EXTENDING THE LIFE OF AN ESP WHILE MAINTAINING THE ABILITY TO INJECT

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ABSTRACT

The purpose of this paper is to present a solution to the adverse impact of fallback sand and debris on ESPs (Electrical Submersible Pumps). When these solids accumulate on an ESP during operational shutdowns, it poses a significant risk of damage and subsequent failures upon restarting the system. Once sand and other solids settle in and above the upper stages of the ESP, the increased amperage needed to overcome the friction force to restart the motor may overcome the driveshaft material strength and result in a shear event.

Installing a Fallback Filter utilizing a Labyrinth-Chamber Method directly above the ESP solves this problem. The Labyrinth-Chamber Fallback Filter (LCFF) efficiently captures and reintroduces accumulated solids while maintaining the ability to inject through the ESP.

The LCFF is an apparatus that demonstrates the proprietary method for controlling debris. This consists of a tubular joint that internally houses a series of (Chambers) fixed to the wall, overlapping, and alternating in 180-degree orientations. An area of clear flow (Labyrinth) is maintained behind the chambers providing a means for fluid communication to the ESP. This Labyrinth section of the Fallback Filter provides the distinctive feature of allowing fluid injection downhole, through the ESP for chemical treatments, testing, and flushing.

When the ESP is inactive, gravity causes the solids in the tubing string to fall and enter the top of the LCFF. These first solids accumulate in the uppermost chamber until that chamber’s capacity is reached. Excess sand and any new solids that are introduced will spill over into the next chamber below. This process continues until all solids are captured. Upon restarting the ESP, the produced fluid flushes out the solids in the reverse order that they were collected, reintroduced to the tubing, and produced to the surface (see *Figure 1* of the Appendix).

A visualization of the internal structure of the LCFF can be seen in from the cut-away model in *Figures 2* & *3* of the Appendix.

PART I: DESIGN AND MATERIALS

The functional components of the LCFF are entirely housed in a 4.00” OD, L-80 casing joint (“Housing”). Therefore, the structural integrity of the tool maintains the same ratings as a standard casing joint. An “Inner Maze” is contained inside the Housing, a series of seals between the Inner Maze and the Housing forms the chambers between the two assemblies. This prevents fluid flow from bypassing the internal components in both directions. Pin and box end subs (for bottom and top, respectively), either 2-7/8” or 3-1/2” EUE, are threaded and torqued onto the ends of the casing. This ensures that the Inner Maze component remains within the confines of the casing housing.

PART II: LABORATORY TESTING

Flow Test, Part I: Pressure Drop and Continuous Flow

PetroQuip Energy Services (PQES) provided a certified 3rd party testing company with a 400 Series (4.00” OD) LCFF tool with crossovers to adapt to the 3rd party’s flow loop, 100 mesh sand, DUO-VIS suspension agent, and a test procedure (see *Figures 5* and 6 of the Appendix for the test setup).The testing efforts were initiated on Monday, April 18, 2022, and continued until May 18, 2022.

Test Medium:

- 2% Sand Slurry Suspended in Water
- DUO-VIS Biopolymer Viscosifier

Test Equipment:

- Flow Loop
- Storage Tank
- Pressure Transducers (Inlet and Outlet of tool)
- FlowMeter (Inlet of tool)
- Centrifugal Pump
- 5 million lb. Load Frame

Test Temperature:

- Ambient

Procedure:

1. The storage/mixing tank was filled with a pre-defined amount of tap water.
2. Sand and DUOVIS suspension agent was added into the tank to create a 2% sand concentration.
3. The tank was agitated continuously with sump pumps to prevent the sand slurry mixture from falling to the bottom of the tank.

4. Once the LCFF has been placed in the flow loop, begin circulating at the following rates to establish pressure drops across the tool with no slurry in the fluid:

   - 0.35 bbl/min (500 bbl/day)
   - 0.70 bbl/min (1000 bbl/day)
   - 1.40 bbl/min (2000 bbl/day)
   - 1.70 bbl/min (2450 bbl/day) – Maximum pump output

At the direction of PQES, the Flow Test, Part I commenced which varied the flow rate to obtain a pressure drop curve. Prior to testing, the flow meter was verified by flowing into a known volume and timing the time it took to fill the volume. This was compared to the digital output on the flow meter and was deemed to be within acceptable limits. The test was repeated on May 18, 2022, with water only. The pressure drop curves obtained during testing can be seen in *Figure 7* of the Appendix. At the conclusion of the pressure drop test, the Flow Test, Part 2 began.

<u>Flow Test, Part II: Erosion Resistance</u>

Test Objective:

Flow a sand slurry through LCFF assembly to determine how much erosion occurs during the life of the tool. During this portion of the flow test, the pump rate will be capped at 1.7 bbl/min (2450 bbl/day).

Procedure:

1. Prepare a slurry with 2% sand. Mix in xanthan gum to suspend the sand in solution. Slurry mix should follow these example recipes:
   - 30 gallons sand to 35 bbl (1470 gal) water
   - 42 gallons sand to 50 bbl (2100 gal) water

2. Once the slurry has been added to a holding tank, maintain agitation inside the tank with bilge or sump pumps to avoid sand settling out of solution. Observe.

3. Circulate at low rate (0.5 bbl/min) for 15 minutes to fill the system and establish a uniform distribution of slurry. Once this is complete, follow this daily flow schedule for seven (7) days:

   - Observe inlet deflector for noticeable/significant erosion.
   - Establish circulation at 0.25 to 0.50 bbl/min for 15 minutes to re-distribute slurry evenly.
   - Increase circulation to 1.70 bbl/min (2450 bbl/day) for the remainder of the day (10 hours), stopping every two (2) hours to observe inlet deflector.

4. If no noticeable degradation of the inlet deflector is indicated within the first few observations, the observation period can be extended to a once-daily activity. At the end of each day: shut down pump and allow fluid to stabilize.

This test was performed to simulate the erosion resistance of the inner components of the LCFF. The flow was adjusted and ran continuously near 2800 bbl/day for slightly over 13 days. The test was stopped for periodic inspections by PQES personnel and pump maintenance. A modification was made to the provided test procedure and the pump flowed the sand slurry 24 hours a day, 7 days a week as erosion was not observed during the regular PQES inspections. The total test time was also extended to 13 total days.

As production fluids enter the LCFF, it first contacts the component known as the "Deflector Plate". This is the most critical component which would see the most potential erosion. After 13 days, the Deflector Plate saw no signs of erosion (*Figures 8, 9, and 10* of Appendix).

