MORE ON LUBRICATION

Properties of a good vacuum pump lubricant:

1. Low gas solubility
2. Low vapor pressure
3. High flash point
4. High Fire point
5. High autoignition temperature
6. Color
7. Good Thermal stability
8. Good Oxidation resistance
9. Good Chemical resistance
10. Low cost
11. Viscosity

1. **Low gas solubility** is important for a number of reason: Dissolved gas increases the pumps base pressure and time to reach a base pressure due to the vaporization of the dissolves gases that can evolve when exposed to vacuum. It also reduces the viscosity of the oil, can cause foaming and these gases can react with the system atmosphere being pumped.

2. **Low vapor pressure** in the lubricant is essential to prevent the oil from contaminating the region of the pump that creates the vacuum. As the pump operates high vapor pressure oils offgas into the working region of the pump and add to the load of molecules that must be removed from the system to achieve vacuum. So the pump is working to remove the molecules from the system gas and at the same time adding more.

3. **Flash point** refers to the temperature where a material can ignite but not maintain combustion. With the refined mineral oils there is a limit to how high the flash point can be but generally it is sufficiently high to prevent ignition at around 464° F (240 °C).

4. **Fire point** is the temperature where a material will continue to combust once it ignites. While generally not a concern it is important to factor into the housekeeping efforts expended in an area where vacuum equipment is present, heat treating facilities in particular. Keep fluid contained and off the floor. If a leak is identified contain it and schedule a repair so controlling fluid spills does not become a chronic safety issue. Poor housekeeping of oil spills can result in slips and falls, often with injurious results.

5. **The autoignition temperature** identifies the temperature where a material will ignite spontaneously. The ignition characteristics are determined by the vapor quantity, characteristics of the container and spark energy or more correctly Minimum ignition energy (MIE) which is the minimum amount of energy required to ignite a combustible vapor, gas or dust cloud. Another important factor is that the Ignition of a fuel/air mixture is possible only when the rate of escape of heat near the ignition zone is greater than the heat loss by conduction.

7. **Color/Appearance** can be an effective diagnostic tool for determining oil contamination. If the new oil color is known a small sample of oil can be placed onto a white background and compared. Most sight glasses have a bright background to facilitate this inspection readily. Monitoring the sight glass for oil level and color can be a useful daily confirmation of the status of the lubricant. If the oil is opaque and discolored light brown it might be an indication of water contamination which can be remedied by opening your gas ballast valves slightly, on pumps so equipped, to let the pump work the water vapor out of the system. This technique works for other dissolved gasses as well.

8. **Good oxidation resistance** is difficult to achieve in hydrocarbon oils (mineral and synthetic) used in mechanical pumps. They display fair to poor qualities. Oils used for highly reactive gas atmospheres or high oxygen concentrations are formulated from perflouropolyether (Krytox is one brand) and have far superior oxidation resistance but have toxic byproducts at higher temperatures. Diffusion pump specific oils like silicones and Polyphenyl Ether have excellent oxidation resistance. If the vacuum pump oil does not have rust or oxidation (R&O) additives, it will have very low vapor pressure so a very good base vacuum. The snag is it will turn to sticky varnish/ glop when the temperature rises and that will cause more rapid wear and earlier pump rebuilding. This is prevalent in hot running vane pumps like Edwards E2M275's and Leybold SV630's. When you get an additive package that really works, the base vacuum will rise. This is normally not a problem as most mechanical pumps have a blower front- end which essentially "masks" the high base vacuum on the mechanical pump. So, in most cases, use an oil that has a decent R&O package. Multi viscosity heavy duty diesel engine oils fill this bill quite nicely. They also have anti-wear additive packages that extend the life of closely fitting parts.

