3M Purification Inc.

Petroleum Refining

Innovative Filtration Solutions

Quality. Consistency. Performance.

Superior Filtration Performance

Refineries around the world depend on 3M Purification advanced filtration technologies for efficient contaminant removal and superior equipment protection! 3M Purification products significantly lower production costs while helping to provide the highest quality, contaminant-free final product. From grease blending to the most select grades of petroleum products, 3M Purification leads the way in refinery filtration technology.

Process Protection with Exceptional Service Life

When protected by 3M Purification Filtration Systems, refining processes operate more efficiently. 3M Purification's filtration systems provide:

- Consistent effluent quality
- Reproducible filtration efficiency
- Exceptional service life

Complete Filtration Systems

3M Purification offers a broad range of liquid and gas filter systems that combine user friendly housings with some of the industry's most effective filter products:

- Betapure™ PK Series Filter Elements
- Betapure™ BK Series Filter Elements
- Betapure™ NT-T Filter Cartridges
- CUNO™ EF Series Self Cleaning Metal Filter Systems
- 3M™ ES Series Filter Housings

Systems for Petroleum Refining

Contents

3M Purification, with over 100 years of providing cost effective solutions to industry, designs and manufactures filtration and separation systems for a broad customer base including:

- Industrial – Oil and Gas, Chemical/ Petrochemical, Coatings, Electronics, and Food & Beverage
- Health Care – Pharmaceutical, Biotechnology, and Diagnostics
- Consumer – Drinking water, Food Service, and Commercial

Figure 1 - Petroleum refiners the world over depend on 3M Purification's Betapure™ PK Series filter cartridge to provide superior product quality and process protection.

The Ultimate in Process and Equipment Protection

3M Purification filtration systems used in refineries around the world have provided improved process efficiency while reducing Total Filtration Costs. From removing solids in catalytic process feed streams to ensuring that final products meet your customer's specifications, 3M Purification filtration systems deliver these benefits:

- Superior process and equipment protection to minimize process downtime and maximize production
- Exceptional service life without sacrificing removal efficiencies to dramatically reduce filter, labor and disposal costs
- Optimal process protection with Total Filtration Cost reduction

3M Purification Filtration Technology for Petroleum Refining

As refiners work toward the goal of increasing production, maximizing productivity, and reducing operating costs, 3M Purification's filtration technologies provide the solution. 3M Purification is able to provide a broad line of products ideally suited for the following groups of refinery applications:

- Hydrotreating, Hydrocracking, Catalytic Cracking, and Catalytic Reforming
- Amine Plant and Sour Water Stripping
- Lube Oil Systems, Boiler Feed Water, and Fuel Oil Filtration
- Final Product Filtration

3M Purification's filtration technologies designed to provide maximum performance and exceptional value include:

- Rigid structure depth filters that feature graded-porosity construction for enhanced contaminant removal, superior dirt holding capacity, and exceptionally long service life
- Self-cleaning metal-edge filters that eliminate disposal costs while providing reliable filtration even under the most extreme operating conditions are ideally suited for very high viscosity fluids
- 3M Purification has a broad range of standard filter housings that feature ease of use and cleaning, and a superior engineering capability to design and manufacture to special requirements

Table 1 - Petroleum Refining Filter Key

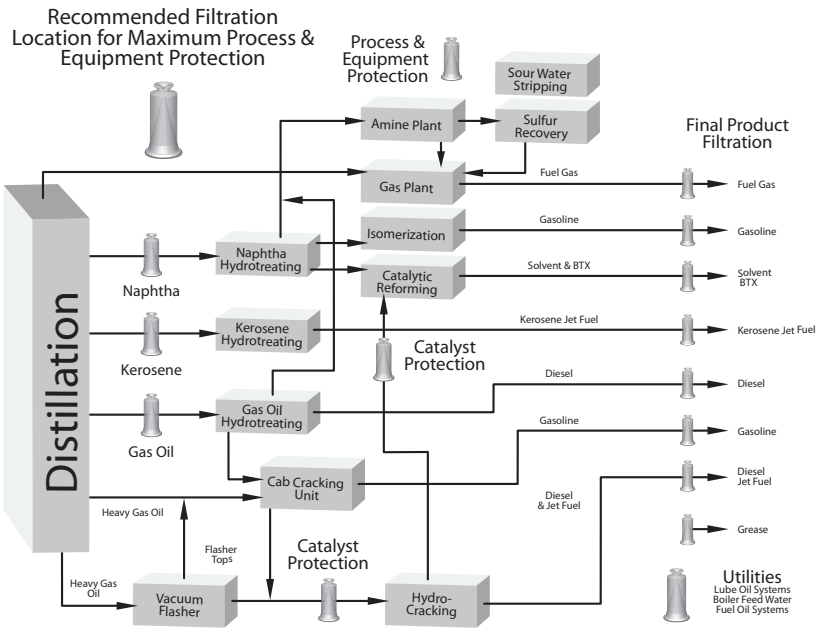
Application	3M Purification Filter Product	See Page
Hydrotreater Catalyst Protection	Betapure™ PK	5
Amine Plant Process Protection	Betapure™ PK	7
Sour Water Stripping	Beta-Klean™	8
Lube Oil Systems	Beta-Klean™	9
Boiler Feed Water	Beta-Klean™	10
Fuel Oil Systems	CUNO™ EF Series Self Cleaning Metal Filters	11
Finished Product Filtration	Betapure™ PK	12

About this Catalog

For the purpose of this catalog, filtration applications in refining operations can be grouped into the four primary categories shown in Figure 2, i.e., catalyst protection, process and equipment protection, utilities, and final product filtration. Although these categories combine operations that use different materials and, perhaps, production methods, the function of filtration within the process remains the same.

Each section of the catalog, including the product section, is designed to provide the most current information available. However, as refining processes change and 3M Purification develops new products this catalog will be updated. To ensure that you receive the latest materials for reference or evaluation, contact your local 3M Purification Master Distributor.

Figure 2

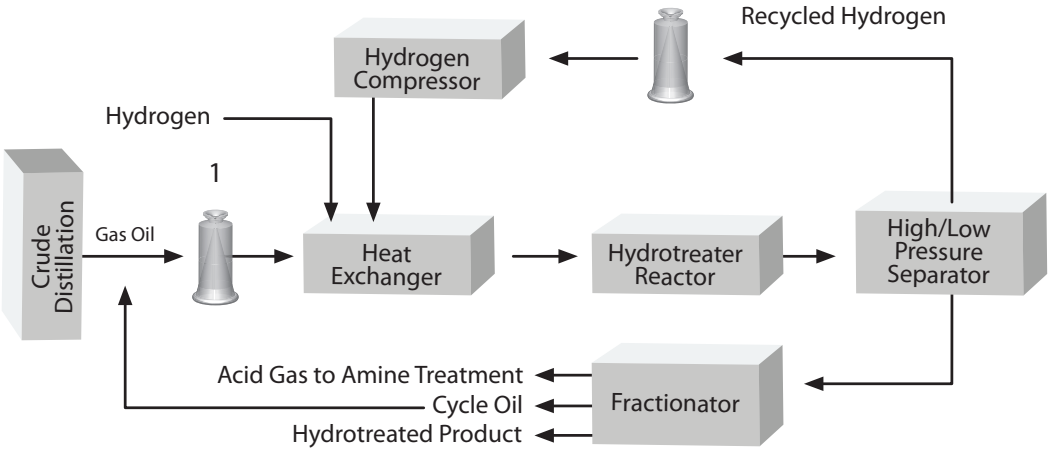


Hydrotreater Catalyst Protection

The Process

In the hydrotreating process, the gas oil inlet stream, typically naphtha, kerosene, diesel or other gas oil from the crude oil distillation column, is mixed with hydrogen gas, heated, and fed to the fixed bed catalyst hydrotreater or reactor (Figure 3). The removal of sulfur is primarily a function of pressure, temperature, catalyst activity, hydrogen purity, and the hydrogen/gas oil ratio. The high temperature and pressure reaction generates hydrogen sulfide from sulfur compounds in the gas oil feed and ammonia if nitrogen compounds are in the feedstock. The hydrogen sulfide and ammonia gases are removed in a distillation column (fractionator) following the high/low pressure separator after the hydrotreater reactor.

