LUBRICANTS WORLD 2004 Product of the Year

Nye Lubricants UniFlor™ 8917

By Rob Harvan, Senior Editor

The identification and selection of the **Lubricants World** Product of the Year is a fascinating but difficult task. It gives the Selection Committee the opportunity to learn about new applications and products in the lubricants industry. This doesn't always mean that the product and application are new. Sometimes it's a case of "building the better mousetrap"; that is to say, finding a better way to do it.

The 2004 Product of the Year falls into this latter category, a new product for an existing need. UniFlor™ 8917 from Nye Lubricants of Fairhaven, Massachusetts, is a perfluoropolyether (PFPE)-based grease developed to meet the demanding and specific performance criteria for automotive electrical connector lubricants. These connectors, typically numbering in the hundreds, help run everything from headlights to DVD players, body impact sensors and global positioning systems, and their use is growing.

Electrical connectors are a big business. Bishop & Associates – a St. Charles, Illinois-based consulting firm that follows the connector business – estimates 2001 shipments exceeded US$25 B. Yet, while the dollar amounts are significant, the need for connectors to function effectively is of even greater importance.

Nowhere is this requirement more important than with automotive connectors. They must operate in a harsh environment. They must also be designed so they can be joined for initial electrical system assembly, and taken apart/rejoined for any repairs. Terminal junction pins in connectors are vulnerable to water, heat/cold cycles, road grit, mechanical vibrations, and stress, all of which can be catalysts for oxidation on contacts and fretting corrosion. The corrosive processes create resistive oxides, which in turn cause intermittent faults or electrical failure. Thus, the connections must remain tight, and maintain a current flow for extended periods in harsh conditions. Current standards force automakers to guarantee that contact resistance will remain below 10 milliohms over 10 matings of separable connectors.

Meanwhile, increasingly stringent ergonomics standards have made their way to the assembly line. To help prevent carpal tunnel syndrome and other repetitive stress injuries among workers, the United States Council for Automotive Research (USCAR) recently slashed the allowable mating force for separable connectors to 16 pounds, a value that must persist over 10 matings per connector. Thus, achieving the tight, reliable con- nection cannot rely on the use of brute force during assembly.

Connectors in the engine compartment must survive rapid and repeated cycles of heating and cooling, exposure to corrosive gases and fluids, as well as road grit. Power mirrors, door locks, and other external systems face water and deter- gent baths in car washes. High levels of humidity threaten connector performance between door panels. Temperatures inside the passenger compartment can soar when exposed to sun, and drop well below freezing in cold climates. Throughout the vehicle, connectors are subject to vibration from the engine, drive train, suspension system, and related components. As carmakers lengthen warranties and increase reliance on electrical and electronic systems, the challenge for connector manufacturers is to extend the operating life of connectors in ever more harsh environments.

The Role of Lubricants in Connector Performance

Connector quality depends on many factors, including mate- rials, contact geometry, normal force, and design of springs, crimp mechanisms, and housings. Lubrication also plays an important role, especially for low-voltage connectors (those under 0.5 watts).

A properly selected lubricant lowers insertion force by decreasing the coefficient of friction between mating surfaces. It reduces mechanical wear by placing a film of oil between the surfaces. With additives, a lubricant minimizes corrosion. Vibrations can be caused by the motion of nearby compo- nents, such as fans or small motors; thermal expansion; and vehicular motion in general.

Lubricants also reduce fretting corrosion, a special type of mechanical wear caused by low amplitude vibration. Typically occurring with tin-plated contacts, fretting corrosion continually exposes fresh layers of metal to oxidation. An anti-fretting lubricant reduces mechanical wear, provides an oxygen barrier, and helps to move any oxide debris away from the contact area.

For gold-plated connectors, a lubricant reduces noble metal wear during mating and separation, while also protecting against substrate corrosion. Thin gold plating can be microscopically porous and subject to substrate oxidation, which can eventually exude through the substrate pores, build up on the noble metal surface, and lead to high contact resistance. By sealing microscopic pores, lubricants also enable manufacturers to apply thinner plating and reduce costs. Generally, a lubricant's ability to reduce wear and retard oxidative resistance extends connector life.

Evolution of Connector Lubricants at Nye

Nye has been actively involved in the design and manufacture of lubricants for separable connectors since 1964. At that time, the company introduced NyeTact® lubricant dispersions, a three-product line of lubricants made up of synthetic oil or grease, dispersed at various concentrations by weight in a solvent. Typically, polyphenyl ether oils were used for gold contacts, with synthetic oils used with tin/lead contacts. Later, dispersions using PFPE oils were added because they offered more broad operating temperature ranges than polyphenyl ethers and/or synthetic hydrocarbons. Greases made by mixing an oil with a solid thickening agent were formulated with soaps, silicas, or clays.

