Public Swimming Pools

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Note: In determining your answers to the CE questions, use only the material presented in the corresponding continuing education article. Using information from other materials may result in a wrong answer.

The goal of any quality pool design should be to maximize patron safety while providing an enjoyable water-based environment. The design approach should be to develop a system that provides maximum water quality from both a clarity and a bacterial safety standpoint. Potential hazards such as suction or limb entrapment, hair entanglement, or tripping concerns must be examined and eliminated. Local health department codes are designed to ensure that these criteria are met, but the codes merely provide minimum standards. A quality design should go well beyond the minimum requirements.

This chapter is organized to assist a designer, possibly unfamiliar with swimming pool design, in undertaking such a project. The first sections can be used for the preparation of an initial scope outline of the project's size, type, and location. The "Pool Operating Systems and Components" section discusses the key elements that are required for a complete circulation, filtration, water heating, and chemical control system. It can be used to make initial decisions on the basic types of systems to consider. The "Component Evaluation and Selection" section provides guidelines for making specific equipment selections. It will assist the designer in collecting pertinent data on the various products to assist in writing specifications.

CODES AND STANDARDS

In addition to the plumbing codes, swimming pool construction and operation are usually governed by state health department regulations and the requirements of local authorities. Publications by the Association of Pool and Spa Professionals (APSP) and the National Swimming Pool Foundation (NSPF) are often-referenced standards. The codes usually govern circulation rates, filtration rates for various types of filters, and the spacing of main drains, as well as maximum velocities through main drain grate-free areas. Also of importance are the locations and types of inlets, the spacing and capacities of gutter drains, and requirements for the use of surge tanks or skimmers. Heating requirements and feed capacities for disinfection systems are other areas requiring review.

In addition to the standards noted above, if the pool is to be used for competitions, the rules and regulations of the International Amateur Swimming Federation (FINA) must be reviewed to ensure that the pool meets international standards.

In the remainder of this chapter, any entity governing the various aspects of public swimming pools will be referred to as the authority having jurisdiction (AHJ).

Virginia Graeme Baker Pool and Spa Safety Act

In December 2007, a federal law called the Virginia Graeme Baker Pool and Spa Safety Act (P&SS Act) was enacted, which set stringent requirements on main drain sizes, velocities, and piping configurations as well as testing protocols to be regulated according to ASME A112.19.8: *Suction Fittings for Use in Swimming Pools, Wading Pools, Spas, and Hot Tubs*. At a minimum, all main drain covers and grates must be a compliant cover or grate bearing the P&SS Act stamp provided by the manufacturer or be field-certified by a licensed professional engineer attesting to its compliance with ASME A112.19.8. In cases where a single main drain is direct-connected to the pump suction, some form of automatic vacuum release or some form of piping that provides an air break to prevent suction entrapment is required. (Refer to ASME A112.19.8 for specific details on sumps, piping, and cover and grate requirements.)

The intent of the P&SS Act is twofold: to prevent suction entrapment and to prevent entrapment due to hair entanglement. The second issue (hair entanglement) is the reason why velocity through main drain grates is an issue. Hair entanglement, consistently the No. 1 cause of entrapment in pools, is caused by high velocities through main drain grates. When a swimmer's hair is drawn through the grate, high velocity can cause it to swirl and become tied in a knot on the other side of the grate.

Suction entrapment has nothing to do with velocity through the grate. The P&SS Act addresses suction entrapment by requiring all pools to have multiple main drains spaced at least 3 feet (0.91 m) apart, which makes them "unblockable" in the verbiage of the act. In instances where there is only one main drain, it must flow by gravity back to a surge tank (i.e., not be direct-connected to the pump suction), be of an "unblockable" size (i.e., larger than 18x23 inches [0.46x0.58 m] or with a diagonal dimension greater than 29 inches [0.74 m]), or have another means of preventing suction entrapment. The most common means of accomplishing this is the addition of some type of automatic vacuum safety release. Several products are on the market, but all manufacturers insist that their devices be installed by a certified installer. However, all manufacturers of these products add the disclaimer "will not prevent disembowelment" to their product literature.

ASME A112.19.8 also details tests for finger entrapment, measuring the force needed to pull the cover or grate out of the frame, and resistance to ultraviolet (UV) degradation, which could make the cover or grate brittle and fail to attach. These are important parts of the ASME testing because many of the entrapment accidents that occur are due to detached covers or grates.

The P&SS Act also requires main drain covers and grates to be sized for the maximum flow of the system. The combined maximum possible flow that the system pumps can produce (which is usually greater than the design flow) must not exceed the maximum flow rating for the cover or grate intended for installation. In fact, the P&SS Act goes one step further. In the instance where one cover or grate is blocked or partially blocked, the remaining main drain covers or grates must be sized to handle the full flow of the system. In other words, where there are two main drains, each cover or grate must be sized for the full flow of the system. With three main drains, each cover or grate must be sized for 50 percent of the system flow.

It is important to note the use of the term *system*. That is because many pools have water feature pumps that pull from the same surge tank as the circulation pumps. The total possible flows of all of those pumps must be added to determine the full flow of the swimming pool system. The fact that the covers or grates flow by gravity back to the surge tank might eliminate the first concern of the P&SS Act—entrapment—but it has no bearing on the second concern, hair entanglement. The velocity through the covers or grates is the same when water flows to the surge tank by gravity as the velocity when the main drains are direct-connected to the pump suction.

The final important requirement of the P&SS Act is the ASME A112.19.8 protocol regarding main drain sump dimensions. Many field-fabricated sumps do not meet ASME requirements and are considered noncompliant. The reason for these required sump dimensions is somewhat complicated, but basically it ensures even flow across the cover or grate, which is the only way to ensure that the velocities calculated for flow through the free area of the grate are uniformly less than 1.5 feet per second (fps) (0.46 m/s) at all points on the face of the cover or grate. Attaching a compliant cover or grate to a noncompliant pre-fabricated sump may not create a secure connection that will meet ASME pull test requirements. The Consumer Product Safety Commission (CPSC) has expressed concern that the P&SS Act doesn't address this attachment issue thoroughly enough since most entrapment occurrences have been due to a missing or displaced cover or grate.

A misconception that raises additional concern is the belief of some owners that their system is fully compliant once the state approves changes to the covers or grates. That is not the case. Most state codes do not address sump dimensions, and they also don't all require multiple covers or grates to be able to handle full system flow or some percentage of full flow based on the number of main drain sumps. Thus, in addition to the state public health code, the design must adhere to the requirements of the P&SS Act.

State Swimming Pool Health Code Requirements

State health code requirements become an issue when changes are made to main drains. Any changes in a pool's circulation piping or main drains are considered alterations, and in most states alterations to a pool design require submission by a Professional Engineer licensed by that state. Many owners are unwilling to adhere to this requirement because it adds costs to their attempts to become compliant with the P&SS Act.

One of the primary areas of conflict between the P&SS Act and state health codes is a result of the approach taken by manufacturers to design compliant grates. Most of the designs for grates that will prevent suction entrapment result in covers and grates that are raised anywhere from ½ inch to 2 inches, which results in protrusions from the floor of the pool when these new "compliant" covers or grates are installed. This is not allowed by most state codes because it can present a tripping hazard. However, many states have made, or are making, changes to their codes to allow main drain protrusions no greater than 2 inches above the pool surface.

Important Considerations

When investigating what steps to take to comply with the regulations in the Virginia Graeme Baker Pool and Spa Safety Act, the designer must keep in mind that anything done to meet the requirements of the federal act must not be in conflict with the state code. This does not mean that the state code takes precedence; it is merely meant to draw attention to the fact that there are two AHJs and that satisfying one set of requirements does not automatically mean full compliance. Pool compliance inspections will be done by both the local code authority for adherence to the local code and the CPSC for adherence to the requirements of the P&SS Act.

PRELIMINARY DESIGN PARAMETERS

Before the plumbing for a swimming pool project can be designed, the following information should be obtained: occupant capacity, facility size (including pool volume), facility location and configuration, pool style, times of use, availability to infants and children (which may necessitate a separate pool), tournament and racing requirements, toilet requirements, concession and vending requirements, and bathhouse requirements.

Occupant Capacity and Facility Size

Assuming that the swimming pool is part of a complex that includes other outdoor facilities (such as ball fields, tennis courts, and basketball courts), following are the generally accepted criteria for estimating the number of swimmers:

- The total membership of the facility can be estimated to be 10 percent of the total population of the community it serves.
- The maximum attendance on the peak day can be estimated to be 68 percent of the total membership.
- Maximum attendance at the public swimming pool facility can be estimated to be 40 percent of the projected maximum attendance on the peak day.
- The maximum number of swimmers is approximately 33 percent of the maximum attendance.

This method of determining the maximum number of swimmers cannot be applied to all swimming pools. The social and economic conditions of a particular local community must be taken into account when designing a public swimming pool facility. Swimming pool occupancy, or capacity, restrictions are subject to local regulations and vary from one jurisdiction to another. Supervision capability also may limit pool capacity.

The desirability of accommodating competitive swimming should be considered when designing a swimming pool. The requirements for such events are 25- and 50-yard lengths for U.S. competitive meets and 25- and 50-meter lengths for international events. Normal competition pools are divided into a minimum of six swimming lanes, with each lane having a minimum width of 7 feet (2 m). An additional 3 feet (0.9 m) should be divided equally between the two outside lanes to aid in wave quelling. The shallow-end depth should be a minimum of 4.5 feet (1.35 m) for competitive pools and 3.5 feet (1.1 m) for recreational pools, depending on local codes. The deep-end minimum depth of pools with springboards is between 9 and 12 feet (2.7 and 3.7 m) for a 3-foot (1-m) board and 11.5 and 13 feet (3.5 and 4 m) for a 10-foot (3-m) board, depending on local codes. Platform diving is performed in specially designed pools, which are outside the scope of this chapter.

Facility Location

There are no generally accepted rules for choosing the location of a public swimming pool facility. Only careful investigation of the available sites and the use of common sense will result in a suitable location.

First, consideration must be given to the accessibility of the location. A public swimming pool will be used in direct proportion to the local population's convenience in reaching the facility. Distance is a barrier, and so are stoplights and railroad tracks. The engineer also must consider the traffic flow in the area and the relative safety for pedestrians and bicycle riders of the routes normally taken to and from the public swimming pool facility.

Equally important at this stage are the physical properties of the proposed swimming pool site, including its soil quality, groundwater locations, and subsurface obstructions such as rocks. Attention also must be given to the availability of water, gas, sewers, and electricity. If all utilities are not available or if extensive clearing, grading, or difficult excavation is required at or near the proposed site, significant additional expenses may be incurred. The plumbing engineer may not be involved with the project at this stage, but it is a good idea to consult with someone familiar with all swimming pool requirements at this time.

