ROD DROP MONITORING, DOES IT REALLY WORK?

by

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ABSTRACT

In 1994, the Twenty-Third Turbomachinery Symposium featured the first session of Discussion Group 12, "Reciprocating Compressors." Each year since its inception, there has been one consistent discussion topic brought up year after year. As the discussion group leader puts the topic up on the flip chart, it is typically listed as "Rod drop monitoring, does it really work?" or something very similar. As the topic is discussed, the room is usually split, almost precisely in half. One group details the problems they have had, and how rod drop monitoring has been ineffective. The other half describes the tremendous saves they have experienced and how rod drop monitoring has revolutionized their reciprocating compressor maintenance program. The intent of this paper is to describe the measurement, the basic assumptions that must be met, and the issues that can make the difference between a system that really works, and one that is ineffective. A discussion of some basic research into rod dynamic motion is presented in an effort to help those who make this measurement understand what obstacles they may face. The important aspects of an effective system are described. Finally, a series of case histories will be presented that show instances where the system really did work, as well as instances where problems occurred and how they were addressed.

INTRODUCTION AND MEASUREMENT DESCRIPTION

There has over the years been a misunderstanding as to the purpose of rod drop monitoring, what it is and what it is not. Rod drop monitoring is applied to reciprocating compressor pistons that use rider bands to support the piston in the cylinder clearance. The bottom line purpose of the measurement is to determine when a piston rider band is worn out, and to give the operator time to shut the machine down before there is damaging contact between the piston and the cylinder wall. The basic assumption of rod drop monitoring is that gravity acts on the piston such that the piston rides in the bottom of the cylinder clearance. Based on this assumption, as the rider band wears, the position of the piston in the cylinder clearance "drops." If we can measure this drop, and we know how thick the rider band is, we can determine when the rider band is worn out and shut down the machine. Measuring the piston position directly is difficult, so the position of the piston rod is measured, which is more accessible. Rod drop monitoring gives no indication of the condition of piston rings or packing rings, as they both float in their clearances. On pistons that do not have rider bands, rod drop monitoring can give some indication of wear in the cylinder wall, but cylinder walls do not typically wear evenly, so the point in the stroke where the measurement is made will be important in determining cylinder wear.

Nonlubricated compressor cylinders are excellent candidates for rod drop measurements. Conversely, there is not much justification for a rider band measurement on lubricated reciprocating machines that compress clean, sweet, dry gas (for example, a natural gas pipeline compressor), since there is little rider band wear. The only exception is for protecting against loss of lubrication to the piston. In this event, rider band wear is rapid and the rod drop indication provides early warning. Most machines in chemical plants and refineries fall into a gray area, having lubricated pistons but compressing gases that are not clean, sweet, and dry. Water and other contaminates in the gas stream can wash out or break down lubrication, resulting in rider band wear. Hydrogen machines in refineries are excellent candidates for rod drop since they are fairly critical and are prone to water and other contaminates, especially iron sulfides and other sulfur compounds and acids.

There are currently two primary methods to indicate rod drop: proximity probe measurement and mechanical/eutectic indicators. In a proximity-based system, a proximity probe is mounted either vertically above or below the rod. Proximity probes use eddy current technology to measure the distance between the face of the sensor and some metal object, in this case the piston rod (Figure 1). As the rod moves relative to the sensor, the change in rod position is indicated on an electronic monitor, similar to a thrust monitor for a piece of turbo equipment. This measurement allows for the recording and trending of the rod position over time.

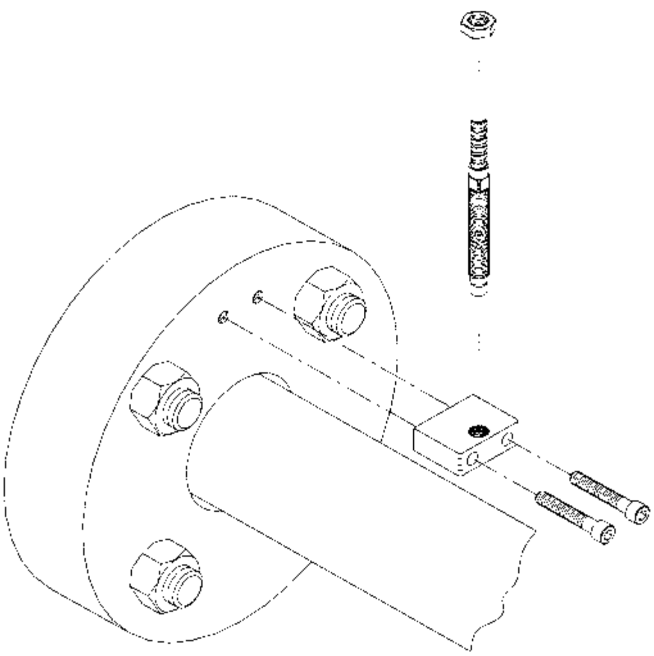

Figure 1. Proximity Probe Type Rod Drop Detector.

There are two primary types of mechanical rod drop devices. The first is a eutectic device (Figure 2) that uses a block of abradable material mounted directly under the rod. This block has a pocket inside that is attached to a nitrogen supply. As the rod drops, it contacts this block and wears it. When the rod has dropped sufficiently, the rod wears the block to a point where the pocket is opened and the nitrogen leaks out. This leak is detected as drop in supply pressure and either provides an alarm to the operator, or can be directly hooked to shut down the unit. The second type of mechanical device is a roller that is mounted under the rod (Figure 3). As the rider band wears and the rod drops to the point where the rod contacts the roller, the roller spins and locks, again opening a nitrogen leak path. The main disadvantage of either mechanical system is that there is no trend information. We do not know that the rider band is getting close to wearing out, we just get an alarm when it is worn to the point that action must be taken. With the proximity system we can see a trend, which allows for better maintenance planning.

BASIC ASSUMPTIONS

As mentioned previously, the basic assumption of the rod drop measurement is that the piston rides in the bottom of the cylinder (rigid piston rod, crosshead rides on bottom guide). If the piston is lifted or floating in the cylinder clearance, as would be the case with a vertical piston, the measurement cannot be effective. A corollary to this assumption is that the change in position of the piston rod where the measurement is made is proportional to the change in position of the piston as the rider band wears. It must also be assumed that the only thing that changes the piston rod

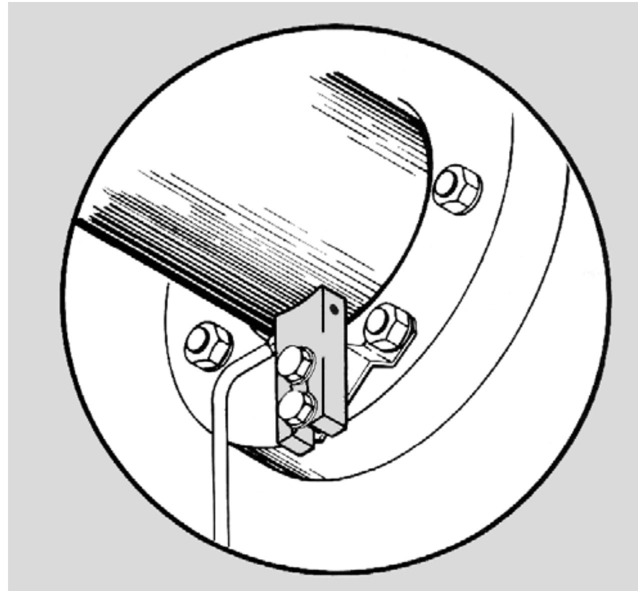

Figure 2. Eutectic Rod Drop Detector. (Courtesy, Exline Corporation)

