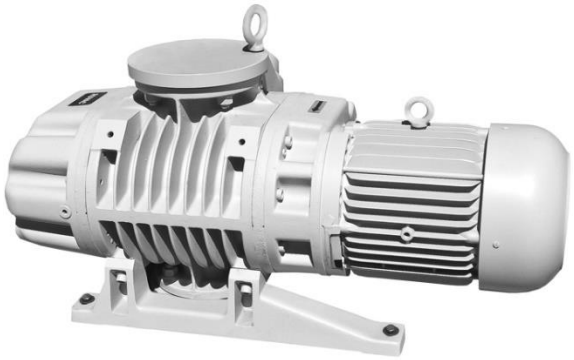
Converting From PFPE to Hydrocarbon Oil

The most inert vacuum pumping oil is called PFPE type and sold by Ideal Vacuum as brand names, Fomblin and Krytox, these fluorinated oils are expensive because they contain carbon-fluorine (C-F) bonds instead of carbon-hydrogen (C-H) bonds. Some customers want to switch their pump back to hydrocarbon oil as they are no longer using the pump in a chemical application. This is a common request as the PFPE oils are expensive, they can cost around $1,500 per gallon. The hydrocarbon oil is much less expensive. The process of switching to hydrocarbon oil is easy. With the pump correctly installed, you simply fill the pump with new hydrocarbon oil, run for an hour or so, drain and repeat. It takes 2 or 3 of these (fill, run, and drain) cycles to get most of the PFPE oil out of the pump. The hydrocarbon oil will become clear as seen in the sight glass. The pump is now ready for service as a standard hydrocarbon oil pump.



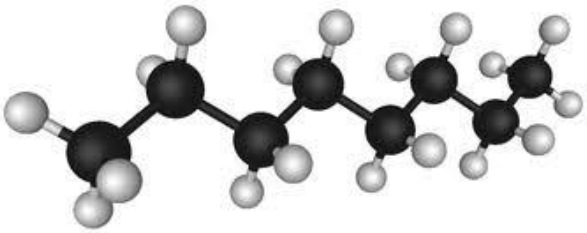
Guidelines

Please make sure you download and follow the instructions supplied by the manufacturer of your vacuum pump on how to correctly install and conduct an oil change. Ideal Vacuum offers for download 1000's of user's manuals on our website, these are a great reference for our customers, downloads are available at:

https://www.idealvac.com/manuals.asp

Background on subject

Hydrocarbon oil is made up of carbon-carbon (C-C) and carbon-hydrogen (C-H) bonds which is a low-cost vacuum fluid but not very chemical resistant. An example of a hydrocarbon oil molecule is show here.



The PFPE oils are made up of carbon-carbon and carbon-fluorine bonds, (C-C) and (C-F). The C-F bond is stronger than the C-H bond, this is what makes PFPE oils more chemically inert. The PFPE oils are like liquid PTFE or can be thought of as liquid Teflon™.

Important

The two oil types (hydrocarbon and PFPE oils) are liquids that cannot dissolve in each other, they are called immiscible liquids and will not mix. They can't form a homogeneous mixture, like water and oil. See the example photo below of two immiscible liquids, the liquid with lower density is on top while the heavier higher density liquid is on the bottom. The white layer in the middle is called an emulsion, it is a fine dispersion of miniature droplets of one liquid in another, this emulsion looks white or milky. This is a signal that two immiscible liquids that have been blended together. If left standing for a long period of time they will separate again, with a well visible boundary between them.

This will happen inside the vacuum pump if the two different oil types are added (hydrocarbon and fluorinated), the oil will look milky. It is important to learn that this is not harmful to the pump, both are good vacuum pump oils, they just cannot dissolve into each other.

Looking to pump chemicals in your vacuum application?

Welch Vacuum manufacturers a chemical resistant series of vacuum pumps, called CHEMSTAR and their documentation is a good reference for customers with a chemical containing vacuum application. The information below is focused on the Welch Vacuum CHEMSTAR pumps but it is applicable for pumps made by other manufacturers, we recommend studying this documentation.

We often get this question:

How do I switch my CHEMSTAR from factory prepared hydrocarbon oil (DIRECTORR Gold) to the very chemical resistant PFPE fluorinated oils (Fomblin Y06/6), and what should I consider when doing this?

