

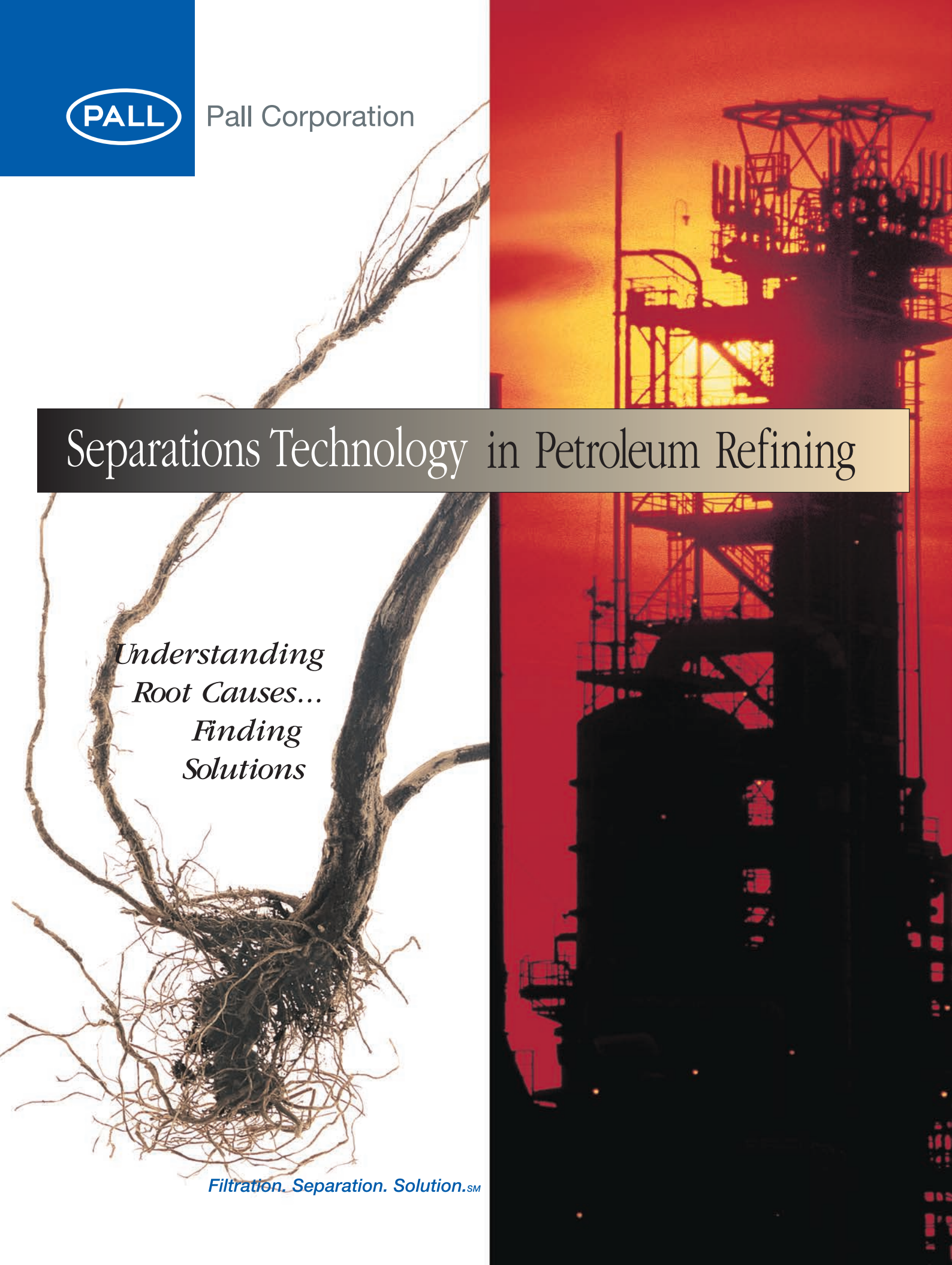


Pall Corporation

Separations Technology in Petroleum Refining

*Understanding
Root Causes...
Finding
Solutions*

Filtration. Separation. Solution.SM





Searching for root causes and applying separations technology.

Refiners are constantly looking to increase production capabilities, reduce costs, and generate increased revenues and profits. To accomplish this goal, refiners regularly search for new ways to improve efficiency, while continuing to deliver high-quality products at profitable prices. Pall can play a key role in this continuous improvement process. Our products and services help optimize productivity, reliability, quality, safety, and environmental protection, while reducing overall operating costs.

Pall understands the importance of improving these key business components. Success here can directly impact a refiner's bottom line.

The first step to continuous improvement is to identify problem areas and understand the root cause. After proper detection and documentation, Pall works to develop a solution to the problem that best utilizes our advanced separations and filtration technology.

We put decades of experience and know-how to work to design and implement long lasting solutions that enable refiners to:

- Meet tighter clean fuels product specifications
- Meet tougher environmental regulations
- Maintain or increase refinery throughput
- Lengthen run time
- Reduce maintenance

Pall Corporation maintains its position as the world leader in filtration and separations technology with a steady stream of innovative, high-quality products backed by excellent service and support. We invest heavily in R&D and technical service to provide the refining industry with exceptional returns on their investment.

Our filtration and separations solutions have been successfully deployed within refineries throughout the world.

Our customized Total Fluid ManagementSM approach helps refiners

- Increase production
- Reduce unscheduled downtime
- Meet environmental emission standards
- Reduce corrosion rates, lengthen plant life, and improve safety
- Raise product yield and conversion
- Minimize product reprocessing
- Enable capacity expansion with minimum capital expense
- Help to debottleneck existing plants during revamps or clean fuels upgrades
- Help to utilize opportunity crudes
- Enable refiners to meet tighter product specifications
- Lower energy costs
- Lower maintenance costs
- Protect catalyst beds

Pall offers a full range of high-quality filtration and separations systems that meet the unique requirements of the diversified refineries that we serve. We design and manufacture nearly all of our media, elements, vessels, and fully integrated separations systems. By supplying the broadest array of polymeric, inorganic, metallic, and ceramic media available, Pall is able to select the optimal filter medium to meet specific process requirements.

In rare cases, where Pall does not have an appropriate product, we work with the customer to develop a new, customized product that can solve the problem. We are eager to take on new challenges and are committed to keeping up with evolving market demands.

Pall offers worldwide technology consultation and support through our Scientific and Laboratory Services (SLS) department. SLS is a worldwide network of scientists and engineers experienced in investigating and solving various and often complex problems encountered in fluid clarification and separation processes. In addition, a specialized group of scientists and engineers is solely dedicated to customers in the petroleum refining industry. Pall has state-of-the-art laboratories located throughout the United States, Europe, and Asia.

All Pall manufacturing facilities adhere to uniform manufacturing procedures and have been granted International Standards Organization (ISO) certification to ISO 9001. This ensures that Pall filtration products and systems will perform exactly as specified, no matter where they are installed.

Root cause analysis and Total Fluid Management are the principles on which we base our success in the petroleum refining industry. We look forward to applying our knowledge, technology, and experience to help you achieve a higher level of process control and efficiency in your operations.

Contents

- Separation of Solids from Liquids
Pages 9-15
- Separation of Solids from Gases
Pages 16-20
- Separation of Liquids and Solids from Gases
Pages 21-22
- Separation of Liquids from Liquids
Pages 23-24



SLS test facility.

Refinery Filtration Recommendations

The process diagram and corresponding charts illustrate typical applications within a refinery. Processes are detailed within the drawing and include major filter locations and applications. The numbered items coincide with the recommended filter/separation application tables below. Note: should a particular concern or filtration/separation application arise that is not addressed in this brochure, please contact your local Pall representative for assistance.

Particulate Filters/Backwash Filters ¹		
Application	Problem	Benefits
① Aromatics	Liquid hydrocarbon and particulates cause foaming and fouling problems.	Reduced solvent losses and foaming; improved energy consumption; reduced maintenance, labor, and disposal costs.
② Catalyst Protection	Solid particulates plug and deactivate catalyst bed and foul feed exchanger; water can deactivate some catalysts.	Improved conversion efficiency and profitability; fewer catalyst change-outs; improved conversion/yield; lower maintenance, labor, and catalyst costs; longer cycle times; less backwash fluid reprocessing; extended campaign life.
③ Final Product Filtration	Refinery final products contain particulates and water.	Improved product quality; fewer reprocessing and contamination costs; lower maintenance and disposal costs.
④ Fluid Catalytic Cracking Unit Slurry Oil	Catalyst fines reduce value of slurry oil.	Improved product quality and revenue; reduced critical nozzle erosion; increased yield; reduced coke formation in FCC reactor; less backwash fluid to reprocess; higher profitability of FCCU.
⑤ Rich / Amine Loop	Amine foaming.	Amine losses prevented; sulfur plant operation improved.