<u>Flow Test, Part III: Injection Pressure Drop</u>

A 400 Series LCFF was filled with sand and pumped through to measure the pressure drop at different injection rates. First, the LCFF was lifted vertically at the PQES test facility, then filled with water and 35 cups of sand. Water was then pumped through from top to bottom to simulate injecting into the well with a LCFF at maximum sand holding capacity. The flow rate was gradually increased from 1 bbl/min to 3 bbl/min.

As the LCFF always has an open flow path through the center, regardless of being full of sand or not, it maintains the ability to be injected through to reach the ESP and beyond. The injection pressure drop chart can be seen in *Figure 11* of the Appendix.

<u>Structural & Mechanical Integrity Tests</u>

Following the flow tests, separate tension and pressure proof load tests were performed in the 3rd party testing facility's 5 million lb. load frame per PQES procedure. The tests were completed on May 11, 2022. The 400 Series LCFF tool completed all load steps without any visible deformation or leaks. See *Figure 12* in the Appendix for this test setup.

<u>PART III: FIELD TESTING</u>

<u>Permian Basin Test</u>

A 400 Series LCFF was installed in a test well on July 20th, 2022, then pulled on October 20, 2022, to replace the ESP with a larger pump and to install another LCFF. PQES received the used LCFF to inspect it for any erosion or degradation resulting from the 3 months that it was in service.

The test well is in Ward County in West Texas. Over the 3 months, the well produced an average of 350 MCF/day of gas, 140 bbl/day of oil, and 1040 bbl/day of water (see *Figure 13* in the Appendix). During this time, the ESP had experienced 5 downtime / shutoff events. The operator was able to restart the ESP in each of the 5 shutdowns without any damage or increased amperage load due to sand blocking the ESP stages.

The LCFF trapped all fallback sand and debris and kept the ESP clean for easy restart each time. Then the completion was pulled, the LCFF was full of sand and the ESP was entirely free of sand and debris.

The LCFF was returned to PetroQuip's facility in Waller, TX for tear-down and inspection. The SandMaze was flushed with water to remove the captured sand during the ESP shutdown before pulling the completion (*Figure 14* of Appendix). The SandMaze was cut apart and the different components were inspected for wear and erosion. After 3 months of functioning in the test well, the deflector showed no wear (see *Figure 15* in the Appendix).

A full inspection showed no internal wear after 3 months. Hardened coating still existed on the chambers and deflector components where erosional concerns were present. There was slight surface rust due to the water content of the produced fluids and contact with air during transit back to the facility (see *Figures 16* and *17* of Appendix). The LCFF performed as expected by keeping sand away from the ESP. This resulted in allowing the client to achieve multiple restarts while avoiding any hard start or premature ESP failure.

<u>Bakken Tests with Flush / Restart Data</u>

In this set of Bakken field tests, the LCFF tool demonstrated its injection compatibility by handling rates averaging between 2 to 3 bbl/min. During these trials, 100 barrels were successfully pumped through the casing, while an additional 100 barrels were pumped through the tubing. Following the injection/flush operation, the ESPs were restarted with minimal friction resistance and motor amperage, further affirming the efficiency and compatibility of the LCFF tool in solids-laden environments. These successes have been comprehensively documented with charts provided for six wells, illustrating consistent and reproducible results across different operational scenarios (see *Figures 18 – 24* of the Appendix).

The LCFF tool maintains its injection capability even when at full sand / solids holding capacity because of the unique internal design. The Chambers are oriented and spaced in a way that leaves a flow path open and available for connecting the top and bottom ends of the tool.

Bakken Field Test for ESP Run Life

A large-scale field test, consisting of LCFF tools being installed in 48 wells, was conducted with a major operator in the Bakken with the goal of quantifying the difference in run life of the wells with an LCFF installed compared to those without. The average ESP run lives on the wells that did not have an LCFF installed was 200 days, while the wells with an LCFF experienced a substantial increase of the average run life of 351 days. This data demonstrates that the LCFF directly caused a 75.5% increase in ESP run life.

CONCLUSION

Through extensive laboratory and field testing, the Fallback Filter using the Labyrinth-Chamber Method has proven its efficacy in extending the operational lifespans of ESPs while avoiding costly workovers while maintaining the ability to inject into the wellbores. This injection feature has been proven through extensive laboratory / field test data and helps to extend ESP life by facilitating chemical transport (i.e. scale and corrosion inhibitors) and reducing chemical-related failures.

Overall, the field data proved viability and effectiveness of the LCFF SandMaze resulting in a 75.5% increase in ESP run life while maintaining mechanical integrity and erosion resistance.

This paper will provide data to support the advantages of this Fallback Filter provided by oil companies' data.

