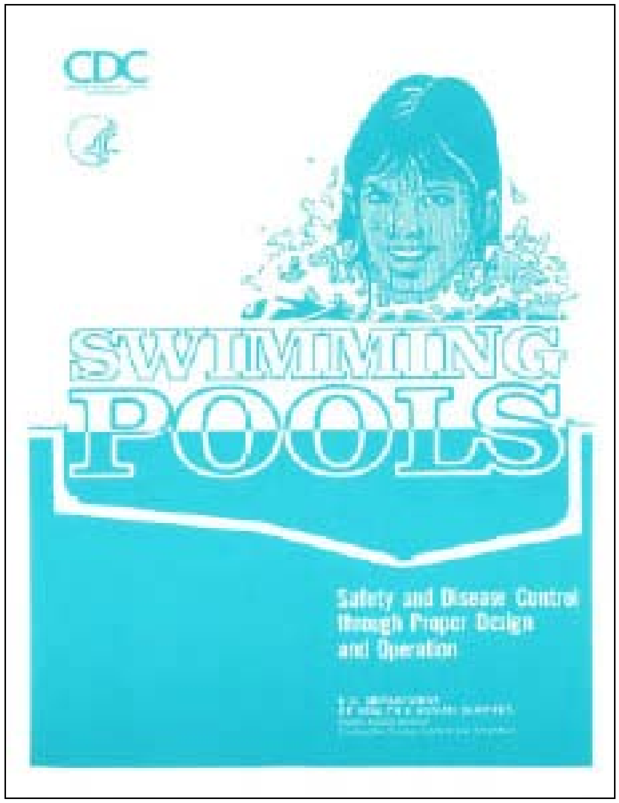
CDC
SWIMMING
POOLS
Safety and Disease Control
through Proper Design
and Operation

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U.S. DEPARTMENT
OF HEALTH & HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention

SWIMMING POOLS

Safety and Disease Control through Proper Design and Operation

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES / PUBLIC HEALTH SERVICE / CENTERS FOR DISEASE CONTROL
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Foreword

Since man normally does not live in an aquatic environment, he is potentially at risk each time he consumes or has bodily contact with water. Diseases such as typhoid and paratyphoid fever, amoebic dysentery, leptospirosis, and bacillary dysentery, sometimes associated with contaminated drinking water, can also be spread through contact with the contaminated water of swimming pools. In addition, the swimming pool and surrounding areas are often the source of injuries and frequently play a role in the transmission of infections of the eye, ear, nose, and throat, and in the spread of athlete's foot, impetigo, and other dermatoses. In light of these considerations, the proper construction and maintenance of public swimming pools is a public health problem of great importance.

The first edition of this training manual was published in 1959. It was prepared for use by health jurisdictions in training programs designed specifically for public health workers and swimming pool operators. The intervening years have brought many changes in the concepts of swimming pool chemistry and disinfection, testing, and operation. Professor David G. Thomas of the State University of New York has assisted in updating this manual.

This edition represents the latest information on design, construction, operation, maintenance, and the effect of each on disease control practices and safety procedures. It is organized specifically to serve as a training and reference guide for State and local personnel, and especially for further use in the conduct of their own in-service training programs. In addition, it is hoped that this volume will be useful in the development of training programs which will benefit operators and owners of swimming pools.

Comments provided by the reviewers were especially helpful. These reviewers include individuals from the Georgia Department of Human Resources, East Tennessee State University, California Department of Health, Fairfax County Health Department, Florida Department of Health and Rehabilitative Services, and the Public Health Joint Committee on Swimming Pools and Bathing Places of the American Public Health Association. Their assistance in the preparation of this manual is greatly appreciated.

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CHAPTER 1

Introduction to Swimming Pool Sanitation

I. Swimming Pools and Health

A. GENERAL

Current epidemiologic evidence indicates that well constructed and operated swimming pools and other public bathing places are not a major public health problem, but potentially they could become one.

B. DISEASES OF CONCERN

1. **Intestinal diseases** – Typhoid fever, paratyphoid fever, amoebic dysentery, leptospirosis, and bacillary dysentery can be a problem where swimming waters are polluted by domestic or animal sewage or wastes.

   Swimming pools have been implicated in outbreaks of leptospirosis in Wyoming, Idaho, and Georgia.

2. **Respiratory diseases** – Colds, sinusitis, and septic sore throat can spread more readily in swimming areas due to close contact, coupled with lowered resistance due to exertion.

3. **Eye, ear, nose, throat, and skin infections** – The exposure of delicate mucous membranes, the movement of harmful organisms into ear and nasal passages, the excessive use of water treatment chemicals, and the presence of harmful agents in the water can contribute to eye, ear, nose, throat, and skin infections. Close physical contact and the presence of fomites also help to spread athlete's foot, impetigo, and dermatitis.

C. INJURIES

Injuries and drowning deaths are by far the greatest problem at swimming pools. Lack of bather supervision is a prime cause, as is the improper construction, use, and maintenance of equipment. Some particular problem areas are:

1. Loose diving board.
2. Poorly located water slides.
3. Projecting or ungrated pipes
4. Improperly installed or maintained electrical equipment.
5. Improperly vented chlorinators.
6. Glass objects in the pool area.

II. The Role of the Official Regulatory Agency

A. The agency cooperates with local governing bodies toward the adoption of sound swimming pool construction and operation ordinances.

B. It serves as consultant to swimming pool contractors, architects, and engineers.

C. It reviews plans and specifications for new and remodeled pools.

1. **Importance of preconstruction plan review**
   a. Avoid code violations.
   b. Build in useful details which are not part of the code.
   c. Develop the owner-agency relationship on a sound basis from the start.
      (1) This first contact can build a "consultant" relationship.
      (2) Working with the owner affords an opportunity to discuss agency operational requirements and procedures.

2. **Rules of thumb for plan review**
   a. Process plans quickly.
   b. Apply regulations **UNIFORMLY** to all situations.
   c. Apply rules firmly, but with understanding.
   d. See that personnel who review plans are competent in pool design and layout methods.
   e. Assist prospective builders in clearing plans with other official departments.

D. The official agency follows up on construction of new and remodeled pools.

E. The agency provides inspectional services.

1. **Public and semipublic bathing places** – These pools should be inspected before opening, during operation, and at closing time.
2. **Private bathing places** – Inspection of these pools is usually on a request or complaint basis, depending on the workload of the department.

F. The agency develops educational programs for the public pool contractors, pool operators, and official agency personnel.

III. Types of Swimming Places

A. Natural outdoor ponds, rivers, and tidal waters are difficult to control from a sanitary standpoint.

B. Outdoor pools, partly artificial, partly natural, are also difficult to control from a sanitary standpoint. A typical example would be the widening of a stream bed with masonry units and using the stream flow to control water conditions.

C. Pools, outdoor or indoor, entirely of artificial construction.

1. Fill and draw pools depend on frequent emptying and refilling to maintain sanitary conditions and are generally no longer approved.
2. Natural flow-through pools are similar to those described in "B", but generally are more sanitary structures because of their more regular construction features. They depend on the flow of a stream, lake, or flowing well which has been diverted to flow in and out of the pool tanks.
3. Artificial flow-through pools are similar to natural flow-through pools, but are usually furnished with more suitable appurtenances for directing flow in, through, and out of the pool. Even so, uniform distribution of pool water is difficult to attain.

4. Recirculatory pools are the most satisfactory from the public health standpoint. They have, as part of the pool, equipment which filters and recirculates pool water to maintain satisfactory water quality.

IV. Basic Principles for Healthful Swimming

A. Control the introduction of dirt and infective material into the pool.

1. Personal cleanliness of the swimmers is important.
2. Proper design features preclude introduction of surface drainage, sewage pollution, windblown debris, sand, dirt, or vegetation from surrounding areas.

B. Remove or destroy as rapidly as possible any dirt and infective material which enters the pool.

1. Continuous disinfection of pool water helps maintain suitable conditions.
2. Recirculation and filtration at an adequate rate maintains good water conditions.

C. Construct and operate the pool in a satisfactory manner.

1. Pool equipment and appurtenances are safe.
2. Swimmers are supervised at all times.
3. The number of swimmers is controlled.

The following form is a model that can be used in accepting swimming pool plans for review

SWIMMING POOL CONSTRUCTION APPROVAL REQUEST FOR A ☐ **PUBLIC** ☐ **SEMI-PUBLIC**

Pool to Serve: ______________________________
(GIVE NAME OF COMMUNITY, MOTEL, TRAILER PARK, APARTMENT, ETC.)

Location of Pool: ______________________________ City: ______________

Pool Contractor: ______________________________ Phone: ______________

DESIGN DATA:

Pool surface area ______________ sq.ft.
Pool water volume ______________ gallons
Filtration rate *(6 hour turnover)* ______________ gpm

Total Filter Area Required: Diatomaceous earth filters ______________ sq.ft.
Sand filters ______________ sq.ft.
Rapid sand filters ______________ sq.ft.

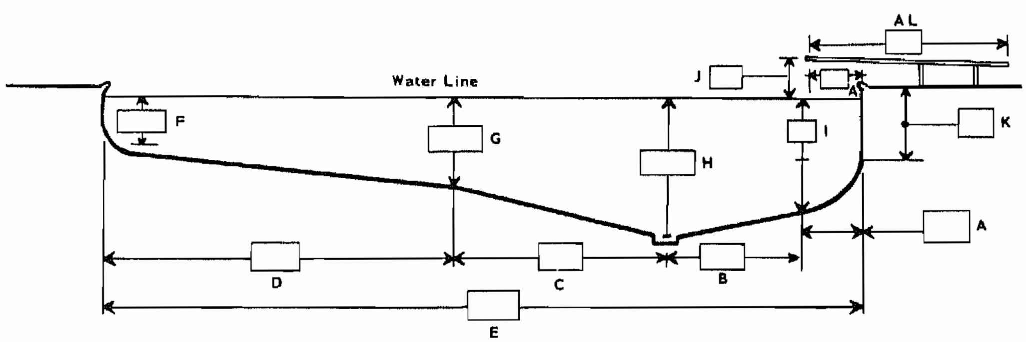
Scum Gutters: ☐ yes ☐ no
(SHOW DETAIL ON PLAN)

Recirculating Skimmers: number ________ mfg. ________ cat. number ________
Total weir length ______________ inches

Inlets: number ______________
☐ adjustable type
☐ orifice plate type

Pump: Distance from main drain ______________ feet
Pump installed ________ feet ☐ above ☐ below water level

SHAPE OF POOL BOTTOM:



INFORMATION TO BE SHOWN ON PLAN:

1. Plot plan — show north and prevailing wind direction and distance to existing water and sewer mains in the area.
2. Plan of pool — with dimensions.
3. Pool piping arrangement — indicating type and size of pipe and location of all valves.
4. Location of inlets, skimmers, main drain, vacuum hose conntection, ladders, steps, depth markers, diving boards, life guard chair, make-up water inlet, life line, point of chlorine application, flow meter, backwash sightglass and other necessary details.
5. Location and profile drawing of filtration equipment — with distance from pool.
6. Method and place of backwash and waste water disposal.
7. Pool deck area — show slope and widths, locate drains if use.
8. Detail of scum gutter if used.
9. If automatic cleaning equipment is to be installed — show piping layout.

GENERAL CONSTRUCTION INFORMATION:

Pool Structure: ☐ Gunite ☐ Poured concrete ☐ Other ____

Trim and Finish:
Pool walls and bottom ____
Coping ____
Tile ____
Depth markers at ____ feet ____ feet ____ feet ____ feet ____ feet ____ feet

Decking:
Type ____
Finish ____
Minimum width ____ feet

Filter Plant: mfg. ____ catalog number ____ NSF approval: ☐ yes ☐ no

Pressure sand and gravel filters:
Number ____ Dia. ____
Height in. ____
Total filter area of plant ____ sq.ft.
Circulation rate ____ gpm
Backwash rate ____ gpm
Turnover rate ____ hours

Diatomaceous earth filters:
Filter elements: ☐ cloth ☐ metal ☐ stone
Number filters ____
☐ Pressure type ☐ gravity ☐ vacuum
Total area of filter plant ____ sq.ft.
Circulation rate ____ gpm
Turnover rate ____ hours
Slurry feeder: ☐ yes ☐ no

Filter Accessories:
Air relief valves: ☐ automatic ☐ hand operated ☐ backwash sightglass
Pressure gauges: quantity ____ size ____
Flow meter mfg. ____
Vacuum gauges: quantity ____ size ____
Catalog number ____

Circulating Pump:
Size ____ x ____ hp Self priming: ☐ yes ☐ no Strainer size ____ in.
Circulating rate ____ gpm ____ tdh Backwash rate ____ gpm ____ tdh

Chemical Feeders: mfg. and type ____ Capacity ____ lbs. Quantity ____

Chlorinator: mfg. ____ Capacity ____ lbs. Quantity ____
☐ Gas type ☐ Electric hypo ☐ Other
☐ Erosion type Erosion rate ____ chlorine (mg/l per gallon)
Capacity ____
Chemical used ____

Other Equipment:
Deck area lights Quantity ____ Watts ____
Underwater lights Quantity ____ Watts ____
Diving boards Quantity ____ Length ____
Ladders Quantity ____ Treads ____
Life guard chairs Quantity ____
Life line Quantity ____ Length ____
Floats ____
Ring buoy Quantity ____ Diam. ____
Length rope ____ ft.
Sheperds crook Quantity ____ Handle ____ ft.
Fill spout ____ Dia. ____ Air gap ____ in.
☐ Above deck ☐ Submerged ** ☐ none
Wall brush: Handles ____ length ____ ft.
Leaf skimmer: Handles ____ length ____ ft.

Test sets: Chlor. res. (mfg.) ____
Model ____
pH (mfg.) ____
Model ____
Cyanuric acid (mfg.) ____
Model ____

Vacuum cleaner: Head size ____ Hose size ____
Length ____ mfg. ____
☐ Portable
☐ Integral *

Automatic cleaning equipment: ☐ yes ☐ no
mfg. ____

REMARKS: ____

Approved ____ STATE DEPARTMENT OF HEALTH Signed ____ CONTRACTOR'S SIGNATURE

Date Address Date

** See note 9, p. 1.*
*** Make-up water line must have check valve and vac. breaker installed and shown on plans.*

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CHAPTER 2

Constructing and Remodeling a Public Swimming Pool and Bathhouse

I. Basic Considerations of Recirculatory Pools

A. POOL FACILITIES LAYOUT

1. **Bathhouse (See Figure 1)** – The bathhouse contains facilities for the comfort and convenience of the patrons and the administration of the pool. It should contain dressing rooms, toilet facilities, showers, a pool control center, and an emergency aid and guard room.

2. **Filter Room** – The pool filter room houses the recirculation and filtration equipment, chemical treatment units (with the exception of gas chlorinators), chemicals, and supplies for repair. The filter room should be easily accessible to facilitate delivery of supplies.

3. **Chlorine Room** – A separate room is required if gas chlorine is used. It should be adjacent to the filter room and have direct access from outside the building.

4. **Equipment Room** – An equipment room should be provided for storage of such items as teaching, safety, and deck equipment; diving boards; and guard chairs. The room should be designed to accept 16-foot diving boards and rescue boats. The equipment room should be directly accessible to facilitate delivery of equipment.

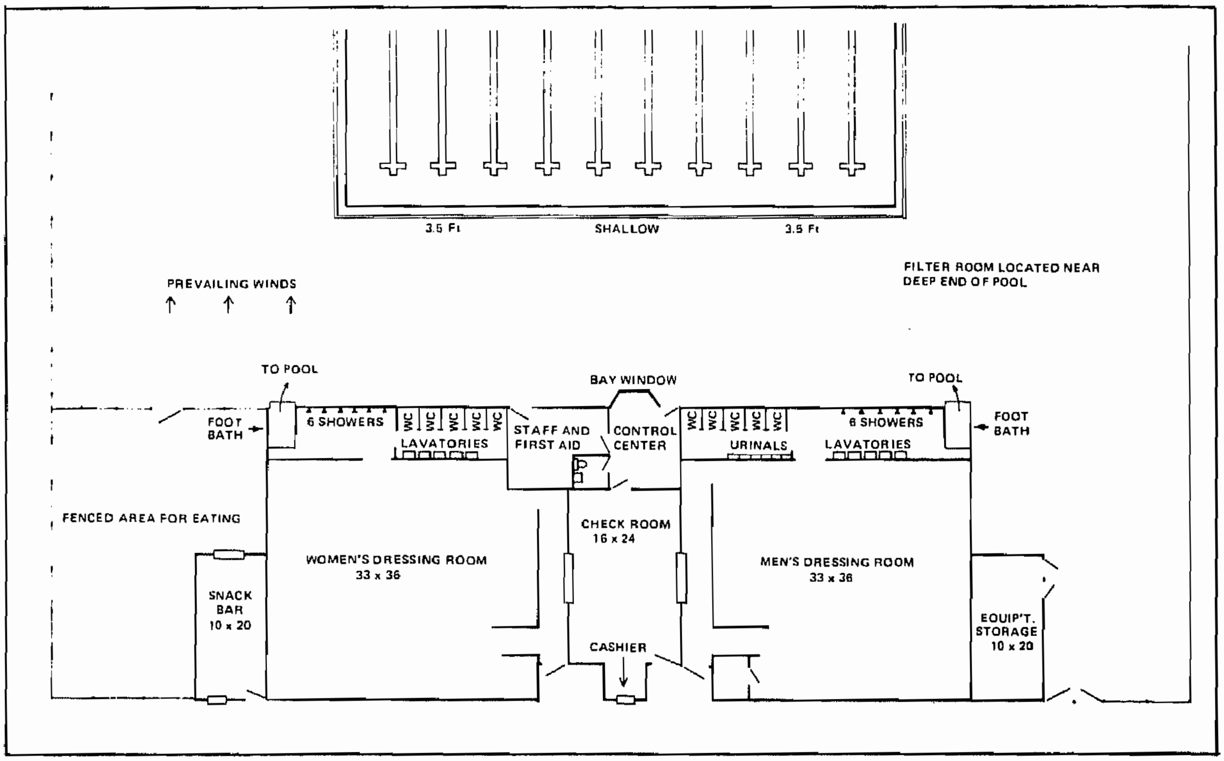
5. **Snack Bar** – Food products are much in demand at outdoor pools. An area separate from the pool deck should be provided for consumption of food. The sales area should have windows opening to the outside of the pool compound to serve spectators, and a window opening into the pool compound for serving those inside. A fence or other definite barrier should separate the food consumption area from the pool deck, and strict enforcement procedures should be developed to keep all food and drink away from the pool deck.

6. **Spectator Area** – Swimming pools are used for instruction, recreation, competition, and water shows. Thus, the spectator area should provide adequate seating with good visibility from all areas and protection from the weather. Access from the spectator area to the pool deck should be provided, but simple, positive control of such access must be maintained to keep spectators off the pool deck and swimmers out of the spectator area.

7. **Swimmers Pavilion at Outdoor Pools** – It is desirable to provide a shelter area accessible to swimmers for protection from the sun and sudden storms.

8. **Swimming Pool** – The ideal relationship between the pool location and service buildings should provide the following:
   a. For safety, the entrance from bathhouse to pool should be at the shallow end of the pool.
   b. For comfort, the bathhouse or other buildings should provide a windbreak from prevailing winds at outdoor pools.
   c. The spectator area should be on the south side of the pool (in northern latitudes) so spectators will not be looking into the sun.
   d. Diving boards should be on the south or west side of the pool so that the vision of divers is not obscured by the sun.
   e. The bathhouse should be on the windward side of the pool to aid in preventing windblown debris from entering the pool.

Figure 1. Bathhouse layout — municipal pool



B. POOL STRUCTURE DESIGN AND POOL FITTINGS (See Figure 2)

1. **Basic Pool Structure** – Most multiple-use pools are constructed with a shallow and a deep area. Except for wading and spray pools, an overflow trough should surround the entire periphery of the pool. The side and end walls should be vertical for a depth of not less than 3½ feet. The bottom of multiple-use pools should slope not more than 1 inch per foot. Sixty to eighty percent of the area should be less than 5 feet deep. The exact size of the deep area must depend on safety factors prescribed for diving areas.

   Pools built for specific uses (diving, instructional, wading, competitive, or therapy) may present unique problems.

2. Fittings –

   a. A large main drain should be located at the deepest point in the pool.

   b. Surface skimmers collect a portion of the surface water at the perimeter of the pool. It can be substituted as an option in place of the peripheral overflow trough on pools with a perimeter of less than 125 feet.

   c. The fill spout introduces fresh or makeup water. There must be an air gap to prevent backsiphonage.

   d. Gutter drains are located in the overflow gutters to conduct the overflow water for either reuse following filtration or disposal.

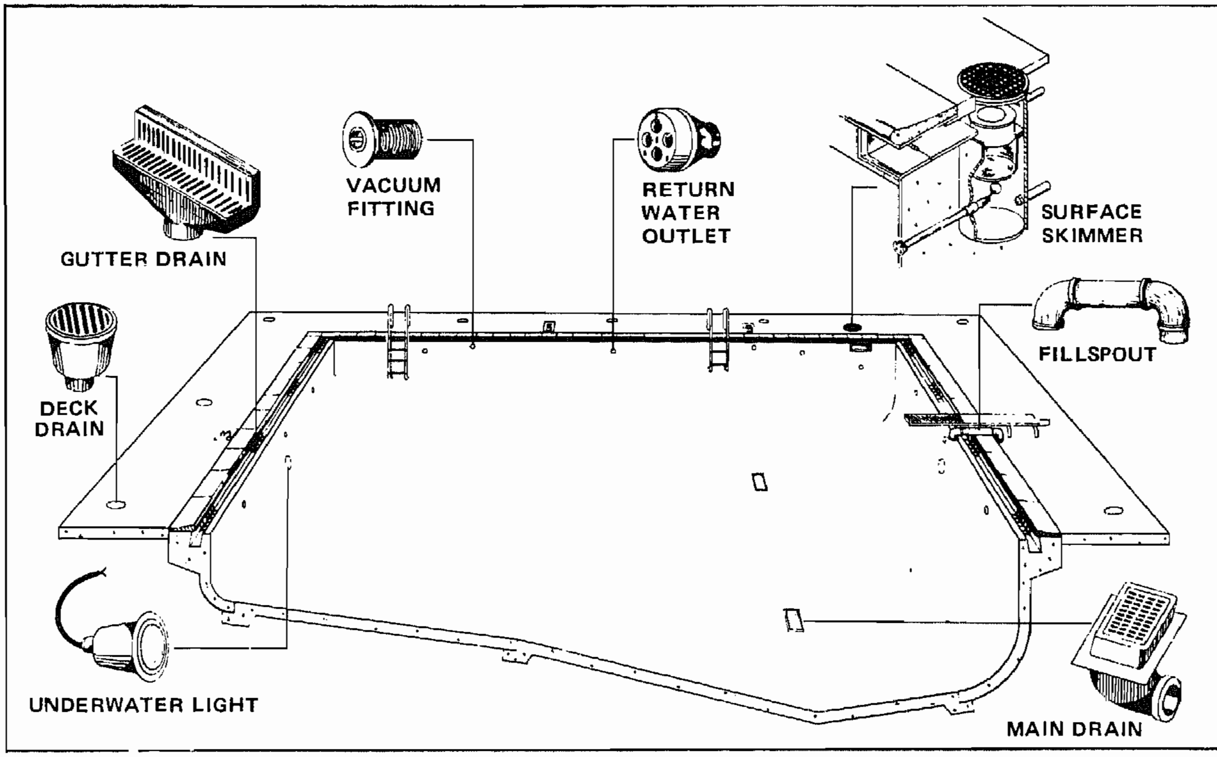
   e. Deck drains drain the pool deck area.

f. Vacuum fittings permit the attachment of a vacuum-cleaning device for pool cleaning.

g. Return water inlets are adjustable and direct the return water back into the pool.

h. Underwater lights are important for safe night or indoor swimming.

Figure 2. Longitudinal section through pool showing fittings



C. WATER FLOW PATTERN (See Figure 3)

1. **Filtering** –

   a. Pool water from the main drain and from the skimmer units is withdrawn by a pump and delivered to the filters.

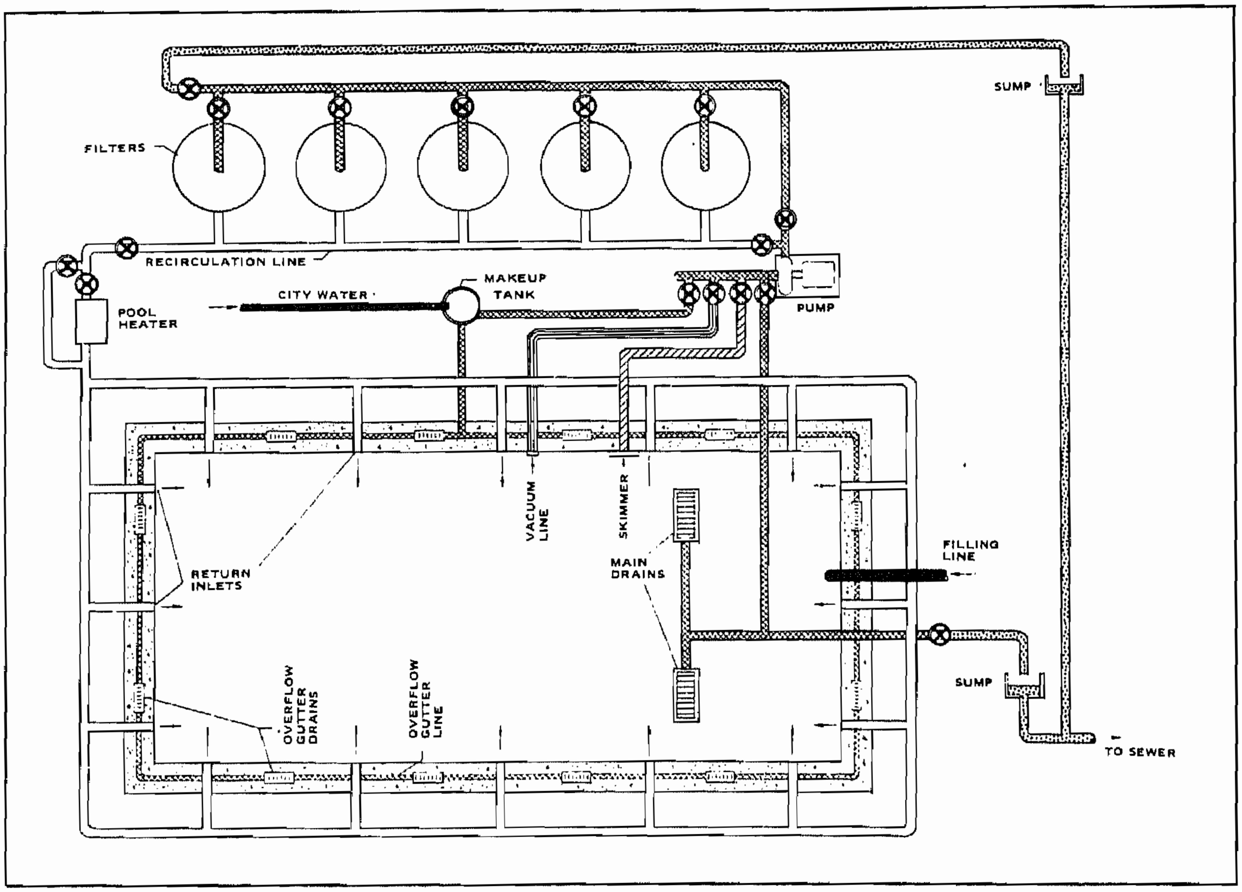
   b. Water overflows from the surface of the pool to a gutter completely circling the pool. Outlet drains in the gutter collect the water and carry it to the pump intake through a makeup tank. Water lost in splashing and evaporation is added at the makeup tank or the fill spout.

   c. Filtered water is returned to the pool through return water inlets.

2. **Vacuum Cleaning** – The lines leading from the main drain and skimmers are throttled or shut off, and the line from the vacuum connection is opened permitting the pump to pull through this line. The vacuum cleaner attached to the vacuum connection, therefore, can remove dirt from the pool sides and bottom and carry it to the filters along with pool water. Manual or self-propelled vacuum equipment can be used.

3. **Backwashing** – Pool water is withdrawn from the pool as for a normal filtering operation, but the flow is reversed through the filters and the accumulated dirt is washed out to the sewer. Pools with diatomaceous earth filters use a different backwash procedure.
4. **Initial Pool Filling** – Pool water is added through a fill spout from the fresh water supply. In some pools water may be added through the makeup tank and filtered before entering the pool.

