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NFI National Filters, Inc. ®



Experts in Filter Manufacturing

Introduction to Hydraulic Filtration



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HFTP-6-060123

What is Fluid Power?

Fluid power is a term describing hydraulic and pneumatic technologies. Both technologies use a fluid (liquid or gas) to transmit power from one location to another. With hydraulics, the fluid is a liquid (usually oil), whereas pneumatics use a gas (usually compressed air).

Both are forms of power transmission, which is the technology of converting power to a more useable form and distributing it to where it is needed. The common methods of power transmission are electrical, mechanical, and fluid power.

Although they are sometimes viewed as competing technologies, no single method of power transmission is the best choice for all applications. In fact, most applications are served by a combination of technologies. However, fluid power offers important advantages over the other technologies.

Fluid power systems easily produce linear motion using hydraulic or pneumatic cylinders, whereas electrical and mechanical methods usually use a mechanical device to convert rotational motion to linear.

Fluid power systems can generally transmit equivalent power within a much smaller space than mechanical or electrical drives, especially when extremely high force or torque is required.

Fluid power systems also offer simple and effective control of direction, speed, force, and torque using simple control valves. Fluid power systems often do not require electrical power, which eliminates the risk of electrical shock, sparks, fire, and explosions.



MANUFACTURER MEMBER

Visit the [National Fluid Power Association](#) for more helpful information & links.

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Introduction to Hydraulic Filtration

Hydraulics

The Basic Idea:

The basic idea behind any hydraulic system is very simple: ***Force that is applied at one point is transmitted to another point using an incompressible fluid.***

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

This creates a mechanical advantage.

Off-highway equipment is probably the most common application of hydraulics. Whether it's construction, mining, agriculture, waste reduction, or utility equipment, hydraulics provides the power and control to tackle the task at hand and often to provide motive power to move equipment from place to place — especially when track drives are involved. Hydraulics are also widely used in heavy industrial equipment in factories, in marine and offshore equipment for lifting, bending, pressing, cutting, forming, and moving heavy work pieces.

Hydraulics - Continued

The basic components that make up a hydraulic system are:

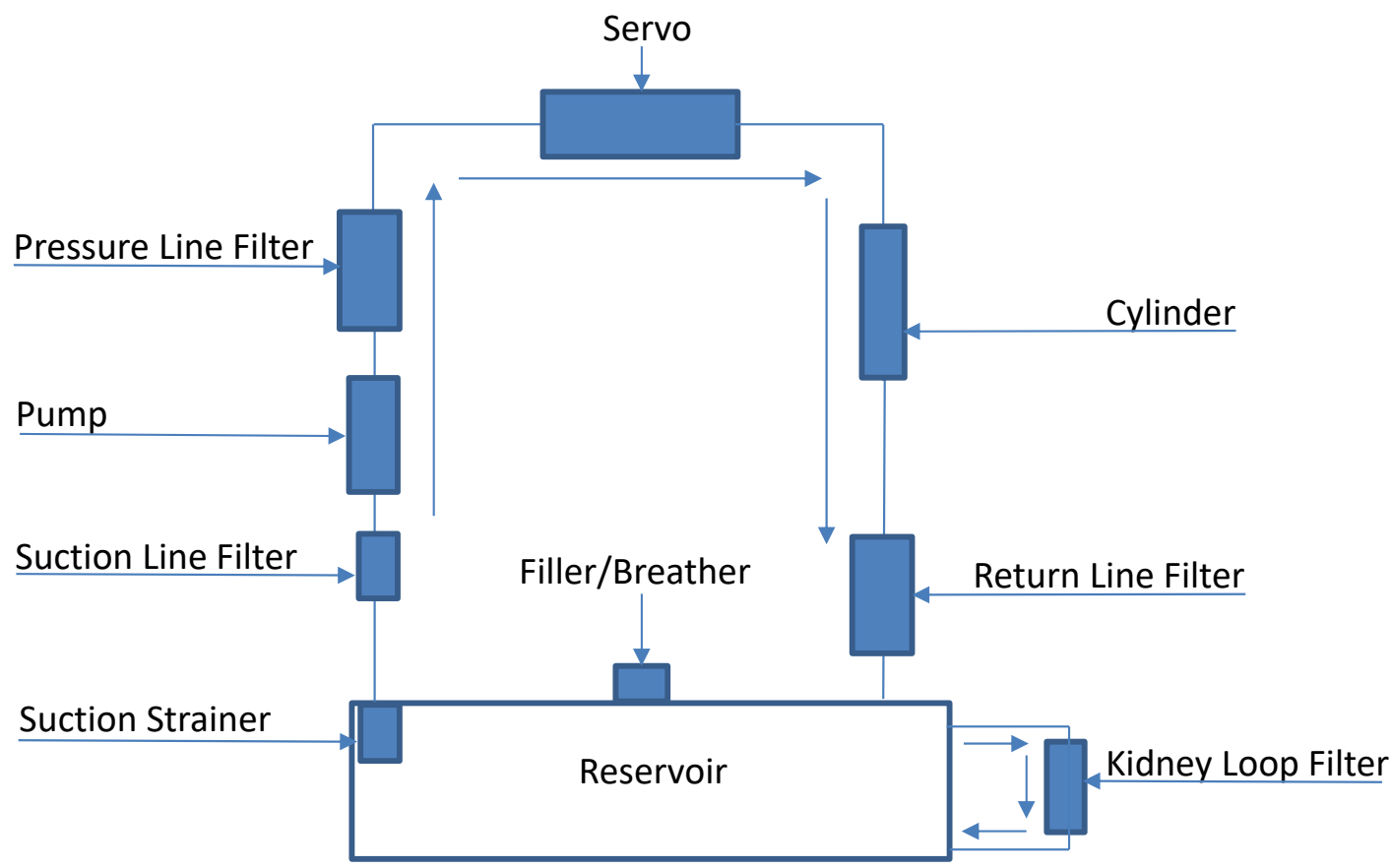
- ❖ Reservoir
- ❖ Pump
- ❖ Valves
- ❖ Fluid
- ❖ Motor
- ❖ Hose
- ❖ Filter
- ❖ Cylinder

The hydraulic reservoir stores non-pressurized hydraulic fluid, typically hydraulic oil. This fluid is the lifeblood of the hydraulic system. The hydraulic oil travels through a filter which collects the impurities.



Hydraulic pumps transfer the fluid from the reservoir to the hydraulic system. This transfer raises the energy level of the fluid by increasing its pressure. The motor provides the power source for the pump.

Basic Hydraulic System Diagram



Advantages of Hydraulics

Variable Speed: The actuator (A device for converting energy into mechanical energy i.e., a motor or cylinder) in a hydraulic system can be driven at different speeds.

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

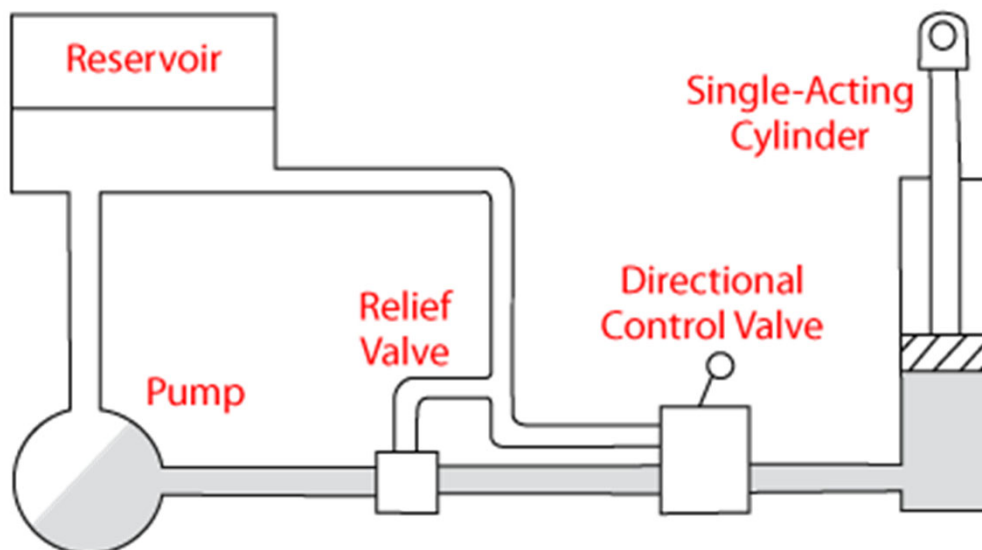
Overload Protection: The pressure relief valve in a hydraulic system protects the system from overload damage.

