INSIGHTS ON POLISHED ROD TRANSDUCER ANALYSIS: DISTINGUISHING THERMAL DRIFT FROM BENDING

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Abstract

The Polished Rod Transducer (PRT) is a practical and effective tool for well analysis, offering the ability to acquire dynamometer data quickly with minimal disruption to pumping operations. This paper provides insights on measurements and guidance on best practices for obtaining reliable PRT readings and improving diagnostic accuracy.

The paper discusses how the PRT measures load through polished rod diameter change, how the system self-calibrates each stroke, and cases where load measurements may be externally impacted. It also presents a case study in which several thousand dynamometer cards were gathered over multiple days using a PRT to analyze downhole friction related to rod rotation. During this extended acquisition, a long-term cyclical load variation was observed that tracked the rotation period of the rod rotator to a high degree of accuracy using the PRT.

A key finding is that thermal drift, particularly from alternating sun and shadow exposure during acquisition, can produce data trends that closely resemble polished rod bending. These thermal effects are visually distinguishable from actual mechanical bending once the operator knows what to look for. The paper presents both phenomena side by side, describes their distinct signatures, and provides practical recommendations for field application. Recognizing this distinction adds a valuable diagnostic skill to the operator's toolkit.

Introduction

The Polished Rod Transducer (PRT) is a useful tool for well analysis. The ability to quickly and accurately diagnose a well's performance by basically tightening a knob is an underrated superpower. The PRT can be installed in less than 30 seconds and requires no special rigging. In some cases, the PRT can be installed while the well continues to pump; however, for safety considerations, the pumping unit should always be stopped and properly secured when the PRT is installed or removed. For most routine analysis, the general shape of the dynamometer card is quite accurate. Absolute loads should be verified against known references when precision matters, but for identifying pump conditions such as gas pound, pumped-off, partial fillage, or no pump action, the PRT is more than sufficient.

When the PRT is used for short-term analysis (a handful of dynamometer cards), the insights in this paper may be of limited concern and may focus primarily on the thermal drift while the PRT acclimates to the environment. If, however, the PRT is used for extended acquisition for dozens or hundreds of cards over several hours, a deeper understanding of how the PRT interacts with its environment becomes important. Two primary phenomena can affect PRT readings over time: temperature changes acting on the transducer, and mechanical bending of the polished rod due to misalignment. Both can alter the apparent load, and both produce trends that an operator might initially attribute to the other. These can occur independently of rod rotation, but rod rotation is a common source of such trends.

This paper describes how the PRT measures load, presents a case study in which both phenomena were encountered during long-term friction analysis, explains the mechanisms behind thermal drift and polished rod bending, and offers practical guidance for distinguishing the two. The goal is to help operators extract more value from PRT data by understanding both the tool's capabilities and the conditions that influence its readings.

How the PRT Measures Load

The PRT obtains polished rod position through a solid-state accelerometer. The acceleration signal is integrated once to derive velocity and a second time to derive displacement. The accelerometer requires no maintenance and acquires data at user-selectable rates from 15 to 480 samples per second, providing a detailed picture of polished rod motion throughout each stroke.

Load measurement is more involved. A traditional horseshoe load cell is a straightforward analog-to-digital conversion but must be installed in the direct axial load path and factory-calibrated. The PRT trades some absolute accuracy for substantial convenience: it clamps onto the polished rod below the carrier bar and is hand-tightened until its output reads near zero. During the pumping stroke, the PRT detects extremely small changes in polished rod diameter caused by axial loading. These diameter changes are measured using sensitive solid-state strain gauges. The radial strain resulting from axial stress is related through a generalized form of Hooke's law ($\varepsilon_r = \mu\varepsilon_z$). Since the Poisson's ratio (μ) for steel is approximately 0.3, the radial strain is about 30% of the axial strain the PRT must be roughly three times more sensitive than a conventional axial strain gauge load cell.

The change in load for each stroke, combined with the calculated polished rod position from the accelerometer, generates a *relative load* surface dynamometer card. Using the wave equation, relative loads and displacements are propagated to the pump. The software then determines the PRT zero-load offset for each individual stroke by identifying the point on the downstroke pump card where the traveling valve is open, at which point the pump applies zero load to the rods. This offset is subtracted from all load values (both surface and pump), converting the relative measurements into actual surface and pump loads. Because this calibration is performed on every stroke, the system is self-correcting and accommodates the slight differences in PRT tightness that occur each time the transducer is installed.

There are two basic calibration points in any load measurement: zero and span. Zero affects the absolute load value; span affects the unit scaling through the range. The calibration to measure change in load is performed in the laboratory using a NIST standard load cell. The operator then pre-loads the sensing element in the PRT to adjust the output to near zero. This process can be thought of as bringing the sensing resolution into focus. With the proper rod-string and well properties, the zero-load point is reasonably known and can be determined from analysis of the data itself. In other words, the load calibration is derived from the downstroke pump card when the traveling valve is open. If temperature change causes the PRT output to drift too far from zero, the PRT tightness may need to be readjusted in the field. In practice, however, the PRT tolerates a wide range of ambient temperature while under measurement.

A key property of this approach is that the general shape of the dynamometer card is largely unaffected by the PRT's measurement method. The wave equation's pump card calculation depends on load *changes*, not absolute values, so the pump card shape is preserved even when the zero reference drifts. The PRT is an excellent device, but it indirectly measures load through a measurement of diameter change. This is not a direct load measurement, but rather a range of load changes. The polished rod itself is the load cell. If the rod string is vertical, intact, free of excessive friction, and the correct lengths are entered into the software, the calculated PRT loads are very accurate. When conditions deviate from this ideal, such as when the polished rod is bending due to misalignment, the PRT loads may carry enough error to affect quantitative analysis. This occurs in perhaps 5–10% of installations.

Background: A Rod Rotator Case Study

A well exhibited unusual behavior related to downhole friction, which was later determined to be connected to rod rotation. This specific example is beyond the core scope of this paper but is presented as it formed the basis for questioning whether bending was in fact occurring. This also provides a compelling example of how accurate the PRT data can be under the right circumstances.

On one particular day, where the water cut reached 100% (which is thought to have exacerbated friction), a definite pattern could be observed through the course of each rotation. This pattern increased and then sharply changed. The shape of the resulting cards and pattern were undeniable and indicated a buildup of friction and a sudden release. This was visually correlated to a deflection of the bridle. On subsequent days, when the water cut returned to approximately 96%, the friction phenomenon initially appeared to have disappeared. On closer inspection of the subsequent dynamometer acquisitions, a different pattern emerged at reduced intensity. The sequence of dynamometer cards at the rotational interval is shown in Figure 1.

