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PRODUCTION TECHNOLOGY

Tubing-retrievable safety valves: Paving the way for all-electric safety solutions

This article explores the history of Tubing-Retrievable Safety Valves (TRSVs), highlighting their development milestones and introducing Halliburton's EcoStar® all-electric TRSV. Created to meet reliability and operational performance needs, this product helps advance safety valve technology and points to a safer industry future.

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Subsurface Safety Valves (SSSVs) are components that maintain the integrity and safety of oilfield operations. These devices prevent the uncontrolled release of hydrocarbons in the event of failure or loss of containment at the surface. Among the SSSV designs, Surface-Controlled Subsurface Safety Valves (SCSSVs) are the most common, and within that category, Tubing-Retrievable Safety Valves (TRSVs) are the most used.

This article explores the evolution of TRSVs, from inception to technological advancements. We examine the progression of these safety devices that inspired Halliburton's all-electric EcoStar® eTRSV—a leap in subsurface safety valve technology.

The first half of the 20th century saw advances in the oil and gas industry, both in engineering methods and equipment technology. These advances enabled operators to explore and produce deeper, higher-pressure reservoirs. As the production of these reservoirs presented a risk of failures, such as containment loss on the surface, due to a collision with a wellhead, the need for devices to prevent the uncontrolled release of hydrocarbons became clear.

As a result, the industry began the development of downhole safety valve technologies to address this challenge. Commercial deployment started in the 1940s. Since then, various design approaches for fail-safe devices have evolved throughout the development of safety valves. Common safety valve concepts include poppet valves, ball-type valves and one-way flapper systems.

Early safety valves were subsurface-controlled and operated on velocity principles, using poppet-style valves that shut when the production flowrate overcame the force required to close the poppet. The original design evolved into a poppet-style velocity valve, designed to be adjustable to suit well conditions. This valve closes when the flowrate surpasses a set threshold, to maintain safety and control in different operational settings. The adjustable features improved the reliability of the design. Known as a Storm ChokeTM, it remains in use today.

EVOLUTION AND RELIABILITY INCREASE

Commercial deployment of poppet-style valves led the industry to consider alternative designs. The primary limitations of poppet-style safety valves included a lack of reliable control, reduced flow areas that lowered production rates, and an inability to pass intervention tools. As a result, the industry developed larger-bore, surface-controlled, tubing-deployed designs. Installation of these designs is part of the completion tubing string from the surface, via a hydraulic control line, set a few hundred to a few thousand meters below the wellhead. Surface control increased reliability and prevented unplanned closures.

SCSSVs operate by the application of hydraulic pressure to a control line to open the valve. Continuous pressure on the hydraulic line keeps the valve open for production or injection. When the control line pressure is released—whether because of intention or surface containment failure—the valve returns to the closed position. A spring mechanism overcomes the hydrostatic pressure on the control line and closes the valve.

Early tubing-deployed valves used a ball-type design, but this caused reliability issues, due to a low debris tolerance that limited operations or rendered the valve inoperable. An inoperable valve stuck in the closed position resulted in lost production and remediation challenges. Mechanical shift-to-open options were unreliable, and drilling through the ball to remove it was not always feasible. As a solution, the industry shifted to tubing-deployed, surface-controlled, one-way flapper-type valves. This design improved reliability and shielded the main flapper/seat seal mechanism from flow, when the valve is in the open position. By the early 1990s, flapper-type tubing-retrievable safety valves had become standard.

TRSVs have evolved steadily in step with industry needs and technological advances. This has led to highly reliable fail-safe devices deployed in wells throughout the world today. Some advances include improved sealing reliability of the flapper seat mechanisms and rod-piston seals, by employing non-elastomeric sealing technologies. TRSVs with contoured flapper designs allow for improved sealing and OD/ID ratios for increased bypass clearance. The ability to exercise the valve by means of intervention, if it becomes contaminated or stuck, as well as the ability to install a retrievable insert (secondary) valve in the TRSV to avoid the immediate need for a well workover, have also progressed the technology.

In deepwater and HP/HT applications, TRSVs handle pressures of 20,000 psi or more and temperatures of 400°F. In high-flowrate applications, some TRSVs support 450 MMscfd slam closure. For deeper-set applications, the industry developed heavily sprung single control line options, though these face depth limitations. Balance line TRSVs eliminated depth restrictions in subsea deepwater applications.[1] A secondary balance line counteracts hydrostatic forces on the control line to make setting depth irrelevant. Magnetic coupling TRSVs set a new reliability standard through the disconnection of the control line from the production tubing flow path, as demonstrated by Halliburton's DepthStar® TRSV. This approach removes the risk of tubing-to-control-line communication failures.[2]

In 1973, industry regulatory requirements established a unified framework for subsurface safety valves. These regulations ensured products met the needed qualifications and functional standards that drove improvements in product reliability.

