PUBLIC SWIMMING POOL OPERATOR'S HANDBOOK

9th Edition February 2014

Florida Department of Health in Sarasota County
1001 Sarasota Center Boulevard
Sarasota, FL 34240
941-861-6675

This handbook is designed to help protect the health, safety, and welfare of the people that use public swimming pools in the State of Florida. We hope that by helping you, the operator of public swimming pools, we can work in partnership to provide a healthy, safe, and enjoyable experience to the people that live in and visit the State of Florida.

TABLE OF CONTENTS

Chapter Titles

APPENDICES

CHAPTER 1:

FLORIDA ADMINISTRATIVE CODE AND OPERATOR RESPONSIBILITY

Chapter 64E-9, Florida Administrative Code, governs the operation of public pools in the State of Florida. The code covers design, construction, and operation of public swimming pools. A good working knowledge of the operational aspects of the code is important to pool operators and owners. Copies 64E-9 FAC can be obtained at you local health department or on the Department of Health (DOH) website at www.doh.state.fl.us.

Operating Standards

It is the responsibility of the operator and management of each pool to make sure that the standards specified in the code are met. Any violations should be corrected promptly.

Water quality

Water quality begins with the water that is used to fill the pool. Therefore, the water that is hooked up to the pool must be an approved potable system. Potable water systems include municipal utilities or wells. If your pool is on a well, it must be certified as potable and regulated by your local health department. In order to prevent contamination of the water source by water of questionable quality (i.e. pool water), a method of backflow prevention must be in place such as a physical air gap in the autofill device and vacuum breakers on all hose bibbs.

Water clarity must be such that the main drain grate is readily visible from the pool deck. Proper filtration and disinfection of the water accomplishes this.

Proper chemistry must be maintained in pools at all times. Chapters 3 and 4 will go into more detail, but for now, know that the code specifies the following chemical parameters:

- **Free active chlorine:** 1-10 parts per million (ppm) in pools, 2-10 ppm in spas (ppm may also read as milligram per liter or mg/L)
- **Free active bromine:** 1.5 - 10 ppm in pools, 3 - 10 ppm in spas
- **pH:** 7.2-7.8
- **Cyanuric Acid:** 100 ppm maximum in pools, 40 ppm maximum in spas
- **Quaternary ammonium:** 5 ppm maximum
- **Copper:** 1 ppm maximum

- **Silver:** 0.1 ppm maximum

A test kit must be kept on site. This kit must be capable of testing for free chlorine or bromine using N,N-Diethyl-p-phenylenediamine (DPD), pH, total alkalinity, and calcium hardness. Furthermore, if any of the following are used in pool maintenance, the test kit must be capable of testing for cyanuric acid, sodium chloride, quaternary ammonium, silver ions, copper ions or salt.

Pool area

The pool and pool deck should be kept clean and inviting in appearance. This means that there should be no floating debris, dirt, or algae. Make sure that food, drink, or glass containers are not in the pool or deck area.

Safety

Pools are required to have certain minimum safety equipment. This includes a safety hook on a 16-foot, one-piece pole and a life ring with sufficient rope attached to reach any point in the pool from any point on the pool deck. **Note:** pools greater than 50 ft in length must have two sets, with one mounted along *each* of the longer sides of the pool. Pools with a slope break must have a 2-inch wide tile band running along the bottom and sides of the pool at the slope break and a safety line mounted two feet before the tile band, towards the shallow end by recessed anchors. Further safety issues include insuring that handrails and ladders, gutter grates, main drain grates, and any other piece of equipment is functioning, properly mounted, and in good repair.

If lifeguards or instructors are present at the pool, they must be certified in lifeguarding or instruction, and in CPR by a national aquatic training agency. Proof of this certification must be on site and available upon demand.

Signage Requirements

Pool and spa rules must be posted and visible from all portions of the pool deck. Letters on each sign must be a minimum of 1 inch high, and contain the following:

- No food, drink, glass or animals in pool or on pool deck.
- Bathing load: _____ persons.
- Pool hours: _____ a.m. to _____ p.m.
- Shower before entering.
- Pools with heaters must post a maximum water temperature of 104°F.
- Pools without approved diving bowls must also post "NO DIVING" in *four-inch* high letters.
- Do not drink the pool water, it is recirculated.

Spas, in addition to the above requirements must also post the following:

- Maximum water temperature 104°F.
- Children under twelve must have adult supervision.
- Pregnant women, small children, people with health problems and people using alcohol, narcotics or other drugs that cause drowsiness should not use spa pools without first consulting a doctor.
- Maximum use 15 minutes.

A spa that is equipped with a shut-off switch and alarm must have additional signage. A sign that is visible from the spa must read “ALARM INDICATES SPA PUMPS OFF. DO NOT USE SPA WHEN ALARM SOUNDS UNTIL ADVISED OTHERWISE”.

A professional engineer must certify the lighting at pools that are to be used for night swimming. The following requirements must be met:

- Outdoor pools must have a minimum of 3 foot candles of illumination at the water's surface and on the deck. Underwater lights must be a minimum of one-half watt per square foot of pool surface area.
- Indoor pools must have a minimum of 10 foot candles at the water's surface and deck. Underwater lights must be a minimum of eight-tenths watt per square foot of pool surface area.

If in doubt that your lighting is adequate to meet these standards, we recommend that you post hours from *dawn* to *dusk*.

Equipment area

It is the operator's responsibility to make sure that each pool that he or she maintains is getting proper flow, that chemical feeding equipment is in use and functioning properly, and that all other equipment is in good repair.

The equipment room itself must be properly ventilated (forced or cross ventilation), with adequate drainage. Lighting must be a minimum of 30 foot candles at floor level. In addition, the equipment room must be kept relatively clean and clutter free.

Liability

The following material is intended only as an introduction and overview. It is not intended to substitute for your legal council.

Responsibility for the operation of a public swimming pool falls upon owners, managers, lifeguards, and operators to ensure that the pool is healthy, safe and sanitary for pool patrons. In practical terms, this means that you are bound to use reasonable care to ensure the health and safety of the people using the pool.

It is recommended for each pool to have at least one "Pool Closed" sign on site and for management or maintenance to post the pool closed in the event of a problem. First, closing the pool protects patrons by warning them of an unsafe condition. Second, it protects the owners and operators from future fines and lawsuits resulting from patron claims of sickness or injury.

Furthermore, operators and owners should obtain proper liability insurance to protect themselves in the event of accident or injury to a bather.

Record Keeping

In addition to being a code requirement, it only makes good sense that each pool keep a daily log (Appendix B) on site. This log should reflect water testing at least once every 24 hours. The reason behind the requirement for record keeping is two-fold:

1. Keeping a close watch on the pool operation and chemistry is the best way to make sure the pool is operating correctly and safely.
2. Keeping accurate records will help owners and/or operators face a claim of sickness or injury from a pool patron.

Another recommended record to have on site is a pool data sheet (Appendix B). In addition to information on the pool, such as volume, size, and equipment, it will allow a new pool operator to quickly pick up some quirks of the pool in the event the current operator leaves.

We recommend that both the operator and management keep copies of all records. The time that each record should be kept varies with the type of record. Some of the National Swimming Pool Foundation recommendations for the storage of records can be found in Table 1

Table 1-1: Record-Keeping Timetable

Record	**Time**
Accident Reports	
Minor	3 years
Major	5 years
Chemical Test Records	3 years
Chemical Costs	3 years
Complaint Records	3 years
Legal Correspondence	Permanently

National Operator Certifications

The code requires that some pool operators be certified by a longer, more in-depth course (CPO, AFO, or equivalent) than offered by Sarasota County. It should be of not less than 16 hours in length, and taught by an organization acceptable to the department. Contact information can be found in Appendix C.

Individuals meeting the following criteria are exempt from the *national* certification requirement but are *not* exempt from the county certification requirement:

- Certified pool contractor
- Owner of a public swimming pool

Even if you do qualify for the national certification exemption, we highly recommend the 16-hour courses. The information and training is excellent, detailed, and is very worthwhile to an operator. A list of Pool certification course approved by the Department of Health can be found on page 104 and on the DOH website at www.doh.state.fl.us.

Note: Only a licensed pool contractor can do repairs, renovations and equipment installations. A certified pool operator is only qualified to clean and treat the pool water and equipment.

Renovations and Modifications

Any modifications to a pool, its recirculation equipment, or its disinfection equipment must be approved in writing by your local health department. Approval may require review of plans submitted by a professional engineer. Replacing old equipment with an equivalent device, or resurfacing a swimming pool are not considered modifications.

If you are planning to resurface a public swimming pool, the County Health Department must be notified in writing prior to starting the resurfacing project. Some local municipalities also require a permit. Call your local health department for more information.

Health Department Responsibility

The Florida Department of Health and its local health departments are mandated to protect the health, safety and welfare of persons using public swimming pools. To do this, they conduct periodic inspections of the operation and maintenance of these pools. Health inspectors are authorized to post a swimming pool closed if *any* of the following conditions are met:

1. The disinfectant level (chlorine or bromine) is below minimum or above the maximum required levels.
2. The pH of the water is not between 7.2 and 7.8.

3. The water is cloudy, and the main drain grate is not visible from the deck.
4. The recirculation or disinfection system is missing or not functioning.
5. The main drain grate is damaged or unsecured.
6. Any condition which endangers the health, safety, or welfare of the persons using the pool.

Most health inspectors hope that your pool never has to be closed. Maintaining it in the manner prescribed in this manual will help keep your pool safe and open.

Remember that your health department can be a tremendous asset as well. If you

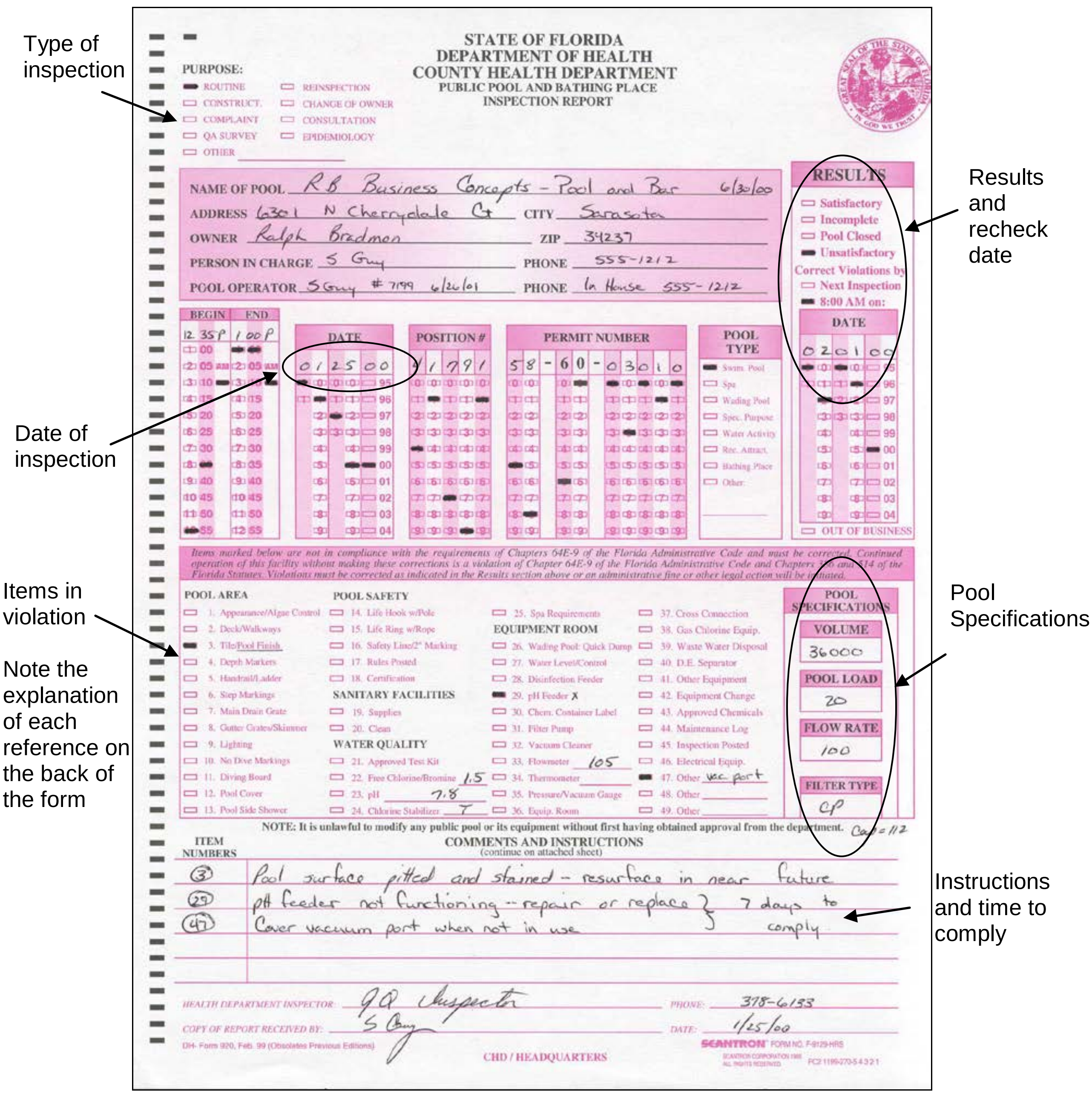


Figure 1-1: State of Florida swimming pool inspection form

have any questions regarding operational standards, the Florida Administrative Code, or physical characteristics of your pool, do not hesitate to call your local health department. They will be happy to help you as best as they can.

Inspections

Health officials are required to inspect every public pool and spa at least once every six months. Some counties may inspect more frequently, depending upon local policies and ordinances.

When a pool or spa is inspected, a copy of the report (Fig. 1-1) will be made available to the pool agent, either in person or sent by mail. It is the agent's responsibility to ensure that the operator has a copy of the report.

We have found that some operators and/or agents read only the comments and instructions section of the report. However, there is much more information there. Figure 1-1 highlights some of the important points. Another useful feature of this form is that the yellow copy received by the agent has a short explanation of each violation on the back of the page. These explanations are intended to help you understand why any violations may be marked on the inspection form. The answers to many common questions can be found there. However, if you still have questions or concerns, do not hesitate to call your local health department.

CHAPTER 2:

DISEASE AND ACCIDENT PREVENTION

Would you use a stranger's dirty bathwater? Well, sharing the use of a swimming pool, spa or wading pool with other people is a form of communal bathing and, without proper maintenance, these pools can become a serious public health threat. Swimmers exposed to contaminated water can become infected with highly contagious, and sometimes lethal, diseases.

Waterborne Disease Transmission

Disease-causing organisms, known as *pathogens*, invade pool and spa water by means of carriers, such as swimmers and local wildlife. Some pathogens are ubiquitous, living naturally in the soil and water in our environment. These pathogens thrive in the warm, moist environment of a poorly maintained pool or spa where they may grow, multiply and gain access to the bodies of unsuspecting swimmers. The type and severity of pool-related waterborne disease depends on type of pathogens present in the water, the part of the body exposed to the contaminated water and the overall health of the person using the pool. Skin eyes and ears of swimmers are vulnerable to bacterial and fungal infections, inhaling steam or water droplets can result in severe lung infections and swallowing small amounts of water result in gastrointestinal or liver disease. Many of these diseases are so contagious that infected swimmers can spread the illness to family members, coworkers and friends through contact even if the swimmer had little or no signs of illness.

Pathogens

There are four major groups of pathogenic organisms associated with pools and spas. These include *bacteria, parasites, viruses,* and *fungi*. Many of these organisms come from the bather's body, carried by the sweat, oils, dirt, and tiny amounts of fecal matter found on the average clean and healthy person. Pathogens may also be transmitted to swimmers by animals. Ducks, snakes, raccoons, and rats are just a few of the frequent poolside visitors. The animals themselves may be completely unaffected

Table 2-1: Bacterial Pathogens Associated with Pool and Spa use

Pathogen	General Disease Description	Occurrence and Comments
Salmonella typhimurium	Mild to severe gastroenteritis (bloody diarrhea, vomiting, dehydration, fever). Individuals may become lifelong carriers	Very common worldwide in man and animals (especially reptiles and birds)
Shigella dysenteriae	Severe gastroenteritis. Can be life-threatening in children and elderly. (Dysentery)	Common in tropical and sub-tropical climates.
***Escherichia coli* O157:H7**	E.coli produces a deadly toxin causing mild to severe gastroenteritis with a risk of kidney failure and death.	More common worldwide as a foodborne, rather than a waterborne disease
Pasturella tularensis	Causes high fever, skin ulcers, pneumonia lasting 3-5 weeks. May be fatal. (Tularemia)	Occurs in man and animals worldwide (especially rabbits), rare in USA.
Vibrio cholerae	Vibrio bacteria produce deadly toxin causing severe life-threatening gastroenteritis. (Cholera)	Very common worldwide. Associated with contaminated water supplies.
Leptospira interrogans	Transmitted by water contaminated with infected animal urine. May cause flu-like infection, gastroenteritis, and kidney failure.	Rats are most common carriers in USA. Bacteria may enter body directly through skin or lungs.
Pseudomonas aeruginosa	A hearty and resistant bacteria that may cause mild to severe skin, ear, eye and urinary tract infections or pneumonia.	Very common worldwide Associated with poorly maintained commercial spas.
Streptococcus* and *Staphylococcus	These pathogens may cause mild to severe skin, ear, eye, urinary tract or respiratory tract infections.	Very common worldwide. Associated with poorly maintained commercial spas.
Legionella pneumophilia	A severe, rapidly progressive and life-threatening pneumonia caused by inhaling steam from contaminated spas. (Legionnaire's disease)	Occurs worldwide. Legionella is a heat-loving pathogen that may thrive in the heater systems of spas.

by the diseases they transfer to pool water through their feces and urine.

Bacteria

Proper chlorine levels effectively eliminate most bacteria in a short period of time. However, certain strains are more chlorine resistant than others and require a higher concentration and longer contact time to be killed.

In a poorly managed pool or spa, bacteria not only thrive but are able to multiply rapidly, doubling their population as often as every 20 minutes. During a routine swim or spa soak these disease-causing bacteria have ready access to many regions of the swimmers body. Due to the nature of spa usage, the most common spa-related diseases are bacterial infections of the skin, bladder, eyes, and respiratory tract. Pool-related bacterial infections, on the other hand, are relatively uncommon and have a tendency to affect the intestinal tract due to the swallowing of contaminated pool water. Table 2-1 lists the some of the bacterial pathogens isolated from commercial pools and spas.

Parasites

Many are surprised to learn that intestinal parasites are *the* most common cause of pool associated disease outbreaks in the USA. Each year thousands of swimmers are infected by tiny single-celled parasites known as protozoa. These

Table 2-2: Common Parasites Associated with Swimming Pools

Pathogen	General Disease Description	Occurrence and Comments
Cryptosporidium parvum	A highly contagious and resistant protozoa causing severe watery diarrhea and vomiting. May be life-threatening in some individuals.	The infective stage (oocyst) is shed by man and animal carriers and can remain in the environment for 6 months.
Giardia lamblia	A protozoa that causes severe vomiting, diarrhea and cramping for 4-6 weeks. Asymptomatic carriers are common.	The most common cause of waterborne disease. Up to 4% of Americans are carriers of Giardia at any given time.
Entamoeba hystolytica	A protozoa that causes severe gastroenteritis (Amoebic dysentery), and may also spread to the liver, lungs, and skin.	Infected people may become carriers of this parasite.

organisms are so small that 10,000 of them can easily fit through a pinhole.

In general, parasites are tough and resourceful. They go through very complex lifecycles and their infective stage is designed to survive a long time outside a host. Some species are highly resistant to halogen disinfection and therefore proper filtration is essential in removing them from a contaminated swimming pool environment.

Unlike bacteria, intestinal parasites cannot multiply in the environment, but they are so highly infectious that it may take fewer than 10 organisms to cause disease. Once they enter a swimmer's mouth, protozoa use the intestinal tract as a breeding ground and an infected person will shed millions of parasite offspring for weeks or even months after they have recovered from the illness. Some individuals may never experience the actual illness, but are still highly contagious carriers of the disease. Table 2-2 contains some of the most common parasites associated with pool use.

