REVOLUTIONARY TECHNOLOGY TRANSFORMS CONTINUOUS ROD INSPECTION

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ABSTRACT

Rod pumping in unconventional wells faces significant challenges due to unpredictable downhole conditions and complex well trajectories. Continuous rod offers a solution by distributing force over a larger contact area, reducing wear and extending run times. However, operators have been challenged by identifying physical defects or discontinuities when adopting continuous rod. Historically, the only method used is a visual, imprecise inspection, often resulting in running bad material back down hole or removing viable assets prematurely. With LPS' proprietary Low Voltage-Electromagnetic Inspection (LV-EMI™) technology, inspecting continuous rod, both round and semi-elliptical at the well site is now possible. Over the past three years, LPS has successfully inspected continuous rod while pulling out of the well without any delay to workover operations.

Due to its compact size, functionality, accuracy, and user-friendly interface, LPS' LV-EMI™ system easily captures real-time data to identify discontinuities in continuous rod. This unit addresses the limitations of conventional electromagnetic inspection methods and overcomes challenges specific to continuous rod. The LV-EMI™ unit utilizes magnetic flux leakage (MFL) and magnetic flux density (MFD) sensors, along with an accelerometer, to provide accurate assessments of rod condition. Field trials have demonstrated its effectiveness in identifying defects, reducing premature rod failures, and optimizing rod string redeployment. As more data is collected, the LV-EMI™ unit will continue to enhance the efficiency and reliability of rod pumping operations, contributing to improved well performance and reduced operational costs.

INTRODUCTION

Rod pumping in unconventional wells presents increasing challenges due to unpredictable downhole conditions. Advances in drilling and completions have led to wells with higher dogleg severity throughout the drilling path. Both unintentional deviations and planned complex trajectories can complicate rod pumping as production declines. These deviations can cause excessive side loading and wear, particularly on the sucker rod string.

Continuous rod offers a viable solution by distributing the force between the rod and the tubing over a much greater contact area, reducing contact pressures to acceptable levels and resulting in longer run times. Despite the many benefits of continuous rod, all rod pumping systems will eventually require intervention. The ability to adequately inspect continuous rod and deem it fit for service has been a struggle for many years.

General Electromagnetic Inspection Principles

A common method of nondestructive testing for determining conventional sucker rod condition is electromagnetic inspection (EMI). This process involves inducing electric currents or magnetic fields inside a test object and observing the electromagnetic response. If conducted properly, a defect inside the test object creates a measurable response. EMI of conventional sucker rods, relies on magnetic flux leakage (MFL) better suited to measuring transverse defects such as corrosion pits or cuts in the rod. With the availability of Hall effect sensors, EMI practices have advanced to monitor magnetic flux density (MFD). Changes in MFD help identify variance in cross-sectional area, measuring loss of cross section and changes in the rod's circumference. These indications are typically a result of wear and hard or soft spots resulting from cycle fatigue or manufacturing discontinuities. When used properly by a trained inspector, this method can provide an accurate rod condition assessment.

The existing technology that incorporated these principles for EMI of conventional sucker rods was not suitable for evaluating continuous rod. This led to visual-only inspection methods that were not qualitative. Visual inspection is imprecise, dependent on the operator’s expertise, and subject to human error. Even the most diligent inspector would have difficulty viewing the entire circumference of the rod. Inherently, defective rod could be reinstalled in the well, resulting in premature failure. Continuous rod could be replaced on each workover to avoid this risk, but this method would also incur additional expense for the operator that potentially could be avoided.

Development of Low Voltage-Electromagnetic Inspection (LV-EMI™) Unit

Other challenges in evaluating continuous rod include lack of physical space to place an EMI unit at the wellhead, lack of guidance to control the rod prior to entering the unit, safety concerns, the coiled shape of continuous rod, varying pull speeds based on well conditions, and the rod not being entirely clean when scanned out of the hole.