Figure 3 - Hydrotreater Catalyst Protection



The Problem

Fluid and gas streams entering the hydrotreater contain solid and semi-solid contaminants that are produced by corrosion in upstream units, tankage, and piping. These contaminants, if allowed to enter the hydrotreating system, will detrimentally impact the productivity and operating efficiencies of the refinery. As the fouling progresses however, differential pressure across the reactor will increase. Contaminants entering the hydrotreater will foul the hydrotreater catalyst bed resulting in:

- an increase in differential pressure across the reactor eventually causes the refiner to reduce gas oil throughput
- catalyst deactivation (coking), and
- an unplanned shutdown of the reactor to remove, or "skim", the prematurely fouled bed and replace the fouled catalyst

Refiners forced to take an unplanned shutdown in the hydrotreating process experience a tremendous loss of revenue and a significant increase in operating costs. For example:

- The value of catalyst in a 40,000 barrel per day hydrotreater is approximately $300,000. Typically 20% of a fouled catalyst bed would be skimmed at a $60,000 cost.
- 10 days of downtime and lost production equal to 400,000 barrels of product lost. That is $8 million in lost revenue alone, if valued at $20/barrel.

Figure 4 - 3M Purification's Betapure™ PK Series Filter Cartridge – rigid depth clarifying filter.

The Solution

3M Purification's Betapure™ BK series and Betapure™ PK series are recommended to provide superior catalytic process protection. Rigid resin-bonded Betapure BK series and Betapure PK series filters have a graded-porosity structure that traps large particles and deformable semi-solids in the outer, more open fiber matrix, while smaller particles are removed by the inner, densely packed matrix (see Figure 15 on page 14). The result is a filter that holds more contaminant, lasts longer, requires fewer filter changes, and will not unload trapped contaminant even under extreme operating conditions.

Process Benefits

- Catalytic column and fixed bed reactor catalyst beds are protected from fouling, extending catalyst service life and enhancing conversion efficiency and process yield
- Compressor efficiency is improved by protecting cylinders and nozzles to extend maintenance intervals while reducing system downtime
- Up to 70% total filtration savings realized by reducing filter, labor and disposal costs

Specific 3M Purification filter recommendations are listed by process in the following table.

Table 2 - Other Catalytic Process Filtration Recommendations

Process	Recommended 3M Purification Filter and Rating	Recommended Flow Per Filter Element	Recommended Housing
Hydrotreating (see Figure 3) 1 Gas Oil Feed 2 Recirculated H2 Stream	Betapure™ BK Series 50-70 Absolute Betapure™ PK Series 10-20 Absolute	2-3 gpm/10" element 90-120 SCFM/10" element	3M™ ES Series Filter Housings
Cat Cracking Cycle Oil	Betapure™ BK Series 20-30 Absolute	3-4 gpm/10" element	3M™ ES Series Filter Housings
Hydrocracking Gas Oil Feed Recirculated H2 Stream	Betapure™ BK Series 10-30 Absolute Betapure™ PK Series 10-20 Absolute	2-3 gpm/10" element 90-120 SCFM/10" element	3M™ ES Series Filter Housings
Catalytic Reforming Naphtha Feeds Recycle/Net H2 Streams Light Ends Product Final Reformate	Betapure™ BK Series 5-15 Absolute Betapure™ PK Series 10-20 Absolute Betapure™ PK Series 10-20 Absolute Betapure™ BK Series 5-15 Absolute	2-3 gpm/10" element 90-120 scfm/10" element 90-120 scfm/10" element 2-3 gpm/10" element	3M™ ES Series Filter Housings

Table 2 - Other Catalytic Process Filtration Recommendations, continued

MTBE Production Feed Stream Final Product Filtration	Betapure™ BK Series 5-15 Absolute Betapure™ 7-15 Absolute	2-3 gpm/10" element 2-3 gpm/10" element	3M™ ES Series Filter Housings ES Housing

Case Study

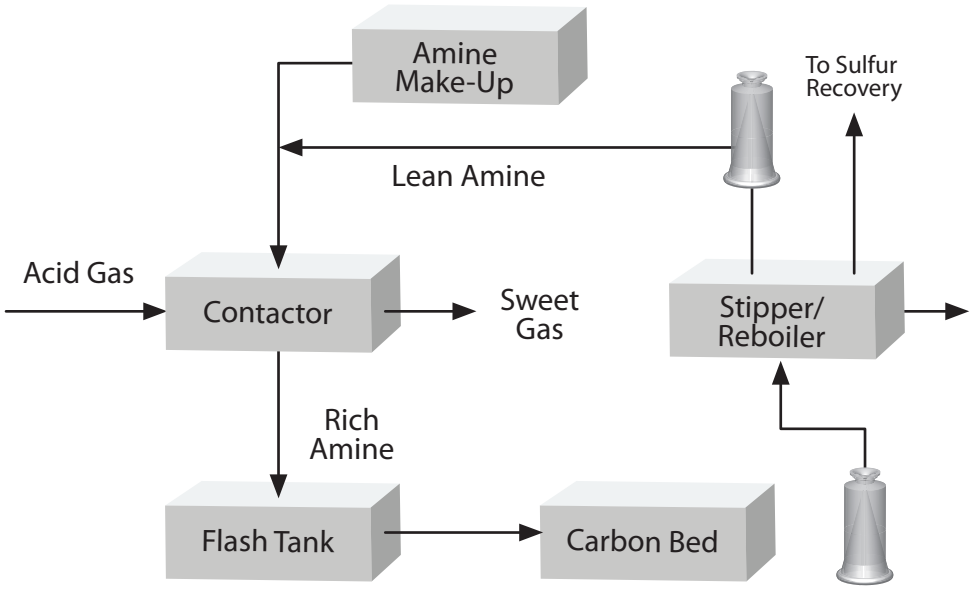
3M Purification depth filtration media has provided a major midwestern refiner with consistently high quality protection of a $1,000,000 catalytic column. Protecting a Diesel Hydrotreater for several years, 3M Purification filter media has handled high contaminant loads, with a 40 to 60 day change-out frequency while withstanding differential pressure up to 35 psid. Few competitive filtration technologies can match this high quality, cost-effective, filtration performance!

Amine Plant Process Protection

The Process

Acid gas containing hydrogen sulfide is primarily generated during hydro-treating processes. Amines, such as MDEA or DEA, are used for the selective removal of the acid gas. Amine and water are pumped through an amine contactor (absorber), while the acid gas stream flows into the bottom of the contactor. As the streams circulate, the amine selectively absorbs the acid gas. The rich amine is then fractionated to separate the hydrogen sulfide. The stripped or lean amine is recycled back to the contactor. The following schematic shows the key filtration points.

Figure 5 - Amine Plant - Process and Equipment Protection



The Problem

Solid and semi-solid contaminants in the amine system cause many problems:

- Foaming causes amine carry-over and reduced system throughput
- Contactor plugging results in amine carry-over, high differential pressure and reduced contactor capacity
- Heat exchanger/reboiler fouling causes poor heat transfer and higher energy consumption
- Carbon bed fouling causes a reduction of adsorptive capacity that ultimately requires frequent regeneration or bed replacement

Figure 6 - 3M Purification's Betapure™ PK Series Filter Cartridge – rigid depth clarifying filter.

The Solution

Amine filtration reduces or eliminates the problems normally associated with the process and is critical to the achievement of an efficient and cost effective operation. Betapure™ PK series filters placed in the recirculating rich and/or lean amine stream, and both up and downstream of the carbon bed, improve amine sweetening system efficiency while providing superior process protection.

- Betapure PK series will not unload or bypass contaminant held within its rigid structure, providing consistent filtration performance
- Graded-porosity Betapure PK series filters provide a significant life advantage over competitive cartridges

Process Benefits

- Consistent protection of amine contactors, reducing or eliminating foaming and amine carry-over
- Reduced fouling of heat transfer surfaces in heat exchangers/reboilers, extending the time between maintenance and shutdowns
- Major reduction in filter cartridge use, labor, and disposal costs–up to 70% total filtration cost reduction

Table 3 - Equipment Protection (Amine) Application Guide

Process	Recommended 3M Purification Filter and Rating	Recommended Flow Per Filter Element	Recommended Housing
Rich/Lean Amine Stream	Betapure™ PK Series 10-30 Absolute	2-4 gpm/10" element	3M™ ES Series Filter Housings ES Housing

Oil Refineries have experienced 50 to 70% reduction in Amine Plant Filtration Costs!

