Paint Filtration

Paint filtration can be one of the simplest or one of the most complicated liquid-particle separations encountered in the process industries. Paint filtration, or to be more accurate, "coatings" filtration, involves paints, oils, varnishes and lacquers that may be very thin and low-viscosity in nature, to very heavy, thixotropic liquids. The percent solids of a coating may vary from zero percent (when filtering solvents or water) to 100% solids, such as pure linseed oil. In a 100%-solids coating, nothing in the can evaporates — everything ends up on the surface to be painted. It is important to understand that "solids", as calculated by the U.S. EPA consists of the pigment particulates plus the non-volatile portion of the vehicle (the vehicle is the liquid component of a coating).

Filtration requires a close look at the pigments used in a formulation. The type, shape, size and flexibility of the pigment varies widely, as do the percent solids, viscosity and rheological properties of the vehicle. Substrates may vary from a clean metal finish (automobile), to dirty steel (a bridge), to wood (home siding) and plastic. It is safe to say that proper filtration is key in producing a quality liquid coating, whether that coating be for homeowner architectural use or industrial or commercial applications including military specifications.

Where Quality Begins

While the focus of this article is on filtering the end-product-coating, one cannot overlook the importance of good filtration techniques that, in many cases, should be applied to incoming liquid raw materials such as resins, emulsions, liquid additives and even water. To assume that the liquids used in coatings are pure and free from particulates is *not* a good assumption. Vegetable oils (e.g. linseed oil or soya oil) can contain "foots". These are small pieces of leftover hull or meal that occur during the grinding and oil-extraction process, even though oils are filtered to remove foots. These particles can make their way into a drum or tank car, often appearing as sediment on the bottom of the container or transportation vessel. If foots get into a paint, they can cause quality problems.

In addition, vehicles, both solventborne or waterborne, are film-formers. It is not unusual for skins of polymeric material to form in a drum or in a tank either during transportation/shipment or during storage (particularly if warehouse or outside/ambient conditions experience wide temperature swings). If skins get into a batch during grinding, mixing or thin-down operations, expensive filtration may be the only way to remove the material. Removal can be difficult because the particulates are soft, pliable and flexible, and easily clog any kind of filter, even if the filter is back-flushable.

Another filtration demand tied to quality comes if a batch of paint experiences "seeding" or flocculation of pigment particles. These problems occur for a number of reasons but can often be tied to workers not properly following batch-manufacturing instructions. For example, pouring one gallon of an additive into a 1000-gallon batch of paint by doing so very, very slowly vs. dumping it in can be very important. Dumping it in all at once may create a polymeric snot that has to be removed by filtration.

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In summary, filtration is often the solution to quality problems that were not addressed during incoming inspection of raw materials, improper storage and temperature exposure of raw materials/ingredients, or errors in the manufacturing process.

Matching the Filter to the Paint

The filtration unit operation should match the quality and requirements of the coating. One can understand that the type of filtration used for an exterior house paint is not the same as that for a high-quality polyurethane varnish, a lacquer containing nitrocellulose and silica, an automotive enamel or an iridescent bridge paint containing large aluminum flakes.

One of the simplest, most widely used and least expensive filters is a multiple layer of cheesecloth tied to the end of a pipe prior to the paint entering the filling machine. This works fine for outside house paints, particularly those that contain diatomaceous earth or large-size pigment particles that act as a flattening agent. Tying a polyester bag to the end of the pipe is the modern day substitute for cheesecloth.

But when the manufacturer produces high-quality, semi-gloss or high-gloss enamels, say a #8 on the Hegman Scale, the manufacturer must turn to higher quality filtration utilizing bags or cartridges with high dirt-loading (particulate-loading) capabilities. And of course, clear coatings (see Sidebar on page XX) or coatings that contain talc flakes or aluminum flakes (see Sidebar on page XX) have special requirements. It is important to match the filter with the quality desired in the end product.