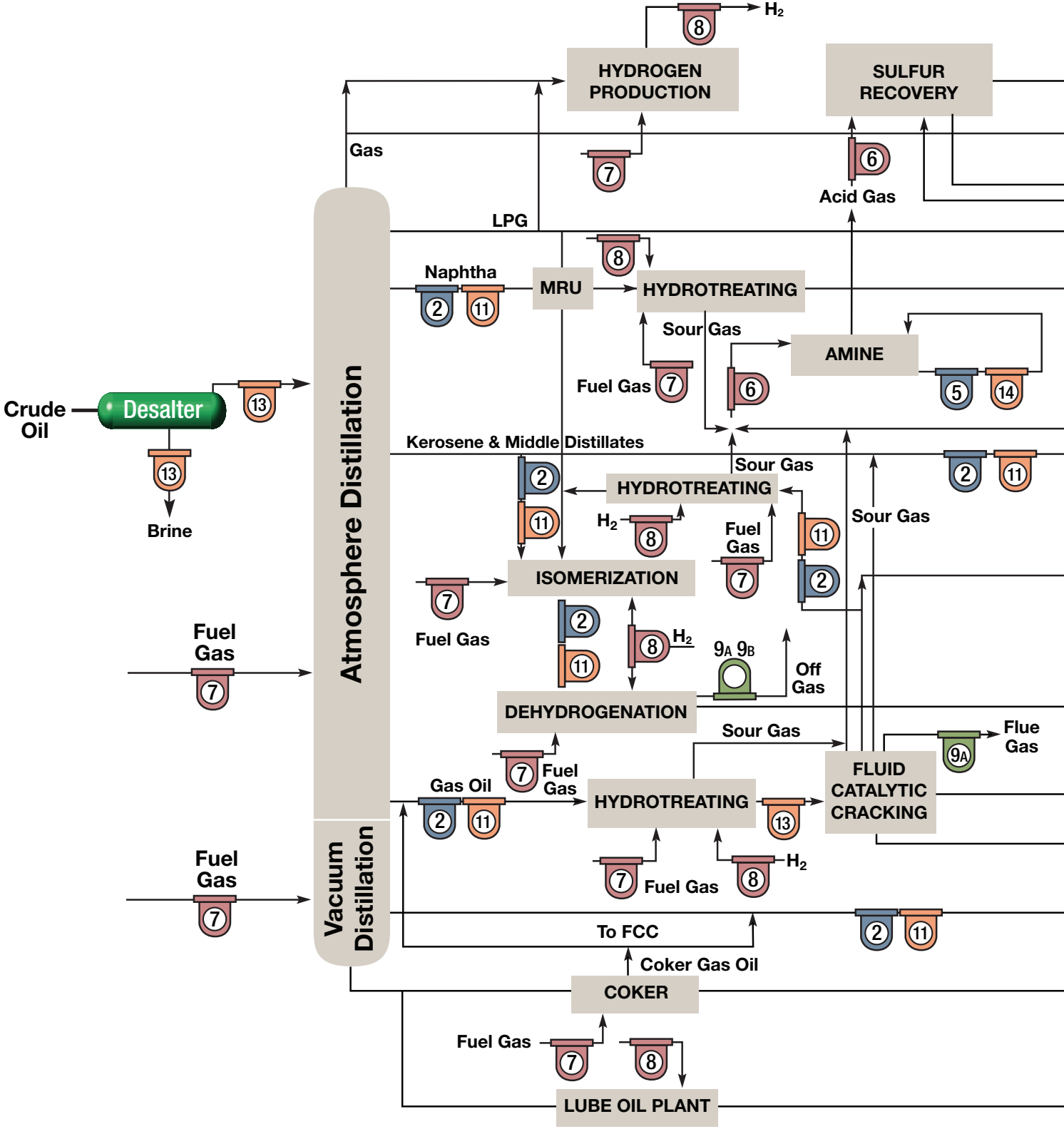
Blowback Filters ¹		
Application	Problem	Benefits
⑨A Reduced Particulate Environmental Emissions	Existing equipment is unable to meet tightening emission levels required by environmental authorities for particulate and micro-particle matter. Poor reliability of turbo expander and inability to meet desired FCC campaign length of 3-5 years between major repairs or overhaul of turbo expander.	Tougher environmental license limits met continuously and FCC plant shutdown and/or capacity reduction averted; turbo expander reliability improved dramatically.
⑨B CCR Recycle Gas	Poor reliability of CCR recycle gas compressor; high maintenance costs; loss of expensive reformer catalyst.	Reliable CCR operation and production of H ₂ and reformat.

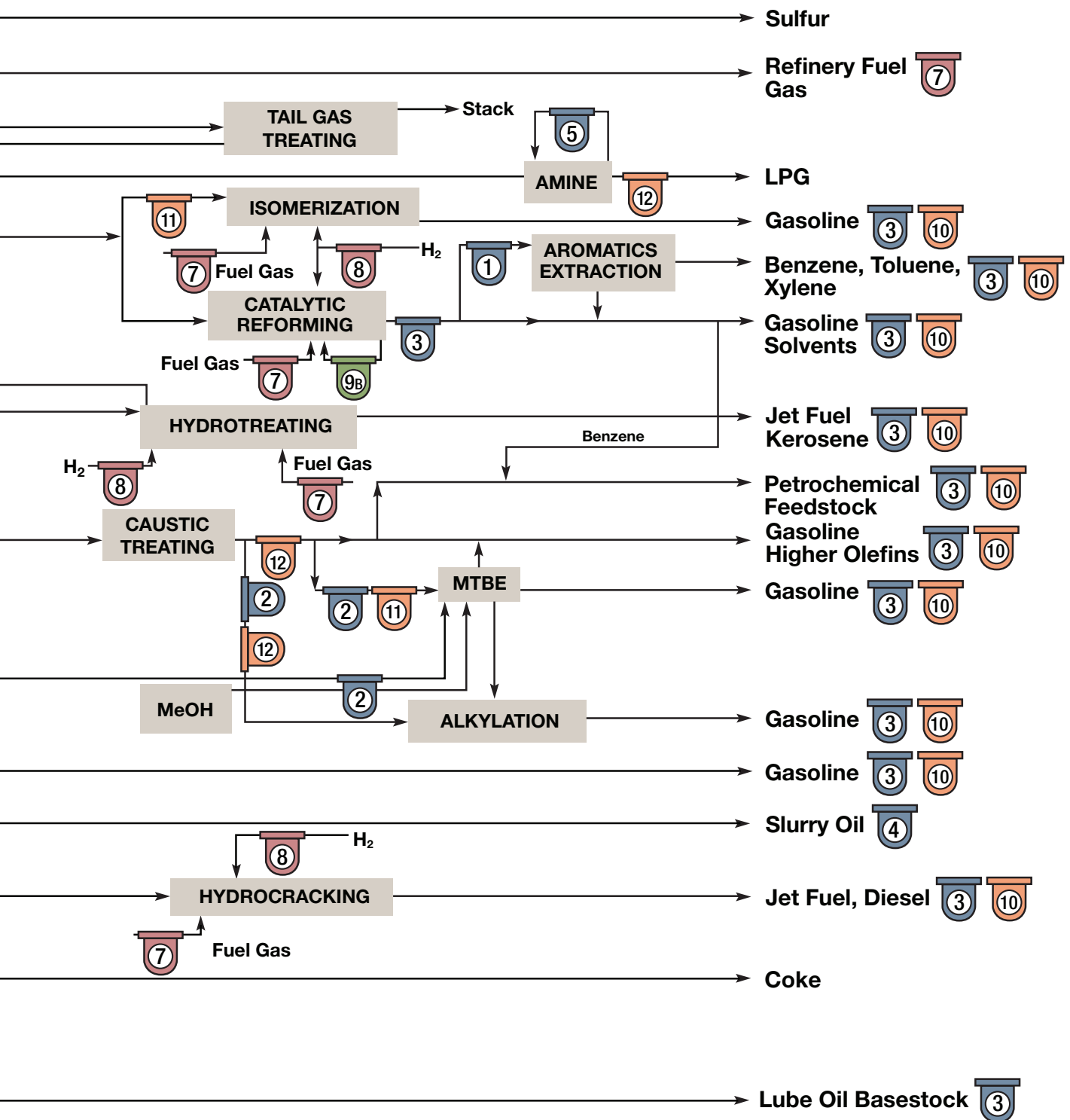
¹ In applications where different options are listed, Pall Corporation will assist project engineers in determining the best filtration solution for their situation.

