PAO-Based Synthetic Lubricants in Industrial Applications

The use of synthetic lubricants containing a proprietary polyalphaolefin (PAO) in the authors' company's plants has resulted in improved equipment reliability, energy efficiency, and reduced overall costs. The high viscosity index of the PAO allows synthetic lubricants containing it to be used in extremely hot or cold temperature environments while its high mechanical and thermal stability protects equipment in severe performance applications. The growing use of synthetic lubricants within the authors' company is one part of a multi-pronged approach to drive plant maintenance costs down.

L. D. MOORE
BP Chemicals Division
Naperville, Illinois
and
D. R. FELS, A. B. SEAY and C. LOPEZ
BP Chemicals Division
Pasadena, Texas
and
K. E. HARRIS and D. A. PECK
BP Chemicals Division
Texas City, Texas

INTRODUCTION

Hydrogenated oligomers of 1-decene, commonly referred to as polyalphaolefins (PAOs), have many desirable properties which contribute to their use in high performance lubricants. For example, PAOs are thermally and hydrolytically stable, have high viscosity indices, low volatility, and low pour points.

The abundant supply of PAO was initially driven by military and, later, automotive industry demand. However, as PAOs became more widely available (and more economical) more industrial and automotive applications were developed with PAO-based synthetic lubricants specifically in mind. PAO-based synthetic lubricants are now the top-tier branded oil offerings of several national manufacturers of rotary-screw compressors (1). Heavy-duty drivetrain component manufacturers such as Eaton and Dana (2), (3) offer extended warranty protection linked to the use of synthetic lubricants while several heavy-duty chassis manufacturers factory fill with synthetics. With few exceptions (4), these synthetics are PAO-based oils or PAO/ester blends. PAO-based synthetic lubricants have also been embraced in many other industrial applications (5).

The authors' company is committed to expanding the supply of PAO and has recently begun building a linear alpha olefins (LAO) plant in Joffre, Alberta (6). This facility is designed with a production capacity of 550 million lb/year, expandable to 825 million lb/year, allowing the company to produce sufficient 1-decene, the raw material used in PAO, to meet customers' needs globally in 2000 and beyond.

POLYALPHAOLEFIN PROCESS

Polyalphaolefins (PAOs) are produced by a multi-step process. In the first step, ethylene is polymerized to decene-1. Decene-1 is then oligomerized

(Continued on next page)
in the presence of a Lewis acid catalyst to a mixture of decene dimers, trimers, tetramers, and higher oligomers. In the final step these oligomers are hydrogenated to produce a fully saturated hydrocarbon mixture with excellent thermal and oxidative stability. These hydrogenated decene oligomers are additionally fractionated to produce the authors’ company’s PAO products with viscosities from 2 cSt at 100°C to 10 cSt at 100°C (Table 1).

In 1999 the authors’ company began supplying high viscosity (40 cSt and 100 cSt at 100, Table 2) PAOs in bulk (7). As with the company’s lower viscosity fluids the high viscosity products are based solely on 1-decene feedstock.

**PERFORMANCE BENEFITS OF PAO-BASED LUBRICANTS**

Relative to mineral-derived lubricants, PAO synthetic lubricants have greater film thickness at high temperatures - a reflection of their higher viscosity indices. This results in superior high temperature protection for equipment lubricated with PAO-based synthetics. PAO-based synthetic lubricants also achieve full lubrication more quickly at low temperatures than do comparable mineral-based lubricants due to their inherently lower pour points and low temperature viscosities. This is an important benefit given that a high percentage of component wear occurs during cold equipment start-up (9).

PAO-based synthetic lubricants are also highly shear stable (Table 3). When oils shear out of grade, usually due to chain scission of polymeric viscosity index improvers, an oil with significantly lower viscosity results which may not be able to prevent metal-metal contact and attendant wear. PAO-containing formulations show little shear loss under demanding conditions and maintain their ability to protect against wear.

PAO-based synthetic lubricants also reduce friction in rotating equipment due to a combination of many of the features described above. Several studies have documented significant reductions in energy consumption when PAO-based synthetic lubricants are used in worm gears (9) and a variety of transportation (10) and industrial-related (11) applications.

