PALL

Pall Corporation

# Pocket Book


ENABLING A GREENER FUTURE℠

*Filtration. Separation. Solution.*℠

## Enabling a Greener Future

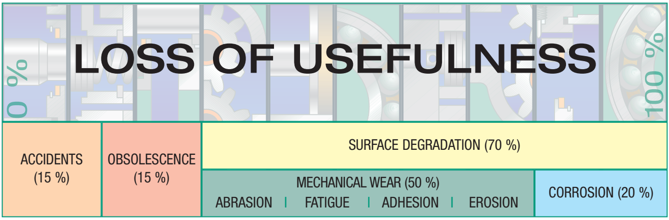
Businesses worldwide are challenged to conserve energy and resources while protecting the environment. Pall Corporation helps customers achieve these goals by providing leading-edge filtration and separation technologies that purify and conserve water, consume less energy, make alternative energy sources possible and practical and minimize emissions and waste. Our collective efforts are enabling a greener, safer, more sustainable future.

ENABLING A GREENER FUTURE℠

www.pall.com/green

# Equipment Life Expectancy Factors

A study by Dr. E Rabinowicz at M.I.T. observed that 70% of component replacements or 'loss of usefulness' is due to surface degradation. In hydraulic and lubricating systems, 20% of these replacements result from corrosion with 50% resulting from mechanical wear.




Presented at the American Society of Lubrication Engineers, Bearing Workshop.

# Sources of Contamination

**Built-in contaminants from components:**

- Assembly of system
- Cylinders, fluids, hydraulic motors, hoses and pipes, pumps, reservoirs, valves, etc.

**Generated contaminants:**

- Operation of system
- Break-in of system
- Fluid breakdown

**External ingression:**

- Reservoir breathing
- Cylinder rod seals
- Bearing seals
- Component seals

**Contaminants introduced during maintenance:**

- Disassembly/assembly
- Make-up oil

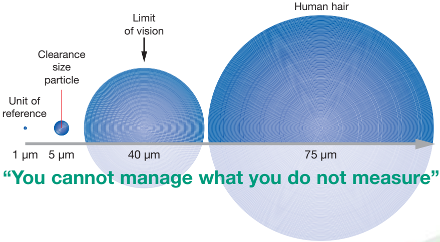
# The Micrometre "µm"

'Micron' = micrometre = µm

The micrometre is the standard for measuring particulate contaminants in lubricating and fluid power systems.

1 micron = 0.001 mm (0.000039 inch)
10 micron = 0.01 mm (0.0004 inch)

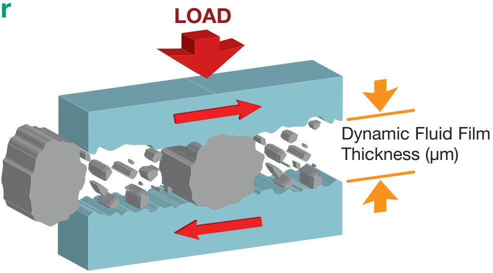
Smallest dot you can see with the naked eye = 40 µm
Thickness of a human hair = 75 µm




**"You cannot manage what you do not measure"**

# Mechanisms of Wear

## Abrasive Wear



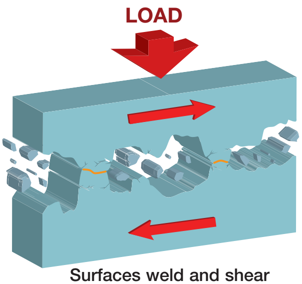

### Abrasive Wear Effects:

- Dimensional changes
- Leakage
- Lower efficiency
- Generated wear: more wear

### Typical components subjected to Abrasion:

- All hydraulic components: pumps, motors, spool valves and cylinders
- Hydraulic motors
- Journal bearings

## Adhesive Wear



Surfaces weld and shear

### Adhesive Wear Effects:

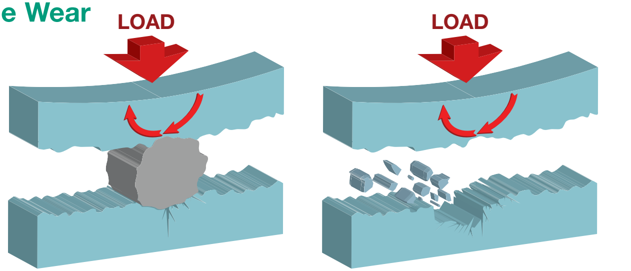
- Metal to metal points of contact
- 'Cold Welding'
- Adhesion and shearing

### Typical components subjected to Adhesion:

- Hydraulic cylinders
- Ball bearings
- Journal bearings

# Mechanisms of Wear (continued)

## Fatigue Wear




Particle caught, surfaces dented and cracking initiated

After 'N' fatigue cycles, cracking spreads, surface fails and particles are released

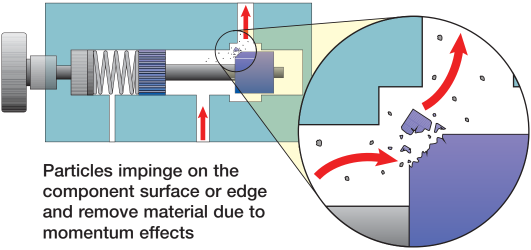
### Fatigue Wear Effects:

- Leakage
- Deterioration of surface finish
- Cracks

### Typical components subjected to Fatigue:

- Journal bearings
- Hydrostatic bearings
- Rolling element bearings
- Geared systems

## Erosive Wear



Particles impinge on the component surface or edge and remove material due to momentum effects

### Erosive Wear Effects:

- Slow response
- Spool jamming/stiction
- Leakage
- Solenoid burnout

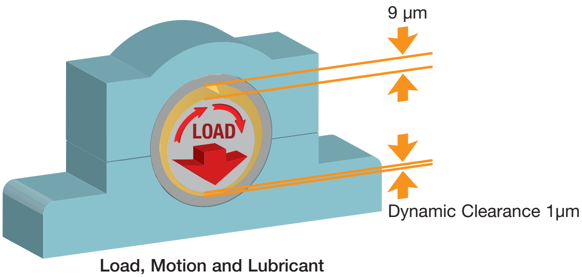
### Typical components subjected to Erosion:

- Servo valves
- Proportional valves
- Directional control valves

# Typical Dynamic (Operating) 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 | 0.4 - 1 µm |
| Journal Bearings | Film Thickness | 0.5 - 125 µm |
| Seals | Seal and Shaft | 0.05 - 0.5 µm |
| Gears | Mating Faces | 0.1 - 1 µm |

*Data from STLE Handbook on Lubrication & Tribology (1994)




**Load, Motion and Lubricant**

# Fluid Analysis Methods for Particulate

| Method | Units | Sampling | Benefits | Limitations |
|---|---|---|---|---|
| Optical Particle Count | Number/mL/ Cleanliness code | Off-line; Laboratory | Provides size distribution. Unaffected by fluid opacity, water and air in fluid sample | Sample preparation time |
| Automatic Particle Count (APC) | Number/mL/ Cleanliness code | Off-line; "Sip" from containers; On-line | Fast and repeatable | Sensitive to 'silts', water, air and gels |
| Filter / Mesh Blockage Technique | Cleanliness code | Off-line; "Sip" from containers; On-line | Not affected by the presence of air or free water in the fluid sample | Does not provide the size distribution of the contamination |
| Patch Test and Fluid Contamination Comparator | Visual comparison/ Cleanliness code | Off-line; Point of use | Rapid analysis of system fluid cleanliness levels in field. Helps to identify types of contamination | Provides approximate contamination levels |
| Ferrography | Scaled number of large/small particles | Off-line; Laboratory | Provides basic information on ferrous and magnetic particles | Low detection efficiency on non-magnetic particles e.g. brass, silica |
| Spectrometry | PPM | Off-line; Laboratory | Identifies and quantifies contaminant material | Limited detection above 5 µm |
| Gravimetric | mg/L | Off-line; Laboratory | Indicates total mass of contaminant | Cannot distinguish particle size. Not suitable for moderate to clean fluids. i.e. below ISO 18/16/13 |

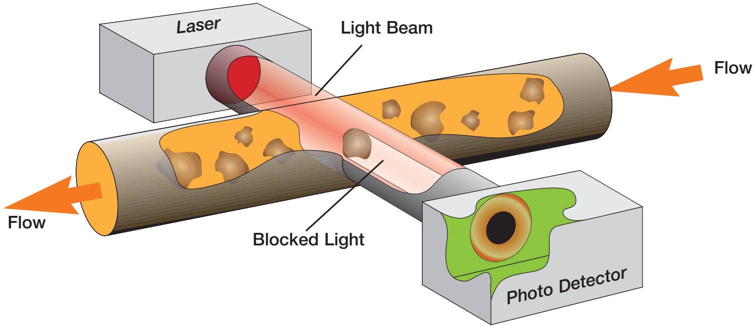
# Monitoring and Measurement Equipment

## Automatic Particle Counters (APCs)

Automatic particle counters are the most common method used by industry for particulate contamination analysis.

## Principle:

As a particle passes through the light beam, the light intensity received by the photo detector is reduced in proportion to the size of the particle.

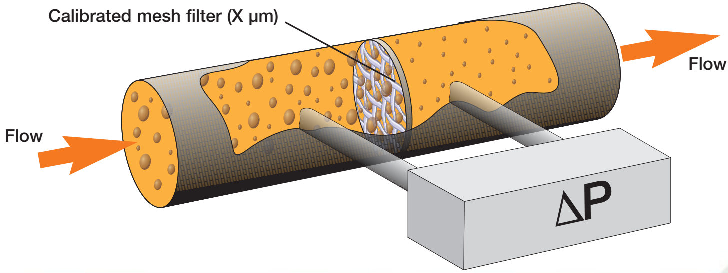



## Mesh Blockage Devices

Filter/mesh blockage devices are an alternative to APCs, especially in conditions where the fluid is opaque or where free water or air is present in the fluid.

