CHAPTER 3

SOLID-LIQUID SEPARATION AND INTERCEPTORS

This chapter will describe the methods used to separate suspended solids (particulates) and liquids from a feedwater stream. Separation is characterized by the recovery of all of the processed water and having the flow of the feedwater, in general, pass through the filter perpendicular to the filter bed or medium. General selection criteria will also be discussed.

FILTER CLASSIFICATION AND TESTING

There are many ways to classify filters:

1. *Filtration types.* Depth, surface, and screen are general filter types.
2. *Driving force.* Flow through the filter can be induced by pumps (pressure), centrifugal force, or gravity.
3. *Function.* The goal of the filtration process is either retention of the dry solid when the filter cake is of value or disposal of the filter cake when process liquid is of value.
4. *Operating cycle.* The cycle of operation can be batch mode or continuous.
5. *Nature of the solid.* The accumulation of solids within a filter matrix can be either deformable (compressible) or rigid (incompressible).

The classification of filters is not exclusive and the distinction between them is arbitrary. Here the characterization of filters will be based on the type of filtration, the characteristic generally used in utility and service water filtration systems.

Interceptors, strainers, and filters are all devices used to reduce (or remove) and retain suspended solids. Other separation processes, such as sedimentation and centrifugation, that are used to treat large quantities of water or for dewatering, are outside the scope of this book. Design and selection criteria for specific contaminant removal are provided where appropriate in various other chapters discussing individual systems.

The distinction between filtration and water purification is arbitrary. Methods such as membrane and membrane exchange filtration that removes ions, allows preferential passage of specific substances, and does not conform to the previous definition of filtration are considered water purification methods and are discussed in Chap. 4.

GENERAL

Feedwater, raw water, and source water are various ways of referring to a solution whose components are intended to be separated. *Filtration* is the process used for separation and retention of suspended and colloidal particles by mechanical capture and adsorption from fluids by passage through a porous medium. Mechanical capture physically prevents a contaminant particle from passing through a barrier with openings (pores). Adsorption is the attraction to and adhering of a particle to the surface of the filter medium. Adsorption can occur even if the pore is larger than the particle. This attraction is due to a variety of surface chemical forces between the particle and filter medium.

The mechanical properties of the particles suspended in the water stream must also be considered. At one extreme are solid, undeformable particles such as sand or quartz, and at the other extreme are gelatinous or deformable materials such as synthetic colloids and bacteria. Because they can deform, they are more likely than hard particles of the same size to pass through a filter.

FILTER CATEGORIES AND DEFINITIONS

Screen, surface, and depth filtration are the three broad categories of the filtering process.

A screen filter is best thought of as a single, thin layer of a material that has a symmetrical arrangement of openings or passages called pores. These pores trap all particles larger than the pore size on the surface of the filter. This process is called sieving, or size exclusion, and is the classic filtration method. Sieving can also be referred to as screening or straining. Screen filtration is essentially absolute because any particle larger than the pore size cannot pass through. Another mechanical capture mechanism, called bridging, occurs as particles captured by direct interception form a particle mat, or bridge, across the filter medium. By partially blocking the filter pores, this bridge or filter cake may produce a smaller filter pore structure that will aid in particle capture. Examples of screen filters are woven metal, nylon, and dacron mesh. Cast polymeric membranes are used where the smallest size pores are required for submicronic and macromolecular separations.

A surface filter is thicker than the screen filter and constructed from thick or multiple layers of filter media, often glass or polymeric fibers. When the water passes through a surface filter, particles larger than the spaces within the fiber matrix are retained, primarily on the surface. Smaller particles are trapped within the matrix, giving this type of filter the properties of both a screen and depth filter.

A depth filter relies on the density and thickness of the layers to mechanically trap the particles, and it will retain relatively large quantities of them. Depth filtration occurs on the surface and throughout all or part of the filter medium as the water passes through a complex network of flow channels. The particles are retained by random adsorption and mechanical entrapment. Depth filters can be of two types, granular and preformed. Preformed depth filters are composed of fibrous or sintered materials that have a random pore structure. Granular depth filters have either a graded or consistent density of granular media and typically are long in length. Graded granular filters have layers of media that become progressively denser through the matrix as water flows through them. Constant density granular filters' have the same size filter media or openings throughout the matrix.

A filter that is hydrophilic is one that has an affinity for water; it can be wetted with almost any liquid. A hydrophobic filter is one that cannot be wetted by an aqueous solution. Some filter materials may leach substances into the fluid as it is processed, thereby affecting its purity. Such substances, called extractables, can be minimized by preflushing. There is a test for plastics conforming to USP class VI that is used to ensure that there will be no adverse reaction of body fluids to extractables from filter housing or media materials.

The molecular weight of any compound is measured in daltons. Some filter media measure passage through the filter by molecular weight for separation of one compound from another.

FILTER RATINGS

Filters and strainers are rated in several ways. Absolute and nominal ratings are based on the size particle the filter is expected to capture and retain. Particles are measured in micrometers (microns), which is 1/1,000,000 m (1/25,000 in) and abbreviated μm. This rating is a single number called the micrometer (micron) rating. The micron rating of a filter or strainer can be absolute or nominal. These ratings are often misunderstood and this is an area of confusion in the filtration industry. Another method is called the beta rating, which is based on actual particle counts of different particle sizes of both the influent and effluent liquid stream. The beta rating is considered the most accurate rating measurement of a filter. Refer to Table 3.1 for the relationship between beta value and percent removal efficiency.

Efficiency is a measure of particle removal. It indicates what percent of particles above a certain size will be retained. For absolute rated filters, the rated pore size indicates 100 percent removal and is based on the log reduction values associated with bacterial retention testing. Because the pore size of some filters is not well defined, it is not possible to assign those filters an absolute rating. Instead they are given a nominal pore rating, which indicates the particle size above which a predictable percentage of particulates will be retained. As an example, a nominally rated 1.0-μm depth filter will remove 90 to 95 percent of all particles 1.0 μm or larger. For a surface filter of the same rating, the efficiency would be 99.99 percent.

An absolute micron rating indicates the smallest size particle that the filter will capture; no particles of that diameter or larger will pass through the filter. The absolute rating generally depends on sieving, since the capture of particles by adsorption is never assured. Since absolute ratings are generally unrealistic for most services, nominal ratings are the most common method used to rate filters. One exception is in pharmaceutical service, where absolute ratings are required to assure that all particulates of a certain size are removed.

Nominal ratings allow the filter rating to consider particles retained by adsorption. The nominal rating has no generally accepted definition in the industry, and there are no industry standards. As defined by ANSI, the nominal rating is an arbitrary micrometer value indicated by the filter manufacturer. Due to its lack of reproducibility, this rating is depreciated. The ambiguity of this rating method makes it difficult to achieve reliable and consistent results. Many manufacturers use different methods to rate their filters, for example, expressing the results gravimetrically, which does not represent the particle size and number in the effluent stream. Some have specific test conditions that do not represent the actual conditions for which the filters will be used. These test conditions may use fine or coarse particles such as AC test dust, latex beads, carbon fines, or bacteria. The nominal rating can be used as a guideline, provided that the micron rating includes the percent removal efficiency rating of that micron size.

TABLE 3.1 Relationship Between Beta Value and Removal Efficiency

Beta ratio	Removal efficiency %
1	0
2	50
10	90
100	99
1,000	99.9
5,000	99.98
10,000	99.99

Void volume of preformed fibrous media is the ratio of pore area to the fiber diameter of the filter media. If all other factors are equal, the medium with the greatest void volume will have the longest life and lowest initial clean pressure drop per unit thickness. Factors such as strength, compressibility of the fiber material under pressure (which reduces void volume), cost, and compatibility of the media with the water contaminants being removed should all be considered when selecting a filter for a specific application.

MEMBRANE FILTER TESTING

An important feature of a membrane filtration system is its ability to be tested before and after filtration runs. Testing can detect a damaged membrane, ineffective seals, or a system leak that may result in passage of contaminants that the filter is designed to trap. These tests are commonly called integrity tests. Testing before and after a run will ensure that the entire system is intact, thereby validating the process. Prior to testing, cleaning to remove large-scale contamination (and sterilizing the filter and apparatus if necessary to ensure elimination of microbial contamination) is required.

The type of test selected is dependent on the specific filter chosen. However, if the previous history of a specific filter is not available, the only accurate method of testing the filter is to place it in service and run an on-site fouling and compatibility test.

Air Permeability Test

An air permeability test is normally used to test wound cartridges. It is a simple, nondestructive test that correlates well with filter performance and it is considered more revealing than micron rating.

Bubble Point Test

Membrane filters have discrete, uniform passages from one side of the membrane to the other which, in effect, are fine uniform capillaries. The bubble point test is based on the fact that a liquid is held in these capillary-like structures by surface tension and the minimum pressure required to force this liquid out of the capillary space is a measure of the capillary diameter. The pressure required is inversely proportional to the largest pore size. After the filter is wetted, air pressure upstream of the filter is increased.

There are two widely used variations of the bubble point test. The first is the visual test. For this variation, the downstream side is watched for the appearance of bubbles, which indicate that the air is passing through the capillaries. The pressure that produces a steady, continuous stream of bubbles is the bubble point pressure. The second variation is the monitored method, where a pressure drop will occur as the gas begins to flow through the filter.

It is not necessary to determine the exact pressure of a given filter to prove its integrity. If the pressure exceeds the minimum point determined by the manufacturer of the filter, its integrity is assured. The bubble point test is also used to test the integrity of the filter cartridge.

