Main Filter Inc.
Hydraulic Filter Manufacturers

Hydraulic Training Manual

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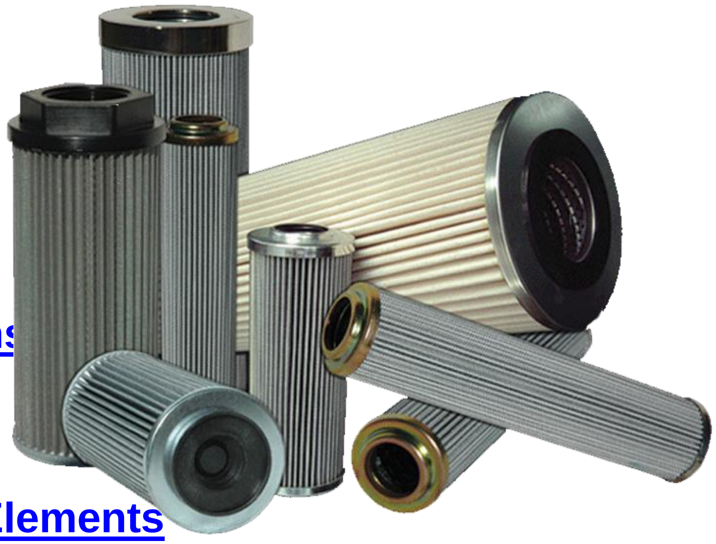

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Definition of Hydraulics

- **Hydraulics** is a branch of science and engineering concerned with the use of fluids to perform mechanical tasks. It is part of the more general discipline of fluid power.

- The word "hydraulics" comes from the Greek word (*hydraulikos*) which means water organ which in turn means water and pipe.

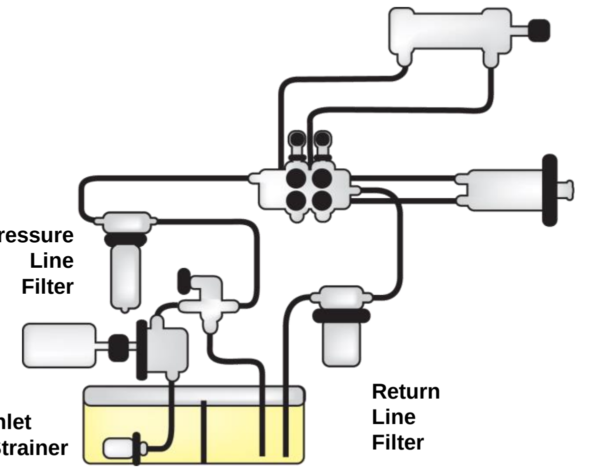
- Typically, the fluid used in a hydraulic system is an incompressible liquid such as a mineral based hydraulic oil. Pressure is applied by a piston to fluid in a cylinder, causing the fluid to press on another piston that delivers energy to a load. If the areas of the two pistons are different, then the force applied to the first piston will be different from the force exerted by the second piston. This creates a mechanical advantage.

Pascal's Law

Pressure applied on a confined fluid is transmitted undiminished in all directions, act with equal force on equal areas, and at right angles to them.

Introduction to Hydraulics

- A hydraulic system is not a source of power. The power source would be a prime mover such as an electric engine which drives the pump.



Advantages of Hydraulics

Variable Speed: The actuator* in a hydraulic system can be driven at different speeds, from maximum to reduced speeds.

* **Actuator** – A device for converting energy into mechanical energy, i.e., a motor or cylinder.

Reversible: A hydraulic actuator can be reversed instantly while in full motion without damage.

Overload Protection: The pressure relief valve in a hydraulic system protects the system from overload damage.

Small Components: Hydraulic components, because of their high speed and pressure capabilities, can provide high power output with very small weight and size.

Can be Stalled: A hydraulic actuator can be stalled without damage when overloaded, and will start up immediately when the load is reduced.

Hydraulic Oil: The oil transmits power readily since it is minimally compressible. The most desirable property of the oil is its lubricating ability.

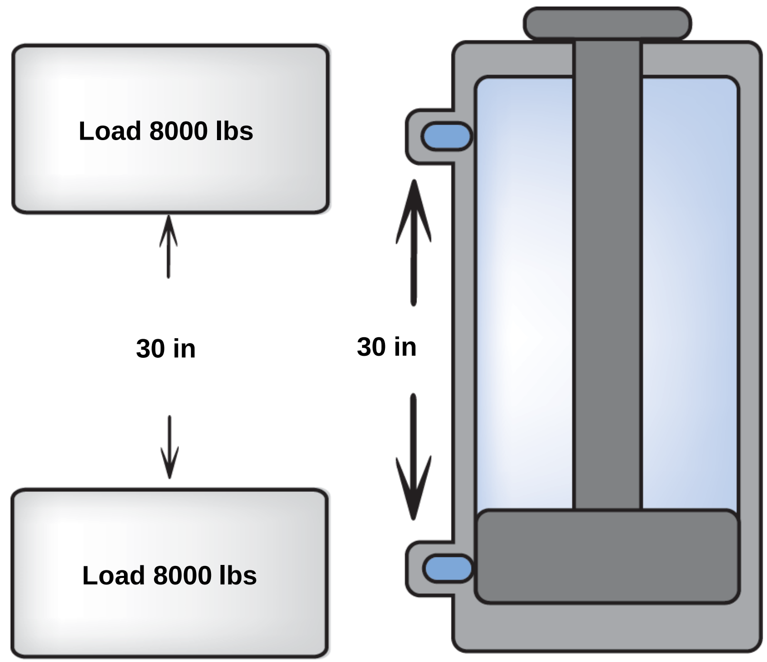
Designing a Simple Hydraulic Circuit

- All circuit design must start with the job you want to achieve. For example; a weight to be lifted, a tool head to be rotated, or piece of work that must be clamped.