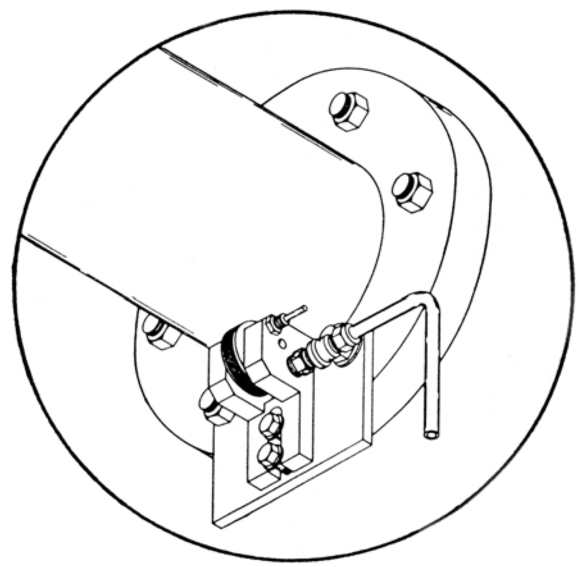

Figure 3. Roller Type Rod Drop Detector. (Courtesy, Exline Corporation)

position is the effect of the rider band wearing. As the many factors are discussed of making a good rod drop measurement, we will see that there are a number of factors that can break down these assumptions.

ROD DROP GEOMETRY

To really grasp how the measurement is made, and why the assumptions must be met if the reading is to be valid, a brief discussion of the geometry of the measurement is necessary. The basic assumption that changes in rod position where the measurement is made are proportional to the changes in piston position due to rider band wear is based on the principal of similar triangles (Figure 4). The rod drop measurement is typically made at or near the packing flange in the distance piece of the compressor cylinder. The measurement is referenced to the piston and rod when the rider band is new, represented by the horizontal line in Figure 4 from the wrist pin to the center of the piston. As the rider band wears, the piston drops below this horizontal line, and at the point of measurement there is a proportional drop in the piston rod. The amount of drop seen at the measurement point *B1* is a ratio of the rider wear *B2*, divided by the length *(L1 + L2)* times the length *L1*:

$$\frac{B2}{L1 + L2} = \frac{B1}{L1} \tag{1}$$

$$B2 = \frac{(B1 \cdot (L1 + L2))}{L1} \tag{2}$$

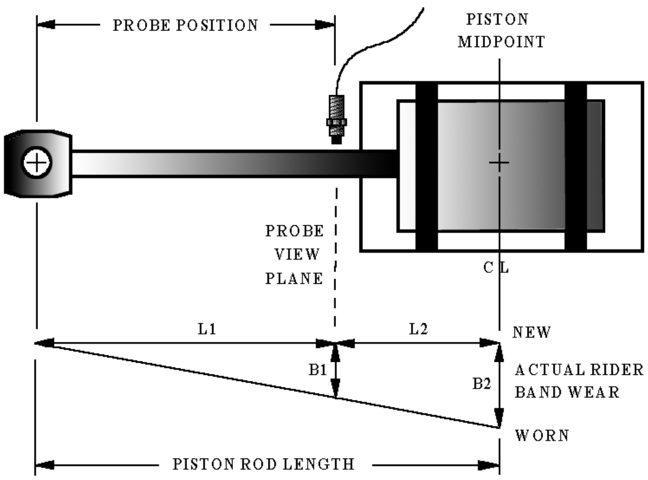

Figure 4. Rod Drop Similar Triangles.

When using a proximity-based rod drop system, the measurement can be corrected in the monitor using this ratio so that the actual rider band wear is indicated on the monitor. The problem with applying this correction factor is that any error in the measurement is then multiplied by the correction factor. With a mechanical system, the initial clearance between the rod and the mechanical indicator must be set to accommodate this difference between actual rider wear and the amount of drop that will occur at the point on the rod where the mechanical indicator is set up. If this is not done, the machine may not trip before the rider band has become dangerously worn.

INSTALLATION AND APPLICATION PITFALLS

There are many installation and application issues that can have a direct effect on the accuracy and validity of the rod drop measurement. The following are just a few of the more important ones.

Sensor Mounting

It is critical that the sensor, whether it is mechanical or proximity, be mounted as close as possible to the cylinder and in a solid fixture. Due to the correction factor discussed previously, the closer the measurement is made to the piston, the less impact any measurement errors will have. This is not usually a problem for low to medium pressure cylinders. On high-pressure small diameter cylinders, even if the probe is mounted to the face of the packing flange, the probe could be two or three feet (.61 to 1 m) away from the piston due to the large number of packing rings required to break down the pressure. In the past, it was common to mount proximity probes through the distance piece using a stinger assembly (Figure 5). This is not a good way to install proximity probes for several reasons. First, in this arrangement, the probe is not as close to the piston as it could be. Second, the probe is now measuring the position of the piston relative to the distance piece, not the cylinder. If there is thermal growth or other movement in the distance piece, then the rod drop measurement will reflect movement of the probe installation, not wear of the rider band.

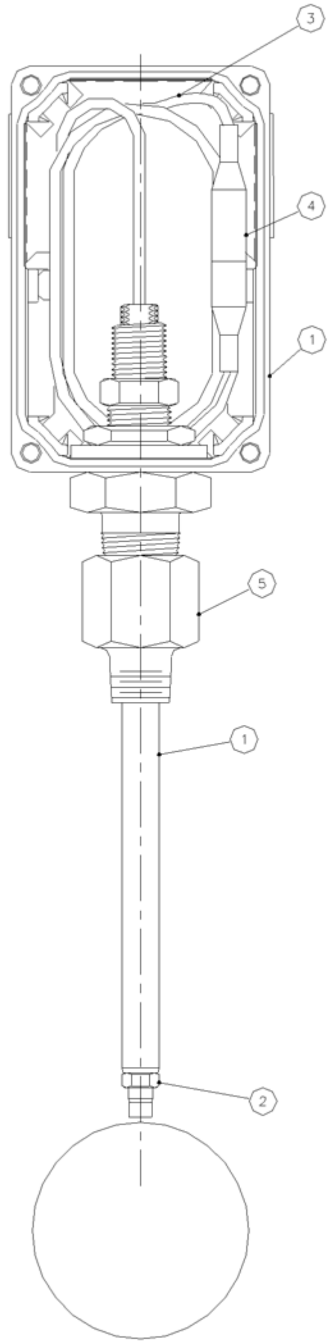

Figure 5. Probe, Probe Sleeve, and Probe Housing.

