Acute Vs. Chronic Risks in Oil Systems!

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Here's a brief explanation of the strange headline. Many years ago, I worked as a lead person on a safety committee for a mid-sized manufacturing facility. As part of our safety program, we had to come up with solutions for many potential hazards, but the one thing that I remember vividly is that we categorized the hazards as either acute or chronic. According to the dictionary, acute is something that is sharp or sever in effect, while chronic is something having long had a disease, weakness, or habit. While most safety programs emphasize acute type injuries and how to stop them, we found that our program was not complete until we emphasized and took action to protect our employees from the chronic injuries as well. That is why you see certain personal protective equipment in place to create barriers from items that we can breathe, removal of items that are known carcinogens, and programs to provide better equipment to deal with repetitive motion type injuries. What was realized was that while the acute type injuries grabbed the headlines, the chronic injuries could, sometimes, cause greater damage to the employee in the long term.

This same thought process can describe the various issues that you will see in an oil system. Whether it be a hydraulic system, gear oil, turbine oil, or diesel fuel, all of those systems will have both acute and chronic risks to the system and the oil life. Almost all equipment manufacturers will provide a filtration system to handle the acute risks (inline pressure filtration) to their equipment, but many do not provide the adequate equipment to handle the long-term or chronic problems that their system will face (a good offline filtration system). Always keep in mind that the goal for the equipment manufacturer is to protect their system from any catastrophic failures. It is your responsibility as the user to make sure that the oil system is protected from the long term effects of contaminated oil, thus extending the life of your oil and the system components.

Inline pressure filters solve most acute problems, but not all of them

Inline pressure filters are designed to handle most of the catastrophic problems within a system, but are very limited in what they can do. They can become overwhelmed in a very dirty environment, which could lead to bypass situations for heavy dirt load and large particle issues. Additionally, most cannot handle any water issues, so if there is a seal or cooler leak, you could have some large amounts of water dumped into a system very quickly. While both particle and water ingression are causes for chronic issues in all systems, in large volumes they can lead to some very quick system failures.

Offline filters solve the remaining problems that result in both Acute and Chronic conditions

Where else do you compromise by only using an inline filter? As a machine operator or owner, your needs are; total system reliability, uptime on equipment, clean oil and cost savings. The equipment manufacturer doesn't always understand your needs to keep the system as robust as possible, and quite frankly, it is your responsibility to make sure that you extend the life of your equipment, not theirs.

I have spoken to many Maintenance Managers through the years that have chronic issues in their systems due to high particle count, water in the oil, varnish issues, acids, etc., and when their equipment fails, they chalk it up to "we have to replace that gearbox every year anyway" or "it has always been done that way". This mindset creates an acceptance of certain repairs, which become so predictable, that companies even write them into their annual budgets. These companies are missing out on the opportunity to ever improve their system and equipment performance and save lots of money!

What is the difference between an inline and an offline filter system?

An inline filter system is designed to handle the full flow of the oil system and is specifically designed to protect the system from acute or catastrophic risks. They typically have very limited abilities to clean the oil and quite frequently need to be changed, because of the low dirt holding capacities of these elements. Due to the need for constant flow of the oil to the equipment, these filters can be bypassed; thus, becoming useless until someone is notified and a new element has been installed. In addition, these filters only filter the oil when the equipment is running.

A properly installed offline filtration system is one that utilizes fine filtration to remove multiple contaminants and cleans all of the oil and the oil reservoir, continuously. These systems do not rely on the actual equipment to be in operation and can be run continuously to keep the oil clean and dry all the time. Some people have used the term "kidney-loop" to describe this type of filter system. However, simply taking the oil out of a reservoir at some random location and returning it to another random location, is not the most effective way to filter the oil. As you will see in the diagrams below, a proper offline filtration system will pull from the bottom-most location on a reservoir (could be a drain port) and deliver back to the opposite side of the reservoir, assuring a good circulation of oils and proper turnover of the tank.

