IMPROVE RELIABILITY AND REDUCE MAINTENANCE COSTS IN ROTARY SCREW AIR COMPRESSORS

The Secret To Controlling Oil Degradation

Fluid Metrics

The #1 factor affecting rotary screw air compressor reliability, maintenance frequency and cost is its oil. These specially formulated compressor "oils" (aka lubricants, coolants, or fluids) are directly and indirectly responsible for most routine compressor maintenance and repairs. Users who ignore their oil's condition and performance, and simply replace it at predetermined intervals, are putting their compressors, their maintenance budget, and the environment in jeopardy.

Due to the severity of the application, most compressor oils in use today are synthetics. These synthetic oils are expensive, time-consuming, and environmentally unfriendly to replace, and the oil type, in-service condition and performance impact every component the oil touches. Compressor oils must circulate throughout the compressor in order to perform a variety of vital functions. But while doing so, they also distribute harmful acids and solid contaminants to critical bearings, coolers, separators, and more. When the oil is not properly maintained (oil replacement is not maintenance), it becomes the primary vehicle for wear, corrosion, and fouling - the root causes of most compressor maintenance and repairs.

Compressor oils are not your typical lubricants. Often referred to as the "lifeblood" of rotary screw air compressors, these oils are advanced, specially formulated fluids that must perform under one of the most extreme oxygen and contaminant-rich operating environments imaginable. These fluids must not only be able to lubricate bearings and gears, cool the compressor, and seal rotor clearances (the easy parts), more importantly they must also resist oxidation, producing acids, forming varnish and deposits, all while protecting vital compressor internals from a highly corrosive environment.

Compressor oil formulation, performance, and service life are critical factors impacting rotary screw compressor reliability and maintenance costs. The better and longer the oil is able to perform and protect compressor internals, the greater the compressor's reliability, and the less maintenance, repairs, downtime and expenses.

WHAT IS OIL DEGRADATION?

Oil Degradation – The Nemesis of Oil Injected Rotary Screw Air Compressors

Unfortunately, compressor oil quality, performance, and service life begin to deteriorate or degrade the moment the oil is put into service. Oil degradation is an ongoing destructive process that is the driving factor for most routine "preventative" compressor maintenance. But what exactly is oil degradation, and more importantly, what are the causes, and what can users do to prevent and control it?

CAUSES OF OIL DEGRADATION

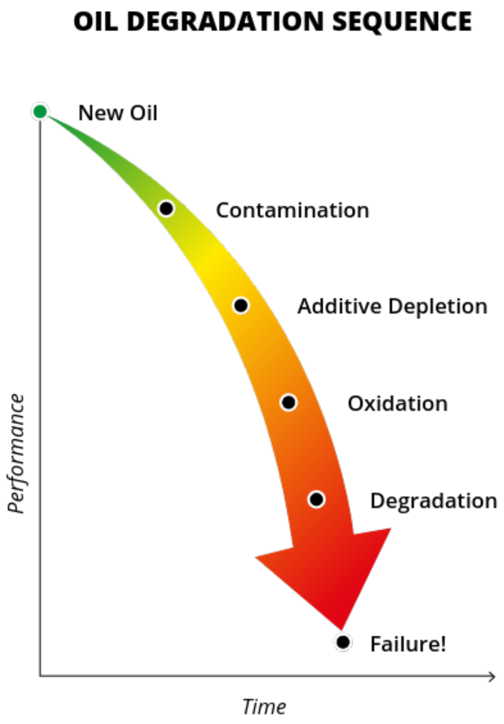
Oil Degradation Mechanisms

The root causes of oil degradation are well known. However, if ignored, the oil degradation process will quickly spiral out of control, the oil will ultimately fail causing damage to the compressor and resulting in costly repairs and extended downtime.

At some point in time, all compressor oils will eventually degrade and fail, but the rate of degradation and and frequency of oil changes varies greatly depending on many factors. The most significant of these include the oil's formulation (base stocks and additives), the compressor's operating temperature and environment (air quality), and the user's maintenance practices. For a better understanding of oil degradation, its causes, effects, and ways compressor users can control it, it is helpful to break it down into a sequence of interrelated steps. These steps occur simultaneously and consecutively, effecting the oil and its additives one molecule at a time, with each step getting progressively worse.

