Mark O'Brien

Hydraulic oils work their best when as as demulsible as possible.
Engine oils need to carry the water through the hot engine during every event of use to allow it to burn off.
Otherwise your oil pan would be full of water to the exclusion of lubricating oil.
This is inadvisable.
Excessive water in hydraulic oil is what prematurely uses up your R&O additives.
This is the cause of that congealed mess that clogs the filters.

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http://www.hydraulicsupermarket.com/black-book

http://www.atsdr.cdc.gov/toxprofiles/tp60-c1.pdf

Calvin Low Conventional hydraulic oils will have issue of reducing pressure after working for some times but synthetic oils with higher VI and thermal stability will solved this issue. Higher oxidation stability is also prolonged period of oil change interval but in real life, leaking is an issue! For fire resistant hydraulic oils, phosphate ester is so far the best but it was toxic in certain way and alternatively TMPTO is a good choice as well as meeting the biodegradable criteria!

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http://www.hydraulicsupermarket.com/personalcoaching.html – hydraulics
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As I until recently worked for Shell I know the formulation for **Shell Tellus S2 68V**. It certainly contains latest generation ZDDP as such not prone to filterability concerns what so ever.
Shell Tellus S3 68M is ashless and of higher performance (S3 vs S2) but without the V which refers to VHVI.
Schalk
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Jean-Michel Demaret   Technical Expert , Concentrating Mill Maintenance at PT Freeport

Hello Kaushal. A good quality engine oil is an excellent oil and can be used in light to medium duty hydraulic system (gear pump, vane pump).

One issue is that multigrade oil shears under stress. For example a SAE 15W-40 is 100 cSt and after few weeks it drops to 50cSt . It does not mean you get more wear, but there will be a lot of questions from the users.

Engine oil can absorb more water than Industrial hydraulic oil. You cannot drain the water out of an engine oil tank... So more likely more wear with a moist oil. Look for an engine oil meeting the old Allison C4 specs or Caterpillar ECF: they have been tested to resist light shearing.

Gary Wood   Regional Sales Manager at Irving Oil
Mono grade motor oils have been used for years in light duty or low pressure hydraulic systems, but while the detergency of motor oil does well to remove contamination from engines, it's emulsification properties are not good with high pressure hydraulic systems.

In high pressure systems, water and solids being carried throughout the system can cause serious damage. "Wet" fluid can cause micro pitting when going through the pump because it has a different film strength than necessary for the higher pressures resulting in cavitation.

Gongde Liu   Lube R&D Dept. Manager at PetroChina Dalian Lube R&D Institute

Due to some hydrolysis stability issues of ZDDP in engine oils, copper corrosion could happen sometimes.

Larry Hajek   senior lubricant technical manager at Citgo

Use of engine oils as hydraulic depends so much on the application. in mobile equipment it is very common but in industrial uses the high additive content can be a problem.

Paul Anning   Reliability Engineer at BHP Billiton

I normally respond by asking "would you put hydraulic oil in your engine?" The response is a resounding "no". Then "why put engine oil in hydraulics?" They are in essence two distinct formulations. A couple of points have already been touched on by others here. There is a wealth of info out there about the pros and cons. And of course you will find the likes of Caterpillar will accept engine oil as second alternative. (for the pure convenience of it - I am sure) Engine oil in hydraulics of course meets Cat's desire for a healthy dose of zinc in the mix and of course emulsification characteristics. A high level of detergency and dispersancy is a double edged sword. There are pluses and minuses. Unfortunately mobile equipment (well one brand anyway) does not have filtration with sufficient efficiency to remove such fine particles. This background level of fine particulate makes it impossible to determine the ISO code of the fluid using a Automatic Particle Counter (APC) due to interference and co-incidence counting. Silt in hydraulics is no-no. Is using engine oil truly detrimental? In many instances any system degradation goes unnoticed - So I guess for many people the convenience is number one and no issues are identified. I will leave you with some advice given by Rexroth regarding premature life problems with slew pumps and motors on a Liebherr digger some years ago. Engine oil was being used. They projected component life to be only 30% of that using a dedicated hydraulic fluid. Did they adjust the truth? - I am not sure. However, my research suggests it does at least have some merit.

Damanik Ramidi   Condition Monitoring at Lenzing Group

Technical aspects include oil specfication and hydraulic component system specification.

Monograde mineral oil in general can be used as hydraulic oil, as we assume the oil's compatibility with the seal material of hydraulic system.
Unfortunately, multigrade engine oil e.g. 15W-30 or 15W-40 with base synthetic can not be used at hydraulic, since synthetic base will leave a serious risk of swell and shrink material of hydraulic seal and caused leakage.
Components system include material surface component can react with additive package.

Paul Anning   Reliability Engineer at BHP Billiton

The rules have changed. Most OEMs (Cat, Komatsu etc., with Hitachi being the dissenting voice) all specify hydraulic oil with a good emulsibility and not demulsibility as we are accustomed. This is, they claim, because of small reservoirs and the short retention time for water to settle. They also claim it is preferable to have the water in an emulsified state rather than having it circulating free in mobile equipment. (why this is different to industrial applications I fail to understand).

Filtration on equipment provided by the major mobile OEMs is of consumable quality with little efficiency making problems with Filterability (ISO 13357) something you are unlikely to come across in mobile.

If you search (Brendan Casey has some good white papers), you will find a number of demands made by mobile OEMs that oppose general opinion and knowledge, especially that in industrial applications - yet mobile earthmoving equipment often uses the very same components. The world of mobile earthmoving equipment is full of "gotchas" and contradictions.

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

Komatsu and Caterpillar are moving away from engine oil / transmission oil in the hydraulic of their heavy excavators. For example Cat for the 6000 series shovels recommend DIN HLP zinc-free, even if they do not market this type of oil.

Komatsu branded hydraulic oil is a zinc free industrial hydraulic oil similar to the Hitachi one (different viscosity).

The pump manufacturers for example Rexroth and Kawasaki are pushing for a change, as you mentioned. High pressure pumps needs industrial hydraulic oils.

Koustuv Mohanty   Owner, KINETICS COMMERCIAL COMPANY

The hydraulic oil for almost all Komatsu excavators (in India) is SAE 10W.

Smith, Alexis CLS   Product Portfolio Manager at BP

New John Deere and Hitachi excavators (they come from the same plant) do recommend a zinc-free multi-grade hydraulic oils. I have seen conflicting data on zinc free additive packages on the basis that they actually do offer superior protection versus zinc based hydraulic fluids. The fact is, not all zinc-free hydraulic oils are the same. Something also to note around zinc-free hydraulic oils, they are classified as low toxicity hydraulic fluids based on test OECD 203. They are not classified as environmentally friendly or inherently biodegradable as the new FTC green guidelines prohibits these unsubstantiated claims.

V.S.S. Sarma

Engine oils and Hydraulic oils differ vastly in their properties. Try to compare a CH-4 oil properties with a DIN 51524 P 2 or P 3 oil and you know what I mean. Engine oils have very high additive content whereas hydraulic oil have very low additive content. Engine oils contain Calcium which is not there in hydraulic oils and which contributes to emulsion forming tendency that is detrimental to hydraulic systems. **Engine oils contain active Zinc whereas high performance hydraulic oils contain what is known as thermally-stable Zinc. Active Zinc forms deposits on hydraulic filters and sometimes the flow itself is affected.** Hence, for hydraulic application, let us use hydraulic oils which are cheaper and more pure than engine oils. Also, note that hydraulic oils can not work as engine oils.

Edem Agnitey da Silveira   CEO Middle East and Africa at Saheli Energy Solutions

Hi Sarma, I'm afraid this is not 100% correct. Many OEMs such as Caterpillar for instance, clearly prescribes to use a CI-4/SL 15W40, Cat ecf-1 or ecf-2 oil grade in both their engine and hydraulic systems. And it works perfectly.
The trend clearly seems to combine many functionalities into a single oil.
Another example is for a Powershift transmission oil, sae 50 grade, Cat TO-4, which can be used in a Powershift transmission, final drive, axle, and in ride control systems.

V.S.S. Sarma

Edem - Where there is a conflict of opinion between what a technical person says and what the manufacturer says, go by the manufacturer. I always maintain that we should go by the manufacturer's recommendation.

V.S.S. Sarma

Gary Wood has rightly distinguished hydraulic transmissions in off-highway equipment vis-a-vis the industrial hydraulic oils. Even in earlier times, manufacturers like Allison recommended using engine oils. For example, C-1, C-2, C-3, C-4 kind of fluids were basically engine oils. API-CD level was used as Allison C-2 fluid. What the focus of this discussion is - can an engine oil be used as industrial hydraulic oil ? In my view, hydraulic oils for industrial purpose are very well formulated. If Caterpillar or Allison kind of manufacturers demand a hydraulic transmission oil, I am sure industry can come up with great formulations. But then, these manufacturers feel that they know about oils more than the oil industry. As a blender, I must accept to produce what my customer wants.

What are the advantages of using zinc free HYDRAULIC OIL?

Rod Beaumont

The main issue with zinc based additives is that they can be prone to hydrolysis in wet environments (which can occur through normal operation in units exposed to high humidity and or stop start operation), this lead to filter blocking. Metal based additives are considered more environmental polluting - sulphur and phosphorus are readily consumed (under the right conditions) by living organisms.

Brett Lukens

....if you have any water in a hydraulic system especially dissolved the zinc additive will react with water and create control issues with valves...what is called "stiction" or "silt lock"...varnish..usually AW hydraulic oils containing ZDDP.

Richard Hassebrock

Some equipment manufacturer's, Hitachi for instance, prefer zinc free hydraulic oils, and the factory fill fluid is zinc free. See their web link:
http://www.hitachi-c-m.com/global/businesses/parts/hydraulic_oils.html

Andrew Monk

Both types of additive formulations work well in hydraulics, but it's already been mentioned here about the environmental effects of ZDDP, which is of course valid, as is the issue with water contamination that Rod speaks about. From my experience both work really well in service and I've never had any issues with either. Don't forget that ZDDP has more than one function in a hydraulic oil, and cost of additives plays it's part as does the marketing aspect.

Paul Bonner

For environmentally friendly hydraulic oils you cannot use zddp due to aquatic toxicity.

Andrew Monk

Both types of additive formulations work well in hydraulics, but it's already been mentioned here about the environmental effects of ZDDP, which is of course valid, as is the issue with water contamination that Rod speaks about. From my experience both work really well in service and I've never had any issues with either. Don't forget that ZDDP has more than one function in a hydraulic oil, and cost of additives plays it's part as does the marketing aspect.

Jean-Michel Demaret

To Petr, I think the English manufacturer Lucas made some pumps with silver coated parts. Lucas CAV closed in 1991. The silver in pumps is getting far apart..

To Richard : Hitachi oil is made by Idemitsu. The story is only Hitachi oil can go to 4000 hours, other oils manufactured by common mortal, even Castrol :-) must be changed before. 4000 hours.. It is a spare part marketing strategy. I think only zinc free are recommended by Hitachi. Komatsu is following suite.