Diffusion Test

In a high volume system where a large volume of water must be displaced before bubbles can be detected, a diffusion test should be performed instead of the bubble point test. This test is based on the fact that in a wetted membrane filter under pressure, air flows through the water-filled pores of the filter at a differential pressure below the bubble point pressure by a diffusion process following Fick's law. In small filters, the flow of air is very slow. But in a large filter it is significant and can be measured to perform a sensitive filter integrity test. In a wetted filter, a constant air pressure is applied at approximately 80 percent of the bubble point pressure established for that particular filter.

There are two widely used variations of the diffusion test. The first is the forward flow test, which relies on direct measurement of the diffusive gas flow rate. This flow rate is measured either by instruments placed in the gas flow upstream of the filter or by calculating the volume of airflow according to the rate of flow of displaced water downstream of the filter. The second method, called the pressure decay method, calculates the loss of diffusion gas pressure from a known volume of gas over a period of time.

Water Breakthrough Test

Similar to the bubble test except that water is used instead of air. Water pressure is increased on the upstream side of the filter, and the pressure that results in a steady stream of water downstream of the filter is recorded. The breakthrough pressure must be correlated to empirical data on contaminant retention from the manufacturer in order to be a valid test.

Water Intrusion Test

Also called the water pressure integrity test, this is often used for hydrophobic filters (which resist wetting by water). This test requires that the filter be wetted by an alcohol/water mixture. Water pressure is applied upstream of the filter and the pressure decay is measured. Care must be taken to test with water from the same source because of variations in surface tension. When used as a vent filter, the membrane must be dried before being placed back in service.

STRAINERS

GENERAL

A strainer is a closed vessel with a cleanable screen or mesh generally used to remove and retain foreign particles larger than 45 μm (325 mesh) from flowing liquids. If a particle is visible to the naked eye, a strainer should be chosen to remove it from the liquid stream. If the device retains particles finer than 45 μm, it is generally considered a filter. The relationship between mesh and opening size is given in Table 3.2. The difference between filters and strainers is one of semantics; a strainer could be considered a coarse filter.

TABLE 3.2 Relationship Between Mesh and Opening Size

Mesh size	Particle diameter, μm
Strainer	
4	5,205
8	2,487
10	1,923
14	1,307
18	1,000
20	840
25	710
30	590
35	500
40	420
45	350
50	297
60	250
70	210
80	177
100	149
120	125
140	105
170	88
200	74
230	62
270	53
Filter	
325	44
400	37
550	25
800	15
1,250	10

TYPES OF STRAINERS

Types of strainers include Y and basket (or bucket) types. Basket strainers are available in self-cleaning models. All types are available with a large variety of jointing methods for insertion into a pipeline, including soldered types available for copper piping. They are available as off-the-shelf models capable of meeting any reasonable need. Manufacturers can construct units for special conditions.

The Y-type strainer, illustrated in Fig. 3.1, is compact in design and is considered for use where space is at a premium. Frequent cleaning is often required. Its construction makes it a good choice for high pressure applications and for gases such as steam, natural gas, and compressed air where pressures are higher and amount of dirt present is low. It has a smaller dirt-holding capacity than similar sizes of basket strainers. It is installed in a pipeline with its strainer element in the down position, and can be positioned either horizontally or vertically. Very often, a valved pipe will be put in the removable end of the strainer so that the accumulated debris can be easily blown out while keeping the line in service.

The basket strainer, illustrated in Fig. 3.2, gets its name from the upright, perforated basket used to trap particles. It is installed upright in the strainer body, and the top of the strainer must be removed for cleaning. Because of its large size, it has the ability to store large quantities of dirt and so has a lower pressure loss than a similar sized Y strainer.

MATERIALS OF CONSTRUCTION

Strainer Bodies

The materials used most commonly for strainer bodies are cast iron, bronze, carbon steel, stainless steel, and plastic.

Because of its low initial cost, cast iron is the most popular strainer body. It is used in systems where the pressure and temperature of the water are not high and the system is not subject to high thermal or mechanical shock. Cast iron is mostly

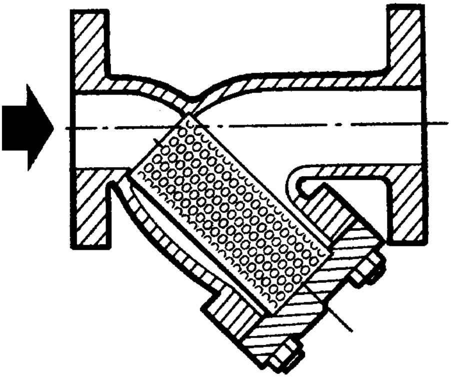


FIGURE 3.1 Y-type strainer.

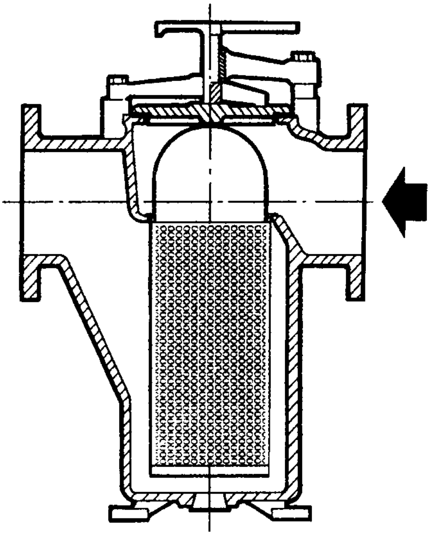


FIGURE 3.2 Basket-type strainer.

used for larger size potable water lines and many nonpotable water systems in addition to a variety of other product and process uses.

A bronze body is preferred for brackish, saline, and seawater service. It is also often used for potable water services in smaller sizes. Its cost is about double that of cast iron.

Carbon steel bodies are used where moderately high temperature and pressure conditions are encountered, and where resistance to high thermal and mechanical shock is required. Carbon steel components are the materials of choice where fire hazards exist, such as in the petroleum and petrochemical industries. Their cost is equal to bronze. For high pressures and temperatures over 1000°F, chrome-moly steel is usually specified for bodies.

Stainless steel is the preferred body, basket, and screen material for the pharmaceutical, food-processing, and chemical industries because of its resistance to corrosion and contamination and ease of cleaning. Stainless steel costs about four times as much as cast iron.

Plastic strainer bodies are available in all of the materials used for pipelines. Baskets and screens of all metallic materials are also available.

Basket and Screen Construction and Materials

The actual collection and retaining of the debris, dirt, and other particles in all strainers is done by the basket or screen that is placed inside the body of the strainer. The size of the openings through a screen is referred to as mesh, and the size of the openings through a basket is referred to as perforations.

The term *mesh* describes a screen that uses a woven wire cloth manufactured from the material chosen for the intended service. The most common material for all applications is stainless steel. Mesh screens are generally available in standard sizes from 20 to 200 mesh, with a variable wire size used depending on the mesh. The mesh size does not indicate the particle size retention, since the size of the mesh opening is determined by the diameter and number of wires per inch. For example, a 100 mesh means 100 vertical and 100 horizontal strands of wire per inch. For critical applications, a screen should be selected on particle retention capability, not mesh size.

Standard perforated screens are manufactured from a light or heavy gauge sheet metal available in standard sizes generally ranging in diameter from 1⁄32 to 1⁄4 in. The baskets should be assembled by either welding or brazing. The strongest are of welded construction. Solder is much weaker and more easily broken. If a basket strainer is required for fine straining, it is common practice to add a wire mesh liner inside the perforated bucket since the screen alone is too weak to provide the necessary mechanical strength.

The material to be used depends both on the intended water service and the body that the strainer is installed into. The most commonly used basket materials are brass and stainless steel. Cast iron strainer bodies commonly use baskets of brass and stainless steel, depending on the intended service. Bronze bodies usually require Monel metal baskets because of the severe service required. Stainless steel baskets are used with stainless steel bodies.

The baskets are made from sheet metal with a wide variety of diameter perforations. A Y strainer is generally furnished with 1⁄16-in perforations in sizes up to 4 in, 1⁄8-in perforations in larger sizes for liquid service, and 3⁄64-in perforations for steam service. If finer straining is required, a wire mesh screen fitted inside a basket is used. In this case, generally accepted practice limits the perforations in the basket to 50 percent of the wall area in order not to lose strength. In addition, this combination usually provides the best ratio of maximum flow rate with adequate strength. The mesh and basket should be an integral unit, with the mesh fastened to the basket both at the top and the bottom to prevent any debris from bypassing the unit.

By generally accepted practice, the open area perforation ratio should be about 4:1 to avoid excessive pressure drop through the unit. A smaller ratio will require frequent cleaning. Additional strainer basket area can be obtained by using a pleated basket. If finer filtration is required after the strainer has been in service, a mesh liner can be added inside the basket. If the size particle to be removed is known, the perforations should be slightly smaller.

Fluid streams may contain iron or steel particles that are small enough to pass through the finest screens. If this is a problem, a strong magnet capable of lifting several times its own weight should be suspended in the basket. The magnet should be installed so that all the water passes over it. This magnet should be encased in an inert material to prevent corrosion.

Baskets, especially when full, are not capable of withstanding the same pressure as the body. A particular phenomenon called runaway buildup is possible, in which the dirt builds up and plugs the mesh or perforations, thereby reducing the free area. The pressure in the strainer increases slowly at first, but faster and faster over time. The water velocity and pressure inside the basket escalate quickly, which causes the resultant flow to stop or be reduced to a trickle. This full-line pressure can burst the basket.

Covers

A cover is provided in order to remove and clean the basket. The most common type is bolted; the bolts must be loosened and removed to provide access to the basket. This type of cover is the strongest and should be used for high pressure applications. However, its removal is time consuming. Another type is the clamping yoke, in which threaded, tee-shaped handles are used to secure the cover to the body. Often, the cover is attached to the body with a hinge mechanism, making it very easy to remove. This type of cover is more expensive than the bolted type.

