Bruce E. Beddow, P.E.
Harald Kannewischer, dipl. Ing.

116 N Edwards Ferry Road, NE, Leesburg, VA 20176

0. Introduction

Water treatment process equipment in commercial swimming pools is the heart of the technical system and requires special care during the planning and arrangement of the selected system components. Special attention is also required to operate the system successfully.

Significant advances in water treatment technology have been made over the past five years. Many improvements in system design and available equipment have been developed in Europe because of the stringent regulations on public swimming pool water quality in European countries. European design standards and equipment, especially from Germany, are making their way into the American market place. These standards have been developed over many years as public pools and their use have changed.

Pools are no longer thought of as simply swimming pools. They are classified by function, such as hot whirlpools, warm water massage pools, therapy pools, water attraction (leisure) pools, exercise pools, mineral pools, and of course swimming pools. Each type of pool design should consider, water temperature, bather frequency, water surface area and specific loading capacity of the chosen water treatment system process, as well as other criteria outlined in this paper.

Water treatment systems have three main components:

1. Pool Hydraulics

- Distribution of disinfectant and heated pool water return
- Optimal removal of unwanted particles present in the pool

2. Water Treatment System

Modern systems contain the following process:

- Flocculation, filtration and automatic water balancing

This provides:

- Removal of impurities and unwanted particles present in the water
- Optimum pH-value regulation and disinfection

3. Disinfection

Modern systems contain one of the following disinfectants:

- Hypochlorous acid (HOCL)
- Hypobromous acid (HBrO)
- Ozone w/HOCL or HOBr residual in the pool

These three main components are each a functioning unit and must be considered together as a total working system.

Incorrect conception and design, improper operation of equipment, improper maintenance or system failure can cause an unsuitable pool water quality and allow a possibly unhygienic situation to develop.

Optimization or economical renovation of water treatment systems is usually performed after identifying one or more of the following:

1. Poorly functioning or defective system components.

2. Poor pool water quality.

3. High operating costs.

Improving these conditions is the goal for either optimization or economic renovation of the system, and should be kept in mind while reading this paper.

This paper looks at current American and International pool water quality standards and the important considerations for proper planning, design and operation of the individual system components, as well as the function of the entire system. It identifies important functions of public swimming pool water treatment systems and is intended to assist individuals responsible for the safety and operation of public swimming pools.

Additional information concerning public swimming pool design can be obtained from B2E Consulting Engineers, PC, Leesburg, VA. An "Available Publications" list is also available.

1. Considerations for the Design and Renovation of New and Existing Pool Water Treatment Systems

Improper function of individual components or of the entire system can lead to unsatisfactory hygienic conditions in the pool and increases the personnel expenses for service, care and repair.

Frequently, the unsatisfactory purifying effect of such systems are compensated for by higher introduction of chemicals and fresh water. This diminishes bather comfort and increases operating costs.

1.1 Water Circulation Capacity

Calculation and sizing of water treatment equipment requires knowledge of the available valid local, national and sometimes international standards. Local standards, such as adopted by state regulating agencies, are usually helpful, but do not offer practical information concerning the performance of a given water treatment process.

National standards, such as provided by the National Spa and Pool Institute (NSPI), which is approved by the American National Standards Institute, Inc. (ANSI), are voluntary standards based on consensus agreement. This means that use of this standard by regulating agencies is voluntary and in the judgment of the ANSI Board of Standard Review, substantial agreement has

been made by directly and materially affected interests (or organizations).
Some international standards, such as the German, Deutsches Institut fuer Normen (DIN) 19643 Treatment and Disinfection of Water for Bathing Water, and the Swiss, Schweizerischer Ingenieur und Architekten-Verein (SIA) 385/1 Requirements on Water and on Water Treatment Systems in Community Pools, are national laws effective throughout the entire country, and they are enforced. They clearly define acceptable water treatment processes, and accept substitutions to these standards only after the system has been put into operation, is tested and meets the conditions of the standard. When a system is inadequately designed or falls out of compliance the pool is shut down.

The German DIN Standards are recognized around the world as one of the most comprehensive international standards and are available in English. Although they are one of the best, the requirements can be more difficult to meet.

For example, the American NSPI Standard for whirlpools states that the water circulation rate should be sufficient to circulate the entire spa water capacity at a minimum of once every thirty minutes. Since a typical system connected to two six person whirlpools contains roughly 15 m^3 (4,000 gal) of water, the required water circulation rate is 30 m^3/h (130 gpm). The German DIN Standard bases the water circulation rate on bather load and the frequency of bathing. Working through the calculations yields a circulation rate of 108 m^3/h (475 gpm) and 90 m^3/h (400 gpm) when ozone is used. This shows a significant difference in required water circulation between the two standards.

This subject will be discussed in more detail in subsequent sections of this paper.

When designing to either the American or German standard the following considerations should be made when planning or evaluating special use pools:

- Children's' splash pools:

If these water playing areas are furnished with a variety of special splash equipment, then a higher filter capacity is required, and should be sized in accordance with the number of bathers and the higher frequency of bathing. Otherwise these pools will maintain a lower hygienic quality.

- Heated pools and massage pools:

These pools typically have smaller water surfaces and are frequently overloaded at public facilities. Consideration of the necessary water surface area for the expected number of bathers is absolutely necessary. This will reduce the possibility for building an undersized pool at an unusually high cost.

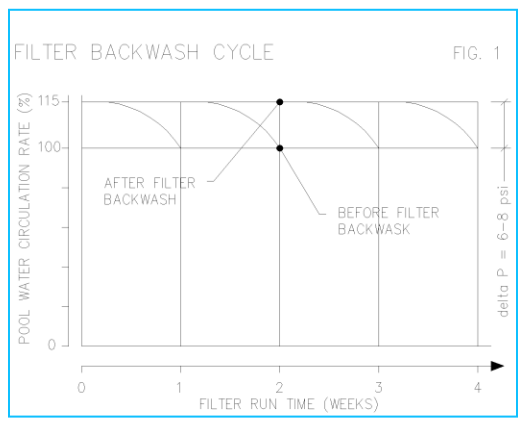
- Water Slides:

These attractions require a properly sized treated water circulation rate calculated in accordance with the frequency of use. For example, 80 people enter the slide circuit 10 times per hour for a total of 800 runs per hour. This would require a treatment capacity of 160 m^3/h (700 gpm) or 0.2 m^3/h run (0.9 gpm/run).

- Hot Whirlpools:

These pools require special attention and are the subject of a separate paper by the same author and available through B2E Consulting Engineers, P.C., Leesburg, VA.

The performance of the pool water treatment system is not constant because the water flow is not constant over time. The flow rate reaches a maximum value immediately after the backwash cycle, and then falls off slowly until the filter resistance climbs to its maximum value before the next backwash cycle.



After the backwash cycle the filter resistance across the sand filter amounts to roughly 0.1 bar (1.5 psi) and climbs until the next backwash cycle approximately 0.5 bar (7.3 psi).

The filter should be equipped with pressure measurement gauges, and each pool system should have a suitable water flow meter. Good flow measurement devices are:

- Inductive process (expensive, precise, reliable)
- Flow meter (rotometer)
- Pitot manometer
- Paddle wheel flow sensor

An inspection of the total system performance is also possible by establishing the pressure difference across the main circulation pumps using the appropriate manufacturer's pumping performance curve.

It is possible that during operation the water flow can drop-off. The cause can be one or more of the following:

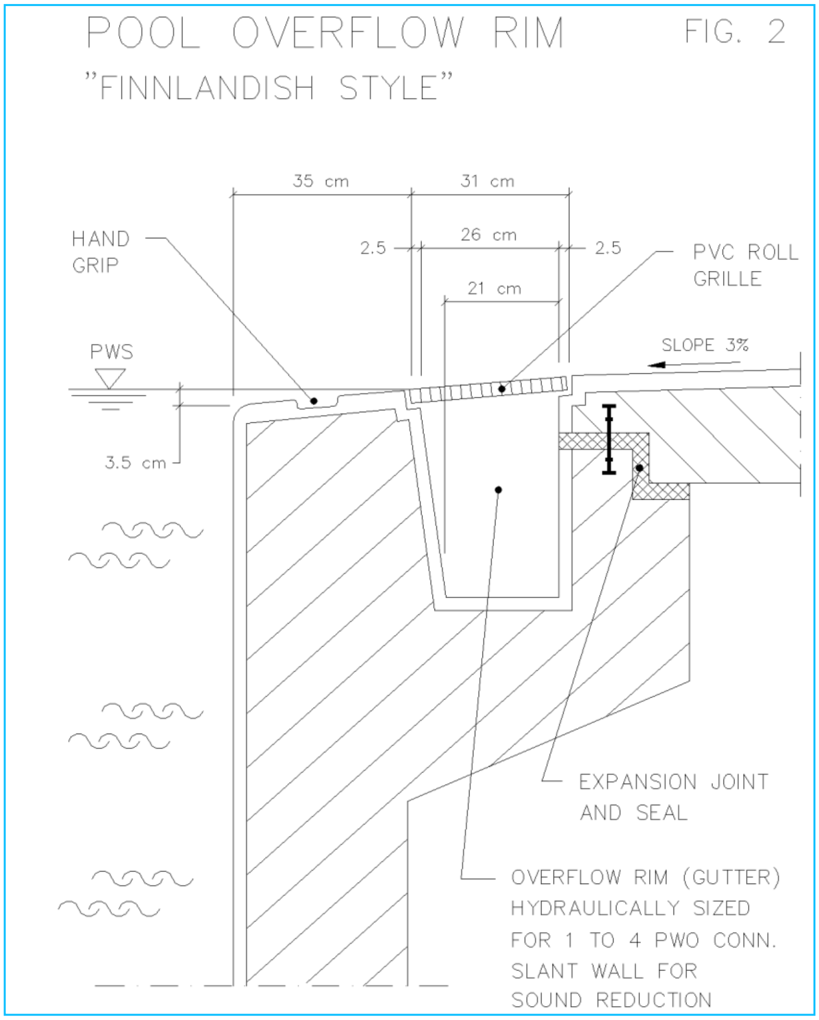
- Corrosion in the prefilter causing restricted flow
- Packing of the filter bed
- Corrosion of the pump impeller or housing
- Calcium build-up in the heat exchangers
- Build-up of dirt, scale, etc.