Thomas Dietz

The elemental composition of a lubricant is irrelevant. What matters is the performance of the specific composition in question.

Just as all zinc based hydraulic oils are not the same, nor is the performance of zinc free formulations. One must always look at the performance of the formulation versus the performance standards one needs for the applications in question. I suggest that you should always ask more than the elemental composition and focus on performance requirements.

David Stevenson

There used to be some cadmium electroplated plated parts in some pumps and zinc is not compatible with cadmium, as the zinc will displace the cadmium (same group of metals, but higher up the periodic table and hence more reactive). It was for this reason that zinc-free oils were developed to eliminate ZDDP. TXP or Tricresyl phosphate were used instead, but we are talking about '80s (and possibly earlier) oil technology here. Things have moved on a lot since then.

E**ka karmila**

As Our Experience work with Hitachi team, Zinc Free Formulation Provides Superior Sludge Control. We support them with Millipore filter test also for they genuine Oil (hitachi 46HN). I also agree with Richard Hassebrock and the link his share. You have to sure and consult to The Equipment OEM. Special For Hitachi they recommended Zinc Free for sludge Issue.

Sam Vance

This is taken directly from a Phillips 66 product data sheet. "Ecoterra Hydraulic Oil is a high-quality, zinc-free antiwear hydraulic oil specifically developed for use in industrial and mobile equipment operating in environmentally sensitive areas. It is specially formulated for reduced environmental impact in case of leaks or spills. It is nontoxic to fish and aquatic species as determined by OECD Test Method 203 1-12, and is classified as inherently biodegradable by the OECD Test Method 301B. It passes the visual “no sheen” requirements of the U.S. EPA Static Sheen Test"

Sam Vance

I have also seen this product and products like it cause some very serious problems. The applications that I am referring to are in very highly humid areas where there is a lot of condensation in the hydraulic reservoir. The problems were rust and scale throughout the system which resulted in a complete tear down of the machines. The oil was replaced with an oil with the ability to emulsify with the water and the problem ceased. This problem was so bad and one piece of Catapillar equipment that was used close to a river that the customer simply went to an AW 46, again after a complete tear down and cleaning of the system, and they had no further problems.

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The anatomy of hydraulic vane pump failure

One of our members wrote to me recently regarding the following problem:

"Recently, we bought a used hydraulic power unit (15HP electric motor directly coupled to a vane pump). A high-pitched, clicking noise is generated when the unit runs. We have checked the following:

1. *We thought it was a motor bearing, so we detached pump from motor, no noise heard.*
2. *Pressure line was connected to tank line (to simulate low pressure < 100 psi), very little noise heard.*
3. *As pressure is increased, noise gets louder and louder, very intolerable.*
4. *Measured current draw of motor - no overload.*

What do you think could be causing the excessive noise?"

Given that the symptoms described above are consistent with a restriction at the pump inlet, I inquired if there was a suction filter in the circuit. Our reader replied:

"The system has a 40 micron suction filter but I haven't checked it because I have to drain the oil and take off the access hatch to get to the filter."

The restriction caused by a suction filter, which increases at low oil temperatures (high viscosity) and as the element clogs, increases the chances of a partial vacuum developing at the pump inlet. Excessive vacuum at the pump inlet causes cavitation erosion and mechanical damage.

Cavitation erosion

When a partial vacuum develops in the pump intake line, the decrease in absolute pressure results in the formation of gas and/or vapor bubbles within the oil. When these bubbles are exposed to elevated pressures at the pump outlet they implode violently. When bubbles collapse in proximity to a metal surface, erosion occurs. Cavitation erosion contaminates the hydraulic oil and damages critical surfaces.

Mechanical damage

When a partial vacuum develops at the pump inlet, the mechanical forces induced by the vacuum itself can cause catastrophic failure. In vane pump designs, the vanes must extend from their retracted position in the rotor during inlet. As this happens, fluid from the pump inlet fills the void in the rotor created by the extending vane. If excessive vacuum exists at the pump inlet - it will act at the base of the vane. This causes the vanes to lose contact with the cam ring during inlet, and they are then hammered back onto the cam ring as pressurized fluid acts on the base of the vane during outlet (figure 1). The impact damages the vane tips and cam ring, leading rapidly to catastrophic failure.

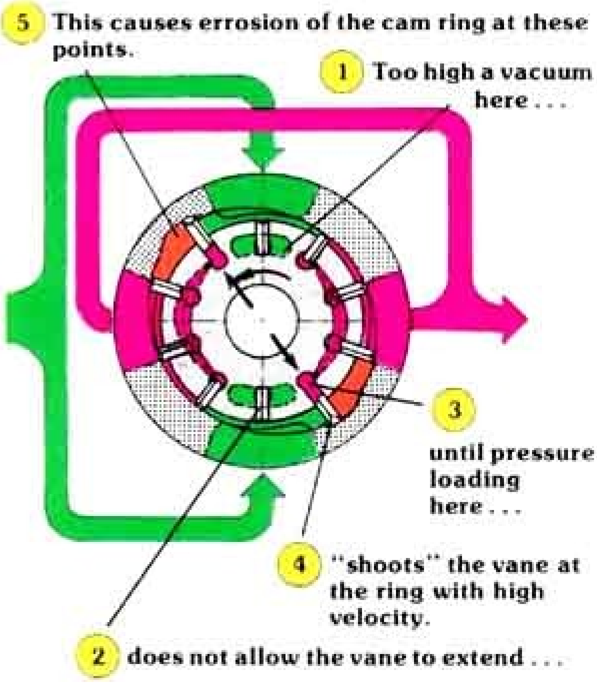

Figure 1. Vane pump section (Bosch Rexroth Corp).

The intolerable noise our reader is referring to is symptomatic of cavitation bubble collapse and the vanes being hammered against the cam ring. Both of these conditions are intensified by increasing system pressure.

The solution to our reader's problem is simple: replace the suction filter or better still, discard it completely. If suction filtration must be installed, follow these precautions to prevent pump damage:

- A filter located outside of the reservoir is preferable to a suction strainer. The inconvenience of servicing a filter located inside the reservoir is a common reason why suction strainers go unserviced - until after the pump fails.

- If a suction strainer is installed, opt for 250 microns rather than the more common 150 microns.
- The filter should be grossly oversized for the pump's flow rate to ensure that pressure drop is minimized, even under the most adverse conditions.
- Regardless of the type of filter employed, it must incorporate a bypass valve to prevent the element from creating a pressure drop that exceeds the safe vacuum limit of the pump.
- A gauge or transducer should be installed downstream of the filter to enable continuous monitoring of absolute pressure at the pump inlet.

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Hydraulic Cylinders
Did YOU know that up to 25% of cylinder rod-seal failures are caused by bent rods?
Shows you step-by-step, how to check cylinder rod-bending loads. PLUS - cylinder types, their construction and seal arrangements are all covered in detail. The chapter concludes with a discussion of cylinder regenerative circuits.

Hydraulic Pumps
When you have pump problems this is the place to start. Explanation of the construction and operating principles of different pump designs is expanded to include the seven factors you must consider when selecting a pump. AND you get the all the application formulas you need - with worked examples included.

Variable Pump Controls
Pump controls are complicated, right? WRONG! Pressure-compensated, constant power (torque-limiting) and load-sensing control will no longer be a mystery to you once you've read this chapter. Pump control functions are illustrated with colour sectional views along with their corresponding graphical symbols.

Hydraulic Motors
When you have motor trouble turn to page 84. Describes how torque is developed in a hydraulic motor and explains the construction and operating principles of different motor designs. The process of selecting and sizing a hydraulic motor is covered in detail, with all necessary formulas included. PLUS - the three most common motor control-circuits are illustrated and explained.

Directional Control Valves
Directional valves are simple, right? Nope. This chapter explains the finer points of directional valve construction, operation and application: spool overlap and ring gap, valve mechanisms, switching positions, pathways, center and transition condition and actuation methods - just to name a few.

Hose and Fittings
Do you know a seven degree twist in a high-pressure hydraulic hose can reduce its service life by 90%? Covers flow velocity and sizing, selection and rating of conductors (pipes, tubes and hoses), including metric tube and metric compression fittings.

Pressure Control Valves
What they do AND how they do it. Covers the application and operation of direct-acting and pilot-operated relief valves - with and without remote pressure control, accumulator-unloading circuits, single and two-stage sequence valves, counterbalance valves and direct-acting and pilot-operated pressure reducing valves. Like all other chapters throughout the book, functional descriptions are illustrated with colour sectional views and their corresponding graphical symbols.

Cartridge Valves and Logic Elements
Do you know that logic elements can be configured for flow in two directions - but only one ensures leak-free operation? This chapter will bring you up to speed on screw-in and slip-in cartridge valves. From the basics, right through to the configuration and control of logic elements

for direction, flow and pressure control applications.

Flow Control Valves
How to navigate the flow control maze. Explains the laws that govern flow rate through an orifice and discusses the use of needle valves as flow controls and their limitations. The operation of pressure and temperature compensated flow controls and their application in meter-in, meter-out, bleed-off and deceleration circuits are explained. PLUS - how a three-way flow control minimizes energy loss in a circuit. The chapter concludes with a practical discussion of flow-divider and priority flow-divider valves.

Hydraulic Oils
The quickest way to gain a comprehensive understanding of the most important component of every system. Absolute and kinematic viscosity is explained and fluid properties such as viscosity index, pour point, oxidisation stability, lubricity, demulsibility, foaming resistance and air release are discussed. Special purpose oils are considered, including a comparison table for petroleum and alternative fluids. The chapter concludes with discussion of bulk modulus and decompression control.

Troubleshooting
What you MUST check to ensure you don't overlook the obvious. Covers six common hydraulic problems and their root causes.

Filters
If you want to control contamination - then you must understand filtration. Explains absolute, nominal and Beta ratings of filters and classification of fluid cleanliness. The difference between surface and depth filters is illustrated. PLUS - the chapter concludes with coverage of clogging indicators and pressure switches.

Accumulators
What you MUST KNOW about hydro-pneumatic accumulators. Application guidelines and formulas for working volume and gas pre-charge. The chapter concludes with illustration and explanation of common accumulator circuits.

Proportional and Servo Control
If you want to know where hydraulics is heading, then this is essential information. Proportional and servo valve construction and operation, valve characteristic definitions and control electronics are all covered in detail.

Reservoirs
Why all hydraulic tanks are NOT made equal. Explains the various functions of the reservoir, and covers reservoir sizing, design and construction. PLUS - the quickest and easiest way to calculate heat dissipation from the reservoir.

Pneumatic Logic Control
Even if this method of control is all new to you, you will make the transition from novice to pro in just one reading. Benefits, application and operating principles of pneumatic logic control are illustrated and explained.

Programmable Logic Controllers
You don't need to be an electrician to understand PLC-controlled equipment. This chapter will give you the knowledge you need. Operation fundamentals, logic functions, programming and integration considerations are explained in detail, with worked examples.

