AADE-25-NTCE-024

Utilization of downhole monitoring system with drillpipe deployed flotation collar in long horizontal

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Abstract

This paper aims to analyze downhole data and force dynamics recorded by the i-Con downhole monitoring sub during completed liner installations in long horizontal wells utilizing a drillpipe deployed Ultra Reach Flotation Collar (URFC).

The drillpipe deployed flotation collar enables floating liners to reach deeper target depths that would be unachievable with conventional deployment methods. This cost-effective approach does not require modifications to the well construction design.

The downhole monitoring sub (DMS) captured internal and external pressure, strain, temperature, and torque at a frequency of 10 readings per second, allowing for detailed analysis of key events including fluid column behavior post-glass disc burst and pressure variations during liner hanger activation.

The DMS data analysis yielded significant insights into downhole dynamics. We observed sudden pressure changes exceeding 7,000 psi occurring in less than a second, resulting in abrupt shifts in tension and compression states with force changes reaching up to 120 kip within milliseconds. These rapid fluctuations represent challenges for hydraulic liner running tools, as they may struggle to adapt effectively to such extreme conditions.

These findings provide critical information for equipment selection, operational planning, and clarifying performance limits of tools under varying downhole conditions. Understanding these dynamic behaviors is crucial for enhancing efficiency and safe operating limits in liner hanger installations.

The material presented outlines an optimized methodology for configuring downhole systems, enhancing liner installation reliability. Insights from DMS data improve the management of extreme pressure fluctuations when floating, leading to more efficient liner hanger installations.

Introduction

The landscape of oil and gas exploration has undergone significant transformation in the last 10 years, driven by the continuous pursuit of enhanced wellbore productivity and operational efficiency. Horizontal drilling technologies have evolved dramatically, with average lateral lengths expanding from just over 5,000 ft in 2015 to more than 10,000 ft in the Delaware Basin by 2024, with some individual well laterals exceeding 15,000 ft. This remarkable progression underscores the industry's technological capabilities and the increasing complexity of modern drilling operations

However, the extension of horizontal well lengths introduces substantial technical challenges that demand innovative solutions. Primary among these challenges is the critical issue of production string deployment, where friction and mechanical limitations significantly constrain operational capabilities. Traditional deployment methods encounter numerous obstacles that compromise the efficiency and reliability of deep horizontal wellbores.

Conventional production string deployment faces multifaceted technical constraints. Casing tensile and compression limitations, torque restrictions, and reduced annular bypass areas create significant operational barriers. These limitations not only compromise the structural integrity of the deployment process but also escalate operational costs and technical complexity. Long string casing systems, while common in intermediate casing designs, demonstrate inherent weaknesses when applied to extended lateral wellbores.

The economic implications are equally significant. Material costs for long string installations are substantially higher compared to liner hanger systems, making innovative deployment technologies not just a technical imperative but also a financial necessity. The industry requires solutions that can navigate increasingly challenging wellbore geometries while maintaining operational efficiency and cost-effectiveness.

Recognizing these challenges, a comprehensive analysis was done to address the complexities of horizontal liner installations. This analysis leveraged advanced downhole monitoring technology to:

- Conduct a detailed analysis of downhole dynamics using a high-resolution downhole monitoring system (DMS).
- Evaluate the performance of both drillpipe and casing deployed flotation collar technologies.
- Quantify pressure and force variations during floated liner installations.