The availability of an adequate water supply is essential. The water supply system provides the means to fill the pool initially with water and to make up water lost through wastewater discharge and evaporation. The preferred supply source for filling the pool and maintaining adequate volume is potable water. In areas with a limited water supply or where the system's capabilities are in doubt, consideration should be given to filtration equipment, which requires minimum backwash water, or an off-peak filling and servicing schedule. Well water is often of good quality and may be used directly; however, the mineral content may be sufficiently high to require treatment. All water should be given a detailed chemical analysis in the early planning stages to determine whether treatment (e.g., softening or pH control) should be considered. In general, using softened water for filling and makeup water is not recommended for swimming pools.

Protection of the potable water supply system through air gaps or backflow prevention equipment is mandatory. The type required must be determined by checking with the local AHJ. Some codes may not allow direct connection, even with reduced pressure zone backflow preventers installed on the freshwater supply.

The rate of water evaporation from the pool should be estimated to determine the average makeup water required. Direct discharge of swimming pool water into the local storm sewer system or a watercourse without proper treatment may not be allowed, since chlorinated water is harmful to the environment. The chemistry of the proposed effluent should be approved by the AHJ.

General Physical Character

Deciding on the general physical character of a proposed public swimming pool facility involves determining such things as the type of swimming pool, its style, the intended use of the pool, its shape and dimensions, indoor vs. outdoor design, bathhouse planning, and the location and type of equipment. A swimming pool complex with separate recreation pool, diving well, and wading areas accommodates all possible uses, including recreation, training, diving, water sports, exercise, therapy, and competitive swimming. The use of color, walks, deck areas, and plants creates a pleasant and interesting personality, but also substantially increases costs.

Before commencing the design, it is important to determine the style of pool(s) the facility requires and the impact this will have on the space available for mechanical systems. Many facilities are now being designed with multiple pools or one multiuse pool.

Pool styles can range from leisure pools to swimming pools with a wave pool component to 25- and 50-meter competition pools with diving facilities. Many leisure pools that allow younger children to play with interactive water toys and water slides are being designed in conjunction with other pool facilities. These pools usually have water depths ranging from 1 to 4 feet (0.3 to 1.22 m) and may have an uneven bottom, depending on the location of the interactive play toys. The number of toys and the size of the pool will impact space requirements for pumps and filters.

Wave pools and zero-depth pools have become common components of public swimming facilities. These designs allow swimmers to experience the sensation of swimming in ocean-like conditions. Many wave pools are designed so the wave generator can be set to come on at certain times of the day and/or night or when requested by patrons. Both zero-depth and wave pools usually have a beach component at one end of the pool, which requires special consideration to be given to the gutter systems and water pickup at the beachhead, or zero-depth end. The wave-generation equipment requires additional space within the mechanical room, and this needs to be taken into consideration when planning a facility with this component.

Competition pools have very specific regulations that govern the water quality, clarity, turnover rates, temperature, and depth, as well as the markings that are permitted within the pool. These requirements may be more stringent than the local health department's requirements and may require more or larger components to be located within the mechanical room.

Many alternatives of shape and/or dimension are available to the designer. However, public pool configurations most commonly use straight lines and right angles. Pools of this nature are much more adaptable to the use of automatic pool-cleaning equipment.

The question of indoor vs. outdoor swimming pool design is considered during the preliminary planning of the facility. It is well established that, although about 10 percent of the public likes to swim outdoors in the summer, less than 1 percent is interested in swimming in the winter, even if indoor facilities are provided. Therefore, the need for outdoor swimming is addressed first. Then, if the budget permits, indoor facilities can be added. An indoor swimming pool facility costs approximately three to four times more than a comparable outdoor swimming pool facility. If the total cost is of little consideration, the same swimming pool facility can be used for both indoor and outdoor swimming.

A possible solution to the problem of providing indoor swimming is the cooperative funding, planning, and construction of a swimming pool facility adjacent (or connected) to a school. This requires the cooperative effort of the school board, park district, recreation department, and any other taxing body. The engineer should plan such a swimming pool facility to have the following:

- An indoor swimming pool of sufficient size to meet the needs of the school and the local community
- An outdoor swimming pool complex planned and constructed to meet the needs of the local community
- A central shower and toilet area
- Mechanical equipment for water treatment designed to serve both the indoor and the outdoor swimming pools

During the winter, the indoor swimming pool can be used for the school's and community's training and recreational needs. During summer, both indoor and outdoor swimming pools can be scheduled and used. This arrangement allows one pool to be out of service for maintenance while the other remains operational. A facility of this type saves a considerable amount of money and provides a swimming pool facility for year-round comprehensive scheduling, with revenue sufficient to cover the operational and maintenance costs.

Many technical problems are involved in the design of an indoor swimming pool facility. First is the obvious problem of maintaining a proper relationship between the air and water temperatures to control condensation and fogging. To be properly balanced, the water temperature should be in the range of 75 to 80°F (23.8 to 26.7°C), and the air temperature in the building should be maintained 3 to 5°F (1.6 to 2.6°C) above the water temperature. If this relationship is inverted, patrons will be uncomfortable when they exit the pool, and both fogging and condensation are likely to occur.

Secondly are the additional considerations of acoustics, ventilation, and air movement. Maintaining maximum air quality in an indoor pool facility is essential. Evaporation of the pool water and the off-gassing of disinfection by-products such as trihalomethanes and chloramines require careful consideration of relative humidity, the introduction of large quantities of fresh, outside air, and proper air movement in the space. Refrigeration-loop dehumidification systems, as well as physical heat transfer systems to allow some pre-heating of incoming outside air, are frequently employed.

The rules for the bathhouse design generally are specified in great detail by the local public health authority. The preliminary planning of the bathhouse facility must be carried out within the limits of established regulations. Apart from these rules, however, the designer may exercise imagination with considerable latitude in several areas: achieving a pleasing and aesthetic architectural balance, providing an adequate floor area for traffic, and providing adequate storage and management facilities.

Equipment locations should be established during the preliminary design phase. It must be decided, for example, whether equipment will be located in the bathhouse or in a separate enclosure (keeping in mind that it is usually desirable to combine all of these facilities under a single enclosure). The filter assembly should be housed in an area with heat for the offseason and with ample storage space. The filter equipment also should be located in the filter room for easy and efficient operation and maintenance. Consideration needs to be given to the location of the pumps in relation to the water levels in the pool(s). Wherever possible, the pool pumps should be located below the water level determined by the gutter system or surge tank so the pumps will have positive suction. Self-priming pumps are used for a number of pool applications, but this style of pump is subject to greater startup problems and maintenance issues.

Finally, the designer must select the type of filtration and purification equipment to be used. The most obvious considerations are pool size, available space, the type, location, and availability of sewer facilities, soil, rock, and groundwater conditions, and the location, availability, chemistry, and cost of the fill water. If the water is plentiful and inexpensive and space is not a problem, sand filtration may be considered. Scarce or costly water and limited equipment room floor space, plus a desire for maximum water clarity during heavy use, might dictate the use of diatomite filtration. The size of the swimming pool facility, as well as the chemistry of the fill water, will usually determine the type of disinfection equipment to be used.

In areas where freezing temperatures are possible and if the pool is not used year-round, provision must be made for draining the water lines, exposed drains, and plumbing fixtures to prevent damage by freezing. Alternatively, all areas must be provided with minimum heating equipment.

Bathhouses, Toilets, and Showers

Adequate dressing and toilet facilities must be provided. Each swimming pool complex must have separate facilities for male and female bathers, with no interconnections between them. The rooms must be well lighted, drained, and ventilated. They must be constructed of impervious materials, finished in light colors, and developed and planned so good sanitation can be maintained throughout the building at all times.

The partitions used in dressing rooms, showers, and toilets must be made of durable materials and not subject to water damage. They should be designed with spaces under the partitions to allow a thorough cleaning of the walls and floors. If these partitions are subject to vandalism, block walls and vandal-proof devices should be considered.

The showers and dressing booths for females should have curtains or some other means of providing privacy. This rule may not apply for schools and other institutional facilities where a swimming pool may only be open to one sex at a time or where supervision is necessary.

Facilities for the physically challenged that meet all federal, state, and local regulations for private and public facilities also must be provided.

The floors of a bathhouse must be free of joints or openings, be continuous throughout the area, have a slight texture to minimize slipping (but also be relatively smooth to ensure positive drainage of all parts of the building), and have an adequate slope toward the drains. An adequate number of floor drains shall be provided. Floor drains should be positioned based on the requirements of the plumbing and building codes, but in no case should the floor slopes be designed for less than 0.25 inch per foot (6.35 mm/m) to ensure the proper drainage of all floor areas.

An adequate number of 0.75-inch (20-mm) hose bibbs must be provided to wash the dressing rooms and the bathhouse interior. At least one drinking fountain should be provided for bathers of each sex in the bathhouse, with additional drinking fountains provided at the pool.

The minimum sanitary plumbing facilities, as mandated by the local plumbing code, should be provided. These minimum criteria for bathhouse plumbing facilities must be based on the anticipated maximum attendance.

If the local code does not address swimming pool facilities, the following minimum facilities should be provided:

- Three showerheads for the first 150 male users and one showerhead for each additional 50 male bathers
- Two showerheads for the first 100 female users and one showerhead for each 50 additional female bathers

Tempered water of approximately 90 to 100°F (32.2 to 37.8°C) should be provided to all showerheads. Water heaters and thermostatic mixing valves should be inaccessible to the bathers.

Soap dispensers, providing either liquid or powdered soap, must be furnished at each lavatory and between each pair of showerheads. The dispensers should be constructed of metal or plastic; no glass is permitted. Mirrors must be provided over each lavatory. Toilet paper holders must be furnished at each water closet combination. Vandal-proof devices should be considered, if applicable.

POOL OPERATING SYSTEMS AND COMPONENTS

Most provincial and state regulations require pool system components to be certified by an independent testing agency, such as NSF International. This certification ensures that all piping and other components meet a national standard for the quality of materials and that public health and safety issues are addressed. Certification also ensures that the equipment meets consistent quality controls and builds a level of confidence in the product.

When considering the broad spectrum of approaches used for pool design, the designer should attempt to evaluate the major cost and performance differences between lower-quality residential or hotel, motel, and health club-type equipment and higher-end products used on major commercial pool installations. If the owners have not already made some of these assessments on their own, the designer should be prepared to apprise them on the pros and cons of the available choices so they can make an informed decision on the value they wish to place on the quality of the end product.