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

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

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

Basic Hydraulic Circuit



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Introduction to Hydraulic Filtration

Contamination

Properly sized, installed and maintained filter elements are key in maintaining a hydraulic system's functionality.

The role of a hydraulic filter is to remove contamination from the flow of oil, to help prevent premature component wear and system failure, thus reducing operating costs.

Over 75% of all hydraulic system failures are a result of contamination.

Contamination can be very costly within a hydraulic system as it could cause the following problems:

- ❖ Increased overall maintenance costs
- ❖ Loss of production (downtime)
- ❖ Component replacement costs
- ❖ Frequent fluid replacement
- ❖ Increased cost of fluid disposal
- ❖ Increased scrap rate

The disposal cost of a drum of waste oil, can be 4-5 times the cost of a drum of new oil.

Contamination - Continued

Contamination interferes with the main function of hydraulic fluids within a hydraulic system which is to:

- ❖ Lubricate moving parts of components
- ❖ Seal clearances between moving parts
- ❖ Act as an energy transmission medium
- ❖ Act as a heat transfer medium

Examples of contaminant damage:

- ❖ Component wear
- ❖ Orifice blockage
- ❖ Creation of rust or oxidation
- ❖ Depleted additives
- ❖ Biological growth
- ❖ Formation of chemical compounds

There are many types of contamination possible within a hydraulic system, some examples are:

- ❖ Acids & other chemicals
- ❖ Particulate (dirt, dust, rust, paint chips, sand)
- ❖ Metal wear (aluminum, copper, iron, lead, tin)
- ❖ Sealants (silicon, teflon tape, pastes)
- ❖ Sludge, oxidation & other corrosion products
- ❖ Water

Contamination - Continued

Typical Hydraulic Component Clearances

Hydraulic Fluid creates a lubricating film to keep precision parts separated. The film should be thick enough to fill the clearance between moving parts. This reduces wear rates and if the wear rate is kept low enough, a component is more likely to reach the life expectancy.

Component	Micron Size
Anti-friction bearings	0.5
Vane pump	0.5-1
Gear pump	0.5-5
Servo Valves	1-4
Hydrostatic bearings	1-25
Piston pump	5-40
Actuators	50-250

The actual thickness of the film depends on viscosity of the fluid, applied load, and the speed of the two surfaces. In many components the loads are so extreme that they squeeze the lubricant into a very thin film that is less than 1 micrometer thick. If the load becomes too high, the film can be punctured by the surface roughness of the two moving parts. This result creates harmful friction.

Relative Sizes of Particles

Particle sizes are measured on the micrometer scale. One micrometer (or “micron”) is one-millionth of one meter, or 39 millionths of an inch.

Keep in mind that most damage causing particles in hydraulic or lubrication systems are smaller than 40 micron. They are so small that they cannot be seen by the naked eye.

