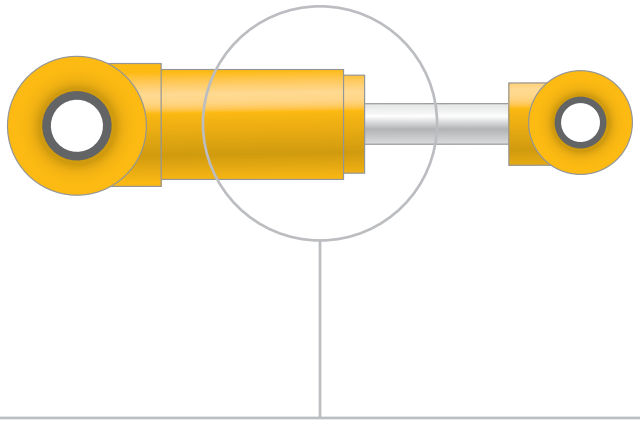

Smarter Hydraulics:

A Three-Step Strategy to Restore Your Contaminated Hydraulic System – And Keep it Clean

By Scott Schneider & Daniel Williams

Little strokes fell great oaks.
-Ben Franklin

Knowledge is power.
- Sir Francis Bacon

Introduction

Machine owners and operators are focused on squeezing the most production possible from their machines to optimize profitability, and since most machines use hydraulic systems in some form, failure of these systems (and the associated downtime) is a persistent threat. For the most part, machine owners and operators are aware that contamination—dirt, in the words of S. R. Majumdar, author of *Oil Hydraulic Systems, Principles, and Maintenance*—is responsible for 75% (or more) of all hydraulic system failures[1]. However, knowing that dirt will destroy your hydraulic system does not translate directly into knowing what to do with it when that happens, or how to prevent contamination from reentering the system and causing another costly failure.

> "Dirt is responsible for 75% (or more) of all hydraulic system failures."
>
> S. R. Majumdar, author of *Oil Hydraulic Systems, Principles, and Maintenance*

Expensive repairs to contaminated systems are the price equipment operators pay for allowing their hydraulic systems to become compromised, but most contamination can be avoided by following a few simple rules and partnering with a competent service provider.

The following paper will explain how to restore your hydraulic system following failure due to contamination, how to keep contamination out of your restored system, and what to look for in a hydraulic system service provider. Most importantly, this paper will explain how equipment operators can save time and money by monitoring their system's status and keeping it clean—and productive.

[1] Majumdar, S. R. *Oil hydraulic systems principles and maintenance*. New York: McGraw-Hill, 2003. Print.

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Contamination Review: How Contamination Compromises Hydraulic Systems

In addition to creating force and motion, the fluid in any hydraulic system forms a protective seal between (and lubricates) the system's interior metal surfaces and regulates the system's temperature. If, for whatever reason, the fluid stops performing any of these duties, the hydraulic system will not perform as designed, and may fail[2]. Contaminated fluid is the primary cause of these failures, and can reduce system efficiencies by as much as 20% before it is recognized that something is wrong[3].

Particulate Contamination

Particulate contamination harms hydraulic system components and compromises their performance in several ways[4]:

- **Abrasive wear:** Hydraulic fluid that has been contaminated loses some of its lubricating and sealing properties. Small particles in the fluid can abrade the moving surfaces of rods, valves, and seals within a contaminated system, compromising the integrity of the system's internal seals—the grinding action of the particles can wear channels or grooves into the smooth surfaces of rods and cylinders, allowing additional contamination to enter the system and hydraulic fluid to escape. Improperly-sealed systems cannot efficiently control fluid flow and pressure, robbing the affected machine of horsepower and generating unwanted heat. Erosion, caused when small particles of contamination in a hydraulic system's fluid rub against internal surfaces, causing wear, is also considered a form of abrasion[5].

- **Adhesive wear:** Small particles of contamination can accumulate inside hydraulic systems in the form of silt or sludge. These collections of tiny particles can impede movement of rods and other moving parts by adhering them to nearby surfaces and causing the components to "stick". An affected machine will perform at a reduced capacity and generate excess heat—the integrity of its seals and the lubricating properties of its oil will also be compromised.

