



DuPont™ Krytox® Performance Lubricants

PRODUCT OVERVIEW



The miracles of science™

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The DuPont™ Krytox® Advantage

Introduction to Krytox® Lubricants

Discovered in 1959, the polymer that would become known worldwide as DuPont™ Krytox® 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.

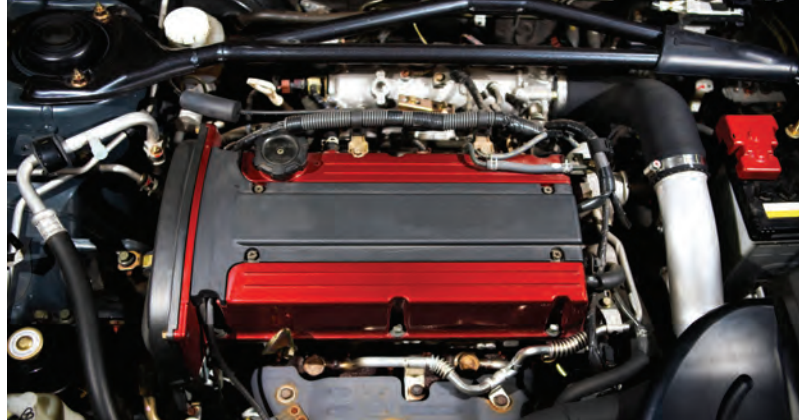
In 1963, Krytox® oil was used in a GE engine test for the supersonic transport aircraft. In 1964, new Krytox® PFPE-based grease formulations were developed jointly with the US Navy and the Air Force, resulting in military specification MIL-G-27617, which was developed specifically to cover Krytox®. The first commercial sales of Krytox® were for non-flammable lubricants for the Apollo space program in 1965.

Prior to 1981, the only commercially available Krytox® lubricants were aerospace oil and greases. Since then, PFPE-based oils and greases have been adopted across a very wide range of industries and applications. There are PFPE oils and greases for industrial operations, vacuum pump fluids, incidental food contact, automotive uses, reactive gas, and of course, military applications — to name just a few.

Today, of course, it's our well-known trademark for high performance synthetic lubricants used for a variety of applications. Krytox® oils are made from only fluorine, carbon, and oxygen — a mixture of compounds collectively known by many names — including perfluoropolyether (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. And, with a global distribution network and world-class technical service, Krytox® is the lubricant of choice for extreme conditions and extreme performance.

The use of PTFE as a 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.

Krytox® performance lubricants provide superior performance and extended life as lubricants, sealants and dielectrics. With exceptional performance and reliability in the toughest conditions — where productivity matters and downtime costs — Krytox® can contribute significantly to lowering the cost of doing business.



Key Benefits

The key benefits of Krytox® lubricants include:

- Extreme temperature stability, with operating ranges from –75 °C up to 350 °C (–103 °F up to 662 °F) and as high as 400 °C (752 °F) with appropriate metallurgy
- Longer lasting lubricant life
- Decreased equipment failure and maintenance: warranty claims and replacement costs may be reduced
- Increased profits: reduced downtime and maintenance costs
- Odorless and colorless
- Inert, nontoxic, and non-flammable
- Stable in 100% liquid or gaseous oxygen environment
- Global distribution
- World-class technical service

Krytox® Base Oil Environmental Advantages

Krytox® lubricants provide longer lasting lubrication which reduces frequency of relubrication, not only reducing operating costs, but also reducing waste and potential impact on the environment. Krytox® lubricants are undamaged by, and non-reactive with, acidic or caustic cleaners and disinfectants, steam, moisture or high temperatures. The original properties of the fluids can be restored through regeneration, thus reducing or minimizing disposal and incineration. DuPont has a regeneration program that reclaims PFPE fluid. This lowers the overall cost of the fluids and reduces or minimizes safety and environmental disposal problems.

Key environmental benefits specific to Krytox® base oil include:

- Chemical, biological, and environmental inertness
- Non-toxic and silicone-free formulation
- No hazardous VOC materials or chlorine content
- Non-hazardous to the atmosphere or ozone layer
- Smaller environmental footprint

DuPont™ Krytox® Performance Characteristics

Extreme Temperature Performance

Krytox® oils and greases are the product of choice in extreme temperature conditions. Most petroleum products begin to degrade above 99 °C (210 °F) and are too viscous at temperatures just below –18 °C (0 °F).

Krytox® synthetic lubricants have extreme temperature stability, with operating ranges from below –75 °C up to 350 °C (–103 °F to 662 °F) and temperatures up to 400 °C (752 °F) with appropriate metallurgy. Under the D-3336 test conditions of 177 °C (350 °F) and 10,000 rpm, the majority of competing hydrocarbon lubricants fail in less than 1,000 hr. But the general purpose line of Krytox® lubricants has been shown to last over 5,000 hr without failure, even at an increased temperature of 200 °C (392 °F). This extreme condition performance is what distinguishes Krytox® performance lubricants from other competing products.

Cost Effective

Krytox® lubricants are cost effective across a wide range of applications. Due to their inert nature, Krytox® lubricants provide a much longer usable life as compared to typical hydrocarbon oils and greases, and the longer usable life allows them to remain for considerable periods of time before needing to be replaced, if they are replaced at all. That translates to savings over time, both by lowering the amount of lubricant purchased and any downtime incurred during relubrication.

Performance Additives

Anti-corrosion additives are combined with Krytox® grease to enhance its ability to protect metallic surfaces from corrosion caused by moisture and oxygen. DuPont also offers a patented oil-soluble additive to give the same corrosion protection to our oils. Krytox® greases containing anti-wear additives have properties that give high specific load-carrying capacity and the highest protection against wear.

Compatibility with Elastomers and Plastics

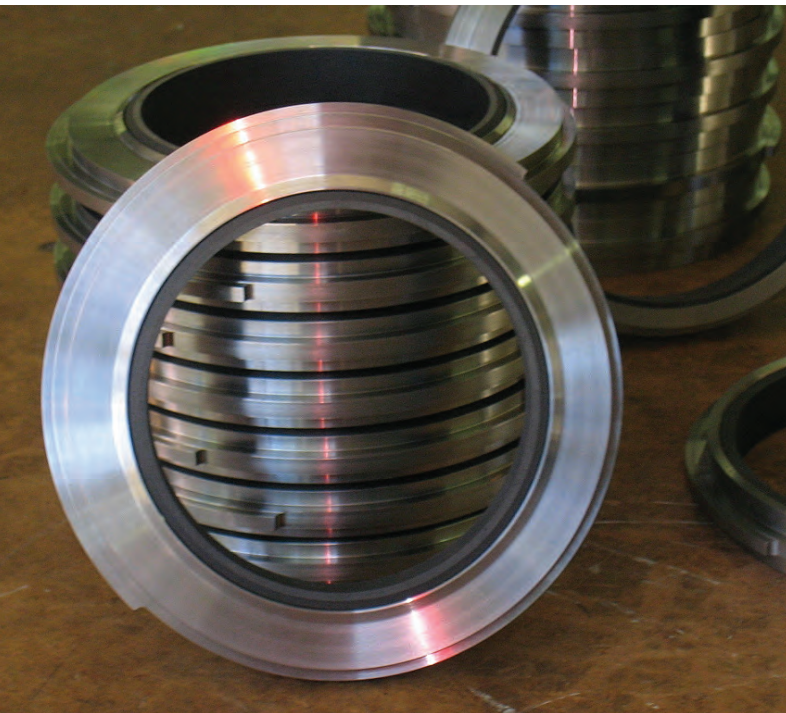
Krytox® base oil is compatible with all elastomeric seal materials and engineering plastics. The limiting factor when using standard¹ Krytox® with any material is the thermal stability of the elastomer or plastic.

