# A NEW SUCKER ROD COUPLING MATERIAL: AN ECONOMICAL SOLUTION FOR DOWNHOLE WEAR IN DEVIATED UNCONVENTIONAL WELLS


Seth Silverman and Logan Stoner
Hess Corporation

William Nielsen and Diane Nielsen
Materion Corporation


## INTRODUCTION

Sucker rod pumping in slightly deviated 10,000 ft unconventional wells comes with unique challenges related to side loading of rods. Rods can flex during the down stroke of the pumping unit, resulting in tubing and coupling wear, significant workover costs, and deferred production. In Hess Corporation's North Dakota Bakken properties, this problem occurs frequently in the lower 1,000 ft of some wells, accounting for nearly half the failure rate in this region. The culprit behind the tubing wear is the spray metal coupling, made of a much harder material than the steel L-80 tubing. Over time, these couplings tend to wear the tubing down to the point of failure. The use of standard T-couplings also can result in tubing wear by a galling mechanism.

## PROCESS

In 2014, the operator determined to solve the problem with an alternate coupling material. The operator selected a CuNiSn high strength spinodal alloy called *ToughMet 3 TS95* to try as the new coupling material. Manufactured by Materion Corporation, the alloy was designed for bearing applications and was an ideal match for sucker rod couplings since it resists abrasion in sliding applications and is compatible with the L-80 tubing. The hardness of the CuNiSn alloy is a maximum of HRC 32 compared to a hardness of HRC 23 for L80 tubing. The alloy contains 15% Ni and 8% Sn, which improves the corrosion resistance compared to other bronze alloys.

A project was initiated to manufacture 1 in. slimhole couplings. The new material was fabricated by a thermomechanical process. This resulted in a spinodal alloy structure made up of homogenous two-phase mixtures as shown in Figure 1. The spinodal hardening increased the yield strength of the base metal and added a high degree of uniformity of composition and microstructure. Table 1 details the mechanical properties of the alloy.

The operator machined prototype couplings following the standard API dimensions for 1 in. slimhole couplings with rolled threads. Controlled make and break tests with strain-gauged rods were conducted to assess whether the standard makeup resulted in the required pin pre-stress compared to a T-grade coupling. Figure 2 shows both the new prototype couplings and the controlled makeup/breakout test setup. The standard circumferential displacement card value supplied by the rod manufacturer for the 1 in. rod size was determined to be sufficient to deliver good pin pre-tension. The lower elastic modulus of this alloy does not affect the makeup characteristics of this coupling. Subsequent breaks and re-makes of the material demonstrated a return to proper pre-stress levels. The addition of copper plating on the threads and changing of the surface finish on the face of the coupling improved the overall makeup performance.

## PILOT TEST – PHASE 1

The operator tested the new couplings in two phases. Phase 1 of the pilot program began with four wells. Hess installed 1 in. slimhole couplings in two wells experiencing tubing wear at a failure frequency rate of about 6 to 8 months. In the other two wells, Hess installed couplings in the top section of the 1 in. sucker rod string where deviated holes were causing wear. Since the installation nearly two years ago, none of the four wells have experienced a failure related to couplings, more than tripling the mean time between failures.

Table 2 lists the Phase 1 pilot wells. The days on production are listed since the installation of the *ToughMet* couplings. The detailed history of four of these wells is discussed below.

## Case History #1 – GO Elvin Garfield

The GO Elvin Garfield well was originally completed in September 2012. In April 2013, after only 9 months of production, the well went down because of a suspected hole in the tubing. In May 2013, the operator pulled and examined the sucker rods, pump, and tubing, discovering some wear on the ¾ in. rods. The operator changed 23 of the 24 couplings and replaced 34 of the ¾ in. rods as well as 14 of the 1 in. rods. A small split was found in the sixth joint above the discharge and 27 other joints were replaced that were worn beyond 35% wall loss. The sinker rod section was also extended by 250 ft. A total of 1,200 ft of the rods were guided (600 ft of the 1 in. and 600 ft of the ¾ in.).