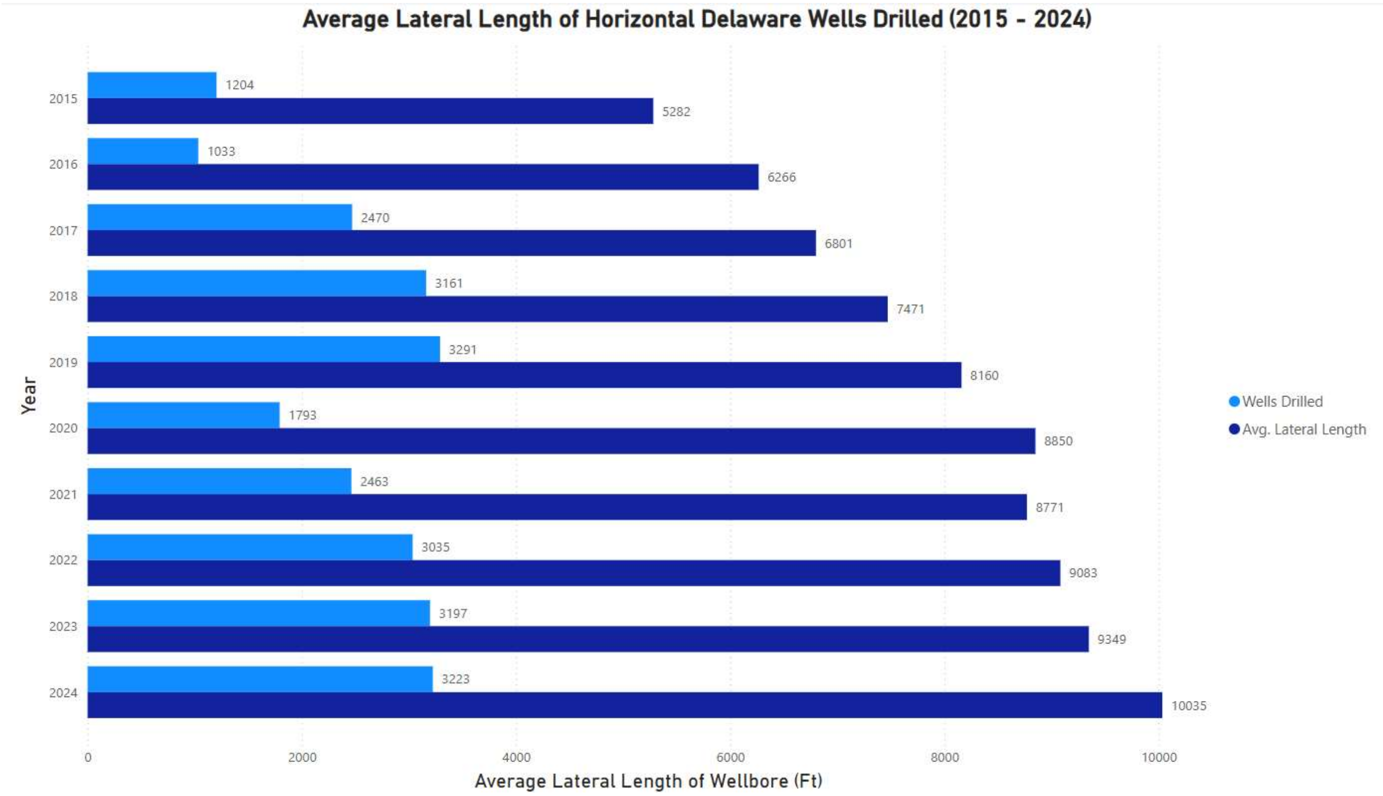

Figure 1 – Delaware Basin Average Lateral Lengths – (Enverus, 2024).

- Monitor and record other critical installation sequences like hanger setting, cementing, and packer activation.

By systematically examining these parameters, this study seeks to provide actionable insights into optimizing deployment methodologies, reducing operational risks, and expanding the technical boundaries of horizontal well completion techniques.

The significance of this study extends beyond immediate operational improvements. It represents a critical step toward developing more robust, efficient, and adaptable drilling technologies that can meet the increasingly demanding requirements of modern hydrocarbon exploration and production.

Methodology

Downhole Monitoring System Description

The downhole monitoring system (DMS) used in this analysis is a sophisticated logging tool designed for high-precision data collection in challenging wellbore environments. The DMS's drillpipe connection compatibility ensures easy integration with various downhole equipment, while its full-bore design minimizes flow restrictions and operational interference. The tool's mechanical properties are matched to the work string, ensuring reliable performance under diverse wellbore conditions.