Krytox® performance lubricants are compatible with most common elastomers and plastics including:

ABS	PEBA
Acetal — homopolymer and copolymer	PEEK
Aramid	Polyamides
Buna N	Polycarbonate
Butyl 325	Polyetheramide block copolymer
Chlorosulfonated polyethylene	Polyethylene
Delrin® acetal	Polypropylene
EPDM	PTFE fluorocarbon
EPT, peroxide cure	PVC
Ethylacrylate	SBR
FEP	SEBS
Fluoroelastomers	Silicone
Fluorosilicone	Styrene ethylene butylene polymer
HDPE	Styrenic polymer
HNBR	Teflon® fluorocarbon
Hydrocarbon rubber	Thermoplastic polyurethane
Hypalon® synthetic rubber	Thermoset polymers
Hytrel® polyester elastomer	Thermoplastic rubber
Kalrez® fluoroelastomer ²	TPE
LDPE	TPU
Methyl silicone	Urethane
Natural rubber	Vamac® ethylene acrylic elastomers
NBR	VespeI® polyimide resin
Neoprene WRT	Viton® fluoroelastomers
Nitrile	Zytel® nylon
Nylon	
Nylon 6	
Nylon 6,6	
Nylon 12	

¹ The “standard” DuPont™ Krytox® lubricant is PTFE-thickened PFPE oil with **no** additives.

² 15–20 vol% swelling at high temperatures when immersed in PFPE oil.



Extreme Pressure (EP)

DuPont™ Krytox® heavy-duty greases are used for high loading or slow speeds. EP greases have high load-carrying capability and good lubrication characteristics under boundary and mixed friction conditions. In addition to the EP additive in Krytox® heavy-duty greases, Krytox® oil provides adequate EP protection as an oil by itself, due to the viscosity build under load and its unique tribo-chemistry.

A common test for analyzing EP performance is the Timken EP method, ASTM D2509. The test is performed by applying pressure between a rotating steel cup and a steel block and simulates line contact conditions. Two conditions are observed; the OK Load is the highest load at which no seizing or welding occurs, and it also reflects the load-carrying capability of the lubricant. The Score Load is the lowest load at which seizing or welding is observed. The scar width, which is the average scar width at the load corresponding to the OK load value, is also recorded. The Timken EP results for various Krytox® greases can be seen in **Table 1**, Timken EP Method.

Table 1
Krytox® Extreme Pressure Properties
by the Timken EP Method — ASTM D2509

	OK Load	Score Load	Scar Width at OK Load
GPL 214	30 lb	40 lb	1.271 mm
GPL 215	30 lb	40 lb	1.507 mm
GPL 225	50 lb	60 lb	1.109 mm
GPL 295	60 lb	70 lb	1.125 mm

Another common test for analyzing EP performance is the Four Ball EP, ASTM D2596. The test is performed by steadily increasing the load on a rotating steel ball in contact with 3 fixed balls until they seize and welding occurs, which simulates point contact conditions. The lowest load at which this welding occurs is called the Weld Point. From this data the Load Wear Index (LWI) is calculated, which is a value that relates how well the grease prevents wear when operating below the weld point. For many competing greases, the LWI can generally fall between 50 and 100. The four ball EP results for various Krytox® greases can be seen in **Table 2**. Krytox® greases typically have an LWI well above 100. This further shows how in addition to extreme condition performance, Krytox® can also outperform most competitive greases in extreme pressure performance.

Table 2
Extreme Pressure Properties*
of Krytox® Greases

	240 AZ	240 AC	250 AC	GPL 225	GPL 226
Load Wear Index	75	127.8	>161	None*	None**
Weld Point, kg	400	620	None	None	—

* ASTM D2596, Measurement of extreme pressure properties of lubricating grease, four ball method.

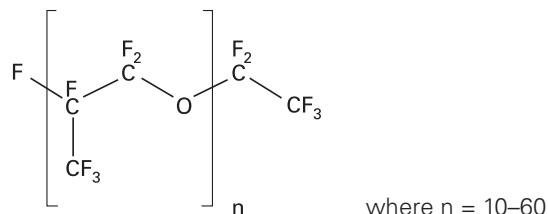
** These samples maxed the load limit of the test apparatus, and a load wear index cannot be determined.

DuPont™ Krytox® Properties

Composition

Oil

Krytox® fluorinated oils are a series of low molecular weight fluorine end-capped homopolymers of hexafluoropropylene epoxide with the following chemical structure:

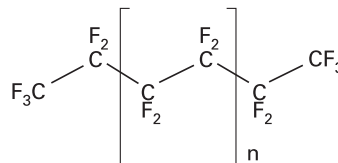


The polymer chain is completely saturated and contains only the elements carbon, oxygen and fluorine. There is no hydrogen present. On a weight basis, Krytox® oil typically contains 21.6% carbon, 9.4% oxygen and 69.0% fluorine.

The Chemical Abstracts Index name for Krytox® is oxirane, trifluoro (trifluoromethyl)-, homopolymer. The CAS Registry Number is 60164-51-4.

Grease

Standard Krytox® grease is formed by blending PFPE base oil with polytetrafluoroethylene (PTFE) powder with the following chemical structure:



Using a fluorinated thickener gives the grease a similar temperature and chemical stability as the base oil, allowing it to be used also in harsh, demanding conditions. The point of adding thickener is to hold the oil near the contact point. The thickener provides a barrier to keep the oil from flowing away from the contact point, allowing for adequate long-term lubrication without the need of a complicated oil recirculation system. The CAS Registry Number for PTFE is 9002-84-0.

Consistency

Oil Viscosity

There are two measurements of viscosity: kinematic and dynamic, or absolute viscosity. The viscosity expressed here is kinematic viscosity, the ratio of dynamic or absolute viscosity to density. This is the value usually measured. It can be converted to dynamic viscosity using the following relation:

Kinematic viscosity x density = Dynamic viscosity
(Centistokes, cSt x g/cc = Centipoise, cP)

Because of the high density of DuPont™ Krytox® fluids, the dynamic is almost double the kinematic viscosity.

