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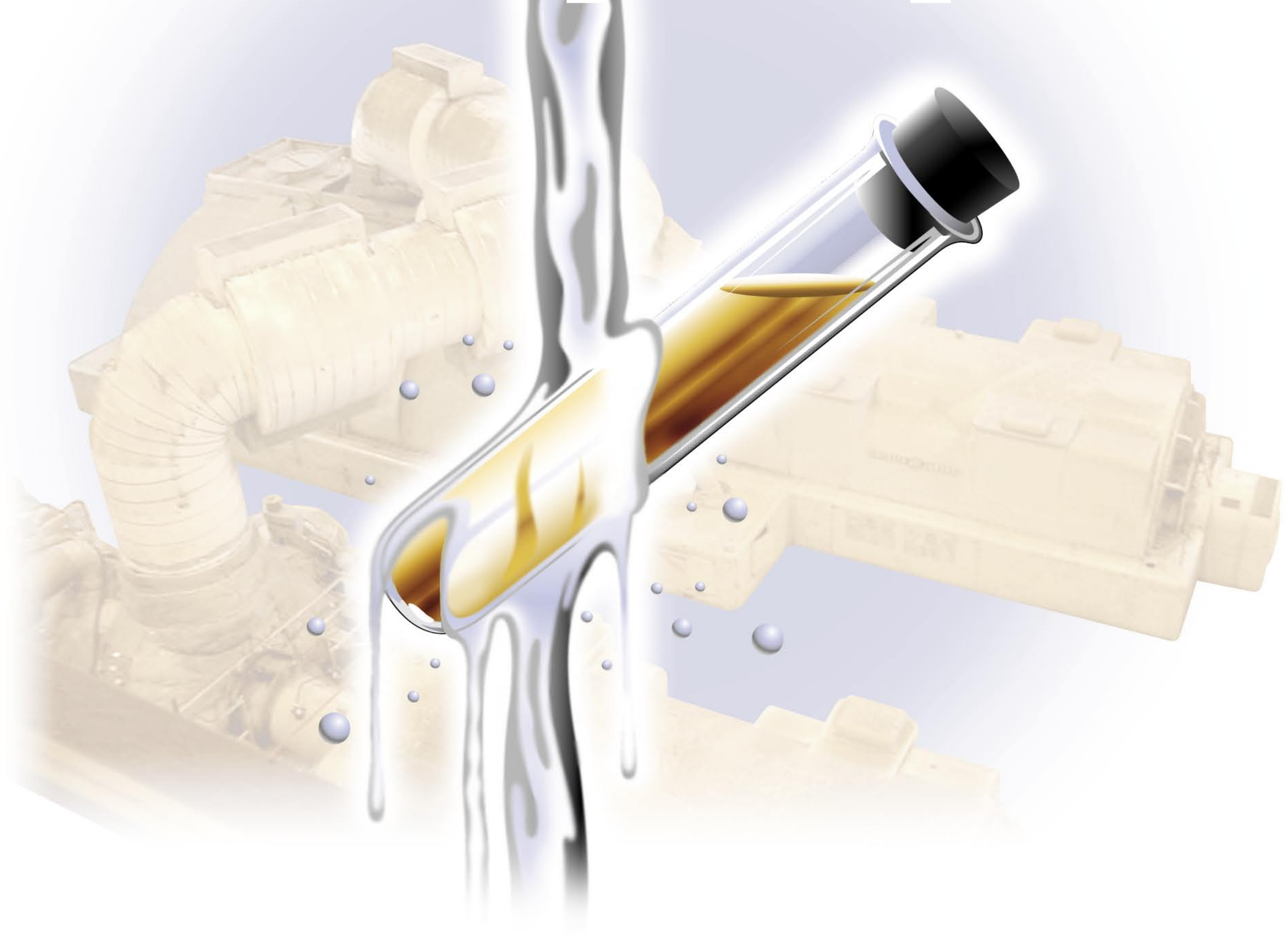
Oil and Water

Filtration Keeps Them Separate



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OIL AND WATER SHOULDN'T MIX

The ability to control water ingression in steam turbine oil conditioning systems varies among filtration technologies. Plant operators need to know what technology offers the best insurance policy to protect their steam turbines.