Substance	Micron Size	Inches
Grain of table salt	100	.0039
Human hair	70	.0027
Lower limit of visibility	40	.0016
Milled Flour	25	.0010
Red blood cells	8	.0003
Bacteria	2	.0001

Where does Contamination come from

Built-in

This contamination can be caused during the manufacturing, assembly, installation and testing of hydraulic components.

New Hydraulic Oil

New hydraulic fluid is contaminated to a level above what is acceptable for most hydraulic systems. Never assume the oil is clean until it has been filtered.

During Operation

The pump, actuators, cylinders, and motors are major sources of contamination. The wear of these components are a hazard to the hydraulic system.

Seals

Due to time, temperature, and viscosity; seals within the system can degrade releasing particulate into the fluid.

Ingested

Contaminates can be ingested into a closed system through breathers, leaking seals and worn cylinder rods.

Induced

Opening the hydraulic system for maintenance or leaving the system open during operations, allows airborne particles to enter the system.

Fluids

High water content fluids tend to allow biological growth and generate organic contaminants and microbes.

Water Contamination

Water is present in all hydraulic systems and just like solid contaminants it must be removed from the hydraulic fluid.

Water can cause damage to a hydraulic system in the following ways:

- Corrosion of metal components
- Abrasive wear
- Oil additive breakdown
- Viscosity change
- Increase in electrical conductivity
- Bearing fatigue

Water can be removed by the following methods:

- Absorption (low concentration free water)
- Centrifuges (high concentration free water)
- Vacuum Dehydration (high concentration free and dissolved states)

Absorption is accomplished by using filter elements that are designed to absorb free water from the fluid.



National Filters is able to co-pleat water absorbing media along with either paper or microglass media layers, to allow for particulate removal as well as the ability to absorb water.

NFI can manufacture water removal elements in all styles of filter elements, except in high pressure filter locations.

ISO Cleanliness Levels

The international rating system for fluid contamination levels is called the ISO contamination code.

Most component manufacturers publish filtration level recommendations using the ISO code.

Manufacturers' ISO contamination levels are based on controlling the amount of particles, 4 μm , 6 μm and 14 μm , in the hydraulic systems oil.

This level is identified by measuring the number of particles 4 μm and greater, 6 μm and greater, and 14 μm and greater, in a 1ml sample of hydraulic oil.

Example:

Larger than 4 μm = 7,000 = Code# 20

Larger than 6 μm = 2,000 = Code# 18

Larger than 14 μm = 200 = Code# 15

ISO Code = 20/18/15

Code Number	More Than	Up to and Including
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	.64	1.3
6	.32	.64

ISO Cleanliness Levels - Continued

Listed are some typical ISO cleanliness recommendations from component manufacturers.

These are guidelines; always check the ratings specified by the manufacturer of the specific component.

Subjecting components to fluid with higher contamination levels may result in much shorter component life.

PRESSURE RATING	<3000 PSI	>3000 PSI
<i>Pumps</i>	<i>ISO RATINGS</i>	
Fixed Gear Pumps	19/17/15	18/16/13
Fixed Vane Pumps	19/17/14	18/16/13
Fixed Piston Pumps	18/16/14	17/15/13
Variable Vane Pump	18/16/14	17/15/13
Variable Piston Pump	17/15/13	16/14/12
<i>Valves</i>	<i>ISO RATINGS</i>	
Directional (solenoid)	20/18/15	19/17/14
Pressure (modulating)	19/17/14	19/17/14
Flow Controls (standard)	19/17/14	19/17/14
Check Valves	20/18/15	20/18/15
Cartridge Valves	20/18/15	19/17/14
Load-sensing Directional Valves	18/16/14	17/15/13
Proportional Pressure Controls	18/16/13	17/15/12
Proportional Cartridge Valves	18/16/13	17/15/12
Servo Valves	16/14/11	15/13/10
<i>Actuators</i>	<i>ISO RATINGS</i>	
Cylinders	20/18/15	20/18/15
Vane Motors	19/17/14	18/16/13
Axial Piston Motors	18/16/13	17/15/12
Gear Motors	20/18/15	19/17/14
Radial Piston Motors	19/17/15	18/16/13

ISO Cleanliness Levels - Continued

Displayed below are suggestions on which NFI media grade to use to achieve the desired ISO cleanliness level.