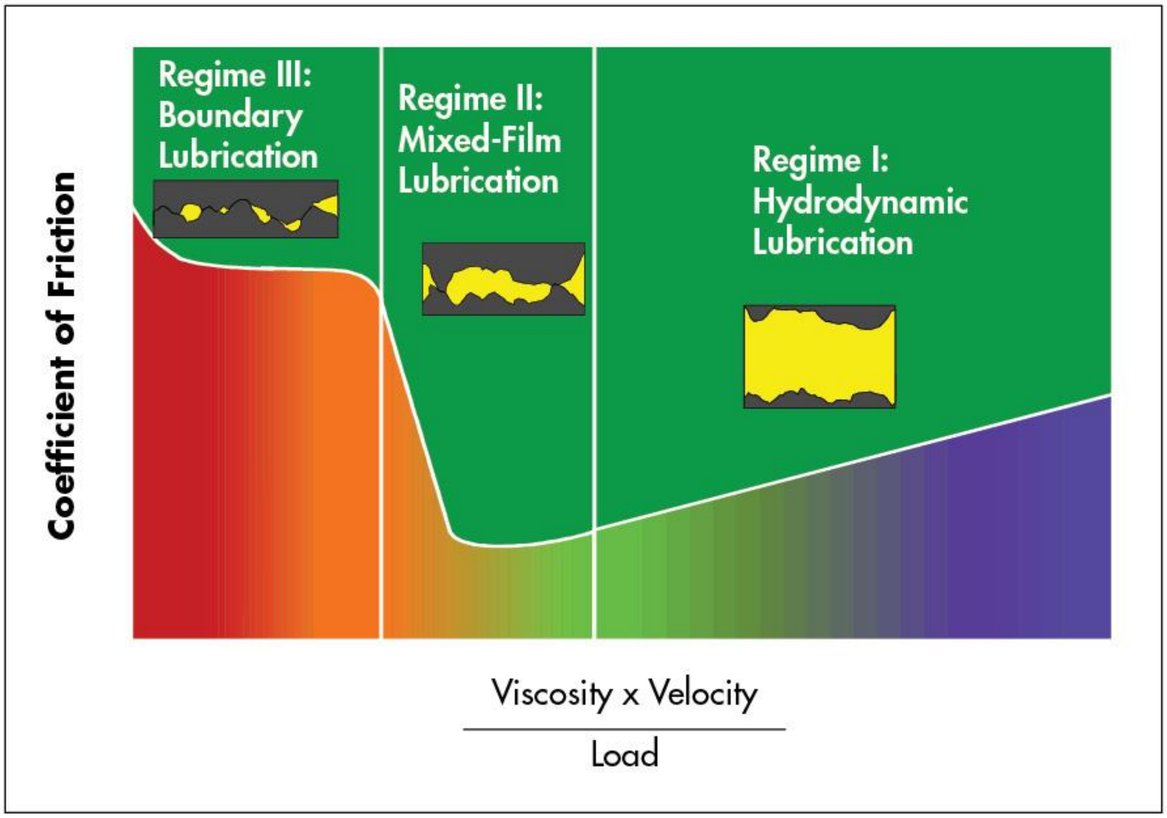
9. **Good chemical resistance** is also tough for hydrocarbon oils. For the most part have poor chemical resistance with some oils better than others. Perflouropolyether, silicones and Polyphenyl ethers are good to excellent.

10**. Cost** is an important factor. In many cases cost is "the" factor since maintaining oil quality can be prohibitive in certain processes that have atmospheres that, by their nature, degrade the oil. Hi cost oil is less likely to be replaced at regular intervals. Often a maintenance program must make compromises about oil selection based on cost and how that effects the maintenance budget. If oil quality is allowed to deteriorate the pump it is designed to protect deteriorates along with it. Select as high a quality oil as you can that meets your budget and preserves your investment in vacuum equipment. Well maintained oil promotes long pump service life and lower rebuild costs.