Synthetic lubricants are also generally acknowledged to have better oxidative stability than comparable mineral-based lubricants. Improved oxidation resistance yields lower viscosity increase in service and less deposit formation and varnish build-up; in other words, the internal surfaces of rotating equipment are cleaner. It is not uncommon for synthetic lubricants to provide five to 10 times longer life than mineral-based fluids. This is particularly evident in air compressors where the lubricant often comes into direct contact with high pressure air at high temperatures (12)-(16).

Several detailed case studies documenting the performance advantages of PAO-based synthetic lubricants over conventional mineral-type gear oils have also been published (17), (18).

**BARRIERS TO RECOGNIZING THE BENEFITS OF SYNTHETIC LUBRICANTS**

Despite the secure supply of PAO and the volume of material published over the last 20 years extolling the virtues of synthetic lubricants, there is still a question in the minds of some whether the higher performance and extended durability offered by synthetic lubricants justifies the added cost. In cases where petroleum based products are simply overmatched, this is an easy decision to make. However, in other instances the temptation to “save money” in the short term by purchasing a lower performing, but less expensive, lubricant can be overwhelming.
There are many barriers to recognizing the benefits of synthetic lubricants. Skeptical by nature, plant maintenance engineers often do not believe that published studies, no matter how meticulously conducted, could really be applicable to their operations. Even when the maintenance engineer grudgingly concedes that a synthetic lubricant might be worth a try, it may be difficult to unambiguously demonstrate benefits unless efforts are made first to resolve underlying operational/maintenance issues.

Some circumstances where lubricant trials are not likely to unambiguously reveal the benefit of synthetic lubricants are discussed below.

**Plant Processes Not Well Controlled**

In some instances, a commercial process may not be well controlled. Such processes are characterized by frequent (often heroic) intervention by operators to adjust basic operating parameters in order to keep production within specification. In the past, before total quality management principles became well established in the U.S. (19), (20), product specifications were simply broadened as needed to account for the wide, and often unpredictable, swings in plant operation. When evaluating the performance of a synthetic lubricant versus a mineral-based lubricant in such an environment, it should be evident that only one outcome is possible: the candidate synthetic lubricant will appear to have no advantage over the incumbent (usually) mineral-derived lubricant.

**No Baseline or Sketchy Baseline**

Even in plants that are operating within established parameters, it is often impossible to gauge the relative performance of a synthetic lubricant when a proper baseline has not been established. Within the authors’ company, the authors have encouraged operators and maintenance staff to share ownership of production assets. To that end, most pieces of rotating equipment are instrumented to provide accurate information on operating temperature, pressure, or other applicable operational parameters. This information is shared between the company’s plant operators and plant maintenance staff. Thus, as part of the company’s process recording and data entry (PRIDE) program (21), plant operators become an equipment reliability resource. In addition, rotating equipment is monitored directly by the maintenance staff an average of eight times per month. Using operational data in conjunction with traditional vibrational and hot-spot analysis, the company’s maintenance engineers have an early warning system for each piece of rotating equipment in operation.

The largest benefit of this monitoring is that needed repairs can be performed during scheduled turnarounds and catastrophic failures can be minimized. An additional benefit of this proactive monitoring is that it provides a good baseline for determining the benefits of a synthetic oil. Unfortunately, in today’s environment where already lean maintenance staffs are called upon to cover ever more demanding operations, it is not unusual for plant maintenance personnel to check only problem or critical equipment once or twice per month. In such an environment, the focus shifts from prevention to rapidly repairing equipment that has failed. Therefore, an accurate baseline will generally not exist for evaluating the benefits of a synthetic lubricant. However, even in this instance synthetic lubricants can often provide a valuable “fix” for problem equipment. Unfortunately, this approach misses many broader opportunities to increase reliability by limiting the use of synthetic lubricants to those applications where mineral oils will simply not work.

**Plants Not Amenable to Short Term, Indirect Testing (The Texas City Experience)**

Gone are the days when a plant produced hundreds of millions of pounds of a single grade, day in and day out. Most companies have embraced flexible manufacturing which allows many customer-specific grades to be manufactured from a single plant. This flexibility has underpinned the just-in-time delivery philosophy that became prevalent in the 80s and 90s (22), (23).