The DMS can simultaneously log the following parameters:

1. Strain (tension and compression)
2. Internal pressure
3. External pressure
4. Torque (bidirectional)
5. Temperature

This comprehensive set of measurements allows for a holistic analysis of the forces and conditions experienced during liner deployment and installation.

The DMS features:

1. Comprehensive electronics package with sensors, flash-type memory, and batteries
2. Configurable sampling frequencies (1-20 Hz)
3. High-resolution sampling for accurate sensor readings
4. Lithium battery power supply for extended operation (minimum 45 days at 1 Hz)
5. Full-bore, short length, and robust construction
6. No additional surface rig-up required

The DMS consists of three primary components:

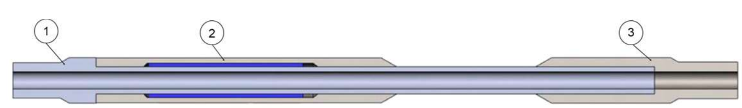

Figure 2 – Simplified Schematic of the Downhole Monitoring System (Brillaud et al., 2024).

1. Main body (inner mandrel): Contains the electrical package and sensors responsible for axial load transfer.
2. Housing: Protects the electrical components and is externally mounted.
3. Tool joint: Mounted on the lower section of the main body, complementing the structural design.

Casing and Drillpipe Deployed Flotation Collars

There are two main types of flotation collars used in the industry: casing and drillpipe. The casing type, which is deployed downhole with the casing, is the more common of the two. The drillpipe ultra reach flotation collar, on the other hand, is a flotation device used mainly during liner installation operations. It is deployed on the drillpipe and helps increase the buoyancy of the casing or liner, significantly reducing friction in long horizontal intervals. This reduction in friction allows for faster achievement of the target depth without the need for additional equipment, manipulation of the string, or other interventions.

The flotation collar has a glass barrier with the trapped air inside, which creates the buoyancy effect in the pipe string. The collar barrier separates the fluids with different densities above it and below.

Typically, the heavier fluid (mud) is added from the surface. The greater the contrast between the trapped fluid below the collar (or air section) and added fluid, the larger the buoyancy effect, leading to a significant reduction in friction. This allows the pipe below the collar to "float" and be pushed down more easily by the heavier density fluid and pipes placed above the collar.

All necessary calculations are performed beforehand during the pre-planning stage of operation. One of the most important ones is the torque and drag (T&D) simulation calculation to determine the optimal flotation collar placement within the pipe string. It is crucial to have an actual well deviation survey and wellbore construction details including multiple string types and open hole section sizes.

Once the liner reaches the target depth, applying the predetermined pressure from the surface breaks the glass, letting the fluid circulate when required for conditioning and cementing operations. The glass particles are very small and can be safely pumped downhole. The illustration of the glass disc flotation collar activation and running configuration (Figures 3 and 4) were presented in the previous work (William Tait et al. 2021), which also talks about the use of interventionless flotation collars.

Figure 3 – Fluid and air sections in the flotation collar.

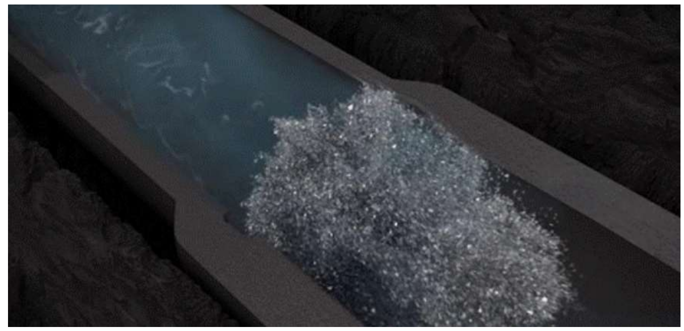
Figure 4 – Animated glass disc rupturing.

