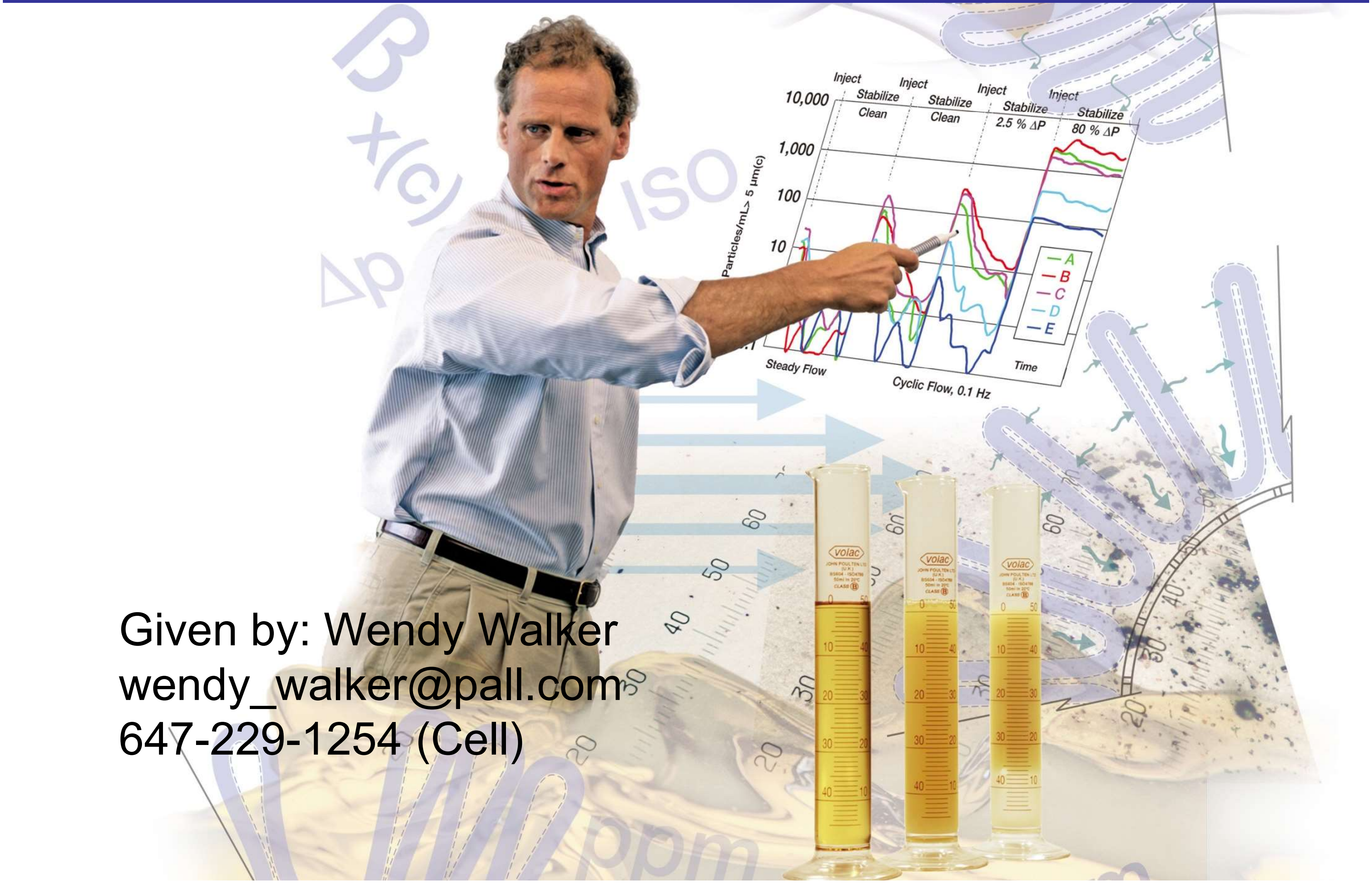
Pall Corporation

Filtration. Separation. Solution.SM

Filtration Fundamentals – STLE Workshop - May15,2019



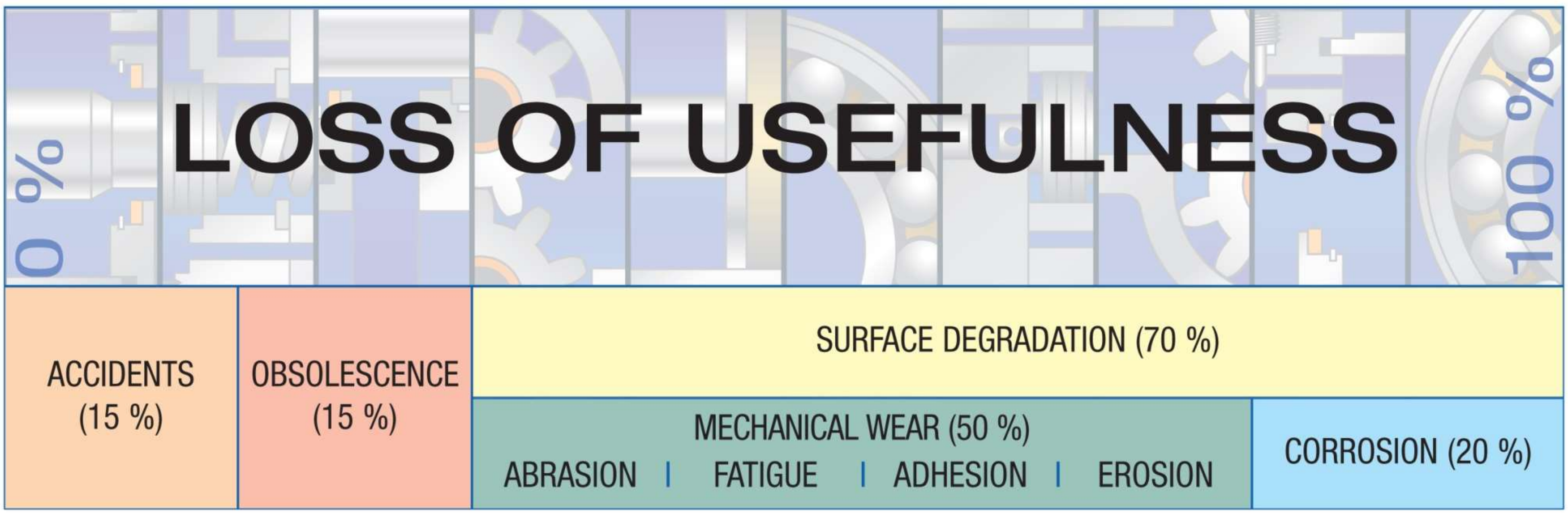
Given by: Wendy Walker
wendy_walker@pall.com
647-229-1254 (Cell)

Contents

Particulate Contamination Control

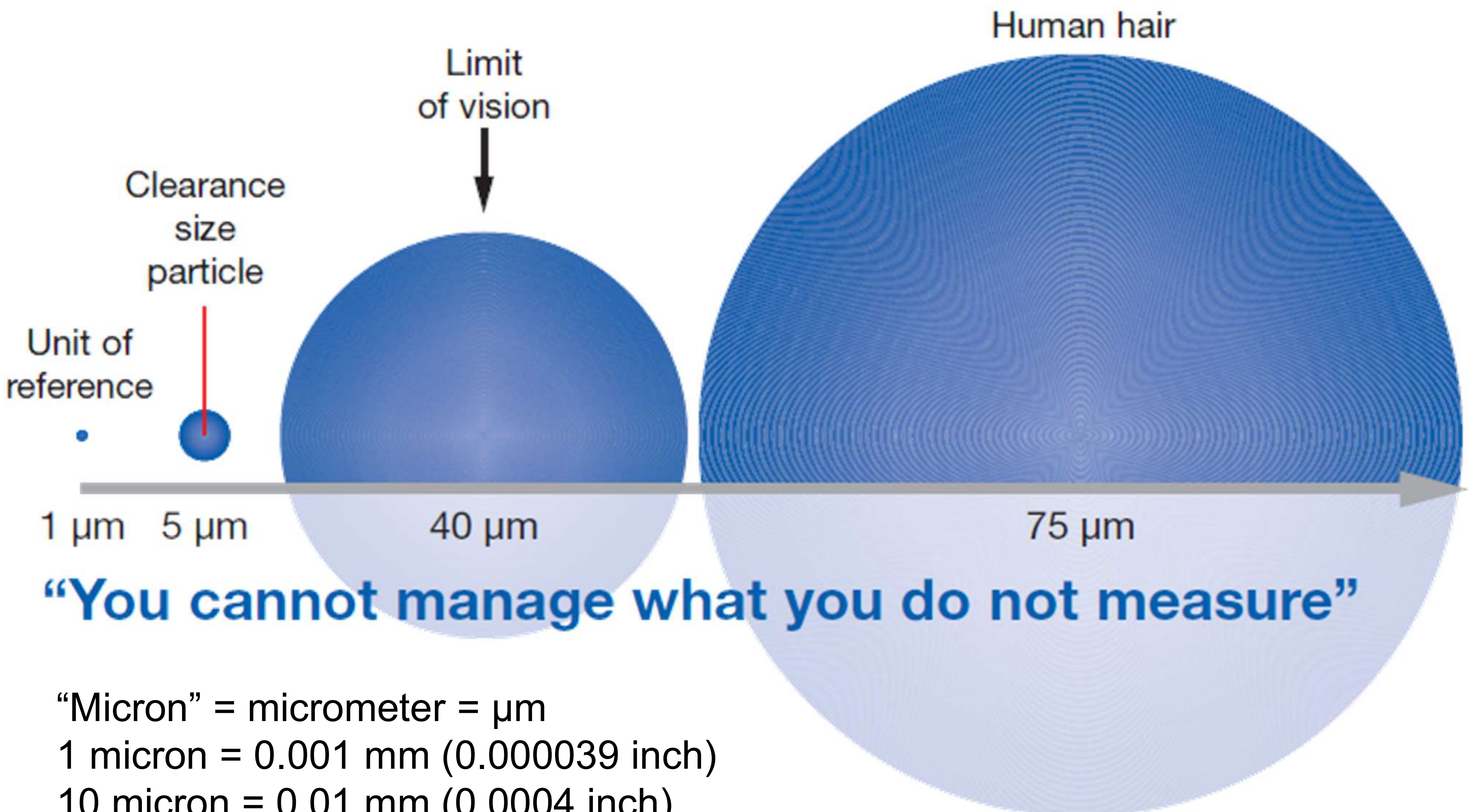
Life Expectancy Factors

An estimated 70 % of component replacement is due to surface degradation, or wear. In hydraulic and lubricating systems, 50 % of these replacements result from mechanical wear with another 20 % resulting from corrosion.