The LV-EMI™ unit was developed to operate like a tubing scanner in order to overcome these challenges. Continuous rod is pulled with a hydraulic injector and spooled through a set of guide arms onto a collapsible service reel. With this process in mind, the unit was designed to be compact, allowing for placement between the last guide arm and the rod spool instead of placement at the wellhead. Prior to entering the guide arms, rubber strippers eliminate excess oil and paraffin. During operation, the rod travels through the guide arms and an additional set of rubber strippers before entering the EMI unit and the collapsible service reel. The secondary set of rubber strippers assist in keeping the rod steady when entering the unit to attain accurate data. Depth counters are used in tandem with every scan to determine where defects are identified in the rod string. The LV-EMI™ unit consists of two components that clamp around the rod, allowing it to be easily installed or removed at any time during operation. The patented design shown in Figure 1 incorporates a permanent magnet ring to induce magnetic fields to test the object and observe responses.

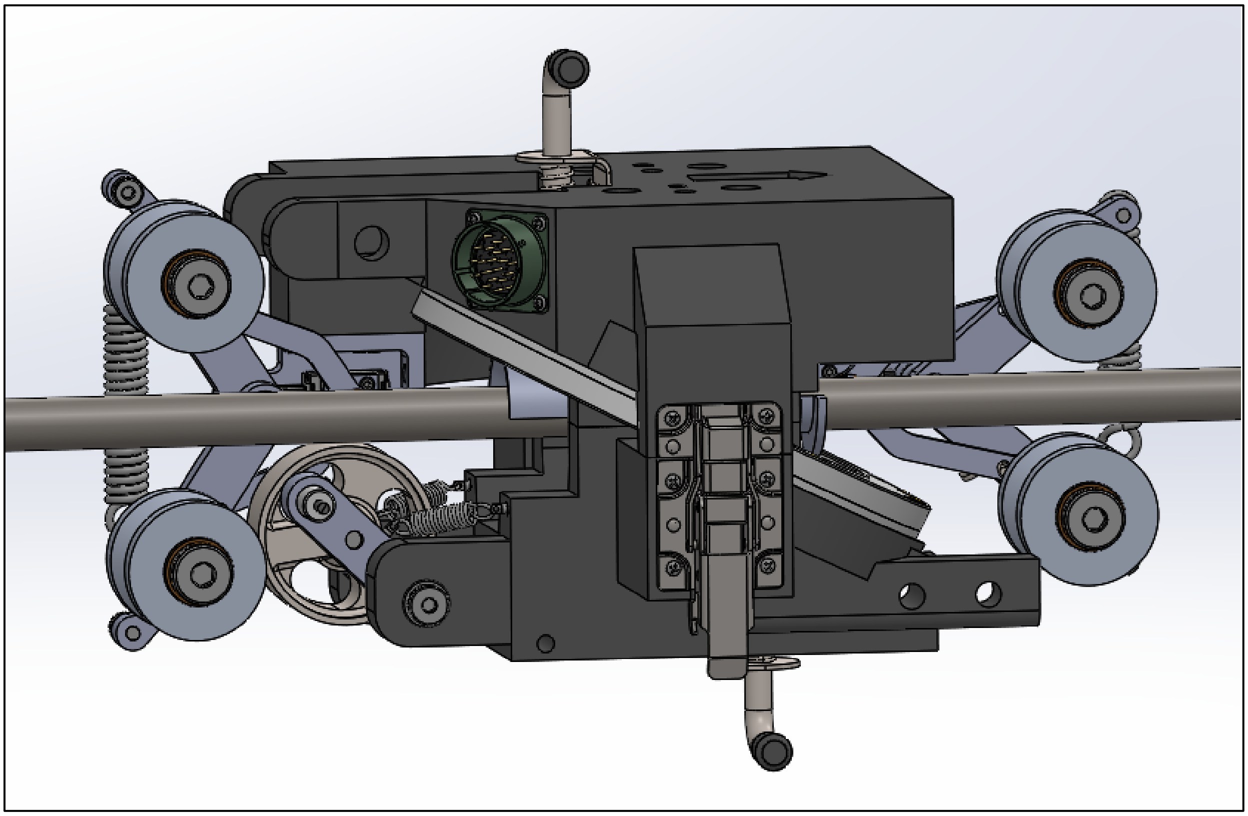

Figure 1. LV-EMI™ inspection unit.

