A SAFE, EFFECTIVE, AND ECONOMICAL APPROACH TO RUNNING, OPERATING AND RETRIEVING ESPS WITH PERMANENT MAGNET MOTORS

Lina Matiz, Ecopetrol Permian
Luis Guanacas and Gustavo Gonzalez, Odessa Separator Inc. (OSI)

ABSTRACT

The installation and retrieval of Electrical Submersible Pumps (ESPs) equipped with Permanent Magnet Motors (PMMs) require robust barriers to prevent shaft rotation and the subsequent generation of voltage. Current methods to provide these barriers involve additional operations, equipment, and personnel, which increase associated risks. This paper introduces a new method that is safe, effective, and economical, improving both safety and operational efficiency during the installation, operation, and retrieval processes.

Installing ESPs with PMMs typically involves surface monitoring techniques and control barriers, such as blanking plugs and sliding sleeves, to manage communication between the tubing and casing. After installation, these barriers must be removed to produce the well and then reinstalled before pulling the equipment, requiring at least four slickline interventions and extended operation times. The proposed method utilizes a single tool that acts as a positive flow barrier during installation, which is removed by pressurizing the tubing before production begins. This initial barrier maintains minimal differential pressure from top to bottom and offers ten times greater pressure resistance from bottom to top, ensuring a complete seal. Similarly, before retrieval, a dart is used to create a mechanical block and a positive flow seal in both directions, while also opening a drain sleeve. This allows the pump to be pulled with dry tubing and a plug in the production tubing, eliminating the need for slickline intervention and maintaining on-site safety standards.

After multiple installations of this new method in the Permian Basin, analysis has shown zero safety incidents during the operation of ESPs with PMMs. Proper training, socialization, and discussion of this method with field personnel have increased awareness of associated risks and promoted responsible operations, resulting in no reported accidents to date. The implementation of this method has also shortened installation and retrieval times, reducing rig time by up to 50%, which in turn lowers operational costs, reduces emissions by minimizing the number of intervention units required, and accelerates the timeline for bringing wells online.

This document will present practical applications and guidelines to clearly explain how this technology can be adapted for various operations, making it easier for operators to use worldwide. As the adoption of PMMs increases, it is crucial to continue developing not only surveillance measures but also mitigation strategies to effectively prevent unforeseen events at well sites.

INTRODUCTION

The deployment of Electrical Submersible Pumps (ESPs) equipped with Permanent Magnet Motors (PMMs) has introduced significant advancements in artificial lift technology, offering enhanced efficiency and performance. However, the traditional methods for installing and retrieving ESP systems—such as the use of blanking plugs and sliding sleeves—remain a time-intensive and operationally complex approach. These methods require multiple interventions, increasing rig time, operational costs, and personnel exposure, which directly impacts the economic and safety metrics of well operations.

Over the past decade, the oil and gas industry has continued to adopt these conventional installation techniques despite their inherent inefficiencies. This has led to prolonged completion times, higher emissions due to extended intervention activities, and delays in achieving first production. The need for a more streamlined and cost-effective solution has become increasingly apparent.

In response to these challenges, a novel method has been developed to optimize the running, operating, and retrieval processes of ESPs with PMMs. This approach leverages an innovative tool design that integrates flow management and pressure control, eliminating the need for multiple slickline interventions and significantly reducing the overall time required for installation and retrieval. By cutting intervention times by up to 50%, this method not only accelerates production timelines but also enhances operational safety and minimizes environmental impact.

This paper aims to present a comprehensive analysis of this innovative approach, detailing its design principles, field implementation, and performance outcomes. Through case studies and lessons learned, we will demonstrate how this methodology addresses the limitations of traditional techniques, delivering measurable improvements in operational efficiency, cost reduction, and safety standards across various field applications.

PERMANENT MAGNET MOTOR (PMM) OVERVIEW

In recent years, the application of Permanent Magnet Motors (PMMs) in Electrical Submersible Pump (ESP) systems has redefined efficiency and operational standards in artificial lift technology. PMMs bring notable advantages compared to traditional Induction Motors (IMs) (*Table. 1*), enabling cost savings, improved energy utilization, and enhanced operational performance.

Table 1 PMMs vs IMs.

