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Synthetic Base Stocks Provide Benefits for Air Compressor Lubricants

Since the early days of hand- and foot-driven bellows, compressed air has been extensively used to drive chemical processes or provide motive power and pneumatic control. Like electricity and water, compressed air is now an essential utility at most manufacturing plants, and any interruption to the air supply can result in reduced manufacturing output and/or expensive downtime.

Correct lubrication of the air compressor helps to ensure the continuous reliability, efficiency and safety of the equipment. Steps for successful lubrication include:
- Evaluating the application
- Using the correct lubricant
- Incorporating good lubrication practices

Application Evaluation: Air Compressors

From a lubrication standpoint, air compressors are one of the most difficult challenges. The compression process creates high temperatures and the oil, either in thin film or small droplets, intimately mixes with hot air. This mixture creates severe oxidation conditions, promoting rapid degradation of the oil.

In these severe operating conditions, synthetic base stocks are widely recognised for their range of potential benefits when used to formulate air compressor lubricants (Figure 1).

Air compressor types

It is possible to compare mineral oils and synthetic base oils for different air compressors:
- Reciprocating piston compressors
- Rotary air compressors

Reciprocating piston compressors

These compressors have been used for many years, especially where high pressures are required. The valves on these compressors, typically spring-loaded plate valves, are one of the weak points in their design and require regular maintenance. As they operate on every stroke of the machine, they are constantly opening and closing. Valve lift is therefore kept low to reduce impact forces and extend fatigue life.

With oil-lubricated machines, the high-temperature discharge air contains oil carried over from the cylinder and piston ring lubrication. This hot oil coats the valves, and the continuous exposure to hot air causes a buildup of carbon deposits on the valve as the oil oxidises. With low valve lift and small clearance, deposits can cause valves to leak, pulling some of the hot compressed air back into the cylinder on the suction stroke.

The deposits therefore reduce volumetric efficiency, increase cylinder temperatures and cause the formation of more deposits. The deposits can also cause valve plate wear and breakage, requiring regular valve removal, dismantling and inspection.

Figure 1
Benefits of Synthetic Base Stocks in Air Compressor Lubricants

- Higher thermal and oxidative stability
  - Helps resist lubricant degradation and extend oil life
  - Can reduce equipment downtime and maintenance costs
  - May reduce oil disposal costs
- Higher Viscosity Indices (VI) and lower pour points
  - Increase the range of operating temperatures
  - Help maintain oil film thickness at high temperatures
  - Improve cold start capability
  - Reduce cold churn and energy losses
  - Provide potential to remove sump heaters and related costs
- Potential for energy savings
  - Through use of lower traction fluids
  - From reduced churning losses when operating at low temperatures
- Enhanced wear protection
  - From high VI fluids increasing viscosity at high temperatures
  - From fluids offering good film strength or lubricity
  - Through rapid circulation on cold startup
- Improved cleanliness
  - Reduced oxidation
  - Reduced filter plugging
  - Reduced valve maintenance and compressor downtime
  - Reduced deposit buildup (particularly with esters)
- Enhanced safety
  - Use of products with higher flash points
  - Lower volatility reduces oil carryover into discharge pipework
  - Low carbon-forming tendencies can reduce deposit formation

Synthetic compressor oils based on esters, however, provide proven performance in reciprocating compressors despite potential problems with hydrolysis (see the discussion on water condensation). The beneficial features of esters are:

- Very good thermal and oxidative stability with a low tendency to form deposits
- Highly polar with good solvency, helping to keep valve surfaces clean

Rotary air compressors

Although the traditional reciprocating piston compressors are still popular, rotary air compressors, such as vane or screw compressors are increasingly used to supply air due to their simpler design and reduced maintenance requirements [1]. Oil-flooded screw and vane compressors, however, probably provide the most severe operating conditions for any compressor lubricant. The rotors ensure that the oil and air are intimately mixed under high pressure and temperatures. The oil is supposed to carry away much of the heat of the compression.

In these rotary machines, mineral oils typically have an oil service life of 1,000 to 2,000 hours. The use of fully synthetic oils can extend oil life up to 8,000 hours or more.