Presented at the American Society of Lubrication Engineers, Bearing Workshop

Contamination Measurement



"You cannot manage what you do not measure"

"Micron" = micrometer = µm
1 micron = 0.001 mm (0.000039 inch)
10 micron = 0.01 mm (0.0004 inch)

Particulate Contamination Control

Particle Count / 100 mL Fluid	ISO Range Code
4,000,000 - 8,000,000	23
2,000,000 - 4,000,000	22
1,000,000 - 2,000,000	21
500,000 - 1,000,000	20
250,000 – 500,000	19
130,000 – 250,000	18
64,000 – 130,000	17
32,000 - 64,000	16
16,000 – 32,000	15
8,000 – 16,000	14
4,000 – 8,000	13
2,000 – 4,000	12
1,000 – 2,000	11

Dirty

Clean

Cleaner

ISO Cleanliness Code: 18 / 16 / 13

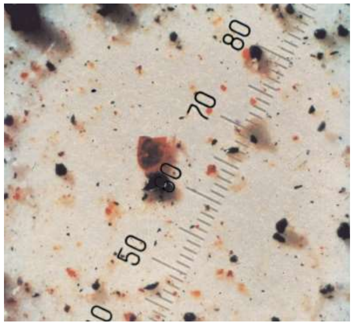
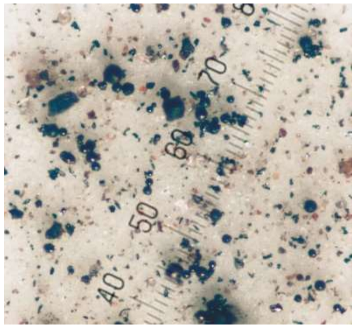
Particle Count Summary

Particle Size	#/ml ≥ Size	Range Code
≥ 4µm(c)	130,000 to 250,000	18
≥ 6µm(c)	32,000 to 64,000	16
≥ 14µm(c)	4,000 to 8,000	13

What I want you to recognize is that for every increase in a range code number (say 18-19) the amount of particulate (or dirt in your fluids) doubles.

Particulate Contamination Control

Cleanliness Level Comparison

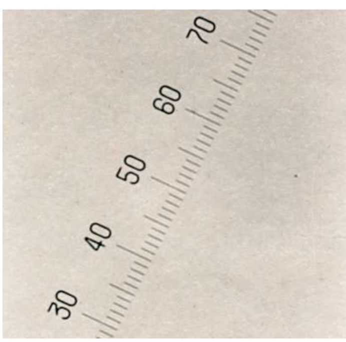
Photomicrograph (100x)	Description	Contaminants	ISO4406 Codes and AS4059 Classes[1,2]
	New oil from barrel	Silica Black metal Bright metal Plastics	21/19/16 (11A/11B/10C)
	New system with built-in contaminants	Bright metal Black metal Rust Silica Plastics	22/20/18 (12A/12B/12C)

1 AS4059 is based on 100 mL

2 AS4059 classes are for the 3 ISO4406 size ranges

Particulate Contamination Control

Cleanliness Level Comparison

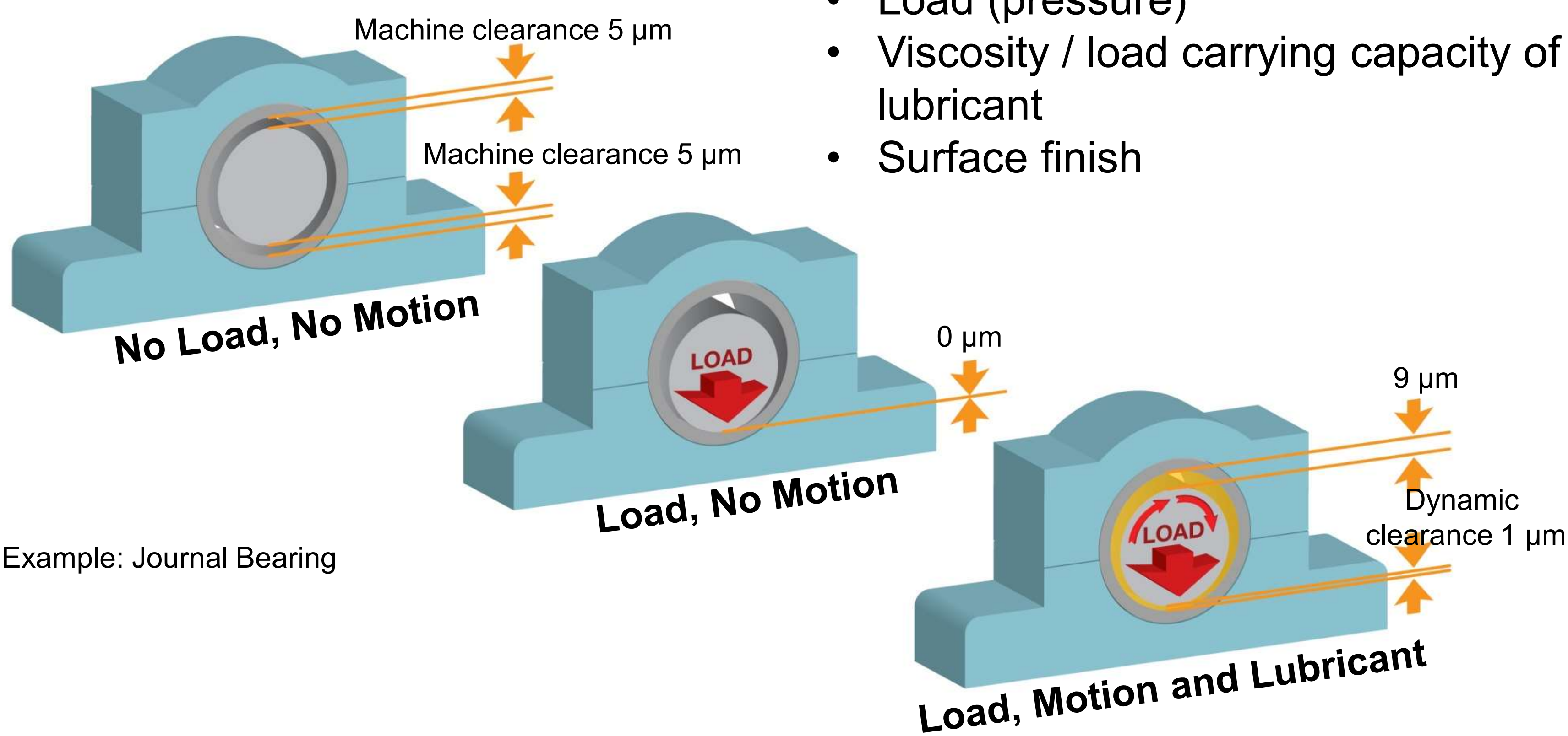
Photomicrograph (100x)	Description	Contaminants	ISO4406 Codes and AS4059 Classes[1,2]
	System with inadequate filtration	Silica Black metal Bright metal Plastics	20/17/14 (10A/9B/9C)
	System β5(c) >1,000 wear control filtration	Some black metal	13/11/09 (3A/3B/4C)

[1] AS4059 is based on 100 mL
[2] AS4059 classes are for the 3 ISO4406 size ranges

Dynamic Operating Clearances

Dynamic clearances depend on:

- Design clearance
- Load (pressure)
- Viscosity / load carrying capacity of lubricant
- Surface finish



Example: Journal Bearing

Particulate Contamination Control

Typical Dynamic Clearances

Component	Details	Clearances
Valves	Servo	1 - 4 µm
	Proportional	1 - 6 µm
	Directional	2 - 8 µm
Variable Volume Piston Pumps	Piston to Bore	5 - 40 µm
	Valve Plate to Cylinder block	0.5 - 5 µm
Vane Pumps	Tip to Case	0.5 - 1 µm
	Sides to Case	5 - 13 µm
Gear Pumps	Tooth Tip to Case	0.5 - 5 µm
	Tooth to Side Plate	0.5 - 5 µm
Ball Bearings	Film Thickness	0.1 - 0.7 µm
Roller Bearings	Film Thickness	0.1 - 1 µm
Journal Bearings	Film Thickness	0.5 - 100 µm
Seals	Seal and Shaft	0.05 – 0.5 µm
Gears	Mating Faces	0.1- 1 µm

