Filtration Basics

Graver Technologies

Marmon Water, Inc.

Unit of Measure

LPF

1 Micron = 1 Micrometer

= 1 µm

= 0.001 millimeter

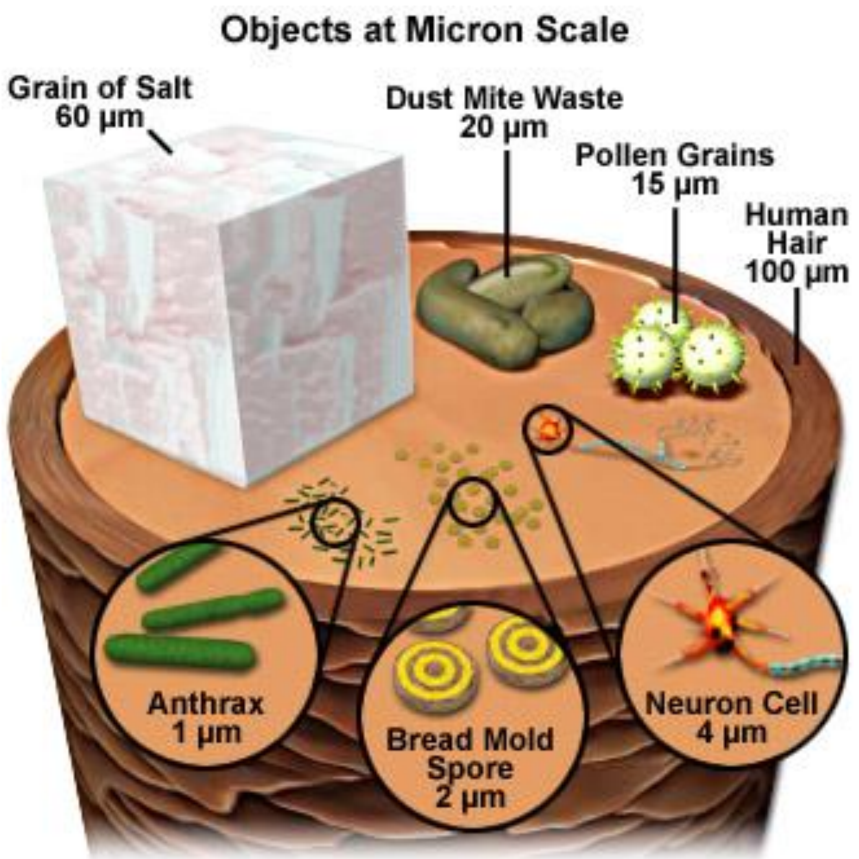
= 1/25,400 Inch

= 1000nm (Nanometer)

Red Blood Cells = 8 Microns

Human hair = 100+ microns

Smallest particle visible to human eye is 30 to 35 Microns



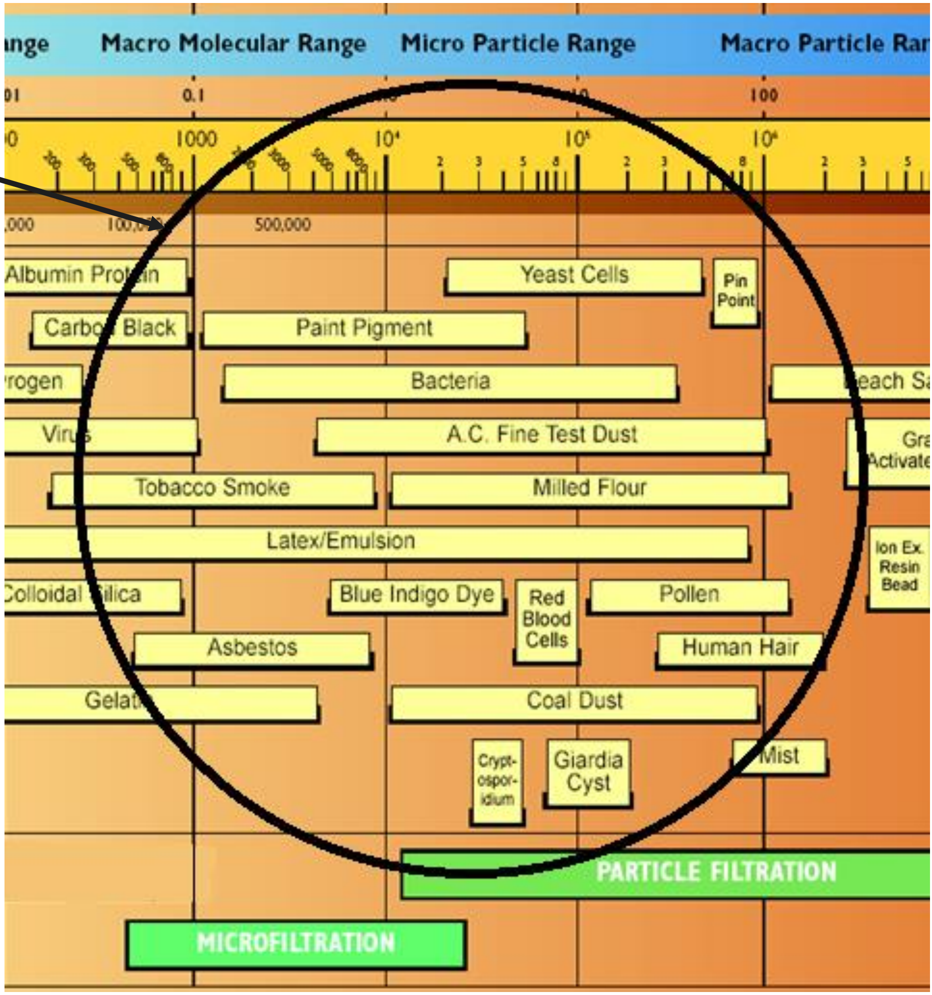
Graver Technologies

Graver LPF Product Range

LPF

LPF specializes in Dead End microfiltration

- Melt blown Filters
- 0.5 to 100 micron range
- Pleated microfiber Filters
- 0.2- 100 micron range
- Pleated Membrane Filters
- 0.03-1.0 micron range



LPF – Liquid Process Filtration

Dead End Filtration

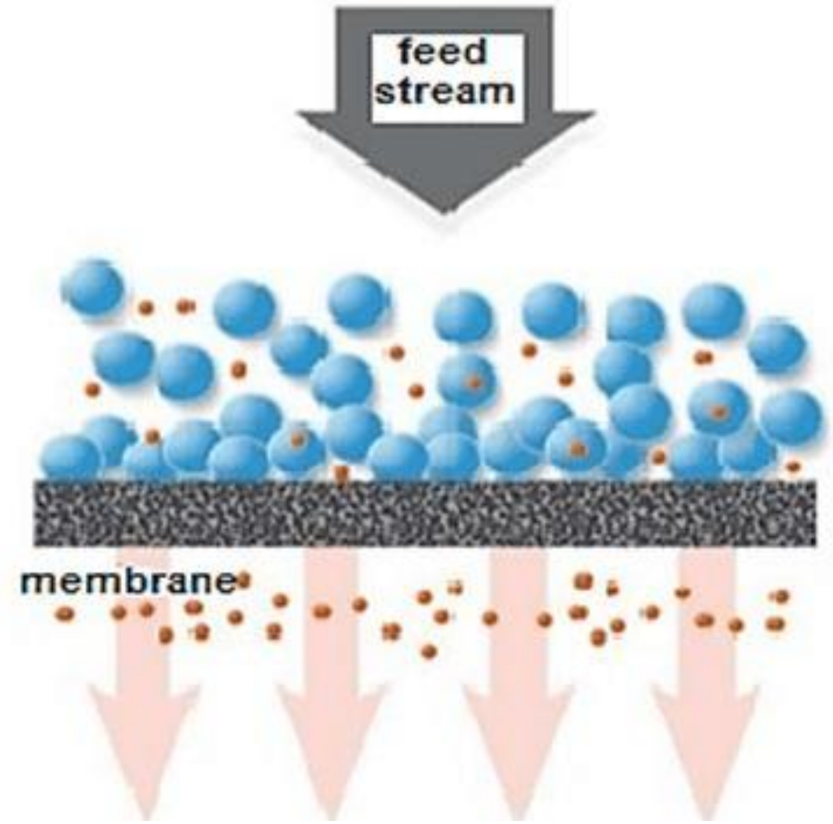
LPF

What is it?

- Particles flow in a 90º direction of filter media and are either captured (dead end) or pass through the media

Mechanism of capture

- Inertial Impaction
- Bridging
- Sieving /direct interception
- Adsorption (charge, hydrophobic interaction



Why Use Liquid Filtration

LPF

FILTRATION…

The removal of undissolved particulate matter from a fluid stream (air or liquid) for the purpose of meeting specifications for solids removal, solids recovery, optical clarity, a specific particle distribution in the fluid or protection of downstream equipment.

Why Use Liquid Filtration: Solids Removal

This is what we commonly think of when we discuss filtration – removing solid particle contamination.

- Incoming water/fluids may contain sand, pipe scale, iron, algae or other unwanted solids
- Fluids may pick up tank debris during transport or in storage tanks
- Prevent mold spores, bacteria, virus and dirt from entering a tank through the tank vent
- Capture carbon, sand, resin or DE (filter aid)

Why Use Liquid Filtration: Solids Recovery

LPF

Some processes require isolation/recovery of the solids in the fluid due to the intrinsic value or it is the product being produced

- Catalyst recovery from a chemical reactor
- Harvesting of protein components

Why Use Liquid Filtration: Optical Clarity

LPF

Visual appearance or the aesthetics require no visible particles (35 microns or larger)

- Distilled Spirits
- Bottled water
- Soft drinks

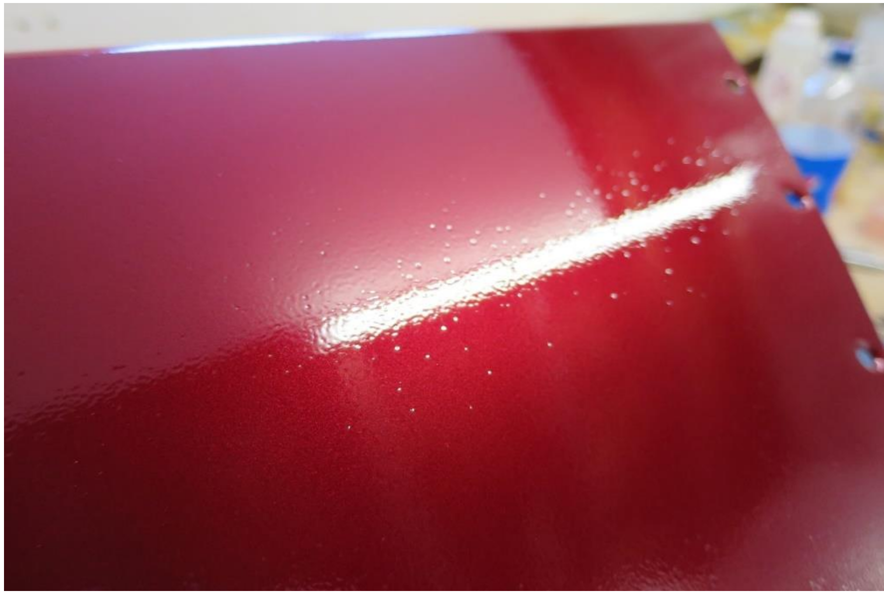
Graver Technologies

Why Use Liquid Filtration: Classification

LPF

Certain processes require some particles to pass such as dyes and pigments while retaining agglomerates and other debris

- Architectural Paints
- Automotive paints
- Inks
- CMP slurries



Why Use Liquid Filtration: equipment Protection

LPF

Preservation of equipment is critical to prevent downtime and repair costs.

