2016 Annex to the Model Aquatic Health Code

Scientific Rationale

DESIGN AND CONSTRUCTION

CS267224A

4.0 Aquatic Facility Design Standards and Construction

The MAHC has worked extensively with ICC and IAPMO to eliminate conflicts between the three CODES. These discussions, along with NEHA participation, have resulted in changes in the MAHC and plans to change items in the other CODES as they are brought up for revision. The MAHC is committed to resolving these conflicts now and in the future as these CODES evolve.

4.0.1 Basic Design Considerations for Handling Particle Contamination Burden, Chlorine and Disinfectant Demand, and Disinfection By-Product Issues

4.0.1.1 Particle Contamination Burden

4.0.1.1.1 Filtration Flow Rate

The particle contamination burden determines the filtration flow rate for a given AQUATIC FACILITY. It is not possible to predict the particle contamination burden for every individual AQUATIC VENUE because the sources will likely vary significantly from one AQUATIC FACILITY to another. However, it is important to understand the upper limit of particle contamination to provide information for filtration designs. If the upper limit of the particle contamination burden is known, then it should be possible for the designer to specify a filtration system that can handle the maximum particle burden and ensure that water turbidity does not increase above an allowable or desirable level. Essentially, the RECIRCULATION SYSTEM needs to be designed to remove particles at least at the same rate at which they are being added by the environment *(e.g., windblown and settling dust)*, BATHERS *(e.g., personal care products, body excretions)*, and other sources.

4.0.1.1.2 Determining Maximum Rate of Particle Contamination

The best means for determining this maximum rate of particle contamination is through direct measurement at operating facilities to ensure the data are indicative of normal activity. The rate of contamination *(n, particles/time/gallon)* is likely to vary by AQUATIC VENUE location, BATHER COUNTS, BATHER age, time of year, time of day, weather, and proximity to urban and desert environments.

4.0.1.1.3 Data Search

An extensive literature search turned up no relevant data defining the particulate contamination burden in AQUATIC FACILITIES. It is recommended that a model be developed that describes particle addition and subsequent removal by the filtration system. This would include developing a correlation between particle size and turbidity or clarity index; this correlation is needed from a practical point of view since regulations are likely to be developed based on turbidity or clarity. These data could then be used for making concrete, data-based decisions on removal rate requirements and help with defining the required filtration and circulation capacities.

4.0.1.2 Disinfectant Demand

Disinfectant consumption can occur by the reaction of the disinfectant with BATHERS, BATHER waste, and other environmentally-introduced CONTAMINANTS, as well as simple decomposition of the active halides *(i.e., HOCl or HOBr)* into inactive halide ions *(chloride or bromide)*. Disinfectant decomposition rates will also vary depending on a variety of factors including pH, water temperature, UV light, and BATHER COUNT. Data on disinfectant demand are generally lacking in the literature on all EPA-registered disinfectants. There are some data available for CHLORINE disinfectant demand, but there are very few for bromine, PHMB, and metal systems.

4.0.1.3 Chlorine Disinfectant Demand

4.0.1.3.1 Contribution of Bather Count

Several studies have investigated the BATHER COUNT'S contribution to CHLORINE demand in AQUATIC VENUE water; however, there is a lack of consistency in how BATHER COUNT was measured. Some studies report data as CHLORINE demand, others as potassium permanganate demand, dissolved organic carbon, or total organic carbon. [27, 28, 29, 30]

4.0.1.3.2 Varies in Magnitude

The available data for CHLORINE disinfectant demand indicates that the CHLORINE demand from BATHERS can vary by over an order of magnitude, with the largest value measured being 10 g Cl_2/BATHER *(or 2.2 lb/100 BATHERS)*.[31]

4.0.1.3.3 Simple Decomposition of Chlorine

There are few published data on the CHLORINE demand that occurs in AQUATIC VENUES due to the simple decomposition of CHLORINE. It is well known that CHLORINE is not stable at high temperatures and in the presence of UV. Both of these factors will reduce active CHLORINE to inactive chloride, without any BATHER waste being present.

4.0.1.3.4 Rate of Chlorine Loss

The rate of CHLORINE loss *(pounds of CHLORINE per hour)* due to UV degradation will depend on a number of factors, including the size of the AQUATIC VENUE, the depth of the water and the intensity of the sunshine. It will also depend on the concentration of CYA present, since CYA can help prevent the decomposition of CHLORINE by UV. Given the number of variables, it is difficult to predict CHLORINE decomposition rates in specific AQUATIC VENUES.

4.0.1.3.5 Reducing Chlorine Loss

The rate of CHLORINE loss can be reduced by the use of other OXIDIZERS, including potassium monopersulfate and ozone, or UV, which can destroy CONTAMINANTS which would otherwise react with CHLORINE. Additional research on the contributing factors to disinfectant demand *(i.e. nitrogenous waste)* may be warranted in the future as treatment

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27 Judd SJ, et al. Disinfection by-product formation in swimming pool waters: a simple mass balance. Water Research (2000); 34(5):1611-1619.
28 Judd SJ, et al. The fate of chlorine and organic materials in swimming pools, Chemosphere (2003); 51:869-879.
29 Keuten MG, et al. Definition and quantification of initial anthropogenic pollutant release in swimming pools. Water Res. 2012 Jul;46(11):3682-92.
30 Seux R. The development of pollution caused by swimmers in swimming pool water in relation to the effect of free chlorine. Translation from J Francais d'Hydrologie (1988);19(2):151-168.
31 Seux R. The development of pollution caused by swimmers in swimming pool water in relation to the effect of free chlorine. Translation from J Francais d'Hydrologie (1988);19(2):151-168.

methods are developed to reduce or eliminate them by means other than OXIDATION. It is anticipated that this research would identify the introduction rate of the CONTAMINANT, resulting concentrations, and the effect that reduction or elimination of this CONTAMINANT would have on disinfectant demand or other ancillary benefits *(i.e. reduction of combined CHLORINES)*.

4.0.1.3.6 Chemical Feed Pump Sizing

Further data collection on CHLORINE usage in real world AQUATIC VENUE situations under different environmental and operational conditions could be used to develop an effective rate law from which the sizing of chemical feed pumps could then be calculated.[32, 33] The criteria for specifying a chemical feed pump for an AQUATIC VENUE are based on its ability to feed against the process piping pressure and to provide sufficient feed rate to maintain a disinfectant residual in the water. Several states require chemical feed pumps for CHLORINE to be capable of providing up to 10 ppm of CHLORINE in the pipe returning water from the RECIRCULATION SYSTEM back to the POOL. Once actual CHLORINE usage is obtained, a surplus SAFETY factor could be introduced to slightly oversize the feed pump to ensure that the disinfectant dosing amount can be increased to meet increases in demand. Any such sizing requirements need to specify the timeframe within which the pump must be able to satisfy the CHLORINE dosing required.

4.0.1.4 Disinfection By-Product Issues

4.0.1.4.1 Chlorination of Water

Chlorination, using CHLORINE as the disinfectant, is the most common procedure for AQUATIC VENUE water DISINFECTION and inactivation of waterborne microbial pathogens. BATHER activity and environmentally-introduced material provides a broad range of precursors with which disinfectants can react *(e.g., perspiration, urine, mucus, skin particles, hair, body lotions, fecal material, soil, etc.)*. When CHLORINE reacts with these precursors, a variety of chemical reactions take place, including the formation of DBPs[34,35,36,37,38]. DBPs may also be introduced into the AQUATIC VENUE via the water used to fill the AQUATIC VENUE depending on the supply water quality. Municipal fill water can also include chloramines as some municipal systems switch from chlorination to

32 March JG, et al. A kinetic model for chlorine consumption in grey water. Desalination (2005); 181:267-273.
33 Haas CN, et al. Kinetics of wastewater chlorine demand exertion. J Water Pollution Control Federation. 1984;56:170-3.
34 Teo TL, et al. Chemical contaminants in swimming pools: Occurrence, implications and control. Environ Int. 2015 Mar;76:16-31.
35 Chowdhury S, et al. Disinfection byproducts in swimming pool: occurrences, implications and future needs. Water Res. 2014 Apr 15;53:68-109.
36 Richardson SD, et al. What's in the pool? A comprehensive identification of disinfection by-products and assessment of mutagenicity of chlorinated and brominated swimming pool water. Environmental Health Perspectives. 2010 Nov;118(11):1523-30.
37 LaKind JS, et al. The good, the bad, and the volatile: can we have both healthy pools and healthy people? Environ Sci Technol. 2010;44(9):3205-10.
38 Zwiener C, et al. Drowning in disinfection byproducts? Assessing swimming pool water. Environ. Sci. Technol. 2007 Jan 15;41(2):363-72.

chloramination to meet EPA DBP requirements.[39] CHLORINE gas, if used, is also extremely toxic.[40,41,42]

4.0.1.4.2 Types of Disinfection By-Products

DBPs can be organic[43,44] *[e.g., THMs, chlorinated phenols, haloketones, haloacetic acids, and haloacetonitriles (HANs)]* or inorganic[45,46,47] *(e.g. chloramines and cyanogen chloride)*. The major by-products of DISINFECTION using HOBr and HOCl are bromoform *($CHBr_3$)* and chloroform *($CHCl_3$)*, respectively. Chloroform and bromoform are highly volatile compounds that can be inhaled in AQUATIC VENUE environments and also readily absorbed through the skin.[48,49,50]

4.0.1.4.3 Classes of Organic DBPs

Some classes of organic DBPs[51] are:

- THMs *(total THM is the sum of the concentrations of chloroform, bromoform, bromodichloromethane, and dibromochloromethane)*;
- Chlorinated phenols *(2-chloro-, 2,4-dichloro- and 2,4,6-trichlorophenol)*, haloketones *(1,1-dichloropropanone, 1,1,1-trichloropropanone)*;
- Haloketones *(bromopropanone, 1,1-dichloropropanone, 1,1,1-trichloropropanone, etc.);*
- Haloacetic acids *(Total haloacetic acids include the sum of the concentrations of mono-, di-, and trichloroacetic acids and mono- and dibromoacetic acids)*;
- Haloacetonitriles *(HANs)* include *(dichloro-, trichloro-, dibromo- and bromochloroacetonitrile)*, chloropicrin, chloral hydrate, 3-chloro-4-*(dichloromethyl)*-5-hydroxy-2(5H)-furanone, etc.; and

39 EPA. Drinking Water Contaminants. Available at: http://water.epa.gov/drink/contaminants/index.cfm. Accessed on April 14, 2016.
40 ATSDR. Toxicological Profile for Chlorine. Available at: http://www.atsdr.cdc.gov/toxfaqs/tfacts172.pdf. Accessed on April 14, 2016.
41 Decker WJ, et al. Chlorine poisoning at the swimming pool: an overlooked hazard. Clinical Toxicology (1978); 13(3): 377-381.
42 Drobnic F, et al. Assessment of chlorine exposure in swimmers during training. Medicine and Science in Sports and Exercise (1996); 28(2): 271-274.
43 Richardson SD, et al. What's in the pool? A comprehensive identification of disinfection by-products and assessment of mutagenicity of chlorinated and brominated swimming pool water. Environmental Health Perspectives. 2010 Nov;118(11):1523-30.
44 Weng AS, et al. Effects of UV254 irradiation on residual chlorine and DBPs in chlorination of model organic-N precursors in swimming pools. Water Res. 2012;46:2674-268.
45 Erdinger L, et al. Chlorate as an inorganic disinfection by-product in swimming pools. Zentralbl Hyg Umweltmed (1999); 202: 61-75.
46 Beech JA, et al. Nitrates, chlorates and trihalomethanes in swimming pool water. American Journal of Public Health (1980); 70(1): 79-82.
47 Robson HL. Chloramines and bromamines; Encyclopedia of Chemical Technology, Kirk-Othmer, 4d ed, Interscience, New York.
48 Aggazzotti G, et al. Blood and breath analyses as biological indicators of exposure to trihalomethanes in indoor swimming pools. Science of the Total Environment (1998);217:155-163.
49 Erdinger L, et al. Haloforms in spas. Zentralbl Hyg Umweltmed (1997);200: 309-317.
50 Hanna JG, et al. Determination of chloroform and bromoform. Anal Chemistry(1950);22(4):569-570.
51 Erdinger L, et al. Chlorate as an inorganic disinfection by-product in swimming pools. Zentralbl Hyg Umweltmed (1999); 202: 61-75.

- Organic chloramines.

4.0.1.4.4 Trihalomethane Concentration in Drinking Water

According to European Union regulations, the concentration of THMs in drinking water should not exceed one hundred micrograms per liter *(100 µg/L)* of water for consumption[52]; while in the United States the US-EPA has established a legal maximum of 80 µg/L[53]. The DIN 19643 Swimming Pool Standard specifies a STANDARD maximum of 20 µg/L.[54]

4.0.1.4.5 Inorganic DBPs

Inorganic DBPs include chloramines and cyanogen chloride. Inorganic chloramines include monochloramine *(NH_2Cl)*, DICHLORAMINE *($NHCl_2$)* and TRICHLORAMINE *(NCl_3)* and are generated from the reaction of hypochlorite with ammonia and amino-compounds that originate from sweat and urine of the swimmers. TRICHLORAMINE is relatively volatile and partitions easily from water into air.[55]

4.0.1.4.6 Factors that Determine DBP Levels

The conditions that determine production and air levels of DBPs have been suggested to depend on several factors:

- Number of swimmers in the AQUATIC VENUE and their associated hygiene;
- CHLORINE concentration;
- Water temperature;
- Concentration of organic precursors in the AQUATIC VENUE water;
- Chemical structure of the organic precursors;
- Bromide content;
- Indoor air circulation;
- The extent of out-gassing of volatile DBPs;
- pH;
- Level of water agitation *(undisturbed vs. being sprayed)*; and
- Concentration of inorganic chloramine from the fill water.

Further research is needed to determine how much DBPs are being created in AQUATIC VENUE water, including the production and retention rate.

4.0.1.4.7 Health Effects

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52 Council Directive 98/83/EC on the Quality of Water Intended for Human Consumption, 1998 O.J. L 330/32.
53 EPA. Drinking Water Contaminants. Available at: http://water.epa.gov/drink/contaminants/index.cfm. Accessed on April 14, 2016.
54 German Standard DIN 19643, 2012. Treatment of Water of Swimming-Pools and Baths. Deutsches Institut Fur Normung E.V. (German National Standard).
55 Holzwarth G, et al. The fate of chlorine and chloramines in cooling towers. Water Res. 1984;18:1421–1427.

Outbreaks of ocular and respiratory distress associated with indoor air quality have been documented.[56,57,58,59,60,61,62] Numerous studies have examined the link between air quality in INDOOR AQUATIC FACILITIES and ocular, dermal, and respiratory health effects, including asthma, with mixed results in swimmers, occupational categories such as lifeguards, and elite swimmers who practice regularly for extended times.[63,64,65,66,67,68,69,70,71,72,73] To date, however, several analyses of the data find the link to asthma is inconclusive.[74,75,76,77] The one prospective study available[78] suggests swimming does not increase the risk of asthma. To the contrary, the study found swimming increased lung function and reduced the risk of asthma symptoms at seven years of age. The health benefits associated with swimming include improvement of asthma symptoms and cardiovascular fitness. Pediatricians have long recommended swimming for asthmatic children because of its lower asthmogenicity compared with other forms of exercise. The

56 CDC. Ocular and respiratory illness associated with an indoor swimming pool--Nebraska, 2006. MMWR Morb Mortal Wkly Rep. 2007 Sep 14;56(36):929-32.
57 CDC. Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort—Ohio, 2007. MMWR Morb Mortal Wkly Rep 2009;58:81–5.
58 Bowen AB, et al. Outbreaks of short-incubation ocular and respiratory illness following exposure to indoor swimming pools. Environmental Health Perspectives (2007); 115(2): 267-271.
59 Kaydos-Daniels SC, et al. Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. Public Health. 2008 Feb;122(2):195-200.
60 Seys SF, et al. An outbreak of swimming-pool related respiratory symptoms: An elusive source of trichloramine in a municipal indoor swimming pool. Int J Hyg Environ Health. 2015 Jun;218(4):386-91.
61 Dang B, et al. Ocular and respiratory symptoms among lifeguards at a hotel indoor waterpark resort. J Occup Environ Med. 2010;52(2):207-13.
62 Hlavsa MC, et al. Outbreaks of illness associated with recreational water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(24):668-672.
63 Williams A, et al. Increased concentration of chlorine in swimming pool water causes exercise-induced bronchoconstriction (EIB). Medicine and Science in Sports and Exercise (2004); 36(5) Supplement abstract 2046.
64 Nemery B, et al. Indoor swimming pools, water chlorination, and respiratory health. Eur. Respir. J. (2002); 19: 790-793.
65 Nordberg GF, et al. Lung function in volunteers before and after exposure to trichloramine in indoor pool environments and asthma in a cohort of pool workers. BMJ Open. 2012 Oct 8;2(5).
66 Lagerkvist BJ, et al. Pulmonary epithelial integrity in children: relationship to ambient ozone exposure and swimming pool attendance. Environ Health Perspect (2004);112:1768-1771.
67 Bernard A, et al. Lung hyperpermeability and asthma prevalence in schoolchildren: unexpected associations with the attendance at indoor chlorinated swimming pools. Occupational and Environmental Medicine (2003); 60: 385-394.
68 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur. Respir. J. (2002)19: 827-832.
69 Mustchin CP, et al. Coughing water: bronchial hyper-reactivity induced by swimming in a chlorinated pool. Thorax (1979); 34(5): 682-683.
70 Rosenman KD, et al. Swimming facilities and work-related asthma. J Asthma. 2015 Feb;52(1):52-8.
71 Font-Ribera L, et al. Indoor swimming pool attendance and respiratory and dermal health in schoolchildren--HITEA Catalonia. Respir Med. 2014 Jul;108(7):1056-9.
72 Andersson M, et al. Swimming pool attendance is related to asthma among atopic school children: a population-based study. Environ Health. 2015 Apr 15;14:37.
73 Font-Ribera L, et al. Swimming pool attendance, asthma, allergies, and lung function in the Avon Longitudinal Study of Parents and Children cohort. Am J Respir Crit Care Med. (2011 Mar 1);183(5):582-8.
74 Goodman M, et al. Asthma and swimming: A meta-analysis. J of Asthma (2008);45(8):639-647.
75 Weisel CP, et al. Childhood asthma and environmental exposures at swimming pools: State of the science and research recommendations. Environ Health Perspect (2009); 117: 500-507.
76 Villanueva CM, et al. Overview of disinfection by-products and associated health effects. Curr Environ Health Rep. 2015 Mar;2(1):107-15.
77 LaKind JS, et al. The good, the bad, and the volatile: can we have both healthy pools and healthy people? Environ Sci Technol. 2010;44(9):3205-10.
78 Font-Ribera L, et al. Swimming pool attendance, asthma, allergies, and lung function in the Avon Longitudinal Study of Parents and Children cohort. Am J Respir Crit Care Med. (2011 Mar 1);183(5):582-8.

Belgian Superior Health Council[79] reviewed the available science related to AQUATIC VENUE swimming and the development of childhood asthma. The Council, in its 2011 report No. 8748 *(and reiterated in its 2012 report)* concludes swimming remains highly advisable, even in the case of asthma. According to the Council, "For this target group, the advantages of swimming under good hygienic conditions in monitored AQUATIC VENUES outweigh the risk of toxicity linked to CHLORINE and its by-products."

Also see Annex 4.6.2.1

4.0.1.4.8 Benefits Outweigh Risks

Despite the health risks of DBPs in general, the concentration of organic DBPs found in AQUATIC VENUES is generally low. Therefore, although research results have shown that DBPs do form in detectable concentrations in most AQUATIC VENUES[80,81,82] and levels of exposure can be measured[83,84], it appears that the benefits of DISINFECTION far outweigh the risks posed by its by-products.[85] The World Health Organization, states that "the risks from exposure to chlorination by-products in reasonably well-managed AQUATIC VENUES would be considered to be small and must be set against the benefits of aerobic exercise and the risks of infectious disease in the absence of DISINFECTION."[86] Improved water quality management is recommended to minimize formation and accumulation of these compounds.

4.0.1.4.9 Urea Concentrations in Pool Water

A major CONTAMINANT in AQUATIC VENUE water is urea. Urea is chiefly derived from swimmers urinating in AQUATIC VENUE water, but is also present in swimmer's sweat. It has been shown that urea reacts with HOCl to produce TRICHLORAMINE. However, while breakpoint destruction of ammonia is very fast, reaction of HOCl with urea is very slow. Therefore, urea is difficult to remove quickly by shocking the AQUATIC VENUE water. There are no guidelines in the U.S. for MONITORING the urea concentration in AQUATIC VENUE

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79 Belgian Superior Health Council. Publication no. 8748: The issue of chlorine in swimming pools: Risk attendant on baby swimming and reflections on the different methods used to disinfect swimming pools.
80 Kim H, et al. Formation of disinfection by-products in chlorinated swimming pool water. Chemosphere (2002); 46:123-130.
81 Bessonneau V, et al. Determinants of chlorination by-products in indoor swimming pools. Int Hyg Environ Health. 2011;215:76-85.
82 Weng S, et al. DBP dynamics in a chlorinated, indoor swimming pool under conditions of heavy use: National swimming competition. Water Res. 2011;45(16):5241-5248.
83 Cammann K, et al. Trihalomethane concentrations in swimmers' and bath attendants' blood and urine after swimming or working in indoor swimming pools. Archives of Environmental Health (1995); 50(1): 61-65.
84 Lindstrom AB, et al. Alveolar breath sampling and analysis to assess trihalomethane exposures during competitive swimming training. Environmental Health Perspectives (1997); 105(6):636-642.
85 WHO (2000). Environmental Health Criteria 216 (including corrigenda from 11/30/2004). Available at http://whqlibdoc.who.int/ehc/WHO_EHC_216.pdf. Accessed on April 14, 2016.
86 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 14, 2016.

water or suggested levels of concern. Input of urea is most effectively minimized by changes in swimmers' behavior and hygiene.[87,88, 89,90,91]

4.1 Plan Submittal

4.1.1 Plan Submittal

4.1.2 Content of Design Report

4.1.2.1 Basis of Design Report

4.1.2.1.1 Names / Addresses

AQUATIC FACILITY plans should include a map indicating the exact location of the AQUATIC FACILITY with street address and geographic location information including the GPS coordinates.

4.1.2.3 Technical Specifications

4.1.2.3.1 Accompanying Drawings

Appurtenances include diving platforms, diving boards, WATERSLIDES, and other AQUATIC FEATURES.

4.1.2.3.2 Technical Details

Detailed specifications including POOL water temperatures, space design, dry bulb and dew point temperatures, and relative humidity are required to ensure that there is no misunderstanding, ambiguity, or omission between the design professional, owner/operator, and the AHJ reviewer.

4.1.2.3.2.1 Intended Use

The owner/operator and design professionals (engineer and architect) need to coordinate intended use, type of AQUATIC VENUE (FLAT WATER, AGITATED WATER, HOT WATER) and intended typical operating water temperature. This is critical towards ensuring owner/operator expectations are fully met. It also helps ensure the HVAC system and building envelope are designed for intended use.

4.1.2.3.5 Theoretical Peak Occupancy

Design professionals need to consider the THEORETICAL PEAK OCCUPANCY of an AQUATIC FACILITY as part of the design process. This requires calculation and integration of peak occupancy numbers for the water as well as the surrounding DECK and seating areas. The

87 Blatchley E, et al. Reaction mechanism for chlorination of urea. Environ Sci Technol. 2010 Nov 15;44(22):8529-34.
88 De Laat J, et al. Concentration levels of urea in swimming pool water and reactivity of chlorine with urea. Water Res. 2011; 45(3) 1139-46.
89 Schmalz C, et al. Trichloramine in swimming pools – Formation and mass transfer. Water Res. 2011;45(8):2681-90.
90 Fuchs J. Chlorination of pool water: urea degradation rate. Chemiker Ztg. -Chem. Apparatur (1962);86(3): 76-82.
91 Gunkel K, et al. The urea problem in swimming pools. Z. gesamte Hyg. (1988); 34(4):248-50.

rationale for the THEORETICAL PEAK OCCUPANCY density factor numbers for specific AQUATIC VENUE types is as follows:

1. FLAT WATER
    a. These AQUATIC VENUES generally are for swimming.
    b. The density factor was established at 20 ft^2 per person. This represents an average horizontal BATHER occupying a five foot *(1.5 m)* by four foot *(1.2 m)* area.
    c. Assuming a BATHER is swimming horizontally; a full body length is an average five foot *(1.5 m)* with a five foot span to equal 25 ft^2 *(2.3 m^2)*. There was a need to account for higher densities in shallow areas where BATHERS wade vertically versus swim horizontally. The middle ground decided was 20 ft^2 *(1.9 m^2)*.
2. AGITATED WATER
    a. These AQUATIC VENUES generally are for wading, splashing, and enjoyment of features without swimming.
    b. The density factor was established at 15 ft^2 *(1.4 m^2)* per BATHER. This represents an average vertical BATHER occupying a five foot *(1.5 m)* by three foot *(91 cm)* area. This also complies with the Illinois State Pool Code.
3. HOT WATER
    a. These AQUATIC VENUES generally are for lounging such as hot tubs, warming POOLS, etc.
    b. The density factor was established at 10 ft^2 *(0.9 m^2)* per BATHER. This represents an average user sitting in a three foot *(91 cm)* by three foot *(91cm)* area.
4. DECK and Spectator Areas
    a. For DECKS at leisure POOLS, one can assume a density factor of 50 ft^2 *(4.6 m^2)* per BATHER of DECK space based on Illinois State Pool Code. When adding seating and tables, which separate groups, the square footage allows for a reduced density.
    b. For spectator areas, the MAHC Committee chose a density factor of 6.6 ft^2 *(0.6 m^2)* per PATRON for STADIUM SEATING from ASHRAE 62.1. This seating is generally well above the water level.

The density factors in MAHC 4.1.2.3.5.3 may be modified for higher BATHER or PATRON density, but they shall not be modified to be lower than the density factors listed. The designer/engineer of the AQUATIC FACILITY or AQUATIC VENUE can document the intended use is different. For example, a swimming POOL that is normally a FLAT WATER venue has a density factor of 20 ft^2 *(1.9 m^2)* per BATHER. However, when designing a FLAT WATER WADING POOL with more vertical use than horizontal swimming, the POOL would have a higher density of BATHERS so the density factor could be modified to 15 ft^2 *(1.4 m^2)* per BATHER.

> Example: Sec 4.1.2.3.5.3 assigns the letter D to represent the BATHER "density factor". The D number is listed in terms of square feet of POOL water surface per BATHER. This means that a numerically lower D results in a numerically higher number of BATHERS. When designing an AQUATIC FACILITY, if the expected use will be more BATHERS per square foot than what is listed, then it can be modified to

reflect that (i.e., if the expected BATHER density for FLAT WATER is 1/10 ft^2 instead of 1/20 ft^2, one can use 1/10 ft^2 BUT they can't use 1/30 ft^2 for FLAT WATER).

4.1.3 Plan Approval

The construction of public AQUATIC FACILITIES should not be undertaken without a thorough review and approval of the proposed construction plans by the AHJ. Construction costs for AQUATIC FACILITIES can be in the millions of dollars and very costly mistakes in design and equipment choices can occur if plans are not reviewed before construction. These mistakes could result in both public health hazards and additional remodeling costs.

Most of the states require that plans be submitted for review and approval by the regulatory authority before a public AQUATIC FACILITY can be constructed. Although there is considerable variation in the amount of information and detail required on the plans, most of the jurisdictions require at least a plot plan with sufficient detail to allow for a reasonable review of the proposed project.

The licensed professional engineer or architect should have at least one year of previous experience with public AQUATIC FACILITY design. Most states will allow any professional engineer or architect to design an AQUATIC FACILITY. However, since AQUATIC DESIGN technology is sufficiently complex, specific prior experience in AQUATIC FACILITY construction and design is strongly recommended. A minimum of one year of previous experience in AQUATIC FACILITY design and construction is recommended.

Any final approval of plans by the AHJ should be dependent on approval by all other appropriate agencies.

For example, the assumption of responsibility for reviewing plans for structural SAFETY and ensuring the AQUATIC FACILITY is designed to withstand anticipated loading, not only the POOL shell, but also in cases where the POOL may be located on an upper floor of a building or a rooftop is generally that of the local building department. If there is no local building CODE department or requirements, the design engineer or architect must assume responsibility. This may include requiring the architect or engineer to certify the structural stability of the POOL shell during full and empty conditions.

4.1.3.3 Replacements

Most jurisdictions allow for replacements in-kind.

4.1.4 Compliance Certificate

4.1.4.4 Systems Commissioning

"Commissioning" or "testing of BATHER SAFETY" means completing a test, evaluation, or demonstration that confirms that the AQUATIC FACILITY, AQUATIC VENUES, AQUATIC VENUE FEATURES, or other equipment in question does not compromise the SAFETY of the PATRONS.

4.2 Materials

4.2.1 Aquatic Venues

4.2.1.5 Design Parameters

There are multiple forms of acceptable finishes available including but not limited to: paint, marcite plaster finish, quartz plaster finish, aggregate plaster finish, vinyl or PVC liner / paneling systems, stainless steel, tile, etc. Each system shall have advantages and disadvantages associated with cost, durability, clean-ability, etc. These advantages and disadvantages are also subject to installation design issues *(e.g. indoors/outdoors, above/below water level, environmental effects, freezing or temperature exposures, etc.)*.

4.2.1.7 Smooth Finish

SKIMMER POOLS require a six inch *(152 mm)* to 12 inch *(305 mm)* high finish due to the varying height of water associated with in-POOL surge capacity of SKIMMER POOL systems. Gutter or POSs require a minimum finish height of two inches *(51 mm)*. If dark colors are utilized for the POOL finish, the POOL finish should not exceed a maximum height of 12 inches *(305 mm)* for contrasting purposes. Typical finishes include: tile, stainless steel, vinyl, fiberglass, etc.

4.2.1.8 Slip Resistant

Water three feet *(0.9 m)* and less is considered shallow water and the majority of BATHERS are capable of walking on the POOL bottom at these depths, so a slip-resistant surface is required. At depths greater than three feet *(0.9 m)*, most BATHERS are sufficiently buoyant making the coefficient of friction for the POOL floor surface less important. Slip resistant surfaces shall meet or exceed the minimum coefficient of friction as set forth by the following groups:

- Americans with Disabilities Act *(ADA)* designated STANDARD
- Occupational Safety and Health Administration *(OSHA)*

4.2.2 Indoor Aquatic Facility

4.2.2.2 Condensation Prevention

Special care should be used in the construction of air-pressure-supported buildings to prevent the movement of moisture into building surfaces, conduits, etc.

4.2.2.2.1 Cold Weather

Paints suitable for use as vapor retarders usually have high solids, and must be carefully applied to achieve a rating of 0.4 perm for one coat. It is important to get very good coverage without gaps or thin spots. The paint supplier or manufacturer should be consulted for ratings and BEST PRACTICES.

4.2.2.2.2 Paint or Coating

One U.S. perm equals 1.0 grain of moisture per square foot per hour per inch-of-mercury differential pressure. One U.S. perm equals 57 SI perm.

4.2.2.3 Mechanical Systems

4.2.2.3.3 Indoor Aquatic Facility Air Pressure

Air-pressure-supported INDOOR AQUATIC FACILITIES may require pressurization of adjoining or connected spaces.

4.2.2.3.4 Air Ducts

Refer to the 2011 ASHRAE Applications Handbook on Natatorium Design for recommendations.

4.2.2.4 Indoor Aquatic Facility Doors

Where exterior doors of an INDOOR AQUATIC FACILITY may be exposed to temperatures below the freezing temperature of water, the frames should be constructed to minimize the risk of the door freezing closed. The issue here is one of emergency exit. There is a large amount of water vapor available to freeze into the gap between doors, etc., that can inhibit emergency exiting.

Exception: Other doors should be acceptable, subject to approval by the AHJ, where heating systems are so arranged as to maintain such doors at least 5°F *(-15°C)* above the freezing temperature of water.

4.2.2.5 Indoor Aquatic Facility Windows

Windows are usually maintained above -air dew point to prevent condensation and mold growth by heated supply air flowing over them. Heavy window frames on the interior side interfere with the proper flow of this heated air by the Coanda *effect (a corollary of Bernoulli's principle)*. There are many ways to mechanically address window condensation issues. Air supply can be dumped on glazing from both above and below. Fin tube heaters have also been effectively employed along sills in many instances.

- *Also see: ASHRAE Handbook of Fundamentals*[92]

4.3 Equipment Standards

4.3.1 General

4.3.1.1 Accredited Standards

Acceptable STANDARDS for common RECIRCULATION SYSTEM components are listed below:

- INLETS – NSF/ANSI
- Overflow System/Gutters – NSF/ANSI
- SKIMMERS – NSF/ANSI
- Valves – NSF/ANSI
- Piping and Face Piping – NSF/ANSI
- Fittings – NSF/ANSI

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92 ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Available at https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ASHRAE-handbook--fundamentals. Accessed on April 14, 2016.

- Strainers – NSF/ANSI
- Gauges – NSF/ANSI
- Flow Meters – NSF/ANSI
- Solar POOL Heaters – NSF/ANSI
- Rapid Sand Filters – NSF/ANSI
- High-Rate Sand Filters – NSF/ANSI
- Pre-Coat Filters – NSF/ANSI
- Filter Media – NSF/ANSI
- Cartridge Filters – NSF/ANSI
- Bottom Drains/Main Drain System – ASME
- Pumps – NSF/ANSI, UL, California Assembly Bill, NEC
- Heaters, HVAC, and Dehumidifiers – UL
- Combustion/Furnaces – ANSI, CSA 2.6-2006 Ga, UL
- Boilers – ASME, ANSI, CSA
- Gas-fired POOL Heaters – ANSI, CSA
- Flues – UL
- Mechanical Chemical Feeding Equipment – NSF/ANSI, UL, CSA
- Ozone – NSF/ANSI, UL, CSA, NEC
- Ultraviolet Light – NSF/ANSI, UL, CSA, NEC
- In-line and Brine Batch Electrolytic Chlorinator or Bromine Generator – NSF/ANSI, UL, CSA, NEC, Canadian PMRA
- Copper/Silver and Copper Ion Generators – NSF/ANSI, UL, CSA, NEC, Canadian PMRA
- CHEMICAL STORAGE – National Fire Code
- AUTOMATED CONTROLLERS – NSF/ANSI, UL, CSA, NEC
- WATER QUALITY TESTING DEVICE – NSF/ANSI
- Electrical – NEC
- Lights – UL
- Diving Boards and Platforms – NSF/ANSI
- Starting Blocks – ANSI/NSPI, FINA, NFSHSA, NCAA
- Lifeguard Chairs – NASI/NSPI
- Ladders – ANSI/NSPI
- Handrails – ANSI/NSPI
- Stairs – ANSI/NSPI
- Handicapped Lifts – ADA
- Safety Covers – ANSI/NSPI, ASTM, UL

4.3.2 Recirculation Systems and Equipment

Notes about Component Requirements: Recirculation Systems and Equipment

NOTE: This section has not been updated from the same section in the 2014 MAHC (1st Edition). The intent is that any new revisions available at the release of the 2016 MAHC (2nd Edition) would be included.

