Filter Types

Surface Filters: Surface filters work by direct interception of particles larger then the pore size of the media. Dirt is trapped on the upstream side of the media with the holding capacity limited by the number of pores in the media. When new, media resistance to flow is small, but as the filter builds up dirt, the resistance to flow rapidly increases. The capacity of most surface filter media is usually measured in grams.

Depth Type Filters: This type of filter works by both direct interception of particles and absorption (molecular attraction of particles). These filters use several types of media to achieve the goal of holding particles. The fluid must take a longer path through the filter before exiting. Normally, these filters have large holding capacities and initially have a higher resistance to flow. However, a drop in pressure occurs as contamination builds up or is trapped.

Filters Systems

Full-Flow Filters: Designed to filter fast flowing oil, full-flow filters protect downstream components from larger size particulate matter. These filters typically hold particles from 20 to 40 microns in size. Their ability to pass large volumes of fluid makes full-flow filters unsuitable for smaller particles; without becoming large and expensive.

Partial-Flow Filters: Sometimes called a kidney loop, these filters are designed to filter a small stream of fluid; returning the filtered fluid to the sump of the system. These filters typically hold particles from 1-10 microns. Smaller quantities of flow allow the filters to remove slighter particles without affecting the normal functions of the system.

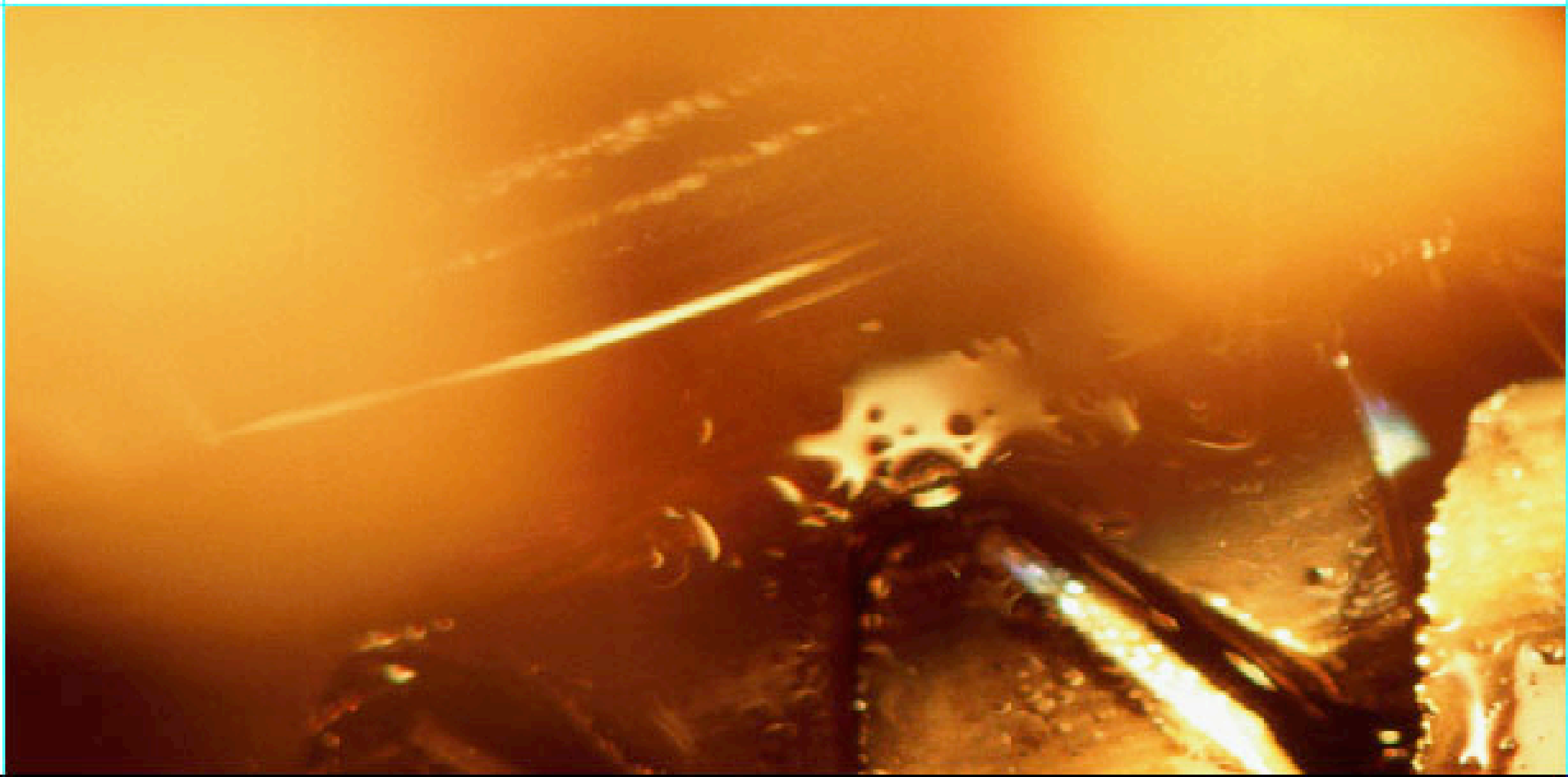
The Functions of Oil

Clean: *This function is to transport undesirable materials in oil to the filter or hold in suspension the particles until the oil is changed. This is the characteristic that keeps internal parts clear of varnish and sludge build up.*

Cool: *An important function of oil is to cool the machine parts it comes into contact with. Some systems require that all cooling be performed by only the oil.*

Seal: *The film of oil that bridges the gap between two surfaces to keep fluids in while keeping air and dirt out is called the seal. An example is the seal that oil provides in a hydraulic ram or spinning shaft, the thin film of oil bridges the gap and isolates two sides.*