If designing a commercial installation for a high school, university, park district, or YMCA, the designer must follow certain basic board of health requirements beyond the scope of the plumbing codes.

Design Parameters

Turnover Rate

The turnover rate (turnovers per day) refers to the time it takes to move a quantity of water, equal to the total volume in the pool and surge vessel, through the filtration system.

Minimum turnover rates for various types of pools are determined by code. Typically, they fall within the following ranges:

- Swimming pool: Six hours (four turnovers per day)
- Wading pool: Two hours (12 turnovers per day)
- Therapy pool: Four hours (six turnovers per day)
- Hot tub and whirlpool: 30 minutes (48 turnovers per day)

Keep in mind that these are minimums. In heavily used pools, quicker turnovers will help maintain water clarity by means of increased filtration and better chemical distribution. Also, pool designs that combine shallow areas, such as zero-depth pools, with deeper swimming areas require a turnover rate that combines the characteristics of both types of pools.

A calculation of the flow rate required to move a quantity of water equal to the gallons (liters) in the shallow area (usually up to 18 inches [0.46 m] in depth) within two hours is combined with the flow rate required to achieve the minimum turnover requirements for the deep area of the pool (six hours). This combined flow requirement will result in a greater number of turnovers per day, usually in the range of six per day (or one turnover every four hours).

One additional point to consider in determining a turnover rate for pools projected to experience heavy usage is the fact that one turnover refers to a volume of water equal to the total gallons (liters) in the pool system. It has been calculated that it takes more than three turnovers for 95 percent of the actual molecules of water in the system to pass through the filter. This is due to the physical characteristics of the pool. The only way to remove the dirt load being introduced into the pool by the users and the environment is through filtration or oxidation. Regardless of how efficient the filter is, it can't remove what isn't put through it.

Filter Media Rate

The filter media rate is the rate, measured in gallons per minute (gpm) per square foot (L/min per m^2) of filter surface area that water is allowed to pass through various types of filters. These maximum rates are established by NSF/ANSI 50: *Equipment for Pools, Spas, Hot Tubs, and Other Recreational Water Facilities,* as well as local health department codes. This rate becomes the determining factor in the sizing of the filter area needed for a given minimum turnover rate and the resultant minimum flow rate.

Flow Rate

The flow rate is the rate at which water moves through the filtration system. It is calculated based on the minimum turnovers per day. The flow rate has a major bearing on pipe sizing in the distribution system.

Many codes limit velocities in suction piping and return piping. In swimming pool parlance, return piping is the piping carrying filtered water returning to the pool. Some common maximums are 5 to 8 feet per second (fps) (1.52 to 2.44 m/s) in suction piping and 8 to 10 fps (2.44 to 3.05 m/s) in return piping.

Required Surge Capacity

The term *surge* describes all water that comes off the top of the pool, either displaced by the swimmers or splashed into the gutters through wind or heavy activity. It must flow to a surge vessel attached to the swimming pool circulation system. Continuous skimming is required even during times of no activity. The skimming that takes place during these quiescent periods is intended to draw material near the water surface into the gutters and back to the filtration equipment.

The skimming action is essentially accomplished by maintaining the level of the water in the pool to no more than ¼ inch (6.35 mm) above the rim of the gutter As the water just barely breaks over the lip of the gutter, the velocity of the skimmed water increases and creates a pull on the water surface. If the water level is too high, little skimming action occurs.

Many years ago, this skimmed water went to waste. Water conservation, as well as the cost of reheating replacement water, has resulted in code requirements for the capture of this water. It now must be filtered, chemically treated, and returned to the pool. Most codes mandate a minimum volume requirement for the vessels that receive and hold this water until it can pass through the filter. The volumes are based on the estimated water displaced by swimmers plus wave action caused by their activities. A common requirement is for 0.6 to 1 gallon (2.27 to 3.79 L) of surge capacity for each square foot (m^2) of pool surface area. The various means of achieving this are covered later in this chapter.

Some smaller pools are allowed to use skimmers to return water from the top of the pool. Their use is restricted, usually based on the size of the pool. Skimmers are covered in more detail in the "Component Evaluation and Selection" section of this chapter.

Main Drain and Grate

No manufacturer is allowed to manufacture or distribute a cover or grate that has not met P&SS Act requirements. All covers and grates or cover/grate and sump systems must bear the P&SS Act-required stamp on the face of the cover or grate. The CPSC is tasked with inspecting all commercial facilities, and they have the authority to shut down and fine facilities that are found noncompliant.

Main Drain Piping and Location

The typical pool has main drain connections at the deepest point of the pool structure. These main drain pipes are connected to a formed concrete sump, stainless steel sump, or prefabricated fiberglass sump covered by a grating.

These connections provide a means of drawing water off the bottom of the pool for filtration purposes. They also usually provide a means of pumping the pool water to waste or draining the pool via gravity to a remote sump for pumping to waste.

In some cases, a reverse flow design is allowed. In this type of design, all filtered water is returned to the pool through inlets in the bottom of the pool. All dirty water is skimmed off the top of the pool. In such a design, a main drain is simply used to drain the pool. Not all codes allow such a design.

Due to entrapment concerns, multiple main drain sumps, piped hydraulically equal, are usually required. Velocities through the gratings covering these sumps are usually mandated to not exceed 1 to 1.5 fps (0.3 to 0.46 m/s) to reduce the chance of hair entanglement.

The free area of the covering grate typically must be at least four times the area of the connected main drain pipe. Codes also require minimum distances between main drain sumps, as well as distances from the pool wall.

Hydrostatic Relief Valve

In areas where hydrostatic forces are a concern, such as in locations with high water tables, protection of the pool structure must be provided. This typically necessitates sufficient underdrain piping below and around the pool structure. A pumped drainage scheme also may be employed.

However, even with proper groundwater removal systems in place, a hydrostatic relief valve (HRV) should be installed in the main drain sump. This device serves as a spring-loaded water stop and relief valve. If the main drain sump is poured concrete, a 2-inch (50.8-mm) pipe, along with a no-leak flange, is situated in the bottom of the pour. The HRV is threaded into the pipe on the pool side of the sump, and a pebble stop is threaded onto the backfill side of the concrete (see Figure 6-1). If the pool is drained, the HRV may be the only way to prevent the pool from being lifted out of the ground (floated like a boat) by releasing hydrostatic forces into the pool. There have been cases where large (up to 200,000-gallon [757,082-L]) outdoor pools have popped as much as 24 inches (0.61 m) out of the ground.

If the pool is internal to a large building with a large basement area and a substantial drainage system, the use of an HRV may not be a concern.

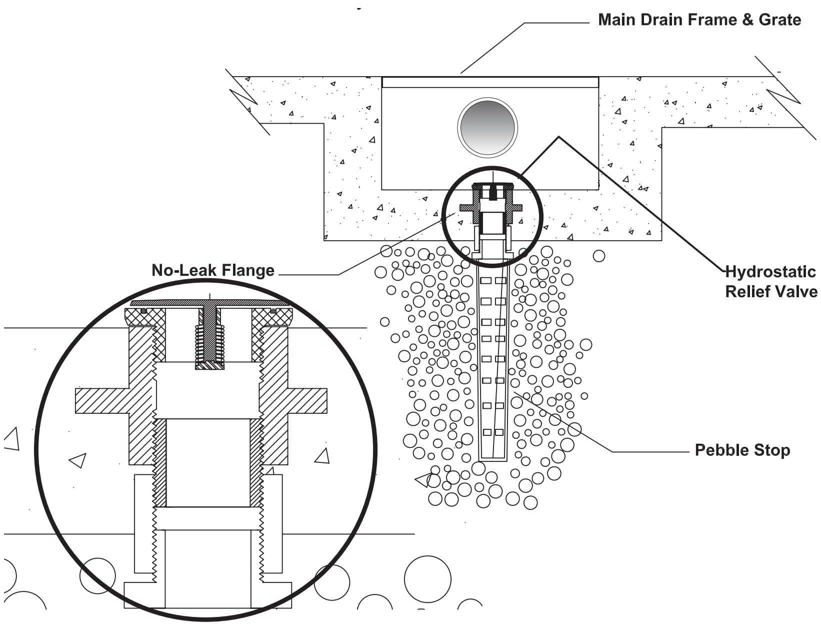

Figure 6-1 Formed Concrete Main Drain Sump with Hydrostatic Relief Valve

Filtered Water Return Piping

In swimming pool system terminology, return piping refers to piping returning filtered, chemically treated water back to the swimming pool inlets. The quantity, location, and spacing of these inlets are covered by the plumbing code. If the volume of these inlets cannot be adjusted, care must be taken in the pipe layout and sizing to ensure the equal distribution of chemical treatment throughout the pool volume.

Basic Piping Schemes

Numerous acceptable piping schemes are available. The major factors determining which approach to take are decisions on the following:

- Where the mechanical equipment room will be located (above or below the pool level)
- The type of surge-holding vessel to be used
- Whether to use skimmers instead of a surge vessel (if the pool is small enough)

Some typical piping layouts are given in Figures 6-2 and 6-3. For simplicity's sake, chemical feed systems and heating systems are not shown on these drawings.

Filtration and Circulation

Surge Vessels

Surge vessels are basically large holding tanks. They accept water flowing by gravity from the top of the pool and hold it until the circulation pump can move it through the filter. To reduce the potential for suction entrapment, the main drain piping should, ideally, flow by gravity to the surge tank.

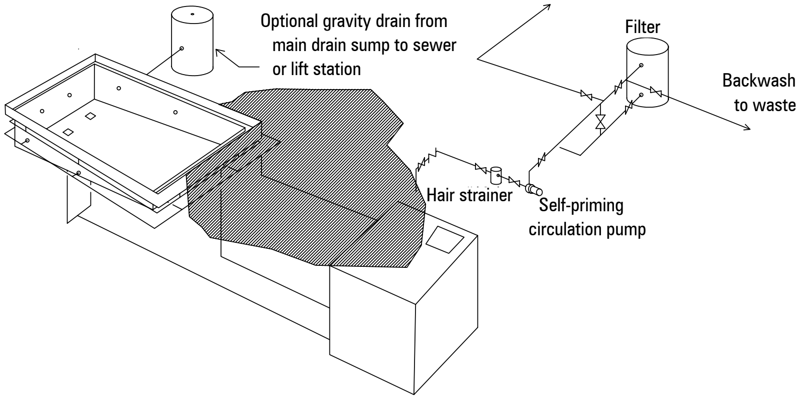

Figure 6-2 Typical Above-Grade Piping Scheme

Gutters

The water from the top of the pool is usually collected by a gutter. In the past, these were simply formed out of concrete with drain connections spaced evenly around the pool. Though this is still done on occasion, the following types of gutters are much more the norm.