The unit contains two MFL sensors that are in constant contact with the rod covering the entire surface, and two MFD sensors are used to identify any rod discontinuities. The unit contains an accelerometer to discern when fluctuations in the magnetic field are due to relative motion instead of actual rod defects. The unit plots the accelerometer signals to monitor for false MFL or MFD signals created by movement. Figure 2 displays what an EMI operator might observe while scanning the rod string.

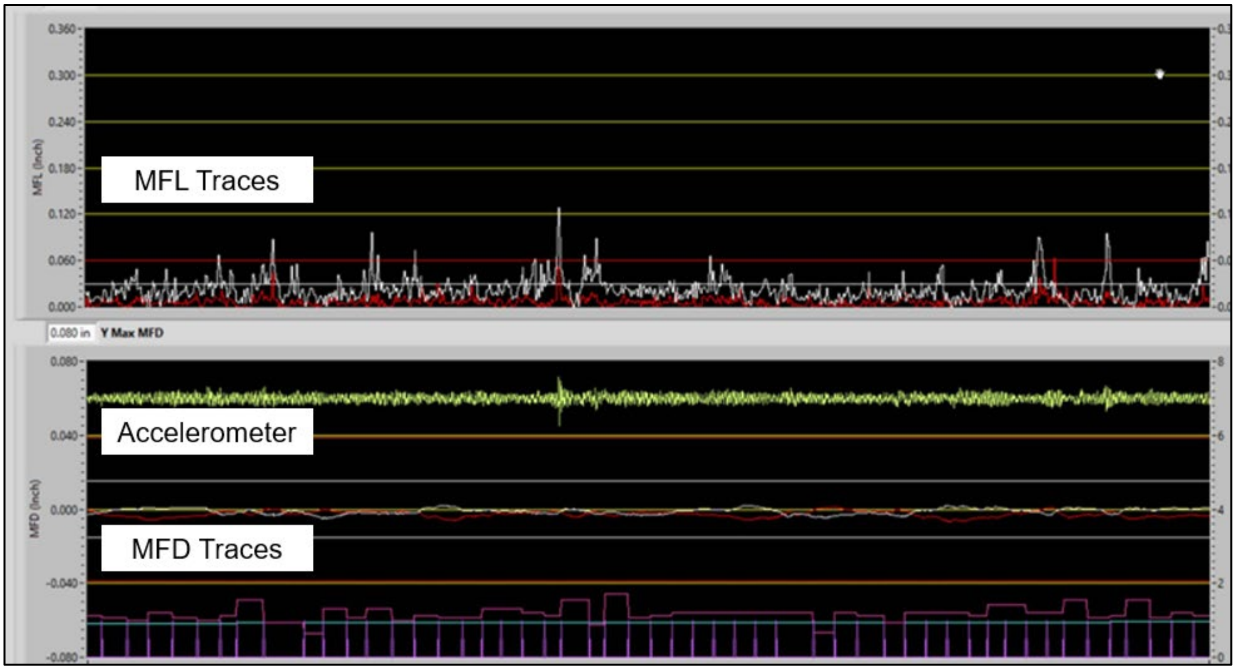

Figure 2. Example of LV-EMI™ charts during continuous rod inspection.

The accelerometer signals coinciding with MFL indications make it easy to discern a false indication from an actual defect in the rod, as shown in Figure 3.