In this light, one should recognize that certain coatings require special materials for both the selection of the media (metal, paper, polyester, polypropylene and others) and the filter housing itself (and ancillaries), which may dictate the use of corrosive-resistant materials or plastics. If plastics are used, the units must be able to withstand the pressure requirements of the filtration system. As a tutorial note, operators should understand that in any filtration operation, there is a point, called the Tiller Point, where additional pressure on the filter no longer achieves any additional throughput.

Understanding Filtration Basics

In the coatings industry, much of the filtration is done with bags or cartridges, where certain types and sizes of particles suspended in the liquid vehicle are allowed to pass through the filter media while the "boulders" are filtered out. Specifically, liquid filtration is the process of separating suspended particles from a liquid by passing the stream through a permeable medium. Dissolved solids generally cannot be removed by filtration without some form of pretreatment. In paints, filter bags and filter cartridges are typically used to remove particles that range in size between 0.5 and 70 microns. A micron represents a dimension of 0.001 millimeters or 0.000039 inches. As an example of size, the smallest particle that can be seen by the unaided eye is 40 microns in diameter.

The basic mechanisms of filtration (Figure 1) are inertial impaction, diffusional interception and direct interception. Since the density of a particle is typically closer to that of a liquid rather than that of a gas, direct interception is the desired mechanism for separating particles from liquids.

By combining the direct interception mechanism with the particle bridging theory, we are able to explain why filter medium with specific size pores or openings are able to capture particles with smaller diameters than those of the pores. According to classic bridging theory, a stable bridge will form over a pore if two or more particles with diameters at least one half that of the pore diameter contact the opening at the same time. This newly formed bridge (Figure 2)

Figure 1 / The basic mechanisms of filtration

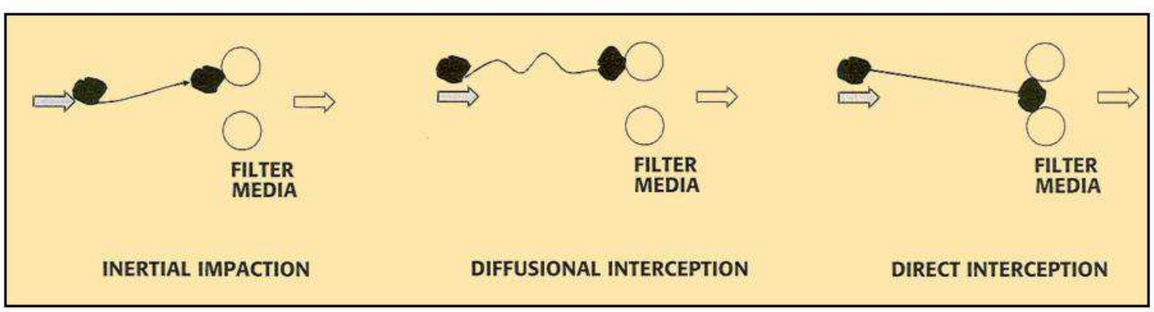
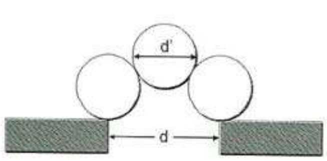
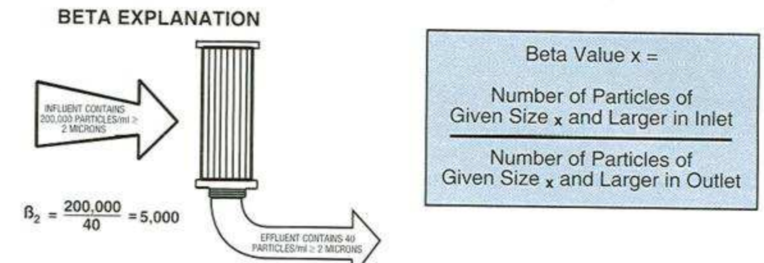


Figure 2 / The bridging theory



d' = diameter of bridging particle
d = diameter of pore throat
If d ≤ 2d', STABLE BRIDGES WILL FORM

Figure 3 / Beta ratios can predict performance of Absolute Rated filters



$$\text{Filter Efficiency (\%)} = \left[\frac{\beta-1}{\beta}\right] \times 100$$

Filtering Clear Varnishes

Clear varnishes can use bag or cartridge filtration, but, during the manufacturing process, particularly in open-fired or closed-kettle varnish cooking, manufacturers do utilize Neutsch-type filters. A filter aid (for example, diatomaceous earth or clay) may be placed on top of a treated paper, and the batch of varnish or resin is passed through the filter unit. Disposal considerations tied to the spent filter are an important cost consideration, especially if handling the aid requires protective clothing or special breathing apparatus. Comparative economics/comparative technologies is normally not part of the schooling of paint makers or varnish cookers.