Get Results with Betapure™ PK Series Filters

A Midwestern refinery switched from melt-blown polypropylene cartridges to 30 micron absolute Betapure PK series filters. The refiner was unhappy with having to change melt-blown polypropylene filters several times during "upset" conditions, and eliminated these frequent filter change-outs by using Betapure PK series cartridges. In addition,

- Amine quality was dramatically improved! Visual amine inspection within days of changing to Betapure PK series cartridges confirmed superior performance

In another case, a major southwestern refinery switched from "sock" type 336 filters to Betapure PK series cartridges to improve amine filtration quality and on stream service life. Betapure PK series 30 micron absolute filter cartridges were installed with the following results:

- The Betapure PK series filters were in service for 4 weeks, as opposed to 1 to 2 weeks for the sock filters
- During the four weeks of service, several "upset" conditions occurred but did not result in filter change-out! Under similar conditions, the sock filter required change-out every 2 to 3 days!

Sour Water Stripping

The Process

Water and water vapor containing hydrogen sulfide along with other "sour" components are produced by many units in the refinery including crude distillation, hydrotreating, and catalytic cracking. The water is stored until treated to remove the "sour" components prior to further processing. Acid gas components are sent to an amine contactor for treatment. The stripped water is recycled for use in the refinery or sent to disposal. The following schematic shows the key filtration points to ensure an efficient system operation.

Figure 7 - Sour Water Stripping

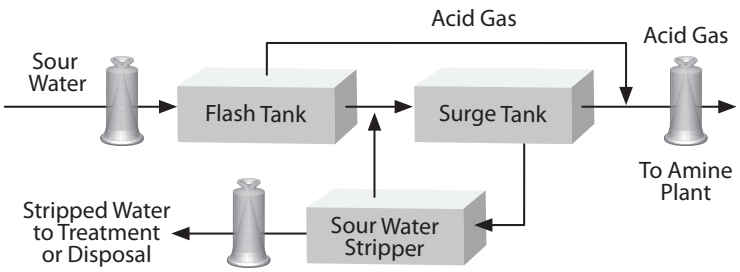


Figure 8 - 3M Purification's Betapure™ BK Series Filter Cartridge – refiners demand its efficiency and economy.

The Problem

Solids, such as iron sulfide and pipe scale in the sour water stream cause fouling of the stripper column, fouling or plugging of the reboiler and heat exchanger, and contamination of downstream processes.

The Solution

The structure of Betapure™ BK series and Betapure™ PK series filter cartridges effectively remove solids and semi-solids from the sour water feed, the stripped water, and acid gas streams.

Process Benefits

- Reduced fouling of the stripping column, heat exchanger, and reboiler, extending service between maintenance and shutdowns
- Elimination of carried over contaminant providing continuous long-term protection of the amine sweetening and sulfur plant processes

Table 4 - Sour Water Stripping Application Guide

Process	Recommended 3M Purification Filter and Rating	Recommended Flow Per Filter Element	Recommended Housing
Sour Water Feed	Betapure™ BK Series 5-15 Absolute	2-4 gpm/10" element	3M™ ES Series Filter Housings
Stripped Water Stream	Betapure™ BK Series 10-30 Absolute	4-5 gpm/10" element	3M™ ES Series Filter Housings
Acid Gas Stream	Betapure™ PK Series 10-20 Absolute	90-120 scfm/10" element	3M™ ES Series Filter Housings

Figure 9

Converting to Betapure™ BK series filtration drastically reduced "condition based" maintenance shutdowns and repairs of compressor lube oil systems with a reduction in contaminant particle counts from 50 to7ppm!

Lube Oil Systems

The Process

Lubricating oil filtration is a key element in the efficient operation and protection of large engines used to power compressors and other equipment in refineries. Without efficient filtration, these systems experience significantly shorter time intervals between turnaround with increased occurrence of emergency maintenance and the resulting downtime.

The Problem

Engine failures and increased maintenance are directly related to contaminated lubricating oil. Rust, crankcase scale, debris from engine component wear must be removed to ensure efficient operation, and trouble-free service life. Inadequate lube oil filtration leads to mechanical shutdowns, lube oil replacement, frequent filter change-out and higher operating costs.

The Solution

Betapure BK series filter elements provide uniformly superior contaminant retention for lube oil filtration. Competitive cartridges with compressible filter structures (sock, stringwound, and melt-blown) frequently unload or lose efficiency as differential pressure increases. Pleated paper elements have a relatively short service life and may rupture in the presence of water. Betapure BK series filtration maintains an unparalleled degree of reliability by providing:

Process Benefits

- Drastic reduction in maintenance shutdowns and repairs,
- Undiminished lube oil cleanliness resulting in minimal cylinder and bearing wear, and
- Significant reduction in required filter change-out providing a 50 to 70% total filtration cost reduction

Table 5 - Lube Oil Filtration Application Guide

Process	Recommended 3M Purification Filter and Rating	Recommended Flow Per Filter Element	Recommended Housing
Lube Oil	Betapure™ BK Series 5-30 Micron Absolute	2-3 gpm/10" element	3M™ ES Series Filter Housing

Case Study

Converting to Betapure™ BK series filtration for compressor lube oil systems at a major northwestern U.S. facility has dramatically reduced "condition based" maintenance shutdown and repair. With the objective of reducing suspended solids levels in their lube oil systems, a Betapure BK series 10 micron absolute cartridge was selected for full scale testing.

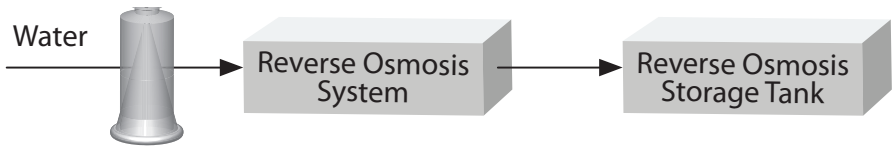
- Average lube oil total suspended solids content dropped from 50 ppm to 7 ppm
- Initial system differential pressure was 6 psid; after 8 months of operation, the differential pressure had risen to 10 psid
- 10 micron absolute Betapure BK series filtration is now the standard for all lube oil systems at this large facility

Boiler Feed Water

The Process

Refineries require a process water filtration system to remove contaminants that cause refining system upsets. The system typically includes a complete reverse osmosis (RO) system, which supplies the refinery all boiler feed water. The following schematic shows the key filtration points.

Table 10 - Boiler Water Filtration



The Problem

If not properly pre-filtered, source water will foul RO membranes necessitating frequent cleaning or back-washing and ultimately RO membrane replacement. The water treatment/RO filtration system must efficiently remove solid and semisolid contaminant in order to prevent fouling of steam generators.

The Solution

The structure of Betapure™ BK series filter cartridges consistently removes solids and semisolids to protect RO membranes effectively from premature failure. Savings of $20,000 per year or more can be realized by the significant reduction in membrane cleaning/sanitization and RO membrane replacement.

Case Study

Conversion from an equivalently rated pleated paper filter to Betapure BK series filters provided immediate improvement in the feed water to a boiler feed water system. Previously, feed water turbidity ranged from 0.8 to 1.1 NTU (nephelometric turbidity units). The quality of the Betapure BK series filtered feed water was consistently at 0.5 NTU. In addition, the reduced filter change-out frequency provided by Betapure BK series filters provided the customer with over $20,000 savings in filter, labor, and cartridge disposal costs.

Process Benefits

- RO membranes are protected from fouling, eliminating frequent cleaning whether in-place or off-line to provide a direct labor and material cost reduction.
- Up to 70% total filtration cost savings by reduced filter, labor, and disposal costs.

Table 6 - Boiler Feed Water Application Guide

Process	Recommended 3M Purification Filter and Rating	Recommended Flow Per Filter Element	Recommended Housing
Pre-RO Water Feed	Betapure™ BK Series 5-15 Absolute	2-4 gpm/10" element	3M™ ES Series Filter Housing
Boiler Feed Water	Betapure™ BK Series 10-30 Absolute	4-5 gpm/10" element	3M™ ES Series Filter Housing

Figure 11 - CUNO™ EF Series Self Cleaning Metal Filters are ideal for a wide variety of refining applications.

