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Development and Qualification of a Gas-Tight Wet Shoe System for Unconventional and Extended-Reach Wells

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Abstract

Intentional wet shoe track completions have become increasingly common in unconventional and extended-reach wells due to their operational and economic advantages over conventional toe sleeve systems. This paper presents the qualification and operational deployment of an API 19AC V0-rated wet shoe system engineered for HPHT well conditions. The system was deployed as part of a long-string completion in a tight shale formation to maximize reservoir exposure while reducing the cost associated with additional completion accessories. The wet shoe system was developed for extended exposure in extreme downhole conditions, incorporating premium grade materials and redundant one-way valves with metal-to-metal seals to ensure reliable performance. Rigorous qualification testing was performed to verify wear resistance, acid resistance of the valve system and reliable back pressure sealing performance in accordance with API 10F and API 19AC requirements. The system was deployed in a 5-1/2-in. long-string completion to eliminate float collar and toe initiators while maximizing reservoir exposure in a tight shale formation. The wet shoe incorporated a latch-in profile that allowed sequential plugs to be securely landed during cementing. Each plug was equipped with a predefined burst disk that ruptured at a specified pressure to enable controlled fluid bypass and create the required wet shoe track length. The final plug incorporated a high-pressure rupture disk for casing pressure test before being ruptured to initiate fracturing operations. Laboratory testing successfully demonstrated API 10F flow durability performance at 15 BPM for 36 hours and no surface cracks/deformation were observed after soaking in 31% HCL acid for 2 Hours. The system subsequently achieved API 19AC V0 qualification with zero gas bubbles during multiple 15,000 psi gas-pressure cycles and sustained 8-hour hold periods at 400°F. Downhole deployments confirmed successful wet shoe execution with reduced shoe-track length, elimination of float collar and toe sleeves/initiators, and increased productive reservoir exposure. The wet shoe design enabled fracturing operations to begin closer to the shoe, improving completion efficiency and reservoir access without the need for conventional toe sleeves. This paper presents the first deployment of the aforementioned wet shoe system qualified to the API 19AC V0 gas-tight standard at 15,000 psi in the Unconventional Area of Interest. The technology reduced total well cost, extended effective lateral coverage, and improved overall well delivery efficiency.

Introduction

The significant development in unconventional reservoirs has substantially improved completion design practices over the years. Long extended reach laterals, massive hydraulic fracturing, and high pressure-high temperature (HPHT) conditions have encouraged the oil and gas industry to continuously optimize completion designs and improve operational efficiency while maximizing reservoir exposure. One such advancement is the transition from conventional cemented shoe-track designs toward intentionally uncemented, or wet shoe, completion systems.

In general, the conventional shoe track offers two primary functions during casing deployment. First, it provides a hydraulic barrier that prevents fluid back flow through a float valves. Second, once the cement is set inside the shoe track, it acts as a well-control barrier. Conventional float equipment was therefore designed with the assumption that cement would remain an integral component of the overall barrier system.

Most unconventional wells are completed with multistage plug, perf and frac operation. However, the plug-and-perf completions require an injectivity into the formation to lower the wireline perforating guns downhole. Early unconventional developments relied primarily on coiled tubing-deployed perforating guns, tubing-conveyed perforating systems, or wireline tractors to establish this initial communication. Although technically effective, these intervention methods significantly increased operational complexity, rig time, and overall completion cost.

As operators continued optimizing unconventional completions, intentional wet shoe systems emerged as an attractive alternative. Rather than maintaining cement inside the shoe track, the cement is intentionally over-displaced so that the float equipment remains free of cement while preserving communication through the shoe assembly. Eliminating the toe sleeve and reducing shoe-track length increases the effective stimulated reservoir interval while simplifying long string completion as shown in Figure 1. The technique also reduces equipment costs and eliminates one potential failure mechanism associated with toe sleeve activation.

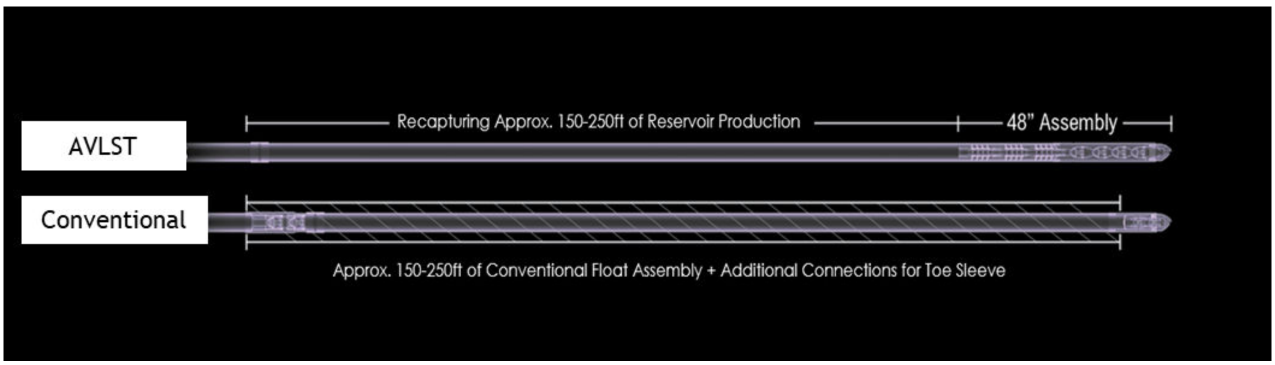

Fig. 1— Comparison of conventional and advanced latch valve wet shoe-track configurations, highlighting the reduced shoe-track length achieved with the wet shoe system.

Although intentional wet shoe completions offer significant operational advantages, they require a robust design to act as a barrier in challenging down hole conditions. In conventional shoe-track designs, well integrity depends on both cured cement and the float valves acting together. In contrast, a wet shoe system relies almost entirely on the long-term performance of the float equipment because cement is intentionally absent from the shoe track. Consequently, conventional float equipment—which was originally developed primarily to prevent cement U-tubing during cement placement—may no longer provide an adequate long-term gas barrier once the supporting cement is removed.

Historical overview of unconventional well development

Long-Lateral Development in Unconventional Reservoirs

The commercial development of unconventional reservoirs has been driven by continuous advances in drilling and completion technologies aimed at increasing reservoir contact, improving well productivity, and reducing overall development costs. Since the early stages of shale development, operators have progressively optimized well designs by simplifying completion practices, minimizing downhole hardware, and reducing well construction time while maintaining well integrity (Weijers et al. 2019).

Early unconventional wells typically employed multiple casing strings, liner systems, tieback assemblies, and separate upper and lower completions. Although these designs provided operational flexibility, they also increased completion complexity, installation time, and overall well cost. As operational experience expanded, many developments transitioned toward monobore long-string completion designs extending from total depth to surface.

This evolution eliminated liner-hanger systems, reduced the number of completion components, simplified hydraulic fracturing operations, and improved overall well reliability (Almasmoom et al. 2020).

In parallel with completion simplification, operators continuously extended horizontal lateral lengths to maximize reservoir exposure. Initial unconventional developments generally incorporated lateral sections between 5,000 and 8,000 ft. Improvements in drilling-fluid performance, rotary steerable systems, directional drilling accuracy, wellbore conditioning, and casing-running practices subsequently enabled routine drilling and completion of 10,000-ft laterals. While these developments significantly increased reservoir contact, they also introduced new operational challenges, including higher torque and drag, reduced weight transfer, elevated bottomhole temperatures, wellbore instability, and increasing difficulty in deploying production casing to total depth in extended-reach wells (Yin et al. 2023).