Choosing what viscosity of oil to use depends on the application. Generally, lower viscosity oils flow more readily and are used in operations where high speed is desired. High viscosity oils are preferred for low speeds or heavy loads. Since viscosity drops as temperature increases and rises as temperature decreases, the choice also depends on temperature. Thus, for the same reference temperature, a lower viscosity oil would be preferred for high speed operations and a higher viscosity oil would be preferred for low speeds. This typically applies to choosing a base oil for grease as well.

National Lubricating Grease Institute (“NLGI”) Grease Consistency

Greases are formed by mixing the base oil with a thickener to form a grease. Krytox® greases use a special, high-thickening efficiency, low-molecular weight PTFE with very small particle sizes as the thickener. It is one of the most thermally stable thickeners for high temperature, long-term greases. The lower thickener content in the grease maximizes the oil for improved grease life. The stiffness of grease is measured by its NLGI grade. This is determined using the penetration ranges listed in **Table 3**. The amount of thickener in the grease determines its stiffness. The more thickener that is added, the stiffer and harder the grease becomes.

Table 3
NLGI Penetration Ranges

NLGI Grade	NLGI Worked Penetration mm/10 at 25 °C (77 °F)	Appearance
000	445–475	Fluid
00	400–430	Almost Fluid
0	355–385	Semifluid
1	310–340	Very Soft
2*	265–295	Soft
3	220–250	Cup Grease
4	175–205	Cup Grease
5	130–160	Cup Grease
6	85–115	Block Grease

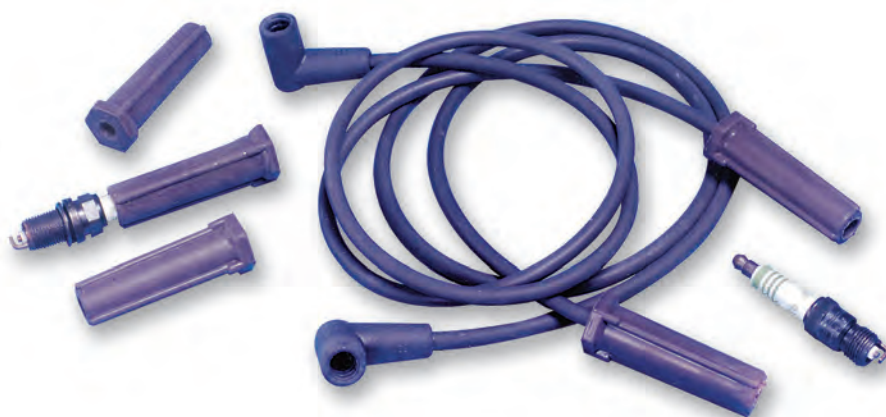
* Standard grade. Others available upon request.

Soft/Fluid Greases

These soft or fluid greases have free-flowing characteristics. They belong to NLGI penetration classes 0-000 and are often used for lubrication of sealed gear drives. Krytox® soft or fluid greases can be ordered in all NLGI grades, but NLGI 2 is standard and will be provided if grade is not specified.

Channeling Greases

Some applications require grease that is stiff and does not fall back easily into the bearing races. These systems often run at higher speeds. Harder NLGI grade 3 Krytox® greases are recommended for these applications.



**Elastomeric components are unaffected
by Krytox® performance lubricants.**

Stability

One of the greatest advantages of using DuPont™ Krytox® lubricants is stability in a wide variety of operating conditions and environments. This inert nature is what allows Krytox® oils and greases to outlast and outperform competing hydrocarbon products.

Nonflammable

Standard Krytox® lubricants contain only carbon, oxygen and fluorine, whereas hydrocarbons contain hydrogen. The absence of hydrogen greatly increases the stability of the lubricants and renders them nonflammable. They will not burn or support combustion, even in an environment of 100% liquid or gaseous oxygen.

Chemically Inert

Krytox® performance lubricants are not only resistant to oxygen but they are also inert to virtually all chemicals used in a variety of industries. They are insoluble in most solvents but are soluble in highly fluorinated fluids and some supercritical fluids such as CO₂.

Compatibility with Oxygen

At elevated temperatures and pressures, PFPE oils are highly resistant to attack by gaseous and liquid oxygen. As a result, Krytox® oils and greases have become preferred lubricants in the oxygen manufacturing industry and in those industries that use oxygen.

Krytox® lubricants do not react with gaseous oxygen under shock loading or with liquid oxygen (LOX), nitrogen tetroxide or inhibited red fuming nitric acid in impact tests. LOX impact tests were conducted in accordance with ASTM D-2512. Other impact tests conducted at 214 J/cm² (200 ft-lb/in²), according to the method described in ASTM Bulletin 250, also showed no reaction.

Krytox® lubricants have also been evaluated by the Western German Federal Institute for Materials Testing (Bundesanstalt fuer Materialpruefung, BAM) for reactivity with gaseous and liquid oxygen under pressure. **Table 4**, "Oxygen Compatibility of DuPont™ Krytox® Lubricants," shows oxygen compatibility of Krytox® lubricants.

Radiation Stability

Krytox® oils are remarkably stable to radiation when compared with many materials used as lubricants or power fluids. Irradiation of Krytox® lubricants causes minor depolymerization, with a consequent reduction in viscosity and formation of volatile products but not solids or sludge. In one test exposure of a Krytox® sample to an electron bombardment of 10⁷ rad at ambient temperature in air resulted in a viscosity decrease of only 8%. The irradiated sample contained no sludge and was unchanged in appearance.

Table 4
Oxygen Compatibility of DuPont™ Krytox® Lubricants

Test Type	Temperature, °C (°F)	Oxygen Pressure, MPa (psi)	Impact Energy, J (ft-lb)	Test Result
Ignition in gaseous oxygen ^a	400 (752)	13 (1,886)		No ignition
Pressure drop in gaseous oxygen bomb ^b	99 (210)	0.7 (100)		No pressure drop after 600 hr
Mechanical impact in liquid oxygen	Ambient		98 (72)	No reaction in 20 trials ^{c,d,e}
Mechanical impact in liquid oxygen	Ambient		122 (90)	No reaction in 10 trials ^a
Mechanical impact in liquid oxygen	Ambient		736 (543)	No reaction in multiple trials ^f

^a British Specification 3N 100.

^b American Society for Testing and Materials D942.

^c Marshall Space Flight Center Specification 106B.

^d National Aeronautics and Space Administration Handbook, 8060.1B, Test 13, Part 1.

^e American Society for Testing and Materials D2512.