11. **Viscosity** is a critical characteristic of vacuum pump lubricants. In oil lubricated pumps (piston, lobe, turbomolecular and vane) and moving parts in vacuum (bearings, feedthroughs) lubricants are essential and knowing the lubricant characteristics is a necessary fundamental knowledge for lubricant selection. In a vacuum environment friction is the enemy of pump longevity and to minimize friction the moving surfaces must be kept from touching each other as they move in the vacuum environment. The "system" functions as the lubricant, the lubricated surfaces and the vacuum environment interact with one another to minimize friction and wear. The lubricant works as a barrier to prevent the moving surfaces from contacting one another. Since convection cooling does not exist in vacuum the proper choice of lubricant that prevents part contact controls heat generated from friction. Unfortunately, vacuum increases lubricant evaporation rates and tends to sort wear particle size and what particles are suspended in the lubricant which can adversely impact lubricant life.

Lubricant interaction in a system is described by three regimes. These regimes can be mathematically defined by the Stribeck Curve which identifies three characteristics of lubricant thickness. Lubricant film thickness is dependent on three factors: The load (L) forcing the two surfaces into contact, the velocity (U) of surfaces relative to one another and the absolute viscosity (η) of the lubricant. The Stribeck curve relates these factors to the coefficient of friction (μ). The two figures below graphically describe the three regimes and the factors associated with the characteristics of the regime. In Regime III: The Boundary Lubrication regime, is a combination of values of low absolute viscosity, low relative speed and high loading resulting in the tops of the irregularities of the two surfaces making contact increasing friction, heat and wear. Regime III is typical of the lubricant condition during start-up, shut down and between surfaces sliding with low surface velocity. Regime I describes the condition where high absolute viscosity, high relative speed and low loading combine to create a condition where the film thickness is substantially greater than the irregularities of the two surfaces. The surfaces ride on a lubricant wedge hydrodynamically with a full film of lubricant preventing the surfaces from contacting. The **lubricant viscosity** is the dominant factor in this regime. Regime II, Mixed Film Lubrication is the Elasto-hydrodynamic region where the lubricant is subjected to higher pressure increases effecting the viscosity and creating a condition where the lubricant behaves like a low shear solid separating the surfaces and reducing the friction. Note that this regime contains the point of minimum friction between the two surfaces.

Figure 1: Stribeck Curve Showing Three Lubrication Regimes



Source: Castrol

Figure 1. Friction relative to Lubricant Viscosity, Relative Surface Velocity and Load(pressure)