APPENDIX

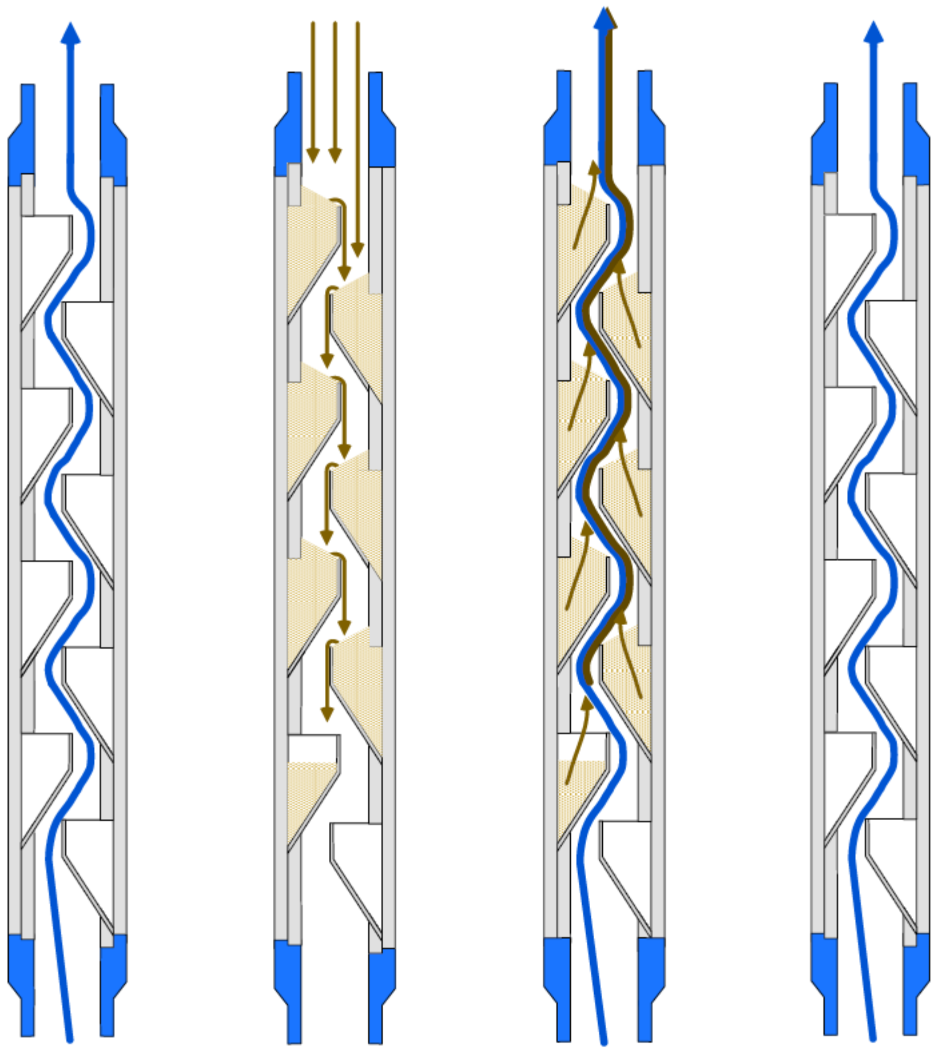

Figure 1: Function Cycle of Fallback Filter Apparatus

Figure 2: Cut-away Side Profile of one of the Sand-Bearing Chambers

Figure 3: Cut-away Side Profile showing Flow Path through tool

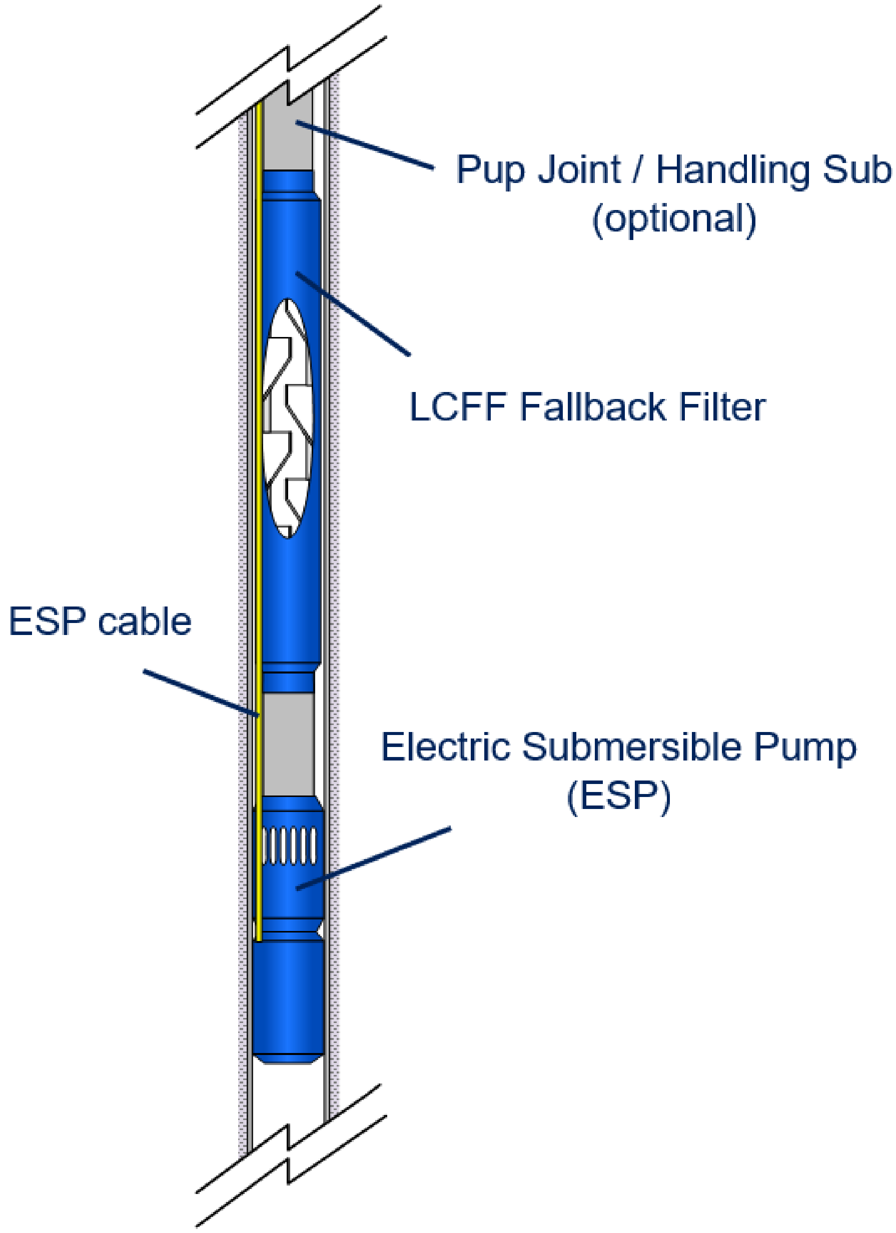

Figure 4: BHA Schematic

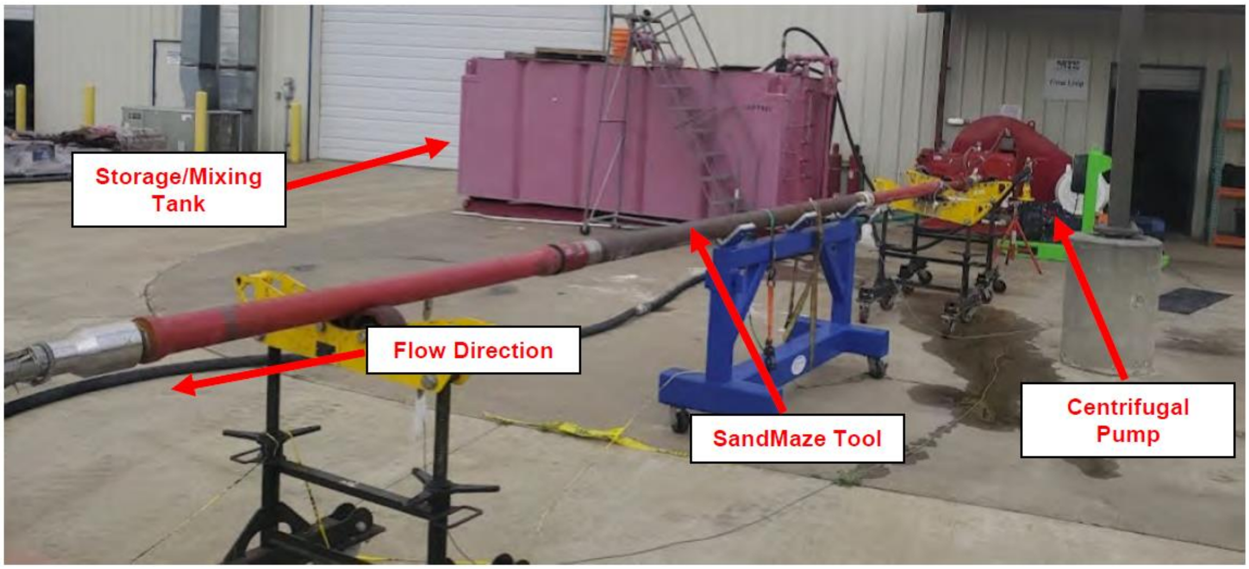

Figure 5: Flow Loop for Pressure Drop Test

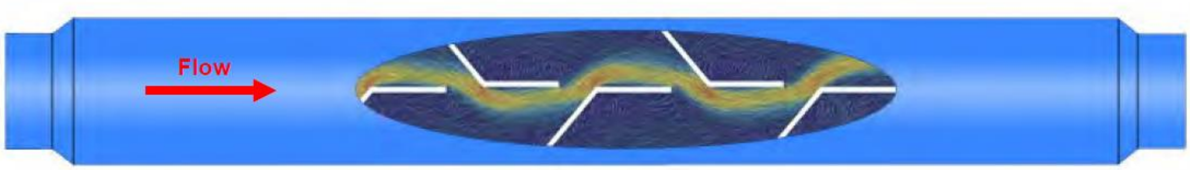

Figure 6: Flow Direction through LCFF (top of tool on left)