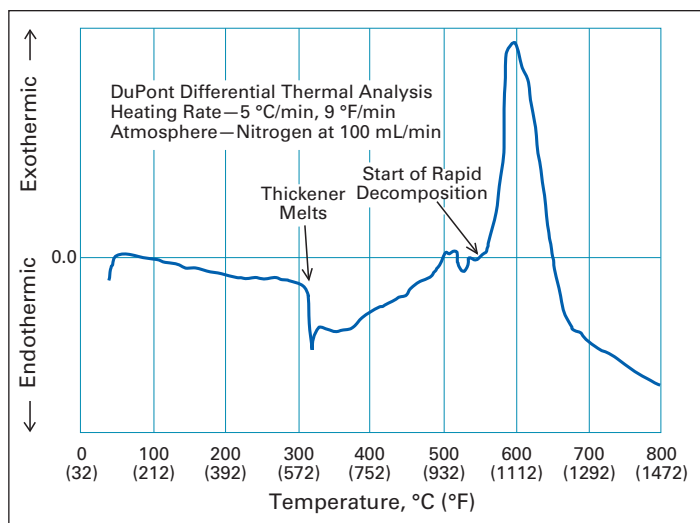
^f West German Federal Institute for Materials Testing (BAM), 8104-411.

Thermal and Oxidative Stability

The temperature at which thermal decomposition of DuPont™ Krytox® lubricants takes place depends on the test method used and how the point of incipient deterioration is measured. By differential thermal analysis, deterioration occurs at about 470 °C (878 °F) in the absence of air. The isoteniscope technique shows an initial decomposition point of 355–360 °C (671–680 °F) as measured by pressure increase. At 355 °C (671 °F), the decomposition rate is approximately 0.03% by weight per day. At 399 °C (750 °F), the decomposition rate increases to 1.30% by weight per day. When tested under nitrogen for 6 hr at 371 °C (700 °F), Krytox® showed no increase in neutralization number and no significant change in viscosity.

The presence of air does not substantially lower the decomposition point of Krytox® lubricants. However, in the presence of certain metal oxides depolymerization of the oil can start as low as 288 °C (550 °F). During depolymerization gaseous decomposition products are emitted and the remaining fluid is less viscous, but no sludge or gummy deposits are formed. In most applications, Krytox® oils have proven serviceable for long periods of time at continuous temperatures up to 350 °C (662 °F) and intermittent temperatures of 399 °C (750 °F). **Figure 1** shows the thermal stability of Krytox® fluorinated grease.

Figure 1. Typical Thermal Stability of Krytox® Fluorinated Grease.
All grease grades are similar.

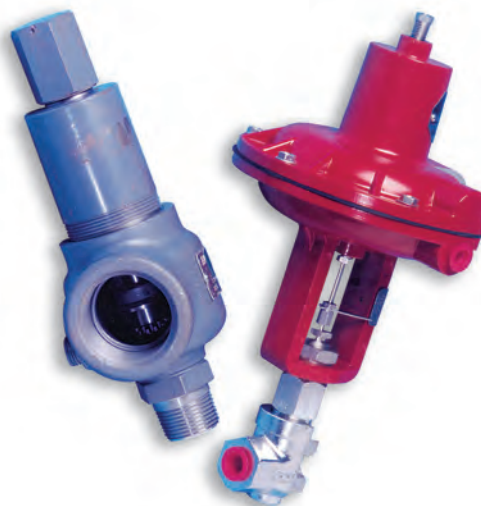


Compatibility with Metals

Because of their low surface tensions, Krytox® lubricants easily wet metallic surfaces. Krytox® lubricants are chemically inert, and therefore, they have no adverse effect on metals when the temperature is below 288 °C (550 °F). Above this point the following metals can be used with Krytox®: many alloy steels, stainless steels, titanium alloy, nickel alloy, and cobalt alloy.

Stability to Lewis Acids

Some depolymerization of all PFPE oils occurs at elevated temperatures in the presence of aluminum trichloride, iron or zinc chlorides, iron fluoride, and boron trifluoride. These Lewis acids, primarily seen in semiconductor manufacturing environments, have significantly less effect on Krytox® than on competitive fluids due to its molecular structure. Additional data is available upon request.



Mechanical Stability

DuPont™ Krytox® greases have excellent mechanical stability in bearings. They neither break down under mechanical stress nor lose their ability to hold oil. To demonstrate, the greases were mixed in a grease worker for 60, 10,000 and 100,000 strokes and tested for changes in hardness. All greases tested had changes of less than 20 points on the NLGI penetration scale and were within 1/2 grade of their original starting point. Roll stability tests were performed according to ASTM D1831 for two hours. The penetration change was minor and was within 1/2 grade of the original starting point.

Electrical Properties

Krytox® lubricants are good insulators. Similarly, the electrical properties of additive-free Krytox® greases approach those of the oils; however, incorporation of some additives may significantly alter these properties. If desired, the conductivity of the grease may be increased through the addition of a conductive additive, such as powdered copper metal.



Hydrocarbon-based lubricants burn; Krytox® does not.



Krytox® grease in hydrocarbon solvent is not dissolved.

General Properties

Many of the standard properties of Krytox® oil can be found in **Table 5**, below. These values are an approximate range, and a Krytox® representative can help you find a product to meet your specific needs.

Table 5
Typical Properties of Krytox® Fluorinated Oil*

Density** 24 °C (75 °F), g/mL 204 °C (400 °F), g/mL 24 °C (75 °F), lb/gal	1.86–1.91 1.52–1.60 15.5–16.0
Refractive Index**, nD25	1.296–1.301
Surface Tension** 26 °C (79 °F), mN/m (dyn/cm)	16–20
Isothermal Secant Bulk Modulus 38 °C (100 °F) and 34.5 MPa (5000 psi) MPa approximate psi approximate	1034 150,000
Average Coefficient of Thermal Expansion per °C (25–99) per °F (77–210)	0.00095–0.00109 0.00053–0.00061
Specific Heat, cal/g·°C or Btu/lb·°F –18 °C (0 °F) 38 °C (100 °F) 99 °C (210 °F) 204 °C (400 °F)	0.20–0.21 0.23–0.24 0.25–0.26 0.29–0.30
Specific Heat, kJ/kg·K –18 °C (0 °F) 38 °C (100 °F) 99 °C (210 °F) 204 °C (400 °F)	0.84–0.88 0.96–1.00 1.05–1.09 1.21–1.26
Thermal Conductivity** Btu·ft/h·ft²·°F at 38 °C (100 °F) Btu·ft/h·ft²·°F at 260 °C (500 °F) W/m·K at 38 °C (100 °F) W/m·K at 260 °C (500 °F)	0.048–0.054 0.040–0.051 0.0831–0.0934 0.0692–0.0883

* This table gives typical properties (not specifications) based on historical production performance. Viscosity may vary within $\pm 10\%$. DuPont does not make any express or implied warranty that these products will continue to have these typical properties.