Thus, many plants transition from one product to another over a period of weeks or months depending on the desired slate of products. It is extremely difficult to differentiate between two lubricants at high statistical confidence when a plant is in transition. Even under nearly ideal conditions, tests performed sequentially must be carefully controlled to generate conclusive results. Unfortunately, it is rarely possible to isolate a piece of equipment to reduce its experimental variability without adversely impacting the production schedule. Nor is there always an option to run two identical pieces of equipment in tandem in order to compare the performance of two oils under identical, if variable, conditions.

Despite these caveats, it is nevertheless tempting to use short term, non-intrusive measures of lubricant performance to show the benefits of synthetic lubricants. Most often, a decrease in the operating temperature of a piece of rotating equipment at constant output is taken as an indication of lower internal friction and wear (24) and other beneficial performance of the lubricant.

Theory supports this approach. In rotating equipment such as pumps, energy can be consumed either through work, i.e., circulating a fluid, or through the generation of excess heat. Therefore, excess heat is equivalent to energy lost. The excess heat can be determined by subtracting the operating temperature of the pump from the ambient temperature, the final operating temperature of the pump being a function of both the frictional heat generated and the ambient temperature. For example, a pump with a temperature rise of 50°C operating at an ambient temperature of 20°C will produce an operating temperature of 70°C (50+20); the same pump operating at 40°C will produce an operating temperature of 90°C (50+40). Operating temperature is significant given that above 71°C, the rate of oil oxidation doubles for every temperature increase of 10°C (25).

When done with rotating equipment that operates continuously under relatively constant load, such indirect measures can indicate genuine differences between lubricants.

(Continued on next page)
and have been used effectively to overcome barriers to purchasing and using synthetic lubricants.

The authors wanted to determine whether the variability of several pieces of rotating equipment associated with the polybutene process, whose operating parameters are always being adjusted to make the production of over a half-dozen grades possible, allows statistically significant differences to be discerned. To this end, seven pieces of rotating equipment located at the Texas City Chemical Plant (polybutene unit) were chosen for monitoring. All evaluation equipment was non-critical; most pieces had a spare unit available in the event of an upset in the piece of equipment being evaluated. Lubricant-related benefits such as reduced maintenance or longer equipment life were not part of this study. The equipment chosen is summarized in Table 4.

To ready the pumps for direct temperature measurement, the oil drain plugs were replaced with thermocouples to measure oil temperature and a pressure transducer was added on the output side of the pumps to measure increases in pump pressure. The electrical leads from these devices were fed into a local data recorder that charted temperature, pressure, and electrical consumption data every two minutes for approximately one month. In addition, the motor controller (MCC), which provides electricity to both the pumps and mixers at the Texas City polybutene unit, was tapped to gain (indirect) information on the electricity going to each of the pumps and mixers. This arrangement was less than ideal given that many losses occur between the source of electricity and the pump or mixer.

For the mixers, oil temperature and tank skin temperature were measured. Input voltage and amperage for the mixers were also measured remotely at the motor control center. In addition to monitoring temperature, pressure, and electrical input, Texas City maintenance staff performed non-invasive vibrational monitoring.

Initially, the pumps were operated using a highly refined rust and oxidation inhibited (R&O) mineral oil of ISO viscosity grade 68. The mixers were operated using a similar mineral oil of ISO viscosity 220 grade.

The authors' company's lubricant supplier provided PAO-based ISO 68 and ISO 220 lubricants for comparison and contributed key personnel for the installation of monitoring equipment.

Data collection started May 20, 1999. Once every week, data from the collectors was downloaded for analysis. The week of July 1, 1999, the ISO 68 and 220 mineral oils were replaced with synthetic oils of identical viscosity. The normal polybutene production schedule was maintained during lubricant testing; a different grade of polybutene was produced roughly every week. No attempt was made to isolate pieces of equipment. Therefore, scheduled pump shutdowns as well as random pump upsets are reflected in the variability of the data. Note that in one instance the mixer data logger was disabled by water in the enclosure. This logger was replaced and the trial continued. Other routine events are tabulated in Table 5.