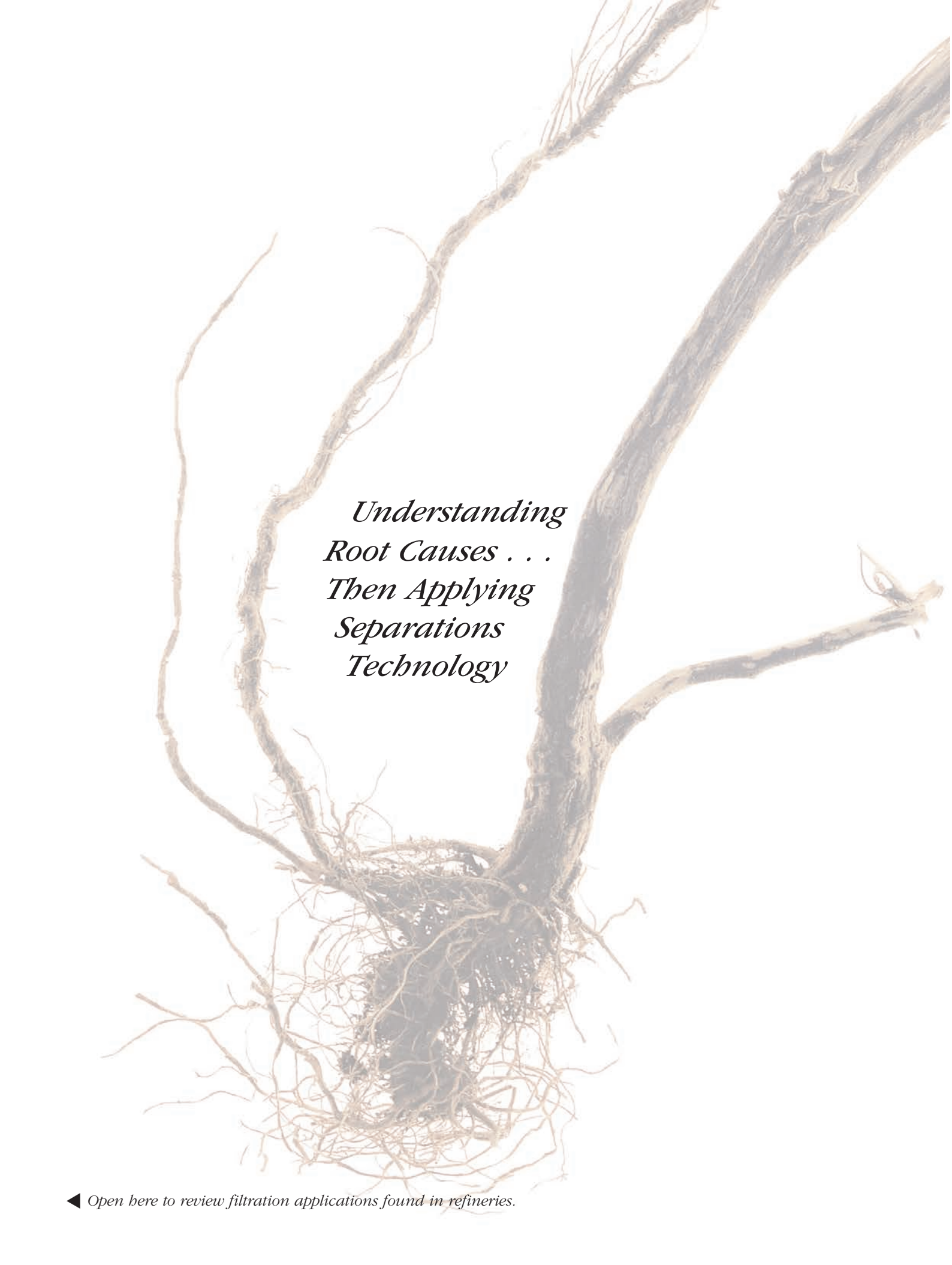
Liquid/Gas Coalescers ¹		
Application	Problem	Benefits
⑥ Amine and Sulfur Recovery Unit	Hydrocarbon carryover into amine plant causes foaming, excessive amine losses, and can lead to either reduced amine plant capacity or impact the ability to meet final product sulfur specifications in fuels. Amine plant upsets; sulfur plant trips; and environmental emissions above license limits.	Minimized or eliminated production losses due to sulfur plant trips; reduced environmental license level exceedance; stable amine plant operations; and increased amine plant capacity.
⑦ Refinery Fuel Gas	Fuel gas composition changes rapidly and contains condensable hydrocarbons; liquids and solids will foul, plug burners and combustors; low NOx and ultra low NOx burners are especially sensitive to plugging.	Reduced or eliminated routine burner cleaning program; improved furnace fine tuning; reduced fuel gas usage; reduced greenhouse gas emissions; safer furnace operation and on-spec NOx emissions.
⑧ Hydrogen Compressor Protection	Liquid hydrocarbons and solid contaminants such as corrosion products or ammonium chloride in hydrogen gas streams can lead to premature failure of reciprocating compressor suction and discharge valves, and piston ring failure resulting in H ₂ compressor downtime and excessive unscheduled maintenance and in some cases can cause lost production.	Reliable hydrogen compressor operation; significantly reduced maintenance and repair costs.

Liquid/Liquid Separators ¹		
Application	Problem	Benefits
⑩ Final Product Filtration	Off-spec products; high salt or clay tower usage; corrosion in storage tanks.	Improved product quality/on-spec products; fewer reprocessing and contamination costs; lower maintenance and disposal costs; free up tank storage; improved cash flow and fewer delayed shipments.
⑪ Catalyst Protection	Water may contain caustic and other solid particulates; plug or deactivate catalyst bed.	Improved conversion efficiency and profitability; fewer catalyst change-outs; lower maintenance, labor, and catalyst costs.
⑫ Treating	Caustic or amine carries over into product stream causing off-spec product; carried-over caustic can disarm sensitive catalyst.	Improved profitability; lower reprocessing costs; reduced maintenance and labor costs.
⑬ Desalter	Desalter upsets can cause oil carryover to waste treatment plant and upset water treatment plant operation and emissions to the environment; desalter upsets or crude charge rate increase can cause brine carryover to CDU and result in high corrosion rates in crude overhead; salt in FCC feed can reduce FCC catalyst yield and shorten catalyst life.	Less emissions from water treatment plant; allows debottlenecking of desalter and reduced corrosion rates in CDU overhead; improved FCC catalyst yield and longer FCC catalyst life.
⑭ Amine Unit Protection	Liquid hydrocarbon ingress; foaming incidents; upsets at sulfur plant.	More stable Amine system operation, reduced foaming, longer A/C life; less sulfur plant trips.

Refinery Filtration Applications







*Understanding
Root Causes . . .
Then Applying
Separations
Technology*


◀ *Open here to review filtration applications found in refineries.*

Products that Meet Refiners' Needs


With an extensive portfolio of filtration and separation products, Pall can help refineries improve fluid quality and increase profitability by optimizing the performance of their processing equipment. Many of Pall's products were developed specifically for the refinery industry, in collaboration with our customers.


Our close relationship with refiners and process licensors has helped Pall understand current and future needs. Our awareness and dedication to this market has fueled our product development programs and sharpened our technical and scientific skills. As a result, Pall is continually introducing new products to help improve the production and efficiency of our customers' operations.

Pall's advanced technologies include:

 Separation of Solids from Liquids

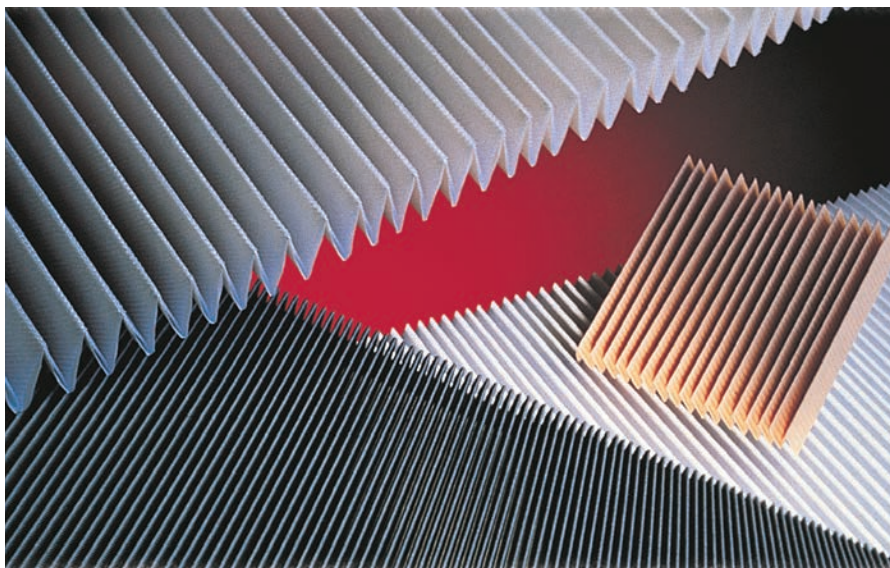
 Separation of Solids from Gases

 Separation of Liquids and Solids from Gases

 Separation of Liquids from Liquids

Details of each technology can be found in the sections that follow.

