Often Overlooked, Lubricants

CAN HELP LOWER ENERGY CONSUMPTION

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Management Summary

It is a simple fact: better lubrication can lead to dramatic energy savings and an improved bottom line. This ought to interest any plant manager who is looking for ways to reduce operating costs, and it is especially significant at a time when stricter government regulations are in direct contradiction to reducing costs. Lubrication reliability is the solution; this article will describe how manufacturing plants can use "lubrication reliability best-practices" to reduce their energy consumption, emissions and operating costs—all at the same time.

Introduction

Energy and its usage are the lifeblood of today's society—economic development and improved standards of living both rely upon its constant availability. According to "The Outlook for Energy: A View to 2030," by Exxon Mobil, energy usage-per-person varies dramatically around the world but equates to an average of 200,000 Btu a day—or 15 billion Btu-per-second (Ref. 1). The same study points out that each person has what it identifies as "direct" and "indirect" energy demands.

Direct demand of energy is the energy that drives our personal vehicles and operates our homes; indirect demand is the energy that heats and cools buildings, generates power, produces goods and services and provides mass transportation of goods and people.

As the lesser-developed parts of the world continue to modernize, their needs for energy will grow accordingly and result in increased costs for fuel worldwide. In addition, many of the world's governments are passing stricter laws regulating clean air and water, toxic waste, pesticides, endangered species and more. These factors—combined with the struggling economy—result in the challenge for plant operations managers, i.e.—reduce operating costs.

This often means doing more with less.

One obvious way to reduce operating costs is to reduce energy consumption. Upgrading and replacing plant equipment with newer, more energy-efficient technologies can reduce energy costs. Unfortunately, in a challenging economic environment, capital may not be available for plant upgrades.

But simple changes in habits can also create considerable savings; one such change is to improve a company's "lubrication reliability program." According to Peter Thorpe, product application specialist at Shell/South Africa, "From a cost point of view alone, lubricant costs are negligible when compared to energy costs, even before the production efficiencies of high-performance lubricants are factored in (Ref. 2)."

Indeed, electric utility bills generally dwarf maintenance and lubricant costs; all three are part of any manufacturing operation. While controlling or reducing maintenance and lubricant costs is important, reducing electric utility usage is critical. This paper will show that tremendous opportunities exist to use an improved lubrication reliability program to decrease plant energy costs and increase profitability.

Sources of Energy

There are various forms of energy (Table 1). Mechanical energy is further broken down into two types: kinetic energy—the energy of motion; and potential energy—energy associated with an object's position. Energy often transforms from one form to another for an end-use purpose. For example: oil, when combusted, contains chemical energy that converts to thermal energy and then to electrical or mechanical energy.

Energy for Work

During these conversions some useable energy is lost; these losses can be extremely costly to society. The science of physics reveals that lubrication can play a role in reducing energy losses by reducing friction.

Society uses many automated tools to perform everyday activities—what we call "work." These tools frequently include many moving parts to accomplish the chore they are designed to perform. As it happens, work and kinetic energy—also called the energy of motion—are directly related. In 1687 Sir Isaac Newton published his laws of motion in *Principia Mathematica*, which effectively determined that the mathematical expression for kinetic energy (K) is:

$K = ½\ mv^2$ (where m is a mass and v is the velocity at which the mass is moved) (1)

It can thus be stated that energy is required to move an object.

The laws of physics also state that work is the force required to move an object a certain distance, as in:

$$W = F\Delta x \qquad (2)$$

(where F is a force and Δx is the change in position)

Work is also equal to the change in kinetic energy, in that:

$$W = \Delta K \qquad (3)$$

In fact, friction is a force that exists in two forms—static friction (F_s) and kinetic friction (F_k).

Friction is represented mathematically by the following:

$$F_s = \mu s N \text{ and } F_k = \mu_k N;$$

where:

μ_s and μ_k are the static and kinetic coefficients of friction, respectively, and N is a force normal to the moving surfaces.(4)

The coefficient of friction is a unit-less number that varies, dependent upon the material composition with which the moving surfaces are made. Obviously, the higher the coefficient of friction, the higher the friction force.

Finally, the equation that describes the total change of kinetic energy (E_T) required in a moving system is the following:

$$E_T = W_m + W_F \qquad (5)$$

where:

W_m is the work to move the machine
and W_F is the work required to overcome friction

Physics shows us that reduced friction would reduce the energy needed to complete the desired work. Placed between two moving surfaces, a lubricant decreases the coefficient of friction; it naturally follows that the more a lubricant decreases friction, the less energy the lubricated machine consumes.

Lubricant Formulation Basics

It has been said that "Oil's oil; just pour it in;" but this statement is far from reality. Simply described, a lubricant is composed of a base fluid and additives. However, many lubricant suppliers formulate their lubricants according to unique recipes intended for specific purposes (applications). Table 2 serves as a primer on the basic types of lubricants and their specific, ingredient-driven categories.