Grade	ISO Cleanliness Level
1G	14/12/9 – 13/11/8
3G	15/13/10 – 14/12/9
5/6G	18/16/13 – 15/13/10
10G	19/17/14 – 18/16/13
20/25G	20/18/15 – 19/17/14

Beta Ratio

Beta ratio is the efficiency of a filter as it relates to a multi-pass test. During the test the number of particles upstream are measured against the number of particles downstream of the filter.

Beta (β) = $N_{\mu x}/N_{dx}$ (x is the pre-selected particle size)
 N_{μ} = number of particles of size x and greater upstream
 N_d = number of particles of size x and greater downstream

Example:

If we are trying to determine the efficiency of the filter at a 10 micron particle size, Beta 10 would refer to the ratio of particles greater than 10 micron upstream divided by the number of particles greater than 10 micron downstream.

$\beta = N_{\mu x}/N_{dx}$
 $= 1,000/5$
 $= 200$

The relationship between the Beta ratio and efficiency is as follows:
 $\% \text{ efficiency} = 100 - (100/(\beta))$

For example: $\beta_{10} = 200$
 $\% \text{ efficiency} = 100 - (100/(\beta))$
 $= 100 - (100/200)$
 $= 99.5\%$

Beta Ratio	Efficiency
2	50%
10	90%
20	95%
75	98.7%
100	99.%
200	99.5%
1,000	99.9%

This means that 99.5% of all particles greater than 10 micron are removed.

Beta Ratio - Continued

Below are the efficiencies for our Paper and Glass media grades:

NFI Paper Media Chart

Grade	$\beta_x > 2$ (50%)
3P	3
5P	5
10P	10
20/25P	20
40P	37

NFI Glass Media Chart

Grade	$\beta_x > 200$ (99.5%)	$\beta_x > 1,000$ (99.9%)
1G	1	2.5
3G	2.9	4
5/6G	4.2	5.5
10	10	12.1
20/25G	20	22.3
40G	35	38.2

NOTE: Many customers confuse Beta 200 and Beta 1,000 as different grades, but glass media is tested to record the efficiency at both intervals as noted with different micron ratings for these efficiencies above.

NFI Media Grades

National Filters can use any of the following media grades in conjunction with any style filter element:

- Absolute Rated Microglass **(G)**
1, 3, 5/6, 10/12, 20/25, 40
- Nominal Rated Cellulose **(P)**
3, 5, 10, 20/25, 40
- Sintered Fiber **(SF)**
3, 5, 10, 20
Available upon request
- Stainless Steel Wire **(SS)**
10, 25, 40, 50, 60, 74,
80, 100, 125, 150, 200,
250, 300, 420, 500, 600,
700, 1000, 2000



NFI can manufacture water removal filters in any size element. We co-pleat the water removal media along with the grade of microglass **(GW)** or cellulose **(PW)** above as per your needs.

Types of filters in a Hydraulic system

Filler/Breather

Located on the hydraulic reservoir to prevent atmospheric contamination from entering and to allow for adequate air movement inside the reservoir.

Suction Line Filter

Normally placed between the reservoir and the pump.

Suction Strainer

Used inside the reservoir to keep large contaminants from entering the pump.

Pressure Line Filter

Cleans the oil that comes from the pump to protect the expensive downstream components.

Return Line Filter

Collects dirt from around the hydraulic system before the oil returns to the reservoir.

Kidney Loop Filter

Often referred to as an off-line system that is separate and independent of the hydraulic system.



