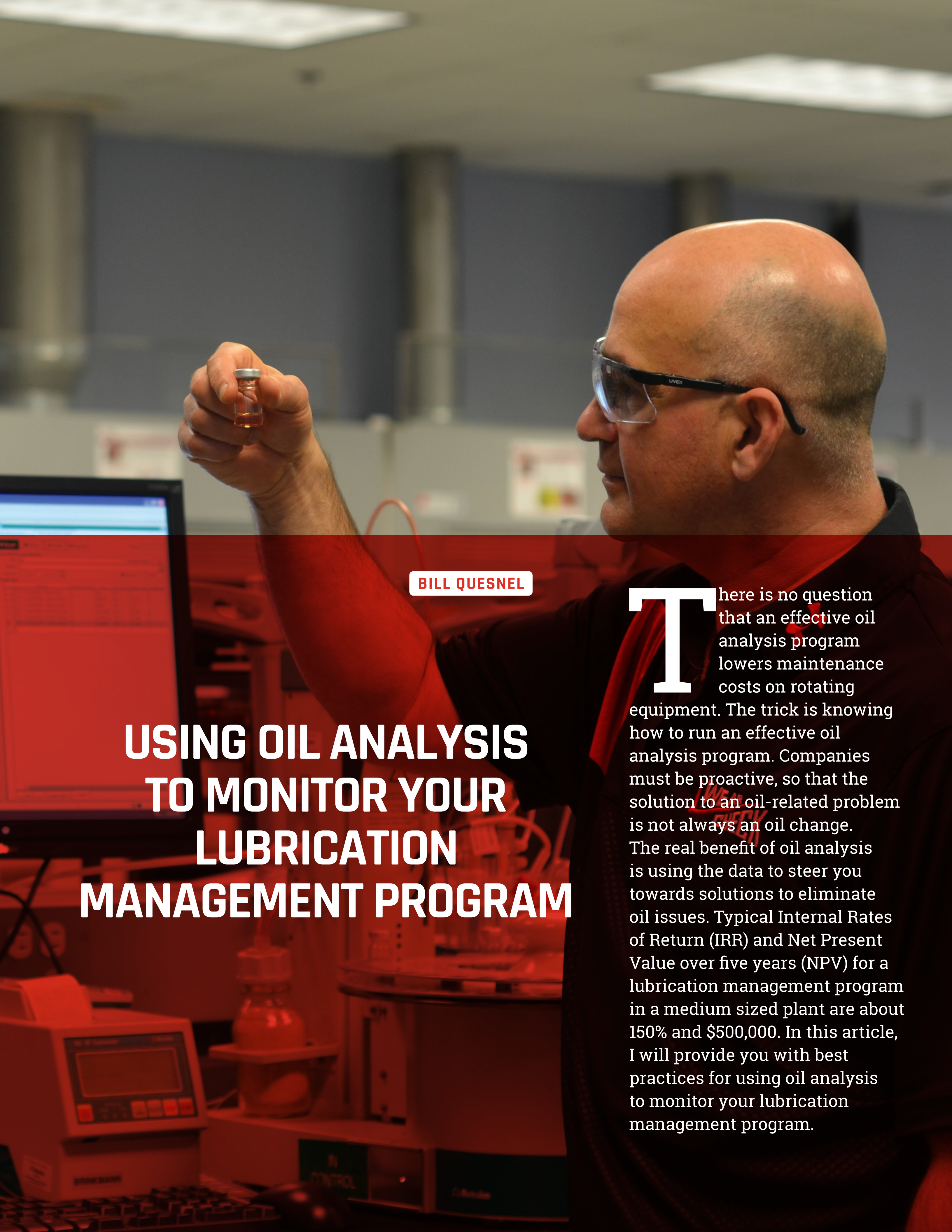


BILL QUESNEL

USING OIL ANALYSIS TO MONITOR YOUR LUBRICATION MANAGEMENT PROGRAM

There is no question that an effective oil analysis program lowers maintenance costs on rotating equipment. The trick is knowing how to run an effective oil analysis program. Companies must be proactive, so that the solution to an oil-related problem is not always an oil change. The real benefit of oil analysis is using the data to steer you towards solutions to eliminate oil issues. Typical Internal Rates of Return (IRR) and Net Present Value over five years (NPV) for a lubrication management program in a medium sized plant are about 150% and $500,000. In this article, I will provide you with best practices for using oil analysis to monitor your lubrication management program.