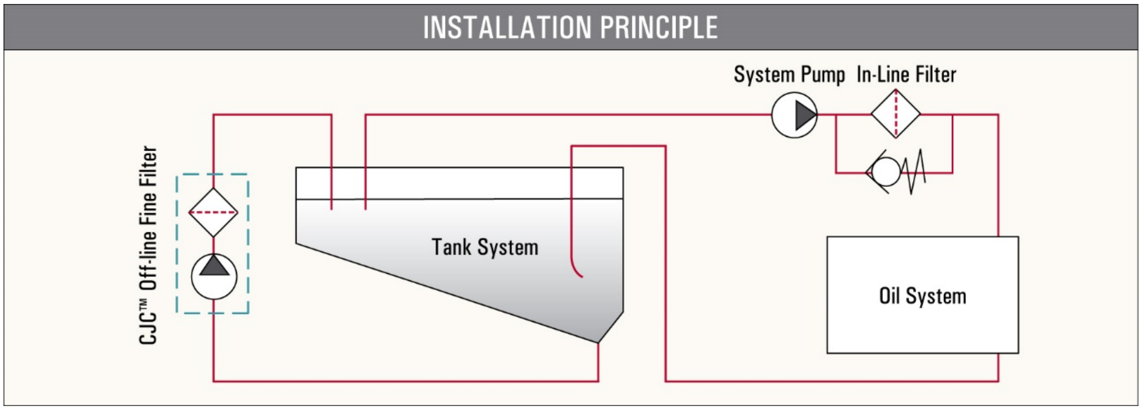


Figure 1: Typical inline and offline filtration installations

A properly installed offline filtration system will pull from the lowest point in a reservoir, allowing for the system to actually do the job it was designed to do, to clean all of the oil and the tank. It will remove contaminants like wear metals, sludge, water, bacterial growth, and rust that your inline filtration system will never touch.

What inline pressure filters do well

Let's discuss the good things about a typical inline filter. As with the safety program example above, solutions for both acute and chronic issues are both needed for a complete oil reliability program. I have been asked many times whether a customer should remove or bypass their inline filter if they install a good offline system. The answer is no. They go hand in hand and, as you will see, an offline filtration system enhances the performance of the system and works to prolong the life of the inline filter as well. A typical inline filter in an oil system ranges from 6-30 microns and can have a multitude of different Beta values. This filter provides a last-chance protection against large particles that make it downstream of the pump, prior to coming in contact with any critical system components. The inline filter is also designed to handle the entire flow rate of the system, to assure delivery of enough volume to the critical system components.

Limitations to inline pressure filters

There are many areas where an inline filter is just not enough to protect your system from long term or chronic type issues. Remember, an inline filter is designed to protect your equipment from catastrophic failures. I had a conversation recently with an engineer, who was referring to a filter element typically used in an inline configuration. He explained to me that he fully understood that the filter used would not clean the oil in his system. His best hopes were that the filter would only be able to maintain whatever cleanliness level they were at when the filter was installed. If you are looking to improve your overall system cleanliness, you must look to a true offline filter to do so.

Now let's discuss a few of the shortcomings of an inline filter. Most inline filters are pleated elements that range from 6-30 microns. The installation point is typically between the pump and critical components, which is a good location for a last-chance filter. However, the pickup location for the inlet of the pump is not always in an ideal position for best filtration practices (we will get to that in a moment). Another issue is the very nature of how the filter is utilized. The filter is working only when there is flow through the system. Many machines have multiple starts and stops, just by nature of how the equipment works and is run. Each of those starts and stops have a pressure shock effect on the filter and can even cause the particles that the filter has trapped to be released back into your clean oil stream.

Take a look at the chart below. This is a test done with a 3 Micron, Beta 1000 filter element from a very reputable manufacturer. The test was to run a 3 minute off/1 hour on cycle after uninterrupted filtration for the first 4 hours of the test, for a total filtration time of 10 hours. The flow rate of the pump was very low, only 0.53 GPM and the system pressure was only 22.48 PSI. The particles are Medium Test Dust (ISO 12103-A3) dosed in at 2 grams per hour. Particle counts are 4 micron per 100 ml according to ISO 4406.