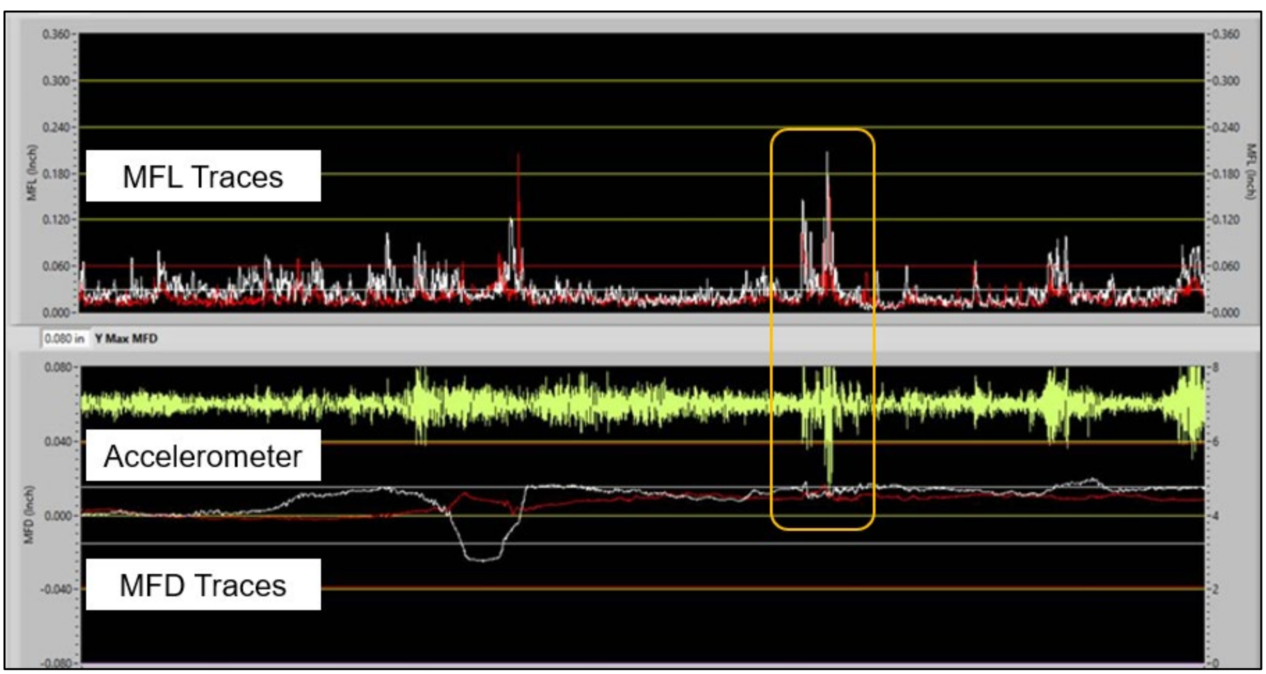

Figure 3. Example of LV-EMI™ charts depicting MFL signal changes reacting to rod movement as shown on the accelerometer.

Current Thresholds

Currently continuous rod is not incorporated in the American Petroleum Institute (API) documents pertaining to sucker rods and related products. API 11BR, *Recommended Practice for the Care and Handling of Sucker Rods,* provides the following thresholds for conventional sucker rods when being inspected.

- Any cracks shall be cause for rejection in all classes.
- Mechanical damage that leaves sharp indications on the rod body shall be cause for rejection in all classes.
- Loss of cross-sectional area due to corrosion, wear, defects, etc., greater than 0.020 inches shall be cause for downgrading to Class II or for rejection.
- Wear between 20% and 30% reduction in cross-sectional area or corrosion pits of 0.040 to 0.060 inches shall be cause for rejection or downgrading to Class III.

Using the existing specifications for conventional sucker rods as a guideline, standards were developed to determine if continuous rod was acceptable for redeployment. Currently, continuous rod is suitable to be reinstalled if there are no transverse defects greater than 60 thousandths when measured using the MFL. Cross-sectional loss cannot be greater than 15% of the rod diameter when measured using the MFD. This value can be as low as 7% depending on the well characteristics and history. These parameters may adjust with additional data over time and can be customized to customer preference or adapted based on field data. As more continuous rod wells are inspected, the acceptance criteria can be further refined.