Fuel Oil Systems

The Problem

Refineries and other facilities require cost effective maintenance-free filtration of fuel oil delivered to boilers, furnaces, and other fuel burning equipment to ensure that solid contaminants do not plug and erode burner nozzles.

The Solution

Ideal for retrofitting inefficient and labor intensive strainers and basket type filters, CUNO™ EF series self cleaning metal filter assemblies provide virtually maintenance-free filtration of fuel oil in refinery applications. Motorized for automatic self-cleaning, CUNO EF series self cleaning edge type filters eliminate the need for frequent burner maintenance and the cleaning or replacement of strainers and baskets.

Case Study

Conversion from a 200 micron basket filter to an CUNO EF series self cleaning metal filters for boiler fuel burner nozzle protection provided the following results after one year of operation:

- Zero maintenance shutdowns and repairs
- Elimination of frequent cleaning or replacement of burner nozzles and basket filters
- Improved burner efficiency with energy savings and zero downtime
- Total cost savings exceeded $30,000 in downtime, repair parts, and labor costs

When considering a change from pleated paper or any cartridge that fits an “industrial geometry” filter housing, Betapure™ BK series filter cartridges are the ideal choice. Betapure™ BK series filtration provides uniformly superior contaminant retention for nozzle protection in fuel systems that require 30-70 micron absolute filtration protection. The rigid graded porosity filter structure will not unload or bypass and provides exceptional service life!

- Drastic reduction in required maintenance shutdowns and repairs
- Significant filter change-out reduction for lower total filtration costs
- Improved fuel oil cleanliness for enhanced burner nozzle protection

Table 7 - Fuel Oil Systems Application Guide

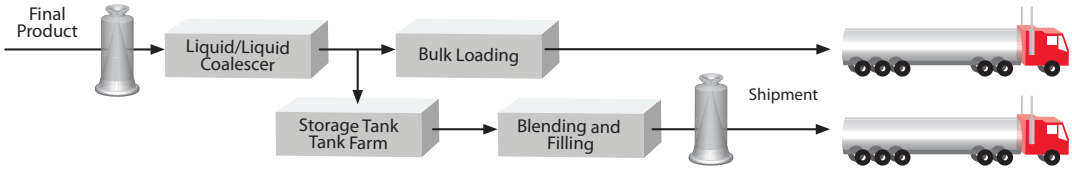
Process	Recommended 3M Purification Filter	Cartridge Dimensions	Filtration (Spacing)
Fuel Oil	CUNO™ EF Series Self Cleaning Metal Filter	4.4" diameter, 14" Long	200 micron (0.0080")
Process	**Recommended 3M Purification Filter and Rating**	**Recommended Flow Per 10" Element**	**Recommended Housing**
Fuel Oil	Betapure™ BK Series - 30-70 micron absolute	3-5 gpm	3M™ ES Series Filter Housing

Finished Product Filtration (Bulk Loading)

The Process

Blended gasoline, diesel fuel, kerosene/jet fuel, and fuel oil are stored and filtered prior to delivery to customers. Each of these final products is a blend of several streams produced by various refinery processes. Filtration of refinery final products ensures product quality by meeting or exceeding product specifications. The following schematic shows the key filtration points.

Figure 12 - Finished Product Filtration (Bulk Loading)



The Problem

Final products containing solid contaminant including rust, pipe scale and other solid particles cause many problems including:

- Solid particulate in jet fuel/gasoline results in product rejections, reprocessing and potential loss of business
- Fouling of distribution equipment including pumps, nozzles, and meters results in unscheduled maintenance and costly repairs
- Fouling of fuel gas streams causes control valve fouling and deposits of solids on burner tips and in transmission lines
- Solid particulates in grease results in product rejection and frequent cleaning of baskets and strainers

Table 8 - Finished Product (Bulk Loading) Application Guide

Process	Recommended 3M Purification Filter and Rating	Recommended Flow Per Filter Element	Recommended Housing
Final Product	Betapure™ BK Series 10-30 Absolute	3-4 gpm/10" element	3M™ ES Series Filter Housing
Fuel Gas	Betapure™ PK Series 10-20 Absolute	90-120 scfm/10" element	3M™ ES Series Filter Housing
Grease	CUNO™ EF Series Self Cleaning Metal Filters 200 Micron	100-150 lbs/minute	3M™ ES Series Filter Housing

Figure 13 - CUNO™ EF Series Self Cleaning Metal Filters are ideal for a wide variety of refining applications.

The Solution

Betapure™ BK series and Betapure™ PK series filter cartridges effectively remove solids and semi-solids in the final product streams to ensure product quality and protect distribution equipment, and, in fuel gas streams, effectively remove corrosion products and iron sulfide.

- Betapure BK series and Betapure PK series filters provide consistent filtration performance and will not unload or bypass contaminant. The rigid, graded-porosity structure provides a significant life advantage over competitive cartridges. They will not require change-out until 35 psid is reached, unlike the 15 psid commonly specified by other manufacturers.

In grease processing operations:

- CUNO™ EF series self-cleaning edge-type filters remove solid contaminant while providing uninterrupted grease production

Process Benefits

- Final products meet specification every time to eliminate loss of time and reprocessing costs
- Eliminate fouling of distribution equipment to avoid costly repair and unscheduled maintenance
- Reduced fouling of fuel gas systems to provide direct cost reduction by limiting burner system maintenance and repair
- Grease quality is ensured by CUNO EF series self cleaning metal filters while providing long trouble-free service

Figure 14

Case Study

A major U.S. refinery was in jeopardy of losing a contract to supply jet fuel to several U.S. Air Force bases and major airports. Having experienced two "black marks" (three "black marks" and the contract is cancelled!) as a result of failing government jet fuel quality testing, the refiner tested 5 micron absolute Betapure™ BK series filters to replace the 10 micron pleated paper filter cartridges suspected of causing the failures.

The Results

- No "black marks" have been recorded in the last 2 years
- Several system upsets occurred that would have typically caused quality specification failures when the pleated paper cartridges were used
- Filter service life (change-out frequency) went from 3 days with the pleated paper to 30 days with Betapure PK series filters
- Total filtration costs were reduced by over 60%!

The 3M Purification Filtration Advantage

Complete Filter Systems

3M Purification's product offering includes a comprehensive range of absolute rated depth filters with broad chemical compatibility and special end fittings specifically engineered to fit existing filter housings. For complete systems, 3M Purification's product offering includes ASME code filter vessels that meet the demands of refining applications.

The Construction Advantage

3M Purification's Betapure PK series and Betapure BK series filters are absolute-rated rigid structure elements that feature the following:

- A grooved surface to increase surface area to provide significantly longer service life
- A true graded porosity media structure that traps large particles in the outer more open portion and finer particles in the inner, more densely packed fiber matrix near the inside diameter of the filter for more efficient contaminant retention and longer service life
- Rigid filter elements that prevent the unloading of captured contaminant even at elevated differential pressures and under severe upset conditions
- Chemically compatible materials of construction ensure durability and long service life

The result is a family of products that have greater service life, enhanced contaminant holding capacity, reduced filter cartridge change-out frequency, and provide higher quality effluent than competitive products.

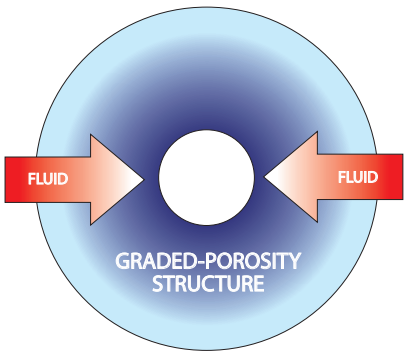


Figure 15 - Each fiber in the filter matrix is locked in place by a thermosetting binder to create a rigid medium that traps large particles near the outer surface and smaller particles near the filter's inside diameter.

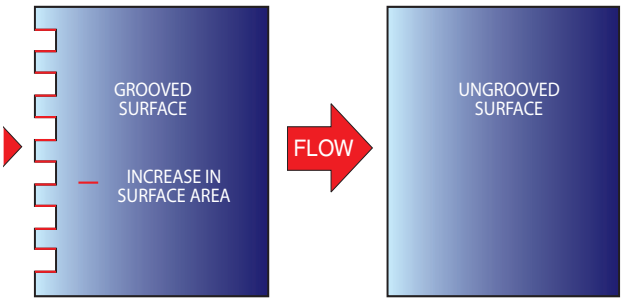


Figure 16 - The grooves increase surface area by 65% and prevent premature blinding of the outer surface by large particles.