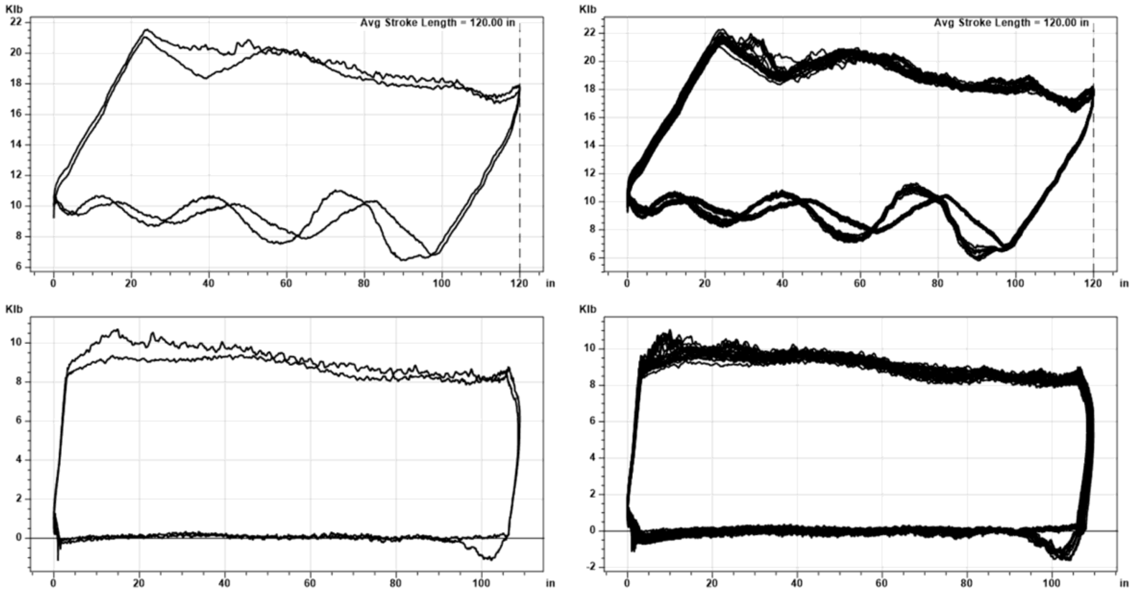


Figure 1 – The initially observed “Interesting” dyno card, gathered with the PRT. This was determined to exhibit rotationally induced frictional card “deformities”. For convenience, the adjacent cards at the torque release event are shown. Intermediate dynos progress gradually from one to the other and then suddenly change across the 2 strokes shown (left). 10 strokes before and after are shown to illustrate how stable this condition was. This was determined to be rotationally induced due to the regularity of the recurrence relative to the rotational period. The source of the friction is believed to be a significant change in fluid properties. During this period the well produced 100% water and was later determined to have a liner failure which likely introduced solids. The well failed due to worn tubing and “flat rods” were observed.

Before the underlying dynamometer signature was identified, a long-term pattern of cyclic load variation was observed in the raw data. The PRT has been commonly known to indicate polished rod bending. This raised a question central to this paper: was the observed cyclical load variation caused by polished rod bending as the rod rotated through a misalignment, or was it caused by thermal effects as the PRT moved in and out of the polished rod’s shadow?

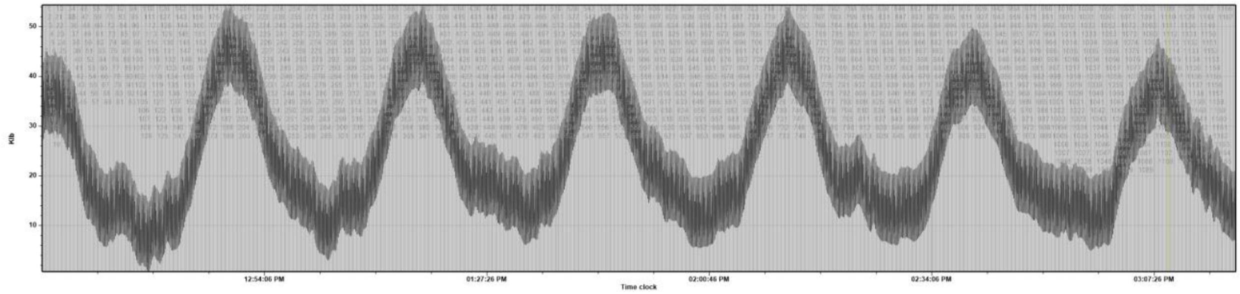


Figure 2 – When the raw data was viewed, a cyclic pattern emerged. This followed the rotator period, but (initially) was not thoroughly understood if this was due to thermal changes in the sensor, or from polished rod bending (this was later determined to be thermally induced).

Brief discussion of Rotational Event Observation in PRT Dynos

Several thousand dynamometer cards were gathered using a PRT across multiple days. Several multi-hour runs were obtained to analyze the well's behavior, with continuous data acquisition while the rod rotator operated normally.

Using a PRT for long-term friction analysis may seem counterintuitive. A horseshoe load cell would provide more accurate absolute load data. However, installing a horseshoe requires stopping the well, which would fundamentally alter the system under measurement. The changing friction was believed to be caused by rod rotation, and so a start/stop cycle may have "dislodged" the rotational resistance. At some point the system would have reached equilibrium again, but this would have introduced uncertainty in the overall analysis and a greater acquisition time requirement. The PRT was installed while the well continued pumping, preserving the continuous operation dynamics and the very friction behavior under investigation. It should be noted that the manufacturer discourages installing the PRT while the unit is pumping as smashed fingers or worse may result.

The results were compelling. A cyclic repeating dynamometer card signature appeared with high regularity. Every 175 strokes (within a stroke or two), corresponding to exactly one full rotation of the rod rotator, an outlier card was observed. A distinct variation in the surface card data occurred at this interval and was absent on cards in between. The outlier cards were subtle; barely different from adjacent cards when viewed individually. In general, these cards did not appear significant, much less "different" by standard interpretation methods. In fact, this was initially missed when reviewing the data because they appeared to simply be normal pumping variation. It was only when viewed in the context of their repeatable appearance at the exact rotational interval, across many days, that the pattern became too consistent to attribute to normal card variation. The PRT data quality was sufficient to detect a load variation of approximately 200 pounds in specific regions of the dynamometer card.