Ref. ASME (American Society of Mechanical Engineers) Wear Handbook

Particulate Contamination Control

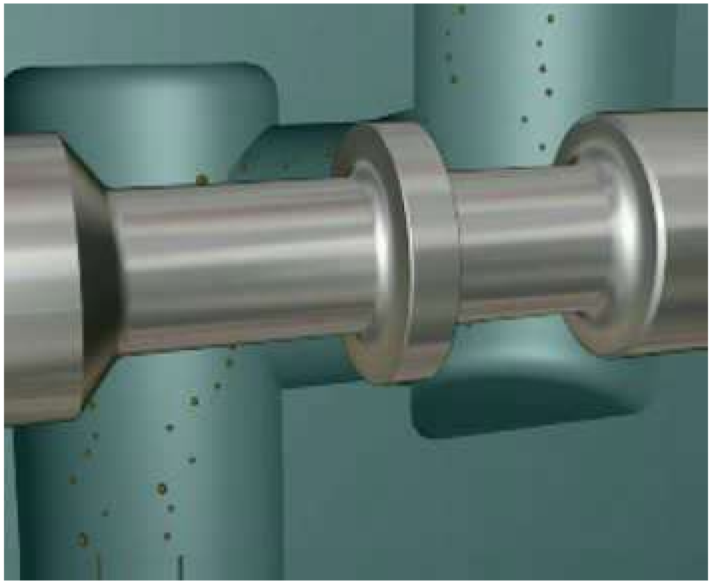
Wear in Components – Valve Wear (Erosive, Silting/Stiction)

- Particulate contamination can cause slow, inaccurate response, leakage and jamming

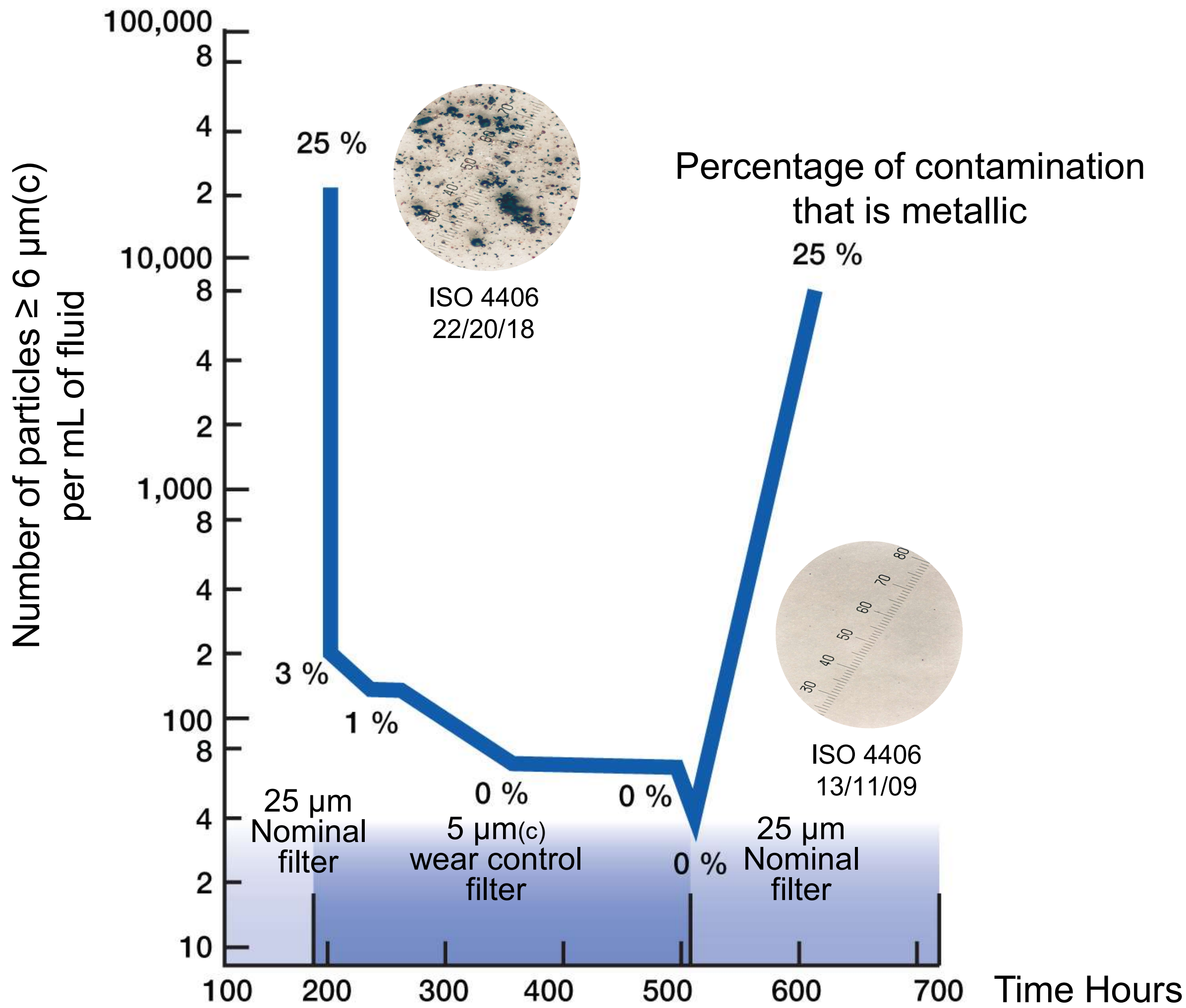
Typical dynamic clearances:

Servo valve	1 - 4 µm
Proportional valve	1 - 6 µm
Directional/control valve	2 - 8 µm

Relative particulate sensitivity: **HIGH**

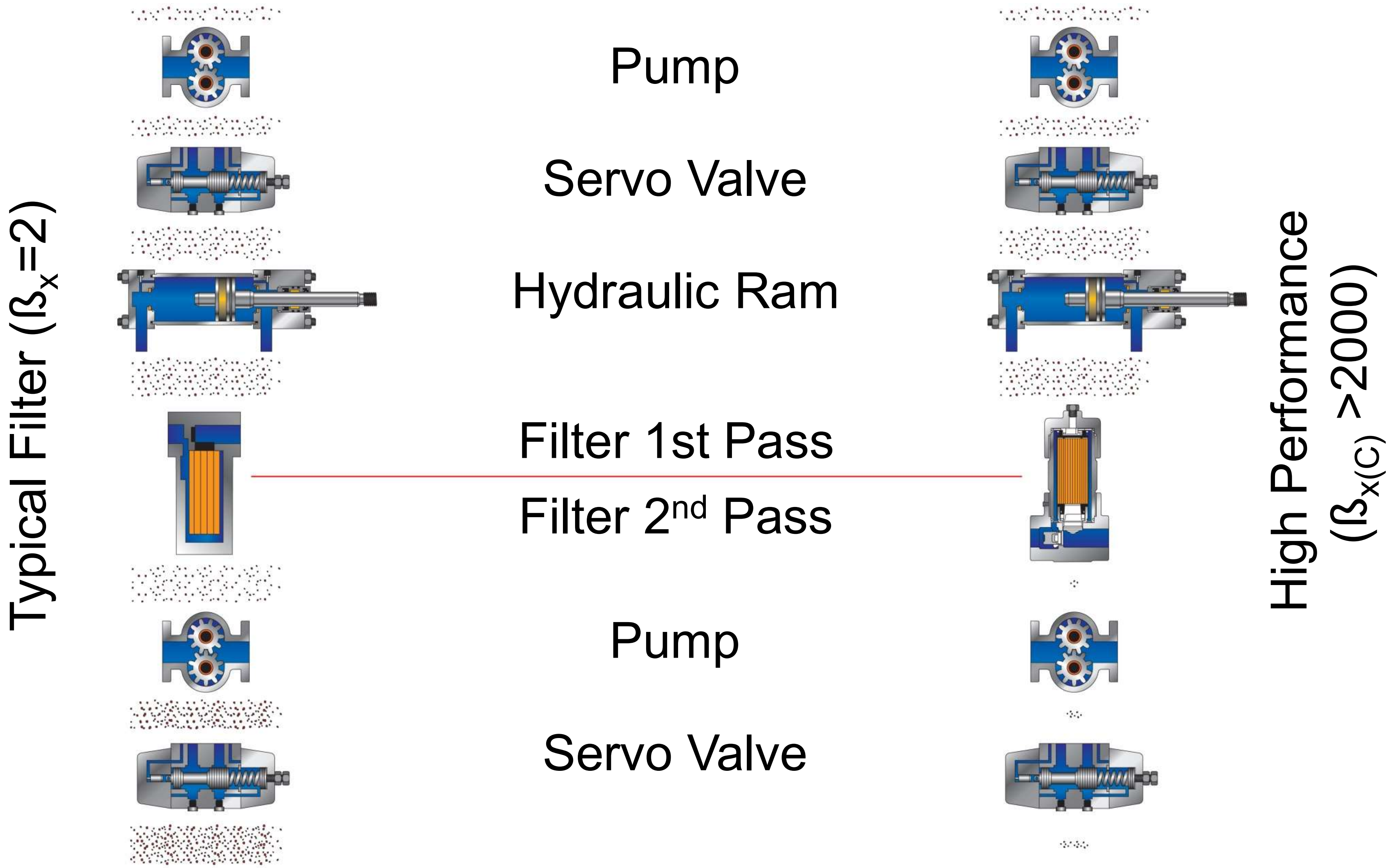


Breaking the Chain Reaction of Wear



Ref: SAE (Society of Automotive Engineers International) Technical Paper 690606

Breaking the Chain Reaction of Wear



Particulate Contamination Control

Impact of Wear Control on Component Life

To minimize wear and maximize component service life, clearance size particles must be removed from the system.

