



# ***Synthetic Lubes Protect Electrical Connections,***

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Claims**

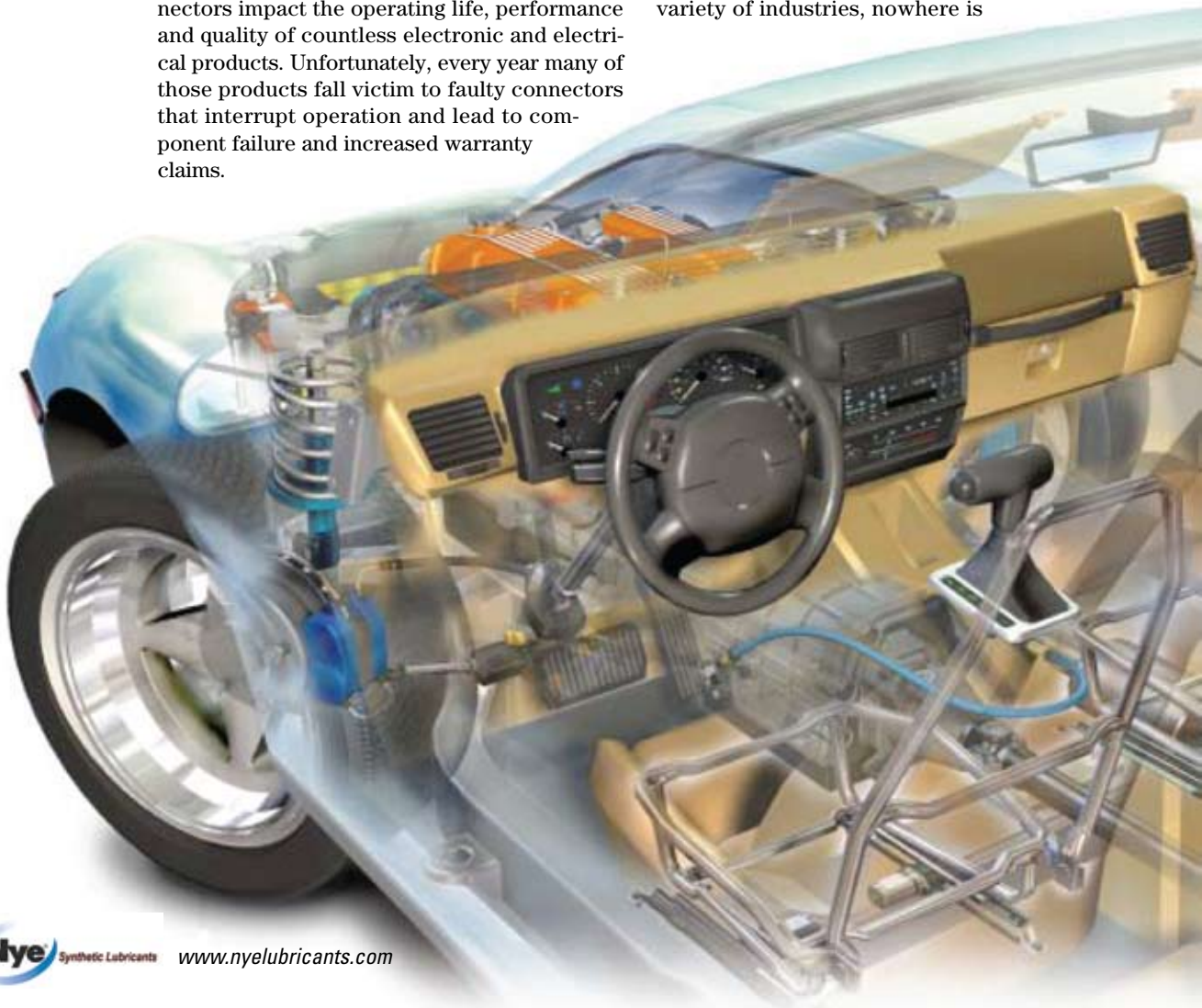
# Synthetic Lubes Protect Electrical Connections, Reduce Warranty Claims

**M**odern machinery and vehicles – from cars to machine tools, appliances to aerospace equipment – rely on an ever-increasing number of sensors and switches to operate properly and keep the driver or operator informed about equipment condition. In addition, everything from refrigerators to farm equipment now includes a variety of convenience and entertainment components to enhance their operation.