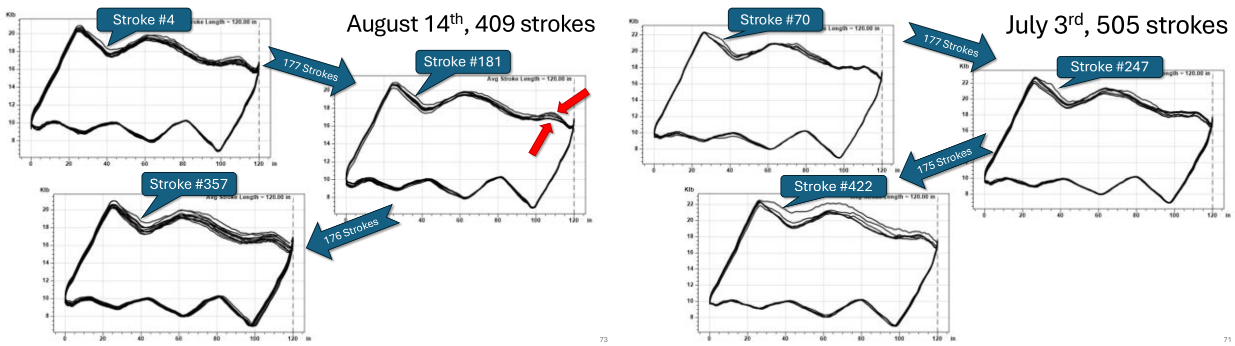


Figure 3 – Once the well returned to producing oil, the rotationally induced friction was believed to have disappeared as well. On closer examination of extended dynamometer acquisitions, over several days, a clear pattern became evident. A very subtle "out of place" dyno was observed with high regularity every 175 strokes, corresponding to the rotational period. This "odd" dyno would otherwise appear inconsequential as it doesn't inherently appear odd. When viewed in the context of several thousand cards, with knowledge that this signature closely follows rod rotation, the pattern becomes apparent.

The well failed after several months. Flat rod boxes and flat-sided rods were observed, despite the rod rotator functioning normally at the surface. The flat rod boxes indicate ineffective rotation whereby the rod string was acting as a torsion bar, absorbing and suddenly releasing torque rather than allowing the rods to freely turn. The flat spots created additional torque requirements to overcome during rotation, which in a deviated well translated to additional normal force at the rod-on-tubing contact. This is precisely the increased tension that appeared in the dynamometer data at the 175-stroke interval. The excessive wear at the rod-on-tubing interface ultimately wore through the tubing. The PRT was able to see these events, but they were so inconspicuous that they were initially written off as normal variations.

Temperature Effects on PRT Readings

Changes in temperature of the PRT, or the polished rod itself, are a primary cause of relative load drift over time. A constant temperature would yield constant measurements, but outdoor ambient conditions cannot be held constant. Further, the PRT sensing element is physically offset from the center of the polished rod, meaning that as a rod rotator turns the polished rod, the PRT passes through the shadow of the polished rod (assuming the sun is at an angle). The polished rod itself, however, is always exposed to the sun in a uniform fashion. While the specific surface facing the sun changes with rotation, its thermal mass is constant. A slowly rotating polished rod reaches thermal equilibrium and maintains effectively the same temperature (and range of tensile-induced diameter change) regardless of rotational angle. The PRT, on the other hand, experiences different thermal expansion depending on whether it is in direct sunlight or in the rod's shadow.

When a rod rotator is present and active during acquisition, a cyclic pattern may appear in the raw data as the PRT alternates between sun and shadow. This pattern may be misinterpreted as polished rod bending. Additionally, the thermal-induced drift may be affected by environmental changes such as clouds temporarily casting a shadow on the PRT. Still other temperature effects may be present, such as a pumping unit positioned so that a shadow is cast on the PRT during part of the stroke. For example, the angle of the sun and position of the horsehead may place the PRT in a shadow only during the bottom of the stroke. This cyclic pattern (in the period of rotation) is only present on sunny days. On partly cloudy days the pattern may appear irregular.

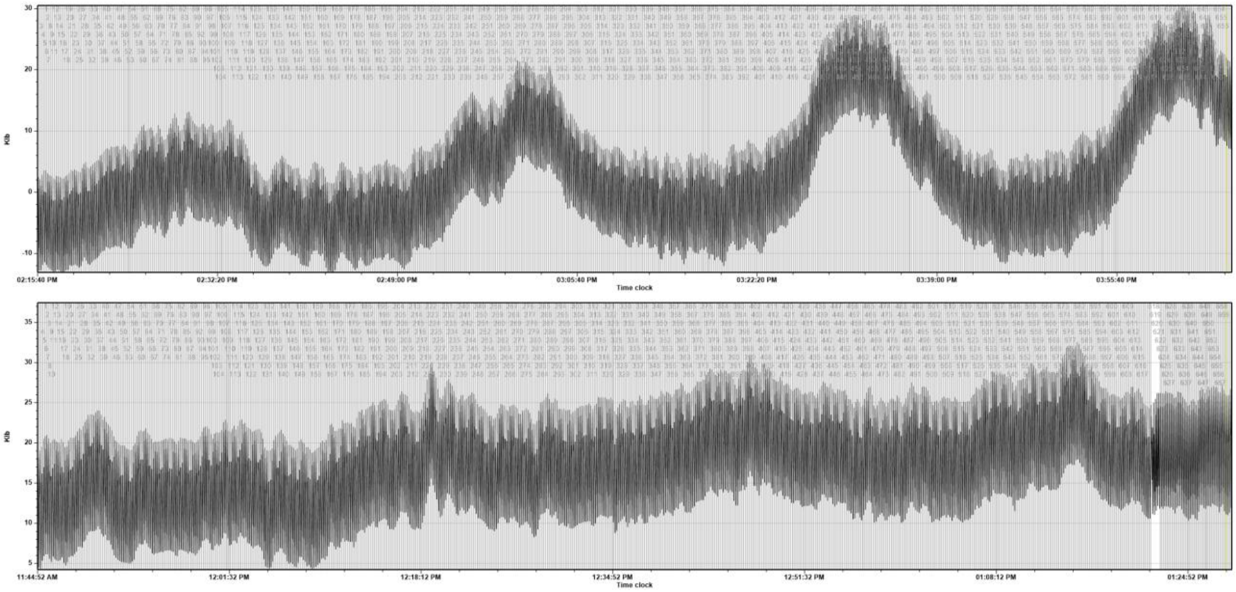


Figure 4 – Top: this shows a sunny day where the raw data follows a clear cyclic pattern (656 strokes). This was coincidentally the day when the initial frictional observation occurred. Bottom: The same well on a different, partly cloudy day, does not exhibit this clear cyclic pattern and appears random. This is likely a factor of the partial cloud cover and was verified from historic weather reports.

