FIELD EVALUATION OF ESP MOTOR COOLING TECHNOLOGIES DEPLOYED IN MULTIZONE PERMIAN WELLS: CASE STUDIES AND LESSONS LEARNED

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ABSTRACT

Electric Submersible Pumps (ESPs) remain one of the most widely deployed artificial lift technologies for maximizing production from Permian wells. Operating companies often find themselves installing ESPs between multiple producing zones or even below the perforated intervals for several reasons, including the goal of maximizing production by setting the pump as deep as possible and increasing natural gas separation to help stabilize operating trends.

Shroud and recirculation systems are the two primary technologies used for ESP motor cooling. In this paper, the performance of both techniques was evaluated, and the main challenges, limitations, and lessons learned are discussed.

A dataset comprising hundreds of ESP installations equipped with motor cooling systems was analyzed to evaluate the performance of both techniques. Survivability curves were used to compare the reliability of these systems, while several Dismantle Inspection and Failure Analysis (DIFA) reports were reviewed to identify the main failure mechanisms and root causes. Numerical simulation was conducted to better understand the physics underlying the recirculation system performance. Operating trends and production data were also examined to further assess the challenges, limitations, and efficiencies of these technologies.

Based on survivability curves, ESPs equipped with cooling systems demonstrated a 45% higher average runtime compared to standard ESPs. Over 400 ESPs with recirculation systems have been installed in the Permian Basin, with an average run life of 1000 days and several wells exceeding 4,000 run days. Numerical simulation indicates that setting the pump below the perforations can achieve up to 95% natural gas separation, ensuring reliable and stable operation. In contrast, pull and DIFA reports show that units installed with shroud systems experienced several critical challenges and failures. These include incidents of holes in the shroud preventing proper cooling, scale and sand deposition inside the shroud reducing production rates, and in many cases causing complete blockage. Additionally, the pump stack inside the shroud often contributes to reliability concerns.

The standardized industry practice for deploying ESP systems below perforations requires the use of a motor cooling system. This study evaluates the reliability of the recirculation system compared to the shroud, providing the industry with best-practice guidance for future ESP installations.

INTRODUCTION

In the capital-intensive landscape of the Permian Basin, maximizing the estimated ultimate recovery (EUR) from unconventional reservoirs depends heavily on the strategic deployment of artificial lift. The Electric Submersible Pump (ESP) remains the industry standard for high-volume fluid production.

A prevailing operational trend in Permian is the deep-set configuration, where the ESP is positioned as close to the reservoir as possible. Often, this involves installing the unit below the perforated intervals. This placement is driven by two critical production objectives:

- Positioning the pump intake at the lowest feasible vertical point maximizes the available drawdown, thereby accelerating fluid inflow from the formation.
- A deep-set intake allows gas bubbles to naturally migrate upward into the annulus. This gravity-based separation reduces the volume of free gas entering the pump stages, which is essential for preventing gas-lock conditions and stabilizing the motor’s power consumption.

While the deep-set strategy optimizes hydraulic performance, it creates a significant mechanical risk: thermal degradation of the motor. In standard installations above the perforations, the velocity of the produced fluid flowing toward the intake provides the convective heat transfer required to cool the motor. When placed below the perforations, the motor is effectively submerged in a stagnant fluid column. Without a forced cooling mechanism, the heat generated by the motor leads to rapid insulation failure and premature electrical burnout. To mitigate this, two primary fluid-steering technologies are deployed: Shroud Systems and Recirculation Systems

Despite the widespread use of both cooling methods, there remains a lack of large-scale, comparative field data regarding their long-term survivability. In this paper, a dataset comprising more than 560 installations between the shroud and recirculation is used to evaluate the performance of both techniques. The average run life and survivability curves are presented, along with case studies and numerical simulations.