** Increases slightly with increasing molecular weight.

DuPont™ Krytox® Lubricants

Krytox® Lubricants for General Purpose Applications

Krytox® GPL 10X oil /20X grease	The GPL 10X oil/20X grease series contains no additives and can be used on components that come in contact with chemicals.	Typical applications include valves or bearings in contact with chemicals, seal barrier fluids, instruments, and oxygen systems.
Krytox® GPL 21X	The GPL 21X series contains molybdenum disulfide for extreme pressure (EP) conditions and should be used for slow speed or heavily loaded applications where there is no danger of the molybdenum disulfide additive reacting with chemicals or causing contamination.	Typical applications include highly loaded gears, CV joints, U-joints, splined shafts, and commercial electrical switches.
Krytox® GPL 22X	The GPL 22X series contains sodium nitrite corrosion/anti-wear inhibitor and is ideal for corrosive environments where there is no danger of the sodium nitrite additive reacting with chemicals or causing contamination problems.	Typical applications are automotive bearings, sealed pump bearings, electric motor bearings, and general purpose bearings.
Krytox® GPL 29X	The GPL 29X greases have EP and anti-corrosion additives and have been formulated for high temperature applications that need both high load carrying capacity and anti-corrosion protection.	Typical applications include slow-speed conveyor bearings that are subjected to vibration, moist conditions, or frequent temperature cycling that could allow condensation and rusting to occur.
Krytox® GPL 2EX	The GPL 2E(X) lubricants are formulated using new anti-rust additives. This grease is similar to the GPL 22X series greases but contains a non-nitrite anti-corrosion additive that is the salt of an organic acid. The new additives are effective at low concentration levels, are environmentally friendly and do not pose any restrictions on long term recyclability of the grease.	Typical applications are automotive bearings, sealed pump bearings, electric motor bearings, and general purpose bearings.

Krytox® Lubricants for Aerospace Applications

Krytox® 143	Krytox® 143 series oils are clear, colorless fluorinated synthetic oils that are nonreactive, nonflammable, safe in chemical and oxygen service, and long-lasting.
Krytox® 240	Krytox® 240 series greases are white, buttery greases with all of the same properties as the 143 series oils that they are made from, but they are in grease form. The 240 AZ, 240 AB and 240 AC meet MIL-PRF-27617 general specifications. Many of the other 240 series products meet other specifications for individual applications.
Krytox® 250	Krytox® 250 series EP greases are black greases which contain molybdenum disulfide added as an extreme pressure additive for highly loaded gears and bearings.
Krytox® 283	Krytox® 283 series anti-corrosion greases are white greases which contain sodium nitrite. These grades provide rust protection at ambient temperatures, corrosion protection at high temperatures, and anti-wear protection.

Krytox® Lubricants for Extreme Pressure Applications

XP 1A series oils/XP 2A series greases	The Krytox® XP lubricant line offers greases and oils with a soluble additive in the oil. It will not be washed away or left behind with the grease thickener. These new patented additives enhance the performance of Krytox® PFPE greases and oils, giving them improved performance properties. Bearings run quieter and wear less because there are no solid additives to make noise. Lower wear will extend bearing and component life. The anti-corrosion protection of the additive will reduce rusting and allow longer grease and bearing life. The extreme pressure properties of the additive protect bearings under high loads. These products can be used in any lubrication application.
Linear series	<p>Krytox® linear perfluoropolyethers (PFPEs) provide exceptional low volatility characteristics for longer lubricant life. The base oils have high viscosity indexes to provide effective lubrication over a wider temperature range. They have the excellent chemical and thermal stability of all Krytox® products, and are nonflammable and safe for use in oxygen and other harsh chemical environments.</p> <p>Six base oil grades are available to meet the needs of all major applications. The standard products are called Krytox® L(grade number) oil or grease. Greases are also available with a choice of two anti-corrosion/anti-wear additives, including our patented XP soluble additive. The greases are thickened with polytetrafluoroethylene (PTFE), which gives a smooth, buttery, white-colored NLGI grade 2 grease.</p>

Krytox® Lubricating Fluids for Vacuum Pump Applications

Krytox® vacuum pump fluids	Krytox® vacuum pump fluids are used in vacuum pumps and vacuum systems and are used when controlled vapor pressure, nonflammability and nonreactivity are needed. These products can be regenerated back to original properties, and reused.
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Krytox® Lubricants for Extra High Temperature Applications

XHT-S, SX	This Krytox® grease is a special high temperature grease with low oil evaporation that provides long bearing life and is compatible with all elastomers and plastics. It has excellent lubrication over a broad temperature range but is designed to work best between temperatures 200–300 °C (400–572 °F). It is nonflammable, oxygen compatible and chemically inert.
XHT-AC, ACX	This Krytox® grease is a special high temperature grease with low oil evaporation that provides long bearing life and is compatible with most elastomers and plastics. This grease contains sodium nitrite corrosion/anti-wear inhibitor and is ideal for corrosive environments where there is no danger of the sodium nitrite additive reacting with chemicals or causing contamination problems. It has excellent lubrication over a broad temperature range but is designed to work best between temperatures 200–300 °C (400–572 °F). It is nonflammable, oxygen compatible and chemically inert.
XHT-RUF, RUFX	This Krytox® grease is similar to the XHT-AC series greases but contains a non-nitrite, anti-corrosion additive that is the salt of an organic acid. The grease is designed to give higher performance in the 200–300 °C (400–572 °F) range. The base oil is an extremely viscous oil that provides good viscosity and lower evaporation at high temperatures.
XHT-BD, BDZ, BDZ	This Krytox® grease is designed for use where the temperatures are in the 300 °C (572 °F) range and higher where there is a danger of melting the standard PTFE thickener. This grease uses a special non-melting high temperature thickener that also provides extreme pressure properties and works as a solid lubricant if the base oil is depleted. The base oil is an extremely viscous oil that provides good viscosity and lower evaporation at high temperatures. The grease is slightly tacky and will coat the surface and stay in place. The oil in the grease can begin to slowly degrade at temperatures above 330 °C (625 °F) and this will occur at an increasing rate as temperatures increase. Relubrication could be required at these temperatures to achieve optimum life. Maximum use temperatures for these greases are 360 °C (680 °F) with intermittent spikes to 400 °C (752 °F).
XHT-NM, NMX	This Krytox® grease is designed for use where the temperatures are in the 300 °C (572 °F) range and higher where there is a danger of melting the standard PTFE thickener. This grease uses a special non-melting high temperature thickener. The base oil is an extremely viscous oil that provides good viscosity and lower evaporation at high temperatures. The grease is for use in low speed bearings and will shear at high speeds, causing loss of oil. The oil in the grease can begin to slowly degrade at temperatures above 330 °C (625 °F) and this will occur at an increasing rate as temperatures increase. Relubrication could be required at these temperatures to achieve optimum life.