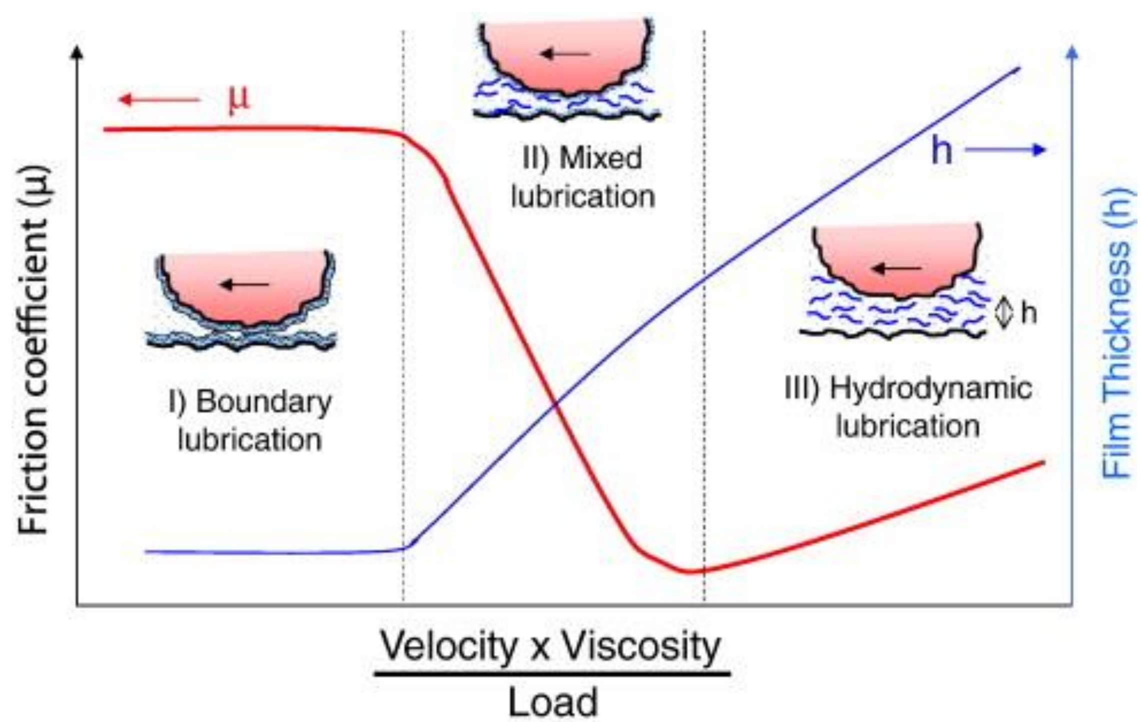


Figure 2. The Stribeck Curve (Red line) showing the relationship of friction to the three factors and indicating the relative trend of lubricant thickness (Blue Line) in each regime.

Now for the problems with viscosity. Note that the Stribeck curve identifies the least friction where the relative viscosity is the highest. So why not make the lubricant highly viscous? Well, while viscosity is your friend for reducing friction high viscosity is the enemy of lubricant movement. Imagine a refrigerated syrup consistency lubricant negotiating the small passages of bearings, oil lines and mechanical seals; all areas in critical need of lubrication.

