Basics of Filtration

Reasons for Filtration

Removal of Water/Fluid Contaminants

A properly designed filter system can eliminate costly problems by removing contaminants making the fluid more valuable and help increase product yields. For example, a filter that plugs prematurely for no apparent reason suggests that there are improper conditions somewhere in the process. Proper filtration can be placed strategically to keep the water flowing continuously until the filter is saturated causing the pressure to drop, therefore requiring a filter cartridge change.

Removing particles from the water prior to ultraviolet purification will ensure the water clarity, which provides higher standards of UV dose. Pathogens have no particles to hide behind therefore UV can do a better job.

Collection of Suspended Solids

As previously described, the water uses filtration as a polishing tool. There are many applications that require cartridge filtration to recover valuable portions of the process fluid such as a precious metal that can be used over again. Applications such as waste effluent must use filtration to collect contaminants before the fluid can be released into the environment for pollution control.

Driving Forces of Filter Cartridges

Filtration

Filtration is the removal of a suspended particle from a fluid, liquid or gas, by passing the fluid through a porous or semi permeable medium.

Separation

Separation is the removal of a dissolved substance from a carrier fluid stream.

It is most usual for cartridge filtration to be pressure driven. There are other types of filtration and separation that use different driving forces such as gravitational settling, centrifugal force, a vacuum and more. The advantages of using pressure as the driving force in cartridge filtration system are as follows:

A. Greater output per unit area.
B. Smaller equipment than when using other driving forces such as settling ponds and deep bed filters.
C. Ease of handling volatile liquids.

Pressure Drop

There must be a difference in pressure between the inlet and outlet sides of a filter in order to push a liquid through the filter. The pressure differential is greatly influenced by the resistance to flow of the filter or medium. The pressure differential is the difference in pounds per square inch (PSI or kPa between the inlet and outlet ports. Pressure differential may be referred to as PSID, ΔP, pressure drop, or differential pressure.

System Pressure Drop

The actual system pressure drop (difference in pressure between the inlet and outlet) is due to loss of PSI, resulting from loss of flow through the cartridge and loss of flow through the housing and any other component in the system. All losses contribute to total ΔP. It is important to note that the cartridge ΔP increases throughout the filtration process as the cartridge collects dirt and the flow becomes restricted.

Cartridge Pressure Drop

Water or fluid flows through channels created by pores in the filter medium called laminar flow. The water moves in orderly layers rather than in a turbulent manner. During the laminar flow, pressure loss resulting from flow through the cartridge is dependent upon:

A. Micron rating
B. Viscosity
C. Flow rate

The following equation can be used to calculate the change in pressure drop:

$$\Delta P = AuQ$$

Where:

ΔP = Pressure Drop
A = Cartridge (laminar) flow constant
U = Viscosity
Q = Flow Rate

Housing Pressure Drop

All flow in a housing must pass through the same inlet and outlet port restrictions, which is only a few square inches in area. The cartridge has several square feet of area that the flow can be divided upon.

Therefore the flow rate per unit area through the filter housing ports is typically higher than the cartridge media. As the flow rate increases, the port size should increase to keep the pressure drop fro increasing. Housing pressure drop is affected by four main variables:

A. Flow rate
B. Fluid density, expressed as specific gravity
C. Inlet and outlet port sizes
D. Number of seat cups (seat plate) in the separator plate

Open, Parallel and Series Filtration

Filtration systems can be arranged in different configurations or plumbing arrangements that affect the ∆P of the system. The open system where clean effluent is dumped into a tank open to atmospheric pressure, the loss is equal to the influent as all system pressure is lost on the downstream side.

Another configuration is to have two or more housings and cartridges plumbed in parallel. The total flow rate will be the sum of the flows of each system. The total ∆P will be the same as the ∆P for each component of the overall set up.

When plumbing the systems in series there are usually higher micron sized cartridges before lower micron sized cartridges to accumulate contaminants. The overall ∆P of the series system is figured by subtracting the outlet pressure from the inlet pressure.

Scope of Cartridge Filtration Particle Size Range

The size of particles removed by cartridge filtration is defined by the term micron. A micron is defined as one millionth of a meter in length.
Micron = $\mu m = 1/1{,}000{,}000\ m = 1 \times 10^6\ m$
Visible particles are greater than 40 µm. Hazes are caused by 15-20 µm particles. Common particle sizes are listed below.

Particle	**Size**
Table salt	100 microns
Human hair	40-70 microns
Talcum powder	10 microns
Fine test dust	0.5 – 176 microns
Pseudomonas diminuta	0.3 microns

Mechanism of Particle Capture

Filter Capture

There are at least seven mechanisms by which a filter can capture particles. All of these mechanisms are at work in a filter at any given time to varying degrees and may change as operating conditions change. The seven mechanisms of particle capture are **“Direct Interception”** where the particle runs into a physical barrier and is captured, **“Bridging”** where particles stick together forming a bridge across a pore**, “Sieving”** where the particle is larger that the pore and creates a type of bridge**, “Inertial Impaction”** where particles flow in a straight line caused by the inertia of the flow captured by the media, **“Diffusion Interception”** where the constant random motion of particles 0.1 to 0.3 microns mostly are intercepted by filter medium because of their higher degree of molecular mobility, **“Electrokinetic Effects**” where electrical charges on the filter medium or the particles causes capture due to attractive forces, **“Gravitational Settling”** where gravity deposits the particles with mass the same as sediment in a settling tank.