## Principle:

Filter/mesh blockage devices determine particulate contamination levels by passing a specifed flow of sample fluid through a series of calibrated mesh screens in a specified sequence. Pressure drop build-up (or flow degradation) is dependent on particulate contamination levels. The mesh is cleaned by backflushing.



# Monitoring and Measurement Equipment

Obtaining accurate and reliable fluid cleanliness data quickly in order to detect abnormal contamination is a key factor in ensuring the efficiency of industrial processes and reducing downtime.

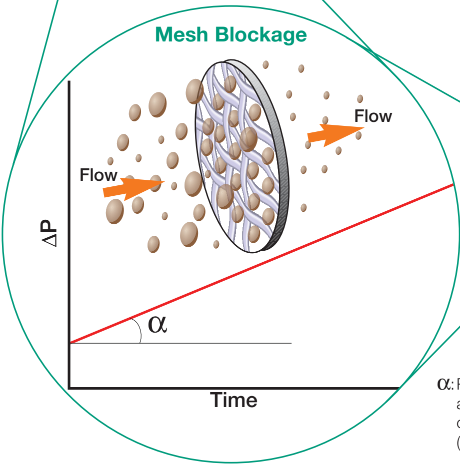
## **Reliable** Monitoring **Solutions**...
## ...**Whatever** the Conditions...**Whatever** the Fluid

PCM200

### Pall Cleanliness Monitors

Provide an assessment of system fluid cleanliness

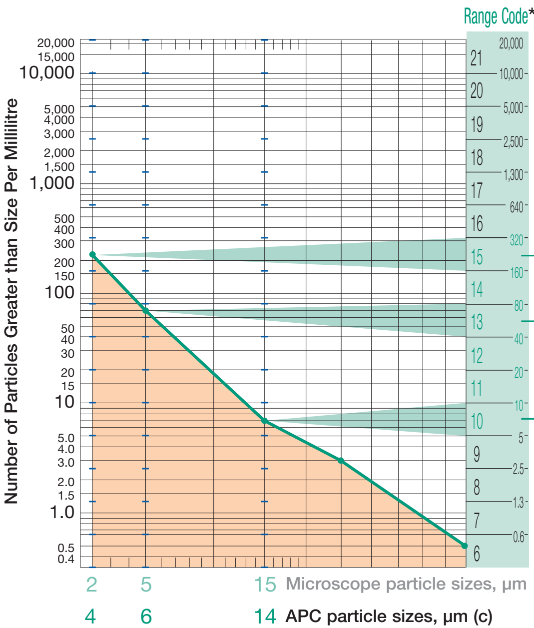
- Proven mesh blockage technology
- On-line and off-line modes of operation
- Results not affected by free water or undissolved air contamination
- Designed for use with dark or cloudy fluids
- ISO 4406, or AS4059 (NAS1638) data output
- Water sensor option




PCM400W

α: Rate of pressure drop increase (slope) across the mesh is based on the level of particulate contamination in the fluid (at constant flow and temperature)

# Understanding the ISO 4406 Cleanliness Code




## Particle Count Summary

| Particle count per mL greater than size | | ISO 4406 Range code |
|---|---|---|
| 4 µm(c) | 230 | 15 |
| 6 µm(c) | 70 | 13 |
| 14 µm(c) | 7 | 10 |

(c) designates 'certified' calibration per ISO 11171, traceable to NIST

* Note: each increase in range number represents a doubling of the contamination level.

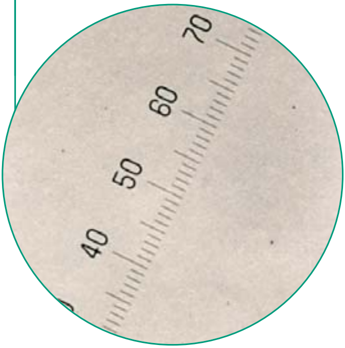
Fluid cleanliness levels found in modern hydraulic systems (typically ISO code <15/13/10 - see the area highlighted in orange) requires on-line monitoring.

The ISO Cleanliness code references the number of particles greater than 4, 6 and 14 µm(c) in one mL of sample fluid.

To determine the ISO Cleanliness code for a fluid, the results of particle counting are plotted on a graph. The corresponding range code, shown at the right of the graph, gives the cleanliness code number for each of the three particle sizes. For the example above the data becones ISO 15/13/10. Where there is not a requirement for data at the first size or the technique used does not give this data e.g. microscope counts and PCM data,"-" is used, e.g. ISO -/13/10.

The ISO 4406 level for a system depends on the sensitivity of the system to contaminant and the level of reliability required by the user. A method for selecting the level for an individual system (called the "Required Cleanliness Level" or "RCL") is described on Pages 37 and 38.

# ISO 4406 Cleanliness Code 13/11/09




**Contaminants:** Some black metal

**Sample Volume:** 25 mL using Ø25 mm membrane filter or 100 mL using Ø47 mm membrane filter

**Magnification:** 100x

**Scale:** 1 division = 10 µm

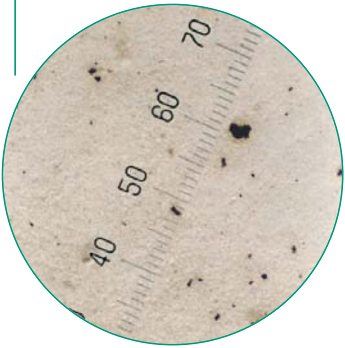
### Particle Count Summary

| Size | Particle Count Range per mL | ISO 4406 Code | SAE AS4059[1,2] (NAS1638) |
|---|---|---|---|
| >4 µm(c) | 52 | 13 | 3A |
| >6 µm(c) | 16 | 11 | 3B |
| >14 µm(c) | 4 | 09 | 3C |

### Description

System with $\beta_{5(c)}>1,000$ wear control filtration

# ISO 4406 Cleanliness Code 19/16/11




**Contaminants:** Bright metal, Black metal, Silica, Plastics

**Sample Volume:** 25 mL using Ø25 mm membrane filter or 100 mL using Ø47 mm membrane filter

**Magnification:** 100x

**Scale:** 1 division = 10 µm

### Particle Count Summary

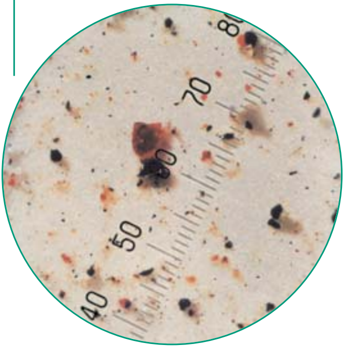
| Size | Particle Count Range per mL | ISO 4406 Code | SAE AS4059[1,2] (NAS1638) |
|---|---|---|---|
| >4 µm(c) | 4,200 | 19 | 10A |
| >6 µm(c) | 540 | 16 | 8B |
| >14 µm(c) | 20 | 11 | 9C |

### Description

System with inadequate filtration.

[1]AS4059 is based on 100 mL. [2]AS4059 classes are for the 3 ISO 4406 size ranges

# ISO 4406 Cleanliness Code 21/19/16



**Sample Volume:** 25 mL using Ø25 mm membrane filter or 100 mL using Ø47 mm membrane filter

**Magnification:** 100x

**Scale:** 1 division = 10 µm

## Particle Count Summary

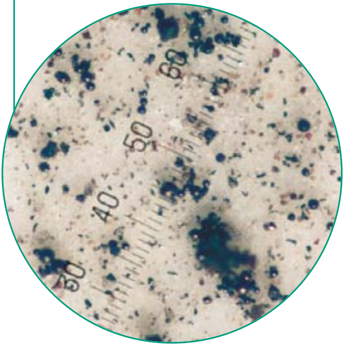
| Size | Particle Count Range per mL | ISO 4406 Code | SAE AS4059[1,2] (NAS1638) |
|---|---|---|---|
| >4 µm(c) | 12,345 | 21 | 11A |
| >6 µm(c) | 3,280 | 19 | 11B |
| >14 µm(c) | 450 | 16 | 11C |

## Description

New oil from barrel

**Contaminants:** Silica, Black metal, Bright metal, Plastics

# ISO 4406 Cleanliness Code 22/20/19



**Sample Volume:** 25 mL using Ø25 mm membrane filter or 100 mL using Ø47 mm membrane filter

**Magnification:** 100x

**Scale:** 1 division = 10 µm

## Particle Count Summary

| Size | Particle Count Range per mL | ISO 4406 Code | SAE AS4059[1,2] (NAS1638) |
|---|---|---|---|
| >4 µm(c) | 31,046 | 22 | 12A |
| >6 µm(c) | 7,502 | 20 | 12B |
| >14 µm(c) | 1,960 | 19 | 12C |

## Description

New system with built-in contaminants

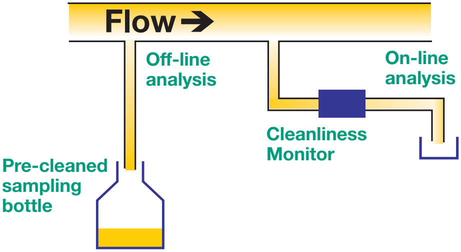
**Contaminants:** Bright metal, Black metal, Rust, Silica, Plastics

[1]AS4059 is based on 100 mL. [2]AS4059 classes are for the 3 ISO 4406 size ranges

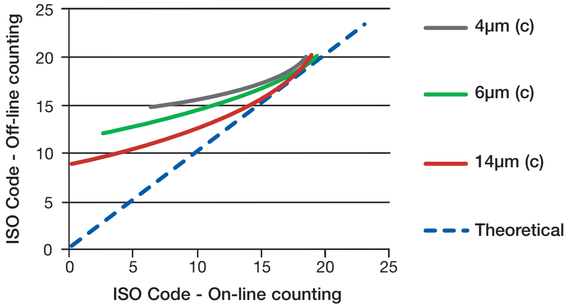
# On-line Particulate Cleanliness Monitoring

## We cannot control what we cannot measure

### Modes of Analysis




### Comparison of on-line counting and off-line counting




Source : Tampere University of Technology, Finland

At the higher contamination levels (higher ISO codes) there is little difference between the two modes of analysis, but as the oil gets cleaner, the level recorded by the off-line analysis inaccurately shows the oil to be dirtier compared to on-line analysis.