Electrical connectors play a critical role in making all the components work properly. Connectors impact the operating life, performance and quality of countless electronic and electrical products. Unfortunately, every year many of those products fall victim to faulty connectors that interrupt operation and lead to component failure and increased warranty claims.

Equipment and automotive OEMs can reduce or eliminate most connector problems simply by applying the right lubricant to the contacts. Connector lubricants protect contacts from corrosion, fretting and wear to ensure long, trouble-free operation. They also reduce insertion force, improving production efficiency and reducing the potential for worker injury. Today, connector lubricants can be found in countless applications to ensure reliable operation long beyond the intended life of the equipment.

While connector failures are an issue in a variety of industries, nowhere is



the proliferation of electrical sensors and components more apparent than in the automotive industry. The auto represents one of the most challenging environments for electrical sensors and connectors, as described below.

## The Connector Explosion

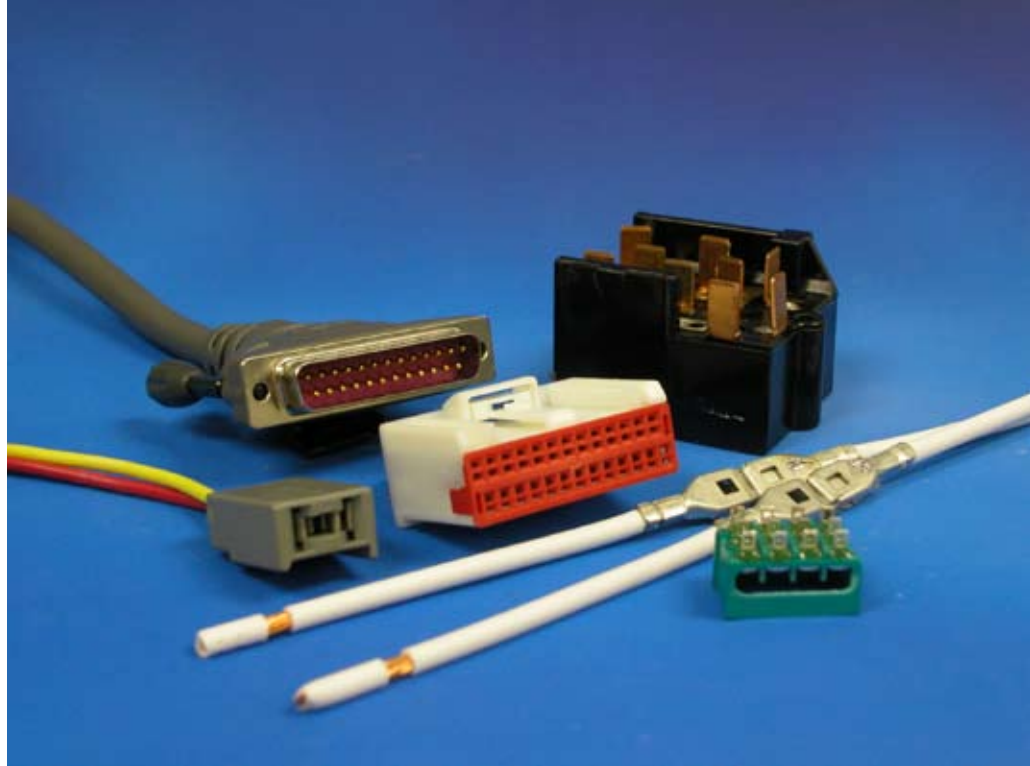
Connectors play a vital role in ensuring the trouble-free operation of cars and light trucks. A modern luxury car, for example, can have more than 400 connectors, ranging from simple two-way connectors up to 120-way connectors, with 3,000 individual terminals. That's 3,000 potential failure points! While the vast majority of connectors and terminals operates reliably for their expected lifetimes, each ultimately represents a potential electrical trouble spot.

Studies show that nearly 30% of signal and accessory circuit failures and more than 50% of power circuit failures in cars can be attributed to connections. The same holds true for other applications. Anecdotally, the Apollo space program experienced more connector failures than any other technical problem.

