Frictionless Open Gear Lubricant

By Hocine Faci, Ivan Bjel, Alex Medrano, Bob Cisler, Castrol Industrial North America

Presented at NLGI's 68th Annual Meeting, October 2001, Palm Beach, Florida, U.S.A.

Tackiness/adhesion, mechanical stability, water resistance, corrosion resistance, thermal retention, low temperature pumpability, and storage stability are suitable characteristics for open gear compounds. The load carrying capacity, strongly impacted by the base fluid viscosity and the extreme pressure (EP) additives, along with the anti-wear (AW) properties are though the critical criteria that determine the performances of open gear lubricants. The component life has always been associated with these two characteristics but less so with the friction reduction (FR) properties. Would it be possible to conceive an open gear compound offering low friction and at the same time displaying strong EP/AW characteristics? In such a case how would be the laboratory and field performances? Presented in this paper are the results of an investigation carried out in order to evaluate the effect of friction reduction on the performances of an open gear lubricant and its impact on the component life. For this purpose the following plan was adopted: (1) determine the EP/AW characteristics along with the coefficient of friction (COF) of a series of commercially available products, (2) set the requirements for the prototype to be developed, (3) develop the prototype, and finally (4) test the product in the field.

Evaluation/Benchmarking

Products: A series of 8 different types of commercially available open gear compounds were selected for benchmarking this study. These products represent a good sample of the open gear lubricant technology presently available in the market (*Table 1*).

These Products may contain the following components:

- Base oils: they include asphaltic compounds, naphthenic oils, paraffinic oils, synthetic fluids, or combinations. The viscosity of the base fluids vary from as low as 250 cSt at 40°C to as high as 800 cSt at 100°C.
- Thickeners: they include lithium 12-hydroxystearate, aluminum complex, calcium sulfonate, bentonite, carbon black and fumed silica.
- Solid lubricants: they include graphite, molybdenum disulfide, calcium carbonate, calcium hydroxide, etc. or combinations.
- Packages of EP/AW additives: including S-P-N compounds, free or in association with metallic elements such as Zn, Mo, Ca, B, Sb, etc.
- Other packages of additives such as anti-corrosion, anti-oxidant, VI improver, tackifiers, etc. may be present.

Testing Equipment

Equipment such as Four Ball EP, Four Ball Wear, Timken, Pin & V-Block, and FZG, to name only a few, have played and still continue to play a major role in the development, testing and selection of lubricants for open gears. In this study, Four Ball EP, Four Ball Wear and SRV have been chosen for determining the EP, AW and Coefficient of Friction (COF) respectively.

Table 1
Commercial Open Gear Lubricants. Lubricity Characteristics.

Product	Thickener Type	Base Fluid Type
P1	Lithium 12-hydroxysearate	Mineral/Synthetic
P2	Lithium 12-hydroxystearate	Mineral
P3	Al Complex	Synthetic
P4	Calcium Sulfonate	Mineral
P5	Non	Asphaltic
P6	Clay	Mineral
P7	Carbon Black	Mineral
P8	Silica	Mineral/Synthetic

Four Ball EP consists of 4 balls arranged in the form of an equilateral tetrahedron. The basic elements of the tetrahedron are 3 balls held stationary in a pot to form a cradle in which the fourth ball or upper ball is rotated around a vertical axis under pre-selected conditions of loads. The rotating speed is 1770 ± 60 rpm. A series of 10 second runs are made successively at higher loads until welding of the four balls occurs.

Four Ball Wear: The operation of the machine is based on the same principles as above. The sample is placed in a pot containing the 3 lower balls. The upper ball rotates at a specified speed under a predescribed load at a controlled temperature. The test duration standard is 1 hour. The diameters of the wear scars on the stationary balls are measured after completion of the test.

Test Conditions: 1200 rpm, 40 kg, 75°C, 1 hour.

The average of the scar diameter is obtained for each run and the average of 2 runs is reported as final scar diameter.

