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Low Flash Point of Turbine, Compressor and Seal Oil could pose a Safety Risk

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The flash point of fresh oil is 202°C. We have been meeting examples from customers, where the flash point of used oil lies between 170-192°C. The question is whether it is safe to operate with such a low flash point? If not – what would be an acceptable level and what could be done to increase the low flash point? These questions are to be discussed and answered in the following article.

As a starting point, some answers and points from an online discussion board concerning the challenge with low flash point are listed below (Source: Noria Message Boards):

- "A low flash point might be caused by use of wrong oil, which differs from the one that is recommended by the manufacturers of the system."
- "Flash point lower than 180°C could be a problem regarding safety issues."
- "It has to be determined, what composition of gas is causing the problem. The viscosity of the oil should also be checked. First you will experience problems with the FP, and for larger gas amounts the viscosity could decrease, and it will not be enough for the hydrodynamic film on the bearings."
- "There are several technologies for removing gasses and increase the flash point."
- "Composition of gas is mandatory for the determination of what kind of removal technology that must be used."

Picture 1 – Turbine break down.

What influence changes in Flash Point?
The answers from the discussion board seem to conclude that a flash point lower than 180°C could pose a safety risk. In order to understand what can be done to reduce the risks of low flash points it is necessary to outline what factors are influencing changes in the flash points of oil.

> **“The flash point is the minimum temperature at which a product of petroleum gives off sufficient flammable vapours to ignite or momentarily flash.”**

An overview of existing literature and case studies on this matter gives a picture of a number of factors, which all together influence changes in the flash point of oil. Extracts of texts and experiences appear from the following sections.

Oil Degradation
Source: “Finding the Root Causes of Oil Degradation” by Greg Livingstone – Ept Inc., Dave Wooton – Wooton Consulting & Brian Thompson – Analyst Inc. The article is published in ‘Practicing Oil Analyses’ (1/2007)

“Fluid degradation can be responsible for many kinds of equipment failures. A lubricant in service is subjected to a wide range of conditions which can degrade its base oil and additive system. Such factors include heat, entrained air, incompatible gases, moisture, internal or external contamination, process constituents, radiation and inadvertent mixing of a different fluid.

Picture 2 - Plugged Filter from a large-frame industrial gas turbine.

Oxidation. Oxidation is the reaction of materials with oxygen. It can be responsible for viscosity increase, varnish formation, sludge and sediment formation, additive depletion, base oil breakdown, filter plugging, loss in foam properties, acid number increase, rust and corrosion. Controlling oxidation is a significant challenge in trying to extend the lubricant's life.

Thermal Breakdown. In a mechanical working environment, the temperature of the lubricant is a primary concern. In addition to separating the moving parts of the machinery, the lubricant must also dissipate heat. This means the lubricant will sometimes be heated above its recommended stable temperature. Overheating can cause the light ends of the lubricant to vaporize or the lubricant itself to decompose. This can cause certain additives to be removed from the system without performing their job, or the viscosity of the lubricant may increase.

At temperatures greatly exceeding the thermal stability point of the lubricant, larger molecules will break apart into smaller molecules. This thermal cracking, often referred to as thermal breakdown, can initiate side reactions, induce polymerization, **produce gaseous by-products**, destroy additives and generate insoluble by-products. In some cases, thermal degradation will cause a decrease in viscosity.

Contamination. Foreign substances can greatly influence the type and rate of lubricant degradation. Metals such as copper and iron are catalysts to the degradation process. Water and air can provide a large source of oxygen to react with the oil. Therefore, a contaminant-free lubricant is ideal and monitoring a fluid's contamination levels provides significant insight to the machine's health.

Air Bobbles. In addition, cavitations may result in increased oil oxidation rates. When an air-ignitable mixture is present within the bubble, ignition may occur from the rise in temperature accompanying the compression process. This process requires only nanoseconds and the localized temperature may be 2,012°F (1,100°C) or higher. This process, also known as the micro-dieseling effect may lead to oxidative degradation of the hydraulic oil, localized hot spots and pressure spikes, and may subsequently lead to cavitations erosion in a hydraulic pump or other component. In addition to these well-known processes, cavitations may lead to the formation of reactive chemical intermediates, which are capable of affecting secondary oxidation and reduction processes.