- If the requirement were simply to raise a load, placing a hydraulic cylinder under it would do the job. The stroke length of the cylinder would have to be at least equal to the distance the load must be moved.

- The cylinder's area would be determined by the force required to raise the load and the desired operating pressure. For example; if an 8000 lb weight is to be raised a distance of 30 inches and the maximum operating pressure must be limited to 1000 psi then the cylinder selected would require a stroke length of at least 30 inches and with an 8 in^2 area piston it would provide a maximum force of 8000 lbs. However this, would not provide any margin for error.

To raise an 8000 lb load 30 inches, a cylinder with at least a 30 inch stroke is required.



Designing a Simple Hydraulic Circuit - Continued

- The better selection would be a 10 in^2 cylinder permitting the load to be raised at 800 psi and providing the capability of lifting up to 10,000 lbs.

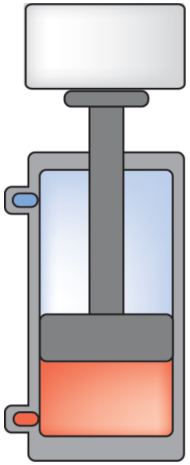
- The upward and downward travel of the piston rod would be controlled by a directional valve. The rate at which the load must travel will determine the pump size. The 10 in^2 piston will displace 10 in^3 for every inch it lifts. Extending the piston rod 30 inches will require 300 in^3 of fluid. If it is to move at the rate of 10 inches per second, it will require 100 in^3 of fluid per second or 6000 in^3 per minute. Since pumps are usually rated in gallons per minute, the following conversion is necessary:

    6000/231

    = 26 gpm

The minimum pressure required to lift the load equals the load divided by the piston area.

Load 8000 lbs



$$\frac{8000\ \text{lbs}}{10\ \text{sq in}} = 800\ \text{psi}$$

If the piston area is 10 sq in.

Designing a Simple Hydraulic Circuit - Continued

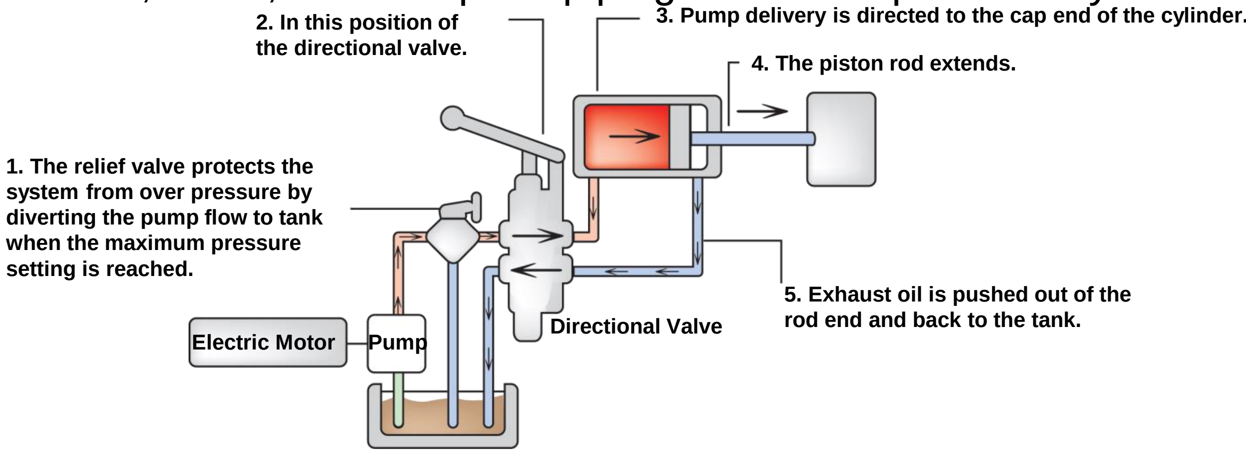
- The horsepower (hp) needed to drive the pump is a function of its delivery and the maximum pressure at which it may operate. The following formula will determine the size of the motor required:

  hp = gpm x psi x 0.0007

  hp = 26x1000x0.0007

  hp=18.2

- To prevent overloading of the motor and to protect the pump and other components from excessive pressure due to overloads or stalling, a relief valve should be set to limit the maximum system pressure and installed in the line between the pump outlet and the pump inlet port to the directional valve (as shown below).
- A reservoir sized to hold approximately two to three times the pump capacity in gallons per minute, filters, and adequate piping would complete the system.