Another type of strainer is the automatic type, which does not require manual cleaning. A rotating, circular screen is used as the basket. The water inlet is directed to the inside of the basket. A rotating backwash inlet inside the basket uses the differential pressure between the atmosphere and line pressure to produce a localized reverse flow across only a portion of the basket, thereby allowing continuous cleaning. This type of strainer is appropriate for large consumers of water such as raw water inlets from rivers and lakes used for cooling and process. Automatic strainers are available to 60-in (150-mm) size.

DESIGN CONSIDERATIONS AND SELECTION CRITERIA

When selecting a strainer, the four main considerations are its physical size, friction loss through the unit, price, and ease of cleaning. The viscosity and specific gravity of the fluid, and the degree of perforation of the basket (or size mesh) all influence the pressure drop. In many cases, the size of the unit is a consideration if it is to fit into an existing space. Generally accepted practice limits the pressure drop to a maximum of 2 psi (13.8 kPa). Another general rule is to have a minimum 4:1 open area ratio of the perforations in the basket. In order to reduce the friction loss, a strainer one or more sizes larger than the pipeline into which it is installed should be selected. In some cases, the basket may become large and unwieldy when filled with debris. If this is a possibility, several smaller units in parallel should be considered. Typical friction loss through a Y-type strainer is given in Fig. 3.3, and for a basket strainer in Fig. 3.4.

Another consideration is the length of time required between cleanings. Past experience with the specific application (if available) should give a good idea of the size and amount of debris expected. Examination of the total suspended solids present in the water analysis allows calculation of the amount of debris to be expected over a period of time. This, along with any specific preference, should provide good guidelines for the proposed size of the unit to be selected.

If continuous operation of the units is critical, duplex strainers should be used. This allows one to be cleaned while permitting full use of the system. Another method is to install two strainers in line, the first with larger openings to trap large particles and the second with a finer mesh or smaller openings for small particles. This would prevent the loading up and frequent cleaning of the strainer in a one-strainer system by spreading out the cleaning load to two strainers.

There are a number of methods used to divert flow between strainers for cleaning. The most common is a multiport plug valve. For large pipe, the plug valve may get too large. For larger strainers, sliding gate valves that have synchronized discs operated by hand wheels to divert flow are often used. Another method is to use synchronized butterfly valves. The actual method selected depends on the available friction loss, available room, and cost.

Basket strainers are usually large units with a high initial cost. In general, Y strainers have a lower initial cost for the same size unit, smaller dirt-holding capacity, and larger friction loss because of their smaller bodies. It is good practice

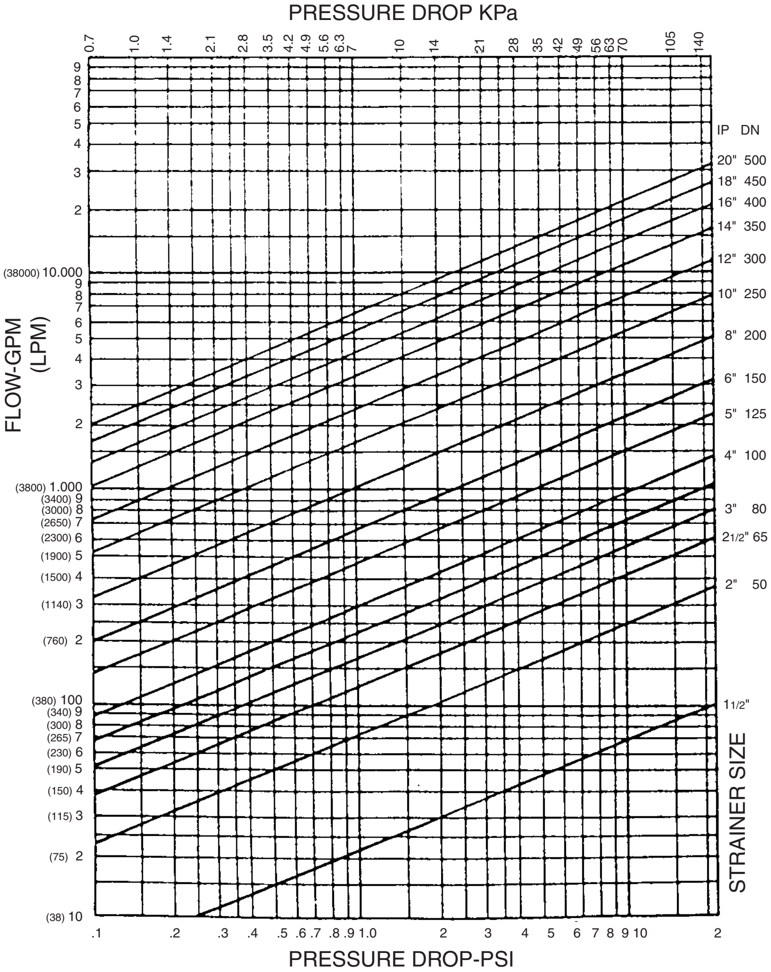


FIGURE 3.3 Pressure drop through Y-type stainers.

to allow higher pressure safety margins due to the possibility that the strainers will be placed in a position to receive water hammer shocks and water slugs. There must be enough room around the unit(s) for the necessary frequent cleaning and laydown of the basket.

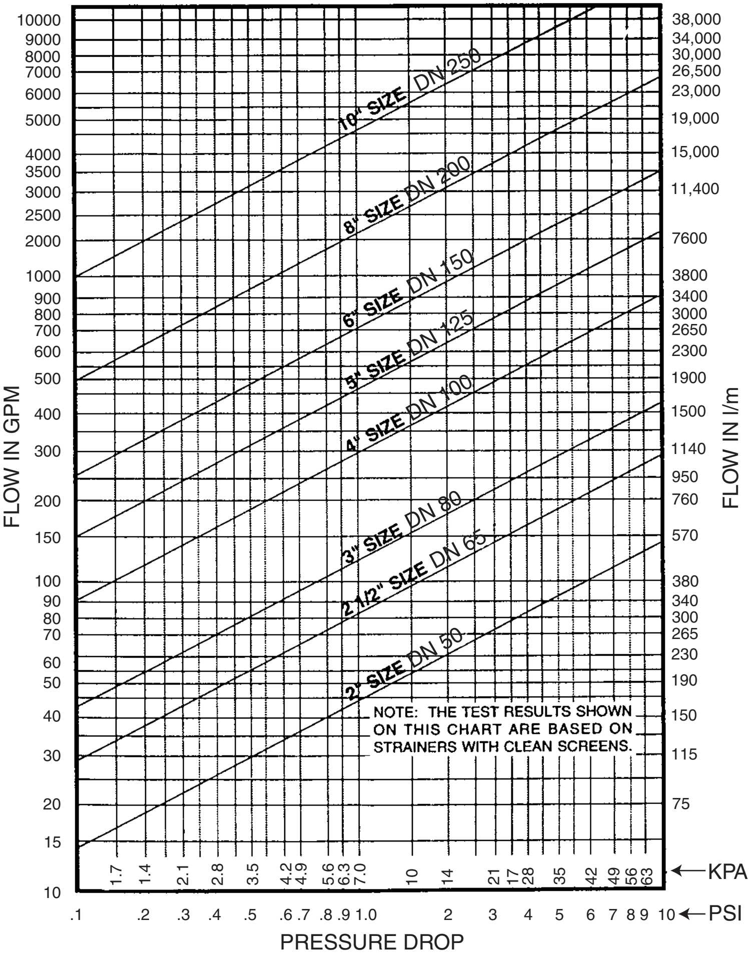


FIGURE 3.4 Presure drop through basket strainers (⅛ perforations).

FILTERS

FILTER CLASSIFICATIONS

In very general terms, a filter is used to remove particles 45 μm (325 mesh) and smaller. Although in practice there are overlapping ranges, the following represents general guidelines.

For particles between 45 and 10 μm, depth-type filters are generally used. Below 10 μm, membrane-type filters are generally selected. In the particulate size range between 10 and 0.02 μm, the separation process is referred to as *microfiltration* and the membrane filter is still the most effective. When the size of particulates falls below about 0.02 μm the removal process is called *ultrafiltration.* Ultrafilters retain material ranging in size from 1,000,000 to 1000 daltons while allowing water to pass through (1 dalton = $\frac{1}{12}$ mass of carbon atom). Filters retaining material below 1000 daltons are often called *nanofilters.* Often, different manufacturers' nomenclature of filter categories becomes blurred. Ultrafiltration and nanofiltration are considered purification methods and are discussed in Chap. 4.

In general, ultrafilters and nanofilters are used to concentrate and purify fluids and to remove particulate contaminants, and microfilters are used to clarify a solution for applications where quantitative retention is not required. In addition, filters are used to sterilize various solutions that cannot use heat due to the loss of biological activity after exposure to elevated temperatures.

TYPES OF FILTERS

Filters are divided into two general categories, depending on their filter media, granular and preformed. Granular filters are depth-type filters using individual grains such as sand and charcoal. Preformed filters can be either screen-, surface-, or depth-type, ranging in thickness from a single thin membrane element to a thick filter mat. Often, filter elements are contained within a housing called a cartridge.

Granular filters are larger units generally used to remove suspended particles larger than 10 μm. Examples of granular filter media are single or multimedia sand and activated charcoal contained in a vessel, tank, or column and septum filters.

Cartridge filters are relatively small, and generally used to clarify a previously filtered stream of water containing suspended particles smaller than 10 μm. When the media is plugged, the cartridge is replaced. Another type of cartridge filter is the capsule filter, in which the filter media is contained in a sealed housing. When plugged, the entire capsule is discarded. Commonly used materials for cartridge filters are paper, cloth, polymetric fibers, and various combinations of these.