Figure 17 - 3M Purification's advanced filter technology provides the performance that refiners demand!

The Performance Advantage

Performance of 3M Purification's Betapure™ PK series and Betapure™ BK series absolute-rated filter cartridges is measured by Beta Ratio. A Beta Ratio, represented by (β), is a measure of a filter's efficiency to remove from a process fluid particles larger than a given size, represented by (βx). The Beta Ratio value is determined by dividing the number of particles upstream of the filter by the number of particles downstream of the filter. A Beta Ratio equal to 1000 (Beta 1000), represents a removal efficiency equal to 99.9%. 3M Purification defines absolute-rated for Betapure PK and Betapure BK series filters as the filter's ability to remove 99.9% of the particles at or above the rating.

The initial Beta Ratio for all grades of Betapure PK and Betapure BK series filter cartridges is equal to or greater than 1000 at its absolute micron rating. The filter cartridges perform at or above this value throughout the usable cartridge life! The Beta Ratio values, at four differential pressures, depicted in Graph 1 illustrate how competitive filters fail to achieve the consistent performance of Betapure PK series filters. As the differential pressure increases, the competitive filters exhibit decreasing or erratic Beta Ratio values. These values depict either the unloading of previously held contaminant or an overall loss of filtration efficiency. This erratic performance is caused by the compression and movement of the filter medium under increased differential pressure, while the rigid Betapure PK series cartridge provides consistent performance even under severe upset conditions.

The tortuous filter matrix paths and long residence time of a contaminant in a 3M Purification Betapure PK and Betapure BK series depth filter increases the likelihood of being trapped and retained by the filter. In contrast, pleated and other surface-type filters can present ineffective barriers to solid and deformable contaminant. In these filters, pores can quickly plug and significantly reduce service life. Previously held contaminant can unload under pressure surges and increased differential pressure. 3M Purification's rigid filter media do not exhibit these detrimental characteristics.

Graph 1 - Beta Ratio Comparison of 10µm Cartridges

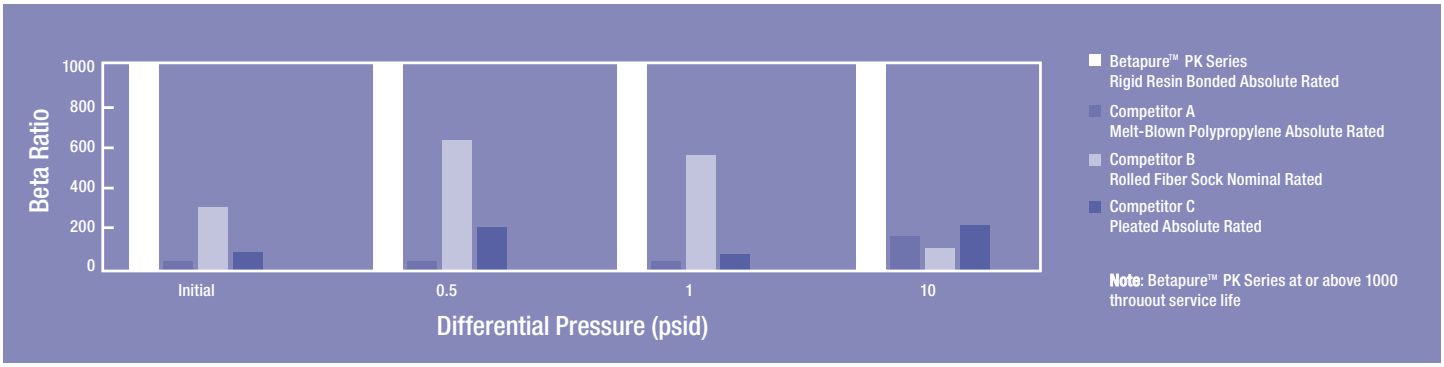


Figure 18 - 3M Purification's Betapure™ PK Series – rigid graded-porosity cartridge filter.

Betapure™ PK Series

The Process

Betapure™ PK series filters are absolute-rated, graded-porosity cartridges manufactured from cellulose fibers, glass fibers, and chemically resistant thermosetting resins to produce a durable, rigid filter structure.

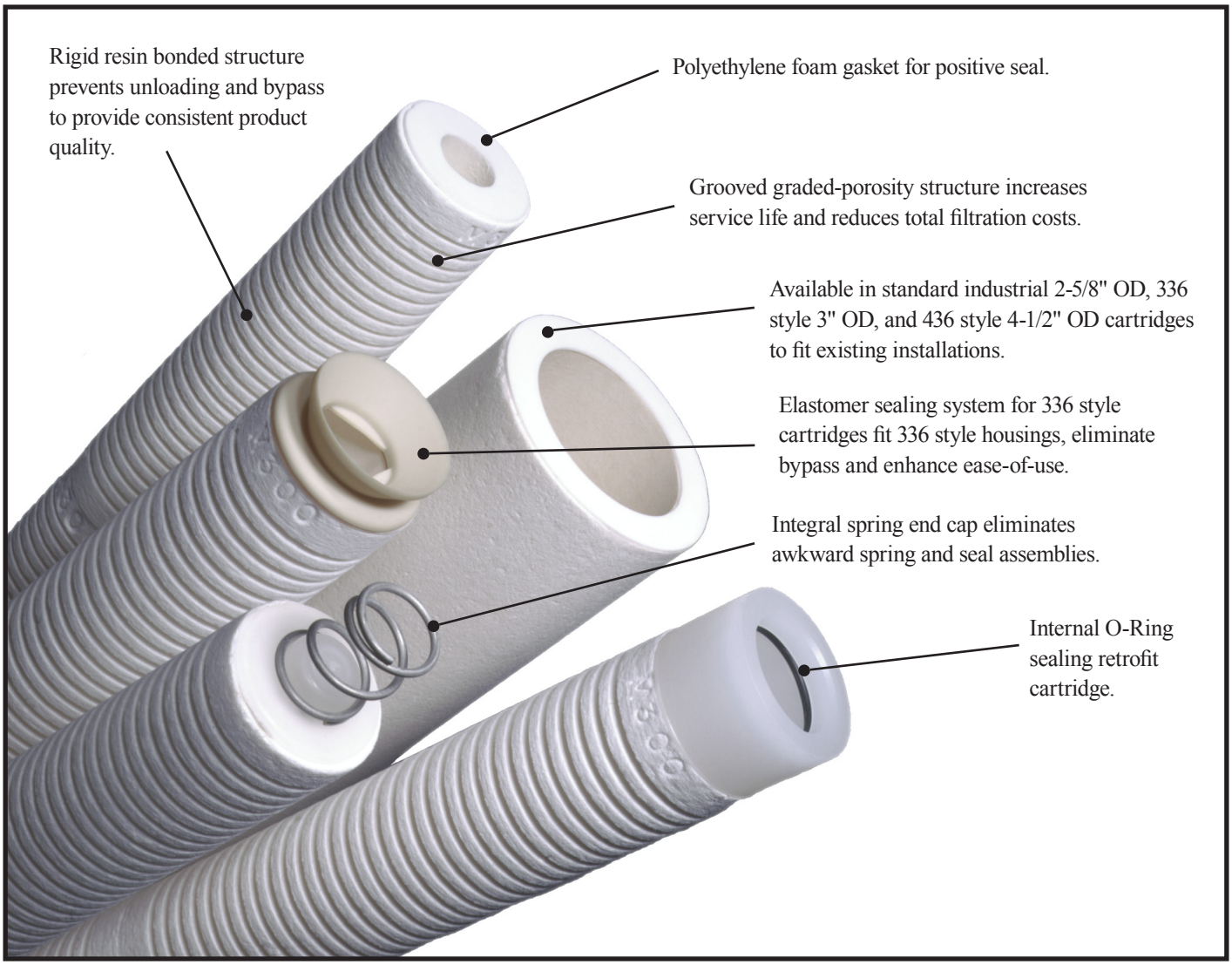
The grooved, graded-porosity structure of Betapure PK series cartridges trap larger particles and deformables like asphaltenes near the outer surface of the cartridge and smaller particles near the absolute rated inner section. The overall effect is to maximize the Betapure PK series cartridge's service life.