GETTING STARTED

Are you waiting until you've implemented basic lubrication management strategies before taking those first oil samples because you know the results will likely be bad? Don't hesitate to start your program. You will likely see many problematic oil samples, but that is no reason to delay sampling. Oil related problems are opportunities for your lubrication management program. The worse that the problem is, the better the opportunity for a cost-effective solution that will mean big savings to your maintenance budget bottom line.

Start sampling before you begin making improvements to establish baselines on the condition of your lubricants and lubricated equipment within the plant. Additionally, the initial oil analysis results will provide you with direction in terms of the solutions that should be implemented, and on which machinery.

WHAT TO LOOK FOR

When you receive your first oil sample results, you will most likely see a number of abnormal sample reports and possibly even some critical sample reports. Let's start with these. The main issues to watch for are water contamination, high levels of oil particulate, improper oil top-up and poor oil condition.

It's possible that you will have sample reports showing abnormal or severe wear in some machines, but the purpose of establishing a lubrication management program is to maintain proper lubrication to avoid unnecessary wear. So let's assume your reliability team is assessing these reports and has the situation in hand, so we'll focus on the oil-related problems.

Let's focus on water and dirt for starters. Water will show up on your sample report as "water" or "H2O". Are these results abnormal or severe? At this point, you have not set any alarm levels for water contamination, so it is fine to use the laboratory defaults for your industry and type of machine. With most rotating equipment, the contamination limit for water will be 0.1%. Limits range as low as 0.03% for turbines, and as high as 0.2% for gearboxes. Some compressors using certain synthetic oils go as high as several percent water.

Dirt will show up on the sample report under silicon (or Si) along with the other elemental data for wear and additives. If you are sampling machines with oil filtration, the laboratory should perform particle count testing. Ensure that you are purchasing the correct test kits for this type of machinery. Pay attention to the ISO Cleanliness Code ("ISO" or "ISO 4406" on your report), as well as the particular particle counts by micron size (namely >4µ, >6µ and >14µ). Abnormal or severe silicon levels and/or particle count results indicate a problem with contamination. Again, the laboratory will be using typical industry limits for silicon and oil cleanliness, which is fine when you are starting your oil analysis program. Typical silicon alarm levels for most equipment are around 25 parts per million (ppm) and ISO cleanliness codes for filtered systems are typically around 19/17/14.

Improper oil top-ups are a bit more difficult to detect, but you should look for comments about changes in the elemental additive levels (phosphorus, zinc, magnesium, boron, barium, sulphur) and monitor any changes in oil viscosity that are +/- 10% from the oil specification. Elemental additive levels in ppm can fluctuate as much as +/- 25%, so a laboratory is looking for other

1 WATER CONTAMINATION	2 HIGH LEVELS OF OIL PARTICULATE	3 IMPROPER OIL TOP-UP	4 POOR OIL CONDITION
Water (H2O): >0.1% **Free Water:** >0.5% **Ferrography:** Ferrous Red Oxides (FRo)	**Silicon (Si):** > 25 ppm **ISO Code:** +2 above target cleanliness code.	**Viscosity:** +/- 10% **One or more of Boron (B), Barium (Ba), Molybdenum (Mo), Magnesium (Mg), Phosphorus (P), Zinc (Zn) :** +/- 25%	**AN:** +1.0 mg/KOH from base **RPVOT:** <25% of new **Oxidation:** >0.20 Abs/.1mm

MAIN OIL RELATED ISSUES - Listed above are the most common oil related issues uncovered by oil analysis and general warning limits.

elements that shouldn't be present, or the lack of an element that should be present in the oil. Some laboratories have very sophisticated algorithms that not only compare the used oil to the new baseline but can determine the fluid type and compare this to the generic fluid type for the oil you have specified. They can alert you when a different type of fluid is being used. You may want to inquire whether your laboratory has the ability to perform this level of comparison.