### Table 4—Texas City Chemical Plant Trial Equipment

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Type</th>
<th>Operating Parameters</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>Pump</td>
<td>30 gpm, Suction 14/ Discharge 80</td>
<td>7.5</td>
</tr>
<tr>
<td>P-2</td>
<td>Pump</td>
<td>20 gpm, Suction 2/ Discharge 20</td>
<td>5</td>
</tr>
<tr>
<td>P-3</td>
<td>Pump</td>
<td>1000 gpm, Suction 51/ Discharge 148</td>
<td>100</td>
</tr>
<tr>
<td>P-4</td>
<td>Pump</td>
<td>235 gpm, Suction 24/ Discharge 219</td>
<td>7.5</td>
</tr>
<tr>
<td>P-5</td>
<td>Pump</td>
<td>1400 gpm, Suction 161/ Discharge 245</td>
<td>125</td>
</tr>
<tr>
<td>M-1</td>
<td>Mixer</td>
<td>output 280 rpm, 6.083:1</td>
<td>50</td>
</tr>
<tr>
<td>M-2</td>
<td>Mixer</td>
<td>output 280 rpm, 6:21:1</td>
<td>25</td>
</tr>
</tbody>
</table>

### Table 5—Summary of Random Production Events for Texas City Plant Trial Equipment

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Type</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>Pump</td>
<td>dip in power and pressure</td>
</tr>
<tr>
<td>P-2</td>
<td>Pump</td>
<td>scheduled shut down for one day</td>
</tr>
<tr>
<td>P-3</td>
<td>Pump</td>
<td>---</td>
</tr>
<tr>
<td>P-4</td>
<td>Pump</td>
<td>---</td>
</tr>
<tr>
<td>P-5</td>
<td>Pump</td>
<td>pump upset; scheduled pump rate change</td>
</tr>
<tr>
<td>M-1</td>
<td>Mixer</td>
<td>---</td>
</tr>
<tr>
<td>M-2</td>
<td>Mixer</td>
<td>mixer data logger disabled by water</td>
</tr>
</tbody>
</table>

### Table 6—Ambient vs. Operating Temperature for Texas City Plant Trial Equipment

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Type</th>
<th>ΔTemp, °F</th>
<th>ΔTemp, °F</th>
<th>ΔTemp, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>Pump</td>
<td>+35</td>
<td>+25</td>
<td>10</td>
</tr>
<tr>
<td>P-2</td>
<td>Pump</td>
<td>+30</td>
<td>+25</td>
<td>5</td>
</tr>
<tr>
<td>P-3</td>
<td>Pump</td>
<td>+14</td>
<td>+16</td>
<td>-2</td>
</tr>
<tr>
<td>P-4</td>
<td>Pump</td>
<td>+24</td>
<td>+25</td>
<td>-1</td>
</tr>
<tr>
<td>P-5</td>
<td>Pump</td>
<td>+39</td>
<td>+32</td>
<td>7</td>
</tr>
<tr>
<td>M-1</td>
<td>Mixer</td>
<td>+48</td>
<td>+48</td>
<td>0</td>
</tr>
<tr>
<td>M-2</td>
<td>Mixer</td>
<td>+58</td>
<td>+60</td>
<td>-2</td>
</tr>
</tbody>
</table>

### Table 7—Paired Difference t-test Data for Texas City Pump Plant Trial Equipment

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3.800000</td>
</tr>
<tr>
<td>Confidence</td>
<td></td>
</tr>
</tbody>
</table>

80% confidence limits: -3.66699 to 7.343001

85% confidence limits: -3.85005 to 7.559995

### Table 5—Summary of Random Production Events for Texas City Plant Trial Equipment

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Type</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>Pump</td>
<td>dip in power and pressure</td>
</tr>
<tr>
<td>P-2</td>
<td>Pump</td>
<td>scheduled shut down for one day</td>
</tr>
<tr>
<td>P-3</td>
<td>Pump</td>
<td>---</td>
</tr>
<tr>
<td>P-4</td>
<td>Pump</td>
<td>---</td>
</tr>
<tr>
<td>P-5</td>
<td>Pump</td>
<td>pump upset; scheduled pump rate change</td>
</tr>
<tr>
<td>M-1</td>
<td>Mixer</td>
<td>---</td>
</tr>
<tr>
<td>M-2</td>
<td>Mixer</td>
<td>mixer data logger disabled by water</td>
</tr>
</tbody>
</table>