Due to advancements in TRSV technology, the industry now prefers hydraulically operated, surface-controlled, flapper-type valves as the standard fail-safe device. This TRSV design offers maximum reliability without limits to the completion of designs or production rates.

The next step in TRSV technology advancement is to electrify the actuating systems and eliminate the cost and risk associated with hydraulic systems, **FIG. 1.**

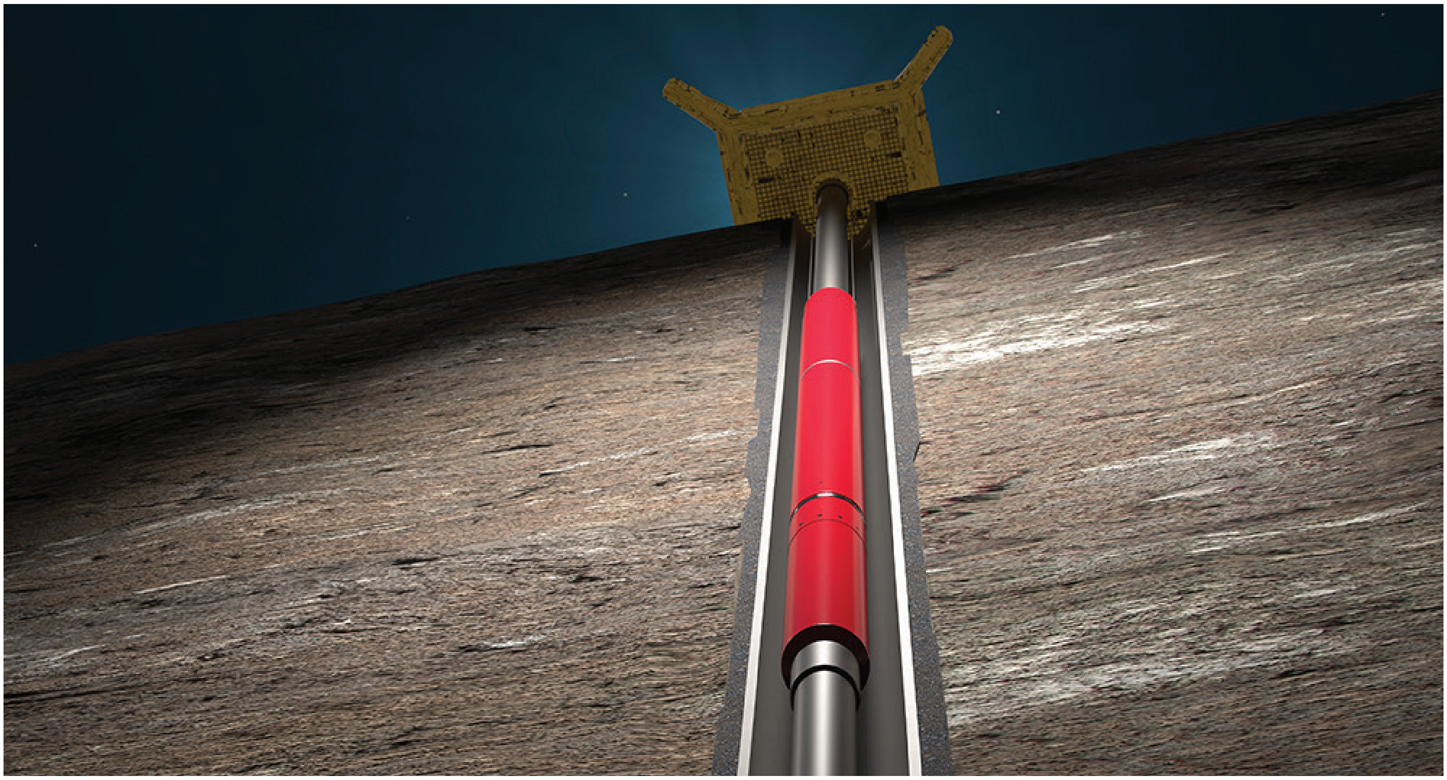

FIG. 1. Designed for deepwater, high-pressure/high-temperature environments, the EcoStar® electric tubing-retrievable safety valve ensures reliable performance and safety in long tieback applications.