DEEP BED GRANULAR (SAND) FILTRATION

Deep bed sand filters consist of a tank containing either silica or garnet sand of constant size (grade), or layers of a multimedia type consisting of a variety of graded material such as anthracite, silica sand, garnet sand, and quartz. This type of filter is most often used as a prefilter to remove larger-sized suspended solids in order to extend the duty cycle of finer filters downstream. It has a relatively large retention capacity of solids and removes particles 10 μm and larger. During normal operation, the raw water to be treated enters at one end (or the top) of the unit, the suspended solids adhere to the media, and the clear water collects at the other end or on the bottom.

Sand filters are either gravity or pressure type. If the tank is atmospheric and water flows through the unit with no assistance from pumps, it is a gravity filter. If the filter is in line and uses the pressure of the water supply to force its way through the filter, it is a pressure type. The pressurized filter is the most commonly used because of its smaller size and higher flow rate. A typical pressure sand filter is illustrated in Fig. 3.5.

Types of Granular Filter Media

The filter media type, particle size, and specific gravity are primarily selected for particle retention capability and ease of restratification of the media in the filter tank after backwash. A typical multimedia filter arrangement has a top bed of anthracite, a middle layer of sand, and a bottom layer of garnet. An additional layer of gravel may sometimes be used as an underlayer on the bottom of the unit to support the media bed. Anthracite usually has 1.1-mm grain size with a specific gravity of not less than 1.4. Typical depth is usually between 8 and 12 in. Silica sand has an effective size of between 0.35 and 0.50 mm with a specific gravity of 2.6. The sand layer is usually between 8 and 12 in in depth. Garnet or ilmenite typically has 0.2-mm grain size and 4.2 specific gravity. Ilmenite is commonly substituted for garnet of the same grain size, has a specific gravity of 4.5, and has

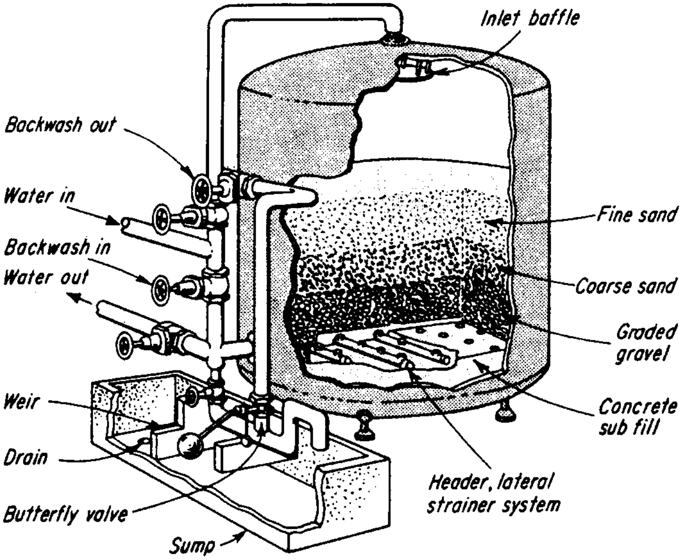


FIGURE 3.5 Typical pressure sand filter.

a typical depth of about 4 in. The gravel depth can range from 6 to 24 in, but usually falls between 10 and 18 in.

Gravity Filters

Roughing-type filters of the gravity type are used for initial treatment (pretreatment) of surface water, and are made to handle large flows economically and remove large particles. These types of filters are most often rectangular, concrete tanks. Conventional gravity filters usually operate on pretreated water and are housed in steel tanks. Gravity filters are usually rated at 2 to 4 gallons per minute per square foot (gpm/ft^2) of cross-sectional bed area. Aluminum or ferric sulfate (which is composed of multivalent ions) could be added as a coagulant to the feedwater in order to neutralize the surface charge of the colloids, thus making their removal easier. The resulting flocculated aggregates removed by the filter are discharged to drain. This type of filter is used to treat large volumes of water for process use and is outside the scope of this handbook.

Pressure Filters

Pressure filters are the most common types used for general utility and service systems. They usually operate under normal water pressure, but may require pumps to overcome excessive friction loss through the unit if available water pressure is too low. Commonly called high rate or rapid sand filters, different designs are available that offer flow rates higher than those available for gravity designs. Three different kinds of granular filters are used: single medium filters with sand media; dual media filters, consisting of a top layer of anthracite and a bottom layer of sand; and multimedia filters, consisting of a three-layer bed of anthracite on top, sand in the center, and garnet on the bottom.

Granular Filter Flow Rates

A single medium filter is usually operated at a flow rate of 3 to 4 gpm/ft^2 of cross-section area. A dual media filter is operated at a flow rate of about 6 gpm/ft^2. A multimedia filter has a typical flow rate of 6 to 15 gpm/ft^2. Another consideration is the face velocity of the feedwater, which is the velocity of the feedwater through the surface layer area of the vessel. The manufacturer establishes a face velocity, based on actual tests, that cannot be exceeded.

Backwashing

Eventually, the suspended particles removed from the water will accumulate in the top layer of the filter medium and obstruct the flow of water through the filter. These solids are removed by backwashing, in which clean water flows backwards through the filter bed and is discharged to drain. The backwash flow and volume should be capable of expanding the filter media by 50 percent to permit complete dislodging of the trapped particles. The optimum rate is determined by the manufacturer of the equipment and is usually in the range of 10 to 15 gpm/ft^2 of filter area for multimedia filters. For single and dual medium filters the rate is lower than that of multimedia filters. A backwash pump provides the pressure needed if the water pressure is not enough, and the typical length of backwash time is between 5 and 15 mm. Where surface water is being filtered and to speed the cleaning process, compressed air mixed with the backwash water may be used to effectively remove algae and other organisms. This is called air scouring. The need to backwash is indicated when, generally the pressure drop falls to between 7 and 11 psi (49 to 77 kPa) above the clean pressure value.

During the backwash cycle, the action of the water in the single medium type filter distributes the coarsest sand at the bottom and the finest at the top. This distribution will result in the accumulation of a majority of particulates removed from the raw water in the fine sand layer on the top where the raw water enters the filter. This quickly reduces its effectiveness, thereby requiring frequent backwash.

Granular Filter Selection Criteria

The advantage of the granular filter is its low initial cost. The advantage of the multimedia filter is the consistent distribution of the various sized media after backwashing, thereby increasing the time between backwash cycles. Tests have shown that the multimedia filter is more effective in removing particulates than the single medium sand filter. It is often cost effective to prefilter a liquid containing large amounts of particulates with a high solid capacity sand filter before putting it through a cartridge filter.

Sand filters can be obtained with either vertical or horizontal tanks depending on the headroom available. The horizontal tank has a larger filter bed area, which requires a higher backflow rate. Compartmentalization of the vessel may offset this requirement somewhat. The key to operation for this type of filter is the arrangement of the filter media, best arranged from coarse to fine in the direction of water flow. In addition, activated carbon added to the filter bed will remove excessive odor and bad taste, although this is usually done in a separate filter.

Problems have resulted from failure of the interior lining of the filter due to abrasion of the lining by the sand during backwash. This abrasion process creates iron corrosion products that can pass through the filter and interfere with downstream purification processes.

It is important to operate these units at the face velocities recommended by the manufacturer to prevent the forcing of the impurities through the filter. This phenomenon is called breakthrough.

Precoat (Septum) Filters

Precoat filters, often called diatomaceous earth filters, are depth-type filters used to clarify water when the solids concentration is low. One of the most frequent uses is to clarify water for swimming pools. A *septum* is a thin, porous membrane with relatively large pores that has little resistance to the flow of water. The filter itself consists of a tank containing one or more vertical filter leaves or plates (septa) onto which a thin coating of filter aid is evenly deposited to form a filter surface, or precoat. The precoat could be pearlite or diatomaceous earth. The most commonly used material is diatomaceous earth. As the feedwater flows through the filter, it passes through the filter precoat first, which traps the particulates. Although pressurized filters are available, most precoat filters use a pump to create a vacuum to pull the water through the filter, with the inlet water level controlled by a float valve. When the filter coat becomes plugged, it must be replaced. This is determined by excessive pressure loss through the filter. The filter is cleaned by backwashing, and the filter aid along with trapped solids are discharged to sewer. Care must be used in redepositing the new filter aid to ensure uniformity. Generally accepted filter aid coverage is 0.1 lb/ft^2 of filter septum surface. The diatomaceous earth media usually have a dry weight of 8 to 10 lb/ft^3 and range from 5 to 64 μm in size.

ACTIVATED CARBON FILTERS

Activated carbon is a depth-type granular filter that depends on adsorption to separate contaminants from the feedwater. It is discussed in this chapter because it falls in the granular filter category and conforms to the definition for filtration. It is not specifically used for particulate removal but rather for reduction of free chlorine, removal of TOCs, soluble organics, and trihalomethanes. Chlorine removal is necessary to protect some RO membranes and ion-exchange resins from attack.

Activated carbon media are carbon granules that have been processed from raw high-carbon materials, such as lignite and bituminous coal, wood, peat, and coconut husks. It is available in powdered and granular forms. Another rarely used method is to have powdered carbon added to a process stream and filtered out downstream. This method will not be discussed.

The most common type of activated carbon for water treatment is the granular form often called activated charcoal, which will be the only one discussed here. Activated carbon is manufactured by grinding the raw material into uniform sizes, adding a binder if necessary, and reducing (burning) the mixture in the presence of steam. This creates skeletal granules with a very large network of micro- and macropores, thereby becoming activated. Bituminous-based coal has the highest bed density and therefore a larger number of pores available for attraction of contaminants. In addition, the bituminous product is more amenable to reactivation. Because of these attributes, this is the material most often used. Granular carbon is usually 8 to 30 mesh, with an effective size of 0.9 mm and a uniformity coefficient of 1.8.