Component	Improvement
Pump motor	4 to 10x increase in pump and motor life
Hydrostatic transmission	4 to 10x increase in hydrostatic transmission (HST) life
Valve	5 to 300x increase in valve life
Valve spool	Elimination of valve stiction
Roller bearing	50x extension of roller bearing fatigue life
Journal bearing	10x extension of journal bearing life
Fluid	Extension of fluid service life and reduction of disposal costs through reduced contamination caused fluid degradation

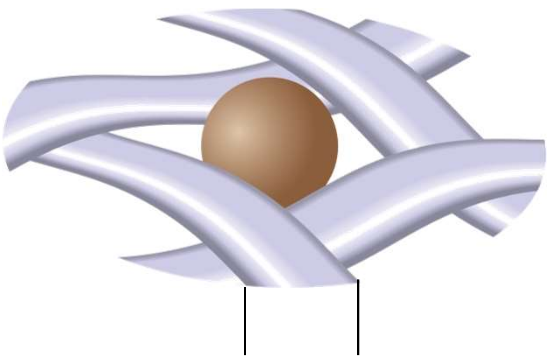
Filtration Fundamentals

Filtration Medium

Importance of fiber size

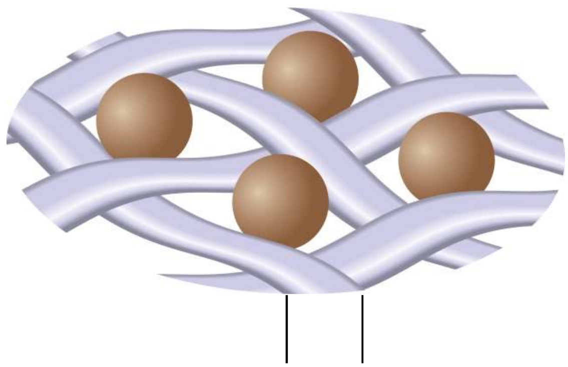
Fiber size and fiber density govern the filter medium’s pore size and porosity

Cellulose



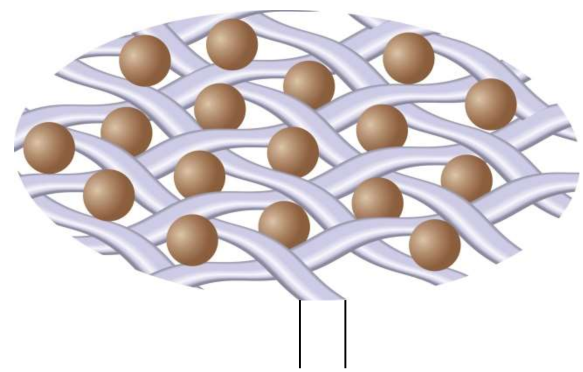
15 to 25 µm

Polymeric



10 to 15 µm

Glass fiber



1 to 5 µm

Benefits of smaller fiber diameter:

- Higher dirt capacity
- Lower pressure drop
- Longer service life

Benefits of inert inorganic fibers:

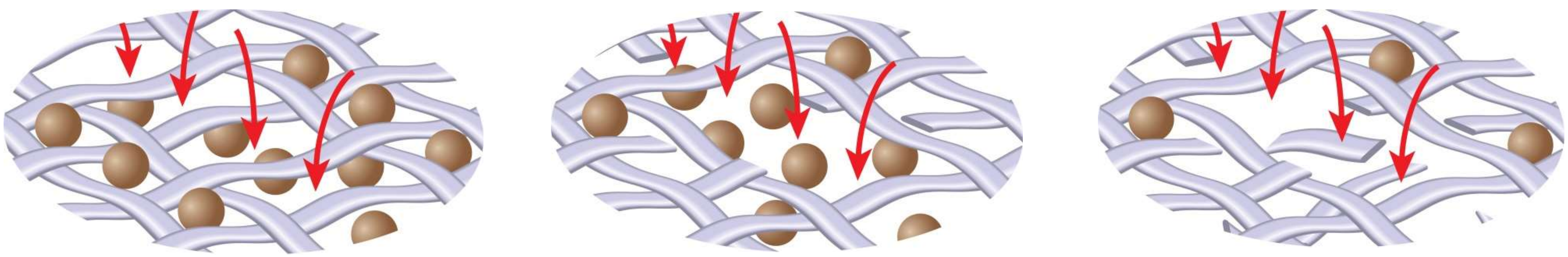
- Wide chemical compatibility
- No swelling
- No shelf life limitations

Filtration Medium

Fixed Pore vs. Non-fixed pore construction

In fixed pore media, fibers are bonded with specially formulated resin to resist deterioration from pressure, flow fluctuations, temperature and age

Fibers in non-fixed pore media are inconsistently or poorly bonded. This facilitates movement of fibers under pressure and flow surges resulting in channeling, unloading and media migration

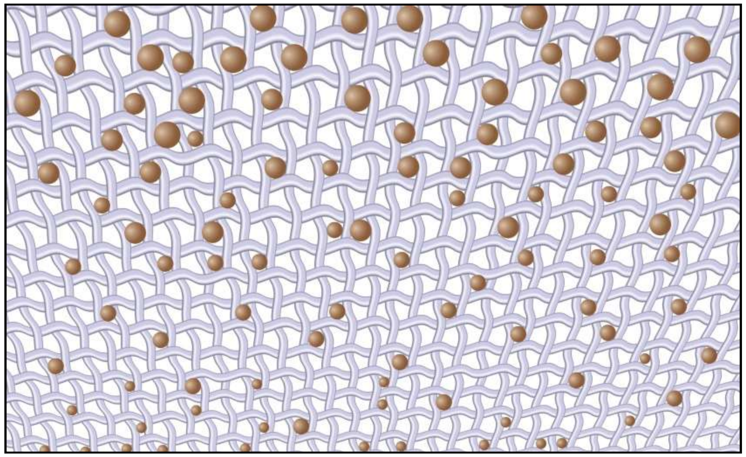


Channeling Unloading Media migration

Filtration Fundamentals

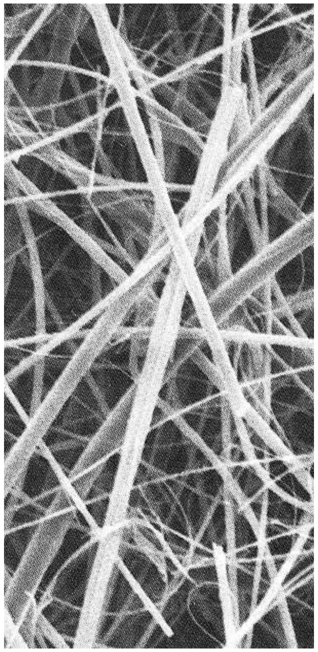
Filtration Medium: Uniform vs. Tapered Pore structure

Tapered Pore Design

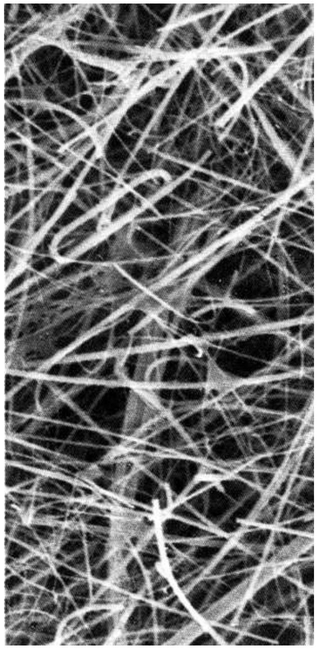


- Coarser upstream surface acts as a pre-filter, capturing larger particles, allowing finer downstream pores to capture critical clearance-sized particles
- **Reduces operating costs by combining maximum particle retention with extended service life**

Tapered Pore Construction



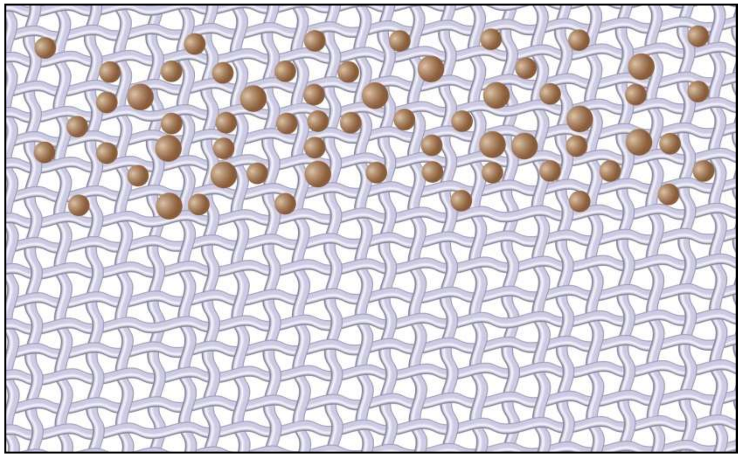
Upstream 500X



Downstream 500X

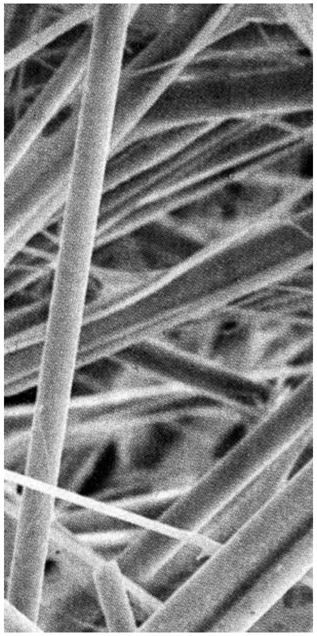
Filtration Medium: Uniform vs. Tapered Pore structure

Uniform Pore Design

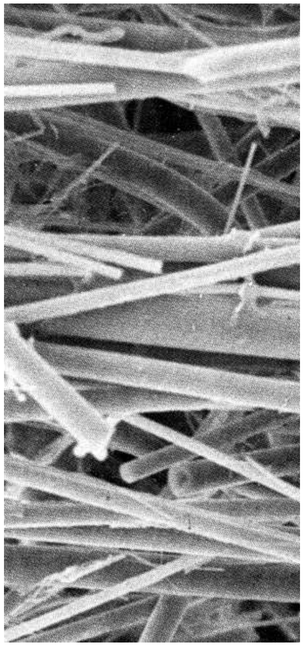


- Limits the effective use of the available void volume to capture particles
- Increases operating costs by reducing the total number of particles captured and hence filter service life