Viruses

Most viruses are fragile, easy killed, and cannot survive for long periods of time outside a host. A few examples of the more common viral disease outbreaks in public pools include *Adenovirus*, *Enterovirus*, and *Hepatitis A* . Although not serious, Adenovirus is responsible for sinus infections, or "head colds," in swimmers exposed to contaminated water. *Enterovirus* infects the digestive tract, causing mild to moderate "stomach flu" symptoms. *Hepatitis A*, on the other hand, is a potentially serious liver infection that may occur as late as 60 days after exposure to the virus. Compared to other viruses, *Hepatitis A* is relatively chlorine resistant, and reported outbreaks have been directly attributed to heavy bathing loads and low Free Active Chlorine.

Fungi

Fungi are plant-like organisms that include molds and yeasts. Most fungal infections are more commonly associated with wet and dirty surfaces around the pool, rather than in the pool itself. Standing water on the deck is ideal for harboring fungi like *Microsporum* and *Tricophyton*. These agents cause ringworm or athlete's foot when the unsuspecting swimmer's skin comes into contact with the contaminated surface. Although fungal skin infections can be uncomfortable and

Table 2-3:
Examples of reported outbreaks traced back to commercial pools and spas

State	Pathogen	Number of Cases	Setting
Minnesota	*Pseudomonas*	10	Hotel spa
Florida	*Cryptosporidium*	22	Community pool
Florida	*Giardia*	77	Community pool
Georgia	*E. coli*	18	Mobile home park pool
Georgia	*Cryptosporidium*	5,449	Water park pool
California	*Cryptosporidium*	3000	Park pool
New Mexico	*Pseudomonas*	4	Apartment complex spa
Minnesota	*Pseudomonas*	6	Hotel spa
Maine	*Pseudomonas*	10	Hotel spa
Washington	*Pseudomonas*	2	Resort spa
Idaho	*Salmonella*	3	Park pool
Washington	*Pseudomonas*	5	Health club spa
Kansas	*Cryptosporidium*	24	Park pool
Nebraska	*Cryptosporidium*	14	Water park pool
Virginia	*Legionella*	23	Spa display in store
Washington	*Pseudomonas*	17	Motel spa

Data from Center for Disease Control *Morbidity and Mortality Weekly Report*

disfiguring, they are rarely a major health threat. Fungal disease transmission can be easily prevented with routine cleaning of the pool deck and furniture.

Outbreaks

Pool and spa related disease outbreaks are rarely reported by the media, therefore a pool operator may be unaware of the risks and liabilities associated with inferior pool maintenance. The incidence reports may be obtained through the Center for Disease Control (CDC), the World Health Organization (WHO), and the Environmental Protection Agency (EPA). Table 2-3 contains a sampling of reported outbreaks published by the CDC from a single year.

Reported outbreaks of pool and spa related diseases are on the increase. This is due to several factors, including more highly resistant and hardy strains of organisms and an increase in pool/spa popularity. The actual number of disease outbreaks are under-reported due to varying incubation periods. The time from exposure to the actual onset of disease in an infected swimmer can range from 2 days to 2 months, depending on the organism. This alone makes it difficult to trace a disease to a specific source with absolute certainty. Consequently, the reported cases may only be a very small percentage of what actually occurs. In the cases where disease outbreaks were traced back to commercial pools and spas, ***poor pool maintenance was the most common cause.*** Therefore, proper maintenance of pools protects the pool operator and the pool patrons.

The risk of disease transmission can be minimized through proper pool maintenance practices, including:

- Balancing <u>all</u> chemical parameters to optimize disinfection
- Maintaining flow to assure 4 volume turnovers a day
- Keeping filters clean and in good repair
- Maintaining all equipment (gauges, flowmeter, pumps, etc.)

- Keeping decks and furniture free of dirt, algae, bird and other animal droppings.
- Draining and freshening spas routinely

Fecal, Blood or Vomit Accidents

The majority of pool related diseases are transmitted via fecal contamination of water. When a human or animal fecal accident has been reported or observed it is important to take the immediate action.

At the end of this chapter, three publications from the Center for Disease Control are provided to guide the pool operator in the management of fecal, blood or vomit contamination of pools. Please refer to *Responding to Fecal Accidents in Disinfected Swimming Venues*, *Vomit and Blood Contamination of Pool Water,* and *Cleaning Up Body Fluid Spills on Pool Surfaces***.**

Because there is a greater risk of disease transmission when dealing with a diarrhea fecal accident, it is recommended you contact the local Health Department and request a bacterial culture of the pool water before reopening the pool.

Safety

When injuries to swimmers or employees occur as a result of ignorance or neglect by another, pool owners and operators may be held responsible. The key to accident prevention is diligence. Those in charge must be fully aware of what constitutes a potential hazard.

Accidents

Pool related casualties fall into three general categories:

1. Drownings cause approximately 350 deaths per year in the state of Florida and are the number one cause of accidental death in Florida children under the age of five. Nationwide, drownings rank 7th among all injury-related causes of death.
2. Diving accidents are responsible for serious, and often fatal, head and spinal cord injuries. Coma, partial, or complete paralysis is typical of diving-related injuries and often result in multi-million dollar lawsuits against the pool owners.
3. Contact accidents occur as a result of neglected surfaces and equipment. Falls due to algae-slick decks or poor lighting, and cuts from broken tiles are just a few of the numerous circumstances that can lead to serious injury. Care must be taken to protect swimmers from potential lacerations, abrasions, contusions, sprains, or fractures.

Accident Prevention

The following recommendations and requirements should be included in routine safety inspections of a pool, spa, and surrounding deck:

Safety Equipment

Check throwrope on liferings for evidence of wear and dry rot. Slope break safety lines must be properly mounted across the pool at all times. Life hooks must be attached to the sixteen-foot pole securely with nuts and bolts. All safety equipment must be clearly visible and accessible. Pictorial instructions regarding safety equipment use are recommended.

Rules Signs

Pool and spa rules must be legible from the pool and pool deck. Replace faded or damaged signs promptly. Make sure all information on the sign is complete and up to date. If your pool is not approved for diving then "NO DIVING" must be posted in 4-inch high letters. Contact your local health department for information on the specific rules that are required to be posted.

Lighting

Underwater lights must be intact and functional. If light fixtures are filled with water, broken, or detached from the wall, repair them immediately. Bathroom and pump room lights must be functional at all times. If the pool is approved for night swimming, check the deck area lighting for burned out or broken bulbs.

Deck Area

Keep deck free of clutter, dirt, algae, and standing water. Deck furniture, blanket rollers, etc. are trip hazards and must be at least 4 feet from the pool edge at all times. All horizontal surfaces must be slip resistant. Cracked, sunken, or uneven areas of the deck due to settling must be corrected.

Sharp Surfaces

Broken tile is as dangerous as broken glass. Repair or replace fractured perimeter tiles, depth marker tiles, and bathroom tiles. Protective rubber caps on ladder feet must be intact in order to prevent "cookie-cutter" injuries from exposed, sharp metal surfaces. Repair all chips and cracks in decks. The sharp concrete borders are a threat to bare feet of swimmers. All grates in rollout gutters and all return covers must be intact to prevent cuts and punctures to fingers and toes.

Entrapment Hazards

Main drain grates must be fully intact. Broken grate ribs can easily ensnare hair, fingers, or toes when a swimmer comes into contact with the grate and result in tragedy. The ladder must rest securely against pool wall. A child can easily squeeze behind a sprung ladder and become trapped. All vacuum ports must be covered. If a vacuum line is left on and the port is uncovered, the power of the suction will tenaciously seize any body part that draws near. The pool should never be vacuumed while swimmers are in it, as they may become entangled in the hose equipment. If a floating blanket is used on the pool or spa, the pool and deck area must be posted closed and made inaccessible to the public by means of a locked gate or door.

Chemical Hazards

Close the pool for routine maintenance to prevent swimmer exposure to high chemical concentrations not yet mixed throughout the water. Be sure all chemicals are locked away and are completely inaccessible to the public. Chemical feeder pumps must be electrically interlocked with the recirculation pump(s) to prevent dangerous accumulations of concentrated chemicals in the recirculation system when pumps are off. Chlorine and acid crocks must be clearly labeled on both the sides and the lids to avoid dangerous chemical mixing.

Spa Hazards

Carefully monitor spa temperature. A thermometer must be installed in the return line of all heated pools and spas. Water temperatures must be no greater than 104°F. It is recommended that a lock on heater temperature controls is installed and an additional thermometer is provided in the spa itself. It is also recommended that spa jets be on timers with a 15-minute maximum setting.

General Recommendations

Install a fence or screened enclosure around the pool. This is not required by law unless a floating blanket is used, but is strongly recommended. A pool fence must be at least 42 inches in height, with a maximum of 4-inch spacing between slats. Gates and doors should be self-latching.

Install "No Diving" markers around the pool every 25 feet. If a pool is new or due for resurfacing, it is required by law. However, it is recommended for all pools.

Provide additional depth markers in metric measurement for pools that have international clientele. If this is not feasible, then provide a metric conversion sign that is visible from the pool itself.

Operator Safety

In addition to keeping the pool patrons safe, we want pool operators to enjoy a safe work environment. Operators come into contact with many different hazards and they need to do what they can to lessen the risk:

1. **Keep a tidy equipment room.** Flooded areas near electrical equipment, poor lighting, damaged or corroded electrical outlets, unmarked chemical containers, and the presence of snakes and rats are all a danger to maintenance personnel.
2. **Report unsafe conditions to the pool manager *in writing* for immediate repair.** Keep a copy for your own records to protect yourself and your pool patrons.
3. **Work with your health department.** We are happy to answer questions or concerns or meet you at the pool for a consultation.

5. Wash hands after handling dirty filters or D.E. There is a high concentration of parasites, bacteria, and fungi on used filter media.

4. Respect your chemicals.

- Follow all instructions on the labels carefully.
- Always add chemicals to water, *never* add water to chemicals. Heat, splashing, and / or gas release may occur.
- Keep wet hands and dirty scoops out of your chemicals.
- *Never* mix two chemicals together, gas release or explosion may occur
- Minimize the number of different chemicals you store.
- Keep chemicals in their original containers and replace the covers tightly after use.
- Store all chemicals in a cool, dry place and keep them away from electrical equipment and heat.
- Wear eye protection while working with concentrated chemicals and wash your hands after handling.
- Label all chemical containers.

Pool owners and operators are legally responsible for the health, safety, and welfare of pool patrons and employees. The risk of injuries associated with pool activities can be significantly reduced with a routine safety surveillance program. It is recommended that those responsible for the pool conduct a systematic weekly inspection using a quick reference checklist. A routine safety check may take only minutes to accomplish and the benefits serve pool patrons, operators and owners alike.

CHAPTER 3:

WATER CHEMISTRY

Water chemistry is the most important factor in the operation of your swimming pool. Proper chemistry is critical in maintaining the health and comfort of pool patrons. Furthermore, the chemistry of the water is important in prolonging the life of equipment and surfaces.

Chlorine Chemistry

As people use the pool, they bring with them their (aun of which you want in the water with you. Bacteria such as *Escheri* d *Pseudomonas aeruginosa*, among others, can thrive in an improperly treated pool or spa. To keep that from happening, halogen disinfectants (chlorine or bromine) must be added.

Hypochlorous Acid Hypochlorite Ion Hydrogen Ion

Chlorine is the most common disinfectant used in swimming pools. It is relatively inexpensive and very effective against most bacteria and parasites. Furthermore, chlorine is a good oxidizer, which means that it will destroy oils and
other organic compounds that tend to make your water look cloudy. There are many different forms in which chlorine can be added to pool water, but they all behave the same way:

Warning! Warning! Chemical formula ahead: do not panic!

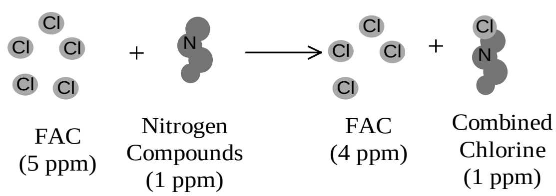
$\leftrightarrow$ $HOCl$ OCl^- + H^+

Chlorine in water exists as hypochlorous acid (HOCl) and the hypochlorite ion (OCl^-). Hypochlorous acid is the active form of chlorine and takes care of the majority of nasty critters in the pool water. However, depending upon the pH, a certain percentage is found as the hypochlorite ion, which is not as effective a sanitizer. So remember, not *all* of the chlorine that you measure in your pool is doing work. We'll discuss pH and its effects on chlorine a bit later.

Groups of chlorine compounds

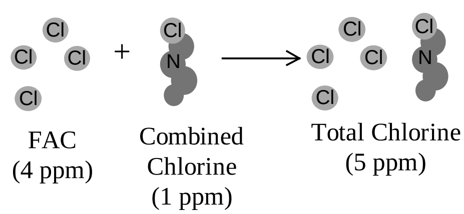
Together, hypochlorous acid and the hypochlorite ion form what is called Free Active Chlorine (FAC). This is what your trusty DPD test kit measures when you check the water in your pool. In public pools, FAC is regulated by local and state health department codes. In Florida it is required to be between 1 and 10 ppm in pools and 2 and 10 ppm in spas.

There is another group of chlorine compounds that we also need to concern ourselves with. This group is called Combined Chlorine (CAC) or chloramines. Combined chlorine forms when certain nitrogen containing organic chemicals, such as urine or sweat, attach to free active chlorine.

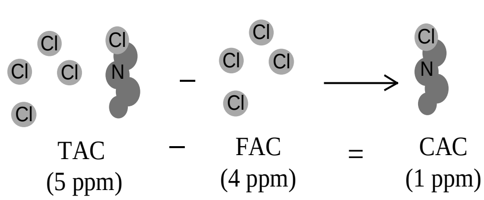


Put simply, combined chlorine is very, very bad in your pool. As a disinfectant, combined chlorine is very slow. Furthermore, it is often the culprit when pool patrons complain about "chlorine smell" and eye irritation. Needless to say, you want as few combined chlorine compounds in your pool as possible. The National Spa and Pool Institute (NSPI) recommends no more than 0.5 ppm.

There is a slight difficulty here. A standard test kit can not directly measure combined chlorine. Therefore, it must be tested for indirectly. Fortunately, in addition to free chlorine, your test kit can determine the total amount of chlorine in the pool, free and combined, i.e., the Total Chlorine (TAC).



Simply measure the total chlorine and the free chlorine concentrations. Subtract the free from the total, and the result is the combined chlorine concentration.



Getting rid of combined chlorine

Now that you've figured out that you've got a combined chlorine problem, the question arises as what to do about it. The chemical bonds that hold the chlorine to the nitrogen compounds are tough. The only way to take care of combined chlorines is to chemically tear them apart in a process called oxidation.

Fortunately for you, pool operator, you have a ready supply of chemical "tearing up" cocktail on hand--chlorine. Chlorine is a very good oxidizer as well as sanitizer. If you put enough in the pool, it will break up the nitrogen compounds into forms that will not combine with your chlorine. The process of adding chlorine to the pool in order to oxidize combined chlorine is called "Breakpoint Chlorination." Breakpoint chlorination means adding 10 times the amount of chlorine to the pool as you have combined chlorine.

Example:

Consider an average size pool of 25,000 gallons. The free active chlorine is 4 ppm and the total chlorine is 5 ppm. This should tell you that you have a combined chlorine problem, as follows:

TAC - FAC = CAC
5 ppm - 4 ppm = 1 ppm

1. In order to completely oxidize the combined chlorines, we need to add an additional 10 ppm of *new* chlorine to the pool.
2. Now, look at table 3-1. Note that it only tells you how much chlorine to add to a pool to get ***1 ppm*** of new chlorine. Any result will need to be multiplied by ten.
3. Also note that there is no column for a 25,000 gallon pool. But there *is* a column for a 20,000 gallon and a 5,000 gallon pool. So, add the amounts from these columns together to equal 25,000 gallons.
4. Determine the percentage of available chlorine that you're using (found on the label). For now, assume you're using liquid chlorine, which is usually 12% available chlorine by volume (the rest is just water and other odds and ends).

Table 3-1. Amount of chlorine compound to introduce 1 ppm of FAC

% Available Chlorine	Volume of water (gallons) 250	400	1000	5000	20000	50000	100000
5	3.90 tsp	2.00 tbsp	2.60 oz	1.60 cp	3.20 pt	4.00 qt	2.00 gal
10	1.90 tsp	1.00 tbsp	1.30 oz	0.80 cp	1.60 pt	2.00 qt	1.00 gal
12	1.60 tsp	0.83 tbsp	1.10 oz	0.67 cp	1.33 pt	1.67 qt	0.83 gal
35	0.088 oz	0.15 oz	0.38 oz	1.91 oz	7.62 oz	1.19 lb	2.38 lb
60	0.056 oz	0.088 oz	0.22 oz	1.11 oz	4.40 oz	11.10 oz	1.39 lb
65	0.052 oz	0.082 oz	0.21 oz	1.03 oz	4.12 oz	10.30 oz	1.29 lb
90	0.037 oz	0.059 oz	0.15 oz	0.74 oz	3.00 oz	7.40 oz	14.8 oz
100	0.033 oz	0.053 oz	0.13 oz	0.67 oz	2.67 oz	6.67 oz	13.3 oz

Table reproduced from Taylor Complete Pool Test Kit manual

5. Now go down the first column to the box that says 12%. Follow the row across to the 5,000 gallon column. The value in that box is 0.67 cup. Continue following the 12% row across to the 20,000 gallon column (1.33 pints.) Add them together (1 pint = 2 cups, so 0.67 cup = 0.335 pt):

   0.335 pt + 1.33 pt = 1.665 pt

6. So, add around 1.66 pints of liquid chlorine to our pool to add ***1 ppm*** of new chlorine. But remember we wanted to add ***10 ppm*** of chlorine to the pool. So multiply your result by 10 as follows:

   1.66 pt x 10 = 16.6 pt = **2.08 gal**

Result: Add a little over 2 gallons of liquid chlorine to the pool to get rid of the nasty combined chlorines.

Non-chlorine oxidizers

There are other products on the market that can oxidize combined chlorines. Mostly potassium monopersulfate, these products are becoming more and more popular. Be aware that these products are not sanitizers. At best, they can be used as "chlorine enhancers." Once again, if you are going to use one of these products, be sure to read and follow the directions on the label.

Instant Review (or what you need to remember about chlorine chemistry)

- Free active chlorine (FAC) is responsible for disinfection of pool water.
- FAC is required to be between 1 and 10 ppm for pools and 2 and 10 ppm for spas.
- Combined chlorines (CAC) are poor disinfectants. They smell bad and cause eye irritation.

- Determine combined chlorines by subtracting the free chlorine concentration from the total chlorine concentration. (TAC - FAC = CAC)
- Get rid of combined chlorines by breakpoint chlorination: adding 10 times the amount of "new" chlorine to the pool as you have combined chlorine.

Table 3-2. pH effect on hypochlorous acid

pH	% HOCl
4.0	100
7.0	75
7.5	48
8.0	22
11.0	0.003

pH

pH is a measure of how acidic a solution is. The pH of the pool water is nearly as important as the chlorine concentration. Letting the pH of your pool water get out of balance can have negative effects on several aspects of your pool.

First of all, pH is another common cause of eye and nose irritation for bathers. The eye and nose have a pH of between 7.4 and 7.6. Bather comfort requires that the pH of the pool be maintained in the same range, and it is the primary reason why the pH of a public swimming pool is required to be between 7.2 and 7.8.

As we mentioned before, the sanitizing effect of chlorine is very dependent upon pH. As the pH ***increases***, the amount of chlorine in the hypochlorous acid form ***decreases*** (Table 3-2). Maintaining sufficient chlorine activity is the second reason why the pH is regulated by your local health department.

The third reason why you want to keep the pH of your pool between 7.2 and 7.8 regards the longevity of the pool surfaces and equipment. Low pH will cause pitting of pool surfaces and corrosion of metal equipment. High pH causes staining of pool surfaces and deposits scale on equipment, which can render it useless.

To understand more about what pH is and what it means, we need to understand a little about acid/base chemistry. Let's look at a strong acid like muriatic acid (hydrochloric acid). In solid form, muriatic acid is a hydrogen ion loosely bound to a chloride ion. However, when you put it in water, the hydrogen ion comes off of the chloride ion:

$$HCl \longrightarrow H^+ + Cl^-$$

Muriatic Acid — Hydrogen Ion — Chloride Ion

The loose hydrogen ion is what makes an acid. In other words, ***an acid is a chemical that donates a hydrogen ion to the surrounding water***.