SRV Machine: Two main reasons were behind the selection of an SRV machine for this study: (1) the end user as well as the OEM (mining) have in possession sufficient data that correlate the performances of a series of open gear compounds to the laboratory results obtained with an SRV machine, and (2) the SRV machine offers the possibility of simulating the open gear contact conditions (starved film).

The SRV machine consists of a test chamber where two test specimens are pressed on each other. The top specimen which can be a ball, pin, ring, rod, or a disk, is oscillated on the bottom specimen (disk) at preprogrammed settings of frequency, stroke, load and temperature. The specimen contact is lubricated with the lubricant sample. Standard specimen contacts are point, line or area. Friction force is affecting the friction, or (2) begin with a high EP level type product and attempt to lower the COF without affecting the load carrying capacity. The second option was adopted since it is generally recognized that the EP property should be granted characteristic that nobody wants to compromise. Therefore, the following requirements were set for the product to be developed: (1) Extreme Pressure: 800 kg weld minimum in Four Ball EP test, (2) Anti-Wear properties: Scar diameter: 0.70 mm maximum in Four Ball Wear test in the conditions specified above, and (3) Coefficient of Friction: 0.08 max. in SRV test in the conditions specified above.

Development

Different combinations of base fluids (petroleum base oils and synthetic fluids) with various viscosity and solvency, added to another combination of solid lubricants, along with diverse packages of extreme pressure, anti wear and friction modifiers, were investigated.

Optimization of Base Fluid Viscosity and Viscosity Index

Different types of base fluids varying from paraffinic and naphthenic oils to synthetic fluids have been used. Different viscosities as well as viscosity indexes (VI) have been subject to investigations. Optimum results were obtained at a given proportion Paraffinic/Naphthenic/Synthetic. An optimized viscosity was an important contributor to lowering the COF. The tackiness, adhesion as well as the response to the additives were also taken into consideration in the final adjustments to the formula.

Optimization of Solid Lubricants

A series of commercially available solid lubricants, with different particle sizes and surfaces area have been investigated at different proportions. The challenge was to obtain an 800 kg "pass" in the Four Ball EP test and, in parallel, aim for the lowest COF possible. Three different types of solids used together at given proportions have significantly contributed to the lower COF ever obtained under the given test conditions.

Optimization of EP/AW/FM

The objective was to screen a series of compounds to be used with a friction modifier in order to improve the friction characteristics without affecting the EP/AW properties. A combination of several compounds was found that, in combination with the optimized base fluids and specific solids, yielded very low coefficient of friction, while maintaining a weld load no lower than 800 kg in the Four Ball EP test and the scar diameter no larger than 0.70 mm in the Four Ball Wear test.

Field Testing

In coordination with the OEM, an extensive SRV testing was carried out in order to determine the performances of the new "Frictionless" Open Gear Lubricant (FLOGL) when used in steel-bronze configurations. Coefficients of friction of 0.02 have been replicated.

The product has been applied in drag gearing, center pintle, slew rack, roller/rail, propels, shafts/bushings in draglines. The results of the field testing were exceptional. They can be summarized in the following customer comment: "FLOGCL was used without interruption in open gears and bushings for 50,400 operating hours. Recent inspections revealed that all bushes had original machining marks intact." This year, the product entered its 7th year of utilization. It continues to maintain its exceptional performances in all the lubrication points in which it is applied.

Conclusions

A coefficient of friction as low as 0.02 (per SRV test) is attainable in open gear compounds. This COF which is the result of a synergetic composition involving specific base oils, solid lubricants and different EP/AW/FM packages selectively optimized, did not alter the EP/AW characteristics of the lubricant. The lab results obtained on the steel-steel configuration have been replicated on the steel-bronze configurations leading to exceptional field performance in open gears as well as in bushing applications.

Acknowledgement

The authors would like to acknowledge and appreciate the assistance of Castrol Performance Testing Laboratory at Downers Grove, Illinois and Applied Chemicals for conducting the lab and field testing.