Inlets

At the release date of the MAHC 1st Edition, INLET products are currently listed by NSF to an engineering specification. Language is ready for ballot into NSF/ ANSI Standard 50.

Overflow System / Gutters

At the release date of the MAHC 1st Edition, overflow system gutters products are currently listed by NSF to an engineering specification. Language is ready for ballot into NSF/ANSI Standard 50.

Skimmers

At the release date of the MAHC 1st Edition, NSF/ANSI Standard 50 2013 is the current version of the applicable STANDARD for SKIMMERS.

Main Drain System

At the release date of the MAHC 1st Edition, ANSI/APSP Standard 16 – 2011, titled "American National Standard for Suction Fittings for Use in Swimming Pools, Wading pools, Spas and Hot Tubs" is the current version of the applicable STANDARD for main drain systems.

Multiport Valves

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for multiport valves.

Face Piping

At the release date of the MAHC 1st Edition, face piping products are currently listed by NSF to an engineering specification. It is currently at the Task Group Level for development of language for inclusion into NSF/ ANSI Standard 50.

Diaphragm Valves

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 14 – 2008e is the current version of the applicable STANDARD for diaphragm valves. Product is currently at the Task Group Level for development of language for inclusion into NSF/ ANSI.

Check Valves

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 14 – 2008e is the current version of the applicable STANDARD for check valves. Product is currently at the Task Group Level for development of language for inclusion into NSF/ ANSI Standard 50 as well.

Fittings

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 14 – 2008e is the current version of the applicable STANDARD for fittings. Product is currently at the Task Group Level for development of language for inclusion into NSF/ ANSI Standard 50 as well.

Pipe

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 14 – 2008e is the current version of the applicable STANDARD for pipe. Product is currently at the Task Group Level for development of language for inclusion into NSF/ ANSI Standard 50 as well.

Pumps

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 - 2013, UL 1081 *(non-metallic pumps up to 5 hp)*, California Assembly Bill 1953, and United States National Electrical Code NFPA- 70 *(2008)* are the current version of the applicable STANDARDS for pumps.

Strainers

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for strainers.

Gauges

At the release date of the MAHC 1st Edition, gauges are currently listed by NSF to an engineering specification. It is currently at the Task Group Level for development of language for inclusion into NSF/ ANSI Standard 50.

Flow Meters

At the release date of the MAHC 1st Edition, flow meters are currently listed by NSF to an engineering specification. Language is ready for ballot into NSF/ ANSI Standard 50.

Notes About Component Requirements: Heaters

HVAC and Dehumidifiers

At the release date of the MAHC 1st Edition, UL 1995 is the current version of the applicable STANDARD for HVAC and dehumidifiers.

Solar Pool Heaters

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for solar POOL heaters.

Furnaces

At the release date of the MAHC 1st Edition, ANSI Z83.8-2006 Gas Heaters and Gas-Fired Duct Furnaces, CSA 2.6 -2006 Gas Heaters and Gas-Fired Duct Furnaces and UL 757 Oil-Fired Furnaces are the current version of the applicable STANDARDS for furnaces.

Boilers

At the release date of the MAHC 1st Edition, ASME Boiler Code, ANSI Z21.13 – CSA 4.9 Gas Fired Hot Water Boilers are the current version of the applicable STANDARDS for boilers.

Gas-Fired Pool Heaters

At the release date of the MAHC 1st Edition, ANSI Z21.10.3 CSA 4.3 and ANSI Z21.56/ CSA 4.7 is the current version of the applicable STANDARDS for gas-fired POOL heaters. Language is ready for ballot into NSF/ ANSI Standard 50.

Flues

At the release date of the MAHC 1st Edition, UL 1777 is the current version of the applicable STANDARD for flues.

Notes About Component Requirements: Filtration

Rapid Sand Filters

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for rapid sand filters.

High-Rate Sand Filters

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for high-rate sand filters

Precoat Filters

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for precoat filters. Filters previously known as diatomaceous earth filters changed to precoat filters based on significant use of alternate filter media such as perlite.

Filter Media

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for filter media.

Cartridge Filters

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for cartridge filters.

Other Filter Types

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for other filter types.

Notes About Component Requirements: Disinfection Equipment

Mechanical Chemical Feeding Equipment

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 – 2013 and UL 1081, CSA C22 are the current versions of the applicable STANDARDS for mechanical chemical feeding equipment.

Ozone

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 - 2013, UL 1081, CSA C22 and United States National Electrical Code NFPA- 70 (2008) are the current versions of the applicable STANDARDS for ozone generators.

Ultraviolet Light

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 – 2013, which includes testing for *Cryptosporidium* validation, CSA C22 and United States National Electrical Code NFPA- 70 (2008) are the current versions of the applicable STANDARDS for UV light systems.

Other potential guidance can be found in the U.S. EPA UV Disinfection Guidance: http://goo.gl/edykzN.

In-line Electrolytic Chlorinator

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 - 2013, UL 1081, CSA C22, United States National Electrical Code NFPA- 70 (2008) and Canadian PMRA are the current versions of the applicable STANDARDS for in-line electrolytic chlorinators.

Brine Batch Electrolytic Chlorine or Bromine Generator

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 - 2013, UL 1081, CSA C22, United States National Electrical Code NFPA- 70 (2008) and Canadian PMRA are the current versions of the applicable STANDARDS for brine batch electrolytic CHLORINE or bromine generators.

Copper/Silver and Copper Ion Generator

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 - 2013, UL 1081, CSA C22, United States National Electrical Code NFPA- 70 (2008) and Canadian PMRA are the current versions of the applicable STANDARDS for copper/ silver and copper ion generators.

Chemical Storage

At the release date of the MAHC 1st Edition, United States National Fire Code NFPA- 1 (2009) is the current version of the applicable STANDARD for CHEMICAL STORAGE.

Automated Controllers

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 - 2013, UL 61010-1, CSA C22.2, and United States National Electrical Code NFPA- 70 (2008) are the current versions of the applicable STANDARDS for AUTOMATED CONTROLLERS.

Water Quality Testing Device

At the release date of the MAHC 1st Edition, NSF/ ANSI Standard 50 2013 is the current version of the applicable STANDARD for WQTDs.

Notes About Component Requirements: Electrical Equipment

National Electrical Code

At the release date of the MAHC 1st Edition, United States National Electrical Code NFPA-70 (2008) is the current version of the applicable STANDARD for general electrical.

Lights

At the release date of the MAHC 1st Edition, UL 1241 – Junction Boxes for Swimming Pool Luminaires, UL 676- Underwater Luminaires and Submersible Junction Boxes, UL8750- Light Emitting Diode (LED) Equipment for Use in Lighting Products, and UL379- Transformers for Fountain, Swimming Pool, and Spa Luminaires are the current versions of the applicable STANDARDS for lights.

Notes About Component Requirements: Deck Equipment

Diving Boards and Platforms

At the release date of the MAHC 1st Edition, ANSI/ NSPI- 1 2003 is the current version of the applicable STANDARD for diving boards and platforms.

Starting Blocks

At the release date of the MAHC 1st Edition, ANSI/ NSPI- 1 2003, FINA, NFSHSA, and NCAA are the current version of the applicable STANDARDS for starting blocks.

Life Guard Chairs

At the release date of the MAHC 1st Edition, ANSI/ NSPI- 1 2003 is the current version of the applicable STANDARD for lifeguard chairs.

Ladders

At the release date of the MAHC 1st Edition, ANSI/ NSPI- 1 2003 is the current version of the applicable STANDARD for ladders.

Handrail

At the release date of the MAHC 1st Edition, ANSI/ NSPI- 1 2003 is the current version of the applicable STANDARD for handrail.

Stairs

At the release date of the MAHC 1st Edition, ANSI/ NSPI- 1 2003 is the current version of the applicable STANDARD for stairs.

Handicapped Lifts

At the release date of the MAHC 1st Edition, the ADA is the applicable STANDARD for handicapped lifts and is regulated by the Department of Justice.

Safety Covers

At the release date of the MAHC 1st Edition, ANSI/ NSPI- 1 2003, ASTM 1346, and UL2452 are the current version of the applicable STANDARDS for SAFETY covers.

4.4 Aquatic Facility and Venue Operation Maintenance [N/A]

4.5 Aquatic Venue Structure

4.5.1 Design for Risk Management

Working with the owner and/or aquatic risk management consultant, the designer can outline the anticipated zones of PATRON surveillance and place fixed lifeguard stations accordingly. It is important to have a person knowledgeable in aquatic risk management to advise on placement of fixed lifeguard stations and the general design of the AQUATIC VENUE as it relates to placement of lifeguards so to avoid blind spots, glare issues, and other obstructions being included in the design. This also allows the owner to influence design so it meets the anticipated labor requirements. In some operations where the AQUATIC VENUE design requires more lifeguards, this puts pressure on owners to minimize labor by extending zones of PATRON surveillance. Small design changes could reduce zone size without taking away from PATRON enjoyment. This is also a critical need when considering alterations such as the addition of new AQUATIC FEATURES (e.g., WATERSLIDES, mushroom) that change visibility and the PATRON zones of surveillance and increase the number of lifeguards needed. This knowledge is important to have while deciding on the benefits of the new AQUATIC FEATURE so they can be balanced with the increased labor cost.

4.5.2 Bottom Slope

4.5.2.1 Under Five Feet

A maximum slope of 1:12 is used in water under five feet *(1.5 m)* for consistency with ADA since these ramps can be used for access. Variances may be considered by the AHJ.

4.5.2.3 Drain

POOLS should be designed to allow for the water to drain to a low point in order to prevent standing water from creating a contamination issue.

4.5.3 Pool Access / Egress

4.5.3.1 Accessibility

As required by the Department of Justice, all POOL designs shall be compliant with the Americans with Disabilities Act *(ADA)*. The POOL design shall not create SAFETY hazards with regards to maintaining necessary clearances, not infringing upon the recirculation of AQUATIC VENUE water, or creating areas for potential entrapment.

4.5.4 Stairs

4.5.4.3 Deep Water

It is common, especially in high-end diving wells with ten-meter towers, for there to be “swim-out” stairs underneath the dive tower. This provision is allowing for those types of deep water stairs without requiring the stairs to continue down to the bottom of the POOL *(which may be 17 feet deep and impractical in the diving well example)*.

4.5.4.5 Dimensions

Dimensions of stair treads for other types of stairs should conform to requirements of

- MAHC Table 4.5.4.5,
- MAHC Figure 4.5.4.5.1,
- MAHC Figure 4.5.4.5.2, and
- MAHC Figure 4.5.4.5.3.

Table 4.5.4.5: Required Dimensions for Stair Treads and Risers

Dimensions	T-1 Standard	T-1 Convex, Concave, Triangular	T-2	W-1	H-1
Minimum	12 inches *(30.5 cm)*	21 inches *(53.3 cm)*	12 inches *(30.5 cm)*	24 inches *(61.0 cm)*	6 inches *(15.2 cm)*
Maximum	18 inches *(45.7 cm)*	24 inches *(61.0 cm)*	16 inches *(40.6 cm)*	N/A	12 inches *(30.5 cm)*

Figure 4.5.4.5.1: Stair Treads and Risers

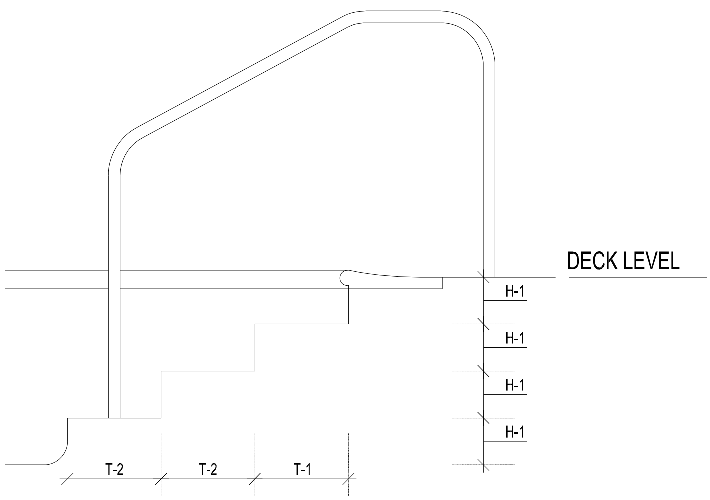
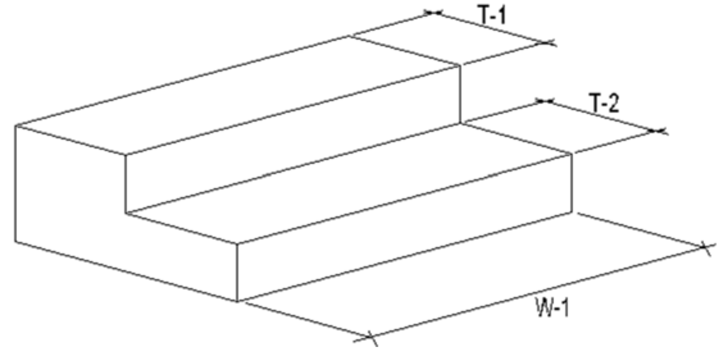
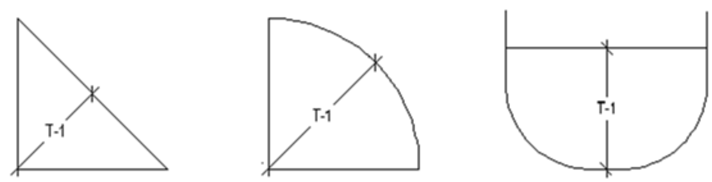


Figure 4.5.4.5.2: Stair Treads



4.5.4.5.3: Unique Stair Treads



4.5.4.8 Perimeter Gutter Systems

It is not the intent of this section to eliminate the "roll out gutter" as they need to be a minimum six inches *(15.2 cm)* from DECK to water level.

4.5.5 Handrails

4.5.5.3 Upper Railing

The 28 inch *(71.1 cm)* minimum may seem inconsistent with ADA. However, most handrails at POOLS are not used for ADA accessibility. If railings are provided for ADA purposes, they will need to meet the ADA 34 inch *(86.4 cm)* STANDARDS. The current MAHC language stipulates that 28 inches *(711 cm)* is a minimum, which does not preclude a designer from using 34 inch *(86.4 cm)* railings.

4.5.5.5 ADA Accessibility

The outside diameter that the handrail configuration and dimensions need to conform to for the POOL access requirements outlined in ADA are not associated with ADA requirements, but these parameters are intended to address the necessary structural requirements which are not addressed in ADA. In the end, ADA STANDARDS will always take precedence over anything in the MAHC.

Another source for guidance is the *Architectural Barrier's Guide* – refer to Swimming Pools, Wading Pools, and Spas section numbers 242 and 1009.

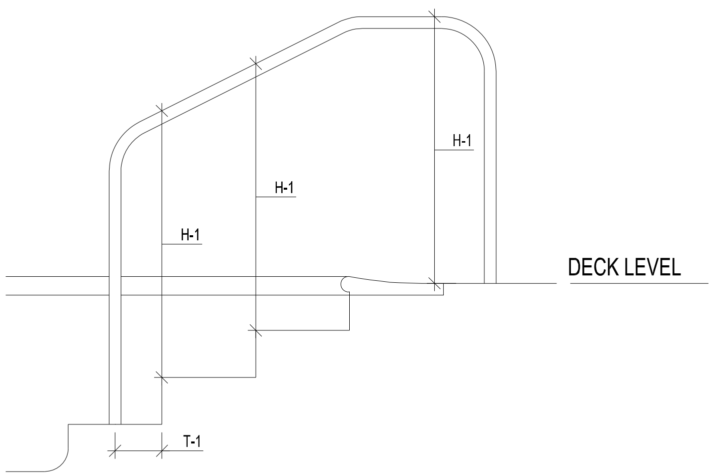
4.5.5.7 Dimensions

Dimensions of handrails should conform to requirements of MAHC Table 4.5.5.7 and MAHC Figure 4.5.5.7.1. Current federal ADA requirements require that top gripping surfaces of handrails shall be 34 inches minimum and 38 inches maximum vertically above stair nosings.

Table 4.5.5.7: Stair Handrail Dimensions

Dimensions	T-1	H-1
Minimum	3 inches *(7.6 cm)*	34 inches *(86.4 cm)*
Maximum	N/A	38 inches *(96.5 cm)*

Figure 4.5.5.7.1: Stair Handrails



4.5.6 Grab Rails

4.5.7 Recessed Steps

4.5.7.4 Dimensions

Dimensions of RECESSED STEPS shall conform to requirements of:

- MAHC Table 4.5.7.4,
- MAHC Figure 4.5.7.4.1, and
- MAHC Figure 4.5.7.4.2.

Table 4.5.7.4: Recessed Step Dimensions

Dimensions	H-1	H-2	W-1	D-1
Minimum	6 inches *(15.2 cm)*	5 inches *(12.7 cm)*	12 inches *(30.5 cm)*	5 inches *(12.7 cm)*

Maximum	12 inches *(30.5 cm)*	N/A	N/A	N/A

Figure 4.5.7.4.1: Recessed Step Dimensions

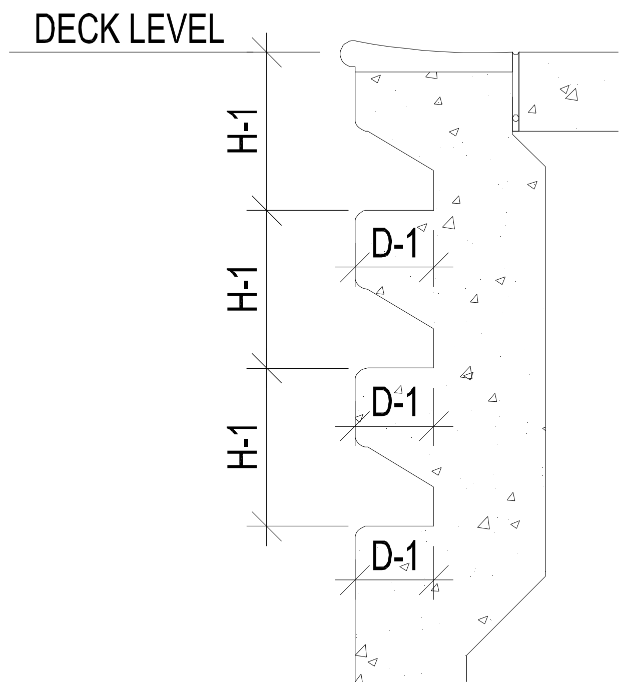
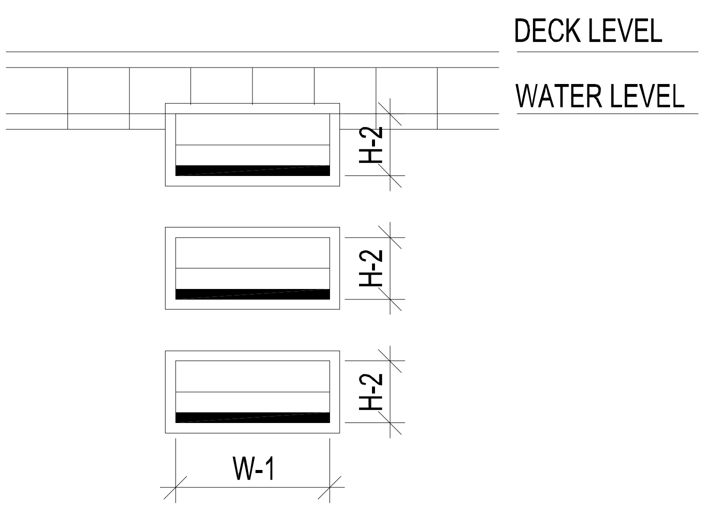


Figure 4.5.7.4.2: Recessed Step Dimensions



4.5.8 Ladders

4.5.8.1 General Guidelines for Ladders

4.5.8.2 Ladder Handrails

ADA Accessibility

This pertains to the handrail comments in MAHC Annex Section 4.5.5.5. The MAHC does not intend to choose only certain aspects of ADA to enforce; the MAHC agrees that all components of the current ADA requirements will stand irrespective of the MAHC language. However, ADA does not address structural requirements.

4.5.8.2.4 Pool Wall

This is a design criterion for POOLS in some of the western states. The initial intent was to design against entrapment between the railing and the POOL wall -- both for fingers and also the hands/wrists/arms of smaller children. CPSC recommends four inches *(10.2 cm)* based on child anthropometry tables. Anthropometric charts were reviewed in establishing the current allowable range.

4.5.8.2.5 Support

The structural requirements in the ladder, handrail, railing section are taken from commercial manufacturers and their recommended data.

4.5.9 Zero Depth (Sloped) Entries

4.5.10 Disabled Access

4.5.10.1 Conform to ADA Standards

Please refer to the governing Department of Justice at www.access-board.gov.

4.5.11 Color and Finish

4.5.11.1 White or Light Pastel

POOL floors and walls should be white or light pastel in color such that the following items can be identified from the POOL DECK:

- Person or body submerged in the water,
- Algae growth,
- Debris or dirt within the POOL, and
- CRACKS in surface finish of the POOL.

The term “light pastel color” should be consistent with Munsell color value 6.5 or higher.

School, facility or team logos incorporated on the POOL finishes are acceptable but will require review by the AHJ to ensure the design of such logos do not impede the color and finish functionality listed above.

Ultimately, water clarity is the primary criteria with which to be concerned. If a POOL has crystal clear water conditions and a BATHER is lying on the floor of a POOL with a blue finish versus one with a white finish, it's logical to think that the BATHER would be more identifiable against the darker finish. However, there's also the argument for recognizing dirt and debris at the bottom of the POOL.

4.5.11.1.1 Munsell Color Value

The State of Wisconsin uses the Munsell color chart and requires values of 6.5 or greater. The Munsell color system looks at color purity, hue, and lightness to assign a value. This system is used in other industries and information on this system is easily available.

A contractor could provide a mock-up during the submittal process to the AHJ or engineer for review and approval. Plaster and other quartz aggregate manufacturers have reflectance testing that is available for finish samples.

The American Plasterer's Council defers to ASTM Standard E 1477 – 98a title "Standard Test Method for Luminous Reflectance Factor of Acoustical Materials by Use of Integrating Sphere Reflectometers" to determine LRV values. It's a fairly simple test method where "Test specimens are measured for *(total)* luminous reflectance factor by standard color-measurement techniques using a spectrophotometer, tristimulus *(filter)* colorimeter, or other reflectometer having a hemispherical optical measuring system, such as an integrating sphere." The specular component is included to provide the total reflectance factor condition. The instrument STANDARD is referenced to the perfect reflecting diffuser. Luminous reflectance factor is calculated as CIE tristimulus value Y for the CIE 1964 *(10°)* standard observer and CIE standard illuminant D 65 *(daylight)* or F 2 *(cool white fluorescent)*.

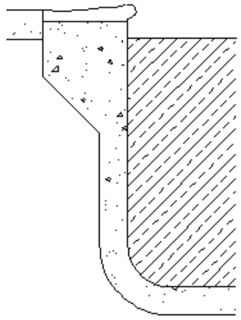
4.5.12 Walls

4.5.12.4 No Projections

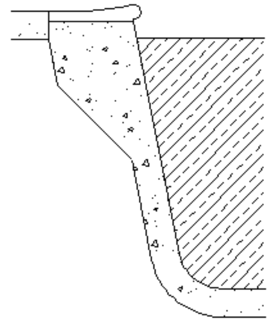
There should be no projections from a POOL wall with the exception of structures or elements such as stairs, grab rails, ladders, hand holds, PENINSULAS, WING WALLS, underwater lights, SAFETY ropes, WATERSLIDES, play features, other approved POOL amenities, UNDERWATER BENCHES, and UNDERWATER LEDGES as described in this section. Refer to MAHC Figure 4.5.12.4 below.

Figure 4.5.12.4: Pool Walls

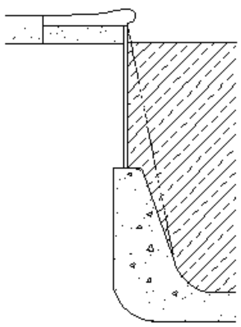
(A) Plumb within a +/- 3 degree tolerance.



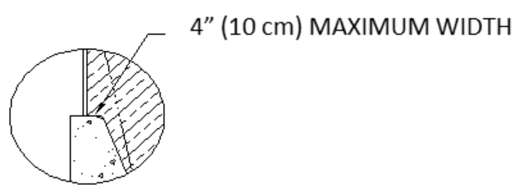
(B) Uniform slope not greater than 11 degrees or 1 in 5 from plumb.



(C) Structural support ledge all within 1 in 5 slope.



(D) Underwater Ledge for support of upper wall.



4.5.13 Structural Stability

Expansion and/or CONSTRUCTION JOINTS should be utilized when determined prudent by a licensed structural engineer. Any joints should utilize waterproofing strategies such as water stops as they are subject to compromising a POOL'S integrity regarding water tightness. The condition of all joints should be inspected regularly to ensure their condition.

4.5.14 Hand Holds

Based on anthropometric data for children between 6.5 to 7.5 years of age, the difference between their stature and vertical grip reach averages 9.3 inches *(23.6 cm)* so this measurement has been reinstated to nine inches *(22.9 cm)* as it was in the original design and construction module posted as part of the MAHC first public comment period.

4.5.15 Infinity Edges

4.5.15.1 Perimeter Restrictions

Often with INFINITY EDGE POOLS, the space immediately on the other side of the INFINITY EDGE is an inaccessible area because the DECK needs to end in order to achieve the "infinity" effect—typically this is achieved by an elevation difference—the DECK continues to extend around the POOL perimeter, but below the edge. The MAHC goal was to allow these types of design features while ensuring that these areas of the POOL are safe and still readily accessible for emergency response.

4.5.15.3 Handholds

INFINITY EDGES can be accomplished with an obtuse angle or knife edge, or even a C701 handhold. It is typically submerged a fraction of an inch.

4.5.15.6 Maximum Height

Building CODES typically require a railing for heights greater than 30 inches *(76.2 cm)* for SAFETY purposes.

4.5.16 Underwater Benches

UNDERWATER BENCHES are intended to allow BATHERS to sit in locations along the POOL wall. These chair/bench-like structures either protrude into the POOL from the POOL wall or are recessed into the POOL wall. To accommodate the size of most people, the seat itself is often 16 inches *(40.6 cm)* to 18 inches *(45.7 cm)* wide and is located 12 inches *(30.5 cm)* to 24 inches *(61.0 cm)* below the water line.

Use of hydrotherapy jets along UNDERWATER BENCHES should be considered during the design phase. Where hydrotherapy jets are used at underwater benches in swimming pools they could potentially push young children from benches, prevent young and weak swimmers from reaching the handhold at the perimeter of the pool in the location of the bench, or could impart motion to an unconscious victim making it more difficult to identify a victim in need of rescue. This could increase risk of drowning particularly for small children not being supervised. In addition, air entrained by hydrotherapy jets obscures visibility below the water surface which can prevent recognition of a victim submerged below the water surface. More data would help assess this potential risk.

4.5.16.1 Slip Resistant

Slip-resistant surfaces shall meet or exceed the minimum coefficient of friction as set forth by the following groups:

- American National Standards Institute (ANSI) designated STANDARD
- Americans with Disabilities Act *(ADA)*
- Occupational Safety and Health Administration *(OSHA)*

4.5.16.3 Maximum Water Depth

The five foot *(1.5 m)* depth restriction is to address the potential SAFETY issue of stepping or otherwise moving off a bench into deep water. The seat depth below the water line is limited to 20 inches *(50.8 cm)* maximum so a non-swimmer may be comfortable at that depth but once they move from the bench into a greater water depth it may exceed their comfort and/or skill level.

4.5.17 Underwater Ledges

4.5.17.1 Slip Resistant

An UNDERWATER TOE LEDGE for resting *("tired swimmer's ledge")* may be appropriate in any POOL with water depths greater than five feet *(1.5 m)*. They may be provided at the deep end of a competition POOL or other POOL with swim lanes. A ledge for resting may also be provided along the sidewalls of the same POOLS to allow resting for swimmers using the POOL for recreational swimming.

4.5.17.3 Five Feet or Greater

A ledge for resting should not allow a person to use the ledge to cross from a shallow area into a deeper area of a POOL.

4.5.17.4 Structural Support

UNDERWATER LEDGES for structural support for an upper wall *(structural ledge)* are often located at a water depth of about three feet *(0.9 m)* depending on the wall manufacturer. The upper wall is a product manufactured of stainless steel, fiberglass, acrylic, or other materials. The support ledge and wall below the ledge is concrete, gunite, or other materials that the wall manufacturer specifies. Although POOLS using this wall structure are generally smaller POOLS, these POOLS can be any depth.

4.5.18 Underwater Shelves

UNDERWATER SHELVES can be areas such as an expanded top tread of a stairway or a separate area many feet wide and long. The main purpose is for lounging in very shallow water or in chairs, or contoured as couches.

4.5.19 Depth Markers and Markings

4.5.19.1 Location

4.5.19.1.2 Depth Measurements

Non-traditional AQUATIC VENUES such as ACTIVITY POOLS and LAZY RIVERS may have designated entry and exit points and are generally consistent in depth throughout the AQUATIC VENUES. Other AQUATIC VENUES may have landscaping or other BARRIERS so that there is a defined entry such as in a LAZY RIVER. AQUATIC VENUES should install depth markers on the AQUATIC VENUE wall or, when defined entry points are provided, post the depth on entry signs.

This requirement is not intended to apply to competition AQUATIC VENUES where skilled divers train and compete in four to six feet *(1.2 to 1.8 m)* of water and are under the supervision of a certified instructor or coach.

4.5.19.1.3 Below Handhold

Vertical depth markings should be provided just below the handhold for POOLS with DECK level gutters. They could also be considered on the wall of the INDOOR AQUATIC FACILITY if within a reasonable distance from the POOL. For DECK level gutter POOLS, vertical depth markings are more visible just below the water level when compared with locating them on a building wall or fence which may be ten feet *(3 m)* to 50 feet *(15.2 m)* away and obstructed by DECK equipment, POOL appurtenances, etc.

4.5.19.2 Construction / Size

4.5.19.2.3 Color and Height

Depth markers four inches *(10.2 cm)* in height is common among several state CODES and found in ANSI/IAF-9 and ANSI/NSPI-1. Also, Human Factors Standards recommends one inch *(2.5 cm)* of letter height to ten feet *(3.0 m)* of viewing distance for oversized letters or one inch *(2.5 cm)* of letter height to 16.6 feet *(5.1 m)* which is ideal. A one inch (2.5 cm) letter height to 30 feet *(9.1 m)* of viewing distance is the minimum.

4.5.19.2.4 Feet and Inches

Some states may require both units of measurement in feet, inches, and meters. Some states do not allow for abbreviation of units.

4.5.19.4 No Diving Markers

4.5.19.4.1 Depths

The symbol is required as it is the universally recognized symbol for "NO DIVING" and can be understood by those who do not read and non-English speaking individuals. Diving boards are permitted only when the diving envelope conforms to the STANDARDS of the certifying agency that regulates diving at the facility - NCAA*,* NFSHSA*,* FINA*, or* U.S. Diving. If the AQUATIC VENUE does not have competitive diving, then the diving envelope must conform to these diving envelope STANDARDS. The intent of this section is to prohibit recreational and/or unsupervised users from performing DECK level diving into water five feet *(1.5 m)* or shallower. It is not intended to apply to competitive divers competing under the auspices of an aquatics governing body *(e.g., FINA, U.S.A. Swimming, NCAA, NFSHSA, YMCA)* or under the supervision of a coach or instructor. The vast majority of current STANDARDS allow for diving off the side of the POOL in water five feet *(1.5 m)* deep or greater. Water depths of at least five feet *(1.5 m)* are generally considered as safe for diving from the edge of a POOL where the coping/DECK is the typical six inches *(150 mm)* above the water surface. AQUATIC VENUE size and geometry may necessitate additional depth marking placements about all sides of the AQUATIC VENUE.

The ARC recommends nine feet *(2.7 m)* of water depth based on analyses of spinal cord injuries.[93] The organization has clarified this recommendation to state, "Be sure water is at least nine-feet deep unless performed with proper supervision and in water depths that conform with the rules of the concerned regulating body, such as USA Swimming, the NCAA, the AAU, the NFSHSA, YMCA of the USA, and FINA."

Although there are some national data on spinal cord injuries *(SCIs)* in general, data on diving-specific SCIs are limited, particularly for SCIs involving public POOL-related competition diving.

General data on spinal cord injuries: For SCIs in general, approximately 40 SCIs/million population occur each year in the US *(about 12,400 injuries for 2010)* with approximately 4.5% related to diving injuries.[94] SCIs are a catastrophic public health problem leading to disability and decreased life expectancy with a large economic and

93 Cusimano MD, et al. Spinal cord injuries due to diving: a framework and call for prevention. J Trauma. 2008;65(5):1180-5.
94 DeVivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. Spinal Cord. 2012 May;50(5):365-72.

social burden for those that suffer the injury.[95,96] The MAHC recommends that these national data be re-analyzed with aquatics in mind to gather more detailed information on SCIs related to diving in treated AQUATIC VENUES, particularly public AQUATIC VENUES.

Deck level diving and swimming pool-related SCIs: Most SCIs are related to diving into open water *(lakes, ocean)*[97] or use of private/residential POOLS. Analysis of the National Spinal Cord Injury Statistical Center data shows that 341 enrollees from 1973-1986 had an SCI as a result of diving into swimming POOLS[98]. Almost all of the injuries *(87%)* resulted from diving into private residential POOLS and 57% of injuries were a result of diving into water less than four feet *(1.2 m)* with almost four out of five dives (76.8%) being DECK level dives. Almost half *(49%)* of injuries involved alcohol use and 46% occurred during parties. In a summary of 194 neck injuries from DECK level dives into in-ground POOLS *(33% private residential)*[99], 86.6% were in water less than or equal to four feet *(1.2 m)*; 99.0% were in water less than or equal to five feet *(1.5 m).* Only one injury occurred in water between six and seven feet *(1.8 to 2.1 m)*. Another global review study showed that 89% of diving-associated neck injuries occurred in water less than five feet.[100] These data support keeping non-competition DECK level diving to water depths greater than five feet *(1.5 m)*.