Step 1: Contamination

The process of oil degradation begins with contamination. Uncontaminated compressor oils do not degrade, "wear out," or ever need to be replaced. For example, rotary screw compressors handling inert nitrogen never need an oil change. However, once the oil is exposed to air containing oxygen and other destructive contaminants, the degradation process begins. And once it starts the only question becomes how long can the oil remain in service before needing to be replaced, or doing harm to the compressor.



Unfortunately, rotary screw air compressors oils are continuously exposed to air. By design these compressors are excellent vacuums and scrubbers of atmospheric air, continuously ingesting high volumes of contaminant-rich air that contains harmful oxygen, water vapor, pollution, acid gases, chemical vapors, particulates, and countless other contaminants. The compressor then forces these contaminants directly into the oil, adding heat (another oil-killing contaminant), and thoroughly mixes everything under pressure, just like a chemical reactor.

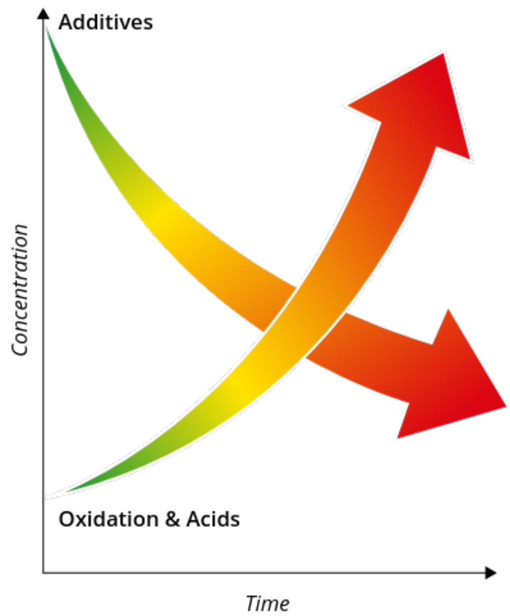
Once in the oil, these contaminants function as both reactants and catalysts that initiate and accelerate a destructive series of chemical reactions. These reactions alter the oil's molecular structure, produce acidic by products, and consume the oil's protective additives, impeding its ability to perform and dramatically reducing its useful life.

Step 2: Additive Depletion

To improve oil performance and service life, oil formulators must rely on special additives to combat these reactions. Special chemical additives are added to the oil in varying amounts depending on the type of base stocks used, their inherent performance weaknesses, and the targeted service life the oil formulator wants to achieve. While these chemicals are typically added sparingly (< 5% by volume), they are expensive and contribute to the high cost of these oils. Generally speaking, up to a point of diminishing returns, the higher the dosage of additives, the better the oil's performance and protection, and the longer its useful life. However, most compressor oil formulators will scrimp on the additives used in their products to cut costs, limit the oil's service life, and help drive replacement new oil sales.

The most important additives used in rotary screw compressor oils are the oxidation and corrosion inhibitors needed to help the oil withstand its extreme oxidative environment. Unfortunately, these additives are sacrificial and continuously deplete in service. As these additive levels decline, so does their ability to protect the oil and compressor internals. As a result, as additives deplete the rate of oil degradation, acid production, internal corrosion, and wear will all increase.

ADDITIVE DEPLETION VS. OXIDATION & ACIDS (TAN)



The rate of oil degradation and additive depletion will vary tremendously depending on several controllable factors.

Specific contaminants like water, acids, and ultra-fine metal particles (present in all compressor oils), act as catalysts that accelerate additive depletion. Likewise, elevated oil temperature is a major accelerant of the chemical reactions that drive additive depletion and oil degradation. The rate of these reactions doubles every 18 deg. F increase in oil temperature. In other words, a compressor oil that operates at 198 deg. F will only reach half the service life of an oil operating at 180 deg. F in the same environment. Given the devastating effects heat, contaminants and water have on oil degradation and additive depletion, you will often hear lubrication engineers preach the benefits of maintaining your oil as “Cool, Clean & Dry” as possible – the first commandment of oil maintenance.