The authors wanted to determine whether the variability of several pieces of rotating equipment associated with the polybutene process, whose operating parameters are always being adjusted to make the production of over a half-dozen grades possible, allows statistically significant differences to be discerned. To this end, seven pieces of rotating equipment located at the Texas City Chemical Plant (polybutene unit) were chosen for monitoring. All evaluation equipment was non-critical; most pieces had a spare unit available in the event of an upset in the piece of equipment being evaluated. Lubricant-related benefits such as reduced maintenance or longer equipment life were not part of this study. The equipment chosen is summarized in Table 4.

To ready the pumps for direct temperature measurement, the oil drain plugs were replaced with thermocouples to measure oil temperature and a pressure transducer was added on the output side of the pumps to measure increases in pump pressure. The electrical leads from these devices were fed into a local data recorder that charted temperature, pressure, and electrical consumption data every two minutes for approximately one month. In addition, the motor controller (MCC), which provides electricity to both the pumps and mixers at the Texas City polybutene unit, was tapped to gain (indirect) information on the electricity going to each of the pumps and mixers. This arrangement was less than ideal given that many losses occur between the source of electricity and the pump or mixer.

For the mixers, oil temperature and tank skin temperature were measured. Input voltage and amperage for the mixers were also measured remotely at the motor control center. In addition to monitoring temperature, pressure, and electrical input, Texas City maintenance staff performed non-invasive vibrational monitoring.

Initially, the pumps were operated using a highly refined rust and oxidation inhibited (R&O) mineral oil of ISO viscosity grade 68. The mixers were operated using a similar mineral oil of ISO viscosity 220 grade.

The authors' company's lubricant supplier provided PAO-based ISO 68 and ISO 220 lubricants for comparison and contributed key personnel for the installation of monitoring equipment.

Data collection started May 20, 1999. Once every week, data from the collectors was downloaded for analysis. The week of July 1, 1999, the ISO 68 and 220 mineral oils were replaced with synthetic oils of identical viscosity. The normal polybutene production schedule was maintained during lubricant testing; a different grade of polybutene was produced roughly every week. No attempt was made to isolate pieces of equipment. Therefore, scheduled pump shutdowns as well as random pump upsets are reflected in the variability of the data. Note that in one instance the mixer data logger was disabled by water in the enclosure. This logger was replaced and the trial continued. Other routine events are tabulated in Table 5.

### PUMP ANALYSIS

For each pump, the pump operating temperature was calculated by subtracting the average measured pump temperature from the average measured ambient temperature. The pump operating temperature data for each pump lubricated using the PAO-based oil was then subtracted from the pump operating temperature of the corresponding pump lubricated using the mineral-based 68 oil (Table 6). This delta difference data was analyzed using a paired difference t-test. Even with the variability inherent in a plant in transition, the mineral oil-lubricated pumps ran statistically hotter than the same pumps lubricated with the PAO-based synthetic oil at 80% confidence (at equal or greater output pressure). Overall, this comparison gives modest evidence that the synthetic lubricant might improve pump life compared to the mineral oil. Unfortunately, a conclusion at greater statistical confidence could not be drawn (Table 7).
MIXER DATA

While the pump data above suggested that the synthetic oil generated less frictional heat than the mineral oil, no statistically significant differences could be discerned from the mixer data. This result was not unexpected. During the study, hot polybutene was added to the storage tanks at random intervals. These additions lowered the viscosity of the polybutene in the tank and hence the load on the mixer. Therefore, a true apples-to-apples comparison between the synthetic oil and the mineral oil could not be made (Table 6).

OTHER MONITORING

Indirect energy consumption measurements were inconclusive. In the future, it may be possible to directly measure the electricity usage at each piece of rotating equipment. However, measuring electricity at the motor control center (MCC) was the only option available in this study. As stated previously, many electricity losses occur between the MCC and the pump or mixer.

Both vibration trend data and comparison of the “before and after” vibration waveforms (June 30, 1999 vs. July 9, 1999) revealed little or no change from one oil to the other. Slight improvements in vibration amplitude were seen for the synthetic oil at some measurement points. However, a comparison of overall vibration amplitudes failed to show any statistically significant differences.