The number of electronic components in the average car has mushroomed over the past several decades and shows no signs of slowing. The average driver now has nearly all the amenities of home and office at his or her fingertips. Cars now brim with a seemingly endless number of accessories and diagnostic sensors to keep drivers abreast of the car's condition. All these amenities require electrical connections, and to speed assembly, terminals are ganged in large connectors that are assembled once and, hopefully, forgotten.

Because of the way engine and passenger compartments are designed, connectors are often buried deep within the vehicle and are difficult to access. As a result, they must be able to survive severe environments for the life of the vehicle to avoid warranty claims and costly, time-consuming repairs.

The automotive environment challenges even the highest quality connector. For example, in the engine compartment, connectors must survive rapid heating and cooling cycles as well as corrosive gasses, fuel, water, salt water and road dirt. Power mirrors, door locks and other external systems must resist rain and snow and even detergent baths in car washes. High levels



of humidity tax connector performance between door panels. Inside the passenger compartment, temperatures can soar when the car sits in the sun and can drop well below freezing in cold climates.

While auto designers try to place connectors away from moisture and water sources, connectors remain susceptible to fretting corrosion. Throughout the vehicle, connectors are subject to vibration from the engine, drive train, suspension system and related components.

An additional challenge faced by connector manufacturers and automakers alike is the ergonomics of the connector design, especially the force required to mate connectors. The National Institute for Occupational Safety and Health (NIOSH) has found that workers performing repetitive wiring tasks on assembly lines may be at risk of developing carpal tunnel syndrome and other disorders of the hand, wrist and arm. The risk of injury is high in the auto industry because workers often have to make connections in hard-to-reach locations. In the past, electrical connectors in vehicles had mating forces over 130 N (30 lb), and repetitive mating resulted in increased worker complaints. As a result, SAE/USCAR-2, Revision 3, *The Performance Standard for Automotive Electrical Connection Systems*, reduced the maximum allowable insertion force to 75 N (16 lb) to avoid workplace injuries.

A final challenge facing connector suppliers is the continuing effort by automakers to reduce weight and costs. Automakers routinely specify the smallest wire gage possible, forcing it to operate at or near its maximum current density, increasing its operating temperature. As a result, the connector often acts as a heat sink, and with

Today's vehicles contain a variety of electrical connectors, some with up to 120 contacts. Such large connectors are difficult to mate by hand unless a connector lubricant is used.

upwards of 120 terminals in a single connector, they can get quite hot.

## The Role of Lubricants in Connector Performance

Experience shows that connector lubricants keep connectors, sensors and switches functioning long after warranties expire. Types of lubricants include:

- Specially-formulated synthetic lubricants that prevent wear, corrosion and fretting caused by vibration and thermal changes in the connector housing.

- Unique synthetic fluids that reduce friction to prevent galling, scratching and deformation of gold-plated contacts (in airbags, for example).

- Fluoroether-based lubricants that survive temperatures in excess of 200°C while limiting insertion forces, especially for multipin connectors, reducing the potential for repetitive-motion injuries.

- Oils that resist oxidation at high temperatures. The contact lubricant is an often-overlooked component in keeping auto electronics operating for the life of the car. These oils, greases and dispersions can actually pay for themselves by reducing both warranty claims and worker injuries.

Contact lubricants play three important roles in protecting electrical circuits. First, they prevent damage to the contact surface from the nearly imperceptible movements that occur during operation. Second, lubricants seal the connection to stop moisture from entering and corroding the contacts. This is especially important for connections exposed to the elements. Finally, the lubricants reduce insertion forces to speed assembly and prevent work-force fatigue and injury.

While connector quality depends on many factors – materials, contact geometry, normal force, housing design, etc. – lubrication can play an equally important role. 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 mating surfaces.

One of the most important functions of connector lubricants is reducing fretting corrosion, a type of mechanical wear caused by low amplitude vibration. The vibration can be caused by vehicle motion in general, the motion of nearby components (such as fans or small motors) and thermal expansion and contraction.

Fretting corrosion results from micromovement that wears the surface of the terminals and over time generates an oxide layer on the contact surface. This insulative film between the connector contacts can create an open circuit, increasing the voltage drop across the terminal. Essentially, the connector becomes a resistor that consumes power rather than passing it through to the operating devices. Coating the contacts with an anti-fretting lubricant reduces mechanical wear, provides an oxygen barrier and helps keep oxide debris away from the contact area.

