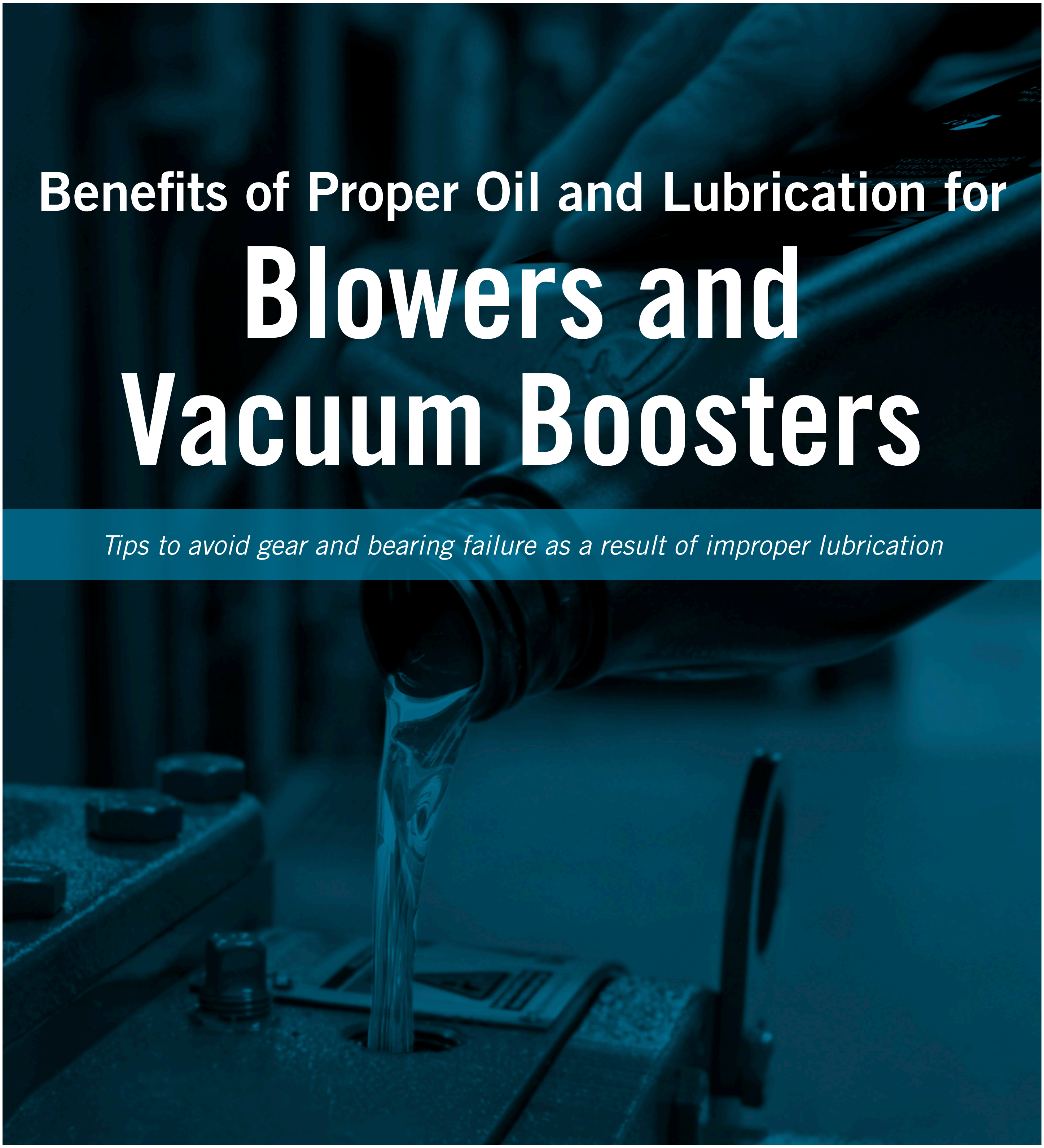
M-D Pneumatics®



Benefits of Proper Oil and Lubrication for Blowers and Vacuum Boosters

Tips to avoid gear and bearing failure as a result of improper lubrication

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You have your equipment, everything is set up and ready to run, but what about your lubricants? Too often, lubricants receive little attention with respect to their use in rotating equipment. Even the most reliable cars in the world will encounter problems on a short commute if the wrong transmission fluid is used during a flush. The same is true for your blower or vacuum booster that operates around the clock. At our Factory Service Center, experience has shown that approximately 80% of all bearing and gear failures are the result of improper lubrication (see Figure 1).

