

IMPROVED RELIABILITY WITH LUBRICANT UPGRADES

ENTERPRISE PRODUCTS DEDICATED RESOURCES TO RELIABILITY, INCLUDING USE OF HIGH GRADE SYNTHETIC LUBE OIL TO SOLVE OPERATING PROBLEMS

Enterprise Products Partners L.P. is one of the largest publicly traded energy partnerships with an enterprise value of more than \$14 billion, and a leading North American provider of midstream energy services to producers and consumers of natural gas, natural gas liquids (NGLs) and crude oil. The company transports natural gas, NGLs and crude oil through 32,500 miles (52,293 km) of onshore and offshore pipelines and is among industry leaders in the development of midstream infrastructure in the Deepwater Trend of the Gulf of Mexico. Just eight years ago, Enterprise Products operated 200,000 bhp (149,120 kW) of equipment, most of which was at its Mont Belvieu facility in Texas, U.S.A. Today, Enterprise Products operates equipment totaling in excess of 1.6 million bhp (1193 MW).

In 1996, the Mont Belvieu facility had no mechanical or reliability engineers on-site. Efforts at predictive maintenance consisted of oil analysis on critical equipment two to three times a year with vibration measurements not exceeding twice yearly. No online equipment monitoring was in place. As a result, the plant was totally in a reactive maintenance mode. Everyone wanted good reliability, but no one wanted to pay to put the people and tools in place to achieve it. Consequently, the plant relied heavily on consultants and vendors resulting in a patchwork of partial solutions to the plant's reliability issues.

Today, very limited reactive maintenance occurs at the Mont Belvieu plant, even though production demands often greatly extend, or even eliminate, routine maintenance and oil change intervals. The key to achieving this was making an ongoing commitment to dedicate resources specifically to reliability, which included on-site engineers with the proper equipment and training. Extensive preventive and predictive maintenance is now in place that includes online monitoring and equipment protection of critical equipment, routine oil analysis and monthly vibration monitoring on all equipment (over 7,000 points monthly). Our latest step in assuring reliability was to make use of a high-grade synthetic lube oil for all the operating equipment in our Mont Belvieu facility.

We learned many things on our journey to improved reliability about the value and proper use of various reliability tools for different applications and how to work as a team to develop a total program. These important aspects in attaining our goals cannot be adequately addressed in this article, but the competent and dedicated efforts of Maintenance Superintendent Tommy Branning and Maintenance Foreman David Wright, can not be overstated. But this story is about how we discovered an important and unexpected reliability tool that might have been completely overlooked, if not for a request for assistance from the operations group to help them reduce oil consumption.

The Mont Belvieu plant operates 25 York centrifugal compressors, 15 of which are in DIB ISO butane service. These 15 compressors averaged 7 to 10 equipment failures each year. The common failure mode was that the 5800 rpm shaft would weld to the babbitted aluminum journal bearing, resulting in a repair cost of \$60,000 to \$150,000 per failure, depending on the damage. These failures were caused because the lubricating oil would absorb hydrocarbon gases causing a significant drop in oil viscosity of two ISO viscosity grades or more. The six "swing service" compressors were particularly susceptible to oil viscosity loss requiring frequent oil changes. While operations accepted the failures as being normal, they viewed the \$200,000 annual lubricant cost for the compressors as being excessive and asked for assistance in reducing this expense.

We elected to run controlled tests using our current lube oil, a major brand polyalphaolefin (PAO) synthetic oil, an alternate major brand poly glycol (PAG) synthetic oil and Royal Purple Synfilm® NGL synthetic oil. Both of the alternate oils are designed to reduce the dilution effects of light hydrocarbons on oil viscosity. All oils had an ISO viscosity of 68. After five months of testing, we determined that the PAG fluid was most resistant to hydrocarbon gas dilution and we converted three compressors to this fluid. That is when we discovered the unintended consequences of our decision. The PAG's tendency to hold water created emulsions in our oil water separator causing an environmental issue. It also resulted in unacceptable moisture traveling downstream of the compressor to the catalyst bed.

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The Mont Belvieu plant operates 25 York centrifugal compressors in the 4000 hp (2982 kW) class, 15 of which are in DIB Isobutane service. It also operates over 500 pumps ranging from 10 to 600 hp (7.45 to 447 kW), 90% of which run at 3600 rpm.



Maintenance Foreman David Wright checked out this two-stage York centrifugal compressor model M255B on Isobutane service coupled up to a Solar T4702S Centaur gas turbine.

In this picture, you can see the associated instrumentation for the lube oil and seal oil systems.

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We had to drain the PAG lubricant from the compressors and thoroughly flush them of all residual oil. We then refilled the six “swing” compressors with Synfilm® NGL, which had originally been our second lubricant choice. Royal Purple claimed that Synfilm® NGL’s high film strength additives offered advantages of greater wear protection and machine reliability, and indeed, we did find a dual benefit from using this oil. In the first year, we not only reduced oil purchases but also reduced historical maintenance costs by \$350,000.

Based on these results, we converted the balance of the compressors to Synfilm® NGL. We still have occasional compressor failures, but the damage is limited to the thrust bearings caused by excessive compressor surge events. We no longer have catastrophic failure modes with bearings welded to shafts. We have even avoided damage on several occasions when process upsets have caused compressors to coast down under low oil pressure alarms. We avoided one catastrophic failure when a faulty shutdown switch allowed one of the York compressors to run for three hours with only one psi of oil pressure. Damage was limited to high wear on the thrust bearing. Over the last seven years, we estimate that the improved compressor lubrication has resulted in maintenance savings of \$800,000 per year.