Figure 3. Swimming pool piping system

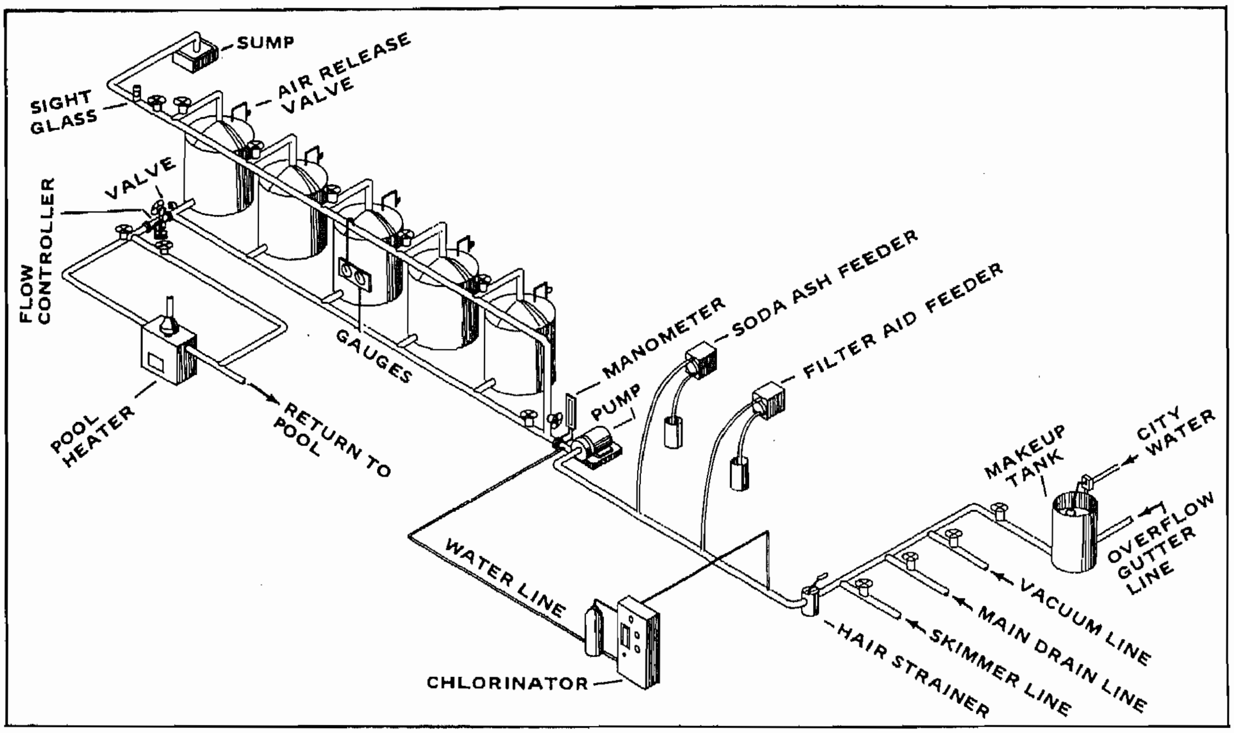


D. FILTRATION EQUIPMENT (See Figure 4)

1. **Makeup Tank (Balance Tank)** – This tank may provide for continuous addition of makeup water for the pool and also serve as a receiving point for overflow gutter water. Makeup water must be added to the tank through an air gap.
2. **Chemical Feeders** – Coagulants, filter aid, pH control agents, and disinfectants are important adjuncts to the filtration system.

3. **Filters** – A variety of filter types may provide for continuous water filtration. All filters are backwashed batchwise by reversing the flow of water.
4. **Pool Heater** – Water temperatures may be maintained during cooler weather for both indoor and outdoor pools with a pool heater.

Figure 4. Swimming pool filtration equipment



II. Designing Pool Size to Fit the Expected Swimming Load

A. GENERAL

This is not primarily an attempt to arrive at a limit for patron load for an existing pool but rather a method of designing the pool area to fit the expected numbers of swimmers.

B. DESIGN DATA

1. Estimated expected loading–
   a. **Large public pools** – Information on expected loading may be obtained from pools in the same general area, from local recreation department statistics, or by conducting special surveys.

      Cities under 30,000 population will generally have a maximum daily attendance at swimming pools of between 5 and 10 percent of the population. This figure will decrease for larger communities. The average daily attendance is about 2 to 3 percent of the population. Peak attendance in the pool at any one time is about one-third of the average daily attendance. Neighborhood pools usually draw their patrons from a distance of 3½ miles. Larger pools usually draw their patrons from a distance of 7 miles with half of them coming from a distance of 2 miles.

b. **Small public or semipublic pools (such as a motel pool)** – Experience may be obtained from similar pools in the general area. A rule of thumb sometimes used for motels is to allow for one person per unit up to 50 available units and one person for each additional two units.

2. **Swimming limit (APHA) – (see example problem, page 40)**
   a. **Diving area** – A design limit of 12 persons is permitted for the area within 10 feet of a diving board or platform.
   b. **Swimming area** – This is the area of the pool deeper than 5 feet but excluding the diving area. The swimming area should be designed for 24 square feet per person.
   c. **Nonswimming area** – For large outdoor pools, 60 to 80 percent of the pool area should be designed for nonswimming activities. Ten square feet per person in this part of the pool is the design limit.

III. Sanitary Construction Requirements

A. POOL WATER SUPPLY

1. The water supply must be of a quality that will permit adherence to the rigid bacteriological standards for pool water. (See Chapter 5, "Inspection of Swimming Pools and Bacteriological Sampling of Swimming Pool Waters.")
2. The chemical and physical properties of the water generally should be the same as those of drinking water. Low turbidity (less than 0.5 units), above neutral pH, and absence of harmful chemical levels are imperative for good operation.
3. The quantity available is important because insufficient quantity requires excessive pool filling times.
4. The water supply system serving the pool must be a sanitary installation. Well supplies, for example, must be protected against surface contamination.
5. Fresh makeup water must be introduced through an air gap or vacuum-breaking device to protect against backsiphonage.

B. POOL AND POOL AREA

1. **Construction**
   a. Poured concrete construction permits inclusion of recessed areas and allows for complete water drainage from the pool tank during periods of nonuse.
   b. Prefabricated steel, aluminum, or plastic construction may be the least expensive for initial installation, but has some drawbacks in maintenance.

c. Gunite concrete construction (spraying concrete into a preformed excavation) is less expensive than poured concrete, but permits less variation in pool design such as vertical wall construction because it depends on arches for structural strength.

2. Pool walls and floor surfaces require a smooth, impervious surfacing for all pool water contact areas.

3. Pool walls and floors must be light-colored for safety and sanitary reasons.

C. POOL SHAPE, DESIGN, AND FLOOR SLOPES

1. The outlet drain should be at the deepest place in the pool.

2. Side and end walls must be vertical for a depth of not less than 3½ feet, and rounded or coved at wall-floor joints. Deep area safety ledges constructed 4 feet below the water surface are sometimes used. These are made 4 to 6 inches wide, sloping ½ inch toward the pool.

3. The following list of suggested dimensions will allow for greatest versatility of use: 75′ x 30′, 75′ x 45′, 75′ x 82′, 75′ x 164′. Also, with the addition of a moveable bulkhead, pools of 110′ x 45′ and 164′ x 60′ are versatile.

   One inch should be added to any pool dimension which is a standard competitive course length, i.e., 75′1″ (25 yards), 82′1″ (25 meters), 150′1″ (50 yards), and 164′1″ (50 meters). Pool widths which are not one of the above should be in multiples of 14 feet to allow for an even number of 7-foot lanes. Many pools have 3 feet added to the width suggested above to allow for an 18 inch space between the outermost lanes and the pool edge. The added inch allows a tolerance within which the contractor can work to be sure that the finished pool will not be any fraction shorter than the prescribed competitive length.

4. The slope of the pool floor should not be greater than 1 inch per foot where the water depth is less than 5½ feet, and there should be no sudden changes in slope in this area. In pools less than 50 feet overall length, the rate of the slope may be increased to 1½ inches per foot.

D. POOL DECK AREA

1. Depth markings of 4 inches minimum height, visible both by day and under artificial lighting, should be placed at regular intervals at the pool periphery and spaced at not more than 25-foot increments. Even small pools should have the markings at the deep and shallow ends and at the 5-foot point. It is recommended that the depth markings be placed both on the deck and at the water surface on the side wall.

2. The pool must be surrounded by an impervious apron extending at least four feet from the pool edge. Widths of 8 to 10 feet are preferred.

3. The deck area should slope away from the pool at about ¼ inch per foot and be provided with one floor drain for each 100 square feet of surface.

4. It is desirable to include a shaded area for the comfort of the pool patrons.

E. MAIN DRAIN

1. The main drain outlet grating should have an area of openings four times the area of the discharge pipe to prevent objectional suction effects.
2. The main drain outlet system located in the deepest section of the pool should be provided with more than one outlet point if the pool width exceeds 20 feet. These outlets should be no farther apart than 20 feet on center and no closer than 10 feet from the side walls.
3. The grating of the main drain outlet should be easily visible. Drains not constructed of shiny metal should be marked with a dark colored circle.
4. Water discharged from the pool to waste must pass through an air gap to preclude backsiphonage. Adding a sand trap or diatomaceous earth separator may be advisable or required by ordinance.

F. RETURN WATER INLETS

1. **Design of inlets** – Return water inlets should be adjustable, and they must be suited to the area of the pool which they serve so that water can be distributed evenly. Some inlets adjust flow by changing internal orifices while others adjust flow by revolving a face plate.
2. **Number and location of inlets** –
   a. All inlets should discharge at a depth of at least 10 to 15 inches below pool overflow level to prevent loss of disinfectant.
   b. In large pools with outlets more than 5 feet from the end wall, inlets should be placed on 20-foot centers entirely around the perimeter of the pool or in the bottom. Pools more than 30 feet wide should have bottom inlets. In pools which may be used for swimming competition, the inlets on the end walls should be placed directly beneath the surface lane line anchors.
   c. In smaller pools when the distance across the shallow end is as great as 15 feet, multiple inlets at the shallow end should be provided. These inlets must serve not more than 15 linear feet each. In spoon-shaped rectangular pools where outlets are located more than 5 feet from the end walls, inlets must be placed at both ends of the pool.
   d. The maximum flow rates through variously sized inlet branches should not be more than listed below:

Inlet size (inches)	1″	1¼″	1½″	2″
Flow rate (GPM)	10	20	30	50

G. ELECTRICAL AND LIGHTING

1. **General** – All electrical installations should comply with Article 680 of the latest edition of the National Electrical Code of the National Fire Protection Association, or local codes if they are more restrictive. Among other provisions, Article 680 specifies grounding requirements and the uses of ground-fault circuit-interrupters.

2. **Lighting** –

   a. The advantages of natural lighting should be sought whenever possible. In indoor pools, windows should be restricted in area and placed high in the walls to reduce reflection from the water surface. Overhead skylights provide the best lighting with the least objectionable reflection.

   b. For artificial lighting the recommendations of the Illuminating Engineering Society Lighting Handbook are as follows:

   Deck lighting – footcandles on the deck or pool surface:

	Outdoor	**Indoor**
Exhibition	20 footcandles	50 footcandles
Recreation	10 footcandles	30 footcandles

   Underwater lighting – values of efficiency for incandescent lamps assumed to be 20 lamp lumens per watt:

   Outdoor – 60 lamp lumens (3 watts) per square foot of pool surface.

   Indoor – 100 lamp lumens (5 watts) per square foot of pool surface .

H. HOSE CONNECTIONS

1. Connections for ¾-inch hose should be provided at the pool deck area for flushing and cleaning. They should be spaced at such intervals that all parts of the pool deck area can be reached with a 50-foot hose. Additional smaller hose connections should be provided for the same purpose in the equipment room and in both dressing rooms.
2. A pressure of at least 20 pounds per square inch should be available.
3. Hose connections should be fitted with vacuum breakers to prevent siphoning contaminated water into the water supply. A practical vacuum breaker for this use is one that is connected with screw threads between the shutoff valve and the hose.

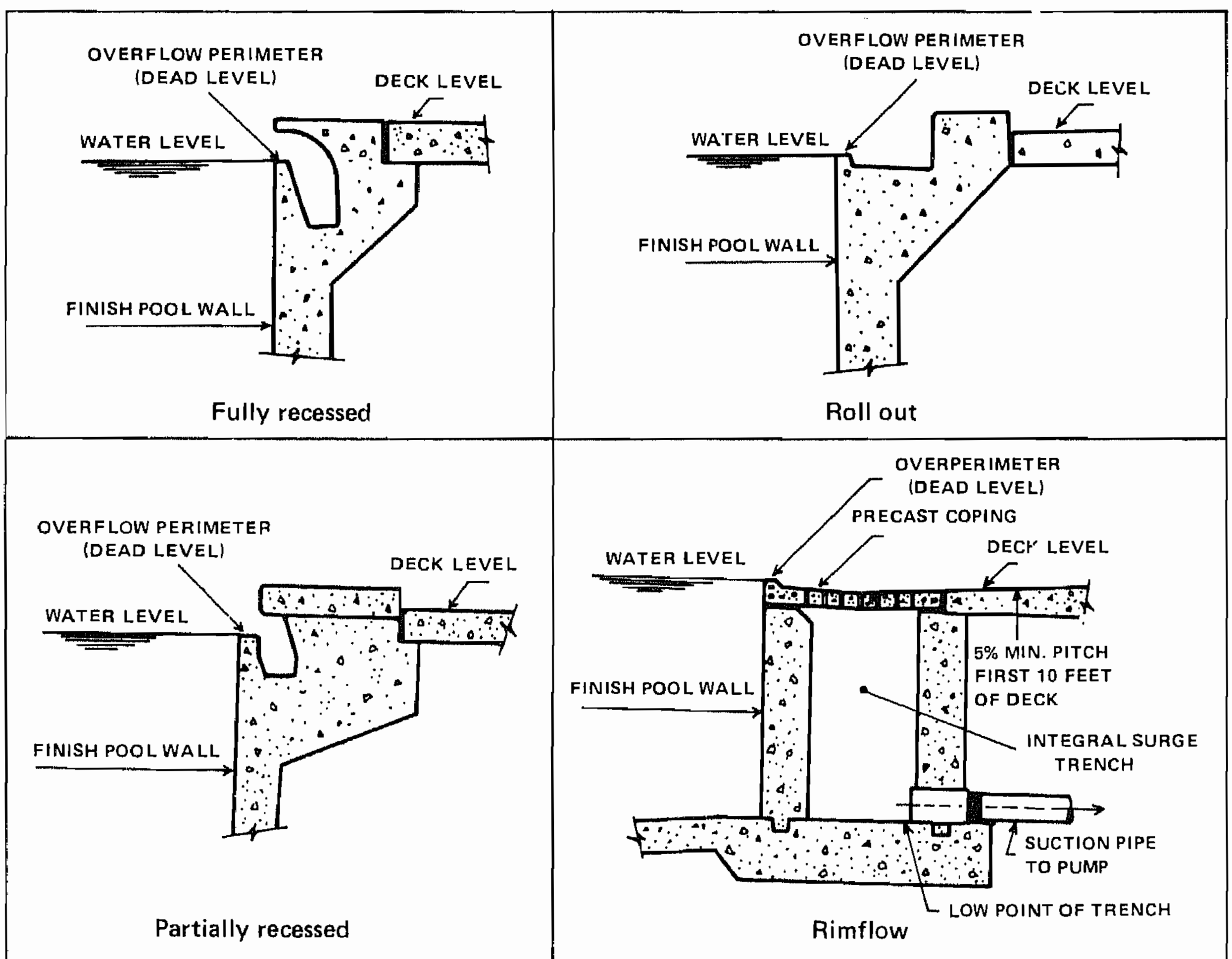
I. OVERFLOW GUTTERS

1. The gutter provides an overflow for pool water for surface cleaning and recirculation.
2. These overflow or scum gutters should be installed completely around the periphery of the pool on a uniform level.
3. The minimum depth should be about 2 to 3 inches to provide a suitable hand hold. They should further be fully open for ease of cleaning and to prevent accidents. The gutter bottom should slope ¼ inch per foot to gutter drains.
4. Gutter drains, preferable of the 90° angle type (see Figure 2) which reduces clogging difficulties, are located on 10- to 15-foot centers in the gutter bottoms. They should be provided with drain lines at least 2½ inches in diameter.
5. Special gutters can be installed to take advantage of their special features (See Figure 5). The "roll-out" or water-level type overflow troughs are constructed so that water which flows over the edge of the pool is captured and led to the filters with no possibility of bouncing back from a vertical surface. In some instances the trough,

covered by a slotted, nonslip ceramic grating, is deep enough to serve as a surge tank to hold displaced water until the pumps can return it to the pool. In other types, the trough is completely open, shallow, and fitted with drains to carry overflow water away before it can reach the pool deck area. This type of overflow system allows patrons to exit from the pool at any point without need for a ladder, creates a smoother surface for teaching beginners, facilitates removal of accident victims, and allows the use of instructional techniques not possible with raised-deck pools.

Cleaning is easiest in the open-trough-type gutter. The custodian does not have to lie on the deck and reach down over the pool edge into the gutter. Scumring is totally eliminated with the deck-level type trough. For competition in this type pool, turn boards and starting blocks are necessary for safety. It is important in designing this type of pool to make the trough drains large enough and close enough to prevent water from going past the trough and onto the deck.

Figure 5. Typical overflow rim systems

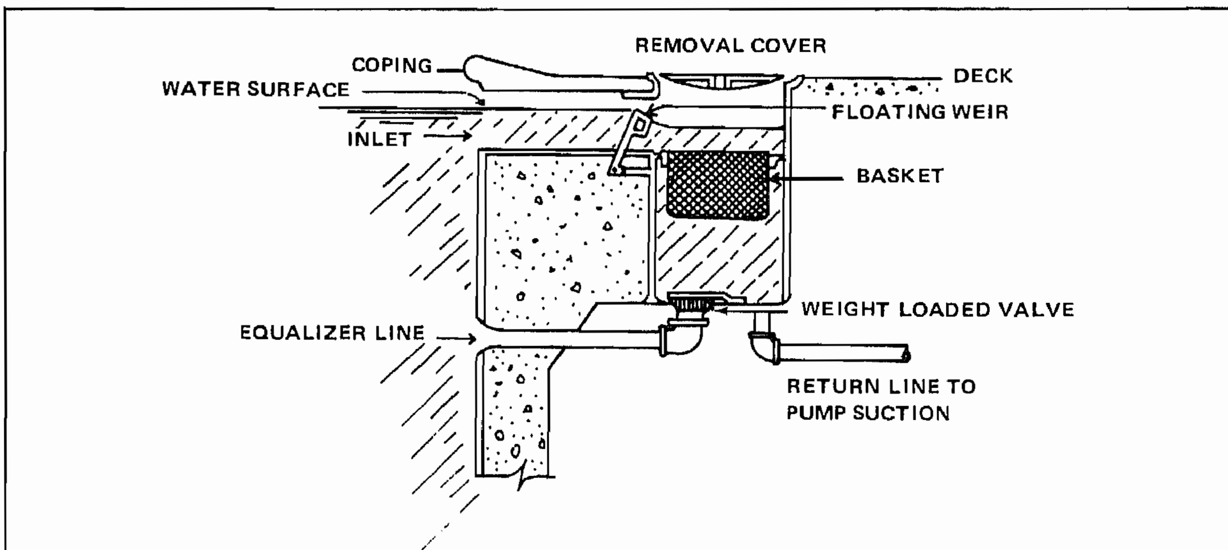


Courtesy of Hoffman Publications, Inc.

J. SURFACE SKIMMERS (See Figure 6)

1. **Purpose** – Skimmers are usually installed on private pools instead of the overflow gutter and yet serve to recirculate a portion of the surface water. On public pools they may serve as an adjunct to or a replacement for the overflow gutter if local regulations permit.
2. **General operation** – These devices may be used individually, in pairs, or at uniform spacing completely around the pool. From a position just below the pool surface they recirculate a large volume of the water by means of a water-adjusted flapper gate. Debris is caught in a wire basket while the water is conveyed to the filtration pump suction.
3. **Installation requirements (if used in lieu of overflow gutters)** –
   a. **Number installed** – at least one skimming device should be provided for each 500 square feet of pool surface or fraction thereof. One skimmer should be placed at a point in the pool opposite the direction of prevailing summer winds.
   b. **Operational criteria** – they should each be designed for a flow-through rate of at least 30 gallons per minute and all skimmers in the pool should be capable of handling approximately 80 percent of the required filter flow of the recirculation system. The overflow weir should be of sufficient length to maintain a rate of flow of at least 20 gallons per minute per linear foot of weir lip.
   c. **Equalizer line** – this should be at least a 2-inch line. It should be installed at least 1 foot below the overflow level of the skimmer to prevent airlock in the suction line if the pool level should drop below the weir level.

Figure 6. Surface skimmer



Courtesy of David G. Thomas and National Swimming Pool Foundation

K. STEPS AND LADDERS

1. A means of egress must be provided at the deep end of the pool and also at the shallow end if the distance from runway to pool bottom is more than 2 feet. One mode of egress should be provided for each 75 feet of pool perimeter, but in no case less than two separate modes of egress should be provided regardless of the dimensions of the pool.
2. Steps must not project into the pool proper. If step holes are used, they must be provided with drainage and nonslip surfacing and be equipped with handrails.
3. If ladders are used there should be a clearance of not more than 6 inches nor less than 3 inches between any ladder and the pool wall. Each ladder must be equipped with a handrail.

L. POOL LOCATION AND SURROUNDINGS

1. The pool should be located away from untreated dirt or gravel roads, heavy industrial areas, dusty parking lots, and playgrounds. The pool buildings should shield the pool from prevailing summer winds.
2. All pools must be enclosed with a fence at least 6 feet high. The fencing should be of a type that cannot be climbed easily.
3. Grass, earth, and sand areas must be excluded from the pool area. Overhanging foliage must also be eliminated.
4. Spectators' Area – All observers in street clothes should be kept out of the pool area. Covered pavilions can provide for spectators' comfort.
5. Angle jet type drinking fountains should be provided for the pool and bathhouse.
6. Waste receptacles that are fly- and water-tight should be placed at convenient places in the pool area.

M. DIVING BOARDS AND FLOATS

1. For indoor pools at least 16 feet of headroom above the highest diving board must be provided.
2. The water depth adjacent to diving boards should conform to the following safety standards:

Elevation of diving board above water (feet)	Minimum depth of water under end of board (feet)	Minimum depth of water 6 ft behind, 20 ft forward, and 8 ft to either side of the end of the diving board
1′ to 4′	10′*	10′*
4′ to 10′	12′	10′
Above 10′ (platforms)	15′ to 18′	12′

* The bottom may not be horizontal but must be sloped to permit drainage.

Standard diving boards are mounted 1 meter and 3 meters (10 feet) above the water and are 16 feet long by 20 inches wide. They should extend 6 or 7 feet beyond the edge of the pool.

N. WADING POOLS

1. **General** – A separate pool, 2 feet deep or less, for small children may be constructed as an auxiliary unit of the main pool.
2. **Water Flow and Treatment** –
   a. **Spray pool** – The most suitable type of unit is one designed to spray fresh (or recirculated) water over the area and waste (or recirculate) it rapidly.

   b. **Fast flowthrough pool** – This type of wading pool will function satisfactorily if the water is very shallow, and if the rate of flow provides a rapid turnover. A flowthrough time of 20 minutes is suggested. This type of design is recommended only as a remodeling measure when revision of an existing wading pool to a spray pool is impractical.

   c. **Water treatment** – Water for these pools can be recirculated with the main pool water or continuously wasted. Recirculation with filtration and disinfection is preferred from the standpoint of water conservation. Isolation valving with discharge to waste should be provided for cleaning.

O. LIFEGUARD STANDS

One lifeguard chair should be provided for each 2,000 square feet of pool surface area or fraction thereof. If a pool is more than 40 feet wide and has more than one lifeguard stand, these stands should be located on opposite sides of the pool.

P. RECIRCULATION SYSTEM AND APPURTENANCES

1. **Size of System** – (See Illustrative Problem 2 – "Calculations and Review of Swimming Pool Plans.")
   a. **Volume of pool** – The greater the volume of water, the larger the system necessary.

   b. **Turnover ratio** – The number of times in 24 hours that the water in the pool is recirculated will affect the size of the treatment system. A turnover ratio of at least 4 is desirable for public pools.

   c. **Hydraulic factors** – The choice of system size will also depend on the hydraulic factors listed below:

      (1) Horizontal distance of the filtration system from the pool.

      (2) Vertical distance of the filtration system above the pool.

      (3) Number of ancillary units such as pool heaters.

2. **Pumping Equipment** (See **Figures** 7, 8, and 9)

   a. **Type of pump** – Centrifugal pumps are used for pool circulation. These are often of the self-priming design.

   b. **Size of pump** – The recirculation pump should be capable of recirculating the entire volume of the pool in 6 hours. Conventional rapid pressure sand filters require a pump which will provide 3 gallons per minute for each square foot of filter surface during the normal filter run, and 12 to 15 gallons per minute per square foot of filter surface for backwash. High rate sand filters require a pump rate of 12 to 20 gallons per minute for each square foot for both filtration and backwash.

   Diatomaceous earth filters require a pump flow rate of 1 or 2 gallons per minute per square foot of surface area, and may require no backwash flow from the pump.

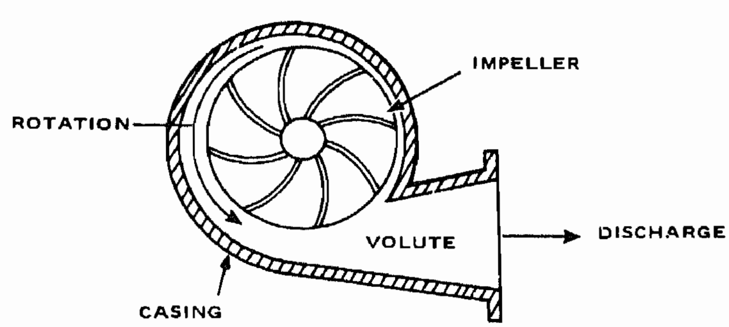
   A pump capable of operating against a 50-ft (22 psi) head is usually sufficient for rapid pressure sand filters. High rate sand and pressure diatomite filters may require a pump head of up to 100 feet (43 psi).

   c. **A formula for pump size** is as follows:

$$\text{horsepower} = \frac{\text{gallons per minutes X head in feet}}{\text{3960 X pumping efficiency}}$$

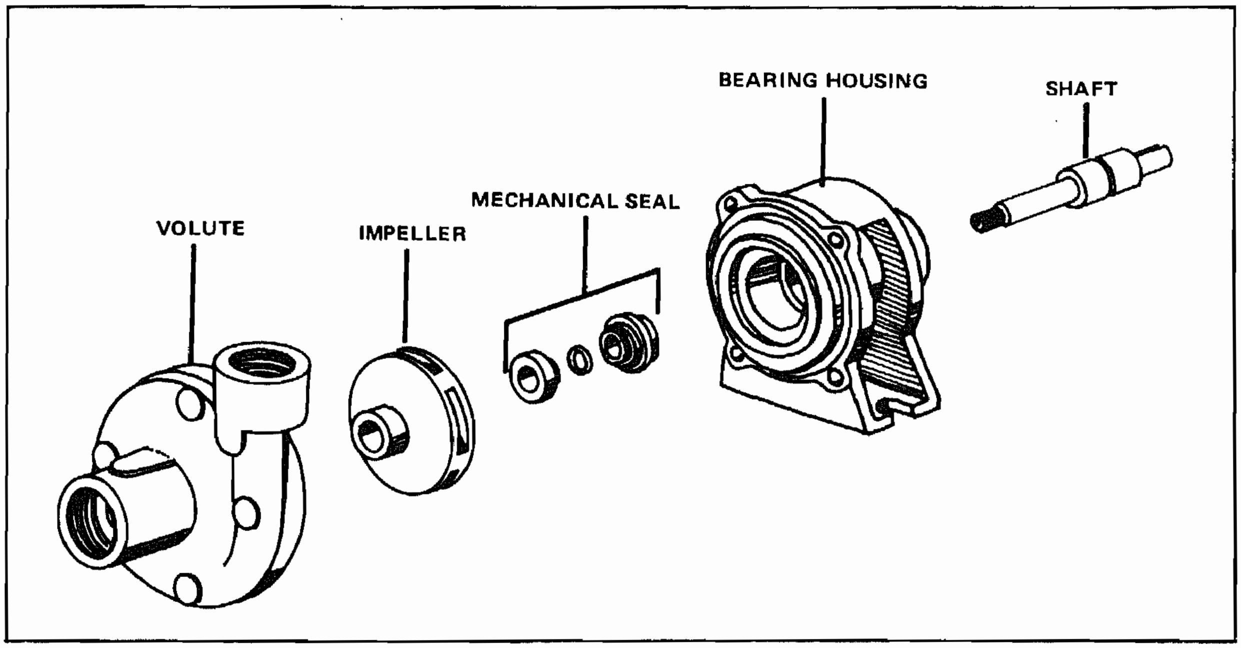
   d. **Vacuum cleaning attachment** – The pump must pull at least 4 gallons per minute per lineal inch of opening in the vacuum cleaning head while operating at a total vacuum (at pump suction) of 15 feet of water (6½ psi).

