A comparison of hydrocarbon and silicone vacuum greases

Discussing the different characteristics of hydrocarbon-based grease versus those of silicone in specific industry applications.

White Paper

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Introduction

There are a number of different options on the market when it comes to vacuum lubricants and sealants. The Apiezon range of hydrocarbon based vacuum greases has a long and recognised track record in providing lubrication and sealing solutions. In more recent times other materials have come onto the market, but in many ways specialist hydrocarbon grease still remains the number one choice.

Another well-established material is silicone high vacuum grease. This product has demonstrable advantages in terms of low vapour pressure and good stability; however some of the unique surface properties of silicone can cause problems for a vacuum engineer, especially when cleanliness is paramount. The following is an examination of two key problem areas, namely *creep* and *contamination*.

Silicone Grease Creep

The reason that silicone grease is so prone to creep is based on the chemistry of the base fluid. Silicone greases are comprised of Polydimethylsiloxane (PDMS) liquid combined with some sort of filler, commonly PTFE or zinc oxide. The PDMS liquid itself has some interesting properties, one of which is that the critical surface tension of wetting is higher than the liquid surface tension [1]. This means that the polymer will spread over its own adsorbed film, in a process known as creep. This can be an advantage in some applications as it means that silicone liquid will readily provide surface coverage for metal protection or mould release. However in the vacuum world this tendency to readily creep has the potential to cause costly problems.

For example, this can mean that in a vacuum chamber a film of silicone can become deposited on surfaces, which can cloud optics or cause issues with electrical contacts. In addition under electrical arcing or partial discharge silicone grease can break down and form solids, which are non-conductive and if this happens on electrical contacts then they will no longer work correctly.

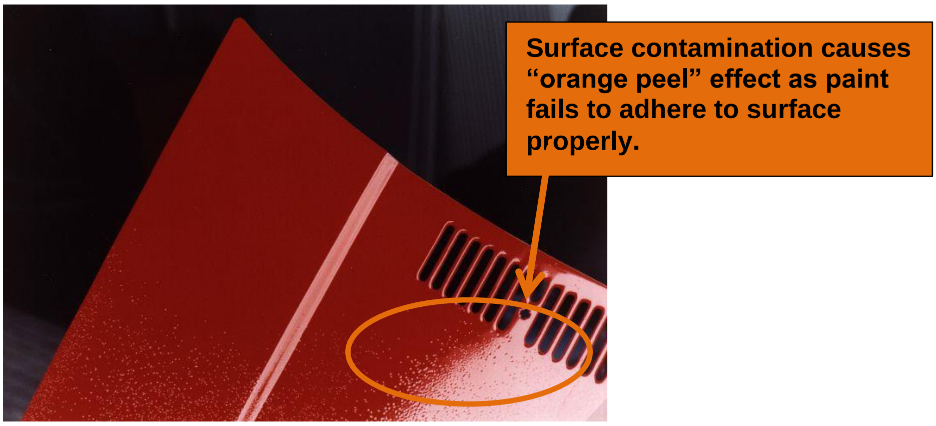
Surface Contamination

Much has been published about the potential for silicone contamination and one example of this comes from the space industry, where a number of solar cells were packaged in shipping foam which was manufactured using a silicone mould release agent. After one year in storage the mould release had transferred to, and permeated through, the solar cell structure. This incident resulted in the loss of solar cells for a large number of solar panels.[2] It is this ability of silicone to migrate and “creep” away from where it is intended to be used that can be damaging if not carefully managed.

For example, a key application where silicones may be less acceptable is in the coating and painting industries. If surfaces become contaminated with silicone it can act as a barrier to adhesion of coatings and cause defects in painted surfaces.

A well-known example of a defect caused by surface contamination is shown in Figure 1. In some cases the use of silicone compounds may be restricted for all process equipment in a paint plant and in this case the use of hydrocarbon grease can offer a very cost effective alternative.

Figure 1 - Defect caused by surface contamination [3]



Another example where the choice of vacuum grease should be carefully considered is in laboratories, where a large amount of specialist glassware is utilised. In many instances there is a need to produce custom items of equipment to perform certain experiments and to cater for this a number of specialist glassblowing workshops exist which can build intricate bespoke glassware. This allows users to have glass reworked or repaired in the event of accidents, but if silicone contamination is present then this can be prevented. Upon heating to the high temperature necessary to shape glass (in excess of 400°C), a fine white powder of silica can be produced which will fuse onto the surface of the glass. If a torch is then applied the silica will burn into the glass, effectively destroying it.[4][5] This can be extremely costly if a piece of custom made glassware is damaged and far outweigh the additional cost of selecting a hydrocarbon grease in place of the silicone.