Autodegradation. Numerous chemical and physical mechanisms may cause an oil to degrade and produce insoluble’s once it is isolated from the circulating system. This condition is called autodegradation. One cause of autodegradation is when the lubricant contains a depleted antioxidant additive system and a large number of free radicals.

Picture 3 - Sludge on reservoir.

Autodegradation can cause the creation of insoluble contaminants in low or no-flow sections in a lubricating circuit, leading to varnish. Often, lines leading to inactive valves are susceptible to autodegradation and subsequently, when the valves are used, they stick.

> **"Various forms of thermal degradation will produce light ends that have the ability to lower the lubricant's flash point."**

Certain degradation mechanisms cause a lubricant's hydrocarbon molecule to crack, producing light end **gases** that are entrained in the oil. The type and distribution of these **gases** can indicate which degradation mechanism is responsible.

Gases that are useful to examine when applying this test to fluid degradation include hydrocarbons (methane, ethane, ethylene and acetylene), carbon oxides (carbon monoxide and carbon dioxide) and hydrogen. Researchers have attempted to identify the specific gases produced once the hydrocarbon molecule is cracked (temperatures in excess of 300°C). Acetylene, for example, is created at temperatures greater than 1,000°C.

Particle Count: ISO 11171, ISO 11500, NAS 1638. This is a test designed to count the number of particles present greater than a given micron size per unit volume of fluid. The results reflect the insoluble contaminants present within that size range and are applied to assess fluid cleanliness and filtration efficiency. Cleanliness levels are also represented by the ISO 4406 classification system to classify the particles larger than 4 µm, 6 µm and 14 µm per milliliter of fluid.

Root cause analysis is a powerful tool to methodically investigate reliability problems including lubricant degradation. Oil analysis is an excellent tool in the root cause analysis toolbox. Measuring chemical changes in the lubricant, along with the creation of insoluble contaminants is the first step in identifying fluid degradation. Remember that one of the major pitfalls in lubricant root cause analysis is that assumptions are made by the investigators. As a result, problems are either incorrectly diagnosed or not solved. By approaching lubricant degradation issues with an open mind and by methodically applying oil analysis tools, the root cause of recurring problems can be solved."

Turbine and Compressor Lubricants

Source: "Compressor Lubrication Best Practices" by Heinz P. Bloch. The article is published in 'Machinery Lubrication' (5/2003).

"The overwhelming majority of compressors are best served by premium-grade turbine oils with ISO viscosity grades of 32 or 46. However, there are many different types of compressors and each manufacturer is likely to recommend lubricants that have been used on a test stand and at controlled user facilities.

Premium-grade ISO VG 32 turbine oils are used more often than the heavier viscosity grades. The typical viscosity index is 97, with a pour point around -37ºC (-35ºF). Oxidation stability (per ASTM D943) should exceed 5,000 hours and the flash point (per ASTM D92, COC) should be **206°C, or 403°F**. These lubricants must provide the following:

- Long life without need for changeout
- Prevention of acidity, sludge, deposit formation
- Excellent protection against rust and corrosion, even during shutdown
- Good demulsibility to shed water that enters the lubrication system
- Easy filterability without additive depletion
- Good foam control

It is not uncommon to operate these systems for many years on the initial fill of lubricant, in some cases beyond 30 years. These long-term lifecycles are associated with premium-grade product selection, large sumps, reasonably good contamination control and the occasional top-off "sweetening" effect on the oil in use.

Extended lifecycles on turbine, turbo-compressor and other R&O type oils used in these applications are also facilitated by the relatively simple additive structure of the product, which minimizes kinds of complications associated with complex additive systems like those found in EP gear lubricants."

Overheated Lubricating Oil
Source: http://www.tpub.com/engine3/en32-53.htm

"The formation of **explosive vapour** from lubricating oil is greatly accelerated by a rise in the temperature of the lubricating oil. A rise in temperature may be due to such factors as insufficient circulation of the oil, inadequate cooling of the oil, a faulty temperature-regulating valve, overloading of the engine, or damaged or excessively worn parts. In addition to creating explosive vapours, overheated lubricating oil can have other serious effects. The viscosity of the lubricating oil will be greatly reduced, and the tendency to form acids will be increased. You, as an Engineman, must take immediate steps to correct any problem associated with overheated lubricating oil. You must maintain the temperature of the lubricating oil within the range of values specified in the NAVSEA technical manual for your machine."