BY: BRIAN MCNEIL, JON SCHNABLE AND TIM MILLS -KAYDON CUSTOM FILTRATION CORPORATION

Oil is the lifeblood of the system, or words to that effect, is a cliché describing the critical role lubrication plays anywhere the potential for metal-to-metal contact exists. Although a cliché, the expression is uncompromisingly true for the steam turbine generator. A host of lubrication problems can threaten system component lifespans, from journals to bearings to seals. What then is the best filtration solution to provide a life insurance policy for the turbine oil lubrication system?

The focus of this article will be on water removal, not particulate removal. The argument will be based on a mathematical model of the performance difference that two particular filtration solutions can offer for water removal, namely, vacuum distillation and coalescing/separating.

THE POTENTIAL FOR DAMAGE

Between the journal and the bearing, clearances are typically designed to be about 20 microns. When the bearing and the journal are in motion, heat expands the metal shrinking that clearance to as little as 10 microns. Then, depending on the speed of rotation, the clearance can be even less (down to 3-5 microns) at the bottom of the journal/bearing interface. Particulate removal typically has been specified in this 3-5 micron range to remove the harmful, abrasive particles that can intrude into the film thickness between the journal and the bearing.

The smaller the micron filtration and more efficient the particle removal in this size range, the better the total filtration — meaning the better the insurance policy. With today's micro-glass media and emerging nano-fiber technology, the micron rating for particulate filtration of any turbine oil system should be at least Beta 3-5 > 1000 per ISO 16889, at a minimum.

But more critical for steam turbine oil conditioning systems is the capability of handling significant water ingression. It is the varying degrees of water ingression which will and should influence the kind of system being considered. Excess water in the lubricating oil increases the operating viscosity and can decrease the film thickness to the point where metal-to-metal contact and "wiping" of the bearing occurs.

Gravity Precipitation – This was one of the first system technologies for removing water. These systems apply one of the earliest coalescing technologies to remove water from light, mineral-based oils like turbine oil. The system's capability is in removing free water. It will not break an emulsion or remove dissolved water. As the contaminated oil flows over a series of hydrophobic screens in the precipitation chamber, the water droplets fall to the bottom, are collected and removed from the system. Process rates are typically lower than any other conditioning solution, less than 0.01 gallons per minute (gpm).

Total water at the system's outlet is typically in the 150 ppm range. Designed to handle reasonably small amounts of water, the systems cannot handle a sudden ingression. The water in oil can easily pass by the separator screens. So, 150 ppm is possible with very little water ingression.

Centrifugal Separation – Here, gravity's natural process is accelerated by a series of conical disks rotating at 7,000 to 8,000 rpm. This increases the force of gravity a minimum of 2,200 times. The water removal process is accelerated. A centrifuge can remove high amounts of water. An adequately sized system can take out more than 0.5 gpm. Their downfall, however, may be their general lack of reliability. Along with the water, they strip out much larger, heavier solid particles during the centrifugation process.

This material can accumulate on the walls of the bowl. Periodic cleaning keeps the unit from being an effective insurance policy; the frequency of maintenance — sometimes as often as weekly or monthly — can cause unscheduled downtime and loss of revenue for the power plant. And, the unit's internal gears and shaft can require regular care, including replacing the lubricating oil as often as every 1,000 hours. Total water to 150 ppm is possible, but a centrifuge will not always break an emulsion.