Lubricate: *Lubrication is the function of oil that allows two moving parts to slide past each other with little friction. This film of oil is important in reducing wear and providing ease of movement within a machine.*



Cleanliness Levels

Since fluids can have such small particles (debris) in suspension and maintaining good cleanliness is so economically and mechanically important, that industry created a standard to quantify particulate build-up. The current standard is ISO 4406c. This standard is used by manufacturers, engineers and maintenance staff to determine how clean fluids should be to provide acceptable performance and service life. The adjacent chart shows the count of particles present in a milliliter of fluid which is used to determine the ISO fluid cleanliness code. This code lists Scale Numbers in a specific order based on the particle count range at 4, 6 and 14 microns and greater. For example, hydraulic oils that are used with Servo valves should have a 16/14/12 code or cleaner while in service.

- *16 = particle count 320 - 640 at 4 microns and greater*
- *14 = particle count 80 - 160 at 6 microns and greater*
- *12 = particle count 20 - 40 at 14 microns and greater*

At this oil cleanliness level, sticky or binding valves should not be a problem and the oil can be in service for an extended time.This coding method can also be used to evaluate contamination control systems or filter performance in a system.

New Oils: *As surprising as it may seem, most new oils purchased today are not filtered before being sold. Yes, it is newly refined and looks translucent, but it has many unwanted particles present than what would be expected in new oil. Typically, new oils delivered to customers are 22/21/18 and sometimes worse. This puts the end user in a position of having to filter the oil before it is put into service to assure it will not cause premature wear and undesirable equipment down time.*

ISO 4406c Cleanliness Code Chart

Number of Particles per Milliliter (Counts/mil)		
More Than	Up to and Including	Scale Number
2500000		>28
1300000	2500000	28
640000	1300000	27
320000	640000	26
160000	320000	25
80000	160000	24
40000	80000	23
20000	40000	22
10000	20000	21
5000	10000	20
2500	5000	19
1300	2500	18
640	1300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12