- Pump seals
- Fine nozzles
- Seal flush glands
- Small orifices
- Heat exchangers

LPF

How Filters are Used

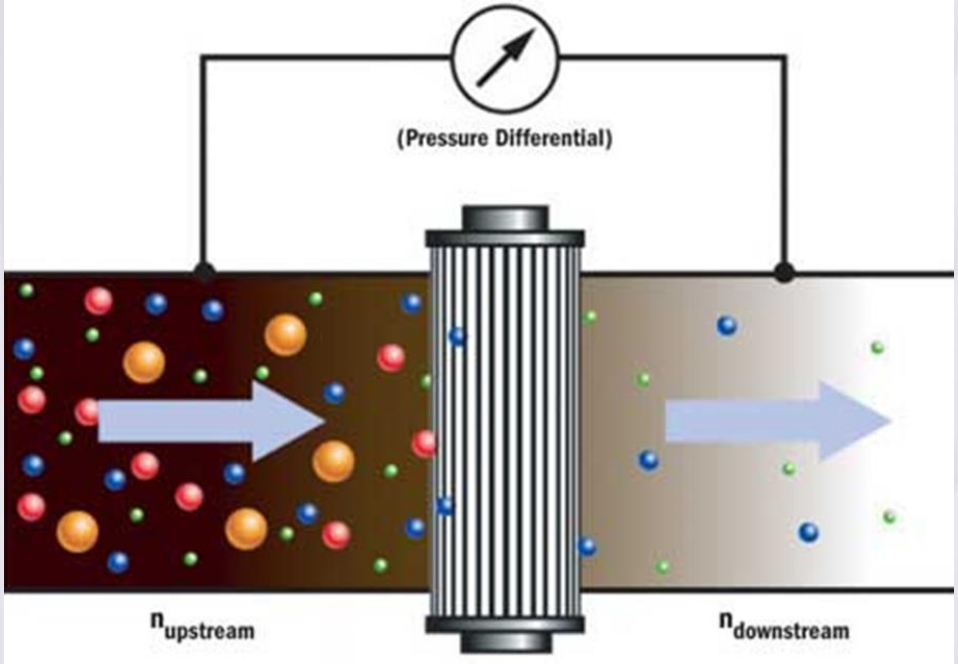
- Optical Clarification
- Tank Vents/Fermentation Feed Air
- DE or Carbon Removal/Polishing
- Protect pump seals
- Classification – remove agglomerates while leaving pigments
- Pre RO
- Process Steam
- Microbial Control

Critical Considerations

- Standards
  - USP Class VI Plastic Testing
  - EU 1935
  - FDA
- Validation information for sterilizing /bioburden reduction filters
- Chemical Compatibility with solvents
- Operating temperatures
- Solids Loading/Contaminant loading levels
- NSF Requirements
  - Standard 61 – Leaching/Migration of Chemical Components

Graver Technologies

Filtration Basics



Filtration Efficiency

Retention Ratings

LPF

Retention ratings refer to what a filter does, not what it is (the size of the pores in the filter).

- *Many mechanisms usually work together to create the filter's actual removal efficiency.*

Retention ratings refer to the efficiency with which a given filter can remove particles of a specific size or size range from a particular carrier fluid under specific conditions.

- *Changing the variables in any of these categories (filter, particle size, etc.) will alter the outcome of filtration.*

May be *arbitrary* values assigned by the Manufacturer

- Difficult for a direct comparison between Manufacturers just based on claims
- Rating ≠ Rating

Graver Technologies

Retention Ratings

Retention Ratings Are Expressed As

- Percentages
- Ratios (beta) between upstream and downstream counts for particles of a specific size

There is no universally accepted way to evaluate filter performance.

- Industry standards are very limited.
- Changing the test parameters on the same filter would yield different results - ie modifying flow
- Filters that are actually quite different might perform identically when modifying test conditions – modify the test particle type.

Retention Ratings

LPF

Standards: There are Few to None

- ASTM- F795-88 Single pass challenge using ISO test dust
- ASTM-F838-05 Bacterial retention of membranes
- Graver Technology uses an ASTM single pass test and measures efficiencies at the start of the tests
- We do not publish membrane efficiencies - All membrane cartridges are considered 99.99+…% efficient at the published micron rating.

ASTM INTERNATIONAL
Helping our world work better

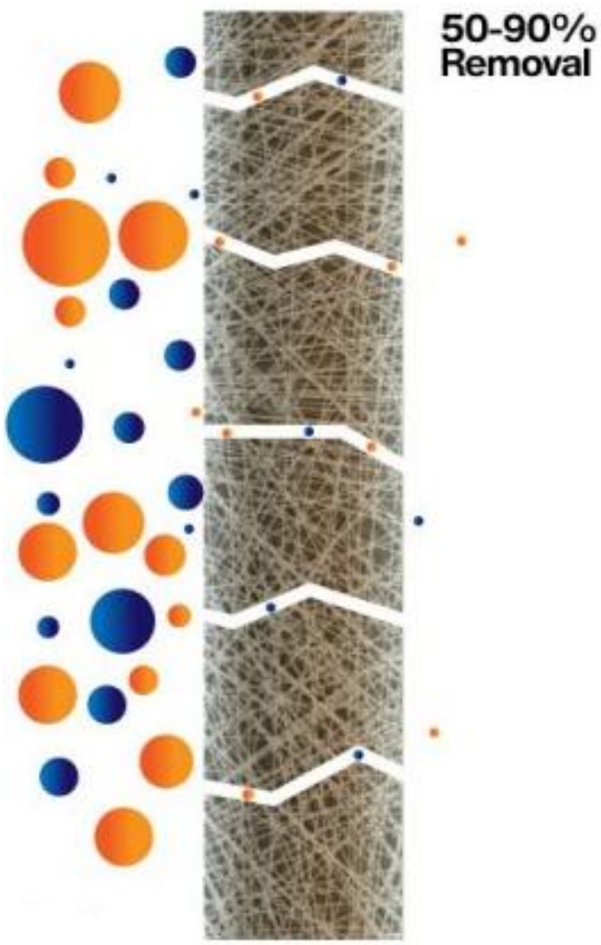
Graver Technologies

Retention Ratings: Nominal

LPF

What do we mean……

- Removes Some/Most Particles at/above the Rated Size
- Typically Used for Depth Filters and lower-end Pleated Filters
- Usually Based on 90% or Less Removal of ISO Test Dust, possibly less than 50% in bags and string wound filters



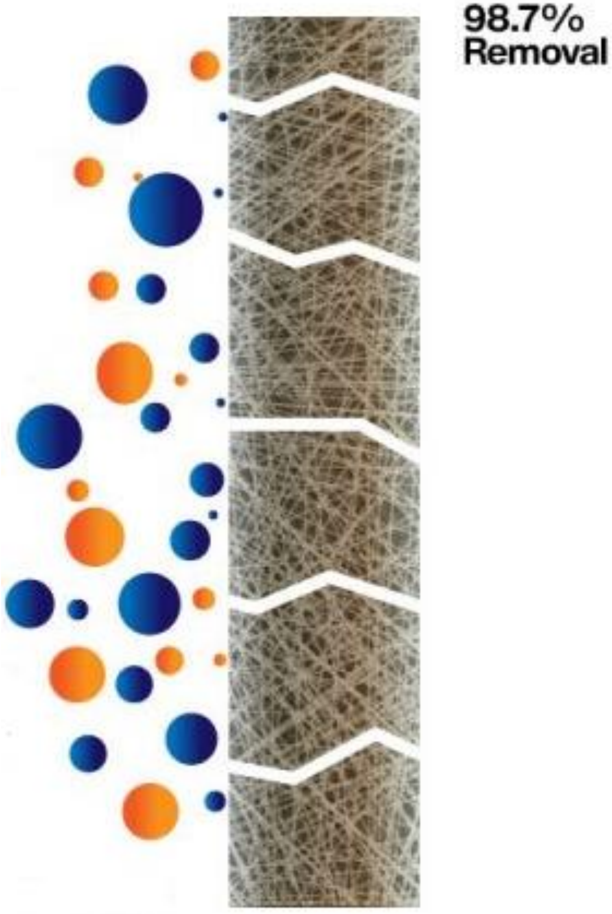
Graver Technologies

Retention Ratings: Absolute

LPF

What do we mean……

- Removes “All” Particles at/above the Rated Size
- In practice, most filter manufacturer’s assign values of 98% to 99.99% to their absolute ratings.
- Values may be:
- Derived under arbitrary test conditions that vary by manufacturer
- Typically single pass, but may be multi-pass (hydraulic)
- Interpreted in a variety of ways
  - Initial Efficiency
  - Average Efficiency
  - Final Efficiency



Graver Technologies

Filtration efficiency

LPF

What do we mean......

- States particulate removal efficiency at a given particle size in percent (%).
- Derived by
  - subtracting outlet count from inlet count
  - dividing by the inlet count
- Example
  - Inlet Particle Count: Particles ≥1 micron in diameter: 1000
  - Outlet Particle Count: Particles ≥ 1 micron in diameter: 1
  - Efficiency
    - (Inlet – outlet) divided by inlet count = (1000 – 1) divided by 1000 = 999/ 1000 = 99.9% removal efficiency at 1 micron

Graver Technologies

Beta Ratio

LPF

What do we mean.....