Principles of Hydraulics

How Pressure is Created

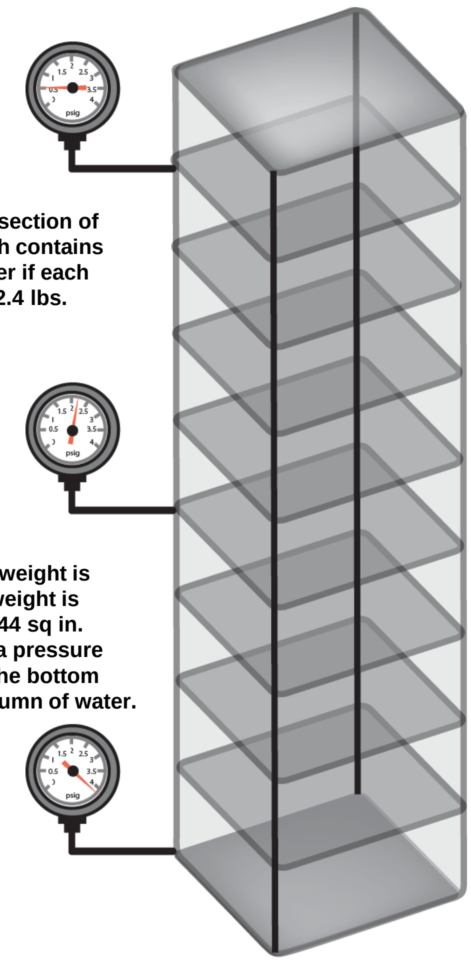
- Pressure results whenever there is resistance to fluid flow or to a force which attempts to make the fluid flow. The tendency to cause flow (or the push) may be supplied by a mechanical pump or may be caused simply by the weight of the fluid.

- It is well known that pressure increases with depth in a body of water. The pressure is always equal at any particular depth due to the weight of the water above it. An Italian scientist named Torricelli proved that if a hole is made in the bottom of a tank of water, the water runs out faster when the tank is full and the flow rate decreases as the water level lowers. In other words, as the “head” of water above the opening lessens, so does the pressure.

- Torricelli expressed that the pressure at the bottom of the tank only as “feet of head,” or the height in feet of the column of water. Today, with the pound per square inch (psi) as a unit pressure, we can express pressure anywhere in any liquid in more convenient terms. All that is required is knowing how much a cubic foot of the fluid weighs.

A foot-square section of water 10 ft high contains 10 cu ft of water if each cu ft weighs 62.4 lbs.

Then the total weight is 624 lbs. This weight is divided over 144 sq in. This gives us a pressure of 4.33 psi at the bottom of the 10 ft column of water.



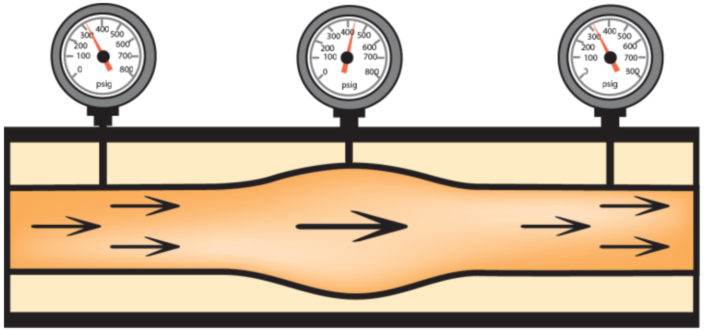
Principles of Hydraulics - Continued

Principles of Flow

- Flow is the action in the hydraulic system that gives the actuator its motion. Pressure gives the actuator its force, but flow is essential to cause movement. Flow in the hydraulic system is created by the pump.

How Flow is Measured

- There are two ways to measure the flow of a fluid: Velocity is the average speed of the fluid's particles past a given point or the average distance the particles travel per unit of time. It is usually measured in feet per second (fps), feet per minute (fpm), or inches per second (ips).
- Flow rate is a measure of the volume of fluid passing a point in a given time. Large volumes are measured in gallons per minute (gpm). Small volumes may be expressed in cubic inches per minute.
- The following illustrates the distinction between velocity and flow rate. A constant flow of one gallon per minute either increases or decreases in velocity when the cross section of the pipe changes size.



Principles of Hydraulics - Continued

Flow rate and Speed

- The speed of a hydraulic actuator, always depends on the actuator's size and the rate of flow into it. Since the size of the actuator will generally be expressed in cubic inches, use this conversion factor:

$$gpm = \frac{in^3/minute}{231}$$

Flow and Pressure Drop

- Whenever a liquid is flowing, there must be a condition of unbalanced force to cause motion. Therefore, when a fluid flows through a constant-diameter pipe, the pressure will always be slightly lower downstream with reference to any point upstream. This difference in pressure, or pressure drop, is required to overcome friction in the line.

Fluid seeks a Level

- Conversely, when there is no pressure difference on a liquid, it simply seeks a level. If the pressure changes at one point the liquid levels at the other points only rise until their weight is sufficient to make up the difference in pressure. The difference in height (head) in the case of oil is one foot per 0.4 psi. Thus it can be seen that additional pressure difference will be required to cause a liquid to flow up a pipe or to lift the fluid since the force (due to the weight of the liquid) must be overcome. In circuit design, naturally, the pressure required to move the oil mass and to overcome friction must be added to the pressure needed to move the load. In most applications, good design minimizes these pressure "drops" to the point where they become almost negligible.