Thermal Drift

The PRT output drifts steadily as the transducer temperature changes, producing a trend in the load data that is clearly correlated with time (and thus sun angle) rather than with any mechanical event in the pumping system. The load span of each individual stroke remains mostly consistent. In other words, the card shape is preserved, but the absolute baseline shifts gradually. Because the dynos are effectively pinned to a minimum load, the span may range over the period of thermal change. In the example well, the peak loads, as shown on the processed dynamometer view, range approximately 1000-2000 lbs (see Figure 1 and Figure 6). Note: this range varied with temperature too (a greater temperature delta yielded a greater card load range), but this temperature drift was slow and steady. This is easily identified as thermal drift in the cyclic pattern of the sunny day, but is harder to distinguish on a partly cloudy day, where the sun might randomly appear for a short period (see Figure 4).

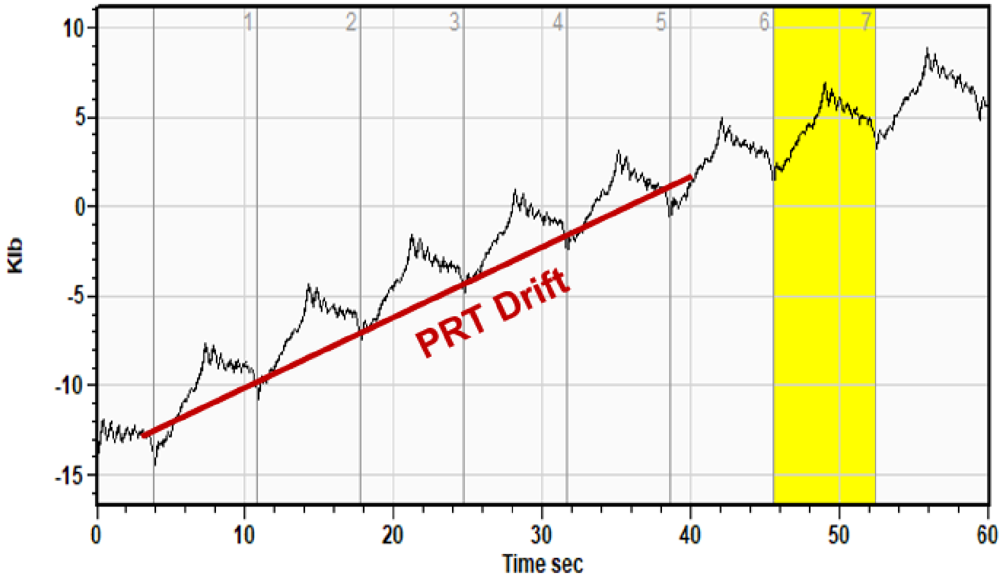


Figure 5 – Temperature Change Results in Relative Load Drift. This is visible when viewing the raw data, but is corrected when viewing the processed dynamometer data.

In terms of qualitative analysis, slow and steady temperature drift has very little effect. The pump card shape, which drives most diagnostic decisions, remains reliable. The load span may change (the card appears taller or shorter), and absolute load values will shift, but conditions like gas pound, pumped-off, or partial fillage are readily identifiable regardless. The impact on rod loading from temperature change can be mitigated by reinstalling the PRT and adjusting the tightness until the output returns to near zero (in other words, readjusting the knob). Rapid temperature change within a stroke can impact the qualitative analysis by skewing the card. This is where temperature drift can be confused with bending and vice versa.

The operator should make an effort to maintain the PRT at the same temperature as the polished rod or allow sufficient time for the PRT to equalize after installation. If temperature changes during acquisition, several mitigation strategies are available:

a) Cover the PRT with a shade to isolate it from intermittent cloud cover, direct sun exposure, or transient shadows from the pumping unit.

b) Disable the rod rotator to prevent the PRT from cycling between sun and shadow. This can be done with a pair of spring clamps and a short cord by simply keeping the rotator arm in the “up” position.

c) Install the PRT on the polished rod well before beginning acquisition, allowing the transducer temperature to equalize with the polished rod. This is particularly important when the PRT is stored in an air-conditioned truck cab between acquisitions.

d) Annotate the test with environmental conditions (time of day, sun angle, cloud cover) so that temperature effects can be considered during analysis.

As noted above, this is of most concern when absolute load values are desired. A deep rod part and a stuck-open valve are functionally identical in terms of detectable load at surface (both present as no pump action at surface). The PRT can identify no pump action but would not reliably distinguish a deep rod part from an up-hole rod part. In other words, a valve issue may be resolved by temporarily tagging the well to jar the trash loose. Deploying a rig in this scenario would be suboptimal. A stuck pump valve can sometimes be addressed by a skilled operator without the need for a rig. In short, to be as accurate as possible with the diagnosis, a horseshoe load cell should be used whenever absolute accurate loads are required. For qualitative analysis, and for relative load analysis (not absolute load), the PRT often provides substantial convenience while maintaining actionable results.