System Setup

The analysis included five liner hanger installations utilizing the DMS in conjunction with both drillpipe (3) and casing deployed flotation collars (2). Key aspects of the test environment include:

- DMS deployment on drillpipe above the top of the liner.
- Downhole data was collected at a high-frequency rate of 10 Hz (10 data points per second), providing detailed insights into rapid downhole events and transitions.
- Variable DMS placement relative to drillpipe deployed flotation collars.
- Production liner hanger strings with casing sizes ranging from 4-1/2-in. to 5-1/2-in.
- Lateral lengths between 10,000 and 15,000 ft
- True vertical depth (TVD) and kickoff points (KOP) approximately 10,000 ft.
- Casing deployed flotation collars placed between 10,000 and 11,000 ft based on pre-job placement analysis.
- Drillpipe deployed flotation collars positioned within 100 ft of the respective Top of Liner (TOL) and liner running tool string.

The setup was designed to capture comprehensive data on downhole dynamics during liner installation. The DMS was integrated into the drill string, allowing for seamless data collection without interfering with operational procedures.

The glass packages of flotation collars are designed with various rupture pressures to meet specific application requirements. Additionally, the thread connection types for flotation collars can be selected to match the drillpipe connections, ensuring compatibility and integrity within the string.

Depending on the application, the placement of the flotation collar may vary. In some cases, it makes sense to install it above the liner hanger, while in others, it is more appropriate to place it below. Typically, the flotation device is placed above KOP, following recommendations of all required pre-job simulation calculations.

Downhole Dynamics Analysis and Key Findings

The DMS provided a comprehensive approach to capturing operational data during liner hanger installations. Recording at 10 Hz, the system enabled exceptional detail in downhole event documentation. After retrieving the liner running tools, data was directly downloaded from the DMS for post-job analysis.

Candidate Well	Casing Size	Well TD (Ft)	DMS Depth (Ft)	Flotation Collar Depth (Ft)
Well 1	5.5-in	21,035	8,152	10,025
Well 2	5.5-in	21,181	10,198	11,519
Well 3	4.5-in	25,902	9,752	9,658
Well 4	4.5-in	25,730	9,255	9,352
Well 5	4.5-in	25,916	9,596	9,696

Table 1 – Candidate well information.