- Refers to a filter's efficiency at removing particles above a given size
- Expressed as a whole number which represents the ratio of upstream to downstream particle counts in a given size range
- Derived by:
  - Dividing inlet (upstream/ influent) count for particles above a given size by the outlet (downstream/ effluent) count for particles in the same size range
- Example
  - Inlet Particle Count: Particles larger than 1 micron: 1,000
  - Outlet Particle Count: Particles larger than 1 micron: 10
  - Beta Ratio:
    - Inlet count divided by outlet count = Beta ratio 1,000 divided by 10 = 100 (equal to 99% efficiency)

Graver Technologies

Efficiency/ Beta Ratio/ LRV*

*(log Reduction Valve)

LPF

EFFICIENCY = 90%	ß = 10	LRV = 1.0
EFFICIENCY = 95%	ß = 20	LRV = 1.3
EFFICIENCY = 98%	ß = 50	LRV = 1.5
EFFICIENCY = 99%	ß = 100	LRV = 2.0
EFFICIENCY = 99.9%	ß =1000	LRV = 3.0
EFFICIENCY = 99.98%	ß = 5000	LRV = 3.7
EFFICIENCY = 99.99%	ß = 10,000	LRV = 4.0
EFFICIENCY = 99.99999%	ß = 10,000,000	LRV = 7.0

$$\text{ß} = \frac{\text{PARTICLES SIZE >=X IN FEED}}{\text{PARTICLES SIZE >= X IN FILTRATE}} = \frac{1}{1 - \text{EFFICIENCY}}$$

$$\text{LRV} = \text{LOG}\frac{\text{FEED}}{\text{FILTRATE}} = \text{LOG ß}$$

At rated pore size

Graver Technologies

Factors Influencing Filtration

LPF

Concentration

- Increase in concentration of particles results in fouling and shorter filter life.
- Microfiltration cartridges are intended for 0.1%- 0.2% maximum. Require additional filtration if loads is higher than about 0.05%

Particle type, size and distribution

- Round – more difficult to retain
- Deformable – able to be extruded through under pressure
- Uniform size vs variable size – may alter the way it plugs the filter

Factors Influencing Filtration

Pressure

- Increase in pressure increases filtrate flow rate which negatively impacts efficiency
- Higher pressure can result in deformable particles passing, decreasing efficiency

Temperature

- Increase in temperature typically reduces viscosity = higher flow rates
- May increases solubility of contaminates, decreasing filtrate quality and accelerates fouling
- Makes certain chemicals more aggressive – reduces compatibility.

Factors Influencing Filtration

LPF

Remember

- Understand the application – flow, pressure, temperature, solids level, process fluid. Identify the critical factors required to understand an application.
- When replacing a competitive product, not always safe to assume that the end user has the correct filter installed – do not duplicate a mistake

  Rating ≠ Rating
- Retention ratings refer to what a filter does, not what it is

Graver Technologies

Membrane Filters

LPF

Factors Effecting Performance

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Filtration Basics

Depth Filters

Graver Technologies

Types of Depth Filters

LPF

Bag Filter

String Wound Filter

Resin Bonded Filter

Melt Blown Filter

Graver Technologies

Depth Filters

LPF

Capture Particles Through Filter the Depth of their Media

- Filters by Inertial Impaction and Direct Interception
- Effective from 0.5um to 100um
- Most are nominally rated, some very nominal
- Price point varies from <$1 to >$15.

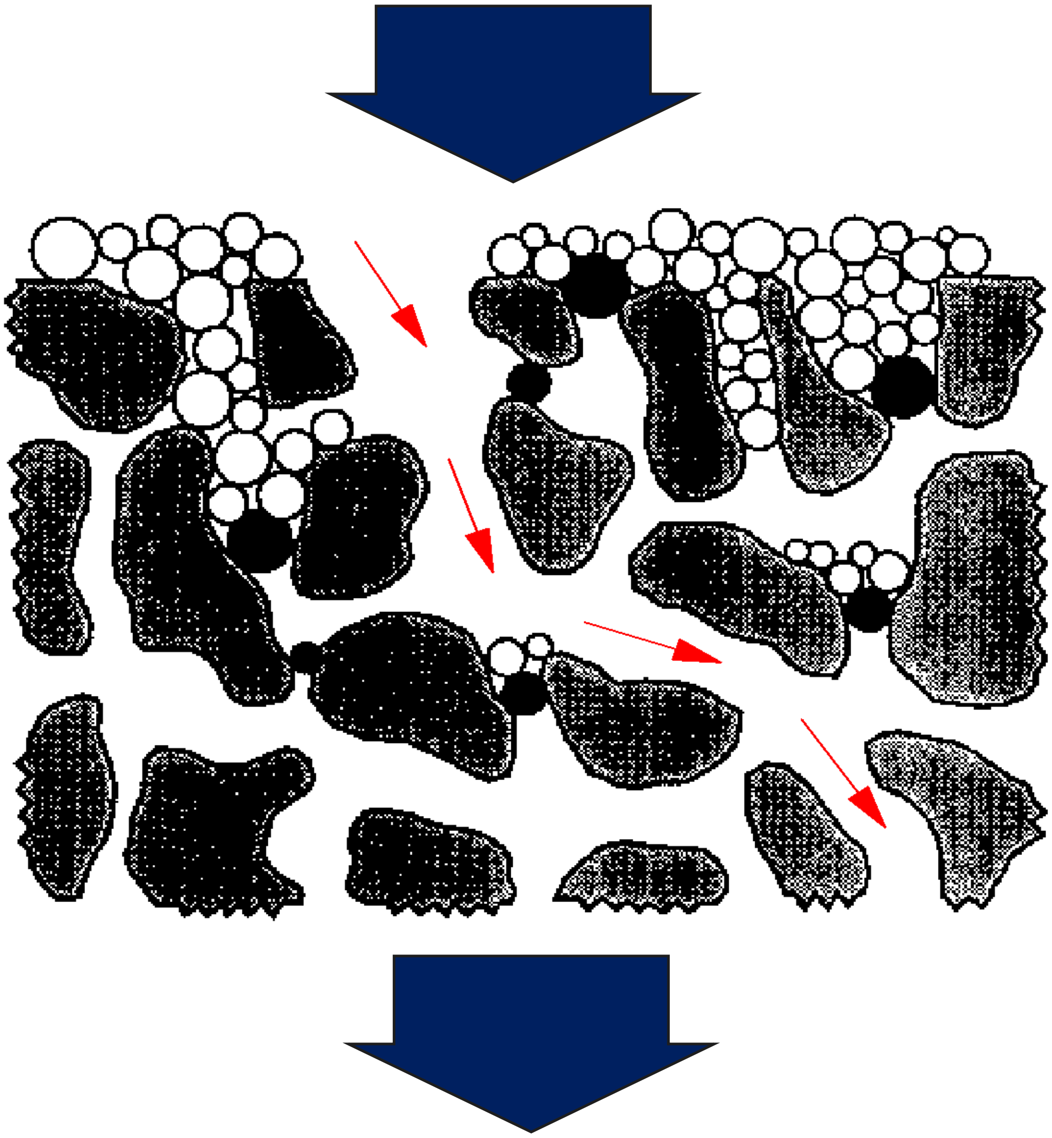
Graded Density vs. Constant Density vs. Graded pore structure

- Constant Density Filters Hold Less Dirt
  - (uniform fiber structure through out the media)
- Graded Density Distributes Filtration Load
  - (Same Fiber size but packed tighter closer to the core)
- Graded pore structure
  - Different fiber sizes to create gradient which results in higher porosity

Graver Technologies

Depth Filters

LPF



- Smaller membrane pores are plugged first.
- Larger pores remain open resulting in pathway for particles to travel through
- Retention decreases with heavy loading
- Decrease in retention occurs before any noticeable pressure drop

Depth Filters: String Wound

LPF

- Constructed by winding a cord (string) around a perforated center core.
- Graver does not offer
- Melt Blown is replacement option

Advantages

- Can be inexpensive
- Constant depth

Disadvantages

- Nominal rated @ low pressure
- Prone to media migration
- Surfactants/Antistatic
- Extractables (Taste)
- Highly Inconsistent

Depth Filters: Bags

LPF

- Constructed of felt with sewn or thermal bonder edges/ends
- Graver does not offer

Advantages

- Can be inexpensive
- Range of materials
- High dirt capacity

Disadvantages

- Tend to be very nominally rated @ low pressure - low efficiency
- High risk of bypass at seal zone

Depth Filters: Resin Bonded

LPF

- Composed of polyester fiber or microfiberglass and coated with resin

Advantages

- Relatively inexpensive for industrial applications
- Graded Depth
- High structural strength
- High temperature tolerance as compared to polypropylene

Disadvantages

- Very Nominally rated @ low pressure
- May have inconsistent performance
- High Extractables (Taste) – not a beverage product.

Graver Technologies

Depth Filters: Melt Blown

LPF

- Molten polypropylene injected into a high velocity air stream.
- May be coreless or have a molded core

Advantages

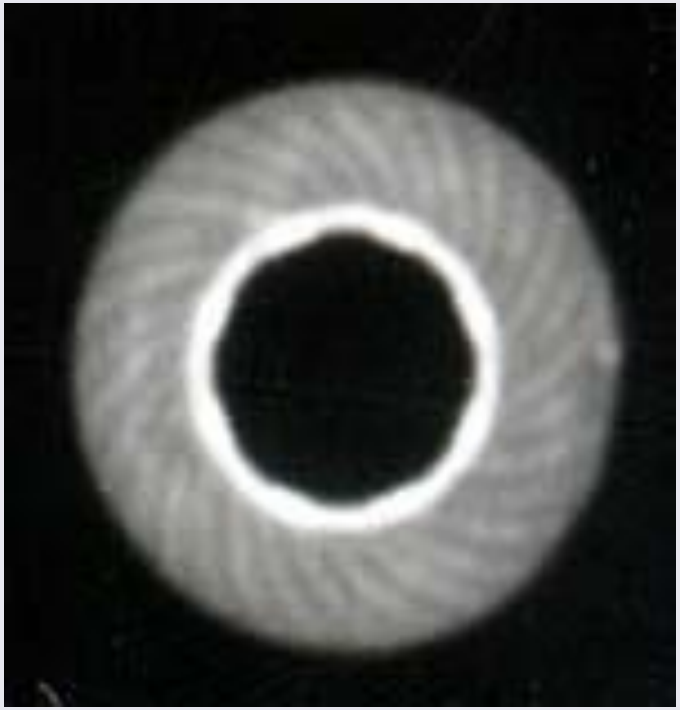
- May be inexpensive
- Low extractables – definitely cleaner than String wound or Resin Bonded
- Can be Absolute or Nominal rated @ low pressure
- Graded Density or Graded Pore Structure

Disadvantages

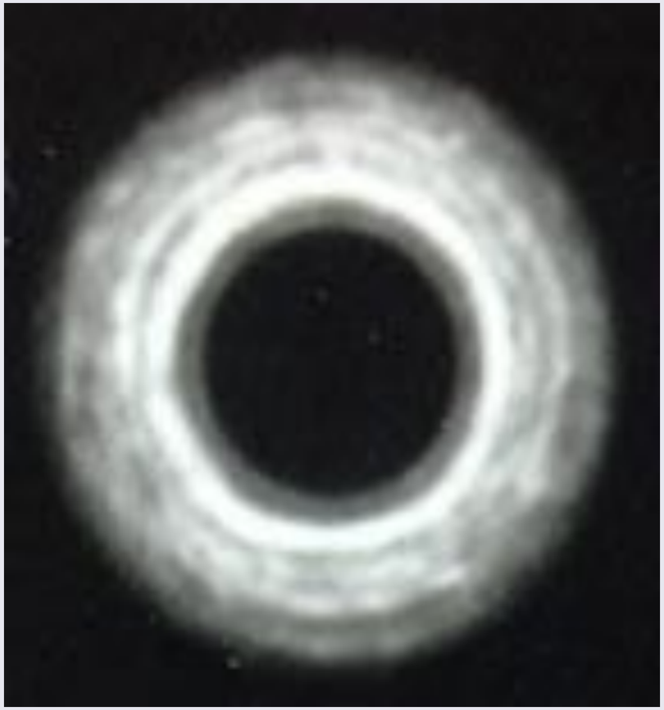
- Relatively low flow rates due to limited surface area
- Relatively Low dirt capacity compared to pleated
- Quality can vary greatly by source
- Consistency may vary greatly.