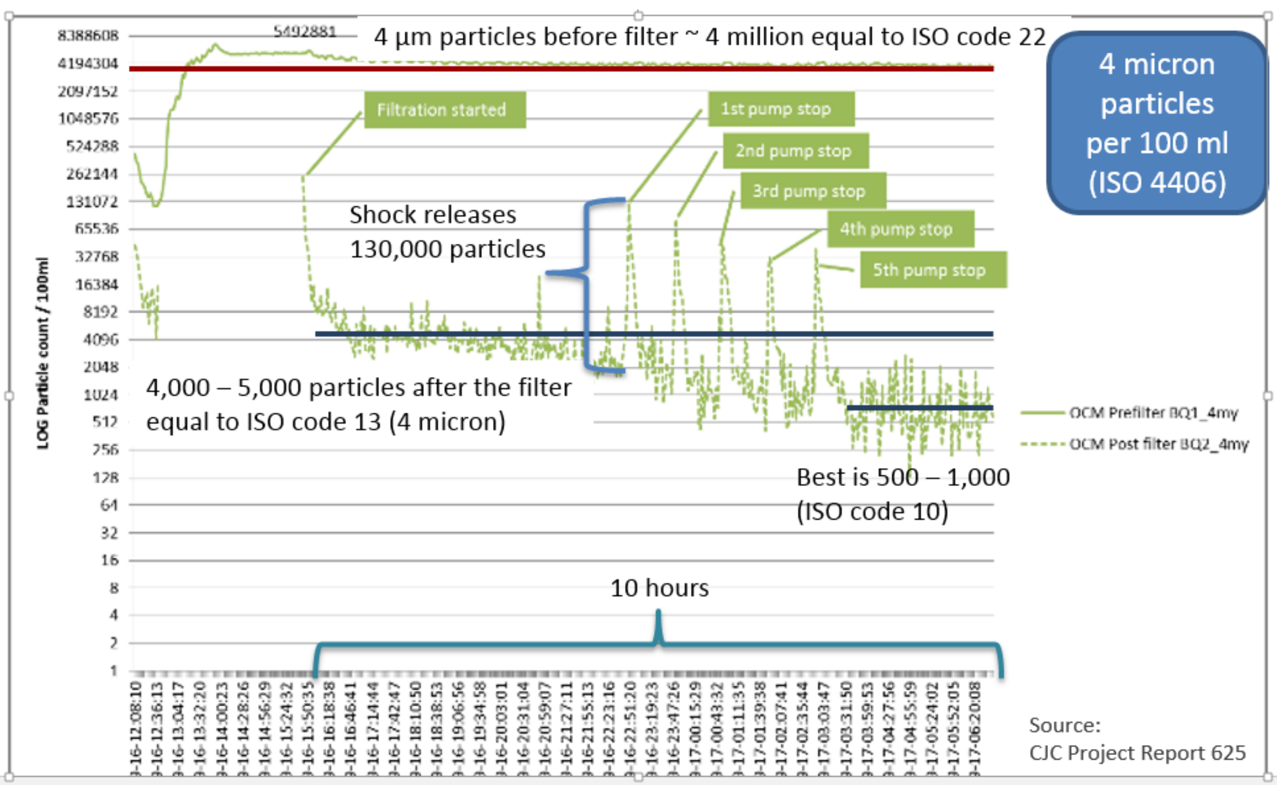


Figure 2: Particles are pushed through Inline filters every time there is a shock to the system

I have expanded the chart to emphasize what really happens when a system is started and stopped, as part of a routine work day. Even with the low flow rate, this inline filter released up to 130,000 of 4 micron particles when the system was restarted. These are particles that are going back into the oil stream, creating hardship for the system by going directly into your machine and causing damage before they are returned to the tank and are filtered again (and again). For a filter with such a high efficiency rating, this is not a very efficient method of cleaning your oil. This chart represents what happens in a system with only ½ GPM flow rate, so just imagine what happens in a high flow system, which depends on these inline, pleated filters to do the job.

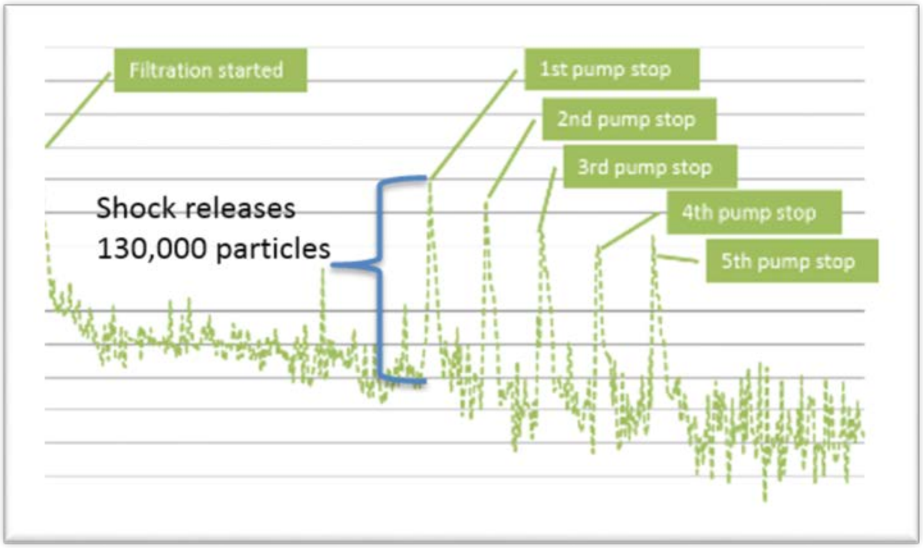


Figure 3: Particle releases during a pump stop and start. **Before start up the 4 micron particle count was 2,048. After pump starts, the particles spike to 131,072 at the peak, an increase from an ISO 12 to an ISO 18.**