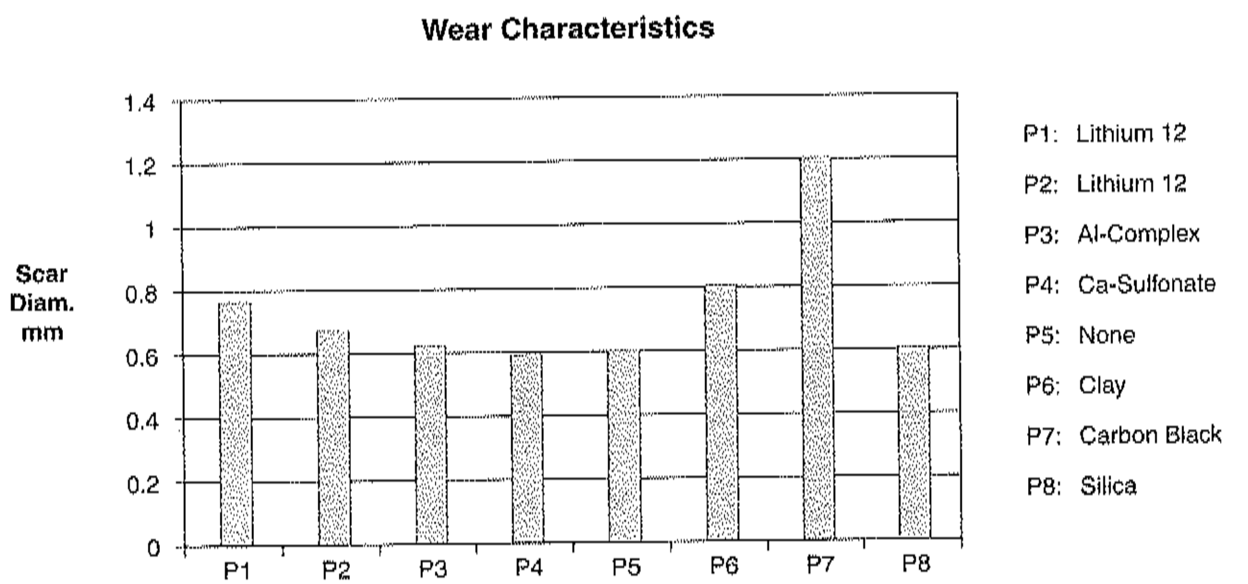

Figure 1 – Wear Characteristics

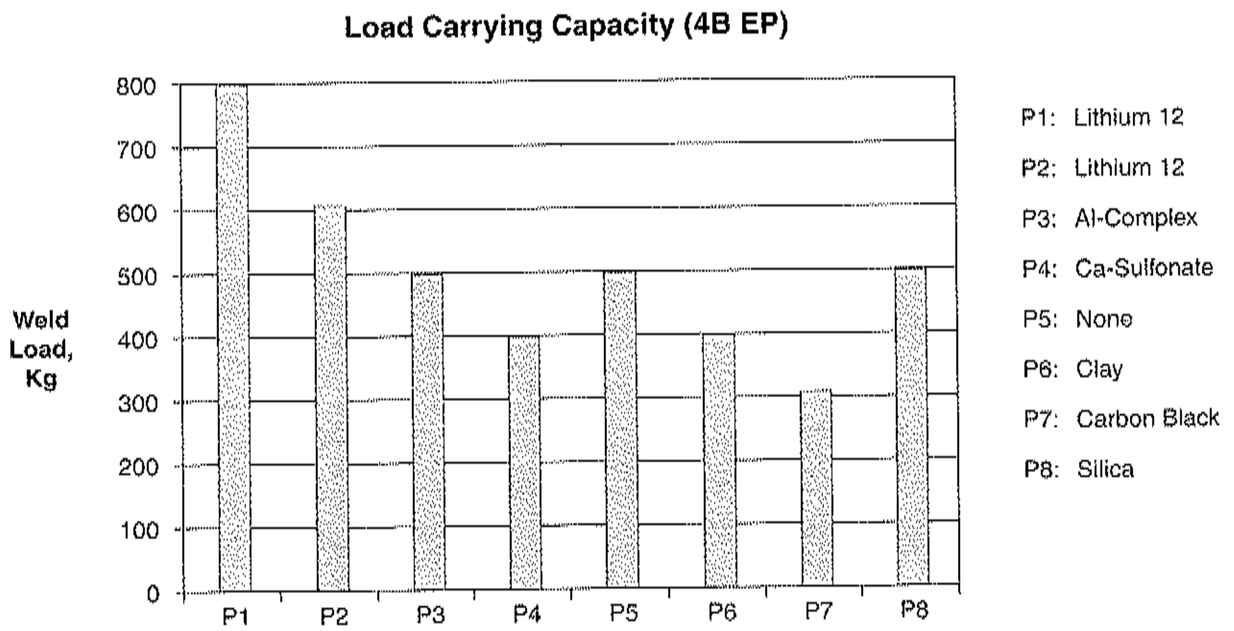