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Introduction to Hydraulic Filtration

Filter Type Characteristics

Suction Line Filters

- Initial stage of filtration.
- Normally placed between the reservoir and pump.
- Easier to service and less expensive than many other types of filters.
- Housing size tends to be larger than similar flow return or pressure filter housings because the restriction in the suction must be kept low.



SUCTION LINE FILTERS

Pressure Line Filters

- Also known as “last-chance” filtration.
- Cleans the oil that comes directly from the pump to protect more expensive downstream components (such as valves & actuators).
- High-efficiency/low micron retention.
- Offers protection from catastrophic pump failure.
- Pressure line filters can be low, medium or high collapse.



PRESSURE LINE FILTERS

Filter Type Characteristics - Continued

Return Line Filters

- Collects contaminants from around the hydraulic system before the fluid returns to the reservoir.
- Usually for low-pressure housings.
- Lower pressure ratings result in lower costs than pressure filters.
- In-line or in-tank for easy access.
- Subject to pressure and flow surges.



Images of Hydraulic Systems



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Common Markets

- Power Generation
- Pulp & Paper
- Steel Mills
- Oil & Gas
- Marine
- Foundries
- Mining
- Wind Turbines
- Automotive Plants
- Construction
- Agricultural
- Off-highway
- Forestry
- Waste Handling
- Cranes
- Lift Trucks
- Military
- Plastic Injection
- Machine Tools
- Packaging Equipment
- Textile Machinery
- Elevators, moving stairways and conveyors
- Equipment Manufacturers that purchase hydraulic components



Key Terms

Absolute Rating

The rating determines the size of the largest glass bead a filter will pass under low pressure differentials and pulsating flows. An absolute rating means that the filter is capable of removing at least 98.7% of a specific size particle.

Beta Ratio

The formula used to calculate the filtration efficiency of a filter using data obtained from a multi-pass test.

By-pass

A secondary passage for fluid.

Differential Pressure

Pressure drop across the filter assembly between the inlet and outlet ports after passing through the filter.

Dirt Holding Capacity

The quantity of contaminant a filter element can trap and hold before the maximum allowable differential pressure is reached.

Element Collapse Pressure

The differential pressure the filter element is capable of withstanding without collapsing.

Filter Media

The material within a filter element that retains suspended solids during the filtration process.

Indicator

A mechanical device with points of scale to provide a visual perspective of the state of a component.

Key Terms - Continued

Kidney Loop

An off-line circulation loop that uses a separate pump that runs continuously, circulating and conditioning the fluid.

Lubricity

The property of the fluid that keeps friction low and maintains adequate film moving between moving parts.

Micron

A unit of measure equal to one millionth of a meter. Also called a micrometer. The measurement used to determine the particle size of contaminants in a fluid system.

Micron Rating

The size, in microns, of the particles a filter will remove.

Multi-pass Testing

A laboratory test that continuously injects fluid, with a uniform amount of contaminant, that is pumped through the filter. The test determines the filter's efficiency by measuring the contamination levels upstream compared to the levels downstream of the filter.

Nominal Rating

A loose value that relates to the removal efficiency of the filter. A nominal rating typically means that the filter is capable of removing 50% of a specific size particle.

Silt

Very fine particulate under 5 micron in size.

Viscosity

The thickness of the fluid as measured by its resistance to flow.

What can NFI offer?

- At National Filters we believe in making it as easy as possible to search, review and purchase hydraulic filters online. View pricing and real time delivery 24/7 @ www.nationalfilters.com.
- When logged in to your account you will have access to everything you need to quote your customer right over the phone.
- Our products are priced very competitively to provide our customers with instant cost savings with the same quality as the OEM.
- Search by competitive filter part number (124k+ cross references) or by popular filter brands (Products).
- Use our [Request-A-Quote](#), [Target Price](#), [Custom Quote](#) and [RGA Request](#) pages for quick and easy processing of your requests.
- To keep up with everything going on at National Filters please join our mailing list, and follow us on Facebook, Twitter and LinkedIn.

