to optimize installation efficiency, as well as the best practices listed below in the During Installation Operations to manage installation challenges

During Installation Operations

Monitor torque and drag in real time - Monitoring provides timely insight into downhole conditions (Shahri et al., 2018, Sun et al., 2023). By observing hook load and torque trends, the team can decide to start rotating before the string encounters excessive compression and potential lock-up. Early rotation (prior to severe buckling) was a common factor in successful runs, as it also helps avoid excessive torque to maintain constant rotation.

Control running speed and slack off weight - Avoid sudden stops and use gentle reciprocation if needed. Smooth, continuous movement minimizes surge pressures and avoids exacerbating compressive forces. If resistance is met, slow down and work the pipe gradually. Minor reciprocation (worked within a short interval) can help redistribute friction but must be controlled to prevent affecting wellbore stability and introducing conditions that may further inhibit efficient progress to TD. Hard reciprocation or forcing the pipe can worsen already difficult wellbore conditions. When excessive reciprocation is needed, consider rotating the string instead.

Maintain continuous rotation (avoid stalling) - Once initiated, attempt to maintain continuous rotation of the string at surface to prevent stalling. Stalling can reduce or eliminate the benefit of friction distribution expected from rotation. In turn, this reduces effective weight transfer due to axial drag immediately rising, possibly resulting in a lock up. Additionally stalling presents the risk of vibrational loads from torsional oscillations similar to those encountered during stick-slip events but rather induced at surface instead of at the bit. Torsional oscillations have been identified as a main driver for damage to drill string connections and BHA components (Kulke et al., 2022, Pettit et al., 2021, Obuobi et al., 2025), with the expectation that similar over torque damage can be generated in casing connections.

Stay within safe operating limits for torque and tension - Adhere to the connection's torque-tension envelope to prevent structural failures. When approaching combined limits, crews monitor parameters closely and adjust practices.

Avoid rotation in one spot - Avoiding prolonged rotation in a single position is critical to prevent cocentrated connection fatigue damage and localized frictional heating. Whenever possible, rotation should be combined with fluid circulation and consistent returns, to dissipate heat. This approach reduces the likelihood of excessive downhole temperature rise, which can derate the steel's yield strength and in severe cases permanently alter the steel's microstructure. Industry experience and documented failures in unconventional wells have shown that working stuck casing without circulation can lead to heat-induced transformations and parting of casing (Benedetto et al., 2020). Regarding connection fatigue damage from rotation in a single position, concentrated high levels of fatigue damage can rapidly accumulate due to the continuous exposure to high dog leg severities and the resulting cyclical tension and compression. Although a stuck casing scenario may not allow for the avoidance of rotation at a single position, monitoring of accumulated damage may inform how long one may choose to rotate.

Post Installation

Review installation data for continuous improvement - Analysis of both demanding and non-demanding casing installations facilitates the identification of factors that distinguish them. Furthermore, recognizing trends can provide valuable insights for optimizing future projects. When operational variables, such as the transition from oil-based mud to water-based mud, trajectory improvements, or flotation sub placement, are deliberately adjusted, reviewing their impact on installation enables accurate model calibration and more reliable forecasting for subsequent wells.

Using these practices in combination, the goal was to create a robust running plan for each well and then adapt on the fly using realtime data. Post-installation analysis allows for a feedback loop to be established, allowing for continuous improvement of casing installation practices. The following sections discuss results from the field, including specific case studies that exemplify the benefits of this approach.

Case Studies

Case Study 1 – Pre-job Modeling and Execution. An operator presented a challenging pad with a well design including tight clearance, high drilling fluid density, and a lateral length greater than 15,000 ft., which introduced high frictional loads, significant buoyancy effects during flotation, and elevated torque requirements during rotation. To address these complexities, the engineering team conducted comprehensive pre-job modeling. The modeling workflow focused on three critical aspects: assessing rotation feasibility, identifying sections where hook load and torque approached operational limits, and where to optimally place the flotation sub. Sensitivity analyses were performed on friction factors, flotation sub placement, and well tortuosity to validate the robustness of the plan under varying scenarios. The placement of the flotation sub was optimized to enhance running efficiency.