Correct Lubricant: Composition of Synthetic Oils

Polyalphaolefins (PAOs) are commonly used in fully synthetic oils, combining good thermal and oxidative stability with good water resistance. Typically, PAO formulations use a solvent co-base stock, such as an ester or alkylated naphthalene (AN), to improve additive solvency and seal capability. Additional performance improvements may be had in selecting alkylated naphthalene over an ester.

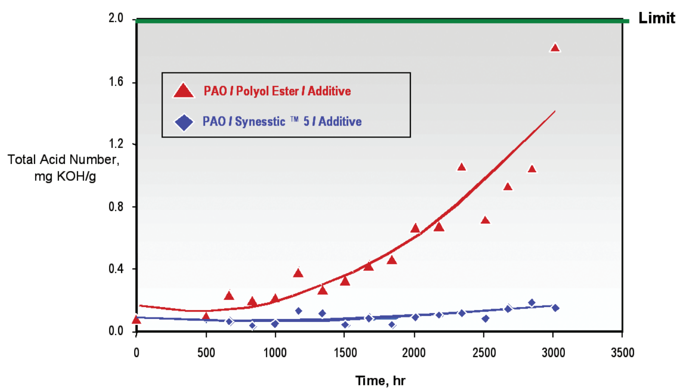
Esters versus alkylated naphthalenes: Hydrolytic stability

Like esters, alkylated naphthalenes have very good thermal and oxidative stability but in contrast to most esters, they are unaffected by water. The hydrolytic stability of lubricants made with these base oils is greatly improved.

Esters versus alkylated naphthalenes: Reduced acidity

Figure 2 shows the reduced acidity when replacing an ester with an equal amount of alkylated naphthalene in a PAO-based

Figure 2
Turbine Oil Stability Test (TOST) ASTM D 943 for an ISO VG 46 Air Compressor oil *(ExxonMobil data)*

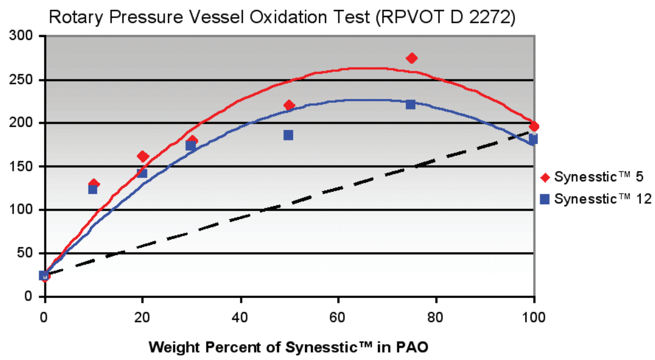


compressor oil, as measured in the Turbine Oil Stability Test (ASTM D943). In the formulation using ester, the oil acidity starts to increase after about 1,000 hours. Replacing the ester with alkylated naphthalene gives a more stable formulation, which can extend oil life significantly.

Esters versus alkylated naphthalenes: Oxidation resistance

When combined with PAO-based oil, alkylated naphthalene also provides a boost in oxidation resistance. Using an ASTM D2272 Rotary Pressure Vessel Oxidation test (RPVOT) (Figure 3), various samples of PAO and PAO/AN blends were tested. It was found that a small amount of alkylated naphthalene, typically 10% to 20%, gave an oxidation time well above expectations, based on extrapolations between the individual PAO and AN results. When antioxidants were added, the overall oxidation resistance times were significantly increased across the board.

Figure 3
Boost in oxidation when adding AN to PAO *(ExxonMobil data)*

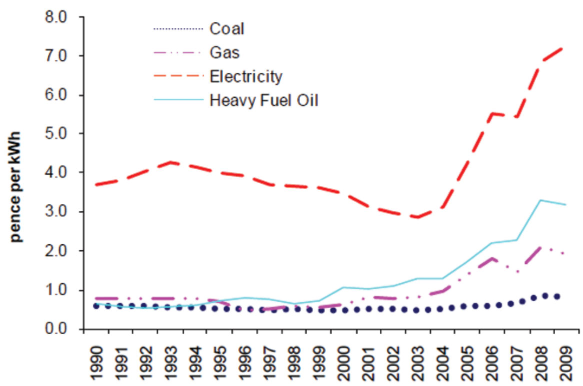


Energy savings

With fuel prices increasing dramatically each year (Figure 4), reducing energy costs is a goal for all businesses. Choosing the correct synthetic oil can help customers drive down their energy requirements. Examples of energy saving factors are:

- Lower traction fluids
- Lower temperature properties

Figure 4
Fuel Prices for UK Manufacturing Industry in Cash Terms 1990 to 2009
Source: UK Department of Energy & Climate Change – Quarterly Energy Prices Publication Sept 2010, Chart 3.1.2



Lower traction fluids

Under the elasto-hydrodynamic (EHD) conditions found in gears, cams and bearings, the surfaces are separated by very thin oil films, and the friction in the contact zone is dominated by the energy required to shear the oil film. The traction coefficient is a measure of the energy required to shear the lubricant film; lower traction fluids offer the possibility of energy savings. The traction properties depend on the type of base stock selected. The uniform molecular structure of PAO reduces the amount of internal friction created by the normal shearing of the oil film during operation and allows the lubricant films to slide over each other more easily than equivalent-viscosity mineral oils. Typically, PAOs have approximately 30% lower traction coefficients than mineral oils, as shown in Figure 5.

Figure 5

Comparison of Traction Between PAO and Mineral Oil

(ExxonMobil data)

Shear Stress as Measured in Traction Rig Tester		
	Shear Stress (psi) at 200,000 psi Contact Stress	Difference
Mineral Oil	9,300	Reference
PAO	6,100	-34%

In the sliding conditions seen in screw and vane compressors, thin oil films under high pressure are continually sheared. The use of PAOs with low traction coefficients can help reduce the energy required to shear those oil films. Reduced traction coefficient can also help reduce scuffing, as demonstrated by Jackson, et al., who studied the influence of lubricant traction characteristics on the load at which scuffing occurs. Benefits of 25% to 220% were observed for low-traction PAO-based lubricants at both high and low specific film thicknesses. [2]

Low-temperature properties

Another way to reduce energy costs is to ensure that low-temperature properties are also optimised. Many compressors are in fixed outdoor installations, fitted to vehicles or featured as mobile equipment. A lubricant providing satisfactory performance at high temperatures may encounter problems when the compressor has been sitting idle (e.g., overnight) in cold conditions. The oil may be too viscous for the compressor to start and, even if it does start, oil circulation can be sluggish. Therefore, there will be higher than normal energy demand until the oil reaches operating temperature. This is where low pour points and high viscosity indices of synthetic lubricants help. Low pour points help keep lubricants fluid at a low temperature. A high VI ensures lower viscosity – and therefore better fluidity – at low temperatures than a similar-viscosity grade of mineral oil while still maintaining high-temperature film thickness.

New developments in PAO technology have seen the introduction of metallocene PAO (mPAO). A new 150cSt mPAO commercial grade has a VI which is 36 points higher than conventional PAO 100cSt.[3] This new type of mPAO also offers lower pour points and significantly better low-temperature Brookfield viscosities than conventional PAO 100cSt, and can easily be used to upgrade lubricant formulations.

Demulsibility and corrosion protection

Good demulsibility and corrosion protection are additional key requirements of compressor lubricants. In addition to the extreme oxidation conditions, the lubricant is also faced with the problem of moisture. Ambient air is a mixture of dry air and superheated water (vapor). As air temperature increases, it can hold more water vapor before becoming saturated. Conversely, as air cools it can reach its dew point at which it becomes saturated and the water vapor is released as condensation.

Compressors operating at high flow rates can generate significant amounts of water, therefore, efficient drain systems are required to remove condensed water from the system.

In addition to removing water, there are problems during idle periods when the equipment cools below the dew point and condensation forms inside the machine. The water formed tends to displace oil films and cause rusting. The rust may get scuffed off when the compressor starts up again, but this can result in excessive wear. The resulting debris will promote deposits, oxidation and wear.

Other uses for synthetic oils

Synthetic oils have applications in vehicular and mobile equipment as well as in the food and beverage industries.

For **vehicular or mobile equipment**, multigrade engine oils are often used because they are readily available and offer a wide operating range. Because water condensation can cause troublesome emulsions with detergent-type engine oils, high VI synthetic oils with good water-separating capabilities are preferred.

For the **food and beverage industries**, both PAO and alkylated naphthalenes are available as NSF H1 registered products allowing the formulation of incidental food contact compressor oils. These types of lubricants can offer high performance in most applications, not only where so-called food grade lubricants are required. Customers can standardise lubricants across their plants, avoiding potential cross-contamination from 'non-food grade' oils in use in other areas.