Uniform Pore Construction



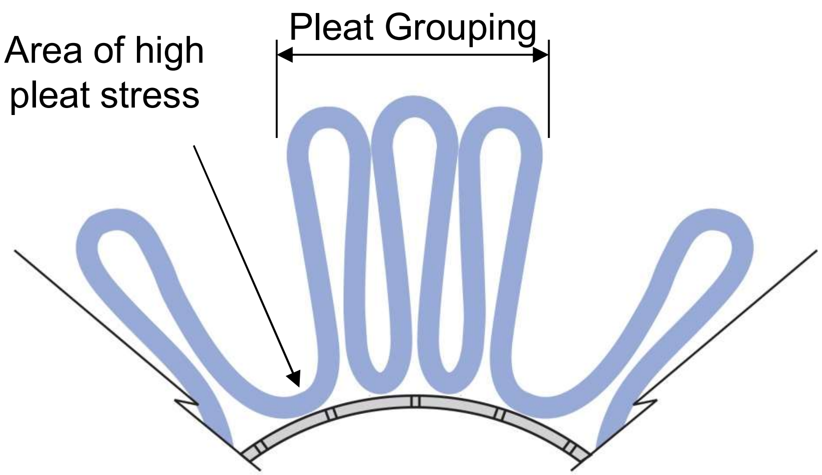
Upstream 500X



Downstream 500X

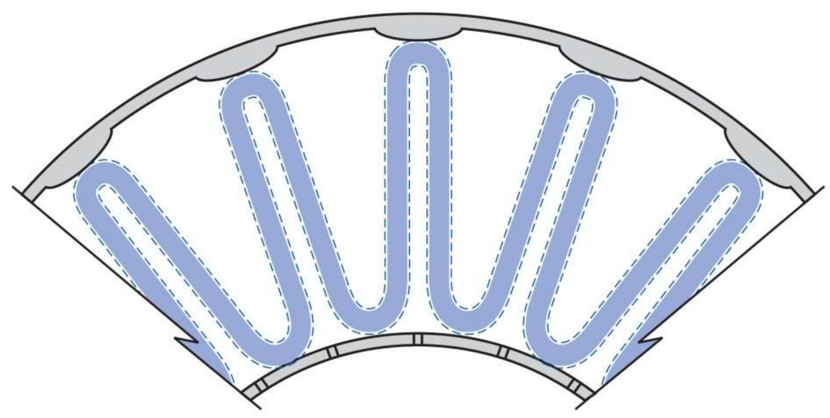
Filter Element Support and Drainage

Unsupported filter element



- Reduces useable filtration area, fluid drainage, and filter element service life under high differential pressure or ‘cold start’ flow conditions

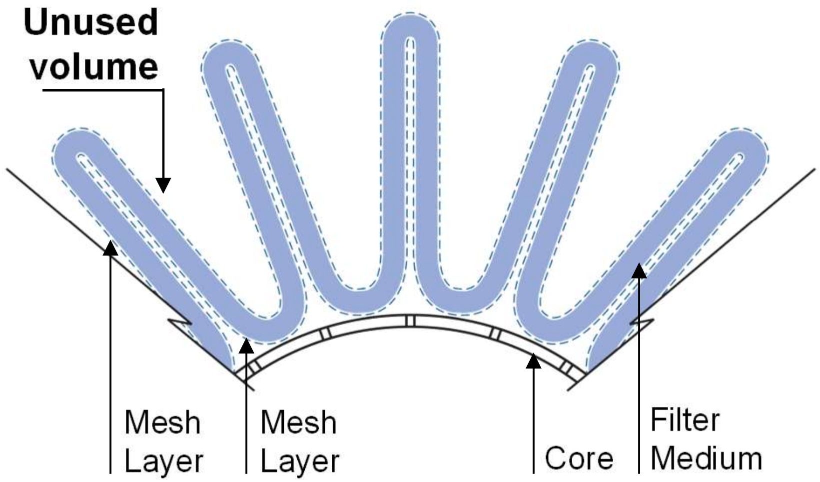
Supported filter element

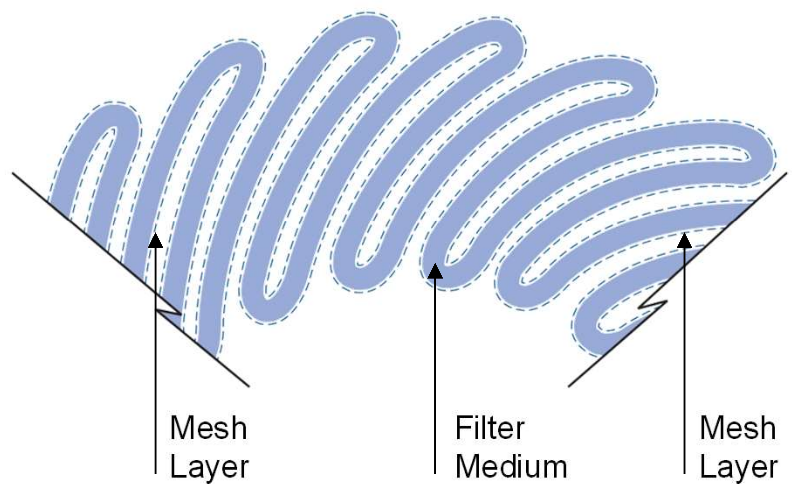


- Provides consistent performance and long service life under high differential pressure or ‘cold start’ flow conditions

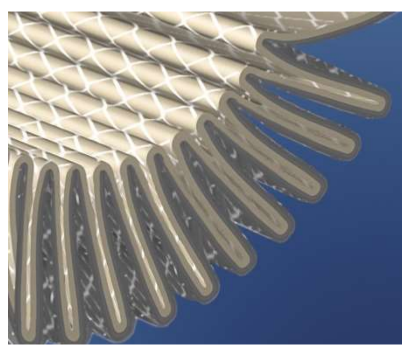
Laid-over Pleat Shape vs. Fan Pleat Shape

Filter area

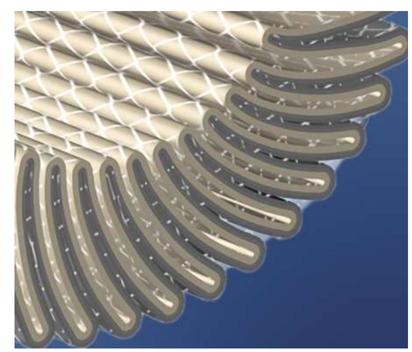




Traditional Fan pleated filter element



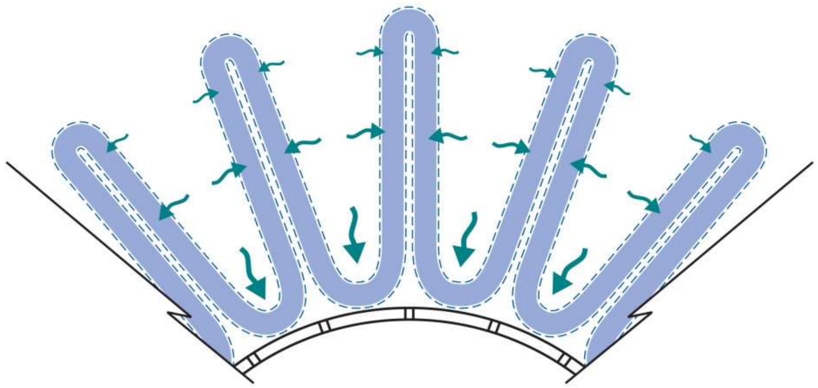
Laid-over pleat filter element



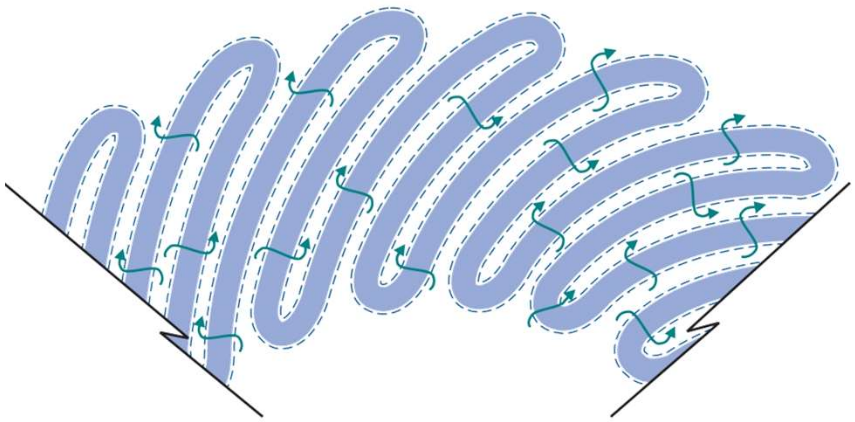
Laid-over Pleat Shape vs. Fan Pleat Shape

Flow distribution

Fan pleated filter element



Laid-over pleat filter element



Laid over pleat construction provides uniform flow distribution resulting in long service life and consistent particle control