### Factors influencing the accuracy of the off-line analysis:

- Introduction of environmental dirt into sample bottle
- Incorrect cleaning of sample bottle
- Inadequate flushing of sampling valve
- Effectiveness of sampling process

# Fluid Sampling Procedure

## Introduction

There are four methods for taking fluid samples, three for extracting samples and one for on-line analysis. Method 1 is the best choice followed by Method 2. Method 3 should only be used if there is no opportunity to take a line sample.

DO NOT obtain a sample from a reservoir drain valve. Always take the sample under the cleanest possible conditions and use pre-cleaned sample bottles.

**If there are no line mounted samplers, fit a Pall sampling device to the Pall filter.**

### Method 1

#### Small ball valve with PTFE or similar seats, or a test point

1. Operate the system for at least 30 minutes prior to taking sample in order to distribute the particulate evenly.
2. Open the sampling valve and flush at least 1 litre of fluid through the valve. Do not close the valve after flushing.
3. When opening the sample bottle, be extremely careful not to contaminate it.
4. Half fill the bottle with system fluid, use this to rinse the inner surfaces and then discard.
5. Repeat step 4 a second time without closing the valve.
6. Collect sufficient fluid to fill 3/4 of bottle (to allow contents to be redistributed).
7. Cap the sample immediately and then close the sample valve.
   **Caution: Do not touch the valve while taking the sample.**
8. Label the sample bottle with system details and enclose in a suitable container for transport.

### Method 2

#### Valve of unknown contamination shedding capabilities

1. Operate the system for at least 30 minutes prior to taking sample in order to distribute particulate evenly.
2. Open the sampling valve and flush at least 3 to 4 Litres of fluid through the valve. (This is best accomplished by connecting the outlet of the valve back to the reservoir by using flexible tubing). Do not close the valve.
3. Having flushed the valve, remove the flexible tubing from the valve with the valve still open and fluid flowing. Remove the cap of the sample bottle and collect sample according to instructions 4 to 6 of Method 1.
4. Cap the sample immediately and then close the sample valve.
   **Caution: Do not touch the valve while taking the sample.**
5. Label the sample bottle with system details and enclose in a suitable container for transport.

# Fluid Sampling Procedure (continued)

## Method 3

### Sampling from Reservoirs and Bulk Containers

Applicable only if Methods 1 and 2 cannot be used

1. Operate the system for at least 30 minutes prior to taking sample in order to distribute the particles evenly.
2. Clean the area of entry to the reservoir where sample will be obtained.
3. Flush the hose of the vacuum sampling device with filtered (0.8 µm) solvent to remove contamination that may be present.
4. Attach a suitable sample bottle to the sampling device, carefully insert the hose into the reservoir so that it is mid-way into the fluid. Take care not to scrape the hose against the sides of the tank or baffles within the tank as contamination may be sucked into the hose.
5. Pull the plunger on the body of the sampling device to produce vacuum and half fill the bottle.
6. Unscrew bottle slightly to release vacuum, allowing hose to drain.
7. Flush the bottle by repeating steps 4 to 6 two or three times.
8. Collect sufficient fluid to 3/4 fill the sample bottle, release the vacuum and unscrew the sample bottle. Immediately recap and label the sample bottle.

## Method 4

### On-line Analysis

This procedure is for portable instruments that have to be connected to the system

1. Check that the sampling position satisfies the reason for sampling and the sampling valves/points complies with the requirements of Method 1;
2. Check that there is sufficient supply pressure to avoid instrument starvation or cavitation;
3. Operate the system for at least 30 min
4. Remove any covers, caps etc from the sampling position and, if practical. clean the exterior of the connection point with a clean solvent.
5. Carefully connect the instrument to the sampling point and minimise the generation of dirt
6. Operate the instrument in accordance with the manufacturer's instructions and flush the sampling lines and instrument with a suitable volume of fluid, as specified by the instrument manufacturer. If not a volume equivalent to 10 times the volume of the connection pipes and instrument is appropriate;
7. The analysis shall be continued until the data from successive samples is either:
   a) within the limits set by the instrument manufacturer; or
   b) the difference is less than 10 % at the minimum particle size being monitored if the required output is particle count; or
   c) the same cleanliness code has been recorded.

# Water Contamination in Oil

### Water contamination in oil systems causes:

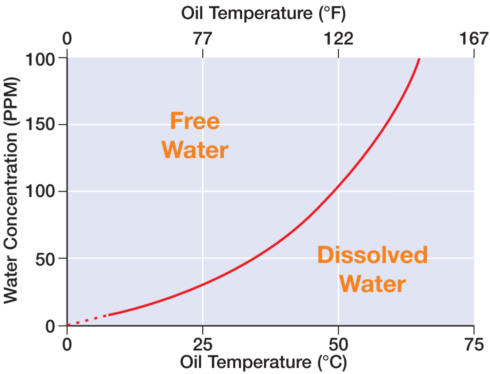
- Oil breakdown, such as additive precipitation and oil oxidation
- Reduced lubricating film thickness
- Accelerated metal surface fatigue
- Corrosion

### Sources of water contamination:

- Heat exchanger leaks
- Seal leaks
- Condensation of humid air
- Inadequate reservoir covers
- Temperature reduction (causing dissolved water to turn into free water)
- Equipment cleaning via high pressure hose

Corrosion in the resevoir

### Typical Water Saturation Curve




Ref: EPRI CS-4555 Turbine oil

Dissolved, emulsified and free water in oil

To minimize the harmful effects of free water, water concentration in oil should be kept as far below the oil saturation point as possible.

### Water Concentration

| | |
|---|---|
| 10,000 PPM | 1% |
| 1,000 PPM | 0.1% |
| 100 PPM | 0.01% |

# Water Content Analysis Methods

| Method | Units | Benefits | Limitations |
|---|---|---|---|
| Crackle Test | None | Quick indicator of presence of free water | Does not permit detection below saturation |
| Chemical (Calcium hydride) | Percentage or PPM | A simple measurement of water content | Not very accurate for dissolved water |
| Distillation | Percentage | Unaffected by oil additives | Limited accuracy on dry oils |
| FTIR | Percentage or PPM | Quick and inexpensive | Accuracy does not permit detection below 0.1% (1,000 PPM) |
| Karl Fischer | Percentage or PPM | Accurate at detecting low levels of water (10 - 1,000 PPM) | Not suitable for high levels of water. Can be affected by additives |
| Capacitive Sensor (Water Sensor) | Percentage of saturation or PPM | Accurate at detecting dissolved water (0 - 100% of saturation) | Cannot measure water levels above saturation (100%) |

# Water Sensor Technology

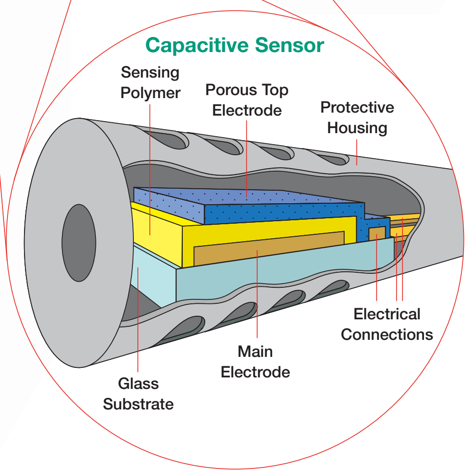
Water contamination in fluids can cause numerous problems such as additive depletion, oil oxidation, corrosion, reduced lubricating film thickness, microbial growth, and reduction of dielectric strength. Water sensors incorporate a probe that can be directly immersed in the fluid to monitor dissolved water content and temperature.

A variety of water sensor models are available including explosion proof options. Contact Pall to determine the most appropriate model for your application.