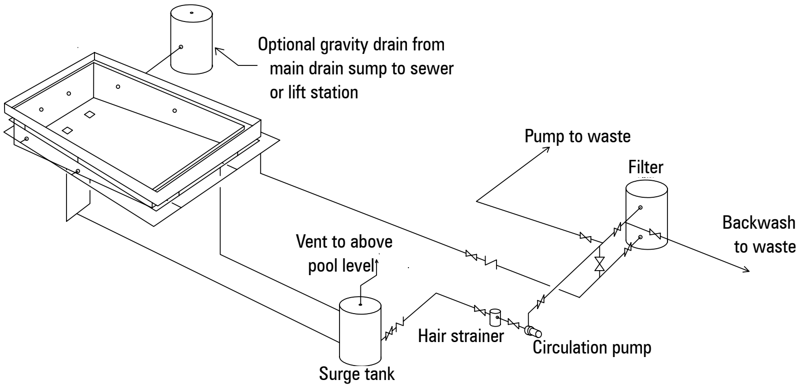

Figure 6-3 Typical Below-Grade Piping Scheme

- Stainless steel gutter: This is a dual-function system. It not only collects the skimmed water from the top of the pool, but it also provides the distribution inlets for returning filtered water. The skimmed water flows into one chamber of the gutter. Through another chamber, separated from the gutter water by a stainless steel wall or a plate welded in place internally in the unit, the filtered water is pumped back to the pool. This pressurized chamber has holes, spaced around the entire perimeter of the pool, that serve as filtered return water inlets.

  One disadvantage of this system is the fact that the inlets are placed very close to the surface of the pool, and distribution throughout the entire pool volume can be affected. Short-circuiting of filtered water back into the gutter is also possible. Of additional concern is the potential for internal breaches between the two flows (gutter water and filtered water). These may develop over time due to corrosion and/or expansion and contraction. These breaches are difficult to detect, and they will result in less-than-minimum turnovers due to the short-circuiting of filtered water right back to the filtration system through the gutter system. To address this concern, some stainless steel gutter manufacturers weld a rectangular stainless steel tube to the face of the rear gutter portion of the assembly, which provides a completely independent chamber for the flow of filtered water back to the pool.
- Surge gutter trench (see Figure 6-4): This is a formed concrete trench of sufficient width and depth to hold the required surge volume. It extends around the entire perimeter of the pool and is usually covered by a grating, which can be as simple as fiberglass bars sitting on a formed lip or as substantial as polymer concrete coping stones. The concrete coping stone is even considered part of the deck, which can be useful when minimum deck widths might otherwise be hard to accomplish.

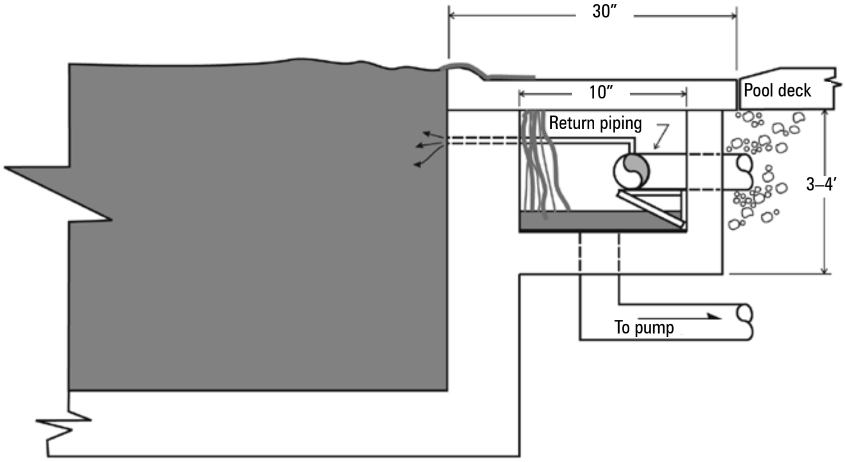

Figure 6-4 Deck-Level Surge Gutter Trench

Skimmers

On smaller pools, codes allow the use of skimmers. These are devices made of various types of plastics that have a floating weir (flapper door) that creates a skimming action at the water surface. They are set in the concrete when it is poured at one or more locations spaced around the perimeter of the pool or hot tub. Since they are directly connected to circulation pump suction, they should be piped to an equalizer fitting that is located well below the pool's operating level (see Figure 6-5). The P&SS Act considers this equalizer fitting a suction outlet and requires it to be covered by a compliant cover or grate or to be removed or disabled.

Skimmers are not as effective as a continuous gutter at skimming debris off the entire surface. That is why they are limited to use on pools with a small surface area. They also are used when budget concerns dictate.

Filters

The filter component of a pool system mechanically removes debris from the pool water. Measurable removal efficiency differences exist between the various types. In selecting a filter type, consideration should be given to the following items:

- Equipment room floor space and ceiling height
- Availability of backwash replacement water
- Filtration efficacy (turbidity of water leaving the filter)
- Water and sewer costs for replacement water
- Ability to handle a possibly large volume of backwash water
- Cost of heating replacement water
- Ease of operation
- Equipment longevity
- Budget requirements

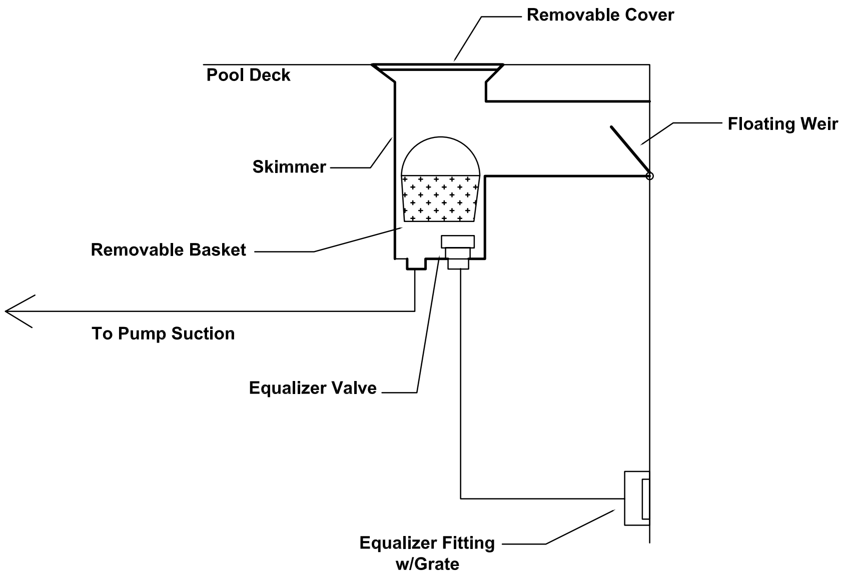

Figure 6-5 Skimmer Detail

Two basic media types are used in filters: sand and diatomaceous earth. Cartridge filters are sometimes used on smaller pools and spas, but they merely use replaceable cartridges, not loose media.

Sand is a granular media (usually #20 or #30 grade filter sand), and a uniformity coefficient is associated with each grade. The filter manufacturer will indicate the recommended grade of sand, as filtration efficiency is affected by the grade used, with #30 sand being more effective at particulate removal than #20 sand. However, more restrictive sand beds result in higher friction losses through the filter.

Diatomaceous earth, known as DE, is considered a disposable media. It is a fine white powder material made up of skeleton-like fossilized diatoms. This powder is mixed with the water in the filter vessel and deposited in a layer on the filter element or septum. DE also comes in various grades. Typically, for swimming pool use, the product used should have permeability in the range of 3 to 5 Darcy. Particulate removal capabilities basically track the permeability range, so the 3-Darcy media would be expected to achieve 99 percent reduction of 3-micron particles.

The filter area required depends on the media selected and the minimum flow rate requirement for the facility being designed. The various filter configurations for each of the two primary media types are covered in the “Component Evaluation and Selection” section of this chapter.

An alternative to DE is perlite, which is derived from volcanic glass/rock. Perlite is lighter than DE, simplifies the backwashing process, doesn’t stick to the filter media, and may lengthen the time between backwashings. Since perlite is lighter than DE, it may float when introduced into the pool, so care must be taken when adding perlite.

Circulation Pump

Circulation pump selection must be based on the ability of the pump to move the required amount of water through the circulation and filtration system under worst-case conditions. As the filter becomes dirty (loaded), it restricts flow. As piping ages and becomes calcified, it also can substantially restrict flow.

For these reasons, many codes mandate that a pump be selected with a design performance point of the minimum flow required, with an available total dynamic head (TDH) capability of 70 to 80 feet. In the absence of such a code requirement, the designer must assume the expected pressure drop through a dirty filter, usually 15 to 20 pounds per square inch (psi) (103.4 to 137.9 kPa).

In addition to the dirty (loaded) filter, all pipe and fitting losses on both the suction and discharge sides of the pump, friction losses through a dirty hair strainer, elevation differences between suction and discharge, and losses through a pool heater or heat exchanger must be calculated. The resultant estimated system head requirement dictates the proper pump selection.

Hair and Lint Strainer

These are devices with removable strainer baskets. They are installed upstream of the pump and are required by code. Their primary purpose is pump protection. Most codes require two strainer baskets, which decreases shutdown times when cleaning and changing a basket.

Flow Sensor and Display

All systems must include a device to indicate that the minimum flow rate and resultant turnover rate are being achieved. Numerous types are available, and their costs vs. accuracy and life expectancies vary considerably.

Many codes require gauges to be located properly on the suction and discharge sides of the circulation pump. These gauges, together with a pump curve for that particular pump, provide the ability to accurately check the performance of the pump and to verify the accuracy of the flow-measuring device.

Flow Control Devices

Consideration must be given to the means that will be used to control the rate and direction of flow to and from the pool. The circulation pump is selected for a worst-case scenario, so if it is allowed to run wide open when the filter, hair strainer, and piping are free and unobstructed, then over-pumping of the filter and heater will result.

Manual butterfly valves also are needed as isolation valves to enable the servicing of system components without draining the system. Valves must be provided to isolate the hair strainer to allow the replacement of a dirty hair strainer basket.

Codes also require the control of flow from the pool. Usually, 80 percent of the circulated water is taken off the top of the pool, and the remaining 20 percent is drawn from the bottom of the pool through the main drain. Some type of float-operated butterfly valve or manual valve usually is used to control this.

For more accurate control, diaphragm-type air-operated butterfly valves or piston-operated butterfly valves with pilot positioners are used. Even if variable-frequency drives (VFDs) are used to control the rate of flow to the pool, some type of manual valve should be in place in case the VFD fails. Manual operation must be able to be controlled while the VFD is out of service.