In January of 2014, the well went down again with a tubing split in Joint 310 caused by rod wear. The operator ran additional guided rods on bottom and laid down 18 joints as well. The operator also installed 1 in. slimhole *ToughMet* couplings in the bottom 1,000 ft of the well.

In June 2014, a tubing leak was discovered in Joint 295 and Joint 25 was found to be crimped. The *ToughMet* couplings were in excellent condition and were re-run. The operator removed one coupling for laboratory examination and it did not show any signs of wear. The original dimensions were all intact.

In August 2015, after 17 months of production (the longest run time to date on this well), another tubing leak was suspected. The plastic coated joint located just above the pump had a hole. Repairs were made and the well was put back on production. The operator reinstalled all the *ToughMet* couplings with the exception of two for dimensional analysis. Figure 3 shows a cross section of one these couplings. Figure 4 shows the mean time between failure versus total run time.

## Case History #2 – Strahan 15-22 H

This well stopped producing in December 2015 because of a deep tubing leak above the pump (not in the vicinity of the *ToughMet* couplings). In this well, T couplings were alternated with *ToughMet* couplings at the bottom of 26 of the 1 in. guided sucker rods. The inspected tubing shows that there was no significant wear in the area covered by the 1 in. rod string. There was, however, more significant wear and corrosion above and below the area covered by the *ToughMet* couplings. Figure 5 shows the *ToughMet* couplings after 20 months of service with no noticeable wear on the OD. The serial numbers are still clearly visible, indicating the corrosion and abrasion resistance of the material. For comparison, the OD measurements were taken on a new *ToughMet* coupling and one of the *ToughMet* couplings retrieved from the well after 20 months service. The data shows that the change in OD was only 0.020 in. or 10 mils per side. This equates to a loss of only 0.5 mil per month. Figure 6 shows the couplings side by side. As expected, the T couplings had a corroded surface and were worn with flat spots. Figure 7 shows a cross section of one of the recovered *ToughMet* couplings.

## Case History #3 – GO Braaten 156-97-3328H-1

This well ran for 15 months from initial artificial lift installment date and required a workover in March 2013 because of a tubing leak. In May 2014, the well was again found to have deep tubing leak in a joint above the sucker rod pump. The operator removed Joints 287 to 306 because of excessive wear. *ToughMet* couplings were run in this area; however, they were alternated with spray metal couplings as a test. The well ran for 623 days versus the previous runtime of 420 days (a 48% increase in run time). In this instance, the crew found a hole in the tubing two joints above the seating nipple. Root cause failure analysis for this well is still under investigation.

## PILOT TEST – PHASE 2

To further reduce friction in the bottom third to lower half of troublesome wells, a second phase of the pilot has been proposed. In this phase, the operator will install ¾ in. full size couplings and 1 in. slimhole couplings in the bottom 4,200 ft of three wells. The purpose is to reduce friction in the lower portion of the string, thereby lowering the peak polished rod loads, lowering gear box loads, reducing power consumption, and increasing pump stroke length. This pilot will commence in Q1 2016.

## Case History #4 – EL Cvancara H3

The EL Cvancara H3 well experienced tubing wear and pitting in 24 joints at the bottom of the well. There were 303 joints in this well above the tubing anchor catcher. Joint 300 experienced 99% wall loss. The operator installed 31 new 1 in. guided rods with 1 in. slimhole *ToughMet* couplings and 24 new ¾ in. guided rods with ¾ in. full size *ToughMet* couplings. The goal was to place the *ToughMet* couplings in the part of the well experiencing the greatest side loading. The pump was also worn and replaced. Figures 8 and 9 show the before and after pump cards and production data. Figure 10 shows additional production data. The well was restored to a production rate of 120 bopd from the pre-workover rate of ~50 bopd. This well has a history of frequent workovers in the 3 to 4 month average range. Success will be determined by the length of the extended run time between failures.