The most blatant types of improper oil top-up or incorrect oil use is when the viscosity varies drastically from the specification. For instance, when you state that you are using an ISO 320 gear oil and the oil viscosity is actually 100 cSt, which indicates a possible top-up with hydraulic, compressor or circulating oil.

For most lubricated plant machinery, oil condition is monitored using the Acid Number (AN) of the oil. When the oil oxidizes, it forms acidic degradation products. Increasing AN indicates oil degradation and once the AN is over the limit for the oil, it's time to schedule an oil change. Large systems like turbines require more advanced testing, including rotating pressure vessel oxidation testing (RPVOT), water separability, rust characteristics, foaming characteristics and air release to determine if the oil is suitable for continued use.

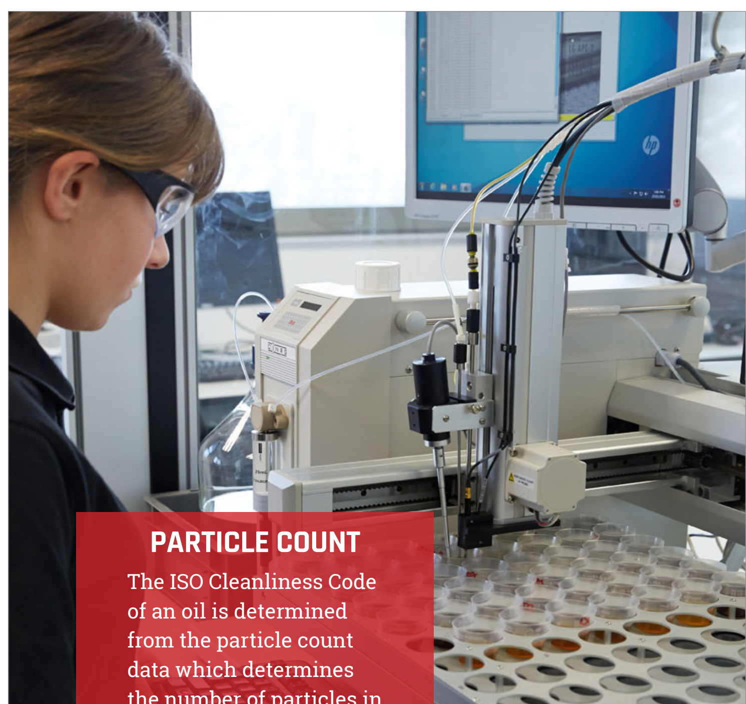
HOW TO CORRECT PROBLEMS

So the oil analysis found some problems. Now what? Realize these oil related problems are opportunities for improvement in the lubrication management program. Most of the suggestions here are low cost and provide a high rate of return on investment. A lot of these suggestions can be implemented within a short time and don't require a huge capital investment. So the sooner you get started, the sooner you'll improve the bottom line on your maintenance budget.

Rated desiccant air breathers are the simplest place to start. Air breathers are an easy-to-implement, low-cost solution for preventing water and particulate from entering lubricated machinery. Air breathers reduce the moisture levels in lubricants, where the oil analysis results are showing 0.2% or less water contamination. Desiccant air breathers dry the air that enters the machinery during operation and also dry the head space in reservoirs, which migrates moisture out of the oil. The result is drier oil. Additionally, these air breathers have a rated micron filter that cleans the air. The result is cleaner oil.