**WS08**
In-Line
Water Sensor

**WS10**
In-Line
Water sensor

**WS09**
Portable
Water Sensor

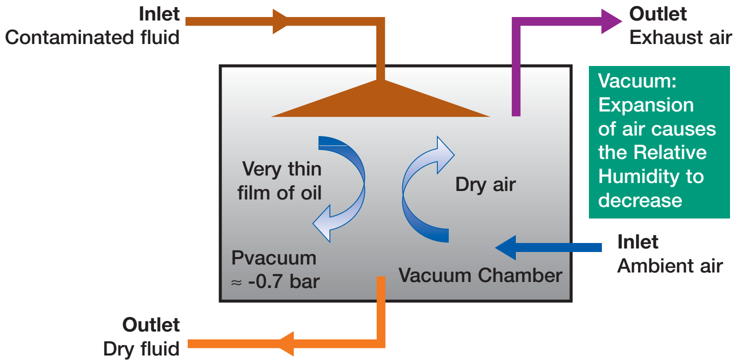



## Capacitive Sensor Principle:

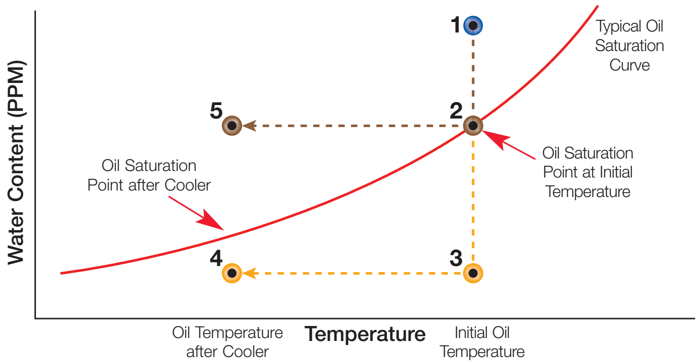
The electrical resistance of the dielectric polymer changes as the relative humidity changes. The water sensor probe is protected to avoid erratic results from solid contaminants settling on the porous top electrode.

# Operating Principle of Pall Fluid Conditioning Purifiers

## Principle: Mass transfer by evaporation under vacuum




## Removing free water is never enough!




**1** Initial water content is above saturation (free water).

**2** Maximum water removal capability of "free water removal" devices (coalescers, centrifuges, etc.) is to the oil's saturation point.

**3** Water content achieved with mass transfer dehydration is significantly below the oil's saturation point.

**4** Water content achieved with mass transfer dehydration remains below the oil's saturation point even after oil is cooled. This prevents the formation of harmful free water.

**5** If only free water is removed at initial temperature, when oil is cooled the amount of harmful free water in the oil can increase significantly.

# Pall Portable Oil Purifiers

Pall HLP6
HVP Series

Pall HNP022
HNP Series

Pall HNP074
HNP Series

Pall oil purifiers are available in a wide range of flowrates: from 10 L/min to 200 L/min (2.6 USgpm to 52.8 USgpm).

**Contact Pall for special variants such as explosion proof, ATEX, or fully remote controlled purifiers**

## Oil Purifier Features

- Removes 100% free and up to 90% dissolved water
- Removes 100% free and up to 90% dissolved gases
- Unlimited water and air removal capacity
- Wide fluid compatibility
- Fully portable for multiple site application
- Simple to operate
- No heating required - does not burn oils
- Low power consumption
- Low operating costs
- Automatic control of the main operating parameters
- Robust and reliable under harsh conditions
- Easy maintenance

## Typical Applications

- Hydraulic oils
- Lubrication oils
- Dielectric oils
- Phosphate-esters
- Quench oils

# Pall Total Cleanliness Management (TCM) for Industrial Manufacturing

**Enhancing Fluid Cleanliness, Advancing productivity, Assuring Reliability**

Customized solutions for process improvement

KEY TARGETS

## Pall TCM program

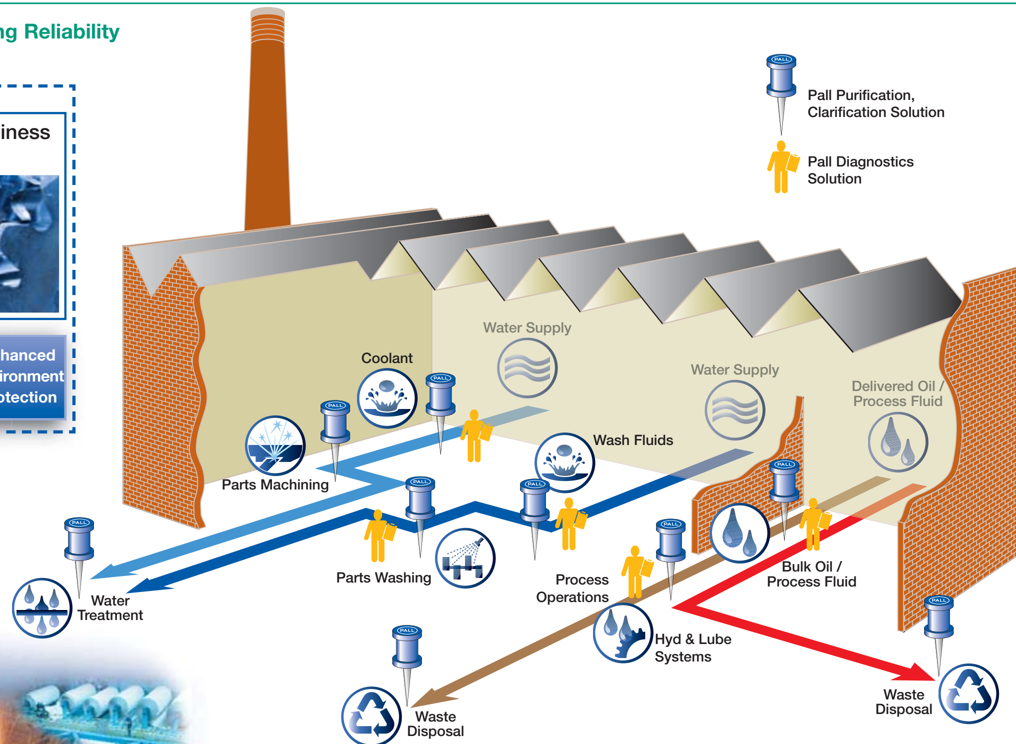
**Fluid Cleanliness Management**

**Component Cleanliness Management**

- Increased Production
- Improved Product Quality
- Enhanced Equipment Reliability
- Improved Health & Safety
- Enhanced Environment Protection

Pall provides customized contamination control solutions to improve system performance and reduce operating costs.

Challenge us to deliver sustainable and cost-effective solutions to all your contamination problems.




## Examples of applications where the Pall TCM program can be implemented

**Typical Fluids**

- Parts washing fluids
- Cutting fluids
- Process fluids
- Water
- Coolants
- Water glycols
- Fuels
- Solvents
- Hydraulic oils
- Lubrication oils
- Dielectric oils
- Phosphate-esters
- Quench oils

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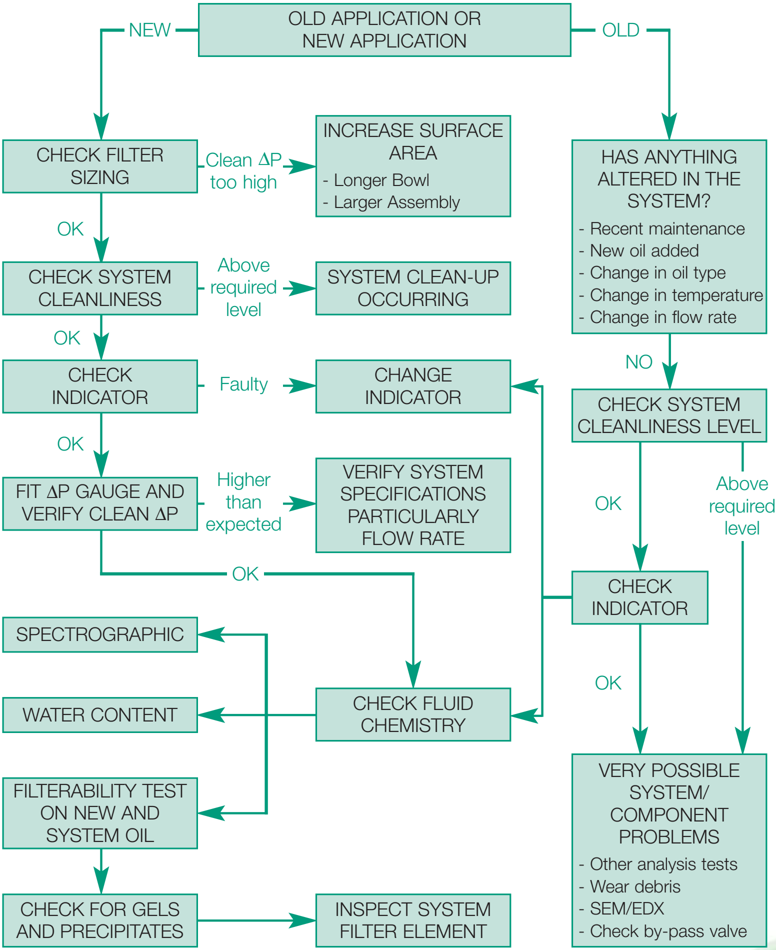
# Short Element Life Checklist



# Lube and Hydraulic Filter Locations

## Pressure Line

- To stop pump wear debris from travelling through the system
- To catch debris from a catastrophic pump failure and prevent secondary system damage
- To act as a Last Chance Filter (LCF) and protect components directly downstream of it

## Return Line

- To capture debris from component wear or ingression travelling to the reservoir
- To promote general system cleanliness

## Kidney loop/off-line

- To control system cleanliness when pressure line flow diminishes (i.e. compensating pumps)
- For systems where pressure or return filtration is impractical
- As a supplement to in-line filters to provide improved cleanliness control and filter service life in high dirt ingression systems