## CONCLUSIONS

The operator has piloted *ToughMet 3 TS95* couplings in 11 wells in its Bakken production unit for over two years now. Thus far, there have been no failures related to the couplings and runtimes have improved up to three times over what they were previously. Material recovered from two wells after 6 months and 20 months shows the couplings to be in almost new condition. The pilot will be expanded throughout 2016.

## ACKNOWLEDGEMENTS

The authors would like to thank both Hess Corporation and Materion Corporation for the opportunity to publish this work. The authors also very much appreciate the efforts of Mr. Charles Panzer (Hess Corporation) for assisting with the workover jobs at the wellsites and analyzing the well operating data. We also appreciate Dr. Robert Kusner (Materion Corporation) for conducting the analysis of the recovered couplings.

Table 1 – Mechanical properties of *ToughMet 3 TS95*

| | |
|---|---|
| 0.2% Offset YS, ksi | 102 ksi |
| UTS, ksi | 112 ksi |
| Elongation in 2 in., % | 24% |
| RA % | 57% |
| CVN, ft-lbs | 55, 55, 70 |
| Hardness, HRB | 98 (20.5 HRC) |

Table 2 – Running time for the first phase of the pilot as of February 8, 2016

| | |
|---|---|
| GO Biwer 157-98-2635 H1 | 705 days |
| GO Braaten 156-07-3329 H1 | 621 days |
| Strahan 15-22 H | 551 days |
| GO Elvin Garfield 156-97-1819 H1 | 713 days |
| SC Tom 153-98-1514 H4 | 390 days |
| SC Tom 153-98-1514 H1 | 363 days |
| SC Tom LS153-98-1514 H1 | 383 days |
| GN Alice 158-97-1324 H3 | 352 days |
| GN EJ 158-97-0706 H1 | 344 days |
| GN-Ring-158-98-1522 H1 | 373 days |

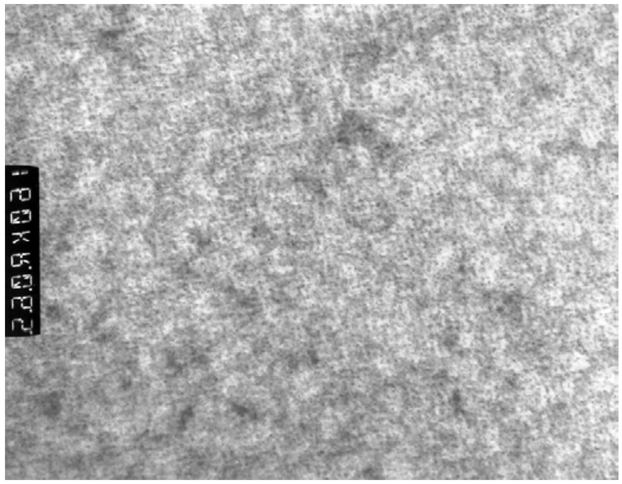

Figure 1 – High resolution electron micrograph (>160,000x) of spinodal structure.

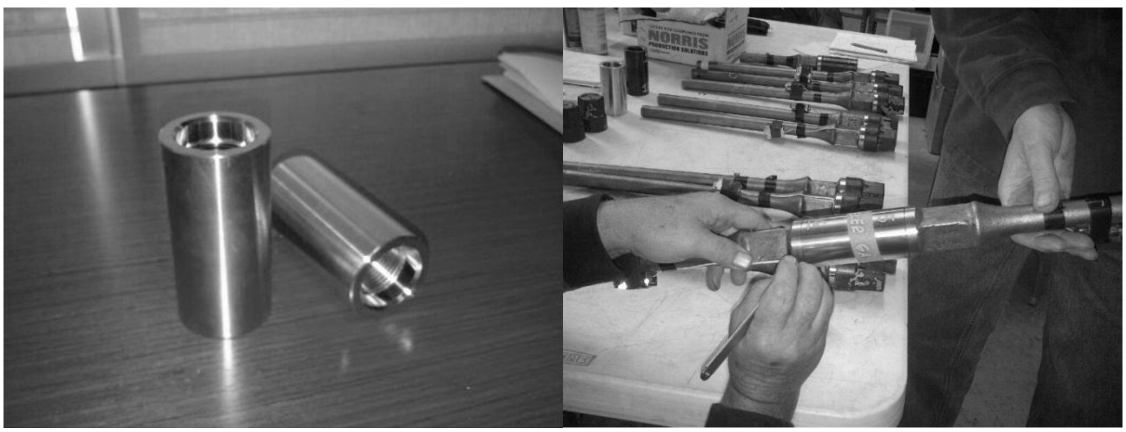


Figure 2 – Left: Prototype 1 in. slimhole couplings. Right: Strain gauged set up for make break tests.