Continued advances in drilling practices, flotation technology, wellbore-cleaning techniques, and casing deployment further extended achievable lateral lengths beyond 15,000 ft. Successful installation of long-string production casing in these wells demonstrated that extended-reach unconventional developments could be completed reliably while maintaining operational efficiency and mechanical integrity (Portillo et al. 2025).

More recently, several unconventional developments have reported lateral lengths exceeding 16,000 ft. As lateral length increased, the economic value associated with every additional foot of productive reservoir became increasingly significant. Consequently, optimization efforts expanded beyond drilling performance to include minimizing nonproductive completion intervals, reducing downhole hardware, and recovering reservoir contact previously occupied by shoe-track assemblies and toe-initiation equipment (Almomen et al. 2026).

These trends closely mirror the broader evolution of North American unconventional developments. During the past two decades, operators have simultaneously increased lateral lengths, fracture-stage counts, and stimulation intensity while reducing drilling and completion costs through continuous optimization of well construction practices. As completion efficiency improved, increasing attention shifted toward maximizing effective stimulated reservoir length by eliminating unnecessary completion hardware and reducing nonproductive intervals near the toe of the well (Weijers et al. 2019; Mayerhofer et al. 2010; Cipolla et al. 2010).

Unconventional Completion Practices

The widespread adoption of horizontal drilling transformed completion practices throughout the unconventional industry. Early shale developments frequently employed open-hole completion systems incorporating swellable packers and mechanically actuated frac sleeves to isolate stimulation stages without requiring cemented casing. These systems were attractive because they simplified completion operations and eliminated perforating requirements. However, as horizontal wells became longer and hydraulic-fracturing treatments became more intensive, maintaining reliable zonal isolation and completion flexibility became increasingly challenging (Gundersen et al. 2023).

These limitations accelerated the industry's transition toward cemented plug-and-perf completions, which rapidly became the preferred completion method in most unconventional reservoirs. In cemented completions, hydraulic fractures are initiated through perforations created in the casing and cement sheath, while temporary frac plugs provide stage isolation. This approach offers greater flexibility in stage spacing, perforation placement, and stimulation design while improving overall completion reliability.

Despite differences in completion designs, both open-hole and cemented systems require an initial hydraulic communication path between the wellbore and the formation before multistage hydraulic fracturing can begin. Establishing this initial toe communication has therefore remained a critical component of unconventional completion design throughout the industry's evolution (Gundersen et al. 2023).

To reduce intervention time and improve operational efficiency, numerous intervention less toe-initiation technologies were subsequently introduced. These included pressure-activated toe sleeves, ball-actuated frac sleeves, and hydraulically activated sleeve systems, all of which were widely implemented across major unconventional developments in the Eagle Ford, Haynesville, Bakken, Permian Basin, Montney, and SCOOP/STACK plays (Johnson et al. 2012; Algadi et al. 2014).

Toe Communication and Wet Shoe Technology

The methods used to establish initial communication between the wellbore and the reservoir have evolved considerably throughout the development of unconventional completions. Early applications relied primarily on intervention-based techniques, including tubing-conveyed perforating, wireline-conveyed perforating, and abrasive jet perforating. Although these methods successfully established toe injectivity, they required additional equipment, increased operational complexity, and extended completion time.

To reduce intervention requirements, pressure-activated toe sleeves became widely adopted as an intervention less method for initiating hydraulic fracturing. Toe sleeves eliminated the need for initial perforating operations and established direct communication with the reservoir after casing pressure test is completed. However, these systems introduced additional completion hardware, increased shoe-track length, added potential leak paths, and occasionally experienced premature activation or failure to open, resulting in costly remedial operations. As horizontal laterals became progressively longer, these limitations became increasingly significant from both operational and economic perspectives (Gundersen et al. 2023).

Recent studies have demonstrated growing industry interest in developing robust wet shoe systems to act as a mechanical barrier in unconventional completions. Champeaux (2020) presented a wet shoe system intended to function as an independent mechanical barrier in unconventional wells. They conducted a successful flow endurance test at 10 bpm for 36 hours using API 10F fluid. Following a flow endurance test, a static liquid test was conducted at 5,000 psi and a static gas test was conducted at 50 psi for low pressure and 5,000 psi for high pressure. All static pressure tests were conducted at 200F. A maximum of 5 SCF/min gas leakage rate was chosen as per API 14A to define a success criterion during an 8-hour pressure held at 200F.

Gundersen (2023) presented a wet shoe system for both liner and long string completions. They addressed the key advantages of using wet shoe system, both technically and commercially. The high flow by area resulting from the full-bore exposure in case of a wet shoe were observed to be significantly higher than the flow area though cement cracks resulting from the toe sleeve activation as shown in Figure 2. They reported a successful deployment of wet shoe in more than 1,000 installations in the United States.

Fig. 2— Illustration of the typical flow path and flow pattern when the toe-initiator is activated.

Ferrin (2026) introduced an integrated reamer float shoe that combines the functions of the reamer shoe and a wet shoe. The flow pattern was optimized as a part of a wet shoe development using Computational fluid dynamics (CFD) to reduce valve erosion during cementing. The API 10F flow endurance test was conducted at 10.25 BPM for 62 hours using API 10F mud. Following a flow endurance test, a static liquid test was conducted at 15,000 psi and a static gas test was conducted at 50 psi for low pressure and 15,000 psi for high pressure. All static pressure tests were conducted at 400F. Zero gas bubbles were observed during a 1-hour period of pressure held.

The test protocols defined in API SPEC 10F were developed to evaluate cementing performance instead of long-term gas containment, which is the case of wet shoe where the shoe may remain exposed to drilling fluids, completion fluids, acids, elevated temperatures, pressure/temperature cycles and formation gases for extended periods. The aforementioned studies lacks the complete qualification of a wet shoe system using API 19AC V0 gas-tight validation together with extended API 10F flow endurance, high-temperature exposure, concentrated hydrochloric acid compatibility, repeated pressure cycling, and downhole deployment in HPHT unconventional wells. The combined evaluation of these performance requirements remains largely absent from the existing literature.

The present work addresses this gap by developing and qualifying a wet shoe system specifically engineered for long-term gas containment in unconventional and extended-reach wells. Unlike previously reported systems, the proposed design incorporates redundant one-way valves, metal-to-metal sealing technology, premium corrosion-resistant materials, and a large-bore flow path, and is qualified through an integrated testing program including API 10F flow endurance, 31% HCl exposure, high-temperature conditioning at 400°F, and repeated API 19AC V0 gas-tight validation at 15,000 psi. Moreover, the system was successfully deployed in an Unconventional Tight Carbonate Area of Interest. These developments extend current wet shoe technology beyond conventional hydraulic qualification toward a validated HPHT gas-tight barrier suitable for modern unconventional completions.

Methodology

Advanced valve latch shoe tool Wet Shoe System Development

The wet shoe system was developed to function as an independent mechanical barrier for unconventional and extended-reach wells where the shoe track is intentionally left uncemented. Contrary to the conventional float equipment, which relies on both float valves and the hard cement within the shoe track, the Advanced Valve Latch Shoe Tool (AVLST) wet shoe system was designed to maintain pressure integrity through redundant mechanical sealing mechanisms as shown in Figure 3.