Betapure PK series filters have broad chemical compatibility specifically optimized for refinery amine sweetening solvent systems and acid gas streams. Available in a wide range of absolute removal ratings and configurations, Betapure PK series filters easily retrofit most filter housings.

Betapure PK series filters are ideally suited for Hydrotreating, Hydrocracking, Catalytic Reforming, Sour Water Stripping, and Amine Plant filtration systems.

Betapure™ PK Series Cartridges are Designed to Fit

Betapure PK series filters are offered in the following configurations and end treatments:



Betapure™ PK Series Advantages

- Absolute rated filtration–uniform efficiency at the specified removal rating throughout the filter life
- Rigid structure–retains contaminant even as differential pressure increases or upset conditions occur
- Graded-porosity structure–enhances contaminant loading capacity and increases service life
- Long service life–for a significant reduction in total filtration cost

For more information, please ask for 3M Purification literature number LITCPTK1.

Table 9 - Betapure™ PK Series Ordering Guide

Betapure™ PK Series Industrial (2 5/8" OD) Filter Cartridges						
Cartridge Type	Length	Grade Type	Surface Modification	Packaging	End Fitting	Gasket
PT - Betapure™	**09** - 9 3/4"	**M100** - 10µm	**G** - Grooved **U** - Ungrooved	**2** - Bulk	**C** - 222 O-ring & Spear	**A** - Silicone
	10 - 10"	**M200** - 20µm			**F** - 222 O-ring & Flat Cap	**B** -
Fluorocarbon	**19** - 19 1/2"	**M300** - 30µm **M400** - 40µm **M600** - 60µm			**N** - None	**C** - EPR **D** - Nitrile **N** - None* **G** - PE Foam*
	20 - 20"				**P** - Polypropylene Core Extender	
	29 - 29 1/4"				**R** - Closed Cap with Stainless Spring	
	30 - 30"				**S** - Stainless Steel Core Extender	
	39 - 39"				**Q** - Same as "R" without spring	
	40 - 40"				**Y** - 222 Single O-ring & Flat Cap (40" length only)	

* For End Fittings N, P, Q, R, and S only.

Betapure™ PK Series 336 Style (3" OD) Filter Cartridges						
Cartridge Type	Length	Grade Type	Surface Modification	Packaging	End Fitting	Gasket
PK - Betapure™	**35** - 35 1/2"	**M100** - 10µm	**G** - Grooved **U** - Ungrooved	**2** - Bulk	**V** - Elastomer Compression Seal (Double Open End)	**S** - Elastomer
	36 - 36"	**M200** - 20µm				
Compression	**37** - 36 1/2" **72** - 72"**	**M300** - 30µm **M400** - 40µm **M600** - 60µm			**W** - Elastomer Compression Seal (Single Open End) **R** - Closed Cap with Spring **Q** - Same as "R" without spring **N** - None (35" & 36" lengths only)	Seal **G** - PE Foam **N** - None*

* For End Fittings N, P, Q, R, and S only.

Betapure™ PK Series (Internal O-Ring Retrofit) Cartridges							
Cartridge Type	Length	Grade Type	Surface Modification	Packaging	End Fitting Temperature Option	End Fitting	Gasket
PR - Betapure™	**39** - 39"	**M100** - 10µm	**G** - Grooved	**2** - Bulk	**S** - Standard	**1** - 1.9" ID O-ring	**B** -
Fluorocarbon		**M200** - 20µm	**U** - Ungrooved		**C** - High Temperature	**2** - 2.2" ID O-ring	**C** - EPR

Figure 19 - 3M Purification's Betapure™ BK Series – rigid graded-porosity cartridge filter.

Betapure™ BK Series

Absolute rated Betapure™ BK series cartridges are a rigid, graded-porosity filter cartridge constructed of acrylic and cellulose fibers, bound together with a chemically resistant thermo-setting resin. Betapure BK series cartridges are grooved to significantly increase surface area and greatly extend service life. Betapure BK series cartridges are manufactured to deliver quality, consistency, and cost effective filtration performance.

Betapure BK series filters, available in ratings from 5 to 70 microns absolute and a wide variety of end modifications, are recommended to protect Hydrotreater, Cat Cracking, and Cat Reformer catalysts. Betapure BK series cartridges are particularly well suited for efficient removal of solids in MTBE feed, process and sour water stripping systems, and final product streams.

Betapure™ BK Series Advantages

- Absolute retention–protection from contaminant at or larger than the specified size throughout the filter's life
- Grooved surface–provides long filter life and lower total filtration costs
- Rigid structure–retains contaminant even as differential pressure increases or upset conditions occur
- Graded-porosity structure–enhances contaminant loading capacity and increases service life
- No cores or metal parts–easy disposal, suitable for incineration or shredding

For more information, please ask for 3M Purification literature number LITCBK001.

Graph 2 - Beta Ratio Comparison of Filter Cartridges, Rated at 20 Microns

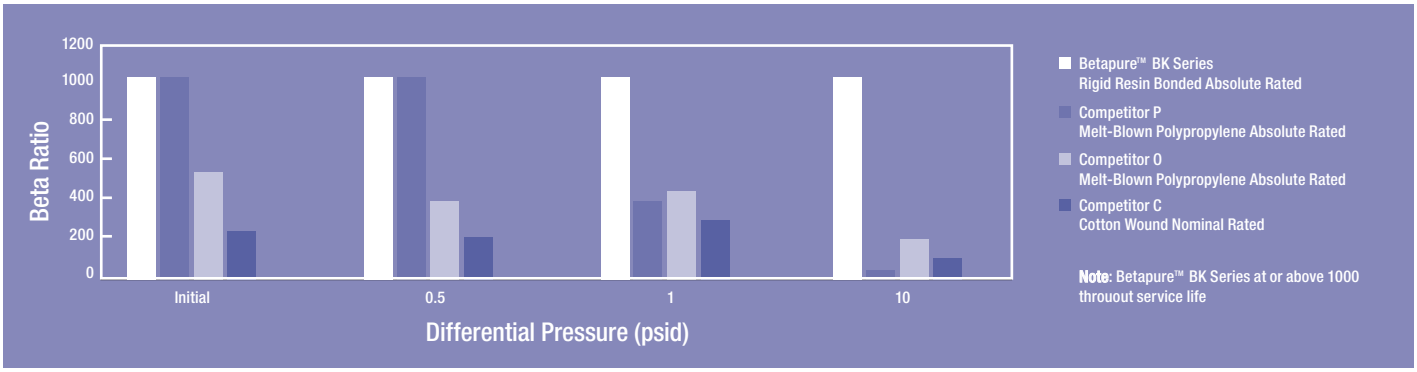


Table 10 - Betapure™ BK Series Ordering Guide

Cartridge Type	Length	Grade-Micron Absolute	Surface	Packaging	Temperature Option	End Modification	Gasket
BK - Betapure™	**09** - 9 3/4"	**Z8050** - 5*	**G** - Grooved **U** - Ungrooved	**1** - Standard Shrink Wrap	**S** - Standard **H** - High Temp.	**C** - 222 O-ring & Spear	**A** - Silicone
	10 - 10"	**Z8070** - 7*				**F** - 222 O-ring & Flat Cap	**B** -
Fluorocarbon	**19** - 19 1/2"	**Z8100** - 10*		**2** - Bulk Pack		**K** - 222 O-Ring, Retaining Clip & Flat Cap	**C** - EPR
	20 - 20"	**Z8140** - 14*				**N** - None	**D** - Nitrile
	29 - 29 1/4"	**Z8150** - 15				**P** - Polypropylene Core Extender	**G** - PE Foam
	30 - 30"	**Z8200** - 20				**Q** - Same as "R" without spring	**N** - None
	39 - 39"	**Z8300** - 30				**R** - Closed Cap with Spring	**Y** - Nylon Film**
	40 - 40"	**Z8400** - 40				**S** - Stainless Steel Core Extender	
		Z8500 - 50					
		Z8700 - 70					

Figure 20

Betapure™ NT-T

Betapure™ NT-T cartridges are 3M Purification's latest advance in depth filtration technology. The all polypropylene filter is constructed using a process that utilizes flow enhancing filter media and an innovative flow pattern. The result is an absoluterated filter with vastly superior on-stream life that provides more cost effective filtration than conventional melt-blown filter technologies. Betapure NT-T cartridges are particularly well suited for MTBE, amine plant, and process and drinking water filtration applications.