CAT SCAN SHOWING GRADED DENSITY

String Wound Filter



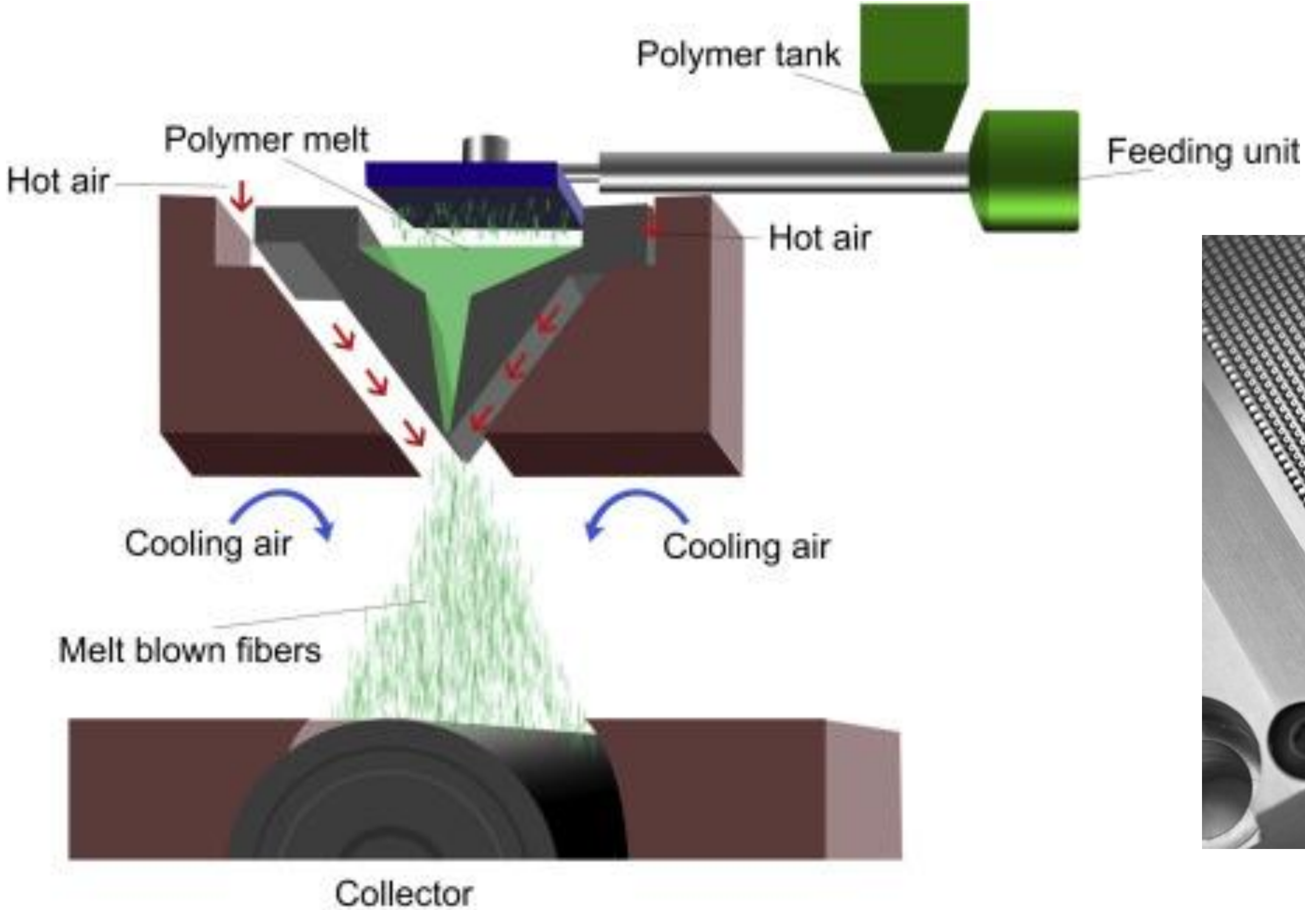
Melt Blown Filter



Depth Filters: Melt Blowing Defined

LPF

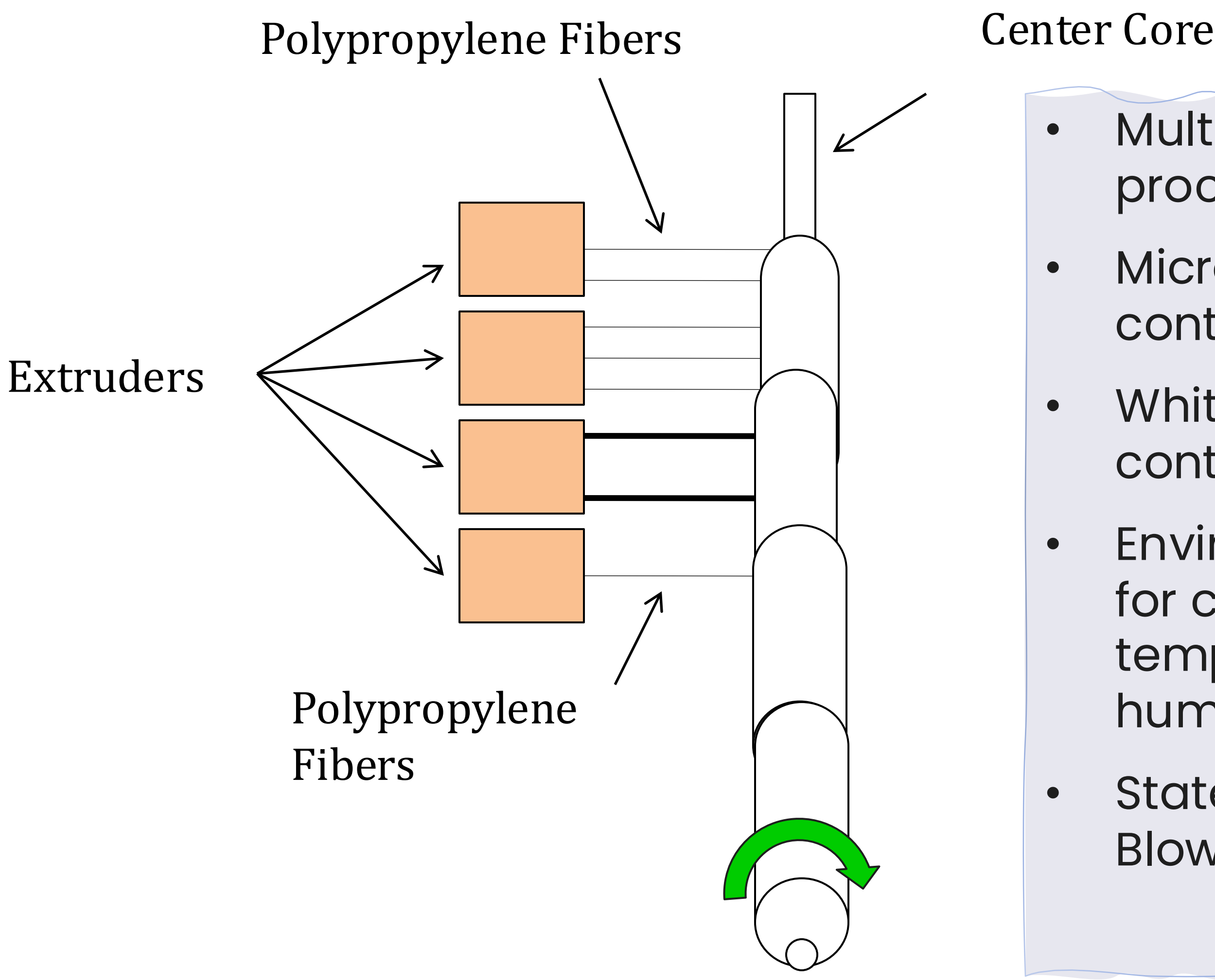
Fabrication method of microfibers where a melted polymer is extruded through small nozzles surrounded by high-speed blowing gas (air) to form randomly deposited fibers on a core.