The design incorporated four independent one-way check valves to prevent reverse flow, with each valve rated to 15,000 psi back pressure. Corrosion-resistant alloy was selected to provide long-term durability under HPHT conditions. A metal-to-metal sealing interface was designed as the primary sealing mechanism to eliminate elastomer degradation concerns during extended exposure to high temperatures/pressures, and acidic environment. The valve assembly was designed with a large internal bore to maximize flow efficiency during fluid displacement.

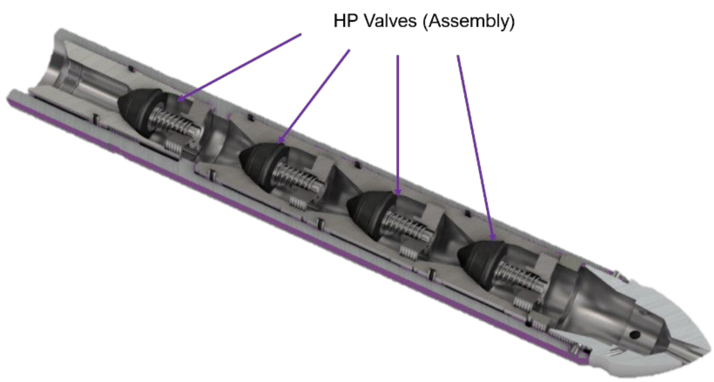

Fig. 3— Advanced valve latch shoe tool wet shoe with four redundant high-pressure valves and an aluminum guide nose designed for efficient casing deployment

To create a wet shoe system, a latch-In type multi-plug system are utilized as shown in Figure 4, where each subsequent plug can land and latch into the succeeding plug. A low pressure (LP) rupture plug displaces the cement into the annulus followed by a retarder water, which is displaced by a high pressure (HP) rupture. Once the LP rupture plug lands into the AVLST wet shoe, the LP rupture plug disk bursts and the calculated retarder water (4-7 BBL) is displacement into the shoe to create an intentional wet shoe as shown in Figure 4. Once the retarder water is displaced, the HP rupture plug lands into the latch profile of LP plug and the casing pressure test could be conducted against the HP plug to proceed for the subsequent wellhead work operation. Prior to completion the HP plug disk is ruptured, and a bridge plug and perforating guns are displaced to initiate the first fracture stage as shown in Figure 5.

Fig. 4— Image showing single bottom plug (left) and double bottom plug (right). Each plug can be equipped with a rupture disk rated according to operational requirements.

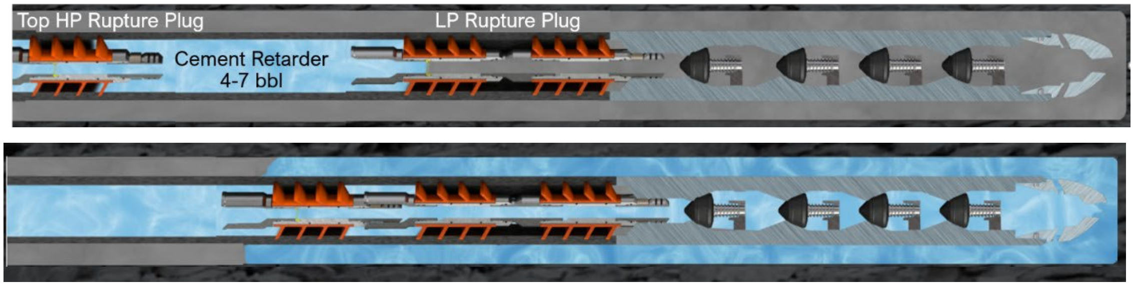

Fig. 5—Operational sequence of the wet shoe system. Top: The low-pressure rupture plug displaces cement into the annulus and lands in the float shoe, followed by retarded water and the high-pressure rupture plug. Bottom: The high-pressure rupture plug displaces the retarded water through the float shoe to establish the wet shoe, then lands and latches onto the lower plug, enabling casing pressure testing. The rupture disc is subsequently burst to establish wellbore communication for fracturing operations.

Experimental Investigation

API 10F Flow Endurance

A test fixture assembled with a single valve of the Advanced valve latch shoe tool system to ensure each individual valve is rated and qualified to meet the requirements. Flow endurance testing was performed as per the guidelines defined in API SPEC 10F using a flow loop as shown in Figure 6. The valve assembly was circulated for 36 hours at 15 bbl/min using an API 10F mud as described in Table 1.

Table 1—Mud properties for API SPEC 10F at 120°F ±5°.

Density	12.0 to 12.5 lb/gal
Sand Content	2 to 4%
Plastic Viscosity	10 to 50 cP
Yield Point	5 to 25 lbf/100 ft2
Gel Strength	>4 lbf/100 ft2

Fig. 6— API 10F flow loop used for the flow durability test

Acid Compatibility

Since wet shoe systems may remain exposed to stimulation fluids before hydraulic fracturing, the valve assembly was uninstalled from flow loop after flow endurance test and then immersed in 31% hydrochloric acid for two hours as shown in Figure 7. Following acid exposure, the specimens were removed and inspected for deformation and erosion.

Fig. 7— Image representing an AVLST valve immersed in a 31% HCL acid bath for 2 hours

API 19AC V0 Testing Protocols

To evaluate the performance of valve under extreme downhole conditions, the API 19AC V0 test protocols were followed to establish a test procedure and the test was conducted in a HPHT chamber modified to monitor the gas bubble as shown in Figure 8. Nitrogen was used as a test fluid. The valve assembly was heated to 400°F and subjected to repeated 15,000 psi gas-pressure cycles. Following each pressure cycle, pressure was completely released, the valve was mechanically reopened, and the assembly was repressurized to verify repeatable sealing performance.

Gas leakage was monitored continuously using an external bubble detection system consisting of a calibrated pressure transducer, submerged bubble chamber, and video recording equipment as shown in Figure 9. Qualification required zero gas bubbles throughout the eight-hour pressure held at 15,000 psi.

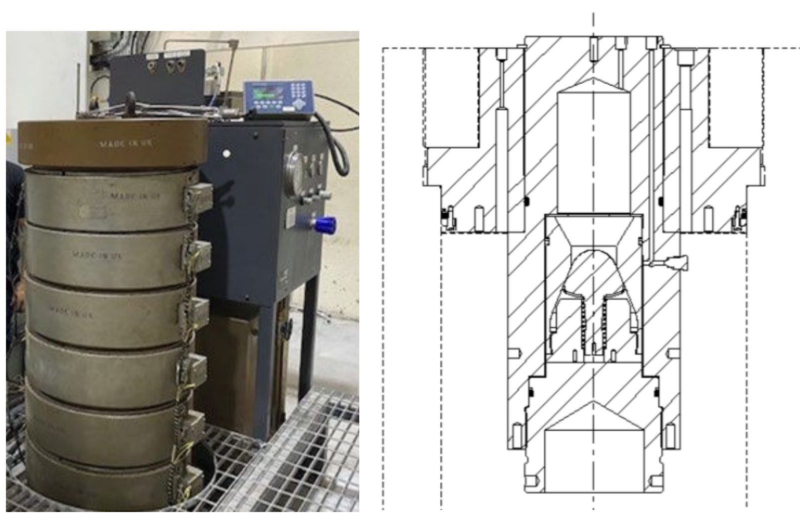

Fig. 8— Image showing the high-pressure, high-temperature (HPHT) test chamber (left) and the AVLST valve installed inside the chamber with flow lines connected for gas-bubble leak detection (right)

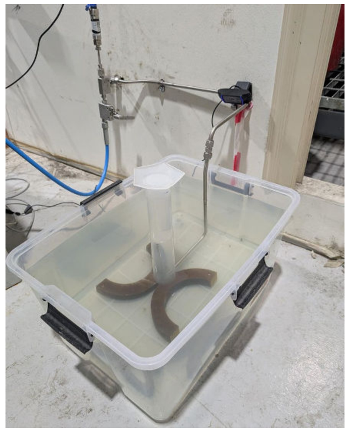

Fig. 9— The flow lines from the HPHT chamber are introduced in the gas bubble detection system to measure the gas leakage

Results and Discussion

Laboratory Results

The API 10F flow endurance test showed that the valve assembly maintained the structural integrity after 36 hours of circulation at 15 bbl/min. The sample showed no evidence of excessive erosion, structural deformation, or degradation of the valve components. The large internal bore and flow by area minimized restriction while preserving sealing integrity after prolonged erosive flow exposure. Following immersion in 31% hydrochloric acid for two hours, the valve components exhibited measurable deterioration or dimensional changes.