Feature	PMM	IM
Rotor	Uses permanent magnets instead of copper bars	Uses copper bars that create a magnetic field when current is induced
Efficiency	Higher efficiency (up to 95%) due to reduced rotor losses	Lower efficiency (typically 85-90%) due to higher rotor losses
Energy Consumption	Reduced power consumption, leading to lower energy costs	Higher energy consumption due to greater electrical losses
Torque Performance	Higher starting torque and better control over speed variations	Lower starting torque and less speed control flexibility
Heat Generation	Lower operating temperatures, reducing thermal stress on components	Higher heat generation, requiring better cooling management
Size & Weight	More compact and lightweight, allowing for easier deployment	Larger and heavier, requiring more space
Operational Lifespan	Longer lifespan due to reduced wear and better efficiency	Shorter lifespan due to higher wear and heat-related degradation

OPERATIONAL RISKS AND MITIGATION STRATEGIES

OPERATIONAL RISKS

Despite previous advantages, PMMs require careful handling due to inherent risks. As an AC generator, the motor can energize the power cable when pump stages rotate, presenting potential hazards under certain conditions:

- Variations in reservoir inflow or bottom-hole pressure (BHP) can induce motor rotation.
- Tubing operations, such as pulling or running, may inadvertently rotate the motor, generating voltage.

- Fluid level equalization between the annulus and tubing can result in unintentional movement.
- Surface fluid pumping may also create conditions where the motor becomes energized.

MITIGATION STRATEGIES

To mitigate these risks, the following strategies should be implemented:

Preventing Motor Rotation Due to Inflow or BHP Variations: Implement real-time monitoring of well conditions and use a braking mechanism or mechanical lock to prevent free rotation.

Minimizing Voltage Generation During Tubing Operations: Establish strict procedural controls, including a controlled tripping process, and use a shaft lock or motor brake during interventions.

Controlling Fluid Level Equalization: Install check valves or control devices to minimize pressure surges and stabilize fluid movement before interventions.

Ensuring Electrical Safety During Surface Fluid Pumping: Electrically isolate the system during surface operations and follow proper grounding procedures to dissipate any induced voltage.

Implementing these mitigation measures enhances the safe handling of PMMs, minimizing operational hazards while optimizing system reliability and efficiency.

PMM GUARDIAN

The PMM Guardian is an advanced flow control device designed to improve the installation, operation, and retrieval of Electrical Submersible Pumps (ESPs) with Permanent Magnet Motors (PMMs). This tool ensures integrity by acting as a mechanical barrier, preventing uncontrolled flow and minimizing operational risks during critical stages.

A key feature of the PMM Guardian is its rupture disc mechanism, which enables precise and reliable pressure testing during installation. The rupture discs are engineered to specific pressure ratings, with an upper disc rated up to 1,000 psi and a lower disc rated up to 15,000 psi (*Figure 1*). This ensures operational safety, controlled wellbore access, and effective fluid management across various well conditions, improving overall ESP system reliability and longevity.

Additionally, the PMM Guardian's robust protective barriers eliminate the need for installing blanking plugs while running the Permanent Magnet Motor (PMM). This not only reduces rig time but also optimizes operational efficiency, leading to substantial cost savings and a significant improvement in Return on Investment (ROI).

The PMM Guardian is available in multiple tubing sizes, including 2-3/8", 2-7/8", 3-1/2", and 4-1/2", providing versatile compatibility for different wellbore configurations and operational requirements.

By incorporating the PMM Guardian, operators can streamline ESP deployment, mitigate the risks associated with PMM backspin and induced voltage, and maintain optimal well performance with enhanced equipment protection.