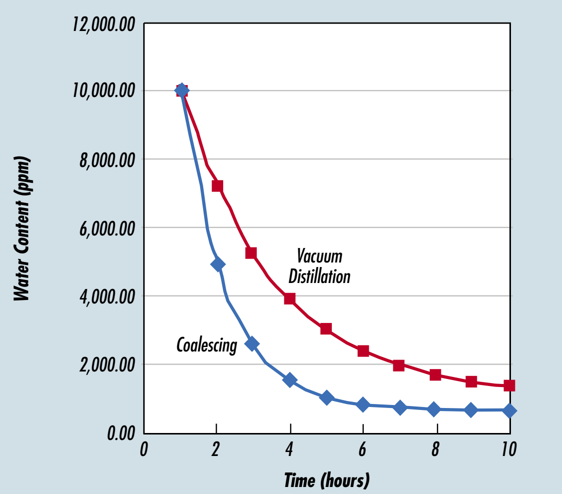
Mass Transfer – As a vacuum dehydration system, a mass transfer conditioning system is one of two water removal technologies that can remove dissolved water. But as discussed later under "vacuum distillation," the process rate in relation to the size of the reservoir may prevent the full capability of the system from being realized. Contaminated oil passes into the top of a separator vessel where the oil flowing downward over the separator elements meets and interfaces with dried and heated air coming in from the bottom of the column. The dry, hot air grabs the water in the oil and absorbs it. The pull of the vacuum then "transfers" the moist air out of the system. The dry oil exits the bottom of the column.

Water removal with mass transfer can reach to below 100 ppm under the right conditions. While the total water capability is excellent, it has a limited water removal rate, about 0.028 gpm in an adequately sized system (rate based on a 45 gpm system). It can be susceptible to large amounts of water ingression. In addition, three pumps (inlet, outlet and vacuum) must be perfectly balanced for effective operation. In effect, the system is simply an accelerated evaporator.

Vacuum Distillation – In distillation, instead of heating the air, the oil is heated, allowing the system to pull out the vapor faster than mass transfer. Contaminated oil passes over heaters that raise the oil to 150-180 F. The heated oil is then passed over several disperser elements, which increase the oil's surface area and make vaporization more rapid. Older systems use the distance between the condensing coils and the disperser chamber, along with a water eductor, to pull a "vacuum," but must heat the oil to 180 F. Newer technology uses an actual vacuum pump to pull a vacuum on the disperser chamber to 26"-28" mercury; thereby, it is able to vaporize the water from the oil at 150 F.

The difficulty with vacuum distillation is finding the right balance between heat and flow. Foaming may also be difficult to control. Capability is somewhere in the range of 0.30 gpm for a 50 gpm system. Total water to 70 ppm can be reached but, along with mass transfer, will equalize back to saturation with the oil inside the reservoir, maintaining the reservoir at 100-120 ppm. Heating the oil also raises the system's average temperature, which raises the oil's saturation point, tending to make it hold more water. So with vacuum dehydration, what is gained at the filtration system outlet might quickly be given up inside the reservoir.

FIGURE 1
COMPARISON FOR TURBINE OIL CONDITIONING



Source: Kaydon Custom Filtration

Coalescing/Separating – A coalescing-type oil conditioner uses a unique combination of media to grab free and emulsified water from the turbine oil. It does this just as its name suggests: it literally coalesces, meaning it "grows together." The water droplets form on the element's drainage layer and eventually enter the oil stream where gravity pulls them to the bottom of the vessel. There they are removed automatically. The hydrophobic separator elements work in conjunction with the coalescer elements to block the water drops and keep them from passing downstream of the coalescer/separator vessel and back to the oil reservoir.

Historically, coalescence has removed total water to below 150 ppm with an extremely high process rate of up to 0.60 gpm. More efficient water removal with newer coalescing technology, such as pleated Turbo-TOC coalescer elements by Kaydon can improve that process rate by as much as 12 percent to 15 percent, and total dryness by greater than 30 percent. One negative to a coalescing system is that certain surfactants can inhibit coalescing, but newer media show resistance to surfactants. The key to coalescing is that it can handle higher ingressions of water and break emulsions. Regular maintenance is relatively simple.

MODELING THE SYSTEMS

In determining which systems to use, a first step is to understand the unique problems inherent in steam turbine lubrication. The key to system performance hinges in the oil film thickness between the rotating journals and the stationary bearings; therefore, removing the harmful water that negatively effects oil viscosity is crucial.

Because each technology will, more or less, remove water from turbine oil, qualifying the "more or less" is a concern. Which systems should be eliminated?

Because of the high maintenance costs and frequent maintenance needs, the centrifuge typically is not reliable enough to be ready when it is needed. It may have the process rates, but there are other considerations. The older gravity separation units do not offer the same process rates as newer coalescing/separating technology. The technology is similar, but performance is not.