ESP COOLING SYSTEMS: CHALLENGES AND SOLUTIONS

Proper fluid circulation around the motor is essential to prevent overheating and premature motor failure. There are two primary scenarios where natural fluid flow is insufficient for adequate cooling:

- Low Flow Rates (ESP above perforations): If the ESP is installed above the perforations and production rates are low, the fluid velocity may fall below the recommended cooling threshold.
- Bypass Flow (ESP below perforations): When the ESP is set below the perforations, fluid flows directly from the reservoir to the intake, completely bypassing the motor.

To mitigate these issues, two primary methods are employed:

1. Shroud System

As shown in Figure 1 (Left), a shroud (or cooling jacket) is installed around the motor, protector, and intake. This jacket is open-ended at the bottom, forcing the fluid through a smaller cross-sectional area. This reduction in space increases the fluid velocity, thereby enhancing the convective cooling of the motor. Shrouds can also assist in gas separation. By changing the flow direction, they leverage the buoyancy of gas bubbles, allowing them to vent up the casing annulus rather than entering the pump intake.

In wells with a high tendency for carbonate scaling, shrouds can be problematic. Scale can deposit between the motor and the shroud or between the shroud and the casing. This buildup restricts circulation, leads to overheating, and can cause the equipment to become stuck in the well.

2. Recirculation Systems

The recirculation system (Figure 1, Right) provides forced cooling by redirecting a portion of the produced fluid. It utilizes a tapered pump system where part of the discharge from the lowest pump stages is sent into a specialized tube that exits below the motor. This fluid then flows upward, cooling the motor as it returns to the intake. To fit within tight casing clearances, the conduct consists of three oval stainless-steel tubes welded to solid round rods. These rods provide structural integrity and prevent the tubes from collapsing if they encounter obstructions.

Chemical Treatment: The system enhances the deployment of scale and corrosion inhibitors. Capillary tubes can be terminated above or below the motor, ensuring that chemicals are continuously circulated around the equipment to prevent scaling.

Pump Selection: The recirculation pump must be sized with a higher flow rate than the primary lift pump to account for the diverted cooling volume. Additionally, it must include enough stages to generate sufficient pressure to overcome frictional losses within the recirculation tube.