When evaluating a system the measured water circulation flow rate should be obtained. According to the sizing requirements the proper circulation capacity is measured immediately before the backwash cycle, and this minimum flow rate should also be provided when a filter is clogged. After the backwash cycle a higher water flow rate will be pumped to the pool water distribution system. (See Figure 1)

1.2 Pool Water Overflow and Return

Even the best treatment systems are ineffective if the treated pool water return is inadequately distributed throughout the entire pool volume. An exact water distribution provides even mixing of disinfectant within 5 to 8 minutes. Fast mixing of the total water volume and efficient removal of surface debris and impurities are important considerations for optimal system operation.

Pool water overflow should be hydrostatically balanced using a pool overflow rim/gutter. Pool rims/gutters of various architectural designs are an important component of the hydraulic system, and should be engineered. This ensures that the pool water displacement and overflow will be channeled to the balance tank. (See Figure 2)



1.3 Prefilter/Fiber Screen

A mesh fiber screen is required to catch large particles before the circulating pumps. A prefilter is especially important with outdoor pools where large quantities of foliage and similar impurities are expected. It is frequently recommended for outdoor pools to install a large filter element before the balance tank. Specially designed pool pumps should be considered for ease of maintenance. (See Figure 3)

Figure 3: Compact pool water circulation pump with built-in suction strainer.

1.4 Flocculation

Flocculation at the sand filter alone is unreliable, and can be helped using a flocculating agent, such as aluminum sulfate, iron (+3) chloride or more recently polyaluminum chloride ($AlCl_3$) or (PAC). These flocculates only work between a limited pH range and require a certain reaction time.

Aluminum sulfate is effective between the range of pH-6.8 to 7.2. With higher pH-values the flocculation will be delayed and leads to cloudy water in the pool. Flocculation will not be achieved with a pH level above 7.4. Today PAC is predominantly used because it is less pH sensitive and provides better water clarity.

Dosage levels are typically from 0.3 to 1.5 g/h per m^3/h (6.8 - 9.5 g/h per 100 gpm) of the required water circulation rate.

It is important that the relationship between pool water loading and flocculate injection is given. Flocculation for outdoor pools is dependent on both the weather and the number of bathers. For example, rainy days usually require 0.3 g/h per m^3/h (6.8 g/h per 100 gpm) and peak days 1.0-1.5 g/h per m^3/h (23 - 34 g/h per 100 gpm). This is likewise true for indoor pools where the number of visitors is changing from day to day.

The injection point should be chosen near the pump discharge, so that optimal mixing is achieved. The injection coupling should be fixed in the center of the flow area of the piping and should have a nozzle to distribute the flocculating agent.

1.5 Filter

A pressurized sand filter functions only as well as the backwash can provide the proper cleaning effect. Backwash is usually performed as a function of the pressure drop across the filter. This normally occurs every 1 to 5 days. The filter must be backwashed at least once per week, even when the pressure gauges indicate that the filter medium is not completely filled.

Example of a semi-automatic backwash program:

1. Drain the filter to the sand level
2. Clean air washing for 5 minutes
3. Mixed water/air washing from 7-10 minutes
4. Clean water washing from 3-5 minutes
5. Filling the filter vessel
6. First filtrate directed into the sanitary sewer (2-3 minutes)

Air washing is an important consideration because it fluidizes the sand bed. The air lifts the sand and the grains rotate and move against one another. This action allows dirt fixed to the grains of sand to be washed out.

The washing process, lifting the sand bed and actual fluidization, should be inspected with open filters. Under these conditions it is also possible to use a stick (sounding rod) to determine whether the sand bed is clogged. With open filters it is certain that uneven or unsymmetrical air/water patterns can be recognized.

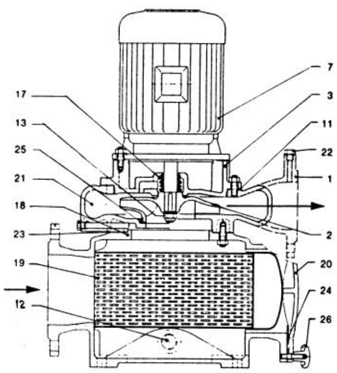


Figure 3

1. Casing
2. Impellar
3. Rear Wall
7. Motor
11. Casing Seal
12. Drain Plug
13. Impellar Nut
17. Mechanical Shaft Seal
18. Filter Housing
19. Strainer
20. Cover
21. Blockage Check Point
22. Manometer Connection
23. Casing Seal
24. O-Ring
25. Casing Seal Ring
26. Star Handle

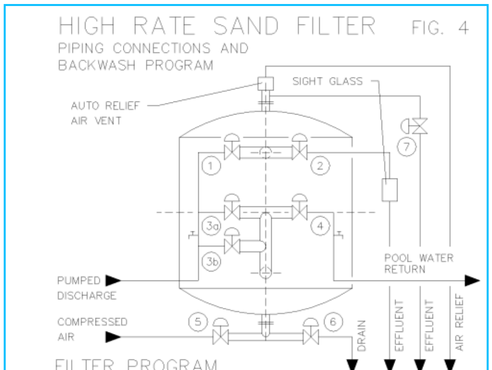
During the filter backwash seven valves service each filter controlled by an exact time program. The exact regulation of the projected backwash program and regulation of the seven valves can only be accomplished using an automatic control system.
(See Figure 4)

It is especially important to be aware that during the operation adjustments cannot be made. Because of the low back pressures during backwash, it is important to have good throttling of the valves. The system is then able to operate with reduced pumping capacity. With high back pressures during the air/water backwash there will be little or no air in the filter, which is undesirable.

For this reason backwash without back pressure is required. This means that with an open inspection port the backwash must operate perfectly. A high water drain connection is therefore not permitted.

It is likely that long operating cycles will allow calcium build-up in the filter media with hard water or pools with high pH-values. This can be such a problem that the media (sand) must be broken-up with a compressor. Additional calcification of the filter can result in water bypass through channels in the media, and result in insufficient filtration.

The filter bottom is basically a baffle (60-70 holes/m2 or 6-7 holes/SF). The holes or nozzles provide an even flow of filtrate and backwash water. The main supply connections and filter distribution network should be designed to distribute the water and air evenly. If the internal filter distribution is designed poorly a portion of the media will be backwashed with air and another with water.



FILTER PROGRAM

AIR–WATER–BACKWASH CYCLE FOR HRS FILTER

	FUNCTION	FILTER RATE	TIME	VALVES OPEN
1	FILTER IN OPERATION	12 gpm/sf		1 4
2	AIR RELIEF + DRAIN		3–5 min.	2 7
3	AIR WASH	3.2 cfm/sf	5 min.	5 7 2
4	AIR–WATER WASH	AIR 3.2 cfm/sf WATER 4.0 gpm/sf	7–10 min.	3b 2 5 7
5	WATER WASH	20 gpm/sf	3–5 min.	3a 2 7
6	FIRST FILTRATE		3 min.	1 6
7	FILTER IN OPERATION	12 gpm/sf		1 4

1.6 Rim/Gutter Overflow Control During Pool Deck Cleaning

A redirection of the pool overflow water is necessary when cleaning fluid is not permitted in the filter. Cleaning fluid introduced into the filter leads to mud (slime) build-up during the backwash cycle. The problem occurs when cleaning fluid is held in the filter vessel after the backwash cycle, because the dissolved dirt will be pumped into the pool. It is best to generously redirect the channeled water containing cleaning agents automatically to the sanitary sewer. (See Figure 5)

1.7 Important Chemical Parameters for Water Treatment

General knowledge of the water analysis of the available drinking water, available from the local water authority, is needed for the planning, renovation and operation of pool water treatment systems.

1.7.1 Water Hardness

The three different measures of water hardness are:

- Calcium Hardness (Temporary Hardness)
- Non-calcium Hardness (Other Metals)
- Total Dissolved Solids (TDS)

TDS is the sum of calcium and non-calcium hardness.

The calcium hardness is the most interesting value of water hardness for swimming pool applications. Calcium hardness consists of both carbonate and bicarbonate ions.

In nature carbonic acid rich water combines with calcium carbonate (lime) as shown by the following reaction:

$CaCO_3 + H_2CO_3 \Rightarrow$
Calcium Carbonate Carbonic Acid

$Ca(HCO_3)_2$
Calcium Bicarbonate

Calcium or magnesium are practically insoluble in pure water. The calcium hardness is therefore dependent upon the carbonic acid content of water.

The stability of calcium carbonate and carbonic acid in water is both temperature and pressure dependent.

As water containing carbonic acid is heated carbon dioxide off-gases and the

$Ca(HCO_3)_2 \xrightarrow{HEAT} \uparrow CO_2 + H2O + CaCO_3$

calcium hardness rises, as shown by the following reaction:
Carbon dioxide also off-gasses when heating pool water and the pH-value begins to rise. As a result calcium carbonate can precipitate out of solution, which is evident as the water quickly becomes turbid. Continuous pH correction, usually with muraitic acid (diluted hydrochloric acid) or hydrochloric acid, is necessary.