Piston Thermal Growth

On large pistons, especially those made of aluminum, the radial growth of the piston between cold shutdown conditions, and hot operating conditions may be significant. Indeed for large cylinders, the manufacturers recommend that the cylinder alignment be set low to the crosshead to accommodate this growth, and cylinders are oversized so the piston will have room to expand. As the piston expands radially as it heats up, the effect is to lift the piston rod relative to the rod drop detector. This must be accounted for when installing the detector and setting its position. On electronic rod drop systems, this is noted as a rod rise during startup and as the unit warms up. On large pistons, this rise may be enough to go out of the range of the proximity probe, or if the probe is mounted above the cylinder and is gapped too close, the rise may even result in the rod damaging the probe. On mechanical systems, if the rise is not accounted for, the piston rod will not drop enough to contact the mechanical element, and the rider band may wear out without an indication that it is happening. This effect is usually noted on pistons above 24 inches (610 mm) in diameter and is especially apparent on aluminum pistons due to the high coefficient of thermal expansion.

Piston Float

One of the basic assumptions discussed previously is that the piston must be riding in the bottom of the cylinder. On certain small diameter pistons, this may not be a good assumption. On pistons less than six inches (150 mm) in diameter, a large percentage of the rod is in the packing. Packing arrangements for high-pressure small diameter cylinders may be three feet (91 mm) long or more. In addition, for this case, the piston is a small percentage of the piston/rod assembly. The result is that misalignment or packing effects may result in the piston either floating in the cylinder clearance, or that the net radial force on the piston is not gravity acting downward but some other combination of forces causing the piston to either ride in the side or the top of the cylinder. If this is the case, the rod drop measurement is rendered ineffective, whether it is a mechanical or proximity measurement. This may be overcome to some extent in an electronic system by using X-Y probes and tracking the rod position in X-Y coordinates.

Rod Flex/Rod Sag

Another problem is long flexible piston rods, especially if attached to large diameter pistons. This is very common in process gas compressors that utilize double or triple compartment distance pieces. The longer the rod, the more flexible it tends to be and, if there is significant rod flexing, the dynamic rod motion may overshadow the rod position measurement. This may also result in wear on mechanical indicators that results in a false alarm. A large diameter piston on a flexible rod may induce moments in the piston rod due to the friction force as the piston changes direction (Figure 6). This is a particular issue on nonlubricated pistons. This also makes it very difficult to use rod drop measurements as an indication of cylinder-crosshead alignment.

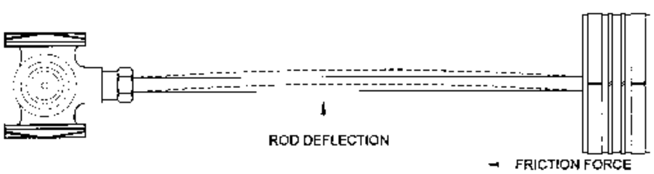

Figure 6. Piston Rod Deflection from Friction and Inertial Forces.

Proximity Probe Application

The basic good practices that apply to any proximity probe installation apply to rod drop as well; however there are some issues that are particularly important in making a rod drop measurement. It is extremely important that the probe be solidly mounted in a bracket that is not subject to either vibration or thermal growth. If the probe is moving relative to the piston rod, the measurement is rendered ineffective. As mentioned earlier, mounting a probe on a "stinger" assembly through the distance piece is asking for problems. The probe should be solidly mounted to the face of the packing flange. The probe should also be calibrated to the piston rod material. Some piston rods are made of unusual materials or have exotic coatings that may affect the calibration of the probe. Small diameter piston rods may be an issue if the probe is not exactly perpendicular to the rod. If the probe is not perpendicular, the scale factor may be affected. For large diameter pistons, it is also important to select an extended range probe so that thermal growth of the piston will not cause the rod to move out of the linear range of the probe. As an additional precaution, it is also recommended to mount the probe underneath the piston rod.

Piston rod flex and crosshead motion affect the average position of the piston rod. Changes in gas loads affect both rod flex and crosshead motion and in turn affect the average rod drop value. In order to reduce the effect of rod flex and piston rod movement on rod drop measurement, the signal from the proximity probe is measured at a single point in the crankshaft revolution. The number of degrees from cylinder top dead center (TDC) to when the rod drop measurement is taken is referred to as a trigger angle. The trigger angle is set on a stable point in the proximity probe waveform that does not change much with cylinder loads.

CROSSHEAD MOTION

Recent studies of piston rod motion of horizontal balanced opposed process compressors indicate crosshead vertical and horizontal motion directly influences the piston rod motion at the pressure packing case. Crosshead vertical motion is caused by a change in the forces acting on the crosshead. The forces acting on a crosshead in a reciprocating compressor include connecting rod load, piston rod load, hydrodynamic, and gravity.

Some of these forces can be calculated directly. The force from gravity can be measured on a scale. Combined inertial and pressure connecting rod load and piston rod load can be calculated from pressure data and mass data. Hydrodynamic forces from oil film interaction are more difficult to calculate.

As the crankshaft turns, the connecting rod, crosshead, and piston rod transmit the force to the piston. During each crankshaft revolution, the connecting rod moves above and below the crankshaft centerline. At each position, the horizontal force in the connecting rod balances out the force generated by the (horizontal) piston rod. Of particular interest are the combined forces acting at the crosshead pin. When the connecting rod is not in the horizontal position, there are basically four cases, as shown in Figure 7. In the first case, the combined inertial and gas load forces acting on the piston and piston rod and the inertial forces acting on the crosshead produce a positive horizontal force on the wrist pin. In order to maintain equilibrium, the connecting rod must exert an equal and opposite horizontal force on the wrist pin. As the connecting rod does not lie in the true horizontal position, the force exerted by the connecting rod produces both horizontal (to counter the gas and inertia forces acting on the wrist pin) and a vertical force. In this case, the vertical force lies in the positive (upward) direction. If the vertical force exceeds the weight of the crosshead and piston rod, the crosshead will move upward vertically against the upper oil film.

In the next case, the combined inertial and gas load forces acting on the piston and piston rod and the inertial forces acting on the crosshead produce a negative force on the wrist pin. In order to maintain equilibrium, the connecting rod must exert an equal and opposite horizontal force on the wrist pin. As the connecting rod does not lie in the true horizontal position, the force exerted by the connecting rod produces both horizontal (to counter the gas and inertia forces acting on the wrist pin) and a vertical force. In this case, the vertical force lies in the negative (downward) direction. The force adds to the weight of the crosshead and forces the crosshead into the lower oil film. A similar scenario exists for each of the last two cases.

As the crankshaft turns, both the connecting rod angle and the combined inertial and gas loads vary. In addition, the location of the crosshead with respect to crankshaft rotation may also affect the vertical force acting on the crosshead (Figure 8).