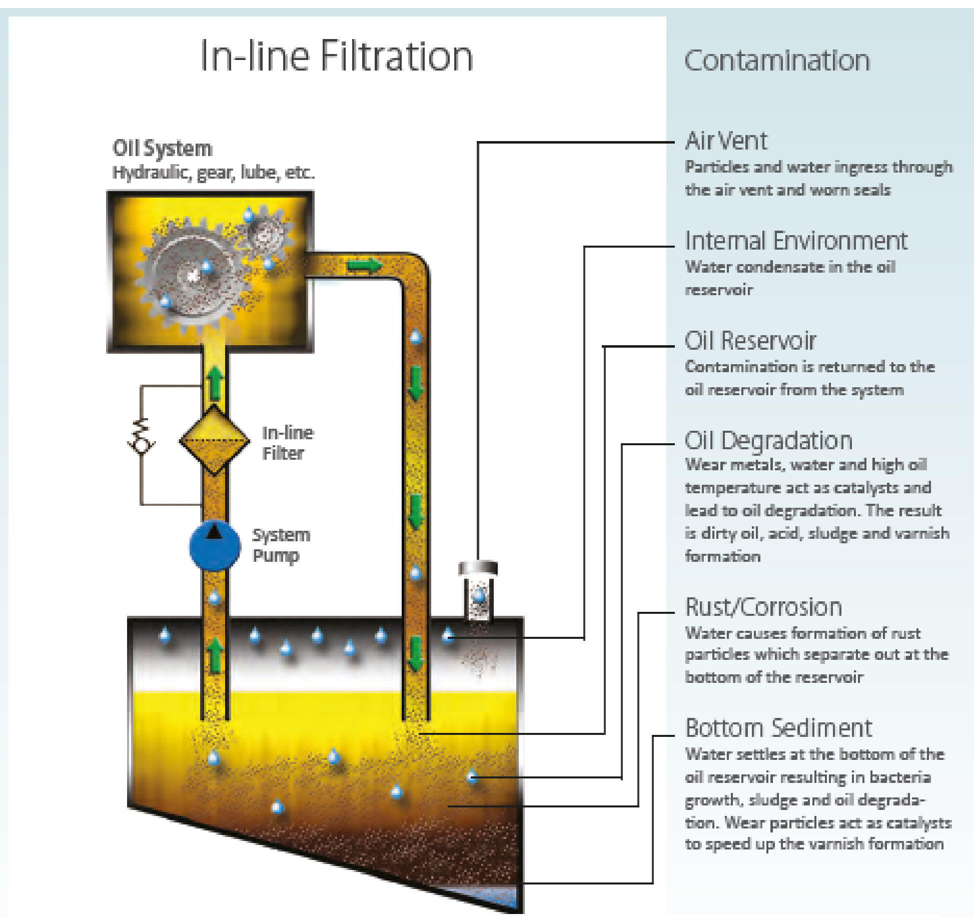


Figure 4: Typical system with only an inline filter

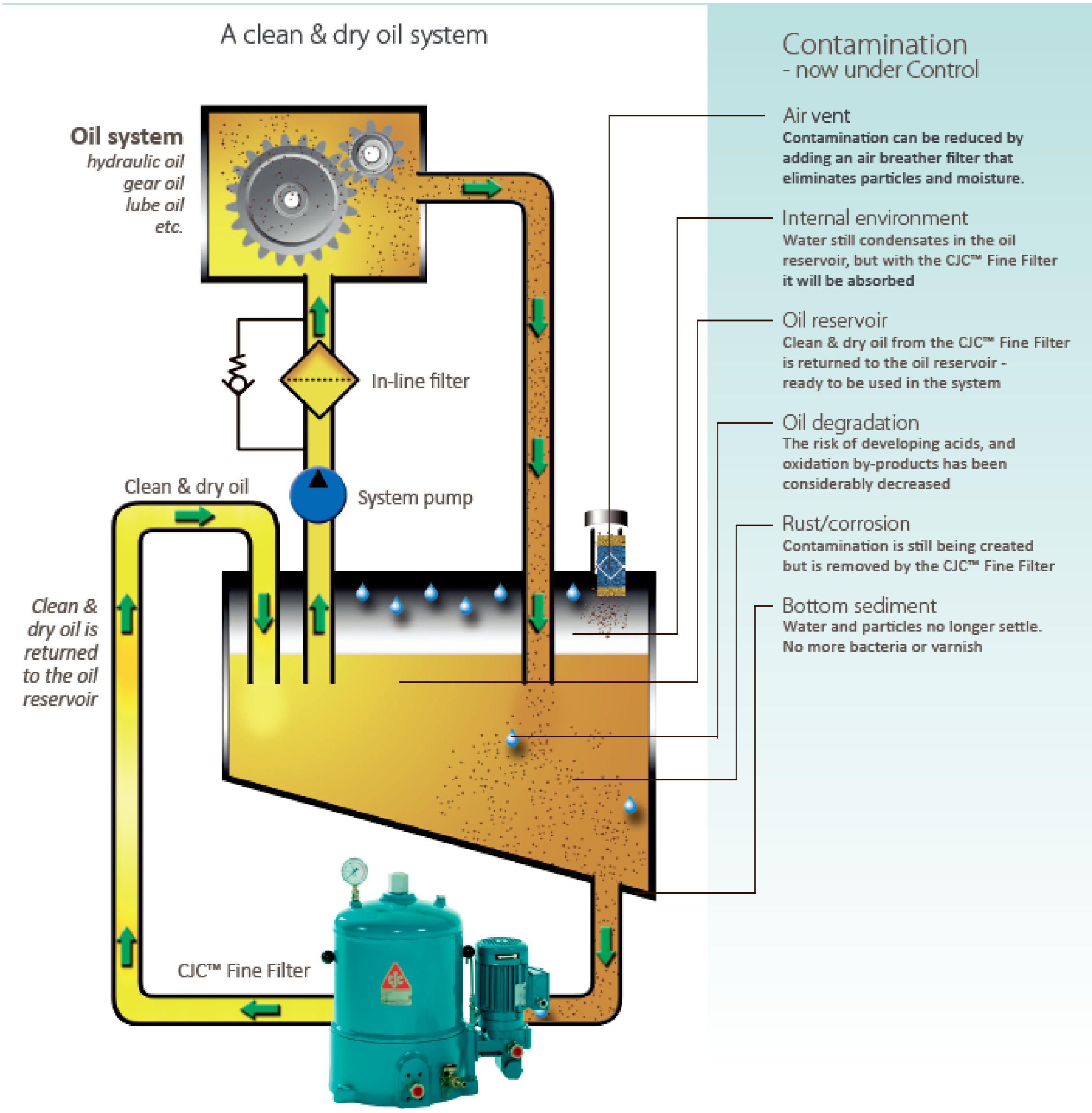


Figure 5: System with both inline and offline Filters

It is commonly understood that all you have to do to empty a pleated inline pressure filter is to start and stop the machine about 6-7 times, so any efficiencies or beta ratings that are claimed do very little to help your real world application. With a good offline filtration system, the filter system is running continuously and will not allow the contaminants to escape because of the routine start and stop shocks to the system.

Earlier I mentioned that the pickup location for the oil or fluid going into the filter was not always in an ideal location for an effective filtration system. A typical inline filter installation will pull from a section in a reservoir well above the bottom of the tank (see illustration below). Pulling from a place near the middle or top of a reservoir is a good method to assure longer life of an inline filter, but does nothing to assure that you are getting the cleanest oil possible. As you can see, contamination like wear metals, sludge, water, bacterial growth, and rust all settle to the bottom of the reservoir and remain in the system until addressed with a properly installed system. Another compromise that you will have with an inline only filtration system is that, because of the limited dirt holding capacity of these filters, combined with the critical need for oil going to the system components, you will have a bypass built into the system. If someone misses an alarm, or the filter gets plugged too quickly, and the inlet pressure is too high, the filter is then bypassed until there is an intervention to change the filter element. Now you go from less than desirable filtration to no filtration at all. Not a very good compromise!