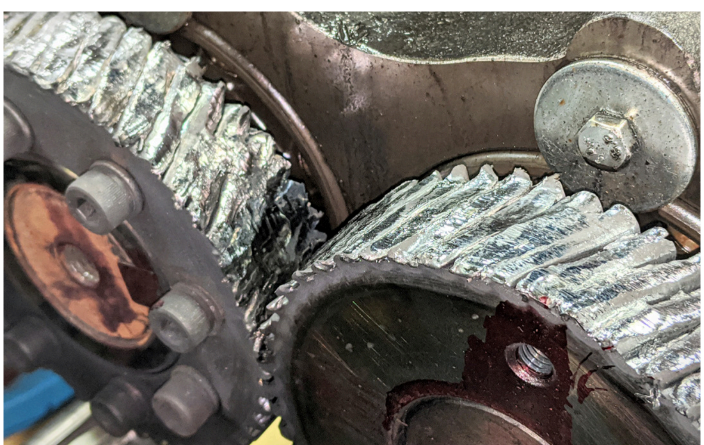

Figure 1 | Example of gear failure from improper lubrication.

Positive displacement rotary lobe blower and vacuum booster oil should be considered as important as any of the machine's other primary components. It is absolutely essential for smooth, efficient machine operation, and the correct oil will easily pay for itself in savings and convenience. In this white paper we will address the following oil topics:

- **OIL'S PURPOSE**
  What does oil really do?
- **OIL SPECIFICATIONS**
  What do they mean and are you selecting the most beneficial oil?
- **CRITICAL LUBRICATED COMPONENTS**
  Which components matter and how can you most effectively protect them?
- **OIL TEMPERATURE**
  Why does it matter and what affects it?
- **OIL DELIVERY METHOD**
  What options are available?
- **USEFUL OIL LIFE**
  What should you do to maximize oil life and how does your oil rank?

OIL'S PURPOSE

For now and the foreseeable future, bearings, gears and oil lubrication are at the heart of rotating equipment. But is correct oil specification really that critical? Isn't oil just a lubricant? It turns out, there's much more to the story.

Lubrication

Of course, the most evident function of oil is to provide lubrication at the interfaces between sliding surfaces. By introducing a thin film between moving components, such as meshing gear teeth, contact is minimized or even eliminated, and the coefficient of kinetic friction is dramatically reduced. This results in less component wear, less frictional heating, and longer asset life.

Protection

Where there is oxygen, corrosion is likely to be found. Oftentimes, copper and iron surfaces act as catalysts for corrosion at temperatures above 200°F, accelerating the corrosion process further. The key is to prevent oxygen and water from contacting corrosion-prone components with a film of oil containing the right barrier forming additives. When oil is specified incorrectly, components may not be protected properly during or between operation cycles, exposing components to corrosive damage.

M-D Pneumatics MD ONE Oil (1 quart and 1 gallon).

Cooling

Most of the heat generated by a positive displacement rotary lobe blower is the result of gas compression as it exits the discharge into a high-pressure region. Some of this heat is carried away with the gas as it is pumped, while some of it is transferred into the blower housing, ports, and end plates via conduction. Since oil can transport heat 5 to 10 times more effectively than air, the blower oil sumps are able to move a small amount of this heat from the end plate to the inside surfaces of the oil covers, and eventually into the ambient air by free convection using the oil as a transport mechanism. Most importantly, the oil transfers the heat away from dynamic contacting parts, protecting them from thermal damage.

Sealing

In applications where lip or mechanical face seals are used, oil serves both as a lubricant and sealant between rotating and stationary parts of the seal. As the oil is drawn into the space between the seal rotor and stator by a combination of capillary action and drag, it augments the seal's ability to do its job without blistering or cracking. Without proper lubrication, seals quickly fail due to the extreme temperature that develops where the rotor and stator meet.

