ASTM D4304 and ASTM D6158: Cleanliness is tested as total insoluble, and the maximum cleanliness by particle count is not stated there.
ASTM D6224 and ASTM D4378: Recommend for check, but the limit of fresh oil is refer to OEM.

ASTM D6224-09 Standard Practice for In-Service Monitoring of Lubricating Oil for Auxiliary Power Plant Equipment. standard by **ASTM** International, 07/01/2009

ASTM D4378 - 13 Standard Practice for In-Service Monitoring of Mineral Turbine Oils for Steam, Gas, and Combined Cycle Turbines

Unless otherwise specified by the OEM, I recommend you to use the in-service limit:
* 17/14 for hydraulic (ASTM D6224)
* 16/13 for turbine (ASTM D4378)
* 22/18 for gearbox (ASTM D6224)

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Philip Johnson I would be a little sceptical of the oil analysis 21/20/18 which is really high especially for the 14 micron particles. I would normally expect to see at least a 5 point spread between the highest and lowest count, so it may be the counter is counting additive or discolouration. Even relatively simple hydraulic circuits should be below 18/16/13 and if you have any kind of expensive pump or control valves I would probably be recommending ISO 16/14/11.
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When using a kidney-loop cart to filter oil, plumb the cart's filters in series. As the primary filter catches debris and starts to plug, the pressure drop across the filter increases. This increase in pressure differential can push previously captured debris through the filter. The secondary filter ends up having a lower pressure differential because most of the debris is captured by the primary filter. This differential allows the secondary filter to retain more of the debris it captures. The secondary filter also acts as a "safety" filter in case the primary filter ruptures. (Paul Tokach, Butler Machinery Co.)

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Recommended ISO cleanliness level for industrial gearboxes

Nick Bokatzian

In a gearbox I prefer using the PQI (particle quantifier index), versus particle count, to trend abrasive wear metals and predict catastrophic failure. Using both would be great but too expensive. Trending the amount of growing iron by comparing amounts 6-8 micron/w ICP (benign wear) and larger particles unseen by ICP >10 micron in PQI (advanced failure mode/catastrophic failure). Darker colored oil is no problem as PQI uses a sensitive magnetometer to measure ferrous density. 1/2 the price of PC which also counts soft materials in the oil that do not necessarily lead to wear.

Nicholas Kominos

I usually recommend ISO 21/19/15, but most of the time it is difficult to maintain this cleanliness during operation.

The accuracy of ISO cleanliness testing of dark coloured gear oils: it produces false positive results.

We always follow up used gear oils with elemental, PQ index, ISO particle count, TAN, viscosity at 40 C and water content.

We offer this to our customer with a very competitive price, max. 40 € per sample.

If there is an indication of abnormal wear, or when we do not detect metal particles at all, we then perform an analytical ferography.

I fully agree that the target has to be set for an oil that is as clean as possible.

I think that from now on I will always recommend additional kidney loop filtration for critical units and desiccant breathers.

I will also target for ISO Cleanliness as close as possible to 19/17/13.

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Jean-Michel Demaret

An easy test to check how dirty is your new oil. Find a clean solvent (in the ISO 8/10 range). Mix 3 parts of solvent for 1 part of oil. Shake, shake shake. The solvent dissolves the additives. Perform another particle count with the oil and solvent and add 2 digits to your result (for example you get a reading of 11, the ISO value of the oil without solvent is 13 (11+2). You get a real value, how much insoluble contaminant is in your NEW oil, and this is what you are interested with.

James Kukulski

To obtain cleaner oil you can request it (at a higher cost) from your provider. Or you can filter it on sight. Depending on the application and amount of oil there are many ways to do this. For polishing oil to below 16/14/13 in larger quantities a large depth media filtration unit with 3um beta 1000 filters does wonders. With a minimum of ten full passes of the lubricant. Smaller filtration does an OK job of keeping the oil at an ISO PC for transfer. It's important to keep in mind that every time you transfer oil, you raise the PC by at least 1 level, if not more. Also, proper storage is imperative. Even sealed containers can condense h2o. Keep it clean and dry.

As much as 80% of lubricated machine failures are lubricant related. If you keep an assets lubricants clean and dry, your assets will live forever.

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Q: Our filter supplier has recommended reducing the micron rating on our full flow filters from 10 micron to 3 micron. We're concerned that we'll have to replace our filter more often if we do this. What would you recommend?

A: It's a common misconception that finer filtration will cause a filter to plug up faster. The reality is that if the system is in balance, meaning that all sources of ingression from the breather to the fill port are sealed, using finer filtration often causes a filter to last longer. While this may seem counterintuitive, it's because once the ingression rate has been stabilized, the only source of contaminants is internal - usually generated by other contaminants. So if the system is kept cleaner, there's nothing to generate more debris and hence nothing to plug the filter.

Having said that, you still need to be careful because a finer filter will often reduce the flow rate, meaning you may need to purchase larger filter housings/elements. This is one of the reasons why bypass or kidney loop filtration is recommended. Since kidney loop filters won't starve the main circulating lube lines, bypass filtration systems can be equipped with finer filters. They also tend to filter more efficiently since flow rate are typically much slower.

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Why is Si considered a contaminant in lubricants?

John Neale

In metal working lubricants silicon can effect subsequent coating processes of parts. It can cause defects in paint or plating processes.

Benny Bernard

You should make a difference. John mentioned **siloxanes, very often used as defoaming agents, and they may cause troubles in painting. Organomodified siloxanes are allegedly free of this potential failure but are also significantly more expensive.** But, silicone present as **silica (SiO2) of course is very hard and abrasive.** You can also meet with **sodium metasilicates as corrosion inhibitors in metalworking fluids**, but they do not act as siloxanes.

Ameet Sevekar

Si (mostly from dust) is very hard, abrasive particle directly responsible for wear of metal parts thereby affecting relationship between metal parts. Simply put, when Si is present, it may cause rotating/sliding part to wear/increase clearances in those parts & create debris. This in turn will have effect on oxidisation of oil & reduced life of metal parts.

Roy Fewkes

As was mentioned previously silicones are often contained in formulations as anti-foam agents and one has to be careful not to confuse those with Si contaminant. When carrying out analysis one should observe a new oil sample which may often indicate **up to about 7 ppm of Si that may be anti-foam**. It is also good to note any reduction in that level as indicative of a potential foam problem due to anti-foam depletion due to **other forms of contamination removing the anti-foam, such as water**. An increase in the Si content however does indeed signify contamination from some other source.

Jean-Michel Demaret

Some mineral like Si may be part of the formulation but it can also be a contaminant (dust). The labs are not able to differentiate the additives and the contaminant. So they give the label contaminant to silicon particles . Silicon dioxide (silica) is very abrasive.

If the silicon appears with aluminium or calcium, it is likely dirt ingress, If there is no apparent sign of metal wear (iron, chromium...), possibly the dirt was added to the sample (check sampling technique). if you have silicone and metal wear you have a problem. If you have silicon only and no wear possibly the silicon is **silicone (seal paste, gasket)** leached out by the oil.

Iván Regalado

Typically, natural relation between Si and Al is 10 ppm / 3 ppm (PRV: in dust). If ppm of Al is higher maybe wear is existing.

Satya Prakash Pathak

Si is considered as contaminant in the lubricants as it acts as abrasive particle which increases the wear in the engine and in the hydraulic equipments. You may find many of the hydraulic pump failure is because of the external contaminants (Si is one of them). Also silicon is used in many additives and seals. So it's important to understand the source of the silicon in the lubricant before giving any comments.

Roy Fewkes

I could be wrong but I think that what Mr Regalado is referring to is the relation of Al to Si that one would normally expect in a typical Aluminium alloy. In which case any wear would naturally show as an increase in Al and a corresponding increase in Si.

Iván Regalado

Hello, When I Wrote Si, I was trying to refer to "Silicates", According the Silicate´s molecules, Al as AL2O3 is present in 0.3% aprox.
In addition; and unfortunately; many times silcates and confused with silicones, **silicones could come from seals**, and of course some ppm to avoid foams(i.e gears oils).
It would be good practice compare same "fresh oil" Vs "used oil"....i.e and my previous example:
* If fresh oil has 3 ppm of Silicates and used oil has 10 ppm, then 7ppm were introduced as contaminant.

* Regarding Al: if a sample has 10 ppm of silicates and 5 ppm of Al , 2 ppm could have been created due to wear.

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http://www.stle.org/resources/articledetails.aspx?did=1816 - Reducing the Varnish Tendency of a Group II Base Oil by Increasing the Solvency

https://www.stle.org/resources/articledetails.aspx?did=1720 - Interpreting Results for the New ASTM Standard for Varnish Potential

http://www.youtube.com/watch?v=NG-iWUgpvcE - oil filters

Ghasem Shilati Technical Manager at Naham Pala Engineering CO.

Pulsating hot oil flushing is a new technology for more efficient hydraulic pipes cleaning. Anybody has experience?

https://www.linkedin.com/pulse/pulsating-hot-oil-flushing-technology-ghasem-shilati

Vibhushit Dave

I have heard about it but In India as far I know no one has used it. I would like to know more about it, if you have any more information.

I know that compressed air is introduced in the oil at intervals which generates the pulsation and generates very high turbulence than the conventional method of high flow pump.

Do let me know on my mail ID hymatservices@yahoo.co.in

Ghasem Shilati Technical Manager at Naham Pala Engineering CO.

I am not agreed for injecting air due to oil aeration and consequent foaming effects.
We have started designing a pulsating oil flushing unit by aid of hydraulic accumulators.
I appreciate any idea which help us improving our initial design.
Our calculation shows by this method Reynolds number can increase instantly up to 10 times!

Vibhushit Dave Proprietor at Hymat Services

Wow. Thais is also a good idea. Only a proper control of release of extra oil from Accumulator is needed. Can you throw some more light on it ? Have you already developed such system ? i will be interested as I am in this system Flushing and Oil filtration business in India since 2001.

Ghasem Shilati

I was in charge of oil flushing and chemical cleaning for more than five years. Now we are trying develop a new unit based on pulse technology for doing the job more efficiently.
Based on my experience oil flushing by even Reynolds number more than 5000 is almost wasting time specially for pipe sizes more than 3 inches. Because existing boundary layer just near the pipe inner wall is about 1mm thickness. It means for big diameter pipes oil flushing without a well done chemical cleaning, is useless!
Theoretically pulse flushing method can be an ideal solution while you can produce very high flow in a matter of seconds (more than 20,000 Re) which breaks boundary layer instantly and stacked particles on pipe wall suspend in oil flow.
Let us complete our design and make a unit. You will receive good news soon!

Robert Bowden, CLS RWB Consulting LLC, CEO

I too am interested in your system. The thing I would be most concerned about is potentially damaging things with the pulses. Don't forget about the POWER of hydraulics. Thermocouples, small pipes that penetrate the system for data collection, or other things, could very easily be destroyed during some of these high RN pulses. Also some things are designed and structrually stressed for laminar flow, so they may not be supported well enough for high RN pulses.

Of course you also need to determine what it is that you are trying to dislodge with the pulses.....is it sediment, or varnish?

Ghasem Shilati Technical Manager at Naham Pala Engineering CO
My practical experience says most of oil flushing projects are just oil circulation for achieving an ISO code without attending the real facts. I believe flushing based on Re>3000 is just a big mistake specially for pipes diameter more than 3 inches. For big diameter pipes a thick boundary layer prevents any contact between turbulent flow and pipe inner wall even with Re> 6000 . That's why chemical cleaning is so important for big diameter pipes.

After all, system we are designing has protections against hammering with controllable pulses. So there is no risk of damages for pipes under flushing.

Paul Anning Analysis & Improvement Engineer

Not so sure it is a new concept. As far back as the late 90's we had a high velocity flushing rig on which we had installed a purpose manufactured full bore reverse flow valve. (expensive little item) We could generate a flow in one direction then reverse it. We always made sure we had an Re as high as possible, much much higher than 4000. A trick used not only by us but others, was to thermal shock into the system. This is easily achieved by periodically turning on an appropriate cooler to drop the temperature rapidly thus contracting pipework and breaking loose scale etc. I can see not reason to "pulsate" the oil other than your equipment is not large to generate massive Reynolds Numbers you actually need. (Not talking about just over 4000 - I mean at least 5 to 10 times that) A big Re should provide more than enough turbulence and maybe even pulsation. Likewise, it depends on what you are removing. Over the many years of experience in this area I am convinced the quickest is to chemical wash, passivate and then high velocity flush. And of course it depends on the contamination to be removed. It is is oxidation etc, no matter what Re you generate your success is limited.