EVALUATION

When a continuous rod string is pulled, the EMI operator will record values based on the traces displayed in the LV-EMI^{TM} software to determine which sections are suitable for installation back into the well. A detailed report is provided based on the results, as shown in Figure 4.

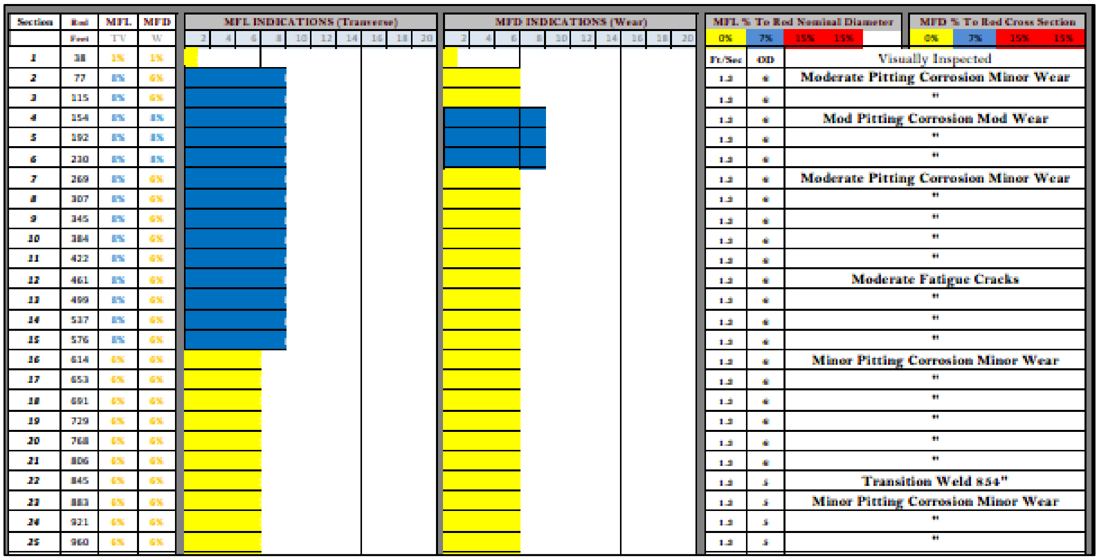

Figure 4. Continuous rod inspection results based on MFL and MFD measurements.

Depending upon the condition of the rod string, certain sections of the string may be replaced during the current workover in order to prevent premature failure when running compromised material. With the ability to cut and replace specific portions of the string, the rod that is fit for service is maximized, and the propensity for rod failure is greatly reduced. Figure 5 highlights an example well where the upper section of the rod string needs to be replaced but the remainder is still viable for redeployment.