THE MYSTERY OF SPECS

More than any other specification, operators and end-users inquire most about the ISO viscosity grade of the oil they should be using to service their equipment. In many cases, no consideration is given to any of the hundreds of other physical or chemical properties and designations of an oil. Imagine the scenario where you call every dealership in town in search of the cheapest, new vehicle with candy apple red paint. Paint color matters, but is the paint or the price really the most important thing about a vehicle? What about the number of seats, the power under the hood, the safety features, or the reliability ratings? Shopping for a vehicle based on paint and price is like shopping for oil based on ISO viscosity grade and price. ISO viscosity grade is important but it is a single line on a new car window sticker. It would be helpful to read and understand the entirety of the window sticker so you don't end up purchasing a candy apple red compact car when you needed a heavy-duty pick-up truck. Let's dive into the following important, but less understood, specifications and properties of lubricating oils:

- **API GROUP**
- **VISCOSITY**
- **VISCOSITY INDEX**
- **ADDITIVE FORMULATION**

API Group

The foundation of any oil is the base stock from which it is derived. The quality of a base stock is a measure of purity and uniformity. For example, a base stock with some long hydrocarbon chains and some short hydrocarbon chains is considered to be less pure than one almost entirely comprised of long ones. The presence of impurities such as aromatics, sulfur, and nitrogen compounds often compromises the oil's physical and chemical properties and leads to a low quality, under-performing lubricant.

MD lubricants are formulated from superior quality, full synthetic polyalphaolefin (PAO) stock. This makes their primary constituent an API (American Petroleum Institute) Group IV base stock, differentiating it categorically from the mineral oils in API Groups I through III, which are refined directly from crude oil. MD lubricants are synthesized in an ethylene oligomerization process producing ultra-high purity oligomers with minimal branching. The resulting product exhibits excellent oxidative stability, an extremely low pour point,

API BASE STOCKS										
	Derivatives	Methods	Saturates (%)		Sulfur (%)		Viscosity Index	Oxidation Stability	Volatility	Low Temp. Attributes
Group I	Mineral (crude oil)	Solvent refining	<90	and/ or	>0.03	and	80 to 120	Good	Fair	Fair
Group II	Mineral (crude oil)	"Hydroprocessing Catalytic dewaxing"	≥90	and	≤0.03		80 to 120	Good	Good	Good
Group III	Mineral (crude oil)	"Hydroprocessing Catalytic dewaxing"	≥90	and	≤0.03		≥120	Very good	Very good	Very good
Group IV	Polyalphaolefins (PAOs)	Oligomerization	-		-		125 to 200	Excellent	Excellent	Excellent
Group V	Naphthenic crude, polyglycols, alkylated aromatics, silicones, esters, polybutenes	Varies	-		-		Wide range	Excellent	Excellent	Excellent

Table 1 | API Base Stock Group Comparisons.

and a very flat viscosity curve. For the equipment operator, this means excellent resistance to breakdown at high temperatures, exceptional flow at low temperatures, and more consistent lubrication across the entire spectrum of operating temperatures (see Table 1).

Viscosity

Two viscosity values are often used to convey the thickness of a fluid: absolute (or dynamic) viscosity and kinematic viscosity. Absolute viscosity is related to the measure of the force required to move an object through the fluid and is solely a function of the fluid's internal friction. Kinematic viscosity is related to the resistance of the fluid to flow under its own weight. Since weight is directly proportional to density, the kinematic viscosity is dependent on both internal friction and fluid density. This can best be illustrated by comparing both types of viscosity for water and mercury at a given temperature. Interestingly, the absolute viscosity of water is only 64% of that for mercury, but the kinematic viscosity of water is 870% of that for mercury. This means that it takes around two thirds the force to move an object through water when compared to mercury, but mercury will flow 8.7 times faster under its own weight.

Because of the simplicity of measurement, the kinematic viscosity at 40°C (KV40) is almost always used to compare lubricating oils. This value, in units of centiStokes (cSt), is placed into one of the viscosity ranges determined by the International Organization for Standardization in ISO 3448. Each of these viscosity ranges is designated as a Viscosity Grade or ISO VG.

Viscosity Index

Personal experience tells us maple syrup flows noteably better at room temperature than straight out of the refrigerator. This is due to viscosity's dependence on temperature. MD oils fall into the range of 100 to 320 ISO VG, but the ISO VG is, quite literally, a single data point on the curve relating kinematic viscosity to temperature. Unless a given positive displacement blower always operates at 40°C, this number is somewhat meaningless without consideration of the rest of the temperature-viscosity curve.