Figure 7. Typical centrifugal pump



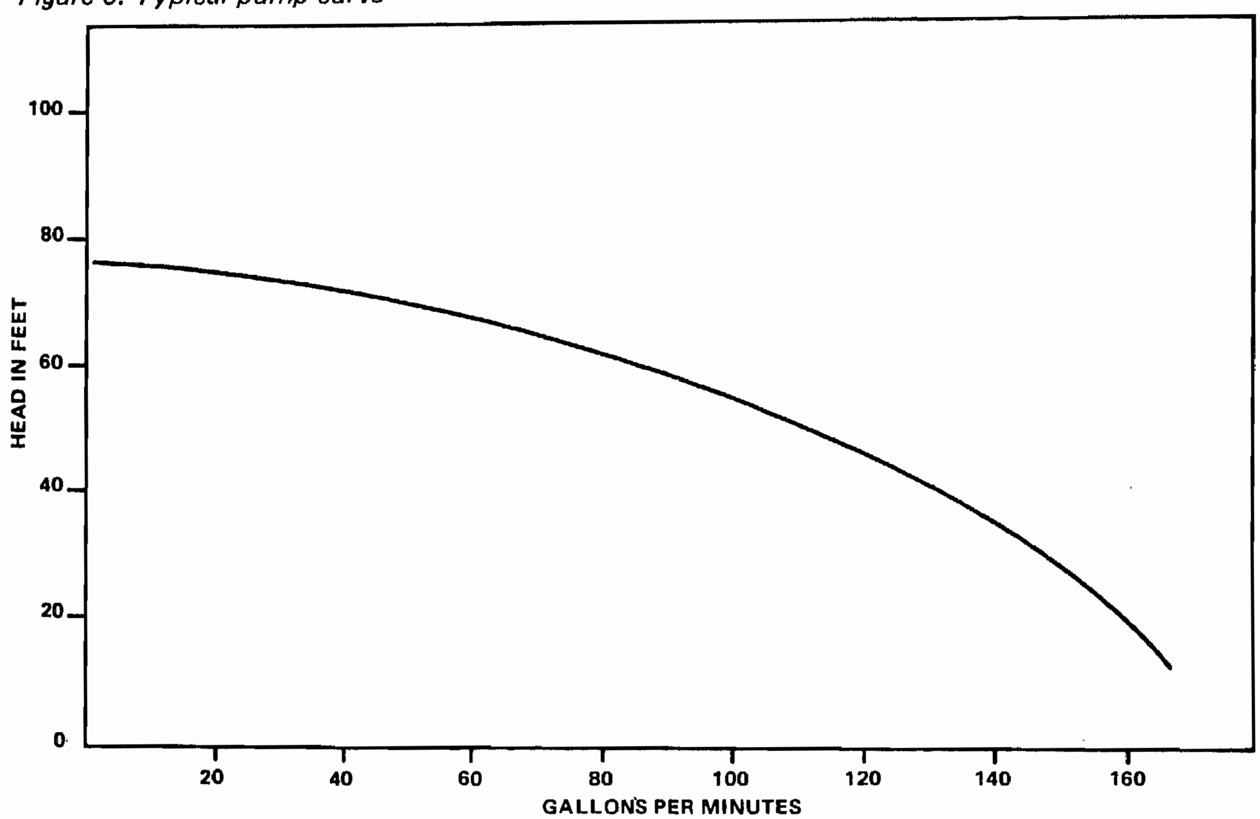
Courtesy of McGraw-Hill Book Company

Figure 8. Exploded view of a centrifugal pump



Courtesy of David G. Thomas and National Swimming Pool Foundation

Figure 9. Typical pump curve

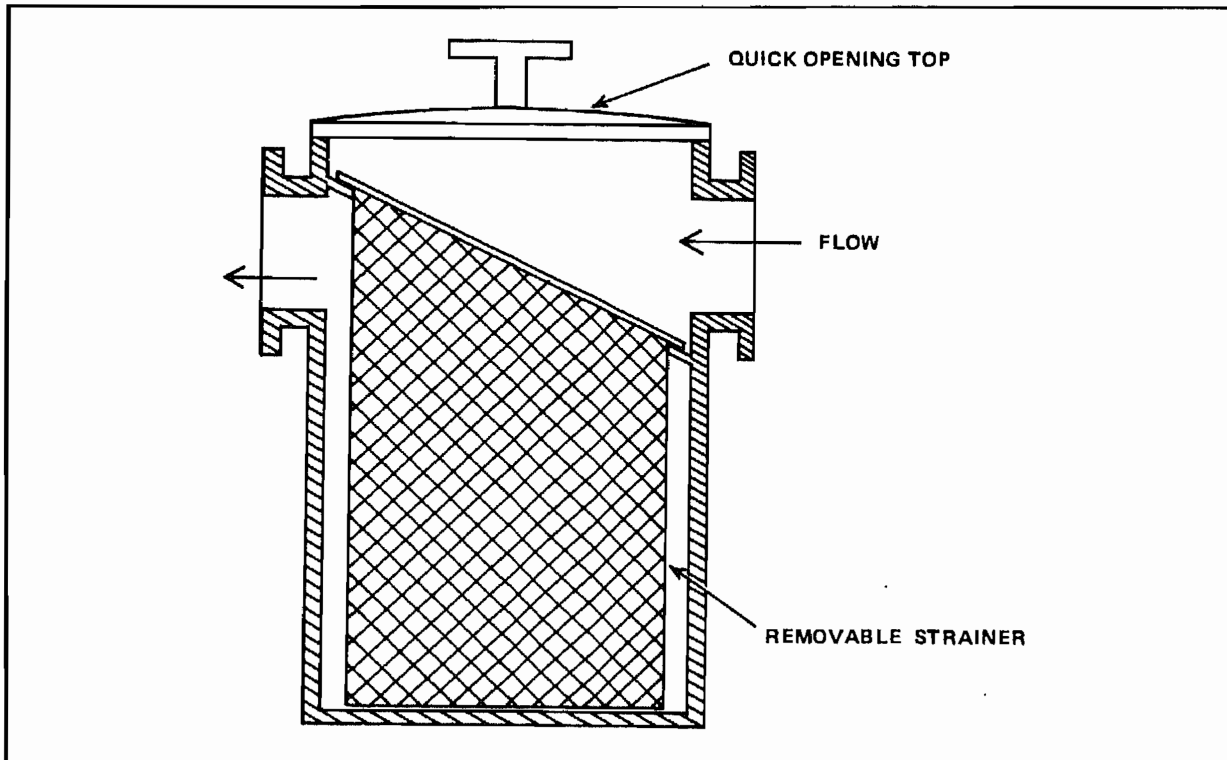


3. **Hair Strainer (See Figure 10)**

   a. **Purpose** – This device protects the pump from clogging and damage from hair, lint, pins, and other foreign material. It is placed between the pool outlet and the suction side of the pump.

   b. **Construction** – The removable portion of the strainer should be constructed of noncorrosive material. The holes in this unit should be not more than 1/8 inch in diameter, and the total area of all the holes should be at least 10 times that of the inlet area.

Figure 10. Hair strainer



Courtesy of David G. Thomas and National Swimming Pool Foundation

4. **Coagulation and pH Control Equipment**

   a. **Purpose of equipment**

      (1) **Coagulation** – Alum and other coagulant chemicals can assist the filtration process in rapid pressure sand filters by forming a mat of coagulant on top of the filter bed. Normally, high rate sand and diatomaceous earth filters do not use coagulants,.

      (2) **pH Control Equipment** – Soda ash, sodium bicarbonate, sodium bisulfate, acid, and other chemicals are fed to maintain optimum pH.

b. **Types of dispensing equipment**

(1) **Dry feeders** – Dry chemicals are automatically measured, weighed, and dissolved before feeding.

(2) **Dissolving device** – Water is passed through an open basket or a closed cylinder containing dry chemicals. The rate of dissolving is controlled by regulating the water flow or by the solubility of the substance.

(3) **Pressure solution feeder (alum pot)** – Heavy metal or plastic pots are connected to the waterflow by small feed lines across an orifice plate installed in the main flow pipe. Needle valves in the inlet or outlet lines control the solution addition.

(4) **Positive displacement chemical feed pump** – A two-valve pump chamber is filled and emptied by a motor-driven flexible diaphragm or piston.

5. **Filter Aid Feeding Equipment** (for Diatomaceous Earth Filters)

a. **Purpose** – The precoat feeder adds diatomaceous earth to the filter to form the prime filtering mat called the precoat. The continuous feeder adds diatomaceous earth to the filter to maintain the filtering capacity of the filtering mat. This is called the body feed.

b. **Mixing** – The feeders have continuous mixing devices to keep the diatomite flowing freely.

c. **Size** – The precoat feeder must be large enough to deliver an initial charge of 2 ounces of diatomaceous earth per square foot of filter area. The body feeder (continuous feeder) must be large enough to deliver 1 to 4 ounces per 1000 gallons of water recirculated.

6. **Filters**

a. **General** – As stated earlier, pool filters should be able to filter the entire contents of the pool in 6 hours (a turnover rate of 4 per day). A good filter unit should remove all particles larger than 10 micrometers (1/2540 of an inch).

b. **Types of filters**

(1) **Rapid pressure sand filters (See Figure 11)**

(a) **Media** – Twenty inches of filter sand with an effective size* of 0.4 to 0.5mm and a uniformity coefficient** of 1.75 underlaid with gravel or other effective support is required. Anthracite if substituted for the sand should have an effective size of 0.70 to 0.75 mm with a uniformity coefficient of 1.60.

(b) **Method of operation** – Recirculated water is passed under pressure through the layer of alum floc on top of the sand and then through the sand at a rate not greater than 3 gallons per minute per square foot of filter surface area. Backwashing requires passing water through the filter

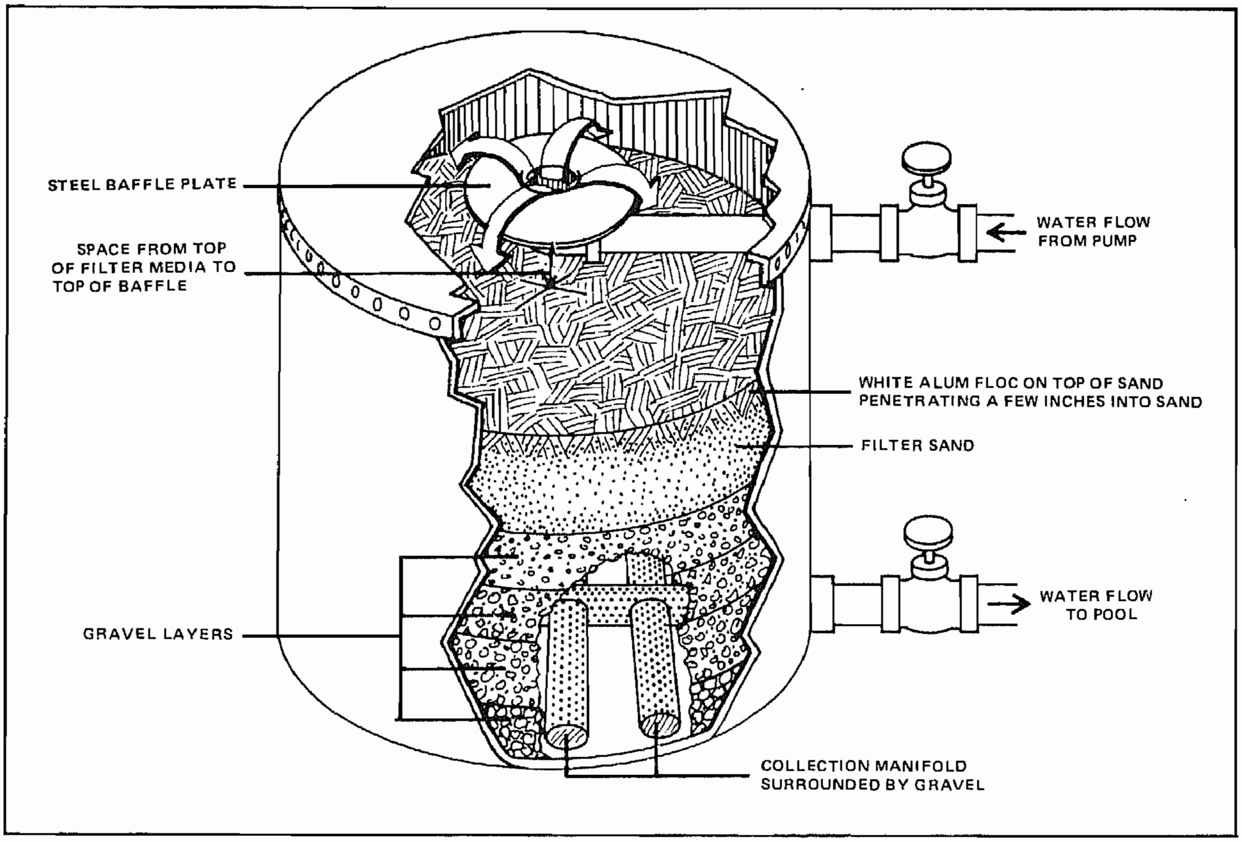
*Effective size is that size of a grain in a sample of sand such that 90 percent by weight of all the grains in the sample are larger.

**Uniformity coefficient is the ratio of that size of grain of which 40 percent are larger to the effective size.

in the opposite direction at a rate of 12-15 gpm per square foot. The backwash rate may be reduced to 8 gpm per sq ft when anthracite is used instead of sand. Eighteen inches of freeboard prevents the filter media from being washed away during backwashing.

(c) **Types of filter vessels** – Vertical vessels are used on pools up to 400,000 gallons in size, while horizontal vessels are used for pools between 300,000 and 1,000,000 gallons.

Figure 11. Rapid sand filter vessel



(d) Accessories

(i) **Pressure gauges** – Gauges tapped into the influent and effluent lines of the filter should be located together at the same elevation.

(ii) **Air relief valve** – This valve located on the top of the filter shell will release entrained air.

(iii) **Rate of flow indicator** – This device measures the flow rates in filtering and backwashing cycles. It should have a range between 10 percent below the established filtration rate and 10 percent above the established backwash rate.

(iv) **Manhole** – The manhole of minimum size 11" x 15" must be accessible and have an easily removable cover for inspection.

(v) **Rate of flow controller** – All public pools should have a rate of flow controller.

(vi) **Sight glass** – A sight glass on the backwash line permits observation of the filter cleaning process.

(e) **Comparison of this type of filter with others** – The rapid pressure sand filter is easy to operate. It will permit rather long filter runs and generally uses less power than other pressure filters. It requires more room than other pressure filters. Generally, four filters must be installed so that the recirculation pump can provide the water needed to backwash one filter. If a lesser number of larger filters are installed, an additional pump is needed for backwashing.

(2) **High rate sand filters**

(a) **Media** – The high rate sand filter uses the same filter media as the rapid sand filter. It does not use a gravel supporting base and normally does not use a coagulant mat on the sand. Specially designed collection manifold orifices are necessary.

(b) **Method of operation** – High rate sand filters operate like rapid sand filters, but are operated at a flow rate of 12 to 20 gallons per minute per square foot. This high filtration rate requires a much higher pressure during operation to force the water through the sand and accumulated dirt. Dirt penetrates the sand to a depth of 8 to 10 inches before backwashing is required.

Backwashing high rate sand filters is accomplished at the same flow rate as the filtering process. Only 2 to 4 minutes is normally required for backwash.

(c) **Accessories** – High rate sand filters require the same gauges, valves, rate of flow instruments, and manholes as rapid sand filters.

(d) **Comparison of this type filter with others** – The high rate sand filter requires about one-third the space of rapid sand filters. It uses less backwash water and little or no coagulant. Some states have not yet accepted the high rate sand filter as equal to the rapid sand filter in efficiency of particle removal.

(3) **Diatomaceous earth filters (See Figures 12, 13)**

(a) **Media** – Diatomaceous earth, the fossil remains of a microscopic marine plant, is used in a thin coating over filter septa or bags.

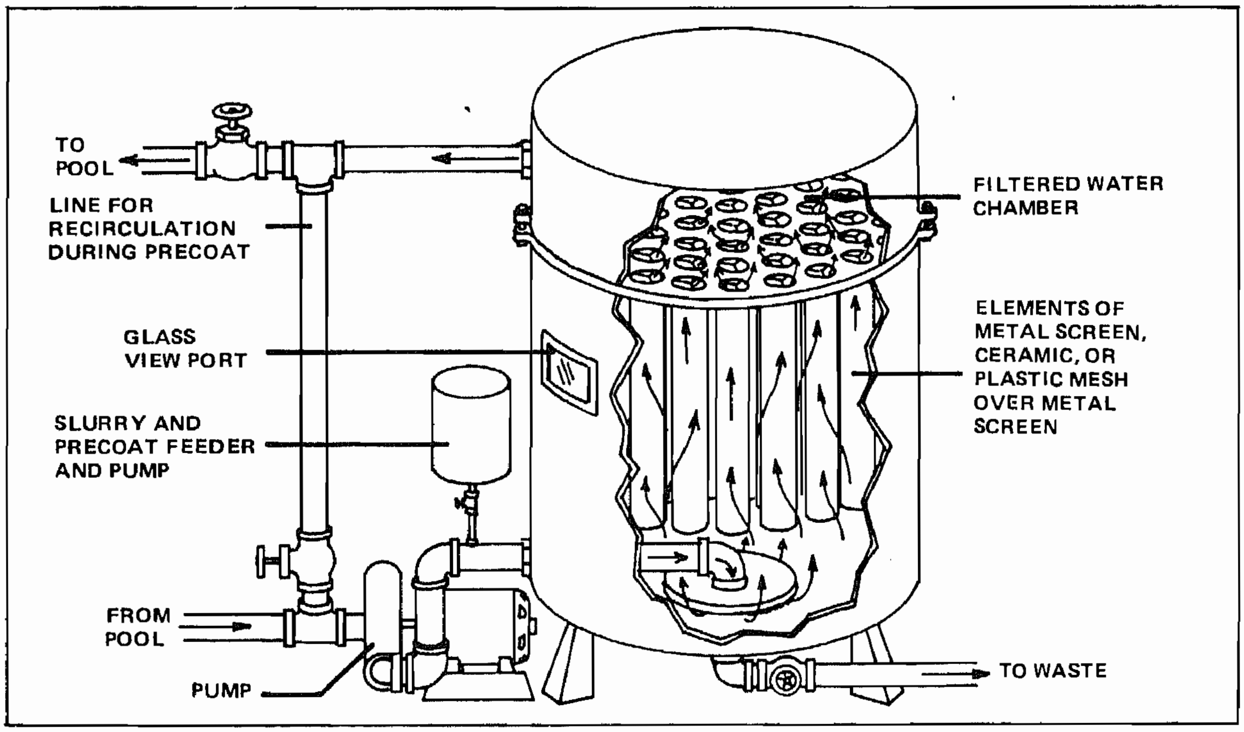
(b) **Methods of operation** -- Recirculated water is filtered by passage through a thin coating of diatomaceous earth which is placed on a filter septum (or leaf). These filter septa are provided with openings, the least dimension of which should not be greater than 0.005 inches.

The filtration may be under positive pressure as with the pressure sand filters, or under a vacuum. In vacuum filters the water is sucked through the filter septa which are submerged in an open basin full of recirculated water. Backwashing is accomplished by reversing flow, by air pressure, or by hand rinsing.

(c) **Accessories** – Diatomaceous earth filters require the same gauges, valves, rate of flow instruments, and manholes as rapid and high rate sand filters.

(d) **Comparison of this type of filter with others** – Diatomaceous earth filters require about 1/3 as much space as rapid sand filters and about the same space as high rate sand filters. Pressure diatomite filters have a greater tendency to element failure and clogging than the vacuum type. These filters use no coagulants, but require continuous feeding of filter media. Diatomite filters require somewhat more attention than sand filters. The used diatomaceous earth must be disposed of in a manner satsifactory to regulatory agencies.

Figure 12. Pressure diatomite filter with cylindrical elements



Courtesy of David G. Thomas and National Swimming Pool Foundation

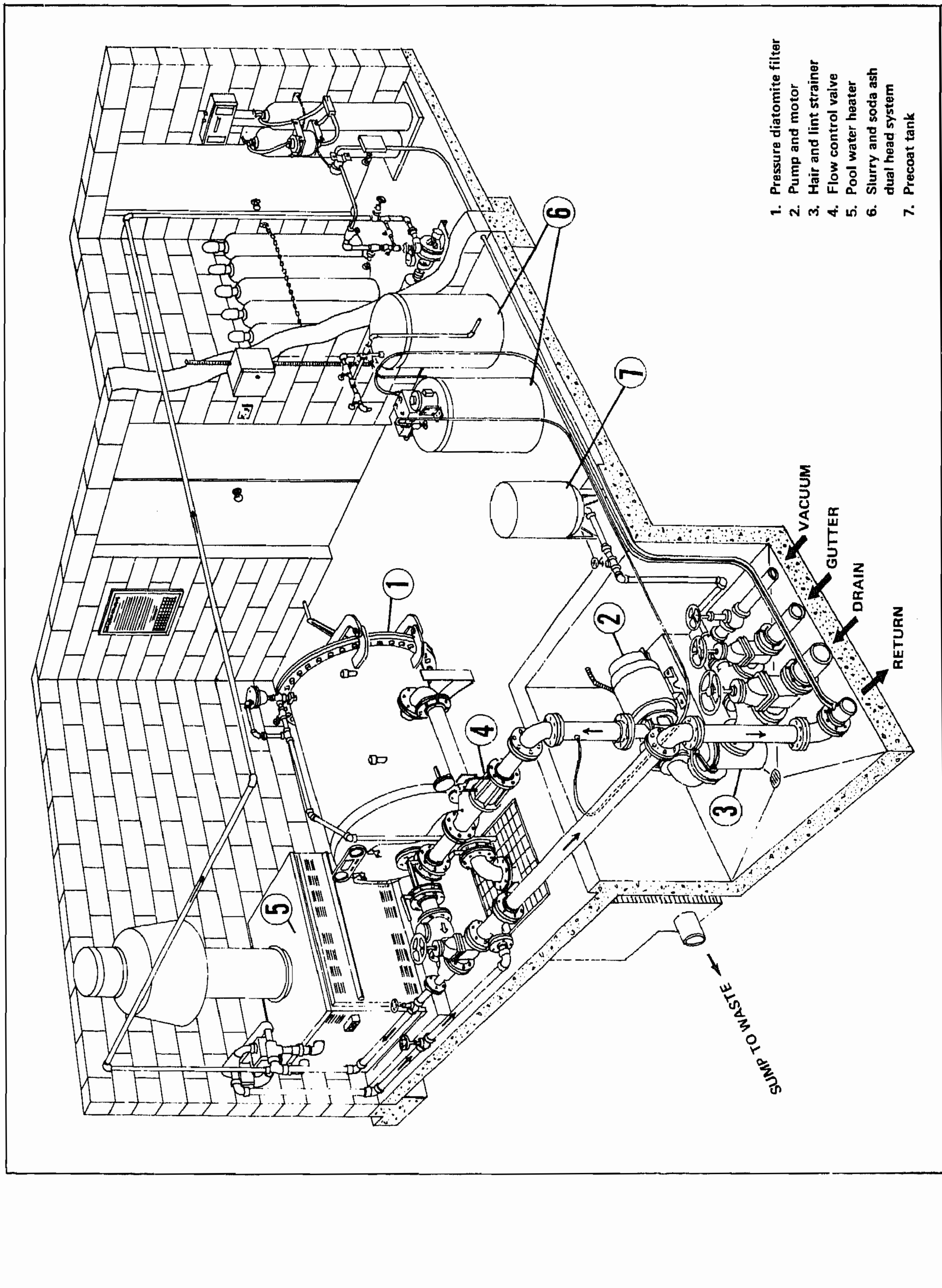


Figure 13. Typical pressure diatomite filter system.

Courtesy of Swimquip Division, Weil-McLain Company, Inc.

(4) **Gravity sand filters**

(a) **Media** – This is essentially the same as for the pressure sand filter.

(b) **Method of operation** – Recirculated water is passed by gravity through a layer of alum floc on top of the sand and then through the sand for filtration. Backwashing requires passing water through the filter in the opposite direction under pressure.

(c) **Accessories**

(i) **Loss of head gauge** – This gauge indicates when the filter needs backwashing because of excessive head loss.

(ii) **Rate of flow controller** – This is the same as noted for the pressure sand filter.

(iii) **Wash water tank** – A tank of sufficient size and of sufficient height above the filter bed to deliver water for backwashing is required. Backwashing may also be accomplished by pumping water directly from the pool.

(d) **Comparison of this type of filter with others** – The distinct advantage of this filter is that its media can be readily inspected during all stages of operation. However, it is generally more costly to build and requires skillful operation.

7. **Makeup Tank**

a. **Purpose** – This tank, connected to the suction side of the recirculatory pump, serves as a means of maintaining a constant level of water in the pool. A fresh water connection, controlled by a float valve, admits fresh water when water is lost through evaporation and splash. It also serves as a place for emergency introduction of chemicals.

b. **Construction features** –

(1) **Fresh water inlet** – This inlet must be protected from back-siphonage by an air gap or siphon breaker.

(2) **Waste fitting** – This fitting provides a suitable path for overflow of water from the tank in the event the float does not operate properly. The overflow pipe should not be connected directly to a sewer.

(3) **Pool overflow connection** – If desired, overflow water passing into the overflow gutters can be directed to flow by gravity to the tank for recirculation through the filter system.

8. **Disinfection Equipment**

a. **Chlorine disinfection**

(1) **Gas chlorination**

(a) **General** – When a tank of liquid chlorine has its pressure removed, it becomes a gas. The liquid chlorine feeder or *chlorinator* is a device which can control the change of liquid into gas, dissolve the chlorine gas in water, and proportion the chlorine solution to the main flow of water. Some chlorinators apply chlorine gas directly into the main flow of water.

(b) **Strength of chlorine** – Chlorine gas (liquid in pressure cylinder) is 100 percent available chlorine.

(c) **Size of chlorinator** – A chlorinator should be provided that will deliver 1 pound of chlorine per day for each 10,000 gallons of water in an indoor pool, and for each 5,000 gallons of water in an outdoor pool.

(d) **Size of pool to warrant gas chlorination** – In general, pools over 150,000 gallons capacity can operate more economically with gas chlorine than with other types of chlorination. The operator must decide if the added danger is worth the savings.

(2) **Calcium and sodium hypochlorination**

(a) **General** – These two forms of chlorine are manufactured by combining an alkali with chlorine to form a hypochlorite.

(b) **Strength of hypochlorite** – Calcium hypochlorite which comes as a solid (powdered) material is available commercially in varying strengths of available chlorine from 70 percent on down. Sodium hypochlorite which comes in a liquid solution form is available commercially in varying strengths of available chlorine from about 4 percent to 12 percent.

(c) **Methods of application**

(i) **Manual** – Dosing by hand is not desirable and should be done only in emergencies.

(ii) **Dissolving devices**

(aa) **Dissolving baskets** – Return water passes into the pool near a submerged basket filled with compressed hypochlorite tablets and carries the active ingredients into solution.

(bb) **Dissolving cylinders** – Controlled fresh water is passed through a cylinder containing hypochlorite tablets and then carried into the pool. Control is provided by varying the volume of entering water.

(iii) **Reduced pressure or suction devices**

(aa) **Pressure solution feeder (alum pot)** – Heavy metal or plastic pots are connected to the water flow by small feed lines across an orifice plate installed in the main flow pipe. Needle valves in the inlet or outlet lines control the hypochlorite addition by varying the flow through the pot which is charged with a hypochlorite solution.

(bb) **Siphon feeder** – This device depends on reduced pressure created by passing a stream of water through a constriction to siphon hypochlorite into the water stream at the constriction.

(cc) **Air controlled suction feeder** – A jar of liquid hypochlorite solution is directly connected into the suction side of the recirculatory pump, and flow is controlled by an air metering device which lets air into the jar to replace the solution which is withdrawn.

(iv) **Positive displacement chemical feed pump (See Figures 14, 15)** – This diaphragm or piston pump is the preferred method of hypochlorination. It delivers a measured amount of hypochlorite through a two-valve pump chamber.

(3) **Chlorine generators** – Recent technology has produced electrolytic cell type chlorinators which use sodium chloride, either in the pool or in a separate cell, to produce chlorine which is then injected into the recirculation line.

b. **Bromine disinfection**

(1) **General** – Bromine is an element in the halogen family which is in a liquid state at room temperature and has suitable properties for pool water disinfection. It is also available in solid organic complex form which is safer to handle, though more expensive.

(2) **Methods of application**

(a) **Brominator** – This device is a simple unit in which fresh or recirculated water is introduced into a bromine jar at atmospheric pressure to form a solution which is conveyed into the pool.

(b) **Contact pot** – This is a pot filled with liquid bromine and placed in a closed pressure system on a bypass line from the pump discharge. The water flows through the pot, dissolves bromine, and carries it into the pool.

(c) **Dissolving chamber** – Sticks of solid bromine compound are placed in a cylinder through which water flows at a controlled rate. The bromine compound dissolves and provides a bromine solution to be injected into the pool.

(3) **Safety precautions** – Since bromine will burn the skin, it should be stored in recessed floor or wall-hung units to prevent accidentally tipping the bottles.

c. **Other disinfection techniques**

(1) **Iodine** – Iodine or iodine released by chlorine (as from sodium or potassium iodide) are two means used for disinfecting swimming pool waters.

(2) **Ionized silver** – Recently new techniques for electrolytic production of silver ions for pool disinfection have been developed. The method is promising, but more time is needed for evaluation in actual use.

(3) **Ozone** – The use of ozone for swimming pool water disinfection is not considered acceptable for pool waters because of the lack of residual effect.

(4) **Ultraviolet ray** – This technique is not in general use for swimming pool disinfection.