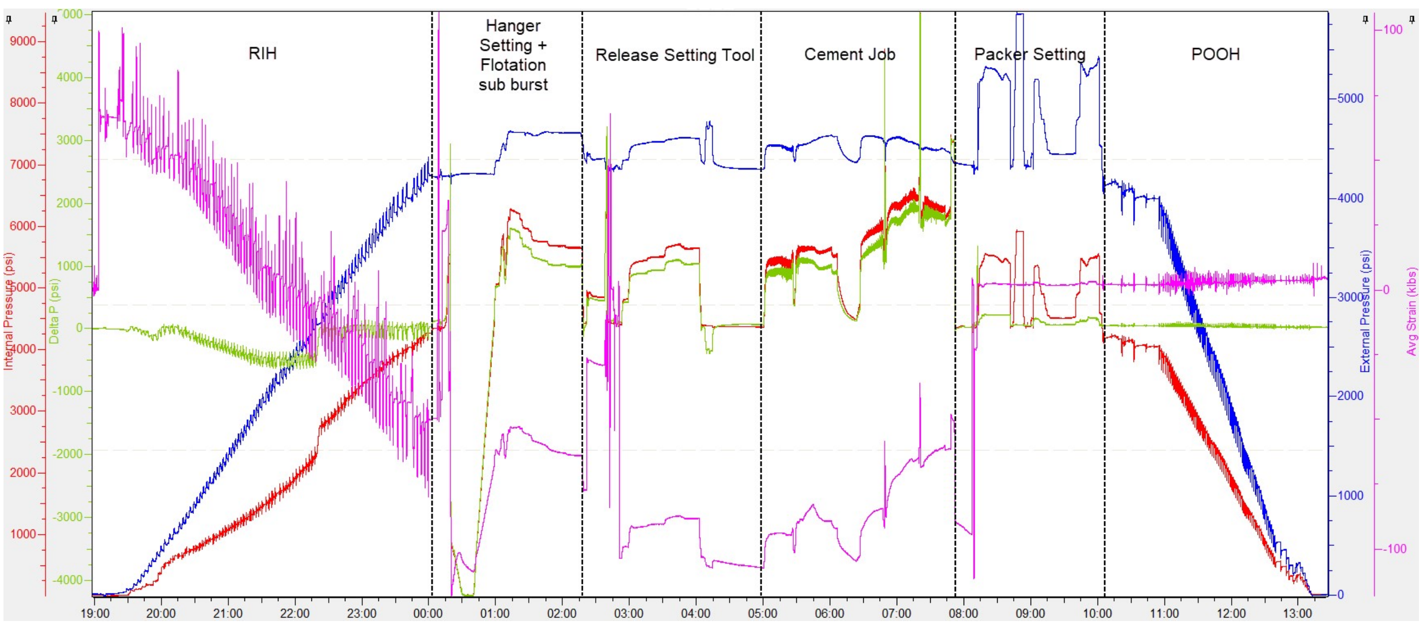

Figure 5 – DMS data overview of a liner hanger installation.

The data processing workflow involved importing the information into specialized trend analysis software, which has the capability to overlay rig surface data. This approach ensured a precise correlation between downhole measurements and the sequence of operational events.

For the purpose of giving an overview of the key findings of the analysis, one example operation of a casing deployed flotation collar (Example 1) and drillpipe deployed flotation collar (Example 2) will be covered to highlight some key differences in pressure and strain behavior between these two different methods, as shown in Table 1.

Examination of Pressure Changes

The primary focus of pressure analysis centered on the flotation collar's glass disc rupture mechanism. Flotation collars are designed with a rated glass package that accounts for hydrostatic pressure, requiring a combination of hydrostatic and applied pressure to initiate rupture.

When the DMS is installed above the flotation collar, internal pressure sensors can directly observe the pressure event. This positioning allows validation of the actual rupture pressure against the designed specifications.

The key objectives of pressure logging included:

1. Confirming glass package shear within the allowable design range
2. Establishing pressure dissipation characteristics through the string
3. Identifying potential post-rupture pressure surge dynamics
4. Monitoring pressure events during subsequent operations

A detailed 10-minute operational analysis has been extracted for each of the examples of the respective candidate wells.

Example 1

In this example, the casing flotation collar was installed around 10,000 ft measured depth and roughly 2,000 ft from the DMS located at the TOL. Once the liner reached setting depth, the string was spaced out and placed in tension. Pressure was gradually built up against the flotation collar, and the hydraulic liner hanger was activated prior to rupturing the flotation collar.

The fluid dynamics following rupture were particularly complex. The sudden fluid drainage exposed the string to a negative differential pressure. Approximately 10 minutes elapsed before the internal pressure stabilized near zero, subsequently increasing as the well was filled and excess air vented out of the string. There were no indications that air vented into the annular, as the external pressure remained stable during this duration.

Example 2

In this candidate well, a liner was floated with a drillpipe flotation collar. The flotation collar was positioned right above TOL at 9,352 ft, and the DMS was positioned 97 ft above the flotation collar at 9,255 ft. The liner was successfully deployed to a setting depth of 25,750 ft, and TD was tagged in compression before the flotation sub was ruptured. Afterward, the hydraulic liner hanger was positioned at the final setting depth and activated by dropping a ball.

The drillpipe flotation collar had a glass package designed to shear at 8,000 psi. As pressure was slowly built up against the glass, the glass ruptured at 8,131 psi, within a 1.6% margin on the designed pressure.