As found in Figure 5, the evaluation of buoyancy effects and strategic positioning of the floatation sub at 12,000 ft MD, versus the originally planned 14,500 ft MD, allowed for the avoidance of a shallow lock up scenario and having to rotate casing early for a calibrated 0.38 open hole friction factor. Through this optimization a predefined rotation start depth was programmed into the casing installation plan to avoid helical buckling and allow for a positive weight trend as the string approached total depth (TD). Additionally, modeling of the shallower floatation sub position confirmed a reduction in the required surface torque for rotation, which informed the top drive setpoints.

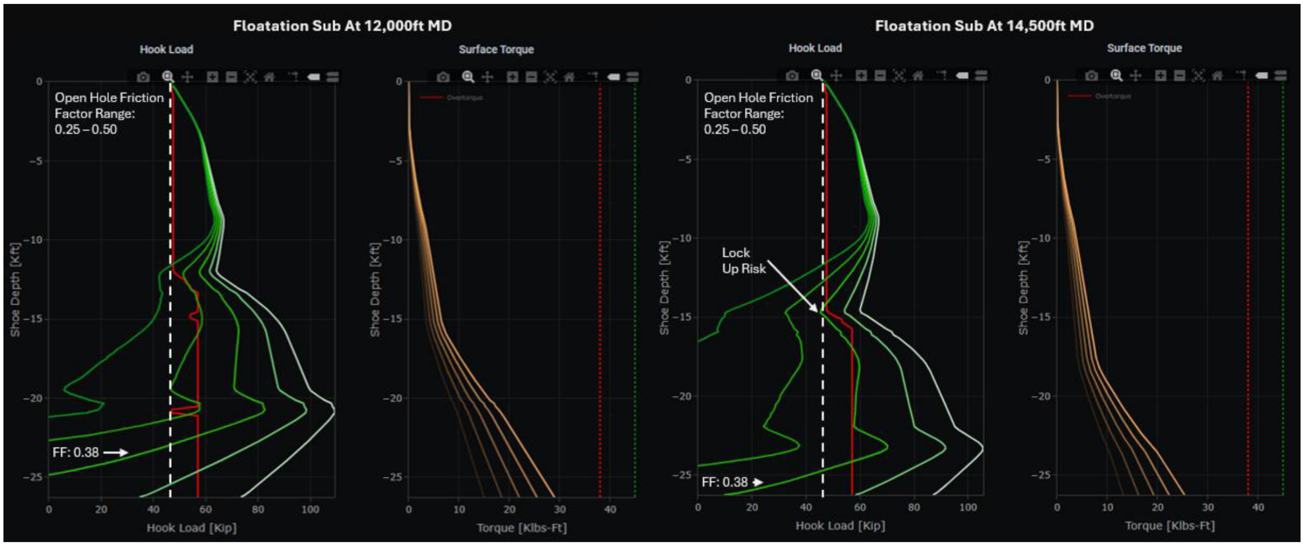

Figure 5—Comparison of pre-installation hookload and surface torque estimations for floatation sub positioning at 12,000 ft MD (Left) and at 14,500 ft MD (Right)

After each well on the pad, models were fine-tuned to increase confidence level. By implementing these strategies, the operator minimized non-productive time and ensured reliable casing installation.

Case Study 2 – Delaware Basin Premature Casing Flotation Sub Burst. The deployment of casing floatation during installation presents the need for risk management and an understanding of how to manage the casing installation if the flotation sub is to be burst intentionally or unexpectedly prior to reaching installation planned depths. For casing floatation installations where progress is interrupted because of formation fluid influx events, concerns of high heat accumulation due to the length of time spent rotating without progress, or the loss of hookload due to the presence of debris or other progress resisting mechanism, the need to burst the floatation sub to circulate drilling fluids becomes necessary. For these cases and cases where the flotation sub is unexpectedly burst, the originally estimated torque and drag scenario sees a significant shift towards a loss of hookload and an increased surface torque requirement that may not have been planned for.