**Sintered metal components
can be lubricated with Krytox®.**

Krytox® Lubricants for Specialty Applications

GPL 246	GPL 206 with copper added so it will conduct electricity.
GPL 407	A silica thickened non-melting thickener for low speed applications in conveyors and other such applications where temperatures might cause PTFE melting.
GPL 577	A grease containing a special EP additive and anti-corrosion additives for use under high loads where corrosion might be a factor.
LVP	A special high vacuum grease for applications where outgassing must be avoided. This is used in high vacuum industries and for sealing joints in laboratory applications.
XP 2C5	The XP 2C5 grease contains an oil soluble additive that is effective at preventing corrosion and reducing wear. It also contains an extreme pressure additive. Typical applications include those in potentially corrosive atmospheres, where vibration or shock loading may be significant and where an element will spend more time experiencing mixed film or boundary lubrication versus the desired full film or hydrodynamic lubrication.
XHT 298 and 299 EP	These greases have been formulated for high-temperature applications that need both high load carrying capacity and anti-corrosion protection. Typical applications include conveyor chains that are subjected to moist conditions or frequent temperature cycling that could allow condensation and rusting to occur.



Industries and Applications

Aerospace, Aviation, and National Defense

DuPont™ Krytox® PFPE-based grease formulations were developed jointly with the US Navy and the Air Force, resulting in military specification MIL-G-27617, which was developed specifically to cover Krytox®. The first commercial sales of Krytox® were for non-flammable lubricants for the Apollo space program in 1965.

- Suborbital, Orbital, and Deep Space Flight — Reliability and long service life of mission-critical mechanical components in the face of high vacuum, temperature extremes, contact with fuels and oxidizers, and radiation exposure
- Commercial, Corporate, and Military Aviation — Reduced maintenance requirements, improved safety and reliability, compliance with a wide range of military specifications

Based on the fluoropolymer technology of DuPont, Krytox® performance lubricants have demonstrated the broad applicability to replace hundreds of purpose-formulated conventional oils and greases throughout the aerospace industry with properties such as:

- Low outgassing
- The wide temperature range of Krytox® performance lubricants
- Robust resistance to change in properties over time, in the face of harsh environmental conditions such as shock, vibration, heat and pressure; aggressive chemical environments, including rocket fuels and oxidizers; and intense radiation exposure
- Resistance to vaporization losses in the vacuum of high-altitude flight, orbit, and deep space
- Excellent frictional properties for long wear and low energy consumption
- Compatibility with all metals, elastomers, plastics, paints and finishes

General Applications (aerospace conditions and environments)

- Bearings — all types
- Seals — valves and pumps
- O-rings — sealants, lubricants

Aerospace-specific Applications

- Oxygen systems — valve and pump packing seals, mechanical seals and connectors
- Rocket engines, liquid fueled — turbines, gimbals, pumps, gears, valves with fuel/oxidizer exposure
- Actuators — mechanical/gear-type actuators for control valves and systems
- Mechanical components — spline shafts, control linkages



Automotive — Squeak and Rattle

DuPont has worked extensively with automakers and suppliers to reduce NVH (noise, vibration and harshness) levels in many vehicles, ranging from luxury cars to light trucks. As a result, Krytox® high-performance oils and greases are used by numerous automakers in many automotive applications to reduce squeaks, rattle and “itch” — a squeak that can develop when rubber or plastic mates against glass or paint. Some of these commercial applications are metal-on-plastic squeak, leather-on-leather itch, window lace, convertible top seals, front and sliding door seals, steering column gaskets, and weather-stripping.

Krytox® is an excellent lubricant, even in barely detectable quantities. It is easy to apply either by spraying or brushing. Because it has low vapor pressure and surface energy, and is insoluble in all common solvents, Krytox® lubricant stays where you put it. It has also been used in conveyors and other critical equipment in manufacturing facilities.



Automotive — Mechanical Systems Design/OEM

As operating conditions become increasingly hotter, the components run faster, standard lubricants begin to fail prematurely, and warranty costs rise, count on DuPont™ Krytox® lubricants to handle the challenge. Krytox® oils and greases are more than lubricants — they are design components. Krytox® lubricants have a superior aesthetic quality and appeal. When a lubricant increases the quality of an automotive component, it becomes as much an essential design element as a gear or a motor.

For over 25 years, Krytox® lubricants have provided state-of-the-art performance for mechanical systems. Krytox® technology can provide optimum equipment performance and low life cycle cost through:

- Prevention of wear and noise from vibration: Krytox® lubricants and coatings can minimize the shock and stress in moving parts that create heat, wear and noise. They stand up to high temperatures and harsh environments, and reduce the chances of component failure.
- Longer lasting lubrication: for many applications, the typical service life will exceed 10 years or 100,000 miles.

The public demands automobiles that are efficient and reliable. Automakers are striving towards extended warranties, expecting cars and trucks that will not require service visits before 100,000 miles or relubrication of sealed bearings and u-joints before 150,000 miles. As consumer and automaker expectations rise, Krytox® high performance synthetic lubricants can provide:

- A wide temperature range.
- Effectiveness: Krytox® lubricants keep performing in the toughest conditions: rain, snow, ice, dust and grit.
- Resistance: Krytox® lubricants can withstand the fuel, coolant, brake fluid and washer solvent of the harsh underhood

environment. They are resistant to evaporation or changes in characteristics over the many years of an automobile's serviceable life.

- Compatibility: Krytox® lubricants have no effect on paint and no compatibility issues with other automotive materials or surfaces they may contact.

In Formula One™³ cars, Krytox® lubricants have been used for suspension and steering components, drive train components, and engine auxiliary parts.

Use Krytox® lubricants to help extend the service life of a variety of car and truck parts:

- Underhood: fan clutch bearings, emission air pumps, spark plug boots, clutch release bearings, antilock brake systems, windshield wiper motors, belt pulleys, oil pressure sensors, alternator bearings, and sintered bearings in motors
- Chassis: wheel bearings, CV/universal joints
- Interior: weatherstripping, sunroof seals, window lift mechanism, leather seats, consoles and trim, flocked and unflocked window seals and channels, door handles, switches, air vents, controls and airbag covers

Krytox® lubricants even help improve performance in the auto manufacturing environment, providing lubrication for paint oven conveyor trolleys.

Chemical and Petrochemical

DuPont has extensive technical expertise in the special needs of the chemical and petrochemical industries, having longstanding experience with systems in these industries that require lubricants to help provide safe operations.

That's why DuPont Performance Lubricants offers non-reactive, nonflammable lubricants, including the Krytox® NRT line of oils and greases. Krytox® lubricant technology delivers:

- Extended equipment life
- No auto ignition at temperatures up to 482 °C (900 °F) in oxygen
- No ignition at pressures up to 350 bar
- Compatibility with polymers used in seals, O-rings, valves

DuPont lubricants have been independently tested by companies and organizations such as BOC, Air Liquide, BAM, NASA and General Dynamics and have been confirmed for use with oxygen and other reactive chemical compatibility.

Krytox® lubricants work in a variety of applications and is approved for use in valves, fans, pumps, agitators, reactors, centrifuges and other components.

³ Formula One is a trademark of Formula One Licensing BV, a Formula One Group Company.