Contamination

- ❖ There is a consensus that 70% to 90% of equipment wear and failure is attributed to contamination. Solid particles, such as dirt, are the chief culprits because of their ability to directly attack metal surfaces. The selection of a High quality filter is a cost effective way of reducing this contaminate.

- ❖ All hydraulic fluids contain dirt to some degree. Dirt in hydraulic fluid is the downfall of even the best designed hydraulic systems. Dirt particles can bring huge and expensive machinery to its knees.

Dirt interferes with Hydraulic Fluid

- ❖ Dirt causes trouble in a hydraulic system because it interferes with the fluid which has four functions:
  1. To act as a medium for energy transmission
  2. To lubricate internal moving parts of hydraulic components
  3. To act as a heat transfer medium
  4. To seal clearances between close fitting moving parts

- ❖ Dirt interferes with three of these functions. It interferes with the transmission of energy by plugging small orifices in hydraulic components like pressure valves and flow control valves. In this condition pressure has a difficult time passing to the other side of the spool. The valve's action is not only unpredictable and non-productive, but unsafe.

- ❖ Because of viscosity, friction, and changing direction hydraulic fluid generates heat during system operation. When the fluid returns to the reservoir, it gives the heat up to the reservoir walls. Dirt particles interfere with liquid cooling by forming a sludge which makes heat transfer to reservoir walls difficult.

Contamination - Continued

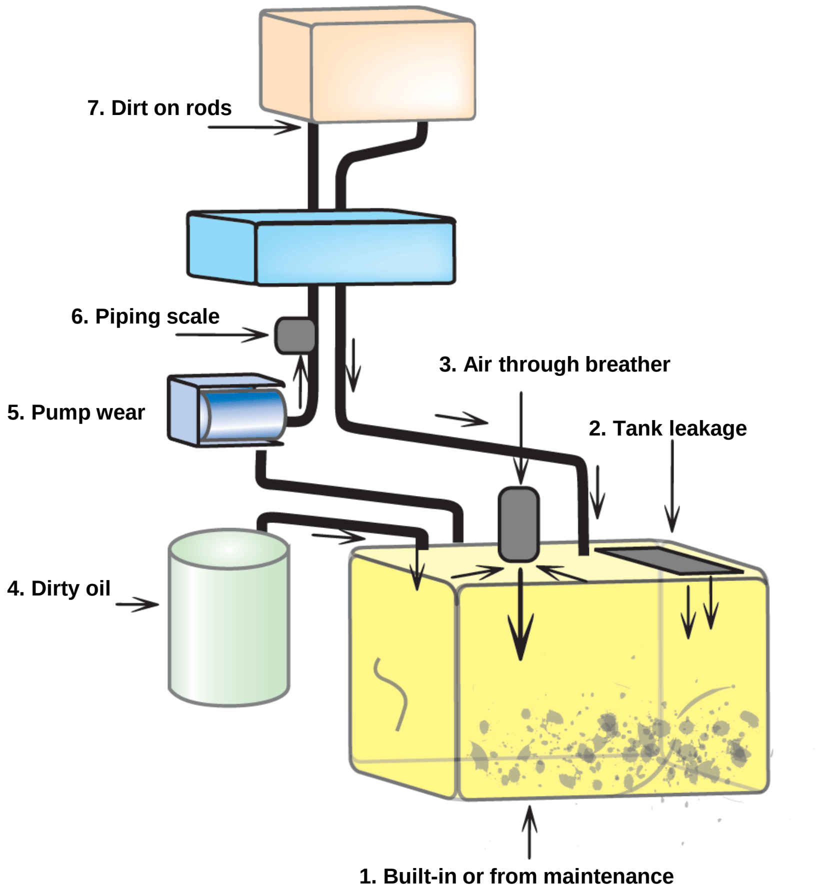
- Clean hydraulic systems run cooler than dirty systems.
- Probably the greatest problem with dirt in a hydraulic system is that it interferes with lubrication.
- Dirt can be divided into three sizes with respect to a particular component's clearances; that is, dirt which is smaller than a clearance, dirt which is the same size, and dirt which is larger than a clearance.
- Extremely fine dirt, which is smaller than a component's clearances, can collect in clearances especially if there are excessive amounts and the valve is not operated frequently. This blocks or obstructs lubricative flow through the passage.
- An accumulation of extremely fine dirt particles in a hydraulic system is known as silting.
- Dirt which is about the same size as a clearance rubs against moving parts breaking down a fluid's lubricative film.
- Large dirt can also interfere with lubrication by collecting at the entrance and blocking fluid flow between moving parts.
- A lack of lubrication causes excessive wear, slow response, erratic operation, solenoid burn out, and early component failure.

Dirt is pollution

- Dirt in a hydraulic system is pollution. It is very similar to bottles, cans, paper and old tires floating in your favorite river or stream. The difference is that hydraulic system pollution is measured using a very small scale. The micrometer scale is used to measure dirt in hydraulic systems.