Now that we understand what an acid is, let's look at a strong base, like the hydroxide ion (the active ingredient in lye). When it is in a solution that contains hydrogen ions, it will attach itself to them, taking them out of circulation and lowering the acidity.

$$OH^- + H^+ \longrightarrow H_2O$$

Hydroxide Ion — Hydrogen Ion — Water

The affinity for H^+ is what makes a base. In other words, ***a base is a chemical that removes hydrogen ions from the surrounding water.***

Now on to what this all has to do with pH. The acidity of water *could* be measured by the concentration of hydrogen ions. Chemists would use the term moles of H^+ per Liter. (I am *not* making this up: 1 mole = 602,000,000,000,000,000,000,000.) However, this would get real complicated and real messy.

There is a simpler way, though. If you take the hydrogen ion concentration in a solution and apply a mathematical slight of hand called the negative logarithm, you get a nice, easy to deal with number called pH (Table 3-3).

One thing that you should notice about table 3-3 is that as the hydrogen ion concentration increases, the pH is smaller and vice versa. In other words, ***a low pH is acidic*** and a ***high pH is basic (or alkaline). A pH of 7 is neutral.***

Table 3-3: H^+ concentration and its relationship to pH

H^+ conc. (moles / L)	pH	
0.01 (1×10^{-2})	2	Stomach Acid
0.001 (1×10^{-3})	3	Vinegar
0.0000001 (1×10^{-7})	7	Pure Water
0.0000000251 (2.51×10^{-8}) 0.0000000398 (3.98×10^{-8})	7.4 7.6	Bodily fluids
0.000000000001 (1×10^{-12})	12	Ammonia

There's another thing that you should notice about table 3-3. Take a look at vinegar (pH 3) and stomach acid (pH 2). The hydrogen ion concentration in stomach acid is ten times that of vinegar, and yet the difference in pH is only one. Further, if you look at the difference between pH 3 and pH 7, you'll find that the difference in H^+ concentration is not 4, but 10,000 times. In other words, the pH scale is a logarithmic scale. It measures in multiples of ten. In other words, a small change in pH may actually mean a *big* change in acidity.

Controlling pH

Most common forms of sanitizer added to pools have an effect on the pH. To counter these effects, automated feeders are required on most pools to feed a pH adjustment solution. Whether to use an acid or a base depends on the type of disinfectant. For instance, sodium hypochlorite (liquid chlorine) is very basic, with a pH of about 13. To maintain the pH within the required range of 7.2 to 7.8 acid needs to be added to the pool.

On occasion, you will find that you need to adjust the pH manually, because of a faulty feeder or when shocking the pool. If the pH is too low (below 7.0 or too acidic), then you need to add base. If the pH is too high (above 7.0 or too basic), add acid. It's that simple. Sodium carbonate (soda ash) is typically used to raise the pH. Muriatic acid or sodium bisulfate (dry acid) is used to lower the pH.

To determine the amount of acid or base that you need to add to reach the desired pH, see chapter 4 for instructions and an example.

Instant Review (or, what you need to know about pH)

- pH needs to be maintained between 7.2 and 7.8
- pH is important for bather comfort, chlorine potency, and longevity of equipment and surfaces
- Low pH is acidic
- High pH is basic (or alkaline)
- pH is a logarithmic scale
- If the pH is too low, add base
- If the pH is too high, add acid

<u>Sanitizers</u>

Chlorine Gas (Cl_2)

Chlorine gas is greenish in color and is heavier than air. It has 100% available strength and is the cheapest form to buy. However, it is *extremely dangerous* and can be lethal if an operator is exposed to the gas. The safe use of chlorine gas requires at minimum: 1) storage indoors in a fire-resistant building, 2) separate room with a vent fan capable of complete air exchange in 1 to 4 minutes, 3) chains or straps to secure chlorine tanks at all times, and 4) a self contained breathing apparatus or gas mask easily visible and accessible in a separate room.

Chlorine gas is very acidic, with a pH of less than 1 due to the formation of hydrochloric acid (HCl) when injected into water:

$$Cl_2 + H_2O \longrightarrow HOCl + HCl$$

Chlorine Gas, Water, Hypochlorous Acid, Hydrochloric Acid

In order to neutralize the acid, a base (typically a solution of soda ash in water) must be added to the pool using an automated feeder system.

Sodium Hypochlorite (NaOCl)

Sodium hypochlorite is a clear, slightly yellow liquid solution. In dilute form, it can be bought as common household bleach. In a commercial form, it provides 12 to 15% available chlorine. It's one of the cheapest forms of chlorine on the market, and is easy and relatively safe to use. Typically, it is fed into the pool water using a peristaltic type pump, but it can be added directly for shock treatment or breakpoint chlorination.

Sodium hypochlorite has a very short shelf life. It should be bought in no more than a two-week supply.

Sodium hydroxide (NaOH) is formed when this form is added to water, so the pH is very high (approx. 13).

$$NaOCl + H_2O \longrightarrow HOCl + NaOH$$

Sodium Hypochlorite, Water, Hypochlorous Acid, Sodium Hydroxide

Acid should be added to the pool to neutralize the increased pH. A dilute muriatic acid solution is typically used.

Calcium Hypochlorite ($Ca(OCl)_2$)

Calcium hypochlorite is found in a solid granular or tablet form. By dry weight, it provides 65% available chlorine and remains stable over long periods. It is also easy to use and inexpensive.

The granular form is typically added to the pool by dissolving in water and feeding through a pump; and it is often kept around for use in shock treatment. The tablet form is fed through an erosion type chlorinator. (*NOTE*: **DO NOT** USE CALCIUM HYPOCHLORITE TABLETS IN THE SAME FEEDER THAT STABILIZED CHLORINE TABLETS HAVE BEEN USED IN. FIRE OR EXPLOSION CAN RESULT)

When manually adding calcium hypochlorite to the pool, it should be broadcast evenly over the surface of the water, because damage to the pool surface can occur if a large amount is added in one place. It can also cloud the water when added due to the formation of insoluble precipitates.

$$\longrightarrow \quad Ca(OCl)_2 + 2H_2O \qquad 2HOCl + Ca(OH)_2$$

Calcium Hypochlorite   Water   Hypochlorous Acid   Calcium Hydroxide

Calcium hydroxide ($Ca(OH)_2$) is formed when it is added to water, so the pH is high (pH = 11.8) and needs to be neutralized with acid.

Lithium Hypochlorite (LiOCl)

Lithium hypochlorite is found in a powder form and is a somewhat new to the market. It provides 35% available chlorine by weight and dissolves readily in water, with no precipitate. One thing that keeps it from being in wider use is it's high expense. Because it dissolves so quickly, the danger of damage to the pool surface is minimized. This property is especially useful in pools with vinyl liners.

Lithium hypochlorite forms lithium hydroxide (LiOH) when added to water, so the pH is somewhat increased (pH = 10.7) when used and needs to be neutralized with acid.

$$\longrightarrow \quad LiOCl + H_2O \qquad HOCl + LiOH$$

Lithium Hypochlorite   Water   Hypochlorous Acid   Lithium Hydroxide

Chlorinated Isocyanurates

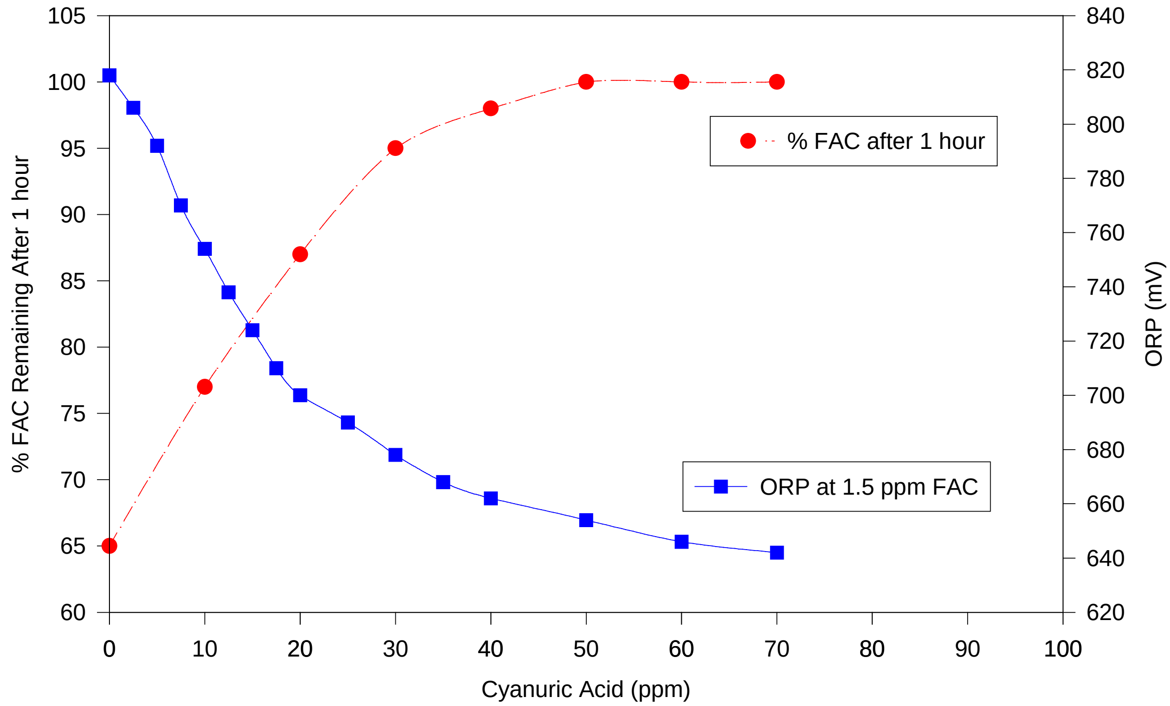
Chlorinated isocyanurates, also called stabilized chlorine are found in two forms, sodium dichloro-s-triazinetrione (dichlor) and sodium trichloro-s-triazinetrione (trichlor). Each is a chlorine compound containing cyanuric acid as a stabilizer. Consistent use of these forms of chlorine requires periodic draining of the pool to reduce the cyanuric acid level. Chlorinated isocyanurates are no longer allowed in spas, wading pools, or interactive water features.

Dichlor

Dichlor is found in a quick dissolving fine granular form providing 56 or 62% available chlorine. The effect of dichlor on pH is minimal, so no pH adjustment is necessary. It is unsuitable for automated addition or for shock treating due to the high cyanuric acid content. Dichlor should only be used on residential pools due to its unsuitability for automated feeding.

Trichlor

Trichlor is found in a white tablet form that is fed through an erosion type feeder (but NEVER through the skimmer basket). It is also found in a quick dissolving granular form.



Data from Stranco

Figure 3-1: Effect of cyanuric acid on chlorine residual and ORP

It contains 90% available chlorine by weight and is very acidic (pH = 2.9). However, due to the high concentration of chlorine in each tablet, a little goes a long way and the pH is typically not radically affected in larger pools. However, due to the high chlorine concentration and low pH, maintaining proper chlorine and pH levels can be a problem in smaller pools and spas.

Cyanuric Acid

Free chlorine is very sensitive to ultraviolet light (UV). It has been shown that up to 1 ppm of FAC can be lost per hour to UV light, and it is helpful in outdoor pools to have some method of stabilizing the chlorine and keeping it from being destroyed. Cyanuric acid helps keep chlorine in the water by loosely attaching itself to chlorine and "holding" it in place (Fig. 3-1).

In high concentrations, however, cyanuric acid can tie up chlorine so that it is not available for disinfection. Figure 3-1 shows that the oxidation reduction potential (ORP) of water is lowered by cyanuric acid. ORP is an indicator of the effectiveness of the chlorine. As ORP increases, more disinfectant needs to be added to achieve the same activity, raising chemical costs.

"Chlorine lock" is a term that refers to tying up of FAC by cyanuric acid. There is some controversy regarding whether cyanuric acid is responsible for chlorine inefficiency at high concentrations or whether excessive total dissolved solids (TDS) are to blame. Regardless, to meet local health department regulations, pools showing a high cyanuric acid concentration should be drained about 20%, the walls brushed, and the pool refilled with fresh water. In pools using stabilized chlorines, daily vacuuming to waste can help delay the necessity of draining and refilling.

Table 3-4: Characteristics of different chlorine compounds

	Gas Chlorine	Sodium Hypochlorite	Calcium Hypochlorite	Lithium Hypochlorite	Dichlor	Trichlor
% Available Chlorine	100%	12-15%	65-70%	35%	56% or 62%	90%
Effect on pH	Lowers (pH < 1.0)	Raises (pH = 13.0)	Raises (pH = 11.8)	Raises (pH = 10.7)	Neutral (pH = 6.9)	Lowers (pH = 2.9)
Cyanuric Acid	No	No	No	No	Yes	Yes
Physical Appearance	Gas	Liquid	Granular or Tablet	Powder	Granular	Granular or Tablet

Data taken from Pool-Spa Operators Handbook

The recommended concentration of cyanuric acid is between 20-30 ppm, with a minimum of 10 and a maximum of 100 ppm in swim pools and a maximum of 40 ppm in spa pools. ***Indoor pools should not use cyanuric acid or stabilized chlorine compounds.***

Bromine (HOBr)

Bromine is, like chlorine, a halogen and shows similar chemistry in water, forming hypobromous acid (HOBr) and the hypobromite ion (OBr^-). Bromine products can be found in two forms: 1) a two part form, where bromine dissolved in water is activated by the addition of a separate oxidizer (typically chlorine), and 2) and a one part stick or tablet containing the oxidizer which is dispensed through an erosion-type brominator.

HOBr is a very effective sanitizer. In addition, combined bromines are effective and display no unpleasant odors. Bromine is not affected so dramatically as chlorine by changes in pH (Tbl. 3-5). Furthermore, it is also somewhat more heat resistant than chlorine and is popular in spas.

Bromine, however, is a poor oxidizer. It cannot be used for shock treatment and the bromine is only half as effective as chlorine at a given concentration. In addition, pools using bromine can appear cloudy after a short time. Finally, bromine cannot be protected from UV light degradation by the use of cyanuric acid.

Table 3-5: pH effects on bromine

pH	% Bromine as HOBr
6.0	100
6.5	99.4
7.0	98.0
7.5	94.0
8.0	83.0
8.5	57.0

Bromine concentration can be measured using a standard DPD pool test kit. If your test block does not have a separate scale for bromine, test just as you would for FAC and multiply the result by 2.

A further problem with bromine is its longevity in pools. Pools that try to switch over from bromine to chlorine may experience problems as hypochlorous acid converts the "used bromine" (bromide ion) back to hypobromous acid:

$$Br^- + HOCl \rightarrow HOBr + Cl^-$$

Bromide Ion Hypochlorous Acid Hydrobromous Acid Chloride Ion

Pools that switch from bromine to chlorine should be drained and rinsed thoroughly before water is added and balanced.

Ozone

Ozone is a very strong oxidizer and bactericide. It has been used in Europe since the early 1900's and has proven popular there. The ozone molecule itself is not the sanitizer. The O_3 molecule is very unstable and quickly splits apart into molecular oxygen (O_2) and an oxygen anion (O^{2-}). O^{2-} is extremely reactive and is a very effective disinfectant.

Ozone is formed in two ways. The first method, and most expensive, is corona discharge. Here, dry air is passed through high voltage electricity. The second method is the photochemical method where dry air is passed next to a UV light. The photochemical method is much less efficient than the Corona discharge method and is useful for small pools of less than 10,000 gal. For larger pools, the corona discharge method or multiple photochemical generators should be used.

Ozone has a very short life span (approx 20 min). It converts to oxygen, which has a benificial effect on the appearance and smell of the water. In addition, the presence of ozone in the water lowers chlorine demand, saving chemical costs and reducing TDS buildup. A further advantage to ozone is its lack of effect on the pH of pool water.

$$O_3 \rightarrow O_2 + O^{2-}$$

Ozone Molecular Oxygen Oxygen Anion

However, due to its short life, ozone must be continuously introduced into the water. It is also ineffective against algae. For this reason, ozone can only be used as a supplemental sanitizer. A halogen (chlorine or bromine) must be added to the pool in addition to ozone and the proper residual maintained.

Metal ions

Silver or copper ions can be added to pool water by passing electric current through an electrode in the recirculation system. These forms of disinfection are quite slow and expensive. In addition, unbalanced water frequently causes the metal ions to deposit on pool walls, forming ugly black and blue stains. Due to its slow activity, an ionizing unit can only be used as a supplement for halogen sanitizers.

Ultraviolet light

As a supplement to halogen sanitizers, ultraviolet (UV) light is a very effective killer of floating organisms. Used in pools, water is simply circulated past a UV light bulb and discharged back to the pool. However, it is *only* effective against organisms in the water. Algae or bacteria attached to the walls and floors of the pool are not affected. Therefore, a halogen disinfectant must also be used.

Instant Review (or, what you need to know about sanitizers)

- Chlorine is the most common sanitizer in use today
- Chlorine gas lowers the pH and should be balanced by adding soda ash
- Hypochlorite compounds (liquid chlorine, granular chlorine) raise the pH and should be balanced by adding acid
- Stabilized chlorines add sanitizer and stabilizer to the pool at the same time
- Cyanuric acid protects chlorine from degradation by UV light
- Bromine has similar chemistry to chlorine but cannot be stabilized
- Ozone, metal ionizers, and UV light are all supplemental sanitizers and must be used in conjunction with a halogen disinfectant

Other Chemical Factors

Alkalinity

Alkalinity is best described as a measure of the buffering capacity of water, or its resistance to changes in pH. Various forms of the carbonate ion (CO_3^{2-}) provide most of this buffering, but other alkalis also assist. Keeping the proper total alkalinity in the pool will greatly improve pH control.

The carbonate ion has the ability to bind up to two hydrogen ions. In other words, it can act as a base. However, if the pH gets too high, the hydrogen ions can be donated back to the surrounding water, lowering the pH, i.e.: it can also act as an acid.

$$\underset{\text{Carbonate ion}}{CO_3^{2-}} + 2H^+ \longleftrightarrow \underset{\text{Bicarbonate ion}}{HCO_3^-} + H^+ \longleftrightarrow \underset{\text{Carbonic acid}}{H_2CO_3}$$

If the water has an excess of hydrogen ions (too acidic), the carbonate ion will pick up one, increasing the pH and forming bicarbonate (HCO_3^-). If the pH is still too low, bicarbonate will bind to the second hydrogen ion, forming carbonic acid. The reverse is also true. If the pH is too high (too basic), carbonic acid will release one or two H^+ ions into the water, lowering the pH and forming bicarbonate or carbonate.

The end result of this is that the carbonate family of compounds will keep pH from dramatically changing (spiking). The National Swimming Pool Foundation recommends that alkalinity be kept at 100- 125 ppm in plaster (marcite) pools and 125 - 150 ppm in fiberglass pools.

Total alkalinity can be controlled by adding sodium bicarbonate (baking soda) if it is too low. If it's too high, dry acid (sodium bisulfate) or muriatic acid should be added slowly and carefully. Be aware that sodium bicarbonate is slightly basic, and will raise the pH of the pool water when added.

Calcium Hardness

Calcium carbonate ($CaCO_3$) is the major component of marcite and is slightly soluble in water. Over time, marcite will dissolve unless the water is already full of calcium (saturated).

The way to protect your pool surfaces is simply to make sure that the water of the pool is saturated with calcium by adding calcium chloride.

On the other hand, if there is too much calcium in the water, it will precipitate out as scale, leading to roughening and discoloration of the pool surface. Scale can also clog pipes, valves, and filters, making them useless. If calcium levels are too high, they can be diluted if the makeup water itself is not too hard. If the source water is unsuitable for dilution, a chelating agent can be added to tie up excess calcium.

The recommended range for calcium hardness is 200-400 ppm, with a maximum of 1000 ppm.

Total Dissolved Solids (TDS)

Total dissolved solids is the total amount all dissolved materials in the water measured in ppm. High TDS reduces the effectiveness of sanitizer, accelerates corrosion of metals, causes cloudiness, and causes discoloration and scaling. Each chemical that is added to the pool for disinfection, stabilization, pH control, etc., will raise the TDS level.