Example: ISO Code 22/21/18

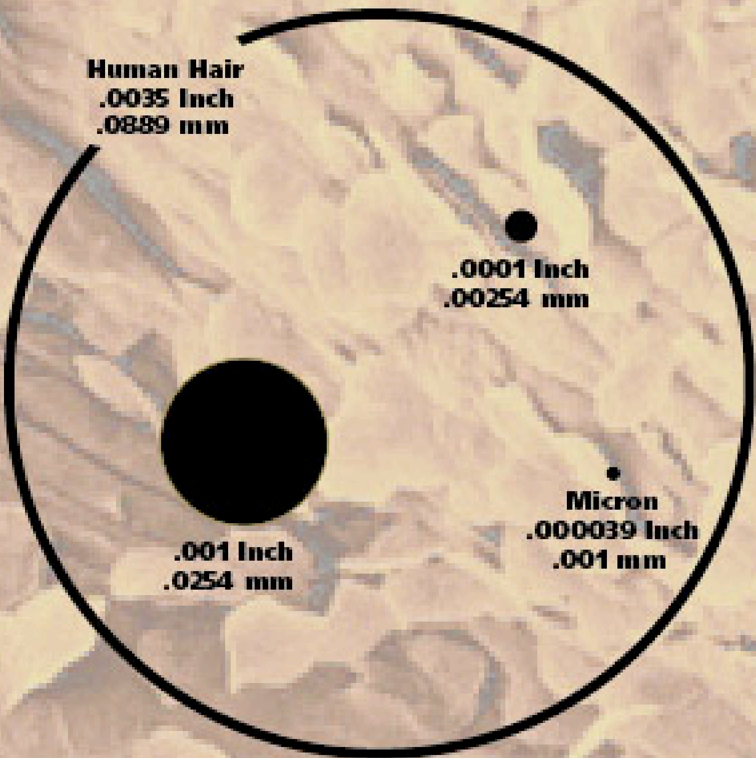
Between 20000 and 40000 particles 4 µm and greater
Between 10000 and 20000 particles 6 µm and greater
Between 1300 and 2500 particles 14 µm and greater

Pump (250 lpm)

Typical New Oil	Harvard Corporation
ISO 22/21/18	ISO 16/14/11
Expected Pump Life: 2 years	Expected Pump Life: 14 years
8000 lbs. of dirt moves through pump per year.	55 lbs. of dirt moves through pump per year.

How big is a Micron?

(1,000 times size)



Size Matters

What is a micron? A micron is one millionth of a meter. To put this in a visual reference, a typical human hair is about 75 microns thick and the unaided human eye can see down to about 40 microns. The individual particles of smoke from a cigarette are about one micron in size. We can see these only because there are so many of them together.

Filters are designed to remove particles that can and will cause damage to machinery. With greater performance and sophistication of today's machinery, higher contamination control is essential. But what size particles will cause damage? What is the thickness of the oil that separates the moving parts?

- The film of oil that separates the engine ring and cylinder wall is 2-3 microns.
- The oil that is between a spool valve and bore is usually 3-5 microns.
- The oil lubricating a sleeve bearing will provide 5-8 micron clearance.

These numbers tell us that standard full-flow filters will not take out nor eliminate particles that cause an abrasive bridge. This bridge of particles connecting the two sides will allow wear to both surfaces, creating even more particles. The main reason we change oil in machinery is to remove small particles in the oil that the filters did not remove and have built up to a point of causing excessive wear to the internal parts of the machine. This is where contamination control in removing particles down to 1 micron will make a significant reduction in the wear of the machinery and lengthen the service life of the oil.

Although particulates that bridge the moving parts do cause wear, this is not the only harm the small particles under 5 microns cause. These slighter particles, referred to as silting build up in the fluid, interfere with proper functions of the fluid, and create costly wear on machinery.

The four functions of oil also help us understand why it is important to maintain high cleanliness levels. Contamination interferes with these functions in the following ways.

Clean: The ability of the fluid to hold particles in suspension is limited. Once the limit is reached the fluid will deposit the particles onto the machinery, leaving sludge and varnish on the parts. It will also further reduce the fluid's ability to cool.

Cool: The oil moves heat from the machine's heat generating locations to a cooler or the outer case of the machine to be radiated to the atmosphere. Fluids with contaminate build-up have a reduced capacity to move heat and aid in cooling the machine as it should.

Seal: The film of oil that seals the gap between two surfaces will maintain the sealing if there are no particles bridging the seal. If contaminants bridge and lift the sealing surfaces apart, it allows fluid out and contaminants in. Take, for example, a seal in a hydraulic ram. As the ram moves out past the seal, the oil is scraped off the shaft. When the ram is viewed under a microscope, the surface looks like the peaks and valleys of a mountain range. Each one of these valleys is a location which can lodge particles that can be drawn into the ram as it is retracted. As the small contaminants build, particles can start to lift the seal off the ram and allow leakage and further contaminate build-up. The increase in contamination, if allowed to continue, will wear on the seal material and cause premature failure.

Lubricate: The bridging action of the particles interferes with lubrication, increasing friction between moving parts, which can lead to higher energy consumption. The quality of lubrication is reduced as contaminants build up in fluids.