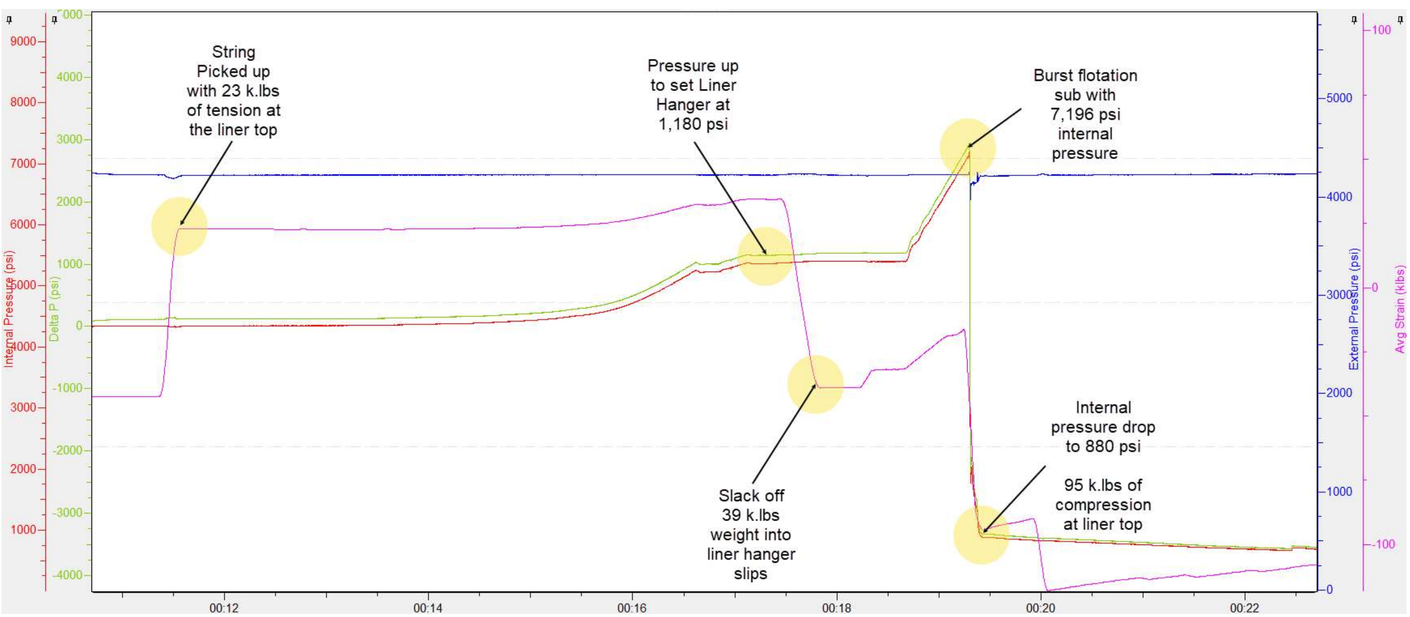

Figure 6 – Casing Flotation Collar Rupture.

Upon reaching the desired rupture pressure of 7,000 psi, the glass disc shattered at 7,196 psi, causing an abrupt pressure dissipation in the string. The DMS recorded a +5,000-psi internal pressure change in less than a second, emphasizing the extremely rapid pressure transition. The external hydrostatic pressure in the annular section of the well remained relatively stable at the time of rupturing the flotation collar. Minor fluctuations were picked up at the time of rupture, most likely as a result of the pressure shock, pipe movement, and sudden reverse ballooning in the string. This is also a good indication that the float equipment functioned properly during this installation.

Internal pressure very rapidly dropped with more than 7,000 psi in less than 1 second and immediately bled off to 341 psi before going back up to 1,150 psi 2 seconds later. These sudden pressure changes emphasize the rapid change in string pressure during the fluid displacement. No major pressure changes were observed on the external pressure sensor in the annular during this time.

Internal pressure slowly stabilized over the next 12 minutes before pressure started to increase as the string was being filled and air vented out.