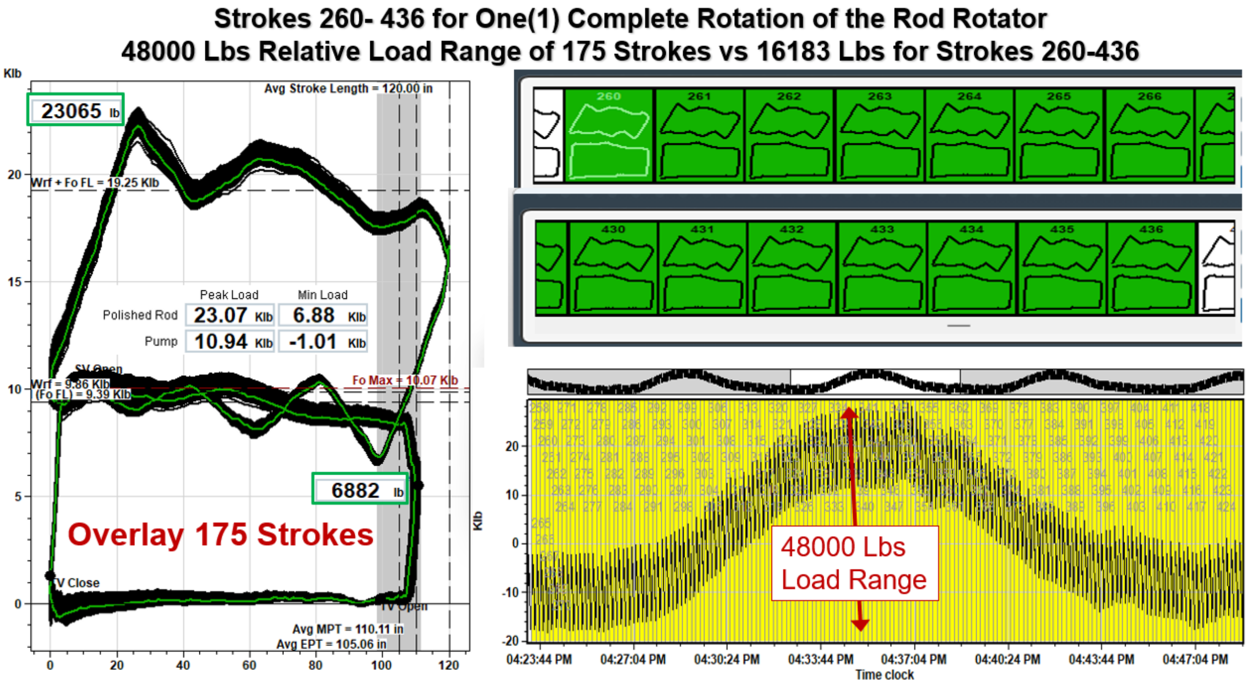

Strokes 260- 436 for One(1) Complete Rotation of the Rod Rotator
48000 Lbs Relative Load Range of 175 Strokes vs 16183 Lbs for Strokes 260-436

Figure 6 – 175 Sequential Strokes Spanning One Complete Rod Rotator Cycle. Both the processed dynamometer data (left) and the raw data (bottom right) are shown. In the raw view, the load appears to drift 48000 lbs, but when corrected and viewed as dynamometer plots, the load range is much narrower.

Figure 6 shows a subset of 175 sequential strokes (stroke 260 through stroke 436) selected from 702 strokes with an average period of 9.245 seconds per stroke, acquired over approximately 1 hour and 48 minutes beginning at 3:43 PM CST on January 7, 2026. These 175 strokes represent one complete 360° rotation of the rod rotator (the rod rotator was not disconnected during this acquisition). During this rotation, the PRT moved through full sun and full shadow. The resulting load data shows a sinusoidal relative load range of approximately 48,000 pounds across the full rotation, while each individual stroke maintained a consistent load range of approximately 16,182 pounds. For reference, stroke 260 (shown in green) had an absolute peak polished rod load of 23,065 pounds and an absolute minimum of 6,882 pounds. Visually, there appears to be approximately 500 pounds of error relative to stroke 260 when compared to the full 175-card overlay of surface and pump dynamometer cards.

In raw terms, this would be classified as extreme PRT drift, but because the temperature change was gradual, the stroke-to-stroke drift was small and the processed dynamometer card shapes remained diagnostically useful. The software's zero-load offset correction places each individual pump card on the zero-load line. The zero offset for each stroke is automatically set by software placing each individual pump card on the zero-load line when the traveling valve is open on the downstroke. However, if the temperature drift is too rapid (within a stroke), the PRT zero-offset load correction may result in each adjusted pump card having more load error.

Polished Rod Bending

Bending of the polished rod produces a fundamentally different effect on PRT data than temperature drift but may also follow the period of a rod rotator. Where thermal effects cause a gradual baseline shift correlated with time and sun angle, bending introduces a load component that is tied to stroke position and repeats with mechanical periodicity. Intermittent shadows from the pumping unit may cause a similar signature within a single stroke. When such a signature is encountered, and bending is suspected, observe the PRT for at least one complete stroke to identify cyclic shadows from the stroking path. Polished rod bending is a significant concern and will likely result in a polished rod failure if left untreated, so particular attention should be given if this condition is suspected; do not assume temperature is the culprit. Verify physical alignment. Frequent stuffing box issues likely accompany this misalignment condition.

Misalignment between the horsehead, wellhead, carrier bar, or polished rod causes the polished rod to flex laterally during each stroke. At 10 SPM, the polished rod undergoes over 5.2 million bending cycles per year. This lateral deflection induces stresses that are not purely axial. The PRT senses a diameter change that includes a bending component, which the software interprets as a load change. The result is a characteristic tilt or distortion in the dynamometer card that varies with PRT orientation relative to the bending axis.

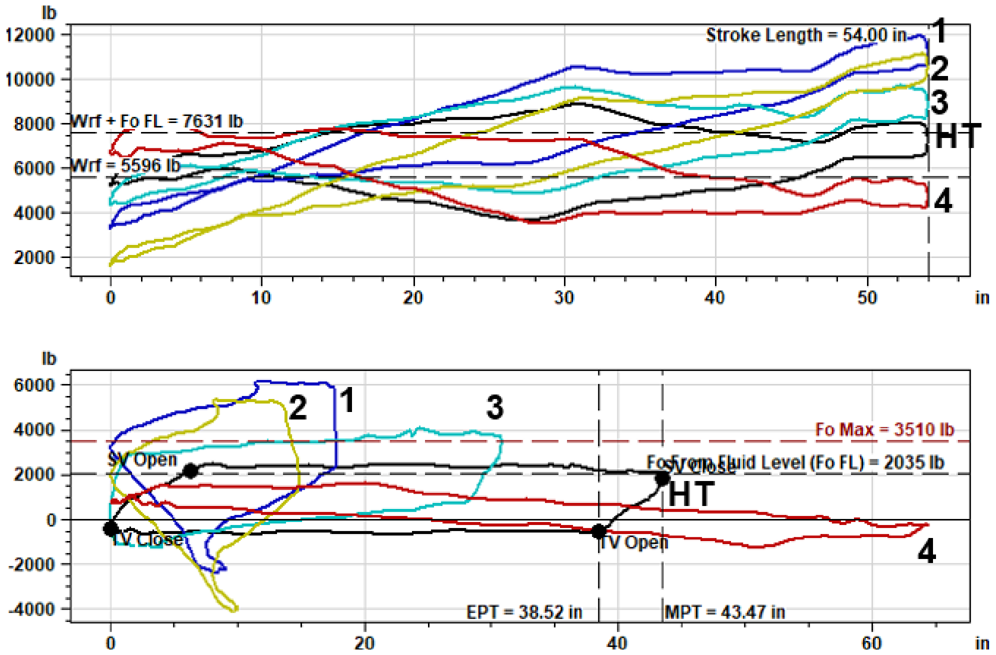
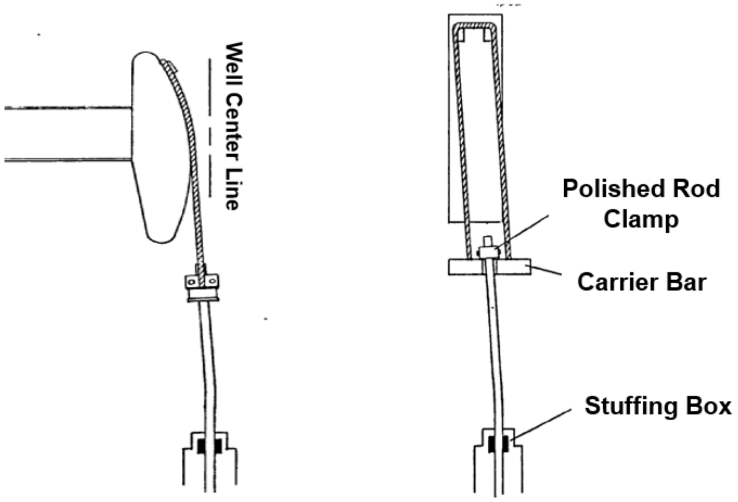


Figure 7 – Bending Due to Misalignment: Loads Change by PRT Placement on Polished Rod at different angles relative to the plane of bending. Note that the load is not simply shifted uniformly but is changing through the stroke. Temperature impacts the load reading uniformly and can be addressed uniformly. This is why temperature changes do not generally alter the card shape (it is a simple zero issue). Bending, however, may create scaling issues which result in irregular changes to the pump card.