Figure 14. Diaphragm type positive displacement pump

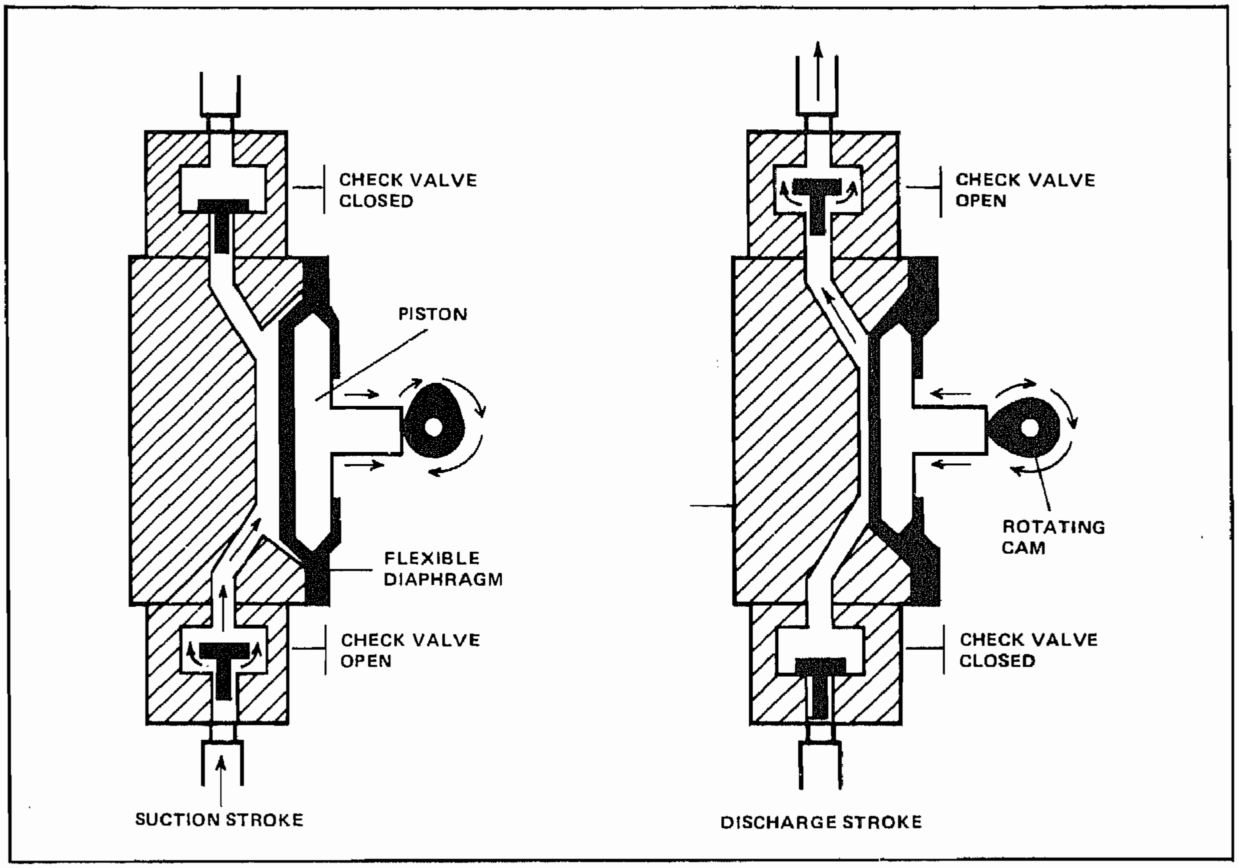
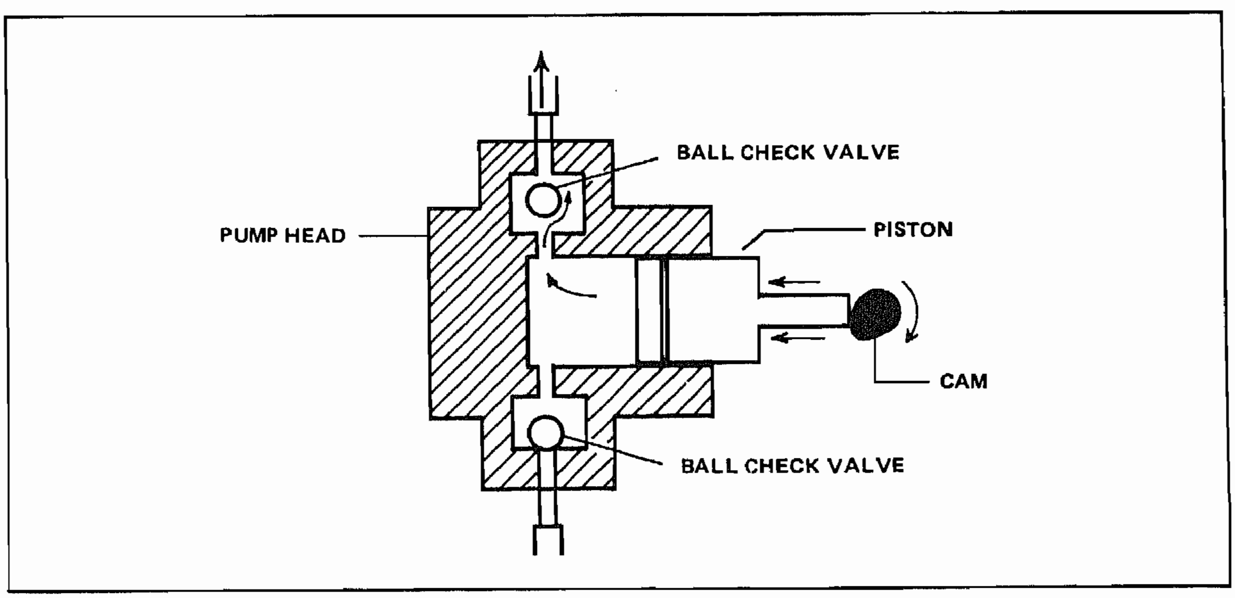


Figure 15. Piston type positive displacement pump



9. **Water Temperature Control Devices**

   a. **Pool water heating**

      (1) **General** – Most indoor and many outdoor pools are equipped with pool water heaters installed as a bypass on the filtered water return line. In order to check heater operation, inline thermometers should be installed on both the unfiltered water line and the filtered water return line.

      (2) **Size requirement** – A heater capacity of 15 Btu per hour for each square foot of pool surface and each °F temperature rise is a standard often used.

   b. **Pool water cooling**

      (1) **General** – Water is cooled as an aid to pool enjoyment during periods of prolonged hot weather. Cooling the water as little as 5°F, will make an appreciable difference to the swimmer.

      (2) **Methods**

         (a) **Aeration sprays** – Bypass lines on return water inlets spray the return water into the air before it reenters the pool.

         (b) **Aeration tower** – Return water is pumped over a spray tower enroute to the pool.

         (c) **Refrigeration** – This method, while expensive, is the most effective in terms of speed and range of temperature drop in humid climates.

Q. FILTER ROOM

1. **Purpose** – This room houses the filtration equipment with the exception of gas chlorination equipment and provides space for pool operation and maintenance supplies.

2. **Construction features**

   a. **Ventilation** – Adequate high and low ventilation by natural or artificial means should be provided in the filter room to remove excessive heat and moisture.

   b. **Lighting** – A minimum light level of 30 footcandles on all working surfaces should be available both during day and night.

   c. **Room size** – Sufficient head room must be provided to permit equipment maintenance. In addition, the area of the floor should be adequate to provide for easy access to all sides of equipment and yet provide room for storage of chemicals and pool accessories such as vacuum equipment.

   d. **Floor** – The floor should be of nonslip design, graded at 1/4 inch per foot to drain to floor drains. A sump pit constructed under equipment that constantly drips (i.e., water lubricated pump) will reduce the flow of water on the floor.

   e. **Egress** – The filter room should have dual egress for safety reasons. This room should not open directly into the chlorine room but should be provided with some means of observing the operations in that room, such as through a nonmovable glass panel at least 8 inches square.

   f. **Location** – Above ground locations are preferable to pit or subsurface installations for ease of maintenance and safety.

R. CHLORINE ROOM

A separate chlorine room at or above grade is required if gas chlorination is used. Existing pit installations should be eliminated. There should be direct access to the room from outside the building, and it should have one or more observation windows for viewing the interior from the outside and from the filter room without entering. The room should be large enough to house the chlorinator and chlorine storage tanks as required. Provision must be made in this room for chaining storage tanks to a wall or post, for installation of scales to weigh chlorine tanks, and for a sparkproof ventilation fan capable of producing a complete exchange of air in 2 minutes. The fan should exhaust from floor level. Provision must be made to store an approved gas mask, for emergency access, directly outside one entrance to the chlorine room. The floor should be of nonslip material, and a separate drain that is not connected to others in the building should be provided. A hose connection is also desirable.

S. BATHHOUSE (See Figure 1)

1. **General** – The bathhouse should protect the pool area from prevailing winds and should be located to provide entrance to the pool area near the shallow end of the pool only.
2. **Bathhouse** – The bathhouse should include a lobby, basket storage, dressing rooms, and toilet facilities. As a rule, these should occupy an area about one-third that of the pool.
3. **Dressing rooms**
   a. **Area provided** – A general size for both dressing rooms is one-fifth the area of the pool.
   b. **Construction features**
      (1) Floors should be of smooth, nonslip, impervious construction, with coved wall-floor joints and sloped to drains at ¼ inch per foot. Applications of nonslip paint are desirable in areas where floors are continuously wet.
      (2) Dressing room booths and furnishings should be of simple design, constructed of impervious and smooth materials that will permit hose cleaning. Partitions in booths should terminate 6 inches above the floor.
      (3) Hose bib connections of 3/4-inch minimum size should be provided for area cleanup. Multiple bibs should be provided for ease in maintenance. The use of suitable racks will prevent accidental tripping over piled hoses.
      (4) Natural or artificial ventilation will enhance conditions in the dressing rooms. Roof construction with the central portion open or open rafter gaps built into long overhangs are desirable features.
      (5) Heating should be provided if the pool is used during the winter. The dressing rooms should have heating facilities that can maintain a constant temperature between 70° and 75° F.
      (6) A minimum lighting level of 10-foot candles at a point 3 feet from the floor should be maintained during both day and night.

4. **Clothing storage area** – When using bag-type storage, an area of 0.75 square feet should be provided for each patron when a two-row high system is used. Additional area that will provide work aisles of 1½ to 2 feet should also be included. If many of the pool patrons are children, wire basket type storage facilities will suffice. A combination of both types of storage facilities might prove valuable.

5. **Sanitary facilities**

   a. **Shower areas**

      (1) **Number of shower heads (based on maximum pool loading)** – One shower should be provided for each 40 swimmers. In some situations, such as schools, the provision of one shower for every three members of the largest class will be ample. A water volume of 3 gpm per shower head is needed.

      (2) **Water temperature control** – A controlled water temperature of 90° to 100° F should be provided through a single, patron-operated valve. This water may be provided from a single source where the water mixing is regulated.

      (3) **Floors** – The floor should be made of nonslip, impervious material and slope to drain at 3/8 inch per foot. The floor-wall joints should be coved.

   b. **Toilet facilities (based on maximum pool loading)**

      (1) **Commodes and urinals** –

         (a) **Men** – One commode and one urinal should be provided for each 60 men.

         (b) **Women** – One commode should be provided for each 40 women. Female urinals, if provided, may be used in the same proportion as for men in (1)(a) above.

      (2) **Lavatories** – One lavatory with hot and cold water and soap should be provided for each 60 patrons. Circular foot-operated lavatories serving several persons at one time may be used in some situations such as schools.

      (3) **Construction** – The same construction requirements as for shower areas apply here. In addition, permanent outside ventilation must be provided in commode areas.

6. **Pool control center** – The pool control center should provide ready access to the pool, both dressing rooms, the checking area, and the admissions control point. It should provide or be adjacent to the pool manager's office. All pool light switches, emergency communications, and public address systems should be located in the control center.

7. **Emergency aid room** – A room equipped with first aid supplies, a bed, water under pressure, and toilet facilities should be part of a well designed bathhouse. To best use such an area, it should contain lockers and serve as a guard room for dressing and for storage of personal items and individual guard equipment.

T. FOOD SERVICE FACILITIES

The food service facilities must conform with applicable State laws and local ordinances.

U. PIPING

It is recommended that all piping be color coded. This will help in training new operators and in solving operating difficulties. The following is a suggested color code:

Fire protection	Red
Potable water	Blue
Recirculated pool water	Yellow
Chlorine and other chemicals	Green
Drain lines to sewer	Black

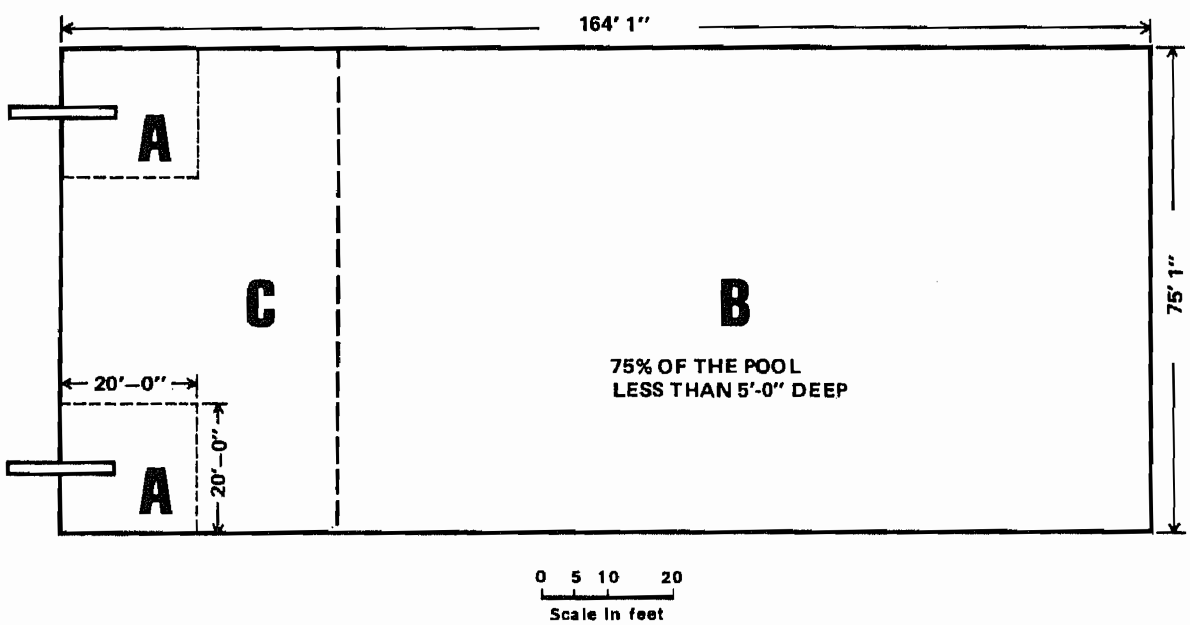
IV. Illustrative Problem 1

Calculation of Maximum Swimmer Load

A. PROBLEM

Based on American Public Health Association criteria, calculate the maximum number of persons that should be allowed in the swimming pool area shown in Figure 16. The pool has overall dimensions of 164′ x 75′ and is equipped with two diving boards which extend 10 feet over the water surface. Seventy-five percent of the pool area has a depth of less than 5 feet.

Figure 16. Plan view of pool for swimmer load problem



B. SOLUTION

1. **Total Pool Area** = 75′ X 164′ = 12,300 sq ft.

2. **Diving Area A**

   a. Two diving areas are provided. An area within 10 feet of each diving board is reserved for divers.

   b. Diving areas = 2(20 X 20) = 800 sq ft.

   c. Allowing 12 persons for each diving area, we have *24 persons.*

3. Nonswimming Area B

a. Seventy-five percent of the pool is less than 5 feet deep and can be considered for use by non-swimmers.

$0.75 \times 12{,}300 = 9{,}225$ sq ft.

b. Allowing 10 sq ft per person,

$\frac{9225}{10} = \textit{923 persons}$

4. Swimming Area C

a. The area left after computing nonswimming and diving areas

$= 12{,}300 - (800 + 9{,}225)$

$= 12{,}300 - 10{,}025$

$= 2{,}275$ sq ft.

b. Allowing 24 sq ft for each swimmer,

$\frac{2275}{24} = \textit{95 persons}$

5. Maximum Swimmer Load

The maximum loading in the pool area equals the totals for divers, nonswimmers and swimmers

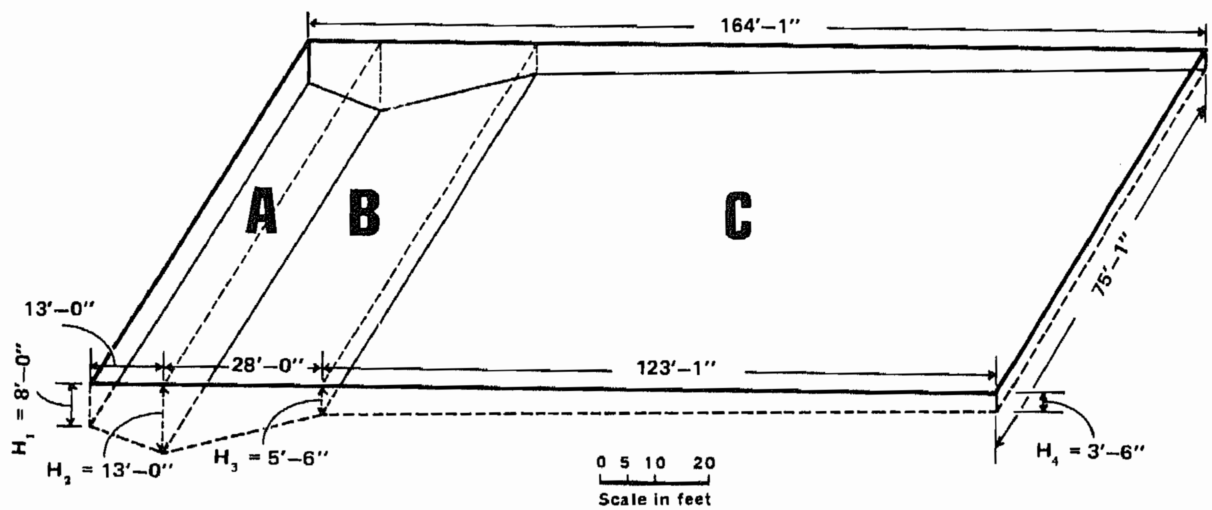
$= 24 + 923 + 95 = \textit{1042 persons}$

V. Illustrative Problem 2
Calculations and Review of Swimming Pool Plans

A. PROBLEM

A swimming pool has the dimensions noted in Figure 17, neglecting curvature in corners. The essential equipment and fittings included with the pool are also noted. The design head loss (resistance to flow through piping and equipment) may be assumed to be 50 feet for both filtering and backwashing cycles.

Figure 17. Isometric view of pool for design problem



The equipment is as follows:

1. **Filters** – Five horizontal sand filter vessels, 8 feet in diameter and 14 feet long.
2. **Pump** – Forty-horsepower, double-suction centrifugal pump rated at 50 percent efficiency under high load conditions.
3. **Alum feeder** – Dry feed machine with a capacity of 200 lb/24 hr.
4. **Soda ash feeder** – Heavy duty diaphragm pump feeder with a capacity of 180 lb/24 hr.
5. **Chlorinator** – Gas chlorinator with a capacity of 70 lb/24 hr.
6. **Main drains** – Four outlets spaced 15 feet on centers at deepest point; outlet pipes 8 inches diameter; gratings 22 inches square.
7. **Return inlets** – Thirty 2-inch adjustable inlets on equal centers completely around the pool.

Determine if the supplied equipment is adequate to provide for a 6-hour turnover (turnover ratio of 4).

B. SOLUTION

1. Volume of pool

a. Volume cu ft = volume A + volume B + volume C

$$= \text{surface area A} \times \frac{H_1 + H_2}{2} + \text{surface area B} \times \frac{H_2 + H_3}{2} + \text{surface area C} \times \frac{H_3 \times H_4}{2}$$

$$= (13 \times 75) \times \frac{8 + 13}{2} + (28 \times 75) \times \frac{13 + 5.5}{2} + (123 \times 75) \times \frac{5.5 \times 3.5}{2}$$

= *71,175 cubic feet*

b. Pool volume, gal = cubic feet X gallons per cubic feet = 71,175 cu ft X 7.48 gal/ cu ft

= *532,289 gallons*

2. Filter check

a. $$\text{filtration flow rate, gal/min} = \frac{\text{pool volume, gal}}{\text{minutes in 6 hours}} = \frac{532{,}389 \text{ gal}}{6 \text{ hr} \times 60 \text{ min/hr}}$$

= *1479 gallons/minute*

b. $$\text{filter area needed, sq ft} = \frac{\text{filtration flow rate, gal/min}}{\text{filtration rate, gal/sq ft, min}} = \frac{1479 \text{ gal/min}}{3 \text{ gal/sq ft, min}}$$

= *493 square feet*

c. From Table 4, "Filtration Area of Horizontal Pressure Sand Filters," we note that each horizontal filter has an area of 101 square feet. All five, therefore, have an area of 505 square feet. This exceeds the minimum area of 493 square feet and is therefore acceptable.

3. Pump size requirements

a. Size of pump needed for filtering

$$\text{pump horsepower} = \frac{\text{pumping rate} \times \text{head}}{3960 \times \text{pump efficiency}} = \frac{1479 \text{ gal/min} \times 50 \text{ ft}}{3960 \times 0.50}$$

= *37.3 horsepower*

b. **Size of pump needed for backwash**

(1) pumping rate for backwash = area of one filter, sq ft X backwash rate, gal/sq ft, min

= 101 sq ft X 15 gal/sq ft, min = *1515 gallons/minutes*

(2)
$$\text{pump horsepower} = \frac{\text{pumping rate X head}}{\text{3960 X pump efficiency}} = \frac{\text{1515 gal/min X 50 ft}}{\text{3960 X 0.50}}$$

= *38.2 horsepower*

It should be noted that one advantage of using five filters is that the backwash and filtration volumes are approximately the same. This is because the usual backwash volume is five times that of the filtration volume when one filter of the five is backwashed at a time.

c. **Check with pump supplied** – The 40-hp pump exceeds the required size as calculated. The extra size provides a margin of safety for emergencies such as difficult backwashing due to incrustation of sand beds. Since head characteristics are also important, actual selection of a pump should be made by consultation with manufacturers.

4. **Chemical feeders**

a. **Alum feeder**

feed rate required = filter area X alum application rate = 505 sq ft X 0.375 lb/sq ft, 24 hr

= *189 lb/24 hr*

Check with chemical feeding equipment supplied – The alum feeder with a capacity of 200 lb/24 hr exceeds the calculated need of 189 lb/24 hr.

b. **Soda ash feeder**

(1) **Desired size** – The necessary feed rate of this device is difficult to determine because of many variables involved. When using a gas chlorinator, however, it is desirable to have a soda ash feeder of *capacity similar to the alum feeder.*

(2) **Check with equipment supplied** – The soda ash feeder with a capacity of 180 lb/24 hr is near enough to the range of the alum requirements to be considered acceptable.

c. **Chlorinator**

(1)
$$\text{capacity required} = \text{volume of pool, gal X } \frac{\text{1 lb}}{\text{10,000 gal, 24 hr}}$$

$$= \text{532,389 gal X } \frac{\text{1 lb}}{\text{10,000 gal, 24 hr}} = \textit{53 lb/24 hr}$$

(2) Check with equipment supplied – The chlorinator with a 70 lb/24 hr capacity exceeds the calculated need of 53 lb/24 hr.

5. **Main drains**

   a. **Size and spacing** – Since the width of the pool exceeds 20 feet, multiple outlets must be provided. They must be no more than 20 feet on center and no closer than 10 feet to the side walls. The area of the outlet grating opening must be at least 4 times that of the discharge pipe.

   b. **Check with main drains supplied.**

      (1) **Number supplied** – Four drains are supplied. This number meets the multiple drain specification.

      (2) **Spacing** – Drains are spaced 15 feet on center and 15 feet from the end walls and therefore also meet the spacing specification.

      (3) **Area of outlet gratings**

         (a) area of opening of one outlet grating = length X width X % open area

         = 22 in X 22 in X 0.50 = *242 sq in*

         (b) area of one outlet drain $= \frac{\pi \times (\text{diameter})^2}{4} = \frac{\pi \times (8\text{ in})^2}{4} = 50\text{ sq in}$

         Since the area of each outlet grating opening is more than four times that of each outlet drain, the gratings have adequate area.

6. **Inlets**

   a. **Size and spacing required** – For this large pool, inlets completely around the pool on no more than 20-foot centers should be provided. The flow rates for 2-inch inlets should not exceed 50 gallons per minute.

   b. **Check with inlets supplied.**

      (1) spacing of inlets $= \frac{\text{perimeter of pool}}{\text{number of inlets}} = \frac{478\text{ ft}}{30\text{ inlets}} = 16\text{ feet/inlet}$

      (2) flow from each inlet $= \frac{\text{filtration flow rate, gal/min}}{\text{number of inlets}} = \frac{1479\text{ gal/min}}{30\text{ inlets}}$

      = *49.3 gal/min, inlet*

      Since the flow is less than 50 gal/min, this requirement is satisfactorily met.

VI. Illustrative Problem 3

Calculating Pool Leaks and Makeup Water

A. It is helpful to be able to calculate the amount of water needed to refill the pool after backwashing, or as the result of splash or evaporation. This can be calculated by measuring the number of inches the water surface must be raised to fill the pool. The formula for this calculation is:

(inches of water added) x (pool surface area in sq ft) x (0.625) = gallons of water.

Example: 4 inches of water was added to a pool 42 ft wide and 75 ft long. How much water was needed?

Using the formula:

4 X 42 X 75 X 0.625 = *7,875 gallons*

B. Pool leakage can be determined by a similar calculation. *Rate* of leakage requires the use of a time factor.

Example: The water level of a pool was marked at 8:00 p.m. when the pool was closed. The next morning at 10:00 a.m. before anyone entered the water, the water level had dropped 3 inches. The pool was 75 ft long and 45 ft wide. What was the rate of water leakage?

Using the formula above:

3 in X 75 ft X 45 ft X 0.625 = *6,328 gallons*

This amount was lost in 14 hours.

$$\frac{6328}{14} = \textit{452 gallons per hour}$$

Table 1

Pool Turnover Rate Chart

Pool capacity gallons	Flow rates gpm		Pool capacity gallons	Flow rates gpm	
	6-hr turnover	8-hr turnover		6-hr turnover	8-hr turnover
50,000	139	104	255	708	531
55	153	115	260	722	542
60	167	125	265	736	552
65	181	135	270	750	562
70	194	146	275,000	764	573
75,000	208	156	280	778	583
80	222	167	285	792	594
85	236	177	290	806	604
90	250	188	295	819	615
95	264	198	300,000	833	625
100,000	278	208	305	847	635
105	292	219	310	861	646
110	306	229	315	875	656
115	319	240	320	889	667
120	333	250	325,000	903	677
125,000	347	260	330	917	688
130	361	271	335	931	698
135	375	281	340	944	708
140	389	292	345	958	719
145	403	302	350,000	972	729
150,000	417	312	355	986	740
155	431	323	360	1,000	750
160	444	333	365	1,014	760
165	458	344	370	1,028	771
170	472	354	375,000	1,042	781
175,000	486	365	380	1,056	792
180	500	375	385	1,069	802
185	514	385	390	1,083	813
190	528	396	395	1,097	823
195	542	406	400,000	1,111	833
200,000	556	417	405	1,125	844
205	569	427	410	1,139	854
210	583	438	415	1,153	865
215	597	448	420	1,167	875
220	611	458	425,000	1,181	885
225,000	625	469	430	1,194	896
230	639	479	435	1,208	906
235	653	490	440	1,222	917
240	667	500	445	1,236	927
245	681	510	450,000	1,250	938
250,000	694	521	455	1,264	948

Table 2

GALLONS PER INCH OF POOL DEPTH

Pool size in feet	Area of pool in square feet	Water in gallons needed for 1 inch depth
50 X 25	1,250	780
60 X 20	1,200	750
60 X 25	1,500	940
60 X 30	1,800	1,125
75 X 30	2,250	1,400
75 X 35	2,265	1,340
75 X 42	3,150	1,970
75 X 45	3,375	2,110
75 X 60	4,500	2,810
82 X 42	3,444	2,150
82 X 45	3,690	2,300
82 X 75	6,150	3,850
100 X 45	4,500	2,810
105 X 45	4,725	2,950
165 X 60	9,900	6,190
165 X 75	12,375	7,735

NOTE: 1,000 square feet of water one inch deep contains approximately 625 gallons.