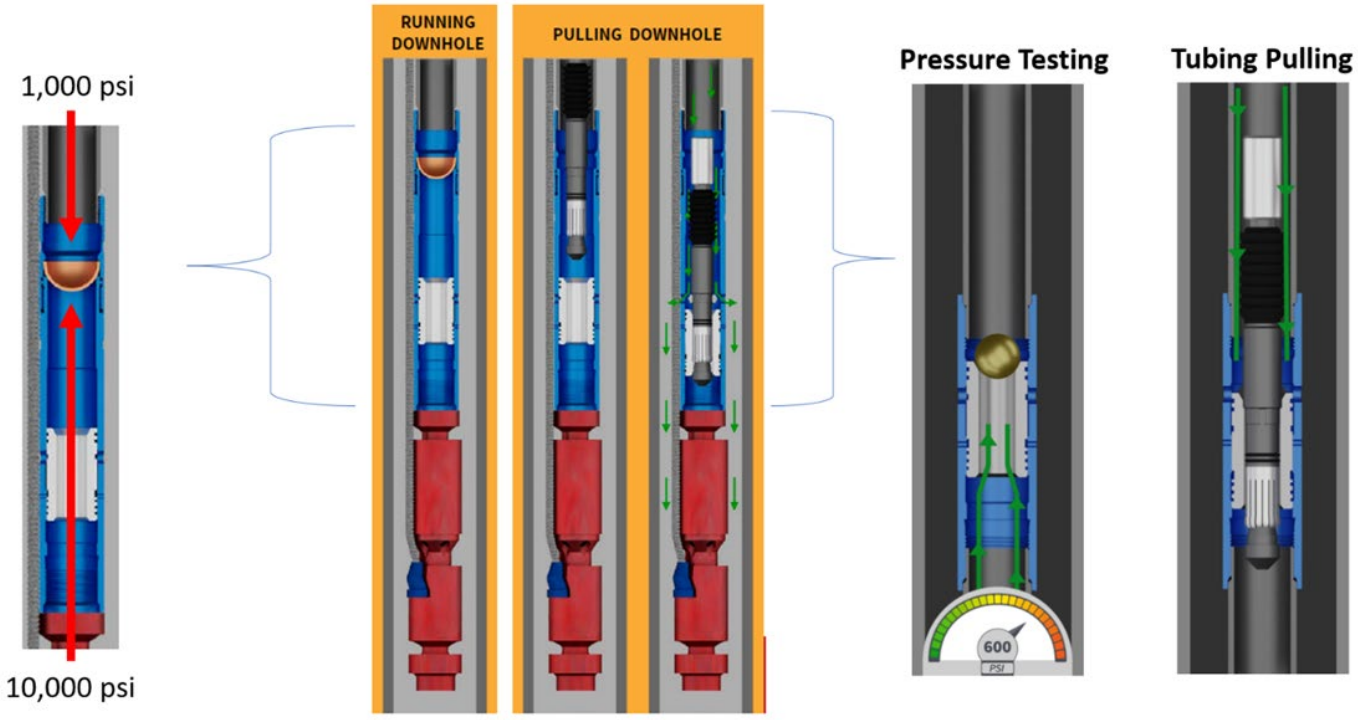

Figure 1 PMM Guardian

Table 2 Tool Specifications

Size	OD	ID	Disc Rating Above	Disc Rating Below	Temperature Rating
Inch/mm	*Inch/mm*	*Inch/mm*	*Psi/Mpa*	*Psi/Mpa*	*°F/°C*
2-3/8 60.33	2.910 73.91	1.955 50.67	1,000 6.9	10,000 68.9	302 150
2-7/8 73.03	3.460 87.88	2.441 62.00	1,000 6.9	10,000 68.9	302 150
3-1/2 88.90	4.180 106.17	2.992 76.00	1,000 6.9	10,000 68.9	302 150
4-1/2 114.30	5.750 146.05	3.930 99.82	1,000 6.9	15,000 68.9	320 160

With a temperature rating of up to 302°F, the tool is designed for high-temperature environments, ensuring durability and performance under challenging conditions.

INSTALATION OF PMM GUARDIAN

The PMM Guardian streamlines the installation process by eliminating the need for bridge plug and retrieval operations, significantly reducing rig time and operational complexity. Its integrated design enhances efficiency, while the rupture disc system facilitates seamless pressure testing and ensures uninterrupted communication through the tubing to the ESP a critical advantage in modern oilfield operations. These features make the PMM Guardian an indispensable tool for optimizing well management. The installation procedure is as follows:

- ✓ The installation begins once the tubing joint above the ESP is in place.
- ✓ The PMM Guardian (available in 2-3/8”, 2-7/8”, 3-1/2”, and 4-1/2” tubing sizes) is lifted to the rig floor with two pre-installed pup joints (box up, pin down) and connected to the top of the tubing joint (*Figure 2*).

- ✓ The built-in mechanical barrier replaces the bridge plug, eliminating the need for additional downhole components and simplifying the completion process. Additionally, tubing integrity can be tested before running the tool using a dissolvable ball, ensuring reliability and operational efficiency.

- ✓ The rupture discs integrated into the PMM Guardian allow for a controlled pressure test (1,000 psi above and 15,000 psi below), ensuring well integrity without requiring further intervention.

- ✓ The remaining tubing string components are installed, finalizing the operation without the need for plug retrieval.

- ✓ The well is brought online with minimal additional steps, reducing rig time, intervention risks, and overall operational costs.