First Part Answer

If you are okay with a small amount of hydrocarbon oil left in the pump, then you are good to drain the new pump of as much hydrocarbon as possible, then fill with PFPE FOMBLIN Y06/6. The oil as seen in the sight glass will become milky, as it still has a small amount hydrocarbon oil inside. Overtime, with future PFPE oil changes, the oil will become less milky. The pump will run fine with no issues having the milky mixture, the pressure will be the same, the pump will last just as long.

Second Part Answer

When should I be concerned? Well, it depends on what you are pumping in your vacuum application and at what concentration. The hydrocarbon oil is not compatible with high concentrations of oxidizers, such as hydrogen chloride (HCl), hydrogen bromide (HBr), Oxygen (O3), Ozone (O3) and other oxidizers. If the percentage of oxidizer is above a small amount, then the pump should be rebuilt, completely taken apart, all hydrocarbon oil removed, and the pump rebuilt using only PFPE oil. Welch gives good guidance on this topic, they state "**WARNING** Do not use DIRECTORR gold oil when pumping gases containing more than 30% oxygen. The use of DIRECTORR gold which is supplied with the pump is a Flammability Hazard if more than 30% oxygen mixtures are pumped. When gases pumped into a CHEMSTAR pump exceed 30% oxygen of gas flow, the CHEMSTAR pump must be prepared with FOMBLIN Y06/6. In these cases, to switch from DIRECTORR Gold oil To Fomblin, the CHEMSTAR pump must be totally disassembled, and all parts cleaned of oil. The pump must then be assembled using Fomblin. Welch can carry out the conversion for you through our repair department. Call Welch factory at 847-676-8800 ext. 1 for details."

It is helpful to understand why

Hot hydrocarbon oil is flammable and will burn in air or in the presence of an oxidizer. When hydrocarbon oil is heated inside the pump and an oxidizer is present, it can auto ignite, this is called reaching the flash point, it will burst into flames without even having a spark present. If the oxidizer concentration is high, the hydrocarbon oil can even spontaneously explode. This is not the case with PFPE oils, they are not flammable, in fact, they will actually put out a fire, acting as a fire retardant.

Our Recommendation

There are a lot of things to consider when your vacuum application requires pumping of chemicals. We recommend that you study the document prepared by Welch, it is helpful, it covers pumping of acids, halogens, oxidizers, anhydrides, and other chemicals. The concentration of the evacuated chemicals is important, you can lower the concentration by diluting the system with dry inert gases, Welch gives good guidance on dilution practices. Please refer to Welch Vacuum document, see section "**USING YOUR CHEMSTAR® PUMP WITH CORROSIVE GASES**" 3rd Edition Applications Booklet, download from our website at:

https://www.idealvac.com/files/manualsII/OwnersManChemstar_1400N_1402N_1376N_1374N.pdf

Converting From PFPE to Hydrocarbon Oil

Some customers want to switch their pump back to hydrocarbon oil as they are no longer using the pump in a chemical application. This is a common request as the PFPE oils are expensive, they can cost around $1,500 per gallon. The hydrocarbon oil is much less expensive. The process of switching to hydrocarbon oil is easy. With the pump correctly installed, you simply fill the pump with new hydrocarbon oil, run for an hour or so, drain and repeat. It takes 2 or 3 of these (fill, run, and drain) cycles to get most of the PFPE oil out of the pump. The hydrocarbon oil will become clear as seen in the sight glass. The pump is now ready for service as a standard hydrocarbon oil pump.

Some Quick Refences (given here)

Welch recommends DIRECTORR® Gold Oil be used with each CHEMSTAR pump when pumping corrosive gases. DIRECTORR Gold is a totally new type of hydrocarbon oil which is a formulated oil rather than refined base stock oil. This product was developed to replace costly perfluoropolyether oils such as Fomblin® and Krytox® in non-oxygen enriched systems. Several reasons exist for why DIRECTORR Gold is a superior hydrocarbon oil for corrosive gas applications compared to standard hydrocarbon oil. These reasons are:

- Less reactive to chemical attack. DIRECTORR Gold is a highly saturated and hydrogenated oil which creates a high-purity product. By vacuum distilling off a narrow fraction of this oil, Welch has produced an oil with more single bonds than other oils. Fewer double bonds make it a less reactive oil.
- Exceptional resistance to water emulsification. Since the oil is saturated, it exhibits less water emulsification compared to standard distilled pump oils. Since water may be in your corrosive gas stream, less water emulsification facilitates passage of corrosive gases out of the pump rather than residing in water-logged oil.
- Low phosphorus content. Phosphorus is one of the most reactive elements present in hydrocarbon oil. DIRECTORR Gold has less than 1 ppm of phosphorus where as standard vacuum distilled oil typically has 3000 to 4000 ppm. Some corrosive gases will combine with phosphorous and under pump operation breakdown oils forming acidic sludge.