In order to reduce the amount of calcium precipitate and to regulate the pH-value, hydrochloric acid is normally injected into the pool water return. The hydrochloric acid, which is a stronger base than carbonic acid, displaces the

$$Ca(HCO_3)_2 + 2\,HCl \Rightarrow CaCl_2 + 2\,H_2CO_3$$

or,

$$CaCO_3 + 2\,HCl \Rightarrow CaCl_2 + H_2CO_3$$

carbonic acid according to the following reactions:

$$H_2CO_3 \Rightarrow \uparrow CO_2 + H_2O$$

The resulting carbonic acid disassociates into,

and the resulting calcium chloride ($CaCl_2$) is very soluble in water and will not precipitate out of solution.

Hard water requires pH regulation with acid.

Soft water requires special attention to determine whether to regulate with calcium bicarbonate (soda ash), phosphates or with marble chips.

During chlorination injecting free hydrochloric acid in water requires sufficient acid capacity (water hardness), otherwise the pH-value may fall-off sharply to values below pH-7.

Sodium hypochlorite can be an appropriate choice as the disinfectant in pools with soft water.

1.7.2 pH-Value

The pH-value is the measure of the hydrogen ion concentration in water solutions. It is the negative exponent of the hydrogen ion concentration as shown by the following equation:

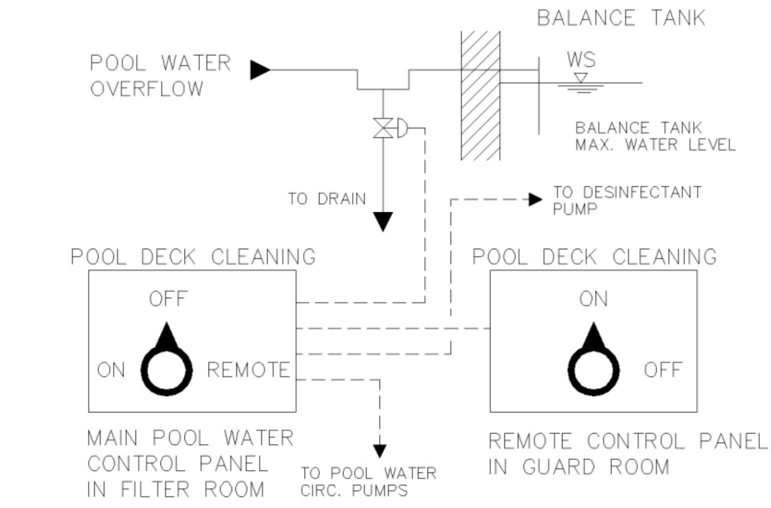
$$PH = \log [H+] = \log (1 / [H+])$$

Where,

[H +] = concentration of hydrogen ions [moles/liter]

FIG.5

RIM/GUTTER OVERFLOW CONTROL
DURING POOL DECK CLEANING



CONTROLLED COMPONENT	MANUAL SWITCH POSITION FOR DECK CLEANING AT MAIN CONTROL PANEL		
	ON	OFF	REMOTE
RIM CONTROL VALVE, PNEUMATIC	OPEN	CLOSED	CONTROLLED IN GUARD ROOM
DECK DESINFECTANT PUMP	OPEN	DISABLED	CONTROLLED IN GUARD ROOM
POOL WATER CIRC. PUMPS	OFF	ON	CONTROLLED IN GUARD ROOM

The pH-value is a significant factor for proper water quality and influences the following:

- The germ destruction rate (ORP)
- The effectiveness of the flocculation agent
- Calcification and corrosion in the system
- Reduction of combined chlorine

The normal pH-range should lie between pH-6.8 and 7.4. The ideal value is pH-7.2.

Careful attention of the pH-value is not only necessary for stabilization of the water hardness, but also to achieve optimal effectiveness of chlorine disinfectant.

The effectiveness of chlorine as a disinfectant in water is strongly dependent upon the pH-value of the water.
(See Figure 6)

- pH-6 With chlorine gas injection, resulting in 97 % hypochlorous acid (free chlorine, HOCl) and 3 % hypochlorite ion, which is less effective.
- pH-7 Results in only 78 % hypochlorous acid (HOCl).
- pH-8 Results in only 24 % hy pochlorous acid (HOCl).

Therefore, it can be seen that as the pH-value climbs, significantly greater quantities of chlorine are necessary to maintain proper chlorine residuals in the pool water.

If the pH-regulation system is not functioning properly high concentrations of acidic or soft water can be pumped into the pool. This can result in corrosion and cause cracking of the pool surface coat.

In addition, it is important to notice that acid vapor in the area of chemical injection equipment will cause immediate corrosion. Therefore, chemical rooms should be closed and ventilated.

1.7.3 pH-Value Regulation with Carbon Dioxide

Private hotel pools and sometimes thermal pools are well served by carbon dioxide (CO_2) for pH-regulation. Therefore, the solubility of CO_2 in water must be examined.

Hard water treatment systems with high circulation rates require higher consumption of CO_2. The injection must occur in regions of high water pressure.

Good injection points are immediately before or after the filter. The sizing and arrangement of the injectors is very important for an even distribution. The injection should be continuous and in small quantities. Carbon dioxide pH-regulation is very expensive for public pools. The advantage, however, is that chlorine concentrations in the pool water tend not to increase and remain more stable than with use of hydrochloric acid (HCl).

Highly loaded pools with hard water, for example, hot whirlpools or massage pools, which are treated with chlorine gas can maintain pH-values ~ 7 without the addition of muraitic acid (diluted hydrochloric acid). This is conditional, however, on the additional disinfectant required to maintain the desired residual hypochlorous acid concentration.

In this case, where pH-value measurements, with for example phyenol red, indicate falling pH-6.8, the fresh water intake will be increased or a marble tower will be built into the design.

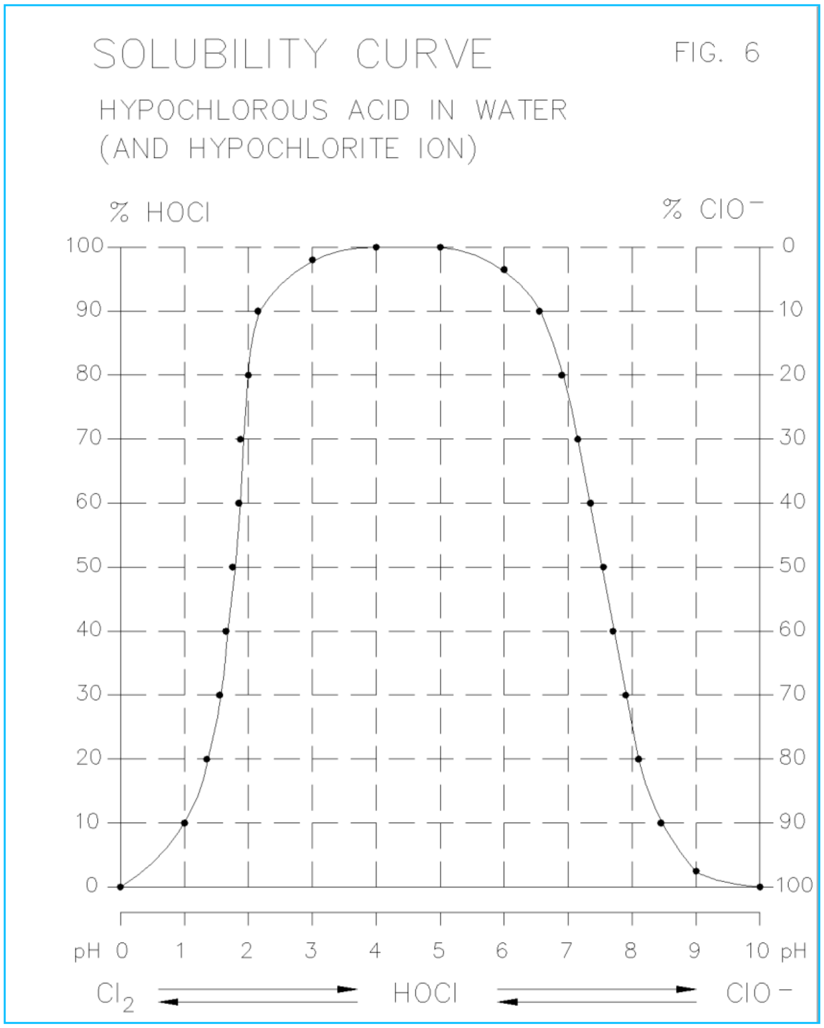
The acid consumption in hard water climbs faster with attractions like waterfalls and slides. This creates an unfavorable, higher concentration of acid in the balance tank. In addition, acid consumption increases through unnecessarily high temperatures at the surface of the heat exchanger.

1.7.4 Oxidation Potential

The concentration of reductant (organic impurities) in the pool water can be measured as the potassium permanganate ($KMnO_4$) consumption of the water tested. Permanganate ion (MnO_4-), a deep purple solution, is used to measure oxidation of these organic impurities which maintain a residual concentration in pool water. The permanganate solution is added to the sample and is reduced. When the sample turns purple the reductants have been oxidized and the permanganate consumption is measured. The following half reaction shows the reduction of permanganate ion:

$$MnO_4 - (aq) \Rightarrow Mn +_2 (aq)$$

Each bather brings a certain quantity of impurities into the pool water. This has been documented as 0.8-1.0g combined nitrogen compounds, measured as NH_4^+, which could be either from urine or sweat. It has also been shown that each bather brings approximately 50-70 ml of urine into the pool, and that a residual concentration of 0.5-1.0 mg/l (ppm) of urine can be found in pool water. The German Standard, DIN 19643 quantifies this amount to correspond to a potassium permanganate consumption of approximately 2-6 g $KMnO_4$.