MEASURING KEY RELIABILITY-RELATED PARAMETERS (THE PASADENA EXPERIENCE)

Although synthetic lubricants have been used in industrial applications for several decades, there is still confusion about their value-added benefits. The higher initial cost of synthetic lubricants (relative to mineral-based lubricants) has been a major impediment to the widespread use of these oils despite the fact that the higher cost can often be fully justified by improvements in equipment performance (see next section). In an all-too-familiar scenario, the plant maintenance engineer is called upon to “prove” the value of the synthetic lubricant as a condition of purchase. Often a lubricant trial is arranged to obtain this proof (of sufficiently short duration to satisfy the demands of all stakeholders). While it is possible to discern true performance differences between lubricants using short-term indirect testing, the authors believe a better approach is to run trials of longer duration and measure key reliability-related parameters directly. These key reliability-related parameters include:

Longer equipment life
Lower maintenance costs
Reduced wear
Reduced downtime
Extended drain intervals
Reduced oil consumption

As will be seen, when key reliability-related parameters are measured, the real benefits of PAO-based synthetic lubricants become quite evident. Shortcuts, while appealing, may mask the superior performance of PAO-based lubricants.

THE PASADENA EXPERIENCE

Within the authors’ company, several cross-functional teams have been established with the aim of improving asset reliability and maintenance effectiveness in order to drive plant operating costs down. These teams have focused on the root causes of poor equipment performance and have embraced the notion that effective lubrication can play an important role in increasing equipment availability. These teams have fundamentally changed maintenance in the company’s chemical sector and moved the culture from an emphasis on initial cost to a focus on total value.

This step change in asset maintenance philosophy has led plants such as the company’s Pasadena, Texas, linear alphaolefins plant to replace nearly all of its mineral-based lubricants with high-performance PAO-based synthetic lubricants. Some of the benefits observed at Pasadena are summarized below.

Centrifugal Pump Experience

At the Pasadena plant, five Ingersoll-Rand single-stage centrifugal pumps are employed to circulate Dow Thermin. The pumps operate between 480°F and 525°F. When these pumps were lubricated with a premium mineral-based lubricant, there were 39 seal failures per year. Replacing these seals cost more than $178,000 not including labor, downtime, and the cost of associated components. When these pumps were converted from an oil reservoir lubricating system to a purge/steam lubrication system and the lubricant changed to an ISO 68 viscosity grade PAO-based lubricant, none of the seals failed within a year’s time. Three seals were replaced when non-lubricant related wear in the pump casings was noted. Upon introduction of the synthetic lubricant, the pump casing temperature decreased 20°F-25°F as did vibration. Note that the pump motor, couplings and turbines were not changed.

High Pressure Ethylene Compressor

Three identical twin-stage reciprocating ethylene compressors are used to supply high-pressure ethylene to a chain growth reactor that produces 1-decene. When these compressors were lubricated with a mineral-based lubricant, the piston rings showed catastrophic wear, usually after only one month (or, at most, two months) of operation. The mineral oil was undoubtedly soluble in ethylene.

If the lubricant is soluble in the gas being compressed, then the gas will dilute the lubricant and decrease its film strength. In extreme cases, as suggested by these results, the lubricant can be washed off the compressor walls by the gas (or liquefied components of the gas) resulting in high wear rates.

Polyalkylene glycol synthetic lubricants have low solubility in ethylene (26) and were briefly considered for this application. However, a PAG-based synthetic lubricant could not be used because small amounts of the lubricant carry over into the chain growth reactor; a PAG would poison the (Continued on next page)
chain growth catalyst. In this case, working closely with the lubricant supplier proved to be advantageous. The Pasadena plant was supplied with a PAO-based lubricant that was formulated with a proprietary polymeric material that reduced the solubility of the lubricant in ethylene. When this PAO-based lubricant was substituted for the mineral-base lubricant, the piston rings operated ‘or more than one year without a problem. Cylinder liner wear was reduced from 80/1000 inch to 2/1000 inch by the synthetic lubricant. Our maintenance engineers further optimized the performance of this compressor by modifying the piston in late 1999. Projected wear following this modification in conjunction with the continued use of the PAO-based synthetic lubricant is 1/1000 inch.