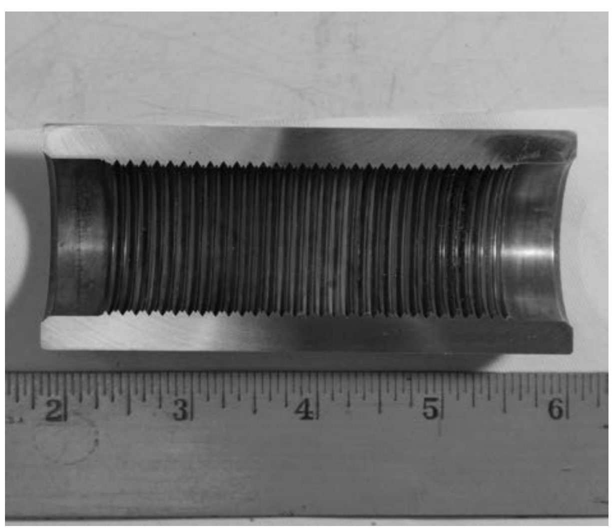


Figure 3 – Cross section of the used sucker rod coupling GO-Elvin Garfield from the June 30, 2014 pull (6 months service life).

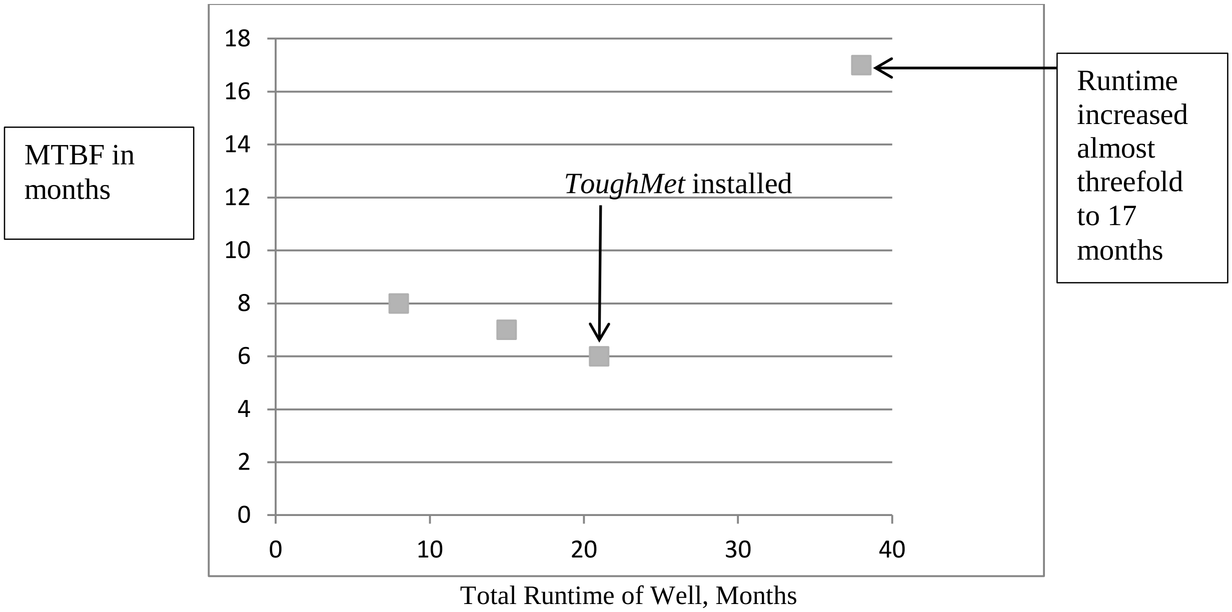


Figure 4 – GO Elvin Garfield well shows significant run time improvement with *ToughMet* couplings in the lower 600 ft of the 1 in. bottom rods.