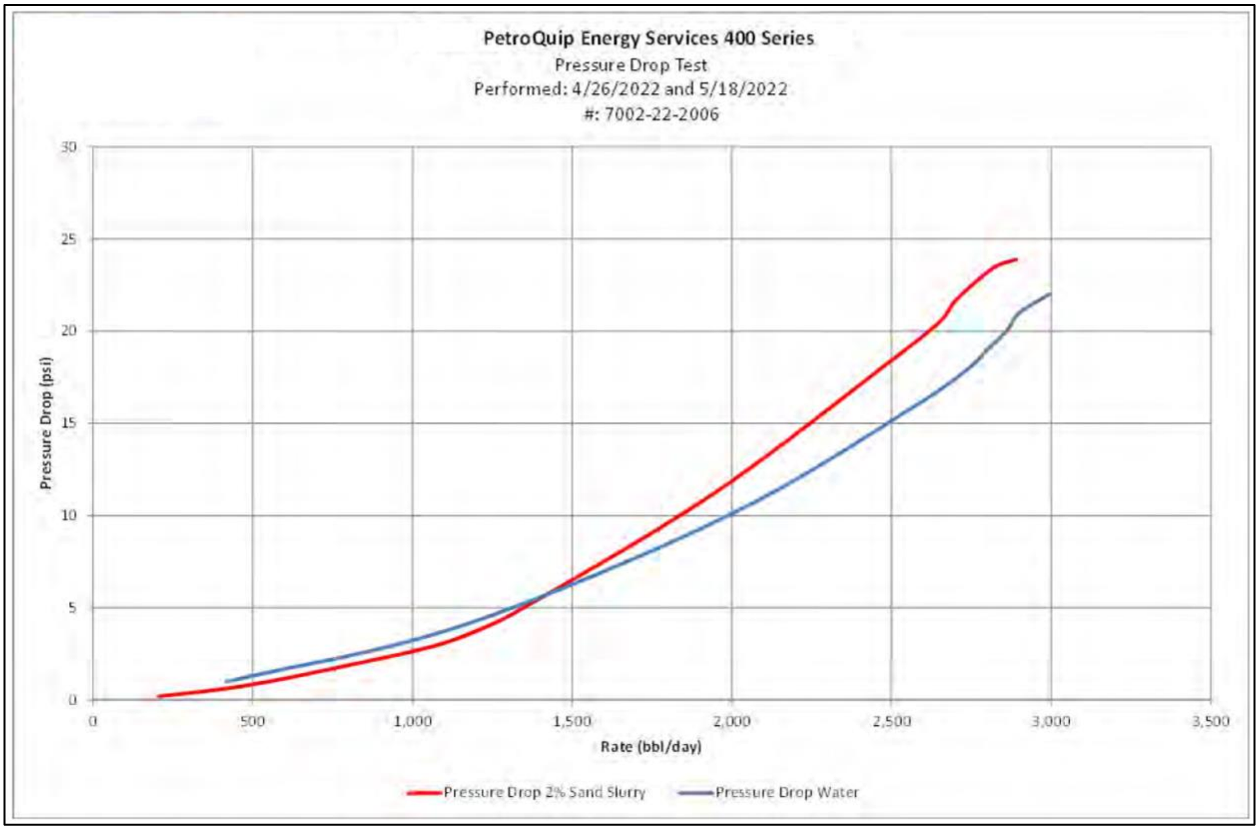

Figure 7: Pressure Drop Chart

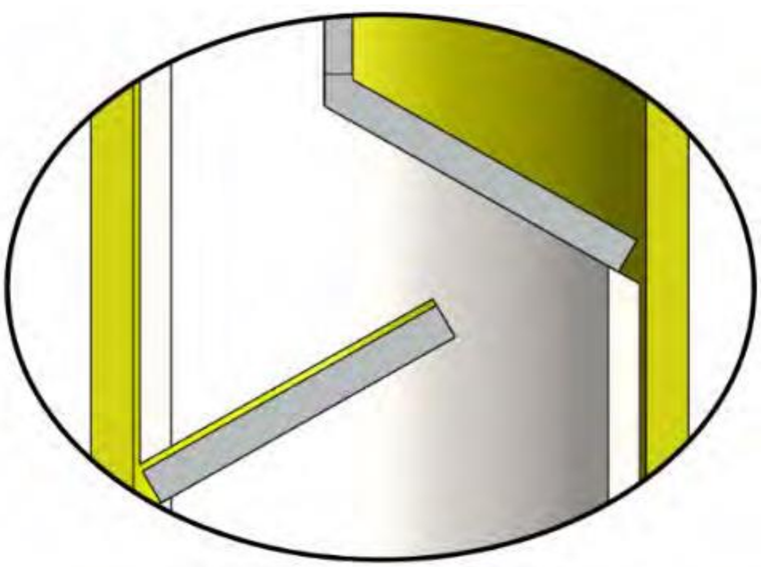

Figure 8: Deflector Plate

Figure 9: Deflector Plate, before Erosion Test

Figure 10: Deflector Plate, after Erosion Test