## Reservoir Air Breather

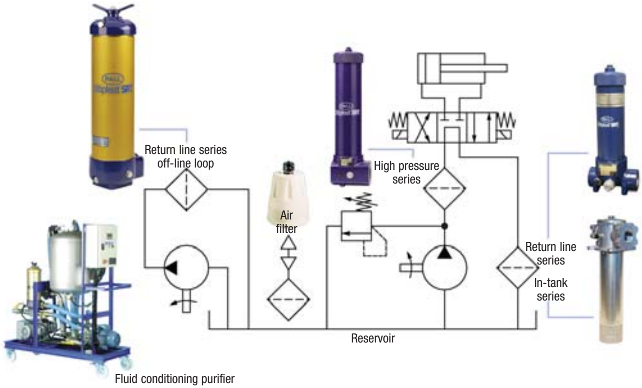
- To prevent ingression of airborne particulate contamination
- To extend system filter element service life
- To maintain system cleanliness

## Additional filters should be placed ahead of critical or sensitive components

- To protect against catastrophic machine failure (often non-bypass filters are used)
- To reduce wear
- To stabilize valve operation (prevents stiction)

## Flushing Filter

- To remove particles that have been built-in to the system during assembly or maintenance before start-up
- To remove large particles that will cause catastrophic failures
- To extend 'in-service' filter element life

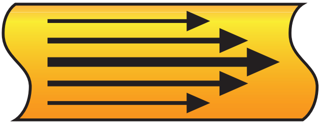


# Flushing Recommendations

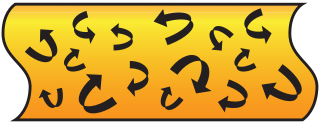
The aim of flushing is to remove contamination from the inside of pipes and components that are introduced during system assembly or maintenance.
This is accomplished by passing clean fluid through the system, usually at a velocity higher than that during normal operation to pick up the particles from the surface and transport them to the flushing filter.

**Omission or curtailment of flushing will inevitably lead to rapid wear of components, malfunction and breakdown.**

**Reynolds Number (Re):** A non-dimensional number that provides a qualification of the degree of turbulence within a pipe or hose.



**Laminar Flow**



**Turbulent Flow**

Laminar Flow - Re < 2,000
Transitional Flow - Re 2,000 - 4,000
Turbulent Flow - Re > 4,000

**For effective flushing procedures the Reynolds Number (Re) should be in excess of 4000**

The flow condition in a pipe or hose can be assessed using Reynolds Number (Re) as follows:

$$Re = \frac{Ud}{\nu} \times 1{,}000 \quad \text{or} \quad Re = 21{,}200 \times Q / (\nu \times d)$$

Re = Reynolds Number
U = Mean flow velocity (m/s)
d = Pipe internal diameter (mm)
$\nu$ = Kinematic viscosity of fluid in cSt ($mm^2/s$)
Q = Flow rate (L/min)

# Filters for Hydraulic and Lubricating Fluids

Whatever your application in hydraulics or lubrication, Pall offers the most innovative filtration technology available to achieve the optimum cleanliness levels of your fluids.

## Pall Filters Offer:

- ß≥1000 removal efficiency
- Low, clean differential pressure
- Long service life
- Environmentally friendly coreless filter pack

## Pall Filtration Milestones

1965 – Ultipor Filters
1966 – Ultipor Dirt Fuse Filters
1986 – Ultipor II Filters
1986 – Ultipor II Dirt Fuse Filters
1991 – Ultipor III Filters
1991 – Ultipor III Dirt Fuse Filters
1993 – Coreless Ultipor III Filters
2000 – Ultipor SRT Filters
2004 – Ultipleat SRT Filters

## A History of “Industry Firsts”

| | |
|---|---|
| • Glass fiber filter media | 1965 |
| • Fixed pore filter media | 1965 |
| • ß≥75 filtration ratings | 1965 |
| • 3000 psid collapse-rated filters | 1966 |
| • Tapered pore filter structure | 1986 |
| • Polymeric drainage meshes | 1986 |
| • ß≥200 filtration ratings | 1986 |
| • Helical outer wrap | 1990 |
| • Coreless/cageless construction | 1993 |
| • ß≥1000 filtration ratings | 1999 |
| • Stress-resistant filter medium | 2000 |
| • ISO Code (CST) filtration ratings | 2004 |
| • Laid-over pleating | 2004 |
| • Triboelectric charge-resistance | 2004 |
| • In-to-out flow path | 2004 |
| • Life-extending drainage meshes | 2009 |

PALL
Ultipleat® SRT FILTRATION

## Ultipleat® SRT Filters

Stress resistant technology, anti-static construction, unequalled filtration performance

## A revolutionary filter technology for hydraulic and lube applications

- Smaller size
- Increased resistance to system stresses
- High flow capability
- Improved cleanliness control
- Increased equipment protection
- Triboelectric charge resistance

PALL Ultipleat® SRT FILTRATION

**Media Substrate Support Layer** (not shown)**:** Provides support for the media and aids in drainage flow

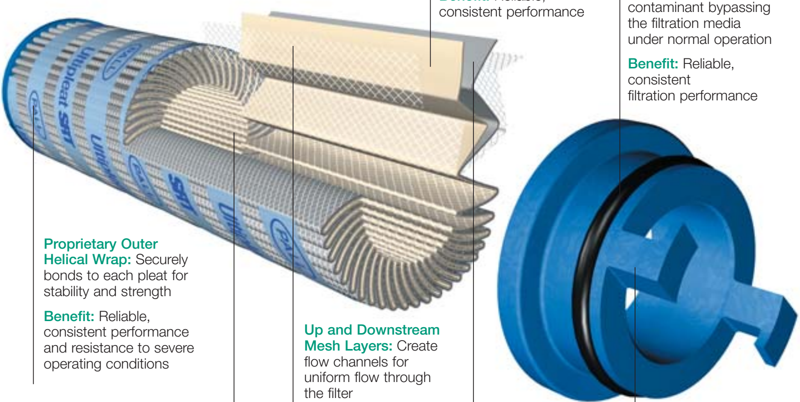
**Benefit:** Reliable, consistent performance

**Proprietary Cushion Layer:** Provides support for the media and protection from handling

**Benefit:** Reliable, consistent performance

**O-ring Seal:** Prevents contaminant bypassing the filtration media under normal operation

**Benefit:** Reliable, consistent filtration performance



**Proprietary Outer Helical Wrap:** Securely bonds to each pleat for stability and strength

**Benefit:** Reliable, consistent performance and resistance to severe operating conditions

**Up and Downstream Mesh Layers:** Create flow channels for uniform flow through the filter

**Benefit:** Extended element life for lower operating costs

**Triboelectric Charge Resistant Design:** Element pack composed of materials for minimized triboelectric charge generation and no electrostatic discharges

**Benefit:** No damage to filter element or housing or other system components from electrostatic discharge; minimizes fluid degradation

**Coreless/Cageless Design:** Outer element cage is a permanent part of the filter housing

**Benefit:** Lighter, environmentally friendly element for reduced disposal costs and ease of element change-out

**SRT Media:** Inert, inorganic fibers securely bonded in a fixed, tapered pore structure with increased resistance to system stresses such as cyclic flow and dirt loading

**Benefit:** Improved performance over the life of the filter and more consistent fluid cleanliness

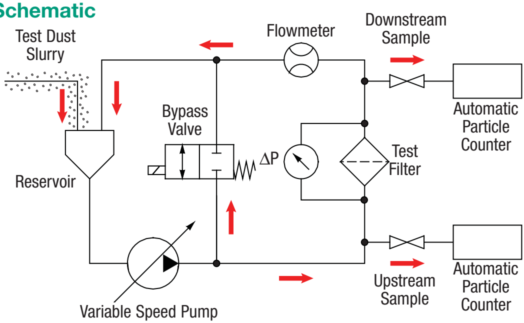
**Auto-Pull Element Removal Tabs:** Corrosion-resistant endcaps feature exclusive Auto-Pull tabs for automatic element extraction upon opening the housing

**Benefit:** Ease of element change-out

# Advanced Test Method for Measuring Filter Performance

## Cyclic Stabilization Test*

### Schematic



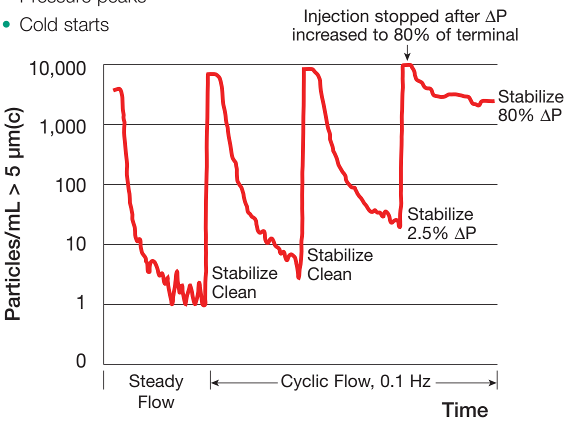

Cyclic Stabilization Test (CST) measures a filter's ability to clean up a contaminated system under cyclic flow (25 to 100 % of rated flow) and contaminant loading conditions

*based on SAE ARP4205

### Concept:

As opposed to ISO 16889 that only tests filters under steady state conditions, the Cyclic Stabilization test is used to evaluate hydraulic filter performance under typical stressful operating cyclic conditions such as:

- Flow surges
- Pressure peaks
- Cold starts




CST ISO 4406 Cleanliness Code ratings are based on the stabilized cleanliness achieved at 80 % of the net terminal pressure drop, considered the worst operating condition