Table 3

FILTRATION AREA OF VERTICAL PRESSURE SAND FILTERS

Tank diameter feet	Filtration area square feet	Tank diameter feet	Filtration area square feet
2½	4.91	6½	33.18
2¾	5.94	6¾	35.78
3	7.07	7	38.48
3¼	8.30	7¼	41.28
3½	9.62	7½	44.18
3¾	11.04	7¾	47.17
4	12.57	8	50.27
4¼	14.19	8¼	53.46
4½	15.90	8½	56.75
4¾	17.72	8¾	60.13
5	19.63	9	63.62
5¼	21.65	9¼	70.88
5½	23.76	9¾	74.66
5¾	25.97	10	78.54
6	28.27		
6¼	30.68		

Table 4

FILTRATION AREA OF HORIZONTAL PRESSURE SAND FILTERS
[Filter Diameter - 8 Feet]

Tank length feet	Average area square feet
10	72
12	86
14	101
16	115
18	130
20	144
22	158
24	173

VII. Suggested Checklist
Sanitary and Public Health Items Relating to Swimming Pools

A. POOL SERVICE BUILDING (Dressing, toilet, storage, and other service rooms)

	COMMENTS
1. The pool building shields the pool area from the prevailing summer winds.	______
2. The patron entrances and exits are located at the shallow end of the pool.	______
3. The service building area is approximately 1/3 that of the pool area.	______
4. Dressing rooms have an area approximately 1/5 that of the pool area.	______
5. The clothing storage area is adequate for maximum pool attendance.	______
6. Toilet rooms are located so that a person must pass through the shower area in going to the pool.	______
7. Dressing room floor surfaces are smooth, impervious, nonslip, and pitch 1/4 inch per foot to drain.	______
8. Toilet and shower room floors pitch 3/8 inch per foot to drains.	______
9. Floor - wall joints are coved.	______
10. Walls and partitions are smooth, impervious, and moisture resistant.	______
11. Booth partitions terminate at least 6 inches above the floor.	______
12. Building facilities are naturally or artificially ventilated so that they will not remain excessively damp.	______
13. Rooms are well lighted so that all parts are visible for cleaning.	______
14. In indoor pools, windows are minimum size, located high, or skylight in ceiling.	______
15. Indoor pools are provided with room heating facilities.	______
16. Waste receptacles are provided in the pool building.	______
17. Hose bibs of 3/4-inch minimum size are provided for cleanup.	______

COMMENTS

18. One lavatory is provided for each 60 patrons (at maximum attendance). ______
19. Hot and cold water or tempered water is provided for the lavatories. ______
20. One shower is provided for each 40 patrons (at maximum attendance). ______
21. Premixed, tempered water is provided for the showers. ______
22. Showers are designed for a minimum flow of 3 gpm. ______
23. One toilet is provided for each 40 women patrons (at maximum attendance). ______
24. One toilet and one urinal is provided for each 60 male patrons (at maximum attendance). ______
25. Food service facilities meet the local food service code. ______

B. CONSTRUCTION FEATURES OF POOL AND POOL AREA (Exclusive of recirculation and disinfection equipment)

1. The pool is located away from untreated roads, heavy industrial areas, and dusty playgrounds or parking lots. ______
2. Grass, earth, or sand areas are excluded from the pool area. No overhanging foliage is present. ______
3. Pool area is enclosed with 6-foot high fencing. ______
4. Four-foot runways extend entirely around the pool. ______
5. Runways slope at least 1/4 inch per foot away from the pool. ______
6. Deck drains are provided for each 100 square feet of deck surface. ______
7. Runway drainage is prevented from flowing back into the pool or from flooding neighboring areas. ______
8. Lifeguard stands are provided for each 200 square feet of pool surface or fraction thereof. ______
9. Hose connections of 3/4-inch minimum size are provided for a pool area cleaning at intervals serving a 50-foot radius. ______
10. The area for spectators is separated from the swimmers' areas. ______

COMMENTS

11. Waste receptacles are provided in the pool area. ________________
12. Drinking fountains of approved design are provided in the pool area. ________________
13. The source of fresh water is approved. ________________
14. Water added to the pool from the supply is through an air gap. ________________
15. Waste water is disposed of in an approved manner. ________________
16. Pool and pool area lighting are satisfactory and all wiring is of a safe design. ________________
17. A ladder or other means of egress is located at the deep end of the pool. ________________
18. A ladder or other means of egress is located at the shallow end of the pool if it is more than 2 feet from the runway to the bottom of the pool. ________________
19. A ladder or other means of egress is provided for each 75 feet of pool perimeter. ________________
20. Steps to not project into the pool. ________________
21. The heights of diving boards conform with maximum pool depths. ________________
22. Sixteen feet of free and unobstructed headroom is provided above the diving boards. ________________
23. Increments of depth are shown on the sides and deck of the pool in letters at least 4 inches high. ________________
24. All internal surfaces are smooth and easily cleaned. ________________
25. The pool lining is light colored. ________________
26. The side and end walls of the pool are vertical for a depth of not less than 3½ feet. ________________
27. Junctions between the floor and walls are rounded. ________________
28. 60-80 percent of the pool area is less than 5 feet deep. ________________
29. The slope of the pool bottom is not greater than 1 foot in 12 feet where the water depth is less than 5½ feet for medium to large pools; and 1 foot in 8 feet for smaller pools. ________________

	COMMENTS
30. There is no sudden change of bottom slope where the water depth is less than 5½ feet.	
31. At least one vacuum outlet is provided.	
32. Inlets of proper number and location for recirculated water are provided to deliver uniform circulation.	
33. Inlets discharge at a depth of 10 to 15 inches below the pool overflow level.	
34. Inlets are adjustable.	
35. Multiple outlets are provided at proper locations where the pool width exceeds 20 feet.	
36. An outlet grating with openings four times the area of the discharge pipe is provided.	
37. Outlets are provided at the deepest part of the pool.	
38. Outlets from the pool are marked by dark colored circles or are easily visible.	
39. Overflow gutters extend completely around the pool.	
40. Overflow gutters are at least 3 inches deep.	
41. Overflow gutter drainage outlets are placed at intervals of at least every 15 feet.	
42. Overflow gutter drain lines are at least 2½ inches in diameter.	
43. Overflow gutter bottoms pitch 1/4 inch per foot to outlets.	
44. Skimming devices, at a ratio of one for every 500 square feet of pool area or fraction thereof, are provided.	
45. One skimmer is placed in the pool at a point opposite the direction of the prevailing summer winds.	
46. Skimmers are capable of handling 80 percent of the recirculated water.	
47. An equalizer line of 2-inch minimum size is provided on each skimmer.	
48. The wading pool is of the spray or fast-flow-through type.	

C. RECIRCULATION AND DISINFECTION AREAS

COMMENTS

1. Suitable general ventilation is provided for all areas. ____________
2. Artificial lighting is provided in all areas. ____________
3. Equipment and chlorinator rooms are provided with nonslip, impervious floors. ____________
4. Floors slope at the rate of 1/4 inch per foot to floor drains. ____________
5. A suitable means of automatically applying a disinfectant is provided. ____________
6. Chlorine tanks and the chlorinator are kept in a separate enclosure visible from the outside of the enclosure. ____________
7. High and low ventilation is provided near the chlorinator. ____________
8. Pit installations of chlorinators are eliminated. ____________
9. Chlorine tanks are provided with wall hung straps or floor recess areas to prevent accidental tipping. ____________
10. A pump and motor of sufficient capacity to deliver a 6-hour pool turnover is provided. ____________
11. The pool piping system is of sufficient size to permit a 6-hour pool turnover. ____________
12. A maximum rate of filtration of 2 to 3 gallons per square foot per minute is adhered to for rapid sand filter. ____________
13. A minimum backwash rate of 10 to 15 gallons per square foot per minute is adhered to for rapid sand filters. ____________
14. Air releases are provided at the highest point on each pressure filter. ____________
15. Pressure gauges are installed on the influent and effluent lines of the filter system. ____________
16. A backwash sight glass is provided. ____________
17. Backwash water is disposed of through an air gap. ____________

18. Backwash water disposed of to a sewerage system passes through a sand trap before entering the sewer. ______________________

19. A hair strainer of the proper design is provided. ______________________

20. A coagulant feeder of the proper size is provided for rapid sand and anthracite filters. ______________________

21. A feeder of the proper size for pH control is provided. ______________________

22. A diatomaceous earth percoat tank of the proper size is provided. ______________________

23. A diatomaceous earth continuous feeder of the proper size is provided. ______________________

24. A rate of flow indicator is provided. ______________________

25. A rate of flow controller is provided. ______________________

26. A makeup tank of proper size and construction is provided. ______________________

27. A pool water heater of proper size and construction is provided. ______________________

CHAPTER 3

Operation and Maintenance of a Public Swimming Pool and Bathhouse

I. Planning for Emergencies

A plan for emergencies should be carefully devised and kept up to date. All employees should be trained and drilled periodically in execution of the plan. **The emergency plan should contemplate drownings, electrical shock, heat prostration, fractures, and poisonings.** Those with training in first aid or other special skills, such as lifeguards, should be identified and assigned special responsibilities.

A list of **emergency telephone numbers should be displayed prominently in the first aid room** and **the filter room.** The list should include telephone numbers of **rescue squads, nearby physicians, ambulances, hospitals, and police and fire departments.**

II. Patron Load Control

A. REASONS FOR MAINTAINING LIMITS

1. **Sanitary operation** – The filtration, recirculation, and disinfection equipment will handle only a reasonable limit of new foreign matter and microorganisms and still maintain good pool water conditions.
2. **Safety** – Overcrowding makes supervision of swimmers and sunbathers a difficult, if not impossible, task.

B. TECHNIQUES FOR SETTING PATRON LIMIT

1. **General limits**
   a. **Bacteriological results** – Pool water sample results derived from samples taken under various loading conditions should be considered as an important guide.
   b. **Pool design loading** – The pool has a design capacity based on surface area which should be considered in setting a patron limit under one of the techniques described below.
2. **Specific formulas for recirculatory pools with continuous disinfection.**
   a. **Mallmann's formula** – A maximum patron load of one patron per 35 to 45 square feet of pool area is indicated by this investigator.
   b. **Becker's formula**

$$L = \frac{3.84\ C}{T^3}$$

where L = maximum daily patron load
C = capacity of pool in gallons
T = turnover period in hours

   c. **Basic method** – The number of patrons in one turnover period (6 hours, if properly designed) should not exceed one per 500 gallons of pool volume.
   d. **APHA method** – This method is discussed and illustrated in Chapter 2.

III. Chemical Treatment of Pool Water

A. CHLORINATION

1. **Chlorine** – Chlorine is the most commonly used bactericide for pools. It is a chemical element of the halogen family. At room temperature and pressure, chlorine is a heavy green gas with a characteristic odor and is extremely toxic. Strict adherence to safety precautions is necessary. Chlorine is cheaper in its gaseous form than in any other form used for pools. The expense of the necessary safety precautions plus the cost of soda ash necessary to maintain pH balance when using gas chlorine tends to offset the price advantage.

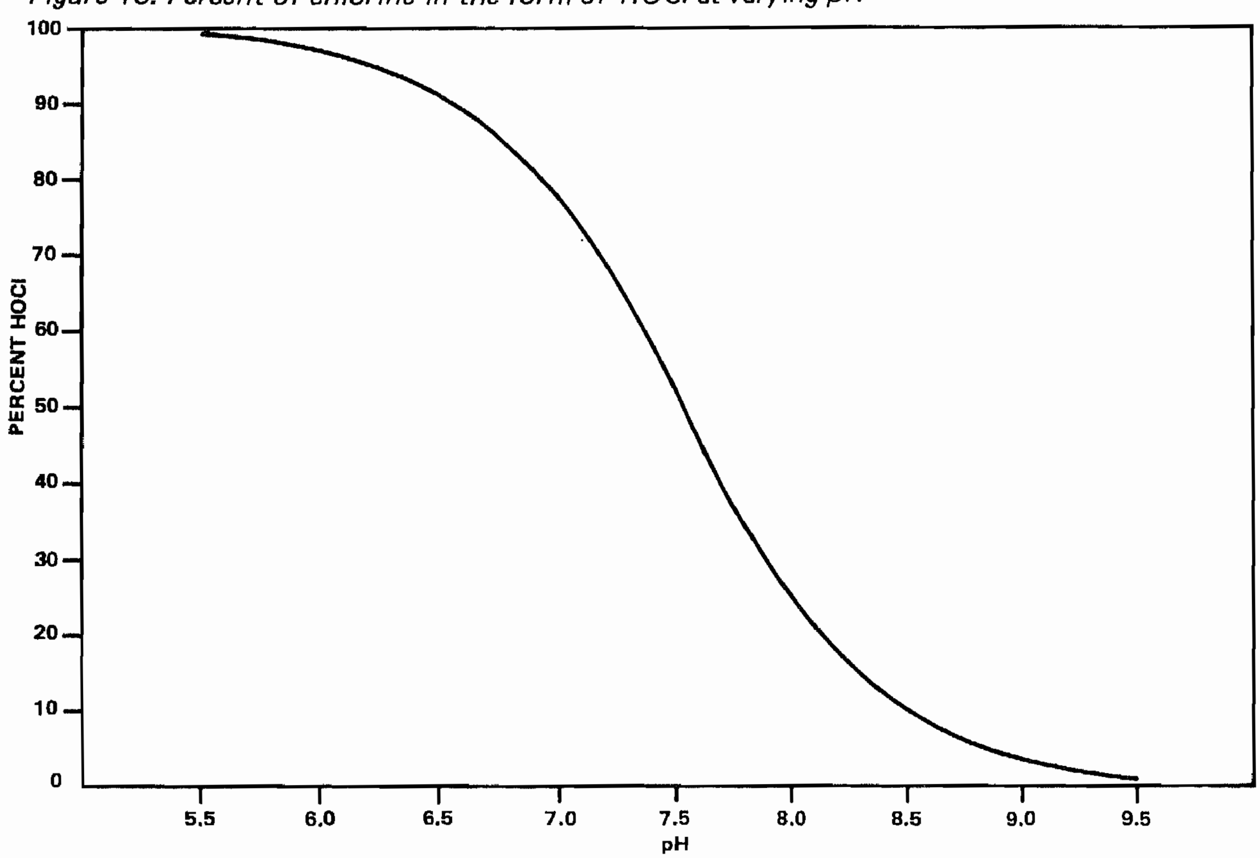
2. **Free residual chlorine** – when chlorine is added to water, two acids are formed: they are hypochlorous acid, HOCl, and hydrochloric acid, HCl.

   a. Hydrochloric acid is considered to be a useless by-product of chlorination and must be neutralized by the addition of 1.25 to 1.5 pounds of soda ash for each pound of chlorine added.

   b. Hypochlorous acid exists in either the molecular or the ionized state. The pH of the water determines the amount in each state. (See Figure 18)

   At a pH of 7.0 the acid is 72 percent molecular.
   At a pH of 7.5 the acid is 50 percent molecular.
   At a pH of 8.0 the acid is 21 percent molecular.

Figure 18. Percent of chlorine in the form of HOCl at varying pH



Hypochlorous acid in its molecular form is an effective bactericide. Hypochlorous acid in its ionized state kills bacteria much more slowly. Therefore, chlorine is a much less effective bactericide at high pH.

c. Hypochlorous acid in either molecular or ionized state is referred to as "free" chlorine in pool water. That portion of hypochlorous acid which remains in the water uncombined with ammonia is called "free residual chlorine." It is this free residual chlorine which must be maintained for adequate disinfection. Free residual chlorine dissipates rapidly in bright sunlight, with high temperatures, and with agitation of the water.

3. **Combined chlorine** – After the chlorine in hypochlorous acid has oxidized organic matter and some inorganic substances, it reacts with ammonia to form compounds called chloramines. The process takes place in steps depending on the relative concentration of ammonia and hypochlorous acid. If allowed to go to completion, the ammonia is completely oxidized and dissipated. If, however, the concentration of hypochlorous acid is too low to carry the reaction to completion, the partially oxidized chloramines will remain in the water. This combination of chlorine and ammonia is called "combined chlorine." Chloramines are bactericides, but the rate of disinfection is on the order to 60 to 100 times slower than that of free chlorine. Because chloramines do not dissipate as rapidly in sunlight and agitation as free chlorine, some pool operators deliberately add ammonia to retain the residual chlorine on hot, sunny days. However, this is not an acceptable practice.

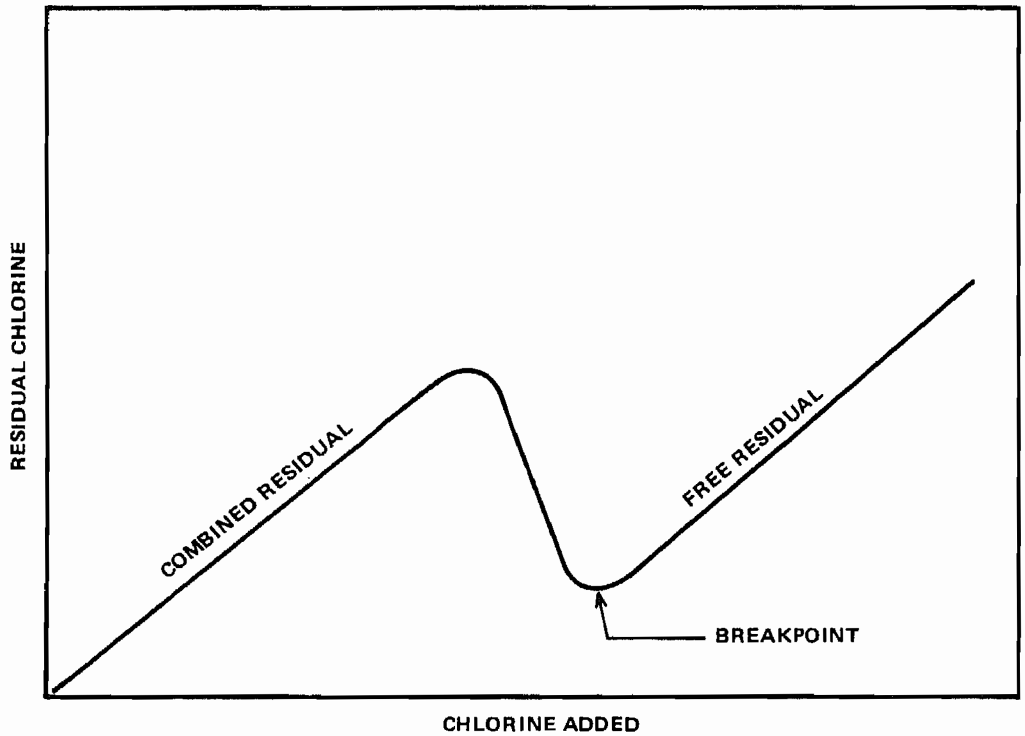
4. **Total residual chlorine** – The total concentration of residual "free chlorine" plus the residual of "combined chlorine" is called "total residual chlorine." When chloramines are allowed to exist, the water can be held to satisfactory bacteria-free standards by maintaining the total residual chlorine at a concentration of 2.0 to 2.5 ppm. This practice is undesirable, however, because the chloramines cause eye irritation and produce objectionable "chlorine" odors.

5. **Stabilized chlorine** – Free chlorine when combined with cyanuric acid is called "stabilized" chlorine. Although it is, in a sense, combined chlorine and exhibits the stability of chloramines in sunlight and agitation, it has significantly greater bacterial effectiveness than chloramines but less than free chlorine. When testing for free residual chlorine, the stabilized chlorine responds to the test as if it were free chlorine.

   The concentration of cyanurate should be held at approximately 50 to 60 ppm. The suggested upper limit is 100 ppm.

6. **Breakpoint chlorination** (See Figure 19) – When chlorine is added to water containing ammonia it reacts with the ammonia to form chloramines. If more chlorine is added to the water, the total residual chlorine continues to rise until the concentration reaches a point that forces the reaction with ammonia to go rapidly to completion. Compounds of nitrogen and chlorine are released from the water, and the apparent residual chlorine decreases. The point at which the residual suddenly drops is called the breakpoint. When enough chlorine is added to pass the breakpoint, all combined chlorine compounds disappear, eye irritation potential and "chlorine odors" disappear, and the chlorine that remains in the water is all in the free state. The breakpoint occurs at different concentrations in different waters. Superchlorination usually results in exceeding the breakpoint. Depending on the pH, a free chlorine concentration of 0.4 to 1.0 ppm should be maintained at all times.

Figure 19. Breakpoint chlorination



7. **Sources of chlorine** – Chlorine for use in pool sanitation can be obtained in various forms.

   a. **Gas chlorine** – Pure chlorine gas can be purchased directly in steel cylinders. The chlorine is compressed into a liquid which reverts to its gaseous state as it is released from the tank.

   b. **Chlorine generators** – Chlorine generators which use sodium chloride to produce chlorine are now available. Salt can be added to the pool water or directly to dissolving chambers. In either case the salt solution is passed through one or more electrolytic cells which separate chlorine from the solution and feed it directly into the pool water.

   c. **Calcium hypochlorite, $Ca(OCl)_2$** – Calcium hypochlorite is a white granular compound, often sold in tablet form. It is 70 percent available chlorine by weight, and remains stable if kept cool and dry.

   d. **Sodium hypochlorite, NaOCl** – Sodium hypochlorite is a clear, slightly yellow liquid solution and in commercial form is 12 to 15 percent available chlorine. The variety sold as household bleach is 5 percent available chlorine. The liquid can be fed directly into the pool. It is not as stable as the dry compounds. It should be stored in a cool, dark place, and should be used within 30 days.

e. **Lithium hypochlorite, LiOCl** – Lithium hypochlorite has been used as a source of chlorine for several years. It is a white granular substance yielding 35 percent available chorine. It is more costly than the sources previously listed.

f. **Chlorinated cyanurates** – These compounds are becoming more popular because chlorine is combined with cyanurate stabilizing compounds which keep the chlorine from dissipating in strong sunlight.

(1) **Sodium dichloro-isocyanurate** – This compound is the most popular of the cyanurates. It is a white powder, quite stable, and safe to handle. It contains 60 percent available chlorine and is readily soluble.

(2) **Trichloro-isocyanuric acid** – This is a white powder only slightly soluble in water. It is 85 percent available chlorine and is used where a very slow release of chlorine is desired.

(3) **Other cyanurates** – Potassium dichloro-isocyanurate and dichloro-isocyanuric acid are also used, but less frequently than the others because of solubility or chlorine yield considerations.

(4) **Chlorine** – After an isocyanuric acid concentration of 50 ppm is reached, additional chlorine can be added in the form of chlorine gas or hypochlorite. This will not only decrease cost, but will prevent excessive concentrations of cyanuric acid.

B. BROMINATION

1. **Bromine** – Bromine is a heavy, dark, reddish-brown, volatile liquid element of the halogen family. Its fumes are toxic and will cause severe eye and respiratory tract irritation on contact. Large quantities of water should be used to flush away spilled bromine.

2. **Application to pools**

a. Liquid bromine is supplied in 1- or 5-pound glass bottles which can be inserted directly into a brominator. Water drops are allowed to rise through the bromine, which has a specific gravity of 3.1. The water drops collect bromine and are injected into the recirculation system.

b. Bromine is also available as a solid white organic complex. It is safer to handle, though more expensive, than liquid bromine. The solid compound is inserted into a cylinder through which water passes. The water dissolves or erodes the solid and carries it into the circulation system.

3. **Chemistry of bromine** – Bromine hydrolizes in water to produce hypobromous acid and bromide ion. The bromide ion is useless in pool sanitation. Hypobromous acid ionizes to form a hypobromite ion to a degree that depends on the pH of the water. Unlike chlorine, however, both the molecular hypobromous acid and the ionized hypobromite ion are effective bactericides.

Hypobromite ion will combine with ammonia to produce bromamines in a manner similar to chlorine, but the bromamines are highly effective bactericides. Bromine, therefore, is effective in situations where chlorine would not be.

Bromine is less subject to dissipation in sunlight and will produce a more stable residual than will chlorine.

Nearly all bromine users agree that bromine is 2 to 4 times more expensive to use than chlorine, but that it does reduce eye irritation.

Bromine is not as effective as chlorine in combatting algae and oxidizing organic matter in the water. It sometimes causes a green color in the pool and occasionally imparts a brown discoloration to pool walls. Where bromination is permitted by local authorities, 1.0 to 1.5 ppm total residual bromine is usually required.

C. USE OF IODINE

1. **Iodine** – Iodine is a purple crystal in pure form. It is a member of the halogen family and reacts like chlorine and bromine. Iodine is not used in its pure form in pool sanitation.

2. **Application to pools** – Swimming pool operators usually use potassium iodide as a source of iodine for pool sanitation.

   White potassium iodide crystals dissolve in water without a precipitate. An oxidizing agent, usually chlorine, is then introduced to the water to produce free iodine according to the equation

   $$2KI + Cl_2 \rightarrow 2KCl + I_2$$

   The formation of iodine is regulated by the amount of potassium iodide in the water and the amount of chlorine introduced. Chlorine may be added by using any of the usual pool chlorine compounds.

3. **Chemistry of iodine** – When molecular iodine is released from its compound by chlorine, it hydrolizes to form hypoiodous acid and the iodide ion. The iodide ion is not an effective bactericide, but it can be reconverted to molecular iodine with chlorine and reused several times.

   At pH 7.0, 52 percent of the iodine remains in molecular form; 48 percent is hydrolyzed. At pH 8.0 only 12 percent is molecular and 88 percent is hydrolyzed. Both molecular iodine and hypoidous acid are effective bactericides, but molecular iodine imparts a green color to the water. Therefore, higher pH prevents water coloration. Addition of iodine does not affect the pH of the water significantly.

   Iodine does not react with ammonia to produce iodamines. It does not bleach hair or swimming suits and reacts only very slowly with organic matter in the water. All iodine users agree that eye irritation is practically nonexistent.

   Because the iodide ion can be reoxidized to molecular iodine and reused up to 12 or 13 times before it is lost, and because iodine is relatively inactive against organic matter, pools can be sanitized at one-third to one-half the cost of chlorination. However, when iodine is used, algae control and removal of organic matter must be accomplished by other means. Since no algicide exists which is compatible with iodine for pool use, intermittent superchlorination is necessary.

4. **Control of iodine** – Free iodine (molecular plus hydrolized) is most effective against bacteria at a concentration of about 0.8 ppm. Swimming pools should contain a "bank" of available iodine in its potassium iodide form at about 0.4 ppm. The total concentration of iodine in all forms should then be kept at 1.2 ppm. A green color will be evident if the total iodine concentration rises to 2.0 ppm. Health authorities believe that the concentration should not exceed 5.0 ppm for safety. Superchlorination releases all the remaining iodine in the "bank" of potassium iodide. For that reason it is best to allow the total iodine concentration to fall to 0.2 ppm before superchlorinating. A new supply of iodine should be added when the chlorine has receded to a concentration of less than 0.3 ppm.

   Iodine has definite advantages in pool sanitation, but the difficulties involved in its use inhibit its popularity.

D. OTHER DISINFECTION CHEMICALS

1. **Silver ion** – Silver ions are bactericides. A recent development in electrolytic production of silver ion for swimming pools appears to make the use of silver economically practical. However, it is known that some organisms develop a resistance to silver and that bactericidal action is slow when compared to the halogens.
2. **Ozone and ultraviolet rays** – Both ozone and ultraviolet ray treatment of pool water have been used. In each case, however, lack of residual bactericide and cost of equipment negate their value as of this date.

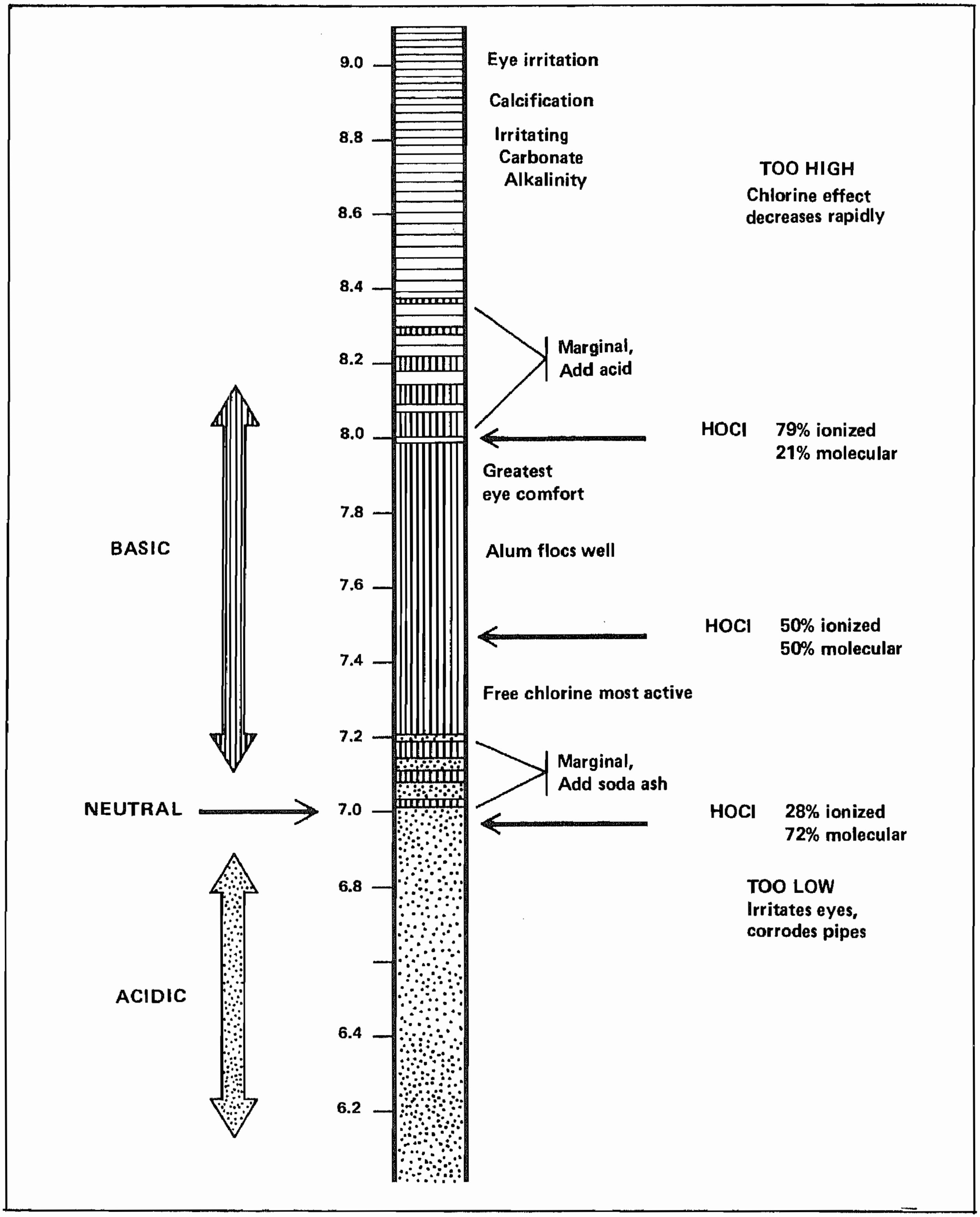
E. ACID-BASE POOL CHEMISTRY

1. **pH** – Water is a chemical compound which ionizes to produce hydrogen ions and hydroxyl ions. An acid is a compound which ionizes to produce an excess of hydrogen ions. A base is a compound which ionizes to produce an excess of hydroxyl ions. When the water ionizes, it produces an equal number of hydrogen and hydroxyl ions. It is a neutral compound, neither acid or base.

   The concentration of hydrogen ions in a solution is expressed by the symbol pH. It ranges in value from 0 to 14. The pH value for pure water is 7.0. As the hydrogen ion concentration of a solution increases above that of water, the pH value for that solution decreases, indicating an acid solution. If the solution has a hydrogen ion concentration less than that of water, the pH value of the solution will be greater than 7.0, indicating a basic solution.

   Swimming pools must maintain a pH value between 7.2 and 8.2, slightly basic. These relationships are shown in Figure 20. The pH is not a measure of the amount of acid or base in a solution but measures only how much is ionized. Thus, a solution could contain a large amount of an unionized compound which would not affect the pH unless, and until, it is ionized.

Figure 20. pH scale



2. **Total alkalinity** – Alkaline compounds are those which produce basic solutions when ionized. It is possible for a solution to contain an alkaline substance in the unionized state. These alkaline substances are referred to as buffers. They are available in the solution to ionize when required, thus providing a means of holding a fairly steady pH. The total amount of such alkaline substance, whether ionized or unionized, is referred to as the *total alkalinity* of the solution.

   Some of the alkaline compounds in water contribute to *hardness;* others do not. Thus, the total alkalinity, total hardness, and pH of a water solution are different, though related, values.