Means of Retention

Mechanical retention occurs when a particle is restricted from passing through the filter medium as in “direct interception”, “sieving” and “bridging”. “Sieving” is the most dependent of the three.

Adsorptive retention is when a particle sticks to the filter surface being absorbed as in the methods of “inertial impaction”, “diffusion interception” and “electrokinetic attraction”.

“Surface Filtration” and “Depth Filtration” are terms describing parameters of the particle size in relation to the pore size present during the filtration process.

A true “surface filter” can be thought of as a screen, which is recognized as “sieving”, as long as the particles are larger than the pores. The process of surface filtration is dependent on the relationship of particle size to the pore size. Pleated filters are designed to enhance surface filtration favouring absolute “sieving”. With a large surface area and thin medium, higher flows are permitted with lower pressure drops giving a high dirt-holding capacity.

A true “depth filter” allows particles to penetrate the filter matrix and become captured throughout the depth of the medium. Again the particle size/pore size relationship must be measured for proper dirt-holding capacity. Depth filters should not be subjected to flows as high as those possible for pleated cartridges.

The economics in choosing depth over surface filtration depends on the micron size of the cartridge (higher cost for low micron rating) as well as the dirt-holding capacity (change out times). The higher cost per cartridge of the pleated versus wound levels out between 3 and 10 microns; below this point pleated is more economical. Another governing factor to consider is flow data. Pleated filters are better in higher flow rates, which would require fewer pleated cartridges with smaller housings and less replacement and disposal costs. One would have to weigh the initial cost and replacement costs.

Principles of Filtration Pore Size

The pore size of the filter is the most important consideration when choosing a cartridge. Pore size is dependent on “Fibre Diameter”, “Porosity” and “Thickness of the Filter Media”. The design of a fibrous filter is a juggle between fibre diameter, porosity and thickness of the filter medium.

As the “fibre diameter” decreases, the mean pore size decreases. A thinner fibre should be used.

“Porosity” is the ratio of the void volume to the total volume of the filter medium. The filter can be made finer by winding a cartridge more tightly. When decreasing the porosity this way, however, the overall ΔD increase, resisting flow.

As the “thickness of the filter media” the pore size decreases and as layers of medium are added to a cartridge, the pores become smaller. Again this causes an increase in the ΔD.

Filtration Variables

Filtration performance (life and efficiency) varies as operating conditions change. A number of conditions affecting the filter life and efficiency are described below.

Flow Rate – High flow rates decrease the efficiency of absorbing particles. This effect is more dramatic in wound filter and higher micron ratings. With low flow rates the particles tend to stick easier. Optimum efficiency seems to occur around 0.5 to 0.75 gpm/1 ft^2 for pleated material.

Differential Pressure – In order to maintain a constant flow as the filter plugs with contaminant, more water must flow through progressively smaller unplugged cartridge area increasing the differential pressure and decreasing efficiency.

Viscosity – Increasing viscosity increase hydrodynamic drag of the water, increases differential pressure required to push the liquid through the filter and decrease the filter efficiency.

Contaminant – The relationship of the particle size distribution to pore size determines the degree of surface versus depth filtration.

Flow Conditions – Cartridge filters are designed for use under steady flow conditions. Pulsation flow can dislodge particles and excessive pulsing can cause structural damage to the filter.

Compatibility – Fluids that are not compatible with a filter can cause filter media to swell, become brittle, dissolve, shrink and separate from end seals and release fibres causing the filter to weaken.

Area – Increasing filter area while keeping flow rate constant reduces the flow density (flow rate per unit area), which increases filter efficiency.

Maximum Recommended Operating Temperatures

Gasket Material	Buna N	250° F (121° C)
	Ethylene Propylene	350° F (177° C)
	Viton	450° F (232° C)
	Teflon	500° F (260° C)
Filter Media	Polyester	300° F (149° C)
	Polypropylene	225° F (107° C)
	Nylon	325° F (163° C)
Housing Media	Carbon Steel	400° F (204° C)
	304 Stainless Steel	400° F (204° C)
	316 Stainless Steel	400° F (204° C)
	PVC	150° F (65° C)
	Polypropylene	150° F (65° C)

Application Suggestions

City and Well Water
Photographic Equipment
RO & DI Pre/Post Filtration
Vending Machines
Safety Equipment
Eye Wash Stations
Plating Re-circulating Baths
Hospital Equipment
Laser Cooling Equipment
Flow Sight Indicators
0-160 gpm OEM Equipment
Recreational Vehicles
Temperature Control Valves
Salt Water Fisheries
Water-based EDM Machines
Microbial Growth Control Systems
In-Line Scale Inhibitor
Bilge Filtration System
Fountain Solution Systems
Coolant Filtration for Machine Tools
Aqueous Cleaner Recycling Systems
Poultry & Meat Wash Water
Softener Pre/Post Filtration
Slurry Filtration
Juices
Chillers
Lab Equipment
Process Filtration
Food Processing
Humidifying Systems
Food Service
Hot Liquids
Tolulene/Xylene
Hydraulic Oils
Gasoline
Spas & Hot Tubs
Whole House
Drip Irrigation
Ice Makers
Agriculture
Green Houses
Vegetable Oils
Alcohols
Paints/Inks
Parts Washers
Glycol Recycling
Ground Water Remediation
Oil and Water Separators
Pressure Washers
Boiler Feed