The API 19AC V0 testing demonstrated zero-bubbles during each required pressure hold period of the test sequence. The valve successfully held the 15,000-psi pressure for 1-hour, then the pressure was bled off to zero. The valve was functioned to the open position allowed to reseat and then, pressure increased to 15,000 psi and held for 8 hours after stabilization period of 7 hours at 400F as shown in Figure 10. During the eight-hour hold period at 400°F, pressure remained stable and no gas bubbles were detected, confirming reliable metal-to-metal sealing under representative HPHT conditions, after flow endurance at 15 BPM for 36 hours and 31% HCL acid exposure for 2 hours.

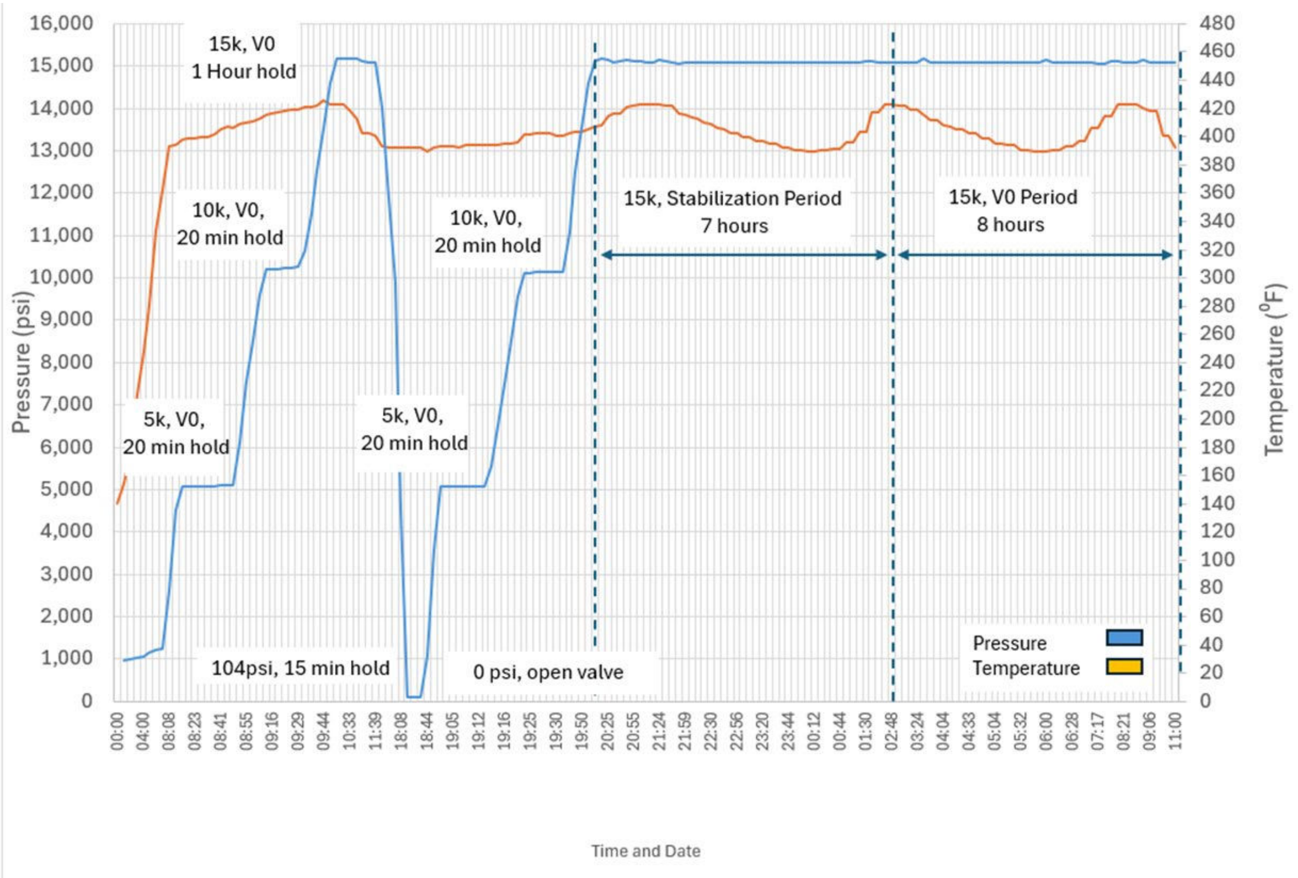

Fig. 10— Pressure chart recorded during HPHT testing conducted in accordance with API 19AC V0 testing protocols

Field Deployment of Advanced valve latch shoe tool Wet Shoe system

Pre-job planning

The operation was conducted in an unconventional tight carbonate reservoir and involved one of the longest wells drilled in the area. The well comprised a 20,500-ft 8-1/2-in. open hole section, drilled to a total measured depth (MD) of 27,724 ft, including an effective lateral length of 16,743 ft. The well was completed with a 5-1/2-in., 26-lb/ft long-string casing consisting of 681 joints. Figure 11 shows the actual well schematic of the well in which the Advanced valve latch shoe tool wet shoe system was deployed. Before execution, comprehensive engineering studies—including well trajectory analysis, torque-and-drag modeling were performed to evaluate casing run ability, identify operational risks, and optimize the completion design

The well presented several operational challenges commonly associated with extended-reach unconventional developments. Elevated drag forces were anticipated and subsequently encountered while running the casing, requiring continuous casing rotation using a top-drive Casing Running Tool (CRT) to advance the string through the lateral section. Because circulation was not possible during casing deployment, the operation relied on continuous rotation (dry reaming) to reduce friction and mechanically work the casing through localized restrictions.

The inability to circulate while running the casing resulted from the installation of a glass-disk casing flotation sub. This device enables mud-over-air casing flotation by maintaining the casing below the flotation sub filled with atmospheric air, thereby significantly reducing the effective submerged weight of the lower casing section and improving casing run ability in extended-reach wells. Although this approach provides substantial drag reduction benefits, it also represents the most severe loading condition for the float equipment. With no internal fluid pressure supporting the float valves, they remain exposed to the full external hydrostatic pressure throughout the entire run-in-hole operation, producing the maximum differential pressure across the float equipment until the flotation sub is activated.

In addition to the deployment challenges, maximizing the productive lateral length available for hydraulic fracturing was a primary completion objective. Consequently, minimizing nonproductive intervals, particularly those associated with conventional shoe-track assemblies, was an important design consideration to maximize reservoir contact and improve overall well productivity.