Step 3: Oxidation

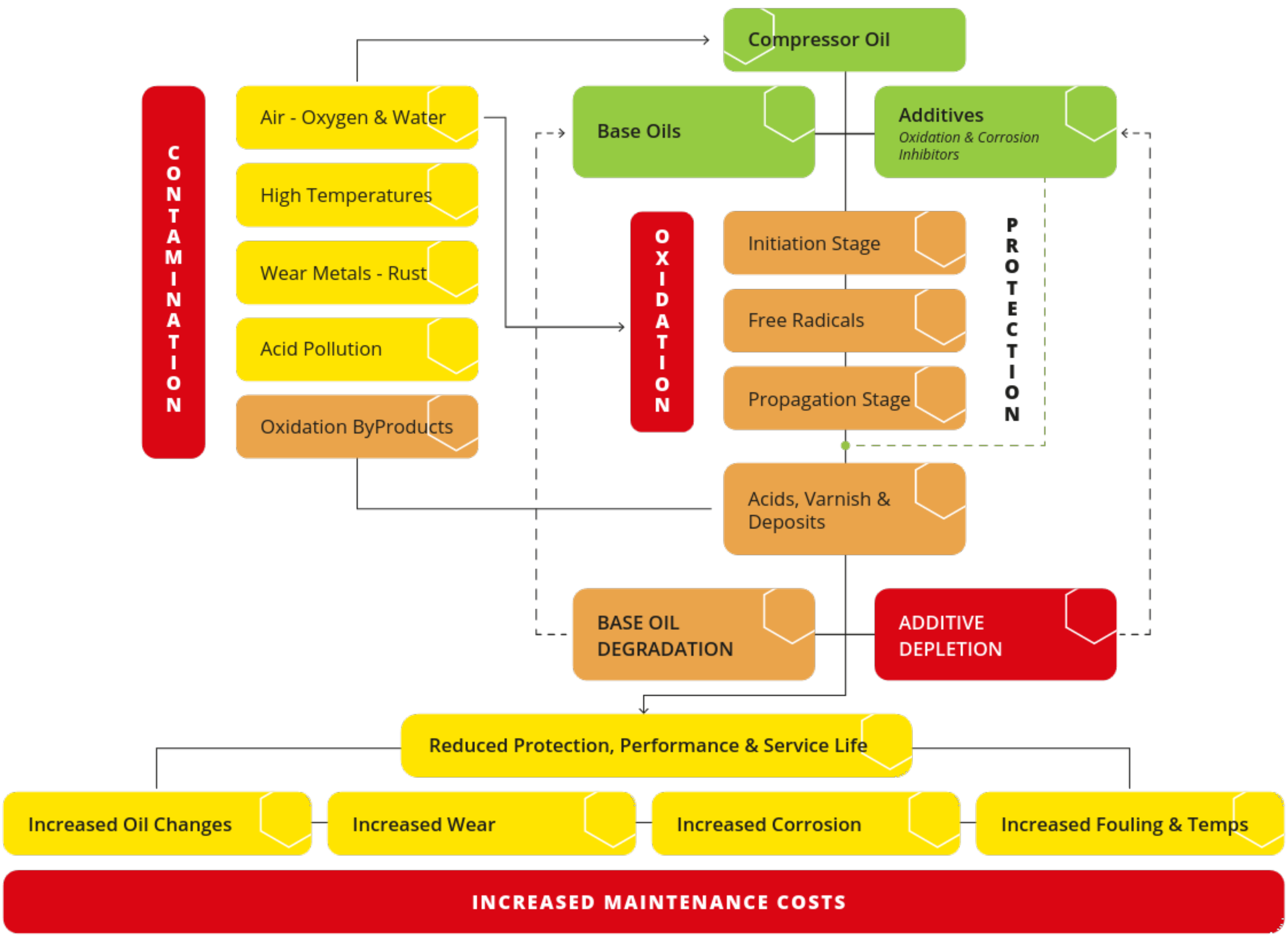
The more oil becomes contaminated and its protective additives depleted, the more it becomes vulnerable to attack by a series of chemical reactions. The most prevalent of these, and the major challenge for oil formulators and compressor users alike, is oxidation.