The granules are placed within a housing and the feedwater to be treated is passed through the granules. The organic removal capacity of the media depends on the diffusion rate of the organic molecules through the pores of the media, the surface area of the media, the pore size, and the source method used to manufacture the carbon. The characteristics of organic impurities also play a role in removal. The impurities' molecular weight, polarity, pH, temperature, and concentration are important factors in the rate of adsorption. This filter is much more effective in stripping compounds of low molecular weight because those of high molecular weight tend to be poorly adsorbed.

One problem with activated carbon filters is the growth of bacteria due to trapped organics, mostly because of the removal of chlorine. This can be controlled by frequent cleaning of the filter with steam, hot water (80°C or higher), or dilute caustic soda backwash.

The activated carbon media gradually lose their adsorptive capacity and have to be periodically replaced or reactivated. Small amounts of media cannot be economically reactivated. Coal-based media can be activated, but all other types are usually replaced. Reactivation is accomplished by heating the media to a temperature of

1600 to 1800°F. Expect a 10 to 20 percent loss of media during reactivation. After treatment, the carbon will lose some of its smaller adsorption pores, reducing its capacity to retain trace level contaminants. If this is an important factor, the media must be replaced with virgin material rather than reactivated. The indication for replacement is an excessive pressure drop through the unit found through periodic testing of the water quality.

A generally accepted conservative method used to select the size of the filter is to use a figure of 5 gpm/ft^3 of media. Use manufacturers' specifications to select the housing size, amount, and type of filter media for specific applications and flow rates.

Activated carbon filters used for pretreatment should allow for a face velocity of about 2 to 4 gpm/ft^2 of cross-sectional area. A minimum depth of 24 in is recommended for most feedwater streams, but the actual depth should be selected to achieve the recommended contact time with the flowing water. These two figures should be adjusted depending on the quantity and type of contaminants. Tests have shown that 1 g of activated carbon is capable of removing 1 g of residual chlorine. Because of anticipated breakthrough of organic material, the media should be replaced approximately every 6 months.

CARTRIDGE DEPTH FILTERS

Cartridge depth filters consist of comparatively thick, replaceable, preformed filter media that are placed inside a housing. The particle size retained by a depth filter is not precisely defined because of the random nature of the fiber matrix. The advantage of the depth filter is that it has superior particle load because the filter is capable of holding particles throughout its entire matrix.

Filter Media

Depth filter media vary and consist of wound fiber (such as cotton, polypropylene, or rayon) or resin-bonded laminates (such as cellulose, acrylic rayon, or fiberglass). Filter cartridges are of the wound or pleated type. The wound fiber type is used most often.

Wound filters have the same effect as a stack of woven cloth, with the filter wound around a round mandrel instead of flat. The characteristics that affect filter operation are the type of fiber, fiber diameter, and cartridge-winding techniques such as yarn tension, winding pattern, and spacing.

Fibers are available in two types, staple and monofilament. Staple fibers such as cotton and wool are spun into a thread or yarn, which is then wound onto the mandrel. Staple fibers have a fuzzy surface, or nap, that provides a high surface area for adsorption in addition to a long, random path for particle interception.

Monofilament fibers, such as those of polypropylene and other plastics, are not spun but are manufactured in any desired diameter. These fibers must be texturized in some fashion to make them suitable for filter media. They can also be produced in smaller diameters and spun into "yarn."

Pleated filters are generally made from resin-bonded materials, with the pore size determined by the type and size of the fiber and the binding method used.

Pleated cartridges usually depend more on sieving than do the wound type, and can better remove particles of a specific size.

Specific Materials

Polysulfone. Polysulfone is a membrane that is basically hydrophilic and has excellent flow rates, low extractability, broad chemical resistance, high mechanical strength, and heat resistance, permitting a variety of sterilization methods.

Nylon. Nylon is a hydrophilic membrane with generally very high flow rates, high tensile strength, low extractables, and limited chemical resistance.

PTFE. PTFE is a naturally hydrophobic membrane often laminated to a polypropylene support for added strength. It has excellent chemical and heat resistance.

Acrylic Copolymer. Acrylic copolymer is a membrane that is basically hydrophilic and has excellent flow rates, low extractables, and a low differential pressure.

Polypropylene. Polypropylene is naturally hydrophobic and is available as a membrane that is chemically inert, has a broad pH stability and high flow rate, and is considered very durable.

Glass. Glass fibers are usually manufactured from borosilicate glass. Thicker fibers are spun and thinner fibers are made into mats with the addition of a binder. They typically have low differential pressures, good wet strength, and high dirt-holding capacity.

Housings

Housing selection for filter cartridges is based on the proposed application. Although housings most often contain a single cartridge, units that hold multiple filters are available. General industrial requirements differ greatly from the sanitary requirements of the pharmaceutical and food service industries. Manufacturers provide filters and housings of standard diameter and length.

There are no industry standards for general industrial housings. The material can range from plastic to stainless steel. For safety, pressurized housings for compressed gas and high-pressure liquid applications must be ASME code stamped.

Sanitary requirements require conformance to 3-A Sanitary standards, such as an interior surface finish of a minimum 150-grit polish, the capability of being completely disassembled and cleaned, welds ground smooth, and flush sanitary connections to piping.

Housings come in three basic styles: tee, in-line, and L-shaped. The tee style offers easy filter changing, and it is easier to fit into an existing pipeline. It usually has the highest pressure drop of the three styles. The in-line style offers the lowest pressure drop of the three styles. The L-shaped style is used most often for multiple cartridge installations in industrial applications.

Seals

Seals are used to prevent the feedwater from bypassing the filter medium. They must be reliable enough to withstand repeated changing of the cartridge. The most common sealing system uses a double open-ended cartridge with a top compression spring on the cartridge. This provides a knife-edge seal on a seat at the top of the cartridge. Single open-ended cartridges, most often used in single cartridge housings, use a piston type O-ring seal contained within the cartridge itself. The material of the seal must be compatible with the type of fluid being processed, the fluid temperature, and the proposed use.

Filter Selection Criteria

There is a wide variety of filter options available to accomplish separation; and many of these options have overlapping effectiveness. Choosing the appropriate method will often involve tradeoffs between performance and value. The following factors should be taken into consideration when selecting a filter based on the intended service and the quality of the feedwater.

1. The first step to decide the suitability of any filter is to obtain an accurate analysis of the feedwater and to determine the size and quantity of the particulates to be removed.

2. It should be decided whether absolute or nominal filter ratings will be used. For filtering service, most filters are selected by using nominal ratings, with the intended use of the water dictating the various degrees of removal.

3. If the particles are deformable, the wound depth filter is more efficient in removing them. They tend to be extruded through a thin, solid, pleated filter. For hard particles, either wound or pleated can be used.

The selection of a pleated or wound filter should be based on the type and quantity of solids to be removed. The pleated filter has about 16 times the effective filtration area of a similar wound filter and so is much more effective in removing smaller particulates captured on the surface. For larger sized particulates or for a large amount of dirt to be held in the filter, the depth-type filter is more effective. Pleated filters are usually more costly than wound filters.

Depth filters have high dirt-holding capacity and are used most often as prefilters for clarification of water prior to treatment by water purification equipment. They are less costly than other types of filters.

4. The removal efficiency of the filter must be known. This value is typically specified by the end user and often based on past experience. Since the micrometer rating alone is not a fair representation of filter efficiency, the degree of removal must also be specified. A rating of 90 percent efficiency at 5 μm means that 90 percent of the particles of that size will be retained on the filter medium.

5. The flow rate must be determined. This is also called the flow density, which relates flow rate to unit of filter area. As the flow rate increases, the contaminant capacity and service life of the filter decrease. Manufacturers have established flow rates for filters. Housings containing multiple cartridges can be selected to lower the flow rate of individual cartridges.

6. The pressure drop across the filter is another consideration. The smaller the pore diameter, the higher the pressure drop across the filter. If the ratio of the initial clean pressure drop through the filter to the total available pressure is high, unacceptably low flow will quickly result even when the particulate-holding capacity is not fully realized. Pressure requirements across the filter from new to plugged condition must also be considered, with the filter selected based on the highest allowable pressure drop. Accepted practice is to have a maximum of 80 percent filter plugging. If the pressure drop is too high or if the amount of plugging is not acceptable, the size of the filter can be increased or multiple filters used. Housings that hold multiple filters are used to reduce the pressure drop when available water pressure is low.

7. If the filter is intended to be an initial filter in the system, the beta rating should be obtained from the manufacturer to determine its removal efficiency and performance characteristics. Ratings for a minimum of five or more particle sizes should be provided. If the filter is used in an intermediate location, the particle sizes will be reduced and the nominal rating of specific particulate sizes will allow for efficient selection.

8. The maximum temperature that the filter media can withstand will determine if they can be used for service where they must be sterilized and if the media are acceptable for sterilization using high-temperature water.

9. The maximum differential pressure is the difference in pressure between the inlet and outlet water pressure beyond which the filter will fail structurally, and is established by the manufacturer.

10. Effective filtration area is the measure of the usable area of the filter media independent of the material or type.

11. The toxicity and pyrogenicity of the filter materials must be compatible with the intended use of the product water.

12. Compatibility with any chemicals intended to be used for sterilization that will come in contact with the filter must be considered.

13. Extractables from the filter media must be reduced to acceptable limits to prevent problems with any downstream process. The method used most often to control and reduce extractables is to preflush the filters prior to use.