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ExxonMobil's series of **environmentally acceptable** lubricants, Mobil SHC Aware H, has recently received approval from hydraulic equipment manufacturer Parker Hannifin Denison as HF1, HF2 and HF6, the company said. It has also passed the Eaton ATS-373 (35VQ25) pump test.

The Mobil SHC Aware H line of products is unique because it complies with the **Vessel General Permit** or VGP regulations implemented by the U.S. Environmental Protection Agency (EPA) last December. To comply with VGP regulations, the product must meet three specific requirements including biodegradability, non-bioaccumulation and minimal toxicity to waterborne creatures, according to Iain White, marine fuels and lubricants field marketing manager. To comply with the VGP requirements, this product line uses a combination of ester base fluids and additives to meet these requirements.
ExxonMobil has other products lines that while environmentally friendly, are not VGP-compliant , such as the Mobil EAL Envirosyn H series.
22/10/2014
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A vane pump requires a higher minimum viscosity than a piston pump.
If your hydraulic system contains a vane pump, the minimum viscosity you should be looking to maintain is 25 centistokes (cSt or mm^2/s).
For mineral oils with a viscosity index of around 100, this equates to a maximum allowable operating temperature of 35 °C if you're using ISO VG22 oil or 65 °C for ISO VG68.
Operating temperatures above 82 °C damage most seal and hose compounds and accelerate degradation of the oil. But for the reasons explained above, a hydraulic system can be running too hot well below this temperature.
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(a) The level of Hydraulic oil (Mineral base, ISO VG 46) used in injection molding machine have gone down just in 1 month time.
(b) A different customer for the same oil of different batch: the oil color became slightly dark after using it for 3 months in an injection molding machine (12 ounce).

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

The drop in oil level is due to a leak. Oil does not evaporate at normal operating temperatures, so they definitely have a leak somewhere even though it may not be evident.
As to the oil getting darker this can be from admixture with a darker product but it probably because of oxidation. You should check the temperature of the system. For every 12 degrees F in operating temperature above 140 F the rate of oxidation will double. The is a geometric value so if the temperature goes from 140 F to 152 the life is cut in half, at 164 the oil life is not 1/4 what it was at 140 F. Relatively small increase in temperature can make a big difference in oil life. Suggest checking the oil cooler on the system to see if it is functioning properly.

Alexey Muralev Lubricants Field Engineer at ExxonMobil

I also think about oxidation as the main reason. Check the viscosity and oxidation by FTIR.
I've seen ISO 46 mineral hydraulic oil going for 10 000 h in plastic injection molding machines without significant darkening (only slight one).
Check their process temperatures vs. factory ones, look for hot spots, check if cooling system works fine. Color also can come from contamination - check if there are particles in the oil and what is the nature of those particles.
I've seen cases of hydraulic oil darkening in hydraulic pumps, when customer used ISO 32 mineral hydraulic oil. Their process temperature was 80 C, while it should be 50 C due to the nature of fluid that they were pumping. So the oil viscosity at working temp was below 8 cSt and manual stated it should be over 10 cSt. So oil was oxidized and very fast, as oxidation is catalyzed by wear metals that are generated by insufficient viscosity.
Also you can find a discussion about darkening here (https://www.linkedin.com/groups/Refrigeration-oil-is-getting-dark-1786018.S.146267093), though it is about refrigeration oils.

Jean-Michel Demaret   Technical Expert , Concentrating Mill Maintenance at PT Freeport
The level drops, Often low viscosity hydraulic oil are quite clear and difficult to spot. Add a fluorescent dye to the oil (dye for lubricant) and with or without an ultraviolet light it is easier to find. Your customer may be right in saying that the oil started to disappear after the change over. Some old with old additives are imbibed in the rubber seals and may react with the new additives shrinking the rubber. It is not often but it may happen.

For the darkening of the oil Amine anti oxidant reacts at higher temperature and darkens the oil. Your customer may operate with low sump level and suck some air. Compressed bubbles heat up during compression and may collapse creating a phenomena similar to diesel combustion (Lorentz effect, micro dieseling) . The oil turn dark very quickly.

Arupanjan Mukherji   Regional Sales Manager

Oil temp rise is due to internal leakages of the Hydraulic system - considering the design adequately done - poppet of the relief valve in the system needs to be checked for internal leakages. DC valves may develop leakages, causing the temp to rise and as the temp rises viscosity drops causing further leakages and consequently further rise in temp -
Use thermography to check the source of internal leakages, highest temp element and remember to use and maintain a clean fluid.

Dan Arkins   Contract packaging and blending. Packaging and equipment design expert

Color change is due to either over heating(unlikely) or a breach in the system aka... Cylinder, valve or seal degradation. Fluid level should not change unless the is a visible leak.

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When oils with different additive chemistry are mixed, there is always a risk of additive 'drop-out'.

At the very least, you should be doing a thorough oil drain and filter change as part of switching oils. But unless it's practical or possible to drain every part of the system, a small percentage of the original oil will remain and be mixed with the new oil.

If the old and new oils have different base stocks, possible swelling or shrinking of seals may need to be considered. And a DOUBLE oil and filter change may be advisable.

This involves an initial oil drain and filter change. The system is then filled with the new oil to the minimum level required and the oil circulated until it's been turned over at least five times. The oil is then drained and the filters changed a second time.

Regardless of which method is used, before making the switch, it's a good idea to mix equal parts of the original and new oil in a glass jar and shake vigorously.

Wait half an hour and observe the solution. Look for changes in color, clarity, viscosity and sediment. If in doubt, or for extra peace of mind, filter 100 milliliters of the old, new and mixed oils through a patch filter - noting the time taken for each. If nothing abnormal is observed, then it should be safe to proceed.

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Additive removal by filters

Evan Zabawski, CLS

Reliability Specialist

You cannot mechanically filter out functioning additives. See http://onlinedigitalpublishing.com/publication/?i=184584&p=28 for an article explaining it fully.

George Abernathy

Fluid Product Specialist at Steiner Electric

I agree with Mark as the moisture content CAN react with additives/anti-oxidants with heat and other catalysts (maybe polymerizing with the "silly string" comment- with a dual purpose way-hyd. oil). I HAVE seen that also!!

We thought it might be fungus-again moisture, running "wet" in the system and the breathers weren't working properly.

Alexey Muralev

Head of Technical Service Department at Kulan Oil

Hmm, and what about ultra-fine filtration during by-pass filtration in DEO?
There are high-molecular VM and suspended defoamers.

Mark O'Brien

Lubrication Excellence Champion

Might be fungus, never ran across that one. Have seen algae in diesel fuel strainers. Good fuel treatment with a de-oxygenator fixes that.

The discussion is based on semantics; Evan's article states that additives cannot be filtered from the product in a "properly maintained" system. Larry said that water can cause the filtering. Both are correct. The additives may not be filterable but the product produced from water contamination is. I have seen the filters with something the technician showing me this called "silly string" clogging the filter. An older and wiser advisor told me that what we were seeing was the results of too much water that had caused the AW additives to be spent prematurely. You add this to what I have heard that fish do in the water and I am swearing off on drinking this stuff ever again.

Alessandro: My doubt is about filterability testing, which is an essential requirement for unused hydraulic fluids, afaik. If "**additive removal by filters** is nonexistent in properly maintained lubricant system", then what filterability testing is about? I thought it was about some high molecular weight additives that are possibly blocked by very fine filtration.

Mark O'Brien

Lubrication Excellence Champion

According to textbook author Tex Leugner:

"Never use "adsorbent depth" type filters. These filters differ from "absorbent depth type" filters in that they contain chemically active media, such as charcoal or fullers earth.

The danger of using these filters is that they while they remove contamination, they may also remove oil additives through a chemical reaction."

Solid lubricants such as graphite can easily be filtered out of the product if their particle size is greater than the filter micron rating. This issue is most prevalent in low-cost, bid-winning oils that rely on cheaper and less refined additives to compete in the price wars. Caveat Emptor.

David Wedlock

Consultant - Base Oils and Lubricants

Molecularly soluble additives like EP and AW will not filter out with normal particulate filters - even fine ones. They will deplete because they lay down on metal surfaces, which is how they work. De-foamers which are mainly, dispersions will filter out - which is why there are so many industry foaming problems in wind turbine gear boxes because of the extremely fine filters OEMs insist on.

To respond to Alessandro - even some base oils cause hydraulic fluids to fail filterability tests - where the same additives will pass with other base oils. This tends to be down to incipient wax crystallisation which can still manifest ABOVE the base oil cloud point. Residual wax has commenced to nucleate even before you see it as a cloud.

Jason Wells   Founder at Novvi, LLC

Generally it should not happen, but experienced lubricant blenders and additive manufacturers know that some additives (functionalized and long-chain polymers, undissolved solids, and silicone anti-foam agents) can be removed by filtration in some cases. It's one of the reasons we do filterability testing on new formulations and why you should follow equipment manufacturers filter specifications. There are some knowledgeable comments about that topic here:
http://www.linkedin.com/groups/Question-On-Additive-stripping-3125819.S.101871605

Larry Hajek   senior lubricant technical manager at Citgo

Water will cause additive to filter out.

Velibor Karanovic   Teaching Assistant at Faculty of Technical Sciences

Ok, first of all thanks Evan for recommendation of interesting article, it should be read by anyone who ask himself about **additive removal by filter**. There is also a nice discussion about the subject which is proposed by Jason. Thank you Jason for that.
Based on what i have read, removal is posilbe under certain conditions. Factors that influence that kind of problem are:
- size of filtration pores vs. size of insoluble additives (such as sulfur and phosphorus...),
- type of filter media or technology of filtration,
- contamination by water - as a most catalistic supstance for additive depletion in hydraulic oil (causing agllomeration, formation of polimeric compounds) which is enhanced by high working temperatures.
So if there any other suggestions to spread this list, I would be pleased to hear it.

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Gongde Liu   Lube R&D Dept. Manager at PetroChina Dalian Lube R&D Institute

It's rather a history to use engine oils as substitutes to hydraulic oils. Besides the common requirements of anti-oxidance and anti-wear properties for the two oils, engine oils focus on detergency and dispersancy, while hydraulic fluid focus on anti-emulsion and copper protection. Especially for construction or mining industry, water contamination is unavoidable. if engine oils were used to replace hydraulic fluid in this circumstance, water caused oil emulsion and consequently wear and corrosion would definitely followed. What's more, engine oils are generally more expensive than hydraulic fluids nowadays, so it's not economical to use engine oils where hydraulic fluids should be applied.

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I have found through experience that when oils that contain ZDDP is mixed with oils containing a non zinc anti-wear additive the proportions are important. I'm not quite sure how the chemistry works here but seems to happen in practise. It is not wise to add a small (5 -10%) of one with the other. The threshold seems to be about 25% so if it is necessary to mix one with another make sure the top up is about 25% of the total volume. The problem appeared as zinc drop-out in the mixture and filter blocking etc. I've seen this occur in large sumps of high speed wire rod mills and some larger hydraulic systems. The presence of water in these also adds to the problem.