For very large systems, dry gas blanketing may be an effective option, especially when there is a readily available source of inert gas present (such as in refineries). A 1-2 psi feed of dry nitrogen into a turbine reservoir, for instance, creates a positive pressure that prevents the introduction of contaminants. The dry gas causes moisture to move out of the oil and into the head space, where it is exhausted externally.

For systems with major water contamination issues (0.5% or more water in the oil), a more involved solution will be necessary. Start by ensuring that all machine hatches and inspection ports are properly sealed. Upgrading of seals may also be necessary. To remove water contaminations between 0.3% and 2.0% on smaller systems (less than 15 gallons of oil), consider using an off-line filtration cart outfitted with water adsorption filter media. If there is too much water, you run the risk of spending a lot of money on filter elements. A bit of consultation with your filter cart provider can help you assess the situation first. If the water contamination issues are chronic (e.g. leaking cooler) and these are large systems (greater than 100 gallons), you need some serious equipment, such as a vacuum dehydrator



PARTICLE COUNT

The ISO Cleanliness Code of an oil is determined from the particle count data which determines the number of particles in 1ml of oil at greater than 4, 6 and 14 microns.

VISCOSITY

The viscosity of the oil is measured on a kinematic viscometer bath at 40°C to determine the ISO viscosity grade.

or by-pass centrifugal filtration system. In this case, you will be investing $25,000 to $100,000.

Particulate contamination can be easily managed with proper lubrication, drain ports and off-line filtration. Purchase an off-line filtration cart that best suits your application. Hydraulic filter carts are fairly straightforward and low cost. Gearbox applications require heavy duty equipment and some time should be spent to ensure that the filter cart has the proper specifications for the application. The addition of lubrication and drain ports to machinery that will be part of your off-line filtration program are essential, as these ports feature quick connections to allow maintenance technicians to easily hook-up a filter cart, and to perform oil top-ups and changes without having to remove fill and drain ports. Additionally, a rated desiccant breather can easily be affixed to the lubrication port, further reducing particulate ingression.

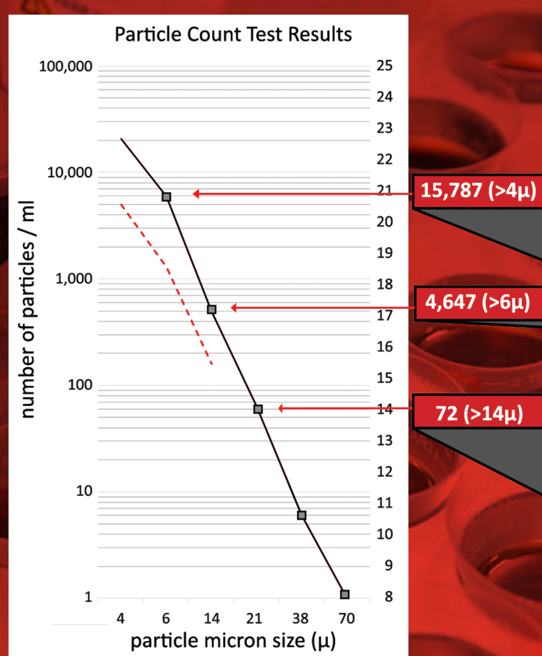
Controlling improper oil top-ups can be easily managed. Start by installing proper lubrication porting on equipment to make oil top-ups easier and provide the right kind of dispensing equipment to empower your lubrication technicians to do the job properly. If you give your maintenance staff the right tools,

UNDERSTANDING THE ISO CLEANLINESS CODE

The Fluid Power Association has shown that 70-85% of hydraulic component failures are due to particulate contamination. As a result particle count testing is of particular importance to clean oil systems. Particle counting instruments count all the particles in the oil including wear particles, process and environmental contaminants.