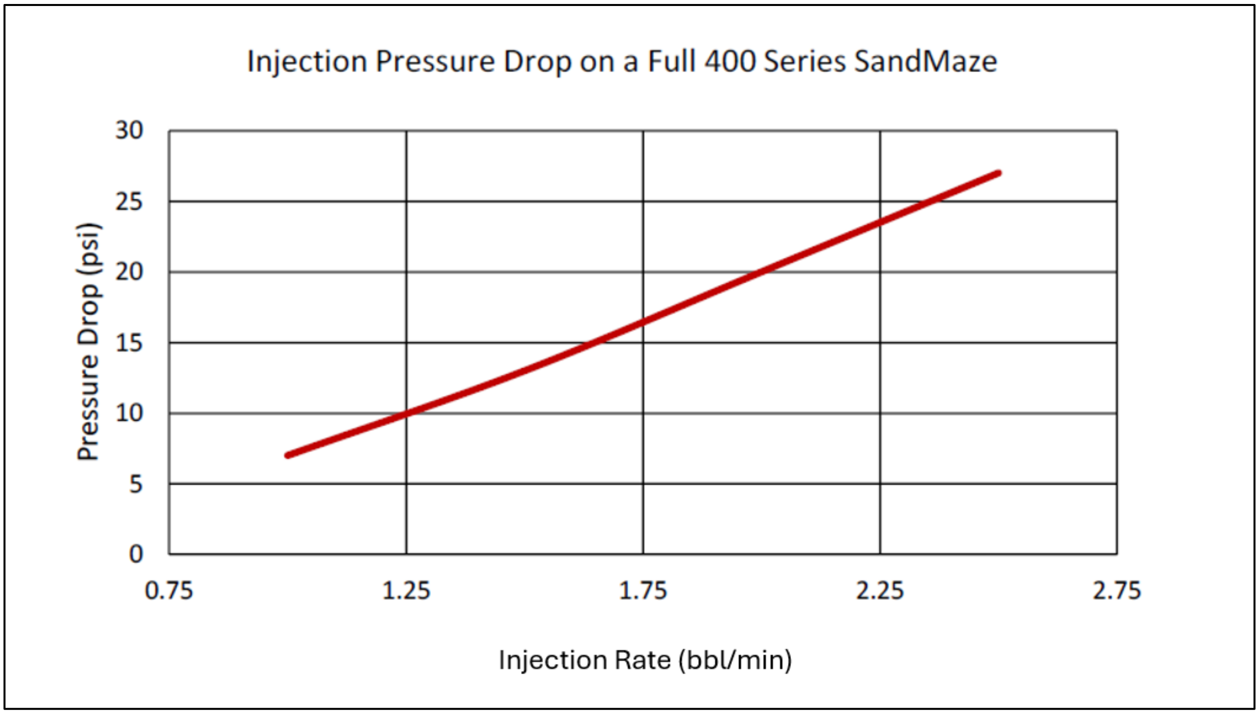

Figure 11: Injection Pressure Drop Chart

Figure 12: Tensile and Compression Proof Load Test Setup

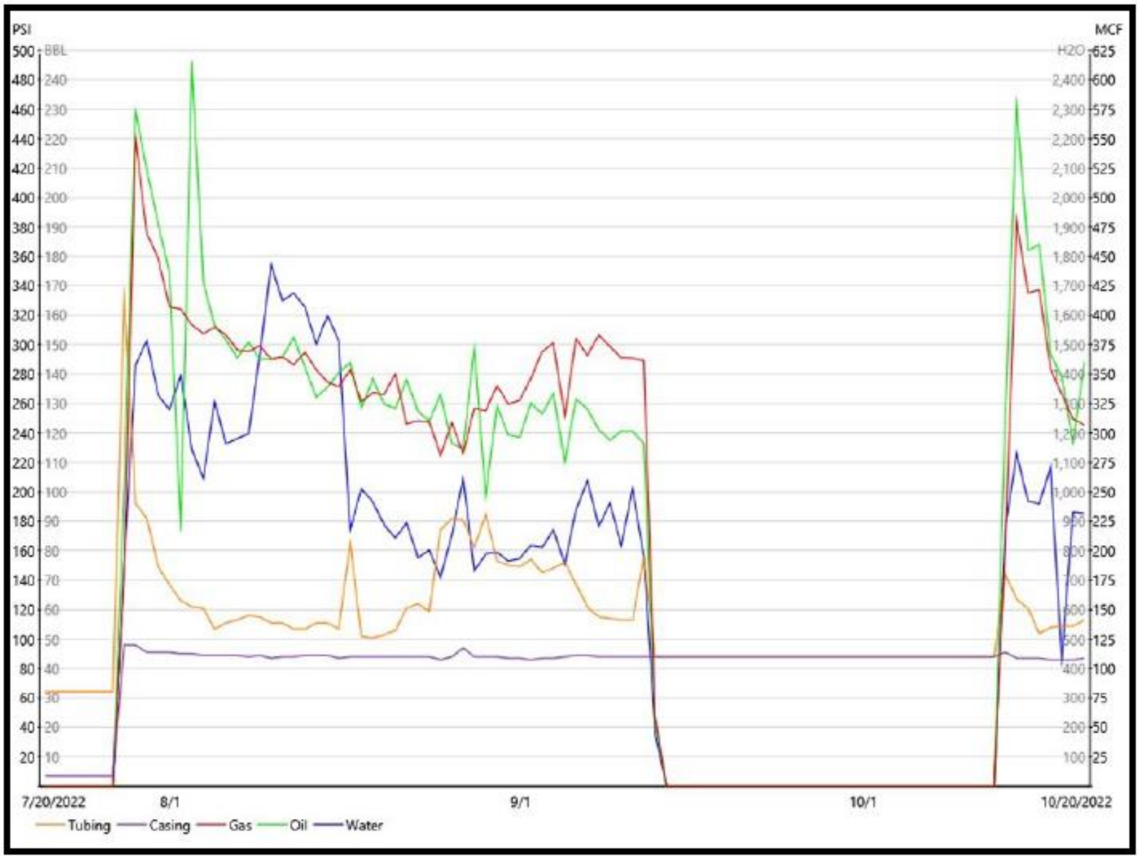

Figure 13: ESP Activity, Pump Rate

Figure 14: 100 Mesh Sand Sample Collected from SandMaze Field Test