For an installation in the Midland Basin, unexpected bursting of the floatation sub occurred 1,609 ft away from TD. Because of active real-time monitoring, the sudden shift in hookload measurements away from the established trend led to a rapid collaborative decision between interested parties on how to further proceed. Torque and drag models were updated to estimate hook load progression, buckling risks, and surface torque expectations for when casing rotation would have to be performed due to the risk of lock up without rotation. In Figure 6, the modified hookload and torque models are presented along with real-time system aggregated field hookload and torque measurements. These models account for the flotation sub until the premature burst, and the fluid distribution inside the casing after. Of interest are the hookload model estimations demonstrating TD is only approachable, by slack off only, with a lower friction factor than what was observed during running. This estimation informed the decision to start rotation, rather than spend time attempting to progress through reciprocation. Additionally, the cumulative fatigue across the string from rotation of the casing in the final 1,609 ft. is included to highlight the segment of casing which incurred the higher levels of cumulative fatigue up to a maximum level of 5.33%.

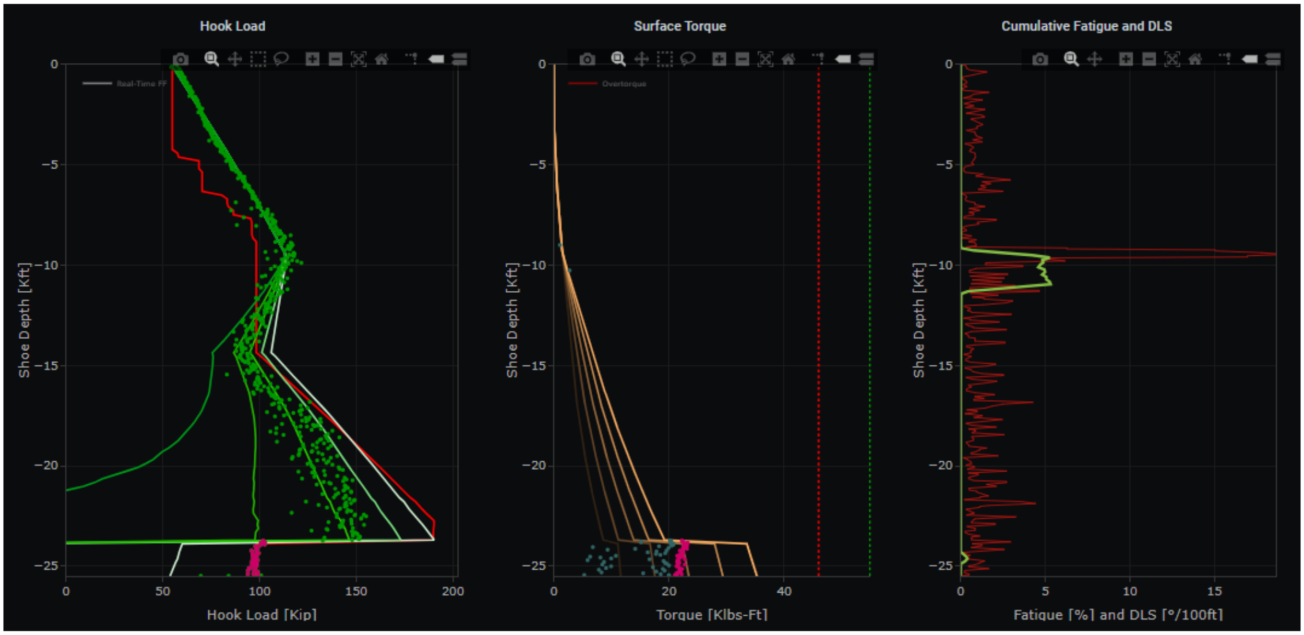

Figure 6—Hook load broomstick plot for adjusted model once flotation sub burst, with good agreement between data and model for both scenarios

For this challenging installation, real-time monitoring enabled insight into the ongoing operation and the availability of actively calibrated torque and drag models that can be adjusted to represent shifted field conditions within moments. Prior to the adoption of this practice, operations would attempt to blindly progress or commit additional time for data coordination and model calibration to understand how casing installation may progress.