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a fraction of a second is all this takes

Today I'm going to explain a nasty complication of over-pressurization.

When a hydraulic system sees a spike in pressure
it won't necessarily blow up with a bang.
But damage can occur in a number of ways.

In fact, a single pressure spike of sufficient magnitude
can render a piston pump or motor unserviceable.

Here's how:

In axial and bent axis piston pump and motor designs,
the cylinder barrel is hydrostatically loaded against
the valve plate.

To maintain full-film lubrication between the
rotating cylinder barrel and the stationary valve plate,
the hydrostatic force holding them in contact is offset
by a hydrostatic force acting to separate the parts.

The higher the operating pressure, the higher
the hydrostatic force holding the cylinder barrel
in contact with the valve plate.

However, if operating pressure exceeds design limits,
the cylinder barrel will separate from the valve plate.

Design geometry prevents a perfect alignment of
the opposing hydrostatic forces. This misalignment
creates a twisting force (torque) on the cylinder barrel.

During normal operation, this torque is supported by the
drive shaft - in axial piston designs or center pin
in bent axis designs.

If operating pressure exceeds design limits,
the magnitude of the torque created
causes elastic deformation of the drive shaft
or center pin. This allows the cylinder barrel
to separate from the valve plate.

Once separation occurs, the lubricating oil film
is lost and the resulting two-body abrasion damages
(scores) the sliding surfaces of the cylinder barrel
and valve plate.

Erosion of the kidney area of the valve plate can also occur as high-pressure fluid escapes into the case at high velocity. This surge of flow into the case can cause excessive case pressure, resulting in shaft seal failure.

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Aeration of hydraulic oil

Air typically enters the hydraulic system through the the pump inlet and, under certain conditions, past the rod seal of a double-acting cylinder.

But air can also invade the system through joints in pressurized plumbing.

When fluid travels through a pipe or hose at relatively high velocity - in a pressure line for example, and has to change direction through a tee or elbow, a venturi effect can be created.

Because the sealing arrangement of the hydraulic connector is designed to withstand positive pressure - but not negative pressure, air can be drawn into the system - even when the plumbing has no apparent leaks.
Wouter Leusden, one of our members from The Netherlands describes it this way:

If you made a glass model of a pipe elbow and connected a measuring point in the middle of the angle, you would see a negative pressure when fluid passed through the elbow at high velocity.

And if you looked carefully, you'd likely see air bubbles entering the system through the seal of the measuring connection.

The moral to this story is of course to use as few sharp angles - tee-pieces, elbows, etc in hydraulic plumbing as possible.

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One recent client, the designer of a three-wheeled vehicle, approached me to design a hydraulic drive. He wanted to power at least two-wheels, ideally three.

To keep cost to a minimum, the machine designer asked me to consider gear pumps and motors.
A gear pump or motor in good condition is 85 percent efficient.

So a gear pump driving a gear motor has a best-case **efficiency** of 0.85 x 0.85 = 0.72. That's 72 percent - not considering losses through valves and conductors.

But say a gear-type flow divider was included to achieve multi-wheel drive. The theoretical efficiency would now be 0.85 x 0.85 x 0.85 = 0.61. That's 61 percent, not including losses through valves and conductors.

Compare this with a chain drive in good condition, which is 97 to 98 percent efficient. This explains why you don't see any hydraulic bicycles around!

In this application where the available input power was limited by space and weight, the question I had to ask my client was: Can you afford to lose 40 to 50 percent of available input power to heat?

In his case, the answer was no.

Contrast this example with another client for whom I'm advising on the design of a 6,000 ton press. Regardless of efficiency, hydraulic power transmission is really his only option.

But this is also a relatively efficient use of hydraulics. One of the reasons for this is the efficiency of a hydraulic cylinder approaches 100 percent.

And because it's a high-pressure application, piston pumps are essential. The overall efficiency of an axial piston pump in good condition is 92 percent. So the theoretical efficiency of the press hydraulic circuit is 0.92 x 1.00 = 0.92 or 92 percent - not including losses through valves and conductors.

A significant, 'built-in' inefficiency in this application however, is the compressibility of the hydraulic fluid:

'Built-in' inefficiency of every hydraulic system: **compression of the oil**.

A fluid's compressibility is defined by its bulk modulus of elasticity - which is the opposite of compressibility. Meaning, as the bulk modulus of elasticity increases, compressibility decreases.

Bulk modulus is an inherent property of the oil and therefore an inherent inefficiency of a hydraulic system.

The fluid in the pipeline and actuator must be pressurized, and consequently compressed, before it will move a load.

Because this compression of the fluid requires work at the input - which cannot be converted to useful work at the output - it is lost work

and therefore a contributing factor to the
overall inefficiency of the hydraulic system.

The larger the actuator and the faster the response time,
the higher the inefficiency attributable to bulk modulus.

And in high-performance, closed-loop electro-hydraulic systems,
deforming oil volumes affect dynamic response,
causing possible stability problems such as self-oscillation.

Unlike viscosity index, bulk modulus cannot be improved
with additives. However, hydraulic equipment users
can take steps to minimize the inefficiencies
and potential control problems associated with
compression of the fluid.

The first is to ensure hydraulic equipment
doesn't run hot. Compressibility of the fluid increases
with temperature. Mineral hydraulic oil
is approximately 30 percent more compressible at 100°C
than it is at 20°C.

Of course, there are many reasons why you should
never allow hydraulic equipment to run hot -
most of which we've already discussed.
Reduced bulk modulus is another one.

The second is to prevent conditions that cause aeration.
Air is 10,000 times more compressible than oil.
One percent of entrained air by volume can
reduce the bulk modulus of oil by as much as 75 percent.

While controlling aeration is largely a design issue -
for example, the amount of dwell time the oil
has in the tank - proper maintenance
also plays an important role.

Dissolved air comes out of solution as temperature increases,
which is another reason to maintain appropriate and
stable operating temperatures.

Also, oxidative degradation and water contamination
inhibit the oil's ability to release air, often resulting
in an increase in entrained air and thus compressibility.
================================
When a **hydrostatic transmission is subject to a
sudden increase in load**, the motor stalls momentarily
and system pressure increases until the increased load
is overcome **or** the high pressure relief valve opens -
whichever occurs first.

While the motor is stalled, there is no return flow

from the outlet of the motor to the inlet of the pump.
This means that the transmission pump will cavitate
for as long as it takes to make-up the volume of fluid
required to develop the pressure needed to overcome
the increased load (or the high-pressure relief valve).

How long the pump cavitates depends on the
output of the charge pump, the magnitude of
the pressure increase, and its influence on
the increase in volume of the pipe or hose,
and the decrease in volume of the fluid.

This is called the 'accumulator effect'.

(For an in-depth analysis of this problem
watch the 20-minute video in 'Hydraulics Made Easy'
http://www.hydraulicsupermarket.com/made-easy)

One way to minimize stalling and pressure spikes
and the resulting 'accumulator effect'
in applications where the load on the transmission
varies - in say drill rigs for example, is to
install a flywheel between the hydraulic motor
and reduction box.

The stored energy in the flywheel assists the
hydrostatic drive to maintain speed and torque,
and minimize the magnitude of pressure fluctuations
resulting from sudden increases in load.
================================
If you're serious about eliminating **hydraulic leaks**,
then the scourge of your hydraulic plumbing is
the tapered thread connection - NPT or BSPT.

I'm a big advocate of eliminating tapered threads
from your hydraulic plumbing - but I also understand
that sometimes, what's ideal is not always feasible.

When they can't be 'engineered out', this is
how I deal with them:

First, don't waste your time with thread tape -
I only ever use it when there's no thread sealing
compound available. I've had best success with
Loctite 567 and 577 (my favourite), which are pastes
rather than liquids like some of the others.

If you're re-sealing a joint, thorough cleaning
of the old adaptor and port is essential. If you're
in your workshop, a brush wheel in a bench grinder
does a marvellous job on the threads of the adaptor.
But the female threads in the port aren't so easy.

Once you've removed all remnants of thread tape
or sealant, the next step is to use the
appropriate Loctite cleaner.
Don't skip this step - you'll regret it.

Next, if you're not able to wait the 6 hours
or so for acceptable cure strength, apply the
Activator 7649 and allow it to dry. If you have
the luxury of leaving the joint overnight
before pressurizing it, you can skip this step.

Starting two threads back, apply a bead of paste
around the entire circumference - completely
filling the threads. Do the same with
the female threads in the port.

Now torque the joint. And I'll have more to say
about correct torque for taper fittings in your
next hydraulics email in a few days time.
==================================
In your last hydraulics email,
I explained the method I use for **sealing
taper threads** - when they can't be 'engineered out'.

When it comes to tightening taper-thread connections,
you must exercise a degree of caution.

Not enough torque and the joint will leak.

But excessive torque can result in broken housings
on pumps and valves - due to the force developed by the
wedge action of the tapered adaptor.
This Parker document, provides a guide
for torquing tapered-thread adaptors -
based on the 'turns from finger tight' (TFFT) method:

http://www.hydraulicsupermarket.com/torque.html

And when it comes to taper-threads, this is
about as scientific as it gets
==================================
Today I want to explain a technique that is
very useful when you're troubleshooting a system
that's overheating.

This technique involves using an **infrared thermometer** -
sometimes called a heat gun, to measure the oil's
temperature drop across the heat exchanger.

The heat rejection of the exchanger can then be
calculated and when this is expressed as a percentage

of input power, it will reveal whether the problem
is in the cooling circuit or elsewhere in the system.

The exact procedure for doing this is explained
in detail on page 21 of 'Preventing Hydraulic Failures'.
http://www.preventinghydraulicfailures.com
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Unlike a vane pump which needs a head of oil on its outlet for the vanes to 'throw' and start pumping, a gear pump is normally considered self-priming - especially when its submerged in hydraulic oil.

To give the new pump the best possible chance of priming, I topped off the oil level at maximum. Still no charge pressure after running for a minute. In the absence of a flow-meter, I decided to lift the electric motor off its bell housing, disconnect the pipes from the pump's outlet penetrations in the top of the tank and turn the pump by hand.

This was revealing. The front section was pumping, but the rear section wasn't. Joy. The rear section was faulty. I continued turning the pump by hand, while I wondered what the chances were of this happening, and contemplated the work involved in lifting the tank lid.

Just as I was about to give up and call for reinforcements, I noticed oil was being displaced from the rear pump's outlet penetration in the top of the tank. It WAS pumping. I reconnected the plumbing, dropped the electric motor back into position and bingo. We had accumulator charge.

Had I been told this story about a gear pump that wouldn't prime itself - I would have struggled to believe it. Yes it IS strange … but true.

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Hydraulic fluid temperatures above 180 F (82 C) damage most seal compounds and accelerate degradation of the oil.

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When fluid moves from a high pressure zone to a
low pressure zone we call this pressure drop.