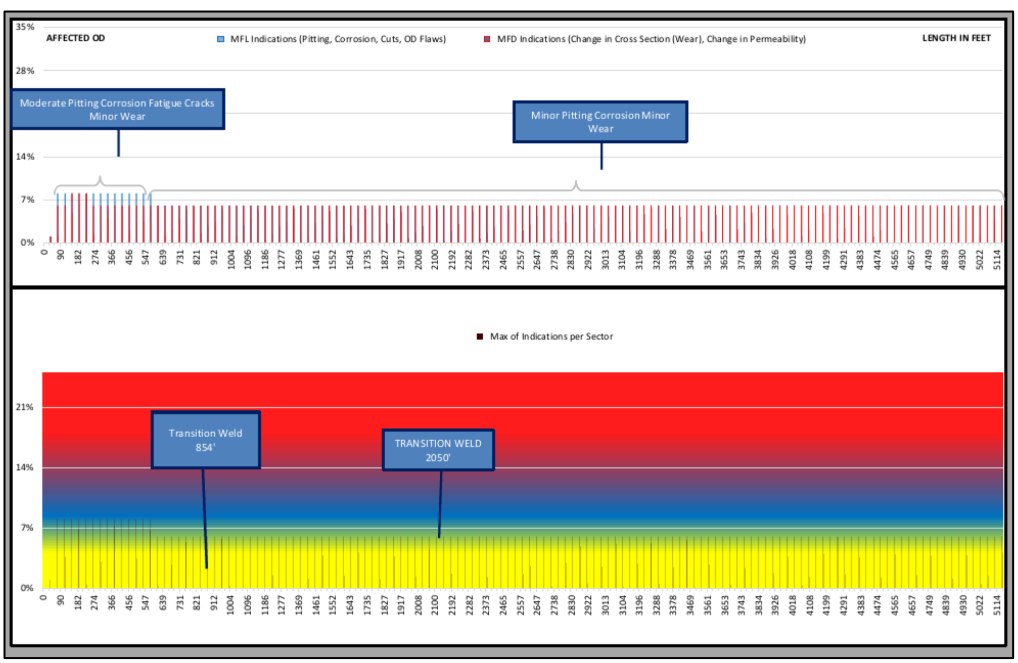

Figure 5. The LV-EMI^{TM} well profile summary depicts defects found in the first 600’, with the remaining rod string falling below the threshold for downgrade.

This quantitative analysis allows operators to make real-time decisions about their existing assets and return wells to production with limited delay while ensuring the material that is installed is not compromised.

RESULTS

Field trials were conducted in the Grater Elk Hills area where continuous rod was used to address challenges with loading at deep pump depths, high fluid rates, and casing restrictions. This operator implemented the use of the LV-EMI^{TM} unit in any high failure rate well or when the failure was related to the continuous rod string. Based on the abundance of continuous rod in the area, over 175 rod inspections have been performed with this technology. Several of these wells have been selected from this subset to highlight the overall program findings.

Well 1

This well contains a semi-elliptical continuous rod taper installed in December 2019 that experienced a rod part at 869' in August of 2021. During this workover, the rod string underwent visual inspection by the rig crew, who observed mild pitting and rod wear, leading them to conclude that the rod string was in acceptable condition for reinstallation. This well was pulled 5 months later due to a pump failure and was inspected at this time. The corresponding MFL and MFD indications for this rod string can be seen in Figure 6.

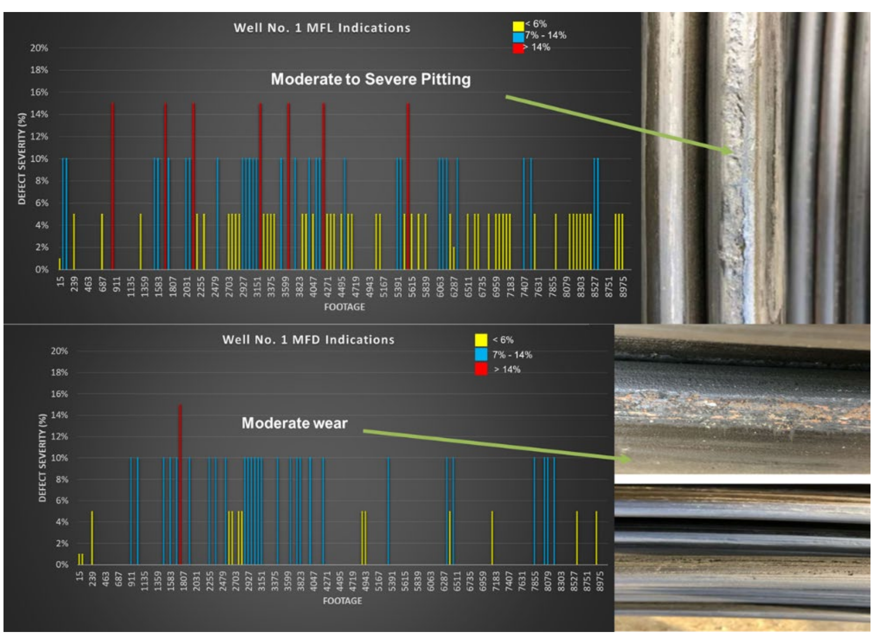

Figure 6. MFL and MFD measurements by depth, along with example images of defects found.