Summary

Hydraulic Systems: With hydraulic systems, fluid is used to transmit power to components, such as motors and rams. The fluid passes through valves which direct the oil to the working components. The higher the system pressure, the closer the tolerances that the components will need to maintain. As a ram is extended and retracted a small amount of contamination is brought into the system. To the naked eye the ram looks smooth but if viewed under a microscope it has many peaks and valleys.

There can also be airborne contamination that can drop onto the cylinder and be drawn into the oil past the seal. This small particulate material is suspended in the oil until removed by the filter or drained at the next servicing. As the small contamination (silting) builds up it can bind or stick valves. Servo valves are particularly sensitive to silting, the patented Harvard Filter System is a cost effective way to eliminate failure due to this. Vane pumps and piston pumps are both components that have an elevated degree of sensitivity to contamination. A 3-5 micron clearance of the vane tip to housing puts particles under pressure, eroding the metal like a sand blaster . The small clearances in these pumps necessitates a need for very clean fluid, which needs to be cleaner then most new oils with ISO cleanliness codes of 20 or greater. Components in the system should have codes of 17 or less.

Hydraulic System Component Cleanliness Levels

System Component	Typical Cleanliness Specification						
Servo Valve	●	●	●				
Proportional Valve		●	●	●			
Variable-displacement Pump			●	●	●		
Cartridge Valve				●	●	●	
Fixed-displacement Piston Pump				●	●	●	
Vane Pump					●	●	●
Pressure or Flow Control Valve					●	●	●
Soleniod Valve					●	●	●
ISO Cleanliness Code	14/12/9	15/13/10	16/14/11	17/15/12	18/16/13	19/17/14	20/18/15

Gear Systems: Gear oils provide lubrication which allows gear teeth to slide past each other. The fluid also keeps the sliding surfaces cool. Contamination in the oil will cause abrasive bridging and wear on the teeth surfaces, generating more particles. Oxidation (thickening) of the oil due to elevated temperatures in the presence of oxygen is an issue that must be controlled to keep gear oils serviceable. Condensation or moisture in the oil, even in small amounts, acts as a catalyst in oxidation and the formation of acids in the oil. By filtering the oil down to 1 micron and removing water in the oil, the lubricant can perform its function better and longer.

Automatic Transmissions: The function of this fluid is threefold: a gear lubricant, a hydraulic fluid in the torque converter, and a coolant. While each function is best performed as a clean fluid, the clutch packs in the system contribute wear-particles continually. Each time the clutches engage, there is a sliding motion while the pressure increases to final engagement. When the clutch pack is released again, it will deposit particles into the fluid. If this contamination is allowed to build up in the fluid, it will wear on the gears, erode the vanes of the torque converter, and accelerate the wear of the clutch packs. All this in addition to generating elevated heat. Adding a kidney loop filtration system to remove particles while still small, has been shown to significantly increase the life of these transmissions.

Engines: Engine oil provides lubrication to all the sliding parts of the engine; sealing between the ring and the cylinder wall, cooling the pistons, and keeping the components clean. This is a demanding service for engine oil. The 2-3 micron gap between ring and cylinder wall provides a seal to keep combustion gases from the crankcase. As the contamination builds, particles will wedge between the two surfaces and break the oil seal allowing combustion product blow-by and increasing oil usage. This also will increase the wear to the surfaces due to the abrasive bridging. The contamination bridge also creates wear on the bearing surfaces, camshaft, and gears.
The addition of a second filter loop, capable of removing moisture and particulate matter under 1 micron in size, has proven to increase oil service life and running time of an engine.

Diesel Fuels: As diesel engines are forced to reduce pollution emissions, pressure in the fuel delivery system has gone up substantially. Some engines are producing 30,000 pounds of pressure at the injector tip to deliver cleaner combustion in the cylinders and better fuel economy. At the same time, the fuel must have sulfur removed which lowers the level of lubrication to the moving parts. Most fuels today are delivered to the tank with ISO grades 19/18/16 or above. Additionally, water in the fuel will promote algae growth in the tanks and if allowed to be pumped into the injector can cause catastrophic failure.

The combination of high pressures, reduced lubrication, and contamination is forcing companies to realize their need for contamination control of the fuel before delivering fuel to the engine. Similar to hydraulic systems, the need for contamination control in fuel systems is just as critical. Cleaner fuel reduces wear on the expensive and sensitive fuel injector parts maintaining peak performance and delivering better fuel economy. In addition, using a contamination control system prior to pumping fuel into the engine tank reduces filter plugging, improves fuel system longevity, and decreases downtime.

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