Figure 15: Deflector Plate from Field Test

Figure 16: Chamber showing no erosion, only surface rust from Field Test

Figure 17: Close-up of Chamber following Field Test

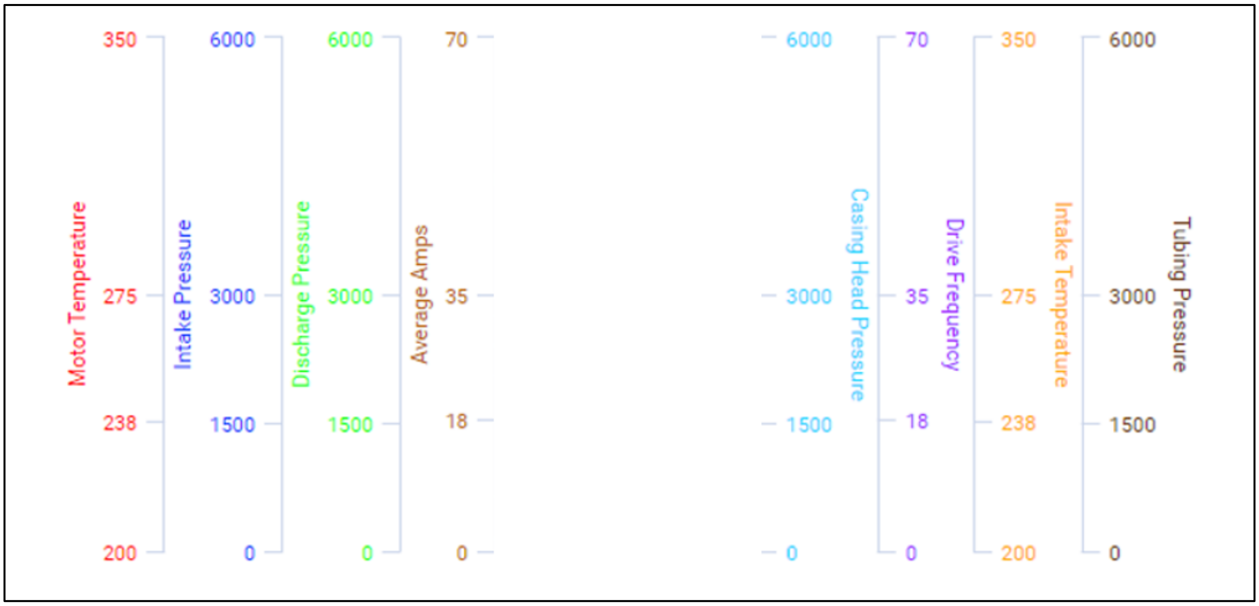

Figure 18: Chart Units and Scale for Reference