Figure 7 compares surface and pump cards collected simultaneously with a horseshoe load cell (black trace) and a PRT positioned at four different angles with respect to the pumping unit axis: 1) 45° CCW, 2) perpendicular, 3) 45° CW, and 4) parallel. The polished rod misalignment was measured at 0.5 inches from vertical over 4 feet of height. The horseshoe load cell-HT, which measures axial load directly through its 12 strain gauges, was unaffected by the bending. The PRT cards, however, varied significantly depending on orientation. The PRT installation angle is not generally controlled. Typically, it is installed with the clamp opening facing the pumping unit but could vary significantly from well to well. This is further complicated by an operational rod rotator that can change its orientation through the acquisition.

The surface stroke length from the PRT and from the horseshoe load cell are the same. This is because position (or surface stroke length) is measured by the accelerometer. Three of the four PRT surface dynamometer cards slope upward and to the right (indicating apparent under-travel), while the fourth slopes downward and to the right (apparent over-travel). The apparent over-travel PRT surface card yields a pump stroke that is erroneously much longer than the 43.47-inch maximum plunger travel indicated by the horseshoe pump card. The remaining PRT pump cards all show under-travel, with progressively shorter pump strokes as the upward slope of the surface dynamometer card increases. This is because the wave equation confuses load for position when erroneous data is input. In other words, only the load interpretation changed while the surface stroke lengths were identical across all measurements.

The reason the surface card is "sloped" is because the tensile component shifts as a triangle (formed by the polished rod and the horizontal offset) gets smaller as the vertical distance changes. In other words, some of this tension load is converted to a horizontal "side load" component placed on the stuffing box. This horizontal component (and thus the measured tensile component) varies with the deflection from the top to bottom of stroke.



Pumping Unit is Too Far Back

Pumping Unit is Right or Left of the Wellhead

Figure 8 – Pumping Unit Misalignment. Pumping unit placement over the wellhead is a complex 3-dimensional problem. In general, the observed misalignments are visible on the polished rod, and most cases can be identified with a bubble level. Note that the pumping unit may appear to be aligned at the top or bottom of stroke, but not at the other end.

Pumping unit misalignment (Figure 8) can occur when the unit is set too far back or forward from the wellhead, positioned to one side, or when the carrier bar itself is misaligned. When an abnormally shaped PRT surface or pump card is identified, visual inspection is recommended: look from different angles to observe how the polished rod moves relative to the horsehead. Check the carrier bar and polished rod with a level. Look for uneven bridle length. Check between the clamp and the carrier bar with a feeler gauge. If it slides under one side, the clamp is not installed correctly. With the clamp removed, look for a worn or dished-out area on the carrier bar where the clamp sits. If a load cell is sitting on the carrier bar, use a leveling plate or spherical washer to spread the rod loading evenly across the carrier bar. Examine the pumping unit frame and base for rust stains where water has moved in and out between the base and frame, and check the pumping unit tie-downs for any signs of movement or looseness.

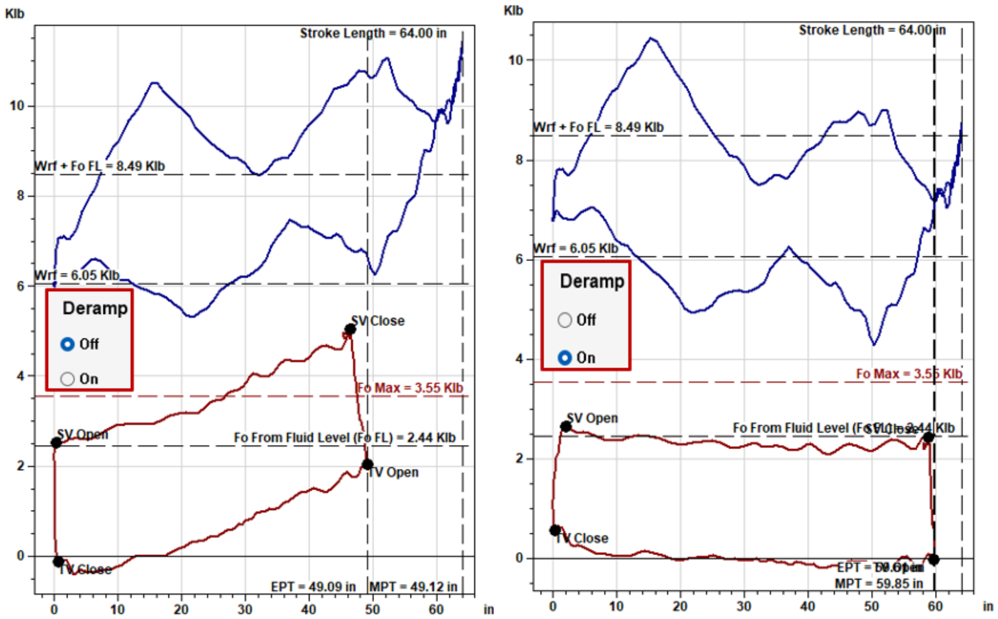


Figure 9 – Deramp Software Correction of Pump Card Tilt. This can be used to further correct load measurement error that scales through the stroke. If the calculated pump card is skewed, the underlying issue that is causing that load scaling error should be investigated. The deramp option is provided to help provide insight to the downhole pump card condition despite surface measurement error.

When a sloped or concave pump card is identified, the deramp software feature can be evaluated to improve the presentation of the pump card relative to the zero-load line (Figure 9). During the upstroke, when the standing valve is open, the differential pressure across the plunger is fairly constant, so the pump card load line should be horizontal. The deramp function eliminates the tilt and redraws the pump card so that the upstroke load is mostly horizontal, which can improve qualitative analysis of the pump card. However, even if the deramp feature corrects the visual appearance of the pump card, the operator should consider using a horseshoe load cell to evaluate the well's performance. The underlying misalignment, if left untreated, can result in a catastrophic polished rod failure and damage to the entire rod string. When bending is suspected using the PRT, and verified with a visual inspection of the alignment, it is recommended to shut down the well until the wellhead and pumping unit are re-aligned.

