State of Pennsylvania

Energy Efficiency

Technical Reference Manual

Energy Efficient Industrial Lubricants: Reducing Energy Consumption with Industrial Lubricants

New Measure

Justin Young, Eric Eriksen, ExxonMobil

6/23/2020

TABLE OF CONTENTS

Table 1 Work Paper Revision History

#	MM/DD/YY	Author, Company	Summary of Changes
1	12/14/2020	Justin Young, Eric Erksen ExxonMobil	New Measure

1 Overview

The energy efficienct industrial lubricant is a measure based on an existing study within the Wisconsin Focus on Energy Technical Reference Manual and numerous academic and independent engineering studies. This measure was measured and verified in 2017 through the Focus on Energy Emerging Technologies Program. This measure is presented with an algorithm for savings calculation as well as a table of deemed savings values for common applications. This measure is expected to consistently deliver energy efficiency during all climate zones and seasons in Pennsylvania and for equipment located both indoors and outdoors.

Total manufacturing output in Pennsylvania in 2018 contributed $95 billion in gross state product (12%) from 12,262 manufacturers. Many of these manufacturers within Pennsylvania have made energy efficiency a corporate priority (e.g. Kiewit, Alcoa, Berry Plastics, etc). In Pennsylvania, the cement, automotive, food, paper, rubber, mining equipment, and general manufacturing sectors can provide a large opportunity to reduce energy consumption. Rubber, plastic and food and beverage manufacturing alone in Pennsylvania have the potential to save **12,247 MW-Hr per year,** (and just one company in the rubber mixing sector shows a potential to reduce 770 MW-Hr per year alone by using an energy efficient gear oil (at 3% energy reduction)).[A]

In addition to manufacturing operations which consume notable quantities of energy, the mobile off-road fluid power market comprises construction, agriculture, material handling, oil and gas, and mining sectors. Combined, these markets consume up to 1.8 quads of energy per year in the United States, corresponding to approximately 6.5% of the total energy consumed in the transportation sector in 2017. [1] There is strong motivation within the hydraulic fluid industry to improve efficiency, productivity, performance, uptime/availability, life cycle costs, maintenance costs, and environment & safety compliance.[1]

Some manufacturers of industrial lubricants have committed to providing products and services that help deliver tangible performance and sustainability related benefits — as well as material economic advantages — to manufacturers. As a result, they have developed an extensive range of high-performance lubricants that can help increase equipment operating efficiency. At the same time, these lubricants can help contribute to reduced energy and resource use, lower emissions, and cost savings for industrial equipment.

The energy efficient industrial lubricants must meet the rigorous criteria for energy efficiency. Statistically valid data must be available to substantiate the energy efficiency claim and demonstrate a statistically significant decrease in energy consumption or increase in efficiency when compared with commercially available products designed and intended for the same application.

2 New Measure Characterizations

DESCRIPTION

Industrial gear reduction systems use gear oil to transfer input energy to output power. Gear oils also protect critical components from premature wear. Energy efficient gear oil lubricants meet these requirements and provide reduced energy consumption. Energy efficient gear oils have a lower coefficient of friction which reduces the friction between two moving parts (two gears meshing together covered in gear oil). This lower coefficient of friction reduces the energy required to yield output power. Second, these oils have a high viscosity index which reduces the effect temperature has on the viscosity of the gear oil. The high viscosity index allows constant viscosity over a range of operating temperatures which optimizes volumetric and mechanical efficiency at the pumps rated output. Additionally, energy efficient gear oils reduce the operating temperature of the gear-reduction gearbox.

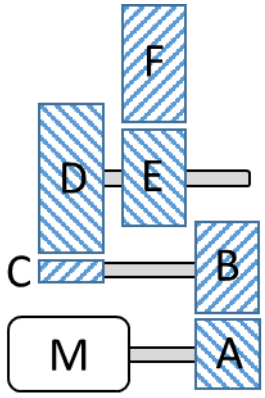
Manufacturers who use electric-motor-driven gear-reduction gearboxes can reduce energy consumption by up to 1% per gear-mesh (e.g. 3% efficiency for a 3-reduction gearbox). This measure was developed to be applicable to the following program types: NC, RF, and Time of Sale – New Equipment.