Sources of Contamination

- When engineering a complex hydraulic system, designers must consider the ways in which contaminants reach the fluid, as well as the quantity and size of the particles. Those factors influence the size, micron rating, and location of filters.



Built-In or From Maintenance (1)

- During manufacturing or maintenance, large quantities of particles and solid debris are introduced. Even the most thorough flushing doesn't eliminate all foreign matter, some of which dislodges once the system is put into operation. Also, there is no guarantee that all of the right procedures will be followed, so, as equipment can sustain significant wear in the first few days after start-up, high quality filtration is essential at this stage.

Sources of Contamination - Continued

Tank Leakage (2)

Loose inspection plates and other unsealed joints in a tank allow a great deal of dirt into the fluid, particularly when surrounding air is polluted.

Air Through Breather (3)

Most hydraulic systems draw in and expel air as the oil level in the reservoir changes. Often, this is a main source of dirt ingestion, especially when filter breathers either are not installed or maintained.

Dirty Oil (4)

New oil is seldom as clean as required for a modern hydraulic system, even when it is described as "clean" by the supplier. When stored improperly or not well-filtered before filling the reservoir, it likely will be many times as contaminated as the system can tolerate.

Pump Wear (5)

Pumps, especially when worn, are a key source of metal wear particles. Hard wear metals are of great concern for several reasons:

1. Potential for damage to valves, cylinders and motors immediately downstream.
2. Ability to generate large numbers of additional particles within the system.
3. Action as a catalyst in the fluid oxidation process.

Sources of Contamination - Continued

Piping Scale (6)

Older pipes can flake off quantities of larger particles, such as scale, rust and welding slag.

Dirt on Cylinder Rods (7)

When sliding back and forth, cylinder rods can draw in large quantities of smaller particles, depending on the concentration of airborne dirt and quality of the rod seals. This is a particular problem in systems with numerous large cylinders.

System Design Considerations

- ❖ The first line of defense against contamination is to exclude particles and moisture to the maximum extent possible. This effort entails a host of actions, such as careful manufacturing and maintenance, thorough flushing, sealed reservoirs and pipe joints, tight seals, and so forth.

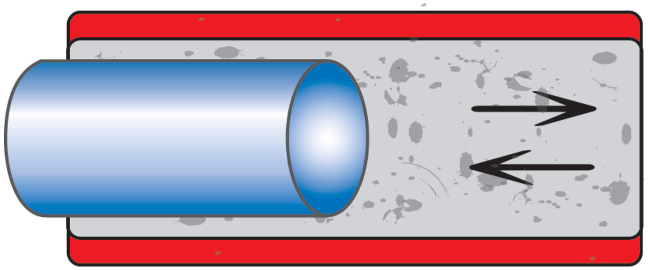
- ❖ Whatever the success in exclusion, though, top quality filters are necessary. Even if it were possible to keep out most contaminants, particle counts would grow rapidly in the fluid for this reason: Any particles thrown off the pump or from other components will generate additional particles at a rapid rate.

The Effects of Contamination

Abrasive Wear

- Anytime two metal surfaces move opposite to one another, they are subject to abrasive wear.
- The amount of metal loss depends on the types of metals, quality of the lubricant, speed, tolerances, and other factors.
- Abrasion results when hard particles about the width of the tolerance become embedded in one of the oppositely moving surfaces, then act like a cutting tool to gouge and scratch the other surface.
- Equipment designed with close tolerances to handle high pressure and speed is particularly subject to abrasion from particles well below 10 microns in size.
- Moreover, only a small loss of metal will reduce equipment performance and shorten its life.

Abrasive Wear



Abrasion is the leading cause of wear.

Embedded hard particles scratch and gouge.

Most seriously affects:
close-tolerance, high speed, high pressure components, such as pumps and motors.

The Effects of Contamination - Continued

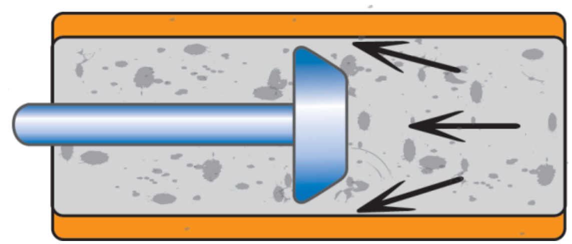
Erosive Wear

- Erosion takes place when particles moving at high speed hit surfaces and pit or wear away the metal.
- Control devices, such as flow controls and relief valves, are especially sensitive to this type of damage.

Silting

- Spool valves, especially proportional and servo types, can lose responsiveness or bind completely because of silt buildup.
- Silt is composed of extremely fine particles, often under five microns in size, which are present in the environment; or which are generated within the system in large quantity.
- Such valves also are affected by abrasion, and, in some cases, particle blockage that leads to total failure.

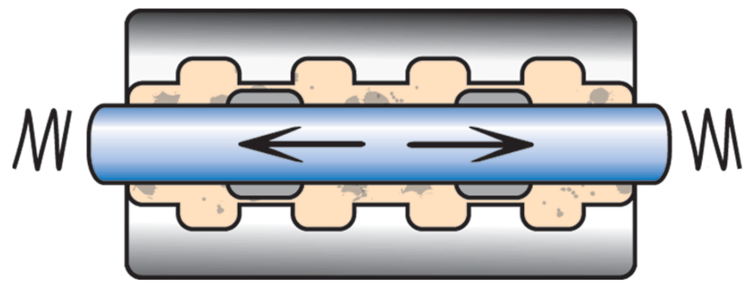
Erosive Wear



High speed particles wear surfaces and edges.