   In order to maintain a satisfactory pH value in a pool, it is necessary to maintain a total alkalinity equivalent to that produced by 80 to 120 ppm of calcium carbonate. In some instances a total alkalinity up to 200 ppm is necessary to maintain proper chemical balance.

   Alkalinity can exist in water in 3 forms: carbonate, bicarbonate, and hydroxide. The relative concentration of each type of alkalinity present is a function of the pH of the solution. At the pH values maintained in swimming pools, nearly all alkalinity is in the bicarbonate form. Some carbonate alkalinity may exist at the higher pH ranges found in pools.

   Bicarbonate alkalinity can be added directly to the pool water by using sodium bicarbonate. This raises the total alkalinity in the pool with very little effect on the pH.

   If sodium carbonate is added to the pool, it immediately takes some hydrogen ions from solution to change the carbonate to bicarbonate. This increases the total alkalinity of the solution, but since it takes hydrogen ions out of solution, it causes a corresponding rise in pH.

3. **Effects of pH** – The pH of swimming pool water affects pool operation in many ways.
   a. **Bacterial rate of kill** – The percent of hypochlorous acid which remains in its highly effective molecular form is a function of the pH. As the pH is raised, more ionization occurs and the disinfectant decreases in effectiveness. A corresponding increase in chlorine concentration is necessary to offset the higher pH.

   b. **Eye irritation** – Experience has shown that in most pools the least eye irritation is encountered when the pH is maintained in the range of 7.6 to 8.0. The presence of chloramines is a real cause of eye irritation, and the pH is a factor in the speed with which chlorine reacts with the chloramines to eliminate them.

   c. **Corrosion of pipes and deterioration of mortar** – If the pH is allowed to remain at 7.0 or below, the water has a corrosive effect on metal pipes and can act as an acid in dissolving mortar and concrete in the grouting and the pool walls.

   d. **Effect on coagulants** – Coagulants used in rapid sand filters require a narrow range of pH to floc and will dissolve with sudden changes in pH. A low pH will prevent proper flocculation and cause the mat already on the filters to dissolve and release dirt.

   e. **Algae growth** – Water with a low pH may encourage growth of algae. A pH of 8.0 will tend to inhibit this growth.

4. **Factors affecting pH.**
   a. Gaseous chlorine lowers pH drastically.
   b. The use of coagulants depletes the total alkalinity. Unless adequate buffer capacity is available, a slight decrease in pH results.
   c. Sodium and calcium hypochlorite tend to raise the pH moderately. Lithium hypochlorite, cyanurates, bromine, and iodine have little effect on pH.
   d. Makeup water added to the pool may affect the pH, depending on the pH of the new water.
   e. Windblown dust, debris, and contaminants brought in by bathers may cause sudden changes in pH.

5. **Control of pH**
   a. **Chemicals used to raise pH.**
      (1) Sodium carbonate (soda ash) is the chemical most commonly used.
      (2) Sodium hydroxide, though somewhat more dangerous to handle, is often used to raise the pH in pools.
      (3) Sodium bicarbonate is usually used for raising total alkalinity, but it can raise the pH if the pH originally is low.
   b. **Chemicals used to lower pH.**
      (1) Sodium bisulfate is recommended as a safe and effective chemical for lowering pH.
      (2) Hydrochloric acid (muriatic acid) is commonly used, though dangerous to handle.
      (3) Sulfuric acid (dilute) is used occasionally but is not recommended.

6. **Control of total alkalinity**
   a. The most effective method for raising total alkalinity without great effect on pH is the addition of sodium bicarbonate.
   b. Total alkalinity can be lowered most effectively by repeated small doses of sodium bisulfate or muriatic acid. As long as the total alkalinity remains fairly high the pH will return to normal after the initial drop induced by the addition of the acid.

F. COAGULANTS

1. **General** – Coagulants (flocculants) can be used to improve the efficiency of rapid sand filters. Occasionally they are used with high rate sand filters. Sodium aluminum sulfate and potassium aluminum sulfate are sometimes used but are not recommended.

2. **Alum** – The most commonly used and most economical coagulant is aluminum sulfate, $Al_2(SO_4)_3$. When aluminum sulfate (alum) is dissolved in pool water of sufficient total alkalinity, it forms a hydrous aluminum hydroxide floc which appears as a white gelatinous substance. It clings to particulate matter in the pool water and hold particles which might otherwise pass through the sand.

The reaction requires 0.88 pounds of alkalinity for each pound of alum. The result is a decrease in total alkalinity and a corresponding drop in pH. Sufficient alkalinity must be present or the flocculation may take place in the pool, causing great turbidity.

The usual recommendation is two ounces of alum for each square foot of filter surface every eight hours.

Alum is added very slowly and sufficiently far ahead of the filters to allow time for it to react with alkalinity before it reaches the filter surface. If added too fast or too close to the filters, it may pass through into the pool causing eye irritation and a sticky sensation on the skin and hair.

3. **Liquid coagulants** – Some operators report excellent and convenient coagulation with liquid coagulants. These can be used either alone or to assist coagulation with alum. One example of a liquid coagulant is a cationic polyelectrolyte formed from dimethyl diallyl ammonium chloride. It is applied by first diluting with water and then injecting with a positive displacement chemical feed pump.

IV. Operation and Maintenance of Pool Recirculation and Disinfection Equipment

A. HAIR STRAINER

1. **Opening for inspection** – This device should be opened at least weekly for inspection. For diatomaceous earth filters the strainer basket can be checked only at backwash intervals. A single screw clamp should be used as a replacement for bolt-type fasteners so that the device will more likely be opened at frequent intervals.
2. **Strainer baskets** – Several extra should be available so that the baskets can be dried and cleaned with a stiff wire brush.

B. MAKEUP TANK

1. **Cross-connections** – If the fresh water supply enters below the highest overflow level of the tank, this entrance pipe should be raised to provide an air gap entrance. For delivery pipes entering over the tank rim, a temporary correction may be made by drilling a 1/8-inch hole into the horizontal pipe bottom above the water surface and upstream of the elbow.
2. **Use as balance tank** – If the tank is elevated so its highest water level is the same as that in the pool proper, it can be used to maintain the pool water surface just at the rim of the overflow gutters.
3. **Emergency use** – This tank can be used to add chemicals such as disinfectants, coagulants, algicides, and pH control compounds into the pool water.

C. PUMPS AND MOTORS

1. **Protection against corrosion**
   a. **Oxidation** – The pump and particularly the motor should be protected against pooled or splashed water or chemicals. Proper floor draining and room ventilation will provide some protection.

b. **Galvanic** – Pumps made of dissimilar metals may be subject to galvanic corrosion. Difficulties due to corrosion can be minimized by using an anodic metal such as cast iron for the pump housing and a cathodic metal such as bronze for the impeller. This will help protect the more important impeller and distribute the corrosion over the large pump housing area. Insulated fittings can be helpful.

2. **Pump operation**

a. **Pump packing glands** – Packing glands in many centrifugal pumps are lubricated by a controlled leakage. Several drops per minute will usually suffice. The adjustment of the stuffing box gland nut will provide sufficient lubrication.

b. **Priming** – Since air prevents successful pump operation, it is excluded by priming. This must be done with the pump not running to prevent damage to the water lubricated packing rings.

c. **Lubrication** – Manufacturer's instructions should be followed in providing lubrication for the ball bearings on the pump and motor. Overlubrication can result in heat damage to bearing surfaces.

d. **Operation difficulties**

(1) **Failure to pump** – This may be caused by lack of priming, wrong direction of impeller rotation, or too low a motor speed.

(2) **Reduced pumping capacity** – Air pockets or leaks in the suction line, a clogged impeller, an excessively worn impeller, or a total head loss in excess of that recommended for the pump may cause this problem.

(3) **Pump losing prime** – This may be caused by air leaks in the suction line, excessive air carried to the pump with pool water, or air entering the line through the stuffing box.

(4) **Mechanical troubles and noise** – This may be caused by misalignment of the motor-pump shaft, a bent shaft, damaged bearings, or an improperly proportioned suction and discharge line combination.

D. DISINFECTION EQUIPMENT

1. **Hypochlorination (See Figure 21)**

a. **Making stock solutions**

(1) **Quantity used** – Stock solutions can be made by mixing sodium or calcium hypochlorite into water. Only enough solution should be prepared at one time to last approximately one month. When exposed to light and at room temperature, prepared solutions will lose up to 7 percent of their active strength during a 14-day storage period. The following table gives quantities for preparing solutions.

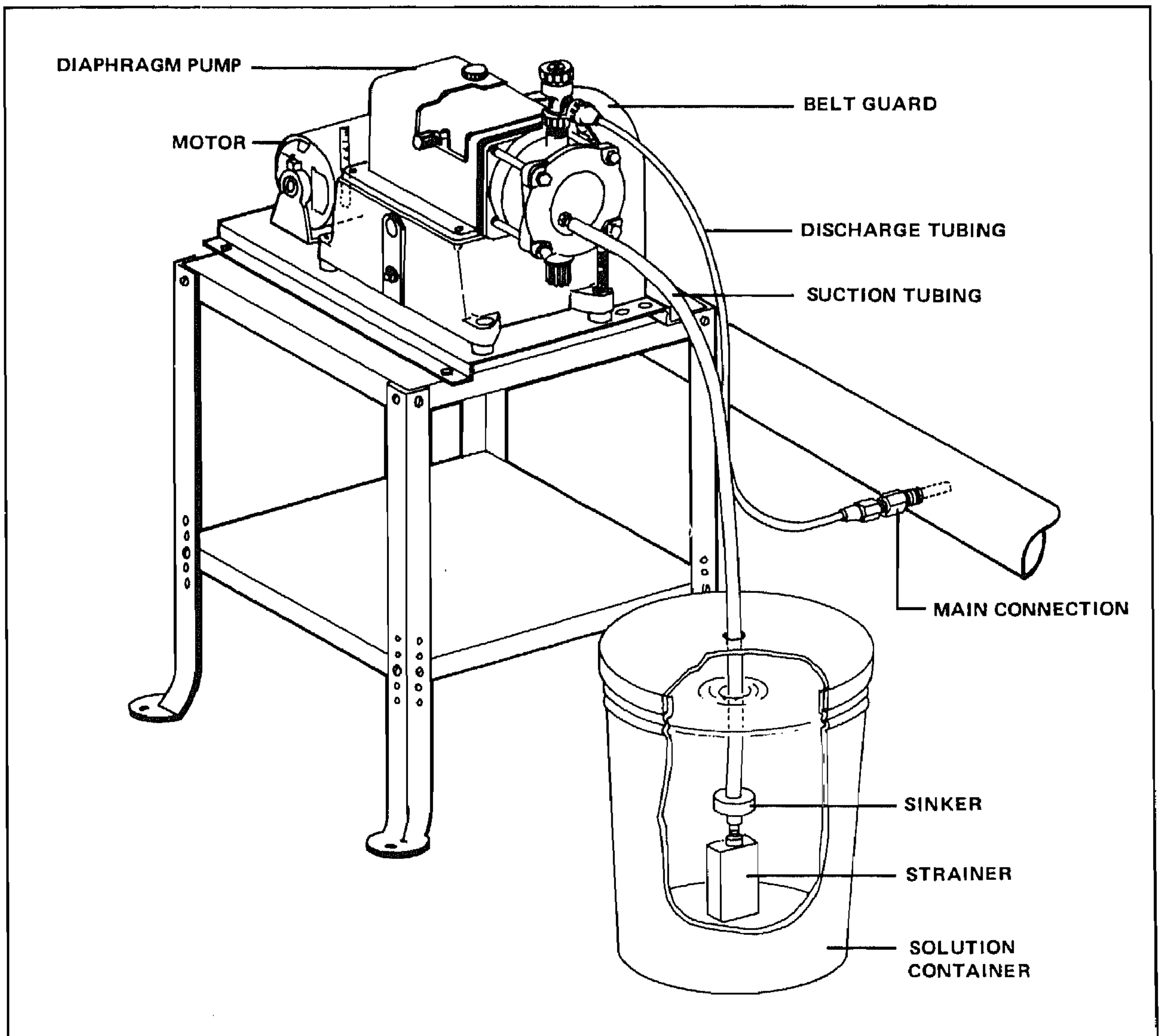
Table 5

PREPARATION OF HYPOCHLORITE SOLUTION

[Basis: 10 gallons of 1 percent solution (10,000 ppm)]

Percent Available Chlorine	Quantity Used
5.0	8 qt sodium hypochlorite
15.0	5½ lb calcium hypochlorite
70.0	10 oz calcium hypochlorite

Figure 21. Hypochlorination system



Courtesy of Wallace & Tiernan Division, Pennwalt Corporation

(2) **Mixing precautions**

(a) **Elimination of sediment**

(i) **Presettling** – To prevent clogging the feeding device's small parts, hypochlorite solutions should be premixed in a suitable crock and the excess carrier allowed to precipitate. The supernatant solution can then be siphoned off and used in the feeding device.

(ii) **Water additives** – When hard water is used for mixing calcium hypochlorite solution, sodium hexametaphosphate or tetrasodium pyrophosphate may be added to prevent excessive sediment formation. These compounds may be mixed in the ratio of 1 to 1½ ounces per 100 gallons for each grain (17.1 ppm) of hardness.

b. **Maintaining the working parts of hypochlorinators**

(1) **Cleaning**

(a) **Daily cleaning** – Flushing all parts with clear water will help maintain the parts in operating condition. The strainer connection on the suction side of the hypochlorinator must be cleaned daily with a brush to prevent clogging the intake orifices.

(b) **Semimonthly cleaning** – Treating the valves and other important parts of the hypochlorinator with acid solutions will be necessary to remove chemical deposits. This is particularly true with pool waters that are high in carbonates, sulfates, and iron. Dilute muriatic (hydrochloric) acid, dilute acetic acid, or undiluted vinegar may be used for the cleaning solution. Brushing with a stiff bristle brush will assist cleaning.

(2) **Replacement parts** – Each pool operator should maintain a supply of replacement parts such as valves, valve seats, diaphragms, and connective hose so that equipment failure will not cause long delays in operation. Many hypochlorinator manufacturers will provide part kits as a packaged unit.

c. **Operating difficulties**

(1) **Clogged lines** – The most common cause of operating difficulty is clogged lines due to chemical deposits. Preventive maintenance cleaning will help avoid this difficulty.

(2) **Interruption of solution discharge**

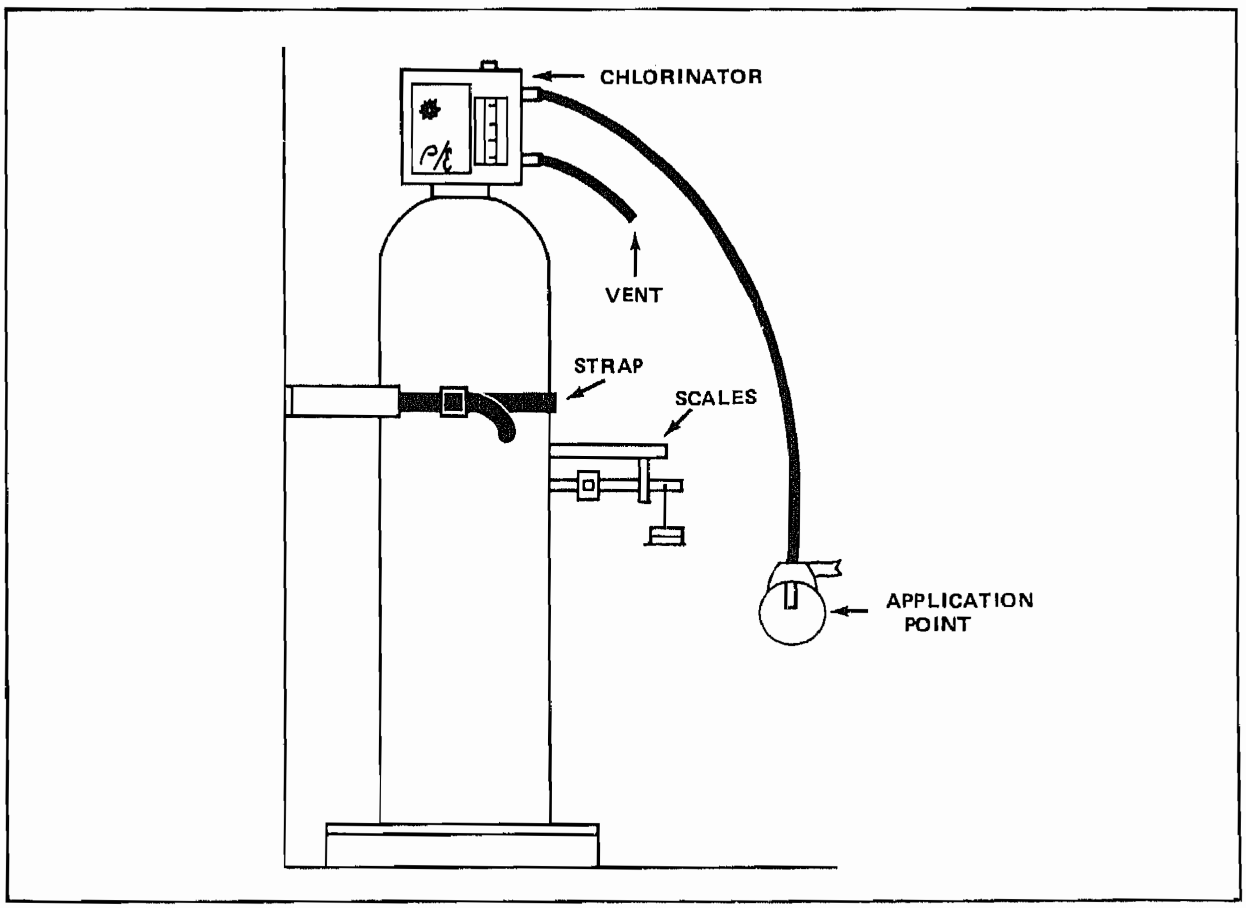
(a) **Suction line trouble** – Priming the suction line is frequently necessary to exclude air and permit solution pickup.

(b) **Discharge line trouble** – If the line pressure into which the chlorine solution is being discharged exceeds the discharge pressure of the hypochlorinator, no solution will be delivered. This can often be remedied by changing the point of chlorine application such as injecting chlorine on the suction side of the recirculation pump instead of the discharge side.

(3) **Uncontrolled change in feed rate** – This can be largely prevented by using a positive displacement pump to inject the hypochlorite solution (Figures 14 and 15).

2. **Chlorination with gas (See Figure 22)**
   a. **Handling chlorine containers**
      (1) **Storage**
         (a) **Safety plugs** – Since these containers have fusible plugs which will melt at 160° F, they should be stored under cover in areas away from excessive heat. They should be separated by a wall from heaters such as pool heaters.
         (b) **Below ground storage** – Since chlorine gas is heavier than air, chlorine should not be stored or used below ground level.
         (c) **Tank in use** – The chlorine tank or cylinder in use must be firmly held in an upright position in a recessed sump, wall hung strap, or similar device to prevent its being knocked over and releasing chlorine gas.
         (d) **Tanks in storage** – Full or empty cylinders in storage must be similarly held in an upright position with the protective cap in place.
      (2) **Transporting cylinders** – Cylinders should never be moved or stored unless the protective cap is in place.

Figure 22. Gas chlorine cylinder in use



Courtesy of David G. Thomas and National Swimming Pool Foundation

b. **Connections from cylinder to chlorinator**

(1) **Temperature considerations** – If the temperature of the chlorine cylinder is higher than the chlorine feed lines, chlorine can condense in the lines. Condensation can be prevented by reducing the pressure with a pressure reducing valve. In no case should supply lines be run along cold walls or exterior windows. If heat must be applied, it should be applied by heating the entire space. Localized heat should not be applied directly to the tank or lines.

(2) **Pipe fittings and connections** - New gaskets should be used on all connections. Piping systems should be well supported and adequately sloped to allow drainage–low spots should be avoided. A lubricating pipe dope suitable for chlorine should be used. Linseed oil and graphite, linseed oil and white lead, or litharge and glycerine (for permanent joints) may be used.

(3) The cylinder valve is opened by turning the valve stem one full turn in a counter-clockwise direction. Special 3/8-inch square box wrenches should be used for turning the valve stem. A wrench longer than 6 inches should not be used. Leaks at this valve can be stopped by tightening the packing nut at the valve stem.

c. **Leak detection**

(1) A small piece of cloth soaked with ammonia and wrapped around the end of a short stick can be used to detect leaks. If chlorine gas leakage is occurring, a white cloud of ammonium chloride will form. Commercial 26° Baumé aqua ammonia should be used; household ammonia is not strong enough.

(2) Avoid contact of ammonia with copper or brass.

(3) Never use water on a chlorine leak. The corrosive action of chlorine and water always will make the leak worse.

d. **Ventilation** – High and low ventilation should be supplied for chlorine rooms. The suction point of exhaust fans should be located at or near floor level. A 2-minute air change should be provided. Switches for all ventilating fans should be provided outside of chlorine rooms even when an inside switch is installed.

e. **Determining when a cylinder is nearly empty**

(1) **Weight** – 100-pound cylinders and 150-pound cylinders will have lost their rated net content.

(2) **Gas pressure** – The gas pressure gauge will show a marked drop when a cylinder is empty.

(3) **Observing the chlorinator** – Visible vacuum type chlorinators (bell jar installations) will begin to bubble air, and other chlorinators will show erratic movements of rotameter dose indicators.

f. **Gas masks** – Gas masks should be provided at a point *accessible* to the operator in the event of an emergency, generally immediately outside the chlorine room door.

(1) Front-mounted or back-mounted gas masks equipped with a chlorine type canister may be used with low concentrations of chlorine in air.

(a) **Oxygen depletion** – This mask will give no protection in areas deficient in oxygen.

(b) **Maintenance of canisters** – Canisters should be replaced even if they are not exhausted in the event that either of the canisters seals has been broken, or if the expiration date on the canister has been exceeded.

(2) Self-contained breathing apparatus with a full facepiece and a cylinder of air or oxygen carried on the body is suitable for high concentrations of chlorine or depleted oxygen and is the preferred means of respiratory protection. The apparatus should be the pressure-demand type in which the pressure inside the facepiece is positive during both inhalation and exhalation.

g. **Emergencies**

(1) **Emergency plan** – In addition to the general emergency plan, a carefully devised plan specific for chlorine gas should be posted. Personnel should be drilled in executing the plan.

(2) **Human exposure** – If a person has been exposed to chlorine gas, remove him to fresh air and seek medical assistance immediately.

(3) **Disposing of chlorine** – Install a standby alkali absorption system. A suitable tank capable of holding the required alkaline solution should be provided. The alkali should be stored in a form so that a solution can be readily prepared when needed. Chlorine should be passed into the solution through a connection properly submerged and weighted to hold it under the surface. The contents of a full 100-pound cylinder of chlorine can be absorbed in 300 pounds of soda ash dissolved in 100 pounds of water, or 125 pounds of caustic soda dissolved in 40 gallons of water.

E. EQUIPMENT FOR CONTROLLING pH

1. **Operation** – These devices feed control chemicals previously described in order to maintain optimum pH conditions.

2. **Operational problems**

a. **Partial loss of floc mat** – If alum is used with a sand filter, it is possible that a part of the sand filter mat may dissolve and cause turbidity in the pool if soda ash is added too rapidly. This may be prevented either by slow feeding to hold the pH constant or by adding batch doses of soda ash after backwashing and before beginning the alum feed.

b. **Creation of a precipitate in the pool** – Soda ash when added to the pool in powdered form can cause precipitation of calcium carbonate. This can be prevented by feeding ahead of the filters in the normally prescribed manner.

c. **Feeder maintenance** – In general, the same maintenance and cleaning procedures applied to hypochlorinators will be effective with these devices.

F. FILTER AID (DIATOMACEOUS EARTH) FEEDING EQUIPMENT

1. **Precoat feeder**

a. **Quantity fed** – A 1/10 to 1/32-inch depth of diatomaceous earth is fed onto the filter septa by delivering about 0.125 pounds of material per square foot of filter surface. This may be fed onto the filter by recirculation for about five minutes.

b. **Operational problems** – Difficulties of impacted filter feed lines may be avoided by flushing the feeding device with pool water after precoating.

2. **Body feeder**

a. **Quantity fed** – To build up a layer of filtering media, a continuous feed of diatomaceous earth should be delivered into the water during the filter run at the rate of about 1 part for each part of water turbidity. In general, this will amount to about 1 to 4 ounces per 10,000 gallons recirculated.

b. **Operational problems**

(1) **Compaction** – The compaction of the filter aid often results in malfunctioning of the feeding device. The addition of a constant mixing device such as mechanical stirring or air agitation will eliminate much of this difficulty.

(2) **Clogged feed lines and dispensing parts** – Flushing the feeding device with pool water (without the addition of diatomaceous earth) before it is shut down for any interval of time minimizes clogging.

G. FILTRATION EQUIPMENT

1. **Gravity Sand Filters** – The installation of this type of filter for swimming pools is no longer common practice. The principles of operation and maintenance are similar to those discussed under pressure sand filters.

2. **Rapid Pressure Sand Filters**

a. **Operation** – These filters are supplied with a filtering mat of coagulant material and operated 24 hours a day at *3 gallons per square foot per minute* until the difference in pressure between the influent pressure gauge and the effluent pressure gauge is in the range of *5 to 7 pounds per square inch.* They should then be backwashed at the rate of *15 gallons per square foot per minute* (8 gallons per square foot per minute for anthrifilt media filters) for about five minutes or until the backwash water appears clear for 2 minutes.

b. **Operational problems**

(1) **Air binding** – Short circuiting of the filter inflow can be caused by air trapped in the top of the filter. An air release valve located in the top of the shell will release this air. Automatic or manual valves are available. When painting the filter unit, avoid painting any automatic valves.

(2) **Mechanical loss of filtering mat** – Shutting down for extended periods of time, such as during the night, will not only prevent good operation based on filter design but will result in a partial loss of the uniform filter mat.

(3) **Inability to read pressure differential** – High range gauges should be replaced with those that read in the range of the filter's operation. In general, gauges reading up to only 30 pounds per square inch are desirable.

Another operational difficulty may be avoided by mounting gauges on the tops of filter lines to prevent clogging with sediment.

(4) **Rate of flow change through filters** – With the pump running at the same speed, the flow of water through the filter will slowly decrease throughout the filter run. A rate of flow controller can be installed to deliver a constant 3 (or 2) gallons per square foot per minute through the filter.

(5) **Filter media difficulties** – Filters that are failing to produce a clear effluent should be inspected by removing the manhole cover and looking at the sand surface after backwashing.

(a) **Clean sand surface** – This indicates satisfactory operation.

(b) **Dirty sand surface** – This indicates unsatisfactory conditions. The filter should be backwashed slowly and the rising water observed.

(i) **Water emerges evenly during test backwash** – More water is needed for backwashing in this case. While an inadequate backwash pump may cause the trouble, temporary relief may be obtained by removing the top layer of sand and washing it in a lye (caustic) solution.

Another technique is to wash the whole sand bed with caustic soda by applying 1 pound of lye per square foot of filter surface after allowing the water to drain down to within 2 inches of the sand bed surface. After 4 to 6 hours of soaking, the filter may be drained and then *thoroughly* backwashed.

(ii) **Water emerges unevenly during test backwash** – This indicates obstructions in the filter bed or underdrains.

This might be caused by mudballs or accumulations of dirt and sand held together by organic growths. This often can be corrected by applying 2 ounces of calcium hypochlorite per square foot of filter surface and soaking the medium as described above. Maintenance of adequate backwash rates and application of pool disinfectant chemicals ahead of the filters will probably prevent this difficulty from recurring.

Some success has been reported with the use of an acid bath for correcting clogged filters and underdrains. Two pounds of sodium bisulfate per square foot of filter area is added, and the filters are permitted to soak as described above. Thorough backwashing is critical after this treatment to prevent damage to the metal parts of the system.

Cementation of sand grains due to mineral compounds normally in the water or used in water treatment may prevent correction by these treatments, in which case the sand might have to be replaced.

Sodium hexametaphosphate may be fed into water to prevent the undesirable effects of excessive hardness. Dosing in the range of 5 ppm is generally accepted. One suggested technique for batch feeding is to add 10 pounds of the compound for each 250,000 gallons of pool capacity at the start and 2 pounds for each 250,000 gallons every other week.

3. **High rate sand filters**

a. **Operation** – These filters contain only sand and should be operated 24 hours per day at the manufacturer's suggested rate (12 to 20 gpm per sq ft). When the filter differential pressure reaches 10 to 15 psi, dirt will have penetrated the sand to a depth of 6 to 10 inches. The high rate filters often operate at pressures up to 30 or 40 psi. At a 10 to 15 psi increase, backwash is necessary for only a 2 to 4 minute period at the same flow rate as the filtering process.

b. **Operational problems**

(1) Backwashing with water that is not clean may clog the orifices in the tank collection manifold. This clogging will cause uneven filter and backwash flow. The sand must be removed and the orifices physically cleaned if the clogging does not correct itself during the next filter run. Draining the pool by use of the backwash cycle will surely cause such clogging of the precision orifices. Failure to clean the orifices will cause increased velocity and finally erosion of the remaining orifices, leading to destruction of the manifold laterals.

(2) Automatic and continuous bleeding of air from the filter tank is essential.

(3) Inadequate backwashing will lead to reduced permeability of the sand and eventual channeling.

(4) In some cases where high rate sand filters have not removed turbidity satisfactorily, the introduction of alum has led to better water quality with no deleterious effects.

4. **Diatomaceous earth filters**

a. **Operation** – These filters are equipped with various types of filtering surfaces which are covered with diatomaceous earth prior to their being put into service. They are generally operated at 1 to 2 gallons per square foot per minute and operated 24 hours a day.