An example of an international "NO DIVING" MARKER:

95 Blanksby BA, et al. Aetiology and occurrence of diving injuries. A review of diving safety. Sports Med. 1997;23(4):228-46.
96 Borius PY, et al. Cervical spine injuries resulting from diving accidents in swimming pools: outcome of 34 patients. Eur Spine J. 2010 Apr;19(4):552-7.
97 Barss P, et al. Risk factors and prevention for spinal cord injury from diving in swimming pools and natural sites in Quebec, Canada: a 44-year study. Accid Anal Prev. 2008;40(2):787-97.
98 DeVivo MJ, et al. Prevention of spinal cord injuries that occur in swimming pools. Spinal Cord. 1997;35(8):509-15.
99 Gabrielsen MA, et al. Diving injuries: The etiology of 486 case studies with recommendations for needed action. 1990. Nova University Press, Ft. Lauderdale, FL.
100 DeVivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. Spinal Cord. 2012 May;50(5):365-72.

Also see: *NEMA/ANSI Z535:* Safety Alerting Standards

4.5.19.5 Depth Marking at Break in Floor Slope

A contrasting band is required at the slope transition between shallow water and deep water as an additional means of caution *(along with the SAFETY rope and warning signage)* to BATHERS.

4.5.19.6 Dual Marking System

A symmetrical AQUATIC VENUE design is a design which is circular in nature where there is a shallow end around the entire perimeter and the bottom slopes from the perimeter towards a deeper portion in the center.

4.5.19.8 Wading Pool Depth Markers

A WATERSLIDE RUN-OUT in a WADING POOL may hold up to six inches *(15.2 cm)* of water without necessitating a no-diving sign or depth marker.

4.5.20 Aquatic Venue Shell Maintenance [N/A]

4.5.21 Special Use Aquatic Venues

During the final comment period, SURF POOLS were identified as different from WAVE POOLS, and many of the requirements for MAHC 4.0: Design and Construction are not applicable to SURF POOLS. The term SPECIAL USE AQUATIC VENUE has been added to potentially allow construction and use of SURF POOLS and any other, yet to be identified, AQUATIC VENUE or POOL that, while meeting the intent of CODE applicability to public AQUATIC FACILITIES, cannot practically be designed to meet existing design STANDARDS and keep the intended use. It is anticipated that appropriate design STANDARDS will be developed and incorporated in the CODE as part of the MAHC revision process.

There are three types of SURF POOL systems currently available or being developed.

1. Sheet flow – this sheet of water typically 1.5 inch *(3.8 cm)* thick moving at a high velocity – example: FlowRider.
2. Thick flow – a deeper section of water typically eight inch *(20.3 cm)* to 14 inch *(35.6 cm)* flowing at a medium velocity – example: Surfstream.
3. Surf POOL – large 20,000 to 80,000 square feet *(1858 to 7432 m^2)* POOLS with reefs intended to produce surfable waves. Wave systems range in design from a flying reef *(example: Wavegarden)* to pneumatic or hydraulic systems *(example: Thyphoon Lagoon)*. SURF POOLS built just for surfing are intended for only a few riders at once and can have fairly complex wave dampening systems on the walls and in shallow water.

4.6 Indoor / Outdoor Environment

4.6.1 Lighting

4.6.1.2 Windows / Natural Light

This would most likely be achieved through the use of photo sensors that would be triggered by a pre-established minimum light level.

Manual controls would almost certainly be set based on time of day. As the amount of daylight fluctuates throughout the year, these would need to be adjusted.

4.6.1.3 Light Levels

The minimum light levels are as recommended in the IESNA RP-6-88, "Recommended Practice for Sports and Recreational Area Lighting" for the recreational class of use. Higher light levels are recommended for various competitive classes of use. There is a difference between indoor and outdoor settings because outdoor settings usually have a higher contrast with darkness that does not occur indoors.

4.6.1.4 Overhead Lighting

Avoid glare by keeping overhead lighting directed 60-90 degrees horizontal of the eye. Glare on water can be avoided by direct lighting *(i.e., the more direct the light, the less opportunity for glare)*. Also consider maintaining a close ratio of the lighting underwater and overhead to obtain a balance thus avoiding glare.

4.6.1.4.1 Artificial Lighting

Glare from artificial light that interferes with the lifeguard's view of the swimmers shall be avoided.

4.6.1.5 Underwater Lighting

Current regulations specify an under-water light level equivalent to ½ watt per square foot of AQUATIC VENUE surface area. This value is based on outdated incandescent lighting technology.

For today's light sources for higher-efficiency lamps *(i.e., more light output per watt)*, this requirement no longer makes sense. Consider using a measure of light output *(e.g., lumens)* instead.

Based on an existing 300W General Electric R40 AQUATIC VENUE lamp that produces 3,750 initial lumens of light output, the conversion between watts and lumens is as follows:

0.5 watts/sq.ft. x 3,750 lumens/300 watts = 6.25 lumens/sq.ft.

Example:

Lighting comparison between Incandescent & LED lamps for a 2,400 square foot (223 m^2) AQUATIC VENUE.

- 300 watt Incandescent Lamps (12.5 lumens per watt = 3,750 lumens per lamp)
  - 2,400 square feet x 0.5 watts/square foot x lamp/300watts = 4 lamps
- 30 watt LED Lamps (125 lumens per watt = 3,750 lumens per lamp)
  - 2,400 square feet x 6.25 lumens/square foot x lamp/3,750 lumens = 4 lamps

Notice that LED lamps are 90% more efficient *(lumens/watt)* than Incandescent lamps.

"A replacement lamp will need to provide 6.25 lumens per square foot of surface area."

Additional Information:

The incandescent lamp has an average life of 2,000 hours. For an AQUATIC VENUE that is operational 12 hours per day for 365 days *(4,380 hours per year)*, the incandescent lamp failure rate would be approximately two times a year. Note that in-water AQUATIC VENUE lighting remains on when the AQUATIC VENUE is closed to swimming. For the 50,000 hour life of an LED lamp, the failure rate would be 11.4 years.

The AQUATIC VENUE surface replacement would be a determination of replacement lamps and not the lamp itself. Annual energy savings per lamp would be 1,183 KWH.

4.6.1.5.1 Minimum Requirement

A common practice has been to express underwater lighting requirements in watts per square foot of POOL surface. Light output efficacy *(lumens per watt)* can vary greatly depending on the light source. Incandescent lighting, the most historically prevalent underwater light source, also has the lowest or worst efficacy. Some of the most common incandescent lamps are listed below, along with their initial lumen output and calculated efficacy.

Table 4.6.1.5.1: Common Incandescent Lamps and Their Initial Lumen Output and Efficacy

Lamp	Initial Lumens	Efficacy *(Lumens/Watt)*
200 Watt PAR 46	*2270*	11.35
200 Watt PAR 56	*2270*	11.35
300 Watt PAR 56	3840	12.80
500 Watt PAR 64	6500	13.00

For the purposes of these requirements, the underwater lighting requirements have been converted from incandescent watt equivalents to initial lamp lumens using a conversion factor of 12.0 lumens per watt. The converted watts per square foot of POOL surface requirements are 0.5 watts [outdoor], 1.5 watts [indoor], 1.5 watts [outdoor-diving], 2.5 watts [indoor-diving].

It is recommended that future studies be conducted to determine minimum lighting requirements based on water depth, hours of operation, and overhead lighting design. The main goal is to be able to see the bottom of the POOL, in particular a person on the bottom, at all times when the POOL is open to the public.

4.6.1.6 Night Swimming with No Underwater Lights

Providing higher lighting levels *(15 footcandles (161 lux))* than the minimum requirements *(10 footcandles (108 lux))* of MAHC 4.6.1.3.1 eliminates the requirement for underwater lighting in outdoor POOLS.

4.6.1.7 Emergency Lighting

This section isn't intended to provide less stringent requirements, just a baseline STANDARD of design for locales that may not address this requirement. The industry commonly uses 0.5 foot-candle (5.4 lux) as an industry design STANDARD.

4.6.1.8 Glare

Consider the sun's positioning through different seasons as well as the window placement to avoid glare. Consider moveable lifeguard stands or positions to avoid glare in different seasons. Consider tint and shades when natural light causes glare.

Windows and any other features providing natural light into the POOL space and overhead POOL lighting should be arranged to avoid glare on the POOL surface that would prevent identification of objects on the POOL bottom.

Careful consideration should be given to the placement of windows and skylights about the POOL. Natural light from directly overhead is less likely to create glare than light through windows at the sides and ends of the POOL.

Control of glare from artificial light is more likely if the angle of incidence of the main light beam is less than 50 degrees from straight down. Diffuse or indirect light sources may also help to minimize glare.

The MAHC had a very difficult time coming to a consensus on MAHC wording regarding glare that could be defended and enforced from a regulatory standpoint. How does a plan reviewer determine that glare based on design documents are excessive *(perhaps only in certain months of the year)*? The MAHC felt that design recommendations would best be addressed in the Annex.

4.6.2 Indoor Aquatic Facility Ventilation

Background of Ventilation and Air Quality Technical Committee Work on the MAHC

Numerous local and state health CODES *(N=28)* plus NEHA recommendations regarding ventilation were reviewed prior to the release of the 1st edition of the MAHC. The MAHC found that:

- Most addressed only moisture control;
- The terms used were sometimes vague with 11 of the 28 CODES having very general language typically stating "adequate" or "proper" ventilation without clear definitions of these terms;
- Only three CODES and NEHA specify compliance with ASHRAE STANDARDS;
- Most refer to their state and/or local ventilation and/or mechanical CODE for compliance requirements;
- Only five have developed other state-specific criteria for air TURNOVER and exchange.

As a result of this varied and sometimes vague approach to defining "proper" ventilation, it is critical that the MAHC begins to better define AIR HANDLING SYSTEMS and establish parameters for air quality that reduces the risk of potential health effects. The aquatics industry has always had a challenge with indoor air quality. With the relatively recent increases in building large indoor waterparks, which have high BATHER COUNTS and contamination burdens and exposure times unseen before, indoor air quality is an increasingly important health concern. The media focus in recent years has highlighted this challenge.

Although the AIR HANDLING SYSTEMS of these AQUATIC FACILITIES are quite sophisticated, there are many variables to consider. In addition, much research is still needed in water chemistry and the use of other technologies to improve indoor air quality. The MAHC outlines the design, performance, and operational parameters that can be detailed using data available at the current time. The Annex information provides insight into the Ventilation and Air Quality Technical Committee's rationale and also identifies areas where more research is needed before additional parameters can be set.

The MAHC's intent is to require the design of an INDOOR AQUATIC FACILITY to be conducted by a licensed professional engineer with experience in the design of mechanical systems. The MAHC approached this section assuming designs will be evaluated by the AHJ in the location in which the system is to be installed. Following the first public comment period, the ventilation requirements were dramatically changed and draft material was removed from both the CODE and Annex. The thinking behind those initial recommendations was saved for future consideration in MAHC Appendix 2.

4.6.2.1 Purpose

The purpose of the AIR HANDLING SYSTEM is to assure the health and comfort of the users of the AQUATIC FACILITY. A variety of health effects can occur as a result of poor ventilation that leads to accumulation of chemical and biological products in the air. The following section reviews some of the issues of concern for INDOOR AQUATIC FACILITIES.

Disinfection By-Products

The OXIDATION of waterborne organic and inorganic compounds by CHLORINE- or other halogen-based products is a complex process leading to creation of a large number of OXIDATION and DBPS during the drinking water and aquatic water treatment processes. The source of these compounds is variable but includes source water CONTAMINANTS, BATHER waste *(e.g., feces, urine, sweat, skin cells)*, and environmental introductions *(e.g.,* *dirt)*. Although the identity of many of these compounds is known, many others are uncharacterized and the health effects associated with short- and long-term exposure to these compounds are only just starting to be characterized for the aquatic environment. Several of these compounds are known to be volatile and can accumulate in the air surrounding an INDOOR AQUATIC VENUE. Multiple reviews discuss the acute and potentially long-term health effects (e.g., asthma, bladder cancer) of exposure to these compounds in the aquatic setting since many of the studies are cross-sectional or ecologic in design, which makes it difficult to definitively link exposures, actual exposure levels, and swimming.[101,102,103,104,105,106,107]

The nitrogenous OXIDATION by-products DICHLORAMINE and TRICHLORAMINE *(e.g., chloramines)* are known to be irritants that cause acute eye and lung distress. Accumulation of these compounds in indoor settings has been previously documented in several occupational settings where workers routinely use chlorinated solutions to rinse organic products such as poultry[108,109] and uncooked produce.[110] Similar symptoms of ocular and respiratory distress have been documented in outbreaks associated with use of INDOOR AQUATIC FACILITIES.[111,112,113,114,115,116] Other suspected chloramine-associated outbreaks are listed in past issues of CDC's Waterborne Disease and Outbreak Surveillance Summaries that can be viewed at www.cdc.gov/healthywater/surveillance/rec-water-surveillance-reports.html.

Also see Annex 4.0.1.4.7.

Biological By-Products

101 LaKind JS, et al. The good, the bad, and the volatile: can we have both healthy pools and healthy people? Environ Sci Technol. 2010;44(9):3205-10.
102 Zwiener C, et al. Drowning in disinfection byproducts? Assessing swimming pool water. Environ Sci Technol. 2007;41(2):363-72.
103 Weisel CP, et al. Childhood asthma and environmental exposures at swimming pools: state of the science and research recommendations. Environ Health Perspect. 2009;117(4):500-7.
104 Villanueva CM, et al. Overview of disinfection by-products and associated health effects. Curr Environ Health Rep. 2015 Mar;2(1):107-15.
105 Goodman M, et al. Asthma and swimming: A meta-analysis. J Asthma (2008);45(8):639-647.
106 Villanueva CM, et al. Disinfection byproducts and bladder cancer: a pooled analysis. Epidemiology. 2004;15(3):357-67.
107 Cantor KP. Carcinogens in drinking water: the epidemiologic evidence. Rev Environ Health. 2010;25(1):9-16.
108 King BS, et al. Eye and respiratory symptoms in poultry processing workers exposed to chlorine by-products. Am J Ind Med. 2006;49(2):119-26.
109 Sanderson W, et al. Case reports: epidemic eye and upper respiratory irritation in poultry processing plants. Appl Occup Environ Hyg 1995;10:43–49.
110 Hery M, et al. Exposure to chloramines in a green salad processing plant. Ann Occup Hyg 1998;42:437–451.
111 Seys SF, et al. An outbreak of swimming-pool related respiratory symptoms: An elusive source of trichloramine in a municipal indoor swimming pool. Int J Hyg Environ Health. 2015 Jun;218(4):386-91.
112 CDC. Ocular and respiratory illness associated with an indoor swimming pool — Nebraska, 2006. MMWR Morb Mortal Wkly Rep 2007;56;929-932.
113 Kaydos-Daniels SC, et al. Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. Public Health 2008;122:195-200.
114 Bowen A, et al. Outbreaks of short-incubation illness following exposure to indoor swimming pools. Environ Health Perspect 2007;115:267-271.
115 CDC. Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort --- Ohio, 2007 MMWR Morb Mortal Wkly Rep 2009;58;81-85
116 Dang B, et al. Ocular and respiratory symptoms among lifeguards at a hotel indoor waterpark resort. J Occup Environ Med. 2010;52(2):207-13.

A variety of biological organisms that grow naturally in the environment *(e.g., Legionella, Mycobacterium avium complex and other non-tuberculous mycobacteria, gram negative bacteria)* or their constituents *(e.g., proteins, lipo-polysaccharides, endotoxin)* can be spread in the INDOOR AQUATIC FACILITY environment and cause infections[117,118] and hypersensitivity/allergic reactions *(e.g., "Hot tub lung"; "Lifeguard lung", Pontiac fever)*.[119,120,121,122,123] The levels of pathogens and their constituents can be minimized with adequate INDOOR AQUATIC FACILITY ventilation, maintenance, and required water quality.

4.6.2.2 Exemptions

The MAHC decided that only "buildings" as defined in the building CODE would be included in the scope of the INDOOR AQUATIC FACILITY definition since there are many variables to consider for places like open buildings *(may not have a roof or missing sides)* such as variations in weather, geographic zone, etc. that would impact AIR HANDLING SYSTEM design even if one was needed. The guidelines in this module are meant to address the SAFETY and health of users in environments in which air quality is managed by mechanical means due to the "closed" environment since fresh air is not able to freely flow through the building.

4.6.2.5 ASHRAE 62.1 Compliance

The hierarchy of design was important in deciding what priorities were taken in the development of the design section. The following hierarchy was determined by the MAHC:

- Indoor air quality - chemical, biological, and physical CONTAMINANT load;
- Moisture removal – humidity and temperature;
- Cost of energy – important to larger sites.

When determining the factors a design professional considers, much discussion centered around ASHRAE 62.1 and the parts of design not specifically listed in ASHRAE 62.1 as it applies to INDOOR AQUATIC FACILITIES.

There are two SAFETY functions of the AIR HANDLING SYSTEM: to bring in fresh air and to protect the PATRONS and the building, which requires movement of air. The current ASHRAE 62.1 STANDARD states 0.48 cfm/ft^2 fresh air is the minimum but still requires an air change. The MAHC needs to consider air delivery rate like TURNOVER for AQUATIC

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117 Fields BS, et al. *Legionella* and Legionnaires' disease: 25 years of investigation. Clin Microbiol Rev. 2002;15(3):506-26.
118 Falkinham JO 3rd. Mycobacterial aerosols and respiratory disease. Emerg Infect Dis. 2003;9(7):763-7.
119 Hanak V, et al. Causes and presenting features in 85 consecutive patients with hypersensitivity pneumonitis. Mayo Clin Proc. 2007;82(7):812-6.
120 Sood A, et al. Hypersensitivity pneumonitis-like granulomatous lung disease with nontuberculous mycobacteria from exposure to hot water aerosols. Environ Health Perspect. 2007;115(2):262-6.
121 Rose CS, et al. "Lifeguard lung": endemic granulomatous pneumonitis in an indoor swimming pool. American J Public Health. 1998;88(12):1795-800.
122 Burnsed LJ, et al. Legionellosis Outbreak Investigation Team. A large, travel-associated outbreak of legionellosis among hotel guests: utility of the urine antigen assay in confirming Pontiac fever. Clin Infect Dis. 2007;44(2):222-8.
123 Tossa P, et al. Pontiac fever: an operational definition for epidemiological studies. BMC Public Health. 2006;6:112.

VENUES. To assure good indoor air quality, it is likely that the design should consider THEORETICAL PEAK OCCUPANCY, water type *(e.g., flat, agitated, hot)* and the size and use of the building.

The current STANDARDS approach to ventilation is based on square footage of the AQUATIC FACILITY and yet AQUATIC FACILITIES vary in size. Some facilities have a 20 foot *(6.1 m)* ceiling and in the case of indoor waterparks and stadium-style INDOOR AQUATIC FACILITIES, the ceiling heights can reach 60+ feet *(18.3 m)*. In addition, the water surface area has a great deal to do with the amount of CONTAMINANTS released into the air but this is generally not included in design criteria.

There are many microclimates in larger AQUATIC FACILITIES with varied AQUATIC VENUES and AQUATIC FEATURES. Air movement will need to be targeted within these microclimates.

The challenge is that ASHRAE 62.1 only takes into account the building square footage and number of spectators rather than BATHERS. ASHRAE fundamentals require an air delivery rate for the volume of air. Designers felt water chemistry, fresh air, THEORETICAL PEAK OCCUPANCY, water surface area and type, and distribution of air (barring condensation) are more or equally as important as the air delivery rate.

4.6.2.6 Air Handling System Design

4.6.2.6.2 Design Factors and Performance Requirements

Known chemical, biological, and physical contaminants:

The MAHC discussed the various chemical and biological CONTAMINANTS, the availability of testing protocols, and data to support developing health effect thresholds.

Table 4.6.2.6.2: Known Chemical, Biological, and Physical Contaminants:

Chemical	Biological
Trichloramines	*Mycobacterium avium* complex
Trihalomethanes	*Legionella* spp. (primarily *L. pneumophila*)
Other chlorinated compounds	Endotoxin

The researchers on the committee were able to provide a list of research regarding the thresholds of such CONTAMINANTS that produced symptoms in users of INDOOR AQUATIC FACILITIES. More detailed summaries of these data can be found in ***Appendix 1: Summary of Health and Exposure Data for Chemical and Biological Contaminants***.

After evaluating possible CONTAMINANTS, the committee felt the most frequently detected adverse health symptoms associated with indoor air quality were related to chemical

CONTAMINANTS. In evaluating the various chemical CONTAMINANTS, it was found that TRICHLORAMINE was the most prevalent CONTAMINANT reported[124]. Therefore, this section of the MAHC focused on TRICHLORAMINE as the major chemical CONTAMINANT for design considerations.

The bullets below summarize findings on the threshold amounts that produced adverse health symptoms.

- Gagniere[125] 0.5 mg/m3
- Levesque[126] 0.37 mg/m3
- Hery[127] 0.5 - 0.7 mg/m3
- Massin[128] 0.5 mg/m3
- Jacobs[129] 0.56 mg/m3 (average)
- Thickett[130] 0.5 mg/m3

In evaluating the TRICHLORAMINE research, it was apparent there is not a single test method used throughout the research. Without a validated test method, it is difficult to compare and benchmark the data from the various studies. As a result, a firm threshold could not be determined solely on the published research to date. Also, without a validated and simple test method, there is not an easy way for health departments or owner/operators to test routinely or with any consistency. For these two reasons, the MAHC felt it could not establish a threshold to be enforced by this section of the MAHC at this time. More research using a validated test method may lead to determination of a threshold level in the future. To enforce such a threshold level, the test also needs to be commercially available and easily performed by aquatics staff and health officials.

Therefore, the performance requirements for the AIR HANDLING SYSTEM have parameters for fresh air and dew point/humidity. To accomplish this, several design criteria were kept in mind:

- Fresh air requirements are established to specific levels. The theory is that if the building mechanical system is able to evacuate enough air to remove TRICHLORAMINE, then by default the other airborne CONTAMINANTS would also be evacuated.

124 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J. 2002;19(5):827-32.
125 Gagnaire F, et al. Comparison of the sensory irritation response in mice to chlorine and nitrogen trichloride. J Appl Toxicol. 1994;14(6):405-9.
126 Lévesque B, et al. The determinants of prevalence of health complaints among young competitive swimmers. Int Arch Occup Environ Health. 2006;80(1):32-9.
127 Hery M, et al. Exposure to chloramines in the atmosphere of indoor swimming pools. Ann Occup Hyg 1995;39(4):427-439.
128 Massin N, et al. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998;55(4):258-63.
129 Jacobs JH, et al. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. Eur Respir J. 2007;29(4):690-8.
130 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J. 2002;19(5):827-32.

- Dew point/humidity levels are set to avoid mold growth and damage to the building structure.

In the future, if a readily available, STANDARD air testing method for TRICHLORAMINE is developed and a TRICHLORAMINE or other CONTAMINANT threshold can be determined, then it is the recommendation of the MAHC that the MAHC adopt such an action threshold for air quality. Additionally, based on the air data threshold set, a threshold should also be re-evaluated and/or revised for combined CHLORINE compounds in water to minimize production and off-gassing of the volatile chloramines. In the interim, bio-MONITORING for TRICHLORAMINES can be effectively accomplished by training POOL operators to be on alert for the distinctive chloramine odor and eye and lung irritation it causes. Since the odor threshold for TRICHLORAMINE is ~0.1 mg/m^3 and, as illustrated above, health symptoms start happening around 0.3-0.5 mg/m^3, odor MONITORING can generally work well as an early warning system.

It was recognized by the MAHC that SECONDARY DISINFECTION SYSTEMS *(e.g., ozone, U.V.)* could help to reduce the amount of off-gassing of DBPs and therefore would need less volumes of outside air to dilute the concentration of these chemicals in the air. Basic treatment includes the use of CHLORINE or bromine and STANDARD filtration and will require a certain amount of outside air per AQUATIC VENUE type. UV/Ozone or other technology that is used to aid in the reduction of DBPs could reduce the amount of outside air required.

The efficacy of UV and ozone are well documented for their effect on biological CONTAMINANTS but the photochemistry taking place is a different reaction for DISINFECTION versus controlling combined CHLORINE levels. Further research is needed to determine the effectiveness of UV and ozone on destroying DBPs before they can be considered in the design of an AIR HANDLING SYSTEM. Guidance is included in the MAHC for the use of UV and ozone for DISINFECTION. It is unknown at this time if the parameters for the equipment to achieve DISINFECTION will also result in the reduction of DBPs.

The initial draft of the MAHC Ventilation and Air Quality Module included discussion of fresh air requirements for facilities utilizing UV and ozone, which allowed for a reduction in the amount of fresh air required for ventilation compared to basic water treatment. However, until the efficacy of these technologies in reducing DBP formation can be established and parameters can be set in which any installation of these technologies can meet minimum requirements, we cannot include these technologies as a method to reduce fresh air requirements. Such information should be considered when efficacy data become available.

For future development of minimum performance requirements for UV and ozone, one should consider dose as a function of concentration and contact time. Many systems are designed for full flow treatment but contact time is very limited. These minimum parameters may help to attain efficacy, but as noted, more research is required. Below are some proposed statements for use once system efficacy can be determined:

- *The Design Professional may reduce the amount of fresh air with the use of UV and/or ozone if the Design Professional can demonstrate the efficacy of the system* *and have it validated by a third party. The system must achieve a XXX% reduction of TRICHLORAMINE in a single pass.*

- *The system must be designed to achieve at minimum, a dose of XXX at the highest and lowest flow rate the system would normally operate.*
- *UV systems must have a wavelength of 254 and/or 282 nanometers to reduce monochloramine, DICHLORAMINE, and TRICHLORAMINE.*

Another concern is that although it is believed UV and ozone are effective at breaking down TRICHLORAMINE, we do not know its effect on the other CONTAMINANTS such as THMs. If one uses the assumption that using fresh air to evacuate TRICHLORAMINE will result in removing other airborne CONTAMINANTS, then one must also consider other chemical CONTAMINANTS. If one reduces the amount of fresh air because a SECONDARY DISINFECTION SYSTEM is used to break down TRICHLORAMINE, it does not mean the other airborne CONTAMINANTS are also destroyed by the SECONDARY DISINFECTION SYSTEM. The photochemistry may be different so efficacy may have to be determined for other compounds.

4.6.2.6.3 Other Air Handling Systems

Ventilation in Chemical Storage Spaces

The design for CHEMICAL STORAGE SPACE was included in the initial version of the MAHC Ventilation and Air Quality module AIR HANDLING SYSTEM design posted for public comment. It was removed in the revised indoor AIR HANDLING SYSTEM design area of the MAHC as part of revising the definition of an INDOOR AQUATIC FACILITY for which the AIR HANDLING SYSTEM does not include CHEMICAL STORAGE SPACE or other space outside the negative pressure zone around the AQUATIC VENUE. However, the building of an INDOOR AQUATIC FACILITY will still require consideration of the ventilation of CHEMICAL STORAGE SPACES using separate AIR HANDLING SYSTEMS so the text has been moved to MAHC 4.9.2.

4.6.2.7 Performance Requirements for Air Handling Systems

4.6.2.7.1 Minimum Outdoor Air Requirements

Significant numbers of public comments were received regarding the proposed increase, above ASHRAE 62.1 STANDARDS of required outdoor air. The commenters noted that the requirements will result in increased costs for equipment and operation while lacking adequate data to support the increase. Based on the potential negative impact and the need for additional research and data to differentiate the causes and sources of indoor air quality problems on design criteria *(e.g., design, inappropriate operation, inadequate maintenance)*, the MAHC decided to defer to ASHRAE 62.1 outdoor air requirements in this version of the MAHC. The MAHC thought it important to preserve the work done by the Technical Committee, so the proposed CODE language for additional outdoor air has been moved to ***Appendix 2: Air Quality Formula*** in the MAHC along with preserving the corresponding Annex discussion. A research agenda should be developed and should be a priority to better address the contributing factors to indoor air quality problems and the appropriate design and operational requirements needed to address those factors.

4.6.2.7.2 System Alarm

There are several methods to add a MONITORING station to the outside air portion of the AIR HANDLING SYSTEM to establish the volume of outside air being introduced into the AQUATIC FACILITY. Such a MONITORING station should be installed. In addition, it should be noted that a negative pressure must be maintained during all operating modes. This negative pressure must be set-up at the commission stage by the installing contractor or by means of automatic operation by the AIR HANDLING SYSTEM or Building Automation System.

4.6.2.7.6 Relative Humidity

Relative humidity is a ratio, expressed in percent, of the amount of atmospheric moisture present relative to the amount that would be present if the air were saturated. Since the amount of atmospheric moisture is dependent on temperature, relative humidity is a function of both moisture content and temperature.

The QUALIFIED OPERATOR and inspection personnel should routinely monitor the relative humidity inside the INDOOR AQUATIC FACILITY. Relative humidity levels should be monitored using a properly calibrated humidity meter, and it can fluctuate based upon a variety of factors, including occupancy and use of the INDOOR AQUATIC FACILITY, but a range of 40% to 60% can be accepted. Maintaining relative humidity within acceptable levels in the INDOOR AQUATIC FACILITY environment is important for a variety of reasons. Research has shown elevated relative humidity levels often coincide with mold growth, damage to building structures, BATHER discomfort, and inadequate ventilation. The engineer should pay particular attention when designing the AIR HANDLING SYSTEM to ensure relative humidity levels can be maintained below the recommended 60% when the INDOOR AQUATIC FACILITY is occupied. It may also be necessary to install properly calibrated and maintained, real-time, relative humidity MONITORING devices inside the AIR HANDLING SYSTEM to ensure the mechanical system can react to changing conditions inside the INDOOR AQUATIC FACILITY.

For consideration in designing the facilities structure, dew point is a better measure of absolute moisture levels. Dew point has a relationship with relative humidity. A high relative humidity indicates that the dew point is closer to the current air temperature. Relative humidity of 100% indicates the dew point is equal to the current temperature and that the air is maximally saturated with water. For human comfort factors, the maximum relative humidity has been specified for a very narrow range of indoor temperatures and thus is an easily measured and understood metric by users and owners of an AQUATIC FACILITY. For the building design, dew point is a more important metric because the outdoor conditions can be over a very wide temperature range. The design professional must be able to calculate the internal dew point for all building structure components to avoid condensation. Condensation occurs when the inside surface temperatures equal the dew point of the space.

Using a properly calibrated instrument designed to measure relative humidity eliminates the complexity of calculating relative humidity by hand. It is important to collect a series of representative relative humidity measurements inside the INDOOR AQUATIC FACILITY. The building should be divided into representative areas if necessary, depending upon size and various AQUATIC FEATURES. Measurements should be taken from each occupied area. Measurements should be taken at DECK level and recorded. Arithmetic average of measurements will provide an estimation of the relative humidity in the INDOOR AQUATIC FACILITY. This may require consultation with design professionals.

4.6.2.7.8 Disinfection By-Product Removal

It is the MAHC's intent not to limit the development of new technologies. Although the efficacy of these technologies are not readily apparent, in the future there is a hope that the CODE will allow for the design professional to decrease the outside air requirements when secondary technology is used and the design professional can prove the efficacy of the added technology. Other methods and technology for decreasing DBPs include:

- Ventilating surge tanks to remove off-gassing TRICHLORAMINE before the water re-enters the POOL area, and
- Use of a cooling tower to force water to off-gas TRICHLORAMINE before reintroducing water to the POOL area.

4.6.2.7.11 Purge

When an AQUATIC FACILITY has an event *(e.g. POOL is shocked)* that requires the introduction of a larger volume of outdoor air, the PURGE mode can be manual triggered to provide a flush of the INTERIOR SPACE. The intent is to run the AIR HANDLING SYSTEM at PURGE capacity until the CONTAMINANT causing odor/eye/lung discomfort has dissipated to an acceptable level. The lack of an assay for airborne chloramines, means that "acceptable" is arbitrary and unenforceable since it relies on an operator assessment. When appropriate tests are available, the MAHC would like to set a numerical action threshold that would be enforceable.

4.6.2.7.12 Air Handling System Filters

Manufacturers/designers could consider developing/incorporating specialized solid phase *(e.g., activated carbon or other media)* chloramine removal air filtration as another means to sequester chloramines and potentially reduce fresh air requirements. However, such systems need to show proven efficacy. With new methods development, such systems could eventually be designed with sensors confirming that the combined CHLORINE levels are at an acceptable level *(when such air measurement methods become available)*. If levels increased, then the AIR HANDLING SYSTEM could proportionally increase the amount of outside air.

Air Quality – Health

No rapid, simple, and commercially available tests for di- and tri-chloramine exist at the current time. However, MONITORING for TRICHLORAMINES can also be effectively accomplished by training POOL operators to be on alert for the distinctive chloramine odor and eye and lung irritation it causes. The odor threshold for TRICHLORAMINE is 0.1 mg/m^3

and health symptoms start happening around 0.3-0.5 mg/m^3, so odor MONITORING generally works well as an early warning system.[131,132,133,134,135,136]

Air Turnover Rates

MONITORING combined CHLORINES in the water or VOC concentrations in the air can be used as an alternative to measuring air quality. The AQUATIC FACILITY design engineer should specify what the alternative measurement limit should be in establishing an alternate ventilation AIR DELIVERY SYSTEM.

4.6.3 Indoor / Outdoor Aquatic Facility Electrical Systems and Components

Nothing in this CODE should be construed as providing relief from any applicable requirements of the NEC or other applicable CODE.

4.6.3.1 General Guidelines

Wiring

Wiring located near or associated with equipment for BODIES OF WATER should be installed in compliance with the NEC or with other applicable CODE, except where the MAHC is more restrictive.

- See NEC Article 100: *Location, Wet*; National Electric Code.
- See NEC Article 110.11: *Deteriorating Agents*; National Electric Code.

Sealed Conduit

Electrical conduit that enters or passes through an INDOOR AQUATIC FACILITY should be sealed at the point of entry into the INDOOR AQUATIC FACILITY against the movement of liquids and vapors through the conduit. Exceptions may include:

- A conduit which only passes through an INDOOR AQUATIC FACILITY, and which has no fittings or joints exposed to INDOOR AQUATIC FACILITY air, should be acceptable without a seal.
- Rigid or intermediate conduit which passes through an INDOOR AQUATIC FACILITY, and which is assembled with threaded couplings only should be acceptable without a seal where at least three threads are engaged at every joint.