Problems with flow controls, relief valves.

Silting



Silt build-up causes;
-stiction
-binding
-poor response

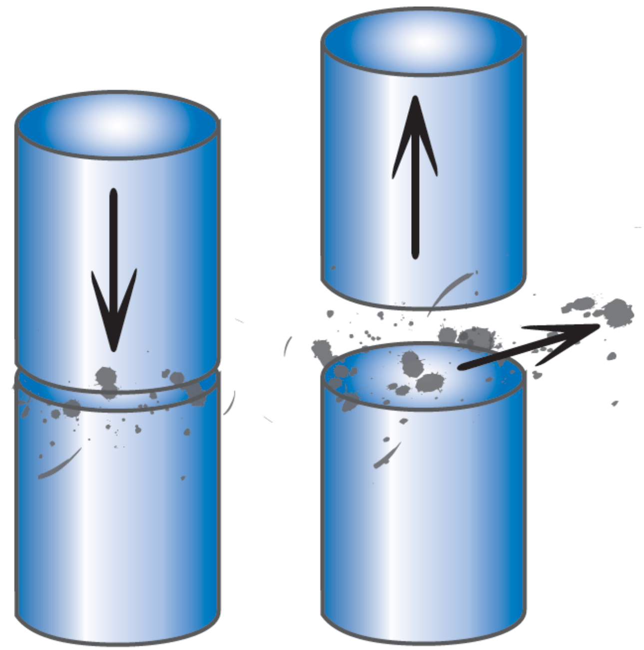
Servo and proportional valves
are subject to the following problems;
-close tolerances
-low operating forces
-requirement for accuracy

The Effects of Contamination - Continued

Fatigue Failure

- Bearings and other components subject heavy axial loading often suffer from metal fatigue.
- Hard particles caught between two surfaces create cracks which continually expand and, eventually, result in spalling.
- The useful life of critical bearings can be prevented simply by improving cleanliness of the oil.
- Analyses by bearing manufacturers and others have shown that the useful life of critical bearings can be greatly lengthened by means of improved dirt exclusion techniques and better filtration.

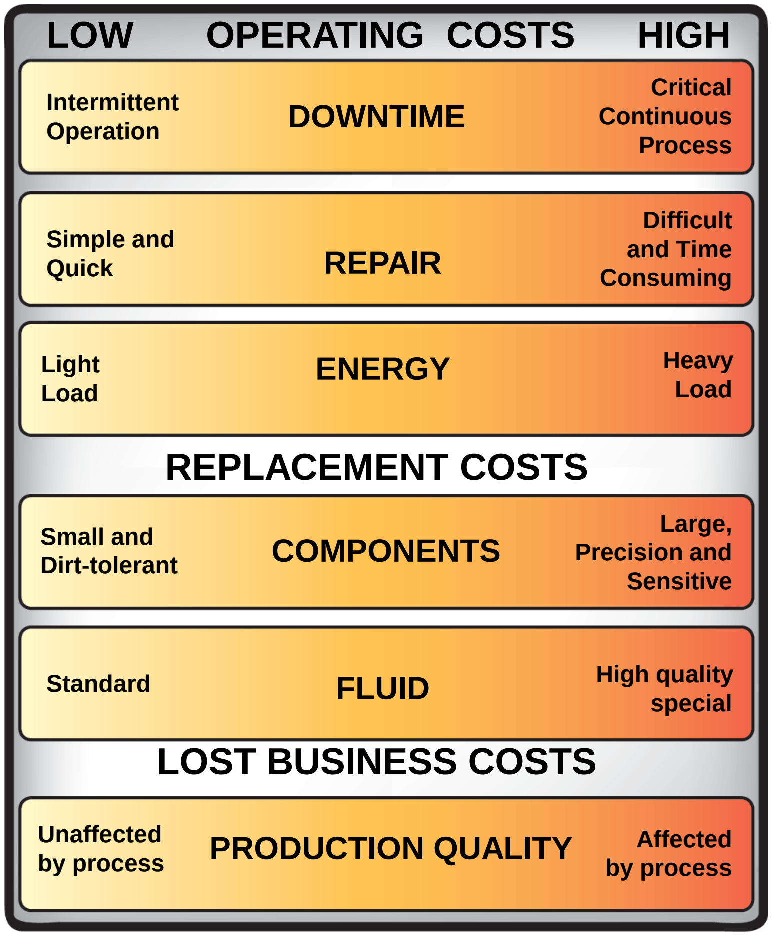
Fatigue Wear



Most common cause of bearing failure

Particulates create cracks and spalling, especially in close tolerance bearings under heavy load

The Costs of Contamination



- When contaminants wear or destroy critical components, the result is an increase in several kinds of costs. It may be impractical to pinpoint the sum of such costs precisely, but not difficult to establish the general magnitude of the problem.