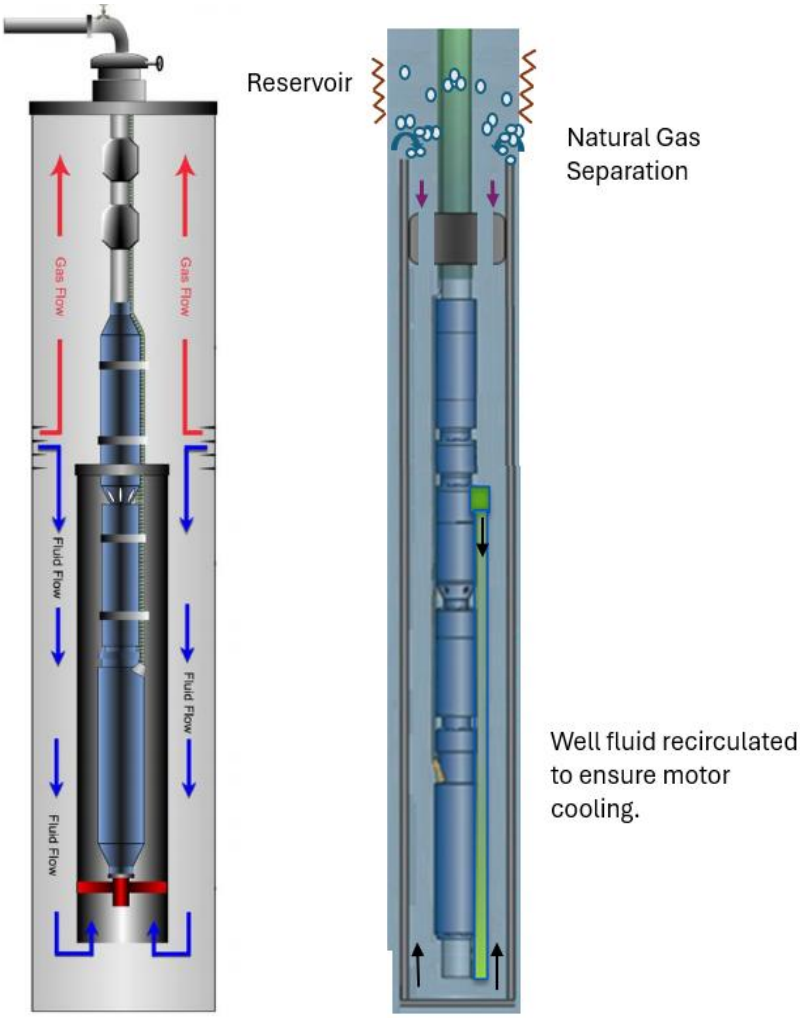

Figure 1. A Shroud System (Left), Recirculation System (Right).

STATISTICS

The survivability curves for the shroud system and the recirculation system are depicted in the figure 2. As shown, the recirculation system outperforms the shroud system in terms of run life. Approximately 50% of the installed shrouds failed within 600 days. It is worth noting the steep decline observed between 320 and 480 days, where survivability dropped by about 20% within roughly 160 days. In contrast, approximately 60% of the installed recirculation systems continued operating beyond 700 days.