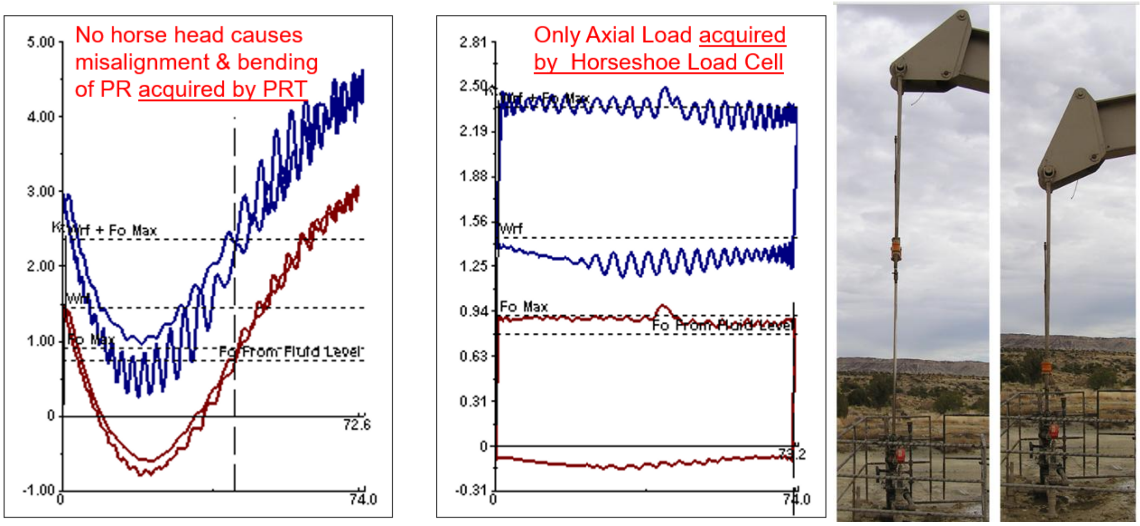


Figure 10 – Polished Rod Deflection on Pumping Unit Without Horsehead. Note the rigid attachment of the polished rod in the photos on the right. A typical pumping unit provides the horsehead to create an arc where the polished rod can remain vertical. In this style pumping unit, the polished rod bends with the arc created by the attachment point. Note: the plot on the left is a dynamometer plot from a PRT, and the middle plot is from a Horseshoe load cell.

Figure 10 shows an INDECO-style pumping unit where the polished rod connects directly to the walking beam without a horsehead. In this geometry, the polished rod does not travel vertically over the wellhead. Instead, it deflects through an arc as the walking beam rotates about the saddle bearing. The dynamometer data collected using the PRT on this type of unit is not usable for quantitative analysis due to the inherent bending. For pumping units without a horsehead, a horseshoe load cell should be used, as it measures only axial load and is not affected by lateral deflection.

Limitations of PRT Bending Detection

A pumping unit may be misaligned, yet the dynamometer card may not positively identify the condition. Several factors can cause bending to go undetected by the PRT.

First, the PRT may be placed on an axis that does not indicate bending. Because the bending-induced diameter change depends on the orientation of the PRT relative to the bending plane, a PRT positioned along the neutral axis of the bend will show minimal distortion. Rotating the PRT 90° is the simplest diagnostic test, but this may not commonly be performed during a routine acquisition.

Second, the PRT may not be exposed to the range of rotational angles where the bending signature is present. If the rod rotator is active, the signature will rotate with the polished rod. A short acquisition may capture only the angles where bending produces little or no effect on the PRT's reading.

Third, the misalignment may not be significant enough to manifest in the polished rod loads. Misalignment is a function of trigonometry in that the angle of the polished rod at the top and bottom of stroke determines the bending force applied. This angle (and thus the bending applied from tension acting at that angle) is generally more significant at the bottom of stroke, though this is not always the case since alignment is a complex three-dimensional problem.

Fourth, the length of polished rod exposed between the wellhead and carrier bar also contributes to the severity of bending. A unit where the bridle is set very close to the wellhead may see more significant bending effects than a unit with several feet between the wellhead and bridle at the bottom of stroke.

Fifth, the type of pumping unit matters as well. Long-stroke linear units, for example, do not change the angle of the mechanical structure from the top of stroke to the bottom in the same way as a beam-style unit that varies the length of exposed cable. For these reasons, the absence of a bending signature in PRT data does not guarantee that the pumping unit is properly aligned. Visual inspection remains essential.

Distinguishing Thermal Drift from Bending

Both thermal drift and polished rod bending can produce trends in PRT data that alter apparent loads over time. However, their signatures are distinct once the operator knows what to look for.

Thermal drift produces a gradual, continuous shift in the load baseline that correlates with environmental conditions. Time may be required to allow a cooler PRT to equalize in temperature to a hot polished rod. Solar heating tracks sun angle, time of day, and cloud cover. If a rod rotator is active, the drift follows a sinusoidal pattern as the PRT moves between sun and shadow. Cloud cover, or sharp ambient temperature changes (i.e. a cold gust of wind) may introduce random thermal drift.

Polished rod bending, by contrast, produces a load distortion that is tied to stroke position. The pump card itself changes shape by tilting, sloping, or curving in ways that depend on where the PRT is oriented relative to the bending axis. This distortion persists regardless of weather or time of day. It does not drift gradually; it may be present and consistent from the first stroke or may appear and disappear as the rotator orients the PRT relative to the bending axis. If the PRT is rotated through 90° around the polished rod and the card shape changes (and thermal impact is minimized), bending is the likely cause.

In the case study presented in this paper, temperature was the primary driver of load variation. An additional phenomenon was present related to downhole frictional resistance. While that frictional resistance affected the dyno card, it was not bending or thermal drift. This was the basis for gathering large volumes of data, from which the long-term sinusoidal load variation was additionally observed. This pattern tracked the rod rotator’s 175-stroke period and correlated with the PRT’s passage through sun and shadow and was attributable to thermal drift. The short-term outlier card appearing at each rotational interval was a mechanical signature of the rod string's torsional resistance being overcome, and a precursor to the eventual tubing wear-through. Neither of these phenomena is directly attributed to polished rod bending. Recognizing which was which was essential to correctly diagnosing the well.