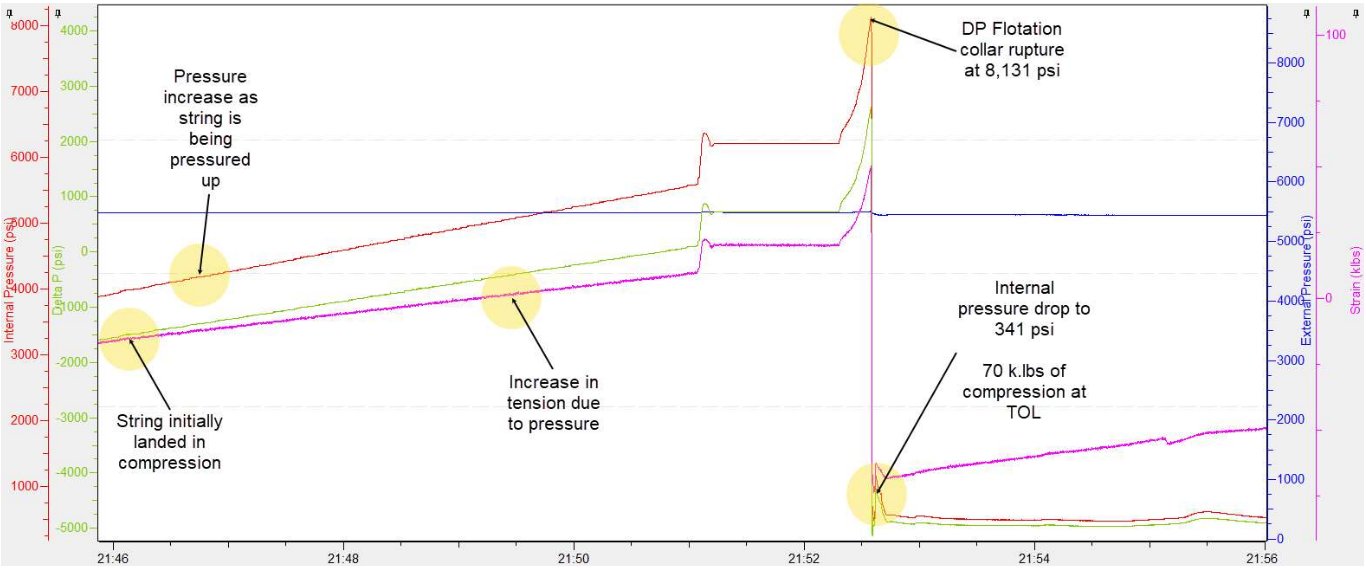

Figure 7 – Drillpipe Flotation Collar Rupture.

Tension and Compression State Variation

Floated liner installation involves frequent and significant transformations in the strain state. The strain at the liner top is influenced by well trajectory, liner casing length, and lateral section friction characteristics. During installation, the liner top frequently transitions between tension and compression. These transitions are critical for validating torque and drag models and assessing the risks of helical buckling.

Pressure events have a direct impact on the strain, with pressure against the flotation sub adding to the tool's strain. The core objective of the DMS was to record strain changes before and after the flotation sub rupture to identify potential overstress in the string. Observations revealed drastic strain changes during the flotation collar rupture. As pressure is applied, the string generates tension. The sudden loss of internal pressure, combined with higher annular hydrostatic pressure, results in a violent strain transition from tension to compression at the liner top.

The severity of these strain changes can be directly correlated with the pressure required to rupture the flotation collar, irrespective of whether it is installed in the liner casing or the drillpipe. Additionally, the initial manipulation of the liner string—such as applying tension or maintaining compression—before the flotation collar is ruptured could affect the strain position after the flotation collar has ruptured.

More steady strain changes were also observed after the flotation collar ruptured as the string was being filled up. As the string became less buoyant, a slow and steady buildup of tension was recorded at the DMS.

Among the different examples analyzed, the DMS recorded strain changes ranging from 80 kip to 120 kip in timeframes of less than one second, demonstrating the extreme mechanical dynamics observed during these events.

Additional Analysis

In addition to the pressure and force analysis during the rupture of the flotation collar, the DMS captured other vital parameters during the installation of the completion liner, which included:

- Validating T&D and hydraulic models during run-in-hole (RIH) using data from the TOL.
- Confirming liner hanger and ball seat activation where applicable.
- Capturing liner wiper plug launches and bump pressure during cementing operations.
- Validating liner top packer set down weights and setting indications.
- Validating well integrity testing where applicable.