INTRODUCTION OF THE ALL-ELECTRIC SAFETY VALVE

Since the late 1990s, subsea oilfield service companies developed and qualified an all-electric subsea production system. However, the SCSSV still used hydraulic fluid, the missed link for a fully electric well.

For years, the industry sought an electric, surface-controlled, subsurface safety valve with low power requirements. The installation of Halliburton's EcoStar® safety valve in 2016 became the first electric, tubing-retrievable safety valve (eTRSV) to meet these requirements, and it solved the 30-year challenge of hydraulic actuation removal, **FIG. 2.** Halliburton's all-electric safety valve represents a leap in safety valve technology and the next step with proven capability: the ability to remove hydraulics and replace them with electric controls. The EcoStar® eTRSV combines flapper/seat sealing technology with a magnetic coupling system and electric actuation. This design increases reliability and improves safety and operational efficiency.

The EcoStar® eTRSV offers redundant capability to control the electric safety valve. Onboard automated monitoring provides feedback on valve performance, to detect micro changes in valve operation, such as scale build-up. This digital feedback offers insights into the management of downhole conditions and the extension of system life, compared to conventional safety valves.

As of writing, the current standard for subsea well control relies on hydraulic technology. A host facility supplies hydraulic fluid to subsea wells through pathways within an umbilical. When it reaches the seafloor, the fluid distributes to wells and interacts with components like the manifold, Christmas tree valves and downhole safety valves.

An all-electric subsea well uses an electric subsea Christmas tree, and an electric downhole safety valve and subsea control modules, with valve control established through an electric cable. The electric downhole safety valve also installs onto conventional trees that use IWIS medium power interface cards and standard electrical feedthroughs for downhole gauges. This allows a transition to electric completions without requiring an electric subsea production system.

The all-electric safety valve reduces production deferment. Analysis shows that the charge and vent time required after an ESD event can take multiple hours when umbilicals are several kilometers long. This required the well to stay offline because the safety valve remained closed. In contrast, the electric safety valve could shut and open in minutes, reducing production deferment.

All-electric systems reduce project costs through the elimination of hydraulics. Hydraulic controls require a network of umbilicals that are complex, difficult to install and costly. To reduce capital expenditure, it is necessary to simplify or remove hydraulics from the umbilicals, subsea production system and surface hydraulic support.

The elimination and replacement of surface hydraulic systems with a simple rack-mount system could result in footprint savings of up to 80%, which could benefit space-constrained areas and lower the carbon footprint.

All-electric subsea systems help reduce environmental and safety risks through the elimination of the possi-

FIG. 2. EcoStar® eTRSV revolutionizes subsea safety with its electric actuation system. As the world's first electric safety valve, EcoStar eTRSV offers unparalleled reliability and completely eliminates the risk of hydraulic fluid exposure, setting a new standard for safety and operational efficiency in subsea operations.

bility of hydraulic fluid release. The removal of high-pressure equipment and containment on topside facilities helps to improve personnel safety.

Electric technology enables advancements in deepwater exploration. It is easier to implement in deep waters and long tie-backs than hydraulic systems. With the potential to significantly save on costs, electric systems demonstrate greater reliability, use less complex subsea distribution and rely on simpler hardware components.

Halliburton installed the world's first electric safety valve in 2016 and demonstrated its ability to develop and deploy all-electric systems with the same functions as conventional safety valve systems.

The Halliburton EcoStar® eTRSV provides operators with life-of-well reliability, a crucial feature for any tubing-retrievable safety valve, as it will help advance developments of further electric capabilities.

FUTURE OF SAFETY VALVES IN OIL FIELDS

The future of safety valves depends on innovation and adaptation to new challenges. Trends show a shift toward automated systems capable of self-diagnosis and predictive maintenance. The EcoStar® all-electric safety valve, born from Halliburton's proven reliability, leads this transformation and delivers improved safety and efficiency. As the industry shifts to more sustainable and advanced operations, innovative safety solutions will play a key role. An electric safety valve serves as a crucial component of an all-electric completion solution.

The industry's move toward electrification will enable capabilities to monitor and diagnose in ways that are not possible with conventional systems. This shift will help operators optimize CAPEX and reduce OPEX.

CONCLUSION

Halliburton addressed two key industry challenges with the EcoStar® eTRSV: the reduction of HSE risks, with the elimination of hydraulic actuation from safety valve systems, and the improvement of field economics. This technology advances the electrification of wellbores and aligns with Halliburton's vision for the Future of Completions®: setting the stage for all-electric completion systems. **WO**

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