Source: Statements from online discussion board
http://control.com/thread/1251647453

"Typically, when lubricating oil temperature is high (approximately 165˚F (74°C)), there is an alarm and if it's allowed to get higher (exceeding 175˚F (79°C)) then the turbine is tripped. The concept is that above approximately 175˚F (79°C) hydrocarbon lube oil vapours, particularly in the bearing housings, are approaching their flash point and could be ignited by an ignition source."

Seal-Oil
Source: BP Group Recommended Practices and Specifications for Engineering – "Lubrication, shaft sealing, and control oil systems for special purpose applications to API 614"

"Reservoirs containing lube oil only shall be vented to atmosphere. The vent system shall be independent from those for reservoirs containing seal oil, and from those for degassing drums. Reservoirs containing seal oil shall be vented to atmosphere. The vent system shall be independent from those for reservoirs containing lube oil only, and from those for the gas-side of degassing drums. On reservoirs containing seal-oil, the vent(s) shall be sized such that overpressure does not occur with maximum gas flow into the reservoir.

Plugged Connections
Purge connections for inert gas shall be provided on all reservoirs. Seal oil reservoirs (whether common with lube oil reservoirs or otherwise) in flammable or toxic gas service, shall be fitted with equipment including isolating valve, flow controller and flow indicator, to provide a continuous inert gas purge. Purge flowrate shall be sufficient to prevent air ingress at all times, including oil system startup, i.e. during reservoir level draw-down, and to avoid 'in-breathing' following shutdown when cooling of the reservoir contents is taking place.

Where an inert gas purge is provided, vents from the machine bearings, and/or seal chambers, shall be returned to their respective reservoirs.

> **"All reservoirs containing seal oil or combined lube/seal oil on flammable or toxic gas service should be purged with nitrogen."**

Although it is known that mixtures of air and oil mist can be flammable, it is considered that the likelihood of an explosive atmosphere is very low for a reservoir containing lube-oil only. As far as is known within BP there have never been any explosions in lube-oil reservoirs. It is not considered necessary to purge reservoirs containing lube-oil only.

Overheated Seal-oil tanks
Mist eliminators shall be supplied on seal-trap vents.

Adequate venting of seal-oil drain traps is important. The gas flow helps the drainage of the contaminated seal oil and prevents migration of seal oil into the compressor. The following points should be considered:

a) Some oil vapour may pass the mist eliminator. If the oil is damaging to the process (e.g. catalyst poisoning, or refrigerant circuit fouling) the vent gas should not be returned to the compressor.

b) The vent lines should not include 'liquid traps' in which lube oil could collect and prevent free venting.

c) If the traps are vented to nominally the same pressure as the sealed pressure, it may be necessary to supply buffer gas to ensure an adequate differential pressure across the trap (i.e. to ensure an adequate gas flow rate through the trap).

Degassing Drum
Seal-oil degassing facilities shall be provided if the gas is toxic, flammable, or liable to degrade the oil.

Oil degradation (reduction in viscosity and flash point) is particularly a problem on heavy hydrocarbon gases, particularly at high pressure. The simple heated degasser (as API 614 Figure 4) will normally remove C3 and lighter hydrocarbons. More complicated degassers using a combination of heating, agitation and inert gas sparging will normally remove hydrocarbons down to C4. Hydrocarbons of C5 and heavier will not be removed. If the gas contains significant quantities of C5 hydrocarbons and heavier, it will be necessary to use a vacuum degassing system.

Vacuum degassing systems can be very effective for removing dissolved gases as well as water and solid contamination. They will be most applicable where contamination by process gas is anticipated. They can be used for combined seal-oil degassing and reservoir-oil clean-up systems.