Two other issues that we haven't yet touched on are water and varnish removal. First, let's discuss water removal. As most of you are aware, water in your oil can do greater damage at times than a high particle count. Water creates corrosion, degrades the oil and causes micro-pitting in gears and bearings. Most of your inline filters are designed to remove particulate and do not address water issues within a system. At only 500 PPM, you cut the designed bearing life in half. However, utilizing a good offline filtration system will address water as well as particles. At 100 PPM (easily achieved by either absorption with cellulose media or coalescence for certain type oils and fuels), you are at 100% bearing life.

As to the varnish in the system, many inline filters are made of synthetic media or glass fiber media, which cannot adsorb the soft contaminants that makes up the varnish. Additionally, these soft contaminants are sub-micron particles which will pass right through the filter media and continue to build up. This leads to more chronic or long-term issues within the system, like sticking valves, inefficient heat exchangers, sandpaper surfaces due to the particles sticking to the components, and increased wear and temperature. Varnish can cause a great deal of downtime in a system and can create some very large maintenance costs for the system owner. One trip of a gas turbine could cost anywhere from $50,000 to $250,000. By utilizing a proper offline filtration system (some of these can remove the soft contaminants by way of adsorption), you will eliminate those problems and enable your systems to run as intended. There are companies now that are providing oils with the claims that they will not experience varnishing issues. However, they claim to hold the varnish in suspension, but they do not remove it from the system. Without removal, there will always be the potential for harm. The best way to protect your system is to have a good varnish removal system in place, from startup. This will keep the system and all components clean all the time and prevent the buildup of varnish in your system.