When applied to the terminal surface, the solvent evaporates, leaving a thin, protective lubricating film with excellent stability against oxidation or aging. Some of the products contain additives to improve surface coating and "stay-in-place" properties. Some also contain a UV-tracer for confirmation of the lubricant on the contact.


Nye Technician mixes a 1,500-lb batch of UniFlor™ 8917 at the company's Fairhaven, Massachusetts, headquarters.

The increasing use of low-voltage stationary separable contacts in data processing equipment, where high loads on the contact are required to assure low contact resistance, increased the need to keep insertion forces from becoming excessive. Furthermore, as normal force increased, the potential for wear on thin metal plating increased as well. Nye responded to this need with new products formulated with ultra-high viscosity synthetic hydrocarbon fluids, stabilized with a special binder.

But, while dispersions are suitable for small-volume applications, cost and solvent recovery often make dispersions impractical for large manufacturing operations. In the early 1980s, with the advent of more sophisticated production line dispensing systems, demand for connector greases grew. About the same time, broader temperature requirements and material compatibility issues forced automotive OEMs and connector manufacturers to look for new lubricants. Some automotive connector manufacturers had begun lubricating female terminals with petroleum-based, lithium-soap grease with a zinc oxide fortification. But, over time, the grease attacked connector housings, which started falling off wire harnesses – an obvious safety, quality, and warranty problem.

In response, Nye introduced NyoGel® 759G, a soft, silica-thickened, high-viscosity synthetic hydrocarbon grease that offered plastic and elastomer compatibility, and an operating temperature range of –40°C to 125°C. The gel solved the problem caused by the petroleum connector grease.

Connector manufacturers then requested a stiffer version to improve production-line injection capabilities that also had higher temperature capability and lower oil separation. This led to the development of NyoGel® 760G, a high-viscosity, silica-thickened, synthetic hydrocarbon grease. Its stiffer consistency enabled presses to run 30 to 50% faster, and much cleaner. A new antioxidant boosted its temperature limit to 135°C, and the addition of a UV dye facilitated quality inspections.

Originally used only in tail lamp connectors, the new product soon became the grease of choice for electronic control modules, exhaust gas recirculation systems, air bag, starter, and anti-lock brake systems, as well as more than 50 other connectors. Eventually, connector manufacturers were also using it on the terminal housing, taking advantage of the grease's water and salt-water resistance to create an added environmental seal.

Testing in the late 1980s and early 1990s suggested that fretting corrosion might be controlled by connector design instead of lubrication. It was felt that the addition of an elastic element inside a separable connection would eliminate movement between mated pin and socket at the contact point.

But, while increasing the normal force on contacts does control fretting corrosion, it also boosts insertion force, a problem that multiplies with the number of pins or blades. In the automotive industry, the problem was compounded by the proliferation of larger connectors in hard-to-reach places. Early resolutions included bolt-together connectors as well as other forms of mechanical assists like cams, levers, gears and slides. Mechanical assists enable a worker to mate connectors with less force, but they come at an increased cost and require additional space. They also increase complexity, which can have an effect on assembly time and service.

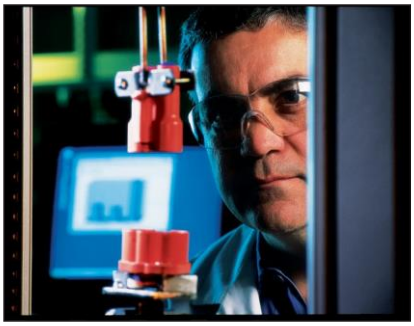
And so, lubricants resurfaced as a cheaper, simpler way to reduce insertion force. However, the proliferation of connections on or near the engine block often disqualified NyoGel® 759G. This gel had an upper end operating temperature of only 135°C, well below normal engine temperatures. Additionally, it was designed with material compatibility and wear and oxidation resistance in mind, not lower insertion force. Connector makers and users needed a grease that reduced the mating force needed.

Nye responded to the need with UniFlor™ 8511 and UniFlor™ 8512, greases that combined PFPE oil (with an operating temperature range of up to 250°C), with polytetrafluoroethylene (PTFE), perhaps the world's most slippery polymer. This mix delivered high-temperature connector capability and excellent insertion force reduction. For example, a dry 6.35-mm terminal has an average insertion force of 4.4 lbs, while a lubricated connector sees the average insertion force drop to 1.3 lbs.

