Oil Analysis as a Diagnostic Tool for Industrial Refrigeration Syste

There is an enormous potential for reducing the cost of operating and maintaining an industrial refrigeration system provided service companies, contractors and end-users are able to use systematic oil analyses as a diagnostic tool. An oil sample from a refrigeration system is like a blood sample from a patient.

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Today many service companies and users of industrial refrigeration systems take oil samples on a regular basis and send them to a laboratory or to the oil company for analysis. Typically, the analysis results are sent to the customer with a statement from the laboratory such as: „oil is suitable for further use", or „oil should be changed".

Accordingly the oil is either kept running or is changed and any other valuable information from the analysis is discarded. This can be a costly oversight because the information could save a great deal of time and money by revealing a number of hidden problems with the system.

Quite often service work is done on systems where symptoms of problems are treated, but the underlying causes are not found. The symptoms inevitably return and have to be cured again. Many of these underlying causes can be diagnosed through oil analysis, provided the service technician knows what to look for and what it means.

An oil sample from a refrigeration system is like a blood sample from a patient: it gives at lot of quantitative information, but you need a trained physician to look into the information and diagnose the illness.

The doctor must be familiar with both the patient's symptoms as well as the blood analysis in order to make the correct diagnosis.

With industrial refrigeration systems a properly trained engineer can diagnose many problems on the basis of oil analysis results, system design intent, and known problems with the system.

Three conditions necessary

There are three conditions necessary for an oil analysis to be of maximum value. The first is that the oil samples must be taken from the correct location, preferably while the compressors are running and the oil is circulating.

Secondly the oil must be degassed for refrigerant content in a dry environment so that no moisture is absorbed by the oil after the sample is taken.

This is especially important for the hygroscopic ester oils. The third condition is that the laboratory performing the analysis must be familiar with the special procedures needed for refrigeration systems.

These procedures are different from those used for diesel engines, gear boxes, hydraulic systems etc.

The contamination limits for used refrigeration oils are very different from those in other mechanical equipment.

Industrial refrigeration oils have much stricter guidelines for purity and do not accept additives.

The limiting values used by the laboratory when they state if oil is fit for further use, must be the values given by the manufacturer of the compressors in question. Each parameter specified by the manufacturer should as minimum be measured and reported.

Additional measurements for example of chloride and sulphur present are also valuable in system diagnostics.

The laboratory can only tell if the oil is suitable for further use with regards to the contamination limiting values.

It cannot advise the customer on potential system problems, where the problems come from, what the consequences or symptoms will be, or what to do about them.

Following are some issues that should be considered when reviewing an oil analysis report.

Additives

In the industrial refrigeration area different types of oils are used, but in general, no additives like EP (Extreme Pressure) additives or emulsifiers are accepted. (The only exception to this is oils for CO_2 systems.) The risk that these additives will react with the refrigerant, materials used in the gaskets, valves and compressors, or incoming air and moisture leaking into the system is very high. The sludge that results from such reactions has been known to obstruct system flow and destroy compressors. Therefore such additives are not acceptable.

If the oil analysis reveals the presence of phosphorus (P), calcium (Ca), and Zinc (Zn) the source of these elements should be investigated as they can cause the formation of sludge within the system. A common reason for the appearance of these substances is using the wrong oil when servicing the compressor and other equipment. Even small amounts of oil with large amounts of additives can, over time, create big problems in refrigeration systems.

Picture 1.

Bearing types

When reviewing oil analysis results it is very important to know which compressor the oil sample has been taken from. Also, the type of bearings in the machine is important. Roller or ball bearings is one type, slide bearings is another type, or the machine may have a combination of these. The two types of bearings can be sensitive to some types of lubrication problems but very tolerant to others. The wear patterns are also different on the two bearing types.

As a „rule of thumb" we can say:

Slide bearings: These are very sensitive to oil viscosity and oil pressure.

They are more tolerant of water content and very small particles (smaller than the oil film thickness) Wear on a slide bearing can be measured as an increase in bearing clearance.

Roller and ball bearings: These are very sensitive to water content in the oil, and contamination from small hard particles. They are more tolerant to variations in oil pressure and viscosity.

Wear on roller and ball bearings can not be measured as an increase in clearance as deterioration in the balls and raceway often begins with small cracks in the material under the surface.

Viscosity

The viscosity of the oil is a very important parameter to measure when evaluating if the oil is suited for further use.

The viscosity must match the values given by the compressor manufacturer at the given running conditions.