Operational Implications

This section covers the implications of rupturing a flotation collar in more detail.

Safety Considerations

Rupturing flotation collars typically requires additional applied surface pressure, which can exceed 3,000 psi in some cases. It is important to ensure that all surface and downhole equipment is properly rated for safety and that personnel remain outside the red zone during these operations. Since strain changes can cause axial movement in the string, rig personnel must maintain a safe distance to avoid potential hazards during these events.

Mechanical Ratings of Casing and Drillpipe

The additional tension generated from increased pressure and compression during flotation collar rupture must be considered in the well design, equipment selection, and operational procedures. The forces generated may exceed the operational limits of the casing or drillpipe, potentially leading to catastrophic failure or accelerated fatigue on equipment. Supplemental equipment, such as liner hangers or running tools, should also withstand these additional forces during planned or contingency operations.

Liner Hanger and Running Tool Equipment Selection

Better understanding the downhole dynamics during floated liner applications helps you make more informed decisions on equipment selection and ultimately increases the reliability and efficiency of the operation.

Running tool selection is critical in designing a completion liner. Conventional hydraulic liner hanger running tools could be more susceptible to rapid fluctuations in pressure and strain, especially if they have mechanical contingency release mechanisms that could prematurely detach the running tool during flotation collar rupture. Hydraulic mechanical running tools, which utilize both mechanical and hydraulic release features, could offer better safeguards against these well events when running a floated liner.

While hydraulic liner hangers are common for production liner installation, careful consideration is needed to ensure they can withstand post-rupture pressure from the flotation collar. Incorporating pressure-balanced features into the liner hanger can enhance reliability and prevent presetting. Liner wiper cementing plugs used in flotation applications should also be designed to withstand fluid columns passing through the liner top, preventing the wiper plug from detaching and compromising the cement job quality.

Conclusions

There are no notable differences in pressure and strain behavior during the rupture of drillpipe versus casing deployed flotation collars. The designed rupture pressure largely determines the severity of these effects.

Each type of flotation collar offers unique benefits, depending on the specific application and operational requirements:

Casing-based flotation collars offer more flexibility in placement within the liner string but expose the liner hanger assembly to applied pressure during rupture.

Drillpipe flotation collars enable the floating of a production liner without affecting the liner casing design. However, they are limited in placement and cannot be positioned below the liner top.

The optimal placement of the flotation collar is determined by factors such as the well trajectory, casing and liner design, and fluid types. Before each installation, it is essential to perform all necessary calculations and address any safety and operational considerations to mitigate any potential risk of failure.

The combination of a flotation collar and a downhole monitoring system enables operators to achieve their objectives for successful casing and liner installations. Using DMS provides a better understanding of the processes occurring downhole during various operational events including extreme pressure fluctuations during floating. This knowledge allows us to optimize operations as needed and select the most suitable tools and techniques to perform the job safely and efficiently.

The selection of equipment depends on the specific requirements for each application, considering many factors, including downhole conditions, desired outcomes, and technical specifications. It is essential to engage in detailed discussions with the tool supplier to ensure that the chosen equipment aligns with these needs and to leverage their expertise in recommending the most suitable options. This collaborative approach helps optimize performance and ensures the safe and flawless execution of the operations.

Acknowledgments

The authors would like to express their appreciation for the hard work and dedication of the sales, applications engineering, and operations teams at NOV Completion Tools in the Permian Basin, as they ensured the successful deployment of all field installations and detailed analysis of the post-job data.

Nomenclature

DMS = *Downhole Monitoring System*
DP = *Drillpipe*
KOP = *Kickoff Point*
MD = *Measured Depth*
T&D = *Torque and Drag*
TOL = *Top of Liner*
TVD = *True Vertical Depth*
RIH = *Run in Hole*
URFC = *Ultra Reach Flotation Collar*

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