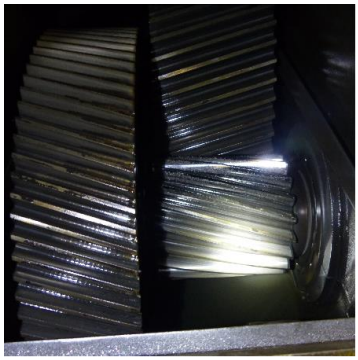
If applied to other program types, the measure should be verified as a custom measure.

DEFINITION OF EFFICIENT EQUIPMENT

This is applicable for small, medium, and large manufacturers in all climate zones using electric motors to power their gear reduction equipment; is applicable both inside and/or outside conditioned areas; or for all gear reduction systems on mobile equipment in all climate zones on Pennsylvania.

This is an example diagram of a 3-reduction gearbox where M = Motor and each gear is labeled A through F with F being the output gear (output shaft not shown in this diagram).





Real picture of the 3 gear-reduction gearbox shown in the diagram on the left. Not all gears are visible in this picture. Gear oil is an oil bath and splash lubrication system.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is defined as gearbox using non-energy efficient industrial gear lubricants which provides no energy efficiency benefits. In the formula below, the baseline equipment is where, η = zero.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years. The energy efficiency is a result of reducing friction in the operating equipment. The useful life of the lubricant is deemed to be 10 years when properly maintained.

The ability to reduce energy consumption (energy efficiency) is an inherent characteristic in the oil which does not deplete over time. As long as the energy efficient oil is in use, it will provide energy efficiency.

DEEMED MEASURE COST

Incremental costs equal the price difference between an energy-efficient gear oil lubricant and a standard gear lubricant which will vary across the state of Pennsylvania.

[3] Public Service Commission of Wisconsin, "Evaluation – Business Program: Measure Life Study," Focus on Energy (2009): page 1-4, Table 1-2 Recommended Measure Life by WISeerts Group Description for Building Shell Equip or Tech measure type, accessed December 3, 2019, https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

[4] Mobil Warranty for Industrial Oils since energy efficieny oil will be used for the life of the equipment.

LOADSHAPE

N/A

COINCIDENCE FACTOR

No coincidence factor though it is noted that reduced consumption for equipment will reduce the overall baseload power demand, especially if a construction operation or manufacturing operation demand more utility power in summer weather (e.g. construction ground work, rubber manufacturing, etc).

Algorithm

CALCULATION OF ENERGY SAVINGS

Savings are calculated based on a reduced coefficient of friction and the shear-stable high viscosity index value associated with energy-efficient gear oils in gear-reduction systems. The algorithm below for Energy Savings, ΔE, is modeled after the Focus on Energy Emerging Technology Program M&V study.

ELECTRIC ENERGY SAVINGS

$$\Delta E = Motor\,HP * \left[\frac{0.746\,kW}{HP}\right] * \left[\frac{\%\ motor\ loaded}{motor\ efficiency}\right] * \left[\frac{Hours\ of\ Operation}{year}\right] * \eta$$

Where:

ΔE = Reduced energy in kWh/Year.

Motor HP = Rated power consumption of electric motor, summed when pumps are in series.

% motor loading (Load) = Output power as a % of rated power and is calculated as follows:

$$\%\ motor\ loading = 100\% * \left[\frac{Measured\ three\ phase\ power\ in\ kW}{Input\ power\ at\ full\ rated\ load\ in\ kW}\right]$$

For example calculations, load% is assumed to be 75%[8]. See chart in reference 8.

Motor efficiency = 93% estimated for motors in the size range typically used. [5, 8] See references; see chart in reference 8.

Hours of Operation per year = Number of operating hours per year.