This condition never improves: it only worsens until the circuit eventually fails. Failure

manifests itself either as an open circuit or an intermittent open circuit. For example, when an owner brings a car in for service, the mechanic typically unplugs the connector to test the supposedly failed component. Then, finding the component operating properly, he or she plugs it back into the circuit, and the component works again. The simple act of disconnecting and reconnecting the connector often is enough to temporarily solve the problem. In fact, most automakers have issued service bulletins instructing mechanics

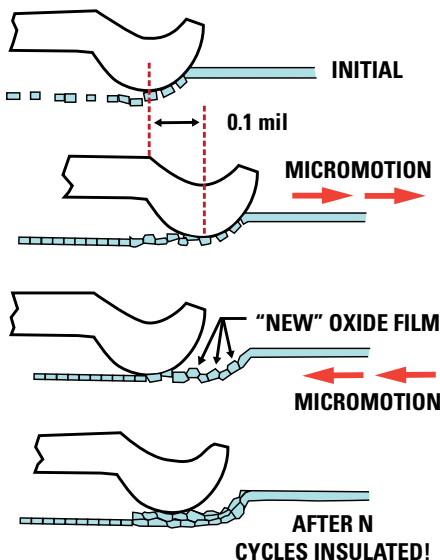


Micromotion causes fretting of the male and female contact surfaces. This eventually leads to corrosion that can interrupt current flow. Contact lubricants cushion the motion and protect the contact from fretting.

to simply unplug and reconnect connectors – or lubricate and replug – to solve intermittent failure problems. However, unless an anti-fretting lubricant is applied, it does not address the root cause of the problem.

## Lubricants in Action

A connector lubricant protects a connector from corrosion in two ways. First, it seals out oxygen to prevent wear particulates from oxidizing and forming an insulating layer and contact surface. Second, it acts as a shock absorber to absorb micromovement and prevent wear particulates from forming.



Stationary electrical connections in vehicles do not remain motionless. Rather, they are subject to micromotion that creates oxide films that, in turn, interfere with electrical contact.

# Connector Lubricant Myths & Realities

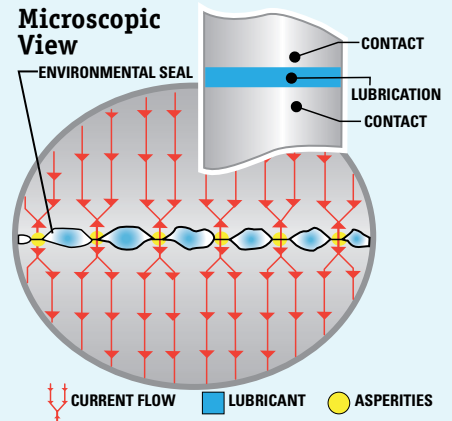
Many myths surround the use of lubricants for electrical connectors. If you are weighing the decision whether or not to use a grease in your application, consider these myths and facts in making your design decision. If added cost is a major concern, keep in mind that lubricating a large 6.35-mm terminal with a premium synthetic grease costs only one penny.

## Myth 1 – Grease Attracts Dirt

Magnets attract, grease does not. While dirt does stick to grease, it only means that the grease is doing its job. Connector lubricants create an environmental barrier, so dirt, dust and moisture are kept away from the contact surface. Without this protection, contact metals oxidize more quickly.

## Myth 2 – Lubricants Interfere with Conductivity

Tests on lubricated and unlubricated connectors show virtually no difference in contact resistance. A contact surface is a series of microscopic peaks and valleys. Current flows through only the contacting asperities. A contact lubricant fills the valleys – protecting the metal from oxidation – and is squeezed out of the asperities – allowing current to flow.



## Myth 3 – Gold-Plated Contacts Don't Need Grease

Contact manufacturers typically apply a thin gold plating on a substrate metal. This plating is microscopically porous and can easily be compromised, even during initial mating. Over time, oxides of the exposed substrate can ooze through the pores of unlubricated gold plating in a volcano effect and cause open circuit resistance. A thin film of lubricant, which costs far less than a thicker layer of gold, seals the pores and guards against scratches and substrate oxidation.