If the flow of strong acids or halogens exceeds 10% of gas flow, you must switch to a perfluoropolyethers such as Fomblin Y06/6 (Welch Cat. Nos. 1408C-06, 1 Kg; 1408C-08, 2Kg) - Fomblin is a registered trademark

of Ausimont. In addition, if ozone is pumped and its concentration exceeds 100 ppm of the gas flow, a perfluoropolyether oil must be used. Perfluoropolyethers are very resistant to chemical attach by strong acids. CAUTION Failure to use Fomblin Y06/6 in applications where strong acids, halogens or ozone exceed recommended gas flow limits given will lead to degradation of the DIRECTORR gold oil and to the CHEMSTAR pump failing.

A. Strong Hydrous Acids: Hydrochloric acid (HCl), Hydrogen bromide (HBO), Sulfuric Acid (H2SO4), Nitric Acid (HNO3).

See section "**USING YOUR CHEMSTAR® PUMP WITH CORROSIVE GASES**" 3rd Edition Applications Booklet

https://www.idealvac.com/files/manualsII/OwnersManChemstar_1400N_1402N_1376N_1374N.pdf

B. Weak Acids: Acetic Acid (HOAC), Carbonic Acid (H2CO3)

See section "**USING YOUR CHEMSTAR® PUMP WITH CORROSIVE GASES**" 3rd Edition Applications Booklet

https://www.idealvac.com/files/manualsII/OwnersManChemstar_1400N_1402N_1376N_1374N.pdf

C. Halogens: Chlorine (Cl2), Bromine (Br2).

If water is not present, small gas flows of chlorine or bromine can be pumped without major difficulty. Welch recommends that when dry chlorine and bromine occupy less than 5% of the total gas flow the gas ballast should be opened. DIRECTORR Gold oil will work well for this gas load. If the flow of dry chlorine or bromine exceeds 5% of gas flow, Welch recommends you dilute the chlorine or bromine by adding dry nitrogen to the stream (See Section 3 B.). The dilution needs to bring the dry chlorine or bromine gas flow back below 5%. If the flow of dry chlorine or bromine cannot be brought below 5% of gas flow but is not above 10%, Welch recommends that our oil filtration system with an alumina element be used (See Section 2 C. for information on the oil filtration system.) If the flow of dry chlorine or bromine goes above 10%, you must switch to a perfluoropolyethers such as Fomblin Y06/6 (Welch Cat. No. 1408C-06, 1 Kg) - Fomblin is a registered trademark of Ausimont. Perfluoropolyethers are very resistant to chemical attack by halogens.

CAUTION Failure to use Fomblin Y06/6 in applications where chlorine or bromine is pumped at concentrations above 10% of gas flow will lead to degradation of the DIRECTORR gold oil and to the CHEMSTAR pump failing.

If the flow of chlorine or bromine is not dry (for example chlorine or bromine in humid air), hydrochloric and hydrobromic acid will appear in the gas stream.

D. Formaldehyde (CH20)

See section "**USING YOUR CHEMSTAR® PUMP WITH CORROSIVE GASES**" 3rd Edition Applications Booklet

https://www.idealvac.com/files/manualsII/OwnersManChemstar_1400N_1402N_1376N_1374N.pdf

E. Trifluoroacetic Acid (F3CC02H)

See section "**USING YOUR CHEMSTAR® PUMP WITH CORROSIVE GASES**" 3rd Edition Applications Booklet

https://www.idealvac.com/files/manualsII/OwnersManChemstar_1400N_1402N_1376N_1374N.pdf

F. Ozone (O3).

Ozone is a strong oxidant and very unstable. **WARNING** Ozone is an explosive hazard in its liquid form. Do not attempt to use a cold trap to condense out the ozone. Prior to working with ozone, read a handbook on hazardous materials (for example, Dangerous Properties of Industrial Materials, Sixth Edition, by N. Irving Sax, Van Nostrand Reinhold Company Inc. NY, NY 1003, 1984) to determine if any gases you will be pumping react dangerously with ozone.