The TDS of pool water should be kept as low as possible. NSPI recommended ranges of 400-500 ppm are difficult to achieve in Florida due to the high TDS of the makeup water (typically 200-500 ppm). As TDS rises, the sanitizer effectiveness decreases and the concentration maintained in the pool should be increased accordingly. At approximately 2000 ppm, pool patrons will begin to notice salty tasting water.

To keep TDS under control as much as possible, pools should be drained and refilled every 3-5 years. Alternately, the water may be "freshened" by the practice of vacuuming about 2 inches of water to waste every week. The savings on chemicals should balance the cost of the water used in this process.

Water Balance

Balanced water can be defined as water that is neither corrosive nor scaling. Several factors interact to affect water balance, including pH, total alkalinity, calcium hardness, TDS, and temperature.

The most common method used to determine the balance of the water is called the Langelier Index (Chapter 4). There is some controversy as to how effective this calculation is in determining the corrosive or scaling tendencies of water. Other calculations, such as the Ryznar Stability Index and the Hamilton Index have been proposed as better solutions, but are not in common use.

Whichever index you decide to use, the water balance of your pool should be calculated periodically, but in general if you keep your chemicals maintained within the range given in this manual, your water should be in balance.

Metal stains

Metal can still be found in the recirculation systems of pools. Older pools, in particular have brass valves and pipes, steel grates, and copper heater cores. Copper and silver ions are also sometimes used as disinfectants.

Metals are very sensitive to changes in pH. If the pH drops below 7.0, even for a short time, metal will be dissolved from pipes and valves. If the pH later rises above 8.4, the metal compounds in solution will plate out on the surface of the pool, forming unsightly stains.

These stains can be cleaned by acid washing, but this accelerates the deterioration of the marcite and can darken colored plaster type pools as well. The best way to handle metal staining is to avoid it altogether by maintaining a pH of 7.4 to 7.6 at all times. In addition, removing metal components from the pool and replacing them with PVC, and by installing newer heaters with non-metallic cores can keep metal ions out of the pool and off of surfaces. Pools that have high metal content in the makeup water may want to add a chelating agent (see below) to the pool as well.

Nitrogen Compounds

Nitrogen compounds can cause many problems with your pool, primarily in improving conditions for algal growth, but also by increasing chlorine demand. Nitrogen compounds enter pool water through many ways: rain, bather urination, or fertilizer blown into the pool by wind.

Ammonium compounds (i.e.: NH_4^+) are reduced forms of nitrogen that, in addition to acting as fertilizer, are responsible for the formation of combined chlorine. Breakpoint chlorination can convert these to an oxidized form. Nitrates (NO_3^-) and nitrites (NO_2^-) are oxidized forms of nitrogen that, while fertilizers, do not react with chlorine. Nitrites can be further oxidized to nitrate. Nitrates cannot be oxidized and can only be removed by dilution.

Algicides

There are many different products on the market that claim to prevent or rid your pool of algae problems. If you wish to use one, make sure that you read the label carefully. Some of them are just chlorine or bromine compounds in an expensive bottle. Others contain ammonium compounds that will use up free chlorine. (Note: if the product you're using eliminates free chlorine, the pool must be closed until a residual of 1 - 5 ppm is restored).

There is more information on algicides in Chapter 7, but the bottom line is that pools that are properly chlorinated at all times rarely have a problem with algae. Use these products sparingly.

Chelating Agents

Chelating agents tie up metal ions in the water, preventing them from forming stains on walls and surfaces of pools. They are popular and useful in pools that have high metal content in the source water. However, some products may strip metal from heater cores or other metal equipment, causing stains and colored water. These products should be used sparingly and in accordance with the directions on the label.

Instant Review (or, what you need to know about other chemical factors)

- Total alkalinity is a measure of the buffering capacity of water (i.e. it's ability to resist drastic changes in pH) and should be maintained between 100-150 ppm.
- Proper total alkalinity greatly improves pH control.
- Calcium hardness should be maintained between 200-400 ppm to prevent pitting of pool surfaces or scale formation.
- Total dissolved solids (TDS) is a measure of all compounds dissolved in water. It should be maintained as low as possible by vacuuming water to waste once a week.
- Metal staining can be avoided by paying close attention to maintaining the proper pH at all times.
- Nitrogen compounds are food for algae and bacteria and should be controlled by dilution

CHAPTER 4:

WATER TESTING AND BALANCE

Pool water does not maintain its clarity and cleanliness by itself. Proper testing and balancing of the water will prolong the life of pool equipment, surfaces, and reduce the liability of pool owners and operators.

Testing

Most chemical tests use similar methods. Two in particular are extremely common in pool water testing:

1. **Colorimetry** This method adds a known amount of reagent to a sample and the color is compared to a standard. The common test for pH, for example, is a colorimetric test.
2. **Titration** In this method, reagents are added to a sample, drop by drop, until a the sample changes color. The acid demand test, for instance, is a titration.

Considerations When Testing

When performing tests, several things need to be considered in order to obtain accurate results.

First, water in a cylinder clings to the sides of the tube and is slightly higher on the sides than in the center. This is called a meniscus (Fig. 4-1) and the volume should be measured from the bottom of the meniscus.

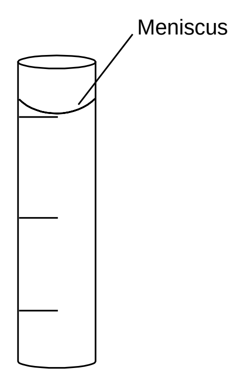


Figure 4-1: The Meniscus

Second, it is recommended that you take your water sample from a depth of approximately 18 inches (i.e. about elbow deep). Pulling samples from the surface layer will give you an inaccurate result. A good method is to invert your test block and plunge it into the water so that the air in the block prevents water from entering. Once the block is about elbow deep, invert the block and allow water to enter.

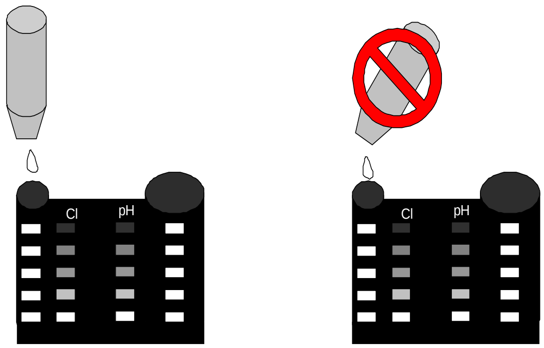


Figure 4-2: The proper way to add reagent

Third, when adding drops of reagent, hold the dropper or bottle straight up and down and not at an angle in order to ensure a consistent size drop (Fig. 4-2).

Check your reagents periodically. If you aren't sure how old they are, buy fresh reagent from the supply store. Bad or expired reagents will *definitely* give you inaccurate results.

Last, but not least, read and follow the directions that come with your kit. This chapter is primarily based on the Taylor® DPD Complete kit, but plenty of other companies make excellent products as well and the directions may vary from kit to kit.

Colorimetric Tests

Colorimetric tests should be done in natural sunlight, with a light or white background. Also, make sure that the test block that you are using is frosted on the correct side. The windows should be

Table 4-1: Chemical standards for public swimming pools

	Min/ Max Range	Rec. Range	When
Chlorine	1-10 ppm (Pools) 2-10 ppm (Spas)	2-3 ppm	3 / day
pH	7.2-7.8	7.4-7.6	3 / day
Cyanuric Acid	0-100 ppm (Pools) 0-40 ppm (Spas)	30-40 ppm	2 / week
Alkalinity	60-180 ppm	80-120 ppm	1 / week
Calcium Hardness	150-1000 ppm	200-400 ppm	1 / week
TDS	300-3000 ppm	1000-2000 ppm	1 /month

clear, with frosting on the back of the block to diffuse incoming light. *If the windows are frosted over, throw the block away and get a new one.*

When mixing samples, it is recommended that you use the plastic covers provided with your kit. Chemicals on your hands such as sweat, will interfere with the water in the sample, leading to an incorrect reading.

Titrations

When doing a titration, swirl after every drop. Not doing so will lead to erroneous conclusions about the endpoint, leading you to add the incorrect amount of adjustment chemical.

When to test

When to test each chemical parameter is based on two major factors. Pool usage, and the time of year are the main determining factors as how often a public pool should be tested. The answer is therefore: as often as necessary. Table 4-1 gives chemical parameters and recommended testing intervals.

Instant Review (or what you need to know about chemical testing)

- There are two common methods for water testing: colorimetric and titration
- Read water volumes from the bottom of the meniscus
- Take water samples from 18” depth
- Hold dropper bottles straight up and down when adding reagent
- Colorimetric tests should be performed in natural sunlight with a light background
- Use the plastic caps on test blocks
- Swirl constantly during titration tests
- Make sure your reagents are fresh
- Test pools as often as needed—the more often the better
- Record and log the results

Tests

Chlorine testing

There are two types of kit commonly used by pool operators to test the amount of chlorine in the pool. One uses orthotolidine (OTO) which, when added to water, turns a shade of yellow proportional to the amount of total chlorine (TAC) in the water. OTO can *only* test for total chlorine, and cannot be used for commercial pools.

The most common kit in use by pool operators is the DPD (diethyl p-phenylenediamine) kit, which turns red when added to chlorinated water in proportion to the amount of chlorine. DPD kits can test for both free chlorine (FAC) and total chlorine (TAC).

Most test kits use similar steps. Here we will use the Taylor® model 2000 DPD kit as the basis for discussion.

Testing for Free Chlorine (FAC)

1. Fill the small tube with pool water to the 9.5 mL line scribed on the outside of the tube.
2. Add 5 drops of reagent R-0001.
3. Add 5 drops of reagent R-0002 (DPD).
4. Cover the tube with a plastic cap (never your finger) and invert several times to mix.
5. Compare the color of the tube with the standard colors printed on the test block. This should be done poolside and in natural sunlight with a white background if possible.
6. If there is no color, there might not be any chlorine in the pool or there might be so much that it is bleaching the color. Dilute the sample 1:2 and re-test (see below).
   A If the chlorine reading seems high ($\geq$ 5 ppm), there may be more chlorine in the water than the test kit can handle. To ensure accurate readings, dilute the sample 1:2 or 1:5 and re-test.
   B Dilution is accomplished by filling the tube one half (or one fifth) full of pool water. On the Taylor® kit, there are lines scribed at the 4.5 mL and 1.8 mL marks that are one-half and one-fifth the volume of the tube, respectively. Add non-chlorinated water to the 9 mL mark and test again using steps 2-5.
   C Multiply the result by 2 or 5, depending upon how much you diluted your sample.

Testing for Total Chlorine (TAC)

1. Fill the tube with pool water and test for FAC as described above.
2. Add 5 drops of reagent R-0003.
3. Cap the tube and invert to mix.
4. Compare the sample color to that of the standard printed on the test block.

Testing pH

The most common pH indicator dye is called phenol red and can test within a range of 6.8 (yellow) to 8.4 (purple).

1. Fill the large tube to the 44 mL line.
2. Add 5 drops of reagent R-0004 (phenol red).
3. Cap and invert to mix
4. Compare the color to the standard on the test block.
5. Note: according to Taylor, high chlorine levels ($\geq$10 ppm) will cause the phenol red indicator to give an erroneous reading, leading operators to assume the pH is too high. If your chlorine is high, add ***one*** drop of reagent R-0007 to the sample before adding the pH reagent.

Testing for Acid and Base Demand

The acid or base demand tests are titration tests. Use them when your pH is out of range and you wish to know how much acid or base to add to the pool to bring it within the parameters that you need.

1. Test for pH as described above.
2. Add R-0005 (acid demand) or R-0006 (base demand) dropwise to the sample. ***Swirl after each drop.***
3. When the color in the sample has reached the color of the desired pH, count the number of drops and refer to Tables 4-9, 4-10, or 4-11 (pp 39-40).

Testing for Cyanuric Acid

The cyanuric acid test uses a different method from those described above. The cyanuric acid test is a turbidity test. When a reagent, melamine in this case, is mixed with water containing cyanuric acid, the water becomes cloudy in proportion to the amount of cyanuric acid in the pool.

1. Fill the testing bottle to the 7 mL fill line with pool water.
2. Fill to the 14 mL line with reagent R-0013 (melamine).
3. Cap and mix for 30 seconds.
4. Add the mixture to the small testing tube slowly, drop by drop until the black dot on the bottom of the tube is no longer visible.
5. Compare the meniscus of the mixture with the scale scribed in ppm on the inside of the tube.

Testing for Total Alkalinity

Total alkalinity is tested by a simple titration test using sulfuric acid and a pH sensitive dye as a color indicator.

1. Fill the large tube to the 25 mL line with pool water.
2. Add 2 drops of reagent R-0007 (Sodium thiosulfate) and mix.
3. Add 5 drops of reagent R-0008 (indicator dye) and mix. The solution should turn green.
4. Add reagent R-0009 (sulfuric acid) dropwise until color changes from green to red. ***Swirl after each drop is added.***
5. Multiply the number of R-0009 drops by 10 to get the total alkalinity in ppm.

Testing for Calcium Hardness

Calcium hardness is measured by titration.

1. Fill the large tube to the 25 mL mark with pool water.
2. Add 20 drops of reagent R-0010 and mix.
3. Add 5 drops of reagent R-0011 and mix. The solution should turn red.
4. Add reagent R-0012 dropwise until the color changes from red to blue. ***Swirl after each drop.***

5. Count the number of drops of R-0012 and multiply by 10 to get the calcium hardness in ppm.

Adjusting Water Balance

Some of this section was covered in Chapter 3, but we're going to go over it in some more detail here.

Adding chemicals to the pool

During normal operation of a public pool, chemicals must be added using an automated feeder system. There are three types of feeders commonly used in swimming pools:

- Gas feeders: gas is injected into the pool using water moving through a venturi device similar to a carburetor, through which the gas is fed.
- Liquid feeders: Liquid chlorine is fed through a pump that uses rollers to force the liquid through a flexible tube (Fig 4-3).
- Tablet feeders: Water is run over slowly eroding tablets and is then fed into the recirculation lines.

Occasionally, you will find that you need to manually add chemicals to the pool. ***When doing this, the pool must be cleared of bathers and posted closed until the chemical has had time to dilute and mix in the pool water***.

ORP Controllers

Oxidation Reduction Potential (ORP) controllers (Fig. 4-3) monitor the disinfectant effectiveness and (often) the pH of the swimming pool or spa water, feeding chemicals as necessary. They go under the trade names of Aquasol®, Chemtrol®, or Stran-Trol®, among others. These controllers are required for newly constructed spas as of December 1998. However, many existing pools and spas have installed them as well.

Some of the advantages to ORP controllers are: 1) better water balance promotes swimmer comfort and safety, 2) better water balance prolongs the life of pool surfaces and equipment, and 3) controllers save chemical cost and wear and tear on the feeders as they are only run when necessary.

Figure 4-3: Liquid feeders controlled by an ORP unit

There are some disadvantages to ORP controllers: 1) expense, 2) sense of complacency, 3) failure of the controllers when exposed to bad weather or pool chemicals, and 4) high cyanuric acid concentrations can cause the probes to read improperly.

We have found that if properly maintained and calibrated, these controllers greatly assist pool operators in maintaining a clean, sanitary, and healthy pool or spa.

Instant Review (or, what you need to know about adding chemicals)

- Routine addition of chemicals must be done by automated feeder systems in public pools
- Manual addition of chemicals requires that the pool be closed for sufficient mixing of the chemical and the chemical parameters have returned to the proper range

Langelier Index

Balanced water is defined as water that is neither corrosive nor scaling. It is often calculated by the Langelier Index. Originally devised for industrial applications, it can be used in a simplified form for swimming pools. The chemical parameters that effect the scaling or corrosive tendencies of water are pH, calcium hardness, total alkalinity, and temperature, and the Langelier Index takes these factors into account to determine the water balance.

1. Measure the temperature, pH, calcium hardness, and total alkalinity of the pool water.
2. Determine the temperature factor (TF), calcium factor (CF), and alkalinity factor (AF) by referring to Table 4-2.
3. Use the following formula to determine the saturation index (SI).

$$SI = pH + TF + CF + AF - 12.1$$

4. A result above 0.5 indicates a potential for scale formation. A result below –0.5 indicates a tendency to corrode. A result between 0.5 and –0.5 indicates balanced water.

Table 4-2: Numerical factors for Langelier Index Formula

Temp (ºF)	Temp Factor (TF)	**Calcium Hardness (ppm)**	Calcium Factor (CF)	**Total Alkalinity (ppm)**	Alkalinity Factor (AF)
32	0.0	5	0.3	5	0.7
37	0.1	25	1.0	25	1.4
46	0.2	50	1.3	50	1.7
53	0.3	75	1.5	75	1.9
60	0.4	100	1.6	100	2.0
66	0.5	150	1.8	150	2.2
76	0.6	200	1.9	200	2.3
84	0.7	300	2.1	300	2.5
94	0.8	400	2.2	400	2.6
105	0.9	800	2.5	800	2.9
128	1.0	1000	2.6	1000	3.0

Example
Consider a pool with a pH of 7.4, a temperature of 85ºF, a total alkalinity of 150 ppm, and a calcium hardness of 300 ppm.

Referring to Table 4-2, we get the following factors:

TF = 0.7
CF = 2.1
AF = 2.2

Next, plug them into the formula below:

SI = 7.4 + 0.7 + 2.1 + 2.2 – 12.1 = **0.3**

Result: the water is in balance.

Adjustment compounds

It is important to know not only what compounds to use in adjusting pool water balance, but also to know what order to add them in. For instance, adding acid to a pool that is not properly buffered (i.e. a low total alkalinity) can lead to spiking and serious damage to equipment and surfaces.

The National Swimming Pool Foundation recommends that chemicals be adjusted in the following order:

1. Chlorine
2. Total Alkalinity
3. pH
4. Cyanuric Acid
5. Calcium Hardness

Remember, when adjusting chemistry manually, the pool must be closed and the chemical allowed ample time to mix before re-opening the pool.

What chemical to add to adjust pool water chemistry has been discussed in Chapter 3, but Table 4-3 will summarize.

Instant Review, or what you need to know about adjusting water balance

- Use the Langelier Index to determine the corrosive or scaling properties of your water
- Add chemicals in the proper order to reduce the chance of equipment damage
- Close the pool when adding chemicals manually and allow them to mix properly before re-opening

Treatment Tables

Unless otherwise noted, the tables below are reproduced from those in the Taylor® DPD 2000 test kit.

Table 4-3: Common Adjustment Compounds

Chemical Parameter	Adjustment Compound to Use: To Raise	To Lower
FAC	Chlorine compound (Tbl. 4-5, 4-6)	Sodium sulfite (Tbl. 4-7) Sodium thiosulfate (Tbl. 4-8)
pH	Soda Ash (Tbl. 4-9)	Muriatic Acid (Tbl. 4-10) Dry Acid (Tbl. 4-11)
Total Alkalinity	Sodium Bicarbonate (Tbl. 4-12)	Muriatic Acid (Tbl. 4-13) Dry Acid (Tbl. 4-14)
Calcium Hardness	Calcium Chloride Dihydrate (Tbl. 4-15)	Dilution
Cyanuric Acid	Cyanuric Acid (Tbl. 4-16)	Dilution

How to Use the Treatment Tables

Each table is laid out in a similar pattern. The top row refers to the volume of the pool that you are interested in adjusting. The first column refers to either the concentration of adjustment compound or the number of drops of reagent added during the test. The intersection of the two tells you how much adjustment compound you need to add to the pool.

Example

Consider a 25,000 gallon pool. The pH of the pool water is 7.2 and you want it to be at 7.6. You could haphazardly add soda ash, hoping that you've added the correct amount, or you could do it as follows:

1. Perform the base demand test and count the number of drops added to reach a reading of 7.6. In this case, we'll call it 3 drops.
2. Look at Table 4-4. Notice that there is no column for a 25,000 gallon pool, so we'll have to add the results for a 5,000 gallon and a 20,000 gallon pool.
3. Go down the first column to the cell marked 3 Drops. Then move across to the 5,000 gallon column. The amount listed is 7.80 oz.
4. Now continue to the 20,000 gallon column (1.95 lb.)
5. Add the two together (1 lb = 16 oz).