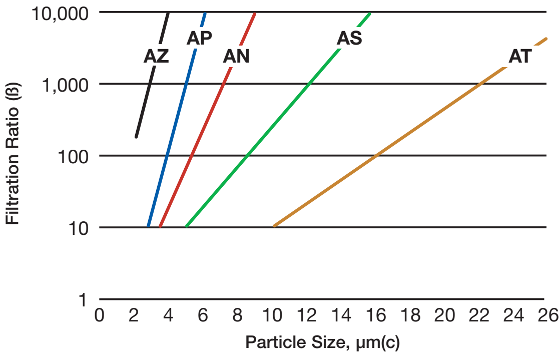
For clarity, only the number of particles/mL >5μm(c) are shown

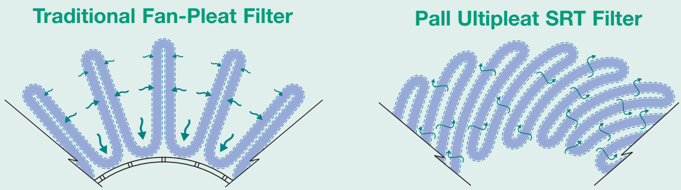
# Pall Ultipleat® SRT Filter Performance Data

| Ultipleat SRT Grade | Cleanliness Code Rating (ISO 4406) from Cyclic Stabilization Test* |
|---|---|
| AZ | 08/04/01 |
| AP | 12/07/02 |
| AN | 15/11/04 |
| AS | 16/13/04 |
| AT | 17/15/08 |

* based on SAE ARP 4205

**Multi-Pass Filter Rating (ISO 16889)**




**The optimized pleat geometry of SRT filtration provides:**

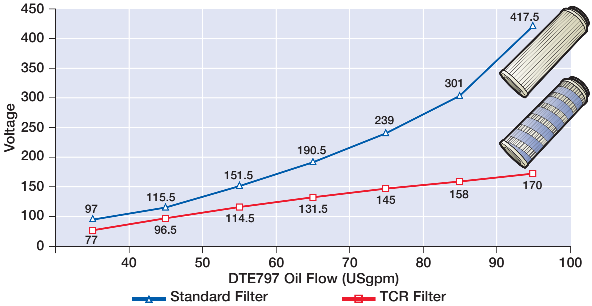
- Uniform flow distribution and increased flow capacity
- Maximum filter surface area and element life

# Triboelectric Charging Effect on Filtration

## Triboelectric Charging Resistant (TCR) Filters

- Designed to dissipate triboelectric charge build-up
- Produce only minimal triboelectric charging of the fluid (as measured by the fluid charge)
- Minimize fluid degradation and varnish formation

Electrical discharge occurring inside oil tank



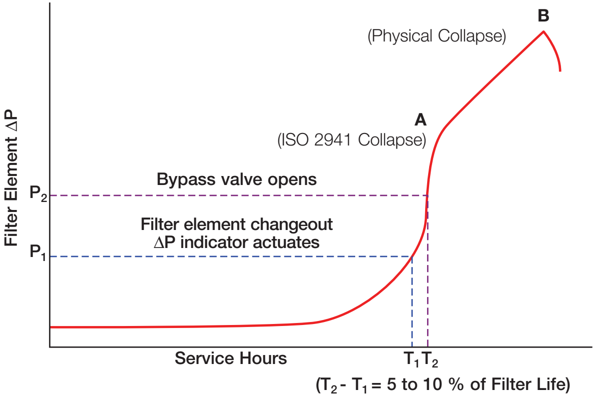

# Filtration & Contamination Standards

| | |
|---|---|
| ISO 2941 | Filter elements - Verification of collapse/burst pressure rating |
| ISO 3968 | Filters - Evaluation of differential pressure versus flow characteristics |
| ISO 4021 | Extraction of fluid samples from lines of an operating system |
| ISO 4407 | Determination of particulate contamination by the counting method using an optical microscope |
| ISO 11171 | Calibration of automatic particle counters for liquids |
| ISO 16889 | Filter elements - Multi-pass method for evaluating filtration performance of a filter element |
| ISO 18413 | Component cleanliness - Inspection document and principles related to contaminant collection, analysis and data reporting |
| ISO 21018-3 | Monitoring the level of particulate contamination of the fluid - Part 3: Use of the filter blockage technique |
| SAE ARP4205 | Filter elements - Method for evaluating dynamic efficiency with cyclic flow |

Note: This is a small selection of ISO standards relevant to hydraulic and lubrication applications.

# Differential Pressure Indicators and Switches

Differential pressure (ΔP) indicators and switches notify the operator of the filter condition. This allows a replacement filter to be installed before filter element bypass occurs.

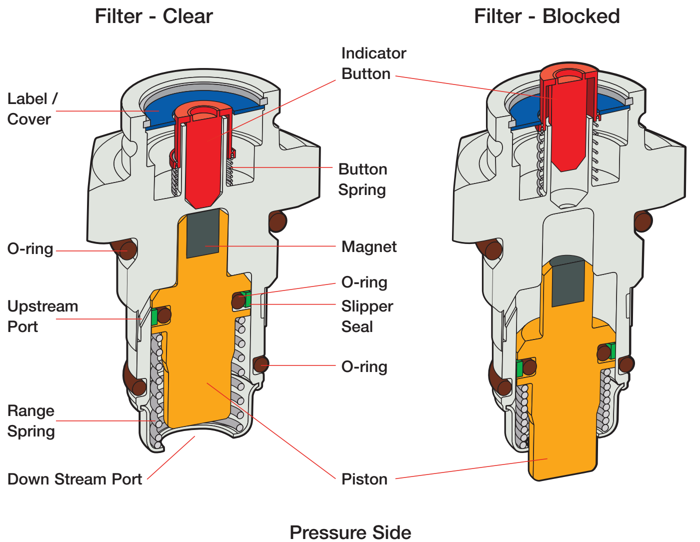



ΔP across the filter increases as contaminant is trapped within the filtration medium. A ΔP indicator actuates at $P_1$, signalling the need for element change before the bypass relief valve opens at $P_2$. The bypass valve protects the filter and system from excessive differential pressure.

Without a bypass valve, continued operation at higher ΔP risks degradation of filtration performance (point A) and filter element collapse (point B) where the integrity of the filter element is lost.

# Differential Pressure Indicators and Switches

## Mechanical and Electrical Options Available




### Technical principle of the mechanical indicators:

Differential pressure indicators operate by sensing the ΔP between ports upstream and downstream of the filter element. When the ΔP across the internal piston/magnet assembly reaches a preset value, determined by the range spring, the piston assembly moves downward, reducing the attractive force between the magnet and indicator button. The indicator button spring then overcomes the reduced magnetic force and releases the button to signal the need for element change. Activation can be visual using a button as shown here or electrical using a microswitch.

A variety of differential pressure indicator models are available. Contact Pall to determine the most appropriate ΔP indicators or switches for your applications.

# Filters for Process Fluids

**Recommended for industrial applications to treat water, fuels, aqueous solutions, and low viscosity process fluids.**

Recognizing that different applications have different fluid cleanliness and filtration requirements, the Pall range of Melt Blown filter products is simply defined to help you choose the best solution at the most economic cost.

## Highly Critical Cleanliness

For applications such as fluid make-up, cleanliness control, polishing or clarification, where the full range of solid contamination removal including silt is required.

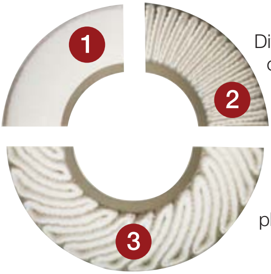
## Critical to General Particulate Control

Cleanliness control in wash applications, machining applications where high surface finish is required, single pass in-line last chance filtration applications, and for general purpose fluid clarification.

## General Particulate Control

Coarser ratings for primary or pre-filtration applications, or higher fluid flow applications where a fluid cleanliness level is not specified.

| Particulate Control | Efficiency Rating% | Recommended Range (μm) |
|---|---|---|
| Highly Critical | 99.98% | 1, 3, 6, 12, 20 |
| Critical to General | 99.9% | 40, 70, 90 |
| General | 90% | 100, 150, 200 |




Different medium configurations can be applied to specific user requirements. The Pall filter element range is available in 1 depth, 2 fan pleated and 3 patented laid over pleat (Ultipleat®) designs.

## Applications

- Component wash fluids
- Cutting fluids
- Process fluids
- Water
- Coolants
- Water glycols
- Mineral and synthetic oils
- Lubricants
- Fuels
- Solvents

# Separation Systems for Process Fluids

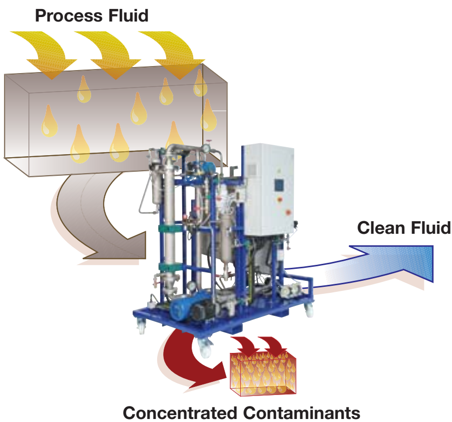
## Tramp Oil Separator

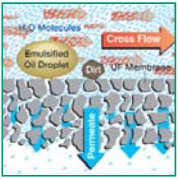
A unique, patented unit designed to remove free and dispersed tramp oil from metal working and parts washing fluids.

Tramp oil is unwanted oil that has entered into the fluid system, such as hydraulic and lubrication oils from the machine itself or cutting fluids and rust inhibitors that have been carried over on the part from previous processes.

## Crossflow Filtration Systems

Pall Clarisep crossflow filtration systems remove tramp oil, suspended solids and bacteria from water-based fluids to maintain the fluid in optimum condition for extended service life. These systems can also be used to process oily wastewater, minimizing the volumes that have to be disposed of off-site.