Corrugating

DuPont™ Krytox® performance lubricants have become the corrugator industry standard for lubricating bearings on heated rolls in single facers and associated equipment. Built upon that history of innovation is DuPont™ Krytox® CorrSurface Protect coatings and our portfolio of H-1 food-grade approved products. Krytox® performance lubricants provide multifaceted investment protection such as:

- Proven success in the industry — DuPont developed the lubrication standard for the paperboard manufacturing industry. With world-class technical service and research, we have more than 20 years of proven success.
- Less downtime and more productivity — helps eliminate breakdowns related to bearings and high costs to repair or replace damaged bearings, corrugator rolls, journals, or flutes.
- Reduced maintenance and cleanup — performs from roll change to roll change no matter how long the interval. Will not carbonize on roll bearings, housings, or machinery, so disassembly and cleanup time are reduced. Extends intervals between relubrication, e.g., every two to three months instead of weekly.
- Reduced safety and environmental problems — not only can Krytox® help reduce slipping hazards and spillage on product, but it also reduces solid waste and contamination of wastewater, thereby reducing the costs and potential impact on the environment.

Krytox® performance lubricants have been developed to provide the best protection for bearings in high-temperature service up to 399 °C (750 °F), resulting in the best value, while exhibiting these other benefits:

- ISO-9002 certified
- Long-term wear resistance
- Decreased wear and bearing failure
- Protection from rust and high-temperature corrosion
- No carbonization
- Superior lubricity
- Compatible with all metals, elastomers, and plastics
- Water, steam, and chemical resistant in the most severe environments

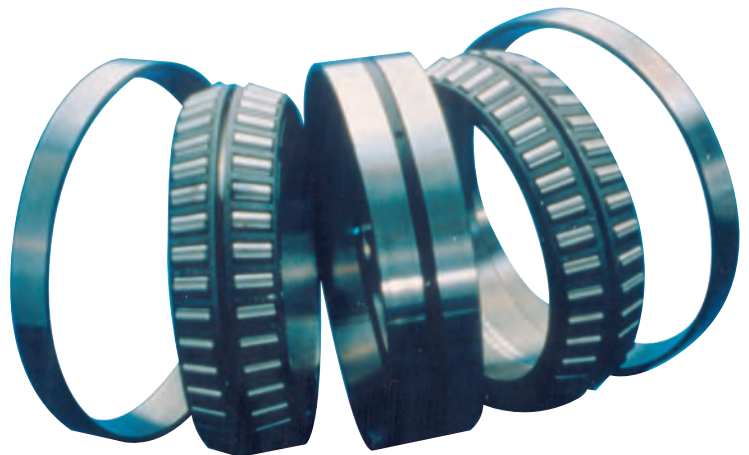
Electronics/Semiconductor

Krytox® lubricants offer excellent safety and protection benefits for the electronics industry. Our oils and greases are recognized by all major vacuum pump manufacturers and OEM equipment suppliers, meeting or exceeding all warranty requirements. Applications include:

- wet and dry vacuum pumps
- vacuum system sealants
- clean rooms
- robotics

Multipurpose, high-temperature and anti-corrosion greases; lubricating oils and vacuum pump fluids are available for every piece of equipment in the production line, including:

- bearings
- valves
- seals
- o-rings
- chains
- compressors
- gear boxes
- mechanical pumps and other components





Food Processing

DuPont™ Krytox® lubricants for use in the food processing industry are:

- Completely clear, odorless oils
- White greases for low and high temperature applications
- Able to protect bearings and other components under all load and speed conditions
- Available in a full line of H-1 PFPE lubricants

Krytox® oils and greases offer unmatched stability and flexibility:

- Nontoxic and made of only carbon, oxygen and fluorine. These oils and greases will not carbonize or burn, even in 100% liquid or gaseous oxygen
- Multipurpose, high-temperature and anti-corrosion greases; lubricating oils and vacuum pump fluids for every piece of equipment in the production line, including bearings, valves, seals, o-rings, chains, compressors, gear boxes, mechanical pumps and other components
- Undamaged by, and non-reactive with, acidic or caustic cleaners and disinfectants, steam, moisture, and high temperatures

Medical Industry Equipment Applications

In medical applications, Krytox® lubricants offer safety and efficacy:

- Oxygen-compatible and good coefficient of friction
- Best lubrication technology available in the medical industry
- H-1 food grade oils and greases available

Krytox® works in a variety of applications:

- Oxygen systems and respirators
- Approved as polymer additives/USP Class VI and can be used in autoclave (as Fluoroguard®)

Metal Processing

With high load tolerance and good water washout resistance, Krytox® protects in the most extreme metals processing environments. Krytox® oils and greases can cut production costs by increasing the life of equipment in rod mills, smelters, acid, steel, foundry, aluminum, copper and gold.

Oxygen and Reactive Gas Service

When working with reactive gas equipment, failure is not an option.

Conventional lubricants that contain mineral oils or conventional synthetics can react with oxygen and halogens such as chlorine, fluorine and bromine, thus increasing the potential for explosion, fire and premature deterioration.

Reactive gas applications require lubricants that help provide safe operations. DuPont Performance Lubricants offers the Krytox® NRT line of oils and greases that deliver:

- No auto ignition at temperatures up to 482 °C (900 °F) in oxygen
- No ignition at pressures up to 350 bar
- Compatibility with polymers used in seals, O-rings, and valves
- DuPont lubricants have been independently tested by companies and organizations such as BOC, Air Liquide, BAM, NASA and General Dynamics, and they have been confirmed for use with oxygen and other reactive chemical compatibility



DuPont lubricants help assure safe operations in reactive gas service. DuPont™ Krytox® technology provides state-of-the-art performance for mechanical systems under harsh conditions. From compressors and bearings — to seals, actuators, valves and more — Krytox® is the ideal choice for use in cryogenic and fire fighting applications, life support systems and equipment and components in reactive gas service.

Power Generation

Krytox® lubricants provide optimum performance for mechanical systems such as turbine auxiliary systems, gearboxes, dampers, valves, gaskets, high voltage and circuit breakers, seals and other components.

Krytox® lubricant technology can provide the best available equipment performance and lowest available life cycle cost through:

- Longer lasting lubrication: reduction of the amount of lubricant needed by 10 times or greater, therefore decreasing costs and frequency of relubrication. Krytox® can extend lubrication intervals from weekly to annually or even longer in some equipment.
- Reduced wear and tear on component parts, reducing the chances of component failure.

Pulp and Paper

Choose the lubricant that can move pulp and paper productivity to new levels.