Most reciprocating compressors in service use double acting cylinder arrangements. For a double acting cylinder on a slow speed (<500 rpm) frame on the right side of Figure 8, vertical force most often acts downward, as shown in Figure 9. Similarly, the same cylinder oriented on the left side of the frame most often has an upward vertical force acting on the crosshead, as shown in Figure 10.

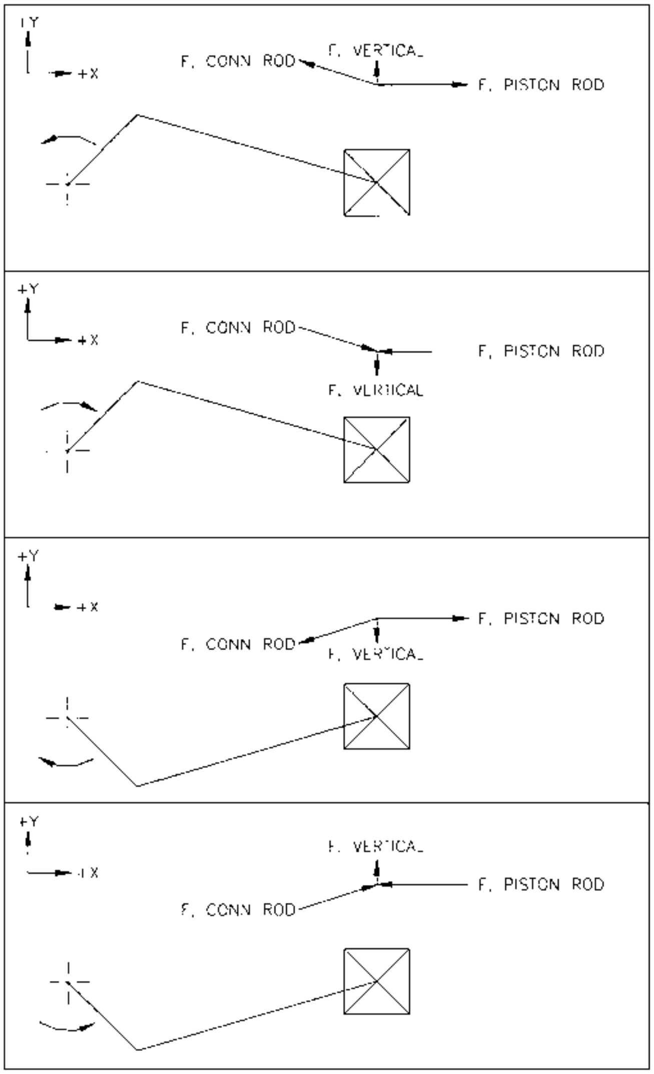

Figure 7. Crosshead Force Balance.

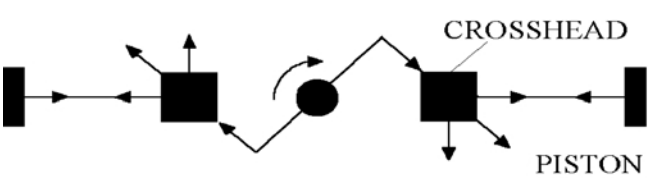

Figure 8. Crosshead Force Balance on Each Side of Crankshaft.

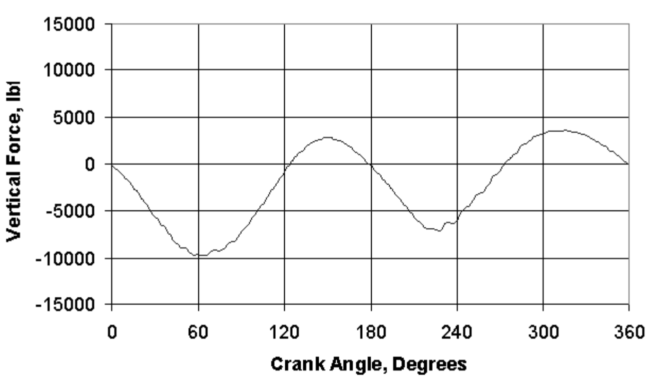

Figure 9. Vertical Force on Down Running Crosshead.

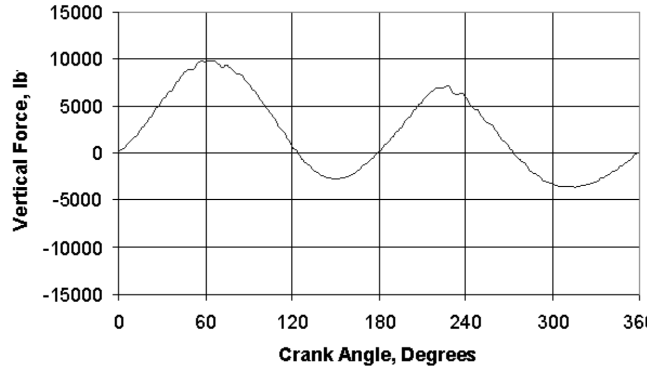

Figure 10. Vertical Force on Up Running Crosshead.

For both cases, the vertical force acting on the crosshead acts in the expected direction for much of the stroke. However, for a small time period in either case, the force does act opposite of the expected direction. As a result, for either case the crosshead may run against both the upper guide and lower guide during the stroke.

The vertical forces at the crosshead result from the connecting rod reaction to both inertial and gas forces acting on the crosshead. Changes in gas load affect the crosshead vertical motion. Loading or unloading a cylinder will change the motion of the crosshead and most likely change the piston rod motion at the pressure packing case.

RESEARCH AND CASE HISTORIES

The following case histories represent some of the work that has gone on over the past few years to better understand the rod drop measurement, and the difficulties in getting reliable data. In several of these cases, additional proximity probes were installed in hopes of clarifying the rod dynamics.

Case History 1

The following sets of data were collected on a large, domestically manufactured reciprocating compressor. In order to collect the data, a set of temporary orthogonal proximity probes was attached to the scraper packing case, intermediate pressure packing case, and the pressure packing case. At each case, one probe was placed in the vertical direction and the other probe in the true horizontal direction, as shown in the first column in Figure 11.

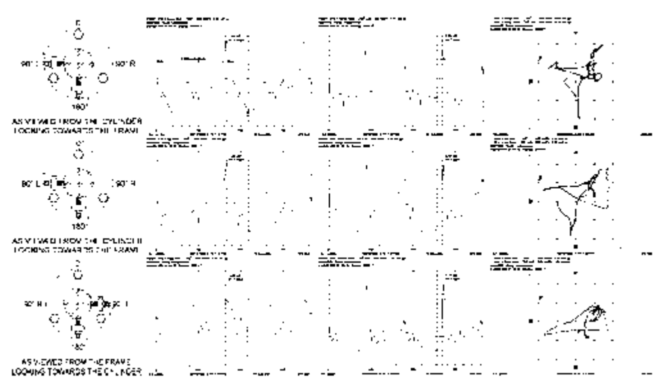

Figure 11. Probe Arrangement and Piston Rod Motion, Scraper at Top, Intermediate in Middle, and Pressure at Bottom.