Particle counters count particles within size ranges, the standard ranges being defined between 4, 6, 14, 21, 38 and 68 microns, usually reported as “greater than ‘x’ microns” with units of number of particles per 1 milliliter (ml).

The number of particles for 4, 6 and 14 microns is reported for the sample using a scale of xx/yy/zz for 4, 6 and 14 microns respectively known as an ISO 4406 Cleanliness Code. Different types of equipment and applications will have different cleanliness levels. The ISO 4406 Cleanliness Code table is based on a doubling of particle concentration for each ISO level, with increasing numbers indicating an increase in particle concentration.



ISO 4406 CLEANLINESS CODE

ISO Code	More than	Up to
25	160,000	320,000
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	4	10
9	2.5	4
8	1.25	2.5

The example depicted shows a 21/19/13 ISO 4406 Cleanliness Code.

they will do the job the way you intended them to. Oil identification tags can be easily attached to lubrication ports and use color and/or symbols to identify the lubricant to be used. Dispensing equipment, like OilSafe dispensing jugs are available in 10 different colors to match. With some basic on-site education on lubrication, your oiling crew is now armed with the tools and knowledge to do the job right.

If the sample report indicates poor oil condition (not contamination), you should schedule an oil change when it is convenient. If this will be an expensive oil change (more than $5,000), it may be prudent to invest in advanced oil testing to determine if an oil change is required immediately or whether the task can be put off for three months or more. Unlike contamination, in 99% of cases, when the oil condition is a problem, you need to change the oil. If you want a better indication of what is happening with the oil, you can request Membrane Patch Colorimetry (MPC) testing for varnish potential and Linear Sweep Voltammetry (LSV or RULER) testing to determine the exact amounts of antioxidant remaining in the oil.

MONITORING YOUR LUBRICATION PROGRAM

Now that you've implemented the solutions, what should you be watching for on your oil sample reports? Once you've properly sealed your reservoirs from contamination, the moisture and particulate levels should start to come down. Within six months, these levels will reach their minimum and it is worth noting the change from the baseline samples and set reasonable targets going forward.

For instance, let's say the water level in your gearbox was initially 0.15% and the ISO Cleanliness Code was 22/20/18 and six months after adding rated desiccant air breathers and an off-line filtration cart program, your moisture levels are 0.03% and ISO Cleanliness Code is 20/18/16. You should inform your laboratory that you want to set new alarm limits on these gearboxes. Set the ISO Cleanliness abnormal alarm at 22/20/18 (two codes above the new average) and the critical alarm at 23/21/19 (three codes above the new target). For moisture, set the abnormal alarm at 0.05% and the critical alarm at 0.10%. Now when you receive abnormal or critical sample reports (based on the water or particulate level), you'll know what corrective action to take – change the desiccant air breather and/or run the off-line filter cart for several days and resample.

If you use oil identification tags and have invested in appropriate dispensing equipment, you should no longer see significant additive changes (more than +/- 25%) or viscosity changes (more than +/- 10%) unless the oil condition is also suspect. When you do see a dramatic change, you need to ensure that any new maintenance staff are properly educated about preventing oil mixing and have been properly trained regarding the use of dispensing equipment. If training is not the issue, you may have an improperly identified oil delivery and should take samples from the suspected totes or barrels.

GAUGING SUCCESS

If you have been using the oil analysis data to track oil related issues in your plant, subsequent management reports should show a decreasing trend in the water, particulate and incorrect oil usage statistics.

If you have decreased the moisture and particulate levels then you've increased the mean time between failures (MTBF) for those machines. In the example above, the gearbox should see an increase of approximately 1.25x based on the moisture reduction and 1.25x for the particulate reduction, which means more than a 50% increase in MTBF. That is significant.