Case Study 3 – Delaware Basin Rotation Stalling. Reports of loss of expected access for plug and related completion tool deployment have led to investigations of casing installation data, resulting in the identification of dynamic vibration loads from torque stalling during rotation as a main driver of over-torqued production casing connections that present a restricted internal diameter and compromised performance. For an operator drilling in the Permian Basin, increased unplanned completion costs due to over torqued connections were accompanying the extension of laterals and reduction of drilling times. Analysis of previous casing installations where restricting over torqued connections were identified provided insight into casing rotation practices, including top drive and casing running tool torque settings, RPMs, slack off speeds, and decisions to adjust such parameters as installation progressed to planned depths. Of primary concern in the analysis was the identification of torque stalling in the EDR data that was accompanied by an erratic RPM, sometimes quickly fluctuating between 30 RPM and 0 RPM as captured in Figure 7.

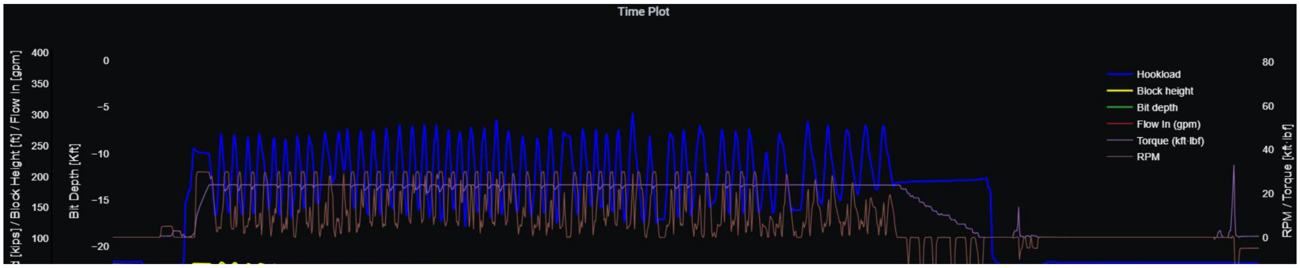

Figure 7—Hook load, block height, surface torque, and RPM during stallout events. Note surface torque static value with RPM and hook load fluctuations

The analysis into offset installations by various rigs in the operators fleet also presented a lack of standard operating procedure for casing rotation operations, as rigs were found to set surface equipment torque setting below the operating torque limit of the deployed connections. In some cases, the hesitation to exceed make-up torque levels referenced during connection make-up were identified. Where low torque settings may have been sufficient in applications with shorter laterals, such settings now resulted in torque stalling that would reduce the benefit of rotation on the distribution of drag forces and induce uncontrolled downhole torsional vibrations that would over torque connections beyond the torque applied at surface.

Through training and the adoption of best practices previously listed, increased installation efficiencies were realized, including consistent rotation from optimized surface torque settings that allowed for the continuous distribution of drag and the reduction of string reciprocation while preserving ID access for completion operations.

Case Study 4 – Eagle Ford Performance Improvements. For an Eagle Ford operator, we monitored and analyzed production casing installations in 17 wells to improve running practices. Of these, 11 wells utilized casing rotation. The analysis focused on a 5-well pad where all wells were rotated, despite having shorter lateral lengths. Review of surveys, drilling fluid programs, and drilling practices confirmed that this pad faced more challenging geological conditions compared to neighboring pads with less rotation. A key finding was that casing reaming speed was 56% lower than the overall trip speed, indicating potential for efficiency gains even under difficult conditions. Similar to the previous case study, detailed EDR data analysis revealed multiple stallouts which contributed to longer casing reaming times. The study determined that initiating rotation with torque values closer to the connection's operational threshold helped maintain consistent rotation speed, reduced the risk of stalling, and shortened total run time.

By adopting this approach, the operator could save an estimated 28.5 hours across the 17 wells, while also lowering the risk of well accessibility issues during completions.