When a pressure drop occurs WITHOUT useful work
heat is generated. For example, the pressure drop
across the ports of a properly functioning motor
produces torque at the motor's drive shaft and
ultimately useful work.

On the other hand, the pressure drop across a relief
valve doesn't produce any work, so this energy is
converted to heat - which is an undesirable heat load
on the system.

Because a pressure drop without useful work creates heat,
an infra-red thermometer can often be used as a quick and
effective means of locating abnormal heat load.

For example, if oil is passing over a relief valve, the
localized heat generation means this component will be
hotter than the rest of the system.
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The end of the month was just a few days away when an OEM customer called and advised its hydraulic cylinder manufacturer that the boom extension cylinder on a rough terrain forklift was SQUEALING.

This single-stage cylinder was 6" bore x 3" rod x 14' stroke.The OEM was in a terrible position because they had 80 machines they could not ship by the end of the month deadline due to the squealing - which could be heard blocks away.

The OEM was demanding that the cylinder manufacturer send a crew of men to change out all 80 cylinders!

But what could the problem be?
Seal stick and slip?
Excessive stroke speed?
Internal leakage?
Load-control valve?

"The squeal was present at all engine speeds - so flow rate / stroke speed was not an issue. Through a process of elimination, I isolated or changed out all cylinder valves. No difference.

I then removed the cylinder from a machine and placed it on a bench. I connected the cylinder to the same new machine with quick disconnects. I removed the rod seal and under no load I stroked the cylinder and it still squealed. I then removed the piston seal and the squeal remained. So it continued to squeal with no seals installed.

I reinstalled the seals and connected the cylinder to an older machine, which was referred to as the "yard machine", while the cylinder was still on the bench. The squeal was gone! I drained the oil from the cylinder and reconnected it to the new machine -- the squeal was back! This eliminated the cylinder.

The General Manager at the OEM was still insisting that I contact my factory and get a crew of men to his plant and change out all 80 cylinders (he was what you might call a duck hunter). By now though I was confident that the cylinders were not the cause of the problem. I asked him to give me another day in order to determine the root cause.

Earlier that day I noticed two things that put me on the right trail. One was the color of the oil that was draining from the cylinder when I disassembled it. The oil looked like ivory soap. The other was a slight hissing sound when I removed the head gland from the cylinder. I knew at this point that aeration was causing the squeal.

But the challenge was trying to convince the customer's engineers. I had to prove where the air was coming from and why. So the big question was: What was different about the new model machine? Were the pumps changed? Was the design of the hydraulic tank changed in any way? How about the suction lines or suction strainer? The answer to all these questions was the same: NO.

When I had connected the cylinder to the new machine the cylinder squealed, when I connected it to the older machine it was quiet. When switching the cylinder from new machine to old machine I had made sure that the cylinder was completely drained of hydraulic fluid.

So now back to the questions. Have you changed oil viscosity, brand, supplier or formula? Again the answer was NO. I insisted that the oil was the source of air in the system and that air was causing the squeal. The oil vendor was called and he stated that to the best of his knowledge the oil was the same. I insisted that the oil vendor contact the blender to ask if the additive package had been changed. They agreed and the next morning a chemist from the oil blender was on site.

In the meantime I went to the nearest CAT dealer and got some of CAT's Anti-Chatter hydraulic oil additive. I added a quart to a machine that was squealing and within 5 minutes the squeal was gone.

Needless to say at this point all eyes turned to the oil blender and their chemist. It turned out that the formula of the oil had been changed and the amount of air-release additive had been reduced. All 80 machines had the hydraulic fluid replaced and their shipment to customers was back on schedule."

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Installed cooling capacity typically ranges between 25 and 40 percent of input power. So if a system has a continuous input power of 100 kilowatts and the exchanger is dissipating 26 kilowatts of heat, this means the efficiency of the system has fallen below 74 percent. If the system is overheating, this is a good indication that there is abnormal heat load somewhere in the system.

On the other hand, if a system has a continuous input power of 100 kilowatts and the exchanger is dissipating 10 kilowatts of heat and the system is overheating, this means that there's a problem somewhere in the cooling circuit or the system does not have enough installed cooling capacity.

Week 1

Defining a hydraulic machine's temperature operating window (TOW) is essential for maximum reliability and minimum downtime. It doesn't matter what else you do, if you allow your machine to operate outside its TOW, it'll give you ongoing problems. Yet, in my experience, most hydraulics users never bother to do this exercise. Some get away with not doing it. Others are not so lucky. But it's just too important to leave to chance.

In this group session, I'll show you how to do this right and you'll leave with the tools you need to do it for your 'clunker' and any other hydraulic machine you're responsible for.
Week 2

You get a personal 30-minute coaching call with me to help you implement what we covered in the previous group session. I'll remove any roadblocks, help you interpret your results, and if something needs to change, we'll work through that as well. Your machine's TOW -- and keeping it operating within, is vitally important for reliability. Hence the time dedicated to getting this right. And doing so will payoff for you for years to come.
Week 3

Every hydraulic system has a 'native' efficiency based on how it's designed and the components used in its construction. The extent to which your machine is inefficient in converting input power into useful work determines the heat load it produces. And this heat load must be properly offset to achieve thermal balance. But not just thermal balance at any old temperature. Thermal balance within the machine's TOW. If thermal balance occurs outside of its safe TOW, the result is a heat-damaged hydraulic system. And a heat-damaged hydraulic machine is an unreliable hydraulic machine.

In this group session, I'll show you how to determine if you've got the right hardware in the right place to achieve and maintain thermal balance within your machine's now defined TOW. By the way, these group sessions will be recorded and call-in times will accommodate participants from all over the world.
Week 4

You get a personal 30-minute coaching call with me to help you implement what we covered in the previous group session (you can see the pattern here). Once again, I'll help you remove any roadblocks, make sense of your results, and if something needs to change, we'll work through the issues involved. Over-temperature events compromise reliability in a major way. The work we'll do in weeks 3 and 4, when fully implemented, will ensure they just don't occur under normal conditions.
Week 5

Defining appropriate oil cleanliness targets is essential for hydraulic system reliability and longevity. But this is not a one-size-fits-all type of decision. In this group session I'll cover all of the issues that need to be considered when choosing targets for particulate and water concentration in the oil. Of course, setting appropriate targets is one thing; achieving them is another. So I'll also explain how to figure out where your machine is at now and what needs to be done in order to hit and maintain the targets you set.
Week 6

You get another personal 30-minute coaching call with me to help you implement what we covered in the previous group session. Once again, I'll help you remove any roadblocks, fine-tune your results, and if something needs to change, we'll work through that together. Effective contamination control is one of the keys to long and trouble-free operation. Which is why I've allocated this time to getting the parameters right -- for your particular hydraulic machine.
Week 7

It costs 10 times more to remove contaminants than it does to exclude them in the first place. And as you're probably already aware, some hydraulic filters can do more harm than good. In this group session I'll explain which filter locations to avoid and why. I'll also cover all the common contaminant ingression points, along with their methods of exclusion. And I'll explain how to get out-of-control particle and/or water concentration back within your newly targeted limits.
Week 8

You get a personal 30-minute coaching call with me to help you implement what we covered in the previous group session. If your machine has a filter located somewhere it shouldn't, I'll help you figure out if it's a genuine exception (there are a few) or not. If something else needs to change, we'll deal with that too. And if there are any other roadblocks to getting this done I'll help you remove those as well. Despite advances in filtration technology and awareness, water and particle contamination are still heavy hitters when it comes to reliability problems and premature failures. Which is why the work we'll do in weeks 5 to 8 will definitely pay off in spades over the long run.
Week 9

Efficient and trouble-free operation of a hydraulic machine requires proper operation and adjustment of installed circuit protection devices. Cavitation, aeration, over-pressurization -- even over-heating, resulting from faulty or incorrectly adjusted circuit protection devices, all affect machine performance and can cause premature component failures. The objective of this group session is for you to be able to identify those circuit protection devices which are critical to your machine's efficient operation and reliability, understand what will happen if they fail to function correctly, and know how to check their operation and adjustment.
Week 10

You get a personal 30-minute coaching call with me to help you implement what we covered in the previous group session. On this call, I'll work with you to ensure you understand what problems will occur if the circuit protection devices on your machine don't function correctly, and I'll assist you with the development of procedures for checking their proper operation and adjustment. Doing this exercise will not only enhance your machine's reliability in the long run - it'll also help you to get to know your machine a lot better!
Week 11

In this final group session we'll switch gears from preventative maintenance to predictive. I'll explain what can be done to assess the current condition of the components on your machine. I'll also explain which types of components are the ones you need to keep a close eye on-and proactively change-out, in order to avoid the collateral damage and expense associated with in-service failures. And I'll discuss what can be done to minimize consequential damage if the risk of in-service failure is high, but a planned change-out cannot be immediately scheduled for economic or operational reasons.
Week 12

You get a personal 30-minute coaching call with me to help you implement what we covered in the final group session. On this call I'll help you review your machine's service history and identify what's likely coming, in terms of achieved service life, and therefore, looming component breakdown. Forewarned is forearmed. Weeks 11 and 12 are strategic sessions designed to help you get 'ahead of the curve' in eliminating unscheduled downtime and the consequential expense of in-service failures.
==

"What is the system's normal operating temperature?
... what's the system's usual operating pressure range?"

answer these two simple questions
about the "vital statistics" of your hydraulic equipment

Here's how I recommend you do it:

First you need an infra-red thermometer, also called a heat gun.
If you don't have, you'll need to invest around 100 bucks
to get one.

Next, using a permanent marker, draw a small target
on the hydraulic tank below minimum oil level and
away from the cooler return. Label it 1. This marks
the spot where you'll take your tank temperature readings.

If the system is a closed circuit hydrostatic transmission,
mark a convenient location on each leg of the transmission loop
and number them 2 and 3. Skip this step for open circuit systems.

Next, mark a target on the cooler inlet and outlet
and number them 4 and 5. This will record the temperature drop
across the cooler.

The idea behind these targets is regardless of who takes
the temperature readings they'll be taken from the same place
each time.

With that done, now draw up a table to record these temperatures
along with the date, time, ambient air temperature, operating
pressure and in the case of a hydrostatic transmission -
charge pressure.

I recommend you take readings on the hottest and coldest days
of the year and on a couple of average temperature days in between.
This provides a baseline of data.

Beyond that, taking readings at regular intervals - daily,
weekly or monthly, can provide early warning of system problems.
And if the system starts to give trouble, taking a set of
readings will reveal if it's operating outside of its
normal parameters.

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According to an article I read in
Hydraulics and Pneumatics magazine,
the average operating pressure
of mobile hydraulic equipment
will soon increase to 450 bar.

This is an interesting development. Because while the
operating pressures of mobile hydraulic equipment
have been on the increase for over 30 years,
they haven't changed much since the current average
operating pressure of 350 bar (5,075 PSI) was reached
in the early 1990's.