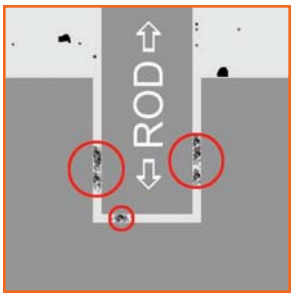

Figure 3: Contaminant particles can accumulate inside hydraulic systems in the form of silt or sludge.

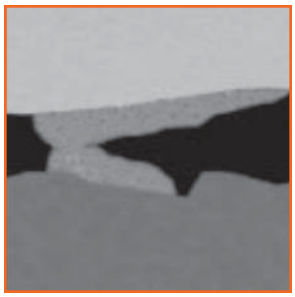

Figure 4: Silt and/or sludge can impede movement of internal parts by adhering them to nearby surfaces.

- **Fatigue wear:** Repeated high-pressure stress loads can cause metal to chip or break from hydraulic components and contaminate the system; relatively large particles can become lodged between moving internal surfaces in a hydraulic system. The affected component will not operate normally, and seize; catastrophic failure can follow.

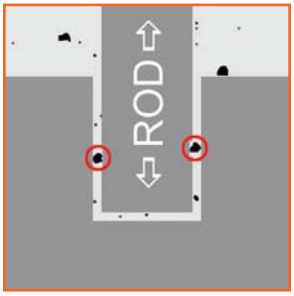

Figure 1: Contaminant particles in hydraulic fluid can abrade the moving surfaces of rods, valves, and seals.

Figure 2: Grinding from contaminant particles can wear channels or grooves into the smooth surfaces of rods and cylinders.

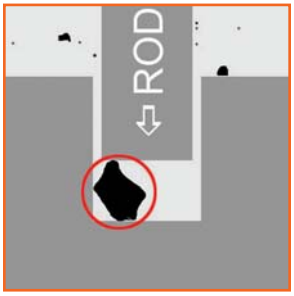

Figure 5: Large contaminant particles can lodge between moving internal surfaces in a hydraulic system.

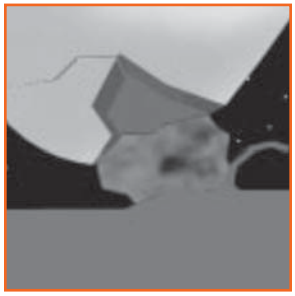

Figure 6: Repeated stress loads can cause metal to chip or break from hydraulic components and contaminate the system.

Penton Media, 2009. Web. 3 Aug. 2009. <http://www.hydraulicspneumatics.com/200/FPE/FluidCleanlines/Article/True/6432/FluidCleanlines>.

[3] *Hydraulic Filtration and Contamination*. Tech. no. 96-3R1. Filter Manufacturers Council, Sept. 1996. Web. 3 Aug. 2009. <http://www.filtercouncil.org/techdata/tsbs/96-3R1.pdf>.

[4] Ibid.

[5] Scott, Robert. "Basic Wear Modes in Lubricated Systems." *Machinery Lubrication* July 2008. *Machinery Lubrication*. Noria Corporation, July 2008. Web. 3 Aug. 2009. http://www.machinerylubrication.com/article_printer_friendly.asp?articleid=1375>.

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Chemical Contamination

In addition to the mechanical threat posed by particulate contamination, hydraulic systems are also subject to chemical contamination from water and other environmental agents, which can alter the composition of their fluids. Changes to the chemical properties, such as acidity and viscosity, of hydraulic fluid will dramatically compromise the longevity and performance of an affected system. According to *Hydraulics & Pneumatics*, "water in hydraulic fluids can have serious adverse effects on the fluids' physical and chemical properties. The loss of crucial fluid properties, which are central to useful service life, can result in inefficient system performance and accelerated mechanical and chemical wear processes[6]." Temperature regulation, an important function of hydraulic fluid, can be compromised through chemical contamination as well, which will in turn allow undesirable heat to accumulate within the affected system, further altering the chemical makeup of its fluid and inducing additional contamination.