Vibhushit Dave

You have mentioned " Based on my experience oil flushing by even Reynolds number more than 5000 is almost wasting time specially for pipe sizes more than 3 inches. Because existing boundary layer just near the pipe inner wall is about 1mm thickness." but I have a doubt. First of all Flushing oil viscosity is relatively low viscosity oil than the Normal Operating Oil and this flushing oil is also heated up to 60 Deg. Cent so during flushing operation the flushing oil viscosity goes down further. This ought to reduce the boundry thickness to a great extent and high Turbulance (Re >3000 / 4000) will clean the pipe. What is your view ?

Ghasem Shilati Technical Manager at Naham Pala Engineering CO
All the methods you mentioned are common in flushing projects. Reversing oil direction or providing thermal tensions or hammering on pipes are very effective but not quite enough!
After all pulse technology is not a completely new concept. At least it has been executed by one Norwegian company.

Dave,
Re number is without dimensions. It means oil viscosity and temperature is being considered for Re calculations.
I have seen and touch so much dirt and particles in pipes under flushing without a well done chemical cleaning. In one case we made 12,000 Re for a 8 inches pipe but without good results due to ineffective chemical cleaning!

Vibhushit Dave

So Pulsation Technology will also need Chemical Treatment - That is what I infer from your message. Am I right ?

Ghasem Shilati Technical Manager at Naham Pala Engineering CO.
Exactly right. I believe chemical cleaning has a major role after piping installation,just before commissioning. Chemical cleaning solves all stains and weld derbies which can not be moved by even 20,000 Re flow. On the other hand oil flushing is still so important.
Here we are NOT proving ineffectiveness of conventional methods. We are trying developing new technologies for better results!

Vibhushit Dave

Could you throw some light on th chemical cleaning process followed by you ? Chemicals used and steps followed. You can send me more details on my mail id hymatservices@yahoo.co.in

Ghasem Shilati

Here are the summary.

1)De-greasing by Tri Sodium Phosphate and Soda.
2) Acid washing by hydrochloric Acid and inhibitors.
3) Neutralizing and passivation by Ammonia, Sodium Nitrite, and Citric Acid.
4) Final washing by DM water and drying.
5)Oil flushing.

Vibhushit Dave

Instead of Hydrochloric Acid how about Oxalic Acid (3 to 4 % by wt of 99% purity)? I understand it is less damaging. Has any one used it ?

Ghasem Shilati

I prefer Citric acid which is so safe and user friendly! The only disadvantage is heating source in order to maintain solution temperature about 85 degree centigrade along with longer cleaning

time.But the final result is perfect.
Please DO NOT forget the title of discussion. Better you open a new discussion for chemical cleaning!!

Theres this company called Kleenoil which **claims to extend oil life by filtering out contaminants down to 1 micron.**
1. Is there any risk of additive depletion by using such filtration systems?
2. Is this type of filtration relevant to slow down the process of TBN depletion / Nitration in case of gas engines?

A: Never seen in gas engines. Other:

Steve Cook Sales Manager at High Purity Northwest, Inc.

In my experience I have not seen additive depletion when filtering down to 1 micron (ß2.5[c]=1000). However, filtering to such a level is overkill. The best practice is to filter to the OEM's recommended ISO cleanliness code. Keep varnish, moisture, TAN and particulate in check is the best way to extend oil life.

Don McNeil Industrial Sales - STLE Certified Lubrication Specialist at Apache Oil Company

In my experience filtering below 2 micron is overkill and is not recommended or supported by any OEM that I am aware of. This is because some additives can be removed at 1 micron. The recommended ISO cleanliness of the OEM is where you should target and I have never seen a recommendation that would require 1 micron.

Brett W. Technical Consultant LubeTrak/Spectro Scientific

Looking at years of sample data on small diesel applications to large diesel (12MW Mann) engines, by-pass filtration works great. Don makes a great point, filtering below 2-micron is over kill and yes, 1-micron and below can effect some oils in the market by eliminating crucial components. A good average is between 2 and 5 micron as this will help control soot, keep TBN life extended, TAN, Moisture and Varnish in check as Steve indicated above. We have seen up to 9000 hours on the same oil with 3516 NG applications and up to 1500 hours on diesel engines with great success, extended engine component life and extended oil life (cost savings). There are some filter companies in the market place to be aware of, they may use some smoke and mirrors as a sales tool, so be careful and do your homework if looking to use By-Pass Filtration, it is a great product.

Don McNeil Industrial Sales - STLE Certified Lubrication Specialist at Apache Oil Company

It is mostly related to the type of additive and the type of oil. Some brands have better filterability than others because they use additives that have better filterability, but all AW and EP tend to be larger molecules and are more prone to be removed with filters below 2 micron than others so it mostly depends on the type of oil, but has little to do with the quality of the base stock. Back to the original question though. I still see almost no evidence that filtering below 2 micron provides any real benefit.

Metin Simsek Independent Machinery Professional

Filters at 1 or 2 microns are usually used as partial flow filter (by-pass filter) as the pressure drop is very high, so you need too big a filter surface to use it to take ful flow. The oil change on filters used as OEM on almost all machines/vehicles are stipulated by machine manufacturers, not oil supliers. Because oil manufacturers test their products under harsh pressure and temperature conditions and brag to keep s prty at least 6000 - 10000 hours. Same oil on a excavator goes 1000 hours whereas it is used several thousand hours on an industrial press. Recently construction

machine manufacturers give oil life as 5000 hours by improving OEM filters.

THAT MEANS, filtration capability under 10 micron (OEM filters) down to 2 micron will increase oil life provided that TAN (TBN for engine oil) and viscosity are within limits. I know hydraulic oils on 5000 hours with TAN value at 0,9 (recommended limit is 1,5 to 2,0).

ADDITIVE DEPLETION: I know that ferrous wear element in oil will pick up some additives if not filtered. I read articles about AW-EP additives being 1 to 5 micron, but it is said real problem is sparking when oil is forced through sub micron clearances in microglass media; real problem to kill additives due to very high temperatures resulting. Another issue to consider is the reliability of statement that filter removes 0,5 micron. The lazer particle counters can analyse down to 2 microns, only electron microscopes can detect 1 micron. There are to many lies so you need to rely on lab analysis at least at the beginning.

Brett W. Technical Consultant LubeTrak/Spectro Scientific

There are many by-pass filters on the market, make sure and do your homework. I agree with Alexander there is a need for a good secondary by-pass (kidney loop) option, but filtering down to .5 micron on engine oils can cause some other item to appear. You need to keep your additives and other components present in the oil, this is why 2 to 3 micron is great for engine applications. If you filter too low on engine oils, varnish, scaring of bearings and other items will show up later in the oil analysis and or ferrography reports.

Now if you are doing fuel, 0.5 micron is great and some hydraulic systems would benefit from 0.5 micron, this would keep ISO Count below 18/16/14 standards and hydraulic systems would be much healthier.

Suggestion when looking for a by-pass filter, look at how complicated the system is. Is there multiple moving parts? Does it need electric hook up to work? Does the filter offer additive packs for the oil? If so, how do you know the additive is compatible with the oil you are using. We have seen hundreds of filtration systems on the market place, so choose wisely.

Perry Thiessen C.C.JENSEN Oil Filtration

Filtering sub micron particles is beneficial for some applications. Similarly, filtering small particles in the 1-5 micron range is also beneficial for most applications. It does not make sense to say filtering to "x" degree is overkill or not.

The important consideration is the oil film thickness and clearances involved. The oil film thickness will dictate what level of filtration is required.

If the film thickness of a hydraulic system is 5-10 micron then there is real benefit to removing particles below that range.

Here is some research results from MacPherson, the MacPherson Curve which shows dramatic life extension of equipment by filtering in the 0-5 micron range.

Mats Norling VD / CEO at Europafilter IM AB

Thank you Alexander for good information. Regarding the filtration capacity whether the size should be above or below 1 micron puts me to the position that one of the largest bearing manufacturer in the world, leading that type of business, within their own information pack states that a particle above 0,5 micron will deteriorate the surfaces of a bearing.

More is that the ISO classes for particles starts at 4 micron, so what about the area in between?

Typically when you in a lab examine the particles in oil, more than 70% of the particle in weight are below 1 micron, meaning that we flush the system continuously with abrasive particles and oxidating products that will stick to valves etc. So my point is that filtration for systems where these factors are important should render with a off line system with good capacity in order to secure uninterupted service and "life long lasting" oil. Why change the oil? Keep it clean!

Roy Fewkes

I only just found this discussion but would like to add that the level of filtration described will remove anti-foam if that is a concern.

==========

Q: What is the best way to get a **Grade 32 synthetic turbine oil** from an ISO 4406/99 **cleanliness of 23/21/15** to the expected level of 18/15/12? Additives, viscosity, TAN and moisture are within acceptable limits.

The turbine has been in service for the last year and a half. It is changed out every 30,000hrs or so. At the last changeout, I had the sump replenished for the first time in over 20 years! It takes 11 drums and the sample is taken at the filter outlet. The filter is 5 microns and I suspect it's old technology, installed since 1989.
What we noticed was that a servo was sticking and causing the machine to behave erratic.I also noticed a dark sticky layer on the walls of the sump which I suspected was oil residue. We used a dual filter to pump in new oil to about NAS 6. As I said, the additives etc are ok but the amount of particulates have me surprised because I pumped fresh clean oil in there.

https://www.linkedin.com/groups/Turbine-Oil-ISO-CLeanliness-3125819.S.235925202?

8 months later:

The turbine package is a natural gas driven Solar Centaur 50. The old oil was drained and the reservoir flushed with some new oil and discarded. No high velocity flushing was used.

Further oil analysis indicated the presence of degradation by-products associated with varnishing. The varnish potential was marginal and the MPC color result was 28. The difference between the optical particle count result (24/22/15) and the pore blockage particle count result (16/15/11) was considered significant and suggested the presence of soft contaminants. The recommendation was to use a filtration system targeting the removal of varnish.

A (originally): Scott Hester
Adding an offline filtration skid with Beta 1000 micro-glass elements will lower your ISO code and take most of the work load off system filters. If there are servo valves in your turbine oil system, you should be maintaining an ISO code 16/14/11 or better. Also have your oil tested for **"Varnish Potential". MPC seems to be a more accurate test**. Most turbine customers are having varnish issues with the new Group 2 turbine oils.

Sounds like varnish to me. Was it the IGV servo that was erratic? If yes, varnish plates out in low flow areas, i.e. - servo pilot lines. During normal operations, since varnish is insoluable, it flows through the system. When you shut the unit down & the oil cools, the varnish plates out in these areas(servos, bath tub ring in tank, gas control valve actuators, system bearings etc.). You mentioned that you have a 5 micron filter. if the element is a Hilco PH718-05 series, the 05 does not mean 5 micron. it is their type code and is actually a 40 micron, Beta 200 filter element. See GE TIL1542-2. Many customers that have GE or Siemens turbines have purchased a Hypro SVR

system to help with varnish mitigation and contamination. They have also witnessed typical AO depletion of 20% a year to only 5% a year. In turn, a 20 year oil life.

Raymond Gomes

Using an ISOPur MR we were recently able to drop the range from NAS 6 to NAS 3 is very short order. The previous filter company had been trying for over a year but could not get the level down. By removing particles below 4 micron down to 0.1 micron the entire level of particles are reduced. A side benefit, varnish is removed and the interior of the machine gets clean. This paper describes the results obtained on GE 7 FA turbines. Look at the oil analysis. If you need more information I can send the original oil analysis.
http://www.isopur.com/Cases/50000_Run_Hours_Same_Oil.pdf

Fernando Balboa

Here at Point comfort, we install a Pall unit(brand name) which is a vacuum dehydrator on our 4 Steam turbines, cause we were experince the same problems Now we maintain 0 water contamation, a ISO CODE of 15/12/10 and have greatly improve the quality of the oil and life. We also run a RPOV test on them oil reserviors once a year. I have not heard of any varnish complaints on them for a long time.

Coy Christoffel

I would have a reputable lab perform a QSA analysis to see what level the varnish is generating. If it is varnish that's the source of your problems I would recommend a high quality electrostatic filtration system to remove the varnish. I would not recommend the chemical treatments that you see on the market for varnish removal as they will adversely affect the make up of the lube. The Electrostatic will help recondition/ reclaim any contaminated fluid, and possibly save considerable $$$. I've seen great success with these systems on both GE, and Westinghouse Super Critical Steam and Gas Turbines. You will also want to be sure your lube sump has good flow. If not you will end up cleaning only a sector of the sump, and not introduce enough good lube back into the system. Through the process the lube will act as a "solvent" to remove the varnish build from the spools in your servos. From your description I would agree that is sounds like a varnish issue. A particulate filtration system will help but not cure the problem. Varnish tends to be "soft" and will bypass most microglass, depth media systems.

I do agree that the ESF units have gotten a bad rap over the years, but I believe that due more to improper application. Unfortunately they're used more often than not in applications that they shouldn't be, or they should have been used in conjunction with traditional depth media. They certainly are not meant for standard particulate contamination removal.