It's interesting because mobile hydraulic equipment

already gets a much harder life than its industrial
counterpart. There are three main reasons for this:

The first is operating environment.
While there's plenty of industrial hydraulic equipment
working in dirty, dusty conditions and temperature extremes
- this is the norm rather than the exception for mobile.

The second is tank size.
Due to space and weight restrictions, the tank capacity
of mobile hydraulic equipment is always less than ideal.
This means that there's less oil circulating in the system
and it has a shorter dwell time in the tank to give up
contaminants such as particles, water and air.

And the third is operating pressure.
Again, while there are plenty of high-pressure industrial
hydraulic systems around, it's mobile that always pushes
the envelope. And the reason for this is simple.

In a hydraulic system, power is a product of flow and pressure.
Similarly, force is a product of area and pressure.
So if pressure is increased, flow and area can decrease
for the same power and force respectively. On machines
where space and weight are an issue the advantages are obvious.

So while this new operating pressure forecast of 450 bar
is not surprising, it will further increase the stress
on mobile hydraulic machines.

Beyond the obvious material-strength issues - seals, hoses
and other components must be designed to withstand the
increased operating pressure, consider for a moment
how this will impact reliability.

As already stated, force in a hydraulic system
is a product of pressure and area. So when
operating pressure increases - so do loads
on lubricated surfaces.

Oil viscosity and film strength are vital to maintain
full-film lubrication between heavily loaded contacts.
I already consider the oil to be THE most important
component of any hydraulic system. But this will
definitely be the case for mobile machines
operating at 450 bar. Selection AND maintenance of the oil
will be critical for optimum reliability.

Similarly, contamination control will be more important
than ever. Why? Because the more heavily loaded the machine
- the more susceptible it is to wear and damage from water
and particle contamination.

My prediction is the 'next generation' of mobile hydraulic
equipment will present real challenges for both
machines designers and equipment owners.

For machine designers with little or no understanding of
hydraulic equipment maintenance and reliability issues
- their mistakes and omissions on the drawing board
are going to be magnified in the field.

For mobile equipment users whose maintenance practices
are unsophisticated or non-existent
- their hydraulic equipment operating costs will soar.

The good news is this new generation of mobile hydraulic
machines is still a couple of years away.

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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.

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.
===

I'm going to
explain the potential pitfalls when measuring
case leakage from a hydrostatic transmission.

A hydrostatic transmission consists of a
variable-displacement pump and a fixed or
variable displacement motor, operating together
in a closed circuit.

In a closed circuit, fluid from the motor outlet
flows directly to the pump inlet, without returning
to the tank.

Because the pump and motor leak internally, which allows
fluid to escape from the loop and drain back to the tank,
a fixed-displacement pump called a charge pump is used to
ensure that the loop remains full of fluid during normal

operation.

In practice, the charge pump not only keeps the loop full of fluid, it pressurizes the loop to between 110 and 360 PSI, depending on the transmission manufacturer.

(If I've lost you at this point, you'll find the hydrostatic transmission, simulation videos in 'Hydraulics Made Easy' extremely helpful: http://www.hydraulicsupermarket.com/hydro-tranny)

When a pump or motor is worn or damaged, internal leakage increases and therefore the flow available to do useful work decreases.

This means that the condition of a pump or motor can be determined by measuring the flow from its case drain line (internal leakage) and expressing it as a percentage of its design flow.

However, using case drain flows to determine the condition of the components of a hydrostatic transmission, without a thorough understanding of the circuit in question, can result in incorrect conclusions and the costly change-out of serviceable components.

In most transmissions, the charge pump relief valve vents into the case of either the pump or the motor.

This means if the motor case drain flushes through the transmission pump case to tank, you would expect to see the flow meter in the transmission pump case drain line reading design charge pump flow. Here's why:

Say charge pump flow is 10 GPM, of which 4 GPM is leaking out of the loop through the motor's internals (case drain) and 2 GPM is leaking out of the loop through the pump's internals. The balance of 4 GPM must therefore be going over the charge relief - but still ends up in either the pump or motor case, depending on the location of the charge relief valve.

In a circuit where the motor case drain flushes through the transmission pump case to tank, you would expect to see the flow meter in the transmission pump case drain line reading the sum of these three flows (10 GPM).

So before any meaningful conclusions can be drawn, the case in which the charge pump relief is venting (motor or pump) must be determined and the two case drain lines (motor and pump) must be isolated from each other.

In your last hydraulic maintenance email,
I explained the pitfalls to look out for when assessing the condition of a hydrostatic transmission by measuring its case drain flow.

There's another component present in most hydrostatic transmissions that complicates this issue further: the flushing valve.

A closed circuit flushing valve (also called a transmission valve or replenishing valve or purge valve) usually comprises a pilot operated directional valve and a low pressure relief valve.

When the hydrostatic transmission is in neutral, the directional valve is centered and the gallery to the low pressure relief valve is blocked.

When the transmission is operated in either forward or reverse, the high pressure side of the loop pilots the directional valve. This opens the low pressure side of the loop to the relief valve gallery.

In a closed circuit, fluid from the motor outlet flows directly to the pump inlet. This means that apart from losses through internal leakage, which are made up by the charge pump, the same fluid circulates continuously between pump and motor. If the transmission is heavily loaded, the fluid circulating in the loop can overheat.

The function of the flushing valve is to positively exchange the fluid in the loop with that in the reservoir.

(You can watch a 2-minute simulation video which explains how it does this, here http://www.hydraulicsupermarket.com/hydro-tranny)

When the hydrostatic transmission is in neutral, the flushing valve has no function and charge pressure is controlled by the charge relief valve in the transmission pump.

When the transmission is operated in either forward or reverse, the flushing valve operates so that charge pressure in the low pressure side of the loop is controlled by the relief valve incorporated in the flushing valve. This relief valve is set around 30 psi lower than the charge pump relief valve located in the transmission pump.

The effect of this is that cool fluid drawn from the reservoir by the charge pump, charges the low pressure side of the loop through the check valve located close to the transmission pump

inlet. The volume of hot fluid leaving the motor outlet,
that is not required to maintain charge pressure in the low pressure side of the loop, vents across the flushing valve relief and back to tank, often via the motor and/or pump case.

So if a flushing valve is fitted to a transmission,
it acts as the charge pump relief valve once the transmission is operated in forward or reverse. So if the flushing valve vents into the case of the motor, then it is possible to determine the condition of the pump by measuring its case drain flow, but not the motor.

If the flushing valve vents into the case of pump, then
it is possible to determine the condition of the motor by measuring its case drain flow, but not the pump.

This reinforces the point that using case drain flows to determine the condition of the components of a hydrostatic transmission, without a thorough understanding of the circuit in question, can result in incorrect conclusions and the costly change-out of serviceable components.

===

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.

How much water is too much?

A number of factors need to be considered when selecting water contamination targets, including the type of hydraulic system and your reliability objectives for the equipment.

It's always wise to control water contamination
at the lowest levels that can reasonably be achieved, but certainly below the oil's saturation point at operating temperature.

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.

Headspace dehumidification - This method involves circulating and drying the air from the reservoir headspace. Water in the oil migrates to the dry air in the headspace and is eventually removed by the dehumidifier.

Vacuum distillation and headspace dehumidification also remove dissolved water.

Prevention is better than cure

Like all other forms of contamination, preventing water ingress is ten times cheaper than removing it from the oil.

On page 27 of 'Preventing Hydraulic Failures' I outline six common water entry points and how to eliminate them:
http://www.preventinghydraulicfailures.com
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http://www.machinerylubrication.com/Read/28753/minimizing-impact-of-built-in-contamination-in-hydraulic-systems-

The assembly and filling process introduces particles into a hydraulic system. Therefore, it is a common practice to verify the contamination level of new systems as they are undergoing functional tests on the assembly line. Portable online particle counters are the preferred instruments for checking the cleanliness level. Online particle counters provide a rapid means of analysis and are not susceptible to the pitfalls of bottle sampling.

If necessary, flush the assembled system to achieve roll-off cleanliness target.

	CONTAMINATION SENSITIVITY	
SYSTEM PRESSURE	HIGH	MEDIUM
≤ 2300 psi (160 bar)	17/15/12	19/17/14
> 2300 psi (160 bar)	16/14/11	18/16/13

Roll-off cleanliness targets for new hydraulic systems

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.

==

Never use ethylene propylene with hydraulic fluid.
Parker Handbook includes a compability chart that list the fluids and the different elastomers regarding compability.

O-Ring Materials Compatible with Hydraulic Oil, Petroleum Base
(4) Good, both for static and dynamic seals
(3) Fair, usually OK for static seals
(2) Sometimes OK for static seals; not OK for dynamic seals
(1) Poor
(0) No Data
Aflas (0) Buna-N (Nitrile) (4) Butyl (0) Chemraz (4) Epichlorohydrin (4) Ethylene-Propylene (1)
Fluorocarbon (4) Fluorosilicone (4) Hypalon (3)
Kalrez (0) Natural Rubber (1) Neoprene (3) Nitrile, Hydrogenated (4) Polyacrylate (0) Polysulfide (4)
Polyurethane, Cast (0) Polyurethane, Millable (0) Silicone (2) Styrene Butadiene (0) Teflon, Virgin (4)
Vamac (4)
From: http://www.efunda.com/designstandards/oring/oring_chemical.cfm#mat

O-Ring Materials Compatible with Di-ester Lubricant MIL-L-7808 (select a material to show its compatible chemicals)		
Aflas (0)	Buna-N (Nitrile) (3)	Butyl (1)
Chemraz (4)	Epichlorohydrin (0)	Ethylene-Propylene (1)
Fluorocarbon (4)	Fluorosilicone (4)	Hypalon (1)
Kalrez (0)	Natural Rubber (1)	Neoprene (1)
Nitrile, Hydrogenated (3)	Polyacrylate (3)	Polysulfide (3)
Polyurethane, Cast (0)	Polyurethane, Millable (1)	Silicone (1)
Styrene Butadiene (1)	Teflon, Virgin (4)	Vamac (0)

O-Ring Materials Compatible with Pyrogard 42, 43, 53, 55 (Phosphate Ester)
(select a material to show its compatible chemicals) Aflas (0) Buna-N (Nitrile) (1) Butyl (4) Chemraz (4) Epichlorohydrin (0) Ethylene-Propylene (4) Fluorocarbon (4) Fluorosilicone (1) Hypalon (1) Kalrez (0) Natural Rubber (1) Neoprene (1) Nitrile, Hydrogenated (1) Polyacrylate (1) Polysulfide (1) Polyurethane, Cast (0) Polyurethane, Millable (1) Silicone (1) Styrene Butadiene (1) Teflon, Virgin (4) Vamac (0)

O-Ring Materials Compatible with Transmission Fluid, Type A
(select a material to show its compatible chemicals) Aflas (0) Buna-N (Nitrile) (4) Butyl (1) Chemraz (4) Epichlorohydrin (4) Ethylene-Propylene (1) Fluorocarbon (4) Fluorosilicone (4) Hypalon (3) Kalrez (0) Natural Rubber (1) Neoprene (3) Nitrile, Hydrogenated (4) Polyacrylate (4) Polysulfide (4) Polyurethane, Cast (0) Polyurethane, Millable (4) Silicone (3) Styrene Butadiene (1) Teflon, Virgin (4) Vamac (4)