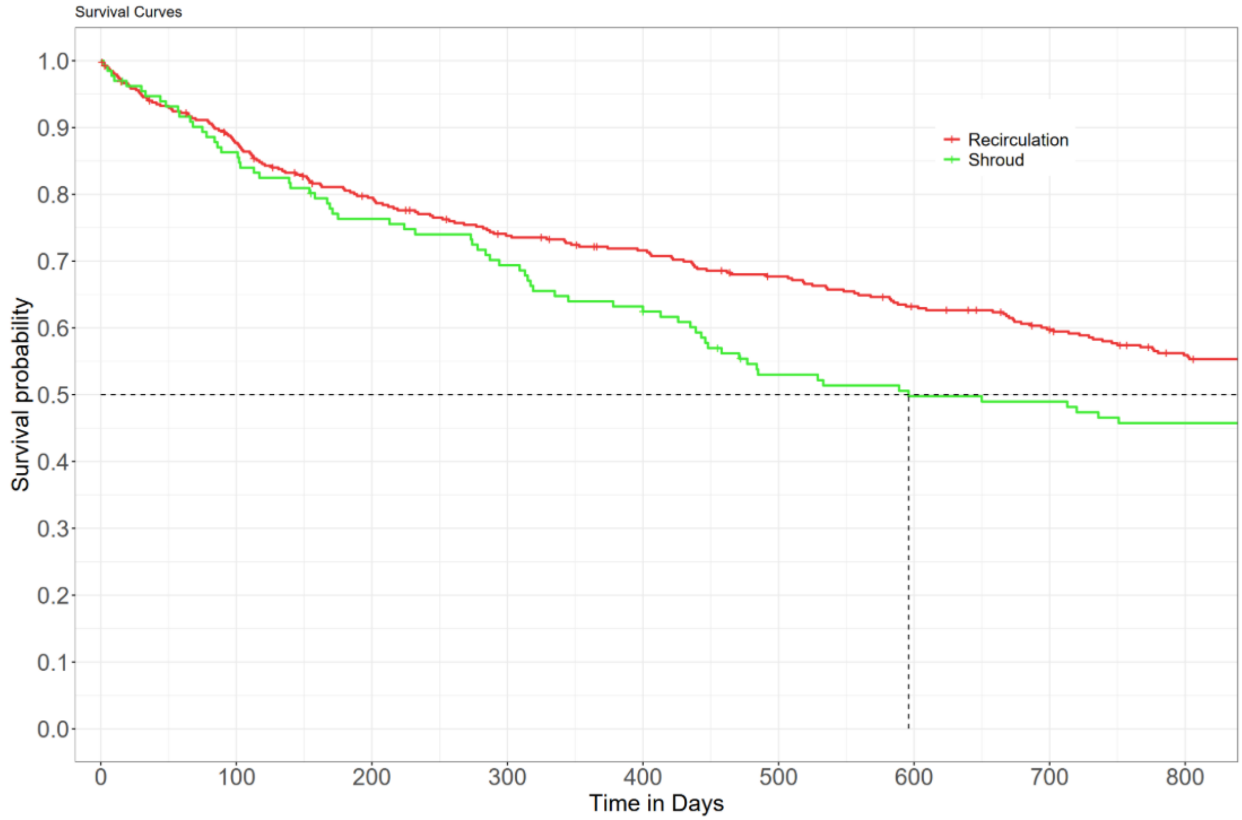

Figure 2. Survivability curves for the shroud and the recirculation system

567 systems installed between shroud and recirculation system. The average run life of shroud system is 892 days. With 5.5” shroud having higher avg run days ~950 days, compared to 4.5” shroud 660 run days. In the other hand 1027 run days is the average run life of Recirculation system. Over 140 systems with shrouds were installed in Permian. A breakdown of the run life is presented in Figure 3. Overall, most of the units run for more than a year with 54% and 63% for 4.5” and 5.5” respectively. Infant short runs were recorded as well, with 18% and 16% respectively. Digging deep into the main failure mode of these short runs reveals that 50% of them were due to Low/No Production.

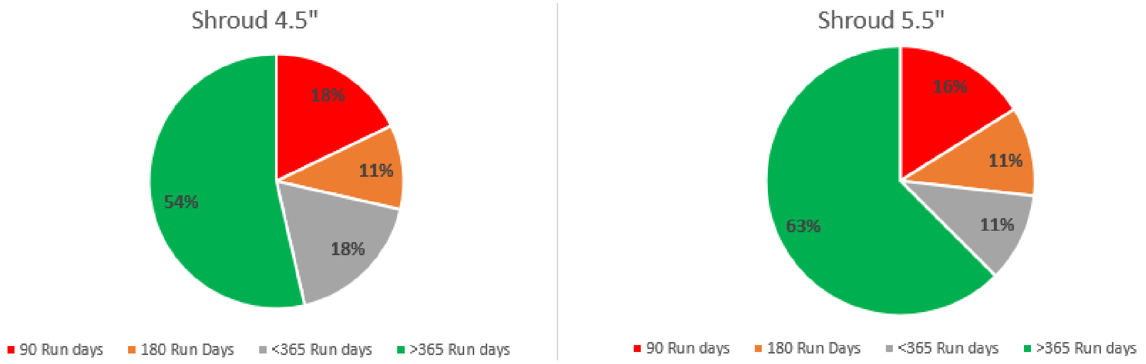

Figure 3. Breakdown of the run life for the shroud.

A breakdown of the run life of over 420 recirculation system installed in the Permian is depicted in Figure 4. 64% of the systems ran over a year. Looking at the infant short runs, Grounded Down Hole and Low/no production were the main reasons for pulling with 21% and 23% respectively.

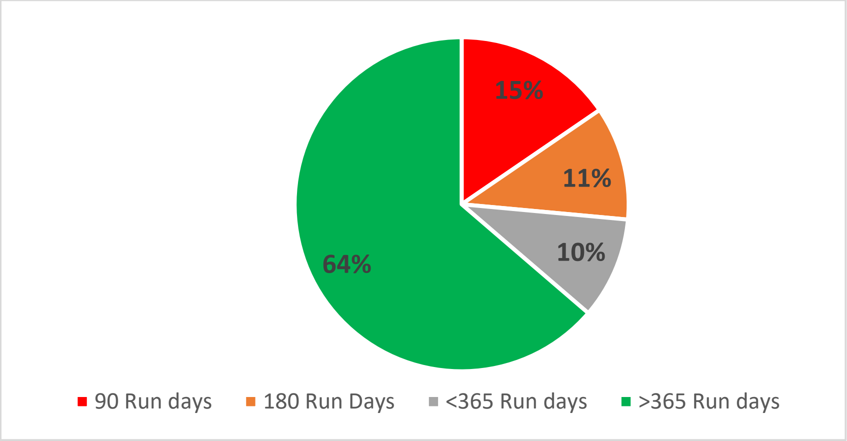

Figure 4. Breakdown of the run life for the recirculation.