131 Gagnaire F, et al. Comparison of the sensory irritation response in mice to chlorine and nitrogen trichloride. J Appl Toxicol. 1994;14(6):405-9.
132 Lévesque B, et al. The determinants of prevalence of health complaints among young competitive swimmers. Int Arch Occup Environ Health. 2006;80(1):32-9.
133 Hery M, et al. Exposure to chloramines in the atmosphere of indoor swimming pools. Ann Occup Hyg 1995;39(4):427-439.
134 Massin N, et al. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998;55(4):258-63.
135 Jacobs JH, et al. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. Eur Respir J. 2007;29(4):690-8.
136 Thickett KM, et al. Occupational asthma caused by chloramines in indoor swimming-pool air. Eur Respir J. 2002;19(5):827-32.

- Conduit which passes through an INDOOR AQUATIC FACILITY, and which is assembled with rain-tight compression fittings only should be acceptable without a seal.
- Otherwise-approved non-metallic conduit assembled by glued joints or other solvent-welding method shall be acceptable without a seal where approved by the AHJ.

***Note**: An explosion-proof seal is not required, unless required by the AHJ.*

- See CSA C22.2, Canadian Standards Association.
- See NEC Art. 110.11: *Deteriorating Agents*; National Electric Code.
- See NEMA 250, National Electrical Manufacturers Association.
- See UL 50, Underwriters Laboratories.
- See UL 508, Underwriters Laboratories.

Where such devices must be installed in an INDOOR AQUATIC FACILITY or in spaces containing INDOOR AQUATIC FACILITY air, ENCLOSURES rated NEMA 4X are preferred.

Electric Panels

Electrical panel boards, distribution centers, motor-control centers, fuse panels, circuit-breaker panels, and similar equipment should not be installed in INDOOR AQUATIC FACILITIES or in any space that normally contains INDOOR AQUATIC FACILITY air. Exceptions may include:

- Equipment which is listed and labeled for the conditions should be acceptable where approved by the AHJ.
- Where SAFETY switches or equipment-disconnect switches must be installed in an INDOOR AQUATIC FACILITY or in spaces containing INDOOR AQUATIC FACILITY air, e.g. per NEC, they should be rated for the conditions.
- Whips consisting of liquid-tight flexible metal conduit are preferable to BX cable or type AC conduit.

For More Information:

- See CSA C22.2, Canadian Standards Association.
- See NEC Art. 110.11: *Deteriorating Agents*; National Electrical Code.
- See NEMA 250, National Electrical Manufacturers Association.
- See UL 50, Underwriters Laboratories.
- See UL 508, Underwriters Laboratories.

Exposed Wiring

Where INDOOR AQUATIC FACILITY lights, attachments, fasteners, and any associated wiring whips are exposed to INDOOR AQUATIC FACILITY air, they should be rated for the conditions.

- See ANSI/IEEE 241, Section 5.17.6.
- See Croft, Terrel and Summers, Wilford, American Electricians' Handbook, Ed.12, Sec. 9-340(b).

- See International Association of Electrical Inspectors, Soares Book on Grounding, 8th Ed., 2001, p157.

See NEC Art. 250-110(2).Metal Raceways

Metal RACEWAYS should be equipped with a grounding conductor sized according to NEC Article 250 to maintain device ground potential in the event of degradation of the RACEWAY.

- See CSA C22.2, Canadian Standards Association.
- See NEC Article 110.11: *Deteriorating Agents,* National Electrical Code

See NEMA 250, National Electrical Manufacturers Association. See UL 50, UL 508, Underwriters Laboratories. Any electrical switch installed in an INDOOR AQUATIC FACILITY shall be rated for the atmosphere. Exception may include a switch which is otherwise protected, as in a gasketed weather-tight box with a weather-tight actuator cover shall be acceptable.

4.6.3.1.2 Indoor Aquatic Facilities

- See NEC Art. 300.7; *Raceways Exposed to Different Temperatures*, National Electrical Code.
- See Durston, Lee. Design, Construction, and Testing of the Commercial Air Barrier.
- US Army Corps of Engineers . 2012. Air Leakage Test Protocol for Building Envelopes. Accessed at:
- U.S. Department of Energy. Air Leakage Testing and Air Sealing in Existing Multifamily Units. http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/air_sealing_multifamily.pdf, and
- http://www.wbdg.org/pdfs/usace_airleakagetestprotocol.pdf

4.6.3.2 Electrical Equipment in Interior Chemical Storage Spaces

Raceways

All RACEWAYS and RACEWAY devices and boxes in a CHEMICAL STORAGE SPACE should be non-metallic or otherwise rated for the atmosphere.

- See Croft, Terrel and Summers, Wilford, American Electricians' Handbook, Ed. 12, Sec. 9-340(b).See NEC Art. 110.11: *Deteriorating Agents.*
- See NEC Art. 378.10: *Non-Metallic Raceways*.
- See NFPA 70HB08, Art. 100, “Labeled”, Explanatory Note.
- See SDS Calcium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Sodium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Hydrochloric Acid, Section 10 Stability and Reactivity Data.
- See SDS Muriatic Acid, Section 10 Stability and Reactivity Data.

Sealed

Raceways should be sealed at the point of entry to the CHEMICAL STORAGE SPACE to prevent the egress of liquids, fumes, vapors, and gases from the CHEMICAL STORAGE SPACE via the conduit.

Note: Explosion-proof seals are not required, unless required by the AHJ.

- See Durston, Lee, *Design, Construction, and Testing of the Commercial Air Barrier*.
- See NEC Art. 300.7: *Raceways Exposed to Different Temperatures*.

Metal Raceways

Metal RACEWAYS should be equipped with a grounding conductor sized according to NEC Article 250 to maintain device ground potential in the event of degradation of the RACEWAY.

- See ANSI/IEEE 241, Section 5.17.6.
- See Croft, Terrel and Summers, Wilford, *American Electricians' Handbook, Ed. 12*, Sec. 9-340(b).
- See International Association of Electrical Inspectors, *Soares Book on Grounding*, 8th Ed., 2001, p157.
- See NEC Article 250-110(2).

Electronics

All electrical equipment, devices and fixtures should be listed and labeled for the expected atmosphere of the space.

- See NFPA 70HB08, Article 100: *Labeled, Explanatory Note*.
- See NFPA 70HB08, Article 100: *Listed, FPN*.

Light Switches

Any light switches installed inside interior CHEMICAL STORAGE SPACES should be approved for use in wet and CORROSIVE atmospheres, or shall be otherwise protected, as by a weather-proof actuator cover with a gasket.

- See NEC Article 110.11: *Deteriorating Agents*.

Permanent Electrical Devices

All permanently connected electrical devices should be grounded per the NEC or other applicable CODE, using a separate grounding conductor which does not depend on the conductive integrity of any metal conduit exposed to CHEMICAL STORAGE SPACE air.

- See ANSI/IEEE 241, Section 5.17.6.
- See Croft, Terrel and Summers, Wilford, *American Electricians' Handbook, Ed. 12*, Sec. 9-340(b).
- See International Association of Electrical Inspectors, *Soares Book on Grounding*, 8th Ed., 2001, p157.
- See NEC Article 250-110(2).

4.6.3.2.1 Wet and Corrosive

- See NEC Article 100: *Location, Wet*.
- See NEC Article 110.11: *Deteriorating Agents.*
- See SDS Calcium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Sodium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Hydrochloric Acid, Section 10 Stability and Reactivity Data.
- See SDS Muriatic Acid, Section 10 Stability and Reactivity Data.

4.6.3.2.2 Electrical Conduit

- See NEC Article 110.11: *Deteriorating Agents.*
- See NEC Article 300.7: *Raceways Exposed to Different Temperatures*.
- See SDS Calcium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Sodium Hypochlorite, Section 10 Stability and Reactivity Data.
- See SDS Hydrochloric Acid, Section 10 Stability and Reactivity Data.
- See SDS Muriatic Acid, Section 10 Stability and Reactivity Data.

4.6.3.2.3 Electrical Devices

Electrical panelboards, circuit breakers, disconnects, motors, motor overloads, and similar devices or equipment are included.

- See NEC Art. 110.11: *Deteriorating Agents.*
- See Zalosh R., *Dust Explosion Fundamentals*, NFPA.

4.6.3.2.4 Protected Against Breakage

- See SDS Calcium Hypochlorite, Section 7 *Handling and Storage*, “Keep away from heat. Keep away from sources of ignition.”
- See SDS Calcium Hypochlorite, Section 10 Stability and Reactivity Data

4.6.4 Pool Water Heating

Evaporation Control

Other CODES do not address the need for constant control of INDOOR AQUATIC FACILITY air temperature in order to control evaporation. They also do not address the need for heat on specific surfaces.

INDOOR AQUATIC FACILITY heating equipment should be selected and installed to preserve compliance with the NEC, the National Fuel Gas Code *(if applicable)*, the International Mechanical Code, or other applicable CODES, the terms of equipment listing and labeling, and with the equipment manufacturer’s installation instructions.

A method of space heating capable of continuously maintaining the temperature of the air in an INDOOR AQUATIC FACILITY at or above the design temperature relative to the POOL water temperature shall be provided. ASHRAE 99.6% climate data is the most reliable for INDOOR AQUATIC FACILITY load calculations.

- See *ASHRAE Handbook of Fundamentals*[137]

Uncontrolled Condensation

Uncontrolled condensation in a building can lead to the growth of molds, with subsequent health effects. Uncontrolled condensation in a building can lead to property damage from rust, rot, ice pressure, and other.

Condensation can be controlled by:

- Controlling the evaporation rate of the water,
- Controlling the temperature and relative humidity of the room air, and
- Maintaining all exposed building surfaces above room-air dew point.

Evaporation Rate

The POOL evaporation rate is affected by the:

- Size of the POOL,
- Agitation of the water,
- Heat of vaporization of the water at that temperature and pressure,
- Temperature difference between the POOL water and the room air and the associated difference in vapor pressures, and
- Speed of the air over the POOL'S surface.
- See Places of Assembly, *ASHRAE Handbook of Fundamentals*[138]

Example for Note: A design POOL-water temperature is 82°F *(27.8°C)* with a design air temperature of 84°F *(28.9°C)*. If it is decided to raise the POOL water temperature to 83°F *(28.3°C)*; the air temperature should be raised to 85°F *(29.4°C)* to maintain the same evaporation rate. Any surface which is exposed to room air and which cools below the dew point of the room air will become wet with condensation. Such surface may not be visible, e.g. inside a wall.

Space Heating

- Space heating should be available year-round.
- Space heating should not be disabled seasonally.

Exceptions may include:

- Space heating need not be provided during such times as the POOL*(s)* may be drained completely, all AQUATIC FEATURES and other evaporative loads are disabled and drained, and the room relative humidity does not rise above the design range.

137 ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Available at https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ashrae-handbook--fundamentals. Accessed on April 18, 2016.
138 ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Available at https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ashrae-handbook--fundamentals. Accessed on April 18, 2016.

- Space heating may not be required if ventilation with outdoor-air is sufficient to prevent room temperature from falling below the design range, and room relative humidity from rising above the design range.

Seasonal Disabling

Where POOLS are filled or partially filled, the evaporation rate will increase as room air temperature decreases. Seasonal disabling of space heating could allow a drop of room temperature, with a subsequent increase in evaporation rate and possible uncontrolled condensation.

Surfaces where the temperature may decrease below the design dew point of the space under normal operation shall be identified as part of the design process. At least one inspection should be done during the first heating season to identify any other such surfaces. The addition of heat to surfaces identified may be necessary to maintain their temperature above the design dew point for the space. Where forced air is used to heat identified surfaces, the heating method specified shall be so installed as to heat the room's air supply. The temperature, flow rate, and delivery of the supply air for each identified surface shall be such as to heat that surface above the design dew point of the space, under the worst-case design conditions. Such surfaces may have low values of thermal resistance. Such surfaces may include, but are not limited to windows and their frames, doors and their frames, any metal structural members that penetrate the vapor retarder, and any under-insulated sections of walls or roofs.

- See Thermal and Water Vapor Transmission Data, *ASHRAE Handbook of Fundamentals*[139]

Combustion Heaters

Where combustion space heaters or combustion heaters required are located inside a building, the space in which the heater*(s)* or an assembly including the heater*(s)* is located shall be considered to be an EQUIPMENT ROOM for the purposes of MAHC 4.9.1. The requirements of MAHC 4.9.1 shall apply. Exceptions may be made for space heaters that have been listed and labeled for installation in the atmosphere without requiring ISOLATION from chemical fumes and vapors.

Note: Not all space heaters listed for heating INDOOR AQUATIC FACILITY air are listed for installation in an INDOOR AQUATIC FACILITY. Combustion space heaters should not be installed in an INDOOR AQUATIC FACILITY, unless the heater is rated for the atmosphere.

4.6.4.1 High Temperature

This temperature limit shall not be construed to be the maximum limit of the bulk water (water in the heater) temperature. Bulk-water temperature limits can be much higher. The temperature limit of MAHC 4.6.4.1 is for water in contact with BATHERS. To meet the limits set in 4.6.4.1, water heaters can:

139 ASHRAE. 2013 ASHRAE Handbook—Fundamentals. Available at https://www.ashrae.org/resources--publications/handbook/description-of-the-2013-ashrae-handbook--fundamentals. Accessed on April 18, 2016.

- Heat the water stream to the limit of MAHC 4.6.4.1 and return the water directly to the AQUATIC VENUE, or
- Heat the bulk water above the limit set in 4.6.4.1 and then use mixing or other methods to ensure that BATHERS are not exposed to temperatures above the limit of MAHC 4.6.4.1.[140]

Examples of "applicable CODES" include but are not limited to:

- International Mechanical Code 304.1.
- National Electric Code,
- National Fire Protection Association 70, and
- National Fuel Gas Code *(if applicable)*,

4.6.4.4 Equipment Room Requirements

Combustion heaters should not be installed in an INDOOR AQUATIC FACILITY, or exposed to other chemical fumes, unless the heater is rated for the atmosphere. Many POOL heaters are located in CORROSIVE environments that can compromise the heater and venting systems leading to an increased risk of building occupant exposure to harmful products of combustion such as carbon monoxide.

4.6.5 First Aid Area

4.6.5.1 Station Design

A conveniently designated first aid station location should be provided for use when BATHERS report with minor injuries and/or illness. The first aid station must be easy to locate and must have first aid supplies to care for minor injuries and more serious injuries until emergency assistance can arrive. Some AQUATIC FACILITIES may have a formal First Aid Station that is a stand-alone and others may have a location for first aid equipment. The MAHC felt it would allow for flexibility in design to call out the location for first aid equipment rather than designate a stand-alone station. Some AQUATIC FACILITIES are large and a single first aid station is not as practical as distributing first aid equipment throughout the AQUATIC FACILITY *(e.g., to individual AQUATIC VENUES)*. From a design standpoint, the designer must address the location of such equipment and as stated in MAHC 4.5.1, should work with the owner and/or aquatic risk management consultant to designate these locations.

4.6.6 Emergency Exit

4.6.7 Drinking Fountains

4.6.7.1 Provided

A drinking fountain is required at an AQUATIC FACILITY simply to encourage swimmers to keep swimmers hydrated and not to drink the POOL water. At an outdoor AQUATIC FACILITY, the drinking fountain can be located inside an adjacent building to allow year-round use

140 Moritz AR, et al. Studies of thermal injury: The relative importance of time and surface temperature in the causation of cutaneous burns. Am J Pathol. 1947 Sep;23(5):695-720.

when the AQUATIC FACILITY is closed for the winter. The drinking fountain would not need to be winterized. When a drinking fountain is not located in the AQUATIC FACILITY, it should not be located more than 25 feet *(7.6 m)* from the AQUATIC FACILITY entrance. The AHJ may approve a bottled water supply in place of a drinking fountain. The water from a bottled water supply shall be as readily accessible to BATHERS as would the water from a drinking fountain.

4.6.8 Garbage Receptacles

4.6.9 Food and Drink Concessions

4.6.10 Spectator Areas

4.6.10.2 Deck

4.6.10.2.1 Additional Width

The MAHC tried to distinguish the word "BARRIER" from "ENCLOSURE." Those definitions are in the glossary. As currently defined, a "BARRIER" is simply intended to be an obstacle intended to deter direct access from one point to another. For example, a simple post and rope solution would meet MAHC intent.

4.6.10.3 Balcony

The intent is to prevent people from using a balcony as a diving platform. If a balcony is close to overhanging an AQUATIC VENUE, some people may try and use it to jump or dive into the AQUATIC VENUE. The more substantial and preventive the BARRIER at the balcony is, the less likely is that a person will use it.

4.6.10.4 Bleachers

Many building CODE jurisdictions may not be aware of the new ICC 300 bleacher STANDARD. Once jurisdictions adopt the 2007 IBC and supplements, the bleacher STANDARD will become better known.

4.7 Recirculation and Water Treatment

4.7.1 Recirculation Systems and Equipment

4.7.1.1 General

Rationale for Prescriptive Approach

Recirculation and water treatment systems guidance tends to be more prescriptive than performance based because it is quite difficult and expensive to measure the performance of the filtration and RECIRCULATION SYSTEM with regard to pathogen removal and/or inactivation. Even the measurement of water clarity *(e.g., turbidity)* can be difficult *(due to potential bubble formation, instrument fouling, and instrument calibration procedures)* and can cost more than a thousand dollars to continuously measure turbidity at a single point.

Reasons to Exceed the Minimum Standards

There is no single TURNOVER time or one type of filtration system that is optimal for every AQUATIC VENUE. Requiring the most aggressive design for every AQUATIC VENUE is not the intent of the MAHC *(or even necessary)*. However, some AQUATIC VENUES, particularly those with high numbers of BATHERS per unit water volume or a BATHER population more likely to contaminate water (e.g., children less than five years of age), could need higher recirculation rates and more efficient filtration than the minimum STANDARDS. Since it is not always possible to predict the number of BATHERS in an AQUATIC VENUE, the MAHC recommends a modest overdesign of the RECIRCULATION SYSTEM pipes and thus ample space be left for expansion of pumping and filtration capacities, which will be referred to henceforth as the hydraulic flexibility recommendation. Future editions of the MAHC could have higher minimum STANDARDS that AQUATIC FACILITIES might wish to comply with without having to remove and replace a lot of concrete to accommodate slightly larger pipes.

Hydraulic Flexibility Recommendation

The hydraulic flexibility recommendation made in the section above will also reduce friction losses in the pipes that may lead to energy savings and reduced operating costs. With the formalization of a new turndown system for AQUATIC VENUES, it is hoped that AQUATIC VENUES may be designed for worst-case conditions and then operated according to the demands placed on the system. A turndown system could be used to operate below the minimum operational STANDARDS set by the MAHC when the AQUATIC VENUES is not occupied as an additional cost-saving measure as long as water quality criteria are maintained.

4.7.1.2 Combined Aquatic Venue Treatment

There are some important considerations to take into account when considering combined AQUATIC VENUES treatment, and this practice is generally discouraged for most installations. First, to respond to a contamination event, it would be necessary to shut down all AQUATIC VENUES and water features on a combined AQUATIC VENUE treatment system since contamination of one AQUATIC VENUE would rapidly contaminate all combined AQUATIC VENUES. Second, including an INCREASED RISK AQUATIC VENUE on a combined system would require secondary DISINFECTION to be installed for all AQUATIC VENUES on the RECIRCULATION SYSTEM. The two scenarios would involve isolating *Cryptosporidium* to a single AQUATIC VENUE *(limiting the number of BATHERS exposed while keeping the concentration high)* or diluting it as much as possible between all AQUATIC VENUES *(to limit the maximum concentration or exposure level while increasing the number exposed).*

Based on the infectious dose concept *(i.e., the number of OOCYSTS required to be ingested to cause an infection)*, diluting *Cryptosporidium* or other CONTAMINANTS is one way of reducing outbreak potential but the high numbers of *Cryptosporidium* OOCYSTS that may be excreted *(e.g., 10^8-10^9 per contamination event[141,142])* may overwhelm modest dilution factors while greatly increasing the number of people exposed. While the number of BATHERS exposed may increase, the exposure level will decrease if circulation rates were

141 Chappell CL, et al. *Cryptosporidium parvum*: intensity of infection and oocyst excretion patterns in healthy volunteers. J Infect Dis. 1996 Jan;173(1):232-6.
142 Goodgame RW, et al. Intensity of infection in AIDS-associated cryptosporidiosis. J Infect Dis. 1993 Mar;167(3):704-9.

the same, meaning dilution of a very small AQUATIC VENUE into a large POOL might reduce the *Cryptosporidium* level from 1000's of OOCYSTS per mL swallowed to less than 1 per mL in the combined system. However, smaller AQUATIC VENUES can be circulated at faster rates through the SECONDARY DISINFECTION SYSTEM and therefore can have OOCYSTS loads reduced faster if they are in a small volume, rapidly circulating AQUATIC VENUE.

Design modeling is needed to compare the efficacy of these two scenarios under different OOCYST concentrations. The dilution scenario only works if an INCREASED RISK AQUATIC VENUE of small volume is combined with a large volume AQUATIC VENUE. For AQUATIC VENUES similar in size, the impact of dilution is small while the number of people exposed might double or more. There could also be benefits with a combined system that would make it easier to provide more stable water quality parameters *(in terms of pH and CHLORINE level)* because larger water volumes tend to be easier to control. Again, the potential positive impact of combined water treatment is limited to combining small POOLS with much larger POOLS, which is not likely if the DISINFECTION requirements differ between the AQUATIC VENUES. Hydraulically isolating a given AQUATIC VENUE on a combined treatment system with valves is discouraged because doing so necessarily prevents filtration and recirculation of the water. However, ISOLATION capabilities are recommended for maintenance purposes *(as well as separate drain piping)*.

4.7.1.3 Inlets

4.7.1.3.1 General

Flow Velocity

The velocity of flow through any INLET orifice *(at between 100% and 150% of the total recirculation flow rate chosen by the designer)* should normally be in the range of seven to 20 feet per second *(2.1 to 6.1 m/s)*. The range of velocities through the INLETS was selected to balance two competing goals.(1) The velocity should be high enough to push water effectively to the center of the POOL *(or to within the range of the floor INLETS for wider POOLS)*, but (2) the velocity should not be so high as to waste an unnecessary amount of energy. The INLETS still being within design range at 150% of the design recirculation flow rate is to accommodate the hydraulic flexibility recommendation discussed previously. This recommendation ensures proper operation at both the current and any future flow rates up to at least 150% of the recirculation flow.

4.7.1.3.2 Floor Inlets

Maintain and Measure

The use of floor INLETS might require additional considerations for draining them when the POOL is not in use. The likelihood of biofilm proliferation in pipes not in use is thought to increase significantly as the FREE CHLORINE RESIDUAL is dissipated. Drinking water distribution pipes are normally coated with biofilm even in the presence of a constant

CHLORINE residual[143,144]. Since it is more difficult to inactivate microorganisms in a biofilm[145], there is potentially increased risk of human exposure to pathogens shielded by biofilm once the POOL reopens. Leoni and coworkers found mycobacteria in 88.2% of POOL water samples analyzed and reported that swimming POOLS provided a suitable habitat for the survival and reproduction of mycobacteria[146]. Significant damage to the RECIRCULATION SYSTEM pipes and surroundings can result from the expansion of water as it freezes. Both dangers may be alleviated by simply draining water from the pipes when the POOL is not in use. Provisions might also be recommended to prevent the pipes from refilling with water once drained.

Floor INLETS are thought to more effectively distribute chlorinated filtered water to the center of the POOL thereby reducing the magnitude or likelihood of dead zones in the center of the POOL. For this reason MAHC 4.7.1.3.1.3.1 requires floor INLETS are required for POOLS greater than 50 feet *(15.2 m)* in width. The designer should take into account climate when designing the INLET system and provide proper drainage instructions.

4.7.1.3.3 Wall Inlets

4.7.1.3.3.1 Effective Mixing

For STANDARD POOLS, since the majority of the water leaving the POOL does so at the surface, locating the INLETS 24 inches *(61.0 cm)* below the design operating water level would reduce short-circuiting of water from the INLETS to the surface removal system.

4.7.1.3.3.3 Inlet Spacing

Wall INLETS have a limited range for how far they can push water out toward the center of the POOL especially as the flow of water is being pulled out of the POOL at the wall via gutters or SKIMMERS. The likelihood of forming regions in the center of the POOL that are not efficiently filtered or chlorinated increases as the width of the POOL increases. For POOLS less than 4 feet *(1.2 m)* in depth, the average velocity of the water is thought to be increased as the volume of water served by a single INLET is expected to decrease assuming equal spacing.

Step areas, swim outs, and similar recessed or isolated areas are likely to create a dead zone. Placement of one or more INLETS in these areas will help ensure distribution of chlorinated, filtered water to these areas.

4.7.1.3.3.5 Dye Testing

Dye testing should be performed to determine and adjust the performance of the RECIRCULATION SYSTEM. Dye studies tend to be qualitative in nature.

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143 Niquette P, et al. Impacts of pipe materials on densities of fixed bacterial biomass in a drinking water distribution system. Water Research. 2000;34(6):1952-1956.
144 Goeres DM, et al. Evaluation of disinfectant efficacy against biofilm and suspended bacteria in a laboratory swimming pool model. Water Research. 2004;38(13):3103-3109.
145 Goeres DM, et al. Evaluation of disinfectant efficacy against biofilm and suspended bacteria in a laboratory swimming pool model. Water Research. 2004;38(13):3103-3109.
146 Leoni E, et al. Prevalence of Mycobacteria in a swimming pool. Environment. J. Applied Microbiology. 1999;87(5):683-688.

A dye test may not be necessary for "STANDARD" designs previously determined to provide effective mixing. It may be particularly important for irregular shaped POOLS.

Some judgment is generally required to determine whether a dye study should be classified as passing or a failing. In general, dead zones (or areas of poor circulation) would indicate a failure that could be fixed by adjusting the INLETS or other system hydraulics. If the POOL does not reach a uniform color within 15-20 minutes, then adjustments are required.

Refer to ***Appendix 3: Dye Testing Procedure*** for additional information.

4.7.1.4 Perimeter Overflow Systems/Gutters

4.7.1.4.1 General

4.7.1.4.1.1 Skimming

Perimeter Overflow/Gutter Systems *(POS)* are intended to remove surface water from the AQUATIC VENUE for treatment and recirculation. The intent of a POS is to remove water from all parts of the POOL equally and preclude "dead spots" from occurring. They need to remove water from all parts of the POOL equally. Much of the dirt, oil, bacteria, floating debris and possibly undissolved chemicals are in the top inch of water. There may also be less DISINFECTANT due to aerosolization and oxidant demand. Indoors, there is some evidence that DBPS build up in the top layer where they are more likely to aerosolize and contribute to poor air quality and BATHER discomfort.

Areas that do not have good circulation due to lack of gutters or return grates *(e.g., zero-depth entries)* or which have gutters that are not level may not have adequate flow in these areas and may develop "dead spots" where the DISINFECTANT is not present at adequate levels to prevent recreational waterborne illnesses or algae growth. The corners of POOLS with SKIMMERS are a case in point. Unsightly debris such as "oil slicks", blowing paper, dead bugs and leaves may also collect in these "dead zones".

Designs

Novel designs *(e.g., gutters located on only the two longest sides of the POOLS)* should be subject to approval by the local authority with proper engineering justification *(e.g., a computational fluid dynamics (CFD) model of the POOL design demonstrating acceptable hydraulic balance and mixing)*.

4.7.1.4.2 Perimeter Overflow System Size and Shape

A value of 125 percent of the total recirculation flow rate chosen by the designer is recommended for hydraulic flexibility.

Oversizing the skimmer capacity for point surge. As PATRONS swim, play, dive, and splash, they create waves that exceed the normal recirculation one might see when the POOL is empty. Upsizing the gutter system allows capture of the waves without flooding the gutter, which would make the gutter ineffective. Human body density is approximately equal to water *(fat is less and muscle is more)* at approximately 1 g/mL.

A 200 pound *(91 kg)* person displaces approximately 24 gallons *(90.8 L)*. *(200 lbs. x 0.454 kg/lb. x 1L/kg x 0.264 gal/L = 24 gallons)* The average PATRON is not 200 pounds, so this conservative parameter provides extra capacity in the surge system for more dynamic wave instances.

Surge capacities recommended by state health departments of 1 gallon per square foot *(40.7 L/m²)* of POOL water are common. For an average of 24 *(typically 16 to 30)* square feet *(2.2 m²; typically 1.5 to 2.8 m²)* of water per person and 24 *(90.8 L)* gallons per person to be conservative, the net surge capacity is 1 gallon per square foot *(40.7 L/m²)* of POOL. This is not new information and was considered over a decade ago. The State of Iowa tried 2 gal/ft² *(81.5 L/m²)* for a few years, but found that to be unnecessary. It continues to work well in POOL designs. Once again, the oversized gutter system is recommended to account for how PATRONS enter and displace the POOL water adjacent to the gutter. The 125% gutter capacity and the 1 gallon of surge per square foot of area both continue to work well in practice. The gutter capacity must be even greater for designs relying on AQUATIC FEATURES and SLIDE flow being returned through the gutter.

4.7.1.4.3 Gutter Outlets

A value of 125 percent of the total recirculation flow rate chosen by the designer is recommended for hydraulic flexibility. The design goal is to avoid inadequate outlet spacing in these old gutter channels. The spacing between drain outlets should not exceed 10 feet *(3.0 m)* for two inch *(5.1 cm)* diameter drains or 15 feet *(4.6 m)* for 2½ inch *(6.4 cm)* drains, unless hydraulically justified by the design engineer.

4.7.1.4.4 Surge Tank Capacity

4.7.1.4.4.1 Net Surge Capacity

The net capacity shall be measured from the minimum operating depth required to maintain pump suction to the bottom of the overflow waste outlet.

Draining

Surge tanks should be provided with means for complete draining to allow routine inspections, maintenance, and cleaning. Proper maintenance will reduce the chances of biofilm formation and bio-corrosion. Surge tanks should also have a means of draining for winterization, where applicable. An overflow is recommended to prevent a POOL from flooding DECK areas *(indoor)* if over filled and flooding filter rooms during rainfall events. An air break is recommended to prevent a CROSS-CONNECTION with the POOL water that could introduce CONTAMINANTS into the POOL.

Contain

Surge tanks can contain valves, piping, float controls, heating system manifolds or heat exchangers, makeup water controls and large basket screens for large AQUATIC FACILITIES. They also can act as a settling basin for large particles and debris coming directly from the main drains and gutters. It is reasonable to drain these tanks to access equipment and remove settled materials.

4.7.1.4.5 Tolerances

Gutter tolerances were chosen to keep water flowing in even proportions from all sections of the POOL and to avoid dead spots and scum lines. Tighter tolerances may be needed for competitive POOLS.

4.7.1.4.6 Makeup Water System

Other BACKFLOW prevention devices may include the following:

- Reduced Pressure principle assembly (RP),
- Pressure Vacuum breaker assembly (PVB),
- Spill-resistant Vacuum Breaker assembly (SVB), or an
- Atmospheric Vacuum Breaker assembly (AVB).

All devices may not be appropriate for all installation conditions.

4.7.1.5 Skimmers and Alternative Gutter Technologies Using In-Pool Surge Capacity

4.7.1.5.1 General

4.7.1.5.1.2 Provided

The use of SKIMMERS could be limited to POOLS with surface areas of less than 1,600 square feet *(149 m^2)*, and the maximum width for POOLS using SKIMMERS could be restricted to less than 30 feet *(9.1 m)*.The use of SKIMMERS has been limited to smaller POOLS with light BATHER COUNTS since their inception. The limitations of SKIMMERS versus gutters appear to be physical in nature. For example, a 30 feet x 50 feet *(9.1 m x 15.2 m)* POOL may be served by three SKIMMERS rated at 500 square feet *(46.4 m^2)* each. If each SKIMMER is one foot *(30.5 cm)* wide, then all of the skimmed water is being drawn off from only three foot *(0.9 m)* of the POOL perimeter *(i.e., 1.9 % of the total perimeter)*. This would lead to higher water velocities over the floating weirs and water being collected from a greater depth *(as opposed to actual surface skimming)* relative to a gutter system that extends around the perimeter of the POOL. In this example, 98.1% of the perimeter of the POOL is not being used to skim water and could produce regions of limited flow and scum collection. Theoretically, enough SKIMMERS might be added to produce effective skimming comparable to a gutter system, but the research to demonstrate this in practice could not be found. Practical experience says that having no scum lines or dead zones in corners with stagnant debris are inherent advantages. There could also be practical hydraulic limitations for heavily BATHER loaded POOLS related to use of in-POOL surge as opposed to a surge tank. Equalizer lines are recommended to prevent SKIMMERS from pulling air into the pump and potentially causing loss of prime, flow surges, and interference with proper filter operation.

4.7.1.5.1.3 Hybrid Systems

Hybrid systems that incorporate surge weirs in the overflow gutters to provide for in-POOL surge shall meet all of the requirements specified for overflow gutters Since the number of BATHERS determines the type of surface overflow system in use, the hybrid systems should be able to meet all CODE requirements regardless of how many BATHERS are present and which components are in active use.

When the POOL is inactive *(no BATHERS in the water)* the surge weirs provide surface skimming. The operating water level during the period when there are no BATHERS in the water is designed to be below the rim of the gutter and flows over the surge weirs by gravity. When BATHERS enter the water, the level rises *(in-POOL surge capacity)*, the surge weir openings close, and the water flows over the gutter as in STANDARD gutters.

4.7.1.5.1.3.1 Surge Weir

The manufacturers of these gutter systems typically have flow capacities (gpm/surge weir) established for their surge weirs. The number of surge weirs necessary to accommodate the portion of the recirculation rate to be removed from the surface is calculated by using the percentage of the total recirculation rate for surface skimming (i.e., 80 % of total flow) divided by the flow rate for each surge weir. The total recirculation rate must not be used for this calculation, as it will result in a greater number of surge weirs; operationally less water will need to be removed from the surface, which will likely result in inadequate flows over the weirs for effective surface skimming.

The required number of surge weirs are to be uniformly spaced around the POOL perimeter in the gutter.

4.7.1.5.1.4 Design Capacity

The 100 percent of the total recirculation flow rate chosen by the designer is recommended as part of the hydraulic flexibility recommendation.

4.7.1.5.3 Skimmer Flow Rate

SKIMMERS should provide for a flow-through rate of 30 GPM *(114 L/min)*, or 3.75 GPM *(14 L/min)* per linear inch *(2.5 cm)* of weir, whichever is greater. The AHJ may approve alternate flow-through rates so long as the SKIMMERS are NSF or equivalent listed and manufacturer's design specifications are not exceeded.