Advances in cartridge technology have led to back-flushable filters with extremely high dirt-holding capacity. These filters are capable of replacing separation equipment that utilize filter aids. This will eliminate the messy and sometimes expensive disposable problem of spent filter aids – a dramatic breakthrough that will influence filter selection in the future.

contains even smaller pores that, in turn, capture smaller particles.

Under certain conditions, collected particles can be released from the filter medium and pass downstream. Variations in flow rates and pressure surges are common causes of particle release. Even under ideal flow conditions, filters can release particles if their medium structure is subject to pore enlargement. This is a typical occurrence in string-wound filters and low-density felt bags whose pore sizes change in response to increased pressure. The best filters are designed with filter medium that have fixed pore structures that are not affected by variations in pressure and flow rate. These facts are particularly important in paint filtration where increased pressure may force flexible particulates through the filter instead of removing them.

Filter Types

The most commonly used filters in paint filtration can be classified as having either a non-fixed, random-pore-size medium or a fixed, controlled-pore-size medium. Understanding the differences between these two types of medium is important in predicting how each of these filters will perform during the filtration process.

Non-fixed, random-pore-size medium filters, such as felts, woven yarns and packed fiberglass, are constructed of media that contain pores of various dimensions that can enlarge as flow rate and differential pressure changes. These types of filters are subject to particle unloading, channeling and media migration.

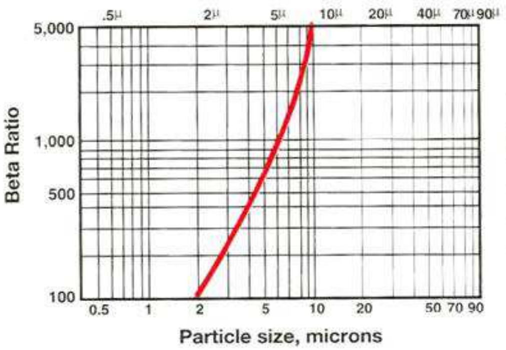
Fixed, controlled-pore-size medium filters are constructed in a manner that prevents the pores from enlarging under pressure and flow changes. Although these filters contain pores of varying sizes, their overall pore structure is controlled during the manufacturing process to assure quantitative removal of particles larger than a given size. With this type of filter, any particles released during impulse conditions should be smaller than those designated by its removal rating.

Removal Ratings

Various systems for rating filter removal efficiency exist today. Two of the most common are the Nominal Rating and the Absolute Rating systems. Unfortunately, each manufacturer is free to utilize variations of the different testing procedures to assign the Nominal or Absolute Ratings of their specific filters.

A Nominal Filter Rating is generally defined as an arbitrary micron value based upon the particle removal by weight of some percentage of all particles of a given size or larger. Common percentages used by various manufacturers include 98%, 95% and 90%. This rating system bases results on gravimetric testing rather than actual particle counting. Problems associated with the Nominal Rating system include a poorly

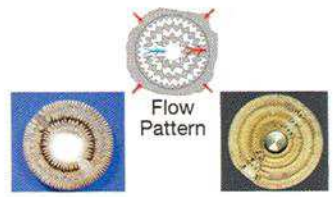
Figure 4 / Plot of a Beta Curve



Typical Beta Values

Beta Value	% Removal
100	99.0
1,000	99.9
5,000	99.98

Figure 5 / Basic design and flow path of an HE/HC filter



defined test procedure, removal percentages may vary with manufacturer, test data is not usually reproducible, and it is not uncommon to find downstream particles larger than the micron rating of the filter.