O-Ring Materials Compatible with Hydraulic Oil, Petroleum Base
(select a material to show its compatible chemicals) Aflas (0) Buna-N (Nitrile) (4) Butyl (0)

Chemraz (4) Epichlorohydrin (4) Ethylene-Propylene (1) Fluorocarbon (4) Fluorosilicone (4) Hypalon (3) Kalrez (0) Natural Rubber (1) Neoprene (3) Nitrile, Hydrogenated (4) Polyacrylate (0) Polysulfide (4) Polyurethane, Cast (0) Polyurethane, Millable (0) Silicone (2) Styrene Butadiene (0) Teflon, Virgin (4) Vamac (4)

O-Ring Materials Compatible with Lubricating Oils, Petroleum Base (select a material to show its compatible chemicals)		
Aflas (0)	Buna-N (Nitrile) (4)	Butyl (1)
Chemraz (4)	Epichlorohydrin (4)	Ethylene-Propylene (1)
Fluorocarbon (4)	Fluorosilicone (4)	Hypalon (1)
Kalrez (0)	Natural Rubber (1)	Neoprene (3)
Nitrile, Hydrogenated (1)	Polyacrylate (4)	Polysulfide (2)
Polyurethane, Cast (0)	Polyurethane, Millable (3)	Silicone (0)
Styrene Butadiene (1)	Teflon, Virgin (4)	Vamac (4)

O-Ring Materials Compatible with Turbine Oil (select a material to show its compatible chemicals)		
Aflas (0)	Buna-N (Nitrile) (3)	Butyl (1)
Chemraz (4)	Epichlorohydrin (4)	Ethylene-Propylene (1)
Fluorocarbon (4)	Fluorosilicone (3)	Hypalon (0)
Kalrez (0)	Natural Rubber (1)	Neoprene (3)
Nitrile, Hydrogenated (4)	Polyacrylate (3)	Polysulfide (4)
Polyurethane, Cast (0)	Polyurethane, Millable (4)	Silicone (1)
Styrene Butadiene (1)	Teflon, Virgin (4)	Vamac (4)

Premium performance hydraulic oil designed for heavy duty use and high levels of performance over a wide range of pressures.

Engineered for performance and anti-wear protection

- Enhanced Anti-wear formula for long life protection of all vane, gear and piston pumps
- Maximizes power transfer efficiency
- Long life formula extends fluid service
- Improves equipment operability over a wide range of temperatures and pressures
- Rust and Corrosion protection
- Excellent anti-foam properties and air entrainment performance
- Superior hydrolytic stability and power transfer propensity
- Reduces Energy consumption
- Thermal stability and oxidation resistance
- Suitable for ultra fine filtration
- Improved water separation
- Highly versatile and compatible with pump designs and seal materials
- Meets or exceeds Dennison HF-O, HF-1, HF-2

Meets or exceeds Vickers 35VQ25, Eaton/Vickers M2950-S, I286-S
Meets or exceeds Cincinnati Machine P-68, P-69, P-70
Meets or exceeds Ford M6C32, Chrysler, General Motors LS-2
Meets or exceeds US Steel 136
Available in ISO 32, 46, 68 viscosity grades.

V.S.S. Sarma • ...only GM-LH-2 specification compels us to control zinc

Samer Akram: Please look at the following specifications and see how many of them are met by Elco's hydraulic oil additives.

AFNOR NF-E 48-603 HL / AFNOR NF-E 48-603 HM / AFNOR NF-E 48-603 HV
AGMA (Mild EP) / AGMA 250.04 / AGMA 9005-D94 / AGMA 9005-D94 (EP)
AGMA 9005-D94 (R&O) / AGMA 9005-E02 / Alsthom HTGD 90 117 / ASTM D6158
Bosch Rexroth RD 90220 / Brugger-Weingarten test / BS 489 / Busak & Shamban Micro-scratching Test / Cetop RP 91 H (HM) / Cetop RP 91 H (HV) / Conestoga pump test ISO 20763 / David Brown S1.53.101 / DBL 6721 1 (HLPD) / Denison HF-0
Denison HF-1 / Denison HF-2 / Denison T6H20C Hybrid Pump test / DIN 51506 VB-L
DIN 51506 VC-L / DIN 51506 VD-L / DIN 51515 P 1 / DIN 51515 P 2 / DIN 51517 P 1 / DIN 51517 P 2 / DIN 51517 P 3 / DIN 51524 P 1 / DIN 51524 P 2 / DIN 51524 P 3 / Eaton Brochure 03-401-2010 / Eaton Vickers 1-286-S / Eaton Vickers 1-286-S3 / Eaton Vickers 35VQ25 / Eaton Vickers M-2950-S / Filterability ISO 13357 Part 1 (Wet) / Filterability ISO 13357 Part 2 (Dry) / GEK 101941A / GEK 107395A / GEK 28568A
GEK 32568F / GM LH-02 (06-1-97) / GM LH-03 (06-1-97) / GM LH-04 (06-1-97) / GM LH-06 (06-1-97) / GM LJ-03 (10-1-97) / GM LJ-03 (10-2-97) / GM LJ-04 (10-1-97) / GM LJ-04 (10-2-97) / GM LJ-06 (10-1-97) / GM LS-1 / GM LS-2 / GM LS-3 / Hoesch HWN 2333 / ISO 11158 / ISO 11158 HM / ISO 11158 HV / ISO 12925-1 CKC / CKD / ISO 6743/4 HM / ISO 6743/4 HV / ISO DP 6521 DAA / ISO DP 6521 DAB / ISO DP 6521 DAG / ISO DP 6521 DAH / JCMAS P041 HK Hydraulic Specn / MAG IAS Gear Oils /
MAG IAS P-34 / MAG IAS P-35 / MAG IAS P-38 / MAG IAS P-39 / MAG IAS P-47 /
MAG IAS P-50 / MAG IAS P-53 / MAG IAS P-54 / MAG IAS P-55 / MAG IAS P-57 / MAG IAS P-59 / MAG IAS P-63 / MAG IAS P-68 / MAG IAS P-69 / MAG IAS P-70
MAG IAS P-74 / MAG IAS P-76 / MAG IAS P-77 / MAG IAS P-78 / MAN N 698-H-LPD (July,87) / MB DBL 6721 / Metso Paper / MIL-PRF-17331J / MIL-PRF-17672D / Morgan No-Twist Rod Mill Lubricant / Morgan Worchester Advanced Lubricant / Morgan Worchester MMC 40003/No-Twist Rod Mill / Morgan Worchester Standard Lubricant
Müller Weingarten Press - Hydraulic Oils DTS 55005/13 and 55005/16 HLP 46 and HLP 48 / Multigrade hydraulic oil for mobile sector / SAE MS 1004 / SEB 181222
SEB 181225 / SEB 181226 / Siemens TLV 9013 / SIS SS 155434 / Solar ES 9-224 Class 1 / Solar ES 9-224 Class 2 / Thyssen TH-N-256132 / Thyssen TH-N-256142 / US Steel 126 / US Steel 127 / US Steel 136 / US Steel 222 / US Steel 223 / US Steel 224
VDMA 24318 / Vickers V-104C / Voith Sulzer VN 108 / VW Steel Corrosion Test P-VW 1425.

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By switching from traditional mineral based oil (Mobil Nuto H 68) to a non-zinc oil (Mobil DTE 10 Excel 68), our customer has experienced a decrease in op temp which potentially could solve an issue with burned up seals. This is likely possible because of the fact that more additives are required in order to manufacture a zinc-free oil.

Petr Vavruch • Ilseok: Not quite. Zinc is not limited in engine oils but phosphorus is limited because phosphorus poisons emission control devices. Phosphorus is contained with zinc and sulphur in ZDTP (=ZDDP). No, ZDTP is not EP or corrosion inhibitor, it is anti-wear and anti-oxidant (due to its coating of metal surfaces). No, hardly anybody worries about

zinc in the air! Lead was in the fuel thus much more of it went into the exhaust.
Switch to non-zinc hydraulic fluids in Europe was because zinc is a heavy metal and they don't want it in the environment (ground, not the air). Sure, hydraulic systems are closed (until a hose bursts) but do you always dispose of used oil responsibly?!

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Myth #5. All oil returning to the hydraulic reservoir should be filtered.

True. With one VERY important exception:
The case drains of hydraulic piston pumps and motors. Connecting case drain lines to return filters can cause excessive case pressure, which has a number of damaging effects.

High case pressure results in excessive load on the lip of the shaft seal. This causes the seal lip to wear a groove in the shaft, which eventually results in a leaking shaft seal.

The effect of high case pressure on in-line piston pumps is the same as excessive vacuum at the pump inlet. Both conditions put the piston ball and slipper-pad socket in tension during intake.

In severe cases this can result in buckling of the piston retaining plate and/or separation of the bronze slipper from the piston, causing major failure.

Under certain conditions, high case pressure can cause the pistons of radial piston motors to be lifted off the cam during outlet. When this happens, the pistons are hammered back onto the cam during inlet, destroying the motor.

For the reasons described above, conventional depth filters are generally NOT recommended on case drain lines.

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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, clean and monitor it regularly.

Control the foam, fluid power systems need fluid and foam is a lousy substitute. Control leaks so you do not throw your oil on the ground, waste time replacing it and allow ingress to whatever contaminant is handy. If you shut down your system and an hour later the clear oil that you use looks like a regular coffee full of bubbles you need better oil. If you cannot maintain a leak-free machine then you need better oil. If your filters seem to be filling up with silly string then you need better oil, that's your R&O additives overwhelmed by too much water and now no longer available in the oil. If we can only see down to 40 microns and your actuators have a 1-5 micron clearance then you have to plan on keeping out dirt too small to see. Whether it's top-off or sampling time but especially when you break the machine apart for service you must eliminate any contaminant

ingress. I have had more than one shop supervisor admit that they often get machines in for repairs shortly after a repair and that stems from doing the work without eliminating the new dirt. You don't always have the ability to perform clean repairs so at least be aware of it and do whatever you can to lessen the impact. Consider any new or rebuilt parts to be dirty and wash, rinse, flush and inspect before installing. Maintain a world class oil analysis program and use the results to take action when necessary and also to prove its own worth by draining oil at the optimum interval and catching potential disasters when they might be quick and cheap to fix and at your discretion and not while you are trying to get some work done. Have written procedures in place and go over them routinely with anyone involved with O&M. Find out who Brendan Casey is.
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I have written extensively on this subject, and if you can handle the Spanish, you can start here:
http://widman.biz/Analisis/interpretacion.html

There are several pages where I talk about **contamination, degradation**, etc, and also sample analysis results for certain cases, selected from about 5000 I have done for my customers.