Flotation Test Procedure

Materials Needed:

- Yellow wooden stars *(55 -110 minimum depending on the POOL'S surface area)*
- Video camera
- Tripod

Conditions Prior to Test:

- TURNOVER time and recirculation flow rate are operated as normal for the POOL
- INLETS and outlets are positioned as normal for the POOL
- SKIMMERS or gutter system is not flooded
- If using SKIMMERS, make sure that the weirs are present
- Water level is at the appropriate height above the weir/gutter *(about ¼ inch or 6.4 mm)*
- Set up video camera to record

Test 1: Circulation

1. Determine how many stars are necessary by using the following:
   - POOL surface area < 2,500 square feet *(232 m^2)*, use a minimum of 55 stars;
   - POOL surface area > 2,500 square feet *(232 m^2)*. use a minimum of 110 stars.
2. Randomly toss the stars into the POOL. Try to toss the stars so that there is an even distribution throughout the surface of the POOL.
3. Record and observe the stars as they travel.
4. Record the motion of the stars in each area of the POOL *(e.g., clockwise, counter-clockwise, no movement)* and any other observations.
5. Passing criteria may vary, but suggestions include 90% removal within one hour.

Test 2: Skimmer/Gutter Draw

1. Stand behind one of the SKIMMERS or the gutter and drop a star into the water at arm's length distance *(about 2 feet (61 cm))* in front of it.
2. Record how long it takes for the star to enter the SKIMMER or gutter. Then repeat this process at the same location three times.

4.7.1.6 Submerged Suction Outlet

Note that in the VGB Act, no specific distances are listed. CPSC's question and answer section for implementation indicates three feet *(0.9 m)* measured center to center.

4.7.1.6.4 Flow Distribution and Control

The 125% of the total recirculation flow rate chosen by the designer is recommended as part of the hydraulic flexibility recommendation in MAHC Annex 4.7.1.1. The proportioning valve*(s)* are recommended to restrict flow by increasing the head loss in the pipe*(s)* typically on the main drain lines where flow rates are less than those from the surface overflow system lines.

The main drain system shall be designed at a minimum to handle recirculation flow of 100% of total design recirculation flow rate. A minimum of two hydraulically balanced filtration system suction outlets are required as protection from suction entrapment. The branch pipe from each main drain outlet shall be designed to carry 100% of the recirculation flow rate so in the event that one drain outlet is blocked the other has the capacity to handle the total flow.

Where three or more main drain outlets are connected by branch piping in accordance with MAHC 4.7.1.6.2.1.1 through 4.7.1.6.2.1.3, it is not necessary that each be designed for 100% flow. Where three or more properly piped drain outlets are provided, the design flow through each drain outlet may be as follows:

- Q_{max} for each drain= Q*(total recirculation rate)* / *(number of drains less one)*
- $Q_{max}=Q_{total} / (N-1)$

The result is that if one drain is blocked, the remaining drains will cumulatively handle 100% of the flow.

Example:

- Q_{total} = 600 gpm recirculation rate
- N = 3 drains

600 / (3-1) = 300 gpm / drain.

4.7.1.7 Piping

4.7.1.7.2 Velocity in Pipes

4.7.1.7.2.1 Discharge Piping

RECIRCULATION SYSTEM piping should be designed so the water velocities should not exceed eight feet *(2.4 m)* per second on the discharge side of the recirculation pump. This is a maximum value as opposed to a good design value. The head loss in a pipe *(and hence the energy loss in the RECIRCULATION SYSTEM)* is proportional to the square of the velocity in the pipe *(i.e., if you cut the velocity in half, then you reduce the head loss to ¼ (25%) of the original value)*. In the interest of conserving energy, velocities in the range of six to eight feet *(1.8 m to 2.4 m)* per second are recommended. Without a minimum INLET velocity, uniform water distribution within the supply piping will not happen.

4.7.1.7.2.2 Suction Piping

The maximum velocity in suction piping is six feet *(1.8 m)* per second. The real limitation in suction piping is NPSH recommended by the pump. NPSH refers to the pressure energy at the suction INLET to the impeller. Pump problems can result from incorrect determination of NPSH. Inadequate NPSH can reduce pump efficiency and capacity and lead to cavitation. If cavitation continues and the pump conditions deteriorate, vibration problems can lead to destruction of the pump impeller and damage to other pump hardware. Failure to provide sufficient NPSH for the pump can result in cavitation, high power usage, and premature failure of the pump and other RECIRCULATION SYSTEM components. The velocities recommended could be lower depending on the size and configuration of the piping as well as the elevation and water temperature. The available NSPH should be at least 20% greater than the recommended NPSH. The available NPSH should be calculated for each AQUATIC VENUE pump and each AQUATIC FEATURE pump. The available NPSH should be compared with the NPSH recommended by each pump manufacturer. Cavitation will occur if the available NPSH is less than the recommended NPSH. The available NPSH is calculated as follows *(all terms in feet)*:

Absolute pressure on the liquid surface

– friction losses in the suction line

– vapor pressure of the water

+ static head of liquid above impeller eye.

Hydraulic calculations for piping and pumps should be prepared by a qualified engineer.

4.7.1.7.2.3 Additional Considerations

Gravity piping must be sufficiently sized to accommodate the recommended flow *(including surges)* without water surcharging above the INLET. Careful consideration of available head, the head losses, and the combined flow from multiple inputs into a single pipe is a necessity. The two feet *(61.0 cm)* per second value is a value derived from common practice with no clearly identifiable theoretical basis.

4.7.1.7.3 Drainage and Installation

Draining Recommendation

The draining recommendation for all equipment and piping serves multiple functions. First, any sediment or rust particles that gather in the pipe can be flushed by means of the drainage system. Since bacteria and biofilms are mostly water, drying out a biofilm can be an effective means of controlling growth. Whereas leaving a pipe full of water during a period of maintenance or no use could lead to dissipation of the CHLORINE residual and proliferation of a biofilm inside of pipes and/or equipment. Biofilms can lead to bio-corrosion of metal components of the RECIRCULATION SYSTEM and serve as protection for microbes and pathogens.

Designed

All equipment and piping should be designed and constructed to drain completely by use of drain plugs, drain valves, and/or other means. All piping should be supported continuously or at sufficiently close intervals to prevent sagging and settlement. All suction piping should be sloped in one direction, preferably toward the pump. All supply and return pipe lines to the AQUATIC VENUE should be provided to allow the piping to be drained completely.

Individual Drain

The individual drain to facilitate emptying the POOL in case of an accidental gross contamination event is intended to prevent further contamination of any pipes, pumps, multi-port valves, filters, or other equipment associated with the RECIRCULATION SYSTEM, which might be more difficult to clean than the inside of the AQUATIC VENUE. In the case of combined AQUATIC VENUE treatment systems, this drain could prevent cross-contamination of multiple AQUATIC VENUES.

4.7.1.7.4 Piping and Component Identification

4.7.1.7.4.1 Clearly Marked

Clearly marking pipes will prevent misidentification that could lead to CROSS-CONNECTIONS and contamination of the AQUATIC VENUE. Pipe marking will also facilitate easier identification of locations for additional equipment installation and/or sample lines.

Color Coding Recommendations: Pipes and valves, when color-coded, may be color-coded in accordance with the following:

- Potable water lines *(Dark blue)*,
- Backwash waste *(Dark brown)*,

- Filtered water *(Aqua)*,
- Sewer *(Dark gray)*,
- SKIMMER or gutter return *(Olive green)*,
- DECK drains *(Light brown)*,
- Main drain *(Black)*,
- Alum *(Orange)*,
- CHLORINE *(gas/solution) (Yellow)*,
- Compressed air *(Dark green)*,
- Soda ash *(White)*,
- Gas *(Red)*, and
- Acid *(Pink)*.

4.7.1.8 Strainers and Pumps

4.7.1.8.2 Pumping Equipment

4.7.1.8.2.1 Variable Frequency Drives

VFDs may be allowed because the energy savings could be substantial if flow is reduced at night and water quality criteria are continuously maintained. At this time, we are not aware of public health benefits or deficits associated with VFD use so these pumps are allowed but not required. Operators should be aware that VFDs can flatten out a pump curve so if they are installed on a filter pump, operators may want more active control to maintain operations. It is recommended that operators use VFDs with a compatible flow meter with a feedback control to optimize VFD function.

4.7.1.8.2.2 Total Dynamic Head

The recirculation pump should be selected to meet the recommendations of the designer for the system. However, the following guidelines are suggested as starting points for designers. The recirculation pump*(s)* must be selected to provide the recommended recirculation flow against a minimum TDH of the system, which is normally at least 50 feet *(15.2 m)* for all vacuum filters, 70 feet *(21.3 m)* for granular media and cartridge filters, or 60 feet *(18.3 m)* for precoat filters. A lower TDH could be shown to be hydraulically appropriate by the designer by calculating the total head loss of the system components under worst-case conditions.

4.7.1.8.3 Operating Gauges

Pressure Measurements

A second set of pressure measurement ports could be recommended *(tapped into the pump volute and discharge casing)* to accurately calculate the flow of the pump. These gauges are a way of verifying the pump curve is correct. One can also use the pressure/vacuum gauges and pump curve to verify the flow meter reading and look for differences between the two. During startup, it is possible to shut off a valve on the discharge side of the pump and verify that the maximum discharge pressure measured agrees with the value on the pump curve.

It is recommended that all pumps be located on a base so as to be easily accessible for motor service.

Vacuum Limit Switches

The vacuum limit switch is intended to shut down the pump if the vacuum increases to a point which could cause damage to the pump *(cavitation)*.

4.7.1.9 Flow Measurement and Control

4.7.1.9.1 Flow Meters

Over 22% *(approximately 20,000)* of the POOL inspections that led to POOL closures in the state of Florida in 2012 were caused by non-functioning flow meters. This section of the MAHC is intended to improve this flow meter reliability problem *(as well as to address a problem with accuracy)*. Since flow rates are critical for proper filtration, sizing, and operational calculations, it is recommended that operators purchase a more accurate flow meter for all systems or when replacing older flow meters on their existing system. Improved accuracy improves an operator's chance of understanding the true flow in their system. Operators should be mindful of flow meter placement by installing according to manufacturer recommendations and adhering to recommended distance parameters.

A flow meter or other device that gives a continuous indication of the flow rate in GPM *(L/min)* through each filter should be provided. If granular media filters are used, a device should be provided to measure the backwash flow rate in GPM *(L/min)* for each filter. Flow meters should have a measurement capacity of at least 150% of the design recirculation flow rate through each filter, and each flow meter should be accurate within +/-5% of the actual design recirculation flow rate. The flow measuring device should have an operating range appropriate for the anticipated flow rates and be installed where it is readily accessible for reading and routine maintenance. Flow meters should be installed with 10 pipe diameters of straight pipe upstream and 5 pipe diameters of straight pipe downstream or in accordance with the manufacturer's recommendations. Acrylic flow meters will not meet the accuracy requirement *(and are prone to fouling/clogging)* and hence should not be installed as the primary flow meter on any RECIRCULATION SYSTEM. However, acrylic flow meters could prove useful as a backup or auxiliary flow meter. A paddle-wheel flow meter, when used, should be located on the effluent side of the filter to prevent fouling.

More accurate flow meters are recommended to conserve energy and increase regulatory compliance. Magnetic and ultrasonic flow meters offer greater accuracy *(typically less than +/- 1% error)* and less potential for fouling, but the aforementioned flow meters tend to be more expensive *(e.g., $1,000 or more)*. An ultrasonic flow meter *(such as clamp-on transit-time models)* can be used to measure flows through the wall of a pipe, so they can be installed and uninstalled without modifying the existing plumbing. One ultrasonic flow meter could be used to routinely verify the flow readings of multiple other flow meters that are more prone to error. An annual cleaning and evaluation of flow meter accuracy could be useful in maintaining compliance with existing regulations.

4.7.1.10 Flow Rates / Turnover

Table 4.7.1.10: Aquatic Venue Maximum Allowable Turnover Times prior to the release of the 2014 MAHC

Type of Pools	Turnover Maximum	States with these Values in their Codes
Activity Pools	2 hours or less	FL, WI
Diving Pools	8 hours or less	IL, KY, MS, OR, UT, MD, MO-KC
Interactive Play*	0.5 hours or less	WI, MT, OH, AL-Baldwin, GA, MO-STL, NE
Lazy River	2 hours or less	MT, IL, IA, WI, MI
Plunge Pools	1 hour or less	IA, MA, MI, MT, NE, NH, WI, AL-Baldwin, OR, SC, TN
Runout Slide	1 hour or less	IA, UT, TN, SC, WI, NE, GA-Fulton, DE
Wading Pools*	1 hour or less	CO, GA, IN, IA, MI, MT, NH,OR, SC, TN, WA, FL, DE, MO-St. Charles, NE, TX, UT
Wave Pools	2 hours or less	IN, IA, SC, WI, AL-Baldwin, MT, NY, SD
All Other Pools	6 hours or less	MOST
*Shall have secondary disinfection systems		

Spa, Therapy*, & Exercise Pools (from WI; similar to SC)		
Temperatures	**Load**	**Turnover Maximum**
≤ 72^0-93^0F (*22^0-34^0*C)	> 2500 gals/person (*9.46 m^3*)	4 hours or less
≤ 72^0-93^0F (*22^0-34^0*C)	> 450 gals/person (*1.7 m^3*)	2 hours or less
≤ 72^0-93^0F (*22^0-34^0*C)	≤ 450 gals/person (*1.7 m^3*)	1 hour or less
≥ 93-104^0F (*34^0-40^0*C)	All	0.5 hours or less
*Shall have secondary disinfection systems		

4.7.1.10.2 Calculated

A new methodology is being proposed for use in the future that calculates the recommended minimum design recirculation flow rate, which is called the maximum sustainable BATHER LOAD *(MSBL)* calculation. The MSBL calculation is based on the values in MAHC Annex Table 4.7.1.10.2 *(below)* and adjusted by all applicable multipliers in MAHC Annex Table 4.7.1.10.3 *(below)* as the maximum TURNOVER time allowable based on the pathogen load and CHLORINE demand imparted by BATHERS. Whereas, the traditional TURNOVER time values *(required in MAHC Table 4.7.1.10 above)* are based on physical transport processes of CONTAMINANTS and disinfectant in the POOL. The MSBL design TURNOVER RATES should use the adjustment factors provided. For mixed-use POOLS, each zone of the POOL should individually meet the recommended TURNOVER time for the zone based on the lesser TURNOVER time calculated by the procedures already described. All of the maximum TURNOVER times provided in MAHC Table 4.7.1.10 are required for AQUATIC VENUES as defined in the MAHC. The MSBL values calculated might help to identify POOLS that could be slightly over-designed to meet the demands placed on the AQUATIC VENUE. Furthermore, the MSBL approach actually identifies risk factors that might require higher or lower levels of treatment based on the actual system.

- ***Zone Volume*** (ft^3) = Zone Surface Area (ft^2) x Average Depth (ft)

- ***Zone Bather Load Factor*** (BATHERS/ft^3) =
  1 / {Surface Area per BATHER (ft^2/BATHER)} x (Average Depth (ft))

- ***Estimated Maximum Number of Bathers Per Zone*** =
  Zone BATHER LOAD Factor (BATHER/ft^3) x Zone Volume (ft^3)

- ***Raw Recirculation Flow Rate Per Zone*** (gal/min) =
  Estimated Maximum Number of BATHERS Per Zone x 5.34 (a constant)

- ***Turnover Time*** (h) =
  Water volume (gal) / {Recirculation rate (gal/min) x (60 min / 1 hr)}

Table 4.7.1.10.2: Bather Loading Estimates

Water Depth	Surface Area Per Bather
Under 3 feet *(0.9 m)*	25 ft^2 *(2.3 m^2)*
3 to 6 feet *(0.9 m to 1.8 m)*	30 ft^2 *(2.8 m^2)*
6.1 to 10 feet *(1.9 m to 3.0 m)*	22 ft^2 *(2.0 m^2)*
Over 10.1 feet *(3.1 m)*	16 ft^2 *(1.5 m^2)*

Table 4.7.1.10.3: Recirculation Rate Multipliers (Adjustment Factors)

Adjustment Reason	Adjustment Factor	Recommendation(s)
Edge Loading *(more bathers at edge of larger pools)*	1.1	Pools must be greater than 100,000 gallons *(378, 541 L)* Spas must be greater than 10,000 gallons *(37,854 L)*
Increased-Risk *(diaper-aged patrons present)*	0.75	Pool designed for at least 10% of patrons to be diaper-aged.
Activity / Line *(attractions increase bather density)*	0.5	Any pool/spa with an associated ride or activity *(besides swimming)* or line to enter
High-Temperature *(increased sweat production)*	0.5	Pool/Spa with water temperatures routinely exceeding 95 F.
Indoor *(protected from some environmental factors)*	1.15	Pool/Spa must be located completely indoors year round.
Limited-Use *(pools that are frequently lightly loaded)*	1.33	Pool must be at an Apartment, Condominium, or Hotel/Motel with no associated attraction or activity.
Showering Recommended *(showering reduces bather load)*	1.15	Pool/Spa must recommend showering prior to entry.

Example Calculation

For example, here is a set of example calculations for an indoor POOL in a hotel that is 20 feet *(6.1 m)* wide by 30 feet *(9.1 m)* long with an even floor slope that goes from 4 feet *(1.2 m)* at the shallow end to 6 feet *(1.8 m)* at the deep end.

- ***Zone Volume*** (ft^3)

  = 20 ft x 30 ft x 5 ft = 3,000 ft^3

- ***Zone Bather Load Factor*** (BATHERS/ft^3)

  = 1/(30 ft^2/BATHER) x (5ft) = 0.00666 BATHERS/ft^3

- ***Estimated Maximum Number of Bathers Per Zone***

  = 0.00666 BATHER/ft^3 x 3,000 ft^3 = 20 BATHERS

- ***Raw Recirculation Flow Rate Per Zone*** (gal/min)

= 20 BATHERS x 5.34 = 106.8 gal/min

- ***Turnover Time*** (h)

  = 3,000 ft^3 x 7.48 gal/ft^3/(106.8 gal/min) x (60 min/1 hr) = 3.5 h

- ***Adjustments for indoor pool and limited use pool***:

  3.5 h x 1.15 x 1.33 = 5.35 h

Compare the MSBL value of 5.35 h to the value in Table 4.7.1.10.3 of 5 h and use the lower value = 5 h. Additional example calculations are provided in Table 4.7.1.10.4.

Table 4.7.1.10.4: Recirculation Rate Calculation Examples by Pool Type Based on Bather Load

	Large Indoor Pool	Wave Pool	Activity Pool	Spray Pad	Kiddie Pool	Spa	Deep Diving Pool	Small Pool
Volume	322,000 gals. *(1,218,902.6 L)*	750,000 gals. *(2,839,058.8 L)*	50,000 gals. *(189,270.6 L)*	20,000 gals. *(75,708.2 L)*	1,000 gals. *(3,785.4 L)*	750 gals. *(2,839.1 L)*	100,000 gals. *(378,541.2 L)*	35,000 gals. *(132,489.4 L)*
Average Depth	7.33 ft. *(2.23 m)*	4.98 ft. *(1.52 m)*	3.00 ft. *(91.44 cm)*	1.00 ft. *(30.48 cm)*	1.00 ft. *(30.48 cm)*	1.50 ft. *(42.72 cm)*	16.00 ft. *(4.88 m)*	5.00 ft. *(1.52 m)*
Surf Area	5870.20 ft^2 *(545.36 m^2)*	20120.5 ft^2 *(1,869.26 m^2)*	2228.16 ft^2 *(207.00 m^2)*	2673.80 ft^2 *(248.40 m^2)*	133.69 ft^2 *(12.42 m^2)*	66.84 ft^2 *(6.21 m^2)*	835.56 ft^2 *(77.63 m^2)*	935.83 ft^2 *(86.94 m^2)*
Square Side	76.62 ft. *(23.35 m)*	141.85 ft. *(43.24 m)*	47.20 ft. *(14.39 m)*	51.71 ft. *(15.76 m)*	11.56 ft. *(3.52 m)*	8.18 ft. *(2.49 m)*	28.91 ft. *(8.81 m)*	30.59 ft. *(9.32 m)*
Factor 1 (bathers/ft^3)	0.007346	0.025	0.02	0.04	0.04	0.02667	0.003906	0.00945
Factor 2 (bathers/ft^3)	0.006011	0.00778	0.009445	0.04	0.04	0.02667	0.003906	0.00735
Factor 3 (bathers/ft^3)	0.003821	0.00504	0.009445	0.04	0.04	0.02667	0.003906	0.00655
Total Bathers	219.09	797.52	78.81	106.95	5.35	2.67	52.22	34.93
K	5.34	5.34	5.34	5.34	5.34	5.34	5.34	5.34
gpm Q	1171	4261	421	571	29	14	279	187
Minimum Turnover	275	176	119	35	35	53	358	188
Raw Turnover	4.58	2.93	1.98	0.58	0.58	0.58	5.97	3.13
>100K gallons/Large Pool Edge Load Factor	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Small Pool High Risk Factor	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Activity Pools Density/Line Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
>90°F (32°C) Hot Water High Temp. Factor	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Indoor Pools Env. Protect Factor	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Shower Required Bather Load Reduction	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Plain Pools Only: Apartment/ Condo/Hotel Limited Use Factor	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Final Turnover (Hours)	5.8	1.61	0.99	0.22	0.44	0.22	7.56	4.16
w/ a Required Shower	6.67	1.86	1.14	0.25	0.5	0.25	8.69	4.78
Standard Table Values	4.0-5.0	1.5-2	1-1.5	0.25	0.50	.25-.5	6.0-8.0	5.0

When POOL recirculation rate recommendations are broken down to their essential elements, it is essentially about removing suspended *matter (including microbial CONTAMINANTS)* with the filters and effectively maintaining uniform FREE CHLORINE RESIDUAL at the proper pH. Both the FREE CHLORINE RESIDUAL and the microbial concentrations are a function of the number of BATHERS in a given volume of water. While it is not possible to always accurately predict the BATHER COUNT for a given POOL on a given day, it is generally possible to estimate the maximum number of BATHERS likely to be in any given type of POOL per unit surface area *(since most BATHERS have at least their head above water most of the time and the primary activity in a pool often dictates the comfort level in regards to BATHERS per unit surface area and hence the likelihood of BATHERS entering or leaving the pool)*. After establishing a maximum sustainable BATHER load *(MSBL)* or maximum number of BATHERS expected in a POOL, it is possible to calculate the recommended flow of recirculated water necessary to be treated in order to handle the pathogen load and CHLORINE demand imparted by the BATHERS. An empirically-derived multiplier was used by PWTAG[147] to convert the MSBL to the recommended recirculation rate. The empirical multiplier used in this CODE was derived independently using English units specifically for use in the U.S. The value of the U.S. multiplier is approximately 29% smaller than the

147 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.

PWTAG value using equivalent units because POOL design in the UK is more conservative than in the US.

4.7.1.10.2.1 Unfiltered Water

Unfiltered water shall not factor into TURNOVER time. This section is to address/clarify water that may be withdrawn from and returned to the AQUATIC VENUE for such AQUATIC FEATURES as SLIDES, features, etc. by a pump separate from the filtration system. That flow rate from the separate pump system shall not be included in the turnover time calculation.

4.7.1.10.3 Turnover Times

The recommended design TURNOVER time can then be calculated by dividing the volume by the recommended flow. This procedure can be performed for individual sections of a POOL or the entire POOL depending on the number of zones, which are based on depth of the water. Adjustments can then be made to this calculation to account for extraordinary conditions. For example, since a SPA has higher water temperature than a POOL, a PATRON would be expected to sweat more; an indoor POOL might experience less contamination from pollen, dust, and rain than an equivalent outdoor POOL; and a POOL filled with diaper-age children would be considered an increased-risk POOL requiring more aggressive treatment. Aquatic facilities that enforce showering prior to POOL entry could reduce the organic load on the POOL by 35-60% with SHOWERS lasting only 17 seconds[148]. The BATHER LOAD calculation based on surface area of the POOL has been proposed by PWTAG[149] in 1999 and has influenced the CODES proposed by the World Health Organization[150] and Australia[151]. This approach has been adapted for use in the U.S. by slightly increasing the area recommended per BATHER in shallow waters and decreasing the area in deep POOLS to account for the intensity of deep water activities, the relatively low surface area to volume ratios of deep waters relative to shallow waters, the typically poorer mixing efficiency in deeper water, the increased amount of time typically spent underwater in deeper water, and the larger average size of BATHERS commonly found in deeper water. These values were empirically derived for the MAHC to match typical U.S. practices at the time of this writing and can be changed as necessary to achieve the desired water quality goals.

Effectively handling BATHER COUNT in terms of pathogen removals and CHLORINE demand is a paramount concern for which the above calculations should provide some science-based guidance. However, there are other factors that must be considered when selecting a recirculation rate for an AQUATIC VENUE. For example, effectively distributing treated water to avoid dead spots recommends minimum water velocities to reach the POOL center and extremities. Similarly, effective surface skimming recommends adequate velocities at the surface of the POOL to remove floating CONTAMINANTS. Due to the kinetics

148 Keuten MG, et al. Definition and quantification of initial anthropogenic pollutant release in swimming pools. Water Res. 2012 Jul;46(11):3682-92.
149 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
150 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 18, 2016.
151 NSW Department of Health. Public Swimming Pool and Spa Pool Code of Practice. 2010. Available at: http://www.health.nsw.gov.au/environment/publicpools/Pages/default.aspx.Accessed on April 18, 2016.

of DISINFECTION and CHLORINE decay, CHLORINE must be replenished at some minimum intervals to maintain the recommended FREE CHLORINE RESIDUAL. For these reasons, MAHC Table 4.7.1.10 was developed to provide some maximum TURNOVER time limits for AQUATIC VENUES that are not dominantly influenced by BATHER LOAD to help ensure proper physical transport of CONTAMINANTS and DISINFECTANT. Values in this table are derived from historical practice and design experience worldwide. All AQUATIC VENUES must be designed to meet the lesser of the two maximum TURNOVER times.

4.7.1.10.4 Reuse Ratio

This section is intended to address those INTERACTIVE WATER PLAY VENUE designs that remove water from the INTERACTIVE WATER PLAY treatment tank by an AQUATIC FEATURE pump separate from the filtration system pump. The limit/ratio of INTERACTIVE WATER PLAY FEATURE water pump rate to the filtration system water pump rate is to acknowledge the typically high level of contaminates and turbidity introduced to the INTERACTIVE WATER PLAY treatment tank. The introduction and build-up of turbidity can exceed the rate at which it is removed by the filtration system which can result in interference with chemical DISINFECTION and UV treatment.

4.7.1.10.5 Flow Turndown System

The flow turndown system is intended to reduce energy consumption when AQUATIC VENUES are unoccupied without doing so at the expense of water quality. A turbidity goal of less than 0.5 NTU has been chosen by a number of U.S. state CODES *(e.g., Florida)* as well as the PWTAG[152] and WHO[153]. The maximum turndown of 25% was selected to save energy while not necessarily compromising the ability of the RECIRCULATION SYSTEM to remove, treat, and return water to the center and other extremities of the POOL. The MAHC does not allow stopping recirculation since uncirculated water would soon become stagnant and loose residual disinfectant likely leading to biofilm proliferation in pipes and filters. This could compromise water quality and increase the risk to BATHERS. Future research could determine that more aggressive turndown rates are acceptable. Some POOLS are already reportedly using the turndown system without a turbidimeter or precise flow rates. The intent of this section is to formalize a system for doing the turndown that does not compromise public health and SAFETY. Additional research in this area could identify innovative ways to optimize and improve this type of system. The likelihood of turbidimeters being cleaned and maintained is likely to be good because turbidimeters tend to give higher reading when not maintained properly.

AQUATIC VENUES designed above the minimum design STANDARDS would have the flexibility to increase system flows to maintain excellent water quality during periods of peak activity. The flow turndown system is intended to reduce energy consumption when AQUATIC VENUES are unoccupied without doing so at the expense of water quality.

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152 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
153 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 18, 2016.

An electronic turbidity and RECIRCULATION SYSTEM flow feedback system would provide a quantifiable means of determining the water quality suitability if a facility desires to "turndown" the recirculation pumps to achieve a flow of up to 25% less than the minimum required recirculation flow rate when the AQUATIC VENUES is not occupied. The integration of feedback from both the flow meter and turbidimeter must be maintained for the VFD to be able to reduce the system flow rate below the level required to achieve the TURNOVER time requirement.

Variable Frequency Drives

VFDs offer the benefits of energy savings, operational flexibility, and in most cases the ability to automatically increase the pump flow as the filter clogs by interfacing the VFD with a flow meter *(or potentially a filter effluent pressure transducer)* by means of a proportional-integral-derivative *(PID)* controller. VFDs may also offer the added benefits of protecting piping, pumps, and valves. Energy savings and benefits will vary depending on the design of the system.

4.7.2 Filtration

System Design

The filtration system should be designed to remove physical CONTAMINANTS and maintain the clarity and appearance of the AQUATIC VENUE water. However, good clarity does not mean that water is microbiologically safe. With CHLORINE-tolerant human pathogens like *Cryptosporidium* becoming increasingly common in AQUATIC VENUES, effective filtration is a crucial process in controlling waterborne disease transmission and protecting public health. The filtration system of U.S. AQUATIC VENUES has traditionally been designed to remove physical CONTAMINANTS and maintain the clarity and appearance of the AQUATIC VENUE water. Good clarity is important and will help prevent drowning and underwater collisions. Poor clarity can actually compromise the DISINFECTION process as well as leaving CHLORINE-tolerant pathogens suspended in the water for longer periods of time. As a future recommendation for discussion, filtration systems should be capable of removing *Cryptosporidium OOCYSTS* or an acceptable 4.5-micron surrogate particle with an efficiency of at least 90% *(i.e., a minimum of 1 log reduction)* in a single pass.

Water Quality

If filtration is poor, water clarity will decline and drowning risks increase since swimmers in distress cannot be seen from the surface as well as needed. DISINFECTION will also be compromised, as particles associated with turbidity can surround microorganisms and shield them from the action of disinfectants. Particulate removal through coagulation and filtration is important for removing *Cryptosporidium* OOCYSTS and *Giardia* cysts and some other protozoa that are resistant to chemical DISINFECTION.[154]

Pathogen Removal

One of the most significant recommended changes of the MAHC is changing the filtration system from one that only provides good clarity and appearance to one that efficiently

154 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 18, 2016.

removes waterborne human pathogens from the AQUATIC VENUE water. Water clarity is only an indicator of potential microbial CONTAMINATION, but it is the most rapid indicator of possible high CONTAMINATION levels. CHLORINE residual can be sufficiently high to kill indicator bacteria while leaving protozoa relatively unharmed and infective. Therefore, testing for indicator bacteria may not be useful as a measure of AQUATIC VENUE water quality, and testing for *Giardia* cysts and *Cryptosporidium* is very expensive and time-consuming. So, both measures are impractical as an operational tool for water quality measurement. *Cryptosporidium* is a widespread threat responsible for causing outbreaks in AQUATIC VENUES each year in the U.S.[155,156] With CHLORINE-tolerant human pathogens like *Cryptosporidium* becoming increasingly common in AQUATIC VENUES, effective filtration is a crucial process in controlling waterborne disease transmission and protecting public health.[157,158] Furthermore, an accidental fecal release could overwhelm the DISINFECTANT residual and leave physical removal as the only means of removing pathogens.[159] Filtration has been cited as the "critical step" for the removal of *Cryptosporidium*, *Giardia*, and free-living amebae that can harbor opportunistic bacteria like *Legionella* and *Mycobacterium* species.[160]

Cryptosporidium

Cryptosporidium is a CHLORINE-tolerant protozoan pathogen that causes the majority of waterborne disease outbreaks in swimming POOLS in the U.S. as shown in MAHC Annex Figure 4.7.2.1.[161] Surveillance for cryptosporidiosis in the United States indicates that the reported incidence of infection has increased dramatically since 2004.[162] MAHC Annex Figures 4.7.2.2 and 4.7.2.3 demonstrate the increased cryptosporidiosis incidence post 2004 and total percentage of recreational water–associated outbreaks caused by *Cryptosporidium* since 2003, respectively.[163]

FIGURE 4.7.2.1: Recreational water-associated outbreaks of acute gastrointestinal illness, by type of exposure and etiology — United States, 2003–2012[164]

155 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. MMWR Suppl. 2015 May 1;64(3):1-14.
156 Hlavsa MC, et al. Outbreaks of Illness Associated with Recreational Water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(24):668-72.
157 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 18, 2016.
158 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
159 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 18, 2016.
160 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 18, 2016.
161 Hlavsa MC, et al. Outbreaks of Illness Associated with Recreational Water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(24):668-72.
162 Painter JE, et al. Evolving epidemiology of reported cryptosporidiosis cases in the United States, 1995–2012. Epidemiol Infect 2015; doi:10.1017/S0950268815003131.
163 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. MMWR Suppl. 2015 May 1;64(3):1-14.
164 Hlavsa MC, et al. Outbreaks of Illness Associated with Recreational Water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(24):668-72.