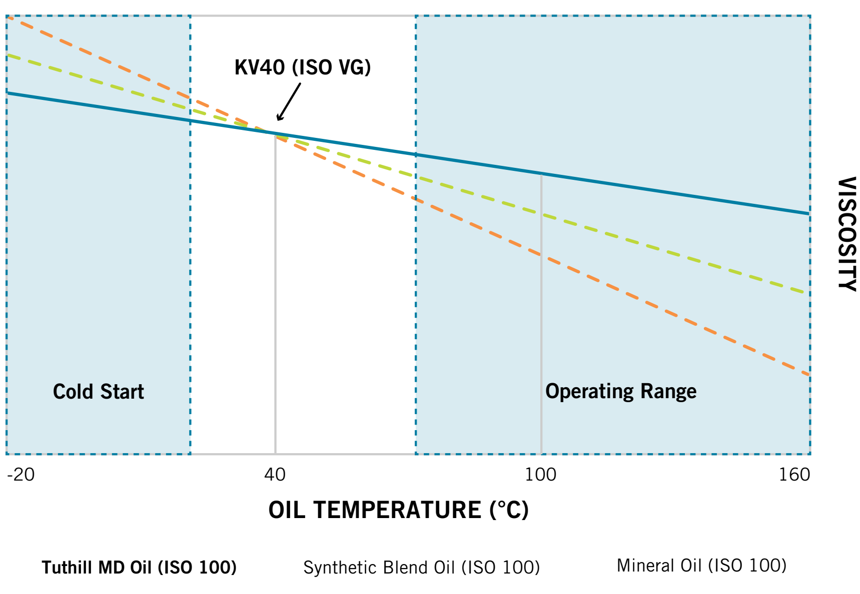

Figure 2 | VI comparison.

For example, if the oil in a particular blower generally operates at 100°C, then another fluid property, namely the viscosity index, should receive attention. This value is a characterization of the amount of dependence the viscosity has on changing temperature. A higher VI is usually desirable since this means the oil will maintain its thickness better at temperatures above 40°C and will better resist thickening at temperatures below 40°C. By their very nature, full synthetic MD oils exhibit extremely high VIs, positioning them above all mineral oils, blends, and synthetic blends.

For the operator or owner, this makes colder startups and higher running temperatures possible without sacrificing protection for critical internal components (see Figure 2).

Additives Formulation

The formulation and preparation of a lubricant additive package is similar to baking. A good baker would not add the butter to a pie crust after it was baked and expect the result to be successful. Introducing additives after the lubricant is already in use is less effective than using a lubricant that is correctly formulated from the beginning. Similarly, a good baker would never triple the amount of butter in the pie crust in an attempt to guarantee it will not stick to the pie tin. The ratio and timing of the ingredients in a good recipe is a delicate balance between flavor, chemistry, and physics. The same concepts apply to lubricant formulation.

For example, surface-active additives such as rust inhibitors and anti-wear additives must compete for space on the metal surfaces in the oil sumps. In some cases, one type of additive may work to deactivate another type. At some point, adding more of one additive or the other will become a detriment to the performance of the oil and equipment rather than an enhancement.

Figure 3 | Photo of bearing.

The goal of a highly engineered additive package is to find the optimal balance of the correct additives which target the precise needs of a given application. MD oils are formulated specifically for M-D Pneumatics™ equipment in order to achieve this balance and substitutions should not be used.

CRITICAL LUBRICATED COMPONENTS

In selecting the right oil for an application, one must consider the three primary components the oil is formulated to protect: bearings, seals, and gears. Oftentimes, the best option for one of these is not the same as the best option for the others, so a choice needs to be made for the most critical component, while also accounting for the secondary ones. Failure to use the correctly specified oil often results in higher operating temperatures, reduced performance, unexpected maintenance, and catastrophic failure. All of these affect the end-user's bottom dollar and production.

Bearings

The differential pressure, rotor weight, belt tension, and helical gear loads are all fully supported by the bearings. They have a big job to perform and must do so at full speed for months or years without failing. Additionally, roller and ball type bearings are often a considerable source of wear metals and heat. Correct oil specification is critical for protecting these key components from metal-to-metal contact, high temperatures, sludge build-up, corrosion, and chemical attack. We observe the recommendations of our bearing suppliers when specifying the optimal oil formulation by balancing various factors such as bearing type, speed, size, and loading characteristics (see Figure 3).