Hydrocarbon Grease

The alternative to all these issues is to use hydrocarbon-based grease, as this family of materials is far less prone to creep and does not exhibit the migration behaviour of silicones.

This is primarily due to the higher surface tension of hydrocarbon grease, when compared to silicone and other alternatives such as PFPE, as shown in table 1.

Table 1 - Comparison of typical surface tension by base oil [6][7][8]

Base Oil Type	Surface Tension dyne/cm
Hydrocarbon	30
Silicone	16 - 21
PFPE	18

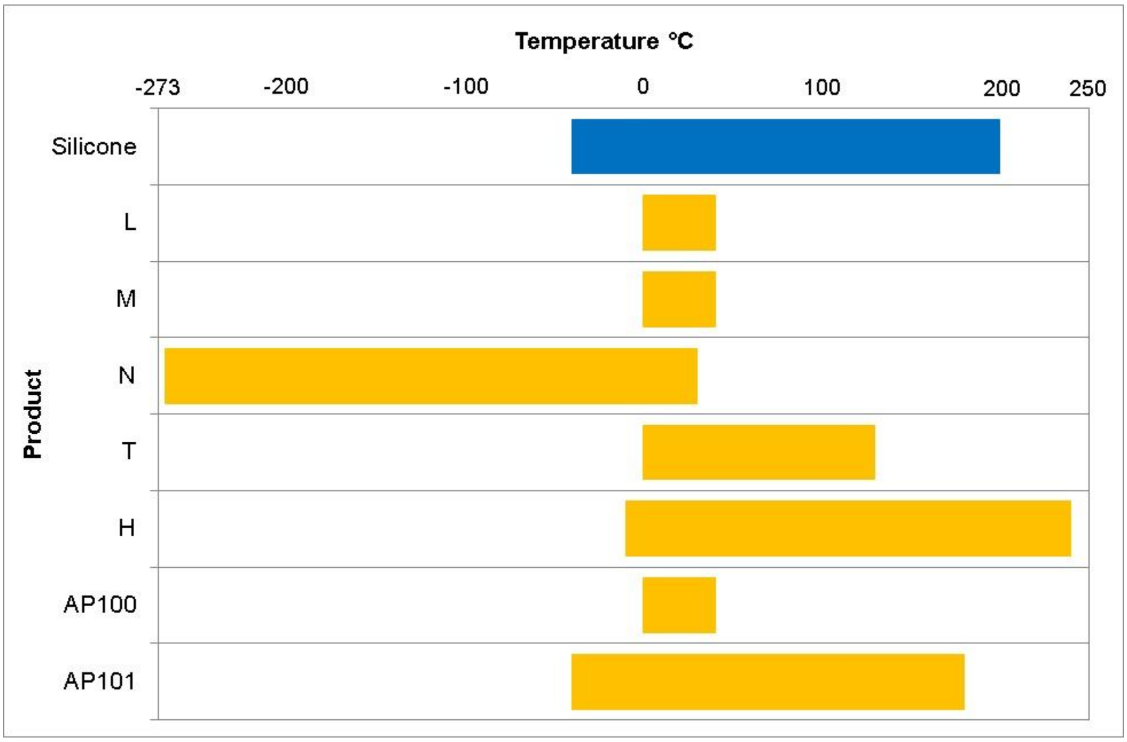
Hydrocarbon grease is also easier to remove from surfaces than silicone products. In the case of laboratory glassware the application of simple soap and water can be sufficient to remove hydrocarbon grease and if this is not suitable solvents such as limonene can be utilised to dissolve and completely remove the product. Silicone on the other hand is more likely to leave a residue behind even after thorough cleaning and can change the surface behaviour with regard to adhesives and paints.

In many cases a hydrocarbon product can be selected which gives the necessary vacuum performance. It is also worth noting that in the case of metal to metal lubrication hydrocarbon grease gives far superior performance to silicone based materials. It is also possible to dissolve unfilled hydrocarbon based greases in solvents to aid application of very small quantities.

Operating Temperature Range

One area where silicone vacuum grease can seem advantageous is in the available operating temperature range as this is typically from -40 to 200°C [9]. Hydrocarbon greases can provide a similar operating range and there are also products which extend this range down into cryogenic temperatures and up above the capabilities of silicone. The chart in figure 2 shows the range of operating temperatures for a variety of hydrocarbon greases in the Apiezon range.