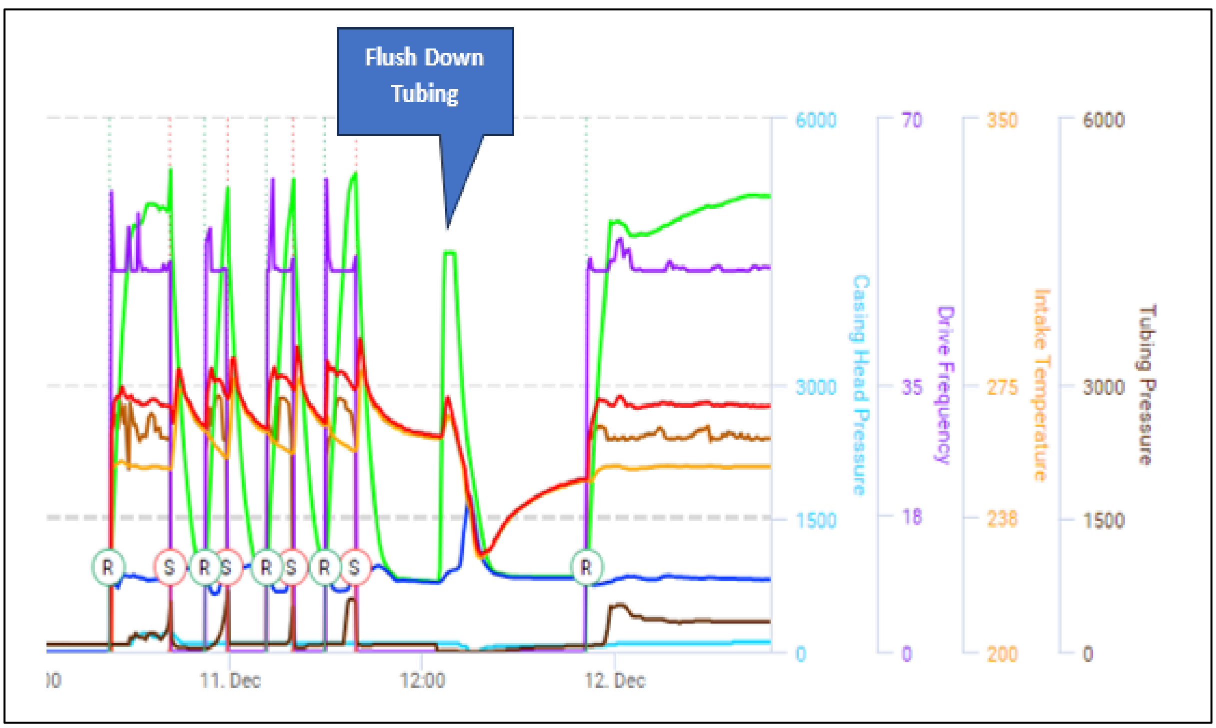

Figure 19: Flush & ESP Restart, Well #1

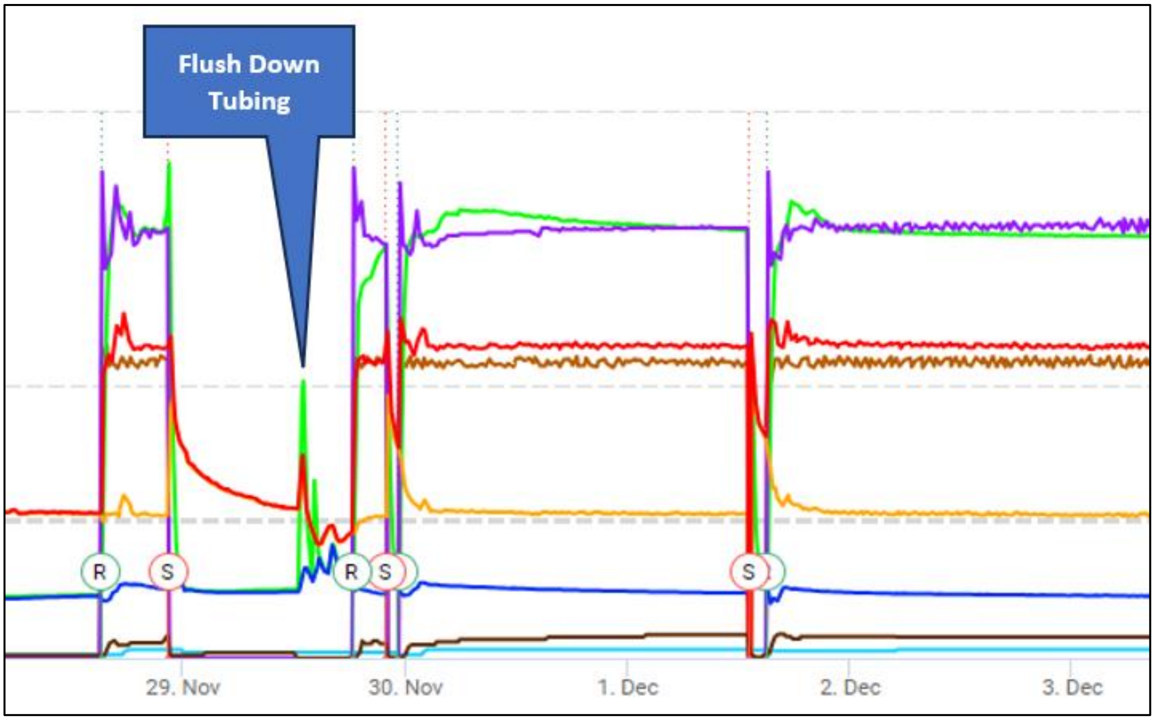

Figure 20: Flush & ESP Restart, Well #2

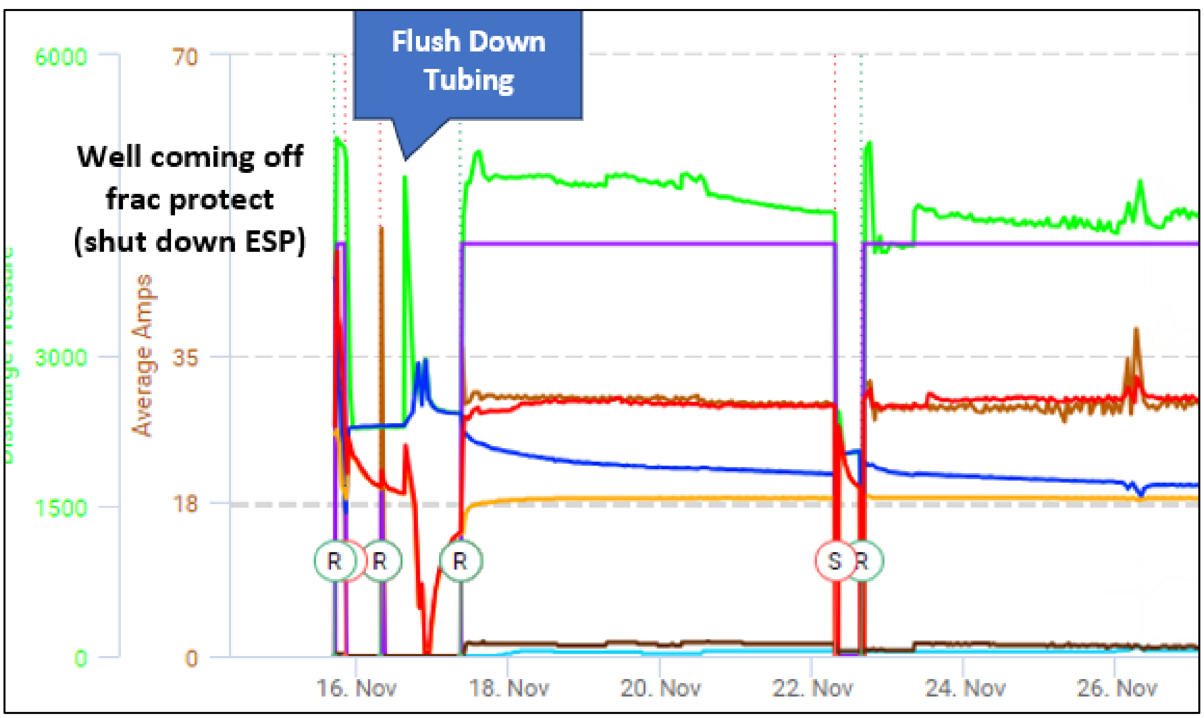

Figure 21: Flush & ESP Restart, Well #3