In addition to its deleterious effects on the chemical properties of a hydraulic system's fluids, acid, formed from fluid breakdown within a system, or improperly mixed (or contaminated) fluid, can physically damage components within an affected system by corroding their surfaces. Water trapped in a hydraulic system can induce cavitation—pitting of internal component surfaces—by vaporizing from internal heat and expanding in a pressurized environment.

Particulate contamination such as Abrasive, Adhesive, and Fatigue wear harms hydraulic system components and compromises their performance. In addition to these mechanical threats, hydraulic systems are also subject to chemical contamination from water and other environmental agents.

Smarter Hydraulics: A Three-Step Strategy to Restore Your Contaminated Hydraulic System—And Keep it Clean

Keeping your equipment's hydraulic systems clean and well-maintained is obviously very important, and literature on the subject is widespread and authoritative. However, if your equipment has failed from hydraulic system contamination, no amount of preventative action can return it to its profitable, pre-failure state. Your first action should be to diagnose the failure: why did the system fail? How did contamination get in?

If your equipment has failed from hydraulic system contamination, no amount of preventative action can return it to it's profitable, pre-failure state.

STEP 1. Diagnose the Failure – and Your Service Provider

As an equipment owner, you should find some small consolation in the fact that repairing or rebuilding your machine's compromised system is an opportunity to learn about *why* hydraulic systems fail in general, and specifically why *your* system failed… The operation will also give you an opportunity to evaluate your service provider's competence and contamination control procedures. Your service provider should be able to identify the specific source of the contamination that compromised your system by examining the system's damaged components. This information, which will allow your provider to determine the extent and severity to which your system is contaminated, will determine your provider's appropriate response. Various repair options differ in price and complexity, so this information is of value to you, as well: you may be surprised to find how easily some expensive repairs can be avoided. Ask your service provider how contamination entered your machine's system, and don't be surprised to hear that a simple scratch or dent was to blame.

[6] Ibid. 2.

Dents and Scratches Introduce Contamination

An exposed piston rod is the weakest point of any hydraulic system, and damaged piston rods are by far the most common cause of rod seal failure[7]. In addition to being exposed to the air at jobsites, warehouses, and other dusty, debris-ridden areas, these components are often abused by machine operators (and occasionally technicians):

Piston rods are at risk of damage from tools such as spanners and wrenches used in installation, falling objects, and even operators using cylinders as steps to gain access to machines! If the piston rod receives only a slight knock, denting can occur which can lead to fluid leakage even if the seal itself is not damaged: the size and shape of the denting may allow the hydraulic fluid to bypass the seal. Severe damage can lead to tearing of the seal and a more obvious source of leakage.[8]

The small openings formed by dents and scratches to an exposed piston rod compromise the integrity of its cylinder's seals – the seals around the rod are meant to fit snugly against the rod's surface, and they won't touch the bottom of a dent or scratch.

The small openings formed by dents and scratches to an exposed piston rod compromise the integrity of its cylinder's seals—the seals around the rod are meant to fit snugly against the rod's surface, and they won't touch the bottom of a dent or scratch. Even a slight imperfection on a rod's surface can allow hydraulic fluid to escape, and if you can see fluid on an external rod surface, it's safe to assume contamination is inside, as well. When a dented or scratched rod enters an otherwise clean system during rod retraction, it will bring contamination with it —exposed fluid attracts environmental particulate matter like flypaper, and drags it into the system. While a rod wiper/scraper can minimize these intrusions, avoiding damage to exposed piston rods is the only real solution. An induction-hardened cylinder rod—a rod that has been case-hardened before being chromed—is more durable than a regular steel piston rod, and thus better able resist damage from dents and scratches (see Step Three).

Recondition Faulty Cylinders

Your service provider may diagnose your faulty cylinder as having been compromised due to dents or scratches, torn seals, or another source, but no matter the cause, a faulty cylinder—one that leaks or otherwise performs poorly—should be rebuilt *before* it fails. Total failure of a hydraulic cylinder can take other components with it; contamination from an overloaded filter, for example, can disperse debris throughout the system and possibly contaminate other parts of your machine. Ask your service provider if this was the case with your machine, and in the future, plan to recondition a cylinder in your machine if you spot a leak or notice impaired performance—there's no need to recondition it otherwise, and no set service interval.