Oxidation is a complex chemical reaction between oxygen from the air and the oil and its additives. It is also where the real damage to the oil's physical and chemical properties occurs. Everyday examples of oxidation's destructive nature include combustion and carbon residue, corrosion and rust, rotting fruit, decaying flesh, and a bottle of wine becoming acidic after exposure to air.

Oxidation of rotary screw compressor oils and acids go hand-in-hand. The oxidation reaction is "autocatalytic," meaning that once acids are produced, they become a catalyst that speeds up the reaction to produce more and more acids and consume additives at an ever-increasing rate. Like a runaway freight train heading downhill, oxidation continuously gathers speed, and if ignored, inevitably leads to catastrophic failure.

Most acids found in compressor oils are the byproduct of oxidation and are relatively weak by nature (pH > 5.0). However, airborne "acid-gases," commonly found in pollution and industrial environments, are routinely ingested by air compressors and are typically much stronger and more destructive. Both weak and strong acids will accumulate in the oil and act as catalysts to accelerate oxidation, additive depletion, oil degradation, and corrosion. The following diagram shows the stages of oil oxidation:

OIL OXIDATION - DEGRADATION



Step 4: Degradation

In addition to producing acids and adverse physical and chemical changes to the oil, oxidation can lead to other harmful reactions. Polycondensation, hydrolysis, and polymerization can also occur with some base stocks, including mineral oils, diesters, synthetic hydrocarbons (SHCs), and polyalphaolefins (PAOs).

Polymerization is known to cause sharp increases in the oil's viscosity and produce undesired insoluble solids, sludge and varnish. Higher viscosities combined with insoluble solids and varnish restricts oil flow, fouls coolers, and reduces heat transfer causing the compressor to run hot. These higher temperatures accelerate the oil degradation process, which further inhibits heat transfer and causes temperatures to steadily climb.

Step 5: Failure

As the destructive sequence of contamination, additive depletion, oxidation, and degradation steadily progresses, the oil's ability to lubricate, cool, clean, and protect compressor internals steadily deteriorates. Once the oil's protective additives become critically low, and acids and other catalytic contaminants accumulate, the oil will become "brittle" and can rapidly fail.

An oil's specific failure mode will vary depending on the type of base stocks used in its formulation. Some oil base stocks, like the SHCs and PAOs frequently used by many compressor OEMs, will see their viscosity spike upwards as they polymerize into a sticky, semi-solid varnish. If left undetected, varnish will completely lock down a compressor's air end requiring expensive repairs, chemical cleaning, and extended downtime. Varnish is a rotary screw air compressor's worst nightmare. Fortunately, varnish can be easily prevented using base stocks with "varnish-free" chemistries, like the PAG/POE (polyalkylene glycol / polyol ester) synthetic fluids readily available today.

So "how long" should a new compressor oil be expected to perform and protect before it becomes too degraded and ultimately fails? The answer is that no one knows. Too many variables impact oil degradation and failure rates, chief among them are the oil's base stock, additive package, compressor inlet air quality / contaminant loading, operating temperature, and the user's maintenance practices. These variables make "time" or "operating hours" an unreliable indicator of an oil's actual condition or predictor of its useful life, and should never be used to determine a compressor's oil change interval.

Fluid Metrics

OIL DEGRADATION CONTROL STRATEGIES

Controlling oil degradation and its impact on compressor reliability and maintenance costs requires a multifaceted proactive strategy. The good news is that advanced lubricant chemistries, contaminant control methods, and fluid conditioning technologies, unavailable 50+ years ago when rotary screw compressors were introduced, make this task easier than ever.