Much of the criticism of electrostatic units comes from the very vocal competition. The facts are that they work. They work at all temperatures. We even have some operating at very elevated temperatures used in oil bases heaters, even though or competition would have you believe they can't work.

We found that the clean oil that results from one of these units actually cleans the filter and limits the length of time a filter can be used. Waiting for a differential pressure alarm is waiting too long. Our filters are designed for 120 GPM even though we run them at 10. Unless your oil is extremely dirty, the filter will not produce a large DP.

We have looked at the data other companies get when they try a cleanup or varnish removal on a lubricating system. They also must change filters more often that they admit. One company recently complained of lack of performance by our machine. It turns out that they only uses 3 filters in the past 7 years. Not enough!

GE puts an Isopur machine on all new gas turbines. If used properly they work very well. Used wrong, they won't work well.

Perry Thiessen

C.C.JENSEN Offline Oil Filtration Systems (Canadian distributor)

See below links for more information on the Varnish Removal Unit (VRU)

Varnish Removal Unit (VRU) Brochure:
https://docs.google.com/file/d/0B7nAqMFDdbWtdkcxS2tpVkJ1NFk/edit?usp=sharing

Reference:
http://www.cjc.dk/contact/local-subsidiary-info/usa/references/

Case Studies
https://docs.google.com/file/d/0B7nAqMFDdbWtdDlaSEVBWkQ2MGM/edit?usp=sharing

here is a good slide show with some pictures and case studies:
https://docs.google.com/presentation/d/1vE13OhnXxwttl1xBMGcQ1i2_SFfkfvu3IQgV5Sceq0I/edit?usp=sharing

Scott Howard

Hey Raymond. I am not going to speak for Fluitec other than mentioning what I and others heard Brian state about trying to force dissolved oxidation byproduct out of solution. I am not convinced dissolved oxidation byproduct can be forced out of solution quick enough to be captured in a filter skid during a single pass. ASTM now has a procedure in place, which requires residence time for the oil to release the oversaturated oxidation byproduct, which takes several hours.

Concerning the auto-degradation discussion I remember when this theory was being speculated within the power generation community. At that time I thought the theory had no merrit, but the people proposing the theory to me were power plant personnel, not labs or lab equipment suppliers. What led many people I know to believe the theory was the observation of the MPC/QSA value rising and falling, with no real stabilization. This led some to theorize comtaminant was feeding off itself. We now know what was occurring. It is simply temperature related when the turbine oil is already saturated. The MPC/QSA value will fluctuate as the oil releases, then redissolves oxidation byproduct as temperature changes while the oil is saturated.

Maintaining oxidation byproduct levels at oil saturation is not difficult at all. We (Hy-Pro) can maintain oxidation levels via mechanical filtration with our varnish removal filter media. We (Hy-Pro) also have an electrostatic contamination removal skid we can offer to maintain oxidation levels at saturation. I do not recommend either product for turbine oil as the preferred or best method for maintaining oxidation byproduct levels because neither addresses the vast majority of dissolved oxidation byproduct. Though both can have minimal impact on dissolved contaminants as temperature changes, the oil remains at saturation, which does not slow the oil additive package depletion rate. In addition to not slowing additive package depletion rate, varnish is not completely cleaned off internal surfaces since the oil has no capacity to scavenge this plated out oxidation byproduct. The Hy-Pro/EPT soluble varnish removal (SVR) skid we manufacture does drain the oil of dissolved oxidation byproduct, and as a result the entire system is cleaned of plated out varnish + additive package depletion rate is significantly reduced to as low as 2-5% annually. MPC values are routinely maintained at <10, and lately with our new EPT resin formulations we are confirming normal MPC levels in the 2-5 MPC value range.

There is a major diference in the technologies. Mechanical filtration & electrostatic contamination removal technologies are limited in their ability to control varnish & cannot slow additive package depletion rate. The SVR with ICB technology does drain the oil of dissolved oxidation byproduct, resulting in a significant slowing of the oil additive package depletion rate.

Ghasem Shilati
Usually when you renew oil for a highly varnish contaminated turbine, some insoluble traces of varnish settles on internal parts and solves in new oil as soon as you run the turbine.
This type of varnish is solving in oil and can not be separated by usual filters even with lower than 1 micron pore size. These type of filters make the situation worst due to electrostatic discharge and producing more varnish residues.
For more information regarding to varnish contamination and solutions you can refer to our group.
http://www.linkedin.com/groups?gid=7433120&trk=my_groups-b-grp-v

H. Pablo Agostini

Experience with the Centaur Solar Gas Turbines and the degradation of its lubricants: As you might know, this kind of equipments demand to the lube oil a high resistance to thermal degradation. The lubricant is always at the edge. If the lubricant has not the right properties, or the machine has abnormal hot spots in some part that could affect the lubricant, or the thermal degradation of the oil was not detected on time (oil not changed on time); the result will definitely be varnish formation inside the lubrication system. The varnish will be stronger near to the hot spots and lighter in the reservoir. The varnishes gradually unstick from tubing internal walls due to oil flow, and that is the high ISO code you have seen. To solve the problem you have to find the root cause first. After that, a chemical flushing will be needed for sure, but not only inside the reservoir, but throughout all the lubrication lines too. To flush the system just with fresh new oil is not enough to get the varnish out. ISOPur systems are pretty good to keep varnish formation under control, but they are (at least that was my experience) not so fast to remove old varnishes quickly and get the ISO code down to normal values.

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OIL CLEANLINESS

NAS 1638 represents the counts of particles in five size groups:

- 5 to 15 microns per 100 milliliters (mL)
- 15 to 25 microns per 100 mL
- 25 to 50 microns per 100 mL
- 50 to 100 microns per 100 mL
- >100 microns per 100 mL

http://www.machinerylubrication.com/Read/29465/understanding-nas-values

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http://www.ehp-eg.com/hydraulic-training/hydraulic-oil/hydraulic-oil-contamination/ - Hydraulic oil contamination (NAS, ISO)

http://www.oilsolutions.com.au/oilsolutions/oil_cleanliness_codes.htm - Understanding Oil Cleanliness / Oil Cleanliness Codes

Evan Zabawski, CLS • I posted this previously within this group to answer a similar question:

NAS 1638 is a method for classifying particle count results, similar to ISO 4406:1999.

The key difference is that NAS is a differential count per 100 ml of sample, and ISO is a cumulative count per 1 ml of sample.

NAS 1638 categories are: 5 to 15 microns particles, 15 to 25 micron particles, 25 to 50 micron particles, 50 to 100 micron particles and >100 microns. It is possible to report more larger particles than small particles.

ISO 4406:1999 categories are: 4 microns and larger, 6 microns and larger, 14 microns and larger, 21 microns and larger, 38 microns and larger, and 70 microns and larger. Because each category includes some of the next scale, it is not possible to report higher numbers in larger categories.

To see a tabular representation of the NAS 1638 classifications, see: http://www.ehp-eg.com/hydraulic-training/hydraulic-oil/hydraulic-oil-contamination/

Rüdiger Krethe • To avoid misunderstandings, a short view to the history is useful. Don't be worry, is has to be a little more detailed to get the whole picture:

1. ISO 4406

Before 1999 ISO 4406 counted in classes >5µm and >15µm, automatic counters used the class >2µm too. This class ">2µm" was defined only in a draft version of the standard.

1999 they had to switch to a different test dust for calibration (Before 1999: ACFTD, after 1999: NIST). In the same time the size definition of a particle was changed (from max length to calculated "circular particle of equal area"). Therefore and to be compatible with the old test result the particle size was changed from >2µm, >5µm, >15µ to >4µm, >6µm, >14 µm. Due to this circumstances this new size classes have to be writen in detail llike this: >4µm(c), >6µm(c), >14mµ(c)

The "unit" particles per 1 ml and per 100 ml can be handled easy. It's like cm in comparison to m.

The ISO never counted particles >14µm in different, seperate classes. Only because of most of the counters produced ISO and NAS or SAE based on the same particle measurement they had to do this. The ISO 4406 standard has only one particle number for this: >14µm (old version>15µm).

2. NAS 1638 and SAE AS 4059

SAE 4059 was designed to replace NAS 1638. (In practice NAS 1638 is often still in use.) The changes:

The test dust is now also the "new" NIST type mentioned above.

Now also the SAE AS counts cummulative, that means >4µm, >6µ (!)

But in the SAE table a "conversation" between the old calibration (ACFTD) and new one (NIST) is given (old / new)

>1µm / >4µm

>5µm / >6µm

>15µm / >14µm

>25µm / >21 µm

>50µm / >38µm

>100µm / > 70µm

And - be surprised - the NAS 1638 results can be calculated from the "new" SAE AS 4059 results too! The only thing: The first "channel" of the new SAE AS 4059 has to be ignored -the NAS 1638 started with >5µm.

You don't believe that? Check it out and summarize all the particle numbers of NAS 1638 for example class 00 and compare it with the number you find in the table SAE AS 4059 under 00 in channel B (>5µm). The result is the same. Why? To allow trending with the old values...

But again: A direct precise comparance between ISO and NAS or SAE is not possible. The problem is not the different volume of 1ml or 100ml, this is easy to calculate. But one standard (SAE or NAS) counts bigger particles in more classes than the other (ISO). Only if you assume a similiar particle distribution you can compare that. For practical issues IMO this is OK.

Perry Thiessen

> C.C.JENSEN Offline Oil Filtration Systems (Canadian distributor)
>
> Hi Malcolm, I think the ISO 4406 particle count is an ok reference point. Of course if you have particles larger than 14 micron then this is of serious concern. As others have mentioned usually a clean particle count such as 15/13/11 is indicative of a system clean of larger particles.
>
> Something we have seen in hydraulic press systems is varnishing of the oil because the systems run very hot. We supply offline filter systems that continually filter down to 3 micron absolute and also remove varnish from the system.
>
> In my opinion the ISO 4406 particle count will fall out of mainstream use in the future (at least I hope so). As we learn more about oil contamination and equipment failures it is apparent that small particles are the most damaging. Going forward I believe the focus should be on cleaning oil from particles 1-5 micron in size. In addition cleaning submicron particles and soft contaminants is also important (varnish). I take it for granted that any critical oil system should be free of any particles greater than 15 micron (if this is not the case then a solution should be implemented).
>
> This is a case study we just completed here in Canada on a hydraulic press system in a pulp and paper mill.

Bob Smith

Managing Director of Clean Oil Services Pty Ltd and Lubemaster Australia Pty Ltd

Hi Malcolm. Put very simply, it is highly unlikely that a realistic 13/12/12 particle count is possible. If you understand ISO4406 as has been correctly described in the above comments, the next count up includes the previous count. In other words if we take it as X/Y/Z, the Y count includes all of the particles counted in the X so the count is truly X + Y so then the Z count is X + Y + Z. How then can you have 2 phases with the same count - It can happen but is most unlikely even more so given that your count is seeing 2978 particles at 21 mıcron, 2585 at 38 mıcron and 159 particles at 70um.
My suggestion is that you lab does not have the correct calibration on their instrument and is consequently feeding you dud results.
Each single digit increase or decrease will represent either a doubling or a halving of the previous count so you 21u and 38um are both in the same range which says that the larger 38um is the overriding range.

If you have large particles, you must have smaller ones as the as the large particles can only break up and reduce in size or cause increased wear of smaller particles, so you either have the wrong information as your particle count or you have a monumental failure occurring. Sorry Perry, CCJ cannot come to the rescue in this instance!!
ISO4406 is a good system but was originally designed by Vickers for hydraulic systems and light oils but in later days, the Tribology Gurus have been trying to pick it up an all lube systems where, particularly for gearing where it is useless as it is only as good as the lab instruments which are only as good as the sample supplied, hence a lot of people are being mislead by a misunderstood system.
Your best option is to do a microscopic count but again, it is only as good as the sample provided which is only as good as the accuracy of the lab.
If you would like any further information, please mail me on Bob@cleanoilservices.com

Ken Brown

Owner at Eco Fluid Center Ltd.

The 3 digit ISO system does have faults but if you got a report with 159 particles >70 microns something is very wrong. You can see them with the naked eye. So first, the person taking the samples should have seen them, or the person preparing them for shipping and then then lab should have reported in something in Appearance or whatever as visible particles. You can also quickly assess their ferrous content with a magnet and their approximate SG by shaking. Do not relay on your lab for the obvious. If no one saw any particles then the problem is with the counting. What did they use, pore blockage, light extinction, etc and did they have procedures to eliminate air bubbles, water, etc.? In any case with a high count there should be an automatic patch test with photos to try to confirm and identify. If you really had counts this high it is likely now too late to prevent consequential damage.