If your cylinder has been compromised, you must recondition it, but before taking any further action, you should satisfy yourself that your provider has is properly trained and has an established contamination control plan at their facility. It's pointless to recondition a hydraulic cylinder in a contaminated environment: the system will simply fail again, and require another expensive repair. There are, however, a series of best practices that all service providers should follow to keep your reconditioned cylinder clean.

A properly trained service provider will follow the steps below in reconditioning a faulty cylinder:

- ✓ Thoroughly steam clean the assembled cylinder.
- ✓ Inspect all bearing surfaces on eyes, clevises, and trunion mounts.
- ✓ Disassemble the cylinder, and collect, label, and save samples of any large contaminant particles, if present.
- ✓ Carefully examine the rod to verify straightness and identify presence of any dents, scratches, scoring, etc.
- ✓ Fabricate a replacement cylinder rod using the existing rod eye and bearing, if necessary.
- ✓ Inspect the gland to verify integrity of its seal surfaces, threads, and critical diameters.
- ✓ Inspect the piston to verify integrity of its seal surfaces, threads, and critical diameters.

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[7] Parker Hannifin - Parker Sales UK. "*Piston rods - a suitable case for hardening.*" Engineering Talk. Pro-Talk Ltd., 14 Mar. 2000. Web. 3 Aug. 2009. <http://www.engineeringtalk.com/news/par/par149.html>.

[8] Ibid.

- ✓ Inspect the barrel to verify integrity of its seal surfaces, threads, and critical diameters.
- ✓ Light hone the barrel to remove minor scratches or other imperfections, maintaining specified clearances for bore size within .003", then thoroughly clean it to remove contaminants from honing and the reconditioning process.
- ✓ Install new piston, rod and head seals.
- ✓ Reassemble the cylinder and cap all ports.
- ✓ Test the cylinder at the recommended pressure.
- ✓ Replace all grease zerks on the cylinder.
- ✓ Align the cylinder's rod eye and base to proper configuration for reinstallation.
- ✓ Paint the cylinder.
- ✓ Inform you of the probable reason the cylinder became damaged and advise you of the recommended predictive or preventative actions to be taken (system cleaning, system flush, etc.).

Every step is important—nothing on the list above is a "luxury" purchase. Ask your service provider about the steps above before you allow them to rebuild your cylinder. Do they test their rebuilt cylinders at operating pressure? Will they hone your barrel? (Over time and use, the barrel becomes glazed and loses some of its ability to mate with its seals; honing resets the crosshatching on the barrel surface, allowing the seals to seal at their fullest ability.) Omitting any of the steps above is an act of neglect, and choosing a service provider who does not perform all of the services about is not the best use of your dollar. A compromised system, whether it was contaminated when it was manufactured, rebuilt, or repaired, will eventually fail. Make sure your provider does it right the first time.

Since contamination is responsible for the vast majority of hydraulic system failures, it's safe to assume that any failed system will require a thorough cleaning to be returned to optimal condition.

STEP 2. Restore the System

Since contamination is responsible for the vast majority of hydraulic system failures, it's safe to assume that any failed system will require a thorough cleaning to be returned to optimal condition. The extent to which contamination is present in a system will determine your appropriate response; kidney-looping, using a powered flushing machine to remove impurities from your system, may be sufficient, or a complete system rebuild may be necessary. Talk to your service provider about their diagnosis: what response is appropriate for your machine?

Hydraulic System Restoration the "Easy" Way: Kidney-looping

Kidney-looping your contaminated hydraulic system may be sufficient to restore its performance if the system's internal components have not been significantly compromised—a kidney-looping machine will remove sludge, microbial deposits, and particulate contamination from your system's fluid[9] and may restore it to its pre-contaminated state and performance. Unless you are confident that your system's internal components have been severely compromised, a kidney-looping session may be a money-saving option (compared to a complete rebuild) to restore your system.

To kidney-loop your hydraulic system, your service provider will circulate hydraulic fluid from your machine through a set of external filters, removing contamination. The fluid is then directed through the kidney-loop machine and further filtered. The machine is equipped with various mechanisms to adjust fluid flow, using pressure to dislodge contaminants and filter them out[10]. Your service provider will periodically analyze the fluid during this operation to determine if the system is sufficiently clean for use. In some cases, the operation will succeed. If your system has been extensively damaged, though, the system must be completely disassembled, cleaned, and rebuilt. This is a fairly involved—and usually expensive—proposition, but if performed by a competent provider, will eradicate all contamination in your system.