Pressure filters are backwashed when the influent and effluent pressure differential is in the range of 25 to 50 psi, depending on the type used. Vacuum filters are backwashed at a vacuum gauge reading of about 10 to 15 inches of mercury.

b. **Operational problems**

(1) **Short filter runs** – While a shorter filter run than obtained with a sand filter is expected with this type of filter, extended hours of use can be obtained by careful attention to the application of body feed throughout the operation of the filter cycle.

(2) **Clogged filter elements or septa** – Elements made of metallic material or synthetic fiber cloth may be freed from encrusted debris by one of the following treatments:

(a) **Diatomite and organic matter clogging** – This may be removed by soaking the elements in an 8 percent solution of sodium hexametaphosphate for 2 hours and then scrubbing them with a wire brush.

(b) **Iron clogging (rust colored deposit)** – This may be removed by soaking in hydrochloric (muriatic) acid or by brushing with oxalic acid solution.

(c) **Manganese clogging (gray-black deposit)** – This may be cleaned by soaking in a solution of hydrochloric acid to which a small amount of sodium sulfite has been added.

(d) **Calcium and magnesium deposits** – Water hardness chemicals can be removed from the elements by the application of hydrochloric acid as noted in (b) above.

H. POOL HEATERS

1. **Intermittent operation** – In cool weather when the pool heater is first put into operation, it is best not to turn the heater off and on intermittently. Best results will be obtained by setting the thermostat to prevent the pool water temperature from dropping below 65° F. This will permit warming the pool to a comfortable swimming temperature in a shorter time.
2. **Descaling the unit** – The water side of the heat transfer surface will eventually become scaled if the water is hard. The unit can be descaled by flushing it with a 50-50 mixture of inhibited hydrochloric (muriatic) acid and water until the chemical foaming action stops. The flushing can be facilitated by shutting off the inlet and outlet water lines, opening the heater drain and pouring the acid mixture in through a high standpipe installed on the discharge line. Displaced air may be vented through another standpipe installed on the inlet line. It is important to flush thoroughly with water immediately after acid treatment.

V. Algae Control

A. GENERAL

These plant forms are brought into the pool by the wind, with the bathers, and with makeup water. If uncontrolled, they will grow abundantly in the presence of sunlight. They are found in the free floating and clinging varieties. The clinging type will embed itself into pores and crevices in concrete and is a more persistent type to treat.

B. OBJECTIONAL FEATURES OF ALGAE

1. **Chlorine demand** – Algae will create a high chlorine demand. Once they have become established in the pool, the maintenance of residual chlorine is difficult.
2. **Water turbidity** – The increased turbidity in the pool due to algae is not only esthetically objectionable, but creates a hazard to proper swimmer supervision.
3. **Slipping** – Algae growths may increase pool accidents from patrons slipping on pool bottoms, sides, walkways, and ladders.
4. **Effect on bacterial growth** – In addition to buffering bacteria from the effects of chlorine by creating a high chlorine demand themselves, algae also may actually foster bacterial growth.
5. **Odor** – Algae create odor problems, particularly when reacting with chlorine.

C. DETECTING ALGAE GROWTH EARLY

Algae require carbon dioxide in order to manufacture food. In the process of removing carbon dioxide from water, there is a definite increase in the pH. This may be seen in a radical jump in pH (from 7.5 to 8.0 as an example) in several hours, before there is any noticable growth in the water.

D. METHODS OF CONTROL

1. **Routine chlorination** – The maintenance of free residual chlorine in the pool at all times will help prevent the start of algae troubles.
2. **Pool shading** – Since algae need sunlight for growth, shading the pool will deter growth.
3. **Temperature** – Pool water at a temperature of less than 80° F will minimize the algae problem.
4. **Superchlorination** – One of the most effective treatments is the development of 10 ppm free residual chlorine in the pool during nonswimming hours.

   Excessively high residuals may be reduced to permit swimming by adding sodium thiosulfate to the water at the rate of 1.0 to 1.5 ppm for each 1.0 ppm of residual chlorine being removed.
5. **Pool scrubbing** – As a last resort the pool may be drained, and the bottom and sides scrubbed with a 5 percent hypochlorite slurry or copper sulfate solution to remove tenacious algae growths.

VI. Pool and Pool Area Maintenance

A. CRACKS IN THE POOL

1. **Loss of water** – The loss of water through cracks in the pool can amount to a considerable volume. A loss of 1 inch of water from a pool in an overnight period represents 625 gallons for each 1,000 square feet of pool surface.
2. **Repair** – Special hydraulic cement compounds can be used to patch small to medium-sized cracks. Tar and asphalt fillers should not be used, as they are unsightly and will extrude into the pool.
3. **Prevention of cracks caused by "earth-heave"** – Many pools, especially those constructed by the gunite process, will crack if drained for any length of time. It is desirable in these cases to leave water in the pool at all times.

B. POOL CLEANING

1. **Suction cleaners** – Suction cleaners, installed as part of the system or maintained as a separate system, are a valuable adjunct to the pool maintenance program. Devices are available which will operate from a common garden hose. Daily use of these devices is a necessity. Self-propelled vacuum cleaners can be left in the pool with automatic shutoff devices to save man-hours of cleaning time.
2. **Rake** – A long handled wire net is useful in clearing insects and leaves from the water surface each morning.

3. **Magnet collector** – A magnet on a long stick is useful in removing metallic objects such as hairpins from the pool.
4. **Pool interior surface stains** – A cleaning compound containing trisodium phosphate can be used for daily cleaning of the overflow gutters and water level areas of the pool.
5. A 5 percent solution of hydrochloric acid is useful in removing tenacious calcium deposits from the pool structure.

VII. Offseason Protection

A. RECIRCULATION EQUIPMENT

1. **Filters** – These should be inspected and operational problems corrected before being thoroughly backwashed and completely drained.
2. **Feeding equipment and makeup tank** – All feeders should be thoroughly cleaned and completely drained. Light applications of petrolatum and clear oil will help prevent corrosion during storage.
3. **Disinfection equipment** – All parts of this equipment should be completely drained and metal parts coated with petrolatum.
4. **Pump** – This should be drained and greased, and the fuses removed from the pump switch.

B. POOL PROPER

1. **Ice thrust** – Wood poles may be placed along one side and one end as a protection against ice thrust pressure.
2. **Pool cover** – A plastic pool cover will prevent accumulation of debris and growths of algae. These covers should be securely installed to prevent entry.

C. POOL AREA

1. **Deck equipment** – All deck equipment should be stored inside to prevent damage or vandalism. Springboards should be placed on a flat, dry surface to prevent warping.
2. **Drinking fountains** – These should be drained and covered to prevent staining.
3. **Lighting** – Floodlight bulbs and reflectors should be removed and the sockets plugged. Reflectors may be coated with a clear oil to protect against rusting.

D. SERVICE BUILDINGS

1. **Water supply** – The water supply should be turned off at the service point and all fixtures drained.
2. **Electrical service** – The service should be disconnected and all fuses removed.

VIII. Service Operations and Maintenance

A. LOCKER FACILITIES

Care must be taken not to crowd clothes storage units too close together. Adequate ventilation between storage units is necessary. Baskets and lockers should be cleaned weekly and inspected regularly.

B. LIGHTING

Adequate lighting is important for safety and cleanliness.

C. VENTILATION

The worth of a pool will be determined by what a patron sees or smells. Deodorants should not be used as a substitute for routine cleaning and good ventilation.

Damage to plumbing and metal structural members, wood rot, unsightly stains, and plaster deterioration are all results of poor ventilation.

D. MAINTENANCE OF SANITARY FACILITIES

Lavatories, urinals, and toilets should be cleaned and disinfected at least twice daily. Soap, single-use towels, and toilet tissue must be available at all times.

E. APPURTENANCES

1. Furniture including dressing booths should be kept as simple as possible. Timely painting will prolong the life of wooden articles.
2. Waste receptacles which are water tight and fly proof should be provided in all dressing rooms.

F. FLOOR CLEANING AND MAINTENANCE

1. **Floor conditions**
   a. Frequent applications of strong nonacid cleaning powders will render smooth concrete or terrazzo surfaces less slippery.

   b. Nonslip paint is available as durable paint with grit added to reduce hazards from slippery surfaces.
2. **Floor cleaning and disinfection**
   a. **Disinfection** – The application of a 0.3 to 0.6 percent solution of hypochlorite is an acceptable method of floor disinfection.

   b. **Cleaning combined with disinfection**

      (1) **Method 1** – A combined cleaner and disinfectant is used to mop the floor. One such product combines detergent with benzylated phenol.

      (2) **Method 2** – The floors are hosed and then a lye (caustic) solution is applied with a stiff brush. The lye solution is made by mixing one-half can of lye in a bucket of hot water.

G. ATHLETE'S FOOT CONTROL

1. **General** – The fungi that cause athlete's foot are frequently transmitted through bathhouse floors, mats, and floor coverings.

2. **Personal prevention**
   a. **Foot protection** – Patrons should wear their own clogs while using the bathhouse facilities.
   b. **Drying agents** – Moisture is an important factor in protecting against this fungus infection. Medicated powders keep the feet dry and often contain preventive or curative chemicals.

3. **Other prevention**
   a. **Wooden walkways and mats** – These must be eliminated since they are extremely difficult to disinfect. Mats on springboards can be replaced with nonslip granular surfacing materials.
   b. **Foot treatment**
      (1) **Foot baths** – Foot baths that consist of a reservoir to be filled with a disinfectant solution should be replaced by fast flow-through foot baths. The only function of a flow-through foot bath is to wash off debris from the feet before the patron enters the pool area.
      (2) **Foot tougheners** – A pad soaked with salt (10 percent NaCl) is a device for toughening the bottom of the feet to prevent fungus attack. The fungus cannot live in the strong salt solution in the pad.

H. SWIMMER PERSONAL REGULATIONS

1. **Cleansing showers** – Showers will be more acceptable if tempered water is provided for the patron. Adherence to the practice of showering before entering the pool lightens the load on filtration and disinfection equipment.
2. **Exclusion** – Persons with open lesions should be excluded from the pool.

I. SAFETY

1. **Life saving equipment**
   a. **Reaching poles** – One or more light poles no less than 12 feet long should be available for making reaching assists.
   b. **Throwing buoys** – Buoys, not more than 15 inches in diameter, having at least 60 feet of 3/16-inch manilla line attached, should be placed on racks at strategic points adjacent to the pool.
   c. **Rescue tubes** – These are plastic foam buoys similar to large water ski belts, with 8 feet of line attached to one end and a snap clasp on the other end. These tubes permit safe and easy swimming rescues, and allow artificial respiration to be applied in deep water.

2. **First aid equipment and facilities**
   a. **First aid equipment**
      (1) **First aid kit** – A standard 24-unit first aid kit should be kept filled and readily accessible for emergency use.
      (2) **Additional equipment** – A stretcher and blankets should also be available.
      (3) **Backboard** – A standard plywood backboard or other acceptable splint made to the specifications of the American National Red Cross should be available for back and neck injuries.
   b. **First aid room** – An area or room should be set aside for the emergency care of casualties.
   c. **Telephone** – As previously noted, every swimming pool should have a telephone, and near it a list of current emergency numbers such as the nearest available physician, ambulance service, hospital, rescue squad, police department and fire department.

J. OPERATIONAL RECORDS

The efficiency of any endeavor depends on suitable records. A suggested record form for the pool manager and operator is included in this manual.

The following form is suggested for keeping operational records at swimming pools.

POOL OPERATOR'S WEEKLY REPORT – WEEK BEGINNING ____________ ____________ Swimming Pool

Type of Pool ____________________ **Location** ________________________________

Number of Swimmers			Remarks	Daily Tests					
				pH	Chlorine or other disinfectant Residual (ppm)				Temperature of water (°F)
					Deep End		Shallow End		
Day	Male	Female			AM	PM	AM	PM	
Sun.									
Mon.									
Tues.									
Wed.									
Thurs.									
Fri.									
Sat.									

Number of Hours Operation			Length of Time Each Filter Backwashed (min)	Volume of makeup water Added (Gallons)	Pounds of Chemical Added			
Day	Filters	Disinfecting Equipment			Soda Ash or other pH Control Substance	Alum or Other Coagulant	Disinfectant	Algicide
Sun.								
Mon.								
Tues.								
Wed.								
Thurs.								
Fri.								
Sat.								

Signed ________________________________

This report should be posted for inspection by the ______________________________ Health Department.

CHAPTER 4

Testing Swimming Pool Water for Chemical Content

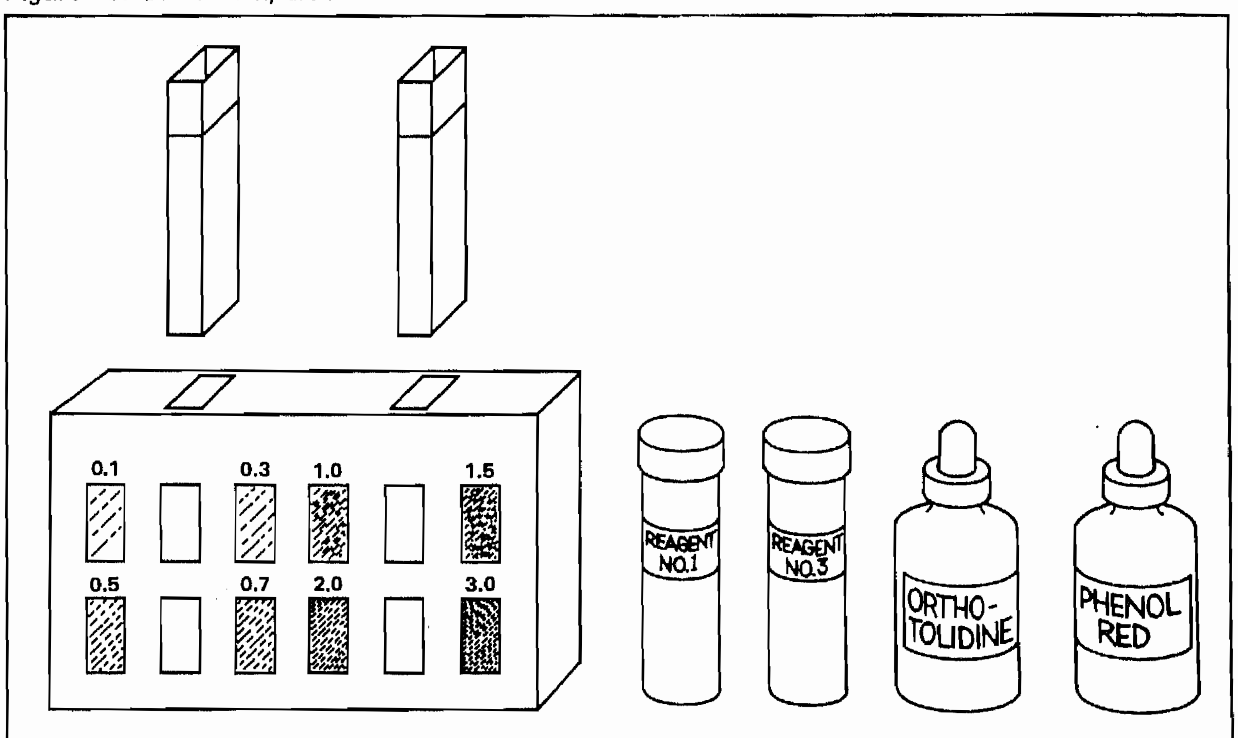
I. Testing for Residual Chlorine

A. GENERAL

Nearly all tests for residual chlorine in swimming pool water are accomplished with a colorimeter, a device which compares colors of solutions with color standards prepared in a laboratory. (See Figure 23). Inherent inaccuracies should not be multiplied by poor technique. The following rules apply to all chemical testing apparatus.

1. Follow directions carefully. Be particularly accurate in measuring amounts of reagents, and in observing time and temperature requirements.
2. Be scrupulously clean. Be sure all solution tubes, eye droppers, reagent bottles, and equipment are rinsed thoroughly after each use, both inside and outside. Do not handle the equipment with dirty hands. Rinse off immediately any reagents which touch the skin. Store the equipment, properly boxed or encased, in a clean, protected place. Do not interchange parts such as solution tubes, bottle caps, or droppers.
3. Be sure all reagents are fresh, and that they have been supplied by the same manufacturer who made the color samples. Each manufacturer develops reagents which are compatible with his own instruments, and not all reagents of the same name are of equal composition or concentration. Reagents lose their strength on aging and exposure to light and should not be kept longer than recommended by the manufacturer.
4. Avoid subjecting color standards and reagents to prolonged direct sunlight, or temperatures over 100 degrees or below freezing.

Figure 23. Color comparator



NOTE: Typical of the comparators used for orthotolidine tests for chlorine and bromine, Palin DPD test for chlorine, phenol red test for pH, and Black and Whittle test for iodine.

B. ORTHOTOLIDINE TEST

The most common test for residual chlorine is the orthotolodine test. It is based on the fact that a yellow color results when orthotolidine is added to a sample containing free or combined chlorine. At high concentrations of chlorine a deep orange or red color develops.

1. **Equipment** – Nearly all manufacturers of residual chlorine test equipment supply a kit containing color standards, a test vial, and a bottle of test reagent (orthotolidine). The color standards may be on a wheel, a slide, or a plastic block next to which the test vial is held to compare colors.

2. **Procedure** –

   a. Fill the test vial to the mark (usually about 10 ml) and add the amount of orthotolidine recommended (usually about 1.0 ml from a marked dropper). Mix, and *immediately* (within 10 seconds) place the test vial in the test kit next to the color standards and read the concentration of the color standard it matches. If the reading is made within 10 seconds, it will be a fair approximation of the free residual chlorine in the sample in ppm.

   b. Set the sample in a dark place for 5 minutes and then take a second reading. The second reading will be the total residual chlorine in the sample, including both free and combined chlorine.

   c. In some kits a second test vial filled with pool water is placed behind the color standard to compensate for pool turbidity and increase accuracy.

C. PALIN DPD TEST FOR RESIDUAL CHLORINE

The orthotolidine test is at best an approximation when used for free residual chlorine. Because of the several sources of possible error in this method, a more accurate method using diethyl-p-phenylenediamine (DPD) was developed in England by A. T. Palin. The Palin method allows for quantitative measurement of free chlorine, monochloramine, dichloramine, and total chlorine.

1. **Equipment** – One commercial Palin DPD test kit is composed of a color standard block with receptacles for test vials, two test vials, and four different tubes of reagent tablets.

2. **Procedure**

   a. For free residual chlorine, only tablet No. 1 is needed.

      (1) Place about 1 ml of pool water in a test vial and add a tablet from the No. 1 tablet tube.

      (2) Using a glass rod, crush the tablet into powder.

      (3) Fill the test vial with pool water to the mark, place a cap on the test vial and shake until dissolved.

      (4) Insert the test vial in the colorimeter block and compare with color standards. Read free residual chlorine directly in ppm.

   b. For determining total chlorine and combined chlorine, reagent tablets No. 1 and No. 3 are needed.

(1) Using the test solution from the procedure above, or after completing steps 1 thru 4 above, add reagent tablet No. 3 and shake until dissolved.

(2) Place test vial in colorimeter and read *total* chlorine directly in ppm.

(3) Subtracting free chlorine from total chlorine gives combined chlorine.

II. Testing for Residual Bromine

A. GENERAL

Since both free and combined bromine are effective bactericides, it is necessary only to test for total residual bromine. Bromine reacts with orthotolidine in the same manner as chlorine, but the colors produced are not as intense.

B. ORTHOTOLIDINE TEST

1. **Equipment** – The orthotolidine colorimeter can be used for bromine, but the color standards should be made especially for bromine.
2. **Procedures**
   a. If bromine color standards are used, the procedures are the same as for testing for chlorine.
   b. If chlorine color standards are used in testing for bromine, it is necessary to multiply the apparent result by 2.
   c. Ample time should be allowed for color development before reading the test.

III.Testing for Iodine

A. GENERAL

Iodine exists in pool water in four oxidation states: iodide (in potassium iodide), molecular iodine, hypoiodous acid (ionized and molecular), and iodate.

The iodate ion is the end result of oxidation and is of no value. No test is needed. The iodide ion is the iodine available for release, the so-called iodine bank. It is included in the test for total iodine and should be held at about 0.4 ppm. The molecular iodine and hypoiodous acid are considered to be free iodine and should be maintained at a residual concentration of about 0.8 ppm.

B. ORTHOTOLIDINE TEST FOR FREE IODINE

1. **Theory** – Orthotolidine does not react with free iodine in the presence of iodide, but the addition of mercuric chloride to the test sample forms a complex with the iodide ion and effectively removes it from the sample. Free iodine can then be measured.
2. **Equipment** – A standard orthotolidine test kit for chlorine can be used with the addition of a set of special color standards for iodine.

3. **Procedure**
   a. Add one drop of mercuric chloride reagent to 25 ml of pool water and mix well.
   b. Put 1 ml of orthotolidine reagent in a test kit vial and fill to the mark with the sample containing mercuric chloride.
   c. Compare the color developed with iodine color standards.
   d. If the iodide reserve has been properly maintained, no free chlorine will be present to cause a false reading in the test. If the possibility exists that free chlorine could be present the following procedure will negate the error.
      (1) Add orthotolidine directly to a pool sample and read the results.
      (2) Add one drop of mercuric chloride solution, mix well, and read again.
      (3) The difference between the two readings will be the iodine concentration.
   e. Caution: Mercuric chloride is a poison. Handle carefully; wash hands thoroughly before eating or smoking.

C. BLACK AND WHITTLE TEST FOR FREE IODINE

1. **Equipment** – Special Black and Whittle iodine test kits are available.
2. **Procedure**
   a. Add to a pool sample a special buffer-inhibitor solution to bring the sample to pH 4.0.
   b. Add the leuco crystal violet indicator which produces a violet color with free iodine.
   c. Compare the color developed with prepared color standards.
   d. The possible presence of chlorine does not affect this test.

D. BLACK AND WHITTLE TEST FOR IODIDE CONCENTRATION

1. **Equipment** – The Black and Whittle iodine test kit.
2. **Procedure**
   a. After testing for free iodine, prepare a second sample containing the buffer-inhibitor.
   b. Add a special oxone reagent to oxidize iodide ion to free iodine.
   c. Add leuco crystal violet reagent and compare with color standards.
   d. Subtract the result of the first test for free iodine from the result of the second test. The remainder will represent the concentration of the iodide ion in the iodine bank.

IV. Testing for pH

A. GENERAL

Colorimetric determination of pH is based on the ability of certain organic indicator solutions to change color in varying hydrogen ion concentrations. Addition of a small amount of the indicator to a sample of pool water and comparison with color standards permits rapid determination of pH.

B. PHENOL RED METHOD

1. **Equipment** – Usually the same colorimeter used for chlorine determination is used for phenol red pH determination with the addition of pH color standards and phenol red liquid or tablet reagents.
2. **Procedure**
   a. Fill a test vial with pool water to the mark (usually 10 ml) and add the specified amount of phenol red (usually 1 ml or 1 tablet).
   b. Mix and compare with color standards. Read pH directly.

V. Testing for Total Alkalinity

A. GENERAL

A total alkalinity concentration of approximately 80 to 100 ppm is necessary in pools to keep the pH from undue fluctuation and to insure proper flocculation of alum on rapid sand filters.

B. TITRATION METHOD

1. **Equipment** – Small field test kits, sufficiently accurate for swimming pool tests, are available from several manufacturers.
2. **Procedure**
   a. Fill the test vial exactly to the mark with pool water and add the required amount of bromcresol green-methyl red indicator reagent. A green color will result.
   b. From a special dropper bottle provided, drop the sulfuric acid reagent one drop at a time into the test vial until a red color appears. Count the number of drops needed to produce the color change.
   c. Multiply the number of drops of sulfuric acid reagent needed by 10. The result is the total alkalinity in parts per million.

VI. Testing for Cyanuric Acid

A. GENERAL

Cyanuric acid, when used as a stabilizer for chlorine, should be maintained at a concentration of 30 to 50 ppm. The upper limit for safety is 100 ppm. It may be introduced in acid form as a stabilizer, or it may be present as a result of using cyanurates as a source of chlorine.

B. MELAMINE TURBIDITY TEST FOR CYANURIC ACID

1. **Equipment** – A field test kit can be obtained from several manufacturers.
2. **Procedure**
   a. Prepare a solution of pool water and melamine according to test kit instructions. A turbid solution will result.
   b. Pour the prepared turbid solution slowly into the calibrated vial with a black disc in the bottom.
   c. When the solution is deep enough so that the turbidity just obscures the black disc, read the concentration of cyanurate in parts per million directly from the scale on the calibrated vial.

VII. Electronic Testing and Control

A. EQUIPMENT

At least five different systems are now available for electronic surveillance, testing, and control of disinfectant and pH. These electronic systems consist of glass, liquid, or special electrodes which measure electrolytic properties of the water continuously and convert the information into readings of concentration or pH. They may provide the information on readout dials or on permanent charts or printouts. Automatic feeding mechanisms can be connected to the system to add disinfectant or pH control chemicals automatically. Automatic visual and audio alarms are provided for indicating failure of the circulation system or lack of chemicals for correction.

B. VALUE

These electronic systems are sensitive and accurate, and maintain the proper chemical balance better than the operator can with manual methods. They maintain free residual chlorine as opposed to combined residual, and make pool operation more economical by eliminating fluctuations in chemical treatment.

It is recommended that such electronic controls be used in all public and institutional pools wherever possible.

C. OPERATION

1. A small stream of pool water is diverted from the main recirculation system and is passed through the electronic control sensors. A platinum electrode is used for the chlorine sensor, and a glass electrode for the pH sensor. A potassium chloride (KCl) reference cell requiring yearly recharging is used in some models. In other models a special reference electrode is used which does not require liquid junctions and recharging with KCl.
2. The pH is continuously monitored by measuring the difference in potential between a glass electrode and a reference electrode. The pH is directly proportional to the difference. The control mechanism automatically resets the chemical feeder systems to maintain a desired pH within a range of ± 0.02 pH units.
3. Residual chlorine is monitored by potentiometric sensing and controlled by that fraction of free available chlorine which exists as hypochlorous acid. The oxidation-reduction potential sensing and control range is about ± 600 millivolts. This allows control of free residual chlorine with an accuracy of ± 0.1 ppm.
4. Special alarm systems built into the controller alert the pool operator when chemical supplies are exhausted or when pH or residual chlorine reaches preselected values. The controller will automatically shut down chemical feeders if the main circulation pump fails, or if control chemicals are depleted.

CHAPTER 5

Inspection of Swimming Pools and Bacteriological Sampling of Water

I. Swimming Pool Inspections

A. GENERAL

The routine inspection of swimming pools is basically an inventory of operations and maintenance procedures carried out at the pool. This inspection is not intended to evaluate the soundness of original or remodeled construction features. The detection of structural and equipment defects which exist because of poor operation and maintenance are, however, important goals of this type of visit. Structural changes necessitated by changes in normal pool load or operational character are also matters of concern in the routine inspection.

B. INSPECTION POLICIES

1. **Frequency of inspection** – A minimum frequency of one visit each 3 weeks during the swimming season is essential for outdoor pools.

   Indoor pools which are used all year and which do not have the heavy loading problem of outdoor pools might be inspected as seldom as once every 2 months.

   These suggested intervals are for the average pool, and less frequent or more frequent inspection might be in order for the unusual pool.

2. **Time of inspection** – Inspections at times of least use and most use are as valuable in this field as they are in other fields of environmental health (i.e., restaurant inspection). Operational problems such as difficulty in maintaining disinfectant residuals will necessitate review during high loading, while problems of backwashing procedure might be helped by inspection during low loading.

3. **Inspection routine** – The most efficient technique is one that will permit a thorough inspection in the least possible time without excessively retracing steps. One suggested technique is to review the service buildings first, proceed to the pool area and pool tank, and finish with an inspection of the equipment room or rooms.

   The pool manager or equipment operator should accompany the person making the inspection as he tours the facilities. This will increase the effectiveness of the inspection.

C. MAKING THE INSPECTION – (See suggested "Swimming Pool Inspection Report.")

1. **Service Buildings** – The person making the inspection will be concerned with the details discussed in Chapter 3 as they pertain to dressing rooms, toilet and shower rooms, clothing storage, first aid and safety equipment, swimmer supervision, maintenance of records, and food service.

   Typical items include checking shower heads for water temperature and flow, and critical but constructive review of the techniques for handling clothing.

2. **Pool and pool area** – The problems of pool surroundings, spectator control, pool structure, pool fittings and appurtenances, and water quality will be of major importance.

   Testing disinfection level and pH will be a routine procedure. See Chapter 4, "Testing Swimming Pool Water for Chemical Content," for details.

   Other chemical tests of the pool water will ordinarily not be run routinely, but field kit testing for hardness and carbon dioxide content may be useful. Field test kits for this purpose are available commercially.

   Clarity of the pool water is ordinarily tested by visual inspection, but a 6-inch black disc painted on a white background may be used. This device on the end of a stout cord is thrown into the deep end of the pool and observed from the pool edge.

   Bacteriological sampling, normally done at this time, is described in Section II of this chapter.

3. **Filter rooms** – In this most important area, the filtration, recirculation, and disinfection equipment and appurtenances will be inspected carefully. Items of concern should be the hair strainer, the chlorinator, and the chemical feed devices.

   At least once during the swimming season, and preferably at the beginning, the filter surfaces should be inspected. Routine inspection of the filters should include a check of the air release valves, flow rate indicators, pressure gauges, and condition of piping and tanks.

   Each inspection of this area must also include a review of all operational reports concerning the equipment. This often proves to be a most valuable tool in gaining an insight into the causes of operational problems.

4. **Summary and review of findings** – A detailed summary of the defective items should be made in the space provided under remarks on the inspection report. Reference should be made to the numerical items checked on the body of the report. In this way the responsible person may be instructed on details of the defect and may be advised on how and when correction should be made.