Graver Technologies

Depth Filters: Graver Multi Extruder

LPF

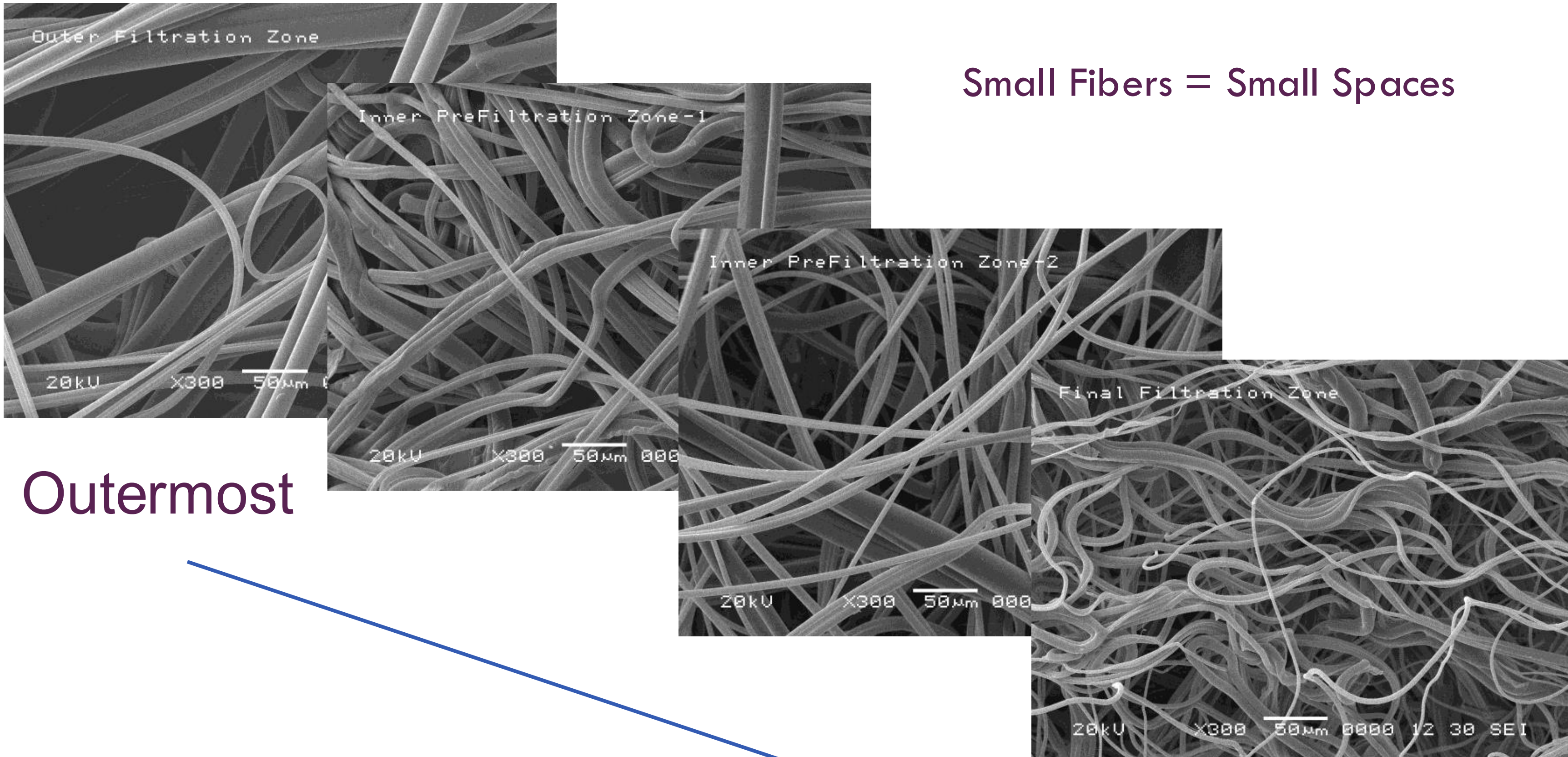


- Multi Extruder (4) process
- Microprocessor controlled recipes
- White room for contamination control
- Environmental controls for consistent temperature and humidity
- State-of-the-art Melt Blowing machinery

Depth Filters: Grade Pore Structure

LPF

Small Fibers = Small Spaces



Outermost

Innermost

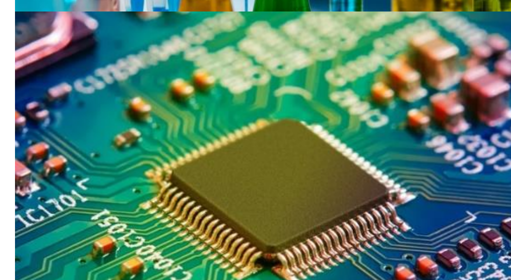
Multi-Zone – Not compressed to create gradient

Graver Technologies

Depth Filters: Applications

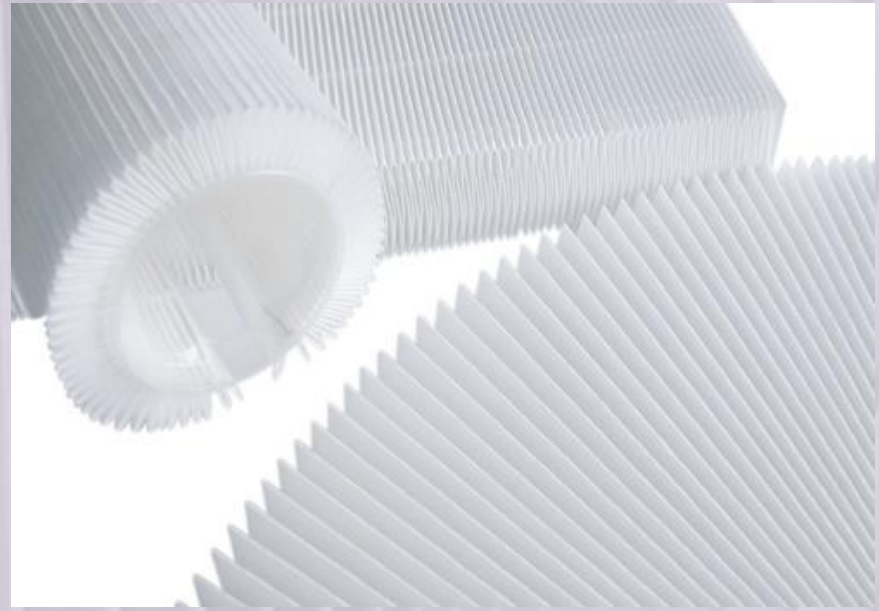
LPF

- Machine coolants
- Plating solutions
- Parts washing
- Process water
- Resin trap
- Carbon trap
- Pre RO filtration
- Utility Water
- Water disposal
- Municipal Water
- Everywhere



Graver Technologies

Filtration Basics



Pleated Filters

Graver Technologies

Pleated Filters: Cartridge Design

LPF

Layer(s) of flat sheet microfiber media, pleated and placed around a center perforated core.

Advantages

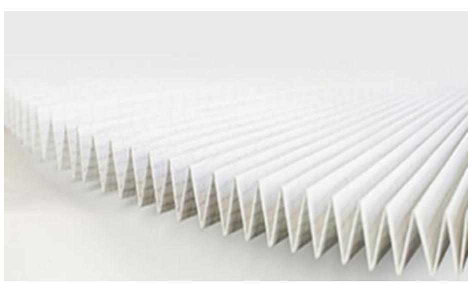
- High dirt capacities due to having 10-15 X surface area of Depth
- Higher efficiencies @ higher pressure (>15 psid)
- High flows/lower pressure
- Low Media Migration

Disadvantages

- Expensive when compared to depth type filters
- Narrower particle size retention vs. depth filters
- Typically retain gels less effectively

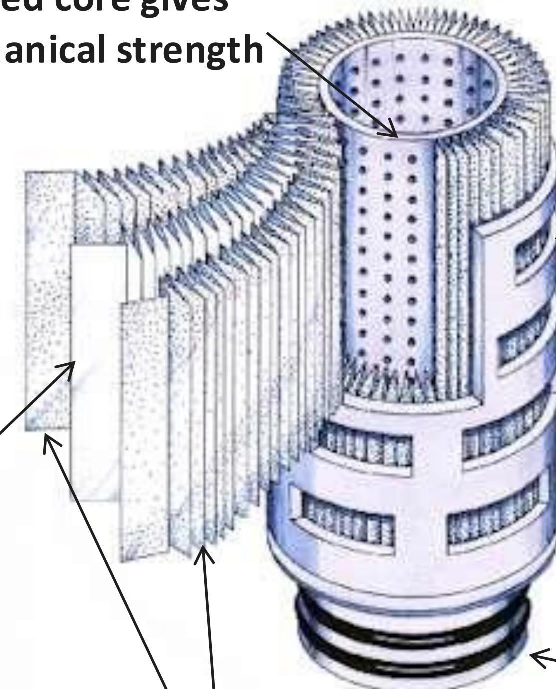
Pleated Filters: Cartridge Design

LPF



Molded core gives mechanical strength

Molded cage protects against physical damage



End cap melt-sealed to filter

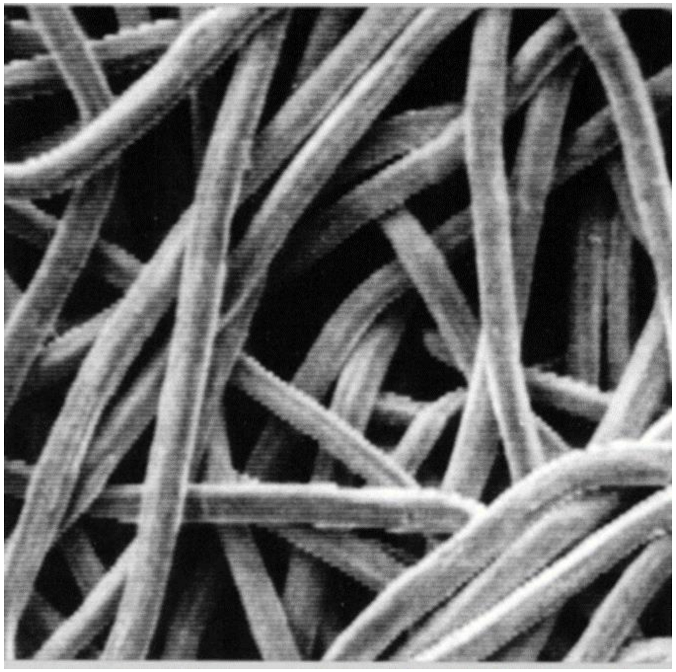
Filter layer(s), one or more, provide effective filtration area

Pleat support and drainage layers give strength and minimize pressure loss

Pleated Filters: Cartridge Design

LPF

- 2.55" and 2.7" OD (3.25" & 4.5" also in market)
- Effective from 0.2µm to 100µm – calendared 1 micron and below
- Available as Absolute or Nominal
- Typically supported by a Core and Outer Sleeve (cage).
- Flow pattern typically outside – in.
- Pleated for High Surface Area
- Multiple Microfiber Media Materials
  - Glass
  - Polypropylene
  - Cellulose
  - Polyester

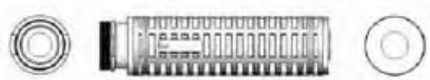
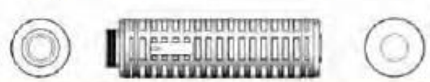


Random Fiber Matrix

Graver Technologies

Pleated Filters: Cartridge Design

LPF

Style	DOE or SOE	Visual
P	DOE	Thermally bonded-plastic caps with flat gasket seal on both open ends 
P2	SOE	226 double o-ring on open end; Flat on closed end 
P3	SOE	222 double o-ring on open end; Flat on closed end 
P6	SOE	Plastic spring on closed end; Gasket or NN on open end 
P7	SOE	226 double o-ring on open end; Spear on closed end 
P8	SOE	222 double o-ring on open end; Spear on closed end 

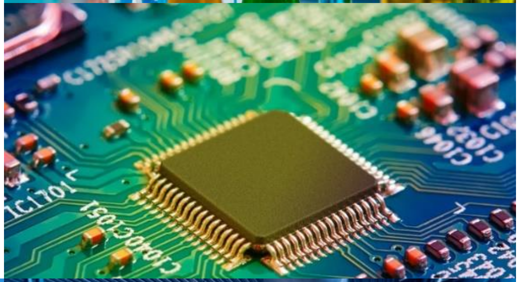
Style	DOE or SOE	Visual
P28	SOE	222 double o-ring with 3 locking tabs; Spear on closed end 
PX	DOE	Flat gasket or NN on both open ends with extended core on one end 
NN	DOE	No endcaps, o-rings or gaskets on either open ends 
DBG	DOE	Santoprene gaskets bonded on both open ends 
AM	SOE	Internal o-ring on open end; Recessed cup on closed end 
NPC	DOE	Internal o-rings on both open ends 