Figure 5 – Photos of *ToughMet* couplings retrieved from Strahan well after 20 months of service.

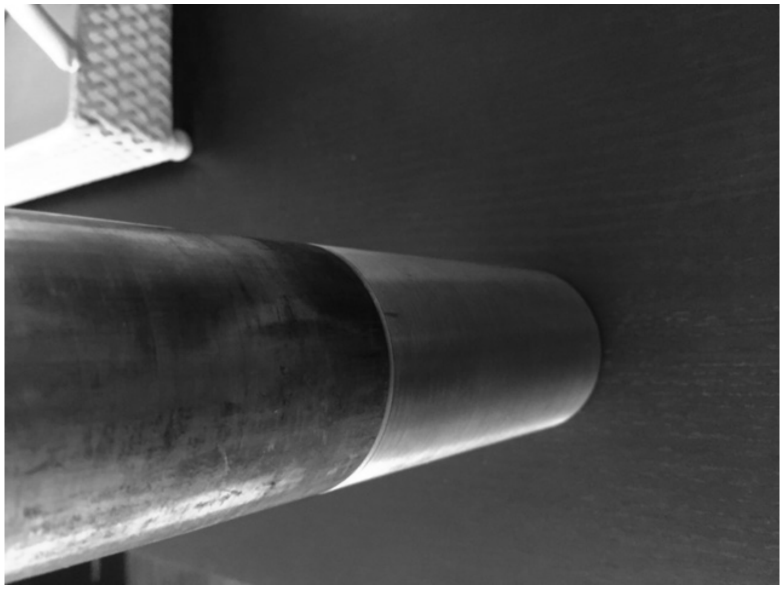

Figure 6 – New versus used *ToughMet* coupling from the Strahan well. The average OD of the new coupling is 1.998 versus and average OD of the used coupling of 1.978 for a diametric loss of 0.020 in. or surface loss of 10 mils over a 20 month period (0.5 mil per month).

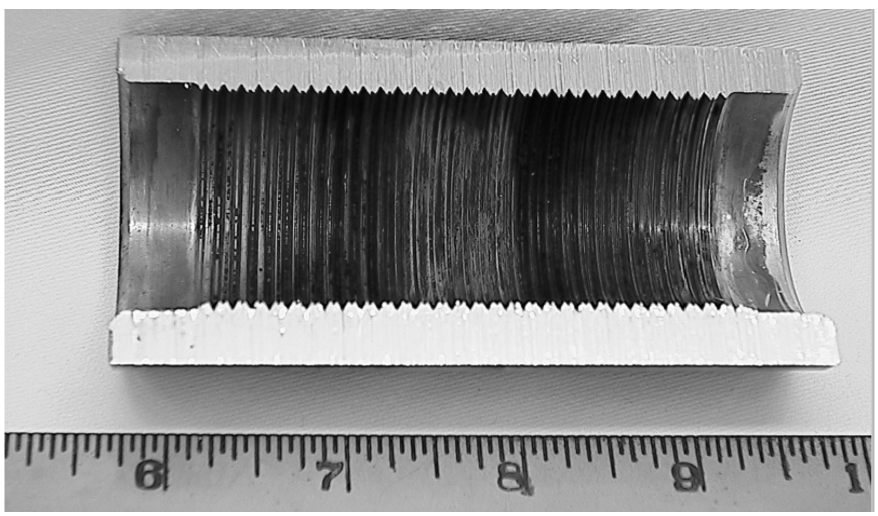


Figure 7 – Cross section of *ToughMet* coupling from the Strahan well after 20 months of service.