   0.48 lb + 1.95 lb = **2.43 lb**

6. So, we need to add 2.43 lb of soda ash to this pool to raise the pH to 7.6

Table 4-4: Raising pH using Soda Ash

Drops of Base Demand Reagent	Volume of water (gallons)				
	250	400	1000	5000	20000
1	0.13oz	0.21 oz	0.52 oz	2.60 oz	10.4 oz
2	0.26 oz	0.42 oz	1.04 oz	5.20 oz	1.30 lb
3	0.39 oz	0.62 oz	1.56 oz	7.80 oz	1.95 lb
4	0.52 oz	0.83 oz	2.08 oz	10.4 oz	2.60 lb

Table 4-5: **Amount of Chlorine Compound to Introduce 1 ppm FAC**

% Available Chlorine	**Volume of water (gallons)** 250	400	1000	5000	20000	50000	100000
5	3.90 tsp	2.00 tbsp	2.60 oz	1.60 cp	3.20 pt	4.00 qt	2.00 gal
10	1.90 tsp	1.00 tbsp	1.30 oz	0.80 cp	1.60 pt	2.00 qt	1.00 gal
12	1.60 tsp	0.83 tbsp	1.10 oz	0.67 cp	1.33 pt	1.67 qt	0.83 gal
35	0.088 oz	0.15 oz	0.38 oz	1.91 oz	7.62 oz	1.19 lb	2.38 lb
60	0.056 oz	0.088 oz	0.22 oz	1.11 oz	4.40 oz	11.10 oz	1.39 lb
65	0.052 oz	0.082 oz	0.21 oz	1.03 oz	4.12 oz	10.30 oz	1.29 lb
90	0.037 oz	0.059 oz	0.15 oz	0.74 oz	3.00 oz	7.40 oz	14.8 oz
100	0.033 oz	0.053 oz	0.13 oz	0.67 oz	2.67 oz	6.67 oz	13.3 oz

Table 4-6: 30 ppm Shock Table for Algae Removal

% Available Chlorine	**Volume of water (gallons)** 250	400	1000	5000	20000	50000	100000
5	2.36 cp	1.89 pt	2.36 qt	2.95 gal	11.8 gal	29.5 gal	59.0 gal
10	1.18 cp	0.94 pt	1.18 qt	1.48 gal	5.90 gal	14.8 gal	29.5 gal
12	0.98 cp	0.78 pt	0.98 qt	1.23 gal	4.92 gal	12.3 gal	24.6 gal
35	2.86 oz	4.58 oz	11.4 oz	3.57 lb	14.3 lb	35.7 lb	71.5 lb
60	1.67 oz	2.67 oz	6.67 oz	2.08 lb	8.34 lb	20.8 lb	41.7 lb
65	1.54 oz	2.46 oz	6.16 oz	1.92 lb	7.70 lb	19.2 lb	38.5 lb
90	1.11 oz	1.80 oz	4.45 oz	1.39 lb	5.56 lb	13.9 lb	27.8 lb
100	1.00 oz	1.60 oz	4.00 oz	1.25 lb	5.00 lb	12.5 lb	25.0 lb

Sodium Hypochlorite is **12-15%** available chlorine (liquid)
Calcium Hypochlorite is **65-70%** available chlorine (tablet or granular)
Trichlor is **90%** available chlorine (tablet or granular)
Dichlor is **56-62%** available chlorine (granular)
Gas Chlorine is **100%** available chlorine**Table 4-7:** Using sodium sulfite to lower FAC

Desired decrease in ppm	Volume of water (gallons) 250	400	1000	5000	20000	50000	100000
1	0.06 oz	0.10 oz	0.24 oz	1.20 oz	4.80 oz	12.0 oz	1.50 lb
2	0.12 oz	0.19 oz	0.48 oz	2.40 oz	9.60 oz	1.50 lb	3.00 lb
3	0.18 oz	0.29 oz	0.72 oz	3.60 oz	14.4 oz	2.25 lb	4.50 lb
4	0.24 oz	0.38 oz	0.96 oz	4.80 oz	1.20 lb	3.00 lb	6.00 lb
5	0.30 oz	0.48 oz	1.20 oz	6.00 oz	1.50 lb	3.75 lb	7.50 lb
10	0.60 oz	0.96 oz	2.40 oz	12.0 oz	3.00 lb	7.50 lb	15.0 lb
20	0.90 oz	1.45 oz	3.62 oz	1.13 lb	4.52 lb	11.3 lb	22.6 lb
30	1.20 oz	1.92 oz	4.80 oz	1.50 lb	6.00 lb	15.0 lb	30.0 lb
40	1.80 oz	2.88 oz	7.20 oz	2.25 lb	9.00 lb	22.5 lb	45.0 lb
50	3.00 oz	4.80 oz	12.0 oz	3.75 lb	15.0 lb	37.5 lb	75.0 lb

Table 4-8: Using sodium thiosulfate to lower FAC

Desired decrease in ppm	Volume of water (gallons) 250	400	1000	5000	20000	50000	100000
1	0.03 oz	0.04 oz	0.10 oz	0.50 oz	2.00 oz	5.00 oz	10.0 oz
2	0.05 oz	0.08 oz	0.20 oz	1.00 oz	4.00 oz	10.0 oz	1.25 lb
3	0.08 oz	0.12 oz	0.30 oz	1.50 oz	6.00 oz	15.0 oz	1.88 lb
4	0.10 oz	0.16 oz	0.40 oz	2.00 oz	8.00 oz	1.25 lb	2.50 lb
5	0.13 oz	0.20 oz	0.50 oz	2.50 oz	10.0 oz	1.57 lb	3.13 lb
10	0.25 oz	0.40 oz	1.00 oz	5.00 oz	1.25 lb	3.13 lb	6.25 lb
20	0.50 oz	0.80 oz	2.00 oz	10.0 oz	2.50 lb	6.25 lb	12.5 lb
30	0.75 oz	1.20 oz	3.00 oz	15.0 oz	3.75 lb	9.38 lb	18.8 lb
40	1.00 oz	1.60 oz	4.00 oz	1.25 lb	5.00 lb	12.5 lb	25.0 lb
50	1.25 oz	2.00 oz	5.00 oz	1.56 lb	6.25 lb	15.6 lb	31.3 lb

Data taken from National Swimming Pool Foundation Pool-Spa Operator's Handbook

Table 4-9: Raising pH using soda ash (sodium carbonate)

Drops of Base Demand Reagent	Volume of water (gallons) 250	400	1000	5000	20000	50000	100000
1	0.13oz	0.21 oz	0.52 oz	2.60 oz	10.4 oz	1.63 lb	3.25 lb
2	0.26 oz	0.42 oz	1.04 oz	5.20 oz	1.30 lb	3.25 lb	6.50 lb
3	0.39 oz	0.62 oz	1.56 oz	7.80 oz	1.95 lb	4.88 lb	9.75 lb
4	0.52 oz	0.83 oz	2.08 oz	10.4 oz	2.60 lb	6.50 lb	13.0 lb
5	0.65 oz	1.04 oz	2.60 oz	13.0 oz	3.25 lb	8.13 lb	16.3 lb
6	0.78 oz	1.25 oz	3.12 oz	15.6 oz	3.90 lb	9.75 lb	19.5 lb
7	0.91 oz	1.46 oz	3.64 oz	1.14 lb	4.55 lb	11.4 lb	22.8 lb
8	1.04 oz	1.66 oz	4.16 oz	1.30 lb	5.20 lb	13.0 lb	26.0 lb
9	1.17 oz	1.87 oz	4.68 oz	1.46 lb	5.85 lb	14.6 lb	29.2 lb
10	1.30 oz	2.08 oz	5.20 oz	1.63 lb	6.50 lb	16.3 lb	32.6 lb

Table 4-10: Lowering pH using muriatic acid

Drops of Acid Demand Reagent	Volume of water (gallons) 250	400	1000	5000	20000	50000	100000
1	1.00 tsp	1.60 tsp	1.33 tbsp	3.33 oz	1.67 cp	1.04 qt	2.08 qt
2	2.00 tsp	1.07 tbsp	1.33 oz	6.66 oz	1.67 pt	2.08 qt	1.04 gal
3	1.00 tbsp	1.60 tbsp	2.00 oz	1.25 cp	1.25 qt	3.12 qt	1.56 gal
4	1.33 tbsp	1.07 oz	2.66 oz	1.67 cp	1.67 qt	1.04 gal	2.08 gal
5	1.67 tbsp	1.34 oz	3.33 oz	1.04 pt	2.08 qt	1.30 gal	2.60 gal
6	1.00 oz	1.60 oz	3.99 oz	1.25 pt	2.50 qt	1.56 gal	3.12 gal
7	1.17 oz	1.87 oz	4.66 oz	1.46 pt	2.92 qt	1.82 gal	3.64 gal
8	1.34 oz	2.14 oz	5.32 oz	1.67 pt	3.34 qt	2.08 gal	4.16 gal
9	1.50 oz	2.40 oz	5.99 oz	1.87 pt	3.76 qt	2.34 gal	4.68 gal
10	1.67 oz	2.67 oz	6.65 oz	1.04 qt	1.04 gal	2.60 gal	5.20 gal

Table 4-11: Lowering pH using dry acid (sodium bisulfate)

Drops of Acid Demand Reagent	Volume of water (gallons) 250	400	1000	5000	20000	50000	100000
1	0.26 oz	0.42 oz	1.04 oz	5.20 oz	1.30 lb	3.25 lb	6.50 lb
2	0.52 oz	0.84 oz	2.08 oz	10.4 oz	2.60 lb	6.50 lb	13.0 lb
3	0.78 oz	1.25 oz	3.12 oz	15.6 oz	3.90 lb	9.75 lb	19.5 lb
4	1.04 oz	1.66 oz	4.16 oz	1.30 lb	5.20 lb	13.0 lb	26.0 lb
5	1.30 oz	2.08 oz	5.20 oz	1.63 lb	6.50 lb	16.3 lb	32.5 lb
6	1.56 oz	2.50 oz	6.24 oz	1.95 lb	7.80 lb	19.5 lb	39.0 lb
7	1.82 oz	2.91 oz	7.28 oz	2.28 lb	9.10 lb	22.8 lb	45.5 lb
8	2.08 oz	3.33 oz	8.32 oz	2.60 lb	10.4 lb	26.0 lb	52.0 lb
9	2.34 oz	3.74 oz	9.36 oz	2.93 lb	11.7 lb	29.3 lb	58.5 lb
10	2.60 oz	4.16 oz	10.4 oz	3.25 lb	13.0 lb	32.5 lb	65.0 lb

Table 4-12: Raising total alkalinity using sodium bicarbonate

Desired increase in ppm	Volume of water (gallons) 250	400	1000	5000	20000	50000	100000
10	0.60 oz	0.96 oz	2.40 oz	12.0 oz	3.00 lb	7.50 lb	15.0 lb
20	1.20 oz	1.92 oz	4.80 oz	1.50 lb	6.00 lb	15.0 lb	30.0 lb
30	1.80 oz	2.88 oz	7.20 oz	2.25 lb	9.00 lb	22.5 lb	45.0 lb
40	2.40 oz	3.84 oz	9.60 oz	3.00 lb	12.0 lb	30.0 lb	60.0 lb
50	3.00 oz	4.80 oz	12.0 oz	3.75 lb	15.0 lb	37.5 lb	75.0 lb
60	3.60 oz	5.76 oz	14.4 oz	4.50 lb	18.0 lb	45.0 lb	90.0 lb
70	4.20 oz	6.72 oz	1.05 lb	5.25 lb	21.0 lb	52.5 lb	105 lb
80	4.80 oz	7.68 oz	1.20 lb	6.00 lb	24.0 lb	60.0 lb	120 lb
90	5.40 oz	8.64 oz	1.35 lb	6.75 lb	27.0 lb	67.5 lb	135 lb
100	6.00 oz	9.60 oz	1.50 lb	7.50 lb	30.0 lb	75.0 lb	150 lb

Table 4-13: Lowering total alkalinity using muriatic acid

Desired decrease in ppm	Volume of water (gallons)						
	250	400	1000	5000	20000	50000	100000
10	1.04 tbsp	1.66 tbsp	2.08 oz	1.30 cp	1.30 qt	3.25 qt	1.63 gal
20	1.04 oz	1.66 oz	4.16 oz	1.30 pt	2.60 qt	1.63 gal	3.26 gal
30	1.56 oz	2.50 oz	6.24 oz	1.95 pt	3.90 qt	2.44 gal	4.89 gal
40	2.08 oz	3.33 oz	1.04 cp	1.30 qt	1.30 gal	3.25 gal	6.52 gal
50	2.60 oz	4.16 oz	1.30 cp	1.63 qt	1.63 gal	4.06 gal	8.15 gal
60	3.12 oz	5.00 oz	1.56 cp	1.95 qt	1.95 gal	4.88 gal	9.78 gal
70	3.64 oz	5.82 oz	1.82 cp	2.28 qt	2.28 gal	5.69 gal	11.4 gal
80	4.16 oz	6.66 oz	1.04 pt	2.60 qt	2.60 gal	6.50 gal	13.0 gal
90	4.68 oz	7.49 oz	1.17 pt	2.93 qt	2.93 gal	7.31 gal	14.7 gal
100	5.20 oz	1.04 cp	1.30 pt	3.25 qt	3.25 gal	8.13 gal	16.3 gal

Table 4-14: Lowering total alkalinity using dry acid (sodium bisulfate)

Desired decrease in ppm	Volume of water (gallons)						
	250	400	1000	5000	20000	50000	100000
10	0.60 oz	0.96 oz	2.40 oz	12.0 oz	3.00 lb	7.50 lb	15.0 lb
20	1.20 oz	1.92 oz	4.80 oz	1.50 lb	6.00 lb	15.0 lb	30.0 lb
30	1.80 oz	2.88 oz	7.20 oz	2.25 lb	9.00 lb	22.5 lb	45.0 lb
40	2.40 oz	3.84 oz	9.60 oz	3.00 lb	12.0 lb	30.0 lb	60.0 lb
50	3.00 oz	4.80 oz	12.0 oz	3.75 lb	15.0 lb	37.5 lb	75.0 lb
60	3.60 oz	5.76 oz	14.4 oz	4.50 lb	18.0 lb	45.0 lb	90.0 lb
70	4.20 oz	6.72 oz	1.05 lb	5.25 lb	21.0 lb	52.5 lb	105 lb
80	4.80 oz	7.68 oz	1.20 lb	6.00 lb	24.0 lb	60.0 lb	120 lb
90	5.40 oz	8.64 oz	1.35 lb	6.75 lb	27.0 lb	67.5 lb	135 lb
100	6.00 oz	9.60 oz	1.50 lb	7.50 lb	30.0 lb	75.0 lb	150 lb

Table 4-15: Raising calcium hardness using 100% calcium chloride dihydrate

Desired increase in ppm	Volume of water (gallons)						
	250	400	1000	5000	20000	50000	100000
10	0.49 oz	0.78 oz	1.96 oz	9.80 oz	2.45 lb	6.12 lb	12.2 lb
20	0.98 oz	1.57 oz	3.92 oz	1.22 lb	4.90 lb	12.2 lb	24.5 lb
30	1.47 oz	2.35 oz	5.88 oz	1.84 lb	7.35 lb	18.4 lb	36.7 lb
40	1.96 oz	3.14 oz	7.84 oz	2.45 lb	9.80 lb	24.5 lb	49.0 lb
50	2.45 oz	3.92 oz	9.80 oz	3.06 lb	12.2 lb	30.6 lb	61.2 lb
60	2.95 oz	4.72 oz	11.8 oz	3.69 lb	14.7 lb	36.9 lb	73.7 lb
70	3.43 oz	5.48 oz	13.7 oz	4.28 lb	17.1 lb	42.8 lb	85.6 lb
80	3.92 oz	6.28 oz	15.7 oz	4.91 lb	19.6 lb	49.1 lb	98.1 lb
90	4.40 oz	7.04 oz	1.10 lb	5.50 lb	22.0 lb	55.0 lb	110 lb
100	4.88 oz	7.81 oz	1.22 lb	6.10 lb	22.4 lb	61.0 lb	122 lb

Table 4-16: Using cyanuric acid to increase stabilizer levels

Desired increase in ppm	Volume of water (gallons)						
	250	400	1000	5000	20000	50000	100000
1	0.03 oz	0.05 oz	0.13 oz	0.65 oz	2.60 oz	6.50 oz	13.0 oz
2	0.07 oz	0.10 oz	0.26 oz	1.30 oz	5.20 oz	13.0 oz	1.63 lb
3	0.10 oz	0.16 oz	0.39 oz	1.95 oz	7.80 oz	1.22 lb	2.44 lb
4	0.14 oz	0.21 oz	0.52 oz	2.60 oz	10.4 oz	1.62 lb	3.25 lb
5	0.17 oz	0.26 oz	0.65 oz	3.25 oz	13.0 oz	2.03 lb	4.06 lb
10	0.34 oz	0.52 oz	1.30 oz	6.50 oz	1.63 lb	4.06 lb	8.13 lb
20	0.68 oz	1.04 oz	2.60 oz	13.0 oz	3.25 lb	8.12 lb	16.3 lb
30	1.02 oz	1.56 oz	3.90 oz	1.22 lb	4.88 lb	12.2 lb	24.4 lb
40	1.36 oz	2.08 oz	5.20 oz	1.63 lb	6.50 lb	16.2 lb	32.5 lb

CHAPTER 5:

RECIRCULATION AND FILTRATION

50	1.70 oz	2.60 oz	6.50 oz	2.03 lb	8.13 lb	20.3 lb	40.6 lb

Data taken from National Swimming Pool Foundation Pool-Spa Operator's Handbook

Recirculation is a very important process in swimming pool operation. Improper recirculation can lead to improper chemical balance, cloudy water, and allow certain chlorine resistant parasites, such as *Cryptosporidium*, to infect pool patrons.

Recirculation

Recirculation is a deceptively simple process. It consists of taking water from the swimming pool, filtering it, chemically treating it, and returning it to the pool. Typically, water follows a similar path. Water flows from the pool, either through the main drain or through the skimmer loop to a collector tank. The pump then moves it through the recirculation system, where it is filtered, chemically treated, and then sent back to the pool.

The pump

The pump is the heart of your recirculation system (Fig. 5-1). Pumps used for swimming pool applications are invariably centrifugal types. This type of pump uses a spinning impeller to "fling" the water through the recirculation system. On

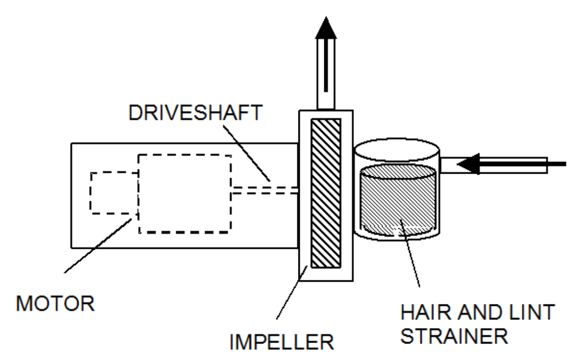


Figure 5-1: The Pump

commercial pools, these pumps must be self-priming. Pressure systems must also have a lint screen. There are two sides to the pump, vacuum (or influent) and pressure (or effluent). Recirculation systems are classified based upon which side of the pump the filters are set on.

Pressure Systems (Fig. 5- 2)

Water is removed from the pool by flowing via gravity through the main drain or skimmer loop to a collector tank. From the collector tank, the pump takes water and forces it through the filter(s) and heater. From there, the water is returned to the pool. Note the flow control and isolation valves, particularly around the heater.

Vacuum and waste disposal is accomplished using the recirculation pump. Valves allow water to be taken from the plumbed-in vacuum line in the side of the pool. Water can then either be pumped through the filters or directly to waste.

Vacuum systems (Fig. 5- 3)

Water is again removed from the pool through the main drain or skimmer loop. However, in a vacuum system, the collector tank doubles as a filter tank. Water is drawn through the filters and then pushed through the heater system.