1) Proper Oil Selection

The first step in controlling compressor oil degradation and optimizing oil performance and service life is selecting the correct type of oil for the application. Air compressor manufacturers typically fill their new compressors with a standard “factory fill” oil. The problem is that not all oil types are suitable for all compressor operating conditions or environments. For instance, polyglycol (PAG) based oils are better suited for hot, humid environments with high operating temperatures and continuous duty applications. While less expensive mineral oils, SHCs, and PAOs may be a better choice for cooler dryer environments, intermittent duties, or as a “throw-away” oil for environments with acid-gas ingestion problems.

Fortunately, oil formulation and additive technologies have evolved dramatically over recent decades, giving today's users much more advanced, extended-life "performance-grade" oils to choose from. Performance oils utilize premium synthetic base stocks and a more robust additive system designed to deliver superior performance, maximum protection, and service life. Unlike OEM's compressor oils that are purposely formulated to be regularly replaced, performance oils are formulated for maximum protection and service life. When combined with condition-based oil changes, performance-grade compressor fluids are proven to:

- ***Eliminate routine time-based oil changes***
- ***Minimize oil consumption***
- ***Reduce maintenance costs***
- ***Reduce waste oil / environmental impact***

2) Oil Analysis and Condition-Based Oil Changes

Traditional preventative or "time-based" oil replacement, first instituted over half a century ago, is outdated, misguided, and proven to be unnecessarily expensive and environmentally unfriendly. By contrast, "condition-based" oil replacement using oil analysis as a guide is the only reliable method for determining when a compressor oil needs to be replaced.

Like a blood test for your compressor, oil analysis quantifies the oil's physical and chemical properties and eliminates the guesswork on the oil's actual in-service condition. Oil analysis also provides compressor users valuable information concerning component wear and corrosion, as well as the oil's contaminant and protective additive levels. When used regularly, oil analysis will alert users to pending problems with the oil and/or compressor, enabling them to take corrective action and avoid costly failures and downtime.

The benefits of routine oil analysis for rotating equipment used in critical applications are many and cannot be overstated. Routine oil analysis is one of the most effective, predictive, and "reliability-centered" maintenance tools available. When used in combination, oil analysis and condition-based oil changes enable compressor users to:

- ***Detect & prevent hidden problems before they occur***
- ***Increase oil service life & optimize change intervals***
- ***Reduce oil & parts consumption***
- ***Improve component life & equipment reliability***
- ***Reduce equipment downtime***
- ***Reduce maintenance costs***
- ***Reduce waste oil disposal & environmental impact***

While oil analysis is valuable for most rotating equipment, it is an absolute must for oil-injected rotary screw air compressors. Unlike a centrifugal air compressor, the rotary screw's unique "forced-contamination" design makes its oil extremely vulnerable to the compressor's environment and operating conditions.

Consider for example, the real-life scenario of two identical rotary screw air compressors using the same type of oil and operating side-by-side in the same facility. One compressor's oil analysis indicated that its oil had turned acidic (the leading cause of compressor oil replacement) and needed to be replaced after only 2,000 hours in service. Meanwhile, many years later, the adjacent compressor's oil analysis showed that all of its oil properties were perfectly normal and fit for continued use after more than 60,000 hours in service! Why the 30-fold difference in oil life, oil consumption and waste oil disposal? Two simple explanations – inlet air quality and compressor maintenance practices. The compressor with the short oil life was close to a cooling tower (ingesting water treatment chemicals) and did not utilize any contaminant control or fluid conditioning measures. In contrast, the compressor with the 60,000-hour oil ingested much cleaner, drier air and was the beneficiary of today's best available contaminant control and fluid conditioning technologies.

3) Contaminant Control

Given that contaminants both initiate and accelerate oxidation, oil degradation, wear, corrosion, and fouling, controlling oil contaminants should be a top priority for all compressor users. And since contaminants come in all forms (solid, liquid, and gas) and originate both externally from the atmosphere and internally as byproducts of oxidation, wear, and corrosion, a multi-prong control strategy is warranted.