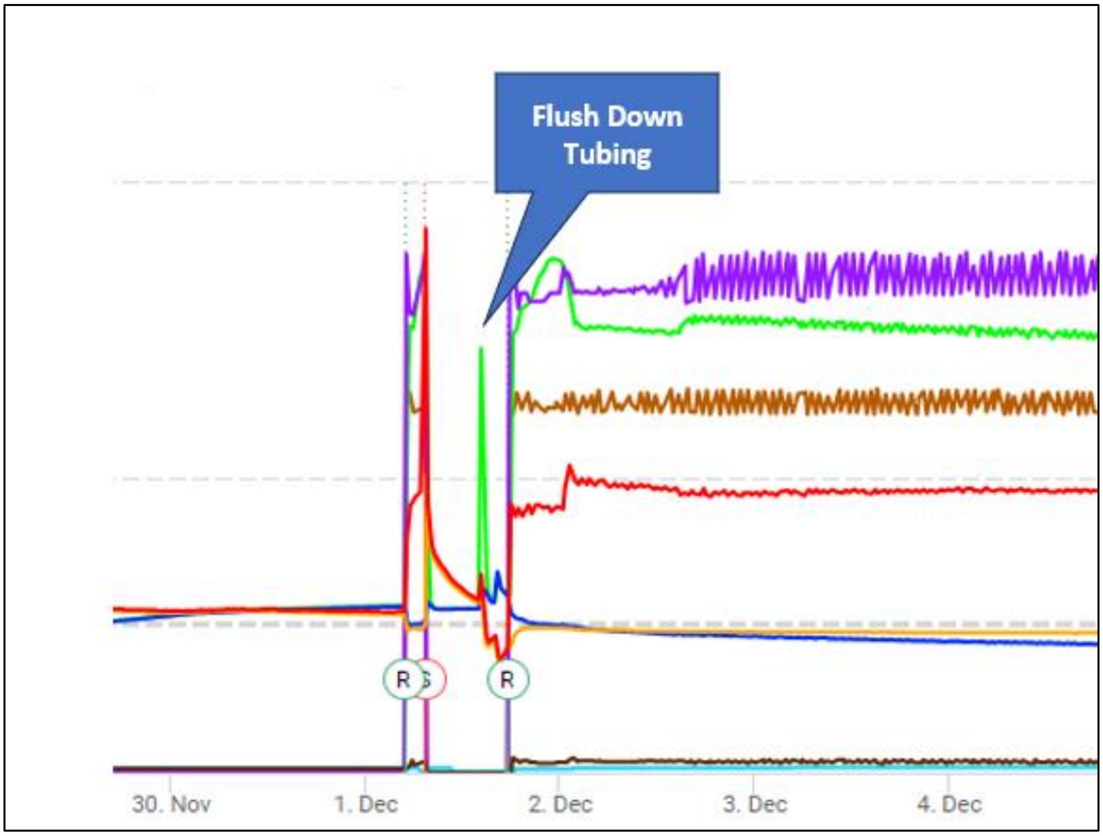

Figure 22: Flush & ESP Restart, Well #4

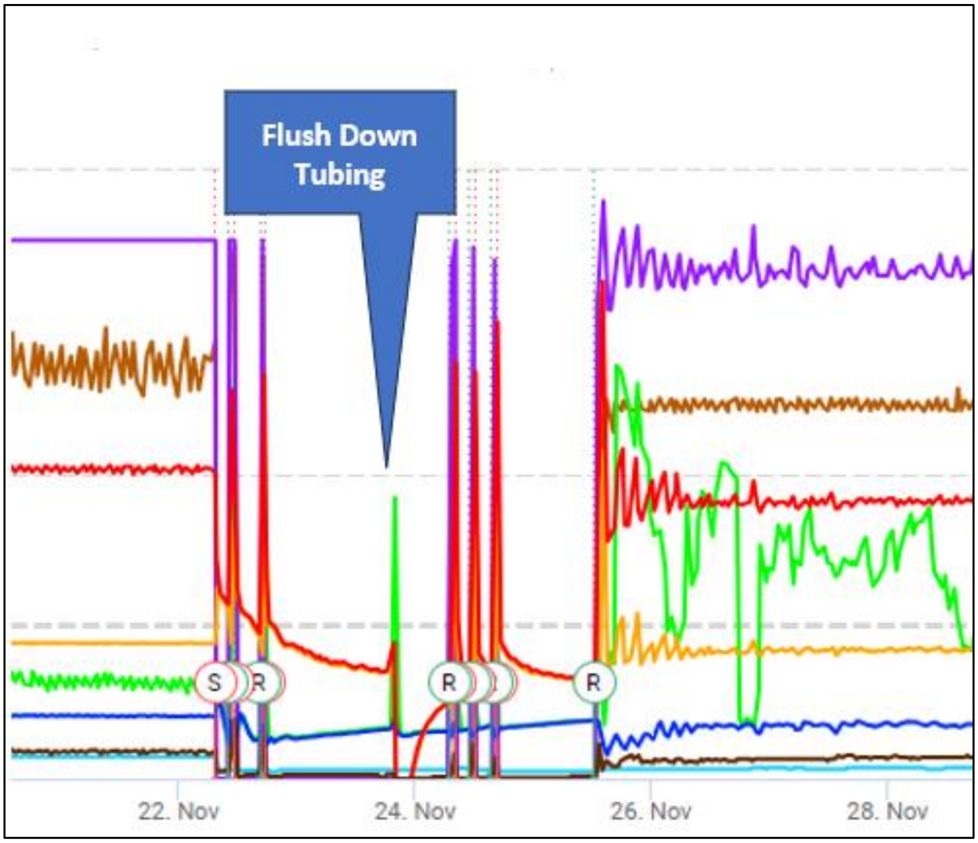

Figure 23: Flush & ESP Restart, Well #5

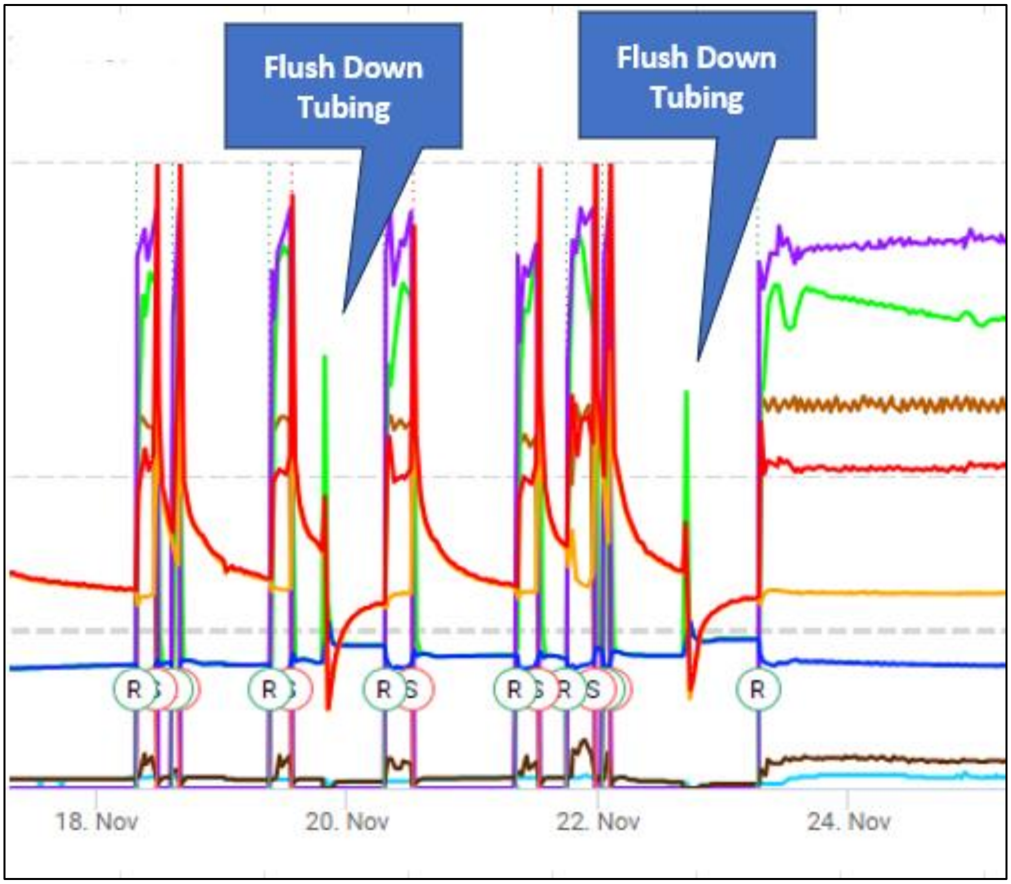

Figure 24: Double Flush & ESP Restart, Well #6