Figure 2 – EP Characteristics

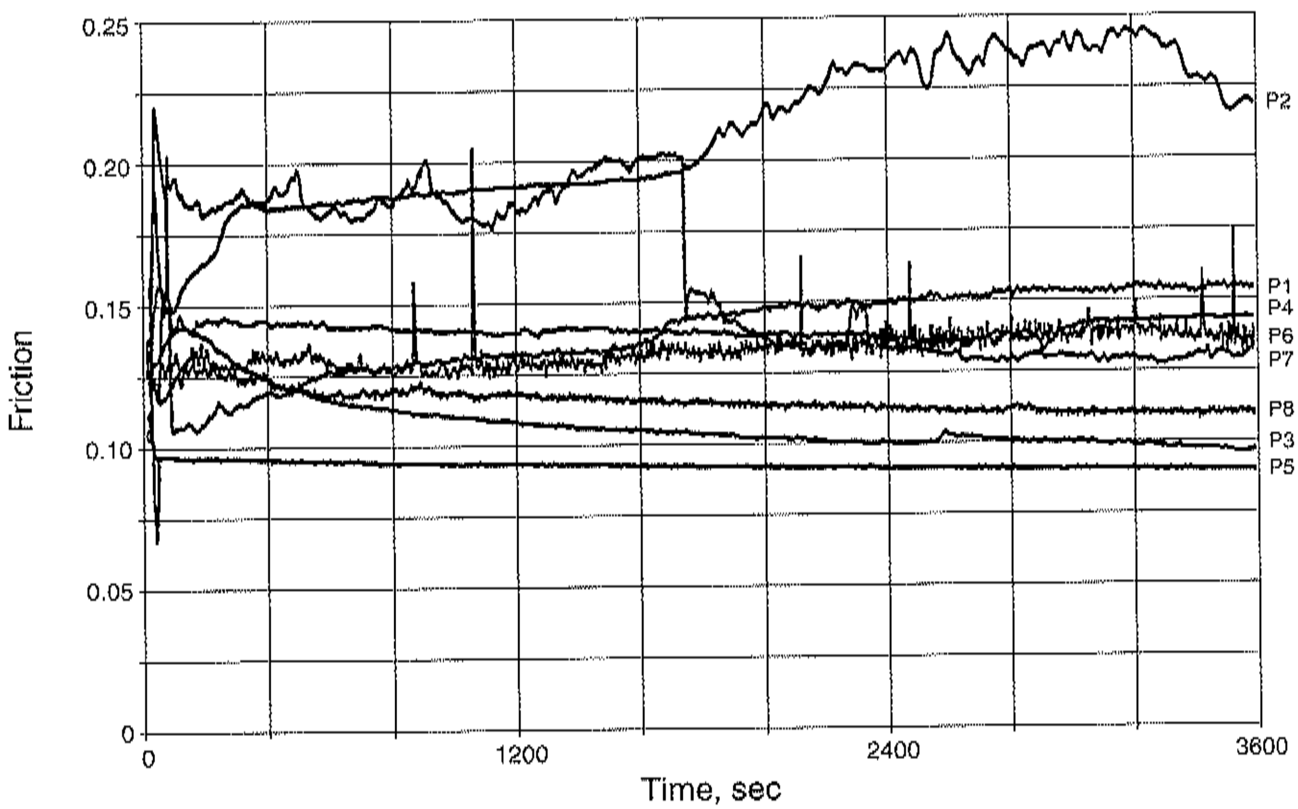

Figure 3 – Coefficient of