Truly clean oil

Let's also look at the typical micron ratings for an inline filter versus what we can achieve with a good offline filtration system. The chart below shows a distribution of particles by size in a medium loaded oil system. Only 10% of all of the particles in the system are larger than 10 micron, while about 70-80% of the particles in the system are between 1-5 micron. Therefore, if an average inline filter is in the 6-30 micron range, by design, you are missing the majority of the particles that are passing through your system. Here you can see that while you may be protecting the system from the acute or catastrophic type issues, you compromise your system and allow for these small particles to wear down your system components and cause those long term or chronic issues. The graphic to the right (MacPherson graphic) shows the impact of bearing life when you introduce fine filtration into your system. A real life example: Your new hydraulic pump with a volumetric efficiency of 98 percent, can easily drop to 80 percent efficiency by pumping contaminated hydraulic oil for some months. That's almost 20 percent slower hydraulic operation and weekly work hours wasted.

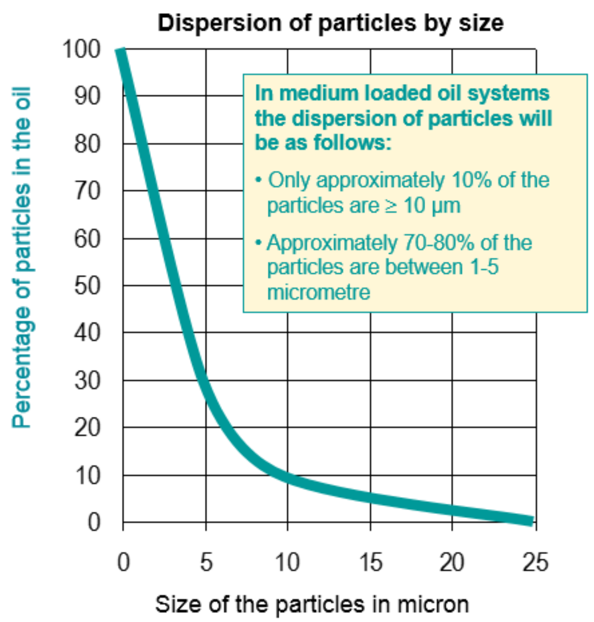


Figure 6: MacPherson, Dispersion of particles by Size

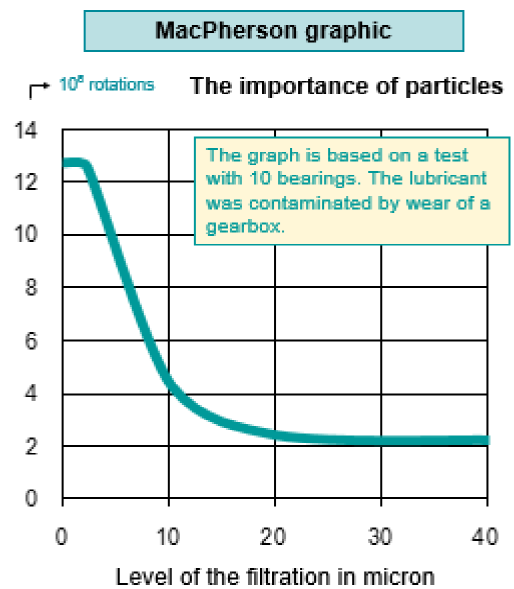
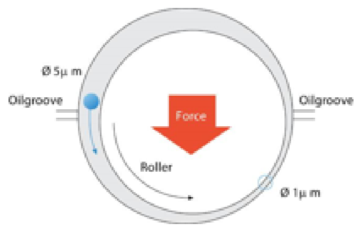


Figure 7: MacPherson, Importance of Particles

The illustration below further emphasizes the need for fine filtration by pointing out the dynamic oil film thickness in various systems. As you can see, some of these systems have some incredibly tight tolerances. If you have particles in your system that are larger than your oil film thickness, the slow death process has already begun.