Seals

Seals perform a crucial function in providing a barrier between the oil in the sumps and the process gas and ambient air. Unlike bearings, which experience mostly rolling friction, lip and mechanical face seals endure perpetual sliding and the resistance and heat generation that accompany it. It is critical that the specified oil is properly suited to provide the adequate film strength and cooling capacity under load and at the operating temperature and speed. Improperly lubricated seals blister, crack, and can even leak (see Figure 4).

Figure 4 | Example of blistered seal.

Gears

Perhaps the most critical components considered when determining the proper oil for a positive displacement rotary lobe blower are the gears. Hardened, matched helical gearsets are used for their higher load capacity, longer life, ease of timing adjustment, and quieter operation (see Figure 5). This style of gear requires special consideration because of the relative sliding that occurs between meshing teeth. The oil must be equipped to handle the accelerated thermal breakdown occurring in localized hot spots which are created by the immense pressure at the points of contact. Viscosity must remain sufficient at the operating temperature in order to maintain a proper film thickness between sliding faces. Improper gear lubrication leads to abrasive and fatigue wear, loss of timing, increased wear metals, and catastrophic failure.

While many positive displacement blower manufacturers use a one size fits all approach or link their lubricant recommendations to ambient conditions outside of the oil sumps, we have taken special care to specify the proper oil for each application based on the recommendations of its bearing and seal suppliers, and the American Gear Manufacturers Association (AGMA). While the ambient air temperature has some effect on the overall temperature of the blower, gears, seals, and bearings are first and foremost concerned with what is occurring inside of the oil sumps, not outside. The oil temperature, speed, shaft diameter, gear size, and bearing type are of primary importance, and overlooking these parameters in specifying the proper oil is an oversimplification that may result in machine damage and a foreshortened operating life. Contact the a Sales Application Engineering team for assistance in determining the best MD oil for your application.

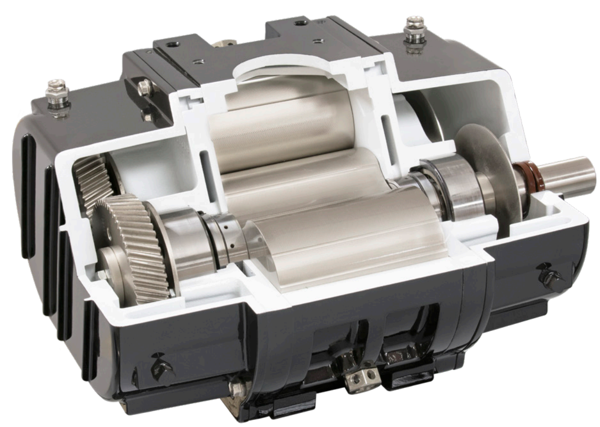

Figure 5 | Transport blower cutaway of internal components.

OIL TEMPERATURE

While blower speed, shaft diameter, gear size, and bearing type are all known with certainty after sizing a blower or booster for an application, bulk oil temperature tends to be a bit more elusive. In an existing installation, this can be measured relatively easily but it may be difficult to predict for new applications. Several factors play a role in pushing the bulk oil temperature one direction or another:

- **INLET AND DISCHARGE TEMPERATURES**
- **COOLING METHODOLOGY**
- **AMBIENT CONDITIONS**
- **BLOWER SPEED**
- **GEOMETRY AND MASS**

Inlet and Discharge Temperatures

The dominant drivers of oil temperature in positive displacement blowers are inlet and discharge gas temperature. With regards to the inlet, a cooler incoming gas produces a notable convective cooling effect. The compression of the process gas produces tremendous heat which is then transferred through the housing and end plates and into the oil sumps where it is absorbed. The discharge temperature is directly dependent on the amount of compression across the machine which is a function of shaft speed and the amount of restriction downstream. The combination of the two phenomena plays a large role in the bulk oil temperature at steady state.

Cooling Methodology

The introduction of an external cooling source drastically impacts the bulk oil temperature and is influenced by the cooling media flow rate, temperature, and thermodynamic properties. Two types of oil cooling options are offered:

- **COOLING COILS**
  Used with splash lubrication configuration, coils are submerged in the oil sumps.
- **EXTERNAL HEAT EXCHANGER**
  Used with integral lubrication configuration, oil is filtered, cooled, and then delivered via a positive displacement pump.