An Absolute Filter Rating is generally defined as the diameter of the largest hard spherical particle that will pass through the filter under specific test conditions. Several recognized tests exist for establishing the Absolute Rating of a filter, and their choice may vary with manufacturers. However, in all tests, the filters are subjected to a particle challenge by pumping a known contaminant through the filter and measuring upstream and downstream particle counts. Only fixed, controlled-pore-size medium filters can have an Absolute Rating.

Beta Ratios

Beta ratios were originally developed for evaluating the performance of hydraulic and lubricating oil filters. Today, these ratios (Figure 3) can be very useful in measuring and predicting the performance of Absolute Rated filters under specific test conditions in a variety of liquids.

The Beta ratio concept involves measuring total particle counts at several different micron levels in both the influent and effluent streams. These counts provide a profile of the filter efficiency at the different micron levels and can be plotted as a Beta Curve (Figure 4) for the given filter.

Filter Selection

In coatings, many factors must be taken into consideration when choosing the filtration system. These include chemical and temperature compatibility, flow rate, acceptable pressure drop, degree of filtration and overall filtration cost. In state-of-the-art filtration systems, the paint filter cartridges are almost always pleated. Depending upon the size of the paint batch, the filter system will normally use a #2 style pleated bag — a high-capacity cartridge filter (HCCF).

These HCCF cartridges generally utilize a staged, pleated filter that is highly efficient and high capacity (HE/HC) that maximizes dirt-holding capacity to assure maximum time between change out (MTBC). Keep in mind that the filtration operation in paint plants can be hazardous, so producers try to keep the units on line as long as possible to improve MTBC. This is particularly true in those operations where kettles, cooking and reactors are used to make the vehicle. There are cases where the materials being filtered are actually toxic.

The HE/HC cartridges feature segregated flow channels and flow chambers to optimize the Alpha Factor (A) — a factor that is the key to determining total cost of filtration operations. Combining this design with the technique of pleating several different filter media together in a single pleat pack maximizes dirt-holding capacity. This design permits the use of many different types of filter media. This is essential for a wide range of fluid and temperature applications. A cross sectional view (Figure 5) details the basic design and flow paths of an HE/HC filter. This unique design works with either an "outside in" or an "inside out" flow path and is not limited to three rows of media.

Materials selection is very important in paint filtration. Since coatings vary in chemical composition, it is difficult to designate a filter medium that is suitable for every purpose. Other complications can arise from the glues and seals used in filter construction. Generally, polypropylene is acceptable. However, operating temperature and presence of hydrocarbons in the system will affect filter choices.

The size of filter housings and pumps is usually dictated by the desired flow rate, pressure drop limitations and required level of filtration. The recommended flow capacity of a filter element is used to determine the total number required for the desired flow rate. Housing size relates directly to the number of filter elements. Sufficient pump pressure must be provided to permit the desired flow rate through the filter element as it plugs, so as to fully use the effective dirt-holding capacity of the filter.

Filtration Costs

Paint companies often underestimate the true cost of the filtration operation. Total filtration costs must include both capital cost and daily cost/or batch costs to operate the system. Paint operations are almost always batch operations, and attaining proper filtration quality can vary depending upon the size of the batch. Specifically, a certain type of filter may be required to assure quality of the end product, but a small (100 gallon) batch may require the use of a filter element that could actually handle a large (2000 gallon) batch. And the same clean up and down time are required for both.

Indeed, most engineers understand capital costs, but product pricing may not cover the true cost of operations and maintenance of the filtration system. This includes cost of labor, installing and removing the element and the actual costs of disposing of the element. In those cases that require special breathing apparatus and protective clothing, the actual cost of the total filtration operation can be quite high. The cost of the filter element itself may be nominal compared to companion costs.