A data collection device sampled the dynamic displacement signal 128 times per revolution. A blank- bright signal generated by a once per revolution mark inline with top dead center (TDC) of the cylinder of interest marks the beginning of each revolution. The dynamic displacement data collected from the true vertical transducer (Figure 11, second column) shows the piston rod motion at the crosshead (wiper or scraper packing), intermediate packing and pressure packing have some common motion. Likewise, the dynamic displacement data collected at the true horizontal probes (Figure 11, third column) show that even in the true horizontal direction the piston rod changes position during the stroke. All three locations have similar piston rod displacement motion.

As the probes lie orthogonal to each other, the data shown in Column 2 and Column 3 of Figure 11 can also be plotted in a Lissajou pattern. Piston rod movement in this configuration is the same as an observer sitting at the crosshead guide would see. Figure 11, Column 4, shows these plots. The Lissajou patterns show similar movement in all three locations, although amplitudes decrease closer to the piston. In this case, dynamic movement of the piston rod suggests forces other than gravity act on the piston rod. Mechanical condition and combined gas and inertial loads most likely have the greatest influence on crosshead (and piston rod) motion.

Case History 2

The following sets of data were collected on a medium size, domestically manufactured, pipeline reciprocating compressor. Cylinder pressure and piston rod displacement data were collected before and after an overhaul. In order to collect the data, a set of orthogonal proximity probes was attached to the scraper packing case and the pressure packing case. At each case, one probe was placed in the true vertical direction and the other probe in the true horizontal direction (shown later in Figure 13, Column 1).

In the vertical direction, the probe at the scraper packing views the bottom of the piston rod, and the probe at the pressure packing views the top of the rod. If the piston rod moves upward (against gravity) in both locations, the probe at the scraper packing sees the piston rod move away, and the probe at the pressure packing sees the piston rod move closer. If the piston rod moves in the same direction at both cases, the waveform recorded at the scraper packing case will be opposite the waveform recorded at the pressure packing case. As Figure 12 shows, inverting the waveform at the scraper packing case corrects for the probe orientation.

The cylinder of interest lies on the right side of the compressor frame. The crankshaft turns in a counterclockwise (CCW) direction, so the crosshead normally runs against the upper guide (up-running crosshead). As Figure 13 shows, during most of the stroke, the piston rod runs away from the probe. At one point during the stroke, the piston rod appears to drop nearer to the probe. The total movement of the piston rod at the scraper is approximately 10 mils, and the total movement of the piston at the pressure packing is seven mils. Plant personnel suspected 10 mils of movement at the crosshead could indicate crosshead clearance at or beyond the recommended OEM limits.

During the next outage, inspection of the crosshead to crosshead guide clearance revealed the clearance to be very near the maximum clearance recommended by the OEM. In addition, the rider bands were also found to be worn. Plant personnel adjusted the crosshead clearance to OEM limits and installed new rider bands and pressure rings. As shown in Figure 14, piston rod motion at the scraper case and pressure packing case decreased.

Case History 3

The following sets of data were collected on a large, domestically manufactured reciprocating compressor. A single proximity probe located below the piston rod provided the data shown in Figure 15. The top graph in Figure 15 shows the rpm versus time. The machine starts up just before midnight of 20 June 1999. The bottom graph shows the average gap voltage provided by the proximity probe. The gap voltage from a proximity probe represents the DC voltage of the signal produced by the proximity probe. The proximity probe system has a 100 mV/mil scale factor. A change in gap of two volts means the average position of the target with respect to the probe changed by 20 mils. In this example, the voltages at the probe

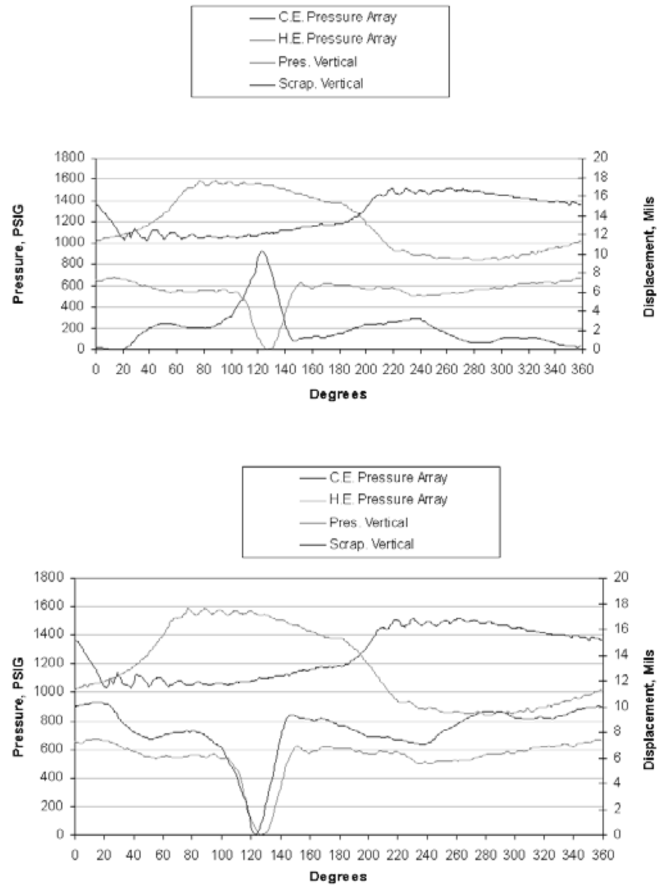

Figure 12. Uncorrected Waveform (Top) and Corrected Waveform (Bottom).

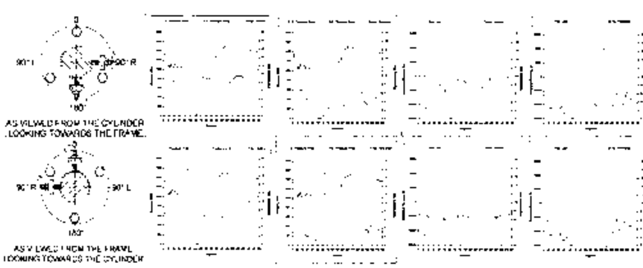

Figure 13. Probe Arrangement and Piston Rod Motion, Scraper at Top and Pressure at Bottom (Before Repair).

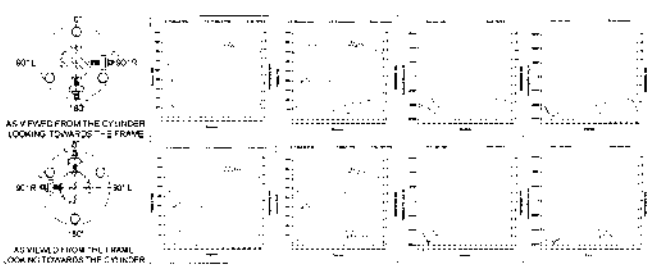

Figure 14. Probe Arrangement and Piston Rod Motion, Scraper at Top and Pressure at Bottom (After Repair).

changed from −6.4 VDC to −8.4 VDC as the machine starts up. The voltage increased in the negative direction and this means the piston rod moved away from the probe (upward). This direction is expected as the temperature inside the cylinder increases, the piston heats up, and the piston rod moves upward.