This success prompted us to look for other opportunities where reliability might be improved through improved lubrication. One such opportunity was a 200 hp (149 kW) Rotoflow warm expander. Two of these machines shared the same oil reservoir. One never failed and the other experienced catastrophic failure every four to five months like clockwork. The failure mode was that two 180° F (82° C) opposed ball bearings would split in half. The manufacturer suggested a change in the lube delivery system but couldn’t provide information where it had ever been successfully implemented. Each failure resulted in a \$30,000 repair cost and \$160,000 in lost production. We elected to try a new lubricant while continuing to work with other consultants and vendors for a solution. We changed the mineral oil 32 to Royal Purple Synfilm® 32, which increased the time to failure to nine months saving over \$200,000. The ultimate solution, however, proved to be the addition of a small needle bearing on the lower gear to relieve thrust loading on the deep groove roller bearings.

We had another problem with the journal bearing in a 10,000 hp (7456 kW) Demag Delaval compressor that routinely developed high temperatures in the summer that limited production. By changing the mineral oil 32 to Royal Purple Synfilm® GT 32, bearing temperatures were reduced from 225° to 170° - 175° F (107° to 77° - 79° C) a 50° F (10° C) drop, eliminating the need to reduce production in summer months.

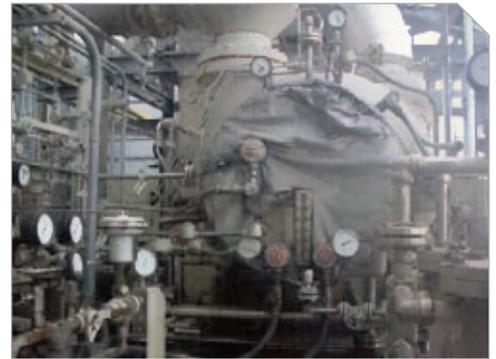
We achieved additional savings after changing our four Solar gaset turbines to this same oil. One turbine experienced a lube oil pump shaft failure which interrupted oil flow to the turbine. The high film strength properties of the new oil enabled the turbine to coast down without damage. This same turbine experienced the same failure six months later with only minor bearing damage in the gear box, resulting in a \$30,000 repair. The potential maintenance savings from using the high film strength oil was \$325,000 per incident.

We have since upgraded the lubricant in all pumps, motors and turbines and have seen improved reliability across the board ... lower temperatures, lower bearing vibration and much longer trend intervals between first diagnosis of bearing problems until failure.

The Mont Belvieu facility operates over 500 pumps ranging from 10 to 600 hp (7.45 to 447 kW), 90% of which run at 3600 rpm. The forty horizontal splitline pipeline pumps averaged one failure in the babbited sleeve bearing and / or ball thrust bearing every six weeks. The failure rate has been reduced to one every six months since changing the oil from the mineral oil 32 to Synfilm® 32. Cooling tower gear boxes that used to experience annual bearing replacements have now exceeded five years in service since upgrading the lubricant. We have reduced the failure rate in our 200 fin-fans from two to three repairs per week to one per month by upgrading to a high film strength synthetic grease. There simply have been no applications where we have elected to upgrade the quality of our lubricants that we did not see measurable improvement.

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Shown is a two-stage York centrifugal compressor model M255B on Isobutane service coupled up to a Solar T4702S Centaur gas turbine.

This illustration shows a front view of the York compressor as well as the associated instrumentation for the lube oil system.

The bearing lube oil system, which uses Royal Purple® NGL 100 oil, is embedded in the compressor body. The lube oil comes in contact with the process gas through the A4 seal during operation. The main oil sump is vented to the suction of the machine, thus oil saturates with process gas.

Consequently, the lubricating properties of the oil are extremely important in order to sustain proper lubrication.



Royal Purple® synthetic lube oil is available in various sizes of containers, from quarts to 55 gallon drums.

Here, drums of Royal Purple® 46 are being readied for charging the lube systems of the Rotoflow expanders.

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When we began implementing a comprehensive maintenance reliability program, lubricant selection was limited to making sure we had the right type and viscosity of oil in our equipment. It was only by chance that we began an initial lubricants evaluation program that quickly taught us how significantly lubricant selection can alter equipment reliability and availability. In hindsight, this should not have been so surprising because most of our rotating equipment maintenance involves the replacement of lubricated components.

While improved lubrication has proven to be only part of the solution to achieving Enterprise Products' significantly improved equipment reliability, our experience has shown it to be an immensely important part, and one that is too frequently discounted or overlooked by many maintenance groups. The key to any successful preventive and predictive maintenance program is competent maintenance personnel. Tommy Branning and David Wright were instrumental in identifying equipment problem areas.

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Shown is a Rotoflow mixed gas expander with a speed reduction gearbox.

The main expander shaft operates at 17,000 rpm, and the output shaft to the generator operates at 1800 rpm. This expander is coupled to a 200 kW generator.

The expander operates at -180° F (-118° C), and the speed reduction gearbox operates at 120° F (49° C).

Note the speed reduction gear box and the cold box body where the expander wheel and the impeller volute are contained. This machine uses Royal Purple® 46 lube oil.