Ambient Conditions

Convective cooling occurs on the exterior of the machine at all times. Ambient temperature, relative humidity, and wind conditions all play a role in the amount of heat carried away via convective cooling. Colder air, higher relative humidity, and higher wind speed all work to cool the machine more effectively. Additional consideration must be given to the ambient temperature at startup. The pour point of MD oils is extremely low, allowing for easier cold startups, often without the need for preheating.

Speed

Varying the blower speed while maintaining constant differential pressure results in a change in oil temperature. This is likely due to one of two trends. The first is a consequence of the convective cooling produced by the gas flowing through the inside of the machine. Faster, more turbulent flow removes heat more effectively than slower, more laminar flow. The second trend is simply a function of friction heating in the oil. The shear rate of the oil between rubbing surfaces like gear teeth or seal faces affects the amount of frictional heat generated in the oil, and consequently the oil temperature. A higher blower speed equates to more frictional heating. These two opposing trends compete with each other so the outcome may be unique for each model and application.

Geometry and Mass

The last driver of oil temperature, and perhaps the most difficult one to predict, has to do with machine geometry, mass distribution, and thermal mass properties. The presence or absence of ribs or cooling features, surface roughness, machine shape, materials of construction, and overall bulkiness all contribute to or diminish heat transfer out of the pumping chamber and into the oil and ambient air.

OIL DELIVERY METHOD

Two types of blower and vacuum booster lubrication systems are offered:

- **SPLASH LUBRICATION**
- **INTEGRAL, OR FORCED, LUBRICATION**

Splash Lubrication

Splash lubrication utilizes the gears and an oil slinger to distribute oil by centrifuge to all critical locations inside the machine. If the blower speed is varied, the amount of oil delivered to the critical components will also vary proportionally. Submerged oil cooling coils are an important option available with splash lubricated models in high-temperature applications.

Integral Lubrication

Integral lubrication distributes the oil to key locations using an on-board positive displacement pump and an oil line distribution network. It also features an oil filter and heat exchanger (cooling coils or shell-and-tube type). For larger blowers and vacuum boosters, the oil sump volume is substantial and distributing adequate lubricant to all of the critical components using splash lubrication becomes challenging, especially in applications where the machine speed is varied to match the changing demand conditions. Forced lubrication allows for greater accuracy in delivering lubricant to critical components such as bearings, gears, and seals, even at varying speeds. For this reason, integral lubrication is recommended for large blowers and vacuum boosters, especially above the 5” gear size.

USEFUL OIL LIFE

All oils eventually wear out and lose their effectiveness over time. The rate at which this occurs can be influenced by many factors including application and operating conditions.

Temperature and Oxygen

Being comprised of a mixture of short and long hydrocarbon chains of varying purity and quality, mineral oils in API groups I through III break down much more quickly and will typically last only 25% as long as MD oils. The tendency for these molecules to interact with oxygen and form more stable compounds is relatively high and the presence of oxygen, acids, water, or other catalysts increase this rate of degradation. The byproducts of this process are organic acids, varnish deposits, and sludge buildup on the components in the oil sumps (see Figure 6).

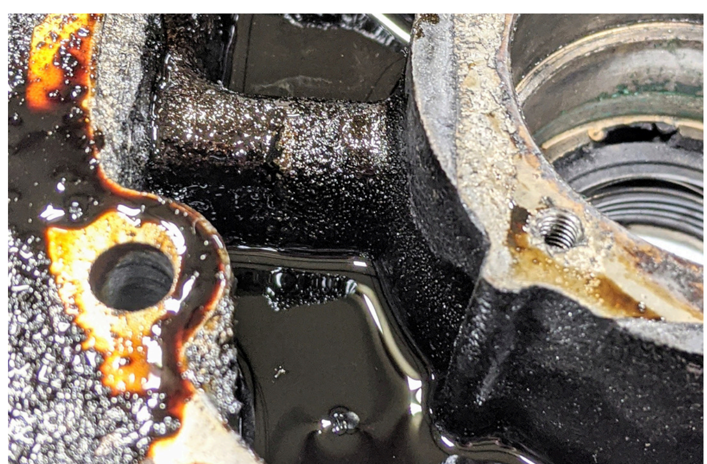

Figure 6 | Example of sludge buildup in oil sump.