An increase or decrease in viscosity can indicate that the oil has broken down due to excessive heat, oxidation or other chemical reactions.

If the used oil was blended from different viscosities by the manufacturer to obtain the correct value, there is a risk that the oil component with low viscosity will escape the compressor through the oil separator, leaving the high viscosity component inside the compressor.

This could be how the oil unintentionally changes to a higher viscosity.

The viscosity is most important for compressors with slide bearings as improper values can lead to immediate seizure of the bearings and total break-down of the compressor. A compressor with only roller and ball bearings will have a shorter service life if the oil has an incorrect viscosity, but the risk of complete seizure after very few running hours is very limited.

Dilution of refrigerant in the oil during operation will reduce the oil viscosity considerably, but oil analysis will not reveal this. So when a compressor suffers from

Picture 1: Compressor suction filters from an ammonia system contaminated with oil additives.

Picture 2. Slide bearing seizure on screw compressor due to lack of oil viscosity.

premature slide bearing damage but the oil analysis reveals no viscosity problem the system should be checked for possibly allowing too much refrigerant to enter the oil.

Picture 2.

Silicon values

A high silicon value may indicate contamination with hard particles like dust, sand and/or grinding materials. (The use of silicon lubricants during service work can also give a high silicon value without any contamination with hard particles.) Silicon particle contamination will reduce the service life of ball bearings, and if the particles are large in size also reduce the life of slide bearings. Recommendations when particles are present include better care during service and maintenance work, increased oil filtration, and cleaning the suction and liquid filters.

Water contamination of oil

It is essential that the oil is checked for the presence of water. Emulsifiers, normally used in motor and gear oils, are not tolerated in refrigeration oils. Emulsifiers work like „dishwashing soap" and enable the oil to completely dissolve a certain amount of water. Without emulsifiers, water will be present as small droplets in the oil film, causing thin oil films to break down under high pressure on a small area. This is one reason why the limit for water content is so low in industrial refrigeration oils (max. 100 ppm). The water content should actually be kept much lower than this value.

According to FAG, a manufacturer of roller and ball bearings, water content in the oil will have the following consequences on the relative bearing life:

- Water content in oil of approx. 100 ppm will begin to reduce service life.
- Water content in oil of approx. 300 ppm reduces service life by 50%.
- Water content in oil of approx. 5000 ppm will drastically reduce service life.

On compressors (typically screw compressors) with roller and/or ball bearings, it is advisable to reduce the time between bearing changes, when too much water is found in the oil. How much the expected running hours should be reduced depends on the amount of water found in the oil, but obviously the bearing change should occur before the parts break down and damage the compressor. On compressors with slide bearings, the presence of water is not a significant reason for bearing replacement.

Water found in the oil of a compressor normally indicates wider spread water contamination within the system. The source of the water should be found and eliminated. The source may be air coming into the system when it runs in a vacuum, but there are also several other ways water can enter. On an ammonia system water can be sucked into the system when refrigerant is vented into a water container if there is no check valve installed in the evacuation hose. Chemical reactions can also produce water. And carelessness during service and repair can leave water in the system.

When significant amounts of water is found in the oil, the water content of the refrigerant should also be checked.

Picture 3.

Picture 4.

Water in ammonia systems:

On ammonia systems, water content should be checked at all liquid separators.

That is, anywhere liquid ammonia is permitted to vaporize and no liquid is drained out. It is there that the water will concentrate.

If a water concentration of 1% or more is found, there will be many problems in the system, although it may not be obvious that the water is the root cause of the problems.

Such problems include:

- Increased power consumption
- Reduced refrigeration capacity
- Lower evaporating pressure at a given temperature.
- Oil breaking down and creating nitro-compounds, which can partly dissolve in the ammonia and colour it.
- Leaks due to brittleness of o-rings and gaskets.
- Leaks due to galvanic corrosion of joints and aluminium gaskets
- Wear and tear on valves and controls.
- Sludge in the system

Profitable ammonia cleaner

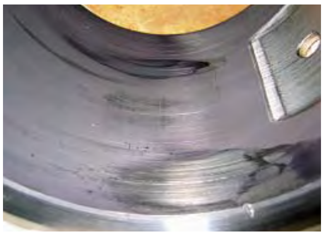
On such a system the recommendation can be to install a special ammonia cleaner, which will remove the water as well as dirt, oil and sludge, and keep the system water free in the future.

Today these devices can be delivered in inexpensive energy-neutral versions with a sophisticated self-regulating system requiring no electrical connections so they are easy to install. Such a unit can have a very short pay back time for the user.

