

MACs vs. PFPEs

Choosing between multiply alkylated cyclopentanes and perfluoropolyethers for vacuum applications

Perfluoropolyether (PFPE) lubricants are valued for their broad temperature range and low vapor pressure, but they are not ideally suited to heavily loaded, metal-on-metal applications. Synthetic hydrocarbon lubricants provide better wear protection than PFPEs but are generally too susceptible to outgassing to perform well in a vacuum. *Pennzane*[®]-based oils and greases bridge that gap. *Pennzane* fluids, multiply alkylated cyclopentanes (MAC), are the only synthetic lubricants that combine the superior wear resistance of a hydrocarbon with the low volatility of a PFPE.

Vapor Pressure Outgassing reduces the effectiveness of a lubricant and can contaminate nearby components. Compared to PFPEs, most hydrocarbons do not exhibit good vapor pressure performance. Lubricants formulated with *Pennzane* synthetic hydrocarbons, however, have a vapor pressure comparable to PFPE lubricants. For example, UniFlor™ 8981, a Z-type PFPE lubricant formulated by Nye, has a vapor pressure of 7×10^{-11} Torr at 25°C, while Nye's Rheolube 2001A, a *Pennzane*-based oil has a vapor pressure of 1×10^{-12} Torr at 25°C.

Wear Protection *Pennzane* polymers have a molecular structure that is less prone to wear-related breakdown than PFPEs. The linear structure of PFPE fluids is susceptible to shearing stresses, while the cyclic structure of a *Pennzane* hydrocarbon is more resilient.

Temperature Range Of all synthetic oils, PFPE lubricants have the widest temperature gradient available, ranging from -90°C to 250°C. *Pennzane* hydrocarbons have a functional temperature range of -50°C to 125°C.

Additive and Materials Compatibility The inertness of PFPE lubricants makes them compatible with nearly all materials. Inertness also means low solubility. Additives designed to reduce corrosion or wear cannot typically be incorporated into PFPE lubricants. *Pennzane* fluids accept a wide variety of additives, and still offer compatibility with a wide range of design materials.

Surface Tension PFPE fluids have an unusually low surface tension, approximately 19 dynes/cm, making them prone to "oil creep." In an application like a bearing raceway, PFPE lubricants can be pushed out of the path of the rolling elements. *Pennzane* lubricants have a higher surface tension, approximately 32 dynes/cm. They offer a comparatively better film strength, coat moving parts, reduce oil creep, and protect loaded components.

Range of Viscosities Shell Global Solutions recently commercialized two new grades of *Pennzane* Synthesized Hydrocarbon Fluid: *Pennzane* X1000 and *Pennzane* X3000. The original *Pennzane* X2000 has a viscosity of 14.5cs at 100°C. The viscosity of the X1000 formulation is ~8cs at 100°C, while the X3000's viscosity is ~220cs at 100°C. Both new grades maintain the wide liquid range, additive solubility and low volatility for which *Pennzane* products are valued. The X1000, X2000 and X3000 fluids are completely compatible, allowing for fluid blending to achieve viscosities between 8cs and 220cs (at 100°C).

Nye Lubricants, Inc. Nye Lubricants, Inc. was the first company to formulate oils and greases from *Pennzane* synthesized hydrocarbon fluids. Nye offers a family of commercialized *Pennzane* lubricants that are already successfully deployed in space, semiconductor manufacturing, and magnetic disk applications. Nye custom formulates *Pennzane* lubricating oils and greases and is Shell Global Solutions' authorized distributor of *Pennzane* fluids in the United States. Nye also designs and manufactures UniFlor lubricants, a complete family of PFPE oils and greases.

Pennzane Lubricants Formulated by Nye The following table lists Nye's commercialized *Pennzane* greases and oils. To learn more about *Pennzane* fluids, request evaluation samples, or discuss a custom-formulated *Pennzane* lubricant for your application, please call Nye at +1.508.996.6721 and ask for Technical Services. You can also e-mail Nye at contact@nyelubricants.com, or visit us on the web at www.nyelubricants.com.

Pennzane® Fluids

Flight Qualified, Space Tested

Studies from Goddard Space Flight Center report *Pennzane* lubricants offer up to five times greater wear protection than PFPE-based lubricants. In oscillatory gimbal bearing tests, *Pennzane* X2000 lubricated bearings still exhibit acceptable torque traces after more than 25,000 hours of tests. In fact, after the first year of testing, none of the bearings lubricated with *Pennzane* synthesized hydrocarbon fluids failed.

In another study presented at The 37th Aerospace Symposium at the Johnson Space Center, bearings lubricated with Nye's Rheolube™ 2001, a *Pennzane*-based lubricant containing a triphenyl phosphate antiwear additive, improved bearing life up to 18 times over PFPE-lubricated bearings.

Oil	Companion Grease	Additives	Grease Thickener
Nye Synthetic Oil 1001-3PB	Nye Synthetic Oil 1000-3PB	Lead naphthenate phenolic antioxidant	Sodium soap
Nye Synthetic Oil 1001	Rheolube® 1000	Amine and phenolic antioxidants alkylated triphenyl phosphate	Sodium Soap
Nye Synthetic Oil 1001A	—	—	—
Nye Synthetic Oil 2001-(x)PbNp	Rheolube® 2000-(x)PbNp	1 to 7% lead naphthenate antioxidants	Sodium soap
Nye Synthetic Oil 2001-3PB	Rheolube® 2004	Lead naphthenate phenolic antioxidant	Sodium soap
Nye Synthetic Oil 2001	Rheolube® 2000	Amine and phenolic antioxidants t-butyphenyl phosphate	Sodium soap
Nye Synthetic Oil 2001A-(x)PbNp	—	1 to 7% lead naphthenate	—
Nye Synthetic Oil 2001A	—	—	—
	NyeTorr® 6200	Phenolic antioxidant	PTFE
Nye Synthetic Oil 3001A	—	—	—
NyeTorr® 6201	—	—	—

Please note that U.S. Department of Commerce Export Administration Regulations and U.S. Department of State International Traffic in Arms Regulations (ITAR; 22 CFR 120-130) restrict the export of certain Nye products. An export license may be required.



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