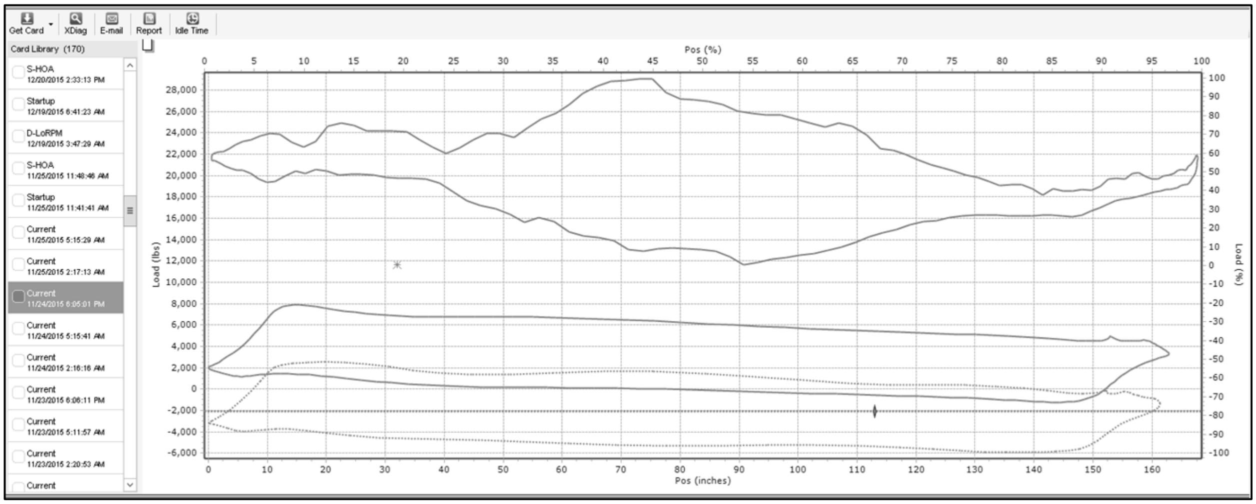


Figure 8 – Pump card of the Cvancara well before installation of the *ToughMet* couplings in the ¾ in. and 1 in. bottom section of the well. Note the erratic movement of the top load curve, indicating possible sticking of rods.

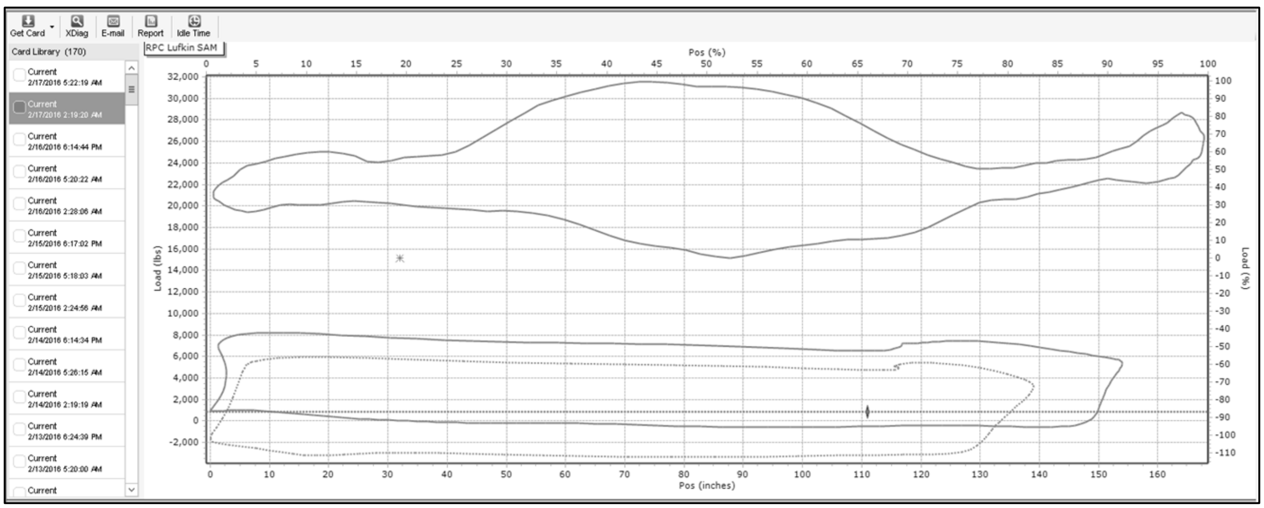


Figure 9 –After installing 24 of the ¾ in. full size *ToughMet* couplings and 31 of the 1 in. slimhole couplings, the pump curve is much smoother. This indicates a potentially lower friction force.