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Table 1—Forms of energy
Chemical
Nuclear
Radiant (light)
Thermal
Sound
Electrical
Mechanical (kinetic/potential)(Ref. 3)

Table 2—Lubricant types	
Automotive (Transportation)	***Industrial (Factories)***
Heavy-duty diesel engine oils	Compressors
Passenger car engine oils	Bearings
Automatic transmission fluids	Gear boxes
Aviation engine oils	Hydraulics
Mobile hydraulic	Turbines
Differential fluids	Chains/wire ropes
Torque fluids	Slide-ways
Chassis lubricants (grease)	Grease

Each of the lubricant types in Table 2 is usually broken down into narrower descriptions based upon the product formulation chemistry. Table 3 lists the categories and the additive types that dictate the categorical description. These descriptions are extremely simplified as there are various base fluid types and even more additive types. Each formula category has its strengths and weaknesses, and should be chosen based upon the needs of the application.

It is a fact that lubricant formulations can be rather complex; but when searching for the best lubricant to minimize friction-induced energy loss, it is typically accepted that "you get what you pay for." This common wisdom is that an inexpensively priced lubricant does not necessarily provide maximum lubrication performance and may require a higher amount of energy consumption—sometimes at higher costs than with a more expensive, better-performing lubricant. However, simply using an expensive lubricant does not ensure maximum lubricant performance and energy savings; aside from being the right lubricant for the application, it must also be properly maintained in order for it to provide maximum performance, e.g.—proper storage and handling, filtration, oil analysis, training and more.

All electro-mechanical equipment requires periodic maintenance to operate at peak efficiency and to minimize unscheduled downtime. Inadequate maintenance can increase energy consumption and lead to high operating temperatures, poor moisture control, excessive contamination and unsafe working environments. Depending on the equipment, maintenance may include the addition or replacement of filters and fluids, inspections, adjustments and repairs (Ref. 4).

But how does the end-user know what to do? The answer is to find a lubrication partner that can help develop a comprehensive lubrication reliability program that includes lubricant selection, protection and maintenance. This partner could be a consultant, but it could also be a lubricant manufacturer that offers customized, comprehensive solutions, including lubricants and all of the related lubrication reliability products.

Table 3—Lubricant categories by ingredient

Category	*Ingredients Described*
Mineral oil	Base fluid derived from refined crude oil
Synthetic	Synthesized base fluids such as PAO, esters, PIB, PAG and more
R&O (rust/oxidation)	Contains rust and oxidation inhibition additives
AW (anti-wear)	Contains wear-reducing additives
EP (extreme pressure)	Contains extreme pressure wear-reducing additives
Multi-grade	Contains viscosity index-improving additives
DI (detergent inhibitor)	Contains detergent, dispersant, oxidation, wear and anti-corrosion additives
Others	De-foamants, emulsifiers, de-mulsifiers, pour point depressants and thickeners

Lubricants and Energy Savings

Energy savings is measured in a variety of ways, including production output, temperature changes or electrical reduction—all of which are addressed below. Yet another measurement is fuel consumption.

Production output. When we use equipment to perform work, it is possible to evaluate the equipment's energy efficiency by recording its production output. For example, if a machine is capable of producing a certain number of parts in a given amount of time and the lubricant is changed—resulting in a higher volume of parts being produced in the same amount of time—then the machine has become more energy-efficient. But one must be careful when using this technique to ensure that nothing changed in the process except the lubricant. This can be overcome by using a larger number of test units or by evaluating productivity over a longer amount of time.

Temperature changes. Monitoring temperature changes is another way to optimize lubrication program performance. Increased friction in a piece of moving equipment results in higher operating temperatures; friction is a result of metal-to-metal contact that occurs between two opposing surfaces moving relative to one another. Even between highly machined surfaces, under microscopic view, asperity contact occurs.

Indeed, the greater the amount of contact, the greater the amount of friction. As a result, more energy is required to move the surfaces relative to one another. This friction results in higher electrical power costs. Lubricants can reduce that friction. Therefore, when friction is reduced, less electricity is required to drive a gearbox, compressor, pump or other piece of equipment.

Sometimes, the bulk oil temperature is monitored in a piece of operating equipment. Another technique for evaluating lubrication performance is thermography; it involves using infrared detection equipment to look for "hot spots" on a piece of equipment that could result from insufficient lubrication, improper lubricant selection or faulty operating parts. In any of these cases, higher temperatures result in wasted energy. It is important, however, to account for ambient environmental temperatures when performing this type of energy efficiency study; obviously, a piece of equipment will run hotter on hot days than on cold days.