## Pall Clarisep Membrane

Pall crossflow systems direct fluid flow across the surface of a porous membrane. Emulsified oil and grease, bacteria, fungi and suspended solids are larger than the membrane pores and are, therefore, held back, allowing clean fluid to pass downstream.

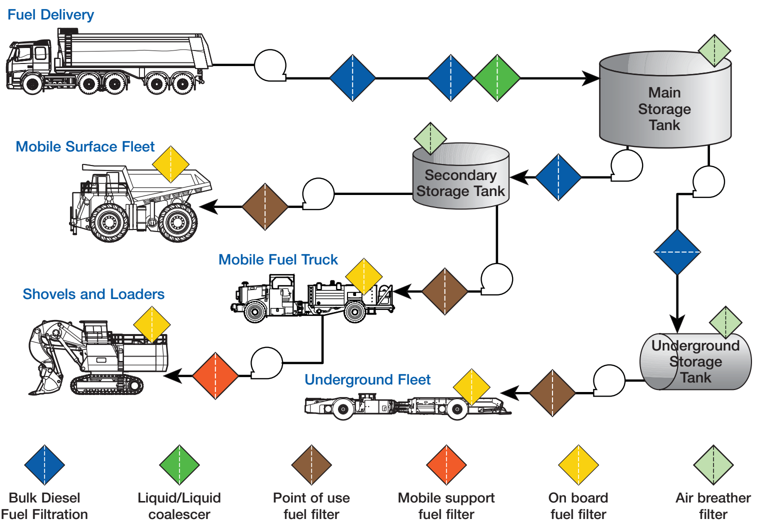
Pall offers a range of membrane technologies, allowing the optimum solution to be selected for a specific application. All Pall Clarisep systems automatically regenerate in-situ for extended life.

# Diesel Fuel Purification

## Diesel Engine Fuel Cleanliness Control - From delivery, to storage, to pump, to injector

The latest injection technology for diesel powered engines requires superclean fuels. Fine filtration and liquid/liquid coalescence are strategically required along the diesel supply chain.

### Example of a Basic Mining Fuel Distribution System




Pall Ultipleat® Diesel Fuel Filter Elements

Pall Ultipleat® SRT Filter Elements

Pall PhaseSep® Coalescers

# Component Cleanliness Management

Component Cleanliness Management (CCM) is a comprehensive program designed to help clients achieve desired component cleanliness. After working with you to validate processes and set cleanliness specifications, the program follows a defined path to assess component cleanliness and identify areas for improvement. We then provide recommendations and assist in their implimentation

**Design it**
**Build it**
**Keep it**
**CLEAN**


## Pall Cleanliness Cabinets

Pall Component Cleanliness Cabinets facilitate the accurate, reliable and repeatable determination of component cleanliness.

- Stainless steel construction
- Controlled extraction environment
- Automated cleaning to “blank” values
- Pressurized solvent dispensing and recycling circuits.
- Meet ISO 18413, ISO 16232 and VDA 19 procedures

# Required Fluid Cleanliness Level Worksheet*

Selection of the appropriate cleanliness level should be based upon careful consideration of the operational and environmental conditions. By working through this list of individual parameters, a total weighting can be obtained from the graph on page 38, to give the Required Cleanliness Level (RCL).

**Table 1. Operating Pressure and Duty Cycle**

| Duty | Examples | Operating Pressure (bar (psi)) 0-70 (0-1000) | >70-170 (>1000-2500) | >170-275 (>2500-4000) | >275-410 (>4000-6000) | >410 (>6000) | Actual |
|---|---|---|---|---|---|---|---|
| Light | Steady duty | 1 | 1 | 2 | 3 | 4 | |
| Medium | Moderate pressure variations | 2 | 3 | 4 | 5 | 6 | |
| Heavy | Zero to full pressure | 3 | 4 | 5 | 6 | 7 | |
| Severe | Zero to full pressure with high frequency transients | 4 | 5 | 6 | 7 | 8 | |

**Table 2. Component Sensitivity**

| Sensitivity | Examples | Weighting | Actual |
|---|---|---|---|
| Minimal | Ram pumps | 1 | |
| Below average | Low performance gear pumps, manual valves, poppet valves | 2 | |
| Average | Vane pumps, spool valves, high performance gear pumps | 3 | |
| Above average | Piston pumps, proportional valves | 4 | |
| High | Servo valves, high pressure proportional valves | 6 | |
| Very high | High performance servo valves | 8 | |

**Table 3. Equipment Life Expectancy**

| Life Expectancy (hours) | Weighting | Actual |
|---|---|---|
| 0-1,000 | 0 | |
| 1,000-5,000 | 1 | |
| 5,000-10,000 | 2 | |
| 10,000-20,000 | 3 | |
| 20,000-40,000 | 4 | |
| >40,000 | 5 | |

**Table 4. Component Replacement Cost**

| Replacement Cost | Examples | Weighting | Actual |
|---|---|---|---|
| Low | Manifold mounted valves, inexpensive pumps | 1 | |
| Average | Line mounted valves and modular valves | 2 | |
| High | Cylinders, proportional valves | 3 | |
| Very high | Large piston pumps, hydrostatic transmission motors, high performance servo components | 4 | |

**Table 5. Equipment Downtime Cost**

| Downtime Cost | Examples | Weighting | Actual |
|---|---|---|---|
| Low | Equipment not critical to production or operation | 1 | |
| Average | Small to medium production plant | 2 | |
| High | High volume production plant | 4 | |
| Very high | Very expensive downtime cost | 6 | |

**Table 6. Safety Liability**

| Safety Liability | Examples | Weighting | Actual |
|---|---|---|---|
| Low | No liability | 1 | |
| Average | Failure may cause hazard | 3 | |
| High | Failure may cause injury | 6 | |

* Adapted from BFPA/P5 Target Cleanliness Level Selector 1999 Issue 3.

**Table 7. System Requirement**

| Cleanliness Requirement Total Weighting | Total |
|---|---|
| Sum of 'Actual' weighting from sections 1 through 6 | |

Using the chart below, determine where the 'Cleanliness Requirement Total Weighting' number from Table 7 intersects the red line. Follow across to the **left** to find the recommended ISO 4406 Code.

**Table 8. Environmental Weighting**

| Environment | Examples | Weighting Single Filter | Weighting Multiple Filters* | Actual |
|---|---|---|---|---|
| Good | Clean areas, few ingression points, filtered fluid filling, air breathers | 0 | -1 | |
| Fair | General machine shops, some control over ingression points | 1 | 0 | |
| Poor | Minimal control over operating environment and ingression points e.g. on-highway mobile equipment) | 3 | 2 | |
| Hostile | Potentially high ingression (e.g. foundries, concrete mfg., component test rigs, off-highway mobile equipment) | 5 | 4 | |

* Single filter or multiple filters with the same media grade on the system.

**Table 9. Required Filtration Level**

| Filtration Requirement Total Weighting | Total |
|---|---|
| Add Environmental Weighting (Table 8) to System Requirement Total (Table 7) | |

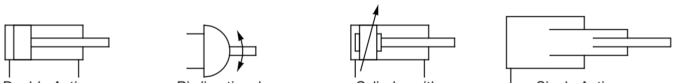
Using the chart below, determine where the 'Required Filtration Level' total in Table 9 intersects the red line. Follow across to the **right** to find the corresponding recommended Pall filter grade.


†Using on-line particle counting

# Common Fluid Power Circuit Diagram Symbols

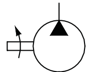
ISO1219-1: Fluid power systems and components - Graphic symbols and circuit diagrams - Part 1: Graphic symbols for conventional use and data processing applications.

## Cylinders and Semi-rotary Actuators

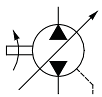


Double Acting Cylinder | Bi-directional Semi-rotary Actuator | Cylinder with Adjustable Cushioning | Single Acting Telescopic Cylinder

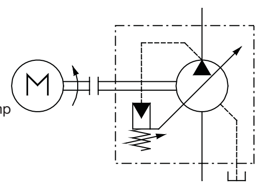
## Pumps and Motors



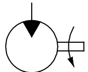
Fixed Displacement Pump
Uni-directional Flow
Anti-clockwise Rotation



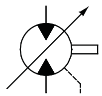
Variable Displacement Pump
Bi-directional Flow
Anti-clockwise Rotation




Pressure Compensated Pump
[Shortform Symbol]
Uni-directional Flow
External Case Drain
Clockwise Rotation
Electric Motor Driven



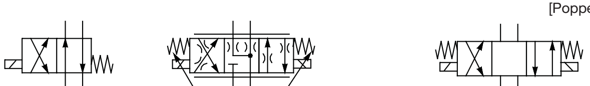
Fixed Displacement Motor
Anti-clockwise Rotation



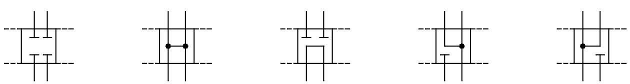
Variable Displacement Motor
Bi-directional Rotation
External Case Drain

## Directional Control Valves (Unspecified Actuation)

2 Port, 2 Position Normally Closed | 2 Port, 2 Position Normally Open | 3 Port, 2 Position Spring Return | 3 Port, 2 Position Spring Return [Poppet type]

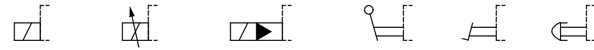


4 Port, 2 Position Spring Return | 4 Port, [3 Position] Proportional | 4 Port, 3 Position, Spring Centred (See Below for Centre Conditions)