Dynamic Oil Film

	Oil film thickness:
Journal, slide and sleeve bearings:	0.5 – 100 microns
Hydraulic cylinders:	5 – 50 microns
Engines, ring/cylinder:	0.3 – 7 microns
Rolling element bearings / ball bearings:	0.1 – 3 microns
Servo and proportional valves:	1 – 3 microns
Gear pumps:	0.5 – 5 microns
Piston pumps:	0.5 – 5 microns
Gears:	0.1 – 1 micron
Dynamic seals:	0.05 – 0.5 micron



Source: Noria Corporation

Figure 8: Dynamic Oil Film

A good offline depth filtration system can remove particles down to less than 1 micron in size. You can then begin to flip the chart above and start removing a good majority of the particles in a system, thus extending the oil life and the life of the system components. As a result, cleaner oil will make a huge difference on the expected component life. Just look at the difference a few ISO codes make in extending the life of your equipment. The example below shows what the impact of cleaning oil from an ISO code of 22/20/17 down to an ISO code of 16/14/11 does for journal bearings and turbo machinery. It extends the life of the system components by a factor of 3.5. This shows you the cost savings a good offline system can provide to you. It extends the life of

LET – Cleanliness Level
ISO Codes, Complete

Source: Noria Corp.

Current Machine Cleanliness (ISO Code)	Expected Cleanliness level (ISO Code)									
	21/19/16	20/18/15	19/17/14	18/16/13	17/15/12	16/14/11	15/13/10	14/12/9	13/11/8	12/10/7
24/22/19	2 1.6 1.8 1.3	3 2 2.3 1.7	4 2.5 3 2	6 3 3.5 2.5	7 3.5 4.5 3	8 4 5.5 3.5	>10 5 7 4	>10 6 8 5	>10 7 10 5.5	>10 >10 >10 8.5
23/21/18	1.5 1.5 1.5 1.3	2 1.7 1.8 1.4	3 2 2.2 1.6	4 2.5 3 2	5 3 3.5 2.5	7 3.5 4.5 3	9 4 5 3.5	>10 5 7 4	>10 7 9 5.5	>10 10 10 8
22/20/17	1.3 1.2 1.2 1.05	1.6 1.5 1.5 1.3	2 1.7 1.8 1.4	3 2 2.3 1.7	4 2.5 3 2	5 3 3.5 2.5	7 4 5 3	9 5 6 4	>10 7 8 5.5	>10 9 10 7
21/19/16		1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.3	2 1.7 1.8 1.5	3 2 2.2 1.7	4 2.5 3 2	5 3 3.5 2.5	7 4 5 3.5	9 6 7 4.5	>10 8 9 6
20/18/15			1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.3	2 1.7 1.8 1.5	3 2 2.3 1.7	4 2.5 3 2	5 3 3.5 2.5	7 4.6 5.5 3.7	>10 6 8 5
19/17/14				1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.3	2 1.7 1.8 1.5	3 2 2.3 1.7	4 2.5 3 2	6 3 4 2.5	8 5 6 3.5
18/16/13					1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.3	2 1.7 1.8 1.5	3 2 2.3 1.8	4 3.5 3.7 3	6 4 4.5 3.5
17/15/12						1.3 1.2 1.2 1.1	1.6 1.5 1.5 1.4	2 1.7 1.8 1.5	3 2 2.3 1.8	4 2.5 3 2.2
16/14/11							1.3 1.3 1.3 1.2	1.6 1.6 1.6 1.4	2 1.8 1.9 1.5	3 2 2.3 1.8
15/13/10								1.4 1.2 1.2 1.1	1.8 1.5 1.6 1.3	2.5 1.8 2 1.6

Hydraulics and Diesel Engines	Rolling Element Bearings
Journal Bearings and Turbo Machinery	Gear Boxes and others

Figure 9: Noria Cleanliness Chart

your oil and equipment, cuts out unnecessary downtime, and reduces unnecessary maintenance costs! That is a huge paradigm shift from “it’s always been done this way”, isn’t it?

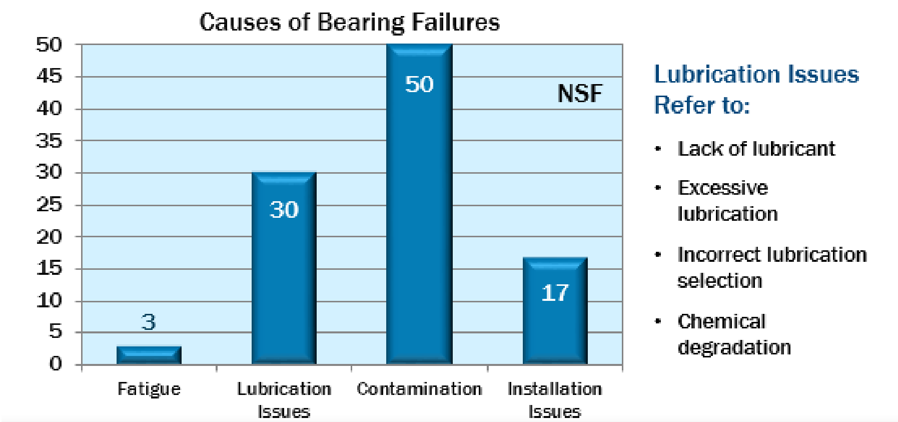


Figure 9: Bearing Failures

So what do the bearing and gear manufacturers have to say about oil cleanliness? These manufacturers fully understand the effect that dirty oil has on equipment life. In fact, as quoted by SKF "Bearings can have an infinite life when particles larger than the lubricant film are removed”. As you can see in the illustration below from NSF, contamination is by far the leading cause of bearing failure (50%).