- In a continuous process (Steel, aluminum, paper, etc.), an emergency shutdown may cost well in excess of $50,000 an hour. Repair work is often difficult and time-consuming, stretching maintenance resources.

- Electrical energy is a key cost factor; therefore, any loss of efficiency due to component wear and damage contributes to cost.

- Components employed in systems that function at high speed and under heavy load carry replacement cost that is related to their size, precision and sensitivity to contamination. Fluid replacement cost varies widely.

The Costs of Contamination - Continued

- In general, the higher the quality and more specialized the fluid, the higher the cost.

- Bearing and gear wear diminishes the accuracy of equipment by causing chattering and vibration. In some circumstances, product quality is reduced (and scrap increased). The end result is a lower quality product and lost income.

- In all cases, an investment in quality filtration pays for itself very quickly. This is especially true when equipment must provide top performance for an extended period of time.

Comparison of Filter Types and Locations

- A **Suction Strainer** is located in the inlet of the pump. The strainer removes contamination from the reservoir fluid before it reaches the pump and the system components. These filters should be set up with an internal bypass valve to prevent starving the pump.

  Advantages

  - Last chance protection for pump

  Disadvantages

  - Must use relatively course media and/or large housing size, to keep pressure drop low due to pump inlet conditions
  - Cost is moderate
  - Does not protect downstream components from pump wear

- A **Pressure Filter** is located downstream of the pump. It is exposed to full system pressure. The filter removes contamination generated or passed by the pump. A particularly contamination sensitive component may be protected by a "point of use filter" located immediately upstream of it.

  Advantages

  - specific component protection
  - Contributes to overall system cleanliness
  - Catches wear debris from pump

  Disadvantages

  - Housing is relatively expensive because it must handle full system pressure
  - Does not catch wear debris from downstream working components

Comparison of Filter Types and Locations - Continued

- A **Return Line Filter** is located downstream of the pump and system components and upstream of the system reservoir. The return filter removes contamination generated or ingested by the pump and components, before the fluid returns to the reservoir.

  Advantages

  - Catches wear debris from components before it enters the reservoir
  - Lower pressure ratings result in lower cost
  - May be in-line or in-tank for easier installations

  Disadvantages

  - No protection from pump generated contamination
  - Return line flow surges may reduce filter performance
  - No direct component protection

- An **Off-Line Filter** is located in a separate loop connected to the reservoir and has its own source of power. The Off-Line Filter operates independently of the main hydraulic system. Cleaning the fluid in the reservoir only.

Filter Test Methods

- **Bubble Point Test:**
  Is the differential gas pressure at which the first steady stream of gas bubbles is emitted from a wetted filter element under specified conditions. The air pressure required to blow the first stream through a pore is inversely proportional to the size of the largest pore in the element.
- **Dirt Capacity Test:**
  Determines the weight of a specified artificial contaminant which must be added to the influent to produce a given differential pressure across a filter at a specified condition. It is used as an indication of relative service life.
- **Multi-Pass Test:**
  The multi-pass test is used to determine the Beta Ratio/micron rating and dirt holding capacity of a filter element and is a destructive test.
- **Patch Test:**
  Visual analysis of a fluid sample. Passing a fluid through a fine media patch. The patch is then analyzed under a microscope.
- **Crackle Test:**
  A Crackle test is run to determine if an oil sample is contaminated with water.
- **Portable Particle Counter:**
  A test that takes less than a minute. It generally gives a particle count and cleanliness classification.
- **Laboratory Analysis:**
  Gives a complete look at a fluid sample. Typical offerings include viscosity, neutralization number, water content, particle count, spectrometric analysis, trending graphs, photomicrograph and recommendation.

Filter Test Methods - Continued

- **Dirt Holding Capacity:**
  The ability of an element to retain dirt or contaminant is referred to as its "Dirt Holding Capacity". It determines the life of the element and the length of service it will perform before it becomes clogged to the point it must be replaced.

- **Contaminant Loading:**
  As an element loads with contamination, the differential pressure will increase over time; slowly at first and then very quickly as the element nears it's maximum life.

- **Pressure Drop:**
  A difference in system pressure between the upstream and downstream sides of the filter.

- **Four Major Factors Contribute to Pressure Drop:**
  - Filter Media
  - Dirt Contamination
  - Flows (higher flows create higher pressure drop)
  - Fluid Viscosity (higher fluid viscosity's mean higher pressure drop)

- **Viscosity:**
  Viscosity is the measure of a fluid's resistance to flow. Fluids that have a high resistance to flow have a high viscosity. Fluids that have a low resistance of flow, have a low viscosity. Fluid viscosity changes with variations in fluid temperatures.

Rating a Filter

- A filter element is typically given a Nominal or Absolute rating by the filter manufacturer. This rating is determined by running a number of tests to determine the filters Beta and Efficiency Ratings.
- **Nominal Rating:**

  An arbitrary micrometer value indicated by the filter manufacturer. Due to the lack of reproductivity, this rating is deprecated.
- **Absolute Rating:**

  The diameter of the largest hard spherical particle that will pass through a filter under specified test conditions. It is an indication of the largest opening in the filter element.