There was one drawback, however. After eight or nine matings, contact resistance of terminals lubricated with UniFlor™ 8511 exceeded allowable USCAR specifications. This was due to a combination of high normal force, heat, and the sliding action of multiple insertions and withdrawals that seemed to burnish the PTFE into the surface of the contact. When this occurred, the contacts became insulated. This problem with elevated resistance set Nye on a path to develop a new grease that would not only reduce insertion force, but also meet USCAR resistance standards.

Development of UniFlor™ 8917

Since PFPE meets demanding temperature requirements and possesses excellent thermo-oxidative stability, it was the base oil of choice for the new connector grease. But, in an effort to make the grease "less slippery," a polyurea was substituted for the PTFE. In so doing, Nye was crossing new ground, because there were no other polyurea-thickened PFPE greases on the market. In addition, PFPE's inert chemistry and high specific gravity make it more challenging than other oils to thicken; these characteristics also tend to promote some oil separation at high temperatures. Further, because PTFE is more lubricious than polyurea, it was counterintuitive to assume that a polyurea would further reduce insertion force. This new product was named UniFlor™ 8917. Nye tested connectors lubricated with NyoGel™ 760G, UniFlor™ 8511, and UniFlor™ 8917. An unlubricated connector was included and tested as the control. The insertion force required to mate a 6.35-mm connector was measured on an Instron 5566 test machine, inserting the connectors 0.375 inches at a rate of 0.0595 in./sec., for 10 insertions.


Using an Instron, a Nye technician tests the Insertion force required to mate an automotive connector lubricated with UniFlor™ 8917.

The unlubricated connector had an average insertion force of 4.4 lbs, virtually unchanged from the first to the tenth mating. NyoGel™ 760G had an insertion force of 3.8 lbs on the first mating, and 2.8 lbs on the tenth mating. UniFlor™ 8511 had an insertion force of 1.3 lbs on the first mating, and 0.5 lbs on the tenth mating. UniFlor™ 8917 had an insertion force of 0.8 lbs on the first mating, and 0.3 lbs on the tenth mating – nearly 50% lower than the PTFE-thickened UniFlor™ 8511, and well within the USCAR insertion force requirements of 16 lbs.

An independent laboratory then tested several terminals lubricated with the new grease formulation, against the USCAR resistance standard. The test was run for 1,008 hours at 150°C with resistance readings recorded before and after the test for both 1 and 10 mates. After 10 mates, the average resistance across the terminals was 0.489 milliohms, easily within the 10 milliohms of resistance allowed by the USCAR standard. The replacement of the PTFE with the polyurea thickener drastically improved the resistance across the connector's surface, hence extending the life of the connector.

The surface of the tested connectors was also analyzed at Nye with a scanning electron microscope to see if there was any significant damage or evidence of oxidation on the surface of the connectors. No evidence of oxidation was found on the surface of the connector, indicating that the surface of the connectors was protected without compromising the electrical resistance requirements. In addition, the insertion force was lowered to within USCAR standards.

During the dropping point test (ASTM D-2265), the grease did exude a drop of oil at 140°C. However, like other PFPE greases, this lower dropping point is caused by the difference in specific gravity between PFPE and the thickener, and not indicative of thickener melting. Importantly, the amount of oil separation is too small to jeopardize connector reliability, or the reliability of nearby components such as relays or switches. There was approximately 15 mg of grease on each 2.8-mm terminal. Oil separation tests (FTM 791B, 321.2) showed that after 24 hours at 150°C, oil loss was only 8.35%, or about 1.25 mg of oil from 15 mg of grease, posing little if any threat to nearby components. Further, oil loss stabilizes quickly over time, which ensures a remaining reservoir of oil to protect the contact. The lubricity of the polyurea further ensures continued low insertion force over time.

Though PFPE's inertness and broad temperature range make it one of the most expensive synthetic oils, the cost per terminal is not be hard to justify. For 2.8-mm terminals, using 15 mg of grease per terminal, one pound of the grease will lubricate 30,266 terminals at $0.0033 per terminal. For 6.35-mm terminals, using 45.9 mg of grease per terminal, one pound of material will lubricate 9,891 terminals at $0.01 per terminal.

Several major connector manufacturers are currently testing the grease, and it is expected that this grease will become the standard for automotive applications where insertion force reduction is a primary concern.

UniFlor™ 8917 exemplifies the best characteristics of a high-quality lubricant: performance that exceeds specifications, outstanding user-friendliness, and cost-effectiveness. It also is built on a formulation strategy that proves the adage that the whole may be greater than the sum of its parts, a particularly cogent lesson relearned time and again in the lubricants industry.

As such, it was the choice for the Lubricants World 2004 Product of the Year.