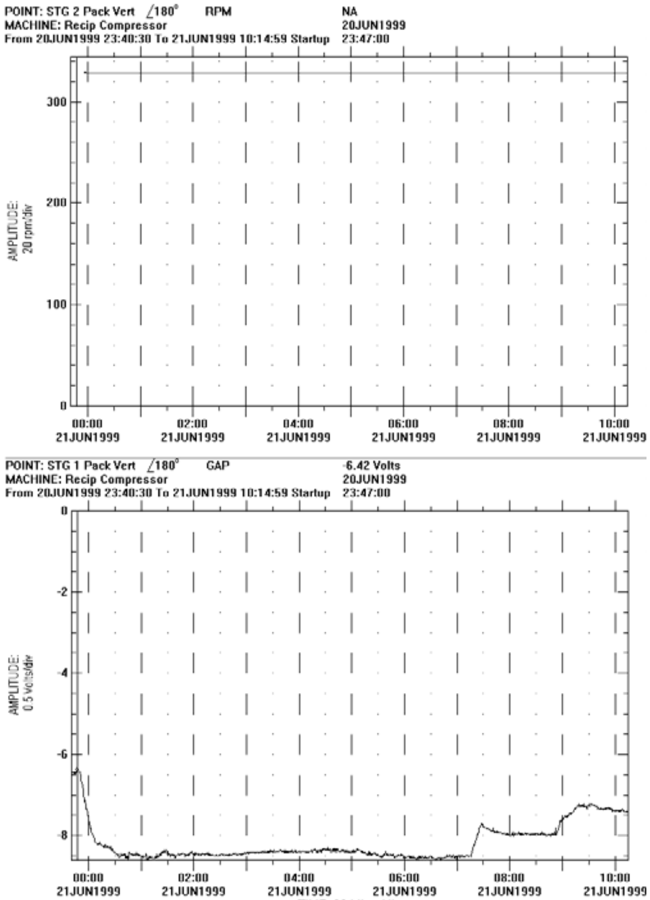

Figure 15. Machine RPM (Top) and Average Piston Rod Position (Bottom)—Case History 3.

In this case, the rider band had approximately 60 mils of wear left. If the rod drop detector had been set to trip at exactly 60 mils of wear when the cylinder was cold, then the thermal growth introduced an error of 20 mils in the measurement. The piston would have worn into the liner 20 mils before the rod drop device triggered an alarm unless the device was adjusted for the operating conditions of the machine.

Case History 4

Data were also collected on the machine in Case 3 during a load change (Figure 16). At approximately 15:45 on 21 June 1999, the head end of the cylinder was loaded. The average temperature inside the cylinder increased and the piston rod moved farther away from the probe. At approximately 16:15, the head end of the cylinder was unloaded. Temperature began to fall in the cylinder and the piston rod moved closer to the probe. At approximately 16:40 the machine stopped, and the piston began to cool off. As the cylinder cools, the piston rod gradually moves closer to the probe. The rod drop device correctly reports changes in the piston rod position, although factors other than rider band wear affect this reading.

Case History 5

Most of the time, a piston rod is thought of as a rigid body. However, all horizontal piston rods sag to some extent. Just as this sag must be accounted for when checking piston rod runout, the sag must also be accounted for when making rod drop measurement. In addition to the sag caused by gravity, gas and inertial axial loads acting on the piston rod will change the rod sag. Axial loads acting in compression will increase the sag and axial loads acting in tension will decrease the sag.

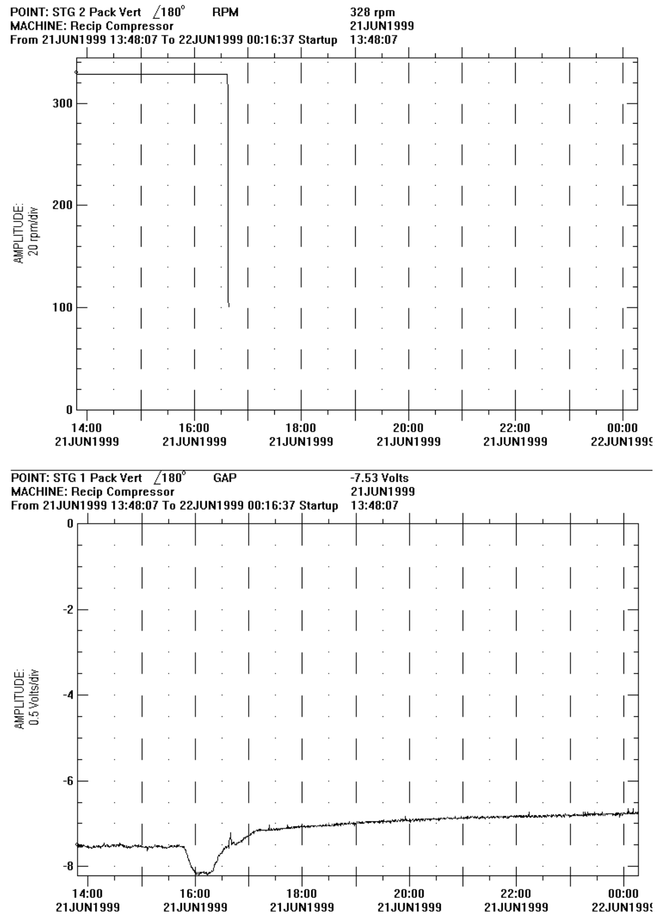

Figure 16. Machine RPM (Top) and Average Piston Rod Position (Bottom)—Case History 4.

Take, for example, a customer who has a small bore, high-pressure application in which babbitted rider bands support the piston. The total amount of allowable rider band wear is 19 mils. After the babbit wears 19 mils, the piston will score the liner. In this application, the piston rod has a diameter of 3-1/4 inches and an unsupported length of approximately 46 inches. Cylinder and crosshead clearances are identical, so neglecting deflection, the rod runout should be zero. The probe is approximately 12 inches from the crosshead when the piston is at TDC and 27 inches from the crosshead at bottom dead center (BDC). Using the static deflection formula in API 618 (1995), the expected rod runout at TDC is:

- TDC
  - Rod diameter = 3.25 in
  - Density = 0.283 lb/in^3
  - Modulus of elasticity, E = 30×10^6 lb/in^2
  - Rod length, B = 46 in
  - Total weight = 109 lb
  - Moment of inertia = 5.477 in^4
  - Indicator position, C = 12 in
  - Deflection at C $= \frac{1}{48} \cdot \frac{W}{EIB} \cdot (3BC^3 - 2C^4 - B^3C) = -0.0003\ in$
- BDC
  - Rod diameter = 3.25 in
  - Density = 0.283 lb/in^3
  - Modulus of elasticity, E = 30×10^6 lb/in^2