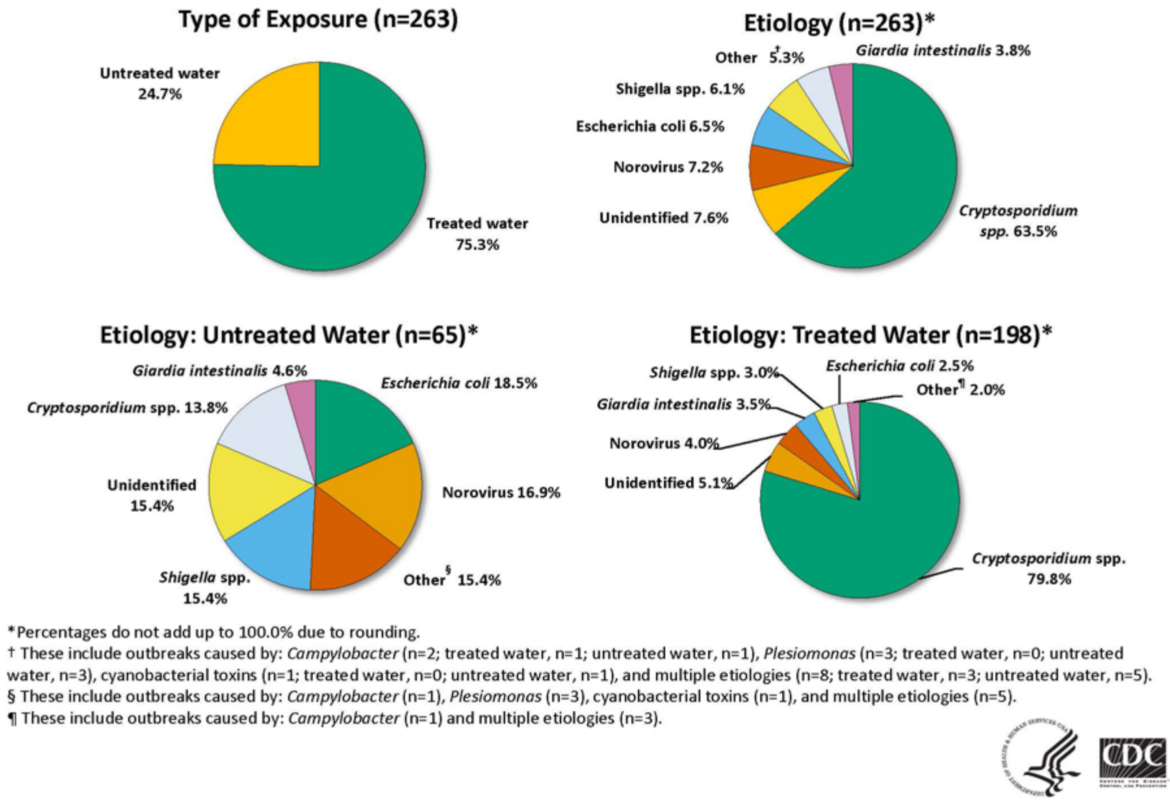
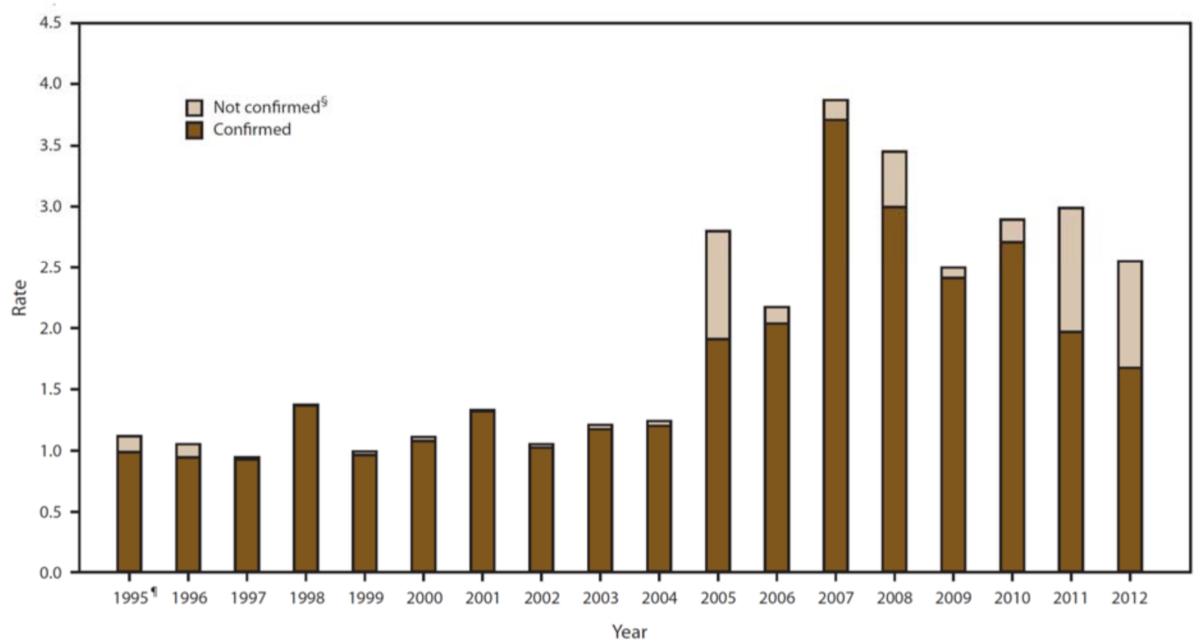


FIGURE 4.7.2.2: Incidence rate* of cryptosporidiosis, by year and case classification — National Notifiable Disease Surveillance System, United States, 1995–2012†[165]

165 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. MMWR Suppl. 2015 May 1;64(3):1-14.



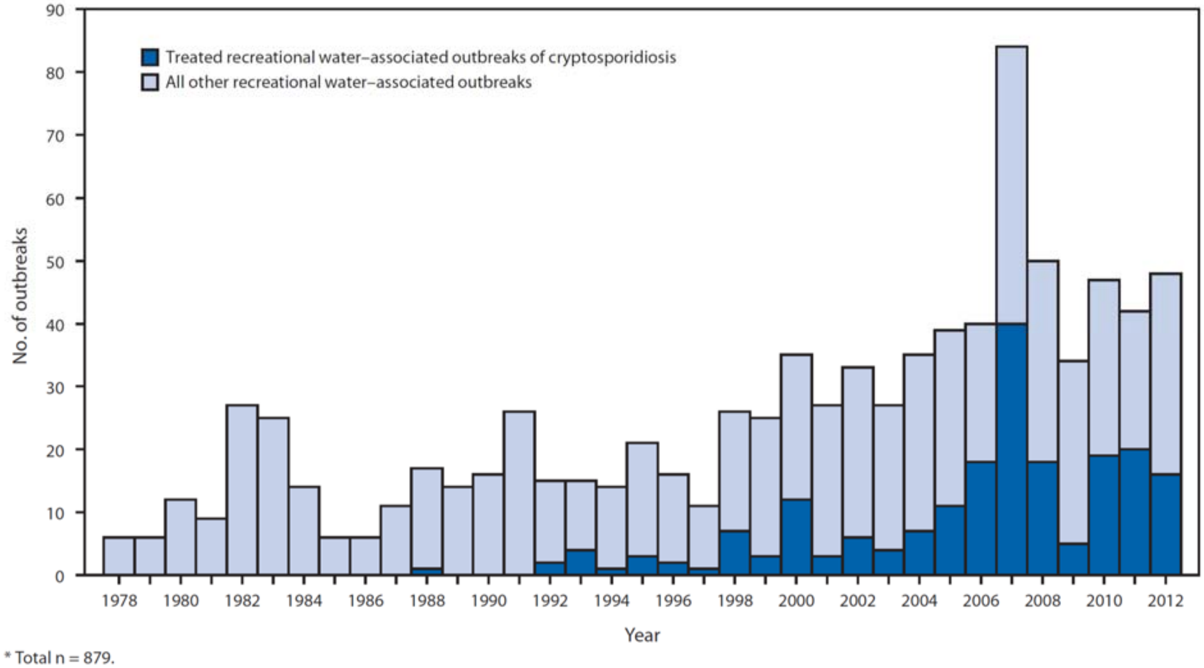
* Cases per 100,000 population.
† N = 102,835.
§ Not confirmed includes probable, suspect, and unknown cases.
¶ First full year of national reporting.

3-Log Reduction

The current CT VALUES for a 3-log reduction in viability of fresh *Cryptosporidium* OOCYSTS with FREE CHLORINE are 10,400 mg/L·min *(Iowa-isolate)*[166] and 15,300 mg/L·min *(Maine-isolate)* at pH 7.5.[167] At a concentration of 1 mg/L, FREE CHLORINE can take more than 10 days to inactivate 99.9% of *Cryptosporidium* OOCYSTS (CT INACTIVATION VALUE *=15,300 mg/L·min)*, but many people are likely to be swimming in the AQUATIC VENUE during that 10-day period and risk being exposed to infective parasite concentrations. Infected individuals might then return to the AQUATIC VENUE and/or visit other AQUATIC VENUES to perpetuate the spread of the parasite. Sand filters are commonly used and often serve as the only potential physical BARRIER to *Cryptosporidium* in U.S. AQUATIC VENUES, but sand filters without coagulant typically only remove about 25% of OOCYSTS per passage through the filter [168]. Based on the slow kinetics of CHLORINE inactivation of *Cryptosporidium*, the known inefficiency of sand filter to remove OOCYSTS, and the recent increased incidence of cryptosporidiosis in the U.S., additional measures appear necessary to effectively safeguard public health.

166 Murphy, JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. Environ Sci Technol 2015;49:7348–55.
167 Shields JM, et al. Inactivation of *Cryptosporidium parvum* under chlorinated recreational water conditions. J Water Health. 2008;6(4):513-520.
168 Amburgey JE, et al. Removal of *Cryptosporidium* and polystyrene microspheres from swimming pool water with sand, cartridge, and precoat filters. J Water Health. 2012;10(1):31-42.

FIGURE 4.7.2.3: Number* of outbreaks associated with recreational water, by year — United States, 1978–2012[169]

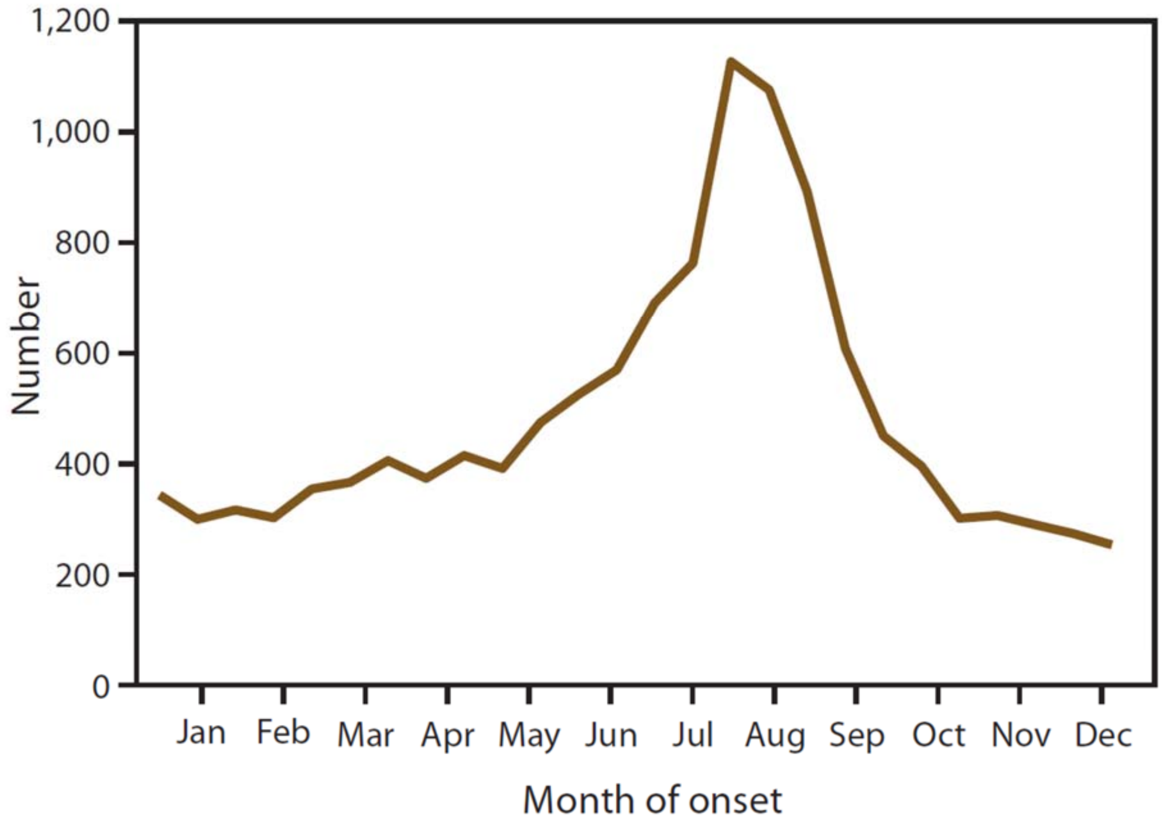


Explanation

MAHC Annex Figure 4.7.2.4 *(below)* shows a dramatic increase in the number of cases of cryptosporidiosis during the warmer months of the year when outdoor public POOLS are normally open in the U.S. While it is difficult to assess the prevalence of protozoan parasites in public POOLS during normal operation, a study of 160 filter backwash water samples from Atlanta, GA showed that 8.1% (13) were positive for *Giardia, Cryptosporidium* or both[170] while another study of 161 filter backwash samples from metro-Atlanta showed 0.6% (one) and 1.2% (two) were positive for *Cryptosporidium* and *Giardia*, respectively[171].

FIGURE 4.7.2.4: Number of cryptosporidiosis case reports,* by date of symptom onset† — National Notifiable Diseases Surveillance System, United States, 2011–2012 [172]

169 Hlavsa MC, et al. Outbreaks of Illness Associated with Recreational Water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64:668-72.
170 Shields JM, et al. Prevalence of Cryptosporidium spp. and Giardia intestinalis in swimming pools, Atlanta, Georgia. Emerging Infectious Diseases. 2008;14(6):948-950.
171 CDC. Microbes in pool filter backwash as evidence of the need for improved swimmer hygiene - metro-Atlanta, Georgia, 2012. MMWR Morb Mortal Wkly Rep. 2013 May 17;62(19):385-8.
172 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. MMWR Suppl. 2015 May 1;64(3):1-14.



* Cases per 100,000 population.
† N = 12,581; date of onset for 4,740 patients was unknown.

Review of Recreational Water Filtration Research Findings

Sand Filters

Sand filters often provide the only physical BARRIER to *Cryptosporidium* in U.S. AQUATIC VENUES, but sand filters meeting the recommendations of pre-existing POOL CODES typically only remove about 25% of OOCYSTS per passage through the filter[173]. A quantitative risk assessment model of *Cryptosporidium* in AQUATIC VENUES confirmed there is a "significant public health risk".[174] Some changes are necessary to effectively safeguard public health and will be discussed subsequently. Recent research in the U.S. and U.K. has shown that sand filters can remove greater than 99% of OOCYSTS per

173 Amburgey JE, et al. Removal of *Cryptosporidium* and polystyrene microspheres from swimming pool water with sand, cartridge, and precoat filters. J Water Health. 2012;10(1):31-42.
174 Pintar KD, et al. A risk assessment model to evaluate the role of fecal contamination in recreational water on the incidence of cryptosporidiosis at the community level in Ontario. Risk Analysis. 2010;30:1:49-64.

passage when a coagulant is added prior to filtration[175,176] . The addition of coagulants to swimming POOL filters used to be common practice in the U.S. with rapid sand filters, but it fell out of favor as high-rate sand filters began to dominate the U.S. POOL market. The importance of coagulant addition to efficient pathogen removal in drinking water is well-documented and recommended in all U.S. surface water treatment facilities for drinking water production by the U.S. EPA.[177,178,179,180,181] The U.S. EPA expects drinking water treatment facilities to remove or inactivate a minimum of 99% *(2 log)* of *Cryptosporidium* OOCYSTS and up to 99.997% *(4.5 log)* for facilities treating source water with the highest concentration of OOCYSTS.[182] While more research and quantitative risk assessment models will be recommended to determine the safe level of removal in most AQUATIC VENUES, it is clear that the current removal rates of approximately 25% can lead to a significant number of outbreaks each year. Based on the research available for existing AQUATIC VENUE filtration technologies and risk models, a new minimum removal goal for *Cryptosporidium* removal by filters used in new and renovated swimming POOLS is recommended to be at least 90% *(1 log)* per single pass.

Filtration Systems

Multiple types of AQUATIC VENUE filtration systems have already been shown to achieve removals exceeding 99% depending on the filter design, water quality, and operational variables.

MAHC Annex Table 4.7.2.1 *(below)* contains a current summary of published research on *Cryptosporidium* or *Cryptosporidium*-sized microsphere removals via filtration in pilot-scale trials. Bench-scale results were not included due to concerns that the laboratory results might not be reproducible at pilot- or full-scale as has been observed in previous studies. MAHC Annex Table 4.7.2.1 is sorted in order of increasing filter removal efficiency, and the data is roughly divided into three groupings *(i.e., <90%, 90-99%, and >99% removal)*. Operating conditions falling into the first group would not be expected to reliably meet the new 90% *(single pass)* removal recommendation that is recommended for all new and renovated AQUATIC VENUES. Coagulant dosage, surface loading rate, and media depth can significantly impact filtration removals. Careful selection of both design and operating values is essential to achieving excellent pathogen removal with AQUATIC VENUE filters.

Table 4.7.2.1: Pilot-Scale Filter Removal Results for Cryptosporidium or Crypto-sized

175 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
176 Croll BT, et al. Simulated Cryptosporidium removal under swimming pool filtration conditions. Water Environment Journal. 2007;21:149-156.
177 Letterman RD. Water Quality and Treatment. 1999. 5th Ed. McGraw-Hill, NY.
178 AWWA. Operational Control of Coagulation and Filtration Processes: AWWA Manual. 2010;M37, 3rd ed. American Water Works Association, Denver, CO. ISBN: 978-1-58321-801-3.
179 Logsdon GS, et al. Alternative filtration methods for removal of Giardia cysts and cyst models. Journal AWWA. 1981;73(2):111-118.
180 Logsdon GS, et al. Getting your money's worth from filtration. Journal AWWA. 1982;74(5):249-256.
181 USEPA. National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule (Proposed Rule). 40 CFR Parts 141 and 142. Federal Register. 2003;68(154).
182 AWWA. Operational Control of Coagulation and Filtration Processes: AWWA Manual. 2010;M37, 3rd ed. American Water Works Association, Denver, CO. ISBN: 978-1-58321-801-3

Microspheres in Pool Water[183]

Filter Type	Media Depth	Surface Loading Rate	Coagulant Type	Coagulant Dosage	Removal (%)
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	None	n/a	25-46%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	PACl	0.014 mg/L as A1	54.2%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	PACl	0.006 mg/L as A1	62.0-64.3%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	Alum	0.06 mg/L as A1	65-68%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	PACl	0.76-0.92 mg/L as A1	87.8-98.0%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	PACl	0.065 mg/L as A1	91.5-97.3%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	Alum	0.1 mg/L as A1	94-95%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	Alum	0.3 mg/L as A1	96-97%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	PACl	0.1 mg/L as A1	99.3-99.7%
Sand	24 in. *(60.96 cm)*	10 gpm/ft^2 *(24.4 m/h)*	PACl	0.21 mg/L as A1	99.6-99.8%

Filtration Products

At the time of this writing, the following filtration products are believed to be untested for *Cryptosporidium*/4.5-micron carboxylated microsphere removal in AQUATIC VENUE water:

- Regenerative media filters,
- Sand followed by cartridge, *(with 5-micron absolute or 1-micron nominal rating)*,
- Macrolite filter media,
- Charged zeolite media,
- Crushed-recycled glass filter media, and
- Any others not listed in MAHC Annex Table 4.7.2.1.

Brief Historical Review of Water Filtration Practices for Aquatic Venues

In the U.S. in the 1920s, rapid sand filters on swimming POOLS were typically operated at 3-5 gpm/ft^2 *(7-12 m/h)* with coagulation prior to filtration, but high-rate sand filters have

183 Croll BT, et al. Simulated Cryptosporidium removal under swimming pool filtration conditions. Water and Environment Journal. 2007;21:149-156.

largely replaced rapid sand filters because they operate at 15-20 gpm/ft^2 *(37-49 m/h)* without coagulant.[184,185] While high-rate sand filters are definitely cheaper and smaller, they are also less effective at removing *Cryptosporidium*-sized particles. The majority of U.S. drinking water treatment facilities still use rapid sand filters with coagulation and typically operate them at 3-5 gpm/ft^2*(7-12 m/h)*. The U.S. EPA, after an extensive review of peer-reviewed research, decided to give drinking water treatment facilities credit for removing 99% of *Cryptosporidium* OOCYSTS for properly employing this technology *(i.e., granular media filtration with coagulation prior to filtration)*. Research has shown that high-rate AQUATIC VENUE sand filters can only consistently deliver 22 to 48% removal of *Cryptosporidium* OOCYSTS and/or a microsphere surrogate without coagulation[186].

Increased Headloss Development Rates

Pressure Development

More efficient filtration of AQUATIC VENUE water will, in most cases, lead to higher rates of pressure development in filters and more frequent backwashing of filters. The smaller the pores in the filter media at the surface of the filter, the more rapidly pressure would be expected to increase. Fortunately, there are a number of options available to design engineers that could reduce the rate of pressure development. These options include:

- The use of more uniformly graded filter media,
- Skimming fines from filter media prior to startup,
- More efficient backwashing of filters,
- Lowering the flow rate per unit surface area, and
- The use of two types of filter media in filters.

4.7.2.2 Granular Media Filters

4.7.2.2.1 General

Design Tip: When a single pump feeds two filters at 10 gpm/ft^2*(24 m/h),* redirecting the entire flow through one filter into the backwash line of the other should result in a backwash rate of approximately 20 gpm/ft^2*(49 m/h).* The backwash water would be unfiltered water that would have to be plumbed to bypass the filter. With three filters, it would be possible to redirect water from two filters into the backwash influent pipe of the third filter to provide clean backwash water.

4.7.2.2.1.3 Listed

Equipment testing of filters to industry STANDARDS is critically important, but it is only one aspect of performance. A filter certified with the hydraulic capability to pass water at 20 gpm/ft^2 *(49 m/h)* does not mean this filter should be operated at 20 gpm/ft^2*(49 m/h)*. Granular media filters perform better at removing particles and microbes at lower filter loading rates *(all other factors equal)*, and this finding has been repeatedly observed in

184 Cary WH. Administration of swimming pool standards in Detroit. Am. J. Public Health 1929;20(7):727-733.
185 Gage SD, et al. Swimming pools and other public bathing places. Am J Public Health (N Y). 1926 Dec;16(12):1186-201.
186 Amburgey JE, et al. Removal of *Cryptosporidium* and polystyrene microspheres from swimming pool water with sand, cartridge, and precoat filters. J Water Health. 2012;10(1):31-42.

practice and can be explained theoretically. Filters might need to be held to higher STANDARDS of performance in terms of water quality than the current industry STANDARD.

Manufacturers and testing laboratories might need to work together to produce more effective filters and new testing procedures. The maximum filtration rate of 15 gpm/ft^2 *(37 m/h)* is the first step toward a change in filter design STANDARDS aimed at improving microbial removal and preventing RWIs. The MAHC is intentionally more restrictive than the current NSF Standard 50 flow requirements.

4.7.2.2.2 Filter Location and Spacing

Sufficient floor space should be available to accommodate installation of additional filters to increase the original filtration surface area by up to 50% should it be recommended by future regulations or to meet current water quality STANDARDS. This is part of the hydraulic flexibility recommendation of newly constructed POOLS. The idea is to recommend space for additional filters should they become necessary at some point in the future. The 'extra' space could be utilized to make EQUIPMENT ROOMS safer and more functional.

A port and ample space for easy removal of filter media is also recommended. Filter media might be changed every 5 years. This process could be exceedingly difficult if filters are not designed with a port for this purpose or if the filters are installed without proper clearance to access the media removal port.

4.7.2.2.3 Filtration and Backwashing Rates

4.7.2.2.3.1 Operate

High-rate granular media filters shall be designed to operate at no more than 15 gpm/ft^2 *(37 m/h)* of filter surface. The minimum depth of filter media above the under-drains *(or laterals)* shall be set by the filter manufacturer. Filters with bed depths less than 15 inches *(38.1 cm)* shall operate at no greater than 12 gpm/ft^2 *(29 m/h)* of filter surface area. A minimum bed depth of 15 inches *(38.1 cm)* is required for flow rates greater than 12 gpm/ft^2 *(29 m/h)* to a maximum of 15 gpm/ft^2 *(37 m/h). Note:* Allowable filter rate is directly related to bed depth.

The granular media filter system should be designed to backwash each filter at a rate of at least 15 GPM per square foot (37 m/h) of filter bed surface area, unless explicitly prohibited by the filter manufacturer. Specially graded filter media should be recommended in filter systems backwashing at less than 20 gpm/ft^2 (48.9 m/h) to be able to expand the bed at least 20% above the fixed bed height at the design backwash flow rate, which is subject to approval by the local authority. Filtration and backwashing at the same flow rate is likely to lead to poor performance of both processes. Backwashing at double the filtration rate is not all that complicated with a 3-filter system, where the flow of two filters is used to backwash the third. Further, backwashing with unfiltered water is possible in a 2-filter system by backwashing with the entire recirculation flow through each filter individually. Variable drive pumping systems and accurate flow meters also contribute to the likelihood of successful backwashing as well as effective filtration.

Effective Filtration

Filtration at 10 gpm/ft^2 *(24 m/h)* is really pushing the envelope for attaining effective filtration and would not be recommended for a municipal drinking water system using sand filters due to doubts about the ability of such a filter to remove particulate CONTAMINANTS reliably. There are instances where multi-media deep bed filters or mono-media filters with large diameter anthracite and 6 foot *(1.8 m)* deep or greater beds of media are used, such as those owned and operated by the Los Angeles Department of Water and Power.

Effective filtration of drinking water at high filtration rates recommends careful and exact management of coagulation. Whereas filtration rates are not explicitly addressed in much of the research on water filtration, the experience of researchers, regulators, and consultants is that high rate filtration recommends extra attention and talent. For example, over three decades ago, the State of California allowed the Contra Costa Water District to operate filters at 10 gpm/ft^2 *(24 m/h)* but other water utilities were not allowed to do this. The exception was permitted because of the design and the high level of operating capability at the plant where the high rate was used.

Operation at very high rates either causes very rapid increases of head loss in sand filters *(water utility experience resulted in the conclusion that operating sand filters at rates above 3 or 4 gpm/ft2 (7-10 m/h) was impractical)* or very little particle removal occurs as water passes through the sand bed, thus enabling filters to operate for a long time at high rates. For this reason following World War II, the use of anthracite and sand filters became the norm for filters designed to operate at 4 or 5 gpm/ft^2 *(10-12 m/h)* or higher. Finally, in the 1980s, workers in Los Angeles showed that a deep *(6 foot (1.8 m))* filter with 1.5 mm effective size anthracite media could effectively filter water at rates of close to 15 gpm/ft^2 *(37 m/h).*

However, for very high rates of filtration to be effective, pretreatment has to be excellent, with proper pH and coagulant dosage, probably use of polymer, and in some cases, use of a pre-oxidant to improve filter performance. This is well understood by filter designers and professors who specialize in water filtration. Articles published on the Los Angeles work done by James Montgomery Engineers showed the importance of proper pretreatment. Papers written by experts on filtration have noted the importance of effective pretreatment *(including proper coagulation)* for dependable filter performance, and those writers were focused on rates employed in municipal filtration plants *(e.g. 3 to 10 gpm/ft^2 (7-24 m/h))*. As filtration rate increases, water velocity through the pores in the sand bed increases, making it more difficult for particles to attach to sand grains and remain in the bed instead of being pushed on through the bed and into filter effluent. When filters do not work effectively for pathogen removal, the burden is put on DISINFECTION to control the pathogens. For *Cryptosporidium,* the DISINFECTION approach that is typically most cost-effective is UV, so a very high rate filter may need to be followed by UV for pathogen inactivation, and the very high rate filters would just have to clarify the water sufficiently that there is no interference from particulate CONTAMINANTS with the UV inactivation process.

4.7.2.2.3.2 Backwash System Design

For a granular media filter system to be able to backwash at a rate of at least 15 GPM per square foot (37 m/h) of filter bed surface area, the pump*(s)*, pipes, and filters must be designed accordingly. As many professionals have sought to improve water quality by decreasing the filtration rate to values lower than 15 gpm/ft^2 *(37 m/h),* they have sometimes failed to recognize that while lowering the filtration rate may generally produce a positive change in performance, a similarly lower backwash rate could lead to a total filtration system failure. In cases where a backwash rate of 15 gpm/ft^2 *(37 m/h)* is explicitly prohibited by the filter manufacturer, the filter may still be used, provided that specially graded filter media is installed that will expand to a minimum of 20% bed expansion at the specified backwash flow rate. Viewing windows are highly recommended in all filters since they will allow direct observation of the bed expansion during backwashing, cleanliness of the media and backwash water, and the depth of the sand in the filter. Croll and coworkers[187] used a backwashing rate of 25 gpm/ft^2 (61 m/h) to achieve 25% bed expansion of their filter.

WHO Recommends

The WHO recommends a backwash rate of 15-17 gpm/ft^2 (37-42 m/h for sand filters, but the media specifications are not given nor is it clear whether or not air-scour is expected prior to backwashing.[188] Backwashing swimming POOL sand filters with air scour is common in the UK and elsewhere.[189.190] It has also been reported that air-scour washed AQUATIC VENUE filters are more efficient than filters washed by water only.[191] It is reasonable that lower backwashing rates would be used for water backwash when following air-scour since the air-scour dislodges most of the particles attached to the media grains *(as opposed to relying on the sheer force of the water passing over the surface of the particles)*. It is not feasible to operate sand filters in drinking water treatment plants without an auxiliary backwash system such as air scour.[192] The practice of operating AQUATIC VENUES and filters *(that were not using coagulation)* without air scour has been STANDARD practice in the U.S. for many years, which has seen mixed results ranging from no problems to total system failures requiring replacement of all filter media. PWTAG recommends air-scouring filters at 32 m/h (13 gpm/ft^2) *(at 0.35 bar)*.[193]

Polyphosphate Products

Polyphosphate products are sometimes used to sequester metals in POOLS, but this practice is not recommended when granular media filters are used because polyphosphate is an effective particle dispersant that can reduce the removal efficiency.

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187 Croll BT, et al. Simulated Cryptosporidium removal under swimming pool filtration conditions. Water Environ J. 2007;21:149-156.
188 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland.
Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 22, 2016.
189 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
190 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland.
Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 22, 2016.
191 Neveu A, et al. Evaluation of Operation and performance of Swimming Pool filtration Plants. Francaisd'Hydrologie. 1988;19:2:203-213.
192 Hendricks D. Water Treatment Unit Processes, Physical and Chemical. 2006. CRC Press (Taylor & Francis Group), Boca Raton, FL. ISBN: 0824706951.
193 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.

Filter Bed Expansion

Sufficient freeboard *(or space between the top of the media and the backwash overflow)* to allow for a minimum of 35% filter bed expansion during backwashing adds a factor of SAFETY when the target bed expansion is 20% to prevent the washout of filter media during backwashing.

The regions underneath the lateral underdrains in granular media filters can become stagnant when filled with sand or gravel, which can lead to low disinfectant residuals and ultimately biofilm growth. Filling this area with concrete at the time of installation may prevent this potential problem.[194] It is fundamentally difficult to suspend *(i.e., fluidize)* and hence clean filter media or gravel that is below the level where the backwash water enters the filter.

4.7.2.2.4 Minimum Filter Media Depth Requirement

The performance of high-rate granular media filters at removing pathogens and particles is contingent upon the depth of the filter media *(as shown in MAHC Annex Table 4.7.2.1)*, especially at rates of 15 gpm/ft^2 (37 m/h), which is why these filters recommend at least 24 inches *(61.0 cm)* of filter media. The WHO recommends filtration at 10-12 gpm/ft^2 *(24-29 m/h)* for sand filters while the PWTAG recommends 4-10 gpm/ft^2 *(10-24 m/h)* as the maximum filtration rate for all non-domestic POOLS using sand filters.[195,196] The STANDARD sand filter bed depth typically varies from 0.55 to 1 m *(22 to 39 inches)* in the UK.[197]

Minimum Depth

For swimming POOL filters with less than 24 inches *(61.0 cm)* of media between the top of the laterals and the top of the filter bed, lower filtration rates *(e.g., 10 gpm/ft^2 (24 m/h)* are recommended to efficiently remove particles and pathogens. Improvements in particle removal with decreasing filtration rates have been documented.[198] Drinking water treatment facilities typically limit filtration to less than 4 gpm/ft^2,(10 m/h), which is similar to the filtration rates recommended in AQUATIC VENUES in the 1920s.[199,200] The minimum depth of sand in POOL filters was 36 inches *(0.9 m)* in 1926.[201] Sand filters are typically designed in drinking water treatment for an *L/d* ratio of 1000 or greater, where *"L"* is the depth of the media and *"d"* is the diameter of the media grain.[202] For example, a 0.6 mm

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194 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
195 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
196 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 22, 2016.
197 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
198 Gregory R. Bench-marking Pool Water Treatment for Coping with Cryptosporidium. J Environ Hlth Res. 2002;1(1):11-18.
199 Logsdon GS, et al. Alternative filtration methods for removal of Giardia cysts and cyst models. Journal AWWA.1981;73(2):111-118.
200 Logsdon GS, et al. Getting your money's worth from filtration. Journal AWWA. 1982;74(5):249-256.
201 Logsdon GS, et al. Getting your money's worth from filtration. Journal AWWA. 1982;74(5):249-256.
202 Cleasby JL, et al. Chapter 8: Granular Bed and Precoat Filtration. In Water Quality and Treatment, 5th Ed. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.

effective size sand would recommend a minimum 0.6 m *(23.6 inches)* bed depth, and a 12 inch *(30.5 cm)* deep sand bed with 0.5 mm grains would have an *L/d* of only 610.

The minimum depth of filter media above the underdrains *(or laterals)* is recommended be 24 inches *(61.0 cm)* or greater with sufficient freeboard *(or space between the top of the media and the backwash overflow)* to allow for a minimum of 35% filter bed expansion during backwashing. Sand or other approved granular media should be carefully graded to ensure fluidization of the entire filter bed during backwashing.

A design backwash rate of at least 30% higher than the minimum fluidization velocity of the d90 size of the media in water at the larger of 86°F *(30°C)* or the maximum anticipated operating temperature is recommended. A backwash rate higher than the minimum could be necessary to effectively clean the media during backwashing. Variations in the media type, density, water temperature, effective size, or uniformity coefficient may cause changes in the recommended backwash flow rate and/or bed expansion, which should be subject to approval by the local authority provided hydraulic justification by the design engineer.