The higher value is valid for pools with higher temperature and increased water movement, such as in hot whirlpools. The standard impurity concentration is formulated in the German, DIN 19643 as:

"The average amount of impurity brought into the pool by one person during the length of stay is characte-

rized by the reduction potential as measured with potassium permanganate consumption in grams of oxygen per person, where 1 g O_2 (≅ 4 g $KMnO_4$) is the basis."

The potassium permanganate consumption is measured at the pool water overflow rim/gutter and at the pool water return, basically before and after the sand filter. The difference in the KMnO4 consumption required to oxidize the reductant of water before and after the filter is used to calculate the specific loading capacity of the water treatment system, where each water treatment process has an associated specific loading capacity. This equation is shown below:

$$\Delta \text{Ox } V = E\,P \quad \textbf{(1)}$$

Where,

Δ Ox — Difference in the reduction of Mn VII → II from overload and return water [g/m3 (ppm)]

V — Treated water volume [m_3]

E — Standard impurity quantity [g]

P — Number of bathers

The specific loading capacity (loading factor), b-value, per person for a specific water treatment process can be obtained as follows:

$$b = \Delta \text{Ox} / E = P / V \ [1/m^3] \text{ or persons}/m^3] \quad \textbf{(2)}$$

where, the standard impurity quantity is,

$$1 \text{ g } O_2 \ (\cong 4 \text{ g } KMnO_4)$$

For example:

An existing pool water treatment system has a measured overflow water $KMnO_4$ consumption value, Δ Ox, ow = 6 g/m3 (ppm) and a return water consumption of, Δ Ox,Rw = 4 g/m3 (ppm). The loading capacity of the water treatment system is:

Δ Ox = Δ Ox,Ow - Δ Ox,Rw $KMnO_4$ [g/m3 (ppm)]
E = 4 g KMnO4

b = 2 g/m3 / 4 g
b = 0.5 1/m3

This specific loading capacity (loading factor) will be used in Section 4.0 of this text to determine the proper water circulation rate of the water treatment system.

The b-values for several water treatment processes have been determined empirically with the following results:

1. b = 0.5 1/m3
   flocculation + filtration + chlorination (3-step process).

2. b = 0.6 1/m3
   flocculation + filtration + ozonation + activated charcoal filtration + chlorination (5-step process).

3. b = 0.5 1/m3
   adsorption to activated charcoal powder + diatomaceous earth filtration w/ activated charcoal powder + chlorination.

In addition, it should be pointed out that the measured potassium permanganate consumption of the pool water return, Δ Ox, Rw, should not exceed a value greater than 3 g/m3 above the fresh water (potable water) supplied by the local water treatment plant.

1.7.5 Oxidation Reduction Potential

The oxidation reduction potential is the measurement of the germ killing velocity of the treated pool return water and is influenced by the pH-value, the free chlorine content, the fresh water intake as well as the concentration of reductant. The oxidation reduction potential is therefore a parameter for overall judgment of the water quality.

Correct values for good water quality with water treatment systems using chlorine as the disinfectant, measured with a mercury chloride (Hg_2Cl_2) electrode and a pH-range between 6.5-7.5 should be > 700 mV.

The oxidation reduction potential should not be used to control disinfectant injection, but should be measured and registered and serves as a confirmation of proper pool water quality.

1.7.6 Chlorination

When using chlorine gas it should be mixed into the pool water return using an injector located in the injector bypass piping, whereby in acidic and neutral pH-ranges hypochlorous acid is formed. When the pH-value is too high hypochlorous acid concentration remains low and hypochlorite ion, which is significantly less effective as a disinfectant, may dominate.

Injection of chlorine in water results in the disassociation of elemental chlorine into hydrochloric acid and hypochlorous acid as shown below:

$$Cl_2 + H_2O \Rightarrow + \ HCl + HOCl$$

Cl_2 = Chlorine
H_2O = Water
HCl = Hydrochloric Acid
HOCl = Hypochlorous Acid

or reaction in the presence of calcium bicarbonate into hypochlorous acid, calcium chloride and carbon dioxide as shown below:

$$2Cl_2 + Ca\,(HCO_3)_2 \Rightarrow 2HOCl + CaCl_2 + 2\,CO_2$$

$2Cl_2$ = Chlorine
$Ca\,(HCO_3)_2$ = Calcium Bicarbonate
2HOCl = Hypochlorous Acid
$CaCl_2$ = Calcium Chloride
2 CO_2 = Carbon Dioxide

When chlorine gas is used a full vacuum pressure regulator and venturi injector system is recommended. This ensures, that in the event of a chlorine gas line break, air will be drawn into the distribution line preventing chlorine from escaping. The regulator will automatically shut-off upon sensing relative overpressure.

The minimum residual concentration of active (free) chlorine in pool water for normal use pools should not fall below 0.3 mg/liter (ppm). This value is subject to locally adopted codes and regulations.

The germ killing velocity of chlorine as a disinfectant in water is very good, much faster than with bromine. The residual free chlorine concentration in pool water should be sufficient to kill 99.9% of E. Coli within 30 seconds.

Combined chlorine and the byproducts of breakpoint chlorination are oxidized products, and cannot be completely removed from the pool water. For this reason a constant supply of fresh water (fresh water intake) is recommended.

1.7.6.1 Free Chlorine

Hypochlorous acid (HOCl) or "free chlorine" is a very weak acid and dissociates quickly as pH rises above 6 as shown below:

$$HOCl \Leftrightarrow H^+ + OCl^-$$

HOCl = Hypochlorous Acid
H^+ = Hydrogen Ion

OCl^- = Hypochlorite Ion

Hypochlorous acid is a much stronger oxidant than hypochlorite ion and is the desired disinfectant in chlorinated swimming pool water. In order to optimize the disinfection effect in pool water a pH - 7.0 - 7.4 is recommended. (See Figure 6)

1.7.6.2 Combined Chlorine

Upon introduction of ammonia (NH_3) into the pool water from bather or ammonia laden make-up (fill) water, organic amines are formed through the following reactions:

$NH_3 + H_2O \Rightarrow NH_4OH$
NH_3 = Ammonia
H_2O = Water
NH_4OH = Ammonia Hydroxide

$NH_4OH + HOCl \Rightarrow NH_4OCl + H_2O$

NH_4OH = Ammonium Hydroxide
$HOCl$ = Hypochlorous Acid
NH_4OCl = Ammonium Hypochlorite
H_2O = Water

The ammonium hypochlorite is, as with most salts, a weak acid and disassociates into water and monochloramine.

$NH_4OCl \Rightarrow NH_2Cl + H_2O$

NH_4OCl = Ammonium Hypochlorite
NH_2Cl = Monochloramine
H_2O = Water

The hypochlorous acid (free chlorine) reacts with the unwanted monochloramine to create dichloramine.

$NH_2Cl + HOCl \Rightarrow NHCl_2 + H_2O$
NH_2Cl = Monochloramine
$HOCl$ = Hypochlorous Acid
$NHCl_2$ = Dichloramine
H_2O = Water

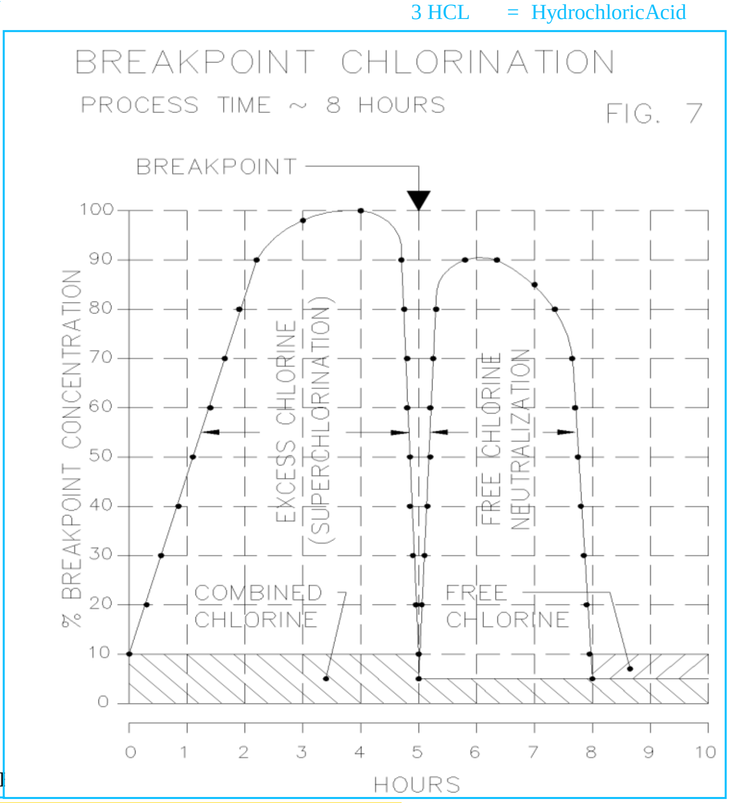
In swimming pool applications (pH - 7 to 8) monochloramine (96%) predominates over dichloramine (4%).