INTERCEPTORS

GENERAL

An interceptor is broadly defined as a device that separates and/or retains a specific substance from a liquid effluent stream without impairing the ability of the remaining effluent to be discharged into a drainage system. It is generally used where the effluent is intended to be discharged into a public sewer system, although it is not limited to that use. The interceptors discussed here are intended to be used inside a building.

There are a number of substances that have the potential to create safety, health, or mechanical problems within a piping network if they are allowed to be discharged directly into a drainage system. For other substances, such as precious metals, recovery is desirable for economic reasons. It is therefore necessary for them to be intercepted, retained, and (possibly) neutralized before this occurs. This is accomplished by interceptors that are designed to protect against specific hazards.

CODE CONSIDERATIONS

Plumbing codes usually have a requirement that any liquid waste containing grease, flammable materials, sand, or any other substance that, in the opinion of the local authorities, is harmful to the building drainage system, the public sewer system, or the sewage treatment process be prevented from being discharged. If there is any question as to the need for a separator, the local authorities should be consulted. Approval of specific separators may also be required.

DESIGN CONSIDERATIONS

The size and shape of the interceptor must be based on the nature of the waste (either lighter or heavier than water), the amount of material to be retained, rate and volume of total discharge into the interceptor, and the corrosion potential of the effluent (acid, caustic, or abrasive).

STRUCTURAL CONSIDERATIONS

In many cases, the interceptor may be installed either on top of or under the slab, with the cover or grate extending up to the finished floor above. Many interceptors are very heavy, and when filled with water they require special support. If the entire cover extends through the slab, additional strengthening of the slab may be required because of the size of the required penetration.

LOCATION

The interceptor must be located so that it is easily accessible for cleaning, servicing, and maintenance. The use of ladders or the need to clear away stored articles in order to remove the intercepted material is a violation of many codes. In addition, if it is easy to clean out the interceptor, it will get done regularly.

Most interceptors require manual removal of trapped substances, and so they must be located in areas where ongoing access will not interfere with normal operations. This must be balanced with the need to locate these interceptors as close as possible to the source of the substances that are being removed.

SPECIFIC SUBSTANCES

Food Related Grease Traps and Interceptors

Grease is most commonly discharged from establishments where food is prepared and/or consumed, such as restaurants, butcher shops, supermarkets and specialty stores. The hazard created is mechanical, because the grease that enters a drainage pipe suspended in hot water will harden as the water cools and accumulate to form a blockage. To be effective, enough retention time through the unit must be allowed in order for grease to float to the top. For smaller units, a flow control device on the inlet is required to reduce the flow to that required to meet unit design requirements. For larger units, the length is usually sufficient to avoid a flow control device.

For purposes of this handbook, a *grease trap* shall be a unit capable of retaining up to approximately 100 lbs. (45 kg) grease holding capacity and is intended to be placed inside a facility adjacent to the fixture or equipment discharging grease. A *grease interceptor* shall be a larger unit retaining more than 100 lbs. (45 kg) intended to be installed outside the facility on the site.

Grease Traps. Grease traps are divided into four categories based on the method used to remove grease from the unit. First is the manual type, in which the unit's cover must be taken off in order to remove the grease by hand. This is the type used most often for smaller installations. Second is the semi-automatic type, in which the grease stored in the top of the unit is discharged through a special valved connection into a separate container. This is done by running hot water through the unit for the purpose of removing the stored grease. Third is an automatic unit that continuously removes grease from the effluent. This type is only used for very large amounts of grease in large projects. A fourth type uses enzymes added to the grease trap to break up the grease inside the unit and allow it to directly enter the sanitary piping system.

The grease trap can be placed either under the floor or above the floor depending on space conditions available and method of grease removal preferred. The semi-automatic removal requires an above-the-floor installation, usually under a sink or in a storage room.

The most common material used for a grease trap is cast iron, although steel can be used for less server service. Refer to Fig. 3.6 for an illustration of a typical grease trap. Figure 3.7 illustrates typical grease trap installations.

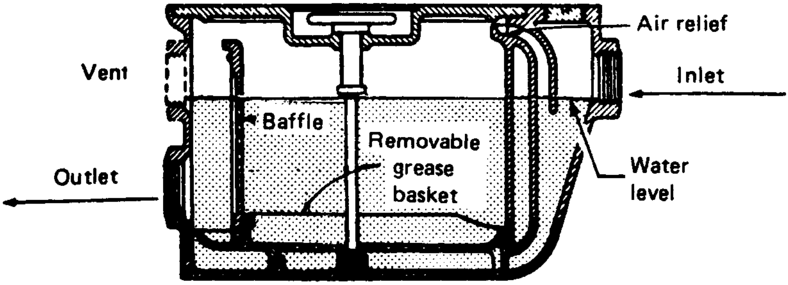


FIGURE 3.6 Grease trap.

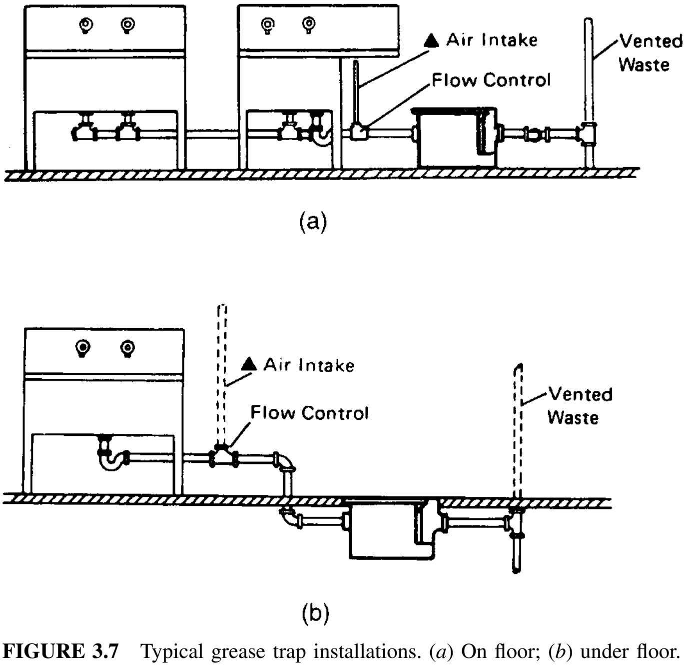


FIGURE 3.7 Typical grease trap installations. (*a*) On floor; (*b*) under floor.

Grease Interceptors. Field testing has proven that solidified grease blockages are common in many public sewer systems. Very often, grease traps installed adjacent to fixtures and equipment do not adequately separate grease from the waste water due to inadequate or no maintenance. It must be emphasized that grease traps adhering to applicable certification standards and properly cleaned remove grease very effectively. Reports indicate they are rarely emptied and maintenance is generally poor. As a result, animal and vegetable fats, oils and grease (AVFOG) flow through the grease trap into the public sewer system causing stoppages. This situation has led many local jurisdictions to require the installation of a larger grease interceptor outside the building on the site. This allows inspection by public authorities to be more convenient, and the larger size provides adequate AVFOG separation and retention. Compared to other extensive testing, rating and certification standards for grease traps originated by the Plumbing and Drainage Institute (PDI) and the American Society of Mechanical Engineers (ASTM), grease interceptors have not had the benefit of wide attention to research concerned with establishing design, configuration and effluent discharge standards.

The following considerations are recommended for the selection of a grease interceptor:

1. The top of concrete units shall meet AASHTO A-20 guidelines where there is a possibility that trucks could pass over the unit. If the unit is in a non-traffic area, the unit shall meet minimum top loading standards.
2. An inlet diverter is necessary to increase the retention time and avoid short circuiting.
3. A rectangular interceptor is believed to be the optimum shape. An approximate ratio of depth to width shall be 1 to 1.5. There should be at least 4 inches above the water level for venting.
4. An allowance of 6 to 12 in (152 to 300 mm) shall be provided on the bottom for sludge accumulation.
5. A minimum depth of 42 in (1070 mm) is suggested.
6. A sample port should be provided to allow ease of sample taking.

Interceptor Sizing Guidelines. The most important consideration is conformance with any code requirements or standards of the authorities having jurisdiction. When these codes or standards are found, they must be followed.

The following guidelines have been adapted from various published standards and codes and are intended to be used only when there are no other applicable requirements.

For establishments other than restaurants, the maximum flow rate method was selected because it relates the flow rate for fixtures to the size of the interceptor.

1. Determine the number and size trap of fixtures and the size of a dishwasher (if any) in the establishment discharging into the interceptor.
2. Add the dishwasher and only the single largest sink together. If there is no dishwasher, add the two largest trap size gpm requirement together. This is the maximum probable flowrate into the interceptor. This figure is based on the probability that no more than two fixtures could discharge at the exact same time.
3. Multiply the flowrate by 30 to calculate the minimum pounds of grease required to be retained. (This figure has a proven past history of success). Pick a standard size interceptor with a capacity equal to or larger than the calculated size.
4. A minimum size shall be chosen on a sliding scale based on the size of the establishment, as follows:
   - ***a.*** For small shops, such as a pizza parlor or other similar establishments—200 gallon (760 l) capacity;
   - ***b.*** For medium-size shops and those with higher FOG potential, such as meat markets, etc.—500 gallon (1900 l) capacity;

   c. For large establishments, such as regular supermarkets—1,000 gallon (3800 l) capacity;
   d. For very large supermarkets and other similar establishments—1500 gallon (5700 l) capacity.