Sand or other approved granular media should be carefully graded to ensure fluidization of the entire filter bed during backwashing. The specifications of POOL filter sand *(or lack thereof)* can lead to filter media being installed that cannot be effectively cleaned during backwashing. Sand that cannot be properly cleaned can lead to filter failures and/or biofilms in the bottom of a filter. Researchers have found nematodes, rotifers, ciliates, zooflagellates, amoebic trophozoites and cysts, as well as bacterial masses in the backwash water of swimming POOL sand filters.[203] A design backwash rate of at least 30% higher than the minimum fluidization velocity of the d90 size of the media in water at the larger of 86°F *(30°C)* or the maximum anticipated operating temperature is recommended, but a backwash rate higher than the minimum could be necessary to effectively clean the media during backwashing. These backwashing recommendations are based on drinking water treatment practice.[204] For a sample of AQUATIC VENUE filter sand examined at University of North Carolina–Charlotte, the d90 size *(i.e., 90% of the grains smaller than this diameter)* of the media was estimated from the sieve analysis results in MAHC Annex Figure 4.7.2.1.4.1 *(below)* to be 1.06 mm. The calculated minimum fluidization velocity of this sized sand grain in water at 86°F *(30°C)* was calculated to be 16.7 gpm/ft^2 *(41 m/h)*. Since this backwash velocity would be expected to leave approximately 10% of the grains in the filter that were larger than the d90 unfluidized, common practice is to recommend a backwashing rate 30% greater than this minimum value *(or 21.7 gpm/ft2) (53 m/h)*. The recommended backwash flow for this media by Kawamura[205] was graphically estimated to be 20.9 gpm/ft^2 *(51 m/h)* at 68°F *(20°C)*. This is the rationale for requiring at least a 15 gpm/ft^2 *(37 m/h)* backwashing rate of all swimming POOL sand filters.

203 Lyons TB, and Kapur R. Limax amoebae in public swimming pools of Albany, Schenectady, and Rensselaer counties, New York: their concentration, correlations, and significance. Applied and Environmental Microbiology. 1977;33(3):551-555.
204 Cleasby JL, et al. Chapter 8: Granular Bed and Precoat Filtration. In Water Quality and Treatment, 5th Ed. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.
205 Kawamura, S. Integrated design and operation of water treatment facilities. 2000. John Wiley and Sons, Inc., NY.

To ensure compatibility with the minimum recommended backwashing rate of 15 gpm/ft^2 *(37 m/h)*, filter sand should pass through a number 20 U.S. STANDARD sieve or equivalent *(i.e., all sand grains should be smaller than approximately 0.85 mm)*. While this recommendation of "#20 Silica sand" is common in swimming POOL manuals and by filter manufacturers, it does not appear to be representative of the actual sand that might be installed. Sieve analyses of two brands of commercially available "POOL filter sand" are provided in MAHC Annex Figures 4.7.2.1.4.1 and 4.7.2.1.4.2. Sand can also be specified by an effective size *(E.S.)* of 0.45 mm with a uniformity coefficient *(U.C.)* of less than or equal to 1.45, which is roughly equivalent to a 20/40 mesh sand. A 20/40 mesh sand would pass through a #20 *(0.85 mm) sieve* and be retained on a #40 *(0.42 mm)* sieve. In order to reduce the rate of headloss accumulation at the top of the filter bed *(and the frequency of backwashing)*, a 20/30 mesh sand could be specified where the smallest grains at the top of the filter would be approximately 0.60 mm *(30 mesh)* instead of 0.42 mm *(40 mesh)*.

Figure 4.7.2.1.4.1: Grain Size Distribution of Pool Filter Sand – Brand A

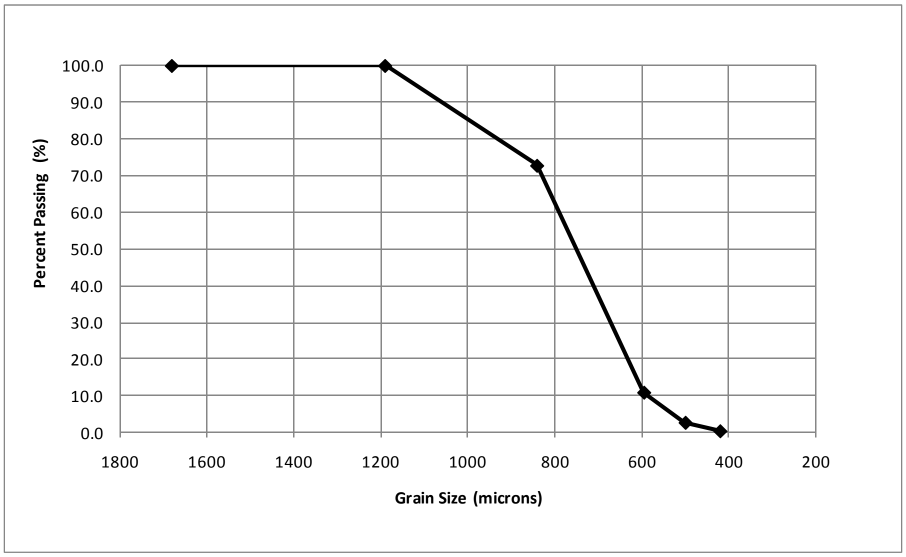
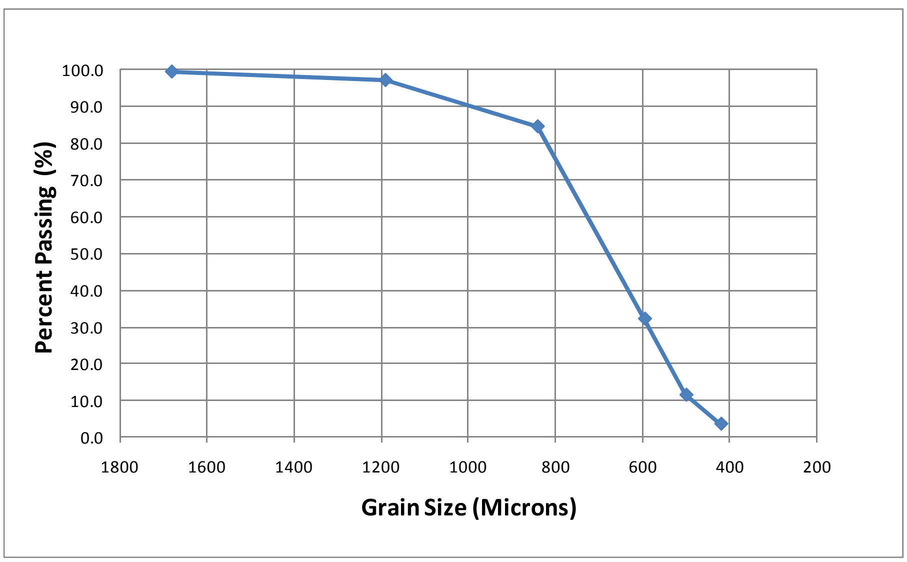


Figure 4.7.2.1.4.2: Grain Size Distribution of Pool Filter Sand – Brand B



The depth of the expanded bed during backwashing should be at least 20% greater than the depth of the fixed bed after backwashing.

Experiments to determine the backwashing rates recommended to fluidize a bed of POOL filter sand in 3-inch *(7.6 cm)* and 6-inch *(15.2 cm)* diameter clear PVC filter columns based on visual observation were conducted. Fluidization is somewhat subjective when observed visually because sand grains could be moving sluggishly prior to fluidization and because the smaller grains at the top of the filter will fluidize long before the larger grains at the bottom. For this reason, bed expansion was measured and recorded along with visual observations of when the bed actually fluidized. Fluidization was visually observed to occur between 20 and 23 gpm/ft^2 *(49-56 m/h)*, which coincided with 19-23% bed expansion in both sized columns for the unaltered commercial filter media at 68°F *(20°C)*. Expansion data from the 3-inch *(7.6 cm)* diameter filter column is shown in MAHC Annex Table 4.7.2.1.4.1 *(below)*. The 20/30 mesh fraction of the same filter media was examined under the same conditions, and the experimental results are provided in MAHC Annex Table 4.7.2.1.4.2. The media was observed to be fully fluidized at 19.9 gpm/ft^2 *(49 m/h)* with a bed expansion of 21.8% at 68°F *(20°C)*. Calculations based on Cleasby and Logsdon[206] indicate that filter backwashing rates should increase by approximately 18% for this media as the temperature is increased from 68° to 86°F *(20° to 30°C)* due to changes in the viscosity of water with temperature.

Fluidization can be somewhat complicated to estimate, but filter bed expansion can be easily measured in the field with granular media filters that use viewing windows. Furthermore, a model exists that can be used to calculate filter bed expansion of sand in a filter during backwashing.[207] This model tends to be sensitive to fixed bed porosity, but using a value of 42% porosity with a sphericity of 0.85 and density of 2.65 g/cm^3 yielded a bed expansion of 22.7% at 20 gpm for water at 86°F *(30°C)*. This is the rationale for requiring the depth of the expanded bed during backwashing being at least 20% greater than the depth of the fixed bed. PWTAG recommends 15-25% bed expansion following air scouring at 32 m/h (13 gpm/ft^2) *(at 0.35 bar)*.[208] In a study funded by PWTAG, researchers used a backwashing rate of 25 gpm/ft^2 *(61 m/h)* to achieve 25% bed expansion of their filters.[209] Variations in the media type, density, water temperature, effective size, or uniformity coefficient may cause changes in the recommended backwash flow rate and/or bed expansion, which should be subject to approval by the local authority provided hydraulic justification by the design engineer.

Table 4.7.2.1.4.1: Pool Filter Sand at 68°F (20° C)

Backwash Flow	Bed Expansion
12.4 gpm/ft^2 *(30.3 m/h)*	3.6%

206 Cleasby JL, et al. Chapter 8: Granular Bed and Precoat Filtration. In Water Quality and Treatment, 5th Ed. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.
207 Dharmarajah AH, et al. Predicting the expansion behavior of filter media. Journ. AWWA. 1986;78(12):66-76.
208 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
209 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.

16.3 gpm/ft^2 *(39.8 m/h)*	11.4%
18.5 gpm/ft^2 *(45.2 m/h)*	16.3 %
20.3 gpm/ft^2 *(49.6 m/h)*	19.3%
22.1 gpm/ft^2 *(54.0 m/h)*	22.5%

Table 4.7.2.1.4.2: Pool Filter Sand Sieved 20/30 mesh at 68°F (20° C)

Backwash Flow	Bed Expansion
12.2 gpm/ft^2 *(29.8 m/h)*	4.8%
15.8 gpm/ft^2 *(38.6 m/h)*	13.0%
17.9 gpm/ft^2 *(43.8 m/h)*	17.4 %
19.9 gpm/ft^2 *(46.6 m/h)*	21.8%
21.5 gpm/ft^2 *(52.6 m/h)*	25.6%
23.9 gpm/ft^2 *(58.4 m/h)*	31.2%

4.7.2.2.6 Coagulant Injection Equipment Installation

To enhance filter performance, a coagulant feed system, when used, should be installed with an injection point located before the filters and, for pressure filters, on the suction side of the recirculation pump*(s)* capable of delivering a variable dose of a coagulant *(e.g., polyaluminum chloride or a* POOL *clarifier product)* to enhance filter performance. Pumps should be properly sized to allow for continuous delivery of the recommended dosage of the selected coagulant. Products used to enhance filter performance should be used according to the manufacturers' recommendations. The coagulant feed system should consist of a pump, supply reservoir, tubing, ISOLATION valve, and BACKFLOW prevention device. Sand filters used as pre-filters for membranes or cartridge filters with 1-micron nominal or 5-micron absolute size ratings or less should not be recommended to have coagulant injection equipment. Specialized granular filter media capable of removing *Cryptosporidium* OOCYSTS or an acceptable 4.5-micron surrogate particle with an efficiency of at least 90% *(i.e., a minimum of 1 log reduction)* without coagulation should not be recommended to provide coagulant injection equipment, but this media should be replaced or reconditioned as recommended to sustain the minimum recommended particle removal efficiency stated above. Sand filters located ahead of a UV or ozone DISINFECTION system may be excluded from supplying coagulation equipment with the approval of the local authorities. Local authorities should consider the efficiency of the SECONDARY DISINFECTION SYSTEM process for *Cryptosporidium* inactivation but should also consider that a side-stream system does not have any effect on the *Cryptosporidium* OOCYSTS that bypass the system on each TURNOVER. For example, a UV system that is 99.999% effective at inactivating *Cryptosporidium* that only treats half of the recirculated water flow is on average only 50% effective *(per pass)* because all of the *Cryptosporidium* in the bypass stream remain unaffected by the UV.

Coagulation is the key to effective granular media filtration, which has long been recognized in the drinking water industry.[210,211,212,213,214] Operation of granular media filters without coagulation is not permitted by U.S. EPA regulations for drinking water treatment, with the exception of slow sand filters. Thus, if pathogen removal is a goal of water filtration for swimming POOL sand filters, coagulation would be essential. This is the rationale for recommending future consideration of coagulation in swimming POOLS. A coagulant feed system should be installed with an injection point located ahead of the filters to facilitate particle removal by filtration *(instead of settling to the bottom of the POOL)*, and injection ahead of the recirculation pump*(s)* will provide mixing to evenly distribute the coagulant among the particles. A variable dose of a coagulant *(e.g., polyaluminum chloride, or POOL clarifier)* is recommended because coagulant dosages may vary with BATHER LOAD. Products used to enhance filter performance should be used according to the manufacturers' recommendations since overfeed or underfeed of coagulants is known to impair performance.

Although polyaluminum chloride *(PACl)* is not a widely used coagulant in the U.S. at present, it has been used extensively abroad.[215,216] However, recommended dosages abroad may not be optimized for pathogen removal. PWTAG recommends a polyaluminum chloride dosage of 0.005 mg/L as Al, but research has shown that 0.05 mg/L is recommended to exceed 90% removal and 0.21 mg/L or higher could be optimal with filters operated based on U.K. STANDARDS.[217]

New Challenges: The Impact of Coagulation on Backwashing

Coagulation is likely to make cleaning of sand filters more challenging. Drinking water treatment facilities in the U.S. employ auxiliary backwash systems such as air-scour to improve the cleaning process. Using water alone for backwashing has not been found to

210 Letterman RD. Water Quality and Treatment. 1999. 5th Ed. McGraw-Hill, NY.
211 AWWA. Operational Control of Coagulation and Filtration Processes: AWWA Manual. 2010;M37, 3rd ed. American Water Works Association, Denver, CO. ISBN: 978-1-58321-801-3.
212 Logsdon GS, et al. Getting your money's worth from filtration. Journal AWWA. 1982;74(5):249-256.
213 USEPA. National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule (Proposed Rule). 40 CFR Parts 141 and 142. Federal Register. 2003;68(154).
214 Logsdon GS. Water filtration practices: including slow sand filters and precoat filtration. 2008. American Water Works Association, Denver, CO. ISBN: 9781583215951.
215 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
216 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland.
Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 22, 2016.
217 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.

be effective for media cleaning in drinking water treatment applications.[218] Air scour systems are common in European AQUATIC VENUE filters and should be investigated further in the U.S. More frequent backwashing is recommended with water-only backwash, and the clean-bed headloss *(pressure)* should be recorded after each backwash to detect early signs of ineffective backwashing and prevent filter system failures.

Initial Headloss and Headloss Accumulation Rate

Increased headloss *(or pressure buildup)* in filters is expected with coagulation as particles are likely to be removed faster *(more efficiently)* and closer to the top of the filter thereby clogging the top of the filter more quickly. This is actually a sign that the coagulation/filtration system is working effectively. The initial headloss after backwashing should remain relatively constant however. Coagulants have been used successfully in the U.S. in the past and are currently being used in POOLS abroad. [219,220,221,222] In systems not properly designed to backwash with filter effluent from other filters, the coagulant feed system should not be operated during backwashing so as to prevent introduction of coagulant into the backwash water.

4.7.2.3 Precoat Filters

4.7.2.3.2 Filtration Rates

The design filtration rate of 2.0 GPM per square foot *(4.9 m/h)* might be overly conservative and is the same upper limit on filtration rate typically used in drinking water treatment applications.[223] However, drinking water applications typically use finer grades of precoat media at application rates of 0.2 lbs/ft^2 *(1 kg/m^2)*.[32] Lange and coworkers[224] have used filtration rates up to 4 gpm/ft^2 *(10 m/h)* with no adverse effect on *Giardia* cyst removal although the removal of turbidity and bacteria were decreased. Ongerth and Hutton[225] found better removals at 2 gpm/ft^2 (5 m/h) than at 1 gpm/ft^2 (2.4 m/h) for *Cryptosporidium* OOCYSTS under drinking water treatment conditions *(i.e., 0.2 lbs/ft^2 (1 kg/m^2) of DE with body-feed)*.

4.7.2.3.3 Precoat Media Introduction System Process

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218 Hendricks D. Water Treatment Unit Processes, Physical and Chemical. 2006. CRC Press (Taylor & Francis Group), Boca Raton, FL. ISBN: 0824706951.
219 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
220 Logsdon GS, et al. Alternative filtration methods for removal of Giardia cysts and cyst models. Journal AWWA. 1981;73(2):111-118.
221 Logsdon GS, et al. Getting your money's worth from filtration. Journal AWWA. 1982;74(5):249-256.
222 DIN. Treatment and Disinfection of Water Used in Bathing Facilities, Part 1: General Requirements. 1997. Ref. No. 19643-1.
223 Logsdon GS. Water filtration practices: including slow sand filters and precoat filtration. 2008. American Water Works Association, Denver, CO. ISBN: 9781583215951.
224 Lange KP, et al. Diatomaceous earth filtration of Giardia cysts and other substances. Journal AWWA. 1986;78(1):76-84.
225 Ongerth JE, et al. Testing of diatomaceous earth filtration for removal of Cryptosporidium oocysts. Journal AWWA. 2001;93(12):54-63.

The precoat process shall follow the manufacturer's recommendations and requirements of NSF/ANSI Standard 50.

Separation Tank

Precoat filter media has the potential to settle out of suspension in sewer pipes depending on the flow velocities, which could lead to fouling or clogging of sewer pipes. Local authorities may recommend removal of precoat media prior to discharge in sewer systems so POOL operators should check the AHJ.

4.7.2.3.4 Continuous Filter Media Feed Equipment

Filter performance can be significantly impacted by the selection of the precoat filter media, which could alter water clarity, pathogen removal, and cycle length. Multiple grades of precoat media are available in the marketplace. Precoat media can be specified by median particle size of the media or by permeability of the media.[226]

4.7.2.4 Cartridge Filters

4.7.2.4.1 Listed

Cartridge filters have not been demonstrated to remove pathogens like *Cryptosporidium* efficiently using the STANDARD swimming POOL cartridges, and the non-standardized manual cleaning methods for cartridges may lead to pathogen and/or chemical exposure risks to PATRONS and employees at AQUATIC VENUES while the fouling of cartridges may lead to AQUATIC VENUES exceeding their maximum recommended TURNOVER times. Poor use of PPE and non-STANDARD cleaning of SPA cartridge filters led to non-tuberculosis mycobacterial infections in SPA workers[227]. Due to these health and SAFETY concerns, cartridge filter use is not recommended in AQUATIC VENUES.

Cleaning procedures for cartridges are not well-established and education in proper cleaning procedures is likely necessary to avoid contaminated cartridges being reinstalled into filters potentially providing a protected region for proliferation of biofilm bacteria the could lead to an outbreak. Cartridge filter elements are typically cleaned manually, usually by hosing them down with a water hose and replacing them. Exposure concerns exist since concentrated streams containing *Legionella*, *Mycobacteria*, *Cryptosporidium*, and other pathogens can potentially be sprayed or splashed on the operator/lifeguard as well as the surrounding environment perhaps even including the inside of the filter or the surfaces surrounding the AQUATIC VENUES.

An extensive survey of manufacturers' cleaning recommendations was conducted after there was a legionellosis outbreak in a facility with cartridge filters. *Legionella, Pseudomonas,* and biofilms were found in the filters. The cleaning procedure employed was to take them outside, rinse them with a water hose, and replace them. Operators

226 Cleasby JL et al. Chapter 8: Granular Bed and Precoat Filtration. In Water Quality and Treatment, 5th Ed. McGraw Hill, Inc. NY:1999. ISBN: 0070016593.
227 Moraga-McHaley SA, et al. Hypersensitivity pneumonitis with Mycobacterium avium complex among spa workers. J Occup Environ Health. 2013;19(1):55-61.

reported that they would occasionally degrease or bleach them. Further investigation revealed that this cleaning procedure was common at other facilities.

Filter manufacturers were surveyed for cleaning procedures and most often did not have a cleaning process and simply deferred to the cartridge manufacturer since many filter manufacturers do not make the cartridges. The cartridge manufacturers also did not have a cleaning procedure or a very minimal one that did not account for biofilms or heavy organic loads commonly encountered in SPAS. CHLORINE is generally ineffective at inactivating bacteria in a biofilm or removing particulate or organic filter foulants. One effective way to control the biofilms is to completely dry them out.

Based on the known poor performance in removing pathogens increasing the likelihood of waterborne disease outbreaks and the potential for dangerous microbial *(and perhaps chemical)* exposures to the operators during routine maintenance and cleaning, cartridge filters are not currently recommended. This is not to say that all of the current issues and/or concerns with cartridge filters could not be resolved.

4.7.2.4.2 Filtration Rates

Cartridge filter elements should have a listed maximum flow rate of 0.375 GPM per square foot *(0.26 L/s/m^2)*, but the design filtration rate for surface-type cartridge filter should not exceed 0.30 GPM per square foot *(0.20 L/s/m^2).*Cartridges don't recover 100% capacity when cleaned after fouling. Systems designed to the maximum limit cannot sustain performance *(or minimum POOL TURNOVER requirements)* over time. For example, if a filter only recovers to 80% of the original flux after cleaning, then a filter flow rate of 0.375 GPM per square foot *(0.26 L/s/m^2)* would become 0.30 GPM per square foot *(0.20 L/s/m^2)*. Cartridge replacement would be necessary following fouling levels greater than 20% of the maximum rated capacity.

4.7.2.4.3 Supplied and Sized

The pore size and surface area of replacement cartridges should match the manufacturer's recommendations.

4.7.2.4.4 Spare Cartridge

An extra set of elements, with at least 100 percent filter area, and appropriate cleaning facilities and equipment should be provided to allow filter cartridges to be thoroughly cleaned. Two sets of filter cartridges should be supplied to allow for immediate replacement and cleaning procedures that involve complete drying of the filter elements.

4.7.3 Disinfection and pH Control

Disinfection and Indoor Air Quality

To provide for a healthy and safe swimming environment in INDOOR AQUATIC FACILITIES, it is important to consider a number of issues that could impact health. Proper ventilation and humidity control are important in removing excess heat, moisture, noxious odors, and harmful DBPs.[228]

Proper Chemical Use

In addition, proper usage of chemicals can also improve the quality of the indoor air environment. [229,230,231]

High Chloramines

High levels of chloramines and other volatile compounds in the air can increase the possibility of health effects such as upper respiratory illnesses and irritation of the mucous membranes including eyes and lungs.[232,233] Furthermore, these CONTAMINANTS can also cause metal structures and equipment to deteriorate.

Shock Oxidizer

While proper ventilation is critical for INDOOR AQUATIC FACILITIES, water chemistry also can dramatically affect air quality. Levels of chloramines and other volatile compounds can be minimized by reducing CONTAMINANTS that lead to their formation *(e.g., urea, creatinine, amino acids, and personal care products)*, as well as by supplemental water treatment. Effective filtration, water replacement, and improved BATHER hygiene can reduce CONTAMINANTS and chloramine formation. Research has shown that the use of non-CHLORINE shock OXIDIZERS is selective in OXIDATION and may not prevent nor reduce inorganic chloramines though they may reduce some organic chloramines.[234] The EPA final guidelines state that manufacturers of "shock OXIDIZERS" may advertise that their "shock OXIDIZER" products "remove," "reduce," or "eliminate" organic CONTAMINANTS. Shock dosing with CHLORINE can destroy inorganic chloramines that are formed. SECONDARY DISINFECTION SYSTEMS such as ozone and UV light may effectively destroy inorganic as well as some organic chloramines.

Swimmer Education

228 Chen L, et al. Health hazard evaluation report: investigation of employee symptoms at an indoor waterpark. Cincinnati, OH: US Department of Health and Human Services, CDC, National Institute for Occupational Safety and Health: 2008. Report no. HETA2007-0163-3062. Available at http://www.cdc.gov/niosh/hhe/reports/pdfs/2007-0163-3062.pdf. Accessed on April 22, 2016.
229 Bowen AB, et al. Outbreaks of short-incubation ocular and respiratory illness following exposure to indoor swimming pools. Environ Health Perspect. 2007 Feb;115(2):267-71.
230 Kaydos-Daniels SC, et al. Health effects associated with indoor swimming pools: a suspected toxic chloramine exposure. Public Health. 2008 Feb;122(2):195-200.
231 CDC. Ocular and respiratory illness associated with an indoor swimming pool--Nebraska, 2006. MMWR Morb Mortal Wkly Rep. 2007 Sep 14;56(36):929-32.
232 Hery M, et al. Exposure to metallic catalyst dust: manufacturing and handling of catalysts in the chemical industry. Ann Occup Hyg. 1994 Apr;38(2):119-35.
233 Massin N, et al. Respiratory symptoms and bronchial responsiveness in lifeguards exposed to nitrogen trichloride in indoor swimming pools. Occup Environ Med. 1998 Apr;55(4):258-63.
234 Anipsitakis GP, et al. Chemical and microbial decontamination of pool water using activated potassium peroxymonosulfate. Water Res. 2008 Jun;42(12):2899-2910.

In addition, swimmers should be educated that their behavior *(e.g., failing to SHOWER, urinating in the POOL)* can negatively impact air quality by introducing nitrogen-containing CONTAMINANTS that form volatile compounds.[235]

Reduce and Minimize Impact

These steps can help reduce the chemical role in creating poor indoor air quality, and help maintain an environment that minimizes health effects on BATHERS as well as decrease deterioration of AQUATIC FACILITIES and equipment.

4.7.3.2 Feed Equipment

4.7.3.2.1 General

If recirculation pumps stop but chemical feed pumps continue to pump chemicals into the return lines it can result in a high concentration of acid and CHLORINE being mixed so that eventually when concentrated solutions of CHLORINE and acid are mixed, CHLORINE gas will be formed. The CHLORINE gas could then be released into the AQUATIC VENUE when the recirculation pump is turned on again or in the pump room if there is an opening in the line as has been documented in CDC's Waterborne Disease and Outbreak Surveillance System[236]. To prevent the hazardous release of CHLORINE gas, the chemical feed system shall be designed so that the CHLORINE and pH feed pumps will be deactivated when there is no or low flow in the RECIRCULATION SYSTEM.

4.7.3.2.2 Sizing of Disinfection Equipment

High use facilities, such as water parks and health clubs, require a greater capacity of feed equipment and production. These facilities generally have higher recirculation rates and experience accelerated consumption and should be sized differently to provide the minimum dosing.

4.7.3.2.5 Types of Feeders

All UV units shall be installed into the system by means of a bypass pipe to allow maintenance on the UV unit while the AQUATIC VENUE is in operation.

4.7.3.2.7 Feeders for pH Adjustment

It is recommended that the solution's reservoir supply be sized to hold a minimum of one week's supply.

4.7.3.2.8 Automated Controllers

Constant and regular MONITORING of key water quality parameters such as the disinfectant level and pH are critical to prevent recreational water illness and outbreaks. AUTOMATED CONTROLLERS are more reliable as a MONITORING device than personnel and hand feeding chemical. Automated chemical controllers are therefore required for use on every AQUATIC

235 Chen L, et al. Health hazard evaluation report: investigation of employee symptoms at an indoor waterpark. Cincinnati, OH: US Department of Health and Human Services, CDC, National Institute for Occupational Safety and Health: 2008. Report no. HETA2007-0163-3062. Available at http://www.cdc.gov/niosh/hhe/reports/pdfs/2007-0163-3062.pdf. Accessed on April 22, 2016.
236 Hlavsa MC, et al. Surveillance for waterborne disease outbreaks and other health events associated with recreational water use — United States, 2007–2008. MMWR Surveill Summ. 2011;60:1-37.

VENUE with a time of one year built in for facilities to become compliant after adoption of this requirement. The use of AUTOMATED CONTROLLERS does not negate the requirements for regular water testing. Automated units require verification of proper function and the probes do fail or slip out of calibration. This can only be detected by MONITORING the water quality.

4.7.3.3 Secondary Disinfection Systems

4.7.3.3.1 General Requirements

4.7.3.3.1.1 ANSI Listing and Labeling

EPA regulates the labeling of pesticides. According to EPA requirement 40 CFR 156.10, the establishment registration number may appear in any suitable location on the pesticide label or immediate container. More information on pesticide establishment registration numbers can be found here:http://www2.epa.gov/pesticide-registration/pesticide-registration-manual-chapter-13-devices.

4.7.3.3.1.2 Required Facilities

Due to the risk of outbreaks of RWIs associated with the disinfectant tolerant parasite *Cryptosporidium*, it is strongly recommended that all AQUATIC FACILITIES include SECONDARY DISINFECTION SYSTEMS to minimize the risk to the public associated with these outbreaks.

Increased Risk Aquatic Venues

However, there are some AQUATIC VENUES where the risk of acquiring a RWI is elevated *(INCREASED RISK AQUATIC VENUES)* due to either the use of the AQUATIC VENUE, or the users. THERAPY POOLS, for example, are often utilized by individuals with compromised immune systems and/or open wounds. The risk of acquiring an RWI is substantially increased under such circumstances. WADING POOLS are utilized by small children who may be in diapers. Incontinent infants and small children are likely to increase the contamination burden *(e.g.: urine and feces)* in the water, thereby creating an increased risk of disease to other users. In addition, cryptosporidiosis is more prevalent in younger children.[237] INTERACTIVE WATER PLAY VENUES such as spray pads, fountains, and similar features are most often used by smaller children who are likely to increase the risk of water contamination occurring. They also may be more likely to suffer from more severe illness when they become infected.

Intent

The intent of requiring a SECONDARY DISINFECTION SYSTEM is to limit the length of time of exposure to agents that cause diarrheal illness, in particular *Cryptosporidium*, after a fecal release in INCREASED RISK AQUATIC VENUES.

Facilities

These facilities include THERAPY POOLS, and WADING POOLS, water ACTIVITY POOLS, INTERACTIVE WATER PLAY AQUATIC VENUES *(e.g., spray pads)*, and other AQUATIC VENUES with no standing water designed primarily for young children, including children less than

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237 CDC. Cryptosporidiosis surveillance -- United States, 2011-2012. MMWR Suppl. 2015 May 1;64(3):1-14.

5 years of age. In these facilities, the potential of diarrheal illness is elevated due to the population mix of the BATHERS and the design of the facility. The pathogens of concern in such facilities are *Cryptosporidium*, *Giardia*, *Shigella*, *E. coli* O157:H7, and Norovirus. *Shigella* and *E coli* 0157:H7 are very sensitive to traditional CHLORINE DISINFECTION. However, the seriousness of illness caused by highly *(Cryptosporidium)* and moderately *(Giardia, norovirus)* CHLORINE tolerant pathogens is the reason a SECONDARY DISINFECTION SYSTEM is ***required*** for all new or SUBSTANTIALLY ALTERED construction of these types of AQUATIC FACILITIES after the adoption of this CODE. When older facilities are SUBSTANTIALLY ALTERED, they must retrofit to meet this treatment requirement.

4.7.3.3.2 3-log Inactivation and Oocyst Reduction

4.7.3.3.2.1 3-log Inactivation

Examples of SECONDARY DISINFECTION SYSTEMS include but are not necessarily limited to UV DISINFECTION and ozone DISINFECTION.

4.7.3.3.2.2 Installation

SECONDARY DISINFECTION SYSTEMS are located in the treatment loop *(post-filtration)* and treat a portion *(up to 100%)* of the filtration flow prior to return of the water to the AQUATIC VENUE or AQUATIC FEATURE. For INTERACTIVE WATER PLAY AQUATIC VENUES, the SECONDARY DISINFECTION SYSTEM is also to be installed on the filtration system loop and not a separate AQUATIC FEATURE line. The filtration system operates continuously, which is necessary to achieve the intended reduction of *Cryptosporidium* in the treatment tank in the specified time period. Installation on an AQUATIC FEATURE loop will not ensure that the intended treatment outcome will be met, especially since the feature pumps do not typically operate continuously throughout the entire day *(24 hours; typically turned off at night)*.

4.7.3.3.2.4 Minimum Flow Rate Calculation

The SECONDARY DISINFECTION SYSTEM is to be designed to reduce an assumed total number of infective *Cryptosporidium* OOCYSTS in the total volume of the AQUATIC VENUE from an assumed 100 million *(10^8)* OOCYSTS to a maximum concentration of one infective OOCYST/100 mL by means of consecutive dilution.

4.7.3.3.2.5 Equation

In considering the potential for outbreaks, it was decided that a treatment system should be designed to limit the outbreak to a reasonable period of time, preferably to a single day of operation. By this, it is meant that all pathogens of concern that may still be present at infective concentrations at the close of operations are reduced to below a level of infectivity by the opening time of the following day. This approach has been recommended because numerous multi-day outbreaks have been well documented. [238,239,240] In order to

238 Causer L, et al. An outbreak of Cryptosporidium hominis infection at an Illinois recreational waterpark. Epidemiol Infect. 2006 February; 134(1): 147–156.
239 Wheeler C, et al. Outbreak of cryptosporidiosis at a California waterpark: employee and patron roles and the long road towards prevention. Epidemiol Infect. 2007 Feb;135(2):302-10.
240 CDC. Communitywide cryptosporidiosis outbreak--Utah, 2007. MMWR Morb Mortal Wkly Rep. 2008 Sep 12;57(36):989-93.

design a treatment system that can reduce the duration of exposure to a single day, the MAHC Committee made the following assumptions:

- The target of concern is *Cryptosporidium*. Based on known CT INACTIVATION VALUES , all other pathogens will be inactivated within an hour if the facility is maintaining at least 1 ppm of free CHLORINE.
- At a concentration of 1 ppm free CHLORINE, any *Cryptosporidium* OOCYSTS left circulating in the water may be infective for up to 15,300 minutes *(>10 days)* after introduction.
- A single contamination event *(e.g. diarrheal incident)* of ~100 mL could introduce 10^8 *Cryptosporidium* OOCYSTS into the water. [241,242]
- Reducing the amount of *Cryptosporidium* below the level at which there is one infectious OOCYST per average volume swallowed by swimmers *(16-128 mL)* would be a reasonable target for overnight remediation of the water to reduce the risk of transmission beyond the day of initial contamination. [243,244] The concentration chosen was one OOCYST/100mL.
- The only effective means currently to reduce the concentration of OOCYST in an AQUATIC VENUE while open for bathing is by dilution *(this does not include HYPERCHLORINATION that requires closure of the water to BATHERS)*. Accomplishing this through the introduction of sufficient makeup water is not practical. Instead, the solution is to remove a portion of the water, treat it to reduce the concentration of infectious OOCYSTS, and then return that water to the AQUATIC VENUE.
- SECONDARY DISINFECTION SYSTEMS can practically achieve a 3-log *(99.9%)* reduction in the number of infective OOCYSTS per pass through the SECONDARY DISINFECTION SYSTEM.
- Due to imperfect mixing and other real work constraints, a SAFETY factor of 1.33 has been applied to the maximum dilution time, as defined as the time it will take for 10^8 OOCYSTS introduced into an AQUATIC VENUE *(e.g. a diarrheal event)* to be reduced to a maximum concentration of 1 OOCYST per 100 mL.
- A reasonable expected overnight closure time for an AQUATIC VENUE is 12 hours *(e.g. 8 p.m. to 8 a.m.)*. Therefore 9 hours has been established as the maximum dilution time *(12 / 1.33 or 12 x 0.75)* to be used when sizing a SECONDARY DISINFECTION SYSTEM. If the actual expected closure time of a venue is less than 12 hours, then 75% of that value shall be used for the dilution time.