Graver Technologies

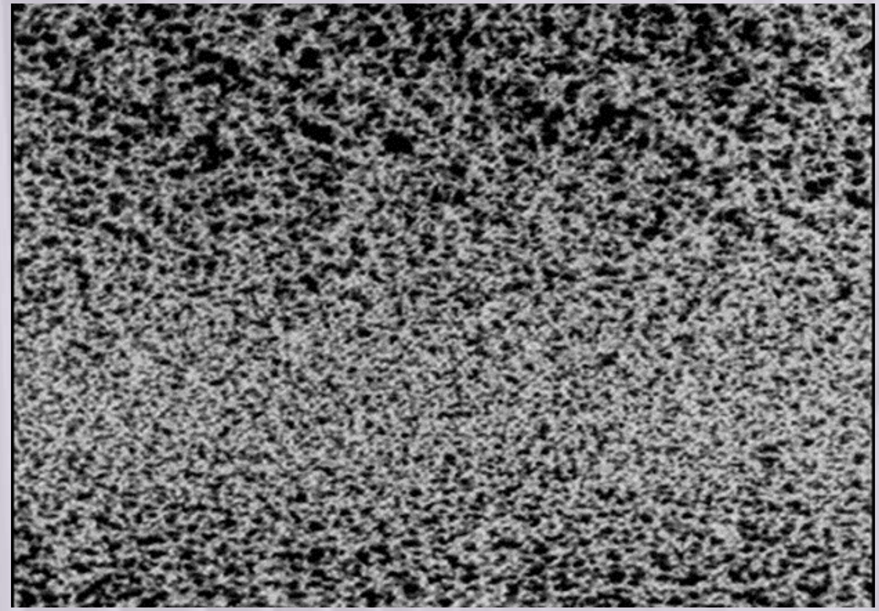
Pleated Filters: Applications

LPF

- Inks, Coatings, CMP slurries (single pass)
- Wine & Beer prefilters
- Pharmaceutical clarifying and classifying filters
- Chemicals final and prefilters
- Semiconductor chemicals
- Process and drinking water



Filtration Basics



Membrane Filters

Membrane Filters Defined

LPF

- Highly efficient - 99.999+%
- Thin semi-permeable films (160 microns thick or less) from 0.03 µm – 1 µm using inert polymeric material – nylon, PVDF, PES
- Pore characteristics closely controlled = Narrow pore size distribution
- Integrity testable – necessary for critical applications to demonstrate function
- Capable of microbial retention

- Within a membrane product families (there are variations of the product that are intended to meet certain application requirements. Grade designation such as:
  - "E" – Electronics
  - "B" – Bioburden reduction
  - "P" - Pharmaceutical
  - "WB" - Food and Beverage

Graver Technologies

Membrane Filters: Defined

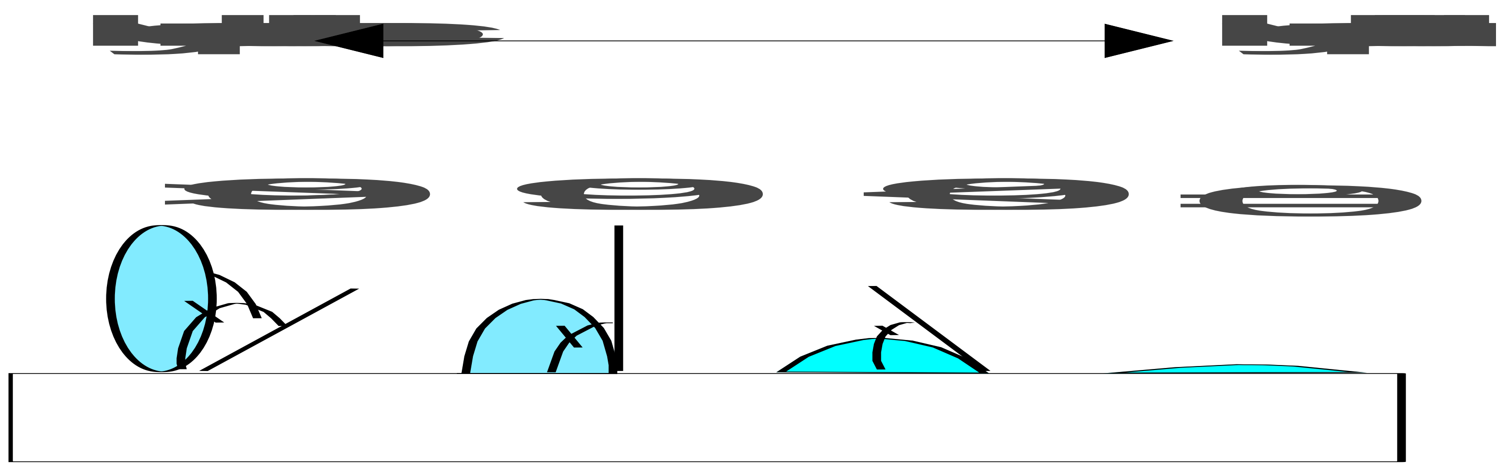
LPF

Hydrophilic:

- "Having an affinity for, absorbing, wetting smoothly with, water."
- Does not require pre-wetting with aqueous fluids.

Hydrophobic:

- "Of or exhibiting hydrophobia.....fear of water; antagonistic to, tending not to combine with water."
- Requires pre-wetting when used with aqueous/high surface tension liquids.



Membrane Filters: Defined

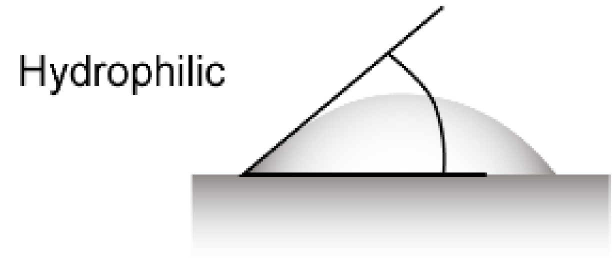
LPF

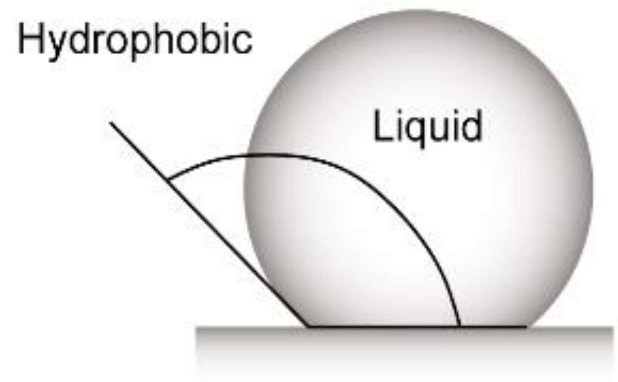
Hydrophilic

- Cellulosic
- Nylon
- Polyester
- Polyethersulfone
- Polysulfone
- Polyvinylidene fluoride (PVDF)

Hydrophobic

- Polypropylene (PP)
- Polytetrafluoroethylene (PTFE)
- Polyvinylidene fluoride (PVDF)