5. A determination of the maximum possible flow rate shall be based on the following table:

Drain outlet or fixture trap size		Drainage fixture unit valve	Peak flow per minute	
in	DN		GPM	DN
1½	40	3	22.5	85
2	50	4	30	115
2½	65	5	35	133
3	80	6	45	170
4	100	8	60	228

Dishwasher tank capacity	GPM	L
Up to 30-gallon (115 l) water tank capacity	15	(57)
Up to 50-gallon (190 l) water tank capacity	25	(95)
Up to 100-gallon (380 l) water tank capacity	40	(152)

For restaurants, the size of the interceptor should be based on the number of seats and the number of meals served, as indicated in eq. 3.1. This formula is based on information taken from the manual written by the EPA. This method was chose because it appears to have the most realistic sizing criteria of all methods examined.

$$D \times GL \times \frac{HR}{2} \times LF \tag{3.1}$$

where D = number of seats in dining room
GL = 5 gallons (20 l) of waste per meal served
HR = number of hours restaurant is open
LF = loading factor*
1.25 where located on interstate freeway
1.00 for other freeways and recreational areas
0.8 for main highway
0.5 other highways (most often used regardless of location)
*The figure should be sufficient for most applications.

The recommended configuration of the interceptor shall be based on the following general criteria. These recommendations should be adjusted to suit specific job conditions and the selection of a specific interceptor.

1. 50 percent of the wetted height of the entire interceptor (both compartments) shall be allowed for the storage of grease.

2. 6 to 12 in on the bottom shall be allowed for the accumulation of settled solids. The smaller figure is usually applied to interceptors smaller than 1,000 gallons.

3. The invert of the inlet pipe shall be 6 to 12 in (152 to 300 mm) off the bottom, clear of the settlement zone. An inlet baffle shall be provided, such as a tee facing sideways or other acceptable method, to direct flow to the side of the interceptor and avoid short circuiting.

4. There should be 4 in (100 mm) freeboard above the top of the outlet pipe as a vent space.
5. Two compartments should be used. A baffle should be installed to divide the compartment into approximate ⅔ (inlet retention) and ⅓ (outlet) sections.
6. A 30-in (760 mm) manhole shall be provided directly over the baffle. A better alternative would be to have a manhole over the center of each compartment.
7. A rectangular interceptor shall be consider a standard shape.

Refer to Fig. 3.8 for an illustration of a typical grease interceptor.

Flammable and Volatile Liquids

Federal, state, and local regulations have established standards for the discharge of volatile liquids, particularly oil, into storm water and sanitary sewage discharges. These standards vary, and the responsible enforcement and code authorities must be consulted to determine the level of removal required.

The most common flammable liquid is oil. The most common sources of oil are automobile-related facilities such as parking garages, service stations, and car washes. Industrial facilities also create oil waste; for example, volatile liquids such as kerosene, gasoline, naphtha, and trisodium phosphate are released from dry-cleaning establishments and other industrial processes. Laboratories also may release various solvents.

The hazard created is that of either safety (e.g., vapors can create an explosive condition or oil can float on water and then be set on fire) or medical (e.g., inhaled vapors can be dangerous to health or chemicals ingested by humans, fishes, and wildlife can be toxic). The common characteristic of all of these substances is that they are lighter than water. Their removal is similar to that of oil.

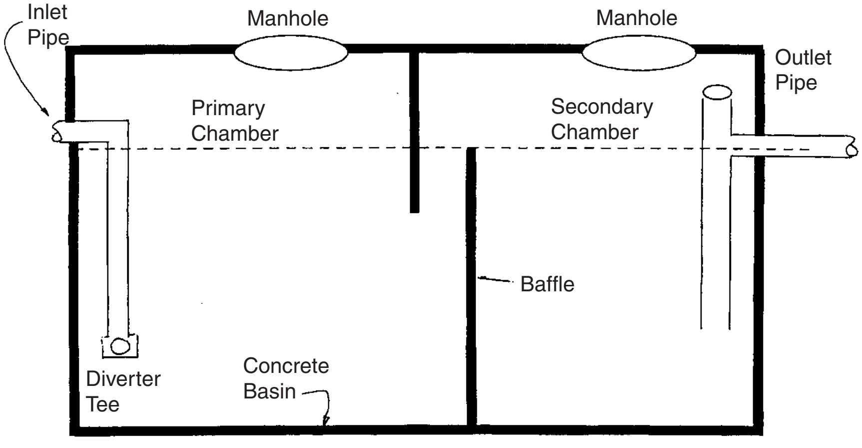


FIGURE 3.8 Typical grease interceptor.

Oil in Water. Oil in water exists in several forms:

1. Free oil.
2. Mechanically dispersed oil is made up of fine droplets ranging in size from micrometers to fractions of a millimeter. It is stable due to electrical charges and other forces, but not because of the presence of surface active agents.
3. Chemically stabilized emulsions are made up of fine droplets that are stable because of surface active agents.
4. Dissolved and dispersed oil is either actually dissolved or suspended in such a small size (typically 5 μm or less) that ordinary filtration is not possible.
5. Oil-wet solids are particulates in which oil adheres to their surface.

Methods of Separation and Treatment. Oil spills and leaks are best treated in their most concentrated state, which is at their source or as close as is reasonable. The primary methods used to separate and remove free oil and oil-wet solids are floatation and centrifugation. Secondary treatment, such as chemical treatment/coalescence or filtration, is then used to break up oil-water emulsions and remove dispersed oil. Finally, tertiary treatment, such as ultrafiltration, biological treatment, or carbon adsorption, will remove the oil to required levels prior to discharge. This section will discuss the general principles of the primary and secondary separation methods and devices only.

The American Petroleum Institute (API) has established criteria for the large-scale removal of globules larger than 150 μm. In abbreviated form, they are:

1. The horizontal velocity through the separator may be up to 15 times the rise velocity of the slowest rising globule, up to a maximum of 3 ft/s.
2. The depth of flow in the separator shall be between 3 and 8 ft.
3. The width of the separator shall be between 6 and 20 ft.
4. The depth-to-width ratio shall be between 0.3 and 0.5.
5. An oil-retention baffle should be located no less than 12 in downstream from a skimming device.

Gravity Separators. Gravity separation is the primary separation method. It is based on the specific gravity difference between immiscible oil globules and water. Since all of these liquids are lighter than an equal volume of water, gravity separators operate on the principle of floatation. As water and oil flow through the unit, the oil floats to the top and is trapped inside a series of internal baffles. Since the oil remains liquid, it is easily drawn off.

Floatation Devices. For service on a larger scale, the floatation of oil and oil-wet solids to the top of the floatation chamber can be increased by the attachment of small bubbles of air to the surface of the slow-rising oil globules. This is done by adding compressed air to the bottom of the floatation chamber in a special manner that will create small bubbles which will mix with, and attach themselves to, the oil globules.

Centrifugal Separators. For service on an even larger scale, the centrifugal separator is used. This device operates on the principle of inducing the combined oil and water mixture to flow around a circular separation chamber. The lighter oil globules will collect around a central vortex, which contains the oil removal mechanism, and the clear water will collect at the outer radial portion of the separation chamber. Methods have evolved that can produce effluent water with only 50 to 70 parts per million (ppm) of oil; proprietary devices exist that can lower oil content to 10 ppm.

Filtration. Using chemical methods first to break oil-water emulsions and then using depth-type filters to remove the destabilized mixture have proven effective in removal of oil globules in sizes between 1 and 50 μm. The velocity and flow rate of the mixture must be carefully controlled to allow optimum effectiveness of the system.

Smaller Systems. Oil separators for small flows usually take the form of a single unit consisting of a drain grating into which the effluent flows and inside which the oil remains to be drawn off manually. Another type of unit uses an overflow arrangement which sends the trapped oil to a remote oil storage tank.

Because there is the possibility that the vapor given off by the flammable liquid could also ignite, it is important to provide a separator vent that terminates in the open air at an approved location above the highest part of the structure. Some codes require that a flame arrester be installed on the vent.

The most common material used for an oil interceptor is cast iron, although steel can be used for less severe service. Gratings must have the strength for the type of vehicle expected.

Refer to Fig. 3.9 for an illustration of a typical small oil interceptor. Figure 3.10 shows the installation of a typical oil interceptor with gravity oil draw-off for garage floor drains.

Sand

Whenever a potential source of solids discharges into the drainage system, a sand interceptor, or trap, should be provided. A mechanical hazard could be created, since the sand could create a blockage in the piping system.

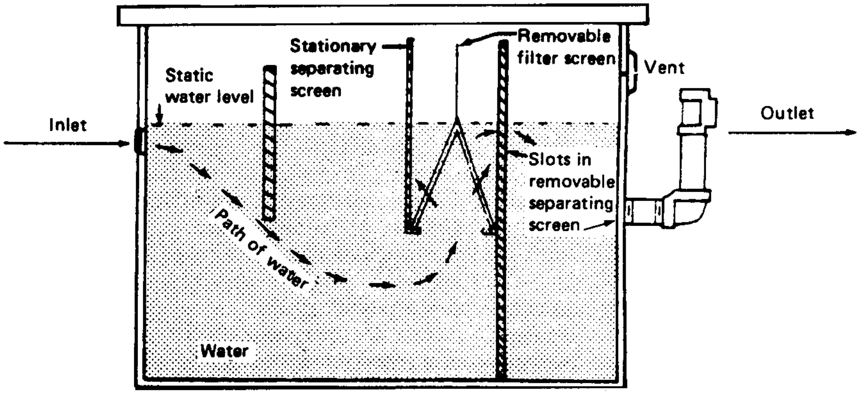


FIGURE 3.9 Typical oil interceptor. (*Courtesy of Rockford Co.*)