Regarding oil mixing, not all incorrect oil top-ups result in lubrication issues, but in several instances, serious damage can be incurred. Adding less than 1% of an emulsifying oil (an oil that is designed to hold water in suspension) will destroy the demulsibility of an oil formulated to separate from water (i.e. bearing circulating oil, turbine oil). Machines with bronze components should not use common extreme pressure (EP) additives. Topping up such a machine with an EP gear oil will not only increase the viscosity but will lead to corrosion of any bronze components long after the problem has been detected and the oil has been changed.

The investment in fluid identification and proper dispensing equipment, and most importantly, in training and education, will drastically reduce the incidence of incorrect oil top-up. It's more difficult to put numbers to the savings,

CASE STUDY - INCORRECT OIL USE

Sometimes the consequences of introducing an incorrect oil into a system can be disastrous. This case study is from a power turbine unit in a hydro-electric power plant. The oil analysis sample indicated a sudden drop in oil viscosity (Chart 1), with a sharp increase in the tin level (Chart 2). At the same time the Acid Number (AN) level jumped up significantly as well.

The maintenance engineers suspected that the improper oil was used to top-up the unit. The additive levels are shown (Chart 3) and it is evident that the additive levels had changed significantly indicating an oil mix-up. A filter debris patch was produced from the oil but did not show signs of large wear particles. It was suspected that the incorrect oil may have caused some corrosion to the thrust bearing.

Maintenance decided to shut down the unit during a planned outage, change the oil and inspect the bearing. During inspection it was apparent that some flaking had occurred to the thrust bearing (Figure 1). It was decided that the bearing would be put back into operation and repaired at the next shut-down since that outage was to be longer and would provide the necessary time to repair the bearing.

The unit continued to be operated, and eventually, as the bearing began to fail, the vibration in the power turbine unit became so excessive that it shook the plant and caused a number of machines to move on their mountings. The end result was a forced shut-down of the plant for three months to re-mount all the equipment (and to repair the thrust bearing on this power unit).