In the extreme conditions of pulp mill and paper machine equipment, the selection of lubricants can affect production equipment uptime and life cycle costs. Krytox® lubricants provide endurance through heat, stay in place in the presence of steam

or water, and do not react with the chemicals used in production processes. In addition, DuPont offers anti-stick coatings for paper machines that prevent the accumulation of 'stickies.' Consider these critical factors:

- Frequency of lubrication: With some lubricants, pulp and paper mill equipment requires frequent relubrication which can impact production and can be costly over time.
- Extreme production environments: High temperatures and harsh chemicals can cause lubricant breakdown, compromising performance and leading to additional maintenance effort.
- Safety and environmental concerns: Some lubricants contain volatile organic chemical or chlorinated materials, which can be hazardous to the environment and to plant employees. Frequent relubrication increases employee exposure to dangerous, high-temperature areas.

As in power generation and other industries, Krytox® lubricants provide optimum performance for mechanical systems such as turbine auxiliary systems, gearboxes, dampers, valves, gaskets, seals and other components.

Krytox® technology can help provide the best available equipment performance and lowest available life cycle cost through:

- Longer lasting lubrication: reduction of the amount of lubricant needed by 10 times or greater, therefore decreasing costs and frequency of relubrication. Krytox® can extend lubrication intervals from weekly to annually — and much longer in some equipment, such as sootblower carriages.
- Reduced wear and tear: Krytox® lubricants can decrease wear on bearings and gears and stand up to the extreme temperatures 107–399 °C (225–750 °F) and harsh chemicals that can significantly reduce maintenance efforts and the chances of component failure.





Textile

DuPont™ Krytox® oils and greases provide superior performance and extended life to textile machinery. These performance lubricants are designed to surpass conventional lubricants. At high temperatures, Krytox® lubricants retain integrity and continue to lubricate. Conventional lubricants carbonize and destroy the bearing or gear.

Krytox® performance lubricants can enhance the function of tenter frame cross screw boxes, steamer and dryer bearings, lifter reel bearings in dye machines, tenter frame chains and gear boxes, high-speed motors, and guiding rails and clips for fabric and film stretching.

Krytox® performance lubricants offer these benefits for textile finishing applications:

- ISO-9002 certified
- No oxidation or degradation
- Protection from rust and high-temperature corrosion
- Superior lubricity
- Compatible with all metals, elastomers, and plastics
- Compatible with oxygen and chlorine

Tire Mold

Krytox® lubricants are ideal for electrically and steam-heated tire molds, because they exceed industry specifications for all components. They can extend product life and reduce the need for reapplication.

- High temperature performance
- Extended reapplication interval
- Excellent adhesion
- High hydrolytic stability
- Elimination of carbon residue build-up on the molds

How to Use DuPont™ Krytox® Lubricants in Rolling Element Bearings

DuPont™ Krytox® greases and oils provide a thick lubricating film for bearings. This film reduces metal-to-metal contact in the bearings, resulting in superior load carrying capability.

Determining Whether to Use Oil or Grease in Bearings

The functions of lubricants in antifriction bearings are to provide a film of lubricant between elements, races and separators and to reduce friction, heat and wear. They also provide protection against corrosion and remove heat. Sealed grease bearings keep dirt out, and oil lubricated systems flush dirt out of the bearing as the oil passes through.

Oils and greases are used over a wide range of speeds and operating temperatures. Selection for a given application is determined by evaluating the bearing housing arrangement, operating temperatures, contamination, bearing type and load.

Grease is recommended when...

- Simple housings and seals are used that are not designed to retain oil or seal out contaminants;
- Protection is required from dirt, dust, water, fumes or other contaminants;
- Long intervals between relubrication are required; or
- Lubrication contamination of the product must be avoided.

Oil is recommended when...

- The operating temperature is consistently high, and oil flow is needed to remove heat and debris;
- Dirt conditions are not excessive, and oil tight reservoirs and seals can be used; or
- Removing debris and contamination from the system using oil and filtering it out with an exterior filter.



Converting from Oil to Grease

Bearings that are converted from oil to grease lubrication generally run hotter internally, because grease does not remove heat as well as circulating oil does. This higher temperature gradient causes greater bearing expansion and can lead to failure if the bearing does not have adequate internal clearance. Depending on the type of equipment and the operating conditions, a bearing with a larger internal clearance may be needed. The bearing or equipment manufacturer should be consulted before converting equipment from oil to grease.

Preparing your Bearings for DuPont™ Krytox® Lubricants

Before adding Krytox® to a bearing, the bearing should be cleaned of all existing greases, oils or preservative oils used to protect it during storage. If left in the bearing, these hydrocarbon oils can form carbon deposits at higher temperatures, which may accelerate bearing failure. Use a solvent that is appropriate for the type of preservative or lubricant that is in the bearing. The Krytox® HC+ cleaner can also be used if desired. Chlorinated solvents should not be used, because they can leave chlorine behind that can cause corrosion. If a bearing has been previously packed with another grease, mechanical agitation or an ultrasonic bath should be used to ensure removal of all the old grease. If solvents are used to clean the bearings, it is also important that the bearing be dry before packing with Krytox® lubricant.

After the bearing surfaces are clean, they should be lubricated/wiped with Krytox® and properly stored to prevent corrosion. If they are not going to be packed with Krytox® immediately, or if they are going to be in storage for an extended period, they can be dipped in a solution of Krytox® XP oil to coat the surface and protect against rust.

Grease fittings should be changed to a different style, such as button-head or pin-type, to ensure that another type of grease is not accidentally injected into the bearing. A dedicated grease gun that matches the fitting should be used.

Filling your Bearing/Speed Factor

The speed factor (DN) indicates the permissible speed range for grease in a rolling bearing. The DN value is the inner race ID in mm x rpm. DN values of 100,000–400,000 and higher have been achieved at temperatures of 204–260 °C (400–500 °F) in actual field service using Krytox® greases.

The speed factor is affected by the base oil type, in addition to viscosity and thickener type, and is a measure of the lubricant's internal friction. The limiting speed for grease-lubricated rolling bearings is dependent on the type of bearing, its load, speed, and precision.

Proper lubrication is achieved by using the correct amount of grease. Too little grease in the bearings causes premature failure. Too much grease at the initial fill or during relubrication can cause overheating of bearings that are running at medium to high speed, resulting in bearing failure.

The amount of grease put in the bearing depends on the application and operating speed. For applications such as conveyor rollers and low-speed machinery with DN values below 50,000 the bearing can be filled to capacity. For medium speed applications, i.e., DN 50,000–200,000, the bearing can be filled 50–70%. For higher speed systems, the fill is typically 30–40%. Some extreme-speed special applications have grease fills of only 10–15%. Because Krytox® is heavier than hydrocarbon lubricants, its higher density must be considered when determining the fill quantity by weight.

Additional Information and Literature Requests

More information and specific properties for each DuPont™ Krytox® lubricant product are available in our detailed literature. For more information or for technical assistance, contact us at (800) 424-7502 or visit us online at www.krytox.com.





DuPont Performance Lubricants

Extreme conditions. Extreme performance.

For more information or for technical assistance, please call **1-800-424-7502** or contact us at **krytox@usa.dupont.com**.

For international sales and support contacts, visit us at **www.lubricants.dupont.com**.

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