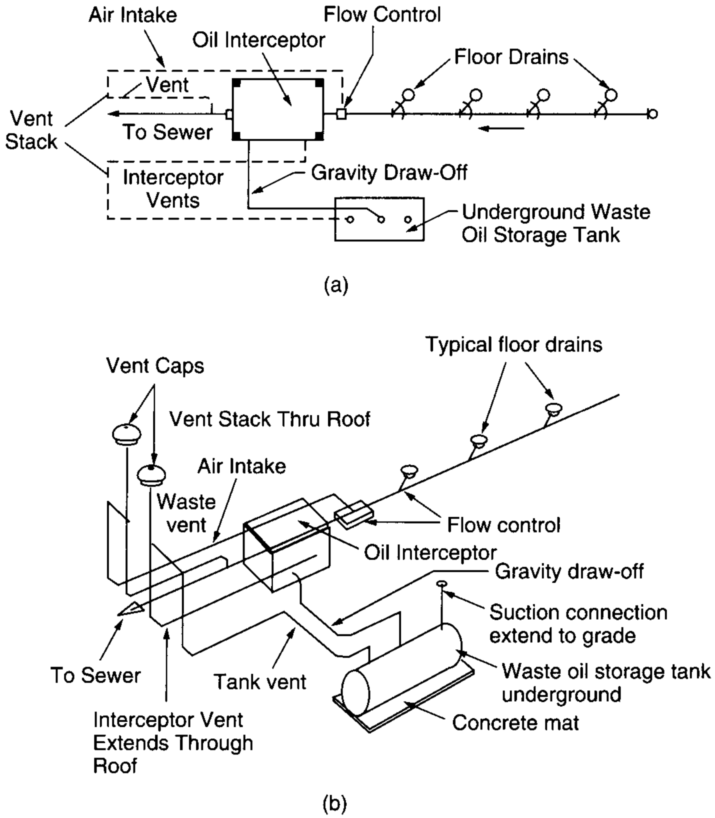


FIGURE 3.10 Typical gravity draw-off installation. (*a*) Plan; (*b*) isometric.

Since the solids are heavier than water, these traps operate on the principle of settlement, permitting the solids to accumulate at the bottom as the effluent flows through the device. The outlet from the sand trap should be located so that the accumulated material is prevented from being discharged. The solids must be removed from the trap by hand. Sufficient space must be available around the trap to make this easy to accomplish.

Sand traps are commonly constructed of masonry, but prefabricated units made of cast iron or steel are also used. Refer to Fig. 3.11 for an illustration of a typical sand interceptor.

Precious Metals

The most common source of gold, silver, or platinum is from jewelry establishments. The small amount of metal discharged would not be detrimental to any drainage system, but it should be recovered because of its value.

A solids interceptor for this type of service is a small, in-line unit, using either a fine wire mesh screen or stainless steel wool as a filter inserted inside a small housing. This housing is installed instead of a trap on a fixture.

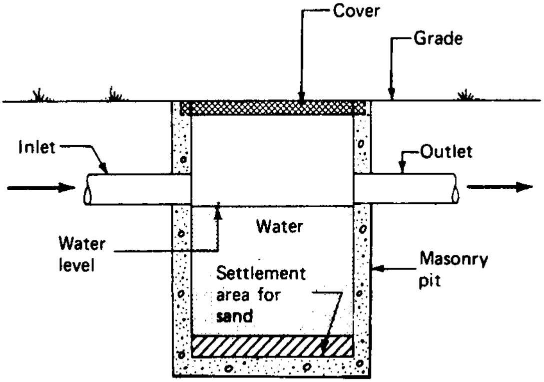


FIGURE 3.11 Sand interceptor.

To recover the precious metals, the housing is disassembled, and the filter is removed and emptied at a remote location. The housing can be made of brass, cast iron, steel, plastic, or any material permitted by local code.

Hair

Hair is discharged from barber shops and beauty parlors, and has the potential to accumulate at some minor obstruction that would not ordinarily cause trouble. The hair will accumulate and eventually cause a blockage.

An interceptor for this type of service is a small, in-line unit, using a perforated basket strainer inserted inside a small housing. This housing is installed instead of a trap on a fixture. To remove the accumulated hair, the housing is disassembled, and the strainer is removed and emptied at a remote location. The housing can be made of brass, cast iron, steel, plastic, or any material permitted by local code. The strainer is usually made of stainless steel. Refer to Fig. 3.12 for an illustration of a typical hair trap.

Acid Neutralizers

Whenever the possibility exists that acid of any kind may be discharged into the drainage system, an acid neutralizer must be provided. As a general rule, many authorities permit waste with a pH of 4 or above to enter the drainage system, where it will be further diluted with other effluent. Acid will attack ordinary piping material and cause it to fail prematurely.

One method used for small, isolated, and intermittent discharges is to percolate the acid through a tank containing limestone chips. These chips range from 1 to 3 in (25 to 75 mm). They are placed in a tank until it is filled to approximately 50 percent of its volume. There is a baffle arrangement to ensure that the effluent is in continuous contact with the chips. Generally used contact periods of between 10 and 15 min are sufficient to neutralize the acid, with shorter times used based on the individual manufacturer's recommendations. The actual required contact time

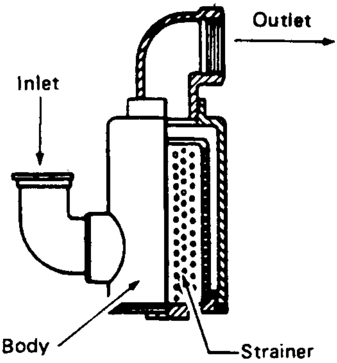


FIGURE 3.12 Typical hair trap.

for proper neutralization should be based on specific interceptors, effluent dilution, and pH values. Neutralization is accomplished by chemical reaction of the acid with the chips. There is no residue. However, the chips must be replenished periodically, depending on the amount of acid that is treated. General figures require 100 lb (45 kg) of chips to treat 98 lb (44 kg) of sulfuric acid and 73 lb (33 kg) of hydrochloric acid.

Unit sizes vary, ranging from small units that can be placed under individual sinks to tanks suitable for large facilities. They must be located in areas where their covers can be readily removed to add new chips. The larger tanks are heavy and need additional structural support. They can be installed either above the floor or below the slab, with the cover extending up to the finished floor above.

Acid-neutralizing basins are made in a variety of materials, depending on the amount and type of acid expected to be encountered. However, for all but the smallest laboratories and pharmaceutical facilities, the neutralizing basin is no longer considered acceptable. The acid must be treated in a manner that will ensure neutralization of the acid to a pH required by the FDA, EPA, and local authorities. This requires the use of a tank or chamber that introduces varying amounts of

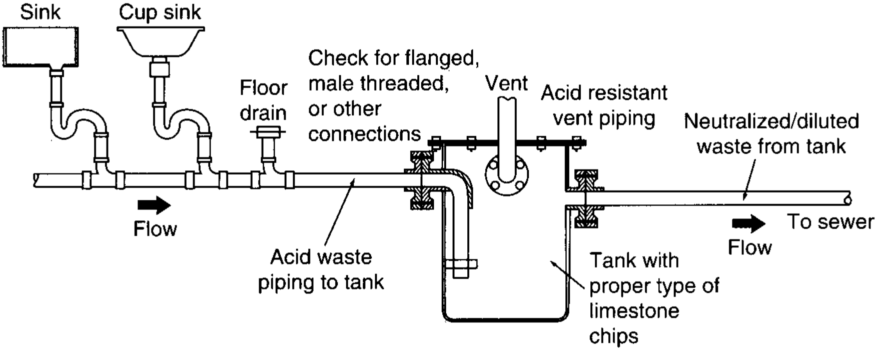
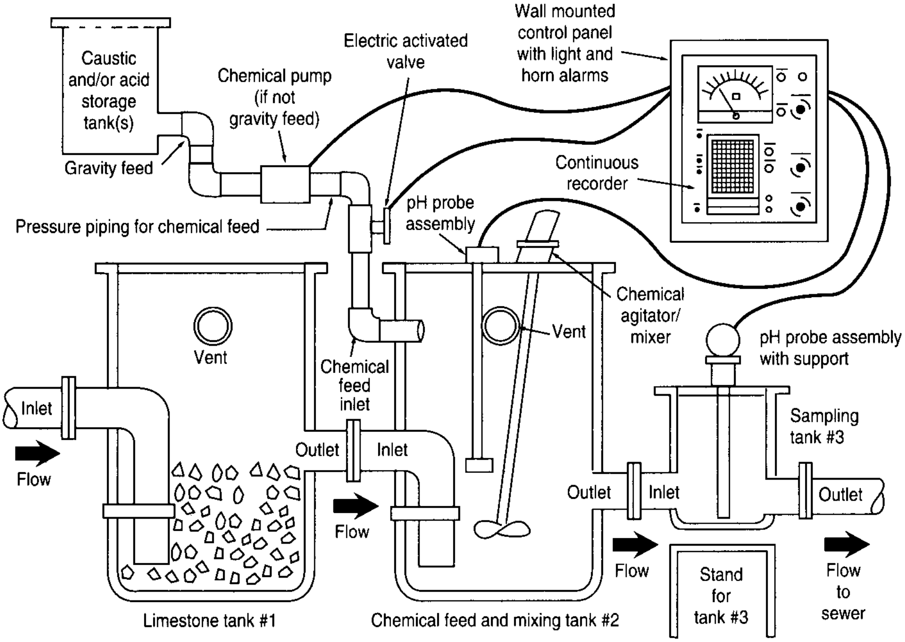


FIGURE 3.13 Small acid-neutralizing basin.



Note: Variations of this setup are available, including one large tank with three compartments instead of three separate tanks.

FIGURE 3.14 Acid-neutralizing system installation.

caustic neutralizing agent to mix with a variable flow rate of acid. A method of sampling must be provided and a record of the pH of the effluent from the facility and after neutralization should be kept.

Refer to Fig. 3.13 for an illustration of a typical acid-neutralizing basin. Figure 3.14 illustrates the installation of an acid-neutralizing system.

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