That leaves three systems to consider. Of the two vacuum technologies, the mass transfer system can be eliminated because of its lower water removal rate than other vacuum configurations. As standard specifications reveal, the mass transfer vacuum system cannot pull the volume of water out that distillation can:

Mass Transfer, 45 gpm System, 40 gallons per day
Vacuum Distillation, 5 gpm System, 72 gallons per day

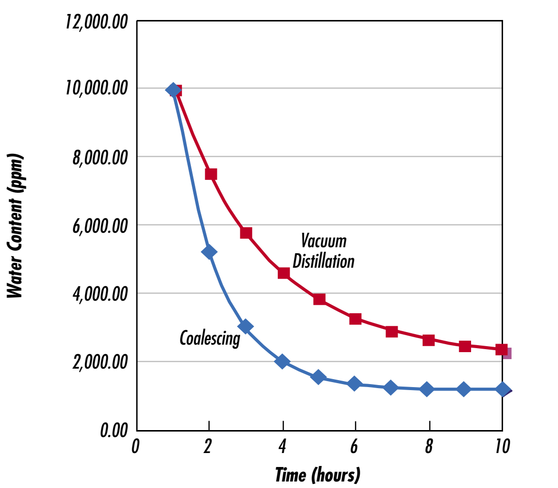
In a steam turbine where the potential for a sudden water ingression exists, a system that can remove water rapidly and attain the dryness manufacturers specify is needed. The "true" vacuum distillation system and the coalescing system seem to offer the best possibility from any practical viewpoint. But which is better?

We have developed a model that predicts water concentration over time for a lube oil reservoir with a constant water ingression. While leak rates in a new steam turbine can be almost nonexistent, they can gradually increase over the turbine's life. For this reason, protection is critical. In the model, a bad leak in a steam turbine is three gallons over one hour. Such a leak without adequate filtration could severely limit bearing life if not corrected. To enhance the comparison, the leak rate was increased to six gallons over one hour. The next step is to examine what would happen in the two systems under consideration: vacuum distillation and coalescing.

The model considers several parameters to be input as the systems specify their capabilities or as testing would reveal. Inputs to the model considered are:

- *Water Ingression in gpm*
- *Flow Rate in gpm*
- *Estimated Water Removal Efficiency*
- *Initial Water Concentration*
- *Volume of Oil in Reservoir*
- *Water Solubility of Oil*

FIGURE 2
COMPARISON FOR TURBINE OIL CONDITIONING



Source: Kaydon Custom Filtration

In gpm, the rates do not seem excessive, but they could overwhelm the steam turbine's lubrication system if not treated effectively.

In the comparison, the published best numbers for both vacuum distillation and coalescing along with the best flow rated systems for an average reservoir size of about 7,500 gallons are used. Figure 1 shows the "bad" leak comparison – 3 gallons per hour, or 0.05 gpm for a reservoir of 7,500 gallons with a 50 gpm vacuum system available to the market and a 100 gpm system for coalescing. But typically, vacuum distillation manufacturers will recommend 30 gpm for this size reservoir, significantly undersized. Efficiencies are 95 percent for vacuum distillation and 98 percent for newer, improved coalescers.

Figure 1 shows how coalescing can better handle the water ingression. Making the water ingression even worse, differences are more exaggerated in the comparison.

A standard best capability coalescing system for the reservoir size, rated at 100 gpm, and a standard best available vacuum distillation system at 50 gpm were used. Industry standard typically recommends turning over the reservoir once every two hours. The cost of a 100 gpm vacuum system could be more than double the cost of the same flow-rate for the coalescing system.

Now examine the next scenario – six gallons of water in an hour, or the equivalent of 0.1 gpm over the test run (Figure 2). The difference between the two systems' capabilities has grown and will continue to grow as the amount of water coming into the system increases.

The model, as such, is not perfect, but the graph clearly shows in what way the coalescing system, for the investment, beats the vacuum system in process rate for water removal. The vacuum system cannot handle the type of severe ingression that threatens the life of steam turbine bearings and the uptime on the turbine itself. PE

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