CASE STUDIES

The following case studies illustrate field applications of both shroud and recirculation ESP cooling systems under different operating conditions. These examples highlight the operational performance, challenges encountered, and the impact of each system on equipment run life and overall well reliability.

Case Study 1

Well 1 was completed with 7-in., 23-lb/ft casing targeting the Upper San Andres formation. The perforated interval is 4365–4497 ft. The operating company opted to an ESP below the perforations to maximize production, enhance natural gas separation, and achieve stable operating conditions. The well produced on average 500 BPD, with 90% water cut (WC) and a gas–liquid ratio (GLR) of 4,000 scf/STB.

An ESP equipped with a shroud system was installed in May 2024, with the ESP sensor set at 4,620 ft. After 168 days of operation, the unit was pulled due to Low/No Production. During retrieval, the equipment was found stuck inside the shroud. Water and acid were pumped into the shroud and allowed to soak overnight, but this intervention was unsuccessful. A welder was required to cut the shroud, allowing the intake, seals, motor, and sensor to be retrieved. The Figure 5 below shows the equipment and the shroud after cutting. Chemical treatments are often less effective when a shroud is installed, and the reduced flow area inside the shroud can increase pressure losses and promote scale deposition.

Figure 5. Equipment and the shroud after cutting.

Operating trends (Figure 6) indicate that the unit initially was operating smoothly. As observed, as scale accumulated inside the shroud and restricted flow, the intake pressure increased, and the unit experienced repeated shutdowns immediately after start-up due to high motor temperature. Chemical treatment using acid and soap did not restore production, leading to the decision to pull the system.

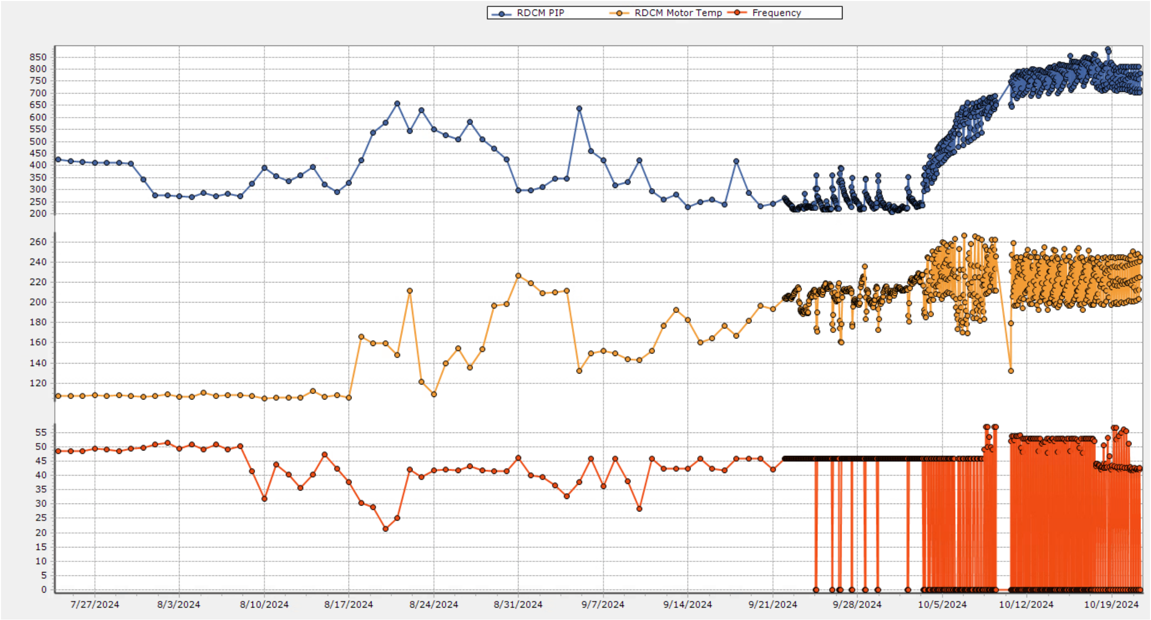

Figure 6. Operating trends with shroud.