η = Efficiency, 1% per gear mesh[2, 6]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

$$\Delta E = Motor\,HP * \left[\frac{0.746\,kW}{HP}\right] * \left[\frac{\%\ motor\ loaded}{motor\ efficiency}\right] * \left[\frac{Hours\ of\ Operation}{year}\right] * \eta$$

Where:

ΔE = Reduced energy in Fuel Consumed/Year. To calculate the quantity of diesel fuel reduced in construction equipment (i.e. haul trucks, etc), multiply the quantity of fuel consumed annually by η. This efficiency translates to the reduced quantity of fuel consumption. [6, 12]

Motor HP = Rated power consumption of electric motor, summed when pumps are in series.

% motor loading (Load) = Output power as a % of rated power and is calculated as follows:

$$\%\, motor\ loading = \ 100\% * \left[\frac{Measured\ three\ phase\ power\ in\ kW}{Input\ power\ at\ full\ rated\ load\ in\ kW}\right]$$

For example calculations, load% is assumed to be 75%[8]. See chart in reference 8.

Motor efficiency = 93% estimated for motors in the size range typically used. [5, 8] See references; see chart in reference 8.

Hours of Operation per year = Number of operating hours per year.

η = Efficiency, minimum 4% in differentials and final drives.[2, 8]

WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Example O&M Cost Adjustment Calculation

$$\Delta E = \ Motor\ HP * \left[\frac{0.746\ kW}{HP}\right] * \left[\frac{\%\ motor\ loaded}{motor\ efficiency}\right] * \left[\frac{Hours\ of\ Operation}{year}\right] * \eta$$

ΔE = kW•Hrs reduced (saved) per year per unit

Motor HP = 100HP

% motor loaded = 75%[9].

Motor efficiency = 93% [5, 8]

Hours of Operation per year = 24 hours per day, 5 days per week, 50 weeks per year = 6,000 hrs

η = Efficiency, 3% (1% per reduction in a 3-reduction gearbox).[2, 6]

$$\Delta E = \ 100\ HP * \left[\frac{0.746\ kW}{HP}\right] * \left[\frac{75\%}{93\%}\right] * \left[\frac{6000 hrs}{year}\right] * 0.03$$

$$\Delta \boldsymbol{E} = \frac{\boldsymbol{10,829\ kW \cdot Hrs}}{\boldsymbol{Year\ * 1\ Gearbox}}$$

Further implied costs and savings are as follows:

TRM O & M Energy Efficiency Calculation

Customer / Contact: **Rubber Manufacturer**
Location: **City, Illinois**
Date (mm/dd/yyyy): **Date, 2020**

Assumptions (entered from Data Input Sheet):

Total Number of Units Helical Gears	No. of Gear Reductions	Avg. Hrs / Yr	Efficiency 1% per gear reduction	Labor Rate ($/Hour)
1	3	6,000	1%	$75.00

Downtime Availability Cost ($/Hour)	Downtime to change gearset (hrs)	Downtime to change brg/seal (hrs)	Electric Motor Power (Hp)	Labor Hrs / Oil Change
$100	48	0	100	1

Electricity Cost ($/kW-hr)	Gear Set Cost ($)	Labor Hrs to (total labor hours)
$0.04	$12,000	100

Seal Cost - all shaft seals ($)	Bearing Cost - all bearings ($)	Labor Hours to replace brgs/seals (total labor hours)
$100	$1,500	6

Total HP #Units X 100 HP	Conversion Factor (HP to kW)	% Loaded Motor Efficiency	Hours of Operation Year	Efficiency	ΔE = Reduced energy in kW-Hr/Yr
100	0.746	0.806451613	6,000	3.00%	10,829

3 References

1. "HIGH-PERFORMANCE FLUIDS AND COATINGS FOR OFFROAD HYDRAULIC COMPONENTS" December 3, 2019, https://www.energy.gov/sites/prod/files/2019/06/f64/ft082_fenske_2019_o%20REVISED_5.28_4.05pm.pdf

2. "Energy Efficiency of Industrial Oils", December 3, 2019, https://www.tandfonline.com/doi/abs/10.1080/10402009908982281

3. Public Service Commission of Wisconsin, "Evaluation – Business Program: Measure Life Study," Focus on Energy (2009): page 1-4, Table 1-2 Recommended Measure Life by WISeerts Group Description for Building Shell Equip or Tech measure type, accessed December 3, 2019, https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

4. Mobil Warranty for Industrial Oils

5. Improving Pumping System Performance: A Sourcebook for Industry" December 3,2019, https://www.energy.gov/sites/prod/files/2014/05/f16/pump.pdf

6. Lubricants & Energy Efficiency: Life-Cycle Analysis, December 3, 2019, https://www.sciencedirect.com/science/article/pii/S0167892205800586

7. https://www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_handbook_web.pdf, Table 3-3, page 3-6.