Figure 2. Schematic set up of PMM Guardian

PULLING OF PMM GUARDIAN

The PMM Guardian revolutionizes the ESP pulling process, significantly reducing rig time and operational complexity. Traditional methods require setting and later retrieving a bridge plug, which adds extra steps, increases risk, and prolongs downtime. In contrast, the PMM Guardian's integrated drainage system allows for seamless pressure equalization and tubing drainage before pulling. Operators can activate the system by either dropping a dart or a 1-3/4" to 2" ball from the surface (*Figure 3*), triggering the internal sleeve to expose the drain ports while maintaining a positive seal to prevent unintended flow. This feature enables safe and controlled depressurization, enhances integrity, and allows for tubing pressure testing during retrieval operations.

By streamlining the pulling procedure and reducing mechanical risks, the PMM Guardian enhances efficiency, reliability, and overall well performance.

Figure 3. Schematic set up of PMM Guardian

To further enhance integrity, the PMM Guardian can be integrated with additional tools to strengthen traditional protection methods. This is why we introduce the **OSI PMM Protection System**, a comprehensive solution designed to optimize ESP PMM performance while safeguarding downhole equipment.

OSI PMM PROTECTION SYSTEM

The OSI PMM Protection System is an enhanced version of traditional ESP protection tools (*Figure 4*), specifically designed to provide comprehensive operational support for Electrical Submersible Pumps (ESPs) equipped with Permanent Magnet Motors (PMMs). This advanced system integrates innovative features to address critical challenges during installation, operation, and retrieval, offering a triple-barrier mechanism for superior performance, safety, and reliability.