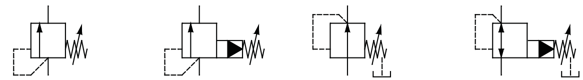
Closed Centre | Open Centre | Tandem Centre | Float Centre | Regeneration Centre

## Directional Control Valve Actuation



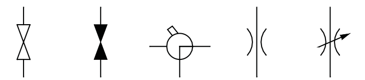
Switching Solenoid | Proportional Solenoid | Electro-Hydraulic (Pilot) Operation | Hand Lever | Foot Pedal | Palm Button

## Pressure Control Valves

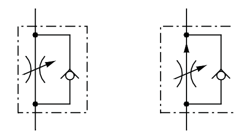


Direct Operated Relief Valve | Pilot Operated Relief Valve | Direct Operated Reducing Valve | Pilot Operated 3 Way Reducing Valve

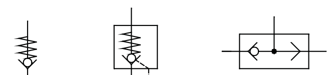
## Isolation and Flow Control Valves



Isolator (Open) | Isolator (Closed) | Diverter Valve | Orifice (Jet) | Throttle Valve

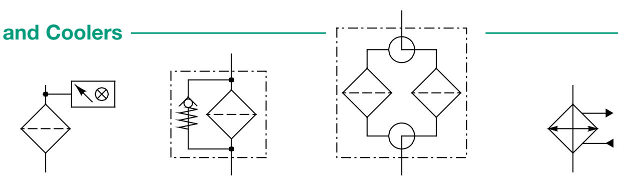


Throttle-Check Valve | Pressure Compensated Flow Control Valve



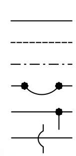
Check Valve | Pilot-to-Open Check Valve | Shuttle Valve

## Filters and Coolers

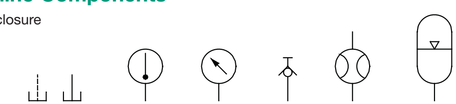


Filter with Visual Clogging Indicator | Filter with Bypass Valve | Duplex Filter with Manual Valve | Cooler (Heat Exchanger)

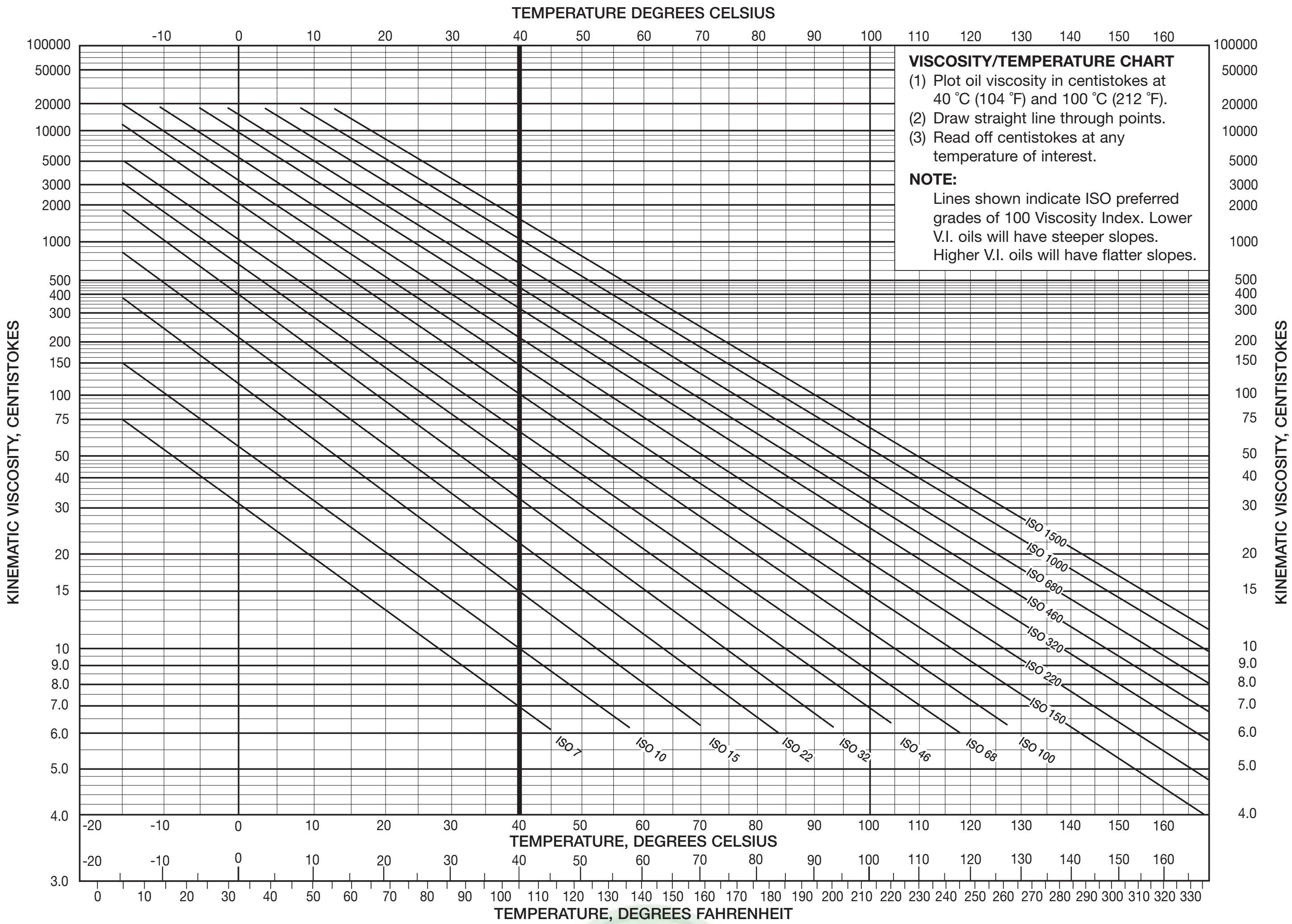
## Instrumentation and Pipeline Components



Flow Line, Symbol Enclosure
Pilot Line, Drain Line
Symbol Enclosure
Flexible Hose
Lines Connecting
Lines Crossing



Connections To Tank | Temp. Gauge | Pressure Gauge | Test Point | Flow meter | Gas loaded accumulator


TEMPERATURE DEGREES CELSIUS
VISCOSITY/TEMPERATURE CHART
(1) Plot oil viscosity in centistokes at 40 °C (104 °F) and 100 °C (212 °F).
(2) Draw straight line through points.
(3) Read off centistokes at any temperature of interest.
NOTE:
Lines shown indicate ISO preferred grades of 100 Viscosity Index. Lower V.I. oils will have steeper slopes. Higher V.I. oils will have flatter slopes.
KINEMATIC VISCOSITY, CENTISTOKES
ISO 1500
ISO 1000
ISO 680
ISO 460
ISO 320
ISO 220
ISO 150
ISO 7
ISO 10
ISO 15
ISO 22
ISO 32
ISO 46
ISO 68
ISO 100
TEMPERATURE, DEGREES CELSIUS
TEMPERATURE, DEGREES FAHRENHEIT

# Measurement Conversion Factors

| To convert → | into | Multiply by |
|---|---|---|
| **into ←** | **To convert** | **Divide by** |
| Litre | Cubic metre | 0.001 |
| Litre | Gallon (US) | 0.2642 |
| Litre | Gallon (UK) | 0.22 |
| Micrometre (Micron) | Inch | 0.000039 |
| Foot | Inch | 12 |
| Inch | Millimetre | 25.4 |
| Metre | Foot | 3.28 |
| Metre | Yard | 1.09 |
| Mile | Kilometre | 1.609 |
| Litre/sec | Cubic metre/min | 0.06 |
| Metre/sec | Kilometre/hour | 3.6 |
| Kilogram | Pound | 2.205 |
| Pound | Ounce | 16 |
| Kilowatt | Horsepower | 1.341 |
| Kilowatt | BTU/hour | 3412 |
| Atmosphere | PSI | 14.7 |
| Bar | PSI | 14.5 |
| KiloPascal | PSI | 0.145 |
| Bar | KiloPascal | 100 |
| Bar | Inches of mercury (Hg) | 29.53 |
| Inches of Water | Pascal (Pa) | 249 |
| Celsius (Centigrade) | Fahrenheit | °C x 1.8 + 32 |
| Degree (Angle) | Radian | 0.01745 |

To convert units appearing in column 1 (left column) into equivalent values in column 2 (centre column), **multiply** by factor in column 3.

Example: To convert 7 Litres into Cubic Metres, multiply 7 by 0.001 = 0.007.

To convert units appearing in column 2 (centre) into equivalent values of units in column 1 (left column), **divide** by factor in column 3.

Example: To convert 25 psi into bar, divide 25 by 14.5 = 1.724.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Because of technological developments related to the products, systems, and/or services described herein, the data and procedures are subject to change without notice. Please consult your Pall representative or visit www.pall.com to verify that this information remains valid. Products in this document may be covered by one or more of the following patent numbers: EP 0 930 926; US 5,480,547; US 6,332,987; EP 0 667 800; EP 0 982 061; EP 1 380 331; US 5,543,047; US 5,690,765; US 5,725,784; US 6,113,784; US 7,083,564; US 7,318,800; EP 0 667 800; EP 0 982 061; EP 1 380 331; US 5,543,047; US 5,690,765; US 5,725,784; US 6,113,784; US 7,083,564; EP 1 656 193; EP 0 470 485; US 5,252,207; US 5,552,048; EP 1 105 201



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