If a large quantity of water is suddenly found in the oil of an ammonia compressor, it can indicate that liquid has been carried over from the low pressure liquid separator. Water can only be drawn to the compressors suction side in large quantities as droplets mixed with ammonia. A system where this happens should be checked for overloading or violent boiling in the liquid separator during operation, allowing liquid to travel into the compressor. This will also give reason to accumulation of liquid refrigerant in the oil and possible viscosity problems, as well as wear and tear on the compressor.

Leaks in water or brine chillers

Picture 3. Broken ball bearing from screw compressor with water contamination of the oil.



Picture 4. Slide bearing suitable for further use from same screw compressor with water contamination of the oil.

Picture 5. Water contamination test sample from ammonia chiller showing water/calcium chloride contamination of the ammonia close to 7%.

Picture 6. Crank shaft on ammonia compressor where the system is suffering from pollution with chlorine.

and water cooled oil coolers can also make a sudden increase in water contamination of the oil, and should also be investigated as a possible reason. *Picture 5.*

Water in synthetic refrigerant systems:

When too much water is reported from an oil analysis on HCFC and CFC systems it will not only be a problem for lubrication in the compressors, but also a sign of serious problems in the rest of the system.

In these systems water reacts with oil and the refrigerant, creating acids which will attack metals (like copper and aluminium), as well as gaskets in joints and assemblies resulting in leaks.

The TAN value (Total Acid Number) of the oil is an important value to evaluate in this connection as it gives valuable information on how much the acid creating process has progressed.

Dissolved copper can be plated out on metal surfaces in an area where there is an electrical potential difference and can be seen as a „golden layer." This „copper plating" very often takes place on the compressor shaft seal making it leak.

If the shaft seal is changed without solving the water/acid problem, it is only a matter of time before the new shaft seal starts leaking.

The water will also be concentrated everywhere in the system where the refrigerant evaporates and can create ice. (This is the case for all the synthetic refrigerants except the banned R12 and R502). When ice is created in regulating valves, filters, etc. it can make a wide variety of problems in the entire refrigeration system.

A green moisture indicator in the hot liquid line on a freezing system is no guaranty for a dry system, as the moisture stays on the low pressure side where the indicator can not „see" it.

In HFC systems the ester oil is very hygroscopic and will easily be contaminated with moisture from being in contact with open air. This makes it very important that an oil sample taken from these systems is handled correctly, so that the measured water content did not enter the oil after the sample was taken.

Wear metals in the oil analysis:

When reading metal content in the oil analysis results, it is very important to understand what the figures mean. The equipment measuring the metals can only detect very small particles up to a maximum size between 5 and 10 microns. So the particles are small enough that they won't be removed by typical oil filters.

Metals dissolved in the oil will also be seen in the analysis results. This must be kept in mind as a high acid content will dissolve metals from the system, and can wrongly be interpreted as particles from bearing wear. Additives which contain dissolved metals can also be mistaken for an indication of bearing wear. Corrosion particles coming from the piping system and into the compressors will give high measurements of iron particles in the analysis, but this does not necessarily mean anything is wrong with the compressor.

These are some of the factors to be evaluated together with the composition and amount of the wear metals in the oil analysis before advising customers to inspect compressor bearings.

Other kinds of contamination:

Many things can contaminate a refrigeration system and create sludge. One of the worst things is if R22 or a chlorine containing cleaning agent gets into an ammonia system, where the chlorine reacts with the ammonia, oil and iron in the compressor. The result can be a terrible amount of sludge, heavy corrosion attacks in the system and compressor, and a high risk of the compressor breaking down.

If chlorine is suspected, the laboratory can perform a special analysis to confirm its presence. This analysis could be performed when components or vessels from R22 systems are reused in ammonia system without a proper cleaning. *Picture 6.*

Conclusion

The measurements provided by an oil analysis can be a very valuable tool when trying to minimize service and running costs on industrial refrigeration systems. But turning the measurements into diagnosis and corrective action demands skills within the areas of: oils, oil analysis, chemistry, refrigeration system trouble shooting, compressors and bearing failure mechanisms.

There are a number of problems that are never discovered in industrial refrigeration systems because this diagnostic tool is not used effectively. However the proper diagnosis on the basis of oil analysis can save the user a lot of money and consequential damages from plant break downs.

It is not enough to accept the laboratory's comment "The oil is suitable for further use" as the complete conclusion if we want to keep a system running at minimal cost.

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