Krytox™
Performance Lubricants

PFPE Lubricants in Aerospace Applications

Krytox™ perfluoropolyether (PFPE) lubricants offer thermal stability and low vapor pressure at very low molecular weights.

Whitepaper

This whitepaper is widely based on an article by James Anderton, posted on Engineering.com, May 25, 2017

Aerospace applications have some of the most demanding requirements when it comes to lubrication. Compared to automotive applications, for example, the temperature ranges where a single lubricant must perform are considerably broader. Military aerospace applications can involve even greater extremes, in addition to other requirements, such as long storage life.

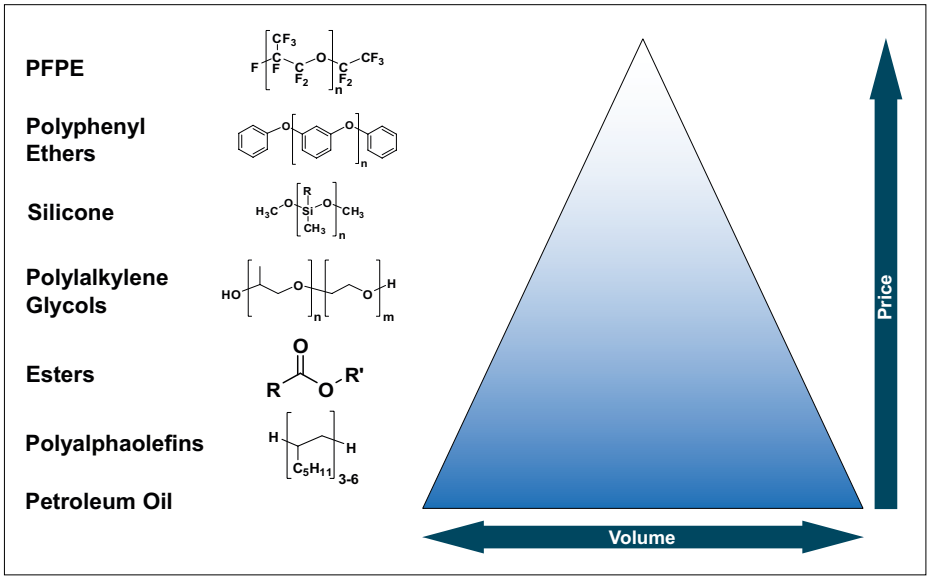
For example, consider an aircraft sitting on the runway in Saudi Arabia, where the ambient temperature might be 50 °C. When the plane reaches cruising altitude, the temperature is about -55 °C. Applications close to engines can reach >200 °C operational temperature, with potential for another 50-100 °C soak-back.

Introduction to Krytox™ perfluoropolyether lubricants (PFPEs)

Krytox™ perfluoropolyether (PFPE) lubricants were discovered in 1959 and showed remarkable thermal and oxidative stability. Potential uses envisioned then included lubricant for the MACH 3+ turbine engine, hydraulic oil, rocket gear box lubricant, and even gyroscope oil.

In 1963, Krytox™ oil was used in a GE engine test for the supersonic transport aircraft. In 1964, new Krytox™ perfluoropolyether (PFPE)-based grease formulations were developed jointly with the U.S. Navy and Air Force, resulting in military specification MIL PRF-27617, which was developed specifically for Krytox™. The first commercial sales of Krytox™ were for nonflammable lubricants for the Apollo space program in 1965.

Chemours™



Compared to other lubricants, PFPEs are the least common and most expensive. This is because the supply chain for PFPEs is much more complex and capital-intensive compared to other lubricants.

Krytox™ oils are made from only fluorine, carbon, and oxygen—a mixture of compounds collectively known by many names—including PFPE, perfluoroalkylether (PFAE), and perfluoropolyalkylether (PFPAE). Krytox™ perfluorinated oils and greases deliver high performance, perform at wide temperature ranges, and provide superior quality lubrication under extreme conditions in comparison to hydrocarbon alternatives.

With a global distribution network and world-class technical service, Krytox™ is the lubricant of choice for extreme conditions and performance. The use of Chemours unique PTFE thickener provides superior chemical and thermal stability to all Krytox™ grease product lines. Many greases are also available with additional anti-wear and anti-corrosion additives to further boost performance in critical operations.

Key properties of Krytox™ lubricants

Component failures in aerospace applications can be catastrophic, not only in terms of the capital costs of the parts themselves, but also because of the ancillary costs of repair and safety risks they engender.

Volatility is especially important in space applications, since the lubricant must be able to operate in a vacuum. Many space applications require lubricants that can function for the lifetime of the component, since there will never be an opportunity to re-lubricate.

Krytox™ performance lubricants have demonstrated the broad applicability to replace hundreds of purpose formulated conventional oils and greases throughout the aerospace industry. There are several key properties that make them well-suited to aerospace applications.