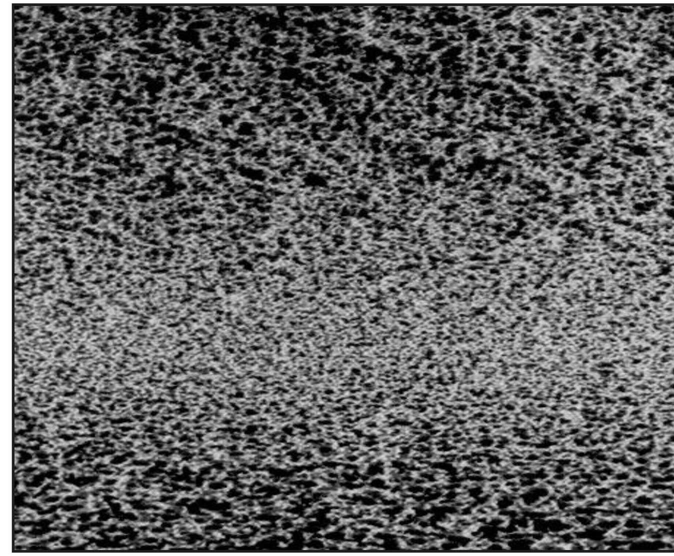


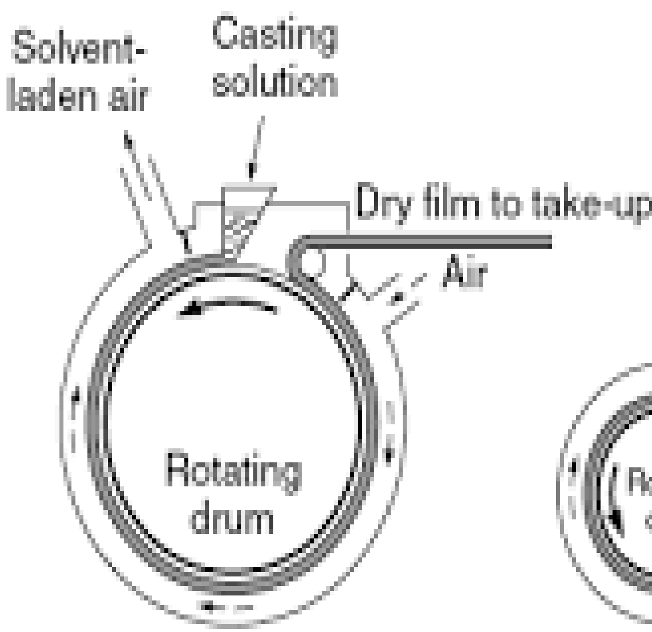
Membrane Filters: Defined

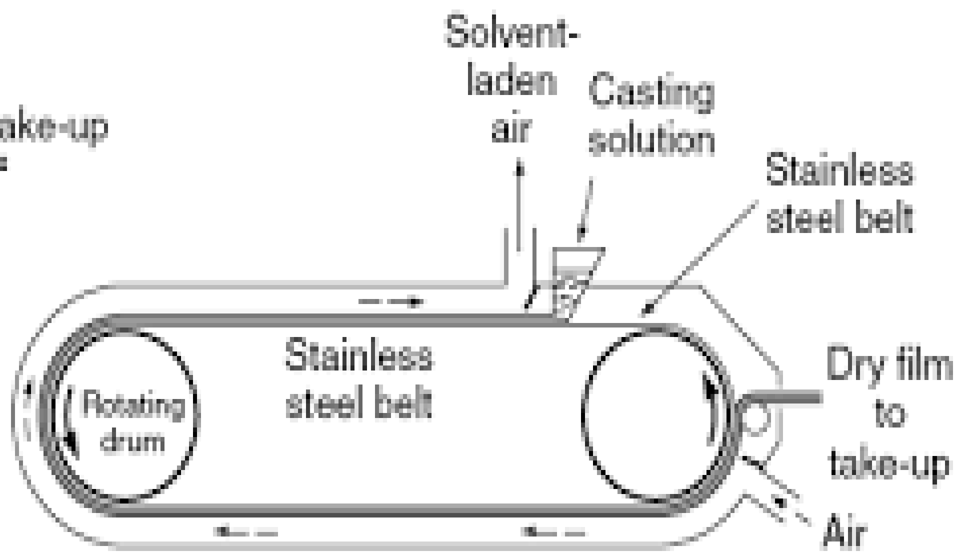
LPF

Manufacturing Methods

- Cast/Phase Inversion
  - Nylon, PES, PVDF
  - Spreading of a thin film







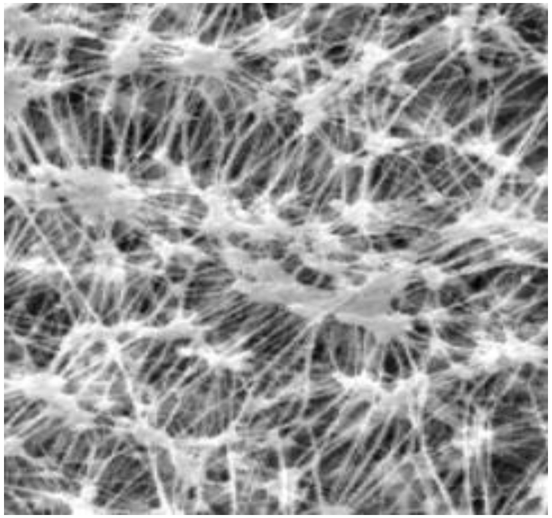
Graver Technologies

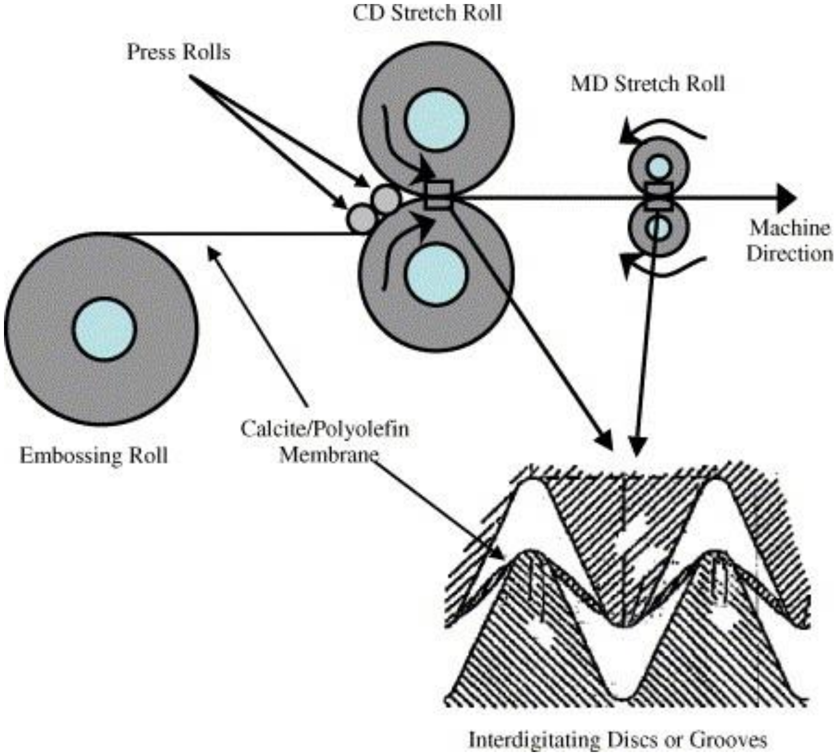
Membrane Filters: Defined

LPF

Manufacturing Methods

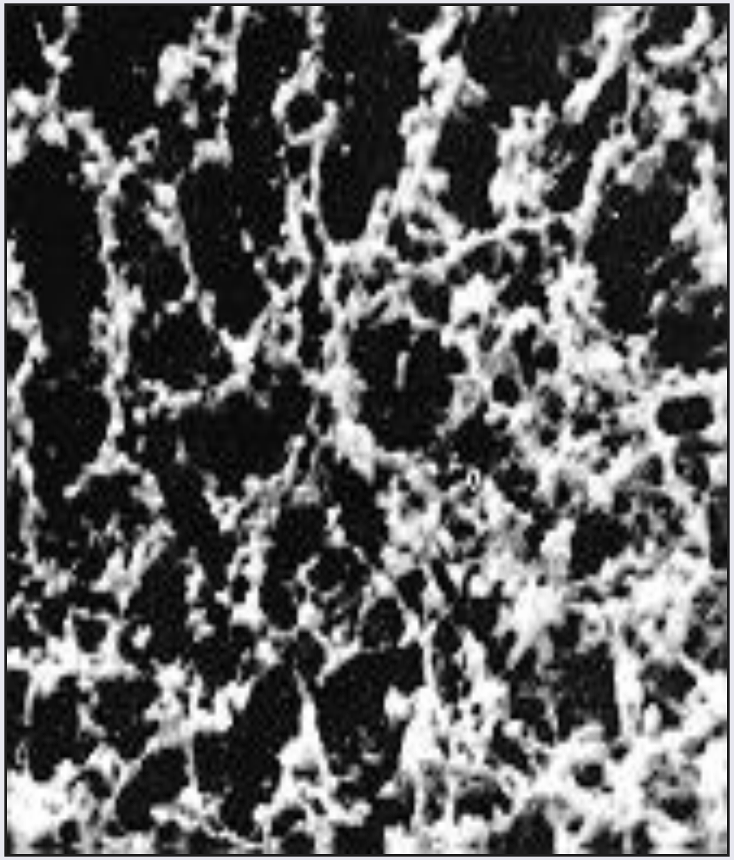
- Stretching
  - PTFE
  - Application of tensile stress (pull) to a dense film