- Rod length, B = 46 in
- Total weight = 109 lb
- Moment of inertia = 5.477 in^4
- Indicator position, C = 27 in
- Deflection at C $= \frac{1}{48} \cdot \frac{W}{EIB} \cdot (3BC^3 - 2C^4 - B^3C) = -0.0003\ in$

There is practically no change in deflection, so rod deflection will probably have a small impact on the rod drop measurement. Consider the same case with a 4.25 inch piston rod, unsupported length of 101.8 inches, and the probe 77 inches from the crosshead at TDC and 92 inches from the crosshead at BDC:

- TDC
  - Rod diameter = 4.25 in
  - Density = 0.283 lb/in^3
  - Modulus of elasticity, E = 30×10^6 lb/in^2
  - Rod length, B = 101.8 in
  - Total weight = 408.7 lb
  - Moment of inertia = 16.015 in^4
  - Indicator position, C = 77 in
  - Deflection at C $= \frac{1}{48} \cdot \frac{W}{EIB} \cdot (3BC^3 - 2C^4 - B^3C) = -0.0021\ in$
- BDC
  - Rod diameter = 4.25 in
  - Density = 0.283 lb/in^3
  - Modulus of elasticity, E = 30×10^6 lb/in^2
  - Rod length, B = 101.8 in
  - Total weight = 408.7 lb
  - Moment of inertia = 16.015 in^4
  - Indicator position, C = 92 in
  - Deflection at C $= \frac{1}{48} \cdot \frac{W}{EIB} \cdot (3BC^3 - 2C^4 - B^3C) = -0.0041\ in$

Even though the rod diameter is larger, the change seen at the rod drop device from rod deflection is on the order of the measurement of interest. In the second case, rod deflection makes accurate measurement difficult.

Case History 6

An ethylene plant decided to install proximity-based rod drop monitors on four large polyethylene reciprocating compressors (Figure 17) based on the successful prediction and trending of rider band wear on the plant's two-stage vent gas reciprocating compressor. It was also decided to monitor valve temperature and both crankcase and crosshead vibration on these machines. The plant wanted to improve its ability to correctly predict valve failures and rider band wear, and to monitor crankcase and crosshead vibration. The crankcase and crosshead vibration monitoring system would also have compressor shutdown capabilities.

Figure 18 is a trend plot of the rod drop on the first stage of the Line 2 primary compressor. Shortly after the compressor startup, the system indicated a rod drop alarm on this cylinder. The trend plot indicated a large amount of rod movement. The compressor was shut down during a scheduled outage. We found that one of the three packing hold down studs had backed out, and the packing had come loose. Without the rod drop monitoring system, we would not have known about this problem. Early detection of the loose packing prevented the entire packing gland from coming loose in the crosshead area. This prevented a long-term outage that could have resulted in extended downtime and high maintenance repair costs.

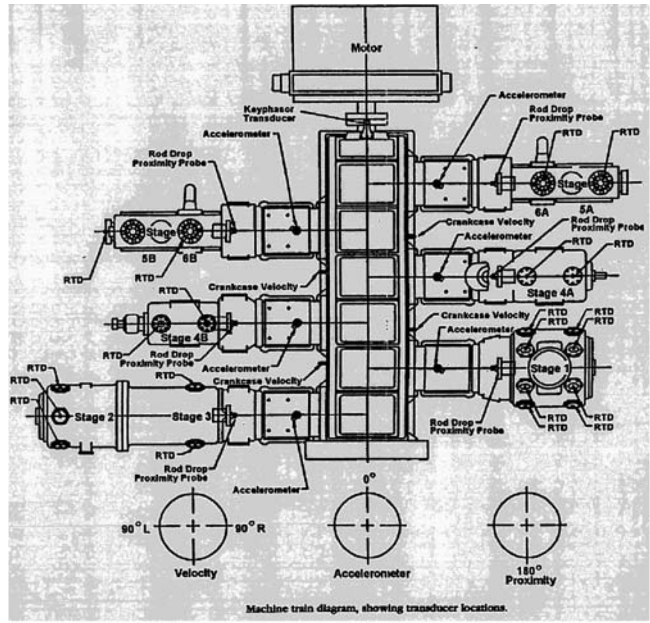

Figure 17. Compressor Machine Layout.

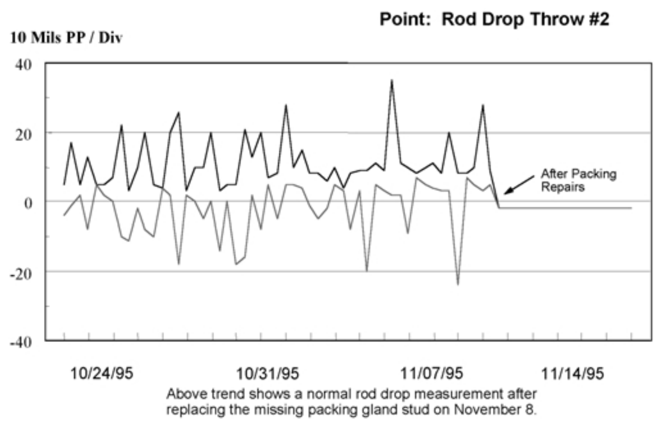

Figure 18. Throw #2 Rod Drop Trend.

In May 1996, a new piston and rings were installed on Throw #3 cylinder of the Line 4 primary compressor. The initial clearance reading taken between the piston and the cylinder was .020 inch. In July 1996, this piston had trended to .018 inch of rod drop (Figure 19). Operations personnel had not seen any indication of reduced performance from this cylinder as the rod drop monitor entered the alarm point. The compressor was shutdown shortly after entering its alarm point and the piston to cylinder clearance inspected. It was found to be less than .002 inch, which is exactly the amount indicated by the rod drop system. The ability to trend this wear and give an early indication of this reduction of clearance between the piston and the cylinder liner decreased the downtime and maintenance costs on this machine.

Case History 7

An end user of a large integral engine compressor had installed a proximity-based rod drop system on the compression cylinders. The monitor reported data that varied greatly over time. No trend or pattern could be established. Normally, the rider bands in this application wear very little, so it was expected that the readings would remain consistent.

Review of the configuration at each cylinder showed the trigger angle had been set on a slope of the waveform. In addition, the estimation of the piston rod load showed the piston rod to be in

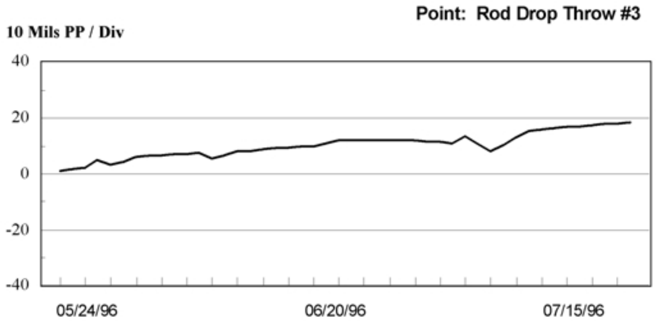

Figure 19. Throw #3 Rod Drop Trend.

compression. In configuring the trigger, the readings should be taken at a flatspot on the waveform and when the piston rod is in tension. Not all the waveforms had a convenient flat spot with the piston rod in tension. Figure 20 shows the trend of estimated rod drop for a cylinder that had a waveform with a flat spot in tension. The readings appear to be stable and repeatable. In contrast, Figure 21 shows the trend of rod drop for a cylinder that had a waveform with no flat spot in tension portion of the rod load. Together, the factors of the trigger on the slope and the rod in compression produced chaotic and unreliable readings.