An unexpected benefit has been that reactor fouling has decreased coinciding with the use of the PAO-based synthetic lubricant. When the tubular design chain growth reactors foul, the cleaning process can take four-to-five days. Therefore, it is imperative to avoid fouling. Several working hypotheses have been advanced. One is that the mineral-based lubricant eventually plates out on the reactor surface where it becomes a site for detrimental polymerization. This issue is now under review.

Dow Therm Pump

In several Dean Brothers ove hung centrifugal pumps used to circulate Dow Therm for the Pasadena alcohol plant, water contamination (due to condensation or small leaks) caused repeated bearing failures. In an inventive use of a synthetic lubricant, the plant maintenance team plugged the water cooling lines and substituted an ISO 46 viscosity grade PAO-based synthetic lubricant for an ISO 68 viscosity grade mineral oil. Even without water cooling, the bearing temperatures decreased by 15°-20°F. Condensation-related failures were obviously eliminated; problem-free operation has continued for more than a year. The lower operating temperatures can in part be explained by more efficient heat transfer by the PAO-based lubricant than the mineral oil. However, these results may also be due to the superior film strength (lower friction) of PAO-based lubricants.

Ethylene Compressor Type B

An ethylene compressor with a design slightly different than that of Compressor A above was also evaluated using a PAO-based synthetic oil. An unexpected outage allowed for a good comparison between the PAO-based lubricant and a premium mineral oil. The cylinder rod, packing, liner, and rings of the ethylene compressor used to test the synthetic lubricant were all replaced. The mineral-based lubricant was used in an identical compressor, rebuilt and started at the same time.

In the compressor lubricated using the mineral-based lubricant as a cylinder lubricant, excessive cylinder wall wear was observed; the rider band needed to be replaced after 120 days. However, in the compressor lubricated with the PAO-based lubricant, rider band wear decreased to the point that replacement has not been required after 15 months. Based on these results, all the remaining plant compressors were converted to PAO-based synthetics. Cylinder, ring and valve wear and rates continue to be monitored. Preliminary data is encouraging.

Rotary Vane Vacuum Pumps

A sliding vane rotary vacuum pump performed unsatisfactorily for several months using a mineral-based lubricant. Rotor bearing failures were common and high rates of vane and cylinder wear were observed. The initial working hypothesis was that mineral oil being employed was of incorrect viscosity. This mineral oil was replaced by a mineral oil of lower viscosity with disastrous results. A PAO-based synthetic was next used to lubricate the cylinder, vane, and bearings. A second PAO-based lubricant of lower viscosity was used to lubricate the mechanical seals. Once again, a PAO-based lubricant is preferred in this application because if leakage past the seals did occur, the lubricant would enter the process. When the mineral oil was used, five-to-six vacuum pumps required repairs each year. Seal failures were responsible for one-to-two of these repairs. Since the mineral oil was replaced by the synthetic lubricants in April 1999, no vacuum pump failures have been recorded to date. Plant maintenance engineers continue to monitor these vacuum pumps.

Other Centrifugal Pumps

PAO-based synthetic lubricants are being used in other conventional centrifugal pump applications with bearing case temps in the 160°-195°F range. Reductions in bearing case temperatures and vibration have been noted (5-10%). Evaluation is still underway, but initial data and failure rates are encouraging.

Overall, by combining effective maintenance practices with the use of high-performance lubricants, compressor failures decreased from 138 in 1997 to 33 in 1999 (a 76 percent reduction); pump failures also decreased from 208 in 1997 to 169 in 1999 (Table 8).

THE ROLE OF THE LUBRICANT SUPPLIER

The lubricant supplier can play an important supporting role in any lubricant evaluation program. In addition to providing on-time lubricant delivery (or management of on-site lubricant inventory), the lubricant supplier can be an important technical resource (27), providing the expertise to formulate basestocks and additives to optimally match the requirements of a specific application. The lubricant supplier can also provide guidance on the compatibility of their lubricants with process chemicals, seal materials, and common paints and plastics.