At the heart of every filtration and separation system is the medium which performs the separation. Pall manufactures 21 distinct families of media, providing over 150 grades of polymeric, inorganic, metal, and ceramic filter products and phase separation systems. This allows Pall to supply high-quality products with the appropriate medium and grade for very specific refinery applications.



Pall's filter media.

● Separation of Solids from Liquids

A variety of filtration methods can be used for solid/liquid separations due to the differing concentration of solids in liquid streams. For high solids loading, a backwash system may be the optimum filtration solution, while disposable filters would be used for lower solids loading applications. In some cases, removal of solids may require a combination of backwash technology followed by a disposable filter for polishing. Regardless of the amount of solids present in the liquid, Pall can provide a product or combination of products to achieve optimum performance and economy.

Pall originally developed backwash technology in the 1960's in response to the needs of hydrogenated chemical producers. This technology was introduced to refiners and started to gain acceptance in the late 1980's when refiners needed to upgrade the value of slurry oil in Fluid Catalytic Cracking (FCC) units by removing catalyst fines.

Today Pall's advanced backwash technology is used in other refining processes for the purpose of extending the life of fixed bed catalyst reactors and improving conversion in hydrotreaters and hydrocrackers. Pall's backwash systems offer significant benefits over conventional wedgewire systems that can be used to protect fixed bed catalyst reactors.

Backwash Filters

- PSS® sintered powder stainless steel filters
- PMF™ metal fiber filters
- Rigimesh® sintered woven wire mesh filters
- AccuSep® sintered stainless steel filters

Disposable Filters

- Profile® II depth filters
- Ultipleat® filters with Profile depth filter media
- Marksman™ pleated filters
- Nexis® melt blown filters
- Claris® melt blown filters
- Duo-Fine® pleated filters with microfiberglass media
- Hi-V® resin bonded filters
- Pleated filters with Epocel® medium, Ultipor® GF Plus medium, HDC® II medium
- Profile Coreless melt blown filters
- Ultipor HT filters
- High Flow filters



Pall's backwash systems have extremely low operating and maintenance costs compared to other technologies such as electrostatic separators and hydrocyclones.

Backwash Systems

A backwash system is designed to remove and/or collect suspended solids from a liquid process stream while periodically regenerating itself. A porous filter medium with suitable pore size will efficiently collect solids on its surface, where they form a permeable cake. During backwash, a reverse flow will be initiated at a predetermined filter pressure drop and/or time interval, discharging the collected solids to recovery. The filter will then be returned to full forward flow. Its pressure drop just after backwash will remain essentially constant through backwash cycles.

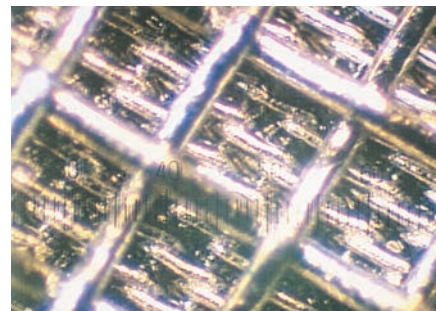
The efficient operation of Pall backwash systems require high standards in vessel design, tubesheet assembly, piping, instrumentation, and valve selection. At the heart of the system is Pall's filtration media. With a variety of porous filter media available, both metallic and nonmetallic, and backwash techniques, Pall's backwash systems are designed and optimized for specific refinery applications.

For example, many hydrotreaters use backwash filters to remove solids from the feed and protect the feed exchanger and catalyst bed. In the past, wedgewire media was used for this purpose. However, this media only provides about three to five percent void volume in this application. Replacing the wedgewire elements in the filter vessel with Pall Rigimesh elements provides approximately seven times higher void volume and twice the filter area. An upgrade should be based on a need for finer filtration and higher throughputs prior to backwash cycles. Retrofits and new, scaleable systems are available.

Benefits of Pall's Backwash Systems

- Longer run times between fixed bed catalyst change-out
- Higher throughputs
- Lower differential pressure
- Longer cycle time between backwash regeneration
- Lower utility costs
- Significantly reduced backwash fluid reprocessing cost (up to seven times less backwash fluid to reprocess)
- Payback in less than one year
- Extremely low cost of operation vs. wedgewire systems

Rigimesh Medium vs. Wedgewire



Rigimesh medium — approximate void volume = 30%.



Typical wedgewire element — approximate void volume = 4%.

Backwash Systems vs. Other Technologies

	Pall Backwash System	Electrostatic Separator	Wedgewire	Hydrocyclones	Sand Beds
Efficiency	High	Medium and Variable	Low	Medium	Low
Solids-Loading Capability	High	Medium	Low	High	High
Operating and Maintenance Cost	Very Low	High	Very High	Low	Low
Backwash Fluid Requirement vs. Throughput	<2%	>10%	2-20%	6%	1-2%
Sensitivity to Flow Rate Change	None	Very High	None	None	None
Temperature Range	High	Low	High	Medium	High
Reliability and Safety of Operations	High	Medium	Low	Medium	Medium



Refineries receive a high return on investment after installing Pall's backwash filters to protect catalyst beds and to remove catalyst fines from FCC slurry oil.

Gas Assist Backwash Method

The gas assist backwash method is used when process flow rates are high or continuous, and uninterrupted flow is required. For backwash, one vessel is isolated and the downstream side of the vessel is pressurized with a controlled quantity of filtered air or other suitable gas. The vessel drain port is rapidly opened, resulting in a hydraulic pulse that "bumps" the collected solids from the filter surface. Forward flow is restored to the vessel and the remaining filter vessels are backwashed sequentially.

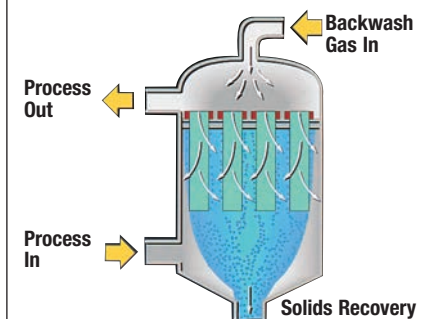
During gas assist backwash, the expanding gas bubble forces the liquid through the elements in the reverse direction (inside-out) at a velocity as high as seven times the normal forward flow velocity. This effectively dislodges the accumulated cake from the elements, while significantly reducing the volume of liquid required. Thus, the concentration of the solids discharge is high.

Benefits of Pall's Gas Assist Backwash Systems

- Longer catalyst life
- Reduced incidence of "off-spec" product
- Low reprocessing and/or disposal costs due to low volume of backwash fluid
- Low maintenance cost for valves and control equipment
- Infrequent "out-of-vessel" element cleaning

Combining the gas assist backwash with the high dirt-holding capacity of Pall's backwash media results in long cycle times between backwashing and reduced reprocessing costs which substantially improve unit economics over the life cycle of the equipment.

Gas Assist Backwash System



- One or more vessels
- Isolate one vessel for backwash
- A compressed volume of gas provides a high-velocity reverse flow of liquid remaining in vessel

Metallic Backwash Filters



PSS Porous Metal Filters

Manufactured of sintered stainless steel powder, the PSS “S” medium offers exceptionally uniform permeability and absolute removal efficiencies.

PSS elements are seamless in construction with a very high void volume (up to 60% in some grades). This provides very high dirt-holding capacity and low pressure loss, especially in very fine grades, which permit design at high flux to help reduce capital costs.

In addition to the standard product made from 316L stainless steel, we supply PSS medium in Inconel², nickel, nickel molybdenum, and aluminide alloys.

² Inconel is a registered trademark of Special Metals Corporation.



PMF Metal Fiber Filters

PMF filters are manufactured of fine diameter 316L stainless steel fibers that are sintered at their points of contact to produce a uniform, strong, tapered-pore medium. This medium provides remarkably high dirt-holding capacity, with one or more inner layers providing absolute-rated filtration.



AccuSep Sintered Metal Filters

AccuSep sintered metal filters are made of sintered stainless steel, in a seamless tubular format. AccuSep elements are produced by a proprietary process which creates a high void volume in a strong and very uniform medium. The medium is relatively thin, resulting in a structure that is up to three times more permeable than most conventional pressed sintered metal tubes.



Rigimesh Stainless Steel Woven Wire Mesh Filters

Pall's patented process permits the use of finer-diameter wires in the manufacturing of Rigimesh stainless steel woven wire mesh filters. The result is low pressure drops, more pores per unit area, and better dirt-holding capacity than other woven metal filters.