Comparison to the Horseshoe Load Cell

The horseshoe transducer measures polished rod load directly using 12 strain gauges mounted on three supporting members. The transducers are manufactured with instrumentation-grade stainless steel and incorporate a high-accuracy accelerometer from which the software computes velocity and position like the PRT. Off-loading or side-loading due to a tilted carrier bar does not affect the accuracy of the load measurement due to the averaging effect of the multiple gauges. The horseshoe transducer is calibrated to yield an overall accuracy of 0.5% of range or better. The 4-inch horseshoe transducer is rated at 30,000 pounds and the 5-inch horseshoe transducer is rated at 50,000 pounds. Because the horseshoe is calibrated to a NIST standard and measures axial load directly, it provides absolute load values without the per-stroke software correction required by the PRT.

The tradeoff is installation complexity. The horseshoe must be placed between the carrier bar and the polished rod clamp, which requires stopping the well and temporarily supporting the rod load. For the standard 4-inch horseshoe, a temporary polished rod clamp and knock-off block are used to create approximately 3 inches of free space between the carrier bar and permanent clamp, into which the transducer is inserted. The 5-inch horseshoe transducer uses a hydraulic jack assembly that raises the polished rod less than one-quarter inch during installation, making it easier and safer. However, the 5-inch system requires a spool/washer assembly to be placed (generally permanently) over the polished rod between the carrier bar and clamp. In either case, the act of installing the horseshoe raises the plunger slightly within the pump barrel, meaning the dynamometer test is performed with the plunger in a slightly different position than during normal operation. The PRT avoids both issues because it *can* be installed without stopping the well and does not alter plunger position. As noted above, the manufacturer discourages PRT installation while running as it presents safety concerns. For a detailed description of horseshoe transducer installation procedures, see Rowlan et al. (2004).

For most routine analysis, the PRT provides sufficient accuracy. The results from the rod rotator frictional resistance identified in the dynamometer cards illustrate this. When quantitative precision is required such as determining the depth of a rod part, performing valve tests under variable thermal conditions, or evaluating a well where polished rod bending is suspected, the horseshoe load cell should be used.

Best Practices

Initial installation is significant. If the PRT is brought from a cold vehicle to the hot desert sun, the temperature difference between the PRT and a polished rod heated by sun and produced fluids may be substantial. It is best to install the PRT on the polished rod at the earliest opportunity after arriving at the well. While the PRT acclimates, the cards gathered will still be useful for qualitative analysis (card shape), but stable temperatures will provide the most accurate results. Absolute loads on the initial cards may differ from later cards if the temperature change is significant.

As discussed above, determining the depth of a rod part is best done with a horseshoe load cell. Identifying "no pump action" in general is easily done with a PRT; however, identifying the approximate location of an actual rod part in the rod string may be misleading. If the rod part is at the pump, a misdiagnosis of pump with traveling valve stuck open would be the worst-case scenario. Conversely, determining a pumped-off or gas pound condition (partial fillage) is well within the capabilities of the PRT.

Valve tests are another example and are best performed when the PRT is at thermal equilibrium. If the sun is actively warming the PRT, the valve test results may be skewed. Special attention should be given on partly cloudy days when the sun may shine on the PRT with irregularity. Optimally the horseshoe load cell should be used for valve tests as this eliminates thermal drift that may be mistaken for a leaky valve. In general, one or more subsequent tests should be performed with a PRT to ensure thermal drift is not mistaken for load variation on the valve test analysis.

If the PRT is used for extended data acquisition, pay attention to long-term peak load trends. These may change due to thermal drift, and care should be taken not to make decisions based on absolute load values without accounting for temperature. Consider noting time of day and weather conditions in the data log.

When PRT dynamometer load data appears to slope, it may be attributable to one of the following:

a) Temperature differential between the PRT and the polished rod. Allow the PRT temperature to equalize, or install the PRT early and let it stabilize before acquisition.
b) Misalignment of the horsehead, wellhead, carrier bar, or polished rod. Visually inspect and re-align as needed.
c) PRT not centered on the polished rod. Use the half-moon cut to center the PRT. Do not push it too far forward, or load drift can occur.
d) PRT too close to a load-bearing clamp or lateral contact point. Attach the PRT at least 6 inches from any clamp. Stress lines are not uniform near the clamp.

e) Rusty or dirty polished rod surface. If the steel surface is not clean and prepped, use emery cloth to clean off loose material and smooth the surface before attaching the PRT.

f) Consider disabling the rod rotator during extended acquisition, because temperature change caused by rotation between sun and shadow can have a large impact on relative loads.

Conclusion

The PRT is a valuable and versatile dynamometer that can be quickly installed simply by clamping it to the polished rod below the carrier bar. The PRT is used to gather load and position data that allows the calculation and determination of a surface dynamometer card, a pump card, and traveling and standing valve tests when using the portable system and software. Accurate qualitative analysis such as pump card shape, pump condition determination, identification of gas pound, pumped-off, and partial fillage, can be achieved reliably with the PRT in virtually all field conditions. The insights presented in this paper add precision, particularly for extended acquisition and quantitative analysis.

The central finding of this paper is that thermal drift and polished rod bending produce superficially similar load trends in raw PRT data, but their underlying mechanisms and diagnostic signatures are distinct. Thermal drift can be caused by differential heating of the PRT as it passes between sun and shadow during rod rotation. It produces a gradual baseline shift that correlates with environmental conditions, preserves card shape when temperature change is slow, and is absent or irregular on overcast days and at night. Polished rod bending is caused by mechanical misalignment between the horsehead, wellhead, and carrier bar. It produces a load distortion that is tied to stroke position, alters card shape depending on PRT orientation, and persists regardless of weather.

In the case study presented here, temperature was the primary driver of load variation during long-term analysis of a well with a rod rotator. The thermal drift tracked the 175-stroke rotation period as the PRT cycled between sun and shadow. A separate mechanical anomaly related to downhole frictional resistance, rather than polished rod bending, was presented for context. This shows compelling results from PRT data that resolved very small *relative* changes in the dynamometer card. The well ultimately failed due to excessive wear at the rod-on-tubing interface, despite a functioning surface rotator. Flat rod boxes and flat-sided rods confirmed that effective downhole rotation was not occurring.

For operators using the PRT for extended data acquisition, the following recommendations apply: install the PRT early to allow thermal equilibration before beginning acquisition; consider disabling the rod rotator if thermal cycling is a concern; annotate environmental conditions in the data log; and when polished rod bending is suspected, rotate the PRT 90° around the polished rod to test whether the card shape changes. If bending is confirmed, use a horseshoe load cell for accurate load measurement and investigate the alignment of the pumping unit and wellhead. Bear in mind that the absence of a bending signature in PRT data does not guarantee proper alignment; a visual inspection of the pumping unit and wellhead remains essential.

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