At Pasadena, a decision was made to use an oil distribution system rather than drums or bottles to lubricate most of
the larger pieces of rotating equipment. The lubricant supplier accommodated the change from bottles and drums to bulk delivery. The oil distribution consists of a 550-gallon tote which is connected to a distribution “header” by a barrel pump. A simple float switch activates the barrel pump when the lubricant needs to be replenished. This oil distribution virtually eliminates contamination by water or dirt and is operationally fool-proof, i.e., there is little possibility of using the wrong lubricant once a trial begins. It is not enough to have a high-quality lubricant; it must be delivered to the rotating equipment in good condition. Working with the lubricant supplier assures that the optimal lubricant is delivered to the equipment in the best possible condition so that the best performance can be achieved.

WORKER SAFETY AND SYNTHETIC LUBRICANTS

It can be argued that the value of PAO-based synthetic lubricants goes far beyond benefits such as higher production rates with fewer interruptions, extended drain interval, and enhanced equipment life. The authors would like to suggest that by increasing equipment reliability, the safety of maintenance and repair workers is also increased. While the connection between increased safety and the use of PAO-based synthetic lubricants has not been established formally, it stands to reason that certain kinds of common plant accidents would become less frequent if rotating equipment became more reliable, i.e., required less intervention. For example, many injuries occur nationally related to the failure to follow proper lock-out/tag-out procedures (28).

While there are many reasons to interrupt the operation of a piece of plant equipment other than repair, might safety be directionally improved if repair-related interruptions could be minimized by the use of a lubricant that increased reliability?

Interestingly, a study of workers at a chemical processing plant in Finland revealed that 41 percent of the occupational injuries to eyes, fingers, and head were concentrated in the machinery maintenance and repair department (29). The authors of this study recommended that plant equipment be redesigned to provide better accessibility. However, might an equally valid approach be to implement practices that reduce the requirement for equipment maintenance altogether (including the use of a superior lubricant)?

It is hoped that this speculation provides a seed of inspiration for those in the industrial hygiene field to explore the link between the use of synthetic lubricants and increased worker safety, if such a link exists.

CONCLUSION

PAO-based synthetic lubricants are now available for all major categories of rotating equipment. If used in many everyday applications, instead of being reserved only for problem applications, PAO-based synthetic oils could help plants save thousands of dollars annually due to reduced maintenance and operating costs and improved equipment performance. Unfortunately, synthetic lubricants are not always evaluated effectively. In some instances, synthetic lubricants are evaluated under conditions where good statistical comparisons are not possible or in environments where good plant maintenance practices are not in place. In those instances, a synthetic lubricant may be judged to be "no different than mineral oil" and not selected due to its higher initial cost. However, in cases where plant processes are well controlled and where appropriate baseline data is available, PAO-based synthetic lubricants can be shown to be more effective than PAOs for themselves. Even in cases where plants operate discontinuously or transition rapidly between grades, the benefits of PAO-based synthetic lubricants can be demonstrated if care is taken to measure direct indicators of performance (reduced wear, extended drain interval, longer machine life, lower maintenance costs, etc.) rather than indirect measures. In summary, the authors believe that when good maintenance practices are combined with synthetic lubricants, the costs of lost production and repair can be drastically reduced. In addition, worker safety may be improved.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of the following individuals: Edwin Dartois, Eric Ziegel, Brad Hatten, Gilbert Solis, Nolan Hughes, Barbara Hamill, Gary Barba, Don Goolsby, Jeff Wyatt, Rye Lira and Art Leining.

Biography

Brown Seay joined Ethyl Corporation in 1977 as an outside machinist after leaving the U.S. Navy’s Nuclear Power Propulsion Program (1970-1976). In 1986, Mr. Seay transferred to the newly formed Technical Support Group at the Pasadena, Texas, plant site. He developed the predictive condition-based maintenance program which consisted of vibration monitoring, lubricant ferrographic analysis, thermal infrared scanning and ultrasonic scanning technologies. Mr. Seay joined Amoco at the acquisition from Albermarle Corporation of the Pasadena Olefins and Alcohols plant site in 1996. Mr. Seay holds certificates as a Level II Ferrographic Analyst and Level I Infrared Thermography Analyst. His current assignment is as the Predictive, Preventative Maintenance Analyst.

REFERENCES


(Continued on next page)
(Continued from previous page)