Case study: A knitting plant in Hendersonville, North Carolina was experiencing overheating problems in its Champion TWT-07 reciprocating compressor while using the recommended commercial-grade lubricant. Even after changing to several synthetic products, it still experienced lubricant foaming and overheating. After changing to an ash-less AW mineral compressor oil, the plant experienced an immediate drop in temperature of 15°F (8°C). Even after three months of continued service, the plant maintained this temperature drop. This study illustrates that certain equipment can have its own lubricant "appetite;" just because a fluid is synthetic does not necessarily mean that it is the best recommendation for a piece of equipment.

Electrical reduction. When most of us think about energy consumption we immediately think about *electrical* consumption, and tracking electrical consumption is a highly reliable way to evaluate improvements in plant energy use. In fact, various companies have been able to document improvements in electrical energy efficiency related to their lubrication programs. Typically, companies that upgrade their lubricants and reliability practices have been able to document a 5 to 15 percent reduction in power requirements—more than enough to pay for a better-performing lubricant. Average documented savings were 15 percent in gearboxes, 12 percent in air compressors and 4 percent in electric motors (Ref. 5).

Electric motors power most plant machinery, including gearboxes, compressors, refrigeration systems, pumps, hydraulic systems and ball mills; kilowatts (kW) are the common unit for measuring electricity. The following equation can determine the amount of electricity used by an electric motor:

$$kW = V/1{,}000 \times A \times 1.73 \quad \text{(where } V \text{ is volts and } A \text{ is amperes)} \tag{6}$$

Both are common metric measurements of electrical current, measured via a voltmeter or ammeter. For a three-phase motor, 1.73 is a standard factor. Data logging equipment is available that allows one to measure and collect data for either amperes, volts, or both. Yet most electrical consumers pay for electricity by kilowatt-hour (kWh)-per-month. The following formula is commonly used to determine the electrical-charge-per-month (ECM):

$$ECM = kW \times h \times EC \tag{7}$$

where h is hours of service and EC is the electrical charge)

Air compressors are an easy target for energy savings in that compressed air is one of the most expensive uses of energy in a manufacturing plant; approximately 70 percent of all manufacturers have a compressed air system. These systems power a variety of equipment, including machine tools, material handling and separation equipment, and spray painting equipment. According to the U.S. Department of Energy (DOE), compressed air systems in the U.S. account for 10 percent of all electricity and roughly 16 percent of U.S. industrial motor system energy use. This adds up to $1.5 billion per year in energy costs and 5 percent in emissions. Energy audits conducted by the DOE suggest that more than 50 percent of compressed air systems at industrial facilities have significant energy conservation opportunities (Ref. 6).

Following are manufacturing case studies in which lubricant changes in air compressors and other plant equipment helped manufacturers reduce their electrical consumption.

Case study 1: A western New York glass and ceramics manufacturer had instituted a program to reduce electricity consumption. The manufacturer targeted its Ingersoll-Rand ESH reciprocating compressor driven by a 440-volt, 75-hp motor because this piece of equipment operated at peak capacity 24 hours per day, seven days a week. At the start of the experiment, when the compressor contained the OEM-specified synthetic oil, the average baseline reading was 89 amps.

A week after draining the oil, cleaning the compressor and refilling with a high-performance, branded synthetic oil, the manufacturer again collected data and found that the average reading had dropped to 82 amps. Knowing that it was using six fewer amps, applying Equations 6 and 7, and knowing that the energy charge was $0.10/kWh, the manufacturer was able to calculate the annual monetary savings due to lubricant-related electrical efficiency improvements as:

$$kW = 6 \text{ amps} \times 440 \text{ volts}/1{,}000 \times 1.73 = 4.57 \tag{8}$$

$$ECM = 4.57\ kW \times 8{,}760\ h/\text{yr} \times \$0.10 = \$4{,}003/\text{yr} \tag{9}$$

Data collection continued for an entire year and the lower amperage remained unchanged. Valve maintenance was performed at the same intervals as with the previous oil—*by which the source of the energy savings was revealed*. The valves were no longer covered with sticky, carbon-varnish build-up, as was the case with the OEM oil; and the new oil appeared to deteriorate less. The manufacturer learned that not all synthetic lubricants are equal.

Case study 2: A South Dakota wastewater treatment plant was looking to reduce operating expenses by using higher-quality lubricants to achieve extended drain service and possible energy savings in three Spencer 50-hp rotary blowers that were part of a biological contactor system. The average electrical reading was 50 amps on each of the blowers while using their current lubricant. After changing to a high-performance lubricant, the average dropped to 38 amps. Based upon electrical rates at that time, the estimated yearly savings was $2,968 per blower—or $8,904 for all three.

continued

Table 4—Typical savings with 5 percent amperage reduction*

Electric Motor (hp rating)	Type of Operation	
	40 hrs/wk	Continuous
10	$74	$297
50	$372	$1,487
100	$746	$2,986
200	$1,493	$5,472

**$0.10 kWh Electricity Rate*

LE's Duolec Lubricant Helps Maintain D.J. Murray Hydro-Dam Gearboxes

Customer Profile: The customer (name withheld upon request) manages eight hydro facilities in Montana and more than 40 power generation facilities nationwide.