## Fact 1 – Lubricants Prevent Corrosion

Without lubricant protection, contact metals are extremely susceptible to corrosion. Lubricants seal contacts from oxygen, moisture, aggressive gasses and other hostile elements. In applications where the connector is exposed to the elements, filling the connector housing with grease before mating is also recommended. The grease acts as a back-up environmental seal.

## Fact 2 – Lubricants Lower Insertion Force

A thin film of lubricant reduces mating force by as much as 80%. For multipin connectors or connectors in hard-to-reach places, low insertion force ensures solid connections and efficient assembly. Lubricants can also bring connectors into compliance with USCAR insertion force standards.

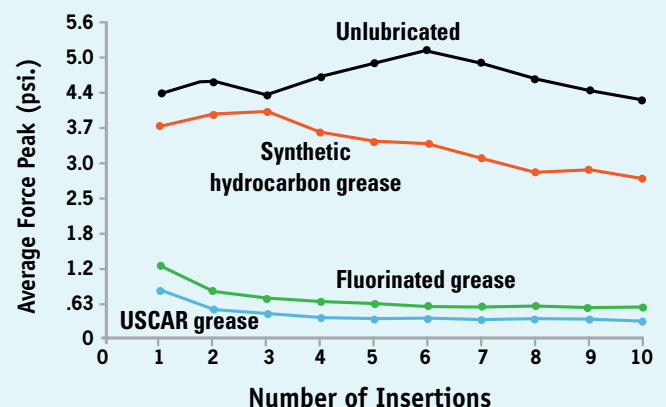
## Fact 3 – Lubricants Dissipate the Effects of Micromotion

Contact metals are subject to fretting corrosion – abrasion resulting from low amplitude vibration caused by motion or thermal expansion and contraction. Abraded metal can build up and break the connection. A lubricant minimizes metal-to-metal wear, protecting the contact from fretting corrosion.

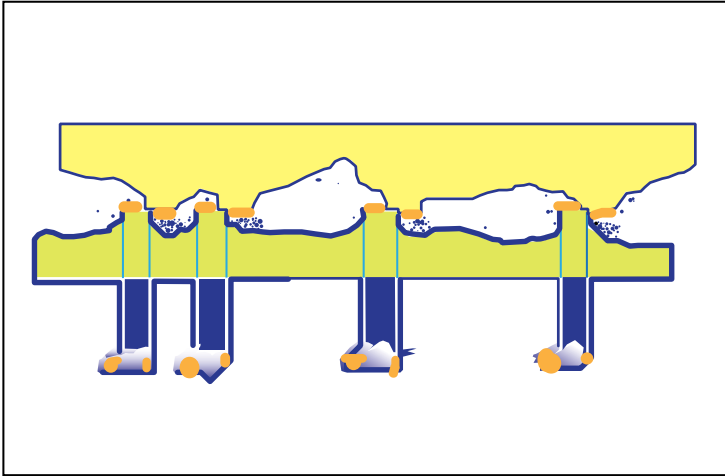
## Fact 4 – Lubricants Save Money

Lubricants improve the performance and extend the operating life of electrical contacts. Consequently, lubricants reduce warranty costs, and improve a company's quality image.

## Insertion Force to Mate 6.35-mm Connector



All lubricants reduce insertion force, but PFPE-based lubricants showed the most significant reductions. The NyoGel® 760G synthetic hydrocarbon grease for tin connectors is useful from -40°C to 130°C. UniFlor™ 8511 fluorinated grease is compatible with any contact or housing material and is useful from -50°C to 225°C. UniFlor 8917 brings connectors into compliance with USCAR insertion force standards and is useful from -70°C to 225°C.



Electrical terminals contact over only about 2% to 6% of their total surface area. The space around the asperities is subject to oxidative corrosion. Connector lubricants fill in this space to protect the contacts.

On average, two mated terminals contact over only about 2% to 6% of their surface area, regardless of terminal material or clamping force. Thus, 96% to 98% of the contact is exposed to air. Even power utility connectors that use mechanical devices and wedges to clamp the contact reach only about 8% contact area. Cold-welded contacts can reach 10% contact area, but the fact remains that the overwhelming majority of the connector surface is exposed to the environment.