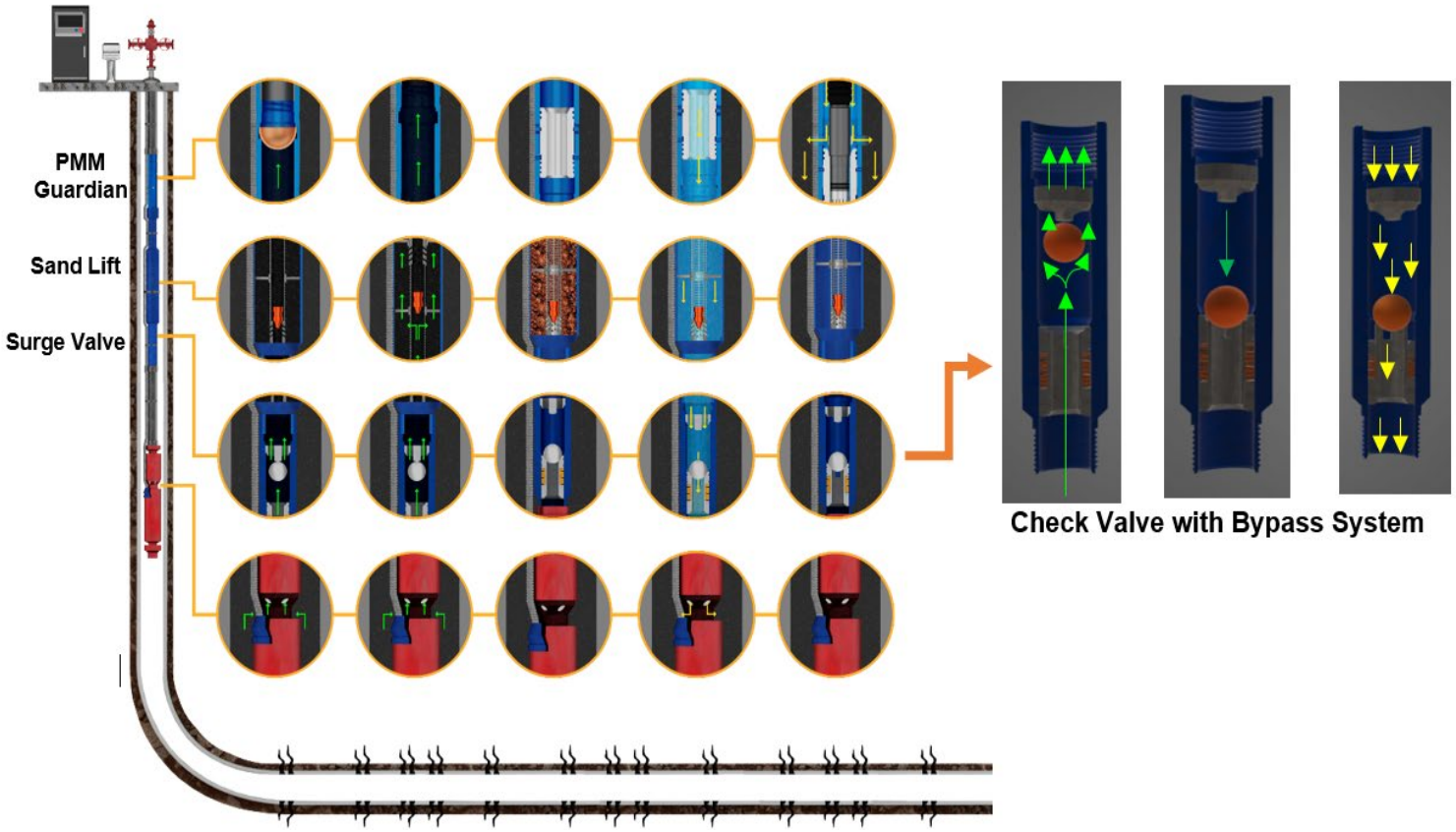

Figure 4. PMM GUARDIAN: Integral Protection System

Triple-Barrier Mechanism:

1. During Run-In-Hole (RIH):

The PMM Guardian, an enhanced flow and pressure barrier, prevents fluid flow from rotating the motor shaft inside the pump stages. This improvement significantly reduces risks associated with voltage generation caused by shaft rotation during installation.

2. During Operation:

    - The Sand Lift system, a key enhancement, prevents solids from settling on top of the pump discharge, protecting the pump from potential damage caused by sand accumulation.
    - The Surge Valve provides a reinforced flow barrier, eliminating the risk of shaft rotation caused by flow back into the pump.

3. While Flushing Down the Tubing:

The Surge Valve automatically opens upon exceeding its set pressure, allowing fluid to flow seamlessly from the Sand Lift system to the pump. This functionality ensures safe and efficient tubing flushing, improving operational efficiency.

4. During Pull-Out-of-Hole (POOH):

By deploying a dart or ball into the PMM Guardian, a secure seal is established, and the sliding sleeve opens. This allows the tubing to drain completely, preventing any fluid flow through the pump and ensuring the motor shaft remains stationary. These enhancements mitigate operational risks and streamline the retrieval process.

Key Enhancements and Advantages:

- **Improved Functionality:** This system integrates the Sand Lift and Surge Valve into the PMM Guardian, offering superior protection against risks like motor shaft rotation, sand accumulation, and flowback.
- **Enhanced Efficiency:** By reducing the need for additional interventions and minimizing rig time, this enhanced tool significantly increases operational efficiency.
- **High-Performance Design:** The tool operates in challenging well conditions, with high-temperature resistance (up to 302°F) and robust pressure ratings (1,000 psi above, 15,000 psi below).
- **Rupture Disc Capability:** The tool features rupture discs to facilitate pressure testing, ensuring accurate and safe well operations.

The OSI PMM Protection System is a next-generation tool that builds traditional designs to provide a safe, effective, and economical solution for managing PMM-equipped ESPs. Its innovative enhancements make it a vital asset for modern oilfield operations.

PRESENCE AND EFFECTIVENESS IN THE PERMIAN BASIN

The OSI PMM Guardian has demonstrated exceptional performance and reliability in field operations within the Permian Basin. Since its initial deployment in December 2023, the tool has consistently achieved zero accidents and incidents, highlighting its robust design and operational safety.

This remarkable safety record can be attributed to the tool's multi-barrier protection mechanism, which effectively mitigates risks associated with running, operating, and retrieving ESPs configured with PMMs.

Operators in the Permian Basin have also reported significant improvements in operational efficiency. The tool has reduced intervention times, enhanced equipment reliability, and minimized downtime, resulting in cost savings and faster well commissioning. Its ability to withstand extreme pressures and temperatures has made it a reliable solution for challenging well conditions commonly encountered in this region.

The continued use and positive results from the Permian Basin underscore the system's value as a cutting-edge tool for modern oilfield operations.

CASES STUDY.

Case Study Well 1.

In this case the system worked with two different filtration stages, 1st stage separates bigger particles (Tubing Screen BHA) and the 2nd stage separates the smaller by using a vortex effect send the sand particles to tail pipes installed below the Vortex Sand Shield (*Figure* 5 & 6). The system was installed in May 2024 and pulled out on august reaching a runtime of 90 days. The dart was sent, and the 6 screws were broken with a pressure higher than 4,500 psi (*Figure 7*), it and the PMM were successfully opened (*Figure 8*).