Vacuum and waste require a separate pump on D.E. vacuum systems. Once again, the water is pulled through a separate vacuum line in the side of the pool and can be diverted to the filters or directly to waste.

The collector tank

The collector tank has several different uses. Required equipment are flow control valves that allow control over the flow from the pool to the tank, and automatic and manual fill devices with air gaps. These devices allow the tank to maintain the proper water level in the pool.

Vacuum filter systems also use the collector tank as a filter holding tank. For D.E. systems, a precoat line is needed in order to keep the D.E. in suspension while recoating the filter elements. (Fig. 5- 3)

Piping

All piping used in commercial pools in the State of Florida must be non-toxic and approved by the National Sanitation Foundation Schedule 40 for potable water use.

Instant Review (or, what you need to know about recirculation)

- Recirculation is removing water from the pool, treating it, and sending it back to the pool.
- Pumps used in swimming pools are centrifugal types and must be self-priming
- All piping must be approved by NSF for potable water applications

Gauges And Flowmeter

Your gauges and your flowmeter are the primary instruments that you use to determine the effectiveness of your filtration and recirculation systems.

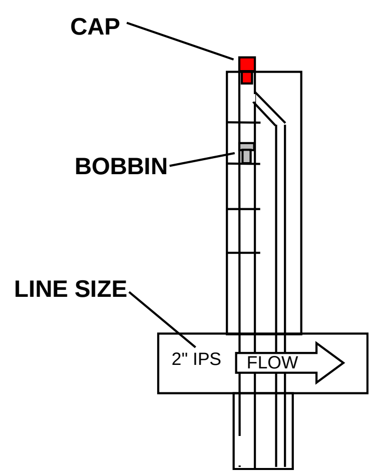


Figure 5-4: Flowmeter

Flowmeter

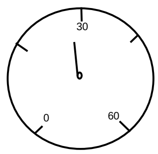
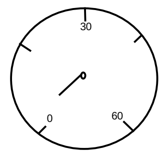
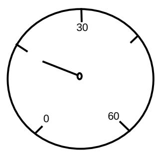
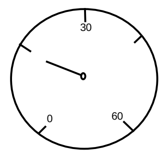
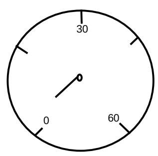
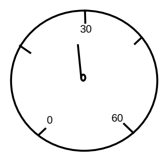
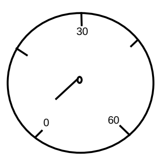
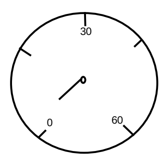
INFLUENT	EFFLUENT	CONCLUSION
		Filter needs cleaning
		Filter OK
		Gauges Broken
		Pump not functioning correctly

Figure 5-5: Pressure gauge readings and conclusions

Your pool is designed to filter water at a rate of one full turnover every three to six hours. The bathing load of your pool is calculated from the flow rate. The flowmeter (Fig. 5- 4) is what tells you this vital tidbit of information.

The flowmeter is a rather touchy instrument. A small piece of grit or precipitated chemical can jam the bobbin so that it does not give the proper reading. Keep an eye on the bobbin. If it's not bouncing up and down a little bit, it's probably jammed. Removing the cap and cleaning with a pipe cleaner may fix the problem. Sometimes, however, removal and a thorough cleaning are the only fix.

If a replacement is called for, make sure that the new flowmeter is designed for the size of your return line. That information is written near the bottom of every flowmeter. In addition, note that the scale of a flowmeter must measure from at least one half to one and one half times the designed flow rate.

Pressure Gauges

On pressure systems, the filters are enclosed in a pressure vessel and the only way to tell when your filters need cleaning are the readings given to you by the pressure gauges. As every pool is different, the filter influent pressure is not necessarily enough. The proper way to tell is the *difference* in pressure between the filter influent and effluent. Therefore, two gauges are required. One measuring the filter influent pressure and one measuring the filter effluent pressure. When the influent is much higher than the effluent reading, it's time to clean or replace the filters (Fig. 5-5). Both gauges must be 2 inches in diameter and capable of reading from 0-60 psi.

Vacuum gauges

The major advantage to a vacuum filter system is the visibility of the filters in the surge tank. You can easily see if the filters are dirty. However, the reading on the vacuum gauge is useful if the filters are clogged with things that are not easily seen, such as oils or scale. For that reason, a vacuum gauge must be mounted between the filter and the pump. The gauge must be 2 inches in diameter and capable of reading from 0-30 inches of mercury (in Hg). Keep an eye on both the gauge and the flowmeter in a vacuum system to determine whether the filters need cleaning.

Flow Rate and Bathing Load

Water is recirculated in gallons per minute. Maintaining the proper amount of water moving through the recirculation system is important to several aspects of good pool maintenance. First, it promotes proper filtration, keeping the pool water clear. Sparkling water is clean and inviting in appearance, and allows you to see a bather in distress if necessary. Second, a proper flow rate promotes vigorous mixing of the pool water, assisting the operator in maintaining balanced water chemistry and temperature throughout the pool or spa.

Swimming Pools

How many gallons of water need to be filtered and treated in a minute depends upon the size of the pool. For a commercial pool in the State of Florida, the minimum flow in a pool is based upon 1 full turnover of pool water every three to six hours.

Examples

Consider a 25,000 gallon pool. All 25,000 gallons must be filtered within six hours. So, in order to determine the minimum flow rate, simply divide the total number of gallons (25,000) by the required turnover time in minutes (360).

25,000 gallons / 360 minutes = **69 gpm**

The maximum bathing load of a swimming pool is based upon the flow rate. The calculation is one person per 5 gpm of flow. For our 25,000 gallon pool, the bathing load would be as follows:

69 gpm / 5 = **13 persons**

Under some conditions, the owner of the pool will want to have a larger bathing load than we've calculated here. Say 20 people in our 25,000 gallon pool. In this case, one needs to calculate the *maximum* flow for a swimming pool. In Florida, the maximum flow is one full turnover every three hours (180 minutes).

25,000 gallons / 180 minutes = **139 gpm**

Note that there are several other things that need to be taken into consideration when determining bathing loads and flow rate. These include filter capacity, collector tank capacity, pipe diameter, and number of living units that a pool serves. Filter capacities will be discussed shortly. The others are beyond the scope of this handbook.

Spas

For calculating the bathing load and minimum flow rate of a spa, the process is somewhat different. Spa pools must turn over a full volume in thirty minutes. So the minimum flow rate for a 1000 gallon spa would be calculated as follows:

1000 gal / 30 min = **33 gpm**

Bathing loads for spas are not based on the minimum required flow rate, however. Bathing load for a spa is calculated based upon the surface area of the spa. In Florida, it is one person for every 10 square foot of spa surface area (See Appendix A for calculation of surface area). If our 1000 gallon spa has 62 square feet of surface area:

62 sq ft / 10 = **6 persons**

Be aware that some pools and spas are overbuilt and are permitted by the health department on that basis. This occasionally results in *higher* minimum flow rates and *lower* bathing loads than the calculations above would indicate. In general, however, these formulas are the same ones that the Health Department uses to calculate bathing loads for public pools and spas. If in doubt, please call your local health department.

A Short Aside on Recessed Skimmers

Pools and spas with automatic recessed skimmers have some specific rules in the code that affects flow rates on pools.

- Recessed automatic skimmer systems must carry 60% of the total flow
- Each skimmer must pull at least 30 gpm.

In other words, a pool with two recessed skimmers must pull a minimum of 60 gpm through the skimmers and 40 gpm through the main drain. As a recessed skimmer system can carry no more than 60% of the design flow rate, such a pool would have a minimum flow rate of 100 gpm.

Instant Review (or, what you need to know about flow rates and bathing loads)

- Minimum flow rate is based upon one turnover every six hours.
- Maximum flow rate is based upon one turnover every three hours.
- Spa water turns over once every thirty minutes.
- Bathing loads in pools are calculated by dividing the permitted flow rate by five.
- Bathing loads in spas are calculated by dividing the spa surface area by ten.

<u>Filters</u>

Foreign matter such as dirt, algae, oils or other suspended solids are constantly introduced into pool water by wind, rain, and bathers. In order to maintain the sparkling purity that is so important in maintaining a sanitary pool, the water needs to be filtered and chemically treated. We've already discussed chemistry in Chapter 3. Filtration is a mechanical process that strains insoluble solids out of the pool water.

Filters come in several types and configurations. They remove suspended matter from the pool simply because the small holes in the filter media are smaller than the dirt and other solids. The size of these small holes (pore size) is different for each different type of filter. Pore size is measured in microns (1 μm = 1/1000 mm).

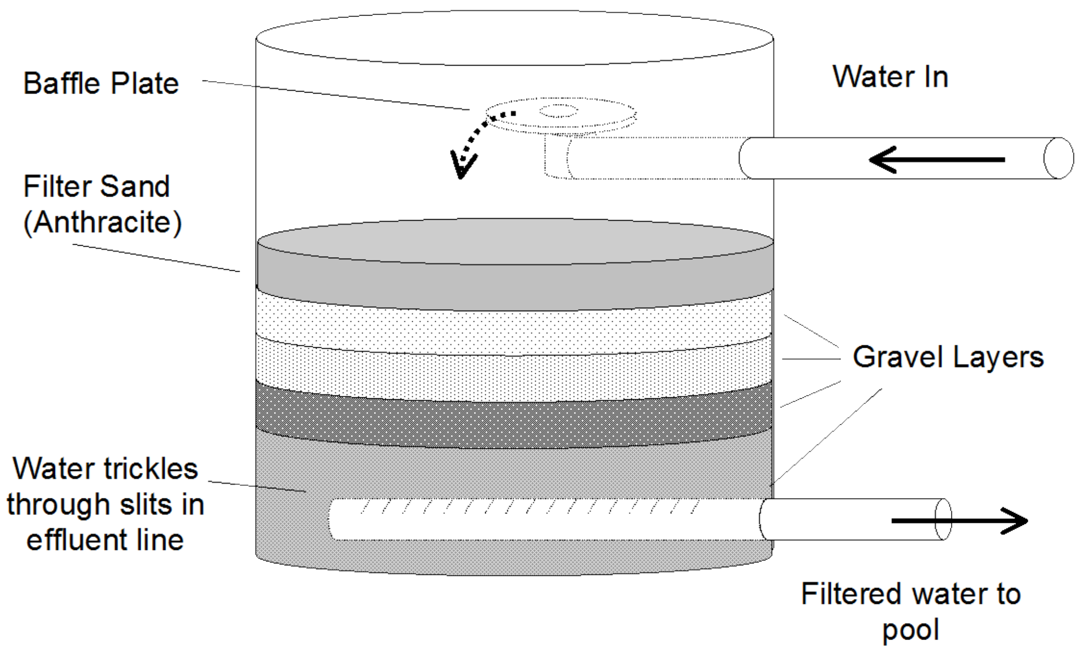


Figure 5-6: Cutaway drawing of a rapid rate sand filter

Regardless of the pore size, filters will eventually clog full of dirt and oils. The water then meets more and more resistance, resulting in a lower than acceptable flow rate. When this happens, the filters must be cleaned.

Each type of filter has a different filter capacity. This is the maximum amount of water that one square foot of a particular filter media can handle. The smaller the capacity, the more filter area you will need for a given size of pool.

When installing or replacing filters remember that enough filter surface area must be installed to meet the minimum required flow rate. Knowing the filter capacity of each different type will allow you to calculate surface area requirements for a particular swimming pool or spa filtration system. Although installing just enough filter capacity to handle the minimum required flow rate is acceptable; it is recommended by the National Swimming Pool Foundation that additional filter capacity be installed to handle 125% of the required flow rate.

Sand Filters

Sand filters are the oldest types of filter system in use, filtering to a pore size of 40 µm. There are two types of sand filters, which are classified by their filter capacity. Rapid rate sand filters are an old design and take up a very large amount of space. Very few rapid rate filters have been installed on new swimming pools in the last decade, but some older pools still have them. High rate sand filters can handle much higher flow rates per square foot of area and are much smaller, making them more popular than the old rapid rate types.

Rapid Rate Sand Filters

A layer of fine sand (or anthracite) filters the water in these systems. The anthracite is placed on top of layers of progressively more porous gravel (Fig. 5- 6). Water enters the filter through a baffle that evenly distributes the water over the surface of the filter. This even distribution is important because an uneven flow causes sand to migrate or channel. The water passes through the filter media and then through several other layers of material, collects in slotted pipes in the bottom layer of gravel, and is piped back to the pool.

Filter rates for these systems vary considerably, but the most accepted number for public swimming pools is 3 gpm per square foot of filter area. In other words, for each 3 gpm of required flow rate, you must have one square foot of filter area. For our 25,000-gallon pool, the required filter surface area would be as follows:

69 gpm / 3 gpm/sq ft = **23 sq ft**
(This would require more than seven 2-foot diameter filter housings.)

High Rate Sand Filters

These filters use finer sand, and owing to a more modern design, the filter rate is much higher than for the old rapid rate filters. Water entering the filter is deflected off of the top of the housing to prevent channeling of the filter sand. The lower layer of material is usually concrete in which the distribution pipes are inset. The filter rate for these systems can range from 12-20 gpm/sq ft, with 15 being standard on commercial pools. So for our same 25,000 gallon pool:

69 gpm / 15 gpm/sq ft = **4.6 sq ft**
(This would only require two 2-foot diameter filter housings.)

Cleaning Sand Filters

Cleaning sand filters involves reversing the flow through the filter so that any accumulated dirt is dislodged and run to waste (backwashing). The flow must be fast enough to dislodge dirt and debris, but not so fast that the sand runs out with the waste. One of the benefits of the newer high rate sand filters is that most of them are equipped with a multiport valve, making it possible to reverse the flow through the filter by turning a single handle rather than the multitude of valves required on the older systems.

Sand filter systems are required to be equipped with a watch glass set into the waste line. These allow the operator to know when the filter is clean by noting when the waste water runs clear.

Cartridge Filters

Modern cartridge filters are similar in construction to oil filters. A single pleated sheet of filter media is arranged around a circular core. A large amount of material is therefore contained in a small amount of space. Cartridge filters can be housed both in enclosed pressure vessels or in the collector tank for use in vacuum systems. The advantage of pressure systems is that they take up less space in the equipment area and give greater flexibility of placement. Vacuum systems allow for easier removal and visual detection of dirt and lint.

Cartridge filters have a pore size of 20 μm. Maximum flow rate through cartridge filters in a commercial pool is 0.375 gpm per square foot. So for our same 25,000 gallon pool:

69 gpm / 0.375 gpm/sq ft = **184 sq ft**

Note that cartridge filters have two capacities listed on the filter and/or housing: one for residential pools and one for commercial. When you are installing new filters, do not make the mistake of using the residential capacity in your calculations.

Cleaning Cartridge Filters

To clean cartridge filters, spray with a high-pressure water hose to remove dirt. Note: spray so that the water hits the filter at a 45° angle to prevent forcing dirt and oils into the filter pores. Cartridge filters should be periodically degreased to remove any oils that can clog the pores. To degrease filters, soak the filter elements in a solution of tri-sodium phosphate (TSP) detergent. If scaling is a problem, after removal of the oils, soak in a 10% muriatic acid solution overnight. ***WARNING! If you soak the filter in acid solution before soaking in detergent, you will set the oils permanently.***

Diatomaceous Earth Filters

Diatomaceous Earth (DE) is a fine, porous medium that is held onto a mesh support by pump pressure or suction. DE is made up of the remains of single celled marine plants called diatoms that were deposited many millions of years ago (Fig 5-7). When viewed microscopically, diatomaceous earth has a very fine, lacelike structure. Per pound, this structure gives DE tremendous surface area. When deposited on filter septa (Fig. 5-8), DE can filter particles out of the water as small as 2 μm in diameter, making it the most effective filter system available.

Figure 5-7: The famous diatom

DE has a maximum flow rate of 2 gpm per square foot. Therefore, our 25,000 gallon pool would require:

69 gpm / 2 gpm/sq ft = **35 sq ft** (this is the equivalent of about eight 19" filter disks)

Cleaning D.E. filters

Cleaning methods range from hosing the

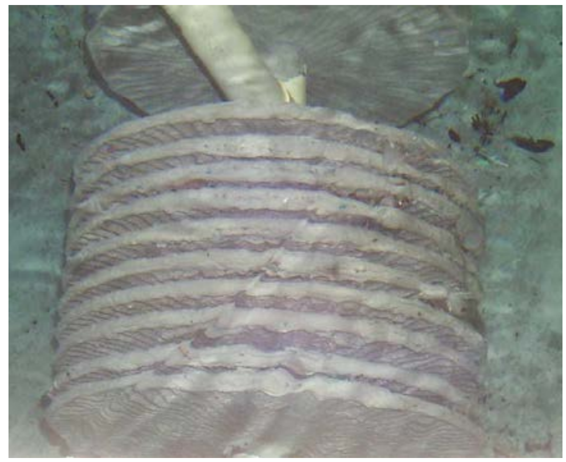


Figure 5-8: DE filter elements

exposed elements with a high pressure water hose for vacuum systems to backwashing for pressure systems. Either way, used DE should be collected in a separator and properly disposed of. Filter elements should be inspected and degreased at least 2-3 times a year.

Vacuum systems

1. Shut off main drain and skimmer drain valves.
2. Shut off recirculation pump when it looses its prime.
3. Close return line valves.
4. Turn on vacuum pump and pump water to waste.
5. Hose used D.E. off of filters. Wash to low end of collector tank.
6. Shut off vacuum pump when it looses its prime.
7. Open main drain and skimmer drain valves to refill collector tank.
8. Open precoat valve.
9. Turn on recirculation pump.
10. When tank is filled, turn off main drain and skimmer drain valves.

11. Add D.E. (1 lb for every 10 sq ft of filter area. A 1 lb coffee can holds about 8 oz of D.E.) to the collector tank. It will take about 15 minutes for the water to clear. ***WARNING! DE can be hazardous if inhaled. You should wear a mask when adding DE to the collector tank.***
12. Open return line.
13. Open main drain and skimmer drain lines.
14. Close precoat valve.

Pressure systems

1. Shut off recirculation pump.
2. Close return line (and heater lines).
3. Open waste valve.
4. Open valves to reverse flow through filter.
5. Turn on recirculation pump
6. Run until water runs clear through sight glass.
7. Shut off recirculation pump.
8. Open valves to allow for normal water flow through filter.
9. Open precoat recirculation lines. (Precoat to waste if no pre-coat line available)
10. Fill precoat pot with D.E. (1 lb for every 10 sq ft of filter area. A 1 lb coffee can holds about 8 oz of D.E.). The collector tank may be used as precoat pot.
11. Turn on recirculation pump and open precoat pot valve.
12. Open return line valve.
13. Close precoat valve.