Betapure™ NT-T Advantages

- Superior service life–as much as 4 times greater dirt holding capacity than competitive filters
- All polypropylene depth filter cartridges for broad chemical and temperature compatibility
- Ratings from 0.5-70 microns to suit a wide range of applications
- Absolute-rated performance for consistent filtration quality
- Exhibits superior particle retention under increasing differential pressure

Betapure™ NT-T Construction

3M Purification designed the Betapure NT-T cartridge to provide significantly superior service life while maintaining a consistent filtration efficiency. Betapure NT-T filters achieve this through an innovative cartridge design that allows uniform distribution of fluid flow and contaminant throughout the entire depth of the cartridge. Betapure NT-T filter construction combines a polypropylene media with fluid distribution netting to form multiple layers. Critically positioned media flow channels allow greater movement of fluid from layer to layer. Three distinct media sections, made from multiple media/netting layers, are combined to form the filter cartridge.

The outer and middle sections contain multiple layers of interleaved filter media and fluid distribution netting. Within each media layer a portion of the fluid travels through the media while the balance of the fluid is delivered directly to the next distribution layer through the flow channels. The fluid distribution netting provides longitudinal and latitudinal flow paths to evenly distribute fluid flow across the surface of each successive media layer.

For more information, please ask for 3M Purification literature number LITCPN1.

Table 11 - Betapure™ NT-T Ordering Guide

Cartridge Type	Length	Grade-Micron	Packaging	Support Ring Option	End Modification	Gasket/ O-Ring
NT - Betapure™	**09** - 9 3/4"	**T005** - 0.5	**S** - Standard	**0** - None	**B** - 226 O-Ring & Spear	**A** - Silicone
	10 - 10"	**T010** - 10		**1** - Polysulfone	**C** - 222 O-Ring & Spear	**B** -
Fluorocarbon	**19** - 19 1/2"*	**T020** - 2 **T030** - 3		**2** - Stainless Steel	**D** - DOE Flat Gasket **F** - 222 O-Ring & Flat Cap **N** - None **P** - Polypropylene Core Extender **Q** - SOE, End Cap without Spring **R** - SOE, End Cap with Spring **Y** - Single O-Ring (40" length only)	**C** - EPR **D** - Nitrile **G** - PE Foam
	20 - 20"	**T050** - 5				
	29 - 29 1/4"*	**T100** - 10				
	30 - 30"	**T200** - 20				
	39 - 39"	**T400** - 40				
	40 - 40"	**T500** - 50				
		T700 - 70				

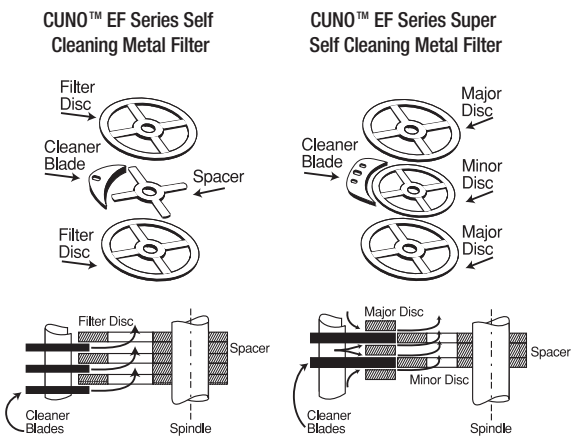


Figure 21

CUNO™ EF Series Self Cleaning Metal Filter and CUNO™ EF Series Super Self Cleaning Metal Filter Systems

CUNO™ EF Series Self Cleaning Metal Filter Cartridges

The edge-type filter cartridge (Figure 21) is an assembled unit composed of wheel-shaped discs, spacers and cleaner blades, stacked on a rotatable shaft. Each disc is separated from the next by a spacer, which conforms in shape to the discs but is without an outer rim or edge.* The thickness of the spacer determines the degree of filtration. A spacing, from .0030" to .062", offers a wide choice from which to select the right degree of filtration. The cleaning blades are mounted on a stationary rod adjacent to the cleaning stack. When the cartridge is rotated (Figure 22), the cleaning blades mechanically and positively "comb-out" the filter slots to their full depth.

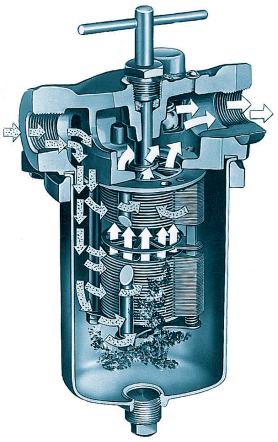


Figure 22

Figure 23 - CUNO™ EF Series Self Cleaning Metal Filters Model MSM, motorized for ease-of-use, is popular in applications with fluid flow rates (100 S.S.U.) up to 30 gpm.

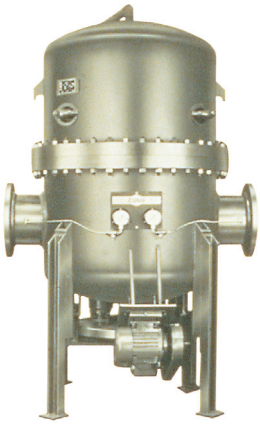


Figure 24 - CUNO™ EF Series Self Cleaning Metal Filters Model MSVR-5, the largest, containing five 7.6" diameter x 24" long cartridges in an ASME code vessel, with fluid flow rates (100 S.S.U.) up to 4700 gpm.

CUNO™ EF Series Super Self Cleaning Metal Filter Cartridges

The CUNO™ EF Series super self cleaning metal filter cartridge (Figure 22) differs from the CUNO EF series self cleaning metal filter in that wheel shaped discs of two different diameters are stacked alternately, one upon the other, on a central rotatable shaft to form a metal edge filter cartridge. Parallel to this is a stack of cleaner blades which fit into the slot formed between the large (major) discs. This is the first stage of filtration. The second stage is the radial gap between the inside diameter of the major discs and the outside diameter of the smaller (minor) discs. The cleaning blade removes entrapped solids from both stages when the stack of discs is rotated. The CUNO EF Series super self cleaning metal filter offers spacing as fine as 0.0015".

CUNO™ EF Series Self Cleaning Metal Filter Advantage

- Available for filtration ranges above 38 microns
- On-line self-cleaning, without flow interruption long lasting filtration
- Positive cleaning action
- Manual or motorized operation

CUNO™ Self Cleaning Metal Filter Family

CUNO™ EF self cleaning metal filters are available in a wide variety of sizes. From low flow manually operated units, to medium flow (30 gpm - see Figure 23) motor-driven units, to high flow (4700 gpm - see Figure 24) multi-element units, 3M Purification manufactures a CUNO EF series self cleaning metal filter to suit your system.

CUNO™ EF Series Self Cleaning Metal Filter Model MPM

The motor driven CUNO EF series self cleaning metal filter Model MPM (not shown) is designed for in-line use. Available with flange or threaded connections, this filter can be constructed for 125, 150, or 300 psi operation. With cartridge spacing from 0.005 to 0.062" (120 to 12 screen mesh equivalent) and fluid flow rates up to 161 gpm (0.062" spacing with 100 S.S.U fluid viscosity, the unit is ideal for applications that require long-term uninterrupted service.

CUNO™ EF Series Self Cleaning Metal Filter Model MPV

The motor driven CUNO EF series self cleaning metal filter Model MPV (not shown) is a floor standing unit that incorporates either one or two CUNO EF series self cleaning metal filter cartridges. Available with either flange or NPT connections, this filter can be constructed for 150 psi and higher operation. With cartridge spacing from 0.005 to 0.062" (120 to 12 screen mesh equivalent) and fluid flow rates up to 180 gpm (Model MPV-1) and 360 gpm (Model MPV-2) using 0.062" spacing with 100 S.S.U fluid viscosity, the unit can be configured for a wide range of applications.

CUNO™ EF Series Self Cleaning Metal Filters – Economic and Environment Friendly

Long lasting, some units have been in field use for 30 years, CUNO EF series self cleaning metal filter provide the user with filtration for pennies per day! Since the metal edge filter is self-cleaning, disposal costs, as well as maintenance labor and process down-time are virtually eliminated.

- Programmable timers, reversing switches, and blow-down kits are available to completely automate the cleaning cycle and remove accumulated sludge from the filter sump
- Motors for automatic cleaning can be customer specified to ensure system compatibility

Consult your local distributor or the factory for any special requirements.