Similarly, heat plays a large role by increasing the rate at which chemical reactions can occur. This rate is governed by a generally accepted rule known as the Arrhenius equation, named for the Swedish chemist Svante Arrhenius. This formula demonstrates the temperature dependence of chemical reaction rates. For mineral oils, the general rule states that the useful life of the oil halves for every 18°F above 160°F. In the oil sumps of blowers and vacuum boosters, the useful oil life of mineral oils is estimated at 1,500 hours if oil temperatures below 160°F are maintained, assuming otherwise ideal conditions. MD oils, being far superior to mineral oils and synthetic blends, can manage heat and oxygen exposure much more successfully due to the stability inherent to its high-quality base stock and advanced additive formulation. The useful life of MD oils is estimated at 8,000 hours with bulk oil temperatures of up to 220°F before the Arrhenius rule takes effect (see Figure 7).

One indication of oxidative breakdown is a change in the total acid number, or TAN. TAN represents the number of milligrams of potassium hydroxide (KOH) needed to fully neutralize 1 gram of oil to a pH of 7.0. Since no blower experiences ideal conditions, monitoring changes in the oil's TAN can be helpful for determining the end of the oil's useful life due to oxidation. It is important to emphasize that new oils may begin their life with a total acid number above zero and that the change in the TAN is important to track. It is recommended that MD oil should be changed when the TAN increases to a value of 3.0 mg KOH/g. Significant changes in TAN indicates a substantial chemical change or contamination has occurred, and the base oil and additive package have been broken down to an ineffective level.

Contamination

Contamination of any kind can prompt a notable change in the tribological, chemical, and thermodynamic properties of any oil. For example, dissolved water content of just 0.1% (1000 ppm) can reduce the bearing life by up to 80%. In some cases, the presence of water can accelerate the oxidation rate of the oil by up to 10 times, resulting in acid generation, corrosion, and additive mortality. If the water content increases beyond the temperature dependent saturation level, additional water can no longer be dissolved and will become emulsified, or suspended, in the oil. A cloudy appearance and a significant viscosity change are the results of emulsified water. MD oil's demulsifying agents work to prevent water from remaining suspended in the oil so that it can settle out on the bottom of the sump and be drained away. Ideally, the oil's condition should never be allowed to reach this point so as to maximize machine life. For this reason, it is important to maintain dry MD oil with a dissolved water content below 1000 ppm.

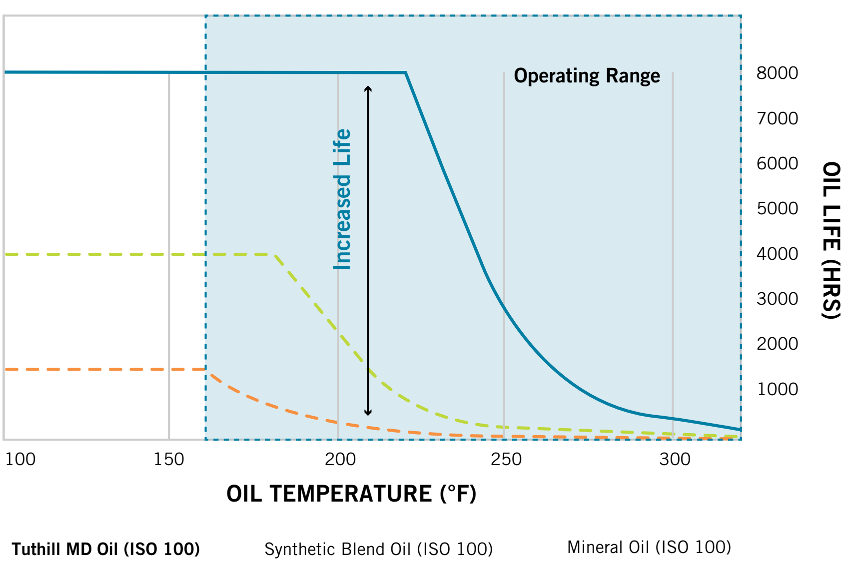

Figure 7 | Lubricant life comparison.