A. External Contaminants – Compressor Environment & Inlet Filtration

The first and best step in controlling external contaminants is eliminating them at the source. Rotary screw air compressors should be located, or a remote inlet air filter installed where they ingest the cleanest, driest, and coolest air possible. Specific care should be taken to locate compressors as far away from equipment and areas listed below, as these are just a few of the more common sources of "acid-gas" contaminants:

- *Cooling towers*
- *Water softeners*
- *Boilers*
- *Thermal Oxidizers*
- *Smelters*
- *Busy highways*
- *Chemical storage areas*
- *Kilns*
- *Welding areas*
- *Maintenance shops*
- *Parts cleaners*
- *Paint booths*

The second step in controlling external contaminants is to ensure the compressor's inlet air filter is doing its job by inspecting it regularly and replacing it as needed based on pressure drop. Most compressor inlet filters are only rated to prevent solids 10 microns (nominal) and larger but do nothing to stop smaller "ultra-fine" solids, acid gases, or other harmful vapors from entering the compressor. These contaminants must be removed after the fact once they've been scrubbed out of the air stream by the oil.

B. Internal Contaminants - Compressor Oil Purification

Even in the most pristine environments absent airborne particulates or acid gases, "clean air" still contains highly reactive oxygen and water vapor which are problematic for any oil. Once the "clean air" comes in contact with the oil inside the compressor, it will begin to oxidize the oil and produce rust inducing acids. These internally generated acids, ultra-fine rust particles, and wear metals gradually accumulate inside the compressor to accelerate oil degradation and take their toll on compressor internals. Like the compressor's inlet air filters, its oil filters are typically rated for 10 microns (nominal) and do nothing to remove the liquid acids or the most destructive ultra-fine "clearance-size" solids from the oil.

To remove both ultra-fine solid and liquid contaminants, a combination of technologies is needed. Answering the call, **Compressor Oil Purifiers** (COPs) specifically designed and developed for rotary screw air compressors, provide the ideal solution. The COP is a simple filter-like device that combines **ion Exchange acid adsorption** with **Ultra-Fine Filtration** to continuously remove harmful acids and ultra-fine solids from compressor oils. The ion exchange technology used in the COP has been extensively tested by the world's leading producer of synthetic air compressor fluids, and is proven to be "extremely effective at removing acids and extending the service life of synthetic compressor lubricants." This finding led them to "fully endorse" ion exchange technology for the purification of rotary screw air compressor lubricants.

Almost two decades later, countless **Compressor Oil Purifiers** with **ion exchange technology** have been installed worldwide on rotary screw air compressors. COP users' oil analysis results and maintenance records confirm their COPs deliver a dramatic increase in oil life and separator life, accompanied by reduced maintenance, downtime, oil and parts consumption, and waste oil disposal.

4) Additive Replenishment

It is well known that an oil's oxidation resistance, protection ability, and useful life are vastly improved by the essential additives used in its formulation. It's also well known that oil additive levels naturally deplete during service when exposed to air, heat, and other contaminants. Therefore, it only stands to reason that maintaining an oil's additives at or near its new oil level will positively impact the oil and the compressor it protects. Fortunately, preblended additive concentrates are available today for use with performance-grade oils. Periodically added to compressor oils in place of make-up oil, these additive concentrates are proven to:

- ***Increase Oxidation Resistance***
- ***Neutralize Acids***
- ***Increase Corrosion Protection***
- ***Extend Oil Service Life***
- ***Reduce Oil Consumption***
- ***Reduce Waste Oil Disposal***

SUMMARY & CONCLUSION

Rotary screw air compressor oils are the most critical and yet the most vulnerable component of the compressor. Compressor oils should be viewed and maintained as the valuable asset they are, and not neglected, ignored or treated like a consumable that should be regularly replaced, repurchased, and hauled off for disposal.

Fortunately, today's advanced contaminant control and fluid conditioning technologies provide compressor users with a wealth of proactive, predictive, and reliability-centered maintenance tools that make maintaining their oil and compressor easier and more effective than ever. By combining extended-life performance-grade oils with compressor oil purifiers, additive concentrates, and routine oil analysis, users can easily control oil degradation, contamination, and the root causes responsible for most compressor maintenance and repairs.