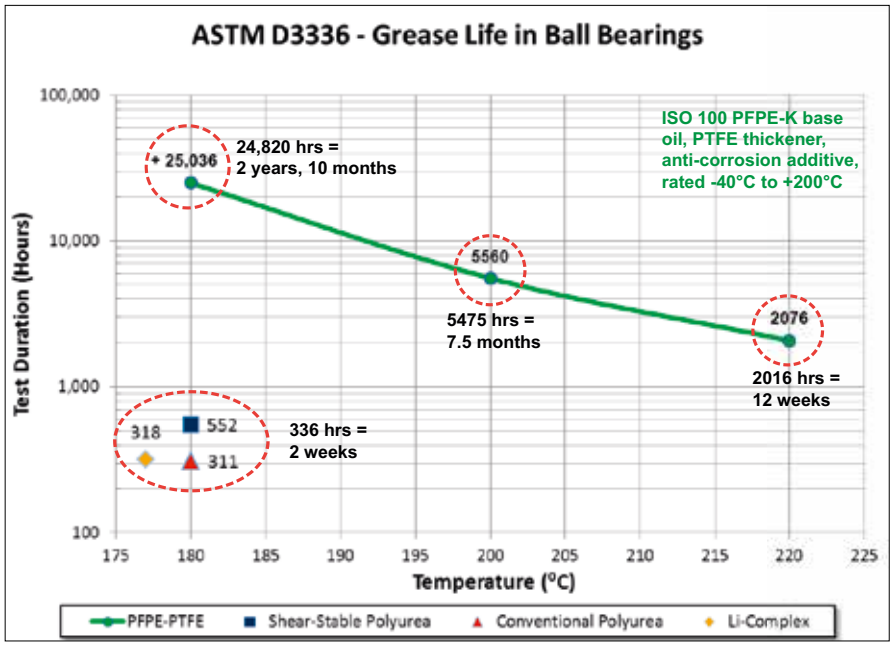
- They will not burn or support combustion, even in fully liquid or gaseous oxygen.
- The various grades of Krytox™ lubricants cover a wide temperature range, from -75 °C to +360 °C continuous, with spikes to temperatures greater than 400 °C.
- Krytox™ lubricants don't degrade or break down in the presence of aggressive chemicals, and offer a long lubricant life with no potential for carbonaceous deposits.
- Their high lubricant film thickness protects them under high loads and across a range of speeds.
- They are compatible with most elastomers, polymers and a wide range of metals, in addition to being nonhazardous, nontoxic, non-regulated and completely chemically inert.

Testing Krytox™ oils and greases

Krytox™ greases are tested using numerous industry standard procedures for evaluating the life of lubricating greases, including ASTM D-3336 and SKF R0F+ testing methods.

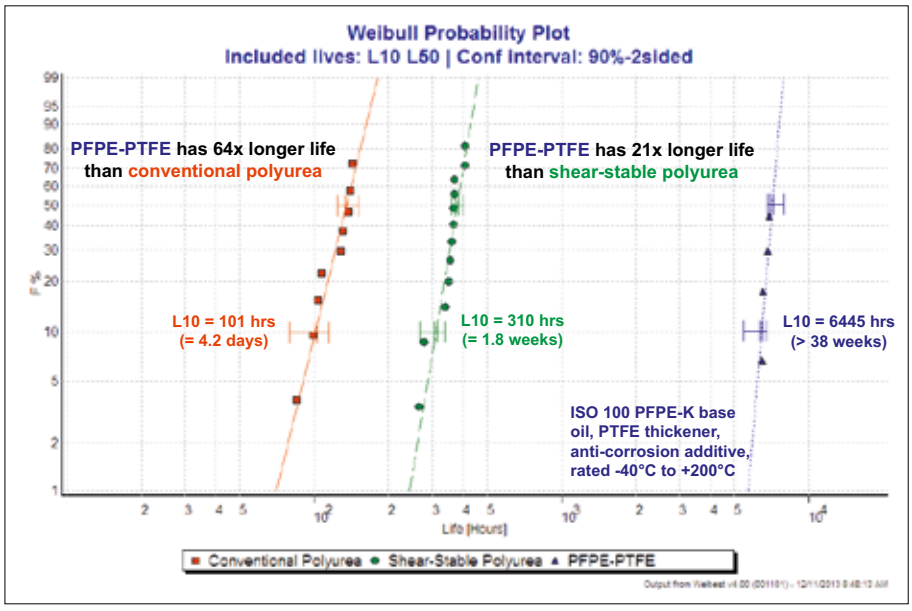
The first procedure involves rotating an SAE No. 204 bearing at 10,000 or 20,000 rpm at an elevated test temperature. Using CRC-type spindles, a thrust load of 5-15 lbs (22-67 N) and a radial load of 15 lbs (67 N) are applied to the bearing.

The test cycle is 20 hours on and 4 hours off for the requisite test temperature. The test result is stated in terms of the number of cumulative hours the bearing will run without exceeding the motor overload set point, torque overload set point, or over temperature limit.