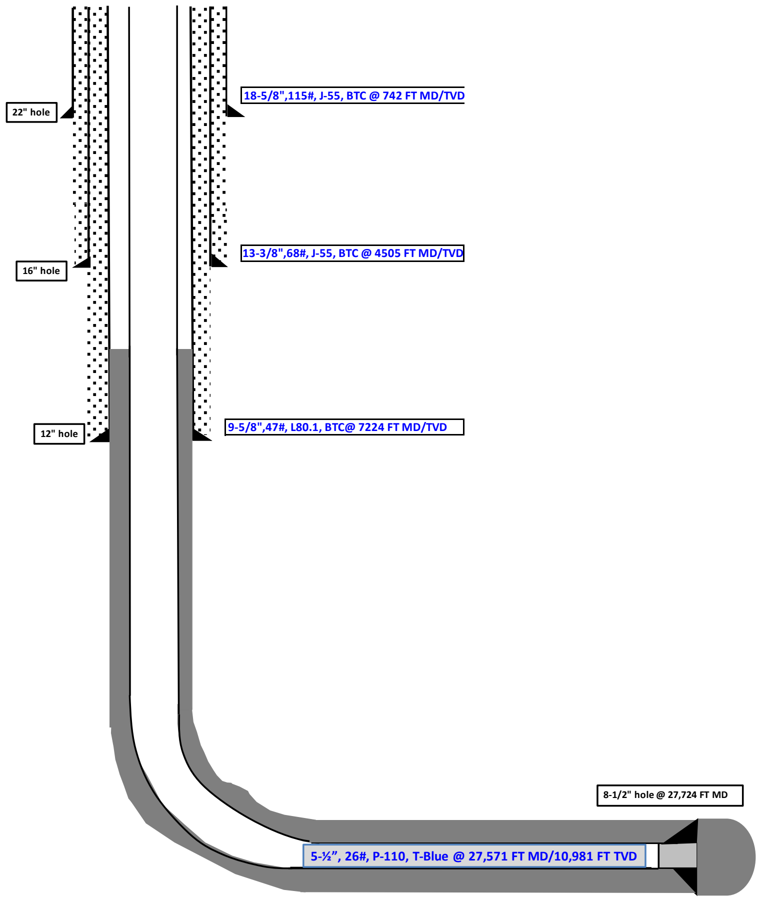

Fig. 11— Actual well schematic of the well in which the Advanced valve latch shoe tool wet shoe system was deployed.

Casing running operation

The 5-1/2-in. AVLST wet shoe was deployed in the 8-1/2-in. open-hole section of an unconventional well with a total measured depth (MD) of 27,724 ft. As anticipated during the planning stage, excessive drag was encountered throughout the extended lateral section, beginning at approximately 22,500 ft, as shown in Figure 12. Initial attempts were made to advance the casing to the planned setting depth without rotation; however, the excessive drag prevented further advancement of the casing through the open hole.

A decision was made to initiate casing rotation at a depth of 24,613 ft. However, the starting torque exceeded the operational torque limit of 19,000 ft-lb. Consequently, the casing string was pulled out of hole by 78 joints before rotation could be successfully initiated. After pulling out 78 joints, the casing rotated smoothly at 15–30 rpm with surface torque ranging from 12,000 to 16,000 ft-lb. Continuous casing rotation using a Casing Running Tool (CRT) was then maintained to advance the casing to the planned setting depth. Attempts to advance the casing without rotation consistently resulted in string hang-up, demonstrating that continuous rotation was essential for successful deployment.

Despite the prolonged run-in-hole operation, the severe drag conditions, and the repeated efforts required to establish and maintain casing rotation, the AVLST wet shoe system successfully maintained a differential back pressure of approximately 8,000 psi throughout the operation, enabling the casing string to reach the planned setting depth without loss of pressure integrity.

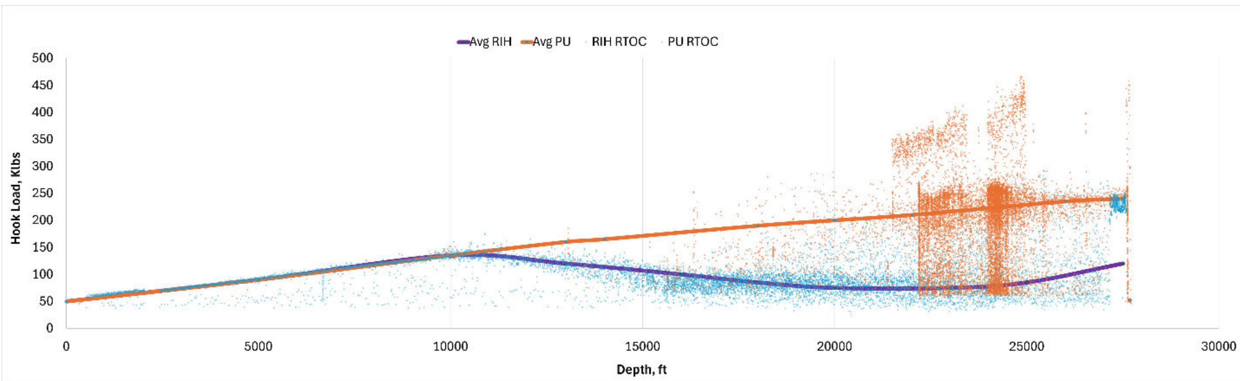

Fig. 12— Real-time run-in-hole data for the 5-1/2-in. long-string casing deployment, showing excessive drag between 22,500 ft and 24,613 ft.

The completion consisted of a 5-1/2-in., 26-lb/ft TSH blue casing string equipped with the AVLST wet shoe and deployed using a glass-disk flotation device as shown in Figure 13. During the run-in-hole (RIH) operation, the AVLST wet shoe maintained a differential pressure of approximately 8,000 psi for more than 150 hours while the casing remained under flotation before reaching total depth. This represented one of the most severe downhole loading conditions for the wet shoe system, as the float valve continuously withstood the full external hydrostatic pressure without internal pressure support. After reaching a depth of 27,571 ft, the cement head was installed, and the flotation device was intentionally ruptured to establish full circulation before cementing.

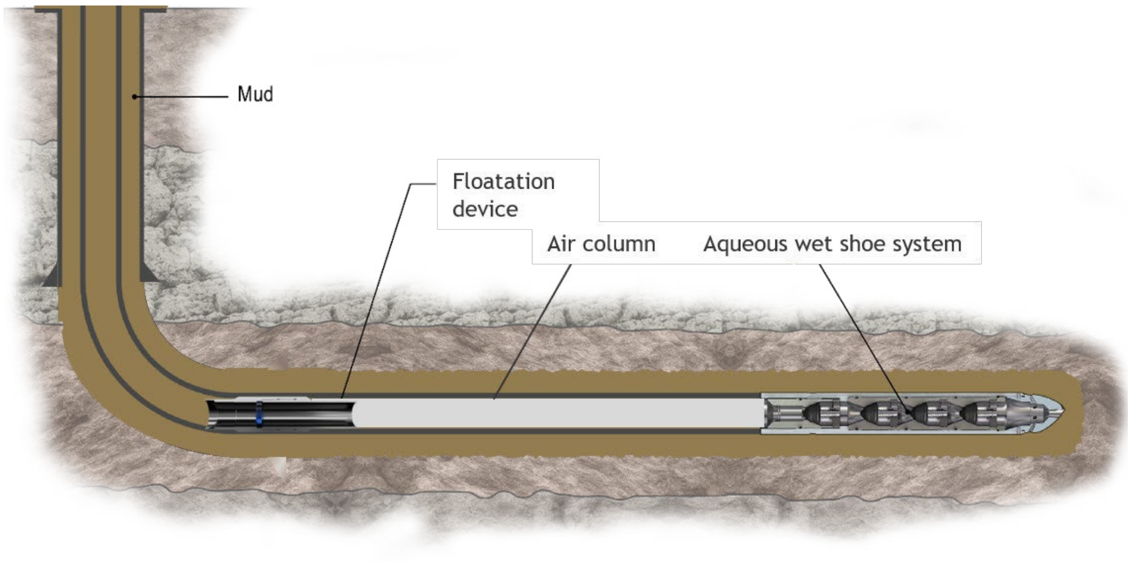

Fig. 13— Illustration of the Advanced valve latch shoe tool wet shoe system during deployment under casing flotation, showing the flotation sub separating the air and mud columns within the 5-1/2-in. long-string casing.