1.7.6.3 Breakpoint Chlorination

When the combined chlorine concentration in the pool water climbs above ~ 1.0 mg/liter (ppm) breakpoint chlorination is required to oxidize or "burn-up" the combined chlorine in the pool thus removing the chloramines. Breakpoint chlorination or "superchlorination" is performed by chlorinating the pool water to approximately 10 to 12 times the normally balanced residual free chlorine concentration. Destruction of combined chlorine, monochloramine and dichloramine, occurs rapidly between pH - 7 and 8 according to the following reactions:

$2\ NH_2Cl + HOCl \Rightarrow \uparrow N_2 + H_2O + 3\ HCL$
$2\ NH_2Cl$ = Monochloramine

$HOCl$ = Hypochlorous Acid
N_2 = Nitrogen
H_2O = Water
$3\ HCL$ = HydrochloricAcid



or

$NH_2Cl + NHCl_2 \Rightarrow \uparrow N_2 + 3\ HCl$

NH_2Cl = Monochloramine
$NHCl_2$ = Dichloramine
N_2 = Nitrogen
$3\ HCl$ = Hydrochloric Acid

Once breakpoint chlorination is achieved the free chlorine residual remains high and a chlorine neutralizer such as sodium bisulfate must be added to bring the residual free chlorine concentration back to an acceptable level for bathing. Care must be taken not to overcompensate during neutralization, which would reduce the free chlorine residual below the required safe limits. If this occurs pool water chlorination must be accelerated to bring the residual disinfectant concentration into compliance before bathers may enter the pool. (See Figure 7)

17.6.4 Fresh Water Intake

If the fresh water, provided by the local water authority, is of suitable quality then a constant supply of fresh water can be introduced into the pool to dilute the combined chlorine and byproducts of breakpoint chlorination. This will extend the period of time between which breakpoint chlorination is required. In addition, it will reduce the concentration of dissolved salts in the pool, renewing the water, and make swimming more comfortable for the bathers. Providing fresh water helps to maintain the pool water balance and to prevent the build-up of unwanted compounds as shown in the table below:

Component	Max. Concentration
Iron (Fe) Manganese (Mn) Ammonium (NH_4^+)	< 0.1 mg/l (ppm) < 0.05 mg/l (ppm) < 2.0 mg/l (ppm)

SALT	ORIGIN
• Chloride Ion Corrosion of metal above ~ 150 mg/l (ppm) Cl-	- All chlorine containing disinfectants - Iron-III Chloride, Aluminum Chloride and Aluminum HydroChloride fluoculant hydrochloric acid
• Sulfate Corrosion of concrete above ~ 150 mg/l SO_4^{2-}	- Aluminum-Sulfate (Floculant) - Sulfuric acid (pH-Regulation) - Sodium bisulfate
• Nitrate Health risks from 20 mg/l (ppm) above the NO_3- content of the freshwater	- Oxidized destruction of urine and other nitrogen containing impurities (ie. Ammonium)
• Calcium Cloudy water and scaling, calcification of the filter media above ~ 70 mg/l	- Dolomite filter material used for pH- stabilization - Leaching of mortar in tiled pools - Calcium hypochlorite disinfectant

Table 1.7.6.4.1 Enrichment of the Pool Water in Salts, their Origin and Potential for Damage

If the fresh water, provided by the local water authority, is not of suitable quality, as shown in the table below, then either one of or a combination of the following may be necessary:

1. Providing fresh water intake from an unpolluted on-site well. (Well water analysis required).

2. Pretreating the fresh water with an activated charcoal powder/high rate sand filtration system.

3. Continuously injecting activated charcoal powder into the pool water pumped discharge before the high rate sand filter to continually remove combined chlorine from the pool. (See Figure 8).

4. Providing a corona discharge ozonator in either the 5-step, complex ozone or combi-block process arrangements.

Table 1.7.6.4.2 Requirements of the Fresh (Fill) Water

1.7.6.5 Halomethanes

Carcinogenic compounds are formed by the reaction of chlorine and bromine in swimming pool water. These compounds, halomethanes, are created by reaction of the disinfectant with bromides and organic impurities brought into the pool by the pool guests. The recommended maximum exposure to halomethanes in pool water is 10 µg/liter (ppb). This value is taken from the "Deutsches Institut für Normung (DIN) 19643 Standard".

The common halomethanes are trichloromethane or "chlorform" ($CHCl_3$), bromodichloromethan ($CHBrCl_2$), dibromochloromethan ($CHClBr_2$) and tribromomethane or "bromoform" ($CHBr_3$).

The following table shows the potential build-up of chlorine and bromine containing haloforms in chlorinated water with varying concentrations of typical organic impurities (bromide and organics).

Table1.7.6.5 Halomethane Concentrations in Pool Water with 2-3 mg/liter (ppm) residual Cl_2

Organic Impurities µl/liter	$CHCl_3$ µl/liter	$CHBrCl_2$ µl/liter	$CHBr_2Cl$ µl/liter	$CHBr_3$ µl/liter	Total µl/liter
24[1]	0.6	0.1	1.5	2.4	4.6
48[2]	0.8	0.5	3.8	3.5	8.6
100[3]	1.3	1.2	6.3	7.7	16.5
200[3]	1.7	1.6	5.8	5.3	14.4

[1] Normal bather load with guest showers before entering pool.
[2] Normal bather load without guest showers before entering pool.
[3] Insufficient pool water circulation rate. (Does not meet DIN 19643 Standard).

Use of bromine instead of chlorine as the residual disinfectant increases halomethane concentrations in the pool water.

1.8 Removal of Impurities Found in Pool Water

The following types of impurities exist in pool water:

1. Suspended impurities (hard particles which are floating, such as hair, textile fibers, dead skin, etc.)

2. Dissolved colloidal impurities (secretions from the throat, nose, ears, fat from the skin, cosmetics, etc.)

3. Completely dissolved impurities (sweat and urine)

All of the aforementioned impurities are brought into the pool over the water surface. An intensive concentration of these impurities can be found in the uppermost 10-20 cm (4-8") of water depth. This is exactly where the bather is moving about with the most sensitive areas of the body, like the nose, ears and mouth.

In spite of proper treated water distribution and mixing and a large portion of the water lead to the overflow rim/gutter, denser particulate matter will sink to the bottom. This cannot be avoided.

Figure 9 shows the general distribution of impurities and particulate matter in cross section through a typical pool.

The problem exists and should be recognized and considered during the design of the treated water return outlet system.

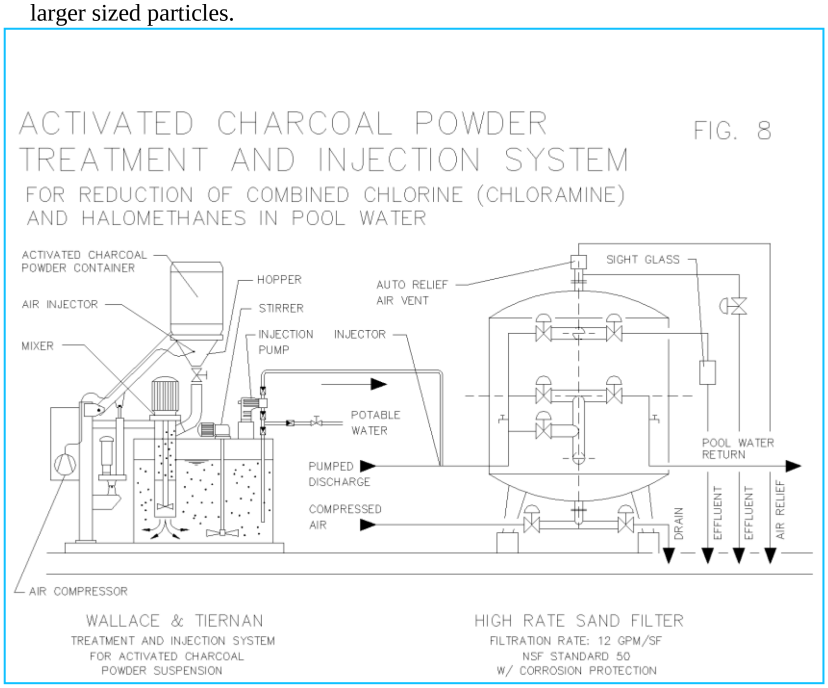
The pool water distribution system is an important component in the water treatment system. In order to disinfect the pool evenly and thoroughly either a vertical or horizontal distribution should be used. If proper mixing of the residual disinfectant is not achieved dead zones can develop reducing pool water quality and causing an increase in the disinfectant injection rate and therefore an increase in chemical consumption.

Removal of the aforementioned impurities is achieved in the following steps:

- Mechanical Filtration
- Flocculation and filtration
- Oxidation
- Dilution

1.8.1 Suspended Impurities

These hard, floating particles should be mechanically filtered on the basis of the strainer effect, electrostatic effect and the wedge effect. The mechanical effects of filtration are only effective for larger sized particles.



1.8.2 Dissolved Colloidal Particles

These dissolved colloidal impurities are negatively charged and repel one another. Flocculation allows these particles to coalesce by aligning the charged particles whereby the colloids tend to ball-up forming larger particles. This effect increases the average size of the particles, therefore increasing the filtration efficiency of the system.

These impurities can be effectively removed either by flocculation or adsorption on activated charcoal media.

1.8.3 Completely Dissolved Impurities

These completely dissolved organic impurities are primarily oxidized using chlorine or ozone. The oxidation process is incomplete in pool water which contains especially high concentrations of organic matter. A small portion of these impurities are removed with direct contact with other flocculating particles and are held in the filter media.

These impurities can be effectively removed after flocculation by activated charcoal powder.

A portion of these impurities and compounds are only able to be diluted with fresh water to the proper hygienic concentration.

The fresh water intake is dependent upon the pool guests' frequency of bathing and on the water treatment process used.

1.8.4 Special Conditions for Outdoor Pools

The impurities in outdoor pools are brought in partly due to the bathers and partly due to the atmosphere. The pool guests use the pool, unlike with indoor pools, without properly cleansing themselves before entering the water and usually more frequently. There will be a large quantity of sun cream, cosmetics, sweat and other impurities carried into the pool.
Additionally, in the absence of small walk-thru pools at the entrance to the pool deck organic impurities from the sun bathing areas will be carried into the pool.