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[9] "Flushing hydraulic systems." *Insider Secrets to Hydraulics*. 2005. Web. 3 Aug. 2009. <http://www.insidersecretstohydraulics.com/flushing-hydraulics.html>.

[10] Ibid.

Hydraulic System Restoration the Hard Way: Rebuild the System (Catastrophic Failure Only)

A totally compromised system, one in which contamination has seriously damaged its internal components, will require additional measures beyond kidney-looping to be returned to optimal performance: it must be completely disassembled and rebuilt. **A contamination-free environment and technicians trained in contamination control procedures are essential to the success of a hydraulic system rebuild.** Inexperienced technicians or an unclean environment can easily re-introduce contamination into a system during a rebuild—the "clean", rebuilt system will still be compromised, and will eventually fail again, necessitating another expensive rebuild.

If your service provider doesn't take the proper precautions to control it, the contamination present in any environment—dust, dirt, and water—will adhere to filler caps, breathers, funnels, transfer pumps, and replacement parts while your system is being rebuilt, and the contamination inherent to new parts—metal burrs, small pieces of Teflon tape used during sealing, etc.—may enter your system, as well[11]. Talk to your service provider about how they manage this contamination, and don't agree to a rebuild unless you are satisfied that they are able to keep your system contamination-free while they service it. A competent provider will most likely have a written policy for managing contamination during hydraulic system rebuilds; ask to see it to satisfy yourself that the technicians repairing your system—and charging you for it—are attentive to your system's particular need for cleanliness.

A complete rebuild will include draining your machine's hydraulic tank, cleaning **every** hose and tube, and reconditioning all cylinders. This should include barrel honing or replacement to reestablish the barrels' sealing surfaces. The cylinders must be assembled with all-new seals and thoroughly tested at operating pressure. Your rebuilt system should perform as well as a brand-new system: accept no less from your service provider. Finally—and this is vital—your service provider should replace **ALL** the filters in your system.

Assume all hydraulic fluid is contaminated. Even "new" hydraulic fluid is contaminated to a level that is higher than acceptable for most hydraulic systems.

Replace ALL Filters

After servicing any hydraulic system, it is imperative to replace **ALL** of that system's filters. Filters are less expensive than any repair operation. Additionally, new filters will remove the contamination present in **ALL** hydraulic fluid—for this reason it is usually wisest to use a "clean-out" filter, rated higher than the system demands, for an initial cleanup following any major system maintenance:

Assume all hydraulic fluid is contaminated. Even "new" hydraulic fluid is contaminated to a level that is higher than acceptable for most hydraulic systems. Always filter new hydraulic fluid for system filling or just "topping-off" a system. Otherwise contaminants will be introduced into the system by the new hydraulic fluid. Check the hydraulic fluid to be sure it meets the ISO code for the system in which it will operate[12].

The importance of clean and application-correct filters cannot be overstressed. Filters are relatively inexpensive, easy to change, and by far the most effective means of preventing contamination from entering your hydraulic system. A few ounces of prevention are surely worth thousands of dollars of cure—insist that your service provider thoroughly filters and inspects your hydraulic system's fluid to your satisfaction.

STEP 3. Prevent Future Contamination

A fully-restored hydraulic system should perform as well as it did before it was contaminated, but unless several important steps are taken to prevent future contamination, your hydraulic system will require additional costly repairs as further damage compromises its performance. With a bit of care and a regular maintenance schedule, though, it is possible to keep any system, in virtually any application, running smoothly and contamination-free.

Induction-hardened Cylinder Rods: Impact and Scoring Resistant

An induction-hardened rod has a number of beneficial effects when used in a hydraulic system[13]. In addition to it's resistance to damage from external impact (particularly useful in excavators, loaders, and similar applications)

[11] Ibid. 3.