A problem with degassing systems is that some types can remove the additives in the lube oil (i.e. antioxidants, rust inhibitors, etc.). Care should be taken when selecting the degasser type.

a) If the content of C5 and heavier is less than 0.1 mol% degassing is relatively easy and simple, degassing drums (perhaps with nitrogen sparging) are adequate.

b) If the content of C5 and heavier is greater than 0.1 mol% particular care needs to be taken in the specification of the degassing drum. Vacuum degassing may be necessary.

The gas-side vent shall be completely independent from vents from seal-oil reservoirs and seal housings, and from all lube-system vents. It shall be piped to flare or to a well ventilated location where the estimated maximum release of gas will not present a hazard."

Conclusion

From the above inputs from existing literature and case studies, we can conclude that flash points lower than 180˚C could be a problem, regarding safety issues. Furthermore we have experienced that a lower flash point is depending not only of one reason, but of various circumstances within the lubricants oil or the lubricant systems. A short punch list of the most critical factors influencing the flash point is as follows:

1) Oil Degradation – catalyst by contamination, air, water, mixing of different fluid, oxidation etc.

2) Overheated Lubricating Oil – caused by insufficient circulation of the oil, inadequate cooling of the oil, overloading of machine, excessively worn parts etc.

3) Ignition – caused by static electricity, low flash point and vapour gasses.

4) Lack of proper Seal-oil reservoirs, degassing drums, inert gas purge and sufficiently ventilation etc.

Ocean Team presents the Solution

As mentioned, challenges with low flash point of oil are influenced by a multiple number of circumstances. In order to solve these challenges, a solution has to incorporate actions toward all four mentioned influencing critical factors.

Ocean Team is ready to assist you in this matter. Our recommendations to what specific actions, which must be taken, will depend on the individual situation. Below we have listed some general action points, which we would apply in solving the challenges toward the four most critical circumstances mentioned in this article.

1) Oil degradation

I. Take out representative dynamic oil sample from live lubrication system.

II. Send the sampling to Ocean Team for a full spectrum analysis including additive package together with a sample of the new lubricating oil as reference for comparison.

III. The spectrum analysis report will include an evaluation of oil degradation and a solution will be discussed with the customer.

IV. Ocean Team's experience is that very common/often it is necessary to provide a lube oil flushing with turbulent flow velocity higher than RE>3000 of the lubrication oil system to remove contamination and water to stop the negative chemical reaction leading to oxidation, varnish, high temperature, low viscosity and low flash point. Ocean Team can provide efficient oil flushing of your system, and in some cases we are able to provide this service in live systems saving you for expensive production losses.

V. After oil flushing it will be necessary to implement an "Ocean Team Oil-Care Program", which includes periodical trend oil analysis and installation of an oil-purification system for preventive maintenance of the oil and lubricating system. The benefits of our Oil-Care Program are enhanced oil quality, restoration of the lubricating oil viscosity, increased flash point and improved operational performance. Finally it secures you a safety and money saving continues operations.

2) Overheated Lubricating oil

I. Logging of the oil temperature is necessary to identify eventually raising of oil temperature.

II. If integration of cooling water system, logging of cooling water temperature is necessary and eventually a chemical cleaning of cooling water side is required to remove fouling from cooler.

III. If air-cooling is integrated, a lube oil flushing with turbulent flow velocity higher than RE>3000 of the Lube oil Cooler might be required.

IV. Check temperature-regulating valve.

V. Check overloading of the machine.

VI. Check for damaged or excessively worn parts, such as bearings etc.

3) Ignition

Generally Ocean Team, will not recommend adding anything that is not meant to be in the oil or systems, which differs from the original recommendations from oil and machine suppliers. Nevertheless it sometimes might be necessary to look for alternatives, especially regarding safety issues. Ignition, caused by static electricity, low Flash Point and vapour gasses is a considerable safety risk and some machine operators are adding an antistatic additive for use in distillate fuels to reduce the explosion risk. Ocean Team is able to supply you with this antistatic additive.

4) Lack of proper Seal-oil reservoirs, degassing drums, inert gas purge and sufficiently ventilation etc.

Check with machine suppliers for specifications and check for lack of same. Ocean Team is able to assist you by implementing the machine supplier's requirements and recommendations.

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Sources:

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