Outdoor pools, contrary to indoor pools, will experience a very different number of bathers in relation to the number of fair and foul weather days. It is almost unavoidable to have an excessive number of bathers on beautiful days.

The surrounding area and the pool will also be dirtied from wind and storms. Special problems frequently arise from trees planted near the pools.

1.9 Heating

The heat exchanger used to heat the pool water should be manufactured from series 316 stainless steel or better and be easily cleanable. A plate frame heat exchanger is recommended.

In order to minimize carbonic acid offgassing, a low primary hot water temperature should be supplied. The pool water can be heated using a bypass configuration with a bypass pump. This reduces energy consumption as well as the size of the heat exchanger. With this arrangement care must be taken not to heat the pool water above 45°C (115°F).

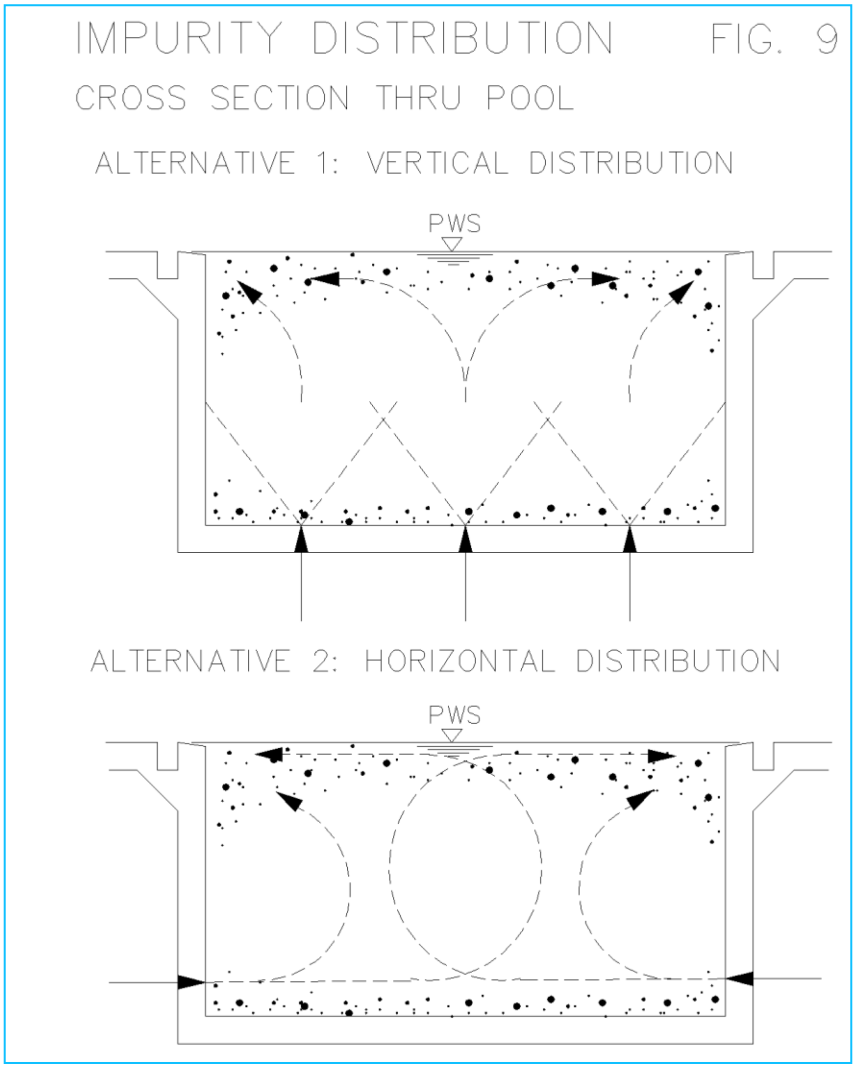
For example, sizing for a primary hot water temperature of 50/35°C

(120/95°F) with a pool water temperature of 27/32°C (80/90°F).

Lower primary water temperature requires greater heat exchange surface area, however, reduction of acid consumption required for neutralization
of the pool water leads to an improvement of pool water quality for the bathers.

1.10 Balance Tank

A balance tank is required for holding pool overflow water due to bather displacement and wave motion as well as backwash water. This tank requires the same hygienic conditions as the pool. That means, the tank should be tiled or surface coated, have a light and portal for inspection and have a proper means of entrance for cleaning.



A regular inspection and cleaning of the balance tank is necessary.

The entrance to the balance tank, whether it be manhole or submarine door, must prevent the escape of vapor into the technical/filter room to protect equipment against corrosion.

In addition, a vent is required to the outside.

The pool water overflow piping running back to the balance tank should be provided with an open tee connection as shown in Figure 10. This helps to reduce the acid concentration as well as scale build-up in the balance tank by allowing CO_2 to off-gas by the reaction of hydrochloric acid with calcium carbonate and calcium bicarbonate in the pool water overflow piping.

1.11 Water Distribution in Hidden Spaces

Pool water return outlets under mechanical floors, submerged pool covers, etc. are required to eliminate build-up of debris. It is usual to open the valves to these outlets during night setback mode for an hour to wash out these hidden spaces.

2. Water Treatment System

As mentioned in the introduction to this paper, the entire water treatment system is made up of the following components:

- Pool Hydraulics
- Treatment System (with flocculation, filtration, and oxidation)
- Disinfection

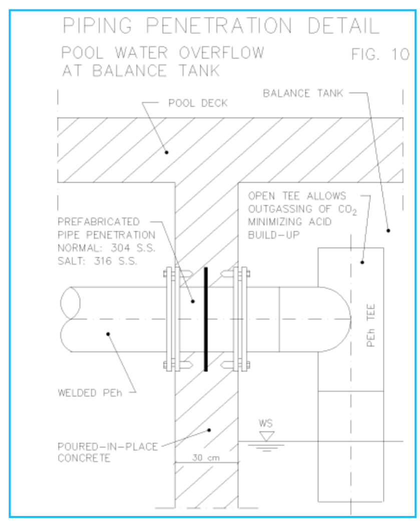
When designing a pool water treatment system these three components must be thought of collectively in order to affect a well integrated and properly working system.

2.1 Water Treatment

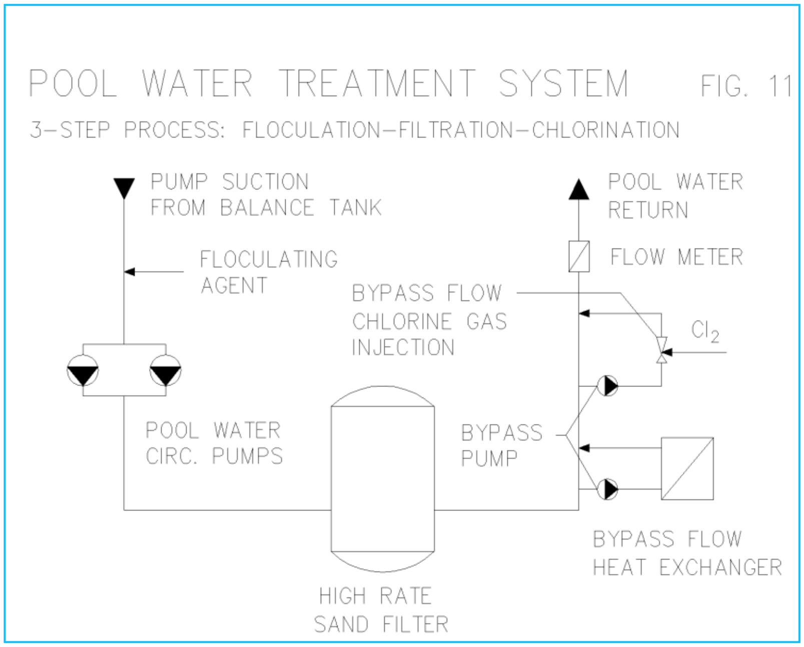
Modern outdoor pools and lightly loaded indoor pools are usually well served by the 3-step water treatment process: Flocculation-Sand Filtration-Chlorination. The specific loading capacity (loading factor) of this process is, b=0.5 1/m3. (See Figure 11)

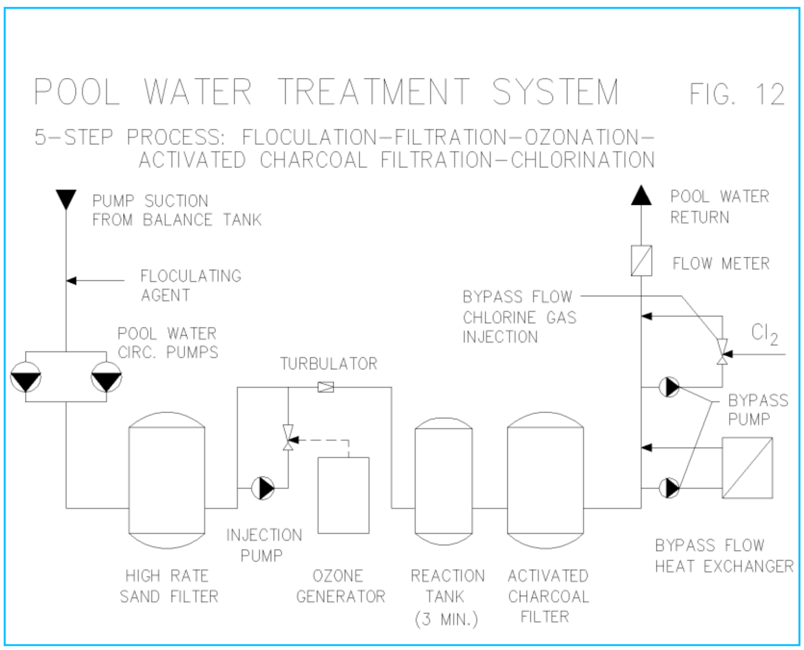
Highly loaded indoor pools, warm pools, hot whirlpools and therapy pools require the 5-step water treatment process: Flocculation-Sand Filtration-ozonation-activated Charcoal Filtration-Chlorination. The loading factor for this process is, b=0.6 1/m3. (See Figure 12)

The 5-step (Incl. Ozone) system may also be suitable for indoor training and competition pools in order to maintain good water quality, because of continual high loading of the pool water throughout the day. This system offers better control and reduces the required flow of fresh water entering the pool.