Filter Performance Ratings

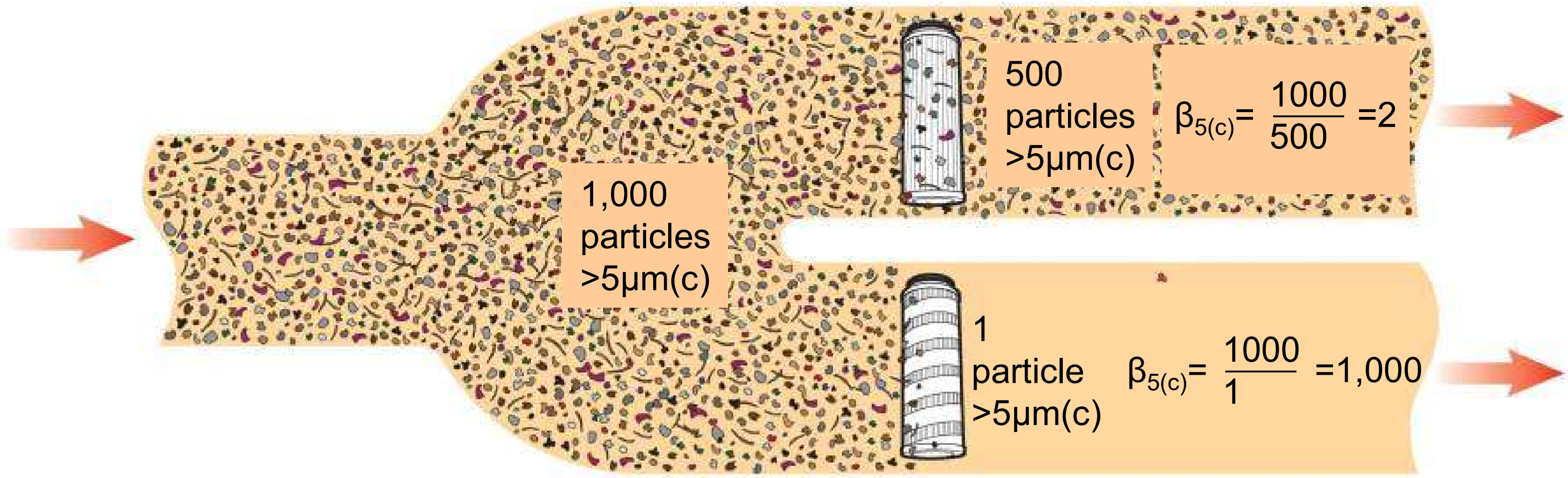
- **Nominal Rating**
  An arbitrary micrometer value, based on weight percent removal, indicated by the filter manufacturer. Due to lack of reproducibility, this rating is rarely used.
- **Absolute Rating**
  The diameter of the largest hard spherical particle that will pass through a filter under specified test conditions. This is an indication of the largest opening in the filter element.
- **Filtration Ratio (ßx(c))***
  The ratio of the number of particles equal to and greater than a given size, X(c), in the influent fluid to the number of particles equal to and greater than the same size, X(c), in the effluent fluid.
- **ISO Code Rating** (from Cyclic Stabilization Test, based on SAE ARP4205)
  The stabilized fluid cleanliness level achieved at 80 % of the net terminal pressure drop under cyclic flow (considered the worst operating condition)

*Note: (c) refers to NIST certified particle sizes determined with an APC calibrated to ISO 11171.

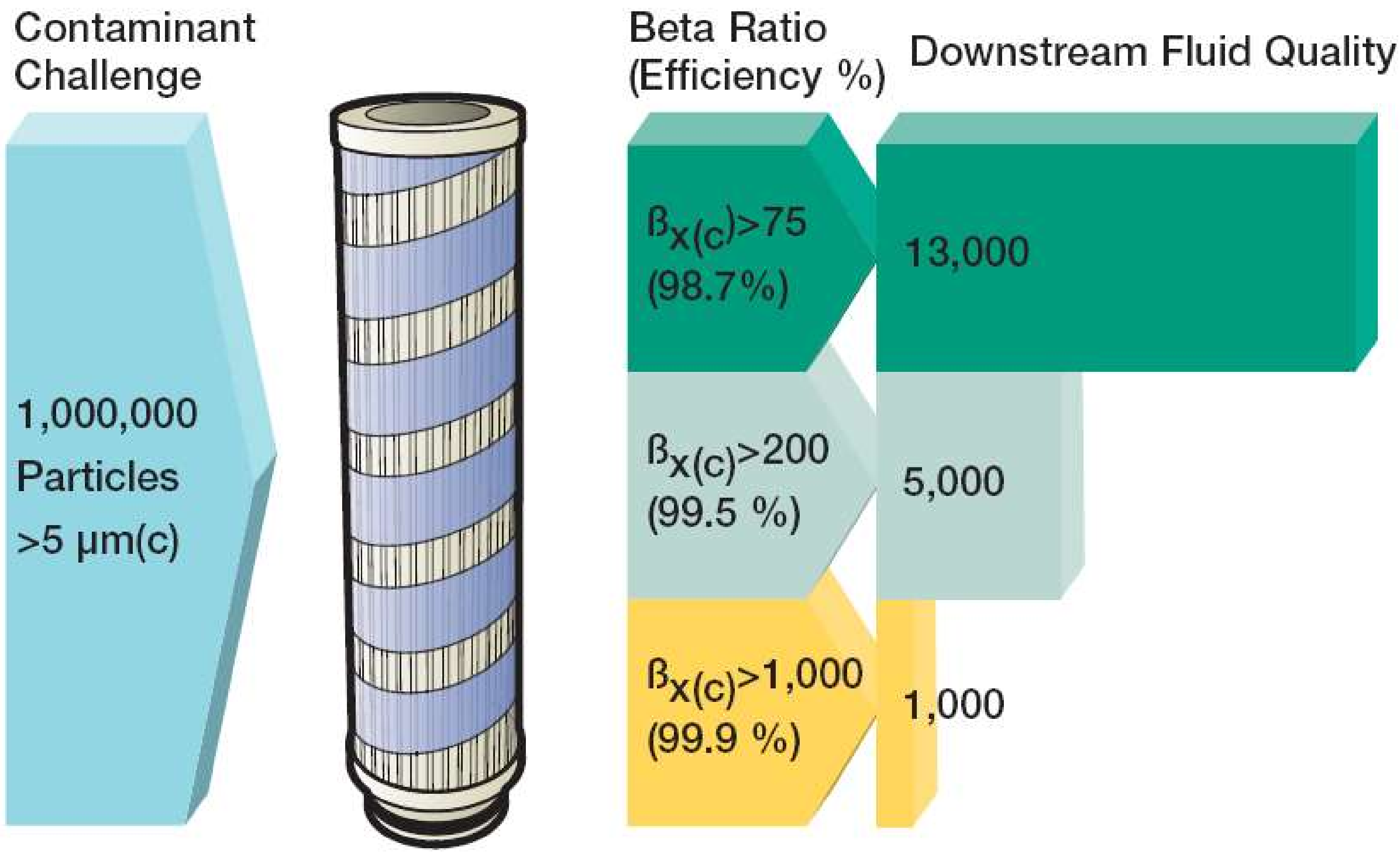
Filtration Fundamentals

Filtration Ratio (Beta Ratio)

$$\text{Filtration ratio } ß_{x(c)} = \frac{\text{Number of upstream particles x µm(c) and larger}}{\text{Number of downstream particles x µm(c) and larger}}$$



Beta Ratio and Downstream Fluid Quality



Water Contamination Control

Water Contamination in Oil

Water contamination in fluid systems causes

- Fluid breakdown (e.g., additive precipitation, oxidation)
- Reduced lubricating film thickness
- Accelerated metal surface fatigue
- Corrosion
- Loss of dielectric strength in insulating fluids

Sources of Water Contamination

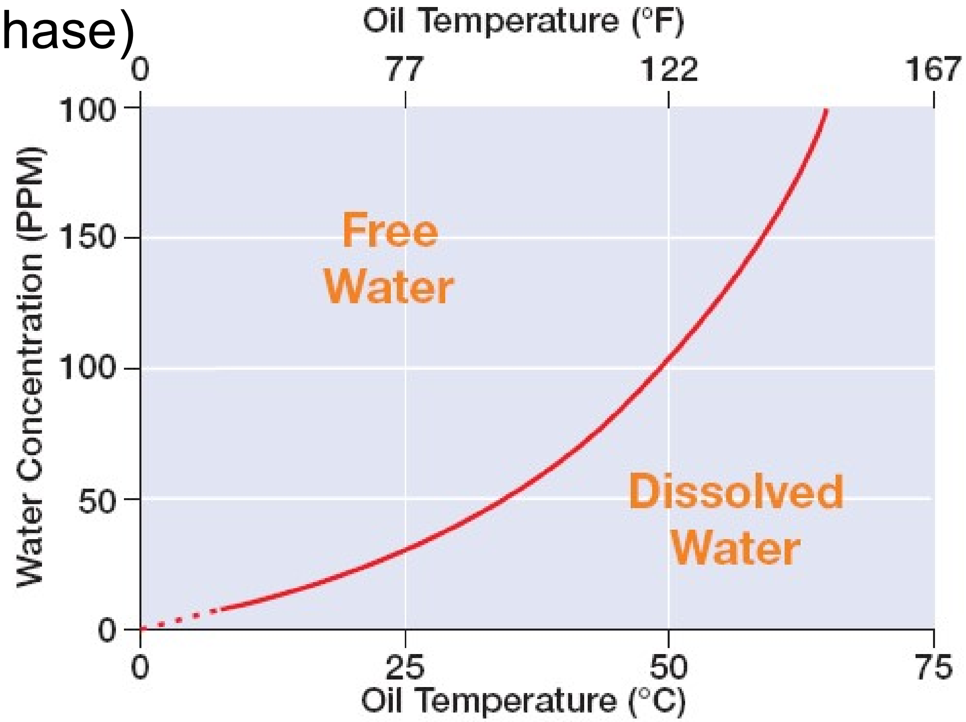
- Heat exchanger leaks
- Seal leaks
- Condensation of humid air
- Inadequate reservoir covers
- Temperature reduction (turning dissolved water into free water)

Dissolved, emulsified and free water in oil, left to right

Water Contamination in Oil

Forms of water in oil

- Free (emulsified or continuous phase)
- Dissolved (below saturation)



Ref: EPRI CS-4555 Turbine oil

Typical Oil Saturation Levels*

- Hydraulic:
  200-400 PPM (0.02-0.04 %)
- Lubrication:
  200-750 PPM (0.02-0.075 %)
- Dielectric:
  30-50 PPM (0.003-0.005 %)
- Industrial Phosphate Ester:
  1,000-3,000 PPM (0.1-0.3 %)