Pool Water Heating Systems

The basic types of heating systems are gas-fired water heaters, steam/hot water heat exchangers, and, infrequently, electric heaters. One possible disadvantage of using heat exchangers is that they require year-round operation of a boiler (if the pool is a 12-month operation). The rest of the facility may not require the use of the boiler, which may make the case for the use of a supplemental electric heater.

Venting capabilities, corrosive ambient air, and equipment space requirements are the primary issues to be given consideration. Many facilities are designed with dehumidification systems that use the heat of condensation to heat the pool water or pool space.

Chemical Control and Feed Systems

Commercial pools must have systems in place that are capable of maintaining the pH and oxidizer/sanitizer levels in the pool water within a code-mandated range. These systems can be as simple as adjustable-rate feed pumps for acid and chlorine solutions. Some codes require the use of an automatic water chemistry controller to constantly measure pH and sanitizer levels in the pool. These controllers will turn on the associated chemical feed pump or system as needed.

Level Control Systems

Level control systems can vary from a simple float-operated main drain valve installed on the main drain pipe after it enters the surge tank to a complex bubbler system (differential pressure controller) controlling an air-operated modulating valve. The decision typically is based on cost vs. accuracy. Specific operational characteristics of these systems are covered in detail later in this chapter.

Freshwater Makeup

Freshwater makeup can be accomplished by an operator regularly checking the pool water level and turning on the manual freshwater fill valve until the pool is filled properly. Most codes require a skimming action to take place constantly, and a good way to ensure this is to provide some form of automatic freshwater makeup system.

From an operational standpoint, since most contaminants in the pool water are introduced at the top portion of the pool, the top layer of water should pass through the filter the quickest. Such a water makeup scheme is closely associated with the water level control scheme employed.

COMPONENT EVALUATION AND SELECTION

Surge Vessels (Surge Tanks)

One method used to create a surge-holding capacity is a buried concrete tank. This type of surge tank is buried somewhere between the pool and the equipment room, usually under the deck that extends around the perimeter of the pool. It is also frequently located under the equipment room floor slab. Water from the perimeter gutter, and ideally the main drain, is piped to this holding tank.

Although the buried tank saves floor space, it complicates accessibility to key components. Access must be provided for cleaning or adjustments. Pump strainers and/or level control devices are often difficult to access. Frequently, draining of the surge tank is necessary. Also, this type of buried concrete structure is considered a confined space, so the operator will be required to follow Occupational Safety and Health Administration (OSHA) guidelines before working in this area, which should be taken into consideration before deciding on this approach.

A freestanding vessel is another type of surge tank that is located in the equipment room. It can be an open or a closed vessel. Open vessels are very common in installations where the equipment room is in a basement or where the location prevents venting of a closed tank. The obvious concern is how to provide protection from flooding if the system shuts down unexpectedly. Properly functioning check valves on the piping downstream of the filter, as well as between the main drain piping and the surge tank (if the main drain isn't connected to the surge tank), are an absolute necessity. The open tank design provides a convenient way to add freshwater with the required air gap.

The closed and vented tank is a much better option for a basement equipment room. A closed vessel, with flanged connections for the gutter piping, pump suction, and possibly the main drain piping, is vented through piping extending above the water level of the pool. Venting is essential, as it allows incoming water from the gutter and/or main drain to displace air in the tank. It also prevents a possibly damaging vacuum situation from occurring if isolation valves are inadvertently closed while the circulation pump is in operation or are left closed when the pump is started. The vent, if of sufficient size, also provides a means of adding freshwater with the required air gap. Figure 6-3 shows such a piping scheme.

Surge Gutter Trench

The surge gutter trench is a continuous concrete trench formed on the exterior of the pool walls around the entire perimeter of the pool. The trench is sloped to an area closest to the pool equipment room. At that low point, a single pipe connection is made to allow the water collected in the trench to be combined with main drain water at the circulation pump suction.

The trench is sized to meet or exceed the minimum surge-holding capacity requirement of 1 gallon per square foot (3.79 L/m^2) of pool surface area. The trench typically is covered by a grating made of fiberglass or Cycolac (a type of ABS thermoplastic resin commonly used for pool components). A slightly raised handhold must be provided at the water's edge of the covering scheme used for this trench to provide swimmers with a place to securely grip if needed.

Another design employs precast polymer concrete coping stones. In this design, the pool water is essentially at deck level, and the coping stone is considered an extension of the deck. Return piping often is run in this trench around the perimeter of the pool, which facilitates pipe repairs, when needed, without breaking up the concrete deck. Figure 6-4 gives a diagrammatic representation of this approach.

Skimmers

Skimmers can be used only on small pools, usually pools less than 20 feet (6.1 m) in width or less than a certain amount of water. They don't effectively skim a very large surface area, and they are directly connected to the pump suction. If the pool's operating level isn't properly maintained and the water level drops below the opening of the skimmer, the circulation pump may possibly suck air and be damaged by cavitation conditions.

To prevent air from reaching the pump suction when using skimmers, it is important to require the installation of an equalizer fitting, located in the wall of the pool a few feet below the skimmer. An equalizer valve and float are then installed inside the body of the skimmer. In this way, if the pool water level drops, water will still be drawn through the equalizer fitting. These items are offered as options with most commercial skimmers. (See the diagram in Figure 6-5.) A P&SS Act-compliant fitting is required for this equalizer connection to the pool since it is considered a suction outlet. Some codes may even require the removal or disabling of these equalizer connections to comply with P&SS Act requirements.

High-Rate Sand Filters

The high-rate sand filter is currently the most common type of filter employed on swimming pool systems. High-rate sand filters have acceptable particulate removal capabilities, and they are simple to operate.

These filters are pressure type, meaning the filter is installed downstream of the circulation pump, and the pump creates pressure to force the dirt-laden pool water through the filter. The water enters the filter at the top of the media bed and is forced through the sand to a set of slotted laterals, which are connected to a collection manifold.

The most common media used in high-rate sand filters is #20 or #30 filter sand, with a specific uniformity coefficient. The #20 sand has a particle size of 0.018 to 0.022 inch (0.35 to 0.56 mm) or an effective size of 0.45 mm and a uniformity coefficient of 1.5 maximum. The #30 grade is not as common as #20 sand. It is a finer sand and is sometimes used when higher filtration efficiency is desired. Not all filters are designed to allow the use of #30 sand, as the underdrain laterals must be manufactured with very close tolerances regarding opening size to disallow the passage of the smaller sand particles back to the pool. Check the filter manufacturer's specifications to ensure that #30 sand can be used.

In general, the flow rate of the water being filtered through this type of filter is in the range of 15 to 20 gpm per square foot (56.8 to 75.7 L/min/m^2) of filter surface area. All pool filters must be tested and certified to NSF/ANSI 50, which prescribes the maximum allowable flow for each listed filter. Many codes use this listing as their design requirement criteria.

The backwash rate for any sand filter is based on research done by the Hydraulic Institute. It has been determined through testing that a minimum of 15 gpm per square foot (56.8 L/min/m^2) of filter area is required to fluidize the sand bed. At less than 15 gpm per square foot (56.8 L/min/m^2), the filter bed doesn't lift up and release debris that is deeply embedded in the sand bed. If this lower-than-required backwash rate continues, mud balls eventually will develop and effectively decrease the usable filter area.

Properly designed high-rate sand filters, using the most common #20 grade media, can effectively capture particles as small as 15 to 20 microns when the filter is clean. As the filter becomes dirty (or loaded), the filtration efficiency of a sand filter actually increases. The interstitial spaces between the grains of sand media become smaller and can possibly capture particles as small as 10 microns.

Horizontal High-Rate Sand Filters

Horizontal high-rate sand filters may require more equipment room floor space than vertical sand filters, but they lend themselves to more accurate design possibilities regarding flow during filtration and backwash. Backwash functions are also more easily automated and are at a lower backwash flow for each individual tank. Multiple tank arrangements may be used to alleviate concerns about the ability of waste piping or transfer pumps to handle large backwash flow rates.

A three-tank horizontal system is shown in Figure 6-6.

Figure 6-6 Three-Tank Horizontal High-Rate Sand Filtration System

Vertical High-Rate Sand Filters

Depending on the required filter area and the shape of the equipment room, vertical high-rate sand filters sometimes can be a more space-conscious option. An 8-foot (2.44-m) diameter vertical filter would have more filter area than two 3-foot-diameter x 6-foot-long (0.91-m-diameter x 1.83-m-long) horizontal filters with a 6.25-foot x 6-foot (1.91-m x 1.83-m) footprint. Three horizontal filters, each with a footprint of 9.5 feet x 6 feet (2.9 m x 1.83 m), would be required to provide a filter area equivalent to that of the 8-foot (2.44-m) diameter vertical filter.

The equipment room floorplan will probably dictate which type of filter is best suited for the application. However, the designer also must consider the backwash water removal capabilities. Since the vertical system is forced to backwash the entire filter area at one time, the backwash flow rate for the vertical filter will be three times that of each individual component of the horizontal system where each tank is backwashed individually.

Multi-Cell Vertical Sand Filters

Multi-call vertical sand filters offer even more floor space savings. That same 8-foot (2.44-m) diameter footprint can accommodate two or three filter cells stacked one above the other. If even distribution across the sand bed is a concern, the method of distribution through each cell should be examined.

Lower filtration efficiencies can result if flow distribution is not uniform. Non-uniform flow results in higher velocities in certain areas of the sand bed, and these higher velocities can drive contaminants through the sand bed. Automated backwashing of each cell, individually, is difficult if not impossible.

Vacuum Sand Filters

A vacuum sand filter system is one in which the circulation pump is located downstream of an open filter vessel. As the filter media restricts pump suction, a vacuum is created that allows atmospheric pressure to force the dirt-laden water through the media. The contaminants are left embedded in the media.

The media used in these filters is usually one or two grades of gravel covered by several inches of #20 filter sand. Media requirements vary by manufacturer. The gravel layer is intended to enhance backwash capabilities.

The NSF/ANSI 50 listing for these filters indicates the maximum allowable flow rate for each listed filter size. These are listed as high as 15 to 20 gpm per square foot (56.8 to 75.7 L/min/m^2) of filter surface area. Individual manufacturers may recommend an even lower filter media rate than that allowed by NSF. The lower flow, frequently around 5 gpm per square foot (18.9 L/min/m²), is intended to allow smaller particles to be captured by the media. However, this requires a larger footprint.

As for any sand filter, the backwash rate needs to be at least 15 gpm per square foot (56.8 L/min/m²) of filter surface area. This is the minimum flow needed to fluidize the sand bed and release trapped particles. Due to the large surface area of these filters, this rate can translate into excessive amounts of wasted water.