Beta Ratios/Efficiencies:

Beta Ratio $B\chi = \frac{\text{number of particles upstream}}{\text{Number of particles downstream}}$

"χ" is equal to the micron size

Example: $B10 = \frac{50{,}000}{10{,}000} = 5$

Beta Ratio	**Efficiency**
1	0%
2	50.00%
5	80.00%
10	90.00%
20	95.00%
75	98.70%
100	99.00%
200	99.50%
1,000	99.90%

Quality Control & The Manufacturing of Elements

- Main Filter prides itself in our high quality elements. To achieve this every time we manufacture, Main Filter has implemented specific manufacturing and process control procedures from raw material arrival to final inspections on the completed product.

- The receiving department inspects raw material that arrives at our warehouse. The raw material is inspected for correct part numbers, dimensions, tolerances and surface treatment. The dimensions and tolerances are derived from drawings, which are then inspected with calipers and height gauges. any parts that do not meet drawing specifications are placed in the non-conforming goods section. The material is then placed in the proper location determined by location number.

- A work order (BOM) is printed and given to the slitter operator when a filter comes up for manufacturing. The operator then picks the correct media by line color and slits it to the correct width. The same is done with scrim and epoxy coated wire mesh if required for the element.

ISO 9001:2000
FM 64557

Quality Control & The Manufacturing of Elements - Continued

- The pleating machine operator checks the work order and pulls one set of components from stock, measures the components using calipers, and sets the pleat height. The media is also checked to make sure it corresponds with the work order. The pleating machine counts the correct number of pleats, using proxy sensors, and at the correct number of pleats the media is marked by blue marking ink. A sample element is run to ensure proper number of pleats and pleat height.

- The element assemblers check the media for correct number of pleats and pleat height. Components are then collected and checked for proper pleating and dimensions using calipers.

- Epoxy glue is used to bond the media and core to the end cap using a pneumatic BI-component glue applicator and then the glue and/or metal seam folder is applied to seal the seam.

- The element is given a visual inspection, checking for even and proper glue flow in the seam and end caps, and is then checked dimensionally using calipers and a height gauge to drawing specifications.

- The element is then bagged, boxed and labeled and ready to ship to a customer or placed in stock.

BSI REGISTERED

ISO 9001:2000
FM 64557

Technical Data Sheets

- Technical data sheets are available on our website at www.mainfilter.com when you are logged in with your customer ID # or by contacting sales representative.

- Our data sheets provide all vital information needed by the end user,

  Which include:

  - dimensions
  - media
  - micron rating
  - ISO accordance
  - operating temperature and pressure
  - filter area
  - flow direction
  - seal material
  - fluid compatibility
  - filter drawing

- Please see the example on the next page:

Technical Data Sheets - Continued

COMPANY LOGO

TECHNICAL DATA SHEET *Item:* CBL537462

7/12/2006

Filter media: IMPREGNATED PAPER

Filter area: 3,840 cm² 596 Sq. inch

Efficiency: 25 µm(c) at β = 2 in accordance to ISO 16889

µm(c) at β = in accordance to ISO 16889

Collapse pressure in accordance to ISO 2941: 5 Bar. 72 Psi.

By-pass valve: SI *By-pass setting:* 1.7 Bar. 24.7 Psi.

Operating temperature: min. -30 °C -22 °F

max. 100 °C 212 °F

Flow: EST-INT *Seal:* NBR

fluid compatibility : mineral oil (HH,HL,HM,HV)

Notes : provided with spring

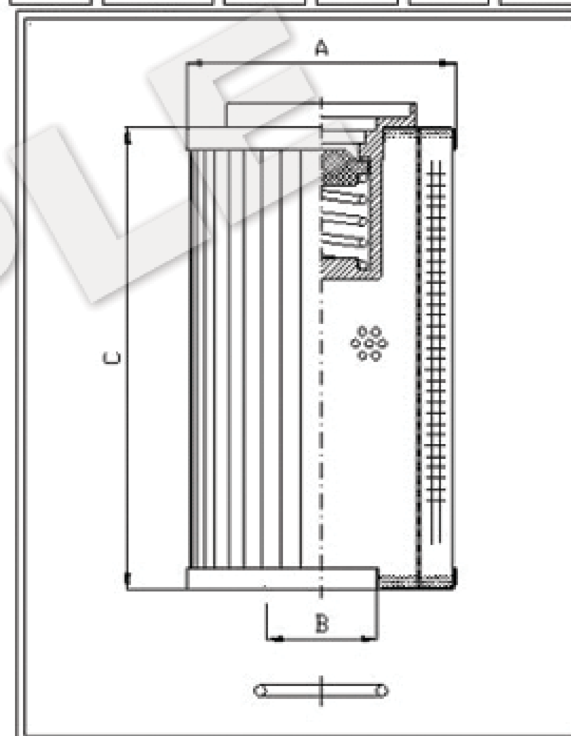
Pressure drop charts in accordance to ISO 3968 (Class B) at clean element 30 cst viscosity 0,86 Kg/dm3 density mineral oil.

Bar

lt/min.

Flow: lt/min. = GPM *Dp:* Bar. = PSI

	A	B	C	D	E	F
mm	99	41	205			
inch	3.90	1.61	8.07			



WE LOOK FORWARD TO WORKING WITH YOU

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