The contacts touch only at asperity points. While oxidation does not infiltrate where peaks are touching, it erodes the sides of the peaks, eventually reaching the interface to break contact. When the contact area drops below ~1%, resistance is so high that current cannot pass through the connector, and the circuit fails.

While fretting is common for tin contacts – which are susceptible to oxidation – gold-plated contacts – which do not oxidize – can also benefit from the use of contact lubricants. Because of its cost, gold is used only in micron thick layers on top of a copper or nickel base metal. Under micromotion, the top layer of material soon wears away to the underlying substrate, which is more susceptible to corrosive buildup.

A contact lubricant reduces gold-metal wear during mating and separation, and it also protects against substrate corrosion. Thin gold-plating can be porous, and a film of lubricant can seal the pores to prevent substrate oxidation. If allowed to oxidize, an insulative film will eventually exude through the pores and lead to high contact resistance. By sealing microscopic pores, lubrication also enables manufacturers to apply thinner plating and reduce costs. Generally, a lubricant's ability to reduce wear and retard oxidative resistance extends connector life.

Another factor to consider is terminal geometry, which controls insertion force and clamping force. However, geometry also makes a big

difference in how fast terminals wear from micromovement. For instance, terminals that generate high normal forces produce very little wear because they minimize micromotion. However, the contact can still corrode due to exposure to the environment or high wear during mating.

The final factor to consider is insertion force. The more connectors in a vehicle, the more time required to mate them – and mate them correctly. Most connectors have locking devices, but high insertion force can prevent proper mating, and the connector can separate. A connector lubricant can help ensure positive mating by reducing insertion force.

Insertion force is also a safety issue, especially in North America. If a production line worker feels there is the potential for injury due to high connector insertion forces, he or she can shut down the line until the problem is remedied. Some manufacturers use a mating device to reduce insertion force below the USCAR limit of 75 N; however, these devices are significantly more expensive than a connector lubricant.

## Evolution of Connector Lubricants

It is unknown when lubricants were first applied in connector applications, but their use was referenced in the 1950s. The first connector lubricants were petroleum-based. They were used to protect the surface from oxidation and corrosion, reduce wear and contamination, and ease mating — the same reasons they are used today. Because petroleum oils degrade at about 100°C, they have limited thermal and oxidative stability. Nonetheless, they are still widely used due to their low cost, especially where environmental demands are not severe.

Early work in synthetics started during the 1960s in the telephone industry, where millions of contacts are used – and are difficult and expensive to maintain. They are not exposed to significant temperature extremes but have a long life expectancy. Studies have shown that polyphenyl ethers (PPEs) provided the best performance; however, PPEs are expensive and have limited low temperature operability, solidifying at +20°C.

Nye Lubricants has been actively involved in the design and manufacture of lubricants for electrical connectors since 1964 with the introduction of NyeFact® dispersions, lubricants consisting of a synthetic oil or grease dispersed in a solvent. PPE oils were used for gold contacts and synthetic hydrocarbons oils for tin.

Later, dispersions using perfluoropolyether (PFPE) oils were added because they perform over a broader operating temperature range. When applied to the terminal surface, the solvent evaporates, leaving a thin, protective lubricating

film with excellent stability against oxidation or aging. Some NyeTacts contain additives to improve surface coating and stay-in-place properties. Some also contain a UV-tracer to allow identification of the lubricant on the contact.

While dispersions are suitable for small-volume applications, cost and solvent recovery often make them impractical for large manufacturing operations. In the early 1980s, with the advent of more sophisticated production line dispensing systems, demand for connector greases grew. At about the same time, the need for wider temperature ranges and material compatibility stimulated the search for new connector lubricants. Some automotive connector manufacturers had begun lubricating female terminals with a petroleum-based, lithium-soap grease containing a zinc oxide fortification. However, over time, the grease attacked connector housings, which started falling off the wiring.

To solve this problem, Nye formulated NyoGel® 759G, a soft, silica-thickened, high-viscosity synthetic hydrocarbon grease. NyoGel 759G is compatible with plastics and elastomers and operates at temperatures between -40°C to 125°C. Connector manufacturers requested a stiffer grease to improve production-line injection capabilities along with higher temperature capability and lower oil separation. Nye responded with NyoGel 760G, a high-viscosity, silica-thickened, synthetic hydrocarbon grease. Its stiffer consistency enabled presses to run 30% to 50% faster and much cleaner. An antioxidant boosted its temperature limit to 135°C.