Table 12 - CUNO™ EF Series Self Cleaning Metal Filters and CUNO™ EF Series Super Metal Filters Ordering Guide

Housing	Basic Cartridge Model	Spacing Style	Oil Flow Capabilities gpm @ Viscosity		Housing/Cartridge Material
			100ssu	2000ssu	
MPM and MPV-1	4.4" Diameter 14" Length	0.0050" (125 mm)	112	22	Stainless Steel or Carbon Steel
		0.0080" (200 mm)	125	29	
		0.0150" (400 mm)	157	36	

Figure 25 - 3M™ ES Series Filter Housings provide premium performance and quality.

3M™ ES Series Filter Housings

The result of 3M Purification's Rapid Manufacturing System, a combination of advanced computer aided design and computer assisted manufacturing, the 3M™ ES series filter housing delivers what you want when you want it! Express Series filter housings are ASME Code vessels available in carbon steel, 304L, or 316L stainless steel and a broad range of sizes to match the filtration needs of the oil refining industry. 3M ES series filter housings have a heavy duty cover lifting device and swing bolt cover fastener to facilitate easy cover removal and cartridge change-out.

3M™ ES Series Filter Housing Advantages

- Durable construction for long service life
- Easy access for filter removal; swing bolts and cover lifting device
- Flexible housing design; accepts a wide range of industrial filter cartridges
- Easy maintenance and cleanup; few parts to clean
- Meets plant safety requirements; ASME Code design housing

The standard housing is offered with 150 or 300 psi designs and can be easily configured for specific system requirements. Options such as outlet and cover lifting device location, radiography, and surface finish can be added onto the base model creating one of the most versatile filter vessel product lines in the industry.

Options

- Corrosion allowance–consult factory
- Side outlet and cover lifting device location can be 90,180, or 270° from the inlet
- Standard swing bolt or optional Fast-Hex cover fastener
- Full, spot, or no radiography
- Choice of inlet/outlet flange size

For more information, please ask for 3M Purification literature number LITCHSES1.

Table 13 - 3M™ ES Series Filter Housing General Specifications

Housing Model	Construction Material	Standard Flange Size (inches)	Aqueous Flow Rate @ 2 psid Pressure Drop	
			gpm	lpm
ES08	Carbon Steel, 304L Stainless Steel, or 316L Stainless Steel	2	92	348
ES12		3	206	780
ES14		4	359	1359
ES16		4	359	1359
ES20		6	813	3077
ES24		6	813	3077
ES30		8	1425	5393
ES36		10	2330	8819

Table 14 - Product Guide 3M™ ES Series Filter Housing

For Standard Cartridges (2.625" Maximum Outside Diameter)							
Housing Model	Housing Diameter	Number of Cartridges	Cartridge Style	Construction Material	Pressure Rating	Gasket Materials	Outlet Location
ES	8	6	**D** - DOE	Carbon Steel, 304L Stainless, or 316L Stainless	150 psi or 300 psi	Nitrile, EPR, Fluorocarbon, or PTFE Encapsulated Fluorocarbon	Bottom, Side 90°, Side 180°, or Side 270°
	12	12					
	14	18					
	16	24					
	20	36					
	24	52					
	30	85					
	36	120					
For Betapure™ PK Series Cartridges (36" long by 3" Maximum Outside Diameter)							
ES	8	3	**P** - Betapure™ PK	Carbon Steel, 304L Stainless, or 316L Stainless	150 psi or 300 psi	Nitrile, EPR, Fluorocarbon, or PTFE Encapsulated Fluorocarbon	Bottom, Side 90°, Side 180°, or Side 270°
	12	9					
	14	12					
	16	17					
	20	27					
	24	39					
	30	63					
	36	91					

3M™ ES Series Filter Housing Options		
Cover Lifting Device Location	Radiography	Surface Finish
Side 90°, Side 180° or Side 270°	Full or Spot	Painted (Carbon Steel), Grit Blast, or Pickle & Passivate

Figure 26

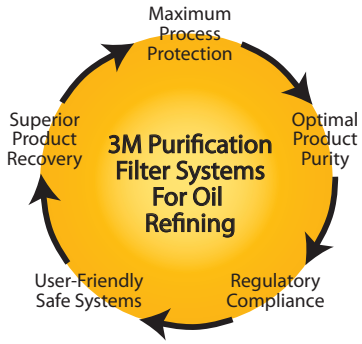
3M™ PC Series Filter Housings

The Process Series (PS) of Industrial Filter Housings is the latest addition to 3M Purification's line of industrial, ASME code designed filter housings. Available in Carbon Steel, 304L and 316L stainless steels and in sizes that accommodate from six to 125 filter cartridges, PS Housings are quality designed and economical to purchase and install. Streamlined manufacturing allows for only the outlet location and gasket material to be selected as options.

Table 15 - Product Guide Process Series Filter Housing

Housing Model	Housing Diameter	# of Ctg. Around	Height (x 10"Nom.)	Material	Pressure Rating	Outlet Location*	Cover Fastener	Gasket Material
PS	08	006	3 or 4	**A** - Steel **B** - 304L S.S. **C** - 316L S.S.	**1** - 150 psi	**B** - Bottom **S** - Side	**B** - Bolt	**GA** - Buna-N **GB** - EPR **GC** - Fluorocarbon **GD** - PTFE Encapsulated Fluorocarbon
	12	012	3 or 4					
	14	018	3 or 4					
	16	022	3 or 4					
	20	036	3 or 4					
	24	052	3 or 4					
	30	080	3 or 4					
	36	125	3 or 4					

* PS36 available with side outlet only.



3M Purification Engineered Filtration Solutions

3M Purification is a world class manufacturer of innovative filtration products with engineers, scientists, and filtration specialists serving customers' needs worldwide. A dedicated staff of market specialists provides engineered filtration solutions to accommodate a wide range of contamination control problems.

3M Purification is renowned for its technical expertise and continues to invest aggressively in research and development, expand laboratory facilities, and develop pilot plant capabilities. Pursuit of innovation has yielded advances in filtration technology and resulted in a multitude of engineered contamination control solutions for a variety of applications.

Such innovation is responsible for the development of many filtration products for refining applications. These products dramatically improve process fluid purity, enabling customers to achieve increased process efficiency, process protection, and reduced manufacturing costs.

3M Purification Inc. - Over 100 Years of Solutions

When looking for refinery filtration solutions, the industry has turned to 3M Purification for performance. 3M Purification has achieved a leadership position by striving to be the best supplier of high quality products designed to provide cost effective solutions.

Some filter manufacturers offer a limited range or a single filter option. 3M Purification, however, understands that each application is unique and there is always an alternative. 3M Purification has both the experience and the breadth of products to provide quality improvements and dramatic cost savings for the customer.

Scientific Applications Support Services (SASS)

The cornerstone of 3M Purification's philosophy is service to customers, not only in product quality and prompt delivery, but also in validation, application support and in the sharing of scientific information.

3M Purification's Scientific Applications Support Services works closely with customers to solve difficult filtration challenges and to recommend the most efficient, economical filter systems. SASS specialists can perform on-site testing and utilize filtration applications expertise to partner with customers.

3M Purification resolves filtration problems promptly and efficiently in a cost-effective, confidential manner with a commercial support group consisting of 3M Purification's in-house customer service staff, application specialists, and engineering services. 3M Purification's broad distributor base and sales offices provide worldwide customer service, local inventory, and field support in virtually every major center of manufacturing for the refining industry.

Quality Management & ISO Standards

ISO 9001 Registered Quality System

3M Purification has maintained its leadership in fluid filtration and purification by continually providing superior products and technical support. 3M Purification filtration systems are designed and manufactured to the most stringent industry standards to assure the reliability of 3M Purification systems that the industry has come to expect.

3M Purification has established a global quality management program which encompasses all facets of its operations. An essential part of the 3M Purification program is the creation of multi-function teams whose combined expertise is devoted to continuous improvement of processes, procedures, and quality systems. In addition, the 3M Purification system ensures the active support and participation of senior management. 3M Purification is fully committed to the tenets of the quality management program and provides a support system for the quality process. The majority of 3M Purification manufacturing plants are ISO 9001 registered. At 3M Purification, Quality is defined by the never-ending pursuit for continuous improvement in products, services, and personnel.

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