Three reliable ozone pool water treatment processes are the 5-step, Complex Ozone and Combi-Block arrangements. These systems can be essential in eliminating "Hyper-Sensitivity Pneumonitis" a bronchial disorder caused by breathing aerosols containing endotoxins (dead micro-organisms). This condition can occur in indoor swimming pools when the water temperatures are greater than 86°F or if the pool has





built-in attractions which agitate the water.

Committing to one of the water treatment processes is one of the significant responsibilities of the consulting engineer. The influential factors to consider are:

- Indoor swimming pool
- Outdoor swimming pool
- Bather frequency
- Pool water temperature and use
- Potable water quality
- Potable water and waste water cost
- Operating costs
- Safety related items
- First Cost
- etc.

2.2 Disinfection

Classic disinfection and oxidation is achieved using pressurized chlorine gas. Chlorine gas is usually delivered in 65 kg (150 lb) steel bottles.

The disinfection process may require chlorine gas or hydrochloric acid delivery and storage which should be considered in the planning and design phase of any project.

The chlorine gas injection system is arranged with a bypass flow of pool water pumped across a low flow, high pressure pump. The water flows through a venture injector creating a vacuum on the connected chlorine gas distribution piping (flexible hose). The chlorine is drawn into the venturi and is mixed with the pool bypass water. The chlorine gas immediately disassociates into hypochlorous acid and hypochlorite ion. The relative concentrations are dependent upon the pH-value of the water.

In addition, hydrochloric acid is present, which is usually ideal for water with average to high carbonate hardness, and serves to maintaining the pH-value.

5-step systems use ozone for the oxidation process and chlorine as the residual disinfectant.

Chlorine gas distribution technology has improved and allows engineers to design a full vacuum system. This type of system significantly improves the level of safety associated with chlorine gas distribution. These systems also provide automatic switching from an empty to a full bottle while the system is in operation.

The danger of such systems is greatly reduced, and hangs solely on the chlorine gas bottle and valve itself. The weak points are the shut-off valve and the valve seal on the bottle. Of course, the pressure reducing valve and housing of the vacuum regulator must be manufactured to handle the high pressure of full gas bottles.

The following chlorine products can be used as alternatives to chlorine gas:

Sodium hypochlorite:

- Delivered as a liquid

- Contains ~ 150-170 g/liter (570-645 g/gal) active chlorine
- Strong alkaline solution, pH-10 to 11.

Advantage

- Well suited with soft water
- Simpler and less dangerous to handle than Chlorine gas

Disadvantage

- Active chlorine concentration decays ~ 1 % per day or 3.8 g/gal day (be aware when storing for long periods)

Sodium hypochlorite by electrolysis:

- Manufactured on site through electrolytic reaction with sodium chloride (NaCl, cooking salt) solution
- Resulting solution contains ~ 2-5 g/liter (8-20 g/gal) active chlorine
- 3-4 kg (6.6-8.8 lb) of sodium chloride and 5-6 kWh of electricity are required to manufacture 1 kg (2.2 lb) of sodium hypochlorite

Advantage

- Only NaCl (cooking salt) is required which can be easily stored and handled
- Same as with delivered sodium hypochlorite for soft water applications

Disadvantage

- Sodium hypochlorite solution generated by the reaction of chlorine gas and hydroxyl ions in water must be stored in a large distribution tank
- Problematic with hard water, increased HCl consumption
- Chlorine gas detectors and alarm system required

Chlorine gas by electrolysis with hydrochloric acid solution:

- Manufactured on site through electrolytic reaction with hydrochloric acid (HCl)
- Electrolysis products are chlorine gas and hydrogen
- 3.3 kg (12.5 gal) of 33 % hydrochloric acid and 2-2.5 kWh of electricity are required to manufacture 1 kg (2.2 lb) of chlorine gas

Advantage

- Produces the same effect as chlorine gas
- Eliminates chlorine gas bottle storage, safer operation.
- Chlorine gas is directly dissolved into the pool water return.
- Hydrochloric acid for both electrolysis and pH-neutralization can be stored in one large acid storage tank.

Disadvantage

- Chlorine detectors and alarm system required.

Bromo-chloro-dimethyl-hydantion (BCDMH)

- Delivered as solid
- Contains both bromine and chlorine
- Strong acid, pH-4

Advantage

- Active hypobromous acid concentration remains stable over fluctuations in pH. At pH - 7.2: 96% active bromine concentration vs 66% active chlorine.
- Indoor/outdoor pools/spas can be switched over from bromine to chlorine for outdoor season.

Disadvantage

- Cost 2 to 3 times higher than with chlorine.
- Disinfection slower (slower germ killing velocity) than chlorine, therefore required residual concentrations twice as high as with chlorine. Residual HOBr = 2 - 4 ppm.
- Bromine cannot be stabilized in outdoor pools/spas against UV degradation.
- Bromine pools must be breakpoint chlorinated more often than with chlorine to eliminate algae growth and organic contaminants.
- Halomethane concentration in pool water higher with bromine as compared to chlorine.

3. Pool Water Distribution and Overflow Rim/Gutter Arrangement

The best water treatment systems are of little use when the pool water distribution system functions unsatisfactorily. A perfect water distribution system will provide an even distribution of the treated water within 5-8 minutes. In addition to proper pool water return distribution, an even, simultaneous overflow at the pool surface water is also necessary. In order to achieve optimal surface water quality with lower impurity concentrations, modern pools are provided with and balanced for 100 % pool water overflow at the overflow rim/gutter.

Existing pools under consideration for renovation should be provided with 100 % pool water overflow systems whenever possible.

Figures 2 and 9 show how the pool water return distribution and overflow rim/gutter can be renovated to provide a better cleaning effect at the pool water surface. The pool water return is delivered through low-lying nozzles located on the pool walls (horizontal distribution) with 100 % of the surface water flowing over the rim/gutter and into the collection channel. The collected pool water is then channeled directly back to the balance tank. Reusing existing floor outlets is also possible when dye tests indicate acceptable distribution and mixing.

4. Sizing the Water Treatment System

The calculation of the water circulation capacity of a public swimming pool is of significant importance for good water quality.

In the United States the water flow rate through a pool is based on turnover rate, which is the number of hours to circulate the pool water volume one time. This method does not account for higher impurity concentrations at the pool water surface, bather frequency or the specific loading capacity of the water treatment process. Two frequently used public pool water treatment standards are the National Spa and Pool Institute (NSPI) and the American Public Health Association (APHA) standards. The required pool water circulation rates are shown below:

- NSPI = Turnover of 8 [1 volume/8 hours]
- APHA = Turnover of 6 [1 volume/6 hours]

The German, Swiss and Austrian, as well as many other northern European pool water quality standards, incorporate bather loading and pool water surface area and the water treatment process into the calculation.

The calculation for sizing the water circulation rate in accordance with the German Standard DIN 19643 is as follows:

$$V = A \times n / a \times b \quad [m3/h]$$

where,

V = water flow rate of the treated water (pool water return) [m^3/h]

A = water surface area of the pool [m^2]

a = water surface area per person [m^2]

n = specific bather frequency per person [1/h]

b = specific loading capacity per person [$1/m^3$]

The appropriate values for "n" and "a" according to the DIN standard are shown below:

Type of Pool	Pool Depth [m]	Specific Bather Frequency n [1/h]	Specific Loading Capacity a [$1/m^2$]
Diver Pool	≥ 3.40 (≥11.0 ft)	1	4.5 (48 sf)
Swimmer Pool	> 1.35 (> 4.5 ft)	1	4.5 (48 sf)
Non-Swimmer Pool	0.6 to 1.35 (2 to 4.5 ft)	1	2.7 (30 sf)
Wading Pool	**** V = 2 turnovers/h **** (Turnover = 0.5)		

Since, $b = P/V$ [$1/m^3$]

as given previously by equation (1), then if a water treatment process is used with b=0.5, each person should have 2.0 m^3 (530 gal) of treated water volume available in which to bathe. (P = 1 person).

There are, however, special cases, which require closer consideration:

- Wading/ Children's attraction pools
- Warm massage/attraction pools
- Water sides
- Thermal/Mineral pools
- Hot Whirlpools

5. Improvement of the Water Quality

Even if no complaints about pool water hygiene are made, improvements can be made to increase bather comfort. An improvement of the water treatment is frequently found when the fresh water intake can be reduced. Inadequate water quality can be the result of problems with the system due to higher bather loads than the system is able to handle. These problems exist, for example, when the following has occurred:

- Subsequent construction on site
- Construction of additional attractions
- Increase of the water temperature setpoint.

- Pools which are not designed for high bather loads and must be adjusted later to meet the latest operational requirements. For example, with hot whirlpools and massage pools or childrens' areas.