Filtration Cost Efficiency (E) is defined as the total costs, direct and indirect, that are associated with removing one pound of solids from a process stream. Direct cost is filter price, and indirect costs include labor and disposal. A lower total cost results in a better efficiency rating. If we disregard equipment depreciation, we can express this relationship by the following formula:

$$E = \frac{P}{H} + \frac{L}{H} + \frac{D}{H}$$

D = Disposal Cost/Filter
H = Dirt-Holding Capacity in Pounds
L = Labor Cost/Filter
P = Filter Price

In paint filtration, which is a batch operation, one must recognize that in small batches an operation may not reach the actual dirt-holding capacity in pounds (H) of the filter. This can dramatically increase the true cost of the filtration operation. However, by knowing dirt loading, you size the filter accordingly. One would select a smaller filter and housing to handle the batch load of a 100-gallon batch vs a 1000-gallon batch. One matches the filter and housing to the size of the batch and the dirt-holding requirements.

Special Filtration of Coatings Containing Aluminum or Talc

Talc (magnesium silicate) is used in architectural coatings as an extender or a flattening agent to create low-gloss paints. But talc also finds its way into expensive automotive enamels, where, like aluminum flakes, it give the topcoat an iridescent look. Both talc flakes or aluminum flakes pose a special filtration problem because of their shape and size. They are large and flat and do not resemble the other pigments used to give color and opaqueness to the coating (such as titanium dioxide or monastral red).

The problem becomes one of allowing both the small, fine pigments to go through a filter while not blinding the pores with the large, flat flakes. One answer is to make the filter out of wedge wire screen (WWS), whose openings (between the wedge wires) will allow the flat flake to slip through on its side while holding back any unwanted pigments that were not ground to the proper diameter.

This "slip through" technique is accomplished by carefully vibrating the internal WWS. When the talc or aluminum flake reaches the screen face, rather than blind it, the vibration turns the flake on its side and it slips through the WWS, while larger, boulder-like particles are filtered out. "Viola," one is able to produce iridescent paint.

In the mid 60's when the Vincent Thomas Bridge was built between San Pedro and Long Beach, CA, formulators tried to use string cartridges to filter the iridescent green paint used as the topcoat for the structure. Particulate removal not only reduced the quality of the iridescence, but lowered the percent solids of the coating so that the state specification was not met. This required reformulation and changes to the filtration being used. The point is, filtration can either positively or negatively affect the quality of the end-product coating.

Figure 6 / The effect of filter surface area on filter life

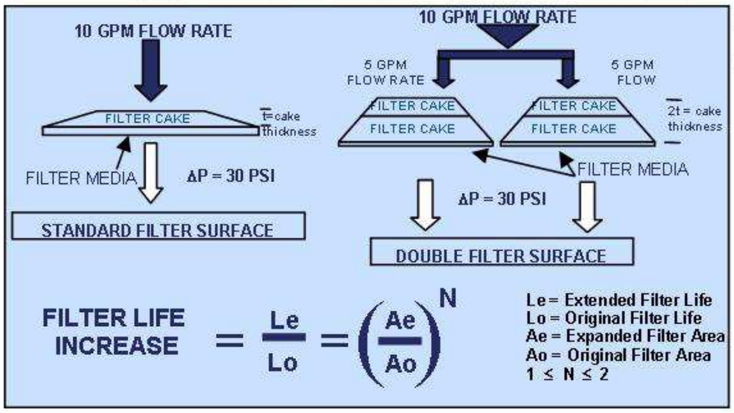


Figure 7 / Pleated filters increase surface area

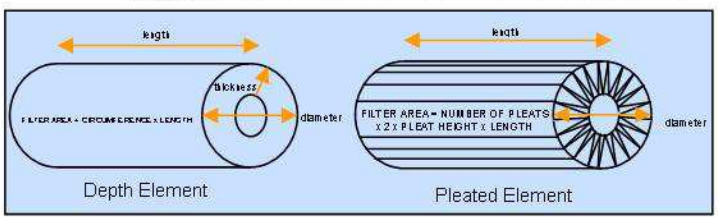


Table 1 / Maximum number of cartridges per vessel considerations

Vessel Internal Diameter	2.5" Standard Cartridge	6.25" HCCF Cartridge
18"	30	30
22"	40	6
28"	70	11
32"	90	16
36"	120	19
42"	200	27

NOTE: Vessels above 22" are not often used in paint filtration operations but are widely used in other parts of the process industries such as petrochemicals, and they are also used in large-scale oil and gas operations.