Case Study 5 – Stuck Pipe Support. In a stuck pipe event where the operator believed that the mechanism was differential pressure sticking, we used an in-house generated torque-tension envelope that is displayed within the real-time monitoring tool as guidance. The envelope references full-scale testing results or, when those are not available, finite-element estimates, both of which can be modified to account for applicable design factors (Zara et al., 2022). The envelope informs torque or tension deration when the rig applies 100% of either. By displaying the torque-tension limits for the specific casing connections together with 1 Hz combined surface tension and torque from the EDR data, the tool enabled us to monitor surface parameters in real time and ensure that all pulling and torquing actions remained within safe operating boundaries. This approach allowed us to make informed decisions quickly, including the decision to incrementally increase tension and torque up to an informed limit, minimizing the risk of damaging the string while freeing it efficiently. After freeing the string, the operator decided to pull out of hole, recondition the wellbore, and trip in with casing again, reaching total depth successfully.

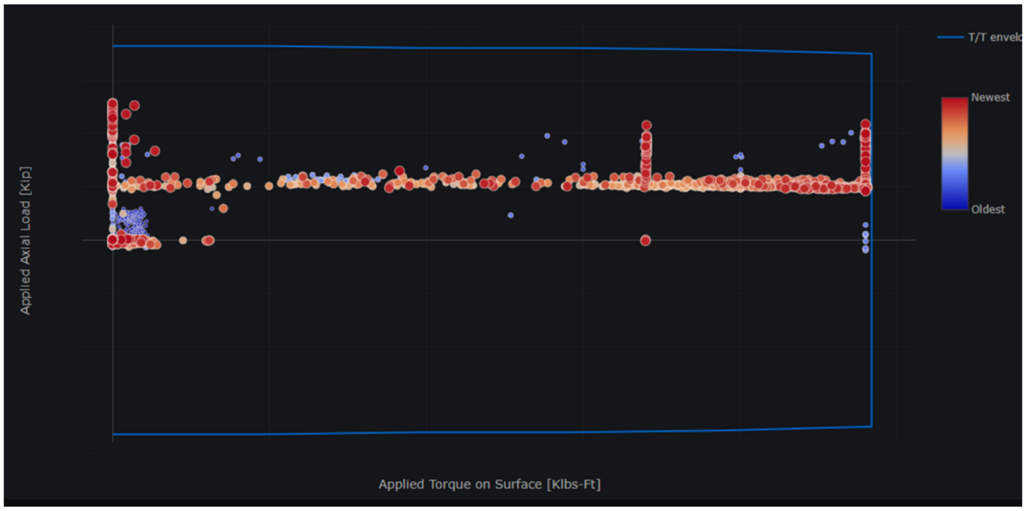

Figure 8—Torque-tension envelope for a threaded and coupled wedge-type connection. Points represent combined EDR hook load and surface torque data within the envelope, with newest points plotted red, and oldest plotted blue. No safety factors applied.

Case Study 6 – Rotation while Cementing Monitoring. Rotation during cementing is essential for achieving effective mud displacement, uniform cement sheath, and long-term zonal isolation, which directly impacts well integrity and stimulation efficiency (Turner et al., 2019, Belvin et al., 2020). To derisk this operation and assess the necessary surface torque and fatigue life during installation and cementing, a series of pre-job simulations were performed. Once a suitable connection was identified for the expected torques and rotation times, the operator also implemented the real-time monitoring system to assess the cumulative fatigue based on rotational cycles, bending stresses, and full-scale laboratory testing data. The figure below shows final cumulative fatigue (green) across the entire production casing string together with the DLS profile (red) after rotating for approximately 3 hours during cement pumping.