OSI

Tally Design

Description	Top Thread Connection	Bottom Thread Connection	Status	Max. OD (in)	Body OD (in)	Length (ft)	Top (ft)	Bottom (ft)	Weight (lb)
X NIPPLE (2.31" ID)	2-7/8" EUE pin	2-7/8" EUE pin	NEW	3.668	3.668	0.5	8636.50	8637.00	6
OXY: 2-7/8" L-80 Tbg with TK 70XT internal coating	2-7/8" EUE box	2-7/8" EUE pin	-	3.668	2.875	31.5	8637.00	8668.50	
2-7/8" X 4' L80 PUP JOINT, BOX X PIN	2-7/8" EUE box	2-7/8" EUE pin	NEW	3.668	2.875	4	8668.50	8672.50	-
OSI ESP PMM Guardian	2-7/8" EUE box	2-7/8" EUE pin	NEW	4.500	4.500	3	8672.50	8675.50	50
2-7/8" X 4' L80 PUP JOINT, BOX X PIN	2-7/8" EUE box	2-7/8" EUE pin	NEW	3.668	2.875	4	8675.50	8679.50	-
OXY: 2-7/8" L-80 Tbg with TK 70XT internal coating QTY 2	2-7/8" EUE box	2-7/8" EUE pin	-	3.668	2.875	63	8679.50	8742.50	-
OSI SAND LIFT 450 SERIES	2-7/8" EUE box	2-7/8" EUE pin	NEW	4.500	4.500	24	8742.50	8766.50	300
OXY: 2-7/8" L-80 Tbg Sub with TK 70XT internal coating	2-7/8" EUE box	2-7/8" EUE pin	-	3.668	2.875	6	8766.50	8772.50	
ESP ASSEMBLY **(Supplied by Baker/Levare)**	2-7/8" EUE box	2-3/8" EUE box	-	-	-	167.10	8772.50	8939.60	0
2-3/8" X 2-7/8" CHANGE OVER NIPPLE	2-3/8" EUE pin	2-7/8 EUE pin	NEW	2.875	2.875	0.5	8939.60	8940.10	6
2-7/8" X 4' L80 PUP JOINT + CENTRALIZER	2-7/8" EUE box	2-7/8" EUE pin	NEW	6.094	2.875	4	8940.10	8944.10	35
2-7/8" X 4' Slotted Sub	2-7/8" EUE box	2-7/8" EUE box	NEW	3.668	2.875	4	8944.10	8948.10	26
2-7/8" TUBING NIPPLE	2-7/8" EUE pin	2-7/8" EUE pin	NEW	2.875	2.875	0.5	8948.10	8948.60	6
DOUBLE CUP PACKER ASSEMBLY W/6-5/8" (20#) OIL STATES CUPS	2-7/8" EUE box	2-7/8" EUE pin	NEW	6.094	2.875	2	8948.60	8950.60	30
2-7/8" X 4' L80 PUP JOINT + CENTRALIZER	2-7/8" EUE box	2-7/8" EUE pin	NEW	6.094	2.875	4	8950.60	8954.60	35
2-7/8" X 10' L80 PUP JOINT, BOX X PIN	2-7/8" EUE box	2-7/8" EUE pin	NEW	3.668	2.875	10	8954.60	8964.60	35
2-7/8" COUPLING	2-7/8" EUE box	2-7/8" EUE box	NEW	3.668	3.668	0.5	8964.60	8965.10	10
5-3/4" NO GO CATCHER	2-7/8" EUE pin	2-7/8" EUE box	NEW	5.750	2.875	1.5	8965.10	8966.60	25
2-7/8" TUBING NIPPLE	2-7/8" EUE pin	2-7/8" EUE pin	NEW	2.875	2.875	0.5	8966.60	8967.10	6
2-7/8" X 4' L80 PUP JOINT, BOX X PIN	2-7/8" EUE box	2-7/8" EUE pin	NEW	3.668	2.875	4	8967.10	8971.10	35
2-7/8" X 5' Top Bypass Valve	2-7/8" EUE box	2-7/8" EUE pin	NEW	3.668	2.875	5	8971.10	8976.10	75
2-7/8" X 24' X 10 SLOT DUAL FLOW TOP TUBING SCREEN	2-7/8" EUE Box	2-7/8" EUE Pin	NEW	3.668	2.875	24	8976.10	9000.10	255
2-7/8" X 24' X 10 SLOT DUAL FLOW CENTER TUBING SCREEN	2-7/8" EUE Box	2-7/8" EUE Pin	NEW	3.668	2.875	24	9000.10	9024.10	255
2-7/8" X 24' X 10 SLOT DUAL FLOW CENTER TUBING SCREEN	2-7/8" EUE Box	2-7/8" EUE Pin	NEW	3.668	2.875	24	9024.10	9048.10	255
2-7/8" X 24' X 10 SLOT DUAL FLOW BOTTOM TUBING SCREEN	2-7/8" EUE Box	2-7/8" EUE Box	NEW	3.668	2.875	24	9048.10	9072.10	255
2-7/8" X 6' Boronized Vortex Sand Shield W/2.9 H.E.	2-7/8" EUE pin	2-7/8" EUE pin	NEW	3.625	3.125	6	9072.10	9078.10	45
TAIL JOINT QTY 10	2-7/8" EUE box	2-7/8" EUE pin	-	-	-	325	9078.10	9403.10	2112.5
2-7/8" COUPLING	2-7/8" EUE box	2-7/8" EUE box	NEW	3.668	3.668	0.5	9403.10	9403.60	10
2-7/8" OVERSIZE BULL PLUG	2-7/8" EUE box	-	NEW	3.668	3.668	0.5	9403.60	9404.10	10
							TOL	8,995	
							NoGo-Xover	28	