Some manufacturers have introduced an air-scouring system in which bubbles of air rise through the sand bed during backwash. The air bubbles are intended to lift the sand bed and allow lower backwash flow (e.g., 10 gpm per square foot [37.9 L/min/m²]), while still achieving acceptable dirt load removal. This is somewhat questionable and may not be allowed by some codes, but manufacturers of these systems claim better filtration efficiencies at lower filter media rates than those achieved with high-rate sand filters. This might seem a logical conclusion, but no definitive independent testing of the turbidity of the water leaving these filters supports that claim. At higher rates, near 15 gpm per square foot (56.8 L/min/m²) of filter surface area, they are at least as good as high-rate sand filters.

Diatomaceous Earth Filters

Fossilized skeletons, primarily of sea plankton, are called diatoms. Large deposits of this fine powder are mined and graded according to particle size. The mined white powder is then heated and milled, resulting in diatomaceous earth (DE) products with varying properties. A coating of DE on a filter element or septum is used to trap and remove debris from the pool water passing through the filter. DE with a permeability of 3 to 5 Darcy units is common for commercial filtration.

In many locales, spent DE must be captured when draining or backwashing the filter to prevent the DE from settling in the sewer system in areas of low flow velocity. Since DE is a light, fine, white powder, proper breathing protection should be worn if the DE could potentially become airborne. Vacuum DE filters require the broadcasting of the DE powder over the water surface of the filled filter vessel, so making the DE airborne in that case is unavoidable.

Respirable (airborne) DE is considered a Class I carcinogen by the International Agency for Research on Cancer (IARC), but skin contact or ingestion is not considered dangerous. In fact, due to the prevalent use of DE for food preparation, such as soda and beer manufacturing processes, DE is classified as an incidental food additive. For purposes of comparison, beach sand, filter sand, sawdust, and drywall dust also are listed as Class I carcinogens.

Vacuum Diatomaceous Earth Filters

Vacuum DE filters are one of the oldest and most efficient (regarding particulate removal) forms of pool filtration. As with any vacuum system, the pump is located downstream of the filter.

The filter itself consists of an open-top vessel, filled with multiple filter elements or septums. The number and shape depend on the filter area needed and the design preference of a specific manufacturer. The septums are covered by a cloth bag or cover (usually polyethylene) that is coated with DE during a pre-coating process. The DE media performs the actual filtration, not the bag or the filter element.

A vacuum safety switch is required between the filter and the suction connection to the circulation pump. This safety switch is connected to the auto-control circuit of the circulation pump. Whenever a vacuum of 10 to 13 inches of mercury (in. Hg) occurs, the pump is automatically shut down. Otherwise, this high vacuum condition could possibly collapse and destroy the filter elements.

The septums can remain coated with DE only through continuous sufficient flow through the media, as the flow of water through the media holds the DE in place. If pump operation is inadvertently interrupted, the DE will drop off the elements. If the pump is then restarted without going through a pre-coat process, some of the DE initially will be pumped out to the pool.

The pre-coat process is a manual operation in which the filter vessel is filled with water and valves are adjusted to direct water pulled through the filter straight back to the stilling chamber of the filter tank. The pump is then started, and the required amount of DE (approximately 1 pound per 10 square feet [0.5 kg per 0.93 m²] of filter area) is broadcast over the surface of the water in the filter tank. Pre-coating is continued until the cloudy water (DE slurry) in the vessel clears sufficiently. Without stopping the pump, the pool return valve is slowly opened to allow filtered water to flow out to the pool. The

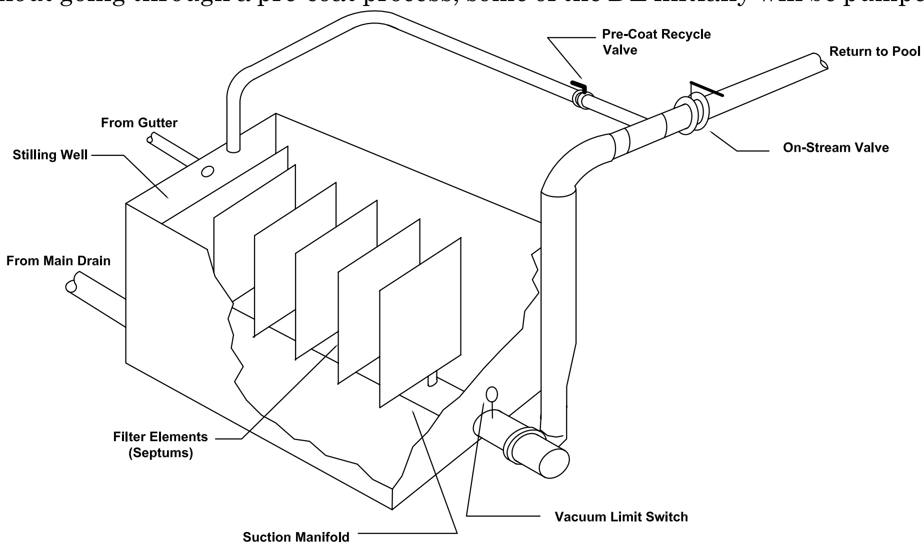

Figure 6-7 Vacuum DE Filter Piping

pre-coat recycle valve is then slowly closed, and the filter is considered online, or in filtering mode. Figure 6-7 shows the piping configuration for the pre-coat loop.

Contingent on the quality of the media selected, these filters can achieve a 99 percent reduction of water impurities in the 3-micron range. The configuration of these filters can also play a major role in their particulate-retention capabilities.

The procedure for cleaning a vacuum DE filter is simply draining the filter completely, hosing off the filter elements, and flushing the old, or spent, DE completely out of the filter tank. This can be a laborious, time-consuming task. If the filter vessel is poorly designed, with a floor that doesn't have sufficient slope to the drain, the old DE will be difficult to wash over to the drain opening. Once the filter and elements are sufficiently cleaned, the filter is filled with water. DE is then added by either broadcasting it over the surface of the water or mixing the required amount of DE in buckets of water and dumping it into the filter vessel. The pre-coating process is then initiated, and after approximately three to five minutes, the filter can be put back online.

Slurry Feed Systems

When DE is mixed with water, a DE/water slurry is formed. To extend the time between DE changes in the filter, additional DE often is added on a continuous basis. For filter media rates above 1.5 gpm per square foot (5.68 L/min/m^2), continuous DE slurry feed (sometimes called body feed) may be required by code. The rate of addition is prescribed by the same code.

A dry slurry feeder uses a rotating auger mounted below a DE holding funnel. As the auger rotates, it carries DE from the funnel out to the end of a trough. The dry DE then drops off the end of the trough into the water-filled filter tank and adds an additional thickness to the coating of DE on the filter elements. These units have digital controls and adjustments for setting the rate of feed in pounds per day.

Wet slurry feeders employ a holding tank filled with water in which a predetermined amount of DE is mixed. An agitator pump is required to keep the DE from settling out on the bottom of the holding tank. A feed pump, usually a diaphragm-type feed pump with a timed auto-flush solenoid keeping the check valves clear, is used to draw the slurry out of the holding tank and inject it into the water stream entering the filter from the pool. Peristaltic pumps also may be used, and since they don't require check valves, they may not require the auto-flush feature.

Pressure Diatomaceous Earth Filters

Pressure DE filters are the most economical regarding equipment room floor space. They are in a vertical configuration, with internal elements that provide a large surface area for filters having such small footprints. Like vacuum DE filters, they provide a high level of filtration efficacy.

Again, in a pressure system, the pump is located upstream of the filter and forces the water requiring cleaning through the filter elements. The actual configuration of the elements varies by manufacturer, but their purpose is to provide a surface for the DE to coat and to act as a filtering media.

Static Cake Diatomaceous Earth Filters

Static cake DE filters receive an initial charge of DE and then are pre-coated in a manner similar to the process described for vacuum DE filters. They filter continuously until the DE becomes plugged to a point where the flow through the filter is dramatically reduced below design operating parameters. Some form of wet slurry feed usually is employed to extend filter cycles. Due to the required frequency of cleaning, these filters are not usually found on large commercial systems.

Regenerative Diatomaceous Earth Filters

Regenerative DE filters are similar to static cake filters in their basic design, but they are far different in their performance characteristics. They typically have a higher initial cost than any other type of filter system, so care must be taken to ensure that the initial cost is commensurate with improved performance.

To eliminate the need for slurry feed and to greatly reduce the frequency of changing DE, regenerative DE filters employ an automatic regenerative process in which the original DE pre-coat is periodically forced (bumped) off the filter elements. The circulation pump is automatically turned off; the filter is automatically bumped; and then the circulation pump is automatically restarted, and a pre-coat cycle is automatically reinstituted. This procedure essentially clears free paths through the DE that is coating the elements and reduces the pressure drop through the media. It allows all of the surfaces of the initial DE charge to be completely used. A regenerative DE filter, of sufficient size to handle flows up to 2,300 gpm (8,706 L/min), is shown in Figure 6-8.

Both static cake and regenerative DE filters are subject to NSF/ANSI 50 testing requirements. They are NSF listed by model number regarding the maximum allowable flow. Typically, these flows range between 1.3 to 1.6 gpm per square foot (4.92 to 6.06 L/min/m^2) of effective filter surface area.

Figure 6-8 Regenerative DE Filter

Filtration efficacy is very dependent on the design and construction of each specific filter. Flow characteristics regarding velocity uniformity and uniform turbulence have a measurable effect on the DE-retention capabilities of each filter design. If the equipment choice is based on filtration quality, the designer should investigate previously installed operating systems of this type.

In general, particulate removal efficacies in a well-designed filter can be expected to track directly with the permeability of the DE media used. With the most common grade of DE used in commercial filters having a permeability of 3 Darcy units, at least a 99 percent removal of 3-micron particles can be expected. Some filters of this type have proven performance in the 1.5-micron range. In this range, a 2-log removal of bacteriological contaminants is possible. That is well worth consideration with the current interest in removing Cryptosporidium bacteria from pool environments. Again, this should be closely investigated to justify the use of these systems.

As stated, static cake filters require frequent cleaning. They also require a pumped backwash to force the DE and dirt out of the weave of the multi-filament fabric of the filter elements. The filter elements themselves require removal and more thorough cleaning, usually on a yearly basis. That is not the case with regenerative DE filters.

The cleaning requirements of a regenerative DE filter vary greatly depending on the load and filter size. In a heavy-use indoor facility, a regenerative DE filter should be recharged every three to four months. For a heavily used outdoor pool, if long filter runs are desired, the filter is sized for a filter media rate of approximately 1 gpm per square foot (3.79 L/min/m^2) of filter area, which usually results in four- to five-week filter runs. When filters are selected for operation near their maximum allowable filter media rate, they will probably require a DE change approximately every two to three weeks.