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http://www.oilsolutions.com.au/oilsolutions/oil_cleanliness_codes.htm - Understanding Oil Cleanliness / Oil Cleanliness Codes

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The following example illustrates the use of the NAS classification:

Particle Size Range	Number of Particles per 100 ml	NAS Classification
5 to 15 microns	35,000	8
15 to 25 microns	5,000	7
25 to 50 microns	200	5
50 to 100 microns	30	5
> 100 microns	2	3

These pump facts are certainly useful when discussing the impact of ISO cleanliness on working hydraulic or circulating system components.

Gear Pumps - expected life 20,000 hours
- Dynamic Clearance
* Tooth to Side Plate: .5 - 5 micron
* Tip to Case: .5 - 5 micron
- Recommended Cleanliness:
* Pressure <1500 psi ISO 17/14
* Pressure 1500 - 2500 PSI ISO 16/14
* Pressure >2500 PSI ISO 16/13

Fixed Vane Pumps - expected life 16,000 hours
- Dynamic Clearance
* Vane Slides: 5 - 13 micron
* Vane Tip: .5 - 1 micron
- Recommended Cleanliness:
* Pressure <1500 psi ISO 17/14
* Pressure 1500 - 2500 PSI ISO 16/14
* Pressure >2500 PSI ISO 16/13

Variable Displacement Vane Pumps -
- Dynamic Clearance
* Vane Slides: 5 - 13 micron
* Vane Tip: .5 - 1 micron
- Recommended Cleanliness:
* Pressure <2000 psi ISO 16/14
* Pressure 2000 - 3000 PSI ISO 15/13

Variable Displacement Piston Pumps - expected life 10,000 hours
- Dynamic Clearance
* Piston to Bore: 5 - 40 micron
* Valve Plate to Cylinder .5 - 5 Micron
- Recommended Cleanliness:
* Pressure <2000 psi ISO 16/14
* Pressure 2000 - 3000 PSI ISO 15/13
* Pressure >3000 PSI ISO 14/12

Thomas H-T:

True, the old (*still used for microscopy based counts) code 4407 only counted 5 and 15 microns, later updated to include 2 microns. ISO 4406,1999 specifies 4, 6 & 14, as a standard.
Similarly the old NAS did not differentiate for particles of 15 microns and less and equally

this has been updated (NAS 1638, starting at 5 microns).

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In recent years, portable **filtration** units, often referred to as filter carts, have become a common tool in the lubrication professional's arsenal. Increasing demand for these systems has led to the development of a wide range of new products and driven down prices, which is a good thing.

When filter carts first came onto the scene they were primarily used by service providers for decontaminating large systems. These early models were typically designed for low viscosity oils in large volume systems and were on the expensive side, making them unsuitable or impractical for many applications. As awareness of precision lubrication and contamination control grew and maintenance programs began utilizing these services more often, many began purchasing their own filter carts, but usually only one unit for an entire plant. Very quickly, plants began to realize they were wasting time and money by switching products, so they started dedicating filter carts for particular lubricants in order to avoid flushing requirements and to increase their capacity to decontaminate systems.

Now, the next evolution in offline filtration is permanently installed kidney loop systems. While portable systems will always have their place, permanent solutions offer several benefits including better average fluid cleanliness and far fewer man-hours.

Ideally, portable filtration should be used as a "condition-based" activity, providing a means to decontaminate systems when the particle count exceeds an acceptable limit. Having this option offers the ability to decontaminate any system in a plant when many of those systems can't justify their own dedicated filtration system. These systems provide additional value with the inclusion of water absorbing filters, offering the ability to remove water from small systems as well.

The potential problem with portable filtration comes with the required resources for moving and setting up the system. If the filter cart was used with another lubricant previously, there are also flushing requirements and possibly filter changes as well. The time requirements may be minimized by properly fitting the reservoirs with quick connect fittings, but it is still a significant drain on resources. This is not really a problem for on demand or condition-based filtration, but when the task is performed regularly, such as every month or every week, this time can really add up. An addition al consideration is that periodic filtration is potentially unable to maintain target cleanliness levels.

It may be that fluid cleanliness targets are only met for a short period after filtration.

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Q: We have been filtering our oil for some time and have achieved some pretty low ISO codes, but continue to see silicon showing up in our oil analysis reports. Can you explain what's happening?

Steve R

A: As you imply in your question, when you see silicon in an oil analysis report this typically means dirt since most common sources of dirt contain high level of the mineral silica. However, there are other possible source of silicon in an oil sample. For example, some oils such as engine oil and certain gear oil contain methyl silicone base antifoam additives. While not all antifoam additive are silicone based, where used the typically show up in the oil sample with between 10-20 ppm of silicon.

Another possible source of silicon is silicone based sealant or gasket materials. Oftentimes, when too much sealant is used, trace amounts will show up in the oil and

can register anywhere from a few ppm to several hundred ppm. If you're sure that the oil is clean but you're still seeing high silicon levels, look for other possible sources. It's important that you determine the reason for elevated silicon since the presence of excess silicone in the oil since can sometime lead to increased rates or air entrainment and foaming.
Silicon will often also show up in new or rebuilt equipment due to the presence of casting sand still present on the surfaces of new cast components. Over the first few hundred hours, this material can slough off into the oil and show up as silicon, though in your case, this is unlikely to be case since cast sand in this form should be larger enough that it can be filtered out.
Silicon in the form of dirt can often be confirmed by the presence of secondary elements, particularly aluminum. Depending on the geological make-up of the dirt, aluminum which comes from the mineral alumina will usually be present at around 15-30% of the levels seen for silicon.

http://files.e2ma.net/23934/assets/docs/ask.pdf

Experience has shown that a 10 micron filter is capable of achieving better than ISO 17/15/12 oil cleanliness level. However, if your optimum target cleanliness level is lower than this, consider a 6 micron filter.
Lube-Tips - 10 Pointers for Filtering Gear Oi
24/4/10
==========

Hypro SVR (Soluble Varnish Removal) experience with turbine oil Varnish Removal, for bringing high MPC value above '50' down to below '15'. How long does it take?

Mohammad Naseer Uddin, CMRP, MLA-ll Senior Reliability Engineer at Petroleum Development Oman Top Contributor

Particle count 24/23/22 at GE Frame 6FA or 7FA

Robert Bowden, CLS RWB Consulting LLC, CEO
I will try to answer this and remain as unbiased as possible, because I am working with a company that sells a varnish removal system that is not an ICB type.

There are several questions that need answers before an answer to your original question is even remotely possible. At BEST it will only be a GUESStimation. One reason is that the varnish generation and extraction rates are moving numbers. Bottomline, the "extraction" rate, has to exceed the "generation" rate in order to make progress. The efficiency of all the varnish removal systems is impacted as they become saturated. They are all more efficient when they are new.

Needed info:
1. reservoir volume
2. type oil, especially viscosity (brand name helps, but not essential)
3. base oil type (Group I or II)
3. bulk oil temp.
4. flow rate of varnish removal system
5. hydraulic system severity (ie...gas turbines more severe than hydro turbines)
6. 24 hr operation ??? (both hyd. system and varnish removal system)
7. Is there a varnish removal "Champion" onsite?
8. do they "bleed and feed" or how old is the oil.
9. geographic location. (ie...Alaska or Australia--dry or humid area - cold or hot)

Answers to these questions will help but believe me, there are no fixed numbers for varnish removal.

Ross Kovanda Owner/Vice President at American Chemical Technologies, Inc.
Agree with all just mentioned, but would like to delve further into this with you from a fluid standpoint and not necessarily a filter perspective. We have a patented additive technology that eliminates varnish in the system, regenerates additives and will not allow the remaining oil to create varnish.

Mohammad Naseer Uddin, CMRP, MLA-ll

The following are the answers to your questions.

1. reservoir volume – 22 000 litres
2. type oil, especially viscosity (brand name helps, but not essential) - ISO VG 32
3. base oil type - Group II
3. bulk oil temp. 75 Degree C
4. flow rate of varnish removal system - Hypro SVR claim 20 liters per minute
5. hydraulic system severity (ie...gas turbines more severe than hydro turbines) - Gas turbine 6. (both hyd. system and varnish removal system) - yes 24 hours operation
7. Is there a varnish removal "Champion" onsite? - not yet but there is plan to place one.
8. do they "bleed and feed" or how old is the oil. - no bleed only feed as the level goes down. Oil is 4 years old
9. geographic location. ..Alaska or Australia--dry or humid area - cold or hot) - Middle East desert environment with dry weather.

We have been proposed with Hypro SVR1200 for our turbines varnish removal. Need advice.

Ross Kovanda
I can tell you what I have heard from the field, these units do a good job, problem we find in any VR filtration is that not only are the units removing varnish, they are also removing some of the amines and phenols in the additive package of the turbine fluid. This compromises the life and integrity of the fluids long term, hence our development of another type of technology.

Mohammad Naseer Uddin, CMRP, MLA-ll

Robert, What is the flow rate of your new varnish removal system? How long will it take for 1X pass for a sump capacity 24 000 liters? Can it remove varnish in solution at operating temperature of lubricant 75 degrees C?

Ross Kovanda
I could have it in single digits in a couple days with a 10-15% treat rate and it would last for years and stop the proliferation of the remaining fluid from doing the same.

keith watson Manager Technical Field Services Asia Hy-Pro Filtration

One of the main benifits of the ICB is its ability yo remove the varnish without adding more contamination into your system. Can you advise current ppm water in oil sample?

keith.watson@hyprofiltration.com

Gerald L. Munson, CLS Managing Partner at Fluid Assets, LLC Sr. Partner at McCormick and Munson, LLC

Before you assume the SVR is responsible for the reduction in Phenols and Amines, Please consider there was a root cause for the Varnish in the first place, which is still in place. Consider looking at

the entire situation and insure that the mail LO filters are non-sparking and see if there is a way to lower the LO temp closer to 60 Degrees to eliminate some of the oxidation there.

Robert, Excellent Data Mining.

Remember, there is never a simple answer.

Mohammad Naseer Uddin, CMRP, MLA-ll Senior Reliability Engineer at Petroleum Development Oman

Top Contributor

Gerald,
Thank you for the comments. Could anyone tell how to check and confirm about the Spark discharge in the Lube Oil filters ? Is there a simple way to ensure the spark discharge in the L.O. filters ?
Regarding the L.O temp, the LO coolers are already functioning but unable to reduce the oil temperature in the tank below 75 deg C, although it is Winter season here, with ambient temp 24 - 28 deg C during the day. During summer the ambient temp reaches to 45-50 deg C, that would obviously cause the LO temp to exceed beyound 80 deg C.

I think the LO coolers fin fan tubes have varnish deposition internally that might be reducing the heat transfer rate. What i think, once we get this varnish layer removed from internals, it would therefore reduce the LO temp. Any suggestions ?

Mohammad Naseer Uddin, CMRP, MLA-ll

I have found the following link to the SVR Case studies for turbine oil varnish removal. Could anyone give the contact details of any of the end users of SVR ?

http://www.cleanoil.com/images/stories/pdfs/EPT%20Case%20Studies%200714.pdf

Ghasem Shilati Technical Manager at Naham Pala Engineering CO.

There are few subjects like vanish contamination containing plenty of myths along with few truth. Regarding to solubility of varnish content in oil, separation process is being complicated. For the same reason a contaminated gas turbine get worst at winters due to temperature reduction and conversion of varnish content to solid phase and settling on sensitive parts like servo control valves by consequent failures.
I believe the weakest point of SVR technology is its theory. Inventors claim it works but they have no scientific reason for that! At least in one case I was witness of dis-efficiency of SVR technology along with huge cost which should be paid for almost nothing.
You may (or should) believe Jesus has gone to sky because this is a miracle but in field of engineering every thing should be based on scientific theories and proven facts. Unfortunately SVR is not miracle. I believe it, if only their inventors describe the scientific theory, not referring to unknown references and manipulated case studies!

Greg Livingstone Lubrication | Marketing & Business Strategy | International Speaking

Thanks for the good question Mohammed. Robert and Gerry have excellent points (and are also extremely experienced with dealing with these issues).

Here's one of my blog posts that discusses how quickly you can expect varnish to be removed from your system: http://www.fluitec.com/blog/?p=130 The bottom line is that it is highly dependent on the level of varnish in your system. You should expect results in 1-3 months.

Here's also a blog post on spark discharge in turbine oil. http://www.turbomachinerymag.com/blog/content/do-you-have-sparks-your-turbine-oil. Although it is possible to measure online, it includes complex instruments and expertise to interpret the results. The easiest way to determine if you have spark discharge is having your main lube and last chance filters inspected by an expert in the field.

These technologies don't remove primary antioxidants in turbine oils. This has been well documented. Please also disregard comments about simply adding some magic foo foo dust to your oil to solve all of your problems. Turbine oils are complex formulations and adding new chemistry to your in-service fluid should not be taken lightly.