NyoGel 760G also minimizes corrosion of exposed copper substrate. NyoGel 760G was originally used in tail lamp connectors but soon was used in electronic control modules (ECMs), exhaust gas recirculation (EGR) controls, air bags, starters, antilock braking systems (ABSs), and more than 50 other connectors. Connector manufacturers use NyoGel 760G on terminal products as well as inside the housing, taking advantage of the grease's water and salt-water resistance to create an added environmental seal.

Research in the late 1980s and early 1990s suggested that fretting corrosion could be controlled by a connector design that increased normal force and compensated for micromovement at the contact point. However, this design also boosted insertion force, which increases exponentially 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 en-

able workers to mate connectors with less force, but they increase costs and require additional space.

Lubricants resurfaced as a less expensive, simpler way to help reduce insertion force. However, the proliferation of connections on or near the engine block required lubricants with higher temperature capability. This led to the development of UniFlor™ 8512 and UniFlor 8511, which combine PFPE oil with polytetrafluoroethylene (PTFE) to provide operating temperatures up to 250°C and excellent insertion-force reduction. However, with repeated insertions, these greases can exceed USCAR recommendations for resistance.

To address the USCAR recommendations, Nye Lubricants developed UniFlor 8917, a urea-thickened PFPE grease. In tests on a standard 6.35-mm connector, UniFlor 8917 reduced insertion force from 4.4 lb to 0.8 lb on the first mating and 0.3 lb on the tenth mating – well below the USCAR insertion force requirements of 75 N.

An independent laboratory then tested several terminals lubricated with UniFlor 8917 to the USCAR resistance standard. The test ran 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 lubricated with UniFlor 8917 was 0.489 mΩ, well within the 10 mΩ resistance allowed by the USCAR standard.

The surface of the tested connectors was also analyzed with a scanning electron microscope (SEM) to determine if there was any significant damage or oxidation on the surface of the connectors. No oxidation was found on the surface of the connector.

The proliferation of connections on or near the engine block require lubricants with higher temperature capability.



In an effort to boost the thermal stability of Polyalphaolefin-based lubricants in a cost-effective formulation, Nye recently introduced NyoGel 761G. This urea-thickened grease is thermally stable to 175°C and reduces insertion force below that of the silica-thickened NyoGel 760G. This lubricant has been accepted by all U.S. Big Three automobile manufacturers, and Nye expects its use to expand in the future.

## What Makes a Good Connector Lubricant

Generally, a connector lubricant should be electrically nonconductive because the oil could cause a short or isolation breakdown if it migrates between connector cavities. The lubricant also should not contain any large solid insulating material, such as zinc oxide used for inspection purposes. This could interfere with electrical conduction through the contact.

To ensure long product life, a good connector lubricant should exceed the requirements of existing test specifications. In addition, it must be compatible with all connector housing plastics. Finally, the lubricant should be thermally stable to at least 125°C.

Thermal stability has become a critical factor in formulating connector lubricants, especially in automotive applications. Engine compartments in modern vehicles consistently reach above 125°C because more aerodynamic car bodies allow less free air flow through the engine com-

partment. This is compounded in front-wheel drive vehicles, which have complex engine and drive trains and more pollution control to take up space and block air flow.

Connector lubricants are available in three forms:

- **Oils** – Most often applied as a field fix to correct a problem. They are occasionally used during production, where they are atomized and sprayed onto terminals as they are stamped.

- **Greases** – Are injected into the female part of the connector. Greases can be applied both before and after a connection is made, and they can contain a variety of additives to solve specific problems.

- **Dispersions** – Consist of greases dissolved in a solvent to make them more liquid. They are easy to apply in the production environment by spraying or dipping. After a dispersion is applied, the solvent evaporates to leave a thin film of lubricant on the contact.

Connector lubricants are formulated from a variety of chemicals:

- Polyalphaolefin (PAO) is the most common synthetic lubricant and is typically known as an anti-fretting lubricant. It is available in a range of grease thickener systems and provides good protection at temperatures to 125°C or higher.