Friction by SRV Test

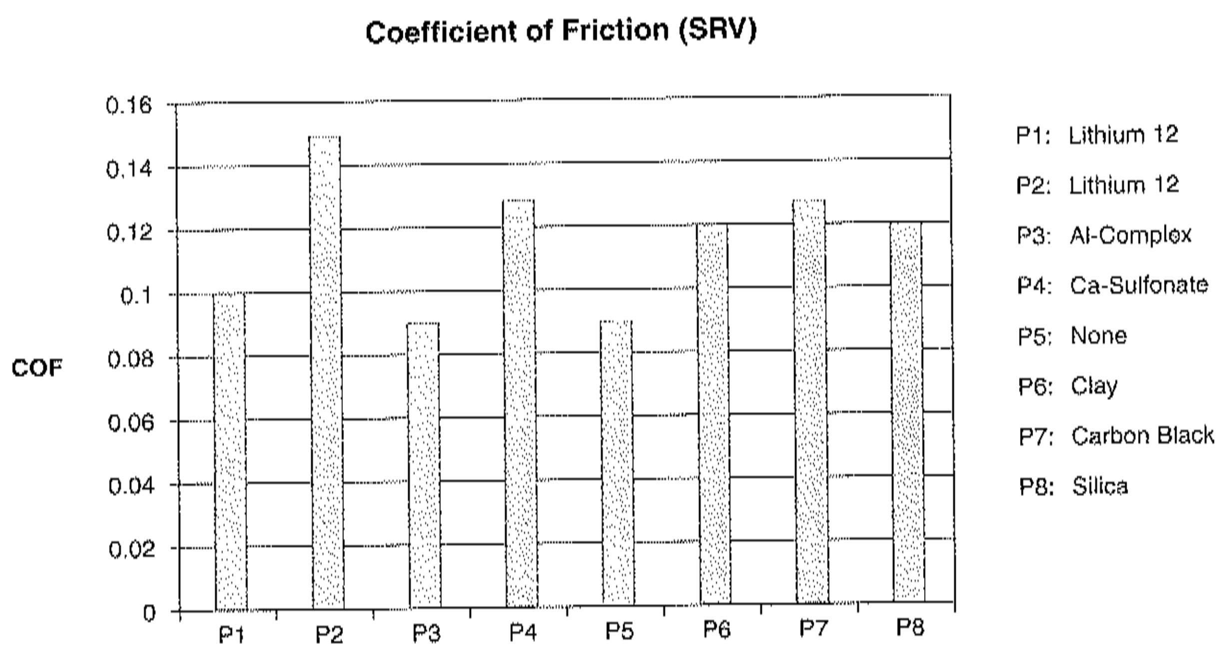

Figure 4 – Coefficient of Friction (Minimum)

