Industrial Filtration Design & Selection

Tank-type systems, like this one at the U.S. Consulate in Beijing, include carbon, iron, sand and multi-media filters, along with softeners, de-alkalizing systems, acid neutralizers and specialty contaminant removal systems.

By Gerry Bulfin

Proper sizing & media selection for successful systems

Industrial water treatment can be classified by the following categories (not including wastewater treatment, which is a separate topic):

- Process water treatment;
- Boiler water treatment; and
- Cooling water treatment.

Water treatment is used to optimize most water-based industrial processes, including heating, cooling, processing, cleaning and rinsing, so that operating costs and risks are reduced.

Inadequately treated water can interact with the surfaces of the pipes and vessels that contain it. As a result, internal pipes and chambers in steam boilers can develop scale or corrosion, requiring more energy to heat the same amount of water.

Cooling towers also can develop scale and corrosion, and—if not treated properly—bacteria and algae can grow, causing equipment to malfunction and allowing potentially dangerous pathogenic bacteria, such as *Legionella*, to develop.

Water treatment also is used to improve the quality of water contacting the manufactured product, e.g., semiconductors, and/or can be part of the product, e.g., beverages and pharmaceuticals. In these instances, poor water treatment can cause defective products.

Filtration & Purification Systems

There are two main types of industrial water filtration systems: tank and membrane. Tank-type systems include carbon filters, iron filters, sand and multimedia filters, softeners, de-alkalizing systems, acid neutralizers, and specialty contaminant removal systems for arsenic, lead, nitrate, chromium, etc.

Membrane systems include microfiltration, nanofiltration, ultrafiltration and reverse osmosis (RO) systems.

Filtration is used for the removal of solids from water, often in conjunction with other processes, such as coagulation and sedimentation. This prepares the water for use as potable, boiler or cooling makeup. These types of pressure filters are not used to remove dissolved solids, but instead are used as prefilters prior to membrane systems such as RO, which do remove dissolved solids.

Down-Flow Design

Conventional pressure rapid filters operate in a down-flow manner, meaning water flows in the top of the filter and down through the filter media. The filter media is usually 15 to 30 in. deep. Various types of filter media are used, depending on the filter's purpose.

A bed of filter gravel supports the filter media to prevent it from entering the under-drain or distributor system. The support bed also serves to distribute backwash water. Typical support beds consist of graded levels of gravel 6 in. or more deep.

These filters are backwashed by reversing the flow of water and allowing it to flow up through the filter bed from bottom to top, then out to drain. After backwashing, a final rinse-to-drain cycle is used before the filter is returned to service.

Flow Rate & Water Temperature

Pressure filters for industrial use typically have cylindrical steel or fiberglass-reinforced shells. The flow rate is usually in the order of 3 to 5 gal per minute (gpm) per sq ft of filter area. For example, a filter tank that is 4 ft in diameter has an effective filter area of 12.5 ft (π x r^2, or 2 x 2 x 3.14 = 12.56 ft).

Because most filter media work effectively at a flow rate of 3 gpm per sq ft of filter area, a filter tank that has a diameter of 4 ft will allow a filtration flow rate of 37.5 to 62.5 gpm.

Vertical filters usually range in diameter from 2 to 10 ft and are used for flow rates up to 300 gpm.

Horizontal pressure filters typically are 8 ft in diameter and 10 to 25 ft long. They have higher surface areas and can filter 200 to 600 gpm. These filters are often segmented into different compartments to allow individual backwashing.

While pressure filters usually are operated at a service flow rate of 3 gpm per sq ft, dual or multimedia filters are designed for 6 to 8 gpm per sq ft. Zeolite alumino-silicate crystal media can be operated at much higher service flow rates, up to 12 gpm per sq ft.

Note that the backwash flow rates required often are two to three times greater than the filter flow rate. For example, at ambient temperature, the recommended filter backwash rate is 6 to 8 gpm per sq ft for anthracite and 13 to 15 gpm per sq ft for sand. If the water is warmer, it is less dense and higher backwash flow rates are required. Consult the specific service and flow rate designs set forth by the manufacturer for best results.

Media for Solids

Silica sands, quartz sands, anthracite coal, garnet, high-purity zeolites, manganese oxide, greensand and other materials are used as filtration media depending on the design and purpose of the filter. Silica sand and anthracite are among the most common types for solids filtration.

Filter media granules come in different sizes and shapes. This affects the efficiency of the filter media in removing solids from water. Filter media that are too angular or sharp can form large spaces and remove less fine material than a similarly sized round media. The filter media should be coarse enough to allow solids to penetrate the bed at least 2 to 6 in.

Sand and anthracite media are rated by their particle size and uniformity. The "effective size" is selected so that approximately 10% of the total granules by weight are smaller and 90% are larger. The effective size is the minimum size of most of the grains. Uniformity is measured by comparison of effective size with the size at which 60% of the grains by weight are smaller and 40% are larger. This latter size, divided by the effective size, is called the uniformity coefficient. The smaller the uniformity coefficient, the more uniform the media particle sizes.

Finer filter sand means shallower areas for the removal of suspended solids. The best media size depends on the suspended solids' characteristics, as well as the effluent quality requirements. In general, rapid sand filters use sand with an effective size of 0.35 to 0.6 mm and a maximum uniformity coefficient of 1.7. Coarse media, often 0.6 to 1 mm, are used for closely controlled coagulation and sedimentation.

One type of natural zeolite mineral (mainly composed of alumino-silicate) is mined, crushed, dried and screened to produce high-quality media that perform better than traditional filter sand. The crystalline mineral material has surface micro-mineral projects with 0.25- to 10-µ spacing that effectively traps suspended solids. This material is lighter than sand and requires less backwash water, yet it has a sought-after uniformity coefficient of 1.7. It often is used as a replacement for sand and anthracite.

Media for Iron & Manganese

For iron and manganese filtration, two popular types of media are greensand and manganese oxide. Traditional greensand is formulated from naturally mined glauconite greensand, which is coated with manganese oxide. A newer type of greensand filter media uses silica as its core. Greensand is a black filter media and is used to remove iron, manganese, arsenic and radium under the right conditions. It is regenerated with a potassium permanganate solution—or, under the right conditions, a chlorine feed ahead of the filter allows it to operate without the use of permanganate.

Manganese oxide is used for removing iron, hydrogen sulfide and manganese from water supplies. It is media that utilize an oxidation-reduction reaction and filtration process similar to greensand, but at a much higher level of performance. Unlike greensand, it is not coated, but is solid and can last many years longer than greensand. Manganese oxide media filters use water that has been chlorinated in a process called continual regeneration. No potassium permanganate is used with manganese oxide filters. In some water, aeration alone is sufficient to keep the media regenerated. *wqp*

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