Table 2 / Monthly operating parameters
(36" ID vessel, contaminate load 72 pounds per month)

Costs	Standard String Wound	Standard Pleated Filter	HCCF Pleated (6.25" OD)
Depreciation	$400.00	$400.00	$400.00
Filter Cost	$2,160.00	$2,040.00	$1,263.50
Labor Cost	$200.00	$50.00	$9.50
Disposal Cost	$960.00	$240.00	$90.25
Total Cost	**$3,720.00**	**$2,730.00**	**$1,763.25**
Alpha Factor (A)	30.0	28.3	17.5

NOTE: This would be applicable to a dedicated filter where thousands of gallons of one product are manufactured in a world-scale facility, for example, a white house paint or a clear polyurethane varnish.

Filter price and dirt-holding capacity are the dominant components in operating cost. The relationship between these two items is defined by the following formula as the Alpha Factor (A).

$$\text{Alpha Factor (A)} = \frac{\text{Filter Price (P)}}{\text{Dirt-Holding Capacity (H)}}$$

Combining the Alpha Factor formula with the Filtration Cost Efficiency formula provides an interesting result.

$$E = A + \frac{L}{H} + \frac{D}{H} \Rightarrow E = A + \frac{L+D}{H}$$

The indirect costs shown in the equation are reduced as the dirt-holding capacity of the filter increases. Therefore, the Alpha Factor becomes the dominant number in the equation. The lowest Alpha Factor results in the lowest filtration cost. One can see that wide variations in the H factor dramatically offset A in order to achieve the same filter cost efficiency (E). With a small batch, one does not necessarily maximize filter life.

Maximizing Filter Life

Filter life is directly related to a filter's dirt-holding capacity. It can be defined as the total volume of fluid that passes through a filter before reaching the maximum operating differential pressure.

Under a constant flow rate, the life of most Absolute Rated filters is significantly increased when their effective surface areas are increased. This property of filter life is a direct result of the relationship between flow density (gallons per minute per square foot) and the resulting differential pressure across the filter area. Under ideal conditions, the maximum increase in filter life is equal to the square of the increase in effective surface area. Doubling the effective filter surface area can increase filter life up to four times (Figure 6).

An easy way to increase filter life using an existing housing is to replace depth filters with pleated filters. In the following diagrams, the surface area of the cylindrical depth element is much less than that of the pleated element (Figure 7).

In paint plants that make very large batches of paint (Table 1), engineers should obviously consider the savings associated with filter housing costs. Many plants design their filtration systems based on a maximum flow rate. If a 2.5" OD or 3.75" OD cartridge is used in the base flow rate calculations, a larger vessel will be required to meet the maximum flow requirements. Using an HCCF design (Table 2) will minimize the filter vessel size (and costs) required for specific flow rates and can result in significant cost reductions when high-pressure filter vessels are required.

Figure 8 / HCCF filter and housing

Conclusion

In conclusion, paint filtration deserves close attention at the plant level because costs can be significant. The filter operation may be an important factor in the actual pricing of the end product.

- Filter elements used in paint systems should be selected based on media that contain fixed, controlled pore sizes.
- Beta ratios provide a profile of a filter's efficiency at different micron levels.
- Total filtration operating cost must include equipment depreciation, filter element cost, labor cost for element change out and element disposal cost.
- A filter element's Alpha Factor (A) is easy to calculate. The lowest Alpha Factor results in the lowest filtration cost.
- An increase in effective surface area or a reduction in flow rate will result in a significant increase in filter life.
- Vehicle filtration is extremely important to assure high quality of the end product, especially when the vehicle is manufactured on site.
- Quality control and filtration of incoming raw materials may be required.

Filtration costs are often an afterthought in paint and coatings operations, and yet can dramatically affect the cost of any particular batch of paint — especially industrial coatings. Filtration can hide real manufacturing costs that dramatically affect profitability, and must be considered in the overall pricing structure of all coatings, especially those small batches that do not take advantage of the maximum dirt-holding capacity of the filter elements.

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