The medium is sintered for improved tensile, yield, shear, and fatigue strength. Rigimesh filters maintain a uniform pore size and exhibit no media migration, even under high temperature and pressure conditions.

Liquid Disposable Filters

When the solids concentration is relatively low (10 ppm), Pall's disposable filters will efficiently and economically remove solids from liquid streams. Disposable filters can be used to remove solids from finished refinery products and from solvents such as amine and sulfolane.

Pall's disposable filters are characterized by high dirt-holding capacity and lot-to-lot uniformity. Our filters provide long service life and improved protection for equipment and personnel. They are designed to prevent both unloading of trapped particles and media migration. The filters are self-aligning in Pall's vessels, with positive sealing to eliminate fluid bypass.

Benefits of Pall's Disposable Filters

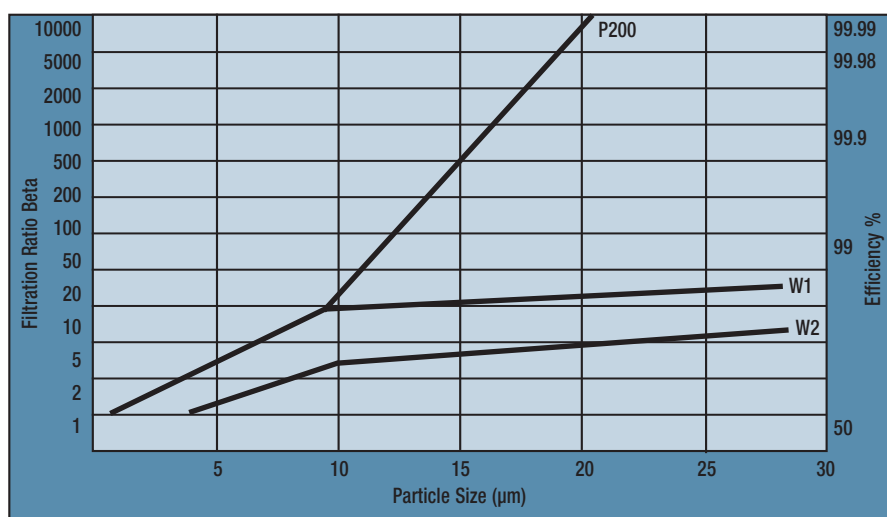
- Gradient of pore sizes for full utilization of the filter
- Strength and durability to withstand changing process conditions
- Chemical and thermal compatibility with process conditions to ensure long life
- Absolute-rated³ for reliable, reproducible performance backed by documented performance data
- Cost-effective, nominally-rated filters are available for less critical applications

³ An absolute rating is defined as $Bx=5000$ as measured utilizing the widely accepted modified OSU F-2 test.

Performance Comparison - Profile II Filters vs. Competitive Depth Filters

Particle Size (µm)	Filter Brand		
	Profile II Filter (P200) 20 µm Absolute $\beta_{20} = 5000$	W1 Wound Filter 1 µm Nominal $\beta_1 = 1$	W2 Spun Depth Filter 1 µm Nominal β_1
	Percent Removal Efficiency		
0.5	NA	NA	NA
1	NA	NA	NA
2	<50%	<50%	<50%
4	75%	75%	50%
10	95%	95%	87.5%
25	>99.98%	96.7%	93.3%
50	>99.98%	98%	96%

Filtration Beta Ratio Comparison - Profile II Filters vs. Competitive Depth Filters



Filtration beta ratio of Profile II filters (P200) and two competitive polypropylene depth filters rated at 1 µm nominal.

Liquid Disposable Filters



Profile II Filters

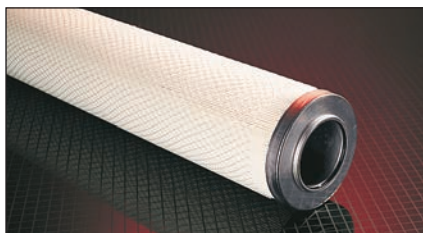
Profile II filters are available in polypropylene, nylon or polyphenylene sulphide (PPS) media. These elements have an upstream continuously graded pore section and a downstream absolute-rated section, which increases service life many times.

These filters are suitable for a wide range of applications, involving both corrosive and non-corrosive fluids. Profile II filters are ideal for prefiltration and final filtration.



Profile Coreless Filters

Profile Coreless filters are absolute-rated filters used to filter gases or liquids. They have high capacity, low cost, and are ideal for applications such as amine loop filtration, compressor protection, or final product filtration. The coreless construction allows for easy and safe filter incineration and disposal.



Ultipor GF Plus Filters

The Ultipor GF Plus medium consists of resin-bonded glass fibers supported by upstream and downstream polymeric substrates. This unique construction provides for a strongly bonded, migration-free, high dirt-holding capacity medium. Ultipor GF Plus filters are used successfully in a variety of refinery applications.



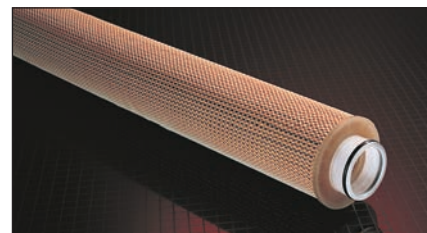
Claris Filters

Claris filters are polypropylene melt blown filters. Claris filters feature an E-core, Extruded Fibrous Core, structure which provides excellent strength. Their gradient pore structure enhances their dirt-holding capacity. Claris filters feature an all polypropylene construction for easy and safe filter incineration and disposal.



HDC II Filters

HDC II filters are constructed of all polypropylene pleated media. These filters feature a high area, high dirt-holding capacity, and extended service life. HDC II filters are ideal for use in applications where economy and reliability are crucial.



Epocel Filters

Epocel filters have a pleated, high-area construction which provides long service life and consistent production. Constructed of epoxy-resin-impregnated cellulose, this fixed-pore construction eliminates unloading and media migration. Epocel filters provide a broad range of chemical compatibility and are recommended for the clarification of a wide range of fluids and gases.



Hi-V Filters

Hi-V filters are resin-bonded disposable filters designed for highly viscous fluids. Hi-V filters use wound resin impregnated fibers that are four to six inches in length, much longer than typical molded filters which use fibers of less than one-eighth inch.

Hi-V filters feature high flow rates, high contaminant-holding capacity, no center cores, and reliable, consistent filtration.



Duo-Fine Filters

Duo-Fine filters are high-capacity pleated filters with microfiberglass media. The microfiberglass media provides exceptional dirt-holding capacity for long service life.

Duo-Fine filters are available in a variety of core options to satisfy a wide-range of temperature compatibilities.



Ultipor HT Filters

Ultipor HT filters are pleated, high area elements designed for long service life. The unique medium structure is a high temperature composite. The filters are qualified for use up to 218°C/425°F with compatible fluids.

Designed specifically for high temperature applications and well suited for many refinery applications, these high temperature filters are used to process tough oil fractions, containing fine suspended solids typically found in processes related to desulfurization and fuels upgrading. Filter operability at high temperatures can often mean elimination of intermediate tanks for product cooling and save energy on product reheating costs upstream of the hydroprocessing units.



Nexis Filters

Nexis high-efficiency depth filters are manufactured using an advanced, microprocessor-controlled, Co-located Large Diameter (CoLD Melt™) production process. This proprietary process allows the creation of multiple filtration zones within a single filter cartridge. The benefits include: efficient contaminant removal, long service life, and improved strength.



Ultipleat High Flow Filters

Ultipleat High Flow filters are coreless, large diameter, single open-ended, pleated filters with an inside-to-outside flow pattern. These filters utilize Pall's patented, crescent-shaped pleats and are available in a range of materials. The Ultipleat High Flow filters come in diameters of 152.4 mm (6 in) and lengths from 508-2023 mm (20-80 in). Ultipleat High Flow technology enables the use of considerably fewer filters and smaller housings for high flow rate applications.



Marksman Filters

Marksman filters are available as high-capacity, pleated, depth filters or high-capacity melt blown filters. These filters feature a large 152.4 mm (6 inch) diameter, high surface area, and high flow capacity. Marksman filters are available in a variety of grades and sizes to meet specific application requirements.



Profile UP Filters

The unique Ultipleat (U) crescent-shaped construction of the Profile (P) depth filter provides longer life than most pleated polypropylene filters. Optimized for the removal of gels and other viscous fluids, the Profile UP depth filter provides excellent chemical compatibility with low extractables. These filters are the appropriate choice for a wide range of applications in the refining industry.