[12] Ibid. 3.

and inadvertent handling damage during cylinder manufacture, an induction-hardened piston rod is less likely than its non-treated counterpart to contaminate your hydraulic system from inside due to internal scoring.

A typical cylinder rod is chromed—the chrome plating is only a few hundredths of an inch thick, and the steel beneath is typically somewhat soft, and prone to damage from the dents and scratches generally caused by external impacts—the chrome takes the shape of the damaged area and forms a void between the cylinder and the sealing surface, allowing contaminants to enter the system with each cycle of the cylinder. An induction-hardened rod's heat-treated surface offers an additional fraction of an inch's worth of protection beneath its chrome surface—the case-hardened steel surrounding its conventional steel core is hard enough to resist damage from impact or scoring, and less likely to release the tiny fragments that further contaminate hydraulic systems. Of course, rods are not the only source of internal contamination in hydraulic systems—valve spools, pump vanes, and hoses gradually degrade and do their part as well[14]—but using an induction-hardened rod is a wise strategy in managing contamination; consider it one weapon in your contamination-fighting arsenal. Choosing the proper seals for your application is equally important.

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The Case for OEM Seals

Aftermarket hydraulic system seals are inexpensive and generally acceptable for use in rebuilding compromised systems. However, OEM seals—the seals produced by the hydraulic system's manufacturer—may still be the better choice for your application, despite their (usually) higher price by comparison to aftermarket versions. Consider that the same engineers who designed the hydraulic cylinders in your machine designed its seals, as well; the level of specificity inherent to an OEM seal is an obvious plus in considering its value versus an aftermarket version, but ultimately the choice is yours. An experienced service provider is your partner in choosing components, and should be familiar with the quality of your various options for hydraulic seals—ask the opinion of a trusted technician.

Monitor the System with Fluid Analysis

After you've rebuilt your contaminated hydraulic system and taken steps to ensure it remains clean, your next (and final) step to keeping your system functioning at optimal performance is to regularly monitor its fluid for particulate and chemical contamination using fluid analysis. According to Michael Konsari of Louisiana State University and E.R. Boorer, "…improved [component] life calls for periodic (typically monthly) laboratory checks of samples for oxidation, viscosity change, and contaminant accumulation.[15]"

Fluid analysis spots problems in your hydraulic system before they happen by analyzing its fluid at the molecular level. Your local analysis technician can detect sediment, contamination, and elemental imbalances using fluid analysis, and is able to identify wear and fatigue trends within your system's components; microscopic degradation of pumps, seals, valves, and rods can be spotted—and its source identified—using fluid analysis. Consider fluid analysis a blood test for your hydraulic system, and contamination a potentially fatal, but manageable, disease.

Competitively-priced fluid analysis services are available from numerous trained providers across the country for a variety of engine systems and applications. There's no hard and fast rule to determine how often you should have your hydraulic fluid analyzed, but since it costs less than any major repair and has substantial predictive value, you should get in touch with your service provider's fluid analysis supervisor—he'll be happy to give you some suggestions to help you determine the appropriate intervals.

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[13] Roberts, William. *Increased resistance to buckling of piston rods through induction hardening*. Rep. Ovako, 15 Jan. 2007. Web. 3 Aug. 2009. <http://www.ovako.com/Data/r4395/v1/CROMAXIH280XBuckling.pdf>.

[14] Ibid. 3.

[15] Konsari, Michael, and E.R. Boorer. "Predicting Lube Life - Heat and Contaminants are the Biggest Enemies of Bearing Grease and Oil." *Machine Design* Mar. 2003. Print.

Conclusion

Catastrophic failure of a hydraulic system due to contamination isn't the end of the world, but it's expensive and time-consuming to correct, and results in a lot of unnecessary downtime for an affected machine. And while it is possible to repair *most* compromised systems, the cost of an overhaul, kidney-looping session, cylinder reconditioning, or complete rebuild will always be higher than the cost of filters and fluid analysis. Use these services—they **will** save you money.

Finally, the importance of partnering with an experienced, well-trained service provider cannot be overstated. Maintaining hydraulic systems requires training and a proper environment. Don't spend your money on a provider who cannot offer both. Ultimately, you are placing your means of doing business—how you make your profits—in your service provider's hands.

Make sure they're clean.

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