The following parameters indicate a need for improvement of the pool water treatment system:

- Burning sensation in the eyes
- Higher concentration of combined chlorine
- Higher portion of the oxidizing chemicals, which is measured as the potassium permanganate ($KMnO_4$) consumption, over 3 mg/liter (ppm)

- Urine (NH_3) concentration, over 1 mg/liter (ppm)

Under such conditions a remedy is to control the total chemical treatment system and to adjust the entire water balance. The procedure in such cases is represented by the following check list:

<u>Check List for the Procedure for Optimizing the Water Treatment</u>

1. Analysis of the Existing Conditions

- Determination of the load
- Fresh water consumption
- Measured water circulation capacity
- Necessary circulation capacity
- $KMnO_4$ consumption before and after the sand filter
- Evaluation of the chemical and bacteriological analysis

2. Causes of Improper Operation (things to look for)

- Proper operation of the pressurized sand filter
- Swimming filter, change filter media, injection correction, change activated charcoal
- Test the injection
- Observe the operation
- Analyze the operation procedure

3. Operation Manual for Optimization of the Existing System

- Correcting the established defect
- Optimization of system operation
- Repeated measurements

4. System Completion

- System completion: Planning for additional installations

5. Commissioning

- Testing for improved water quality with reductions in fresh water supply
- Development of a carefully planned inspection table for detailed analysis of the entire system

It is necessary to consider, after the detailed analysis of the improvements to the water treatment system, whether the water circulation rate should be increases or whether it is meaningful to develop a more intensive treatment process.

The graph shown in Figure 13 shows and example of this problem. (See figure 13)

The curve shows the concentration of dirt in the rim/gutter overflow water as a function of the pool water circulation rate. The dashed lines represent possible water conditions in the pool, once with a lower circulation rate of 33 m^3/h (145 gpm) and once with a higher rate of 100 m^3/h (440 gpm). The dashed parallel lines represent shifts in water quality using a more intensive water treatment process. It is generally true that greater improvements in water quality can be achieved by providing higher pool water circulation rates, than with the costlier methods associated with improving the water treatment process.

The results of this graph can be recorded and verified by measuring the concentration of oxidant in pool water is indicated and measured by the consumption of potassium permanganate ($KMnO_4$) across the water treatment system.

When the circulation rate is increased additional filters are usually necessary. Improvements to the water treatment system capacity can be achieved by addition of activated charcoal filters. The activated charcoal acts as a separation between oxidation and disinfection. Where the treatment system can be arranged for disinfection with chlorine or with the ozone/chlorine process.

A further advantage of the installation of activated charcoal filters exists by the reduction of chloroform byproduct. The Federal Health Office in Berlin, Germany has studied the use of activated charcoal powder injection before the sand filter for use in hot whirlpool applications with very favorable results.

Further possibilities for the improvement of water treatment processes exist by installation of equipment to reduce the concentration of combined chlorine either by innovative use of activated charcoal or by UV-radiation.

Examples of Insufficient Water Quality

- The temperature of the wading/children's attraction pool has been raised. Additional attractions were built, whereby loading at the filters substantially increased and is overloading the water treatment system.

Corrective measures:

- Daily backwash
- Change Floculant and/or increase injection rate
- Increase fresh water intake
- Addition or improvement of a foot wash pool
- Raise chlorine concentration from 0.3 mg/l (ppm) to 0.5 mg/l (ppm) (Subject to local code)

6. Optimization of Energy Savings

A frequent goal of most renovation and improvement projects for water treatment systems is reduction of operating costs.

6.1 Pool Water Heating

Outdoor pools can be heated with sun absorbers. The required absorber surface is approximately 50% of the pool water surface area. If a solar absorber is not possible, because of limited free area for construction, then a heat pump should be recommended. Heating outdoor pools with oil or gas is usually no longer considered.

Indoor pools can be heated by the heat of rejection from a dehumidification heat pump in the ventilation unit, the waste heat from considering boiler exhaust gas or by geothermal heat pump systems.

6.2 Heat Recovery

The heat recovery from the constant pool water effluent offset by the fresh water intake can be economically recovered in indoor swimming pools. The efficiency of the heat exchanger process using a shell and tube or plate frame heat exchanger is between 85 and 90%. This process uses no additional electric energy for the heat transfer between the warm effluent and cool fresh water.

The fresh water can be heated up to between 2 and 4°F of the pool water temperature reducing the fresh water intake heating load considerably.

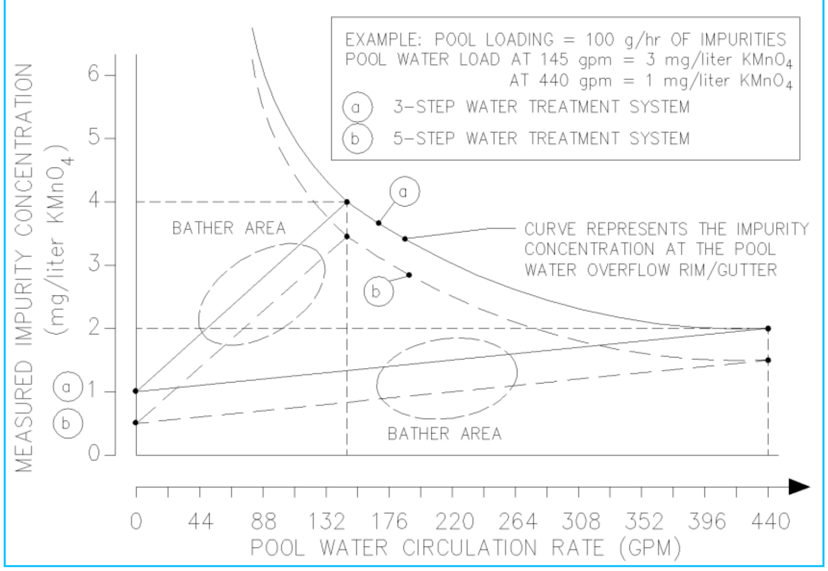
The plate frame heat exchanger usually has a simple payback period of 2 years.

In addition a waste water heat recovery unit, incorporating both recuperative heat exchange as well as heat pump technology, can be installed. These systems are self-cleaning and usually pay for themselves within 6 years.

6.3 Electrical Energy

During night setback operation main circulating pumps can be switched-off saving energy. Therefore, it is recommended to equip each water treatment system with a minimum of two circulating pumps, whereby reduction of the water flow rate is possible. Leaving one of two pumps piped in parallel in operation provides approximately 70% of the circulation capacity
while saving 75% of the unoccupied

POOL WATER TREATMENT EFFICIENCY FIG. 13



mode pumping energy. (Applicability is dependent on the resulting pool water quality, however, is usually not a problem).

In indoor swimming pools with long operating hours the under water lighting system can have a significant influence on the electrical energy and operating costs. A 25-meter, 8 lane pool could have a $5,000 per year difference in operating cost by lighting the pool during the day. (Electricity cost, lamp replacement cost and labor costs). It is always recommended to provide adequate daylighting and reduce the operating time of the underwater lighting system.

Adequate lighting during the day is necessary to improve pool use safety.

6.4 Fresh Water Consumption

The fresh water consumption in a swimming pool is dependent upon the number of visitors to the facility. In indoor swimming pools the entrance counter sales are the measure of the number of visitors and can also be used to adjust the fresh water intake.
In outdoor pools the entrance counter sales are not as reliable because the visitors come and go as they please over the course of the day. A good value to use is twice the number of counter sales. The best method for estimating the number of visitors and therefore, balancing the fresh water intake, is by counting them from time to time throughout the day.

In wading/children's attraction areas the fresh water intake should be calculated using a bather frequency of 2, that is each child uses the pool twice each hour. For example, with an average of 25 children in the area during the day a specific bather frequency of 50 children per hour is used. Then if the children's area is open for 8 hours per day, 400 bathers are used for the fresh water intake calculations. Accordingly the minimum recommended fresh water intake is 400 x 30 l/P = 12 m^3/Day = 0.5 m^3/h (~ 2 gpm).

Normally the fresh water intake for each pool will be divided during initial balancing of the system according to the filter capacity (main pool water circulation rate). This works because the water circulation rate for each pool connected on one filter system has been sized for the expected loading at that particular pool.

During operation variations in water quality between pools on the same filter (water treatment) system may be detected, and at this time a correction of the fresh water distribution to be different pools is necessary.

6.5 Automatic Control and Regulations

Modern public swimming pools are equipped with direct digital control (DDC) systems. The house energy management system (EMS) is usually capable of controlling and managing operation schedules for many building components in addition to the pool water treatment systems. These components, whether mechanical or electrical, are initially balanced and programmed during system start-up (commissioning).

It is important to adjust all automatically controlled equipment for economical optimization of operation. Water treatment systems can be adjusted to minimize electrical energy consumption of electricity driven motors as well as by limiting backwash schedules through time valuing by programming proper operational schedules.

Other water treatment equipment have integral stand-alone controls and must be adjusted individually, such as pH-neutralization and disinfection set-points. These components can only be optimized to minimize chemical usage if accurate log sheets are maintained by operating personnel which can be used by engineers and technicians to understand how the systems are being operated. Log sheets can be obtained by contacting B2E Consulting Engineers, Leesburg, VA.

7. Final Remarks

It has been shown that to improve the water treatment process an examination of all of the appending components and their combined effects is necessary. Experience shows that the following list recognizes problems which occur in many installations:

Examples of Common Problems:

- Automatic pool water balance regulation system test probe water removal near the floor or from main drain piping.
- Automatic pool water balance regulation system test probe water removal position next to a massage jet.
- Automatic pool water balance regulation system test probe water removed from an unloaded area of the pool.
- Regulation ineffective because the chlorine injection system capacity is undersized.
- Fresh water intake and disinfectant injection improperly calculated.
- Back pressure in the filter backwash drain which inhibits an even backwash across the filter media.
- Undersized backwash fluidization air compressor which is unable to generate proper fluidization of the filter media.
- Filter short-circuiting from clogged and calcified filter media (sand filter).
- Increased acid consumption from various causes, such as increased evaporation at water attractions or high heat exchanger surface temperatures.
- Germ growth in the activated charcoal, primarily due to low chlorination in the backwash water.

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