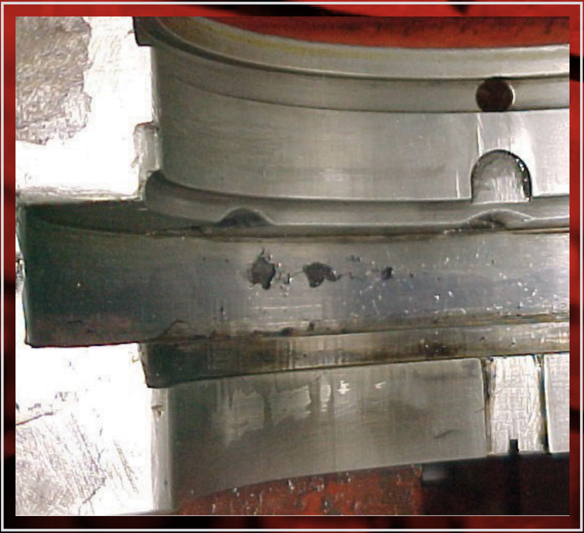


Figure 1

Chart 1

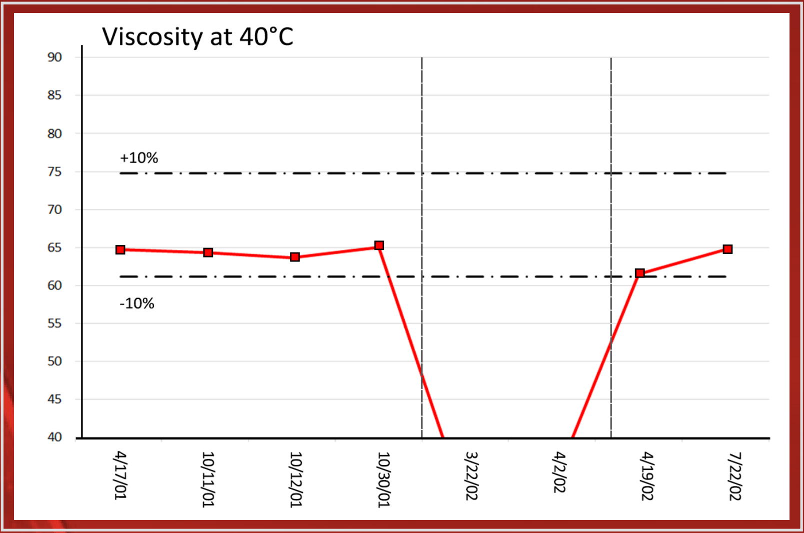


Chart 2

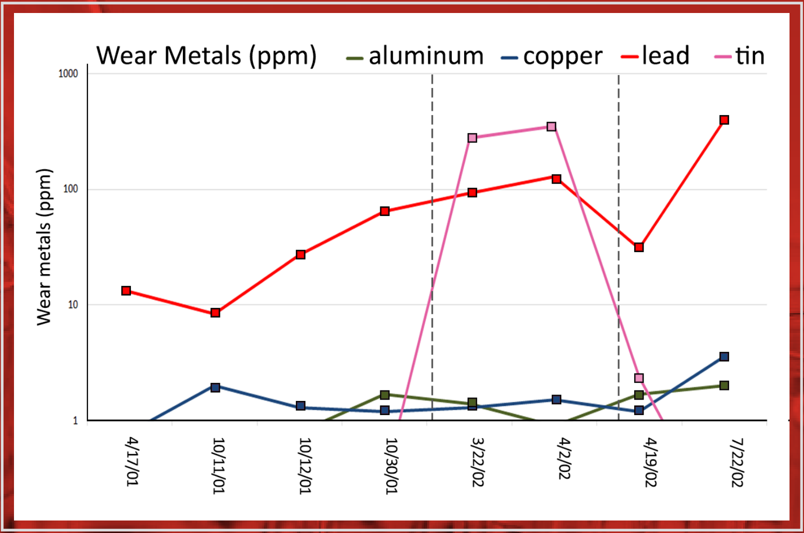
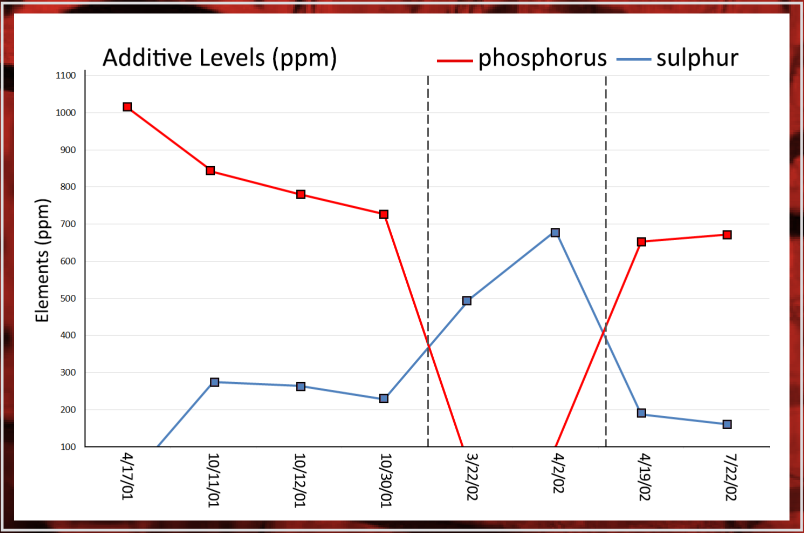


Chart 3



CASE STUDY - WATER CONTAMINATION

This case study illustrates the effect that water ingression can have on an oil's degradation rate. In this medium sized gearbox in a pulp & paper mill, the ingression of a large amount of water is a likely situation. In fact the sample history shows two occurrences of significant water ingression (> 2.0% water) over a period of 3 years.

Each time the water ingression is present, the Acid Number (AN) jumps dramatically over the subsequent sample interval (Chart 1).