The good news is that there are proven technologies to mitigate varnish from your turbine oil system (and also clean varnish from your heat exchanger). Here's a video on our technology which you may find of interest: https://www.youtube.com/watch?v=c1bfKjOrOgM

Ghasem Shilati Technical Manager at Naham Pala Engineering CO.

Regardless of type of technology you are using for varnish removal from your turbine, nobody can guarantee duration of varnish mitigation. Here the reason described.
Varnish solubility in turbine oil has a saturation point. If your turbine is producing varnish continuously for long period of time, some part of it dissolves in oil. Saturated oil can not solve additional varnish ,so settles on coolers and pipes inner side and mostly in main oil tank bottom. When you start varnish separation by a suitable technology (even miracle based) contamination migrates from tank bottom to oil volume and varnish content in the oil remains constant.
So it is very important oil tank bottom and gas turbine internal parts cleaning before employing any varnish removal technology. Even renewing the whole turbine oil will not solve the problem without a suitable cleaning and oil flushing procedure.
Finally as Gerald mentioned, a preventive solution still is the best.

Raymond Gomes Senior Consultant at Retired, Traveling, Consulting and enjoying my Corvettes.

Yes, there is a proven technology called Balanced Charge Agglomeration, BCA. BCA has a great record in varnish mitigation as shown in the longest varnish removal experiment in the industry. The results have been so good that our oil analyst, Analysts Inc, did not believe the results, so they duplicated the testing and got the same results. They are believers.

Not only have we been able to control varnish in 7 GE frame 7 turbines, we have done it since 2005 when our machines were placed on turbines with oil that was 3 years old and varnishing. The turbines are now in their 13th year and over 60,000 run hours on the same oil. The additives are still strong and there have been no servo problems. Also look at the particle counts in the oil samples. This oil is cleaner than new oil.

http://www.isopur.com/Cases/55,000%20Varnish%20Free%20Hours%20Using%20BCA%20Oil%20Purification%20on%20GE%207FA%20Turbines.pdf

Mohammad Naseer Uddin, CMRP, MLA-ll

- I found an article on Google search that gives some more information on SVR. Have a look at the link below,

  http://www.ccj-online.com/4q-2013/lube-oil-maintenance-lubricant-varnishing-and-mitigation-strategies/

Jean-Michel Demaret Technical Expert , Concentrating Mill Maintenance at PT Freeport

GE Frame 6 (I do not know about Frame 7) are notorious for creating a lot of varnish. The presence of varnish on servo valves is an issue, but the worst could be sticky deposit on the emergency valves (Gas emergency shut down).

Some turbine oils have the capability of turning everything yellow as soon as they are in the tank. It is like a paint coating. Some of them last for the long haul in GE, Solar or Alsthom gas turbines. In regard of Viscosity, Particle count, TAN, RPVOT, Ruler and other oxidation test, the oils were well within expected limits, it is just they were painting every component. Likely the additives were the dyes.

The problem/good thing with group III gas turbine oil is that they have no solvency. Very little varnish is dissolved. All particulates are in suspension.

There has been few studies saying that only 30 to 50% of the oil present in a tank would work. (get to the bearings). 3 D infrared imaging shows that often there will be an established current between return and suction. Fluid not in the current would be seldom used. If the varnish drops at the bottom of the tank, unlikely it will be diluted again because the bottom layer of the tank would be saturated oil.

Finally, I have looked after the lubrication system of over 50 turbines, I have never encountered any sparking. I have seen movies, read literature but so far never heard the crackling or seen the flashes.

The turbines oil system were using either a vacuum purifier or the old purifier centrifuge.

Ghasem Shilati

Technical Manager at Naham Pala Engineering CO.

An old interview from machinery lubrication but still interesting!

http://www.machinerylubrication.com/Read/419/ion-exchange-resins-acid

Ghasem Shilati Technical Manager at Naham Pala Engineering CO.

During passed twelve years properties of mineral turbine oil has not been changed yet.
These type of oils are still non-polar and ion exchange will not happen in a non-polar environment even for the next century!

By the way we are discussing here based on scientific facts and I am ready accepting any theory which proves ICB basics. I believe without a proven theory, referring to unknown users or case studies is just wasting time.

Mohammad Naseer Uddin, CMRP, MLA-ll

Senior Reliability Engineer at Petroleum Development Oman

Top Contributor

There has been a 'Patented' invention in year 2009 titled "Process for removing soluble and insoluble oxidation by-products from non-polar lubricating and hydraulic fluids", that describes the details.

We need to be realistic. If we are unable to understand the theory behind it, but this invention is

working for benefiting us, then we need to accept the reality. Have a look at below patent.

Patent no. US 20090001023 A1
http://www.google.com/patents/US20090001023

Greg Livingstone Lubrication | Marketing & Business Strategy | International Speaking

In the old Machinery Lubrication article, Dr. Duchowski correctly states that ion exchange cannot happen in a non-polar environment. (And yes, changes in turbine oil formulations don't impact this!) However, the incorrect assumption in the article was that ion exchange resins undergo an ion exchange process. Ion exchange medias remove oil degradation products through chemisorption. The interesting challenge is that there are thousands of different IX medias available. There are also thousands of different varnish chemistries based on its formulation, mode of degradation and application. We have found great synergies by matching the media to the oil degradation chemistry. In some cases, we see a 10X improvement.

Varnish is a complex subject as can be gleaned by reading the various responses in this post. Everyone seems to have a strong opinion on both the causes and solutions of varnish. The key, as you correctly state, is to have science guide your knowledge and decisions. :)

Lucas Kerley Lubrication Engineer at ExxonMobil

It takes several weeks the hypro filters work.

Ghasem Shilati

- First of all I respect greatly to Peter and Greg as inventors who paid much times for improving a new technology.
1) Everybody knows a patent is just a claim which protects inventors' rights. Patent does not support strength or weakness of a technology. It just records "CLAIMS" of inventors to support their future rights. Personally, as an engineer, I prefer do not accept a theory if I do not access to its basics.

2) As Greg should know, until Oct. 2009 Dr. Dochovwsky was still on his belief that Ion exchange does not work in a non-polar environment. Certain resins may separate certain part of varnish content from oil at certain situations but it should not be Ion exchange.
I suggest ICB base inventors forget about "ion exchange" and describe the basic theory by more suitable words .At least they can say it is working efficiently but we did not know the theory behind it yet.

3) During last three years we had vast investigations in varnish separation. Based on our experiments we did not found polar properties in varnish content! (We can discuss details of experiments later) This matter also puts ICB basics in more shadows.

Mohammad Naseer Uddin, CMRP, MLA-ll

Thank you for the suggestion.
As far as the Hypro SVR is working efficiently in successfully removing varnish from turbine oils, that is OK for most of the turbine users. My original question was about the practical experience of end users about Hypro SVR in removing varnish from turbine oils. And if majority of users are happy with its performance, i have got my answer.
Thank you once again for sharing you comments on the subject.

Jeffry Soliday Plant Manager at Roilgard Inc.

I cant comment directly on the Hypro filtration system, but given your conditions and using an ASL FPRS-S200 (another electrostatic filtration system) it would take just over 2 months. ASL has had

great results when filtering for gas turbines. Here is a link to a list of customers that use this system: http://www.aslfilter.com/Customer%20Page.htm

ASL has been around since the early 90's and has proven that electrostatics work. If you would like I can get you contact info of customers who have had success using the ASL system. Please contact me if you have any other questions.

Perry Thiessen C.C.JENSEN Oil Filtration

For your consideration see below link to the C.C.JENSEN Varnish Removal Unit

http://www.cjc.dk/products/varnish-removal-unit-vru/

We see consistently good results for reduction of particles as well as reduction in varnish. If you would like more information let me know and I can provide additional case studies not shown on the linked page.

Ken Brown Owner at Eco Fluid Center Ltd.

Mohommad, some good comments but I do not think anyone answered your specific question about the Hypro SVR. In particular for their "experience" which I assume would be from another user. Too bad and it is important because there can be all sorts of deposits being called varnish and just as many root causes. I agree with Gerry to solve your root cause if you can and have the time otherwise if you need a 'fix' request a list of references from whomever wants to supply you with a system. Plus, send them a sample of oil to test first and get a money back guarantee. Also what oil are you using and what are the MPC numbers. Do you have other issues?

Sean Kovanda Sales engineer at American Chemical Technologies, Inc.

Though I respect all opinions posted throughout this discussion, I must interject one false statement made throughout the conversation. It was stated that mineral oils have never changed and that is correct. But it was also stated that all fluids are non-polar on the market so varnish will persist. That statement is utterly incorrect. Put aside the sales pitch and internal passion but this is what I've studied, what my background is, and had the option to work at a variety of other lubrication sales positions but I did my homework and found the company that sold the only true solution to varnish. Greg states it's magic foo foo powder. But let's look at this chemically. EcoSafe Revive and TF-25 is the one product on the market that is, in fact, a polar molecule. A PAG fluid that is irrefutably polar in nature. I know we are all intelligent people so I don't need to go into depth but if a fluid is polar, it will solubilize the also polar varnish molecules. There is nothing more that needs to be stated. You can accept the belief that you have to filter out the varnish, or you can use a polar PAG fluid that resolubilizes the varnish and releases the amines and phenolics back into your turbine fluid. Believe chemistry if your going to believe anything, it is some of the few things you can believe in this industry. If you would like more information to the true chemical solution for varnish through a simple 10% addition to a varnished system email me at smkovanda@americanchemtech.com or call me personally at (615)879-8964. We have tons of case studies, technical bulletins, users lists and contacts that we would love to share with you to support our claim. You can also visit www.americanchemtech.com if you'd like to learn more.

typically ISO cleanliness code for hydraulic fluid are 16/14/12 for ISO VG 15-100 and 18/15/12 for ISO VG 150-680

Question:
Silt-size particles are typically in what size range?
Answer:
1 to 10 microns

Scott Hester
Adding an offline filtration skid with Beta 1000 micro-glass elements will lower your ISO code and take most of the work load off system filters. If there are servo valves in your **turbine oil system, you should be** maintaining an **ISO code 16/14/11 or better**. Also have your oil tested for "Varnish Potential". MPC seems to be a more accurate test. Most turbine customers are having varnish issues with the new Group 2 turbine oils.

http://www.youtube.com/watch?v=NG-iWUgpvcE - oil filters

How Clean/Dry Should Hydraulic Oil Be?

Clean Hydraulics: Contaminant Removal

Des-Case Newsletter **December 2012**

Machine Type		Particle Level Target	Moisture Level Target
Hydraulics 1500-2500 psi	With servo valves	15/13/11	125 ppm
	With proportional valves	16/14/12	150 ppm
	Variable volume piston pump	17/15/12	150 ppm
	With cartridge valves/ fixed piston pump	17/16/13	150 ppm
	With vane pump	18/16/14	150 ppm

The information in this chart is a compilation of data from OEM manuals, field knowledge, industry knowledge, etc. It is a general guideline and does not provide all inclusive information; other considerations can change the target particulate and moisture level recommendation.

Myth #3. New hydraulic oil is clean hydraulic oil.

New hydraulic oil straight from the drum, has a typical cleanliness level of ISO 4406 23/21/18.

That is four cleanliness code levels below that considered ideal for a high pressure, high performance hydraulic system.

Looking at it another way, a 25 GPM pump operating continuously in hydraulic oil at 23/21/18 will circulate 3,500 pounds of dirt to the hydraulic system's components each year.

To add hydraulic oil, and not the dirt, always filter new oil prior to use in a hydraulic system.

This can be accomplished by pumping the oil into the hydraulic reservoir through the system's return filter. The easiest way to do this is to install a tee in the return line and attach a quick-connector to the branch of this tee.

Attach the other half of the quick-connector to the discharge hose of a drum pump.

When hydraulic oil needs to be added to the reservoir, the drum pump is coupled to the return line and the oil is pumped into the reservoir through the return filter.

As well as filtering the oil, spills are avoided and the ingress of external contamination is prevented.
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But make sure you have the good breathers and that your particle counts are correct. I recently had a discussion with one client whose bosses did not believe the cleanliness provided by the new filter system in their diesel supply. We had patch tests in his presence that showed 14/13/11. The local CAT lab analyzed it each month with varying numbers between 21/19/17 and 19/18/16. A patch for those levels would be very obvious. We took another sample and sent it to Polaris in the US, to CAT here.
Cat rated it 19/17/14
Polaris rated it 15/14/12
Bottom line is we are looking for better cleanliness than some labs are able to handle.