- Perfluoropolyether (PFPE) is used in high-temperature applications and provides excellent protection at temperatures up to 250°C. It provides good insertion force reduction.

- Polyphenyl ether (PPE) is typically used on gold contacts. It provides a unique film strength capability that prevents galling of gold when the contact is made. PPE is the most expensive lubricant used.

- Specialty silicones are used occasionally for contacts that require high temperature resistance, above 250°C.

Nye has focused on developing lubricants based on fluorinated oils because they have excellent thermal stability and chemical inertness. Linear PFPE base oil meets electrical and temperature requirements of USCAR-2, Rev 3, and has a history in other automotive electrical components. Nye also developed a unique urea thickener that helps reduce wear and coefficient of friction.

Insertion force testing of the PFPE-urea formulation shows a 40% reduction in insertion force for a standard 6.35-mm connector. Electrical testing also showed improved performance, meeting USCAR-2 Class 3 requirements.

## Selecting and Applying Connector Lubricants

In selecting a connector lubricant, the following factors must be considered:



Applying contact lubricants on the automotive assembly line usually is limited to injecting grease or dipping in a dispersion. The process can be automated to minimize operator involvement.

# Lubricants for Stationary, Separable Electrical Connectors

Product	Temperature Range (°C)	Tin Contacts	Noble Metals	Grease	Oil	Dispersion	Plastic Compatibility	UV Tracer*
NyeTact® 502J-20-UV	-40 to 120	●	●			●	●	●
NyeTact® 570H-2	-40 to 225		●			●	●	
NyeTact® 502J-25-UV	-30 to 120		●			●	●	●
NyeTact® 523V-2-UV	0 to 250		●			●		●
NyoGel® 760G	-40 to 135	●	●	●			●	●
NyoGel® 761G	-40 to 175	●	●	●			●	●
NyoSil M25	-70 to 200	●	●		●		●	
Fluorcarbon Gel 813-1	-70 to 200	●	●	●			●	
UniFlor™ 8511	-50 to 225	●	●	●			●	
UniFlor™ 8917**	-70 to 225	●	●	●			●	

\*UV tracer allows easy identification of lubricant on contact surfaces

\*\*Exceptional reduction of insertion are withdrawn forces

■ **Temperature range** – Below 135°C use PAO; above 135°C use PFPE.

■ **Elastomer compatibility** – It is virtually impossible to make accurate, all-inclusive compatibility recommendations without actually testing a lubricant on a material. This is because a single elastomer category (Nitrile, for example) can have as many as 100 possible formulations, each with different compatibility issues. When testing compatibility, materials should be exposed to lubricants under various temperatures and loads. The most accurate compatibility testing is done at the expected operating extremes. For further assurance, test materials of nearby components in case of oil migration or outgassing and condensation.

■ **Insertion force reduction** – PFPE/PTFE provides the greatest reduction.

■ **Cost** – PAO provides the lowest cost where it can be used.

The table above lists the most widely used Nye lubricants for stationary, separable electrical connectors. Additional oils and greases are available to meet a range of requirements.

Connector lubricants are typically applied during contact manufacturing. Terminals are stamped or formed from a continuous strip of metal and can be lubricated by spraying with oil or dipping in a dispersion. Alternatively, grease can be injected in the finished connector housing. Lubricating at the connector installation point on the automotive assembly line usually is limited to injecting grease or dipping in a dispersion. This approach is typically used when solving a field problem. In general, all these processes can be automated to minimize operator involvement.

In conclusion, modern machinery relies on an ever-increasing variety of sensors, switches and connectors to operate properly. The automotive industry, in particular, represents one of the most challenging environments for electrical sensors and connectors. Faulty connections interrupt operation and lead to service calls, expensive maintenance and warranty claims. Synthetic lubricants can help avoid these problems. These inexpensive components can help ensure reliable operation of your equipment long beyond its intended life.

For more information on using synthetic lubricants in vehicles and machinery, contact your local Nye Lubricants office. For a complete list of office locations, visit [www.nyelubricants.com](http://www.nyelubricants.com). To learn more about how synthetic lubricants play a key role in the automotive industry, visit [www.nyeautomotive.com](http://www.nyeautomotive.com).

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