Cementing operation

The cement job was executed through the wet shoe system using a multi-plug system. Prior to cement placement, the well was conditioned with 300 bbl of 102 pcf low-rheology oil-based mud, followed by 200 bbl of 106 pcf spacer at 8 BPM. A 1,000-psi rupture plug was dropped ahead of the cement to prevent contamination. Subsequently, 973 bbl. of 118 pcf cement slurry was pumped at 8 bpm.

After pumping the cement, the cement line was flushed to the rig floor and pre-filled with retarder water. A second 1,000 psi plug was then dropped to isolate the cement from the retarder water and displaced with 3 bbl of retarder water, followed by a third 4,000 psi plug as shown in Figure 14. Displacement was carried out using 37 bbl. of retarded viscous water and 450 bbl. of 85 pcf brine at 8 bpm, with the rate reduced to 3 bpm during the final 67 bbl as shown in Figure 15.

A pressure spike was observed when the second plug landed on the shoe at final circulating pressure of 2,200 psi as shown in Figure 16. Pressure was then increased to 3,200 psi to rupture the second plug, observed by a sudden drop of pressure to 1800 psi. Thus, the second plug ruptured as per the specified rupture rating of 1000 psi. Once the plug ruptured, the retarder water was displaced into the shoe track to intentionally create a wet shoe to provide ease in running perforation guns and bridge plug during frac job in future as shown in Figure 17. A total of 3 bbl. of retarder water was pumped to establish a wet shoe length that allows the first perforation cluster to be placed as close to the shoe as practical while ensuring the cluster remains isolated by cement.

The third plug was subsequently bumped at 3,000 psi. A successful casing pressure test was conducted at 3,000 psi for 30 minutes, and after bleeding off approximately 3 bbl, float valves were confirmed to be holding. Full returns were observed throughout the cementing operation.

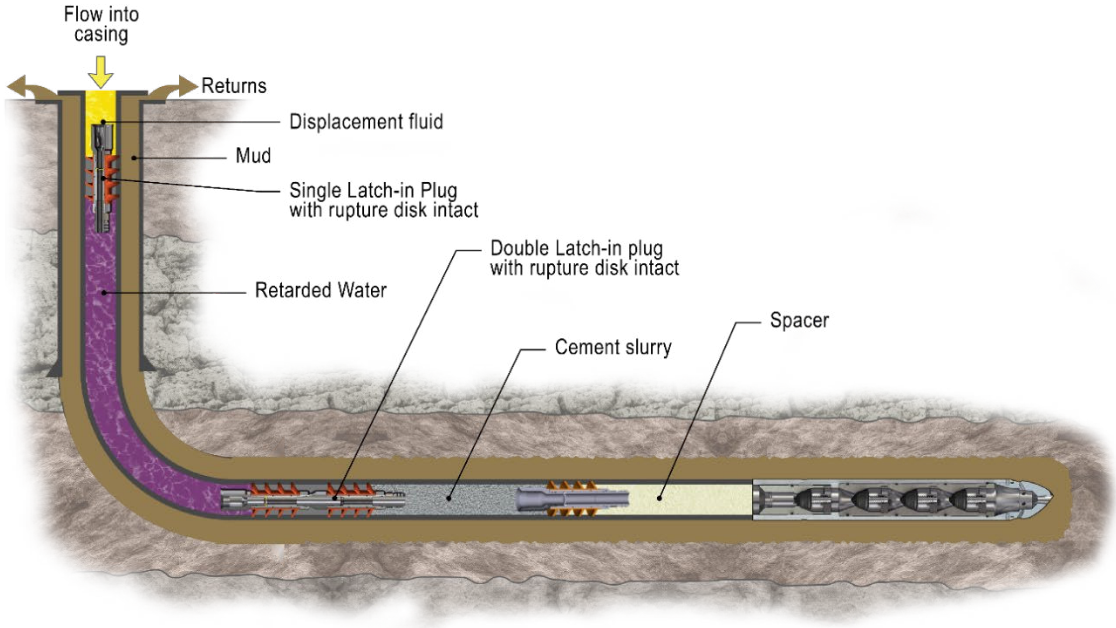

Fig. 14— Illustration of the cementing operation during wet shoe deployment using multiple latch-in plugs to maintain separation between the cement/spacer, cement/retarder water, and retarder water/displacement fluid interfaces.

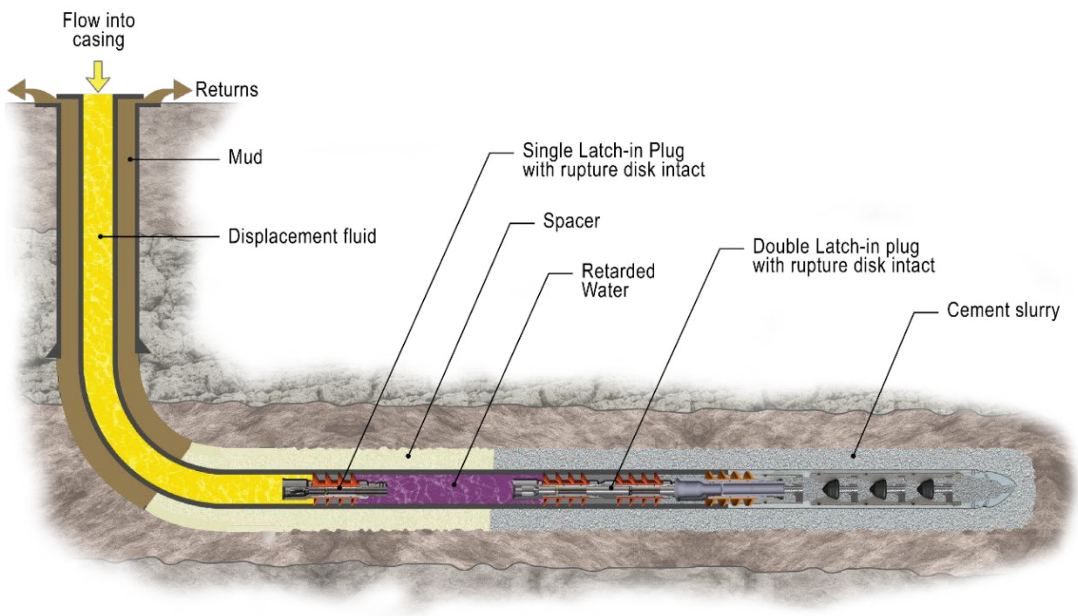

Fig. 15—Illustration of the cementing operation during wet shoe deployment, showing cement displacement after rupture of the first plug, followed by its landing and latching into the Advanced valve latch shoe tool shoe profile and the second plug landing and latching into the first plug profile.