Figure 2 - Operating temperature range for hydrocarbon greases



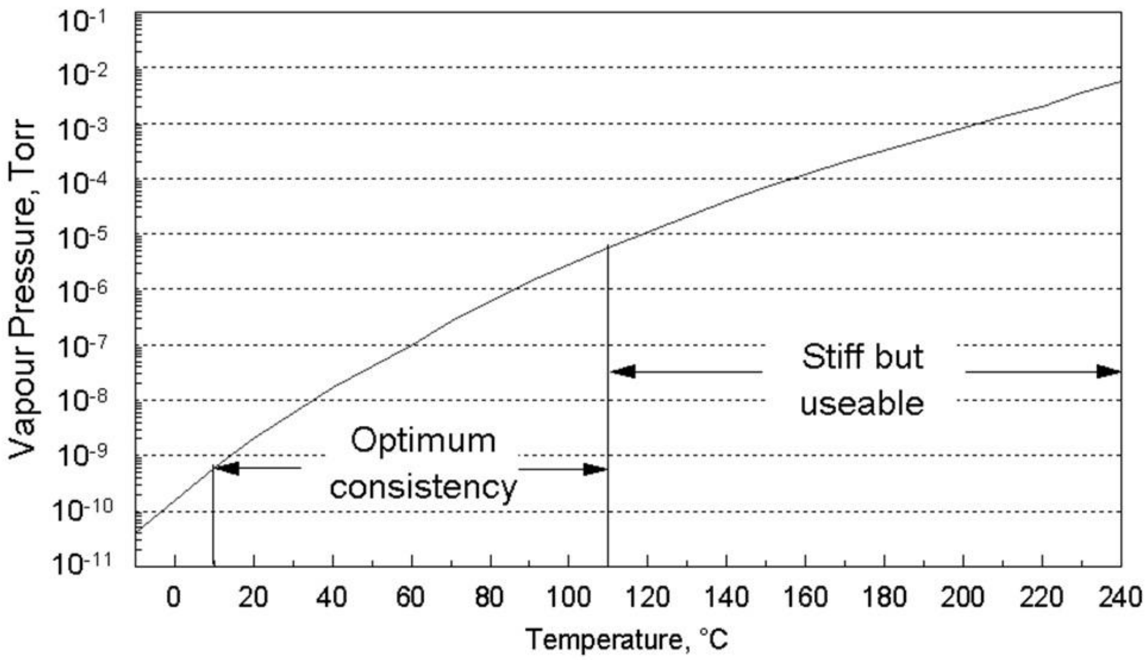
Pressure Operating Range

The other important consideration for a vacuum engineer is the operating pressure range of the vacuum grease and this is directly related to the vapour pressure of the product. The vapour pressure of silicone grease will depend on the performance of the base oil, which is mixed with a thickener to produce the final grease. Typically silicone oils will have a vapour pressure of less than 1Torr at 220°C[10] and silicone grease is recommended for use in systems with ultimate base pressures of $1x10^{-5}$ to $1x10^{-6}$Torr. Preconditioning of the grease at operating pressure and temperature is recommended to avoid contamination of samples.

In comparison high temperature hydrocarbon greases can have vapour pressures of less than $10x10^{-2}$ Torr at 220°C and can be used at $1x10^{-8}$Torr for ambient temperature applications. This makes contamination of surfaces less likely and no preconditioning of the grease is normally required. Other hydrocarbon greases designed for ambient temperatures can operate down to the $1x10^{-10}$Torr range.

The vapour pressure curve in figure 3 shows an example of the behaviour of high temperature hydrocarbon grease and so long as the vacuum pressure is above the curve for a given temperature then the grease will be suitable.

Figure 3 - Vapour pressure curve for high temperature hydrocarbon grease [11]



Conclusions

There are a number of different vacuum greases on the market and two commonly used ones for production, research and laboratory work are hydrocarbon based and silicone based. Although there is a cost and stability advantage to the silicone based grease it is worth assessing the likely impact of contamination and creep before selecting this solution. Inadvertent contamination with silicone can cause serious issues and be almost impossible to clean. There may also be blanket restrictions on the use of silicone containing products in some paint plants and in this case hydrocarbon can offer a viable cost effective solution. The very low vapour pressure and easy removal of hydrocarbon based grease can make it a preferable option in many cases. By carefully selecting the right grease for the application hydrocarbon products can also offer a solution over a wider temperature and vacuum range.

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