Instant Review (or, what you need to know about filters)

- All sand filters have a pore size of 40 μm
- Rapid rate sand filters have a maximum flow rate of 3 gpm per sq ft
- High rate sand filters have a maximum flow rate of 15 gpm per sq ft
- Cartridge filters have a pore size of 20 μm
- Cartridge filters have a maximum flow rate of 0.375 gpm per sq ft
- DE filters have a pore size of 2 μm
- DE filters have a maximum flow rate of 2 gpm per sq ft

Figure 5-2: Pressure recirculation system

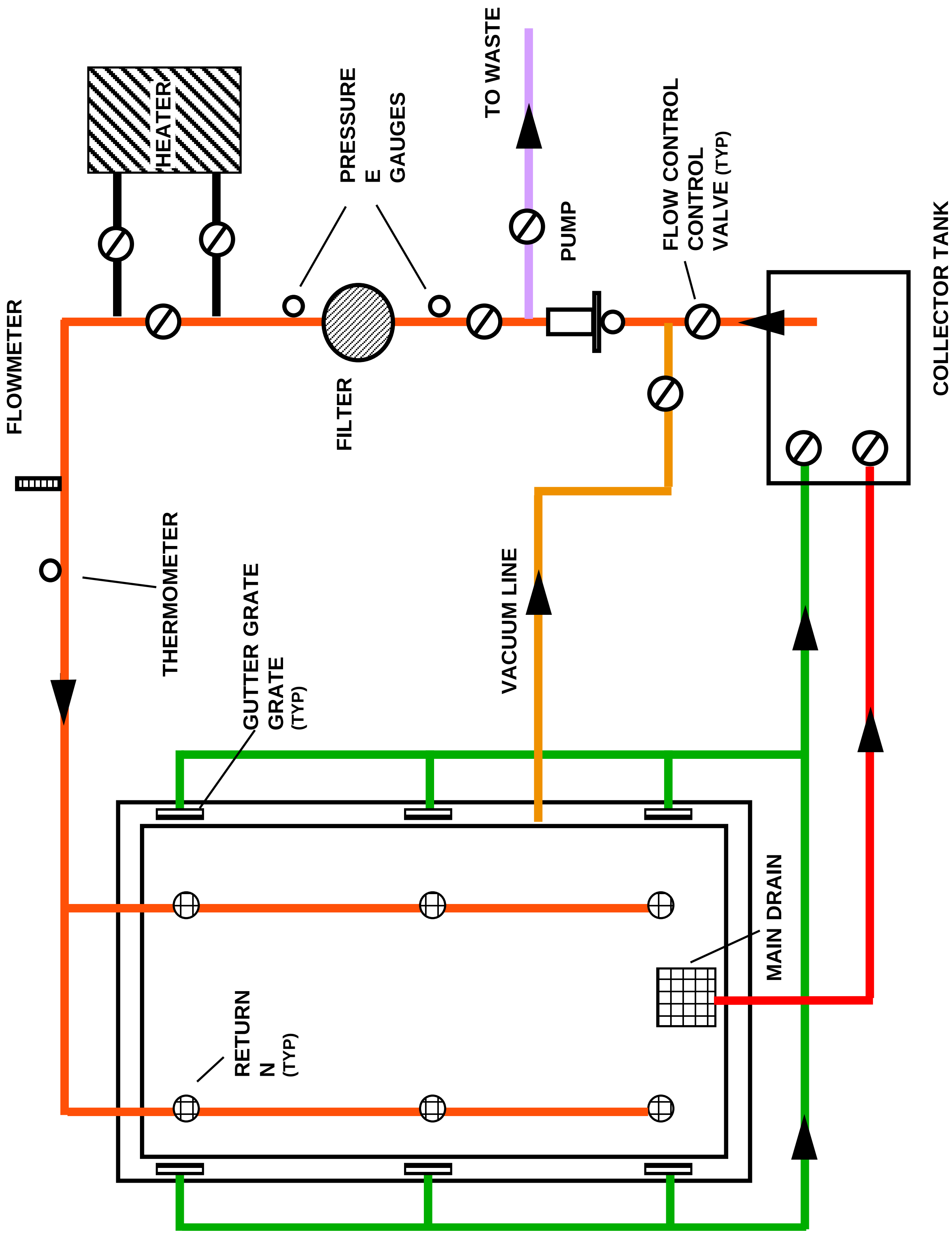
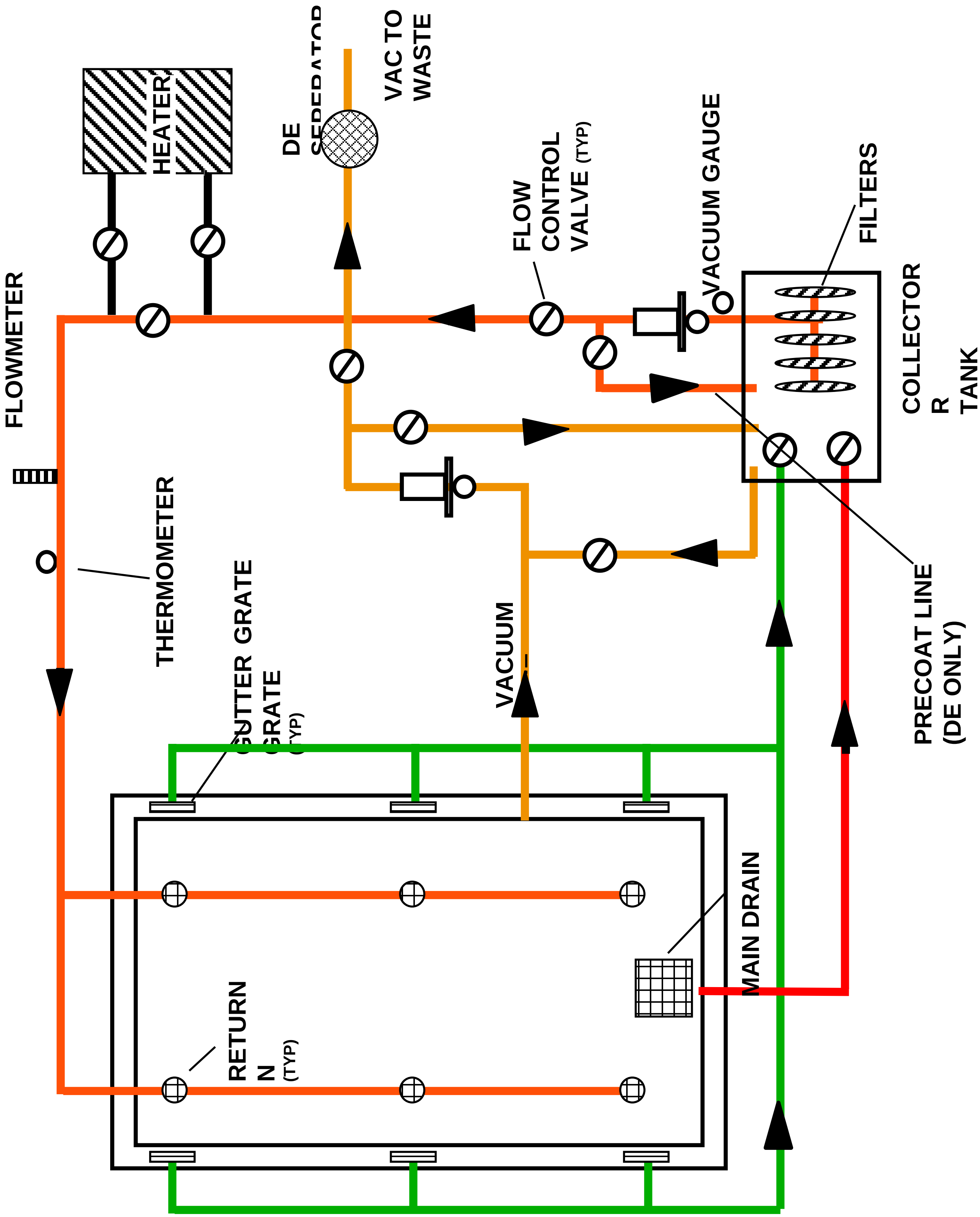


Figure 5-2: Vacuum recirculation system



CHAPTER 6:

ALGAE PREVENTION AND CONTROL

Algae are microscopic aquatic plants that can grow on pool surfaces or float freely in the water where conditions are favorable for their growth. Factors like wind, rain, contaminated swim suits, equipment and debris constantly carry algae spores into pool water. When conditions are right, the spores activate and grow so rapidly that a bloom may occur within a day. Ideal conditions for growth include poorly sanitized water, warm temperatures, sunlight, the presence of nitrates or other nutrients and/or the lack of proper filtration and circulation.

Algae itself is not harmful to swimmers, but its presence indicates improper sanitation and pools with an algae problem may also be harboring disease-causing organisms. Algae also creates a chlorine demand and consumes sanitizer that should be working on other contaminants. It also decreases filter effectiveness by clogging filter elements. In addition, algae breaks down bicarbonates in the water, thereby raising the pH and alkalinity significantly.

Types of Algae

There are over 20,000 varieties of algae, so it is much easier to refer to them by the color they exhibit, rather than naming specific species:

Green Algae

A very common variety, green algae can be found free floating or clinging to pool and spa walls. Green algae can be
easily removed by brushing, and are relatively easy to kill by superchlorination.

Yellow Algae

Also called mustard algae, this has a fuzzy, mold-like appearance and grows in the same broad pattern as green algae. Yellow algae has a preference for the more shaded areas of the pool, particularly the walls of the deep side of the pool and in areas where water circulation may be poor. It is very easy to remove with a brush but can be very stubborn to kill and recurrence is common. Multiple treatments with regular brushing thereafter may be necessary to control a chronic yellow algae bloom.

Black Algae

This species can be your pools' worst nightmare. Black algae, which is actually a dark blue-green in color, grows in concentric layers to form raised, button-like masses ranging from pea size to silver dollar size over pool walls and floors. Characteristics that give this algae such a nasty reputation include the tough, wax-like cap that protects the plant from high levels of chlorine, and its ability to grow so deeply into the plaster and concrete below that, in severe cases, the only solution is to remove the plaster and start over. Before superchlorinating, it is absolutely necessary to scrub all black algae growths aggressively with a stainless steel brush (NOT recommended for fiberglass pools!) in order to break open the protective shell and allow sanitizers or algicides to penetrate the plant. Entering the pool with scuba gear may be the only way to do this properly.

"Pink Algae"

This term is used from time to time in reference to pink streaks growing on pool gutters or walls. This is not an algae at all, but rather a harmless bacteria that is easily removed with brushing and superchlorinating.

<u>Removing Algae</u>

In the fight against algae the first defense is maintaining a clean pool and balanced water. However, weather extremes between service calls and heavy bathing loads can throw even the most carefully maintained pool into a crisis. Depending on the species, algae can become a constant battle once it gains a foothold and steps should be taken immediately to eliminate it when the first few spots appear. To treat any algae bloom it is necessary to:

1. Balance the water and maintain pH 7.2 to 7.6.
2. Turn off the pump and <u>close the pool.</u>
3. Add chlorine to 30 ppm (see shock table). Treatment is most effective in the evening when the water is cooler and the sunlight does not interfere with chlorine levels.
4. Brush walls vigorously.
5. Let sit overnight, repeat brushing in the morning.
6. Vacuum debris to waste, clean filters, and balance the water before reopening the pool.
7. Repeat if necessary.
8. Balance the water and reopen the pool

Table 4-6 (page 34) provides a quick and easy reference to the amount of chemical needed to increase the Free Active Chlorine level to 30 ppm in any pool.

Algicides

Free Active Chlorine is by far the most cost-effective and reliable means of treating algae. However, there is an ever-growing number of alternative algae treatments on the market and it is nearly impossible to give a comprehensive list of available products. If it is necessary to use combination algicides to eliminate a particularly stubborn bloom, it is recommended the pool operator seek the advice from the chemical supplier to determine the combinations that are currently most effective.

Some of the more common classes of compounds you may encounter include:

- **Quaternary Ammonium Based Algicides (QUATS):** Inexpensive organic nitrogen compounds. Although effective, QUATS disappear quickly, tend to foam, and may consume halogen sanitizers.
- **Cationic Polymeric Algicides (Polyquats):** Effective but expensive, polyquats are nearly side effect free. They do not foam and work well with halogen sanitizers.
- **Metal Ions:** Copper or silver ions can be effective in controlling algae under ideal conditions. However, staining can occur if not used properly. (See Chapter 3 page 22).
- **Chlorine or Bromine Compounds:** Very effective algicides. Just be sure that you are not paying for overpriced packaging.

CAUTION!! Never add Copper Sulfate to a swimming pool. The copper in the compound can stain the surface blue-green.

Algae Prevention

No matter your choice in algicides, keep in mind that it takes a great deal of money, time, and effort to eliminate an established algae problem. Prevention is the best approach.

To avoid or minimize the risk of any algae bloom it is necessary to brush the pool routinely to remove accumulation of dirt in rough and pitted areas of the pool surface. In addition, keep filters, skimmer baskets and lint strainers clean, vacuum the pool often to keep it free of spore-carrying leaf debris. If using the same equipment on multiple pools, care must be taken to properly disinfect your cleaning equipment to avoid transfer of algae from one pool to another. Finally, and most importantly, maintain chemically balanced water at all times.

Table 4-6: 30 ppm Shock Table for Algae Removal

% Available Chlorine	Volume of water (gallons) 250	400	1000	5000	20000	50000	100000
5	2.36 cp	1.89 pt	2.36 qt	2.95 gal	11.8 gal	29.5 gal	59.0 gal
10	1.18 cp	0.94 pt	1.18 qt	1.48 gal	5.90 gal	14.8 gal	29.5 gal
12	0.98 cp	0.78 pt	0.98 qt	1.23 gal	4.92 gal	12.3 gal	24.6 gal
35	2.86 oz	4.58 oz	11.4 oz	3.57 lb	14.3 lb	35.7 lb	71.5 lb
60	1.67 oz	2.67 oz	6.67 oz	2.08 lb	8.34 lb	20.8 lb	41.7 lb
65	1.54 oz	2.46 oz	6.16 oz	1.92 lb	7.70 lb	19.2 lb	38.5 lb
90	1.11 oz	1.80 oz	4.45 oz	1.39 lb	5.56 lb	13.9 lb	27.8 lb
100	1.00 oz	1.60 oz	4.00 oz	1.25 lb	5.00 lb	12.5 lb	25.0 lb

1 gallon = 4 quarts = 8 pints = 16 cups = 128 fl ounces
1 quart = 2 pints = 4 cups = 32 fl ounces
1 pint = 2 cups = 16 fl ounces
1 pound (lb) = 16 ounces (oz)

Sodium Hypochlorite is **12-15%** available chlorine (liquid)
Calcium Hypochlorite is **65-70%** available chlorine (tablet or granular)
Trichlor is **90%** available chlorine (tablet or granular)
Dichlor is **56-62%** available chlorine (granular)
Gas Chlorine is **100%** available chlorine

CHAPTER 7:

TROUBLESHOOTING

Problem	Possible Solutions
Cannot keep Chlorine in the pool	1. Check stabilizer level in the pool. Maintain cyanuric acid at 20-30 ppm. 2. Some algicides tie up chlorine. Make sure that any algicide you're using does not. 3. Old chlorine. Make sure that any chlorine you buy is fresh. 4. High chlorine concentration may be bleaching your reagent. Dilute the sample 1:2 or 1:5 and re-test. 5. Pool may be leaking. Check pool for leaks.
Cloudy water	1. Poor filtration. Check to make sure that recirculation system is functioning properly. 2. Early algae growth. Shock pool. 3. pH too high. Maintain pH of 7.2-7.8. 4. High total alkalinity. Maintain 80-120 ppm. 5. High TDS. Drain pool partially and refill with fresh water. 6. Use of calcium products or soda ash (temporary cloudiness) 7. Diatomaceous earth in pool water. If you have a DE filter system, check filter elements for damage.

Problem	Possible Solutions
Low flow	1. Filters dirty. Clean filters. 2. Filters clogged with oils. Degrease filters. 3. Incorrectly sized flowmeter. Install correct flowmeter.

Problem	Possible Solutions
	4. Flowmeter stem clogged or column crusted with scale or dirt. Remove flowmeter and clean with a mild acid solution. 5. Check pipes for obstructions. 6. Check recirculation pump for proper function. (clogged impeller, clogged lint strainer)
Patrons complain of eye and skin irritation	1. Chloramines in pool. Check for combined chlorine and perform breakpoint chlorination if necessary. 2. pH incorrect. Maintain 7.2-7.8. 3. Insufficient or excessive chlorine. Maintain 1-5 ppm in pools and 2-10 ppm in spas. 4. Deteriorating fiberglass pool and spa surfaces with causes rashes and itching of those in contact with the surfaces.
Chronic algae problems	1. Poor water balance. Maintain proper chemistry 2. Inadequate removal of initial bloom. 3. Poor filtration and circulation. See below. 4. Overhanging trees. Remove or prune back trees. 5. Etched and pitted pool surface. 6. Presence of nitrates. Partially drain pool and refill. 7. Presence of phosphates. Use phosphate removing chemical or partially drain and refill pool.
Pool surface is stained *Colors:* *Blue-green--copper.* *Black-purple--manganese.* *Red-brown--iron.*	1. Water may be chemically imbalanced. Maintain proper water chemistry. 2. If system has metal ionizer for disinfection, check for proper function. 3. Small stains (ON MARCITE ONLY) can be removed with #220 grit waterproof sandpaper. 4. Replace metal equipment in recirculation system with plastic. 5. Add sequestering agent to pool. 6. Acid wash pool.

Problem	**Possible Solutions**
Water is discolored	1. Water may be chemically imbalanced. Maintain proper water chemistry. 2. Replace metal equipment in recirculation system with plastic. 3. Add sequestering agent to pool. 4. A low water pH and alkalinity will strip copper from a spa heater and create bright blue-green water when pH is raised. Drain and refill spa. Maintain pH of 7.2-7.8 and alkalinity of 80-120 ppm at all times

Corrosion of metal parts	1. Low pH. Maintain 7.2-7.8. 2. Low total alkalinity. Maintain 80-120 ppm. 3. Chloramines in air (indoor pool) or in water will corrode handrails and ladders. Polish stainless steel routinely, air circulation of the indoor pool facility. maintain pool free of
Scale formation on surfaces and equipment	1. High pH. Maintain 7.2-7.8. 2. High calcium hardness. Maintain 200-400 ppm. 3. High total alkalinity. Maintain 80-120 ppm. 4. High TDS. Partially drain pool and refill.

GLOSSARY

Acid A chemical which lowers pH when added to water.

Acid Demand The amount of acid necessary to lower the pH to the proper range

Algae Microscopic aquatic plant life that grows on pool surfaces or floats freely in the water. The presence of algae discolors the water and/or pool surfaces and indicates improper sanitation. Green, black, and yellow (mustard) algae are most common.

Algicide A chemical used to kill or prevent the growth of algae.

Alkali A term applied to carbonates and hydroxides (See **Base**).

Alkaline The property of a compound that allows it to neutralize an acid.

Alkalinity A measure of the pH-buffering capacity of water.

Ammonia (NH_3) A chemical compound of hydrogen and nitrogen that combines with free chlorine in pools to make chloramines, or combined chlorine.

Amphoteric A chemical compound with the capacity of serving either as an acid or base, such as sodium bicarbonate.

Backwash The process of cleaning a swimming pool filter by reversing the flow of water through it.

Balanced Water Water which has the correct values of pH, alkalinity, and calcium hardness. Water out of balance can cause corrosion or scaling.

Base A chemical which raises the pH when added to water. Sodium carbonate (soda ash) and sodium hydroxide (caustic soda commonly known as lye) are examples of bases.

Bathing Load The maximum number of persons allowed in the pool at one time.

Breakpoint Chlorination The amount of chlorine required to oxidize (remove) all combined chlorine compounds in the water completely.

Bridging Buildup of a body coat on diatomaceous earth filter elements to the point where the body coats of the two adjacent elements touch.

Bromamine A group of bromine-ammonia compounds formed when bromine combines with organic wastes in the water (urine, etc.).

Bromine A sanitizer in the same chemical family as chlorine (halogens).

Bromine Demand The amount of active bromine required to destroy and oxidize bacteria, algae, and organic waste. When the "demand" is satisfied the water is considered safe to use.

Buffer A chemical which helps water resist pH change. Sodium bicarbonate is one type of effective buffer.

Chelate See sequester

Calcium Hardness The amount of calcium dissolved in water.

Calcium Hypochlorite ($Ca(OCl)_2$) A compound of calcium and chlorine used in a white granular or tablet form.

Cartridge Filter A pool water filter that uses paper or fabric-like cartridges as a filtering medium.

Chloramines A group of chlorine-ammonia containing compounds (NH_2Cl) formed when chlorine combines with organic wastes (such as urine) in the water.

Chlorine A commonly used strong oxidizer and sanitizer. Chlorine is added to pool water to destroy and inhibit bacterial and algal growth in addition to oxidizing (burn out) unwanted organic matter.

Chlorine Demand The amount of chlorine necessary to oxidize all organic matter in water before active chlorine residual can be achieved.

Chlorinated Isocyanurates A granular or tablet form of chlorine compounds containing cyanuric acid as a stabilizer.

Chlorine Residual (FAC) Also called free active or free available chlorine (FAC). The amount of chlorine available for sanitation after the chlorine demand has been met.

Coliform Organisms Bacteria found in the intestines of warm-blooded animals. Their presence in pool water indicates the possibility of the presence of disease-causing bacteria.

Combined Chlorine (CAC or CC) The amount of chlorine and ammonia combined to form chloramines. Combined chlorine is a very poor sanitizer.