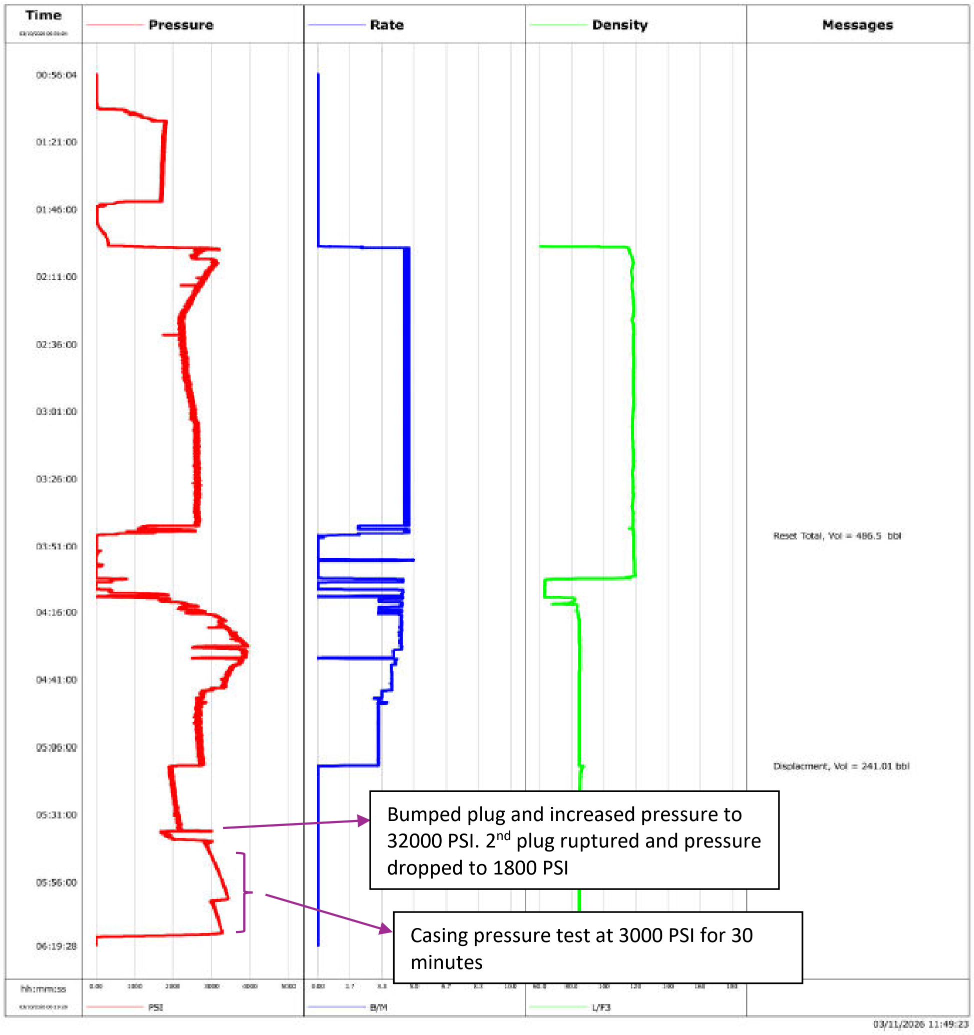

Fig. 16— Cement charts representing the pressure sequence of the wet shoe operation during downhole deployment of AVLST wet shoe system

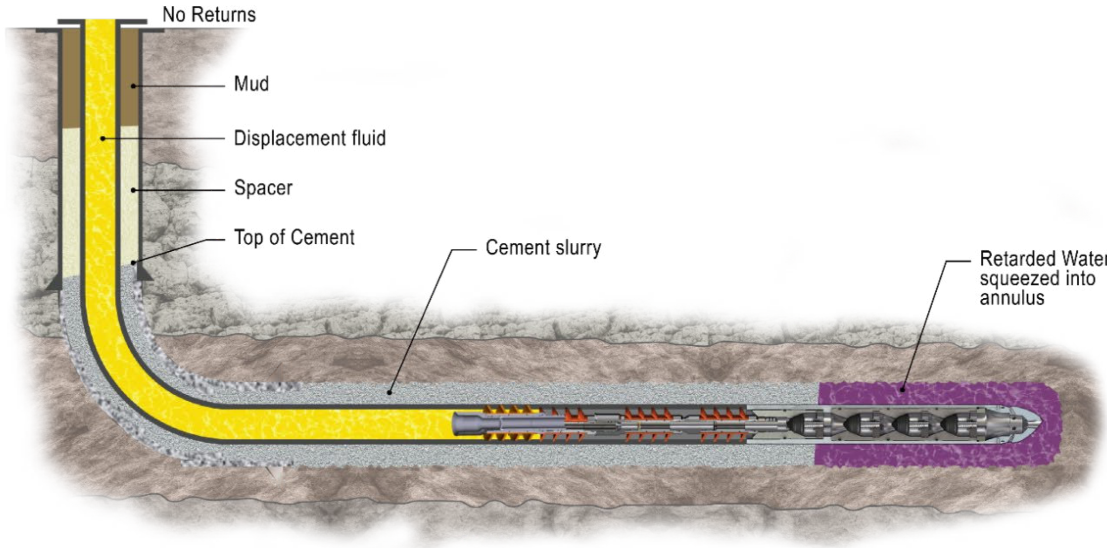

Fig. 17— Illustration of the wet shoe track after completion of the cementing operation. All wiper plugs are latched into their respective profiles, providing a seal that allows the casing to be pressure-tested against the final wiper plug.

Frac initiation/Toe prep operation

Approximately one month after casing deployment, a rig-less operation was conducted as illustrated in Figure 18. The casing was successfully pressure-tested again at 3,000 psi for 30 minutes, after which pressure was increased to rupture the disk contained within the third wiper plug, establishing communication through the wet shoe-track. Injectivity into the formation was successfully established at 9,500 psi. Following rupture disk activation, a 20-bbl squeeze operation was conducted at approximately 0.5 bpm through the wet shoe and into the formation to verify injectivity prior to the planned hydraulic fracturing treatment.

The operational deployment confirmed that the wet shoe system performed successfully under actual operational conditions. The float valves maintained approximately 8,000 psi differential pressure for more than 150 hours while the casing remained under flotation before reaching total depth. This extended pressure-holding capability demonstrated the suitability of the valve system for prolonged deployment during casing installation in extended-reach wells. Compared with conventional completion designs requiring multiple toe initiators and extended shoe-track assemblies, the wet shoe configuration significantly reduced completion complexity while recovering approximately 100–250 ft of productive reservoir that would otherwise remain unstimulated. Elimination of toe initiators also reduced premium threaded connections, eliminated additional completion hardware with potential leak paths and reduced shoe-track length.