Among the 115 bulletins I've published, there are also several that explain these problems and how to extend intervals. (and how to implement a sampling program) Those start here:
http://widman.biz/boletines/boletines.html

You need to take into consideration that the lab will give you results that are very "cold", or average. They will compare your results with norms (which I explain in the first link). BUT only the person who is familiar with the goals of the end user and the conditions where the equipment works can really tell you what is too much. I disagree with a lot of what is published, as my customers do not want to be average. They want extended intervals with long life spans for equipment. We have successfully extended drain intervals in construction and agricultural equipment to 500 hours that sometimes get stretched to 700. But first you have to get a hold of contamination. You need top tier filters (I use only Donaldson) and top tier oils (group II). You could use synthetics, but that is long after you control contamination.

A good CI-4 group II oil can easily take you to those levels even with 2000 ppm of sulfur in the diesel and give you 25,000 hours of engine life between overhauls.

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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zddp a common additive used in many hydraulic oils will be extracted in filtration systems of less than 4 microns and thus deprive the anti wear properties of the additive to perform its function. Used between 0.5-1.2 % its critical that filtration does not extract this vital additive. Most blending plants cannot claim the cleanliness standards that nas system cleanliness standards insist are used on critical pieces of equipment. Open the barrel and whoops airborne material can easily enter the system so be aware you are dealing with particles that require vacuum or pressure cell cleanliness.

Reply: The ZDDP additive is sub-micron in size, around 0.005-0.007 µm. It is not possible to directly, mechanically, filter out this particular additive. In an engine, it is possible that soot adsorbs the ZDDP additive, and in turn, the soot itself is filtered. But it is unlikely to filter out ZDDP in a hydraulic oil.

Answer back: I am aware of ZDDP sub micron particles and its solubility but experience of its solubilty particularly with contaminants such as water. oxidants however small in quantity and size shows that filtration can and does extract zddp possibly by several mechanisms which our filtatration colleagues can describe in detail. These are experiences that are both field based as well as laboratory analysis.

Another view: ZDDP additive chemistry can be damaged during the lubricant is in operation e.g. by moisture, heat, chemical contamination, ageing and other mechanisms. A common effect is the formation of zinc soaps or other oil insoluble reaction products effecting the filterability or forming sludge or residues. We have analysed a lot of those residues out of lube systems or from filter surfaces. Beside a big variety of different reaction chemistry you can often see extreme high Zn levels in the elemental analysis or identify the additive compounds by FTIR. Such critical changes of the oil condition are often hardy detectable by the standard oil analysis especially for systems with large volumes. Additive elements vary only slightly, FTIR shows less changes and a possible decrease of the acid number by additive depletion is compensated by slight increase caused by base oil degradation. Sometimes a strange distribution of ISO 4406 particles codes like e.g. 23/22/12 is an indication of such problems. If the filterability goes down or residues are found in the system further investigation like a detailed analysis of the residue or a more detailed oil analysis e.g. with a the RULER method or a filterability test can be very helpful to identify root causes. By the way I am not aware of those effects for automotive applications and know it only from the industrial site like for big hydraulic systems or from paper mills.

Another: 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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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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Oil Sampling Reveals Air in Oil

While pulling a sample from a reservoir, an exceptional amount of air was found in the hydraulic fluid. The suction-side components were sprayed with mineral oil to locate where air was being ingested. The pump became quieter after the input shaft seal was sprayed. The sprayed oil was seen being drawn into the pump. A check of the pump revealed a worn bearing and shaft seal, which were attributed to oil contamination. The pump was replaced, and the source of contamination entry was located. The bottom line is to listen when your oil talks to you.

(Mike Deal, Alcan Aluminum)

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. ===================

And an issue that is often overlooked and one that came up in a job I was involved in recently, is the combined effect of fluid compressibility and the 'accumulator effect' of conductors (the increase in volume of a hose or pipe as pressure increases).

When a hydrostatic transmission is subject to a sudden increase in load, the motor stalls instantaneously and system pressure increases until the increased load is overcome or the high pressure relief valve opens - whichever occurs first.

While the motor is stalled, there is no return flow from the outlet of the motor to the inlet of the pump. This means that the transmission pump will cavitate for as long as it takes to make-up the volume of fluid required to develop the pressure needed to overcome either the increased load or the high-pressure relief valve. How long the pump cavitates depends on the output of the charge pump, the magnitude of the pressure increase, and its influence on the increase in volume of the conductor and the decrease in volume of the fluid. This is illustrated in the following example.

A hydrostatic transmission operating the drill head on a drill rig is delivering a flow of 35 GPM at a pressure of 1000 PSI. A sudden increase in load on the drill bit instantaneously stalls the motor until sufficient pressure is developed to overcome the increase in load, which for the purposes of this example is 3000 PSI.

In order to increase system pressure from 1000 PSI to 3000 PSI, the transmission pump must make-up additional volume, due to the compression of the hydraulic fluid and the volumetric expansion of the high-pressure hose between the pump and the motor. But because the motor is momentarily stalled, there is no return flow from the outlet of the motor to the inlet of the pump. The only fluid available at the inlet of the transmission pump is 7 GPM from the charge pump, which is around 80% less than required!

In this example, the high-pressure hose between the pump and motor is SAE 100R9AT-16, 36 feet long. The volumetric expansion of this hose, due to the increase in pressure, is 9.7 in^3 and the additional volume required due to compression of the fluid within this hose is 2.8 in^3. Therefore the total, additional fluid volume required to increase the operating pressure from 1000 to 3000 PSI is 12.5 in^3 (9.7 + 2.8 = 12.5).

To calculate the time taken for the operating pressure to increase from 1000 to 3000 PSI, which is equivalent to the length of time the transmission pump will cavitate, we divide the required make-up volume (12.5 in^3) by the volume available from the charge pump per second (27 in^3). In this example, the transmission pump cavitates for 0.46 seconds every time a sudden increase in load demands an increase in system pressure from 1000 to 3000 PSI (12.5 ÷ 27 = 0.46).

This problem occurs in applications where there are sudden fluctuations in load on the transmission. Typical examples include drill rigs, boring machines, and cutter wheels on dredgers. The solution involves increasing available charge volume - usually through the installation of an adequately sized accumulator in the charge circuit.

http://www.insidersecretstohydraulics.com/hydraulic-valve.html

What is cavitation?

Cavitation occurs when the volume of hydraulic fluid demanded by any part of a hydraulic circuit exceeds the volume of fluid being supplied.

This causes the absolute pressure in that part of the circuit to fall below the vapor pressure of the hydraulic fluid. This results in the formation of vapor bubbles within the fluid, which implode when compressed.

Cavitation causes metal erosion, which damages hydraulic components and contaminates the hydraulic fluid. In extreme cases, cavitation can result in major mechanical failure of pumps and motors.

While cavitation commonly occurs in the hydraulic pump, it can occur just about anywhere within a hydraulic circuit.

In the hydraulic valve described above, the metal erosion in the body of the valve was so severe that the valve was no longer serviceable. The valve had literally been eaten away from the inside, as a result of chronic cavitation.

In this particular case the cause of the cavitation was faulty anti-cavitation valves, which are designed to prevent this type of damage from occuring.

How can this type of failure be prevented?

This example highlights the importance of checking the operation and adjustment of circuit protection devices, including anti-cavitation and load control valves, at regular intervals.

As in this case, if the faulty anti-cavitation valves had been identified and replaced early enough, the damage to this hydraulic valve and the significant expense of its replacement could have been avoided.

Brugger Test for Hydraulics? Nein!

By Dick Beercheck • January 29, 2014

In a sometimes intense session at the 19th Colloquium Tribology at the Technische Akademie Esslingen in Germany last week, representatives from Lubrizol and ExxonMobil debunked the value of the Brugger Test for evaluating the antiwear performance of hydraulic fluids.

Lubrizol's Alan Barber explained that the Brugger Test was introduced in the 1980s by hydraulic press manufacturer Mueller Weingarten to assess the load-carrying capacity of oils. It eventually gained status as a DIN (German Institute for Standardization) Standard; however, Barber noted, "It has no precision statement," and a recent round-robin at test laboratories showed that repeatability is quite poor, at only about 20 percent.

But the real difficulty, said Barber, is that the test bears little resemblance to real world conditions experienced by the typical HF-0 hydraulic fluid. The problem is that the Brugger Test is effectively an extreme pressure test, and the typical hydraulic fluid is not formulated for extreme pressure conditions.

Nevertheless, at least one original equipment manufacturer has adopted the test as a requirement for fluids used in its equipment. In an effort to forestall wider adoption of the test, Barber presented results showing that no hydraulic pumps – including vane, piston and gear pumps – have any contacts that resemble the conditions of the Brugger Test.

Worse still, Barber continued, passing the test requires hydraulic fluid formulators to add sulfur-containing extreme pressure agents, which presents a number of problems. All pumps contain a lot of yellow metal, he said, and sulfur compounds are extremely aggressive toward yellow metals. Also, the addition of sulfur EP agents adversely affects thermal, oxidative and hydrolytic stability, as well as seal compatibility.

These findings were corroborated by Sandra Legay of ExxonMobil, who presented data for tests on conventional and premium hydraulic fluids. She explained that the addition of 0.6 percent of a sulfur-containing EP additive increased the Brugger Test value to the specified rating, but in all cases reduced thermal and oxidative stability, and increased copper corrosion.

Although the presentations sparked a healthy debate by members of the audience trying to defend the efficacy of the Brugger Test, "it applies only to a very specific application," Barber concluded, "and has no place as a screening test or requirement in hydraulic fluid specifications."

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How can we improve hydrolytic stability of phosphate ester - Tri xylenyl phosphte - for its use in lubricants as base fluid

Victor Bakunin

Dr.Sci. Petrochemistry

TXP is usually pretty stable against hydrolysis, if compared to TCP. Hydrolysis is catalyzed by STRONG acid impuririties, which can be detected not by TAN, but by pH of aqueous extract. The simplest way to avoid hydrolysis is addition of base-type compounds, e.g. trilakylamines. Activated alumina is also possible. The possibility of PAGs use depends on the application: phosphates are HFDR type fluids, PAGs are related as HFDU fluids.

Josef Barreto-Pohlen

specialist in lubricating greases & oils

Have a look into carbodiimides.

Calvin Low For fire resistant hydraulic oils, phosphate ester is so far the best but it was toxic in certain way and alternatively TMPTO is a good choice as well as meeting the biodegradable criteria!

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315 is a now mostly obsolete ASTM viscosity number - 315 SUS at 100 degrees Fahrenheit, which is roughly equivalent to ISO 68.

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"We installed a pilot-operated check valve
for load-holding purposes. Extension of the cylinder
is smooth and load holding also good. But when retracting
the cylinder (during pilot-line opening of the check valve)
there is a huge shake in the system."

This is not an uncommon mistake.

So I recorded a 3-minute video which explains
WHY pilot-operated check valves shudder
when used in this situation.

Watch it here, now:

http://www.hydraulicsupermarket.com/po-check-shudder