Application: At its Montana hydro dam, the company uses D.J. Murray gearboxes for its wicket gates, with a total of 22 gearboxes on the dam.

Challenge: The gearboxes were extremely contaminated and needed to be changed due to long-term neglect. But without a reliability program in place, the company was unaware of the extent of the contamination. They knew they needed to implement reliability best practices to prevent contamination, as well as to help the gearboxes perform reliably and last longer.

LE Solution: Jim Pezoldt, LE lubrication consultant, recommended that the company follow best practices with a focus on the lubricant and enhanced reliability. This program included the implementation of standard operating procedures such as oil filtration and annual oil sampling. Using those recommendations, the customer developed a reliability program for maintaining its gearboxes—including the best practices listed below:

Reliability Program:

- Best possible flushing procedure (see below)
- Best possible lubricant for the application: LE's Duolec Vari-Purpose gear lubricant (1606)
- Best possible transfer and filter system: AMS model C 10150-1-6x-18DP-120
- Best possible oil analysis program: LEAP Advanced Industrial with PQ
- Appropriate target alarms
- Onsite training
- Annual status report and review of action requirements

Lubricant Recommendation and Oil Analysis

While the gearboxes run for only a few hours each year, they do so under heavy loads. And so, heavy-duty industrial gear oil is required. Duolec 1606 is a (specified) AGMA 6 EP gear lubricant that contains a premium base oil and robust additive package, making it ideal for these gearboxes. Another challenge: the oil must reside in the gearboxes for long service intervals because replacement is problematic. Duolec is designed to perform well under these conditions. And finally, one more hurdle: the necessary longevity of service time and the location of the gearboxes make them susceptible to water contamination. Duolec separates readily from water to provide effective lubrication when moisture is present. Ordinary gear oils will emulsify and foam, causing increased frictional heat and poor lubrication.

The new LEAP Advanced Industrial with PQ test slate is also a good match for this application. The particle quantifier test makes it possible to determine the cleanliness of the oil and to establish the right frequency for using the filter cart.

Flushing Procedure:

Step 1:Add 6% L-X Heavy-Duty Chemical Supplement (2300) to existing oil; run for no more than 50 hours and no less than 4 hours.
Step 2: Drain the oil while warm.
Step 3: Fill with LE's Duolec Vari-Purpose gear lubricant (1606).
Step 4: After 50 hours of service, open ball valve and drain the discolored oil. *Do this while machine is not running* (at least 20 minutes). If extensive discoloration is present, repeat process until only clean LE oil appears.

Other LE products used:

- Almaplex industrial lubricant (1275) for non-food grade bearings
- Monolec R&O com pressor/turbine oil (6404) for turbine and governors
- Quinplex foo machinery lubricant (4024) for wicket gate bear ings
- Quinplex synthetic food grade oil (4046) for waste gate hydraulic system

Results

By implementing this reliability program the customer will be able to better maintain its equipment. The conversion to Duolec 1606 was done in 2010, with follow-up results expected in 2011 or early 2012.

Summary

- Implemented a reliability program for proper maintenance of gearboxes, including an enhanced monitoring system.
- Eliminated abrasive contamination caused by the previous oil.
- Made changes that will contribute to a longer gear lifespan.

(Results based on actual user experience. Individual results may vary. Not intended to supersede manufacturer specifications. Duolec, L-X, Almaplex, Monolec *and* Quinplex *are registered trademarks of Lubrication Engineers, Inc. LE operates under an ISO 9001 Certified Quality System; SIC 4911; LI70822 12-10.*)

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Conclusion

Today there are various reasons to reduce energy consumption—conserving natural resources, reducing emissions and improving profitability among them. Governments and corporate management alike continue looking for ways to reduce energy consumption.

Indirect energy use—more commonly called industrial use—is greater in all regions of the world than direct or personal use. That makes industry the largest consumer of energy and therefore the greatest source for potential reductions. Energy use can be measured through production output, temperature changes and electrical consumption. It is possible to make dramatic gains in energy efficiency by reducing friction, and one of the best ways to do that is to employ good lubrication practices, including the use of high-performance lubricants and adoption of lubrication reliability best-practices. The key to success is finding a lubricant company that will not only provide the right high-performance lubricants for the applications, but will also recommend reliability solutions that will further reduce friction and maximize equipment efficiency.

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