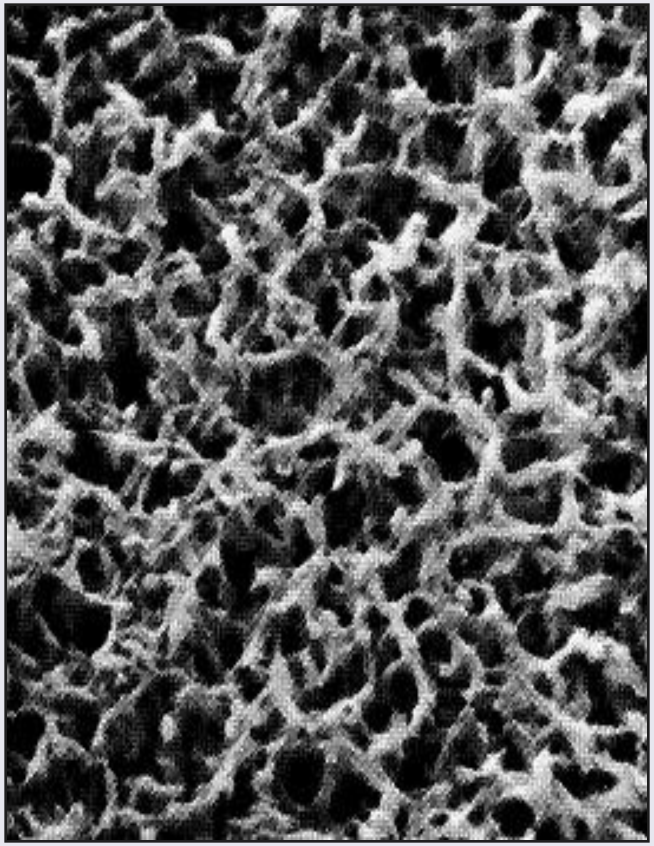


Graver Technologies

Membrane Types



Cellulosic

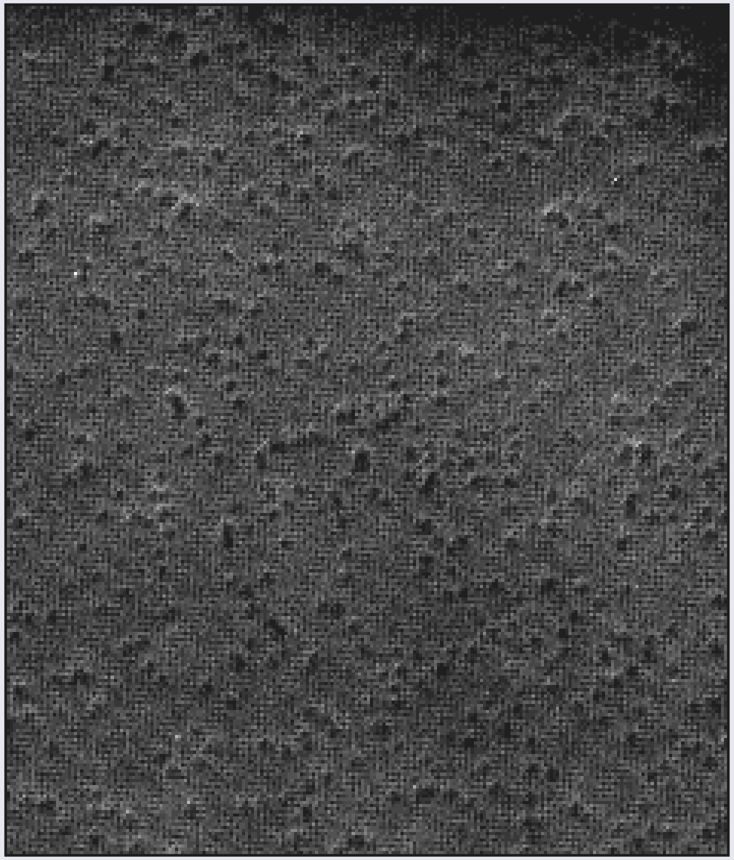


Nylon

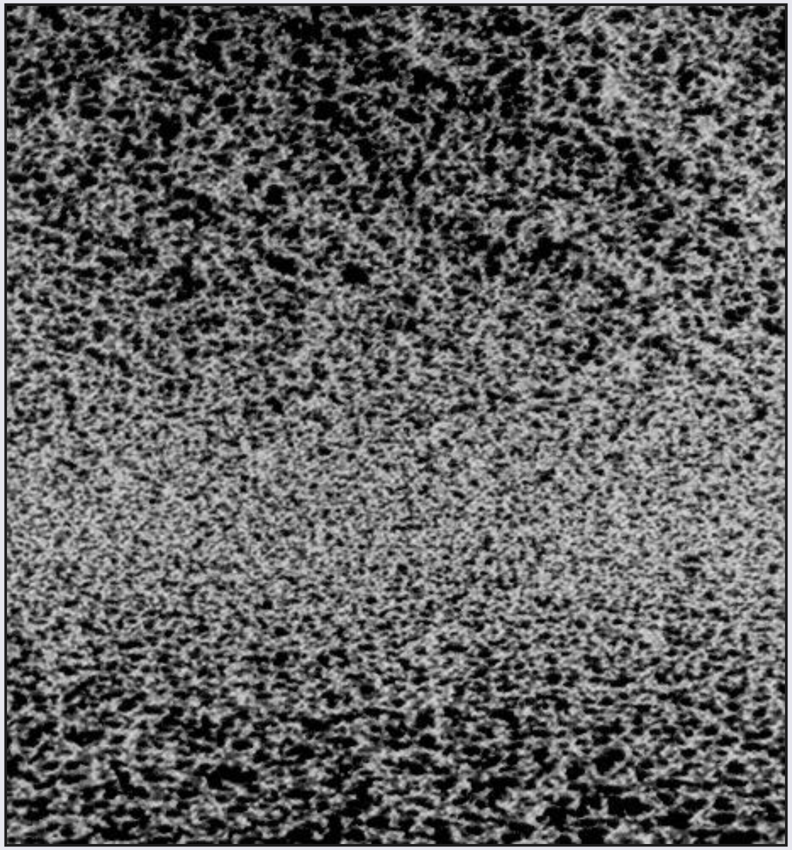
Membrane Filters Defined

LPF

Membrane Types



Track Etch Polyester

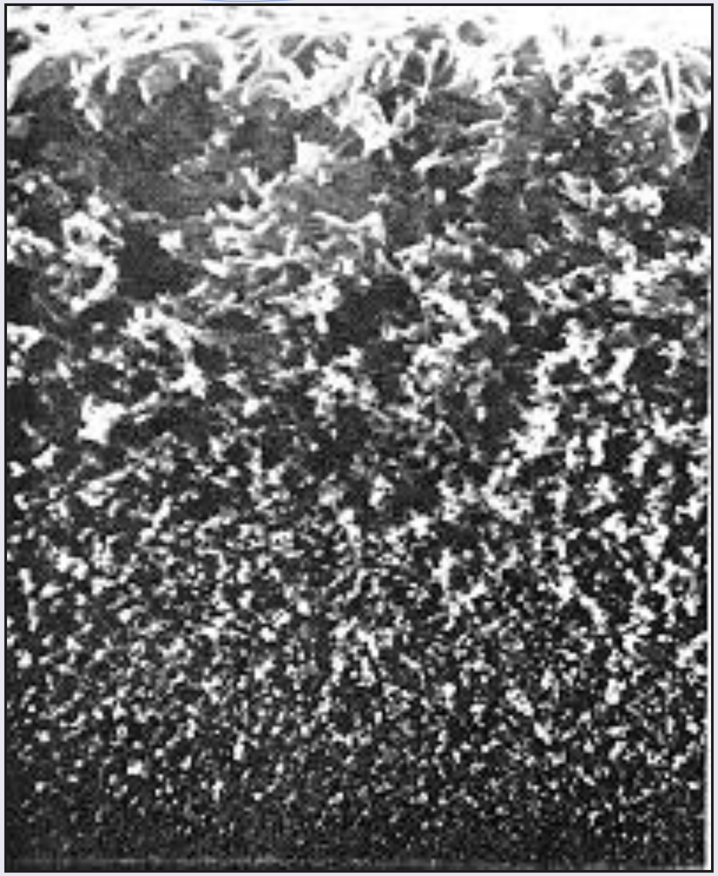


Polyethersulfone

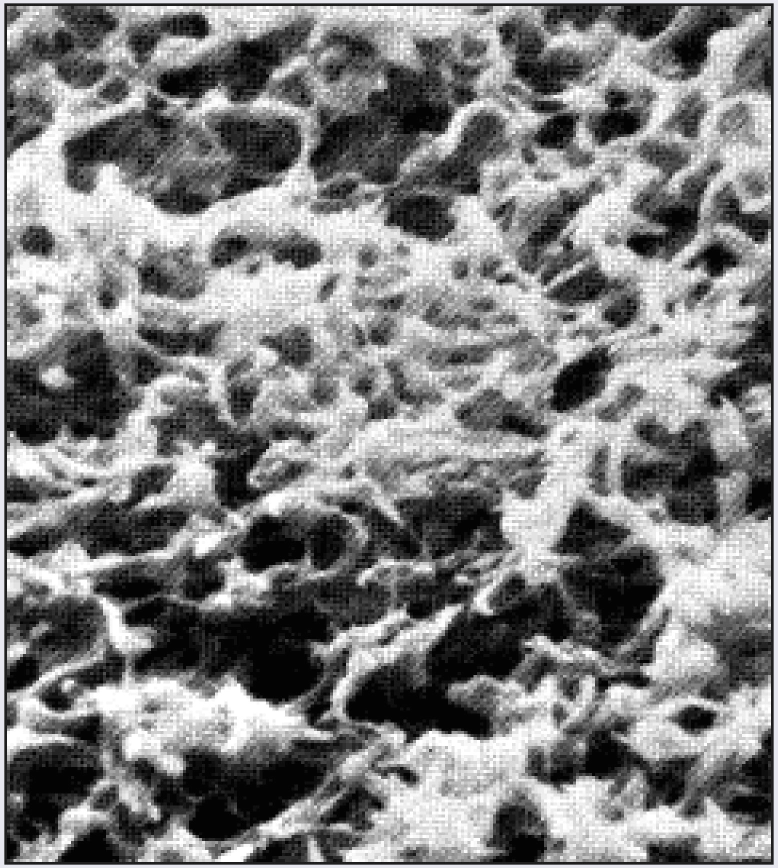
Membrane Filters Defined

LPF

Membrane Types



Polysulfone



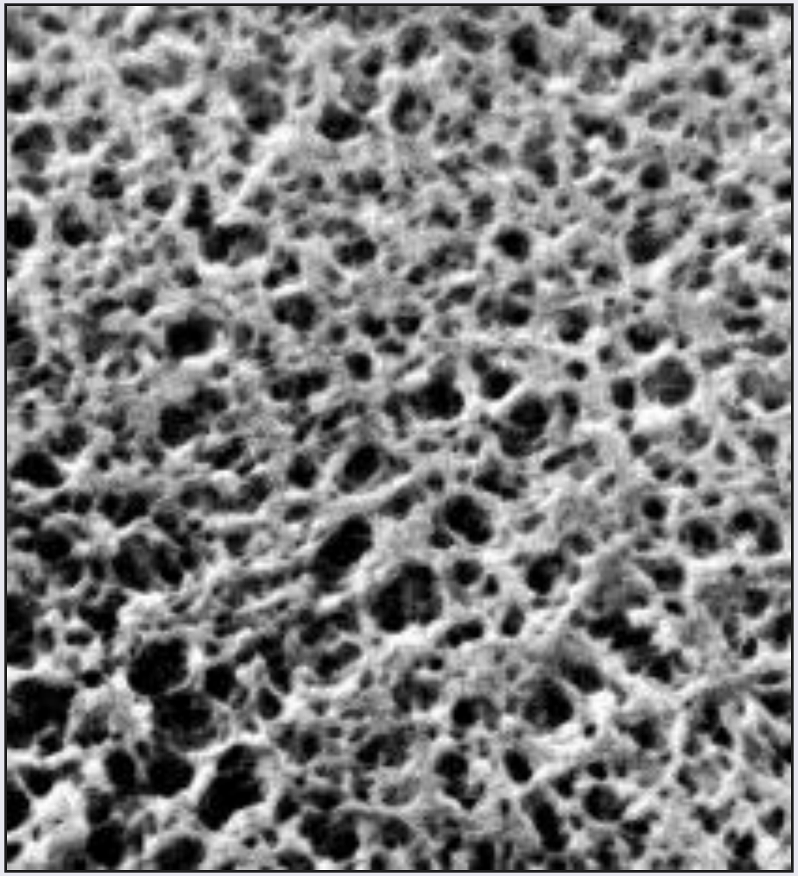
Polyvinylidene Fluoride **(PVDF)**

Graver Technologies

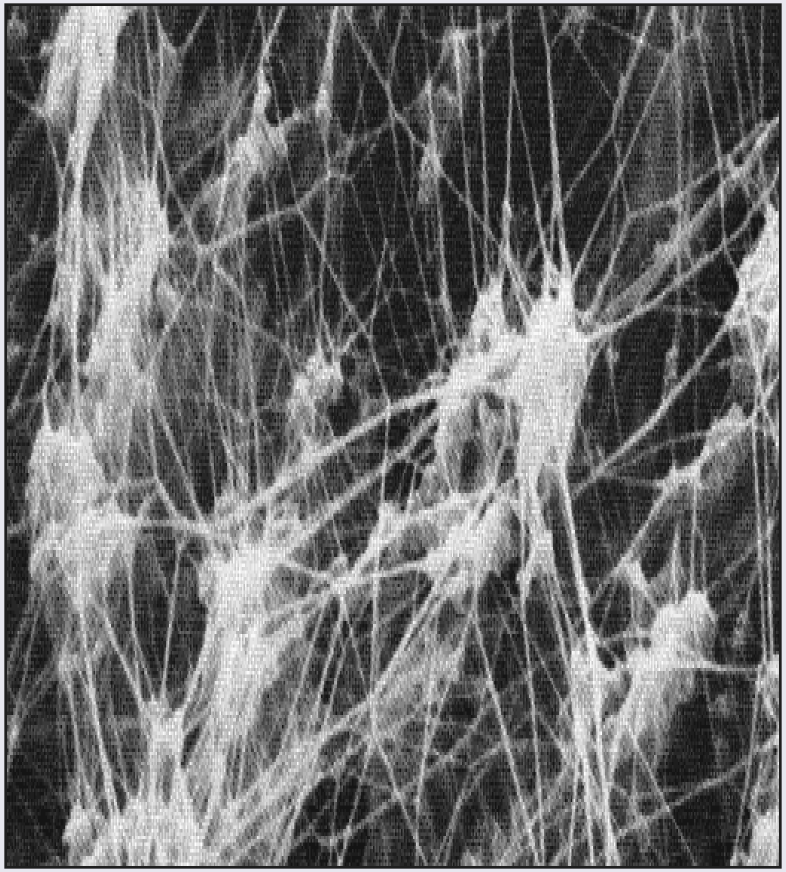
Membrane Filters Defined

LPF

Membrane Types



Polypropylene

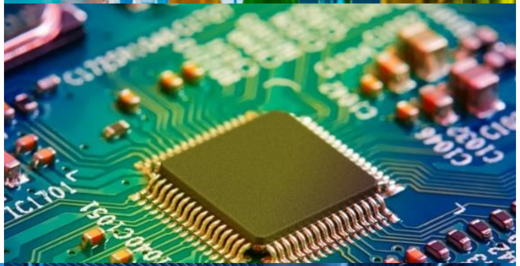


Polytetrafluoroethylene (PTFE)

Membrane Filters: Applications

LPF

- Bottling filters for beer, wine and bottled water
- SVPs and LVP (small/large volume parenterals)
- Tank Vents
- Fermentation Feed Air
- High Purity Water Systems
- Ultra-High Purity Chemicals



Graver Technologies

Knowledge is of two kinds. We know a subject ourselves, or we know where we can find information on it.”

Samuel Johnson

“Your brain is like a sponge that absorbs knowledge, but that’s not exactly how it’s done.”

Questions?