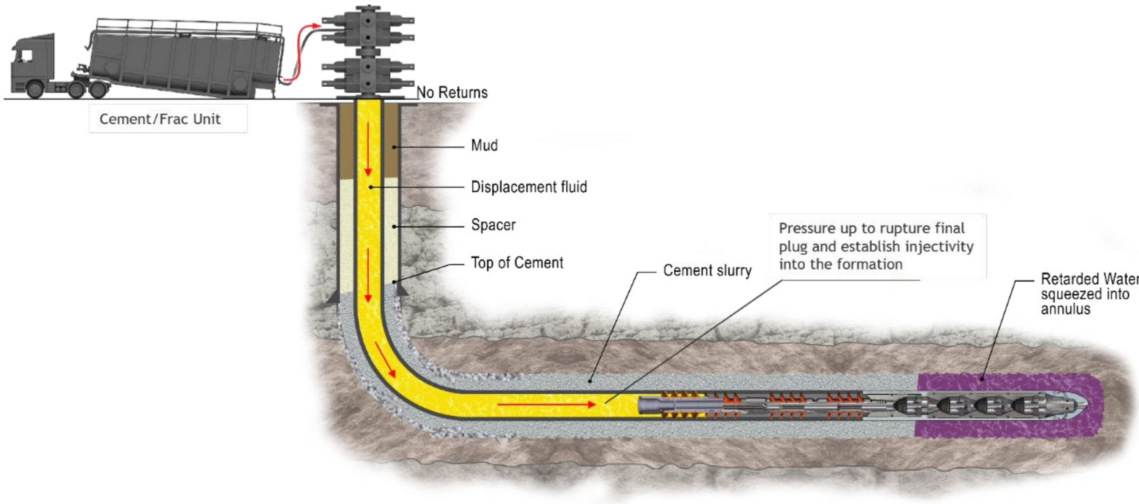

Fig. 18— Illustration of a rigless operation showing a cementing/fracturing unit mobilized to pressure-test the casing and rupture the final plug, thereby establishing injectivity into the formation.

Conclusions

The study concludes that a gas-tight wet shoe system incorporating redundant metal-to-metal sealed float valves was successfully developed for unconventional and extended-reach HPHT wells. The valve assembly successfully completed API 10F flow endurance testing, 31% hydrochloric acid exposure for 2 hours, repeated API 19AC V0 gas-tight qualification at 15,000 psi and while maintaining zero observable gas leakage. Laboratory testing confirmed that prolonged erosive flow, elevated temperature, repeated pressure cycling, and acid exposure did not compromise valve functionality or sealing integrity. Downhole deployment in an unconventional Area of Interest demonstrated reliable casing flotation, successful wet shoe completion, stable circulation, and successful casing pressure testing without operational complications. The wet shoe configuration eliminated conventional toe initiators while substantially reducing shoe-track length, increasing productive reservoir exposure and simplifying long string completion.

Nomenclature

API = American Petroleum Institute
API 10F = Cementing Float Equipment Testing
API 19AC = Specification for Completion Accessories
bbl = barrel
BPM = barrels per minute, bbl/min
CRT = casing running tool
Ft = foot, feet
HPHT = High pressure, high temperature
AVLST = Advanced Valve Latch Shoe Tool
ID = internal diameter
in. = inch(es)
lb = pound
MD = measured depth
OBM = oil-based mud
pcf = pounds per cubic foot
psi = pounds per square inch
RIH = run in hole
RPM = revolutions per minute
TD = total depth
TVD = true vertical depth

References

Algadi, Otman , Filyukov, Ruslan , and David Luna. "Multistage Hydraulic Fracturing Using Coiled Tubing-Activated Frac Sleeves: Case Study From The Permian Basin." Paper presented at the SPE Annual Technical Conference and Exhibition, Amsterdam, The Netherlands, October 2014. doi: https://doi.org/10.2118/170821-MS

Almasmoom, Salahaldeen, Le, Viet, Stonestreet, David, and Omar Al-Faraj. "Unconventional Field Well Delivery Optimization: Drilling Precise Sand-Channel Targets." Paper presented at the International Petroleum Technology Conference, Dhahran, Kingdom of Saudi Arabia, January 2020. doi: https://doi.org/10.2523/IPTC-20051-MS

Almomen, Hassan, Almasmoom, Salahaldeen, Nino, Adriana Contreras, Herrera, Juan Isaias Sarmiento, and Anibal Flores. "Reliable Casing Deployment and Effective Zonal Isolation in Unconventional Extended-Reach Wells." Paper presented at the SPE Conference at Oman Petroleum & Energy Show, Muscat, Oman, May 2026. doi: https://doi.org/10.2118/232429-MS

API RP 10F, Recommended Practice for Performance Testing of Cementing Float Equipment, third edition, Washington DC: API 2002

Champeaux, C.J., Arrazola, A.J., Patin, V., Stair, T., and Rogers, H. 2020. Qualification and Deployment of Float Equipment as an Independent Mechanical Barrier in Unconventional Wells. Presented at the SPE Annual Technical Conference and Exhibition, 26–29 October. SPE-201264-MS.

Ferrin, J.M. 2026. Minimizing Shoe Track Length in Production Casing: A New Reamer Float Shoe Design for Wet Shoe Applications. Presented at the SPE Argentina Exploration and Production of Unconventional Resources Symposium, Neuquén, Argentina, 22–24 April. SPE-231285-MS. https://doi.org/10.2118/231285-MS.

Gundersen, A., Gomez, R., Kadler, C., Broussard, T., and Gandomkar, A. 2023. Intentional Wet Shoetrack Completions for Unconventional Oil and Gas Resources: Methods and Techniques. Presented at the SPE Oklahoma City Oil and Gas Symposium, Oklahoma City, Oklahoma, USA, 17–19 April. SPE-213081-MS. https://doi.org/10.2118/213081-MS.

Hord, R., Scott, T., Weeks, F., and Budde, M. 2011. A Cost-Effective Alternative Method of Deploying Perforating Devices in High-Angle Wells. Presented at the SPE/IADC Drilling Conference and Exhibition, Amsterdam, The Netherlands, 1–3 March. SPE-140304-MS.

Johnson, C. Christopher, Kellner, Justin, and Jason Mailand. "New Pressure-Actuated Valve Allows for Interventionless Access to Formation in Cemented Applications." Paper presented at the SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, October 2012. doi: https://doi.org/10.2118/159589-MS

Khan, S., Siddiqui, S., Siddiqui, T., Zain, M., and Nadeem, Q. 2020. Improved Casing Completion without Shoe Track for Unconventional Gas Wells. Presented at the International Petroleum Technology Conference, Dhahran, Saudi Arabia, 13–15 January. IPTC-20222-MS.

Portillo, Oscar, Almalki, Nawaf, Qahtani, Faris, Almuraisel, Abdulaziz, and Guoqiang Yin. "Systematic Strategies to Conquer the Technical Challenges to Successfully Deliver the First 15,000 Ft Lateral Well in an Unconventional Drilling Operation." Paper presented at the Middle East Oil, Gas and Geosciences Show (MEOS GEO), Manama, Bahrain, September 2025. doi: https://doi.org/10.2118/226974-MS

Tedjani, H.F., Albaijan, N., Gundersen, A., and Al-Jarodi, H. 2025. Novel Method to Drift and Pressure Test a Casing String without Intervention. Presented at the Middle East Oil, Gas and Geosciences Show (MEOS GEO), Manama, Bahrain, 16–18 September. SPE-227043-MS. https://doi.org/10.2118/227043-MS.

Weijers, Leen, Wright, Chris , Mayerhofer, Mike , Pearson, Mark , Griffin, Larry , and Paul Weddle. "Trends in the North American Frac Industry: Invention through the Shale Revolution." Paper presented at the SPE Hydraulic Fracturing Technology Conference and Exhibition, The Woodlands, Texas, USA, February 2019. doi: https://doi.org/10.2118/194345-MS

Yin, Guoqiang, Almasmoom, Salahaldeen, Ali, Mohammad, and Nawaf Almalki. "Technical Challenges and Strategic Solutions for a New Historical Milestone: The Success of Delivering the First Two 10 K ft Lateral Wells in an Unconventional Drilling Operation." Paper presented at the Middle East Oil, Gas and Geosciences Show, Manama, Bahrain, February 2023. doi: https://doi.org/10.2118/213681-MS