Conclusion

Synthetic lubricants can help reduce downtime, maintenance costs and energy usage, which together can produce value that exceeds the cost of the lubricant.

In difficult economic times with continually rising energy costs and increasingly severe operating conditions, the demand for synthetic lubricants will grow even if overall lubricant demand remains static. If you do not have a synthetic compressor formulation in your product range, you are missing an opportunity that your customers already recognise.

References

1) *N. Stosic, I.K. Smith, A. Kovacevic, 'Screw Compressor: A strong link in the development chain', ISSN 1330-3651.*
2) *STLE 47th Annual Meeting Tribol. Transactions, 37(2), 387 - 395 (1994).*
3) *Based on typical properties shown on ExxonMobil Chemical SpectraSyn™ Polyalphaolefin product data sheets.*

Working towards standardisation of the Oil Storage Regulations

David Lummis, CEO of the British Safety Industry Federation (BSIF), discusses the complexity of UK Oil Storage Regulations and the pressing need for standardisation to curb confusion for both suppliers and distributors.

Oil Storage Regulations are part of the devolved legislative framework within the UK. Wales, Scotland, Northern Ireland and England each have separate regulations that suppliers and distributors throughout the UK must abide by; these individual regulations can cause confusion and enforcement difficulties. In many instances companies may be inadvertently breaching Oil Storage Regulations, thereby putting the health and safety of individuals at risk, as well as placing the organisation at danger of heavy penalties. When in fact, the stark reality may be that the organisation believes it is operating within the law, although the laws they are operating within, may actually be for a different country.

It is because of this confusion and a lack of consistency that members of the BSIF wish to see a standardisation of the Oil Storage Regulations within the UK (similar to the Health and Safety regulations). This standardisation would: avoid local confusion within industrial organisations that trade throughout the UK, avoid adverse impacts of local variations by insurers and the application of variable insurance expectations and premiums.

Due to the lack of conformity within the UK regulations, the differences between countries have the potential to cause significant confusion. For example, in Scotland the regulations include indoor oil storage whereas the English regulations do not; in Northern Ireland the regulations include Oil Storage Depots whereas they are specifically excluded from the English and Scottish regulations, in Scotland the regulations include all waste oils such as cooking oil, and the Welsh regulations are still to be established so it is not currently known what will be included.

Unfortunately there is little motivation for the average industrial company using moderate amounts of process oils and petro-chemicals to comply with these regulations as, although penalties are extreme, the likelihood of being caught is minimal. At present, responses from industrial organisations often take the view that "it does not really matter as I am unlikely to get caught". Additionally many industrial organisations believe that they are insured for environmental risks in the same way as they are for health and safety risks and whilst this is not always accurate there is a belief that "providing I am acting responsibly in 'my' terms there is not really a problem because the insurer will pay the bill". To help curb these beliefs, standardisation of the UK Oil Storage Regulations would help enforce a more stringent law that can be policed consistently throughout the UK.

The Federation believes that from a cost-management basis the argument for harmonisation of the regulations is strong. For example industrial companies storing oil need to act differently in all countries (Scotland, England and Northern Ireland). If the organisation carries out multi-branch operations in all three administrations, this will naturally create management procedure variations which, by the fact of the differences, will cause confusion, possible lack of compliance and potentially adoption of the lowest common denominator. Harmonised regulations would also allow a more cohesive and rigorous approach to industry monitoring, hence the true nature of personal accidents and injuries could be discovered.

Whilst the oil storage regulations are about preventing leaks and spills, when these do occur they will need to be dealt with and in most instances it will be people dealing with them. By the very nature of this task, people are at risk, however, these dangers can be minimised if sensible storage precautions are taken. With the current regulations, there are a number of potential problems where contact contamination could arise as well as potential for injury through 'slips and trips'. An example is the potential increase in unreported spills of waste oil in England (where certain waste oils are not within the scope of the regulations) and the possible rise in spills in oil storage depots in England and Scotland (where oil storage depots are not within the scope of the regulations).

Without doubt the regional variations of these regulations are confusing, standardised Oil Regulations throughout the UK and indeed Europe would facilitate better practice for suppliers and distributors, as well as allowing them to provide superior advice to end users.

LINK
www.bsif.co.uk