Results of the ASTM D-3336 testing on a Krytox™ grease compared against standard electric motor bearing greases. They are for a lightly loaded 6204 bearing at 10,000 rpm. The test cycle was 20 hours on and 4 hours off.

The SKF R0F+ bearing grease life testing method involves running five groups of two bearings. Various different bearing types and sizes can be used at speeds between 5,000 and 25,000 rpm and from room temperature up to a maximum of 230 °C. The pneumatic loads on these bearings can be set between 50-900 N radially and 100–1100 N axially. The bearings are run until failure, allowing for Weibull statistical life distribution after just one test.



Results from SKF R0F+ bench bearing life test using 6204 bearings at 10,000 rpm at 177 °C.

Common aerospace applications for Krytox™ lubricants

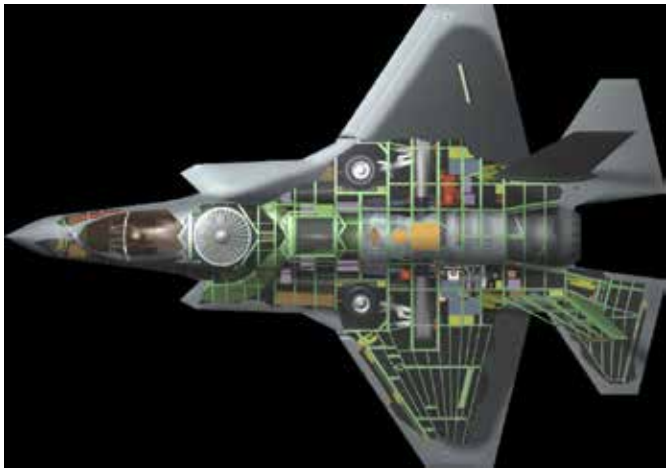
Perfluoropolyether lubricants have been used in a whole host of aerospace applications, including:

- Oxygen system couplings, valves, regulators and seals
- Liquid fueled rocket engines and ground support systems
- Instruments, gyroscopes and gimbals
- Seals, valves and pneumatics
- Bearings
- Leadscrews and ballscrews
- Electro-mechanical actuators
- Engine ancillary gearbox spline couplings
- Anti-friction mounts, engine oil tanks
- Non-conducting lubricant for sealing of electrical connectors
- IR sensors and optics

There are also several specific examples of Krytox grease applications:

- Krytox™ 283AD grease is used for the engine starter spline shaft in PW 400-series engines and is the only product specified for this application. Krytox™ 250AD grease is approved for hydraulic and fuel pump splines on PW engines for the A330, A340 and A380 aircraft. Chemours is also currently working with a major OEM on next-generation grease-lubricated fuel pump splines.
- Krytox™ AGL683 grease was specifically developed for electro-mechanical actuator bearings, gears and ballscrews. It's approved for devices in cabin air conditioning and nitrogen generation systems. The light, semi-fluid grease is designed for lifetime lubrication across a temperature range of -70 °C to +180 °C and is specifically formulated for low-temperature starting torque with an additive package designed for anti-fretting and anti-corrosion.
- Krytox™ AGL829 grease was developed as a fire-proof grease for thrust reverser drive units to eliminate the need for external fire blankets. The light gearbox grease is specifically designed to be a sealed-for-life lubricant for low-temperature applications (-60 °C) that are subject to high vibration and loads.
- The Krytox™ XHT-BD series of greases were developed for extra-high temperature applications and are based on triply fluorinated high-viscosity base oils with a high-adhesion, non-melting thickener. Krytox™ XHT-BDX is specified for O-rings and flexible couplings in environmental control systems that are used to direct hot engine air for wing and tail de-icing. Components in this application regularly see temperatures of 315 °C.

One of the most interesting applications for PFPE lubricants is in the F-35 short take-off and vertical landing (STOVL) variant. In this case, Krytox™ extreme temperature lubricants are used for exhaust duct bearings, drive gears and actuators, all of which routinely exceed 320 °C. The F-35 also offers an example of using PPFE lubricants to improve performance for traditionally non-lubricated materials, such as the Vespel variable vane brushes found in the F-35 lift fan.



F-35 cutaway. (Image courtesy of Charles R. Davis/USAF.)

Krytox™ lubricants in aerospace

Failure in aerospace applications is not an option, especially since operating conditions in aerospace can be severe. Inadequate lubrication or lubricants that do not perform as intended can lead to increased aircraft maintenance downtime and component failures.

The combination of thermal stability, chemical inertness and the capacity for low vapor pressures at very low molecular weights makes Krytox™ lubricants ideal for a range of civil and military applications. From engine mounts, to fuel tank valves, to fighter canopy slide rollers and seat adjuster mechanisms, Krytox™ is the only way to fly.

F-35 STOVL lifting off at Eglin Air Force Base. (Image courtesy of USAF/Samuel King Jr.)

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