● Separation of Solids from Gases

Pall continually develops state-of-the-art technology for solid/gas separation to deal with aggressive environments, extreme temperatures, and high contaminant concentrations. Pall has worked with both refiners and process licensors to develop blowback systems that efficiently separate solid particulates from gas streams.

A filter medium with sufficiently small pores is selected for this application. Solids form a permeable cake on the filter's surface that is dislodged at a predetermined pressure drop (a function of cake thickness and compressibility) by initiating a reverse pulse (blowback). The dislodged solids are purged from the filter system, where they may be returned directly to the process for reuse, or removed from the process stream and sent to a storage or collection unit. The filter is then returned to full forward flow and to an initial pressure drop that remains essentially constant through repeated blowback cycles.

Pall's blowback systems use either porous metal composite or ceramic filters. The comprehensive capabilities of Pall's blowback systems are highlighted in the chart to the right.

<p>Blowback Filters</p> <ul style="list-style-type: none"> • PSS sintered powder stainless steel filters • PMF metal fiber filters • Rigimesh sintered woven wire mesh filters <p>Gas Particle Disposable Filters</p> <ul style="list-style-type: none"> • Pall pleated filters with Ultipor GF Plus medium, HDC II medium, or Epocel medium • Ultipleat filters with Profile depth filter media • Profile II filters • Profile coreless filters



Pall's blowback filter system in operation.

Blowback Systems vs. Other Technologies

	Pall Blowback Filters	Cyclone	Baghouse	Scrubber	Electrostatic Precipitator
Efficiency of Solid Separation from Gas Stream	>99.99%	98%	99.9%	99%	99%
Separation Efficiency Varies with Solids Loading	No	Yes	No	Yes	Yes
Relative Operating Pressure Drop	Medium	Medium	Medium	High	Low
Maximum Operating Temperature	899°C (1650°F)	1093°C (>2000°F)	232°C (450°F)	232°C (450°F)	482°C (900°F)
Sensitivity to Changes in Flow Rate	Insensitive	Very Sensitive	Some Sensitivity	Very Sensitive	Very Sensitive
Precooling Required Upstream of Solid Separation Device	No	No	Yes	Yes	Yes
Solids-Loading Reduction Prior to Final Separation Required	No	No	Yes	Yes	Yes
Reliability and Safety of Operation	High	High	Low	Medium	Medium

Blowback Filters



PSS Porous Metal Filters

Manufactured of sintered stainless steel powder, the PSS “S” medium offers exceptionally uniform permeability and absolute removal efficiencies.

PSS elements are seamless in construction with a high void volume (up to 60% in some grades). This provides high dirt-holding capacity and low pressure loss, especially in fine grades, which permit design at high flux to help reduce capital costs.

In addition to the standard product made from 316L stainless steel, we supply PSS medium in Inconel, nickel, nickel molybdenum, and aluminide alloys.



Dia-Schumalith® Ceramic Filters

Dia-Schumalith ceramic filters are better suited for applications requiring higher temperatures and greater corrosion resistance than most sintered metal alloy filters. The silicon carbide support body and alumina membrane of the Dia-Schumalith filter ensures a low differential pressure at high flux rates.



PMF Metal Fiber Filters

PMF filters are manufactured of fine diameter 316L stainless steel fibers that are sintered at their points of contact to produce a uniform, strong, tapered-pore medium. This medium provides exceptionally high dirt-holding capacity, with one or more inner layers providing absolute-rated filtration.



Dynalloy® Stainless Steel Filters

Dynalloy filters are made of depth-type, stainless steel fiber media manufactured under strict ISO 9001 quality control measures.

Fabrication begins with the manufacturing of discrete micron size fibers. A uniform mat of these fibers is constructed in a randomly laid orientation. The mat is compacted and sintered (metallurgically bonded) to provide strength and integrity. The result is a high void volume, closely controlled pore size media ideal for corrosion-resistant applications.



Rigimesh Stainless Steel Woven Wire Mesh Filters

Pall's patented process permits the use of finer-diameter wires in the manufacturing of Rigimesh stainless steel woven wire mesh filters. The result is low pressure drops, more pores per unit area, and high dirt-holding capacity.

The medium is sintered for improved tensile, yield, shear, and fatigue strength. Rigimesh filters maintain a uniform pore size and exhibit no media migration, even under high temperature and pressure conditions.

Gas Particle Disposable Filters



HDC II Filters

HDC II filters are constructed of all polypropylene pleated media. These filters feature a high area, high dirt-holding capacity, and extended service life. HDC II filters are ideal for use in applications where economy and reliability are crucial.



Epocel Filters

Epocel filters have a pleated, high-area construction which provides long service life and consistent production. Constructed of epoxy-resin-impregnated cellulose, this fixed-pore construction eliminates unloading and media migration. Epocel filters provide a broad range of chemical compatibility and are recommended for the clarification of a wide range of fluids and gases.



Ultipor GF Plus Filters

The Ultipor GF Plus medium consists of resin-bonded glass fibers supported by upstream and downstream polymeric substrates. This unique construction provides for a strongly bonded, migration-free, high dirt-holding capacity medium. Ultipor GF Plus filters are used successfully in a variety of refinery applications.



Profile II Filters

Profile II filters are available in polypropylene, nylon or polyphenylene sulphide (PPS) media. These elements have an upstream continuously graded pore section and a downstream absolute-rated section, which increases service life many times.

These filters are suitable for a wide range of applications, involving both corrosive and non-corrosive fluids. Profile II filters are ideal for prefiltration and final filtration.



Profile Coreless Filters

Profile Coreless filters are absolute-rated filters used to filter gases or liquids. They have high capacity, low cost, and are ideal for applications such as amine loop filtration, compressor protection, or final product filtration. The coreless construction allows for easy and safe filter incineration and disposal.



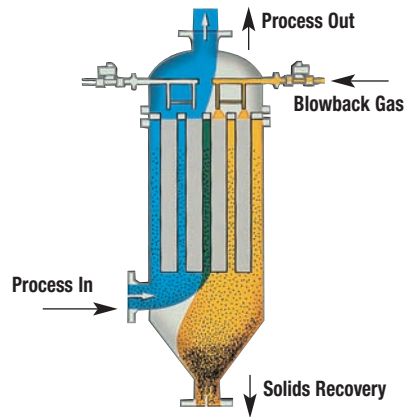
Ultipor HT Filters

Ultipor HT filters are pleated, high area elements designed for long service life. The unique medium structure is a high temperature composite. The filters are qualified for use up to 218°C/425°F with compatible fluids.

Jet Pulse Blowback Method

The jet pulse blowback method eliminates the need for large vessel isolation valves. Full forward flow is maintained at all times. Groups of elements are blown back sequentially by directing a high-pressure pulse of gas into the throat of each element. The pulses last between 0.1 and 1.0 seconds, at two to three times the process pressure. During this period, the flow to the elements being cleaned is reversed momentarily by a high-pressure jet pulse. The shock wave set up by the reverse pulse, enhanced by the venturi in the element throat, effectively removes the accumulated cake from the elements.

Pall's Blowback System



- *One or more vessels*
- *Full forward flow maintained*
- *Groups of elements blowback sequentially*
- *Forward flow overcome by high-pressure pulse in reverse flow. Short duration (0.1 to 1.0 seconds)*



Pall's blowback filters are used to remove catalyst fines from vent gas.

Pall's blowback systems are used in many applications. A few of the more common ones are listed below.

Catalytic Reforming

Pall's blowback systems are used in catalytic reforming units where catalyst is continuously regenerated to protect against erosive wear and fouling of the recycle gas compressor. These systems filter the elutriation gas that is recycled back to the regenerator. For this application, Pall's PSS porous stainless steel filters (rated one micron in gaseous service) with jet pulse (blowback) in-situ cleaning are used. PSS filters have been installed successfully at refineries throughout the world.

Catalytic Cracking

Blowback systems used to remove catalyst fines from FCC flue gas allow the refiner to:

- Meet emission guidelines
- Fully protect downstream process equipment.

The current permissible particulate emission for a fluidized-bed catalytic cracker (FCC) globally is $<50 \text{ mg/Nm}^3$. This mark is moving to $<40 \text{ mg/Nm}^3$ for the world, and in some cases as low as 10 mg/Nm^3 for given countries.

Depending upon the economics at a specific refinery, there are several blowback options:

A) Where turbo expanders are in service – a hot gas filter is recommended upstream of the expander to maintain maximum power recovery and extend turbine blade life.

In hot gas applications (up to $850^\circ\text{C}/1560^\circ\text{F}$) as related to coal gasifiers and fluid bed coal combustors

with an even more corrosive and hotter environment than FCC, Pall's PSS porous stainless steel filters or Dia-Schumalith ceramic filters have proven to be efficient and reliable. Unlike cyclones, the removal efficiency of Pall blowback filters remains constant during variations in gas flow rate.