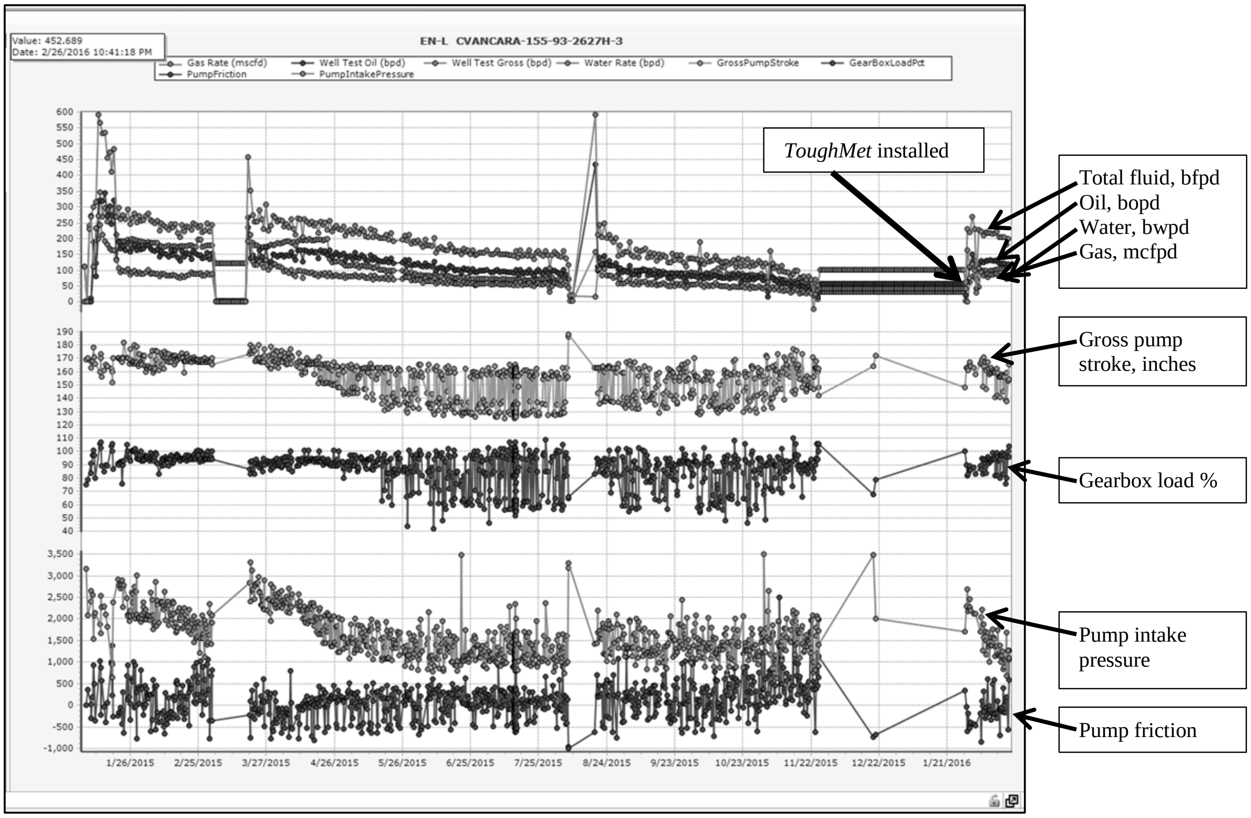


Figure 10 – A complete history of the Cvancara well production data from January 2015 to date.