There were several instances of moderate to severe pitting as well as moderate wear throughout the rod string. Based on these results, it was determined that the string should be laid down for a new string replacement. This well is still producing without failure, and it is unlikely that the existing string could have achieved this run time.

Well 2

This semi-elliptical continuous rod string was originally installed in January 2020. After nearly two years of operation, the rod string parted in January 2022 at the transition between the tapers at a depth of 7,252’. During this workover, the rod string underwent a visual inspection by the rig crew, who concluded that the rod string was in acceptable condition for redeployment. In August 2022, the rod string was pulled due to a pump failure, prompting the string to be scanned with the LV-EMI™ unit. Upon inspection, stress cracking was found in the top 1,500’ of the rod string, with minor indications of rod wear, as depicted in Figure 7.

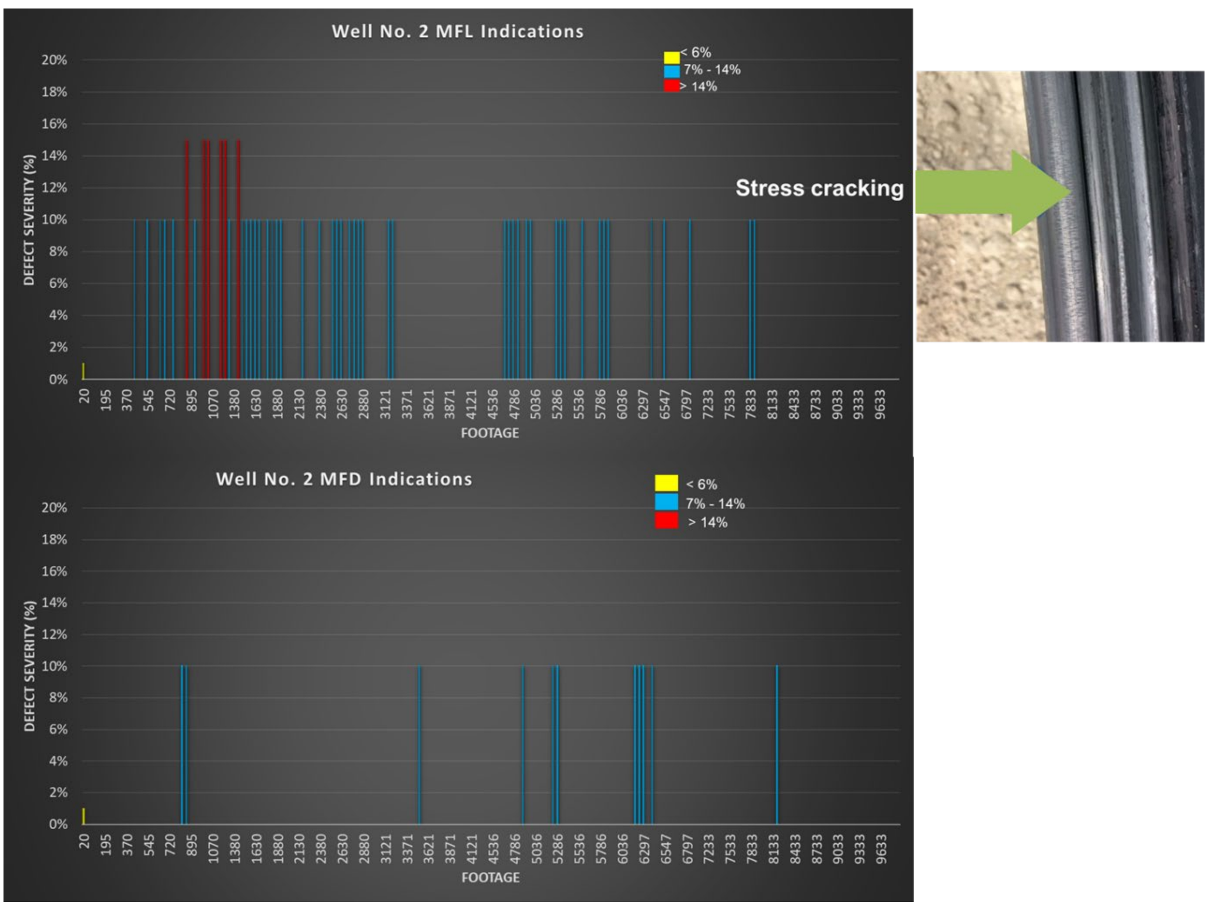

Figure 7. MFL and MFD measurements by depth, along with images of stress cracking discovered.