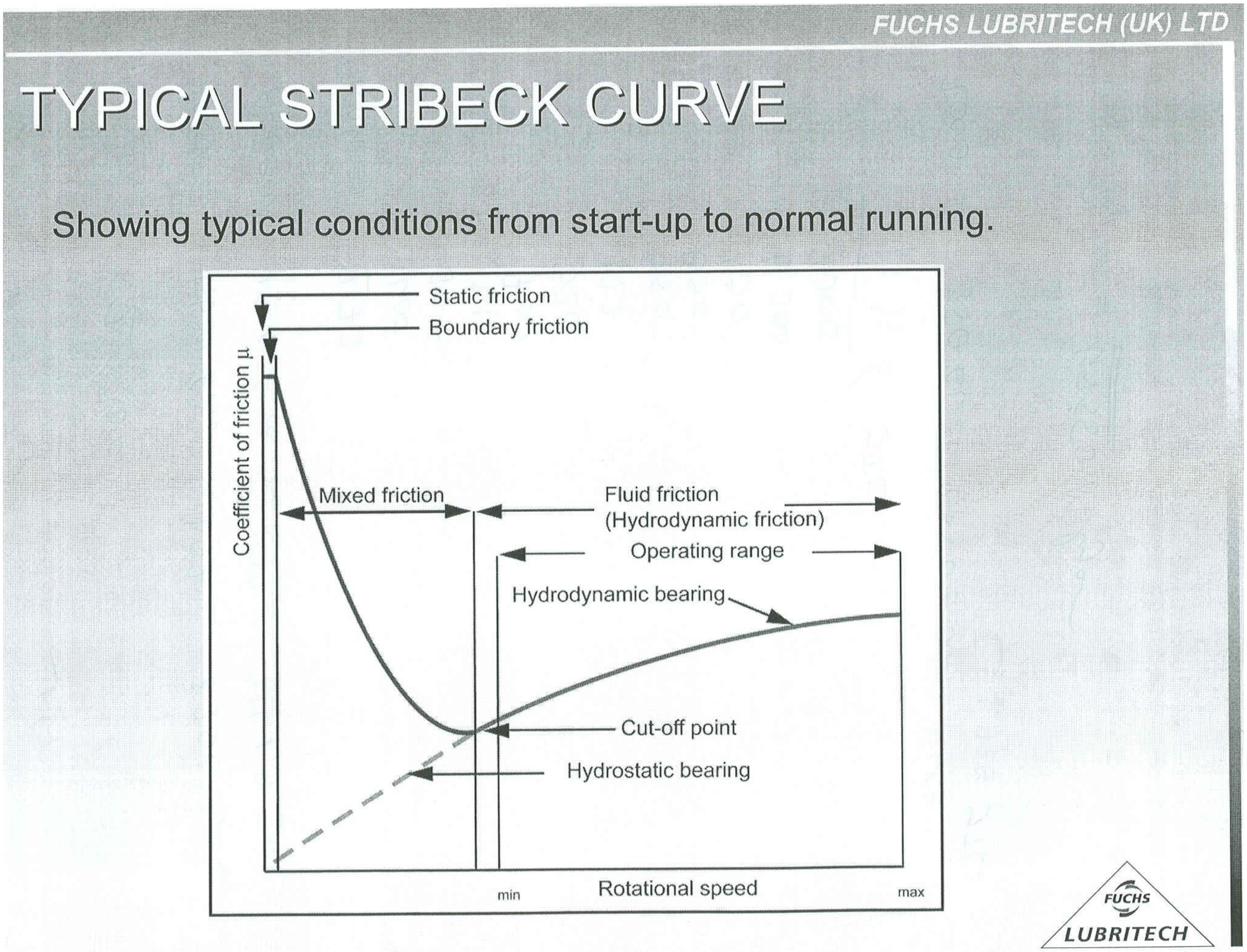


Figure 3. The Stribeck Curve and friction characteristics in the three lubricant regimes factoring in rotational

Speed from start-up to operational speed.

Additionally, gears, lip seals and mechanical seals do not function well when lubricated with higher viscosity lubricants. As an example in a mechanical blower (roots type) there are three functional areas demanding lubrication, the gears on the drive end of the blower, the bearings supporting the impellers at both ends and the lip seals or mechanical seals used to place a barrier to atmosphere. Each of these mechanical components require a specific set of characteristics in the oil that would be best suited for their function. Some of these characteristics are in common but some are not. At the end of the day the seals, being the most sensitive mechanical components, drive the selection of lubricant that must be used for the blower. It is a series of compromises rather than finding an ideal lubricant. The same can be said for Rotary Piston Pump lubricants as mentioned under Oxidation Resistance where lubricants with additives are essential but additives increase the base pressure.

So, what does all this mean and how can it help in the selection of lubricants? First off, it demonstrates that finding the perfect lubricant is an elusive process because there are competing requirements that do not perfectly fit classic or modern lubricant properties and are at the same time economical to obtain and incorporate into a preventive maintenance plan. MHV is always looking for lubricants that improve performance so we have experimented with a number of lubricants over the years and settled on, what we think, are a selection that balances the lubricant characteristics and provide good service at reasonable cost.

For mechanical pumps we recommend Super 15W40, Shell, is one brand of motor oil with great storage, start-up and good base pressure characteristics even with the rust and oxidation additives. This oil is prepped with a higher Total Acid Number (TAN) to combat acidic conditions and has a suitable viscosity. This oil is easily acquired from local distributors or MHV and costs the same as the identical oil used for your car and truck.

On Roots type blowers Kendall AW 100 or ISO VG-100 (MHV “H” oil) Hydraulic oil have been found to be the best choice that satisfies mechanical and lip seal needs as well as bearings and gear lubrication requirements. A good second choice is our MHV 77. Both oils will extend blower life if properly maintained.

Our Ring Jet Boosters like the Stokes 16 inch RJB and Diffusion Pumps use the 702 or the 704 silicone diffusion pump oil. These oils have excellent oxidation resistance, low vapor pressure so a very good base vacuum can be achieved. These great qualities come at a price but fortunately these oils can be reclaimed.

The other lessons learned from thousands of pump rebuilds is that maintaining the oil quality is essential to extending pump life. Change the oil often enough to keep it clean looking in the oil sight glasses and maintain proper oil levels. Drain the water from the exhaust drip legs and oil sumps as needed to keep these areas from accumulating excess water or sediments. And, finally support your maintenance groups so your vacuum pump oils are clean and maintained as well as your own personal vehicles.