The procedure for replacing the DE is quite simple. The filter is bumped and then drained. No pumped backwash is required. After one or two additional fills with pool water for rinsing, the filter is refilled with DE, usually through a specially designed vacuuming system, which eliminates the concern about airborne DE. The infrequent need for DE changes, along with the fact that these filters don't require a pumped backwash, can be a major factor in reducing the water replacement and reheating requirements inherent in other systems.

Regenerative Alternative Media Filters

Some filters listed as regenerative DE filters under NSF/ANSI 50 have been tested using alternative media, and perlite and cellulose have been approved under NSF/ANSI 50 as DE substitutes. However, independent test results indicate that cellulose has filtration efficacies only slightly better than sand media filters.

A paper presented at the National Swimming Pool Foundation (NSPF) World Aquatic Health Conference in October 2009 ("Improving Bacteriological Safety: A Comparison of DE and Perlite") offered findings resulting from careful testing of the filtration efficacy of perlite compared with DE. When the two media were tested at the same permeability (1.5 Darcy), the same coating thickness (0.125 inch) on the filter elements (tortuous path), and the same filter media rate (1.5 gpm per square foot), the DE gave a reasonable expectation of a 4-log (99.99 percent) capture of Cryptosporidium-sized particles, compared with a 2-log (99 percent) capture by perlite. That is a sizeable difference when a single diarrheal accident can contain millions of Crypto oocysts. If 1 million oocysts are filtered by a DE filter, less than 100 will make it through. The same million oocysts encountering a perlite-coated filter have a much better chance of making it through and out to the pool. At a 2-log removal capability, perlite would allow almost 10,000 oocysts to pass through. Since it only takes 10 oocysts to infect a susceptible swimmer, the media choice is an important consideration.

If the choice of a regenerative DE filter is predicated on Crypto-removal capability, some type of performance specification should be established. The above test results were arrived at through the use of a "perfect" filter for testing. Actual results in the field will be affected by the design of the filter selected, as well as the piping layout in the equipment room.

Chemical Control and Feed Systems

The owner or operator of any commercial or public swimming pool is expected to maintain a safe environment regarding water quality. The water environment that is shared by the patrons must be clear and free of debris and contain no bacteriological contaminants.

To ensure this safety factor, codes place minimum requirements regarding oxidizer/sanitizer levels in the pool water, as well as a proper range in which the pH of the water must be maintained. In all but extreme cases, these levels provide proper bacteria kill as well as help maintain water clarity.

Proper pH and Sanitizer Levels

Typical sanitizer levels and pH ranges can be found in APSP publications as well as NSPF textbooks. These ranges are as follows:

- Pool sanitizer levels: 1 to 5 parts per million (ppm) when some form of chlorine is used as the sanitizer/oxidizer and 4 to 5 ppm when bromine is used as the sanitizer/oxidizer
- Pool pH levels: 7.2 to 7.8 pH (acceptable), 7.4 to 7.6 pH (ideal)
- Whirlpool and hot tub sanitizer levels: 2 to 3 ppm when chlorine is used and 4 to 5 ppm when bromine is used

Many people do not recognize the importance of maintaining pH in the proper range. In fact, the pH of the water is the primary factor in determining the killing power of the chlorine. When any type of chlorine is dissolved in water, it forms hypochlorous acid, which is the most active form the dissolved chlorine can take. Hypochlorous acid is a strong oxidizer/sanitizer, but the pH of the water is the determining factor for how much of the dissolved chlorine remains as hypochlorous acid. Hypochlorous acid easily disassociates into a hypochlorite ion (OCl-) and a hydrogen ion (H+), and this disassociation is much greater at a higher pH. The hypochlorite ion is still an oxidizer/sanitizer, but it is considerably weaker than hypochlorous acid. Thus, at a higher pH, less of the chlorine in the pool water is in the strong hypochlorous acid form.

For example, at a pH of 8, it will take a residual of 3 ppm of free chlorine to have the equivalent killing power that 1 ppm of free chlorine has at a pH of 7.4. This merely emphasizes the fact that just as much attention must be paid to the output capability of the acid or pH adjustment system as is paid to the chlorine feed system. If proper pH control cannot be maintained, the sanitizing characteristics in the pool water cannot be effectively controlled.

Water Balance

Water balance is based on a combination of factors. It is a measurement of five primary chemical levels that determine whether the pool water is scale forming (oversaturated) or corrosive (undersaturated). The Langelier index is the most common calculation used to determine this.

Water is the universal solvent. It will try to dissolve anything it comes into contact with until it becomes satisfied (saturated). At this point, any additional solids introduced into the solution cause it to become oversaturated. These solids eventually will settle out or form layers of calcification on the surfaces or components of the circulation system. This calcification can degrade system performance, and oversaturated water also affects water clarity. Undersaturation, or corrosive conditions, can also degrade performance as well as destroy the pool's structure (i.e., tile, grout) and metallic system components.

All of these factors point out the importance of maintaining proper water balance. The chemistry of the fill and makeup water of any facility should be examined. It can be a major factor in determining the proper chemical feed system to use.

Choosing Proper Control Chemicals

The chemistry of the source water at a potential pool location should be examined to see if it could impact a decision on the type of control chemicals to use. If the fill and/or makeup water is essentially balanced, almost any of the various sanitizer/oxidizer and pH-adjustment systems can be used. Balanced water would fall within the following ranges:

- Total alkalinity: 80 to 120 ppm
- pH: 7.2 to 7.8
- Calcium hardness: 200 to 400 ppm
- Total dissolved solids (TDS): <1,000 ppm

Gas chlorine is seldom used. The acceptable sanitizers/oxidizers are primarily chlorines (stabilized or unstabilized) and bromine. Lithium hypochlorite is sometimes suggested by various suppliers but is seldom used. Its relatively low active strength (29 percent) and high cost relegate its use primarily to backyard pools, where it is ideal for use on vinyl-liner pools.

Acid is used to lower pH; soda ash (calcium carbonate) is used to raise pH. The available acids commonly used are muriatic acid (diluted hydrochloric acid) and sodium bisulfate. Sometimes carbon dioxide is used. When carbon dioxide is injected into the return water, it forms carbonic acid (a weak acid).

Where high total alkalinity is present or when designing an indoor pool facility, care should be taken when considering carbon dioxide for pH control. Since carbon dioxide raises alkalinity when injected into the pool water, it could potentially make an existing total alkalinity problem worse. High total alkalinity encourages high pH levels, and more acid (carbonic acid) is needed to offset this. The required feeding of more carbon dioxide results in even greater increases in alkalinity levels.

Source water with high calcium hardness levels, more than 400 ppm, presents similar difficulties, and using calcium hypochlorite as the sanitizer/oxidizer may compound the problem. It may be necessary to consider sodium hypochlorite as the sanitizing and oxidizing agent.

Other factors to consider are the different effects that unstabilized chlorine products can have on water balance and the need for pH adjustment. Calcium hypochlorite has a pH of approximately 10 when dissolved in water; sodium hypochlorite (a liquid) has a pH of approximately 13. This higher pH can require almost twice the amount of acid used for pH control. Sodium hypochlorite also introduces approximately two times more TDS into the pool water. Most codes limit the amount of total dissolved solids in pool water to less than 2,500 ppm (sometimes as low as 1,500 ppm). Another common criteria is to maintain TDS at no more than 1,500 ppm over the TDS of the incoming source water.

Stabilized chlorines are chlorine products that have been combined with a stabilizing chemical (cyanuric acid). The available choices are trichlor (trichloro-s-triazinetrione) and dichlor (dichloro-s-triazinetrione), which are chlorine products that have been chemically combined with cyanuric acid. The cyanuric acid (also called stabilizer or conditioner) is used to reduce the amount of chlorine burned off by the ultraviolet (UV) rays of the sun striking the pool water. Since indoor pools are seldom faced with a problem of excessive sunlight conditions, these stabilized products are normally recommended only for outdoor pools and are sometimes not allowed by code for indoor applications.

The use of stabilized chlorine can, over time, result in the buildup of high levels of cyanuric acid in the pool water, and the cyanuric acid does not degrade. It remains in the pool until it is backwashed away or splashed out. Most codes limit the level of cyanuric acid to 100 ppm because levels exceeding 30 ppm substantially limit the time it takes for the chlorine residual in the pool to oxidize the contaminants or kill bacteria, which can lead to unsafe conditions. These concerns are frequently enough to relegate isocyanuric chemicals to private backyard pools because the patron loading on these pools is substantially lower than any commercial facility.

Instead of using stabilized chlorines, calcium hypochlorite or sodium hypochlorite with the manual addition of a small amount of cyanuric acid to the pool will have a reasonable resistance to UV degradation. This can be done at a much lower chemical cost and without the unwanted buildup of cyanuric acid.

The final consideration regarding pH control is the effect that the adjustment chemical used can have on the longevity of the mechanical equipment. The strongest form of acid used in the pool industry to lower pH is muriatic acid. If the feed equipment handling the muriatic acid is not sealed properly, the fumes emanating from the acid will rapidly destroy or corrode all metal components in the equipment room.

Chemical Controllers

Automatic water chemistry controllers have become the norm on almost every design of a new pool facility or the upgrade or retrofit of an older system. Some codes only require controllers on pools; others require them on pools and hot tubs.

Numerous choices are available. Low-cost controllers simply measure pH and oxidizer/sanitizer levels and then send power to the associated feed equipment to bring either back into the proper range.

Most controllers measure these chemical levels through the use of measuring probes immersed in a stream of filtered pool water or in a larger sample cell with pool water flowing through it. These probes produce a millivolt signal, which is the feedback to the controller that allows that control device to maintain proper pH and chlorine levels. The millivolt output of the pH probe is directly related to the pH level of the pool water. The chlorine or bromine level is not given directly by the probe.

The probe measuring the chlorine or bromine level is actually measuring how active the sanitizer is, not the quantity of it in the pool water. This activity is defined as oxidation reduction potential (ORP). In other words, the probe is measuring the potential of the sanitizer for oxidizing contaminants.

As discussed earlier, changes in pH levels affect the activity of chlorine. The controller can only control to an ORP setpoint, measured in millivolts. If the pH rises, the ORP of the chlorine (i.e., the millivolt signal from the ORP probe) decreases. As a result, the controller will turn on the chlorine feed system, often when the chlorine level is actually in the desired range. This relationship reinforces the premise that pH is equal in importance to chlorine in maintaining safe water conditions. High pH results in weak chlorine; low pH results in the controller underfeeding chlorine on a ppm basis.