Rex Burgner • Good Morning Keron! This is one of those questions where you could get many opinion guided (biased) answers. There are many different ways to get your oil to the required cleanliness level. Here is what I have came across in the field... Please bare with me, this may be lengthy.
We should honestly start at your bulk oil storage. Even though your new oil is considered "clean", it may not meet the 18/15/12 that your OEM requires, even straight from the barrel. If you bulk fluids are not stored correctly, this only adds to the issue.
So with this, If you have a large bulk container, it is important to have a good quality breather on it which captures both moisture and contaminants. This will help your downstream cleanliness. As you are pumping the oil from the tank/barrel, I always recommend to install an in-line filter directly on the outlet of the pump. There are many filter manufacturers out there and most of the filters will work, one thing to keep in mind is that if a standard hydraulic filter is installed, it is designed for multi-pass cleaning as most hydraulic filtration is recirculation. If you use one of these, the filter may not become efficient for a very long time. To explain what I am talking about, a new hydraulic filter is not 100% efficient when it is new. It uses the larger particles it captures to close the passages, becoming part of the filter element itself. So as the filter captures particles, it becomes more efficient. There is another manufacture out there who manufacturers a single-pass filter which gets you to 16/14/13 on a single pass. This is designed for bulk storage system. It is lower pressure and not designed to go into a hydraulic system. It is efficient as soon as it is installed. This ensures that your oil is at 16/14/13 as it is delivered to your point of use.
Now to the point of use. Many people like external loop systems which do not alter the operation of the system itself. Some like filter carts which are used on a temporary basis and moved from machine to machine as needed. Again, preventing external contaminants from entering your reservoir is very important, so the installation of a good-quality breather (moisture/contaminant removal) will help tremendously.
If your system already has an in-line filtration system, having the correct filters installed is very important, making sure you watch flow-rates and pressure ratings of the system. But if you need an external system, I always have preferred a permanent wall-mounted system which can be set to run

continuously to ensure that the oil is kept at the required cleanliness level. My issue with a port-a-cart style system is that it can cause contaminants to be shared from system to system and causing cross contamination.

Doug Harris • Hello Keron,

Absolutely agree with Rex Burgner - you can readily filter the oil to the required level from tank to machine, but you need to keep it clean on the machine as well, all the applications mentioned by Rex will get you & your client to the required level. In addition, the machine operator might need to consider water ingress from the machine, or storage if a desiccant breather is not in use, and invest in an oil purifier. Follow the link below for pointers on the wide range of possibilities!

http://www.pall.com/pdfs/misc/PGCAPABEN.pdf

Regards, Doug

Guillaume Kalfon • On top of the great answers already given, and in no way undermining them, is the less obvious question whether this is all really particles, of if part of it is also agglomerated soft contaminants. The particle counter is optical and therefore has no clue if the particles it counts are really particles, or soft contaminants. There two possible ways to investigate this: one is to run ISO 4406 again on same oil, but after heating it to 80C for one hour. If the particle count on the heated oil is significantly less than on the oil at ambient, then you know the difference is not "particles". Another way, more indirect, is to run ASTM D-7843, membrane patch colorimetry (MPC). If MPC is high, then you definitely have soft contaminants, and then, maybe, some of them get counted in agglomerated form in ISO 4406 (especially the first class). D-7843 is recommended by both GE and Siemens, and definitely a good idea.

Richard Widman • In general I like the Donaldson solutions written up here:
http://www.donaldson.com/en/engine/news/081417.html

But make sure you have the good breathers and that your particle counts are correct. I recently had a discussion with one client whose bosses did not believe the cleanliness provided by the new filter system in their diesel supply. We had patch tests in his presence that showed 14/13/11. The local CAT lab analyzed it each month with varying numbers between 21/19/17 and 19/18/16. A patch for those levels would be very obvious. We took another sample and sent it to Polaris in the US, to CAT here.
Cat rated it 19/17/14
Polaris rated it 15/14/12

Bottom line is we are looking for better cleanliness than some labs are able to handle.

Bob Smith • Hi Keron, I must question some of the above answers and ask why would you want to add a quite expensive addition to your machine which only has the ability to clean the oil down to a certain level (filter integrity) and no further and involves the addition of often very expensive filter elements which sometimes need replacing in the case of Pall elements at up to $1500 per element? Today's market offers a very diverse range of centrifuge filtration which is often cheaper to purchase and set up than conventional filters and can be set in a way that there are no ongoing operational costs.
Centrifuges will remove particles to sub micron levels and maintain your oil in pristine condition without taking your equipment offline and without ongoing costs.
ISO4406 is not a good guide to oil management if we take the numbers mentioned above, 15/24/12, This is not clean as every 1 ml of your fluid can contain from 20 to 40 particles, per ml of oil, which

are over 15um in size and can be up to any size.
I am glad that this is not my turbine!!
You will find a lot of information about centrifuge filtration on my web site
www.cleanoilservices.com

we install a Pall unit(brand name) which is a vacuum dehydrator on our 4 Steam turbines, cause we were experince the same problems Now we maintain 0 water contamation, a ISO CODE of 15/12/10 and have greatly improve the quailty of the oil and life. We also run a RPOV test on them oil reserviors once a year. I have not heard of any varnish complaints on them for a long time.

By Fernando Balboa

Much of the criticism of electrostatic units comes from the very vocal competition. The facts are that they work. They work at all temperatures. We even have some operating at very elevated temperatures used in oil bases heaters, even though or competition would have you believe they can't work.

We found that the clean oil that results from one of these units actually cleans the filter and limits the length of time a filter can be used. Waiting for a differential pressure alarm is waiting too long. Our filters are designed for 120 GPM even though we run them at 10. Unless your oil is extremely dirty, the filter will not produce a large DP.

We have looked at the data other companies get when they try a cleanup or varnish removal on a lubricating system. They also must change filters more often that they admit. One company recently complained of lack of performance by our machine. It turns out that they only uses 3 filters in the past 7 years. Not enough!

GE puts an Isopur machine on all new gas turbines. If used properly they work very well. Used wrong, they won't work well.

By Raymond Gomes

Scott Howard • Raymond, I believe you are referring to a round table discussion recently at the GE 7E conference in South Carolina, though I could be mistaken. BCA was not in this particular conversation, and for good reason. It is widely known this product has many limitations. One of which a BCA machine will not reduce the oil saturation level of oxidation byproduct below 100%. Therefore, oil additive package depletion rate is not slowed using BCA. Additionally as the filter elements see any rise in d/p the particles that are attracted to each other magnetically are not strong enough to withstand this force and are broken up and sent downstream.

In that round table meeting I stated depth media with a heat exchanger could not induce dissolved oxidation byproduct 'fallout' in the amount of time the oil spends in the loop of the filter skid, theoretically less than 1 minute. Brian Thompson of Fluitek, previously of Analysts, Inc., then stepped up and confirmed my statement by saying his lab tried every way possible to induce fallout, and nothing was succesful. One must wait a period of time (hours) for the oil to release the oversaturated dissolved oxidation byproduct. Oxidation byproduct in a dissolved state cannot be forced out any sooner, rendering mechanical filtration with a heat exchanger quite limited in its ability to remove varnish. BCA or Electrostatic contamination removal will not remove dissolved oxidation byproduct either, with or without a heat exchanger.

Raymond Gomes • As usual we were not aware of this meeting and not invited. This was another Fluitek show, I assume. The understanding of how our system works was determined by 20 years of operation and testing along with good oil analysis on real operating systems. It was not determined by contriving tests to show proof of a system with little operational experience.

The things you say about BCA are the standard line from Fluitek. They are trying to find a way to distinguish their machines from others in the business. We are always astonished at the things they believe. Remember Auto-degradation? It was a contrived condition that only resin based purification could solve. Chemists and engineers I talked to could only describe it as BS. It is no longer mentioned by the people who made it up, because it did not exist.

Somehow our little worthless machines have managed against all odds to clean up over a thousand GE power plants around the world. They even worked in places like Saudi Arabia, where the ambient temperature should guarantee failure according to Fluitek. Same with the 7 GE frame 7 machines described in the previously mentioned case study. Not only is their oil cleaner than new oil after 11 years in a gas turbine, their additive levels have remained very high. Much of the loss in additives, we feel, was due to operating the turbines without an oil purifier during the first three years in service.

In several power plants in SE Asia, additive levels went up after using BCA. We know this is impossible and it is just due

the the affect of very clean oil on the RPVOT test. However, purifying oil, that is removing everything, not just varnish, results in clean systems, and dramatically reduced depletion of additives in real operating turbines. It does seem that we were able to remove the dissolved varnish, or these results would not be possible.

Scott Howard • Hey Mark. In my experience vacuum dehydration works well once temperature is in the 130-160F range. Some synthetics are more stable and require a higher temp to remove water down to <5% saturation. The lower the temperature you choose to dehydrate the higher the vacuum required, typically 23-26" Hg. If there is a large amount of water present a lower vacuum is required initially to avoid foaming due to water violently flashing to steam. Once the water content begins to drop vacuum can be slowly increased to maximize water removal rate.

However, I have found the temperature can be lowered and with less vacuum the water will be reduced, but the process is slowed. Generically I would say use 120F as the floor, and adjust vacuum accordingly to maintain water content or remove excess water. Hope this helps.

I would have a reputable lab perform a QSA analysis to see what level the varnish is generating. If it is varnish that's the source of your problems I would recommend a high quality electrostatic filtration system to remove the varnish. I would not recommend the chemical treatments that you see on the market for varnish removal as they will adversely affect the make up of the lube. The Electrostatic will help recondition/ reclaim any contaminated fluid, and possibly save considerable $$$. I've seen great success with these systems on both GE, and Westinghouse Super Critical Steam and Gas Turbines. You will also want to be sure your lube sump has good flow. If not you will end up cleaning only a sector of the sump, and not introduce enough good lube back into the system. Through the process the lube will act as a "solvent" to remove the varnish build from the spools in your servos. From your description I would agree that is sounds like a varnish issue. A particulate filtration system will help but not cure the problem. Varnish tends to be "soft" and will bypass most microglass, depth media systems.

By Coy Christoffel

I agree that the ESF units have gotten a bad rap over the years, but I believe that due more to improper application. Unfortunately they're used more often than not in applications that they shouldn't be, or they should have been used in conjunction with traditional depth media. They certainly are not meant for standard patticulate contamination removal.

By Coy Christoffel

Do all the lubricating oils need special filtration systems ? Is a 25 micron filter sufficient to filter all lubricants before filling ?...

One can also use them in metalworking and grinding. We would place a rod magnet into a capped pvc tube such that we could pull the metal off, clean it up, and re-use in about 5 mins.

By George Abernathy

Scott Howard • Hey Raymond. I am not going to speak for Fluitec other than mentioning what I and others heard Brian state about trying to force dissolved oxidation byproduct out of solution. I am not convinced dissolved oxidation byproduct can be forced out of solution quick enough to be captured in a filter skid during a single pass. ASTM now has a procedure in place, which requires residence time for the oil to release the oversaturated oxidation byproduct, which takes several hours.

Concerning the auto-degradation discussion I remember when this theory was being speculated within the power generation community. At that time I thought the theory had no merit, but the people proposing the theory to me were power plant personnel, not labs or lab equipment suppliers. What led many people I know to believe the theory was the observation of the MPC/QSA value

rising and falling, with no real stabilization. This led some to theorize contaminant was feeding off itself. We now know what was occurring. It is simply temperature related when the turbine oil is already saturated. The MPC/QSA value will fluctuate as the oil releases, then redissolves oxidation by-product as temperature changes while the oil is saturated.

Maintaining oxidation byproduct levels at oil saturation is not difficult at all. We (Hy-Pro) can maintain oxidation levels via mechanical filtration with our varnish removal filter media. We (Hy-Pro) also have an electrostatic contamination removal skid we can offer to maintain oxidation levels at saturation. I do not recommend either product for turbine oil as the preferred or best method for maintaining oxidation byproduct levels because neither addresses the vast majority of dissolved oxidation by-product. Though both can have minimal impact on dissolved contaminants as temperature changes, the oil remains at saturation, which does not slow the oil additive package depletion rate. In addition to not slowing additive package depletion rate, varnish is not completely cleaned off internal surfaces since the oil has no capacity to scavenge this plated out oxidation byproduct. The Hy-Pro/EPT soluble varnish removal (SVR) skid we manufacture does drain the oil of dissolved oxidation byproduct, and as a result the entire system is cleaned of plated out varnish + additive package depletion rate is significantly reduced to as low as 2-5% annually. MPC values are routinely maintained at <10, and lately with our new EPT resin formulations we are confirming normal MPC levels in the 2-5 MPC value range.

There is a major difference in the technologies. Mechanical filtration & electrostatic contamination removal technologies are limited in their ability to control varnish & cannot slow additive package depletion rate. The SVR with ICB technology does drain the oil of dissolved oxidation byproduct, resulting in a significant slowing of the oil additive package depletion rate.