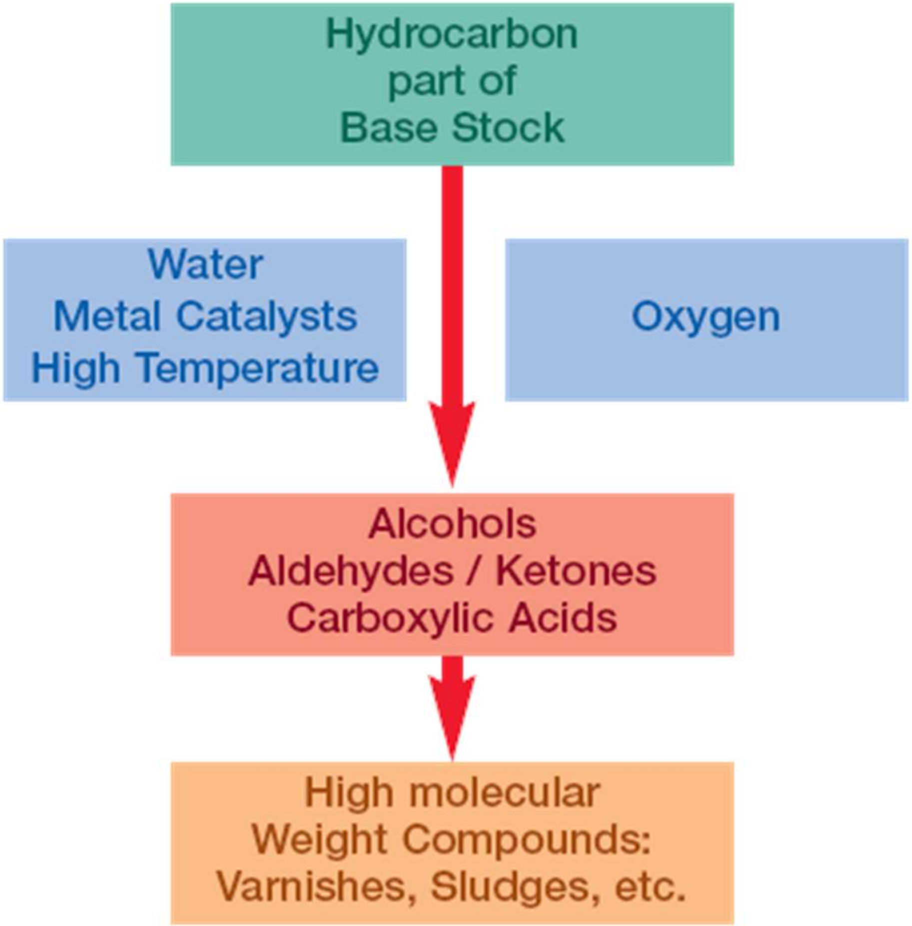
*Actual levels will depend on oil type and additives.

The recommended maximum water content is 50 % of the fluid's saturation level at operating temperature.

Detrimental Impact of Water on Fluid – Thermo-oxidative Stability

Item	Catalyst	Water	Hours	Final Neutralization Number
1	None	No	3,500+	0.17
2	None	Yes	3,500+	0.90
3	Iron	No	3,500+	0.65
4	Iron	Yes	400	8.10
5	Copper	No	3,000	0.89
6	Copper	Yes	100	11.20

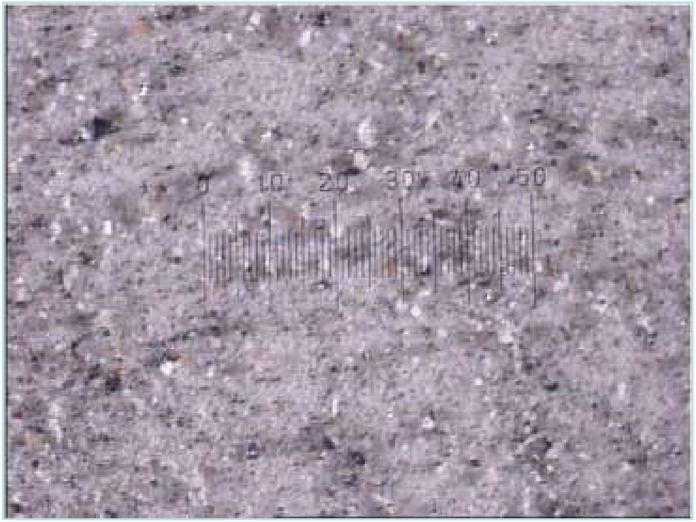
Reference: Weinschelbaum, M., Proceedings of the National Conference on Fluid Power



Detrimental Impact of Water on Fluid – Additive Precipitation

Additives can precipitate from the fluids as solids due to:

- Presence of significant concentrations of water
- Mixing of different fluid brands or different types of fluids



Precipitate of calcium/sulfur containing additive in paper machine lube oil

Water Contamination Control

Detrimental Impact of Water on Gear and Vane Pumps

Pump Sensitivity to Water Contamination

Gear Pump Wear Testing with AC Fine Test Dust, 0-30 µm Fraction		
Fluid condition	**Reduction in volumetric efficiency after 30 minutes**	
Dry Fluid	8 %	
Fluid with 1 % (10,000 PPM) water	33 %	
Vane Pump Wear Testing		
Fluid condition	**Component mass loss (mg)**	
	Oil X	Oil Y
Dry Fluid	60	40
Fluid with 500 PPM water	130	28,000

Reference: Fluid Power Research Center, Oklahoma State University

Controlling Water Contamination

Coalescence

- Removes only free water

Centrifugation

- Removes only free water

Absorption

- Removes only free water, optimum performance on low flow and low viscosity applications; can be quick but expensive

Flash Distillation

- Utilizes high heat and vacuum to remove free and dissolved water; high heat could lead to thermal degradation of the oil

Vacuum Dehydration

- Removes free and dissolved water and gases

Vacuum dehydration is the best method for the removal of free and dissolved water at minimum cost and ease of use. It cannot “burn” or otherwise significantly alter the working properties of the oil.

Controlling Electrostatic Discharge

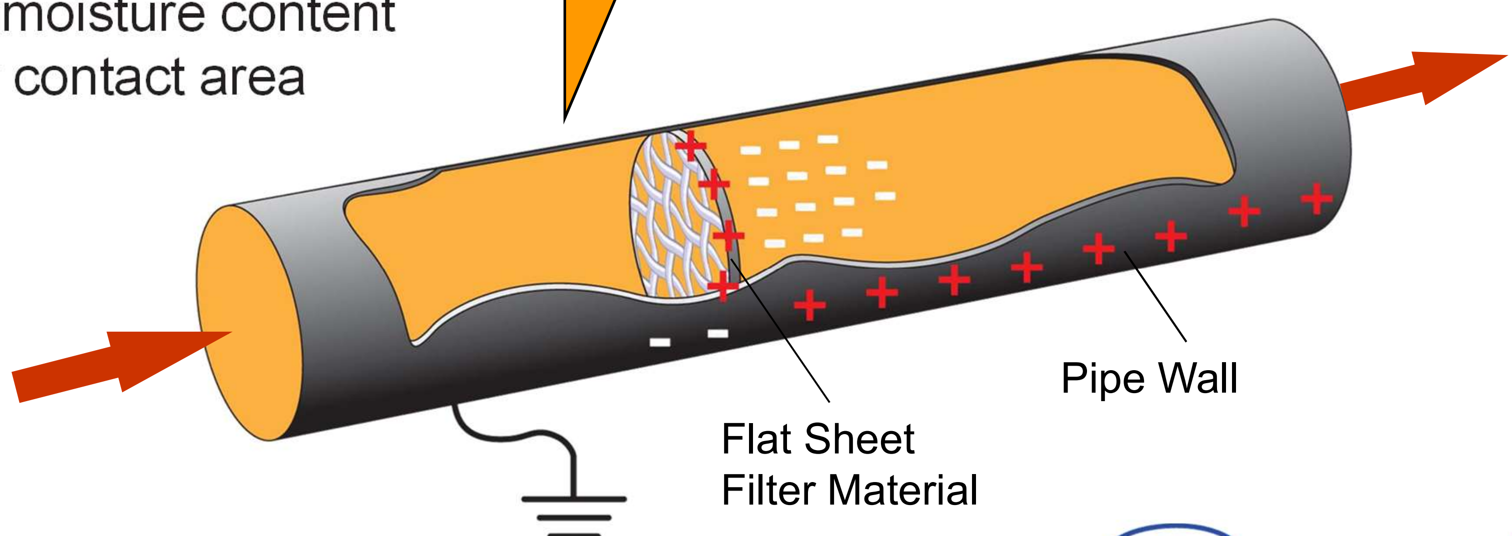
Triboelectric Charging and Electrostatic Discharge

Frictional contact between fluid and component surfaces results in electrostatic charge generation.