Other controllers that are programmable actually control to a ppm setpoint. This type of controller uses curve fitting (high-end, floating-point math) to calculate ppm based on standard ppm curves on a pH vs. ORP axis provided by the manufacturer of the probe.

The last type of automatic controller treats pool water samples on an intermittent schedule with test chemicals. It then compares the color of the sample to a standardized series of colors and determines pH and chlorine levels directly. This type of controller requires regular replenishment of the test chemicals.

In general, more complex controllers have a higher initial cost. Controllers with unnecessary bells and whistles may require frequent service calls and related service costs. This should be considered when designing an operator-friendly system.

pH Control Systems

Two distinct systems control pH. Chemical feed pumps can be used to pump some form of acid to lower pH. The same style of pump can also feed soda ash to raise pH if that is what the pool requires.

Typically, if using sodium hypochlorite (a liquid sometimes incorrectly referred to as bleach) or calcium hypochlorite (a dry chemical that is mixed with water) as the oxidizer/sanitizer, acid would need to be used as the pH control chemical. Sodium hypochlorite has a pH of approximately 13, and calcium hypochlorite has a pH of approximately 10. Obviously, using these products to maintain proper sanitizer residuals would increase the pH of the pool water.

The other system that is sometimes employed to lower pH is a carbon dioxide feed system. The carbon dioxide gas is injected into the water returning to the pool, and it forms carbonic acid when dissolved in the stream of water. Carbonic acid is weak, but it will effectively lower pH.

Acid Feed Pumps

Two basic types of chemical feed pumps are used on pool systems. They each have advantages and disadvantages.

Peristaltic pumps use a motor-driven series of rollers that rotate in an enclosed pump head, and as the assembly rotates, it squeezes a feed tube. This creates a vacuum on one end of the tube, which allows atmospheric pressure to push the acid solution into the evacuated area of the feed tube. The next roller then forces that solution toward the other end of the tube and creates a new evacuated area of tube in its wake.

In the past, there were concerns that the pressure developed by peristaltic pumps (usually no more than 25 psi [172.4 kPa]) might be insufficient to inject chemicals into the circulation system. However, this is seldom true. Chemicals must be injected downstream of all system components, such as heaters, heat exchangers, and dehumidification equipment.

At that area of the return piping, the only backpressure or system head remaining is merely due to elevation head, small return pipe and fitting losses, and friction and discharge losses through the filtered water inlets. It is seldom more than 7 to 10 psi (48.3 to 68.9 kPa). In cases where pressures greater than 25 psi (172.4 kPa) are expected, some peristaltic pumps can create output pressures as high as 100 psi (689.5 kPa).

These are relatively inexpensive pumps. The internal components don't usually have a long life expectancy, but they are not costly to replace. The only other concern is that peristaltic pumps must be placed close to the acid solution holding tank. The weak vacuum that they create does not allow for long suction tubing runs.

The other type, the diaphragm pump, uses a rotating cam to move a diaphragm in an enclosed housing. Check valves are used on both the suction and discharge sides of the diaphragm enclosure. The rotating cam controls the inward and outward movement of the diaphragm. When the diaphragm moves outward, a vacuum is created in the enclosure. This vacuum closes the discharge check valve and opens the suction check valve. Thus, the outward motion allows the chemicals to be drawn from the solution tank. The inward movement of the diaphragm has the opposite effect: pressure is created in the housing. That pressure closes the suction check valve and opens the discharge side to allow chemicals to be pumped into the piping system.

As many as four check valves can be used with this type of pump. If the chemical being pumped is prone to calcification or particulate buildup, frequent cleaning will be required. If sediment impairs the operation of the check valves, pumping will cease.

These pumps usually create pressures in excess of 100 psi (689.5 kPa). Caution must be taken to ensure that the check valve, usually installed at the chemical injection point into the circulation piping, doesn't become blocked. If the diaphragm pump becomes dead-headed, the resultant high pressure in the feed tubing can cause it to burst.

Carbon Dioxide Feed Systems

Carbon dioxide has become an alternate choice for lowering pH. When it is injected into the circulation system, it forms carbonic acid. It also has a tendency to increase total alkalinity in the pool water. If the makeup water for the pool already has high total alkalinity characteristics, carbon dioxide may not be a good choice for pH control.

Carbon dioxide comes in 50-pound (23-kg) or 150-pound (68-kg) high-pressure tanks. For large facilities or especially for outdoor pools, permanent installation of 750-pound (340-kg) tanks can be employed. These are usually set up to be refilled from outside the pool building.

In general, a gas-control electric solenoid is used to regulate the flow of the carbon dioxide gas. The solenoid is most commonly connected to an automatic water chemistry controller. Some system manufacturers use a side stream with a venturi and possibly a booster pump to create a vacuum to assist in drawing in the gas and dissolving it in the return water.

Carbon dioxide is heavier than air. It is best located in a separate, force-ventilated area. The vent fan intake should be positioned near the floor.

Sanitizer/Oxidizer Feed Systems

Feed pumps are used when the oxidizer/sanitizer chemical is in liquid form. This can be sodium hypochlorite (sold as a liquid), a dry calcium hypochlorite, or granular dichlor dissolved in water. The pumps used for feeding chlorine solutions are the same as those indicated earlier for pH-adjusting acid feed systems. However, since acid solutions do not generate calcium carbonate (calcification) and do not contain insolubles or sediment, the working parts of the pump operate in a much cleaner environment. Chlorine solutions are much more prone to sediment and calcification concerns. This should be considered when deciding on the type of pump to use.

Erosion feeders are used where the control chemical is manufactured in a tablet or briquette form. The briquettes or tablets are dissolved by either a flow of water across their surface or contact with a water spray. The feeder can be either atmospheric or pressurized. NSF requires that only the chemical product prescribed by the manufacturer be used in a given feeder. This mandate is directly related to concerns about mixing different chemicals, as well as maintaining NSF-verified feeder output capabilities (pounds per day of available chlorine).

Calcium hypochlorite is often manufactured in a tablet or briquette form and has to be dissolved in some manner. Several types of these systems are available. The feeder can be installed in a side stream, with or without a booster pump. The design can be as simple as a flow-through device or a more complex spray device with a venturi and a booster pump. Overflow protection is usually provided as part of the feeder design. Most codes require a certain output capability, in pounds per day based on the gallons in the system being treated. This will be the determining factor for specifying the size of the feeder.

The stabilized chlorine product trichlor is introduced into the pool using a pressurized feeder. The feeder is filled with the trichlor tablets and then sealed. When pool water flows through the feeder, the tablets dissolve. Trichlor feeders are usually installed in a side stream with isolation valves. Feed of the chemical can be accomplished by manually opening the isolation valves or by using a normally closed solenoid on the influent side of the feeder. Use of a solenoid requires an automatic water chemistry controller to be part of the system. The solenoid is opened by the automatic chemical controller when it senses a drop in chlorine residual.

If trichlor is selected as the oxidizer/sanitizer, there are some concerns regarding the buildup of stabilizer in the pool water. As more and more trichlor is fed to replace what is used for sanitation purposes, the stabilizer remains and builds to higher ppm levels. Automatic water chemistry controllers rely on the millivolt signal from the ORP probe for feedback regarding chlorine levels in the pool water. High stabilizer levels cause inaccuracies in the output of the ORP probes.

In its elemental form, bromine is no longer allowed by U.S. EPA regulations. Thus, when used as a spa disinfectant, bromine must be provided in some other form. One form is sodium bromide activated by potassium monopersulfate (an oxidizer). This two-part system is not used on commercial systems, so it is mentioned here for informational purposes only. The second means of introducing bromine into the pool water is an erosion feeder. The pressurized feeder is filled with bromine tablets. The flow-through feeder is installed in a side stream, with isolation valves and possibly a solenoid. The solenoid is only used if an automatic water chemistry controller is part of the system.

Pound for pound, bromine is a much weaker sanitizer/oxidizer than chlorine. It requires approximately 2.25 times more bromine to achieve the same oxidation and sanitation results available with chlorine use. Its main advantage is that it is less prone to degradation due to high water temperatures. For that reason, bromine is often the choice for hot tub and whirlpool applications where 104°F (40°C) temperatures are the norm. If heavy user loads are expected, chlorine, due to its greater oxidizing and sanitizing properties, may still be the proper choice.

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Expiration date: Continuing education credit will be given for this examination through **March 31, 2017**.

CE Questions — "Public Swimming Pools" (CEU 233)

1. The Virginia Graeme Baker Pool and Spa Safety Act requires main drain sizes, velocities, piping configurations, and testing protocols to be regulated according to ________.
   a. APSP A112.19.8
   b. ASME A112.18.9
   c. ASME A112.19.8
   d. APSP A112.18.9

2. Maximum attendance at a public swimming pool facility can be estimated to be ________ percent of the projected maximum attendance on the peak day.
   a. 10
   b. 33
   c. 40
   d. 68

3. The water temperature of an indoor swimming pool should be in the range of ________.
   a. 70 to 80°F
   b. 75 to 80°F
   c. 75 to 85°F
   d. 75 to 90°F

4. Bathhouse floors should be sloped at least ________ to ensure the proper drainage of all floor areas.
   a. 0.20 in./ft
   b. 0.22 in./ft
   c. 0.24 in./ft
   d. 0.25 in./ft

5. What is the typical minimum turnover rate for a wading pool?
   a. 30 minutes
   b. two hours
   c. four hours
   d. six hours

6. The ________ is the rate at which water moves through the filtration system.
   a. filter media rate
   b. surge
   c. overflow
   d. flow rate

7. The velocity through the grating of a main drain sump typically is mandated to not exceed ________.
   a. 1 to 1.5 fps
   b. 1 to 1.8 fps
   c. 1 fps
   d. none of the above

8. Which of the following filter media types can be used in swimming pool applications?
   a. sand
   b. perlite
   c. diatomaceous earth
   d. all of the above

9. When using a skimmer, what is used to prevent air from reaching the pump suction?
   a. equalizer fitting
   b. air-operated modulating valve
   c. float-operated butterfly valve
   d. pilot positioner

10. For any sand filter, the backwash rate needs to be at least ________ of filter surface area.
    a. 5 gpm/ft^2
    b. 10 gpm/ft^2
    c. 15 gpm/ft^2
    d. 20 gpm/ft^2

11. What is the ideal pool pH level?
    a. 7.2 to 7.8
    b. 7.4 to 7.8
    c. 7.6 to 7.8
    d. 7.4 to 7.6

12. Which of the following types of chemical feed pump is used on pool systems?
    a. peristaltic
    b. diaphragm
    c. regenerative
    d. both a and b