The effect of water ingression on the oil is further exacerbated by the presence of Extreme Pressure (EP) additives in the oil. The combination of water with these corrosive EP additives causes a rapid increase in acidity level in the oil and the subsequent attack of the oil on bronze and Babbitt components. This is evidenced by the increase in copper, aluminum and lead levels after the second serious water ingression (Chart 2)

Chart 1

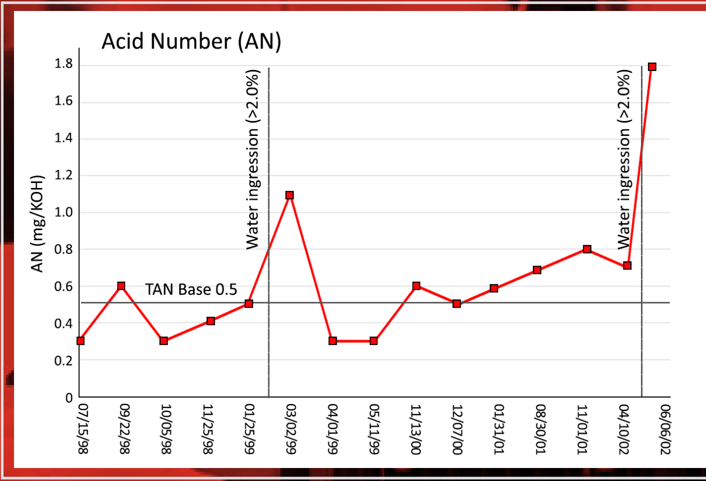
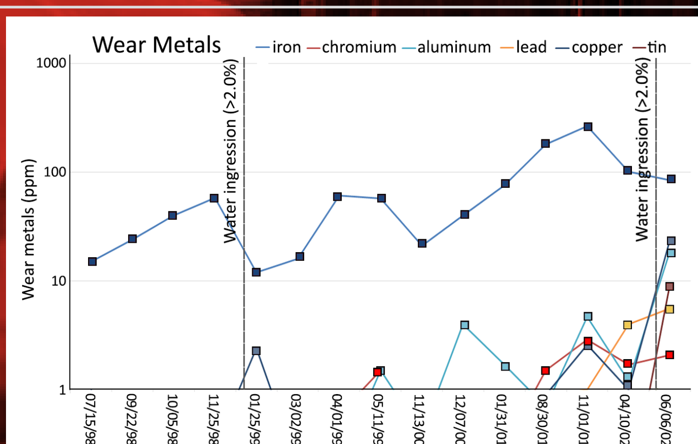


Chart 2



but any averted catastrophe warrants the improvement.

> Your initial investment in lubrication management has likely eliminated 80% of your oil related problems. The next 20% is going to take a lot of continual effort.

NEXT STEPS

You've no doubt improved your lubrication program several orders of magnitude. As I mentioned earlier, typical internal rates of Return (IRR) and net present value (NPV) over five years for a lubrication management program in a medium sized plant are about 150% and $500,000.

Next steps involve submitting a proposal for capital expenditure. Invest in a world-class lubrication room complete with an advanced oil storage system, cabinets and lubrication handling carts. Replace the off-line filter cart program with permanently mounted filtration systems on critical equipment. Augment your standard oil analysis program with an advanced oil monitoring program for critical machines and machines with large oil sumps (in excess of 250 gallons/1000 litres).

As you continue to improve the condition of your lubricants, revisit your wear, oil condition and contamination alarm levels and tighten them up. Your initial investment in lubrication management has likely eliminated 80% of your oil related problems. The next 20% is going to take a lot of continual effort. To eliminate remaining problems continue to look for incremental improvement throughout the plant. It is essential that you continue to educate yourself on lubrication best practices and continue to seek opportunities for improvement to your lubrication program. Remember, world-class is a moving target, so my advice is to get started now.