8. Determining Electric Motor Load & Efficiency, June 23, 2020: https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf

9. Attachment: Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles, 2010, National Academies of Science Engineering Medicine. Also available at http://nap.edu/12845

FOOTNOTE A: There are hundreds of manufacturers in Pennsylvania which will be able to achieve savings from energy efficient gear oil. Specifically, there are 567 rubber, plastic, and food and beverage manufacturers in PA. Assuming each site has at least two (2) 100-HP motors driving a gear-drive component. As demonstrated in several in-situ application studies, a 3% reduction in energy consumption is noted for a 3-reduction gear box. Operational time assumes 24 hours per day, 5 days per week, 50 weeks per year. This yields (2) X 10,829 kW-Hr/Yr = 21,658 kW-Hr per year per company.

21.6 MW-Hr per year for 567 companies at this production rate has the **potential to reduce 12,247 MW-Hr per year** in Pennsylvania.

In one specific case, one company in the rubber mixing sector showing potential to reduce 770 MW-Hr per year alone by using an energy efficient gear oil (at 3% energy reduction). They use four (4) 2,150 HP gearboxes that are 3-reduction gearboxes (operation of 15 hours per day, 5 days per week, 52 weeks per year).

4 Stakeholder Comments

5 Appendix and Supporting Documentation

Proof of performance

Mobil SHC
Performance by ExxonMobil

Mobil SHC Gear 220 helps improve gearbox reliability and efficiency*

Energy lives here™

Falk helical gear double reduction gearbox | Mining operation | Minnesota, United States

Situation

A Minnesota-based mining company operates a conveyor driven by Falk double reduction gearboxes. These gearboxes, which were lubricated with a mineral-based gear oil, are critically important to the customer's operation, but have a high energy demand. Seeking to improve the reliability and efficiency of these drives, the company approached ExxonMobil engineers for an alternative lubricant solution.

Recommendation

ExxonMobil engineers recommended the company use **Mobil SHC™ Gear 220** synthetic gear oil. Formulated with synthetic base fluids and an advanced proprietary additive system, **Mobil SHC Gear 220** is specifically designed to provide excellent wear protection and extended oil life even under extreme conditions.
In addition, ExxonMobil engineers worked closely with the company to develop an energy efficiency test protocol to evaluate the synthetic gear oil's performance.

Benefit

Mobil SHC Gear 220 synthetic gear oil has helped this mining company increase gearbox efficiency and extend oil drain intervals to deliver a company-estimated annual savings of US $7,400 in energy, labor and lubricant expenses.

Impact

After switching to **Mobil SHC Gear 220** synthetic gear oil and completing a thorough energy efficiency test protocol with ExxonMobil engineering support, the company reports that it has increased gearbox efficiency by an average of 3.6 percent. In addition to expected improvements in gear and bearing protection provided by **Mobil SHC Gear 220**, the company expects to triple current oil drain intervals. Collectively, these benefits have helped the company save US $7,400 annually in energy, labor and lubricant expenses.

3.6% Increase in gearbox efficiency

Industrial Lubricants | Advancing Productivity™

Advancing productivity

Helping you reach your Safety, Environmental Care** and Productivity goals through our innovative lubricants and services is our highest priority. That's Advancing Productivity. And that's how we help you achieve your broader vision of success.

*This Proof of Performance is based on the experience of a single customer. Actual results can vary depending upon the type of equipment used and its maintenance, operating conditions and environment, and any prior lubricant used.

**Visit mobilindustrial.com to learn how certain Mobil-branded lubricants may provide benefits to help reduce environmental impact. Actual benefits will depend upon product selected, operating conditions and applications.

mobilindustrial.com