Although some portions of the string could have been salvaged, it was determined that it would be best to retire the string and replace it with new material. Given the nature of the defects, it is likely that a repeat rod failure was avoided.

Well 3

Again, this well contains a semi-elliptical continuous rod taper originally installed in May 2019. In November 2023, the rod string was pulled for elective well work. During this workover, the rod string underwent a visual inspection by the rig crew, who concluded that the rod string had light pitting and wear but was in acceptable condition for redeployment. After running for only one week following this workover, a rod failure occurred, prompting a scan. Severe pitting was found in the top 650’ of the rod string, as shown in Figure 8.

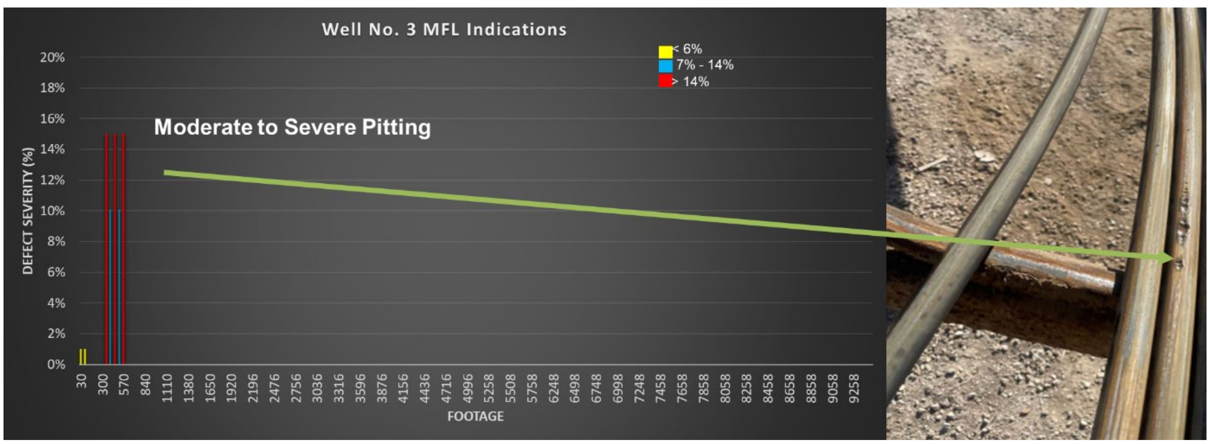

Figure 8. MFL traces indicating severe pitting found in the upper section of the well.

Provided the MFD portion of the evaluation showed minimal indications, only the top 650’ of the rod string was replaced, allowing the majority of the rod string to be reinstalled. No additional rod failures have occurred to date, validating that an LV-EMI™ inspection could have prevented a rod failure had it been implemented at the time of the first failure.

CONCLUSIONS

The development and implementation of the LV-EMI™ unit have significantly improved the inspection and evaluation of continuous rod strings in rod pumping systems. By addressing the limitations of conventional electromagnetic inspection methods and overcoming challenges specific to continuous rod, the LV-EMI™ unit provides a reliable and accurate assessment of rod condition. Field trials have demonstrated its effectiveness in identifying defects, reducing premature rod failures, and optimizing rod string redeployment. As more data is collected and acceptance criteria are refined, the LV-EMI™ unit will continue to enhance the efficiency and reliability of rod pumping operations, ultimately contributing to better well performance and reduced operational costs.

REFERENCES

API 11BR Recommended Practice for the Care and Handling of Sucker Rods

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