The operating company subsequently decided to replace the system with a recirculation system. The new system has been operating for more than 400 days. The ESP sensor is currently set at 4,400 ft. The recirculation tube enables improved chemical distribution, helping prevent scale deposition around the motor and intake.

Based on the matched case analysis, the gas separation efficiency is estimated at approximately 96%, reducing the free gas entering the pump to about 25%. The resulting lower gas volume fraction (GVF) inside the pump ensures stable operating trends, minimal motor current fluctuations, and fewer shutdown events, as illustrated in the operating trends shown in the Figure 7.

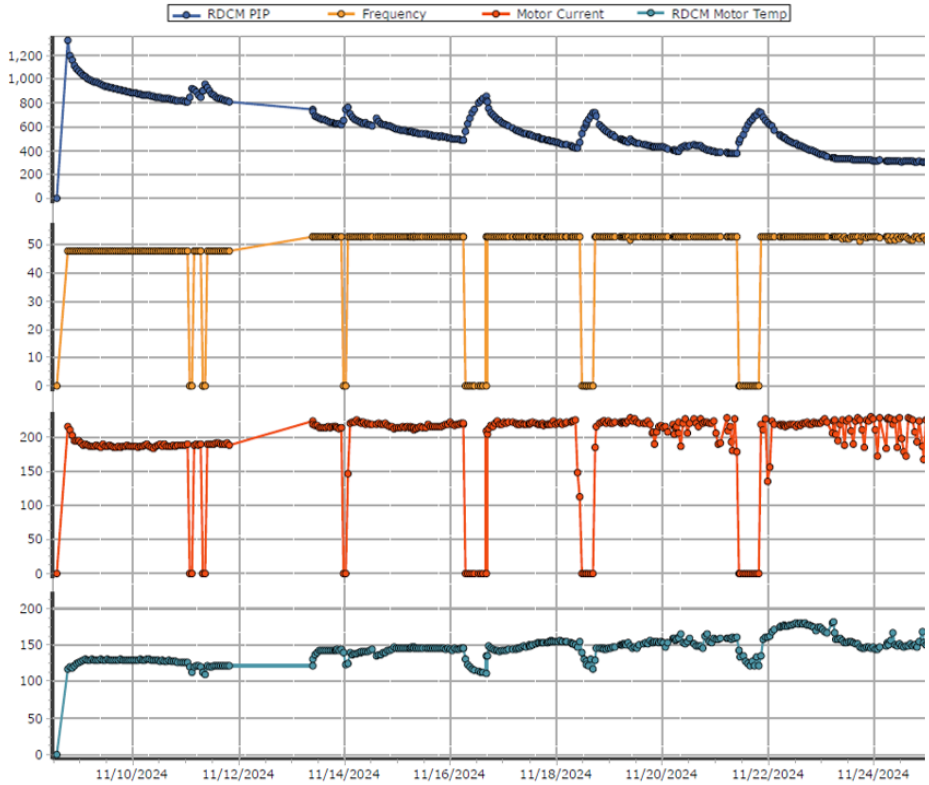

Figure 7. Operating trends with recirculation.

Case Study 2

A major operating company in the Permian Basin has many wells that operate in highly corrosive environments, where pulled shrouds were often found severely corroded with multiple holes. These failures allowed reservoir fluids to bypass the motor, significantly reducing the cooling flow around the ESP motor (MTR) and leading to high motor temperature shutdowns.

Field observations also indicated that ESP systems equipped with shrouds tend to operate at higher temperatures, which promotes scale and asphaltene deposition inside the shroud. Another operational challenge in these wells is that large portions of the casing are perforated, making it difficult to determine which zones contribute most to production. This uncertainty further complicates the effectiveness of shroud-based cooling systems.