Figure 5. Tally Design Case Study 1.

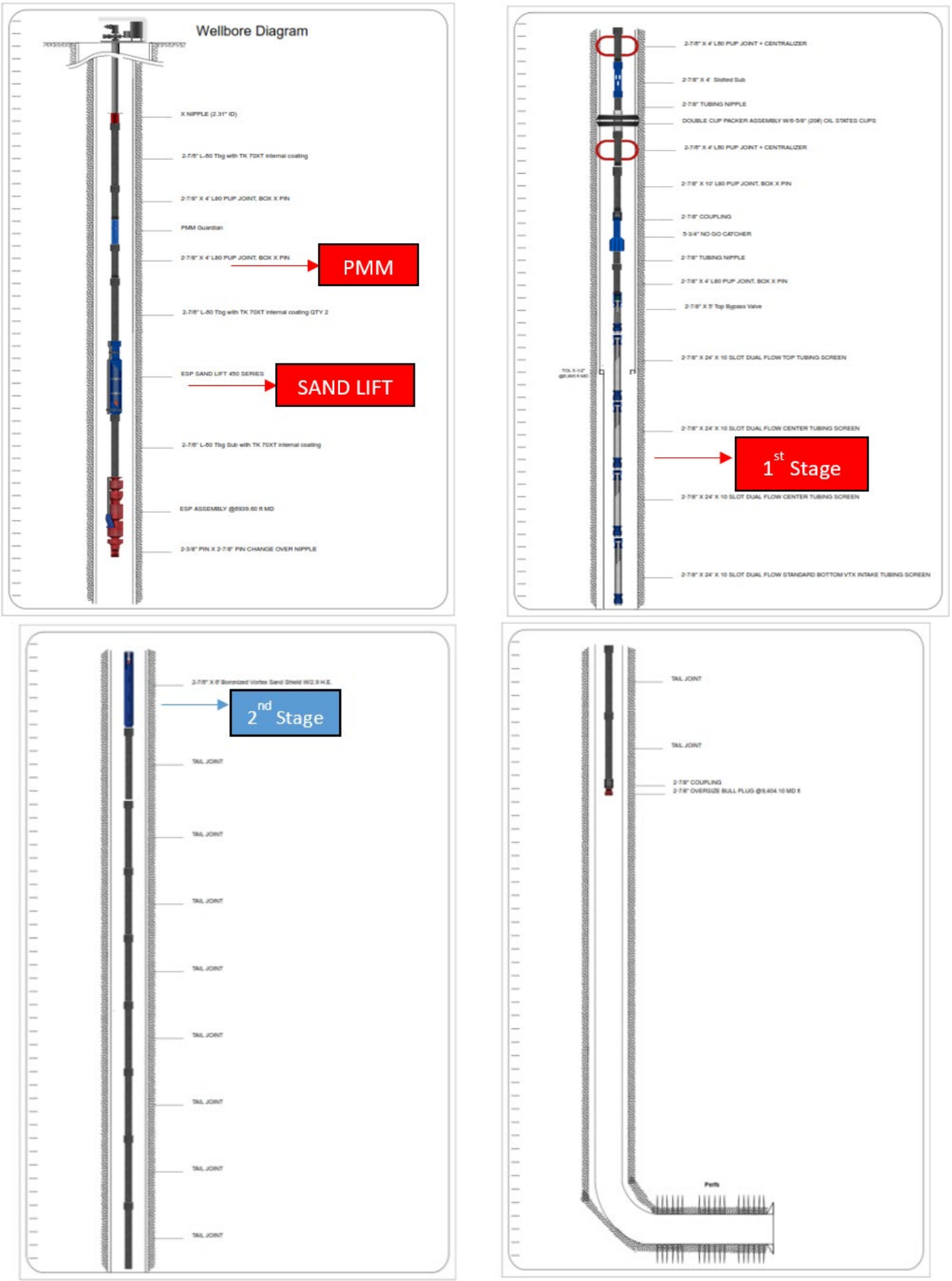

Figure 6. Wellbore Diagram Case Study 1

	PMM GUARDIAN	Version 1.1

Well name:	
Company:	

INPUT DATA

Specific Gravity of Fluid	1.1	
Water Constant	2.31	
Intake Pressure	0	psi
PMM Depth	8675.5	ft

OUTPUT DATA

Hydrostatic Pressure	4131.19	psi
Quantity of screws in the tool	6	
Set Point (PMM GUARDIAN)	4500	psi

Notes: Therefore, if they had 0 psi intake pressure, it would take 369 psi at surface to pop it once the dart/ball is on seat. If the PIP is higher than 0 psi it will take the surface pressure plus intake pressure. In this case 369 psi

As you remove screws, take them out 180 degrees apart from each other so you don't end up with your remaining screws all on one side of the tool.
If you add screws back in after they've been removed, you want to take them until they are tight then come back ¼ of a turn

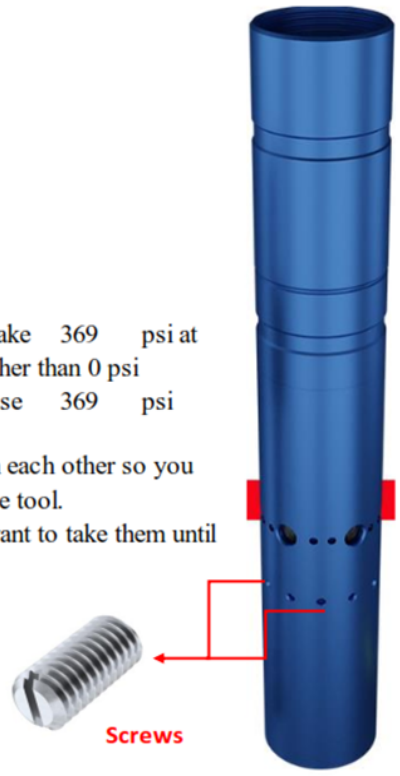

Figure 7. The set pressure to break the 6 screws

Figure 8. PMM Guardian pulled

CONCLUSIONS

- The PMM Guardian significantly reduces rig time, cutting intervention times by up to 50%.
- Zero safety incidents have been reported since the tool's initial deployment, demonstrating its robust design and operational reliability.
- This method promotes environmental sustainability by reducing emissions and minimizing equipment use during operations.