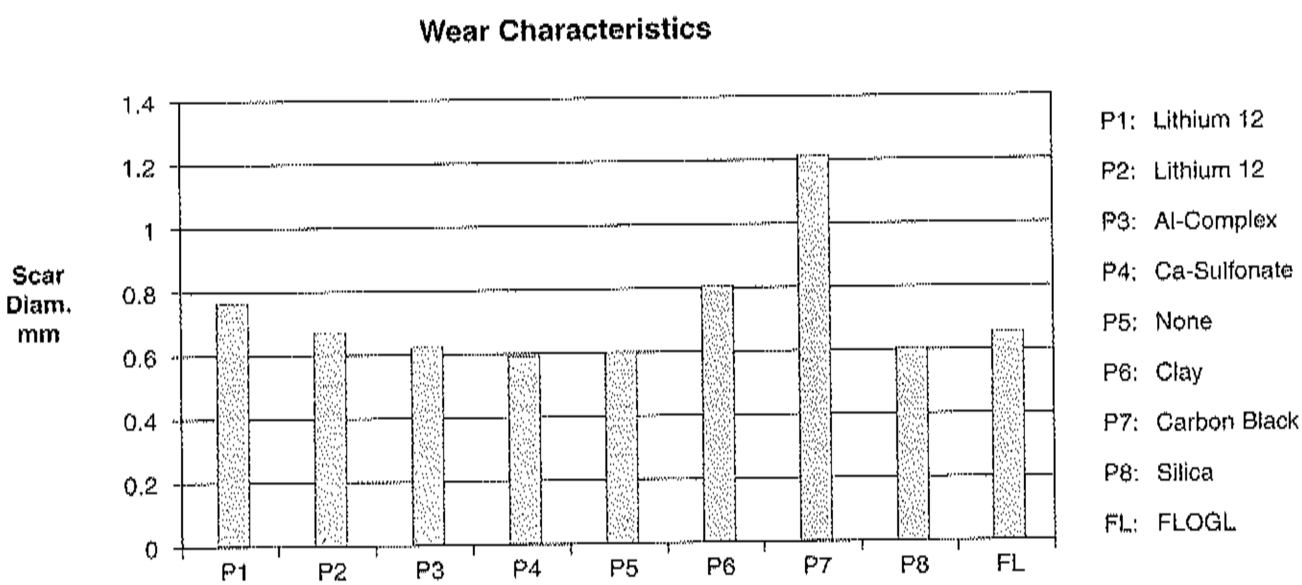

Figure 5 – Wear Characteristics

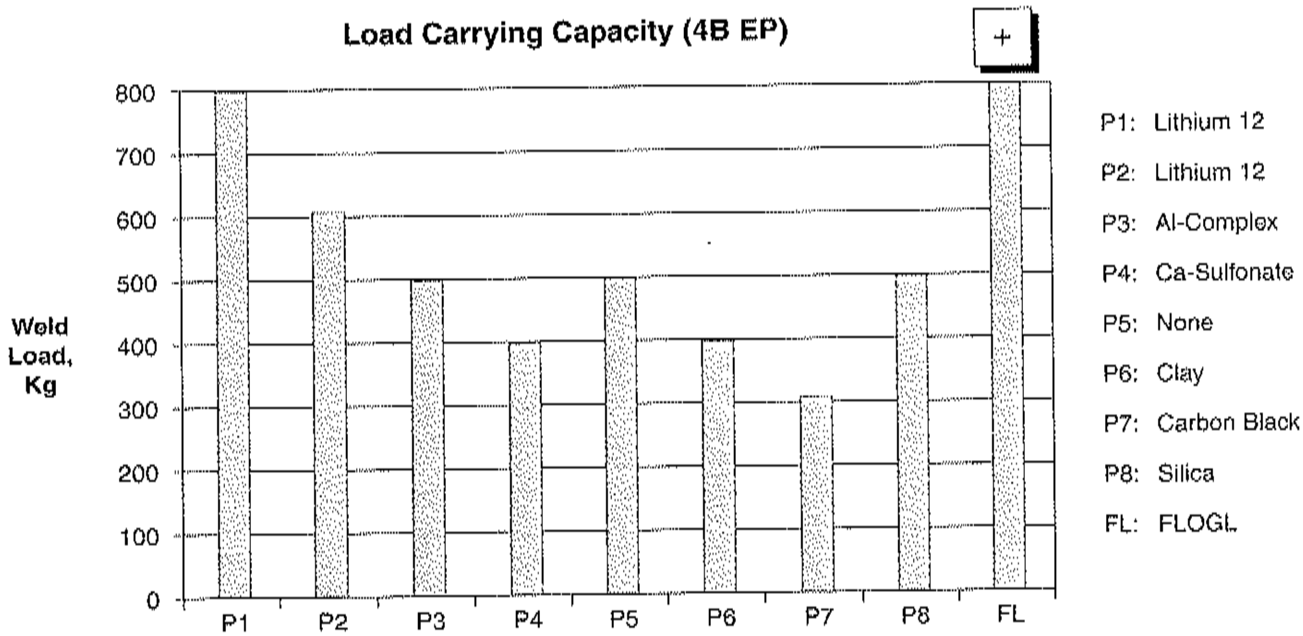

Figure 6 – EP Characteristics

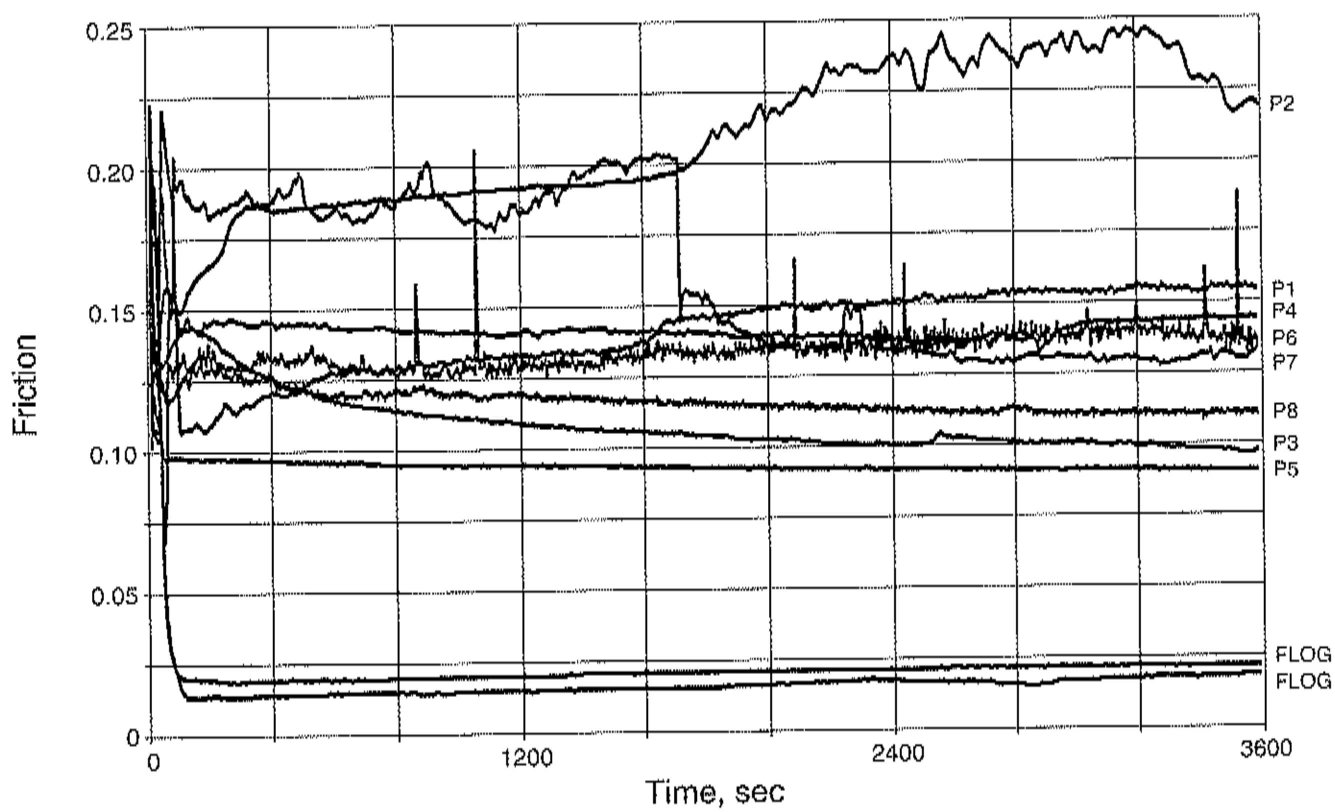

Figure 7 – Coefficient of Friction by SRV Test