Perry Thiessen • Hi Keron, I emailed you several case studies. C.C.JENSEN has developed a unit specifically designed to remove varnish from gas and steam turbines. The varnish removal unit (VRU) will remove 80% of varnish in one pass. I have not seen any unit on the market that will achieve that level of varnish removal in one pass. Once the system has been cleaned up you can expect an operating varnish level of 2 to 3 MPC. You can expect to see an ISO in the range of 16/14/12.
Varnish Removal Unit (VRU) Brochure:
https://docs.google.com/file/d/0B7nAqMFDdbWtdkcxS2tpVkJ1NFk/edit?usp=sharing
Reference:
http://www.cjc.dk/contact/local-subsidiary-info/usa/references/
Case Studies
https://docs.google.com/file/d/0B7nAqMFDdbWtdDlaSEVBWkQ2MGM/edit?usp=sharing

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The first questions that need to be answered is what type of turbine (brand and series) do you have and what is the specific lubricant being used. Your post notes "synthetic turbine oil" and one of your comments note that the reservoir contains 11) drums of fluid, which makes the total volume less than 600 gallons. I also note somewhere in the comment thread a question pertaining to a Cat / Solar turbine.

You also need to determine the accuracy of your sample process as well as how the lab is determining your ISO cleaniness code (laser particle counter or pore blockage). I prefer laser particle counts but the accuracy of these units can be impeded if the fluid is dark, wet or has entrained air bubbles.

Next we need to determine if your valve issues are a result of hard particles (ISO clenaliness code)

or due to varnish. MPC testing has been mentioned within the thread but note that this test only pertains to mineral-based (Groups I & II) oils and not to some of the synthetic lubricants being used by some turbine manufacturers (PAG, POE and Phosphate Ester as examples).

My suspicion is that you are having varnish related issues as well as possibly having ISO cleanliness issues. Varnish occurs due to the degradation of the lubricant from oxidation. Eventually the amount of oxidation by-products exceed the solvency level of the basestock and these by-products fall out of solution. The resulting particle is typically below 1 micron, soft and polar. Over time these small particles will "plate" to metal surfaces until the resulting varnish is large enough to see and cause problems. The best example of this is a coral reef. We cannot see the individual coral but we can see the reef.

Know that each type of fluid being used within the various gas turbines have to be treaded differently for maximum effectivess when combatting varnish / fluid deposits. I can give you more insight once I know the answers to the first questions posed.
By Richard Trent

Turbine Oil ISO Cleanliness...

The answer is to gather the facts before making recommendations. We don't know the type of turbine (gas or steam), the brand or type of oil, or anything other than what I saw posted in one place stating the oil capacity was about 11 drums and was changed about a year ago after being in operation for 20 years. We don't know what flushing procedures were used at the time the oil was installed nor what type of filters are used, so making recommendations to solve his problem can't be done properly without more information. I suspect they may have not used good procedures when changing the oil which has contributed to their problem since the turbine apparently operated normally for 20 years and only experienced a problem after changing the oil. We also don't know if they changed the oil type or brand when they recharged the system. Bottom line is we have more things we don't know than those which we do know. I doubt that varnish is his problem if Keron';s original statement :"Additives, viscosity, TAN and moisture are within acceptable limits." Sounds like a problem with the procedures used in establishing the original cleanliness of the oil or in maintain the cleanliness,

By Don McNeil

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All oils are prone to oil degradation, which can lead to the production of varnish. Varnish production is as a result the breakdown of the oil, either due to operational effects, such as shear stress and temperature and from contamination in the oil, such as wear metals, water and oxidation. This degradation process is what causes sludge to form and results in varnish deposits.
Varnish deposits on a journal bearing can cause dirt and particulate to stick to it, giving rise to excessive wear or loss of lubricity. Oil degradation can also result in increased viscosity and higher levels of acidity in the oil.
You cannot stop oil degradation happening, but you can take steps to reduce the effect of varnish and the production of varnish by removing the wear particles, water and reducing acidity build up.
http://www.cjc.dk/contamination/oil-degradation/
Frequent topping up of the oil will not cause varnish production, in fact it will act as a "cleaner" to dissolve some of the varnish back in to the system. Using such a system

indicated in the link will help remove the contaminants from the oil and will then allow the oil's natural detergency to help clean the system of varnish over time. A recent development in this technology has vastly improved the efficiency of varnish removal to reduce the time taken to clean a system.
Simple tests, such as colourimetric millipore membrane analysis or QSA looks at the colour of a membrane after drawing a sample of the oil through it. The level of staining from yellow to dark brown will give an indication of potential varnish. Monitoring the anti oxidant additives is also a way of checking on oil life using the RULER test or RBOT or RPVOT tests. Ultracentrifuge tests give a good indication and Infrared Spectroscopy are some others. You should not, however, forget to check oil viscosity and TAN levels as this is also a good indication of the condition of the oil. Increased viscosity, high acidity, dark brown oil colour and a sour smell of the oil all indicate a high level of oil degradation and the likelihood of potential varnish products in the oil.

The main problem with water in HFDU fluids is that it will cause acidity, which can have a serious affect on seals in the machinery. I have seen the results of a company using HFDU the same way as HFDA, mixing with water. Very expensive mistake!
There are ways to ensure moisture does not build up in the fluid, causing acidity and oil degradation, which leads to sludge and varnish production.

High temperatures can cause thermal degradation of the oil and combined with wear elements and water, which act as catalysts, can further degrade the oil. It will create acids and water. This will result in the production of a soft sludge which can stick to hot spots, or to cooler parts, such as filters, cooler plates/tubes and spool valves, where lacquering will occur, causing damage to fine tolerances, block filters and make coolers inefficient. Removal of varnish and acidity will help keep components cleaner and reduce the risk of outages caused by degraded oil.

The process you described is called "hydrolysis" and is the most common degradation manner of any synthetic ester fluid, HFDU included. Water is the primary cause of hydrolysis, but high temperatures can contribute to it.
I would also say that people commonly refer to Varnish as the degradation product formed by mineral paraffinic lubricants, where HFDU hydrolysis normally generates the soft sludge that Sandy wrote about. In my experience, HFDU degradation needs to be monitored using a different approach than mineral oil degradation. With HFDU fluids, the most important indicator of oil ageing is Acid Number, because it directly measures the concentration of the non-esterified (that is: hydrolized) fatty acids.
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Generally, the rate of lubricant degradation doubles with every 18 degrees F increase in temperature. Once formulated with antioxidant additives, PAO-based lubricants have a lower baseline rate of oxidative degradation. At low temperatures, a PAO's increased oxidative life may not be noticeable, particularly if you have to change the oil at some point for other reasons. At higher temperatures, the synthetic may last noticeably longer.

Typically, you begin to notice the extra life provided by a PAO above 160 degrees F (71 C). If it is above 180 degrees F, and especially 200 degrees F, the difference in oxidative life becomes quite apparent. However, the point at which a change to synthetic is justified is dependent perhaps on a handful of additional "program management" parameters such as:

1. Do you intend to run your gear oils with an appropriate use of filtration and oil analysis to support life-cycle extensions for many years?

2. Are you currently doing oil analysis and performing condition-based changes?

3. Do you have, and have you communicated to your lab, oxidation limits that flag impending oxidation problems?

4. Does the machine's operating temperature vary a great deal (a PAO's high viscosity index enables it to operate across a wider temperature range)?

5. Do you have an effective contamination control program in place that will enable you to fully exploit the PAO's extended life?

With the appropriate management strategy, a change to a high-performance product can actually cost considerably less than the equivalent mineral oil product type. Outside of these considerations, somewhere around 165 degrees F represents the point at which you probably should begin to consider the use of synthetics for the sake of lubricant longevity, if not for the sake of reliability.

http://www.machinerylubrication.com/Read/28606/hot-for-synthetic
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Mobil 932 Turbine Oil

Russell Flagg PdM/Reliability Specialist

Has ayone have any operating experience using the exxon Mobil 932 product in GE combustion turbines? If so I would appreciate what your findings are in regard to varnish prevention and servo valve performance.

Cristián Schmid

Businees Development

Russell. Our experience is that the best strategy for that is to perform a varnishing flushing in a outage or overhaul, and install a technology to prevent the varnishing formation like ISOPur. This technology is recommended by the GE TIL.

Kevin Barnidge MLA II

Safety and Operations Manager at Petrolink USA, LLC.
We just completed a flush at refinery that was using the 932 and had a varnish problem. Turns out they also had a water problem and high particle count. After the flush, they were at a 16/14/11 and maintain it by side stream filtration.
First, pull a sample and send it in to get an MPC test for the amount of insolubles in the oil and have PC and Karl Fischer ran as well.

Mishel Sidorin

Power Plant Manager

The real problem is the lack of engineering in the turbine oil system, the main oil filters, installed to protect the pump integrity normally have 25 microns, the filter in the servo control oil is 8 microns, but the internal moog filter have 0,5 microns. nothing clean the oil plus if you have a gear box, the problema is worse.
I recommend to use an external good capacity filters system with 1 micrón, keep your eyes on the oil cleanse and additives integrity and try to keep the oil hot to prevent varnish formation ,turn off the FFcoollers if your cycle your machines daily

Kevin Barnidge MLA II

Safety and Operations Manager at Petrolink USA, LLC.

Absolutely. We have installed 1 µm Beta 1000 filters at all the turbines and field fill lines at a plant in Mississippi. I like to say we work ourselves out of work there but that is always a great problem to have.

Fernando Oscar Bilotti

Senior Field Engineer Support - Argentina Area -Minería y Marine & Aviation Lubricants en Axion Energy S.R.L.

Very good comments. I agree with all of you: You need to check MPC and Ultracentrifuge UC test too, in order to check the pontential formation of varnish. I agree with the technology of ISOPUR or others. GE had tested some of them and contribute to reduce the varnish problems. I have only question. Do you refer to Mobil DTE 932 GT?

Take in consideration the following comment.

Particularly suited for General Electric frame 6, 7 and 9 applications where varnish control of the hydraulic system is desired.

Raymond Gomes

CEO at ISOPur Fluid Technologies, Inc

Actually, GE uses Isopur exclusively on its gas turbines, and now steam, as well. When used properly, they work. See the paper on our home page for the longest running test of an Isopur system on a GE frame 7. The oil is at 55,000 hours, 12 years on the original oil. They serviced servo-valves for the first time during the ten year tear-down.
http://www.isopur.com/Cases/55,000%20Varnish%20Free%20Hours%20Using%20BCA%20Oil%20Purification%20on%20GE%207FA%20Turbines.pdf

G Shilati Technical Manager at Naham Pala Engineering CO.

What is making varnish contamination so difficult to handle is its degree of solubility which is directly depends on turbine oil temperature.

Varnish content is being solved at high temperature areas of turbine, then passing through even sub-micron filters and settles on colder sensitive parts like servo Moog valves.

I am sure there is no filter invented yet which capable of separating soluble varnish at turbine running temperature.

But we had good results in our company for separation of varnish contamination in gas turbines by on-line transferring it to dissolved phase and then separating by electrostatic technology.

Finally before wasting your money for solutions please be sure that your turbine oil remaining age and foaming factor are still in acceptable range. Otherwise renew the whole oil.

Raymond Gomes CEO at ISOPur Fluid Technologies, Inc

You are right. **Power turbine manufacturers have chosen the single sump method for lube, hydraulic and seal oil. It is cheaper, so it gives them a price advantage.**

I attended a meeting at a major turbine supplier where I was talking about the single sump problem to the service and operations staff. One older engineers stood up and said, who would be so stupid as to use a single sump. One engineer at the back of the room pointed to himself and mouthed the words, we did.

As for temperature effects, this is the selling point for our competitor's solution. They needed something to set them apart from the electrostatic filtration systems that were working so well, so they came up with the temperature solubility issue. Of course, they were the only ones with a solution to this problem.

When you look at the results we got at TECO, you have to wonder, was it a miracle that seven Frame 7 turbines have run the same oil for 12 years and it is still cleaner than new? Maybe there is something wrong with this solubility issue. The turbines managed to remain varnish free in a semitropical area using our machines for over 55,000 run hours. They did not sent a single servo valve from 7 turbines out for repair until the 10 year tear-down. Could it be there is more to the temperature issue than the competitor claims? How have the 50 Isopur machines in Saudi manage to work so well? I believe much of this issue was contrived to sell machines.

Look at the original video that several companies use that shows "varnish" going into solution as the temperature of the oil is raised. You will note that at one point, the "varnish" is white. I believe it is the additive PANA that was used by several large oil suppliers 10 years ago. This additive is a waxy substance that melts around 45 C. I once had a chance to experiment with it and got the same results as our competitor. It fell out of solution as it cooled and became a solid and went back into solution when heated as it melted.