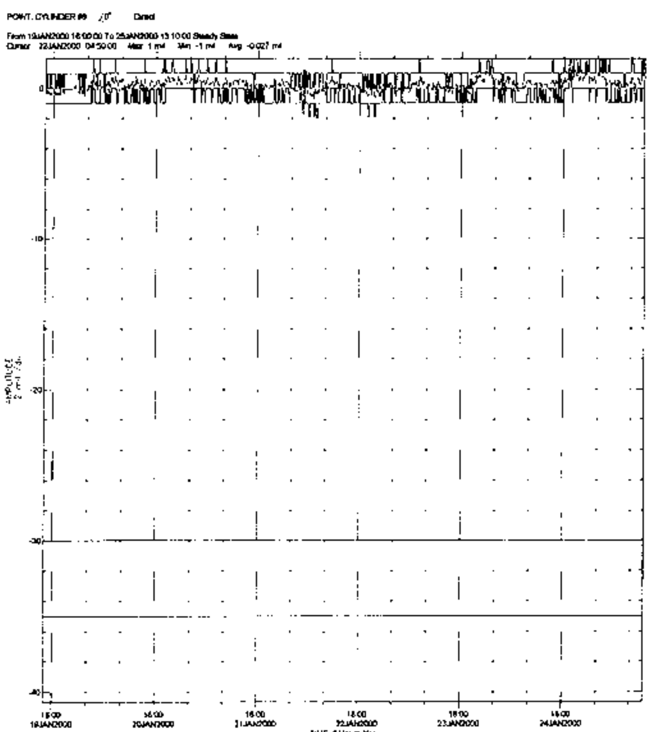

Figure 20. Rod Drop Monitor Values, Cylinder #6.

CONCLUSION

Based on the issues discussed, it becomes very apparent why there is such mixed success in rod drop applications. It is interesting to note that many of the application issues did not come out until the application of the proximity probe to this measurement. A mechanical indicator without the ability to trend and analyze the measurement data gave no indication if the system were really going to work or not. Troubleshooting proximity probe applications has brought the issues to light.

Rod drop is a very complex measurement with many factors that affect the results. If we understand the basic measurement assumptions, and work to avoid the application issues, a successful

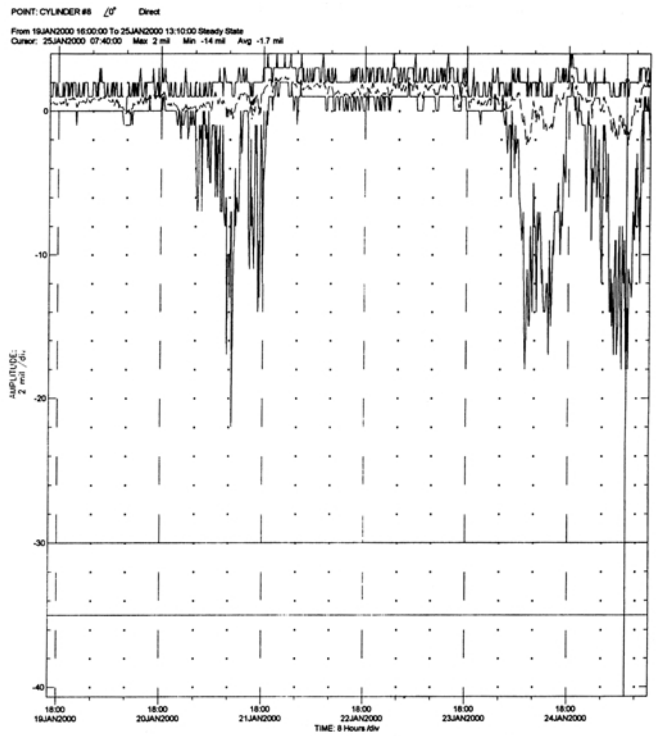

Figure 21. Rod Drop Monitor Values, Cylinder #4.

installation is possible, whether mechanical or proximity-based. So what is the answer to the question, "Rod drop monitoring, does it really work?" The answer is a qualified yes. The qualification is that the measurement must be properly installed and applied, and that may be easier said than done. It is our hope that the installation checklist provided will help guide those making this measurement to an effective system. Perhaps in years to come this question will no longer be a staple of Discussion Group 12, Reciprocating Compressors.

APPENDIX A

Reviewing and checking the following facts may provide some assistance in deciding how to use the tools currently available to effectively monitor and measure rod drop. In addition, the applicable paragraph number of API 670, Fourth Edition (Draft), is cross-referenced:

- Place the detection device as close to piston as possible, typically mounting directly to the packing flange is the best. This minimizes the effect of measurement errors (paragraph 4.1.3.1).
- Proximity probes should never be mounted on stingers through the distance piece.
- Assure that the detector mounting is short, stiff, and tight. If the detector is moving relative to the rod, it is difficult to accurately determine the rod position (paragraph 4.1.3.1).
- Check rod sag and piston rod runout. The runout/sag can introduce an error on the same order of magnitude as the measurement.
- Small pistons, less than 6 inches (150 mm) in diameter, on short stiff piston rods will typically be very difficult to get good measurements on. If the plant personnel are not willing to spend some time and effort experimenting with the system to get the best data on these cylinders, it may be better to avoid using rod drop on these pistons.
- Pistons with long rods (e.g., those with double or triple compartment distance pieces) may be subject to rod flex. This is difficult to deal with in a mechanical rod drop detector. A

proximity system can accommodate rod flex by selecting the optimal trigger angle. The best trigger angle may have to be determined by experiment (paragraph 3.4.4.2).

• On large diameter pistons (24 inches (610 mm) or greater), especially those made of aluminum, the system will have to be adjusted to accommodate piston thermal expansion. On a mechanical detector, the cold clearance will have to be set closer to the rod to factor in the expansion. On proximity probe systems, an extended range probe may be required, and the monitor may have to be rezeroed a few hours after startup (paragraph 4.1.3.5).

• For proximity-based systems, the proximity probe system should be calibrated on the individual piston rod (paragraph 4.1.3.4, 3.4.4.9, 3.4.4.10).

REFERENCES

API Standard 618, 1995, "Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services," Fourth Edition, American Petroleum Institute, Washington, D.C.

API Standard 670, Fourth Edition Draft, "Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems," American Petroleum Institute, Washington, D.C.