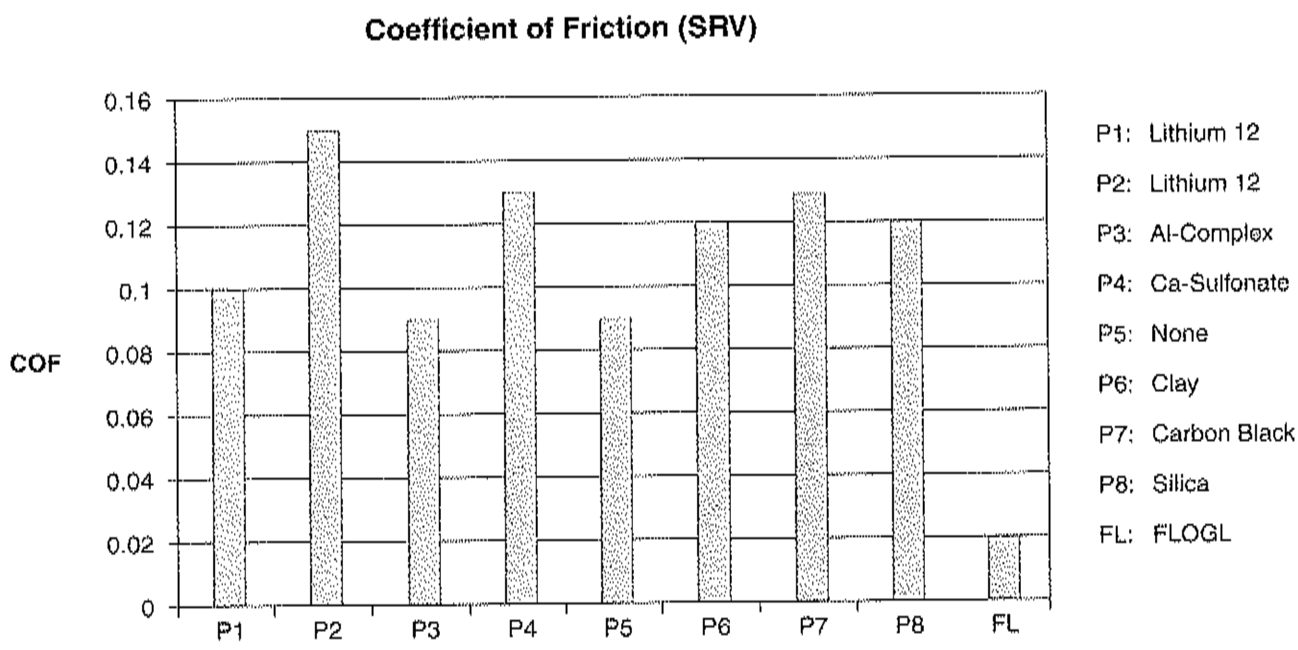

Figure 8 – Coefficient of Friction (Minimum)

About the Author

Hocine Faci, BS, PhD (Chemical Engineering), Institute of Petroleum and Gas, Romania. Currently a Development Scientist in charge of grease development at Castrol Industrial North America, Performance Lubricant Division. Has been active in petroleum refining and lubricant for over 16 years. Has 2 patents pending and is a Certified Lubricant Specialist. Member of STLE, ACS and AICHE.