This solubility - temperature issue has been repeated so often, that it is now believed to be true by everyone. I believe there is more to the story. Either we create miracles with our machines, or the solubility-temperature issue is wrong. I don't believe in miracles!

Edmund T Bird Advanced Fluid Systems, Inc. MA, RI, NH, ME & VT Sales Engineer

Varnish is formed by thermal events, heating and cooling. If your system shares sumps, it means critical servos are at risk. But even in systems where sumps are separate, I have seen varnish become an issue. The Iso-pure system is an electrostatic system, and is good up to a point. We sell the Hy-Pro SVR, it addresses both soluble and free varnish. It utilizes both mechanical filtration for free varnish, and dry Ion charge bonded elements to remove varnish in solution. It draws the varnish from surfaces in the system that can be left behind and become problematic using other methods. There are over 200 of these units being successfully used on turbines today.

Perry Thiessen C.C.JENSEN Offline Oil Filtration Systems (Canadian distributor)

We continue seeing good results with the C.C.JENSEN Varnish Removal Unit (VRU). We recommend 24/7 dedicated kidney loop filtration for turbine oil, rather than one time servicing.

The VRU keeps both particle counts and varnish levels very low by operating on a continual basis. We consistently see good data return from the field on Alstom, Siemens, and GE turbines.
http://www.cjc.dk/products/varnish-removal-unit-vru/

Edmund T Bird Advanced Fluid Systems, Inc. MA, RI, NH, ME & VT Sales Engineer

https://www.hyprofiltration.com/case-studies/detail/general/svr-lube-oil-varnish-removal-success/?query=misc0.eq.1&back=CaseStudies

Brent Winter Industrial Field Marketing Advisor at ExxonMobil

Mobil DTE 932GT is a relatively new gas turbine oil when you think about turbine life cycle and the market standard of products. The Mobil DTE 932GT is designed to address the common problem in Gas turbines, minimize varnish. This product is currently in 30 turbines in the US and one has just eclipsed 30,000 hours.

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Product Feature

New Drum Pump Filtration System

Actively filtering lubricants from storage drums can prevent contamination related problems. Trico's Drum Pump Filtration System can prevent contamination or remove it when used in daily operations, including filtering oil directly from the storage drum to fill totes and transfer containers. The Drum Pump Filtration System provides a dispensing nozzle capable of delivering a flow up to 6.8 gpm and is rated for use with lubricants up to a viscosity of 7,000 SUS, depending on motor selection. The Drum Pump Filtration System comes standard with a 10 micron absolute Beta>200 spin-on filter element and a sealing bung adapter. The universal design of the Drum Pump Filtration System integrates a quick change hand wheel design, allowing the motor to be transferred from one Drum Pump Filtration System to another without buying additional motors or removing the entire apparatus. This follows industries best handling practices by avoiding cross contamination of different lubricant types, reduces further particle contamination and eliminates messy lubricant spills. For more information visit our website:

http://www.tricocorp.com/product-category/contamination-control/

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Water in hydraulic fluid:

- Depletes some additives and reacts with others to form corrosive by-products which attack some metals.
- Reduces lubricant film-strength, which leaves critical surfaces vulnerable to wear and corrosion.
- Reduces filterability and clogs filters.
- Reduces the oils ability to release air.
- Increases the likelihood of cavitation occurring.

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Water removal methods

Methods for removing free (unstable suspension) and emulsified (stable suspension) water include:

1. polymeric filters;
2. vacuum distillation; and
3. headspace dehumidification.

Polymeric filters - These look like conventional particulate filters, however the media is impregnated with a super-absorbent polymer.

Water causes the polymer to swell, which traps the water

within the media. Polymeric filters are best suited for removing small volumes of water and/or maintaining water contamination within pre-determined limits.

Vacuum distillation - This technique employs a combination of heat and vacuum. At 25 inches of mercury, water boils at 133°F (56°C). This enables water to be removed at a temperature that does not damage the oil or its additives.

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http://www.preventinghydraulicfailures.com
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http://www.machinerylubrication.com/Read/28753/minimizing-impact-of-built-in-contamination-in-hydraulic-systems-

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Once a system is assembled, purified and shipped to the customer, it should remain sealed to prevent contamination. Oil changes in the first 2,000 hours of machine operation frequently do more harm than good. This is because new oils are not necessarily clean, and end users often lack the equipment required to filter fluid into the system.

Starting a machine with a clean hydraulic system is the first step in achieving long and

reliable equipment life.
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Hydraulics:
Contaminant control I think is key. This includes particulate, moisture, and mixing of different fluids. I am big on tank breathers that remove moisture and high quality filters with an absolute rating of 98.7% removal at 2 micron. Generally hydraulic systems are very tight tolerance by nature. If you are using rams in a very dirty conditions ram boots should be a consideration. Also temperature control is very important and properly sized tanks that allow flood cooling and settling are important. Just a few thoughts. I also agree with Tom's input on analysis as a very important component of system management.

Too often people overlook the basics and look for a silver bullet that'll fix all, Mark's comments above highlight the basic necessities nicely, keep in cool, dry,
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Widman:

In general I alert customers when their silicon (dirt) levels pass 7 ppm for the 500 hours and flag them at 10 ppm. I alert when the fuel dilution is at 1% and flag to stop the equipment if it causes the viscosity to fall below 12.5 (with a 15W-40).

Here in the tropics (400 meters above sea level, I alert above 0.5% and flag 1% soot, but equipment operating in the west of the country at 4000 meters has a normal soot of around 1 to 1.5%, getting my alerts above 2%.

In hydraulics the conditions are similar all over, but I strive to get them to use breathers and good filters. I tell the ceramic plants to change their hydraulic oils when I can determine there clay mix from the elements in the oil. Again, filtration is the key, since this can vary between 4000 and 8000 hours in different plants with the same equipment but different maintenance programs. I will also note this is with group II hydraulic fluids. I've had experience where one plant decided to use a cheaper group I product and was not able to get through 400 hours without doubling the viscosity and the oil turning black with oxidation.

When looking at silicon, up until the SN category you normally would not see any. Most of the SN oils, to meet the anti-foam characteristics use about 6 ppm of a silicon anti-foam agent that the analysis can't differentiate from dirt. To my knowledge, no diesel formulations use silicon.
One identifier is aluminum. Aluminum, in an average environment, will be about 1/3 of the dust particles in the air. So if you have 10 ppm of silicon, and only 2 ppm of aluminum, you probably only have 6 dirt. If aluminum is more than 40% of the silicon, you definitely have a wear problem (hope that is clear).

This point on Aluminium & Silicon relationship is noted. Where Silicon alone raises but not Aluminium, we should think that entry of dirt is not a problem. Entry of dirt would mean that both would be increasing. The Silicon may be getting generated internally from components such as seals and it does not indicate potential for catastrophic wear.

On use of Silicone anti-foam - Robert Widman should know what we blenders do. We take 1 Kg of Silicone fluid (12,500 molecular weight), add to it 99 Kg of Kerosine and make a diluted anti-foam fluid. We use about 3 ppm of this diluted fluid as an anti-foam to suppress foam. This is used across all lubricating oils (Passenger Car Motor Oils, Diesel

Engine Oils, Hydraulic Oils, Gear Oils, etc.) except Turbine oils wherein the Silicone anti-foam can affect air-release value adversely and hence we use a polymer as an anti-foam (this is some 40 times costlier than the Silicone fluid approach).

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Water in engine oil:

Anthony Gomes

Ashok, it depends upon the additive package which usually contributes around 200 ppm in an fresh engine oil when tested by ASTM D 6304 Procedure C. By crackle test, water content should be nil.

Edward Eckert - CLS, OMA I

I do not believe there is an industry standard for maximum allowable water in new/unused engine oil. It typically is an internal standard determined by the manufacturer, From an oil analysis laboratory point of view, typically >0.05% is considered trace, and 0.10% or greater is flagged as excessive. Usually with engine oil the end user will notice a slight hazy appearance starting @ 0.05%, which puts pressure on the lab to note water at that level. With engine oil and very low levels of water, once the oil is up to temperature in the engine it will dissipate and not cause any problems.

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Most common level of NAS in new oil is 7-8. Oil companies will probably argue this and i would accept a NAS 6 if we are talking 1 gallon plastic containers tapped on site. But in barrels and in bulk it will for obvious reasons be much higher (logistics chain and container type).

It has become more and more common for the aware maintenance crew to do a filling through a filter. (hope they have a fixed filter on the system or it will be in vain, due to accumulated dirt in te tank).

Comment to Changbao Ma: Spot on comment, because cleanliness levels should be compared to dynamic clearances in the system. Look at the clearances and then consider if an in-line 10 micron filter will have much effect on wear...

But ISO code Class is mentioned with only 2 numbers. This is normal for lube oils (SAE grade engine oils) because soot particles are so abundant. All other oil types should show 3 numbers (4406, 4,6,14 micron ranges). if only two numbers are given it is the 4 micron range that is omitted, so you are looking at 6 and 14 micron numbers. Have a look at the dynamic clearances again an let me know if the analysis provides much useful info...

On the topic of additives or the "removal" of same... Yes the filter often gets the blame. But don't blame the gun, blame the shooter. If a filter removed additives, it is because of other factors influencing the system. The filter does what it is intended to do: keep the system clean and dry. The filter only removes particles within the rate/range of filtration given and as stated by Mr. Gupta, most additives are soluble in the oil and most machinery manufacturers specify "all additives must be soluble". One exemption though, Anti-foam silicone can sometimes be inadequately distributed in the oil and appear as droplets larger than they should be. They will agglomerate if particles are

present and if they are large enough, the filter removes the lot. Funny thing is, that if silicone agglomerates, they loose the AF capability. They still show up on the spectral analysis but they are not active. Hence the filter gets the blame, regardless if the AF capabilities are unchanged if you should compare the two oils (oil with effective filter vs. oil with no filter and high particle count).

Simple solution, use acrylate as AF. But of course this shows on the pricetag.

And please beware, in any case particles less than stated in the standard (NAS or ISO) will not be counted, regardless of how abundant they are represented. You can have a ok cleanliness on paper, but in real life the oil is pitch black, just think of diesel engine oils.
Also beware that a single analysis/particle count only represents a moment in time. A trend gives so much more information.

Last: It's different a soluble system like two or more fully miscible liquids than another system like any small solid component dispersed in liquid. In this case of ZnDDP is a liquid component without solid component but a Zinc incorporated in any organic structure.

All adittives have an recommended temperature because can to occur a degradation of structure of ZnDDP that produce a separation of Zinc of the organic component. Moisture can to produce an partial hydrolysis. If this occur the Zinc will be filtered out of the system, but you would make a change oil.
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Today I want to discuss another of the
'big three' contaminants of hydraulic oil - AIR.

Air can be present in four forms:

Free air - such as a pocket of air trapped in part of a system.
Dissolved air - hydraulic fluid contains between 6 & 12 percent
by volume of dissolved air.
Entrained air - air bubbles typically less than 1 mm in diameter
dispersed in the fluid.
Foam - air bubbles typically greater than 1 mm in diameter which
congregate on the surface of the fluid.

Of these four forms, entrained air is the most problematic.

Pre-filling components and proper bleeding of the
hydraulic system during start-up will largely eliminate free air.

Small amounts of foam are cosmetic and do not pose a problem.
However, if large volumes of foam are present, sufficient to cause
the reservoir to overflow for example, this can be a symptom of
a more serious air contamination and/or fluid degradation problem.

Negative effects of entrained air include:

- Reduced bulk modulus, resulting in spongy operation and
  poor control system response.
- Increased heat-load.
- Reduced thermal conductivity.

- Fluid deterioration.
- Reduced fluid viscosity, which leaves critical surfaces vulnerable to wear.
- Cavitation erosion.
- Increased noise levels.
- Decreased efficiency.

As pointed out above, hydraulic fluid can contain up to 12 percent dissolved air by volume. Certain conditions can cause this dissolved air to come out of solution, resulting in entrained air.

When fluid temperature increases or static pressure decreases, air solubility is reduced and bubbles can form within the fluid. This release of dissolved air is known as gaseous cavitation.

Decrease in static pressure and subsequent release of dissolved air can occur at the pump inlet, as a result of:

-Clogged inlet filters or suction strainers.
-Turbulence caused by intake-line isolation valves.
-Poorly designed inlet.
-Collapsed or otherwise restricted intake line.
-Excessive lift.
-Clogged or undersized reservoir breather. **Water in hydraulic fluid:**
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Air entrainment can also occur through external ingestion.
Like gaseous cavitation, this commonly occurs
at the pump - as a result of:

-Loose intake-line clamps or fittings.
-Porous intake lines.
-Low reservoir fluid level.
-Faulty pump shaft seal.

Like other hydraulic problems,
proper equipment maintenance
will prevent the occurrence of
most air contamination problems.

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