Ok, so now that we understand that contamination is the main cause of component failure in a system, what does a clean system look like? Here are some general guidelines for hydraulic and gear oil systems.

ISO Class	NAS 1638	Description	Suitable for	Dirt/year
ISO 14/12/09	NAS 3	Very clean oil	All critical systems	2 kg *
ISO 16/14/11	NAS 5	Clean Oil	Servo valves, high pressure hydraulics, Common rail diesel	4 kg *
ISO 17/15/12	NAS 6	Light contaminated oil	Standard hydraulics, lube oil systems	9 kg *
ISO 19/17/14	NAS 8	New oil (unfiltered)	Low loaded gears, low pressure systems	36 kg *
ISO 22/20/17	NAS 11	Very contaminated oil	Not suitable for oil systems	144 kg *

**) The amount of dirt passing the pump per year, if the oil passes with a capacity of 150 ltr/min (40 GPM), 20 hours per day, 200 working days per year*

If you are prematurely replacing components in these systems and they are causing unplanned outages and down time, you need to look at your lubrication system. You may very well have a contamination problem that could be easily addressed and could have a huge impact both your uptime and bottom line.

Additionally, I would like to point out where new oil often falls in charts like the ones above, very close to the bottom. A lot of users don't realize that the levels of contamination in their new oil is oftentimes higher than recommended by the OEMs for use in their systems. Many good Preventative Maintenance Programs now include filtration of new oils with an offline filter, prior to introduction into their systems.

Chronic issues that only offline filtration can solve

We spoke briefly above, about the ability to remove varnish from a system with a good offline filtration system. The efficiency of the filter elements and the materials of construction for most of your inline filters make it very improbable that they will do anything to impact the results of varnish in the system.

Another area of concern is buildup of sludge in the system reservoirs, heat exchangers and the system itself. In fact, one of the main purposes of an oil reservoir is to allow time for the oil to dissipate heat. If you continuously build layers and layers of sludge and contamination, the reservoir will lose this property and cause an increase the oil temperature, leading to further breakdown and shortening the life of your oil.

Keep in mind that very clean oil acts like a detergent in the system, pulling contaminants and sludge from all system components. With a good offline filtration system, your reservoirs stay clean, your cooling loop stays clean, and your system components stay clean, which leads to extended life for your oil and your system and less problems with unexpected downtime and loss of production.

Benefits of a complete filtration system

We have discussed some of the shortcomings of using only an inline pressure filter. Now let's review the benefits that you achieve with a complete filtration system, utilizing both inline pressure filters and offline filtration:

- Clean and dry oil, all the time – Good offline filtration systems can remove particles down to 1 micron and should be able to guarantee an oil cleanliness level of 16/14/11 or lower. Water removal rates should be down 100ppm or less.
- Better uptime and equipment reliability – Cleaner oil results in more reliable rotating equipment. The offline system compliments your inline pressure filters as you will have much cleaner oil going through them, reducing both downtime to change these filters and material costs.

Additionally, pulling from the bottom of the reservoir and continuous filtration of your oils and/or fuels will keep the reservoir and system components clean as well, reducing planned and unplanned shutdowns to clean these reservoirs and components.

- Oil life extension – By removing the contaminants that cause the oil to break down, we can extend the life of your oil 3-5 times or more.
- Varnish removal – Removal of the soft contaminants that create the varnish, results in a much more reliable system and can eliminate the unexpected downtime that comes as a result of varnish build up in the system.

To recap, a good reliability program will address all of the issues, both acute and chronic. The need for good inline filters for your system will always be there and they are a very good at protecting your system from catastrophic failures. Equipment manufacturers realize this and that is why these type filtration systems are typically included as part of the system package. However, inline filters are designed to protect the system from the acute problems, they are not designed to protect against the chronic issues. A good offline filtration system will allow you to properly clean the oil and give you the extended life and system reliability that you need and your companies now demand.

More Information

For more information about Offline Filter Systems for lubricated machinery, please contact C.C .JENSEN, Inc. at ccjensen@ccjensen.com, or call (800) 221 1430, or visit www.ccjensen.com