   The report can be summarized in the office on a form similar to the one shown. It gives the personnel of the agency a succinct summary of the pool's operational conditions over a considerable period of time.

   Another valuable office record is a tabulation of sampling results. A suggested office form titled "Water Sampling Report" is included for that purpose. With this form a record may be kept of the chlorine, pH, and bacteriological sampling results from a pool over an entire swimming season. This record form by itself serves as one good measure of a pool's operating efficiency.

The following form is suggested for routine swimming pool inspections

---

NOTICE: ***This report shall not be defaced or removed except by the Public Health Director or his representative.***

________________________ **HEALTH DEPARTMENT**

SWIMMING POOL — INSPECTION REPORT

Name ________________________ **Type** ________________________

Address ____

Sir: An inspection of your swimming pool has been made this day and you are directed to correct conditions marked (x).

A. Pool Structure:

1. Floors, walls, runways ( )
2. Scum gutters, skimmers ( )
3. Ladders, stairs, stepholes ( )
4. Diving boards, floats, depth ( )
5. Inlets, outlets, circulation ( )
6. Piping ( )
7. Fencing ( )
8. ________________ ( )

B. Supplemental Facilities

1. Food service ( )
2. Emergency equipment ( )
3. ________________ ( )

C. Recirculation and Disinfection System

1. Filtration ( )
2. Hair strainer ( )
3. Disinfection ( )
4. Chemical feeders ( )
5. ________________ ( )

D. Buildings, Galleries, Enclosures

1. Walls, floors, ceilings, partitions ( )
2. Lighting, heating, ventilation ( )
3. Plumbing, drainage ( )
4. Surroundings ( )
5. Appurtenances ( )
6. ________________ ( )

E. Water

1. Disinfectant level ____ ppm ( )
2. Freedom from turbidity, debris, growths ( )
3. pH ________________ ( )
4. ________________ ( )

F. Showers, Toilets, Dressing Rooms

1. Clean, adequate, accessible ( )
2. Ventilation ( )
3. Hot, cold water ( )
4. Soap, towels ( )
5. Disinfection ( )
6. Lavatories ( )
7. Clothing Storage ( )
8. Refuse Containers ( )
9. ________________ ( )

G. Records

1. Number of bathers ( )
2. Temperature of water ( )
3. Other operational data ( )
4. ________________ ( )

H. Swimmer Control

1. Cleansing shower ( )
2. Supervision ( )
3. Open sores ( )
4. Placards displayed ( )
5. ________________ ( )

Remarks: ____

Suggested office form for recording test of water sampled from a swimming pool.

PUBLIC HEALTH DEPARTMENT
DIVISION OF SANITATION
WATER SAMPLING SUMMARY

Name ______________________

Address ______________________

Type ______________________

Operator ______________________

Date	Sample	Tubes Positive or Coliform per 100 ml	Bacteria Plate Count per ml	pH	Residual Chlorine (ppm)	Sanitarian

Suggested office form for recording defects found on inspection of swimming pools.

PUBLIC HEALTH DEPARTMENT
DIVISION OF SANITATION
SWIMMING POOL INSPECTION SUMMARY

Name ______________________ **Type** ______________________

Address ______________________ **Operator** ______________________

Date	A Construction								B Other			C System					D Building						E Water				F Dressing Rooms									G Records				H-Swimmer Control					Sani-tarian
	1	2	3	4	5	6	7	8	1	2	3	1	2	3	4	5	1	2	3	4	5	6	1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	

II. Bacteriological Sampling of Pool Waters

A. SAMPLE BOTTLES

All sample bottles must be sterilized and treated with sodium thiosulfate to reduce the chlorine present in the water at the moment the sample is collected. If sodium thiosulfate were not used, the chlorine would be acting on the bacteria in the sample while it was being held or transported for testing.

B. COLLECTION OF SAMPLES

1. **Time of collection** – Samples should generally be collected only when the pool is in use and preferably during periods of heaviest swimmer load. The hour of the day and day of the week should be varied to obtain, over a period of time, a representative cross section of the sanitary quality of the pool.
2. **Place of collection** – It has often been suggested that the pool be sampled at the shallow end to obtain water of the poorest quality in the pool. This is not necessarily true. The sampling point should be varied, but preferably in the vicinity of groups of swimmers.

   It is not necessary or desirable to have a swimmer collect a sample from the middle of the pool to avoid collection of heavily chlorinated return water. This problem may be avoided by collecting samples at points between return water inlets.
3. **Technique of sampling** – The first step in sampling is to carefully remove the cap and stopper from the bottle without touching the inner surfaces of the stopper. Hold the sterile bottle near its base and at a 45° angle. Fill in one slow sweep down through the water with the mouth of the bottle always ahead of the hand. Care should be taken to avoid contamination of the sample by floating debris. The stopper and cap are then replaced. The bottle must not be rinsed in the pool or the sodium thiosulfate will be removed.

C. DISPOSITION OF SAMPLE

The samples should be refrigerated immediately upon collection and held at less than 10° C during transport to the laboratory. The samples should be tested within 6 hours of collection. Pertinent data such as sampling time, location of sample, sampler's identification, and desired analysis should accompany the sample.

III. Bacteriological Analysis of Pool Waters

A. TESTS FOR BACTERIOLOGICAL QUALITY OF WATER

1. **Presence of the coliform group of organisms** – The coliform organisms, most of which are harmless, are present in large numbers in the intestinal tract of man and other warm-blooded animals. The normal feces of man contain 100,000 to 1,000,000,000 coliform organisms per gram. Coliform organisms are easily tested for, and the test is sensitive. No appreciable quantity of fresh fecal material can be present in a water and escape detection when the coliform test is properly carried out.

2. **Total numbers of bacteria by the standard plate count** – This is a valuable measure of the quality of pool water and when used with the coliform test gives important complementary information.

B. INTERPRETATION OF TEST RESULTS

Authorities differ somewhat on details for standards for swimming pool waters. One state uses the following standard: "The presence of organisms of the coliform group, or a standard plate count of more than 200 bacteria per milliliter, or both, in 2 consecutive samples or in more than 10 percent of the samples in a series shall be deemed as unacceptable water quality."

C. REASONS FOR BACTERIAL LIMIT VIOLATIONS

1. **Pool area and equipment**
   a. **Structure of pool** – The lack of a smooth inner pool surface contributes to the harborage of foreign matter and micro-organism growths.
   b. **Disinfection** – Inadequate disinfection devices, poor pool algae control, and easy access of foreign matter such as leaves and other organic matter will soon result in poor bacteriological reports.
   c. **Water treatment equipment** – Filtration equipment of inadequate design or size is a prime cause of poor water condition.
2. **Swimmer control** – The simple matter of overlooking the requirement of cleansing showers for swimmers can result in poor bacteriological reports.
3. **Makeup water** – Poor quality makeup water added to the pool will obviously result in the contamination of otherwise satisfactory water.
4. **Sampling procedure** – Deviation from recommended sampling procedures could yield false results.

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APPENDIX
American National Standard Specifications for Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped

1. Scope and Purpose

1.1 Scope

1.1.1 This standard applies to all buildings and facilities used by the public. It applies to temporary or emergency conditions as well as permanent conditions. It does not apply to private residences.

1.1.2 This standard is concerned with non-ambulatory disabilities, semi-ambulatory disabilities, sight disabilities, hearing disabilities, disabilities of incoordination, and aging.[1]

1.2 Purpose. This standard is intended to make all buildings and facilities used by the public accessible to, and functional for, the physically handicapped, to, through, and within their doors, without loss of function, space, or facility where the general public is concerned. It supplements existing American Standards, and reflects great concern for safety of life and limb. In cases of practical difficulty, unnecessary hardship, or extreme differences, administrative authorities may grant exceptions from the literal requirements of this standard or permit the use of other methods or materials, but only when it is clearly evident that equivalent facilitation and protection are thereby secured.

2. Definitions

2.1 Non-ambulatory Disabilities. Impairments that, regardless of cause or manifestation, for all practical purposes, confine individuals to wheelchairs.

2.2 Semi-ambulatory Disabilities. Impairments that cause individuals to walk with difficulty or insecurity. Individuals using braces or crutches, amputees, arthritics, spastics, and those with pulmonary and cardiac ills may be semi-ambulatory.

2.3 Sight Disabilities. Total blindness or impairments affecting sight to the extent that the individual functioning in public areas is insecure or exposed to danger.

2.4 Hearing Disabilities. Deafness or hearing handicaps that might make an individual insecure in public areas because he is unable to communicate or hear warning signals.

2.5 Disabilities of Incoordination. Faulty coordination or palsy from brain, spinal, or peripheral nerve injury.

2.6 Aging. Those manifestations of the aging processes that significantly reduce mobility, flexibility, coordination, and perceptiveness but are not accounted for in the aforementioned categories.

2.7 Standard. When this term appears in small letters and is not preceded by the word "American," it is descriptive and does not refer to an American Standard approved by ASA; for example, a "standard" wheelchair is one characterized as standard by the manufacturers.

2.8 Fixed Turning Radius, Wheel to Wheel. The tracking of the caster wheels and large wheels of a wheelchair when pivoting on a spot.

2.9 Fixed Turning Radius, Front Structure to Rear Structure. The turning radius of a wheelchair, left front-foot platform to right rear wheel, or right front-foot platform to left rear wheel, when pivoting on a spot.

2.10 Involved (Involvement). A portion or portions of the human anatomy or physiology, or both, that have a loss or impairment of normal function as a result of genesis, trauma, disease, inflammation, or degeneration.

2.11 Ramps, Ramps with Gradients. Because the term "ramp" has a multitude of meanings and uses, its use in this text is clearly defined as ramps with gradients (or ramps with slopes) that deviate from what would otherwise be considered the normal level. An exterior ramp, as distinguished from a "walk," would be considered an appendage to a building leading to a level above or below existing ground level. As such, a ramp shall meet certain requirements similar to those imposed upon stairs.

2.12 Walk, Walks. Because the terms "walk" and "walks" have a multitude of meanings and uses, their use in this text is clearly defined as a predetermined, prepared-surface, exterior pathway leading to or from a building or facility, or from one exterior area to another, placed on the existing ground level and not deviating from the level of the existing ground immediately adjacent.

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[1] See definitions in Section 2.

2.13 Appropriate Number. As used in this text, appropriate number means the number of a specific item that would be necessary, in accord with the purpose and function of a building or facility, to accommodate individuals with specific disabilities in proportion to the anticipated number of individuals with disabilities who would use a particular building or facility.

EXAMPLE: Although these specifications shall apply to all buildings and facilities used by the public, the numerical need for a specific item would differ, for example, between a major transportation terminal, where many individuals with diverse disabilities would be continually coming and going, an office building or factory, where varying numbers of individuals with disabilities of varying manifestations (in many instances, very large numbers) might be employed or have reason for frequent visits, a school or church, where the number of individuals may be fixed and activities more definitive, and the many other buildings and facilities dedicated to specific functions and purposes.

NOTE: Disabilities are specific and where the individual has been properly evaluated and properly oriented and where architectural barriers have been eliminated, a specific disability does not constitute a handicap. It should be emphasized that more and more of those physically disabled are becoming *participants*, rather than spectators, in the fullest meaning of the word.

3. General Principles and Considerations

3.1 Wheelchair Specifications. The collapsible-model wheelchair of tubular metal construction with plastic upholstery for back and seat is most commonly used. The standard model of all manufacturers falls within the following limits, which were used as the basis of consideration:

(1) Length: 42 inches
(2) Width, when open: 25 inches
(3) Height of seat from floor: 19½ inches
(4) Height of armrest from floor: 29 inches
(5) Height of pusher handles (rear) from floor: 36 inches
(6) Width, when collapsed: 11 inches

3.2 The Functioning of a Wheelchair

3.2.1 The fixed turning radius of a standard wheelchair, wheel to wheel, is 18 inches. The fixed turning radius, front structure to rear structure, is 31.5 inches.

3.2.2 The average turning space required (180 and 360 degrees) is 60 x 60 inches.

NOTE: Actually, a turning space that is longer than it is wide, specifically, 63 x 56 inches, is more workable and desirable. In an area with two open ends. such as might be the case in a corridor, a minimum of 54 inches between two walls would permit a 360-degree turn.

3.2.3 A minimum width of 60 inches is required for two individuals in wheelchairs to pass each other.

3.3 The Adult Individual Functioning in a Wheelchair[2]

3.3.1 The average unilateral vertical reach is 60 inches and ranges from 54 inches to 78 inches.

3.3.2 The average horizontal working (table) reach is 30.8 inches and ranges from 28.5 inches to 33.2 inches.

3.3.3 The bilateral horizontal reach, both arms extended to each side, shoulder high, ranges from 54 inches to 71 inches and averages 64.5 inches.

3.3.4 An individual reaching diagonally, as would be required in using a wall-mounted dial telephone or towel dispenser, would make the average reach (on the wall) 48 inches from the floor.

3.4 The Individual Functioning on Crutches[3]

3.4.1 On the average, individuals 5 feet 6 inches tall require an average of 31 inches between crutch tips in the normally accepted gaits.[4]

3.4.2 On the average, individuals 6 feet 0 inches tall require an average of 32.5 inches between crutch tips in the normally accepted gaits.[4]

4. Site Development[5]

4.1 Grading. The grading of ground, even contrary to existing topography, so that it attains a level with a normal entrance will make a facility accessible to individuals with physical disabilities.

4.2 Walks

4.2.1 Public walks should be at least 48 inches wide and should have a gradient not greater than 5 percent.[6]

4.2.2 Such walks shall be of a continuing common surface, not interrupted by steps or abrupt changes in level.

NOTE: 4.1 and 4.2, separately or collectively, are greatly aided by terracing, retaining walls, and winding walks allowing for more gradual incline, thereby making almost any building accessible to individuals with permanent physical disabilities, while contributing to its esthetic qualities.

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[2]Extremely small, large, strong, or weak and involved individuals could fall outside the ranges in 3.3.1, 3.3.2, 3.3.3, and their reach could differ from the figure given in 3.3.4. However, these reaches were determined using a large number of individuals who were functionally trained, with a wide range in individual size and involvement.

[3]Most individuals ambulating on braces or crutches, or both, or on canes are able to manipulate within the specifications prescribed for wheelchairs, although doors present quite a problem at times. However, attention is called to the fact that a crutch tip extending laterally from an individual is not obvious to others in heavily trafficked areas, certainly not as obvious or protective as a wheelchair and is, therefore, a source of vulnerability.

[4]Some cerebral palsied individuals, and some severe arthritics, would be extreme exceptions to 3.4.1 and 3.4.2.

[5]Site development is the most effective means to resolve the problems created by topography, definitive architectural designs or concepts, water table, existing streets, and atypical problems, singularly or collectively, so that aggress, ingress, and egress to buildings by physically disabled can be facilitated while preserving the desired design and effect of the architecture.

4.2.3 Wherever walks cross other walks, driveways, or parking lots they should blend to a common level.[7]

4.2.4 A walk shall have a level platform at the top which is at least 5 feet by 5 feet, if a door swings out onto the platform or toward the walk. This platform shall extend at least 1 foot beyond each side of the doorway.

4.2.5 A walk shall have a level platform at least 3 feet deep and 5 feet wide, if the door does not swing onto the platform or toward the walk. This platform shall extend at least 1 foot beyond each side of the doorway.

4.3 Parking Lots

4.3.1 Spaces that are accessible and approximate to the facility should be set aside and identified for use by individuals with physical disabilities.

4.3.2 A parking space open on one side, allowing room for individuals in wheelchairs or individuals on braces and crutches to get in and out of an automobile onto a level surface, suitable for wheeling and walking, is adequate.

4.3.3 Parking spaces for individuals with physical disabilities when placed between two conventional diagonal or head-on parking spaces should be 12 feet wide.

4.3.4 Care in planning should be exercised so that individuals in wheelchairs and individuals using braces and crutches are not compelled to wheel or walk behind parked cars.

4.3.5 Consideration should be given the distribution of spaces for use by the disabled in accordance with the frequency and persistency of parking needs.

4.3.6 Walks shall be in conformity with 4.2.

5. Buildings

5.1 Ramps with Gradients. Where ramps with gradients are necessary or desired, they shall conform to the following specifications:

5.1.1 A ramp shall not have a slope greater than 1 foot rise in 12 feet, or 8.33 percent, or 4 degrees 50 minutes.

5.1.2 A ramp shall have handrails on at least one side, and preferably two sides, that are 32 inches in height, measured from the surface of the ramp, that are smooth, that extend 1 foot beyond the top and bottom of the ramp, and that otherwise conform with American Standard Safety Code for Floor and Wall Openings, Railings, and Toe Boards, A12.1-1973.

NOTE 1: Where codes specify handrails to be of heights other than 32 inches, it is recommended that two sets of handrails be installed to serve all people. Where major traffic is predominantly children, particularly physically disabled children, extra care should be exercised in the placement of handrails, in accordance with the nature of the facility and the age group or groups being serviced.

NOTE 2: Care should be taken that the extension of the handrail is not in itself a hazard. The extension may be made on the side of a continuing wall.

5.1.3 A ramp shall have a surface that is nonslip.

5.1.4 A ramp shall have a level platform at the top which is at least 5 feet by 5 feet, if a door swings out onto the platform or toward the ramp. This platform shall extend at least 1 foot beyond each side of the doorway.

5.1.5 A ramp shall have a level platform at least 3 feet deep and 5 feet wide, if the door does not swing onto the platform or toward the ramp. This platform shall extend at least 1 foot beyond each side of the doorway.

5.1.6 Each ramp shall have at least 6 feet of straight clearance at the bottom.

5.1.7 Ramps shall have level platforms at 30-foot intervals for purposes of rest and safety and shall have level platforms wherever they turn.

5.2 Entrances

5.2.1 At least one primary entrance to each building shall be usable by individuals in wheelchairs.

NOTE: Because entrances also serve as exits, some being particularly important in case of an emergency, and because the proximity of such exits to all parts of buildings and facilities, in accordance with their design and function, is essential (see 112 and 2000 through 2031 of American Standard Code for Safety to Life from Fire in Buildings and Structures, A9.1-1974) it is preferable that all or most entrances (exits) should be accessible to, and usable by, individuals in wheelchairs and individuals with other forms of physical disability herein applicable.

[6]It is essential that the gradient of walks and driveways be less than that prescribed for ramps, since walks would be void of handrails and curbs and would be considerably longer and more vulnerable to the elements. Walks of near maximum grade and considerable length should have level areas at intervals for purposes of rest and safety. Walks or driveways should have a nonslip surface.

[7]This specification does not require the elimination of curbs, which, particularly if they occur at regular intersections, are a distinct safety feature for all of the handicapped, particularly the blind. The preferred method of meeting the specification is to have the walk incline to the level of the street. However, at principal intersections, it is vitally important that the curb run parallel to the street, up to the point where the walk is inclined, at which point the curb would turn in and gradually meet the level of the walk at its highest point. A less preferred method would be to gradually bring the surface of the driveway or street to the level of the walk. The disadvantage of this method is that a blind person would not know when he has left the protection of a walk and entered the hazards of a street or driveway.

5.2.2 At least one entrance usable by individuals in wheelchairs shall be on a level that would make the elevators accessible.

5.3 Doors and Doorways

5.3.1 Doors shall have a clear opening of no less than 32 inches when open and shall be operable by a single effort.

NOTE 1: Two-leaf doors are not usable by those with disabilities defined in 2.1, 2.2, and 2.5 unless they operate by a single effort, or unless one of the two leaves meets the requirement of 5.3.1.

NOTE 2: It is recommended that all doors have kick plates extending from the bottom of the door to at least 16 inches from the floor, or be made of a material and finish that would safely withstand the abuse they might receive from canes, crutches, wheelchair foot-platforms, or wheelchair wheels.

5.3.2 The floor on the inside and outside of each doorway shall be level for a distance of 5 feet from the door in the direction the door swings and shall extend 1 foot beyond each side of the door.

5.3.3 Sharp inclines and abrupt changes in level shall be avoided at doorsills. As much as possible, thesholds shall be flush with the floor.

NOTE 1: Care should be taken in the selection, placement, and setting of door closers so that they do not prevent the use of doors by the physically disabled. Time-delay door closers are recommended.

NOTE 2: Automatic doors that otherwise conform to 5.3.1, 5.3.2, and 5.3.3 are very satisfactory.

NOTE 3: These specifications apply both to exterior and interior doors and doorways.

5.4 Stairs. Stairs shall conform to American Standard Code for Safety to Life from Fire in Buildings and Structures, A9.1-1974, with the following additional considerations:

5.4.1 Steps in stairs that might require use by those with disabilities defined in 2.2 and 2.5 or by the aged shall not have abrupt (square) nosing. (See Fig. 1.)

NOTE: Individuals with restrictions in the knee, ankle, or hip, with artificial legs, long leg braces, or comparable conditions cannot, without great difficulty and hazard, use steps with nosing as illustrated in Fig. 1a, but can safely and with minimum difficulty use steps with nosing as illustrated in Fig. 1b.

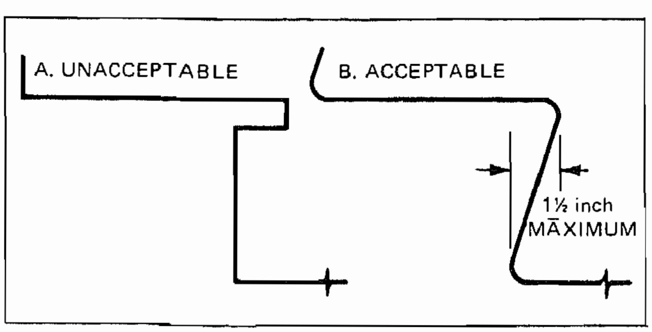

FIGURE 1. Steps.

5.4.2 Stairs shall have handrails 32 inches high as measured from the tread at the face of the riser.

NOTE: Where codes specify handrails to be at heights other than 32 inches, it is recommended that two sets of handrails be installed to serve all people. Where traffic is predominantly children, particularly physically disabled children, extra care should be exercised in the placement of handrails in accordance with the nature of the facility and the age group or groups being serviced. Dual handrails may be necessary.

5.4.3 Stairs shall have at least one handrail that extends at least 18 inches beyond the top step and beyond the bottom step.

NOTE: Care should be taken that the extension of the handrails is not in itself a hazard. The extension may be made on the side of a continuing wall.

5.4.4 Steps should, wherever possible, and in conformation with existing step formulas, have risers that do not exceed 7 inches.

5.5 Floors

5.5.1 Floors shall have a surface that is nonslip.

5.5.2 Floors on a given story shall be of a common level throughout or be connected by a ramp in accord with 5.1.1 through 5.1.6, inclusive.

EXAMPLE 1: There shall not be a difference between the level of the floor of a corridor and the level of the floor of the toilet rooms.

EXAMPLE 2: There should not be a difference between the level of the floor of a corridor and the level of a meeting room, dining room, or any other room, unless proper ramps are provided.

5.6 Toilet Rooms. It is essential that an appropriate number[8] of toilet rooms, in accordance with the nature and use of a specific building or facility, be made accessible to, and usable by, the physically handicapped.

5.6.1 Toilet rooms shall have space to allow traffic of individuals in wheelchairs, in accordance with 3.1, 3.2, and 3.3

5.6.2 Toilet rooms shall have at least one toilet stall that–

(1) Is 3 feet wide

(2) Is at least 4 feet 8 inches, preferably 5 feet, deep

(3) Has a door (where doors are used) that is 32 inches wide and swings out

(4) Has handrails on each side, 33 inches high and parallel to the floor, 1½ inches in outside diameter, with 1½ inches clearance between rail and wall, and fastened securely at ends and center

(5) Has a water closet with the seat 20 inches from the floor

NOTE: The design and mounting of the water closet is of considerable importance. A wall-mounted water closet with a narrow

understructure that recedes sharply is most desirable. If a floor-mounted water closet must be used, it should not have a front that is wide and perpendicular to the floor at the front of the seat. The bowl should be shallow at the front of the seat and turn backward more than downward to allow the individual in a wheelchair to get close to the water closet with the seat of the wheelchair.

5.6.3 Toilet rooms shall have lavatories with narrow aprons, which when mounted at standard height are usable by individuals in wheelchairs; or shall have lavatories mounted higher, when particular designs demand, so that they are usable by individuals in wheelchairs.

NOTE: It is important that drain pipes and hot-water pipes under a lavatory be covered or insulated so that a wheelchair individual without sensation will not burn himself.

5.6.4 Some mirrors and shelves shall be provided above lavatories at a height as low as possible and no higher than 40 inches above the floor, measured from the top of the shelf and the bottom of the mirror.

5.6.5 Toilet rooms for men shall have wall-mounted urinals with the opening of the basin 19 inches from the floor, or shall have floor-mounted urinals that are on level with the main floor of the toilet room.

5.6.6 Toilet rooms shall have an appropriate number[8] of towel racks, towel dispensers, and other dispensers and disposal units mounted no higher than 40 inches from the floor.

5.7 Water Fountains. An appropriate number[8] of water fountains or other water-dispensing means shall be accessible to, and usable by, the physically disabled.

5.7.1 Water fountains or coolers shall have up-front spouts and controls.

5.7.2 Water fountains or coolers shall be hand-operated or hand- and foot-operated. (See also American Standard Specifications for Drinking Fountains, and Self-Contained Mechanically-Refrigerated Drinking-Water Coolers, A 112.11.1-1973.).

NOTE 1: Conventional floor-mounted water coolers can be serviceable to individuals in wheelchairs if a small fountain is mounted on the side of the cooler 30 inches above the floor.

NOTE 2: Wall-mounted, hand-operated coolers of the latest design, manufactured by many companies, can serve the able-bodied and the physically disabled equally well when the cooler is mounted with the basin 36 inches from the floor.

NOTE 3: Fully recessed water fountains are not recommended.

NOTE 4: Water fountains should not be set into an alcove unless the alcove is wider than a wheelchair. (See 3.1.)

5.8 Public Telephones. An appropriate number[8] of public telephones should be made accessible to, and usable by, the physically disabled.

NOTE: The conventional public telephone booth is not usable by most physically disabled individuals. There are many ways in which public telephones can be made accessible and usable. It is recommended that architects and builders confer with the telephone company in the planning of the building or facility.

5.8.1 Such telephones should be placed so that the dial and the handset can be reached by individuals in wheelchairs, in accordance with 3.3.

5.8.2 An appropriate number* of public telephones should be equipped for those with hearing disabilities and so identified with instructions for use.

NOTE: Such telephones can be used by everyone.

5.9 Elevators. In a multiple-story building, elevators are essential to the successful functioning of physically disabled individuals. They shall conform to the following requirements:

5.9.1 Elevators shall be accessible to, and usable by, the physically disabled on the level that they use to enter the building, and at all levels normally used by the general public.

5.9.2 Elevators shall allow for traffic by wheelchairs, in accordance with 3.1, 3.2, 3.3 and 5.3.

5.10 Controls. Switches and controls for light heat, ventilation, windows, draperies, fire alarms, and all similar controls of frequent or essential use, shall be placed within the reach of individuals in wheelchairs. (See 3.3.)

5.11 Identification. Appropriate identification of specific facilities within a building used by the public is particularly essential to the blind.

5.11.1 Raised letters or numbers shall be used to identify rooms or offices.

5.11.2 Such identification should be placed on the wall, to the right or left of the door, at a height between 4 feet 6 inches and 5 feet 6 inches, measured from the floor, and preferably at 5 feet.

5.11.3 Doors that are not intended for normal use, and that might prove dangerous if a blind person were to exit or enter by them, should be made quickly identifiable to the touch by knurling the door handle or knob. (See Fig. 2.)

EXAMPLE: Such doors might lead to loading platforms, boiler rooms, stages, fire escapes, etc.

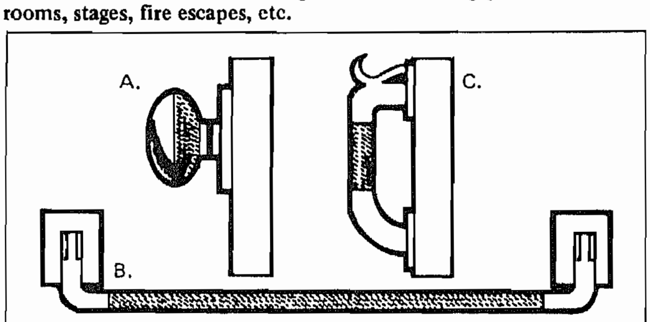

FIGURE 2. Door Handles and Knobs.

*See 2.13.

5.12 Warning Signals

5.12.1 Audible warning signals shall be accompanied by simultaneous visual signals for the benefit of those with hearing disabilities.

5.12.2 Visual signals shall be accompanied by simultaneous audible signals for the benefit of the blind.

5.13 Hazards. Every effort shall be exercised to obviate hazards to individuals with physical disabilities.

5.13.1 Access panels or manholes in floors, walks, and walls can be extremely hazardous, particularly when in use, and should be avoided.

5.13.2 When manholes or access panels are open and in use, or when an open excavation exists on a site, particularly when it is approximate to normal pedestrian traffic, barricades shall be placed on all open sides, at least 8 feet from the hazard, and warning devices shall be installed in accord with 5.12.2.

5.13.3 Low-hanging door closers that remain within the opening of a doorway when the door is open, or that protrude hazardously into regular corridors or traffic ways when the door is closed, shall be avoided.

5.13.4 Low-hanging signs, ceiling lights, and similar objects or signs and fixtures that protrude into regular corridors or traffic ways shall be avoided. A minimum height of 7 feet, measured from the floor, is recommended.

5.13.5 Lighting on ramps shall be in accord with 1201, 1202, 1203, and 1204 of American Standard Code for Safety to Life from Fire in Buildings and Structures, A 9.1-1974.

5.13.6 Exit signs shall be in accord with 1205 of American Standard Code for Safety to Life from Fire in Buildings and Structures, A 9.1-1974, except as modified by 5.11 of this standard.

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