Corrosion The tendency for metal parts or plaster to be eaten away, usually due to acidic or very soft water conditions.

Cross Connection An unprotected connection between pool water and a water supply source. Protective measures, such as air gaps or vacuum breakers, prevent contamination of public drinking water.

C/T Constant Free chlorine (in ppm) times contact time (in minutes).

Cyanuric Acid (CYA) The chemical 2,4,6, trihydroxy-s-triazine, also known as stabilizer or conditioner. Prevents sunlight from dissipating chlorine.

Diatomaceous Earth (DE) A white powder composed of fossilized skeletons of one-celled organisms called diatoms. Used as a filter medium.

DPD (N,N-Diethyl-p-phenylenediamine) The reagent used in test kits to indicate free active chlorine or bromine. DPD turns pink when chlorine or bromine is present.

Disinfect To kill bacteria, viruses, and parasites in pool water.

Dry Acid A granular chemical that slowly lowers pH and total alkalinity. Sodium bisulfate is a strong dry acid.

Effluent The outflow of water from a pump, filter, or pool.

Equalizer Line A line from below the pool surface to the skimmer, designed to prevent air being drawn into the system when the water level drops below the skimmer inlet.

Filter A device for removing suspended particles from pool water.

Filter Cycle The time of filter operation between cleaning procedures.

Filter Capacity The maximum amount of flow a filter system can process.

Filter Septum That part of a filter on which DE is deposited. Usually consists of cloth or other fine mesh material.

Flocculent A chemical that can be added to the water to combine or coagulate small dirt particles into larger ones.

Flow Meter A calibrated device that indicates the rate of flow at that given point (as gallons per minute or gpm).

Flow Rate Amount of water flowing through a recirculation system. Typically measured in gallons per minute (gpm).

Halogens Any of the five elements fluorine, chlorine, bromine, iodine, and astatine that form part of group VII A of the periodic table.

Hydrochloric Acid (HCl) Commonly called muriatic acid when diluted. A very strong acid used in pools for pH control and for certain cleaning needs. Use extreme caution when handling.

Hypobromous Acid (HOBr) Termed "free bromine," it is one of the active forms present in bromine treated water.

Hypochlorous Acid (HOCl) An unstable, weak acid, formed by chlorine in water. HOCl has strong bleaching and disinfectant characteristics (see chlorine residual or FAC).

Influent Water flowing into a filter, a pump, a chemical feeder, or pool.

Liquid Chlorine Sodium hypochlorite

Langelier Index (see saturation index)

Micron or Micrometer (µm) Unit of measure representing one thousandth of a millimeter.

Muriatic Acid A 30% solution of hydrochloric acid.

O-ring A small rubber ring found in filter valves and wedged tightly between the lid and the main opening to the pump and its strainer pot. It ensures a tight seal and, therefore, the proper pressure in the pump or filter.

Organic Wastes Waste such as saliva, urine, perspiration, fecal matter, and suntan oils which swimmers introduce into the pool. Organic wastes do not filter out and must be chemically oxidized (see shock treatment).

ORP or Oxidation-Reduction Potential Also called Redox, ORP is a measure of the oxidizing properties of the sanitizer in the water. This is determined by a special electrode and expressed in milivolts (mV).

OTO or Orthotolidine A chemical reagent which reacts with total chlorine or bromine and turns yellow. ***OTO is not approved for use in commercial swimming pools.***

Oxalic Acid A mild organic acid, usually in the form of a white granular substance. Used specifically to dissolve rust stains on pool surfaces. Poisonous; handle with caution.

Pathogen A microorganism that causes disease (bacteria, fungi, parasites, viruses).

pH A term used to describe the water's acidity or basicity (alkalinity). The pH range is from 0 to 14. A pH value of 7 is neutral. pH values below 7 are acidic and values higher than 7 are basic.

Phenol Red The most commonly used test reagent for measuring pH in pools.

Parts Per Million (ppm) A concentration unit used to indicate the trace presence of various chemicals in pool water. ppm may also be expressed as milligrams per liter or mg/L.

Precoat The layer of DE deposited on the filter septa at the start of the filter run.

Pressure Differential The difference in pressure between two points in a hydraulic system (i.e., the pressure difference between the influent and effluent points of a filter).

Quaternary Ammonium Compounds Also known as QUATS, used to combat algae growth in pools.

Reagents Standardized chemicals used to test various aspects of pool water chemistry (pH, chlorine, etc.).

Sanitizer A chemical which disinfects.

Saturation Index A mathematical calculation that predicts if the pool water is corrosive, scale-forming or balanced.

Scale Hard, insoluble mineral deposits (usually calcium carbonate) which form on pool surfaces and clog filters, heaters, pumps, and flow meters.

Sequester or Chelate Addition of specially formulated compounds to tie up iron, copper, or calcium carbonates to prevent staining or scaling.

Shock Treatment (Superchlorination) A process in which excess chlorine is added to the pool water, usually in the range of 10 to 20 ppm, to remove (oxidize) organic wastes.

Soda Ash (Na_2CO_3) Sodium Carbonate used to raise pH and increase total alkalinity in pool water.

Sodium Bicarbonate ($NaHCO_3$) A chemical used to raise total alkalinity content of a pool with little change in pH.

Sodium Bisulfate ($NaHSO_4$) A dry white powder that produces an acid solution when dissolved in water. Used to lower pH. Also called Dry Acid.

Sodium Hypochlorite (NaOCl) A liquid that provides 12% to 15% available chlorine. One of the most commonly used products for chlorination of pools.

Sodium Thiosulfate A chemical used to lower chlorine residual swimming pools.

Stabilizer (see cyanuric acid).

Titration A chemical test involving dropwise addition of a reagent until an endpoint or color change is reached.

Total Alkalinity (TA) The total amount of alkaline material (bases such as carbonate, bicarbonates, and hydroxides) present in the water. Total Alkalinity is a buffer. If too high, it makes pH hard to adjust. If too low, the pH will fluctuate excessively (see also Alkalinity).

Total Available Chlorine (TAC or TC) The combined amount of free active chlorine (FAC) and combined chlorine (CAC) in the pool water. (TC = FAC + CAC.)

Total Dissolved Solids (TDS) The total of dissolved materials in the water.

Turbidity Degree to which suspended particles in pool water obscure visibility

Water Hardness Refers to the amount of dissolved solids in the form of mineral salts, such as calcium and magnesium, in the water which can readily precipitate with some organic matter such as soaps, etc. Water hardness is usually expressed as the calcium carbonates ($CaCO_3$) content on water.

Wet Deck The 4 foot wide area around the pool perimeter and 16 feet towards the restrooms.

ABBREVIATIONS

AFO: Aquatic facilities operator
CAC or CC: Combined Available Chlorine or Combined Chlorine (Chloramines)
$CaCl_2$: Calcium chloride
$CaCO_3$: Calcium carbonate
$Ca(OCl)_2$: Calcium hypochlorite (granular chlorine)
CCC: Chlorine Chemistry Council
CDC: Center for Disease Control and Prevention
CH: Calcium hardness
Cl_2: Chlorine gas
CO_2: Carbon dioxide
CPO: Certified pool operator
CYA: Cyanuric acid (chlorine stabilizer)
DE: Diatomaceous earth
DPD: Diethyl-P Phenyenediamine
EPA: Environmental Protection Agency
FAC: 1.- Free ACTIVE Chlorine 2.- Florida Administrative Code.
H^+ : Hydrogen ion
HOCL : Hypochlorous acid (the active form of chlorine)
H_2O: Water
HCl: Hydrochloric acid.
Mg/L : milligram per liter (same amount as ppm.)
MMWR : Morbidity and Mortality Weekly Report (a CDC publication)
Na_2CO_3: Sodium carbonate (Baking soda)
$NaHSO_4$: Sodium bisulfate (Dry acid)
NaOCl: Sodium hypochlorite (Liquid Chlorine)
NRPA: National Recreation and Parks Association
NSF: National Sanitation Foundation

NSPF: National Swimming Pool Foundation
NSPI: National Spa and Pool Institute
OCl^-: Hypochlorite ion
ORP: Oxidation-reduction potential
OTO: Orthotolidine
pH : Potential hydrogen
PPM : Part per million (same amount as mg/L)
PPOA: Professional Pool Operators of America
TA: Total alkalinity
TAC or TC: Total available chlorine
TDS: Total dissolved solids
QUATS: Quaternary ammonia compounds
WHO: World Health Organization

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APPENDIX A:

SWIMMING POOL CALCULATIONS

Conversion Factors

Below are some conversion factors that may be useful in your career as a pool operator.

- 1 ft = 12 in
- 1 sq ft -- a square 12 in wide by 12 in long. 1 sq ft = 144 sq in.
- 1 cu ft -- a cube 12 in wide by 12 in long by 12 in high. 1 cu ft = 1728 sq in.
- °F = 9/5 (°C +32)
- °C = (5/9 x °F) + 32
- 1 cu ft = 7.48 gal = 62.4 lb
- 1 gal = 4 qt = 128 fl oz
- 1 qt = 2 pt = 32 fl oz
- 1 pt = 2 cup = 16 fl oz
- 1 lb = 16 oz
- 1 yd = 3 ft
- 1 m = 3.28 ft

Calculation of Surface Area

Calculation of pool surface areas can come in handy in a myriad of ways. The functions are very simple and can be accomplished with an inexpensive calculator.

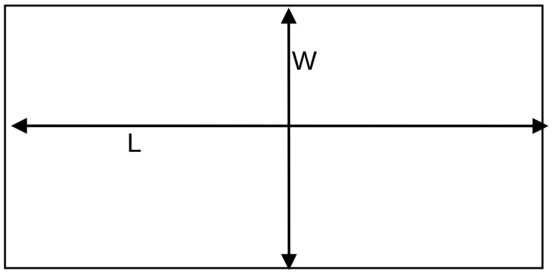
Some constant abbreviations we will use are summarized below.

D = depth
A = area
V = volume
L = length
W = width
r = radius (1/2 the diameter)
π = pi = 3.14

Calculating the surface area of the most common shapes are explained below.

Area of a rectangle

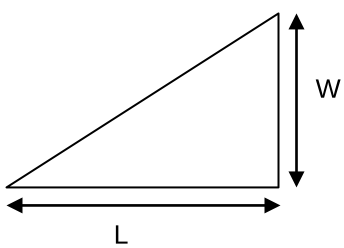
A = L x W



Example:
L = 35 ft.
W = 20 ft
A = L x W = 35 ft x 20 ft = **700 sq ft**

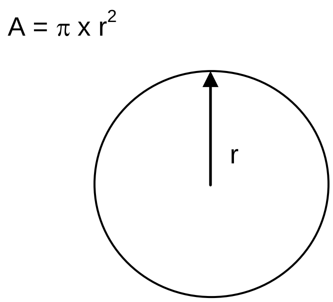
Area of a Triangle

A = 1/2 x L x W



Example:
L = 15 ft
W = 10 ft
A = 1/2 x L x W = 1/2 x 15 ft x 10 ft = **75 sq ft**

Area of a circle



Example:
r = 10 ft
A = $\pi \times r^2$ = 3.14 x 100 sq ft = **314 sq ft**

The formulas for some more unusual shapes are summarized in Fig. A-1.
When calculating surface area of a complex shape, it is advised to break the shape into multiple simple shapes.

Example 1: Calculation of internal surface area of a circular pool

You are bidding to resurface a circular wading pool 14 ft wide and 2 feet deep. What is the internal surface area of the pool?

First, calculate the surface area of the bottom:

r = 7 ft
A = $\pi \times r^2$ = 3.14 x $(7 \text{ ft})^2$ = 153.86 sq ft

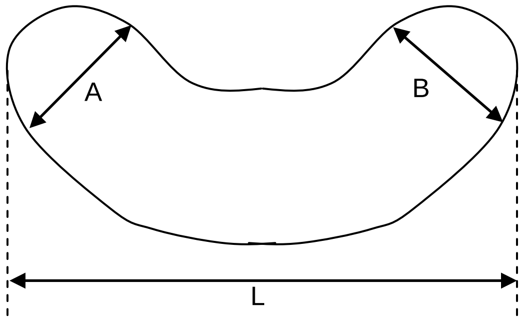
Second, calculate the surface area of the walls (use the area of a cylinder: Fig A-1).

r = 7 ft
D = 2 ft
A = 2 x π x r x D = 2 x 3.14 x 7ft x 2 ft = 87.92 sq ft

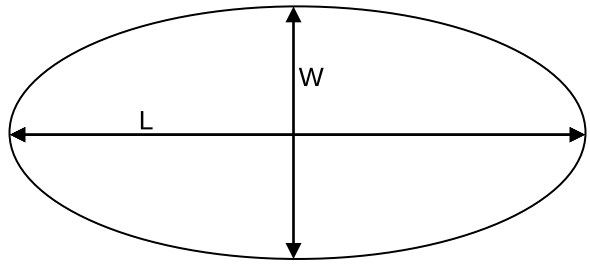
Finally, add the two together:

153.86 sq ft + 87.92 sq ft = ***241.8 sq ft***

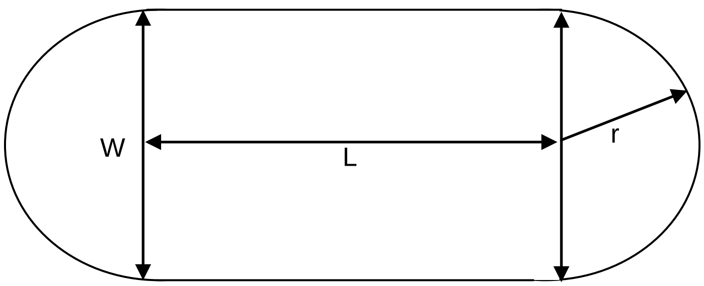
Figure A-1. Calculation of surface area for different shapes



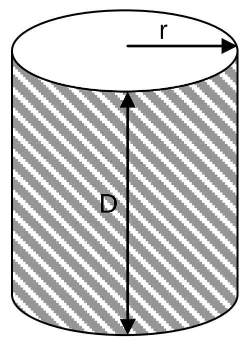
Area of Kidney Shape =
$(A + B) \times L \times 0.45$



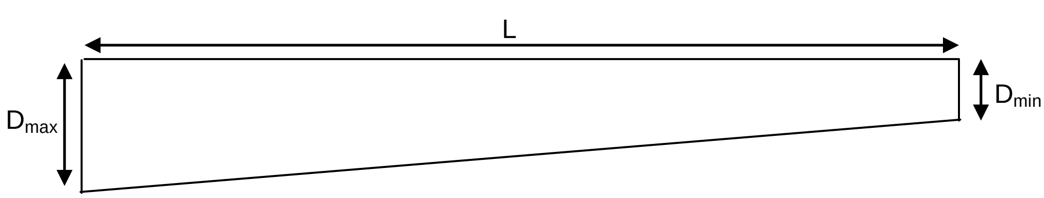
Area of Oval =
$$\frac{(L \times W)}{2} \times \pi$$



Area of Oblong =
$(L \times W) + \pi \times r^2$



Area of Cylinder Walls =
$2 \times \pi \times r \times D$



Area of Internal Pool Wall =
$$\frac{L \times (D_{min} + D_{max})}{2}$$

Calculation of volume

Volume is important information to know about a swimming pool. It is particularly useful when maintaining proper chemistry requires manual addition of chemicals to the pool and for calculating minimum required filtration rates for commercial pools.

Calculating average depth

For pools with a constant depth, no calculation is needed. For pools with a sloping bottom, assuming constant slope,
average depth is simply minimum depth plus the maximum depth divided by two.

$$D_{avg} = \frac{(D_{min} + D_{max})}{2}$$

Example 2: Calculation of average depth

Consider a pool with the shallow end depth of 3 ft and a deep end depth of 7 ft. What is the average depth?

$$D_{avg} = \frac{(D_{min} + D_{max})}{2}$$

Calculating volume

Volume is simply the surface area of the pool multiplied by the average depth.

$$V = A \times D_{avg}$$

Example 3: Pools with constant depth

A circular wading pool has a radius of 10 ft and a constant depth of 2.5 ft. What is the volume?

r = 10 ft
$A = \pi \times r^2 = 3.14 \times (10\text{ ft})^2 = 314$ sq ft.
D = 2.5 ft
V = A x D = 314 sq ft x 2.5 ft = 785 cu ft

V = 785 cu ft x 7.48 gal/cu ft = ***5,872 gal***

Note that the final value of 785 cu ft had to be multiplied by 7.48 in order to convert the answer to gallons.

Example 4: Pools with constant slope

An oval pool 35 ft long and 20 ft wide has a shallow end depth of 3 ft and a deep end of 6 ft. Assuming the bottom slope is constant, what is the volume?

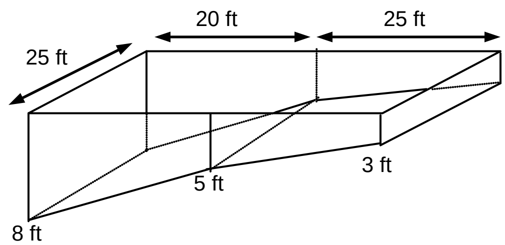
$A = (L/2 \times W/2) \times \pi = (87.5 \text{ sq ft}) \times 3.14 = 549.5 \text{ sq ft}$

$D_{avg} = (D_{min} + D_{max}) / 2 = (3 \text{ ft} + 6 \text{ ft}) / 2 = 4.5 \text{ ft}$

$V = A \times D_{avg} = 549.5 \text{ sq ft} \times 4.5 \text{ ft} = 2472.75 \text{ cu ft} \times 7.48 \text{ gal/cu ft} =$ ***18,496 gal***

Calculating volume of pools with slope breaks

If the pool you are trying to calculate for has a slope break, calculating the average depth



by averaging the minimum and maximum depths will not work. The way to handle these problems is to split the pool into two (or more) sections and calculate each one separately.

Example 5: Pools with a slope break

Consider a rectangular pool 45 ft long by 25 ft wide. The shallow end is 3 ft. The slope break is 5 ft, occurring 25 ft from the shallow end wall. The deep end is 8 ft.

The best way to handle this is to calculate the volume from the shallow end to the slope break, and from the slope break to the deep end, then add the two together.

$$D_{avg} = \frac{(3 \text{ ft} + 7 \text{ ft})}{2} = \boldsymbol{5 \text{ ft}}$$

Shallow end volume (V_s)

$W = 25$ ft
$L_s = 25$ ft
$A_s = L_s \times W = 25 \text{ ft} \times 25 \text{ ft} = 625 \text{ sq ft}$
$D_s = (D_{min} + D_{slope\ brk})/2 = (3 \text{ ft} + 5 \text{ ft})/2 = 4 \text{ ft}$
$V_s = A_s \times D_s = 625 \text{ sq ft} \times 4 \text{ ft} = 2{,}500 \text{ cu ft} \times 7.48 \text{ gal/cu ft} = 18{,}700 \text{ gal}$

Deep end volume (V_d)

$W = 25$ ft
$L_d = 20$ ft
$A_d = L_d \times W = 25 \text{ ft} \times 20 \text{ ft} = 500 \text{ sq ft}$
$D_d = (D_{sb} + D_{max})/2 = (5 \text{ ft} + 8 \text{ ft})/2 = 6.5 \text{ ft}$
$V_d = A_d \times D_d = 500 \text{ sq ft} \times 6.5 \text{ ft} = 3{,}250 \text{ cu ft} \times 7.48 \text{ gal/cu ft} = 24{,}310 \text{ gal}$

<u>Total volume</u>

$V_s + V_d$ = 18,700 gal + 24,310 gal = ***43,010 gal***

If you have any questions regarding the volume, required flow rate, or equipment on a public swimming pool, do not hesitate to call your local health department.

APPENDIX B:
Useful Websites

DOH
Florida Department of Health
www.myfloridaeh.com

CDC
Centers for Disease Control
http://www.cdc.gov/healthySwimming/

Pool & Spa News
www.poolspanews.com/

NSPF
National Swimming Pool Foundation
www.nspf.com

NSPI
National Spa and Pool Institute
www.nspi.co.za/

CES
Commercial Energy Specialists
www.ceswaterquality.com/index.php

FSPA
Florida Swimming Pool Association
www.floridapoolpro.com/

PPOA
Professional Pool Operators of America
www.ppoa.org