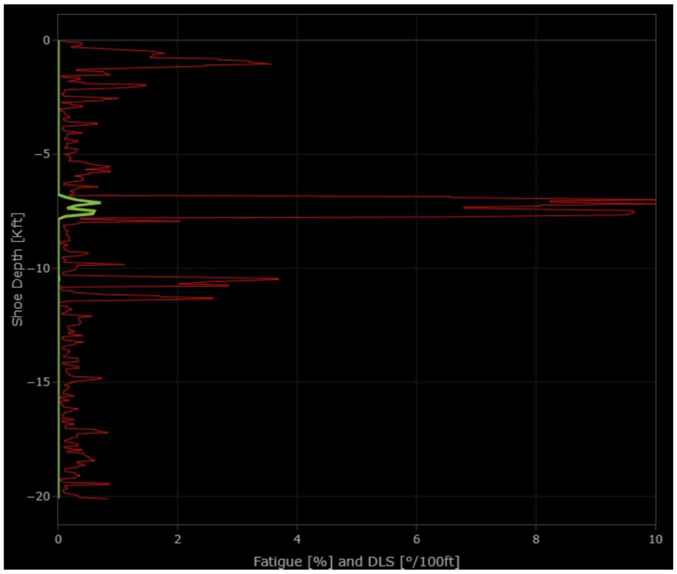

Figure 9—Depth-based connection cumulative fatigue (green) and dog leg severity profile (red)

By continuously tracking fatigue damage accumulation incurred during installation and cementing, the operator mitigated risks of premature casing failure while maintaining rotation speeds necessary for optimal cement placement, delivering improved cement bonding and reduced uncertainty in completion performance.

Conclusions

1. **Extended laterals demand a proactive approach to casing installation.** As lateral lengths increase, the margin for error in casing running decreases. What was once a routine task can become a critical operation. High frictional drag, casing string buckling, and connection torque limits being reached are common in laterals beyond 2.5 miles. Operators should plan for these challenges as a certainty rather than an exception.
2. **Torque and drag modeling is an essential planning tool** for long horizontals. Upfront simulations help predict if and when issues will occur. They inform decisions such as whether to use a flotation sub and when to initiate rotation. Modern T&D software, when used properly, provides a good first-order estimate of expected loads and can prevent the selection of inadequate connections.
3. **Real-time monitoring and data-driven adjustments markedly improve casing run success.** Implementing a real-time T&D monitoring system helped operations. It enabled early detection of anomalies (drag or torque deviations) and guided prompt interventions. As a result, stuck casing events were reduced in the monitored wells.
4. **Rotating the casing string is often necessary and beneficial in extended laterals,** provided high-torque connections are used and best practices are followed. We found that initiating rotation before the onset of severe buckling is critical to maintaining motion. With appropriate connections and real-time torque management, rotation was done safely in hundreds of wells, improving hook load transfer and reducing running time.
5. **Good hole conditions and fluid management remain fundamental.** Proper hole cleaning, managing cuttings, and avoiding excessive wellbore tortuosity all contribute to lower drag.
6. **Standardizing best practices and training crews in these methods leads to more consistent and efficient outcomes.** By developing a clear set of procedures and using the real-time data and physics-based thresholds as a common reference point, variability between crews was reduced. A high level of consistency in casing running performance across multiple rigs and crews was achieved, showing that a systematic approach, rather than ad-hoc handling of problems, yields the best overall performance.
7. **Equipment and design choices,** such as choosing suitable connections, centralizers, and flotation tools, are important considerations for long laterals. In the wells examined, the use of robust high-torque casing connections helped manage the demands of rotation. Incorporating a centralizer strategy, especially fixed centralizers when rotation is required, and having flotation subs available for extended runs offered practical operational benefits and contributed to smoother and faster casing installation.
8. **Continuous improvement: data from each casing run should be captured and fed back into future planning.** Over time, a rich dataset allows for deeper analysis to understand what variables may lead to casing installation challenges. With time, one can refine friction factor estimates, improve model accuracy, and benchmark performance, creating a positive feedback loop.

The integration of pre-job engineering, real-time monitoring, adaptive execution, and post-job analysis has demonstrated tangible benefits for casing installation in unconventional extended-reach wells. Utilizing these methods, operators have been able to decrease non-productive time and minimize risks typically encountered during production casing runs. Challenges such as casing getting stuck before reaching total depth are now more manageable, even as lateral lengths increase. As longer horizontal wells become more common and geological complexity and heterogeneity increase, applying these systematic practices will be necessary for well construction to keep pace with drilling developments, support well integrity, and improve completion outcomes.

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