Popular Brand Search (PRODUCTS page)

- Our [PRODUCTS](#) page allows you to search and view our crosses for the 40 most popular hydraulic filter brands we identify.
- We cross reference 500+ filter brands.

INDUSTRIAL FILTRATION SPECIALISTS

Popular Hydraulic Filter Brands we Cross:

AIRFIL	ARGO	BALDWIN	BEHRINGER
CIM-TEK	DONALDSON	EPPENSTEINER	FAIREY ARLON (PARKER)
FILTER-MART	FILTERSOFT	FILTREC	FINN FILTER (PARKER)
HYDAC/HYCON	HY-PRO	IKRON	INTERNORMEN
MAHLE	MAIN FILTER	MARION FLUID POWER	MOOG
MP FILTRI	NAPA	NORMAN	OMT
PALL	PARKER	PTI/TEXTRON	PUROLATOR/FACET
REFILCO	REXROTH	SCHROEDER	SOFIMA
STAUFF	SWIFT	TRIBOGUARD (DONALDSON)	UFI
VICKERS (EATON)	WESTERN FILTER (DONALDSON)	WIX	ZINGA


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Cross Reference Search

Sample Cross Reference Page

- Customers can type in a part number into the Cross Reference Search field to display our equivalent replacement element.
- Our database will return all matches that begin with the number that is queried. Multiple pages of potential filters may be displayed. **REAL TIME STOCK DISPLAYED.**
- When logged in the user is also able to view the technical data, which opens in a new window, by clicking on the search result.
- If the customer would like to continue with an order or quote they would select the ADD TO CART or ADD TO QUOTE button which would continue the order/quote process.




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hc9600fks8z search results

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NFI P/N: PPL9600-8-10G-V

PRICE: \$52.08

STOCK: 0

PART TYPE: HYDRAULIC FILTER - PRESSURE LINE

Replaces: HC9600FKS8Z | PALL

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Technical Data

Sample Technical Data Screen



PRINT

TECHNICAL DATA FOR PPL9600-8-10G-V



* Element may vary from the image displayed.

Part:	HYDRAULIC FILTER - PRESSURE LINE
Media:	MICROGLASS
Overall Height:	8.31
OD Top (in):	3.12
ID Top (in):	1.70
OD Bottom (in):	3.12
Flow Direction:	OUTSIDE-IN
Seal Material:	VITON
Micron Rating:	10
Beta Ratio:	200/13
Collapse Rating:	305
Operating Temp:	- 13 TO 250

BACK

*Please note that our standard elements are not recommended for Skydrol and other aggressive hydraulic fluids. Please contact our sales department for our compatible version to your application.

Sample Technical Data Sheet

NFI P/N: **PPL9600-8-10G-V**
PART TYPE: **HYDRAULIC FILTER - PRESSURE LINE**
MEDIA: **MICROGLASS**



TECHNICAL INFORMATION

Flow Direction:	OUTSIDE-IN
Seal Material:	VITON
Micron Rating:	10
Beta Ratio:	200/13
Collapse Rating: (psid)	305
Operating Temp:	- 13 TO 250
BPVS Setting: (bar)	
Fluid Compatibility:	HH/HL/HM/HV/HR/HG/HFA/HFB/HFC/HFD

DIMENSIONAL INFORMATION

Overall height:	8.31
OD Top:	3.12
ID Top:	1.70
OD Bottom:	3.12
ID Bottom:	
Burst Rating:	
Thread Size:	

NOTES

- Technical information may change without notice.
- Element may vary from the image displayed.
- Standard elements are not recommended for Skydrol & other aggressive hydraulic fluids.
- Contact sales for our compatible version to your application.
- All dimensions in inches.

***Clicking on the PRINT button in the technical data screen will open the printable technical data sheet.**

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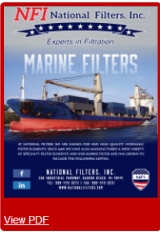
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