When pumping ozone, keep the concentration passing into the pump below 100 ppm. This can be accomplished either by miniaturizing the experimental process to reduce the quantity of ozone used or by dilution of the ozone flow by dry nitrogen.Ozone is well known for chemically attaching vacuum pump oil. DIRECTORR gold oil used in a CHEMSTAR is a highly saturated oil that resists this attack. However you need to monitor the oil closely. An oil filtration system may be need if you are seeing rapid degradation of the oil at the 100 ppm. A cellulose element should be used with the oil filtration system (See Section 2 C. for more details on oil filtration system available from Welch). If you will be pumping ozone at levels above 100 ppm of gas flow, you must switch to a perfluoropolyethers such as Fomblin Y06/6 (Welch Cat. No. 1408C-06, 1 Kg) - Fomblin is a registered trademark of Ausimont. Perfluoropolyethers are very resistant to chemical attack by ozone.

CAUTION Failure to use Fomblin Y06/6 in applications where ozone is pumped at concentrations above 100 ppm will lead to rapid degradation of the DIRECTORR gold oil and CHEMSTAR pump failure.

To switch from DIRECTORR Gold oil To Fomblin, the CHEMSTAR pump must be totally disassembled, and all parts cleaned of oil. The pump must then be assembled using Fomblin. Welch can carry out the conversion for you through our repair department. Call Welch factory at 847-676-8800 ext. 1 for details.

G. Anhydrides: SOX - Sulfur Trioxide (SO3) and Sulfur Dioxide (SO2), Hydrogen Sulfide (H2S)

See section "**USING YOUR CHEMSTAR® PUMP WITH CORROSIVE GASES**" 3rd Edition Applications Booklet

https://www.idealvac.com/files/manualsII/OwnersManChemstar_1400N_1402N_1376N_1374N.pdf

I. Special Note: Pumping oxygen

Whenever mixtures containing oxygen or pure oxygen are used a nonflammable vacuum pump oil such as Fomblin Y06/6. DIRECTORR Gold is a synthetic saturated hydrocarbon oil and is flammable. **WARNING** Do not use DIRECTORR gold oil when pumping gases containing more than 30% oxygen. The use of

DIRECTORR gold which is supplied with the pump is a Flammability Hazard if more than 30% oxygen mixtures are pumped. When gases pumped into a CHEMSTAR pump exceed 30% oxygen of gas flow, the CHEMSTAR pump must be prepared with FOMBLIN Y06/6 (Ausimont registered trademark). Contact the Welch factory for advice or to have your CHEMSTAR pump prepared with FOMBLIN Y06/6 if you will be pumping greater than 30% oxygen gas flows.

H. Fragments of Sulfur Hexafluoride (SF6), Carbon Tetrafluoride CF4) etc.

See section "**USING YOUR CHEMSTAR® PUMP WITH CORROSIVE GASES**" 3rd Edition Applications Booklet

https://www.idealvac.com/files/manualsII/OwnersManChemstar_1400N_1402N_1376N_1374N.pdf

Diluting Corrosive Gases

The lower the % of the gas flow into the CHEMSTAR pump which is corrosive gases the better. Hence, if you have extra pumping capacity in your application and corrosive gases making up more than a few percent the gas load, Welch recommends diluting the gas with dry nitrogen or argon (See specific recommendations for various gases in Section 4). If you are planning a new system, Welch recommends you use a pump with a higher capacity than initially calculated if you plan to dilute the corrosive gases. The dry nitrogen or argon can be bleed into the intake of the CHEMSTAR pump through a needle valve attached to vacuum piping joint to the vacuum chamber. Be sure not to add too much dry nitrogen or argon such that the total pressure of the system rises above 10 Torr. **CAUTION** Be sure the pump is operating at a pressure of 10 Torr or lower for continuous operation. If not, discuss application with Welch Technical Service before proceeding to prevent oil from overheating and breaking down resulting in the pump failing. **CAUTION** Be sure to use argon or nitrogen which is dry rather than wet. Water vapor mixed with corrosive gases can accelerate corrosive in the pump and lead to shorten service life.