Other contamination, such as that from the process gases or from wear metals, can also pose a significant threat to the critical components of the machine. If this type of contamination is unavoidable and significant, a magnetic drain plug (standard on all M-D Pneumatics blowers and vacuum boosters) and an on-board or stand-alone oil filtration system should be considered. The International Organization for Standardization provides guidelines for fluid cleanliness in ISO 4406:99 by setting targets for the maximum number of particles per mL in the size ranges of 4 µm or larger, 6 µm or larger, and 14 µm or larger (see Table 2).

CLEANLINESS TARGET RECOMMENDATIONS		
	ISO 4406:99 Cleanliness Code	Recommended Filter Rating (µm)
Gears	17/15/12	10
Ball Bearings	15/13/10	3
Roller Bearings	16/14/11	5
Mechanical Face Seals	19/17/12	15-20

Table 2 | Cleanliness target recommendations.

The target fluid cleanliness rating for oil used to lubricate gears is 17/15/12. This means that it should contain fewer than or equal to 1,300 particles per mL (code 17) larger than 4 µm, fewer than or equal to 320 particles per mL (code 15) larger than 6 µm, and fewer than or equal to 40 particles per mL (code 12) larger than 14 µm (See Table 3). Table 4 shows another example particle count for a used oil sample with an ISO rating of 18/15/12.

Additional cleanliness targets relevant to M-D Pneumatics blowers and vacuum boosters are shown in Table 2. It is important to note that these are recommended targets and are subject to the risk tolerance of the asset owner.

NUMBER OF PARTICLES/ML		
Lower Limit	Upper Limit	ISO Code
80,000	160,000	24
40,000	80,000	23
20,000	40,000	22
10,000	20,000	21
5,000	10,000	20
2,500	5,000	19
1,300	2,500	18
640	1,300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8

Table 3 | ISO cleanliness codes.

PARTICLE COUNT		
"Size in Microns (µm)"	Number of Particles Larger than Size (per mL)	ISO Code
4	1422	18
6	284	15
10	108	
14	31	12
20	8	
50	2.1	
75	0.15	
100	0.03	

Table 4 | Sample particle count.

Oil Sampling Program

Given the uniqueness of each real-life scenario, it is impossible to accurately predict oil life without firsthand application experience. The oil may become contaminated or wet long before it has reached an unacceptable level of oxidation. It may become diluted with condensable process fumes and lose its viscosity long before it becomes contaminated with particulates or wear metals. Therefore, a regular oil monitoring or sampling program is always recommended to stay ahead of changes in the oil's condition so problems can be addressed before they lead to catastrophic failure and expensive downtime. Oil sample lab analysis is a new service offered to our blower and vacuum booster owners.
This tool can be used to implement a proper preventative maintenance schedule so machines can be proactively serviced at a convenient time.

Every blower and booster order includes MD Oil for startup.

CONCLUDING THOUGHTS

› OIL'S PURPOSE

Oil has an essential job to perform and is multi-functional as a lubricant, protectant, sealant, and coolant.

› OIL SPECIFICATIONS

Some oil specifications are misunderstood or misapplied while others are often overlooked. API group, viscosity, viscosity index, and additive formulation are all specifications to be taken into consideration.

› CRITICAL LUBRICATED COMPONENTS

Proper lubrication for gears, bearings, and seals is critical. Without it, their useful life will be reduced significantly.

› OIL TEMPERATURE

Bulk temperature affects lubricant performance and life, and there is a complex relationship with operating conditions.

› OIL DELIVERY METHOD

Splash lubrication or integral lubrication: one may be better suited than the other, depending on operating conditions and machine size.

› USEFUL OIL LIFE

Lubricant life can be cut short by elevated temperatures, oxidation, moisture, contamination, and other factors. What steps are you taking to maximize lubricant life and protect your equipment?

NOT ALL LUBRICANTS ARE CREATED EQUAL

As you can see, oil is a lot more than just a lubricant. It is crucial to understand the unique role of base oil type, temperature, oxygen exposure, contamination, and water with respect to oil life and the establishment of a proper service interval. With the right oil and proper monitoring, equipment service costs can be predictable and minimal, reducing risk, and saving time and money. Genuine MD oil is specifically engineered to lubricate, protect, cool, and seal. Its proprietary full synthetic PAO formulation is tailored to the precise needs of the bearings, seals, and gears used in M-D Pneumatics equipment and substitution is not recommended. Since MD oils are fully compatible with the lubricants in API groups I through III (mineral oils and blends), no special flushing procedure is necessary to switch.

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