B) If turbo expanders are not used – PSS clean-in-place blowback filters are recommended to consistently meet emission guidelines.

The removal efficiency of PSS filters remains constant during flow surges (upset conditions) and is not affected by changes in the electrostatic charge of the particulate matter, as is the case with electrostatic precipitators.

C) If third- and fourth-stage cyclones are in place, replacing the fourth-stage with PSS filters will improve solids capture, which may be sufficient to meet emission guidelines with minimum capital investment.

The use of fourth-stage blowback filters has proven to be the most cost-effective way to meet $<50 \text{ mg/Nm}^3$ emissions in FCC flue gas applications.

D) FCC hopper vent filters can be used to reduce fugitive emissions during catalyst loading/unloading and transfer.



Filter tubesheet assembly installation

Dehydrogenation Processes

PSS porous stainless steel filters process the catalyst regenerator off-gas at dehydrogenation plants operating fluid bed reactors. Pall's blowback system reduces particulate emissions in a single step, to levels at or below regulatory guidelines. Older plants had used two stages of cyclones followed by flue gas scrubbers to reduce such particulate emissions.

● Separation of Liquids and Solids from Gases

Pall's SepraSol™ liquid/gas (L/G) coalescers have been used in refineries and gas processing plants for more than thirty years. Pall's liquid/gas coalescers provide maximum liquid and solid removal at low saturated pressure drops to reduce maintenance and operating costs associated with contaminated gas. The element's highly effective filtration area and glass fiber resin-bonded pleated cartridge construction is surrounded by non-woven polymeric support and drainage layers. The coalescer is rated at 0.3 μm (99.99% removal efficiency) for solid particles, and produces downstream liquid aerosol concentration as low as 0.003 ppmw. These specifications ensure long service life, minimized operating costs and minimal labor requirements, as well as greatly improved equipment reliability.

Pall's liquid/gas coalescers merge, or coalesce, small droplets of liquid into larger drops. A gas is forced to flow through several layers of filter media, each layer having a progressively larger mean pore opening. As droplets compete for the open pores, they coalesce, and the process continues until the larger drops continually collect and drain into a collecting sump.

Pall's liquid/gas coalescers remove virtually all liquids in gas streams (down to 0.003 ppmw liquid in the effluent gas). In addition, Pall's liquid/gas coalescers have a patented oleophobic/hydrophobic treatment that ensures efficient removal and quick recovery from process upsets that send slugs of liquid downstream.

Liquid/Gas Coalescers

- SepraSol liquid/gas coalescers
- SepraSol Plus liquid/gas coalescers
- SepraSol Double Open-ended liquid/gas coalescers



Pall's liquid/gas coalescers remove liquids and solids from hydrogen and fuel gas, protecting turbo machinery and combustion equipment.

Liquid/Gas Coalescers vs. Other Technologies

	SepraSol High Efficiency L/G Coalescer	Mist Eliminator	Vane Separator	Cyclonic Separator	Knock-out Drum
Smallest Liquid Droplet Efficiently Removed (Micron)	<0.1	5	10	10	300
Relative Operating Pressure Drop	Low	Medium	Medium	Medium	Low
Sensitivity to Increased Liquid Loading	Low	High	Medium	Medium	Medium
Sensitivity to Increased Flow Rate	Medium	High	Medium	Medium	Medium
Sensitivity to "Turn-Down"	Low	High	High	High	Low

Pall's liquid/gas coalescers are used in many applications. A few of the more common ones are listed below.

Hydrogen Recycle Gas Compressor Protection

Pall's liquid/gas coalescers are installed in front of hydrogen compressors to prevent costly unscheduled downtime. Refiners have been able to extend regular maintenance schedules by installing liquid/gas coalescers upstream of the compressors. Because refinery hydrogen streams are particularly prone to changes in purity and liquid concentration, Pall's oleophobic/hydrophobic treatment is extremely beneficial in this application.

Burner Protection

Liquid and solid contamination in fuel gas streams is a universal problem for refineries. By removing such contaminants, liquid/gas coalescers significantly reduce the maintenance associated with plugged burner tips in process furnaces. Low NOx and Ultra Low NOx burners are even more susceptible to plugging. Because the concentration of liquids in fuel gas can change instantaneously, Pall's oleophobic/hydrophobic treatment again is particularly beneficial.

Lube Oil Recovery

Most compressors have an oil lubricating system. Lube oil is often discharged into the process gas in aerosol form. A liquid/gas coalescer placed at the discharge of a compressor will recover the lube oil and prevent contamination of downstream catalyst, desiccant, and activated carbon beds.

Molecular Sieve/PSA Protection

Most mol sieves or PSA's used for drying process streams are sensitive to free water which increases regeneration frequency and reduces the life of adsorbents. SeptraSol L/G

coalescers are recommended to protect mol sieves / PSA's on isomerization units, polypropylene units or in hydrogen plants for hydrogen purification.

Gas Treating Processes / Sulfur Recovery

In amine treating units, foaming can be initiated by liquid hydrocarbon contaminants in the feed gas. Installation of a liquid/gas coalescer upstream of the amine contactor

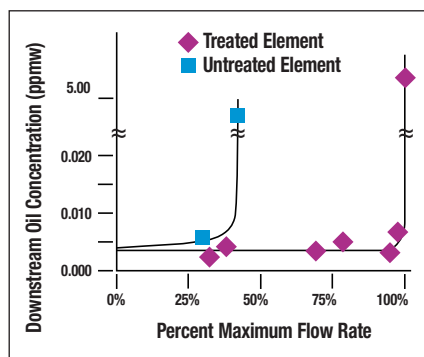
can reduce the costs associated with foaming such as reduced processing capacity and increased amine losses. Liquid/gas coalescers can also recover any amine that is carried over into the acid gas going to the sulfur plant or the sweet gas. By reducing upsets in the amine plant, the sulfur plant can be protected from upsets and the number of trips or incidences of off-spec sulfur can be reduced along with a reduction in environmental emissions.



Liquid / Gas Coalescers for Optimum Performance

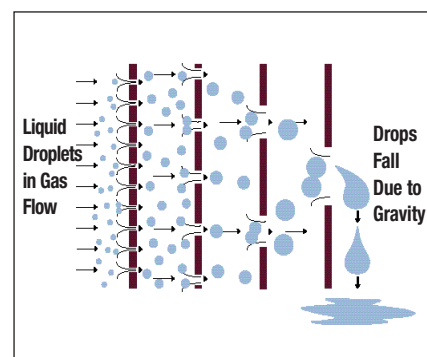
Pall's liquid/gas coalescers perform with maximum removal efficiency and economy that reduces equipment downtime, labor and maintenance costs. Pall's unique filter medium provides single-stage coalescing, separating liquid aerosols smaller than 0.1 micron in size. Pall's patented coalescer treatment improves the drainage of liquids through the coalescer, enabling the use of smaller assemblies and minimizing up-front capital costs. The treatment also lowers operating costs by operating at a lower liquid saturated pressure drop and by recovering quickly from process upsets.

Effect of Chemical Treatment on Coalescer Performance



Chemically treating the medium can significantly increase the flow per cartridge.

Coalescing Mechanism



Small droplets coalesce to form large droplets.

● Separation of Liquids from Liquids

When refinery customers alerted Pall to recurring problems with hazy fuel and caustic carryover, Pall worked with them to provide a long-term solution. As a result, Pall developed two new products – the AquaSep® liquid/liquid coalescer and the PhaseSep® liquid/liquid coalescer. Pall consulted with its customers during every step of the product development cycle to ensure that the new products would meet their needs.

Today, AquaSep Plus coalescers and PhaseSep coalescers are installed in refineries throughout the world and are used in a variety of applications including:

- Removal of water from gasoline, diesel, kerosene, and jet fuel
- Protection of catalysts and adsorbents from water contamination
- Removal of carried-over caustic from caustic treating processes
- Removal of carried-over amine from LPG
- Removal of H/C from amine
- Protection of salt driers and clay towers

Pall's AquaSep Plus coalescer and PhaseSep coalescer are multiple-stage systems. These systems first remove particulate matter, then coalesce and separate the water or liquid contaminant from a hydrocarbon stream. An AquaSep Plus coalescer or PhaseSep coalescer can remove entrained water to a level at or below 15 ppmv.

Pall's PhaseSep liquid/liquid coalescer has been demonstrated to reduce the sodium concentration downstream of a caustic treating unit to below 0.5 ppmw of sodium. In addition,

Pall's liquid/liquid coalescers do not disarm in the presence of surface active agents in the fuel.