Extent of Charge Generation

- Nature of materials in contact
- Higher fluid velocity
- Higher fluid viscosity
- Lower fluid conductivity
- Lower moisture content
- Higher contact area

Higher charging



- Electrostatic charging happens when two dissimilar materials come in contact and separate – resulting in charge separation
- Turbine lube systems are specially prone to charging due to the low conductivity of todays API Group II base-stock oils and the charging characteristics of the standard glass-fiber filters
- Electrostatic charging becomes problematic when the charge generated does not dissipate in time, accumulates and generates a high energy Electrostatic Discharge - resulting in damage to the oil and other components including the filter
  - ESD event generates very high temperature that burns the oil producing byproducts including the resinous, varnish forming material
- Of the options available for ESD mitigation most are not technically or economically feasible for lube and hydraulic systems – except for…….
  - Filters made with anti-static filter media, engineered to generate much lower charge and dissipate it effectively to eliminate ESD and the associated damage
- For turbine lube systems that already have varnish, a novel Varnish Removal Filter (VRF) is available to remove it
  - Use of anti-static filters and varnish removal filters can effectively eliminate the root cause of varnish formation and the existing varnish

Summary

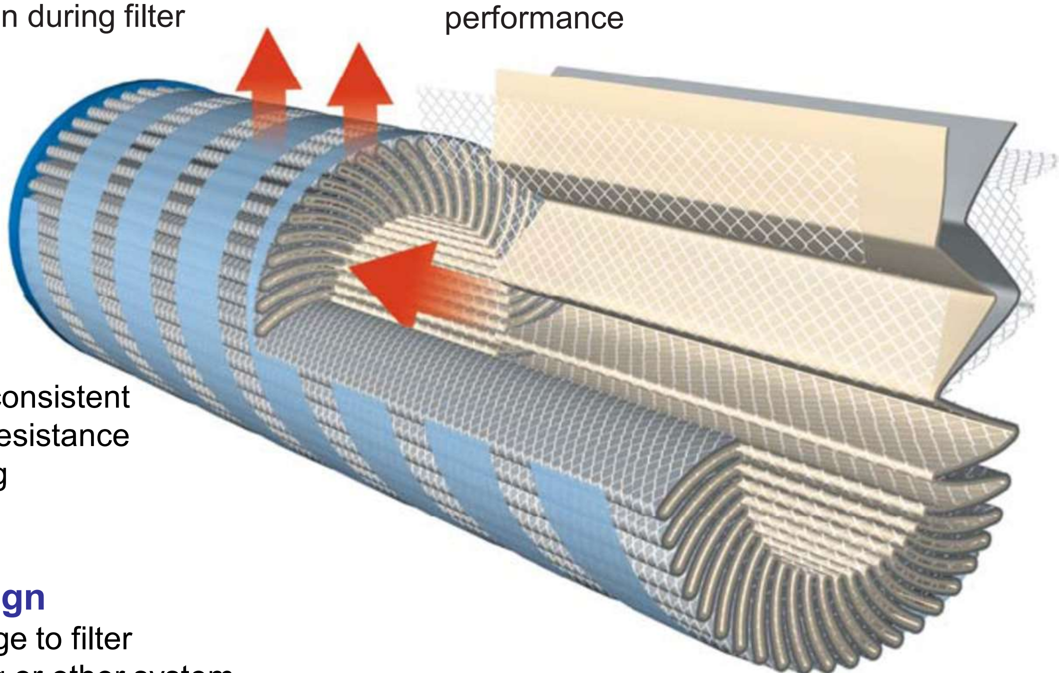
Filtration Fundamentals

High Performance Filter Element Construction

In-to-out flow path
Benefit: Reduces the chance of cross contamination during filter element change

Upstream cushion layer
Benefit: Reliable, consistent performance

High performance filtration medium
Benefit: Improved performance over the service life of the filter element, more consistent fluid cleanliness



Outer helical wrap
Benefit: Reliable consistent performance and resistance to severe operating conditions

Up and downstream mesh layers
Benefit: Extended filter element service life for lower operating costs

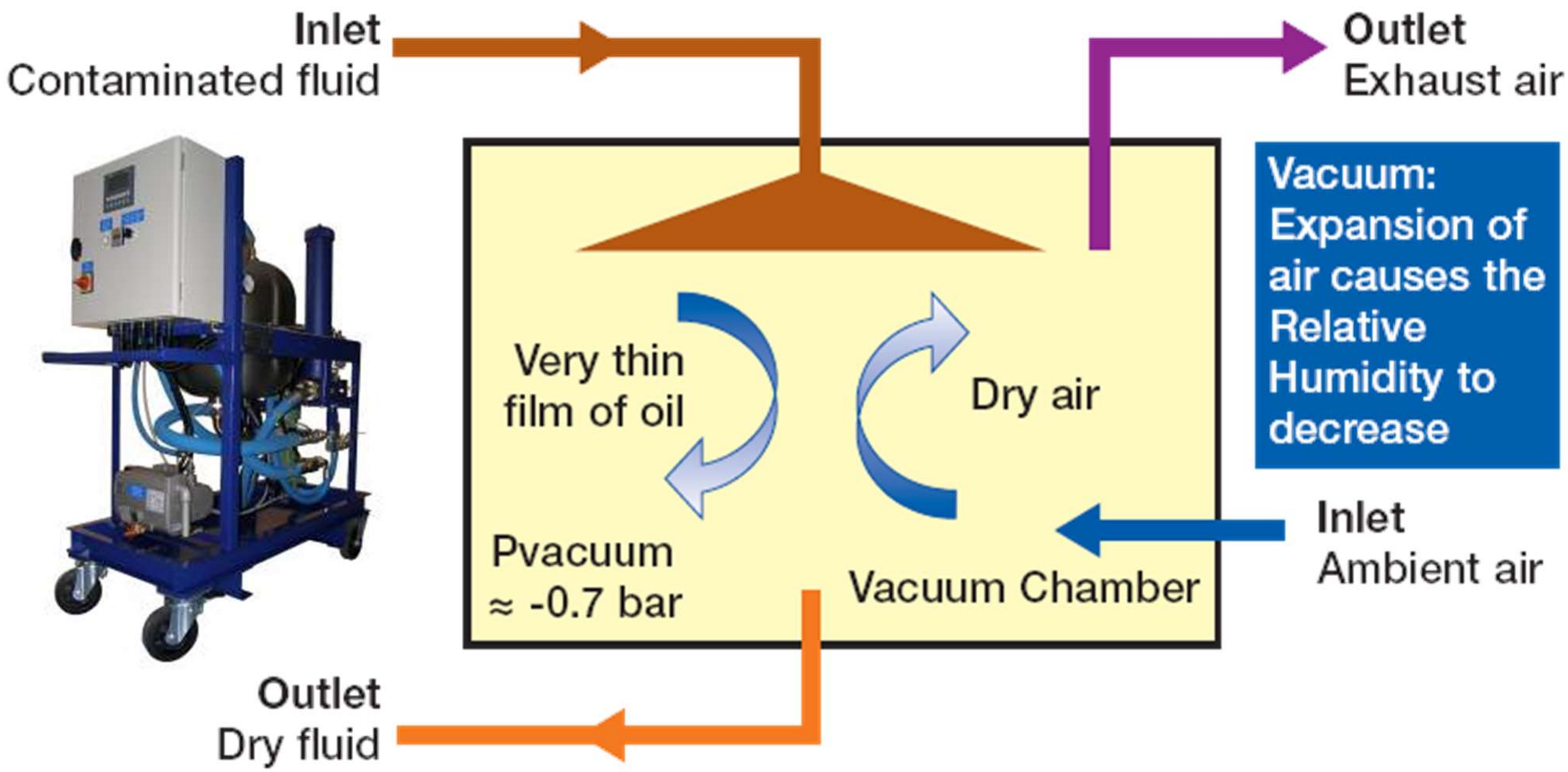
Anti-static design
Benefit: No damage to filter element or housing or other system components from electrostatic discharge; minimizes fluid degradation

Coreless/Cageless design
Benefit: Lighter, environmentally friendly element; reduced disposal costs; easy filter element change-out

Laid-over pleat shape
Benefit: Smaller filter element for an application; improved resistance to cyclic and surge flows and cold starts

Water Contamination Control

Vacuum Dehydration

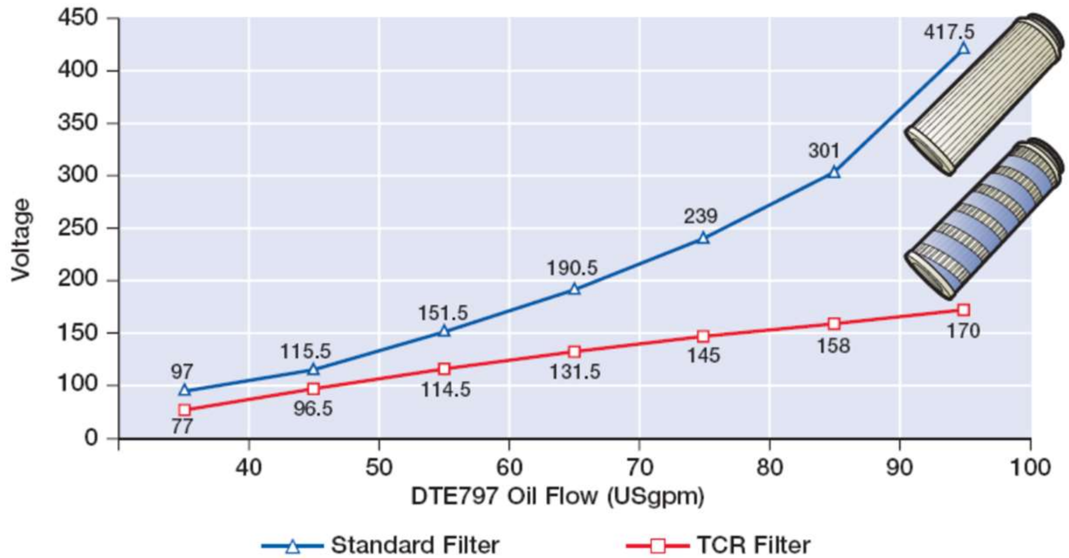


Controlling Electrostatic Discharge

Triboelectric Charging Resistant (TCR) filters

- Filter elements designed to distribute the charge over the filter element;
  - Do not prevent triboelectric charging
  - Only minimize electrostatic discharge/arcing
  - Allow fluid degradation and varnish formation

- TCR filter elements designed to dissipate triboelectric charge build-up:
  - Minimize charge generation and prevent discharging
  - Minimize fluid degradation and varnish formation



ANY QUESTIONS

For more information visit www.pall.com/hydraulics

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