- Enhanced training and awareness among field personnel have further contributed to the successful adoption of this approach.
- The tool's multi-barrier protection mechanism effectively mitigates risks associated with motor shaft rotation and voltage generation.
- Successful field applications in the Permian Basin validate the tool’s effectiveness and adaptability to diverse operational requirements.
- This innovative approach sets a new standard for safety, efficiency, and cost-effectiveness in artificial lift operations, paving the way for broader industry adoption.

REFERENCES

Seczon, L., & Sagalovskiy, A. 2013. “Field Experience with the Application and Operation of Permanent Magnet Motors in the ESP Industry: Success Stories and Lessons Learned”. Paper SPE 165030, presented at the SPE Artificial Lift Conference-Americas, Cartagena, Colombia, 21–22 May.

Villalobos Leon, J. L., Ruales, F., Miranda, S., Godin, F., Velasquez, E., Shirikov, D., Anaya, O., Forero, N., Estupiñan, D., Peña, L., & Gonzalez, L. 2021. Permanent Magnet Motors: The Future of ESP Applications? Paper presented at the SPE Gulf Coast Section Electric Submersible Pumps Symposium, Virtual and The Woodlands, Texas, USA, October 2021. SPE-204485-MS.

Xiao, J. J., & Lastra, R. 2018. Induction vs. Permanent-Magnet Motors for ESP Applications. SPE Production & Operations. Paper SPE-1921177