Liquid/Liquid Coalescers

- AquaSep Plus liquid/liquid coalescers
- PhaseSep liquid/liquid coalescers
- Small flow liquid/liquid coalescers
- Lucid™ liquid/liquid separators



Pall's AquaSep Plus and PhaseSep coalescers are the most cost-effective technology for liquid/liquid separation compared to other methods, including tank settling, electrostatic precipitation, salt drying, sand filtration, and coalescing by mesh pads.

Unique Stack Design

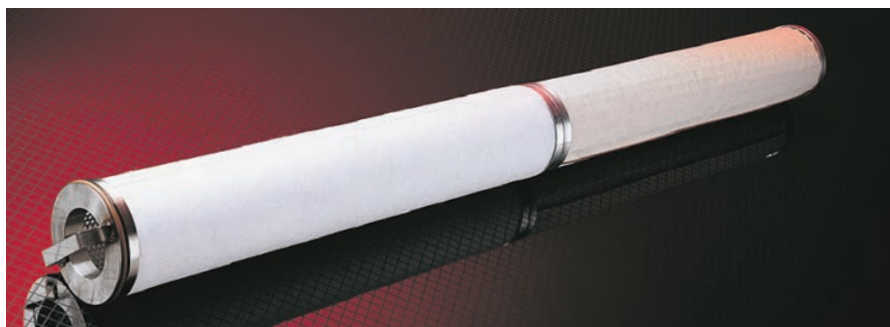
Pall's AquaSep Plus coalescers and PhaseSep coalescers are stacked on top of a separator element. This patented stacking method optimizes the flow distribution from the coalescer to the separator, ensuring that each separator has equal flow. In conventional two-stage systems, the separators are located at different distances from the coalescer, causing unequal distribution of flow to the separator. Also, conventional two-stage systems require several coalescer elements for each separator. Pall's stack design results in an overall smaller assembly size and a longer coalescer/separator life.

Low Interfacial Tension (IFT)

The ability to remove water improves as the IFT between the two phases increases. The IFT effectively measures the stability of an emulsion or dispersion. The IFT is a critical factor when considering liquid/liquid coalescence because the largest possible stable droplet size that will form by the coalescence process will be dictated by IFT. A system with a high IFT (> 20 dyne/cm) can sustain a large stable coalesced droplet size. Systems with low IFT (i.e., water in fuels with additives < 20 dyne/cm) form smaller stable coalesced droplets and require a high-efficiency coalescer/separator.

Disarming

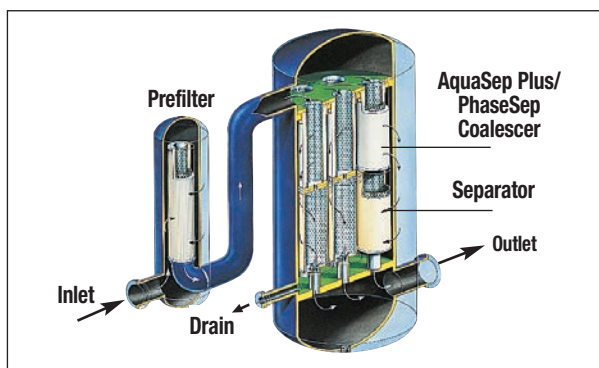
Surfactants in fuels have a tendency to form fuel/water hazes and can degrade the performance or disarm conventional glass fiber coalescers. Pall's liquid/liquid coalescers do not contain glass fiber, instead they are constructed of polymeric material using a unique patented process. This results in a long, reliable, low-maintenance service life when compared to conventional liquid/liquid coalescers. Pall's liquid/liquid coalescers are immune to disarming caused by surface active components like naphthenate or sulfonate carryover, or the addition of corrosion inhibitors, dispersants, and static dissipators.



AquaSep Plus Liquid/Liquid Coalescers and PhaseSep Liquid/Liquid Coalescers

AquaSep Plus liquid/liquid coalescers and PhaseSep liquid/liquid coalescers were developed to efficiently separate very stable liquid/liquid dispersions and provide high-fluid quality and value. They are compatible with highly acidic and basic fluids. The high-performance stack design allows an even flow distribution which permits a high flow rate in a smaller assembly. Also, the long life of the cartridge results in fewer change-outs, which reduces maintenance and disposal costs.

AquaSep Plus and PhaseSep Liquid/Liquid Coalescer



AquaSep Plus/PhaseSep liquid/liquid separation system with coalescer/separator stack in a vertical housing.

Liquid/Liquid Coalescers vs. Other Technologies

	Pall AquaSep Plus/PhaseSep System	Salt and Desiccant Tower	Conventional Coalescers	Pack Bed Tower	Electrostatic Precipitator	Tank Settling
Lowest Interfacial Tension Efficiency Separated	AquaSep Plus: 3 dyne/cm PhaseSep: <2 dyne/cm	<2 dyne/cm	>20 dyne/cm	>20 dyne/cm	>10 dyne/cm	>20 dyne/cm
Relative Operating and Maintenance Costs	Low	High	Medium	Low	High	Low
Effect of Additional Dispersed Liquid on Operating Costs	Low	High	Low	Low	High	Low
Effect of Surface Active Chemical on Efficiency	None	None	Reduced Efficiency	Reduced Efficiency	Reduced Efficiency	Reduced Efficiency
Effect of Additional Dispersed Liquid on Efficiency	Low	Medium	Low	High	Medium	Medium
Sensitivity to Temperature Changes	Low	Medium	Medium	Low	High	Low
Relative Maintenance	Low	High	Medium	Low	High	Low

About Pall Corporation

For more than 60 years, Pall Corporation has been solving complex contamination problems for diverse customers around the world. With revenues of more than \$2.4 billion, Pall is the largest and most diverse filtration, separations, and purifications company in the world. Our products and services allow customers to meet regulatory requirements and increase output while reducing total cost of ownership. Our enabling technologies help make customers' products better, safer and even possible.

Pall continues to develop new products and systems to further its cutting-edge phase separation technology. Pall's core competency in coalescing technology has helped reduce operating and maintenance costs at refineries.

We invite you to learn more about our technology, products, and services. For more information contact your Pall representative or visit us on the web at: www.pall.com.

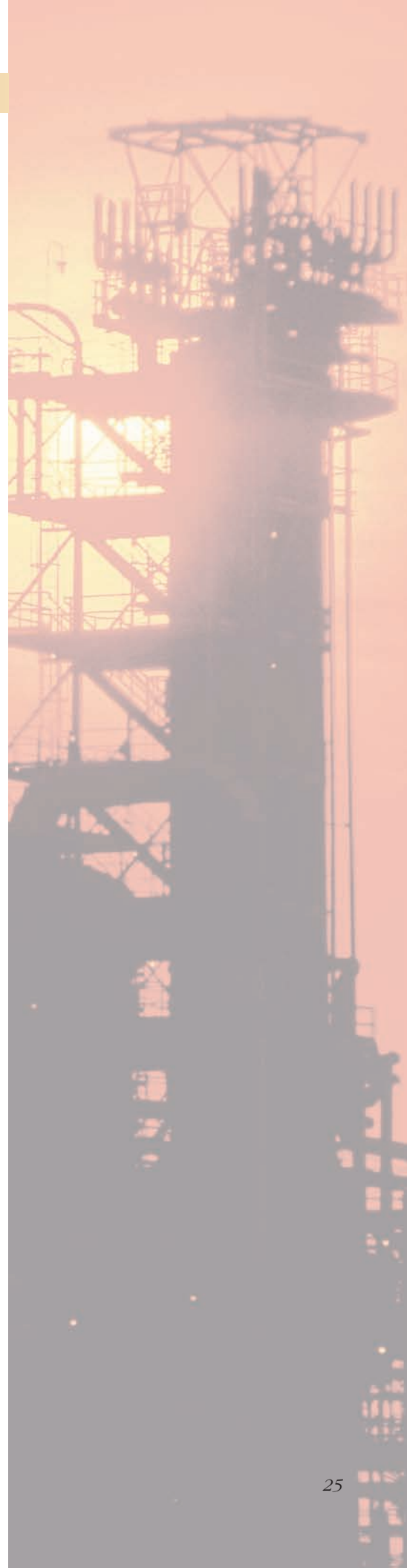
Environmental protection



**ENABLING A
GREENER
FUTURESM**

Pall is dedicated to helping customers minimize their carbon footprint, maximize recycling and waste reduction, and ensure the most efficient utilization of natural resources and raw materials. We are applying the same know-how and dedication to our own operations.

We team with customers in ways specific to their industries, providing them with technologically advanced products and engineered process solutions that improve and strengthen their businesses while reducing their environmental impacts. Customers worldwide look to us to help them purify and conserve water, consume less energy, and minimize emissions and waste. Pall is committed to ENABLING A GREENER FUTURESM. To find out more about our green initiatives, visit us on the web at www.pall.com/green.





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