Well A experienced five ESP installations using a shroud system. The well is completed with 7-in., 26-lb/ft casing, with a perforated interval from 1,540 ft to 2,563 ft. The ESP is set at 2,450 ft, and the well produces an average of 800 BPD with approximately 99% water cut.

Table 1 summarizes the run life and pull comments for each ESP installation in Well A.

Install	Run Days	Pull Reason	Pull Comment
Shroud Install 1	423	Low/No Production	Shroud was heavily pitted and corroded throughout the entire body, with a hole observed approximately halfway down the shroud.
Shroud Install 2	1172	Low/No Production	The shroud was nearly backed out at the connection threads. A hole was observed at the threaded connection, and another hole was found in the bottom section of the shroud.
Shroud Install 3	472	Low/No Production	Multiple holes were observed in the shroud.
Shroud Install 4	1240	Unknown	The shroud was heavily corroded. The tubing was covered in paraffin, and the ESP body was also covered with paraffin and scale.
Shroud Install 5	273	Low/No Production	The pump and intake were locked up.

Figure 8 below shows the condition of the equipment when the unit was pulled. As observed, the shroud was heavily corroded and contained multiple large holes. These openings allowed reservoir fluids to bypass the motor section, preventing adequate motor cooling and contributing to high motor temperature shutdowns.

Figure 8. Condition of the equipment after the pull, Well A.

Well B is completed with 7-in., 26-lb/ft casing, with perforations extending from 1,370 ft to 2,830 ft. The ESP setting depth is 2,850 ft, and the well produces approximately 1,700 BPD with 99% water cut.

Table 2 summarizes the run life and pull comments for each ESP installation in Well B.

Install	Run Days	Pull Reason	Pull Comment
Shroud Install 1	168	Low/No Production	The shroud had corrosion throughout the entire body. Some buildup was observed on the intake and the shroud hanger.
Shroud Install 2	344	Low/No Production	The shroud hanger and the shroud showed significant corrosion.
Shroud Install 3	1054	Low/No Production	The intake, seals, and motor could not be removed from the

			shroud because they were stuck inside.
Shroud Install 4	476	Grounded Down Hole	The shroud was severely pitted. Precautions were taken while pulling the equipment. A significant amount of iron sulfide was observed on the body of the equipment. The shroud remains in the wellbore, and the operating company plans to attempt fishing operations to retrieve it.

Figure 9 presents the condition of the equipment pulled after the forth install. As can be seen, the retrieved shroud has many holes.

Figure 9. Condition of the equipment after the pull, Well B.

After several installations using shroud systems, the fifth installation utilized a recirculation cooling system. The unit has been operating for more than 650 days, and the operating company reported production increases of up to 20% compared with the previous shroud installations. A key advantage of the recirculation system in corrosive environments is that the recirculation tubing is constructed from stainless steel, providing greater resistance to corrosion and improving system reliability. Alternatively, the shroud can be coated with an anti-corrosion protective layer, or its metallurgy can be upgraded to improve corrosion resistance.

CONCLUSIONS

1. Field data shows that both recirculation systems and shroud systems can deliver strong run life and reliable performance in ESP installations. The choice between them depends on application needs, well conditions, solids production, well geometry, and chemical treatment requirements.
2. Regular shroud systems are more susceptible to operational failures in corrosive environments, where corrosion damage can create openings in the shroud, allowing reservoir fluids to bypass the motor and significantly reducing motor cooling efficiency. The shroud can be either coated with an anti-corrosion protective layer, or its metallurgy can be upgraded to improve corrosion resistance.
3. Restricted flow areas within shrouds can promote scale and asphaltene deposition, which increases operating temperatures and can lead to high motor temperature shutdowns and ESP failures.
4. Field trials indicate that recirculation systems provide more effective motor cooling and chemical distribution, resulting in enhanced operational stability and extended equipment run life.
5. Conversion from shroud systems to recirculation systems has shown measurable production improvements, including reported oil production increases of up to 20%, while simultaneously reducing failure frequency and improving overall ESP performance in mature wells.

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