Any treatment system that demonstrates this reduction in *Cryptosporidium* OOCYSTS specified herein is suitable for use. It is not the intent of the MAHC to limit technology only to UV and ozone as discussed in the CODE, but rather to specify the outcome of the treatment.

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241 Chappell CL, et al. Cryptosporidium parvum: intensity of infection and oocyst excretion patterns in healthy volunteers. J Infect Dis. 1996 Jan;173(1):232-6.
242 Goodgame RW, et al. Intensity of infection in AIDS-associated cryptosporidiosis. J Infect Dis. 1993 Mar;167(3):704-9.
243 Dufour AP, et al. Water ingestion during swimming activities in a pool: a pilot study. J Water Health. 2006 Dec;4(4):425-30.
244 Allen LM, et al. Absorption and excretion of cyanuric acid in long-distance swimmers. Drug Metab Rev. 1982;13(3):499-516.

Purpose

The purpose of secondary DISINFECTION is to reduce the viable *Cryptosporidium* OOCYSTS to a number below that which is considered an infective concentration, should the parasite be introduced into an AQUATIC VENUE. While 100% UV treatment of recirculated water is an option, it is important to note that this will not ensure the SAFETY of the BATHERS immediately following a fecal event, but it will reduce the time required for the system to get below an infective dose. While this is beneficial, mandating UV on 100% of the recirculated water flow may lead owners and designers to minimize the total recirculated flow so as to not incur the additional capital and operating cost of the required additional UV, ozone, or other SECONDARY DISINFECTION SYSTEMS. *Cryptosporidium* control is not the only consideration when designing an INCREASED RISK AQUATIC VENUE, and it is important that this requirement does not negatively influence other design considerations—such as amount of filtration needed for particulate removal and control of turbidity.

Consideration was therefore given to what should be the maximum time a system takes to reduce the viable OOCYST concentration to below an effective dose. Because a fecal event can release 100 million OOCYSTS and an infective dose is as little as one OOCYST per 100 mL, it is impossible with available technology today to ensure the SAFETY of BATHERS in the AQUATIC VENUE both at the time the fecal event occurs and in the immediate aftermath. A reasonable and logical maximum time for reducing the OOCYST concentration to below one OOCYST/100mL was determined to be the lesser of nine hours or 75% of the time an AQUATIC VENUE is closed in a 24-hour period. The goal of this is to ensure an AQUATIC VENUE is free of viable *Cryptosporidium* OOCYSTS, or at least have the number below an infective concentration every day the AQUATIC VENUE opens to the public.

Example of Equation

The actual calculation used to determine the amount of needed SECONDARY DISINFECTION is based upon the understanding that the treatment of recirculated AQUATIC VENUES involves serial dilution, whether we are talking about particulate removal or rendering *Cryptosporidium* OOCYST ineffective. Assuming an initial concentration of 10^8 OOCYSTS, recognizing the limit of an infective dose is one OOCYST/100 mL, and allowing for a 99.9% reduction in infective OOCYST by the SECONDARY DISINFECTION SYSTEM, it can be derived that needed flow through the SECONDARY DISINFECTION SYSTEM is as given in the MAHC.

An example of how to calculate for the needed flow is as follows:

$$Q = V \times \{[14.8 - \ln(V)] / (60 \times T)\}$$, where:

- Q = Secondary DISINFECTION system flow rate *(gpm)*
- V = Total water volume of the aquatic venue or AQUATIC FEATURE, including surge tanks, piping, equipment, etc. *(gals)*
- T = Dilution time *(hrs.)*

For a 100,000 gallon *(378,541 L)* AQUATIC VENUE which is closed 12 continuous hours out of every 24 hours, 75% of which is 9 hours:

- $100{,}000 \times \{ [14.8 - \ln(100{,}000)] / (60 \times 9)\} = 609$ gpm

Therefore, the 100,000 gallon *(378,541 L)* AQUATIC VENUE would require a SECONDARY DISINFECTION SYSTEM which has a flow rate of at least 609 gpm. If this AQUATIC VENUE is designed with a two hour filtration TURNOVER RATE, the flow through the filters would be 833 gpm. An owner or designer can choose to size the SECONDARY FILTRATION SYSTEM to be 609 gpm, 833 gpm, or anything in between. If the owner or designer chooses to size the SECONDARY DISINFECTION SYSTEM equal to the filtration flow rate *(833 gpm)* the time it would take to reduce 10^8 OOCYST to 1 OOCYST/100 mL would be 6.6 instead of 9 hours.

4.7.3.3.2.7 Flow Rate Measurements

Consideration was given for simplifying the sizing of the SECONDARY DISINFECTION SYSTEM and having the flow rate through the SECONDARY DISINFECTION SYSTEM equal to the overall treatment system flow rate. While this was initially recommended by the MAHC, ultimately this approach was rejected. A basic premise of the MAHC is to establish performance-based STANDARDS supported by data and science whenever possible. Sizing the SECONDARY DISINFECTION SYSTEM equal to the overall treatment system flow rate, while simplifying the design and operation of the facility, does not meet any defined criteria for reducing or eliminating risk to the PATRONS using the AQUATIC FACILITY. It was felt that establishing specific criteria for sizing the SECONDARY DISINFECTION SYSTEM independent of the criteria for sizing other treatment system processes *(e.g. filtration flow rate)* was the approach most likely to protect the public's health.

Maximum Concentrations

In developing this approach, the MAHC considered establishing maximum permissible concentrations of OOCYSTS, which would be monitored and verified, but the MAHC rejected that approach as impractical since this would require actual lab testing.

Establishing a concentration based STANDARD for the water cannot readily be implemented because:

- There is no practical method to rapidly determine the number of OOCYSTS in the water and thus no method to enforce the STANDARD.
- There are multiple and interrelated biological variables in exposure estimations. These include the number of OOCYSTS released per fecal incident, the number of incidents per day, strain differences in pathogenicity, the amount of water swallowed, and differences in individual susceptibility.
- The circulatory patterns in facilities are complex and unique to each AQUATIC FACILITY.

Requiring that the SECONDARY DISINFECTION SYSTEM deliver a treatment that ensured the OOCYST concentration was reduced to a specified level would require multiple biological assumptions and computer modeling that exceed those currently required for any other water parameter.

4.7.3.3.3 Ultraviolet Light Systems

UV DISINFECTION is a SECONDARY DISINFECTION SYSTEM and must meet the minimum requirements of all SECONDARY DISINFECTION SYSTEMS as defined in MAHC 4.7.3.3. The minimum requirements must be read in conjunction with the clarifications and additional information as detailed below.

Mercury clean-up procedures for broken UV lamps can be found in Section E.1.2 of EPA 815-R-06-007 Appendix E: http://goo.gl/edykzN. The MAHC agrees that knowledge of appropriate mercury clean-up is essential for operator SAFETY. If this is considered for inclusion in the MAHC then additional guidance on training requirements should be included. Guidance should include who should be trained (e.g., owner, operator, manager), the type of training required (e.g., on the job, classwork), and how inspectors should verify operators are trained (e.g., completion certificate, demonstration of knowledge?). Such guidance can be found in Section E.1.2 of EPA 815-R-06-007 Appendix E.

4.7.3.3.3.1 Third Party Validation

Validation to a recognized national STANDARD is carried out by a recognized and capable third party. Such validation needs to take into consideration lamp life, UV MONITORING, and optical water quality. Typical POOL water qualities vary, but a design UV TRANSMISSIVITY assumption of better than 94% T10 should not be used. T10 is the ability of an object to transmit UV. Where possible, transmissivity tests should be obtained for existing facilities.

4.7.3.3.3.1.1 Validation Standard

Validation is a process by which any UV unit is tested against a surrogate microorganism in order to determine its performance. Validation is required because there is no on-line test of a UV unit's ability to disinfect and, due to the relatively short contact time, it is impossible to size units accurately based on just calculations.

It is important to note that evidence of testing is not the same as validation.

Validation must adhere to the following criteria:

- Follow one of the approved validation systems, preferably the USEPA DGM 2006,
- Have been carried out be a genuine third party, and
- Include all the required validation factors and RED BIAS.

The validated performance is based on the flow and transmissivity of the water to be treated. Therefore it is essential that the system is used within its validated performance range. A system operated outside its validated range is NOT acceptable.

Validation Factor

The validation factor is used to account for statistical variations in the recorded data during third party testing. The validation factor is required to ensure that the equipment's actual performance will always be equal to or better than it's validated performance. This figure can be between 15% and 35% depending on the quality of the testing and must be included in any validated performance curve.

Transmissivity (Transmission)

The transmissivity *(often called transmission)* of the water to be treated is an important design factor in sizing a UV system. The transmissivity is normally quoted as a % value in either a 1 cm, 4 cm, or 5 cm cell. It is measured in a UV Spectrophotometer.

In many water treatment applications, this value will vary considerably but AQUATIC VENUES are for the most part consistent, due to the bleaching effect of the CHLORINE used as a residual disinfectant.

Typically AQUATIC VENUES will have a transmission of between 94% and 95% in a 1 cm cell, with splash pads and other INTERACTIVE WATER PLAY VENUES between 92% and 94%.

The installation of a UV unit itself will increase the transmission by perhaps 2% due to the improvement in the POOL water quality so the values noted above refer to a situation where a UV unit is installed and operational.

Design transmissions over 94% are not recommended, and exceptionally heavily loaded AQUATIC VENUES may consider using a lower number as a design basis.

It is also important to understand that as transmission is reduced, the performance of the equipment is reduced and the RED BIAS increases, requiring the UV to deliver more performance. For this reason, the performance difference between any equipment's validated performance at 98% transmissivity and actual field performance at 94% transmissivity can be 40% lower. When presented with validated performance data at 98% transmission, operators should therefore be aware that the equipment may only deliver half the performance when installed.

Validation Range

A validated system will have different performance levels at different water qualities and flows. The relationship between these is traditionally represented as a performance curve where the performance can be noted at any point on this curve. However the lowest transmission test point and the highest flow tested are normally considered the extents of the validated range. This means that any UV unit tested at 95% and above is NOT validated at transmissions lower than 95%. For the same reason, a unit tested at a maximum flow of 500 gpm is NOT validated for any flow over 500 gpm.

Validation factors can reduce equipment validated performance by 30%, so it is essential that systems without validation factors built into performance curves are not considered validated.

The performance of a UV system in the field is measured by a combination of flow and intensity readings from the UV sensors. Performance in the field can be verified on inspection by regulators who will compare actual sensor readings with those indicated on the performance charts, so these charts must be retained at the AQUATIC FACILITY for each validated system.

UV equipment is utilized for its ability to disinfect CHLORINE-tolerant pathogens and for its ability to reduce combined CHLORINES in the POOL water. For the latter, typically a calculated dose of 60mJ/cm^2 is utilized based on the total UV-C and UV-B spectrum. This is similar to the validated dose requirements of the SECONDARY DISINFECTION SYSTEMS.

Where UV is fitted as a SUPPLEMENTAL TREATMENT SYSTEM the CODE allows some operational and equipment concessions. Operators should note that the regulations as stated represent BEST PRACTICE; but where specific circumstances dictate, then the equipment specifications may be reduced.

For a SUPPLEMENTAL TREATMENT SYSTEM, the operator may consider reducing the dose applied to the process. This will reduce performance accordingly and operators should consider carefully such reduction in performance, and assure themselves that the equipment will still provide a beneficial level of performance.

4.7.3.3.3.10 Minimum RED

The U.S. EPA identifies the required dose for various organisms to achieve 3- or 4-log reduction. This dose must be modified by the RED BIAS in order to ensure delivery of validated performance. Depending on the quality of the water, this RED BIAS can be between 35% and 70%.

4.7.3.3.4 Ozone Disinfection

4.7.3.3.4.1 3-log Inactivation

Ozone is a SECONDARY DISINFECTION SYSTEM and must meet the minimum requirements of all SECONDARY DISINFECTION SYSTEMS as defined in MAHC 4.7.3.3.

Ozone is an antimicrobial OXIDIZER. Its use as a SECONDARY DISINFECTION SYSTEM in commercial swimming POOLS in the U.S. dates back to the 1930s. Ozone is proven to kill *Cryptosporidium*[245], *Giardia*[246], *E. coli*[247], and *Pseudomonas aeruginosa*[248], along with any other microorganism potentially found in AQUATIC VENUES, and is a strong OXIDIZER. Exposure to ozone gas can result in irritation to the eyes and respiratory tract if not generated and handled correctly. Therefore OSHA has identified a time weighted average *(TWA)* of 0.1 ppm *(0.1 mg/L)* as the PEL for ozone.

4.7.3.3.4.2 Third Party Validation

Validation is a process by which any ozone unit is tested against a surrogate microorganism in order to determine its performance. Validation is required because there is no on-line test of an ozone unit's ability to disinfect and, due to the relatively short contact time, it is impossible to size units accurately based on just calculations.

It is important to note that evidence of testing is not the same as validation.

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245 Korich DG, et al. Effects of ozone, chlorine dioxide, chlorine, and monochloramine on Cryptosporidium parvum oocyst viability. Appl Environ Microbiol. 1990 May;56(5):1423-8.
246 Wickramanayake GB, et al. Inactivation of Giardia lamblia cysts with ozone. Appl Environ Microbiol. 1984 Sep;48(3):671-2.
247 Cho M, et al. Mechanisms of Escherichia coli inactivation by several disinfectants. Water Res. 2010 Jun;44(11):3410-8.
248 Zuma FN, et al. Kinetics of inactivation of Pseudomonas aeruginosa in aqueous solutions by ozone aeration. J Environ Sci Health A Tox Hazard Subst Environ Eng. 2009 Aug;44(10):929-935.

NSF/ANSI Standard 50 is including the ozone/*Cryptosporidium* validation STANDARD into Standard 50; it is not an Annex but a portion of the ozone section in the whole STANDARD and was published in the 2013 STANDARD.

4.7.3.3.4.3 Suitable for Use

All materials must be ozone resistant.

The strong oxidizing power of ozone shall be considered when choosing materials for pipes, valves, gaskets, pump diaphragms, and sealant. Materials for water piping, tanks, and other conveyance shall be nearly inert.

For generators that produce ozone under pressure and utilize a negative pressure *(Venturi)* ozone delivery system, or introduce ozone under pressure *(such as a pressurized diffuser into an atmospheric holding tank)*, any leak or break in the system will immediately cause the release of ozone gas.

Suitable materials and their uses are:

1. Ozone/Air or Ozone/Oxygen:

- Concentrations above 2500 ppm *(mg/L) (0.4 % wt)*
  - PTFE, FEP *(Teflon®)* – tubing, O-rings, or ozone cell materials
  - PVDF *(Polyvinylidene Fluoride)*, Kynar® *(Pennwalt patent)* – tubing, injection, check valves
  - Stainless Steel, grade 316L – tubing or ozone cell materials
  - Glass and most ceramics – ozone cell materials
  - Aflas® – seals, O-rings, gaskets
- Concentrations below 2500 *(in addition to those above)*
  - Viton® – tubing, seals, O-rings
  - Kel-F® – seals & O-rings

NOTE: *Stainless steel tubing shall only be used when the feed-gas is dried to a dew point below –76 °F (-60° C), and where no chance of water ingress exists. CORROSIVE acids formed in moist air will corrode the pipes from the inside.*

2. Dissolved Ozone in Water (in addition to all those listed above):

- PVC or CPVC *(schedule 40 or 80)*
- EPDM *(Ethylene - propylene terpolymer)*
- PVDF *(Polyvinylidene Fluoride)*, Kynar® *(Pennwalt patent)*

3. Gaskets and O-rings

- Aflas®, Kalrez®, and Teflon® are acceptable gasket materials for both gas and aqueous seals.
- Viton®, EPDM, and “Red Silicon” do not provide sufficient resistance to deterioration at ozone concentrations above 1.5% *(gaseous)* but work well in aqueous ozone solutions. If used for gaseous application, these shall only be used in static seals and replaced regularly.

4. Joint Sealing

Properly applied Teflon tape may be used successfully for sealing joints; however, threaded fittings shall be avoided where possible. Hypalon® and silicone sealers which do not contain rubber filler are also successful.

4.7.3.3.4.7 Installation and Injection Point

4.7.3.3.4.7.2 Gas Monitor / Controller

For generators that produce ozone under pressure and utilize a negative pressure *(Venturi)* ozone delivery system, or introduce ozone under pressure *(such as a pressurized diffuser into an atmospheric holding tank),* any leak or break in the system will immediately cause the release of ozone gas.

4.7.3.4 Supplemental Treatment Systems

4.7.3.4.1 General Requirements

4.7.3.4.1.1 Optional

AQUATIC VENUES that do not require SECONDARY DISINFECTION SYSTEMS have the option to utilize SUPPLEMENTAL TREATMENT SYSTEMS. These systems may not afford DISINFECTION protection against *Cryptosporidium,* and may not remove chloramines as effectively as SECONDARY DISINFECTION SYSTEMS. However, if sized within supplementary treatment system requirements in MAHC 4.7.3.4, a SUPPLEMENTAL TREATMENT SYSTEM may be of benefit in maintaining air quality at indoor facilities, reducing the *Cryptosporidium* burden over an extended period of time, and reducing the amount of disinfectant needed to maintain required disinfectant levels.

Although SUPPLEMENTARY TREATMENT SYSTEMS are optional, it should be noted that this CODE, as written, represents BEST PRACTICE.

4.7.3.4.2 Ultraviolet Light

Refer to information presented in MAHC Annex Section 4.7.3.3.3.

4.7.3.4.3 Ozone

Refer to information presented in MAHC Annex Section 4.7.3.3.4.

4.7.3.4.4 Copper / Silver Ion System

The scientific data available on efficacy of these systems is predominantly for bacterial inactivation and usually includes FAC. [249,250]

There is limited scientific literature that documents the efficacy of these systems on viruses and parasites.

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249 Yahya MT, et al. Disinfection of bacteria in water systems by using electrolytically generated copper:silver and reduced levels of free chlorine. Can J Microbiol. 1990 Feb;36(2):109-16.
250 Beer CW, et al. Swimming pool disinfection: efficacy of copper/silver ions with reduced chlorine levels. J Environmental Health, 61(9): 9-12.

Given the importance and frequency of RWIs associated with these other microorganisms *(viruses and parasites)*, it is essential that DISINFECTION chemicals / systems are also effective against such microorganisms as well.

4.7.3.4.5 Ultraviolet Light / Hydrogen Peroxide Systems

UV/peroxide systems have not been registered by the US EPA as primary disinfectant systems for recreational water. Although UV is a disinfectant, it does not impart a persistent residual disinfecting property to water. To overcome this, UV/peroxide systems claim, or in some cases imply, that the inclusion of hydrogen peroxide in the system supplies a disinfectant in the bulk water in the AQUATIC VENUE. Hydrogen peroxide is used as a hard surface disinfectant and has been granted registration for this purpose by the US EPA. When used as a hard surface disinfectant, hydrogen peroxide is normally used at around 3%. When used in recreational water, hydrogen peroxide is used at 27 to 100 ppm (mg/L), which is 1111 and 300 times, respectively, more dilute than that used on hard surfaces. At these low concentrations hydrogen peroxide is not an effective disinfectant. Thus, UV/peroxide systems do not provide a persistent disinfectant in the bulk of the water in the AQUATIC VENUE. Further, hydrogen peroxide is not registered by the US EPA for use as a disinfectant in recreational water. Since it is not EPA-REGISTERED, the use of hydrogen peroxide as a disinfectant, or any market claims that implies hydrogen peroxide provides any biological control, is a violation of FIFRA.

UV/peroxide system should not be used as a SUPPLEMENTAL TREATMENT SYSTEM on CHLORINE treated AQUATIC VENUES. The addition of hydrogen peroxide to a CHLORINE-treated POOL will inactivate the HOCl. If sufficient hydrogen peroxide is added, the HOCl will be completely eliminated and no disinfectant for inactivation of pathogenic organisms will remain.

4.7.3.5 Water Quality Testing Devices and Kits

WQTDs should be stored as specified by the manufacturer's instructions. Failure to properly store WQTDs will result in incorrect readings. NSF/ANSI Standard 50 for WQTDs in 2013 currently contains specified precision and accuracy requirements for measuring pH, free & total CHLORINE, and free & total bromine. There are three levels of accuracy and precision deemed level 1, 2 and 3, with the highest accuracy and precision in level 1 devices. The test water specifications include alkalinity, calcium hardness, and TDS.

It is important for a QUALIFIED OPERATOR to use equipment that is easy to read and as objective as possible. The current, common means of testing AQUATIC VENUE water using colorimetric test kits is subjective because the color and intensity must be compared. Titration testing for free and combined CHLORINE is an objective test, which is accurate to 0.2 mg/L with an easily recognizable start and end point. Therefore, titration testing is recommended over colorimetric testing. Due to the use of inconsistent concentration gradations *(i.e., the difference in concentration between adjacent color blocks)* and the subsequent rapid darkening of the color blocks *(e.g., above 1.5 mg/L)*, the accuracy of colorimetric test methods is likely to be lower than for titration test methods. Visual colorimetric methods are accurate only to +/- half the difference between the adjacent color blocks, and thus the confidence limits for these methods are wider at higher concentrations *(e.g., above 1.5 mg/L)*. Where portable colorimeter test kits are affordable, these are the most accurate kits available for use at POOLSIDE.

Most water tests involve color development. Interferences in the water can cause them to produce a different color, or produce the wrong color intensity, or be unable to produce the expected color. Color matching tests for CHLORINE/bromine provide accuracy equal to approximately half the difference between known values of the color STANDARDS. As the CHLORINE/bromine concentration rises, the greater the difference will be between the known color STANDARDS. Thus, the readings become subjective as the difference increases. The following MAHC Table 4.7.3.5 summarizes some common interferences and how they impact the test color in disinfectant tests.

Table 4.7.3.5: Water Tests and Interference

Test	***Interference***			
	High Chlorine	**Metals: Cu, Fe, Mn**	**High Calcium**	**Monopersulfate**
Chlorine	At approximately 10 ppm, may cause partial or total bleaching of the DPD reagents, resulting in lower pink color intensity, or no pink color at all.	None	May cause the sample to turn cloudy white when adding DPD #1.	Will cause a false positive (more intense pink color) for combined chlorine at any level and for free chlorine at high levels (over 25 ppm).
pH	May create a different indicator, chlorphenol red, that is purple and pH 6.6 and higher.	None	None	None
Total Alkalinity	May cause the beginning color to be light blue and the end-point to be yellow, rather than the expected starting green color and red (pink) endpoint.	None	None	None
Calcium Hardness	None	Expected blue color never fully develops, and the endpoint approaches blue, but fades to a light purple.	None	None

High Chlorine Effects on Chlorine Testing:

If the water sample indicates high CHLORINE levels, usually over 10 ppm *(10 mg/L)*, the DPD reagents may partially or totally bleach out, resulting in a false low or zero CHLORINE reading. The addition of double the quantity of DPD reagent during testing may minimize this interference or the analyst can use a smaller sample size or dilute the sample with distilled or deionized water *(DI)* water. Reference the WQTD's use instructions to guard against false readings and interferences.

High Chlorine Effects on pH Testing:
If the CHLORINE reading is high, the tester must wait until it is lowered to a normal level before retesting the pH, to assure an accurate reading. Some analysts neutralize the DISINFECTANT first by adding a drop of CHLORINE neutralizer *(i.e., sodium thiosulfate)*. This is not recommended since the reaction between thiosulfate and CHLORINE can change the pH of the sample and give an inaccurate reading.

High Chlorine Effects on Total Alkalinity Testing:
High CHLORINE will affect the Total Alkalinity reading. Some reagents will bleach out and the color change will be from blue to yellow instead of the expected green to red/pink. Refer to the WQTD's instruction manual to prevent false readings and interferences.

Metals:
Be sure to identify the source of the metal in order to remove the problem for the AQUATIC FACILITY owner. Likely sources are copper from algaecides or corroded pipes, or iron and manganese from the fill water.

Effect of Metals on Calcium Testing:
For the calcium test, copper, iron, and manganese dissolved in the water may prevent the expected blue color *(indicating the end of the test)* from fully developing. As the end of the test approaches blue, it fades to a light purple instead, which results from the metals in the water. Repeat the test, but before proceeding with the test instructions, add 5 or 6 drops of titrant. Remember to add the 5 or 6 drops to your final drop count when finished to determine the calcium concentration.

High Calcium Effects on Chlorine Testing:
When high calcium levels are in the water, the sample may turn cloudy with the addition of DPD #1 liquid reagent, which is alkaline. Addition of DPD #2 liquid reagent may not clear up the cloudiness. With high calcium water, adding DPD #2 prior to adding DPD #1 will acidify the sample, turning it slightly pink, and the cloudiness will not appear. Add DPD #1 to complete the test and obtain the proper pink color for the amount of CHLORINE in the water.

Potassium Monopersulfate Shock:
Potassium monopersulfate produces a false high combined CHLORINE reading whenever it is present in the water. Monopersulfate will also produce a false positive FREE RESIDUAL CHLORINE reading when the monopersulfate concentration is high *(over 25 ppm)*. Monopersulfate interference can be removed by a variety of products found in the market place. Refer to the WQTD's instruction manual to prevent false readings and interferences.

4.7.3.6 Microbiological Testing Equipment

Microbiological testing equipment and methods should be EPA-REGISTERED, conforming to the latest edition of Standard Methods for the Examination of Water and Wastewater,[251] existing professional guidelines, or other recognized international guidelines or STANDARDS.

At this time, routine microbiological testing for POOLS, SPAS, and other AQUATIC VENUES is not recommended in the MAHC. Routine MONITORING of chemical levels *(e.g., pH, disinfectant concentration)* and proper operation and maintenance of the AQUATIC VENUE have historically been considered to be sufficient to ensure that proper BARRIERS are maintained to minimize potential infectious disease risks from CHLORINE sensitive pathogens. Currently, routine MONITORING for CHLORINE-tolerant microorganisms *(e.g., Cryptosporidium spp.)* is not a feasible or cost-effective disease prevention approach. Chemical tests such as FREE RESIDUAL CHLORINE, pH, CT INACTIVATION VALUES, and others provide a good indication of operational control of an AQUATIC VENUE. However, while these tests provide an indication of DISINFECTION potential, they may not provide complete assurance of the microbial quality of AQUATIC VENUE water.

While agencies such as the World Health Organization[252], the South Australia Environmental and Public Health Service[253], and the United Kingdom Health Protection Agency[254] have established STANDARDS for routine MONITORING of public and semi-public AQUATIC VENUES for microbial parameters including enteric bacteria *(fecal organisms or E. coli)*, *Pseudomonas aeruginosa,* and *Legionella*, there is insufficient scientific data for the purposes of the MAHC to indicate that these routine MONITORING STANDARDS provide an increased level of public health protection beyond adherence to current BEST PRACTICES. The routine MONITORING recommendations in the MAHC can be reconsidered to potentially include routine MONITORING for microbial parameters if compelling scientific data indicate that such testing provides additional, measurable public health protections beyond use of BEST PRACTICES for DISINFECTION in AQUATIC VENUE operation and maintenance. It should be noted that this section of the Annex is a minimum guideline for microbiological MONITORING. AQUATIC VENUE operators wishing to achieve additional microbial water quality characterization are encouraged to use the references in this Annex regarding water quality MONITORING techniques and STANDARDS established by the United States and in other countries. Microbial water quality STANDARDS established for AQUATIC VENUES by U.S. and international agencies include:

- ***Alberta Public Health***, Alberta Regulation 293/2006 (2006) Swimming Pool, Wading Pool and Water Spray Park Regulation; Alberta, Canada
    - Excerpt, Page 10, Bacterial Limits: Heterotrophic Plate Count less than 100/mL; *Pseudomonas aeruginosa* 0/100 mL, coliforms 0/100 mL

251 APHA, et al. (2012) Standard Methods for the Examination of Water and Wastewater, 22nd ed. E.W. Rice, R.B. Baird, A.D. Eaton, and L.S. Clesceri (eds). New York: American Public Health Association.
252 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 18, 2016..
253 Broadbent C. (1996) Guidance on water quality for heated spas. Rundle Mall, South Australia: Public and Environmental Health Service.
254 Newbold J. (2006) Management of spa pools: controlling the risk of infection. London, United Kingdom: Health Protection Agency.

- ***Code de la Santé Publique, France***, (2007) Arrêté préfectoral en date du 15 juin 2007 fixant les upermens du contrôle sanitaire de la qualité des eaux des piscines *(Prefectural order dated June 15, 2007 establishing STANDARDS for the control of swimming pool water quality)*
    - Excerpt: Determination of the parameters to be analyzed in the field or laboratory:

Standards for Bacteriological Analytical Parameters

• Viable aerobic bacteria at 37°C	<100/ml
• Total coliforms	<10/100ml
• Fecal coliforms (E. coli)	0/100ml
• Pathogenic staphylococci	0/100ml
• *Pseudomonas aeruginosa* (in SPAS)	0/100ml

- ***New Jersey Department of Health and Senior Services*** (2009) New Jersey State Sanitary Code, Chapter IX, Public Recreational Bathing N.J.A.C 8:26
    - Excerpt: pages 20 – 21; Heterotrophic plate count do not exceed 200 colonies per one milliliter sample; Coliforms to be less than one colony per 100 milliliter sample, *Pseudomonas aeruginosa* not to exceed one colony per 100 milliliter sample.

Although routine microbial testing is not recommended by the MAHC at this time, microbiological testing can be useful as supporting data for evaluating the need for *(or effectiveness of)* troubleshooting activities, remediation activities, and AQUATIC FACILITY upgrades. As indicated by WHO[255] recommendations, microbiological testing of water samples from AQUATIC VENUES can be useful for the following reasons:

- Before an AQUATIC VENUE is used for the first time,
- Before it is put back into use after it has been shut down for repairs or cleaning,
- If there are difficulties with the treatment system, or
- As part of any investigation into possible adverse effects on BATHER or PATRON health.

It is known that certain microorganisms, because of their ecology and/or structure, can be tolerant of chemical disinfectants *(e.g., CHLORINE, bromine)*. *Legionella pneumophila*, *Pseudomonas aeruginosa*, *Cryptosporidium parvum*, *Entamoeba histolytica* cysts, and *Mycobacterium avium* complex are a few examples of pathogenic microbes that have been reported to show some tolerance to chemical disinfectants. In addition, sessile *(in the biofilm)* microorganisms in biofilm are likely to receive additional protection from OXIDIZERS *(such as CHLORINE)* when the exposure concentration of these OXIDIZERS is reduced at the interface with the biofilm due to reaction with biofilm material.

255 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 22, 2016.

Biofilm is a complex community of microorganisms which attach to the sides, piping, and filters of AQUATIC VENUES [256]. Even at elevated concentrations, oxidizing and non-oxidizing chemicals have reduced effectiveness in controlling biofilm when their concentrations and contact times are not sufficient for penetrating the biofilm[257]. Biofilm formation in AQUATIC VENUES is also a concern because microorganisms in the biofilm or the biofilm itself can detach and multiply[258]. Following BEST PRACTICE guidelines for AQUATIC VENUE cleaning and continuous DISINFECTION is critical to avoid biofilm growth and expansion problems[259,260].

If biofilm-related problems arise, it can be useful to incorporate biofilm sampling to develop a comprehensive evaluation of the risk factors for water quality impairment and potential solutions to identified problems[261].

MAHC Annex Table 4.7.3.6 *(below)* identifies microorganisms for which chlorination may have, or is known to have, reduced efficacy[262,263,264]. MAHC Annex Table 4.7.3.6 also identifies methods that may be used to detect these microbes in AQUATIC VENUE systems, but the methods identified are not necessarily rapid. Additional research is needed to evaluate the benefits of microbiological testing data for AQUATIC VENUES, especially for improving public health protection. This is particularly important for the protozoans, amoebas, and sessile bacterial pathogens that co-exist in biofilms. It should be noted that the use of fecal indicator organisms for AQUATIC VENUE water quality evaluation may not be sufficient for certain AQUATIC VENUE operation, maintenance, and public health investigations, especially in public health investigations related to inhalation, skin breaks, or ocular exposure routes. Since health risks in AQUATIC VENUES and similar environments may be fecal or non-fecal in origin, investigation of fecal indicators and non-fecally-transmitted microorganisms *(e.g. P. aeruginosa, S. aureus and Legionella spp.)* may be warranted.

256 Camper AK, et al. (1985) Growth and persistence of pathogens on granular activated carbon filters. Journal of Applied Environmental Microbiology, 50:1378–82.
257 Pearson W. (2003) “Legionella 2003.” Association of Water Technologies Inc., Association of Water Technologies, 2003. Web. 19 Aug 2010. Retrieved from http://www.awt.org/IndustryResources/Legionella03.pdf.
258 Declerck P. (2010) Biofilms: the environmental playground of Legionella pneumophila. Environmental Microbiology, 12(3), 557-566.
259 Clements W. (Ed) (2000) ASHRAE guideline: Minimizing the risk of legionellosis associated with building water systems. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc.
260 Donlan RM, et al. (2002) Biofilms: survival mechanisms of clinically relevant microorganisms. Clinical Microbiology Review, 15, 167-93.
261 Paulson D. (Ed.) (2010) Applied biomedical microbiology: A biofilms approach. Chapter 8: Matias F, et. al., Disinfection and its influence on biofilm ecology . Chapter 9: Goerers D, Understanding the importance of biofilm growth in hot tubs. Boca Raton, Fl: CRC Press.
262 Hurst C, et al. (2002) Manual of environmental microbiology. Washington DC: American Public Health Association. 184, 186-188.
263 Heymann D. (Ed.) (2004) Control of communicable diseases manual. Washington, DC: American Public Health Association, pp. 138-141, 230-231, 383-385.
264 APHA, et al. (2012) Standard Methods for the Examination of Water and Wastewater, 22nd ed. E.W. Rice, R.B. Baird, A.D. Eaton, and L.S. Clesceri (eds). New York: American Public Health Association.

Table 4.7.3.6: Known Pathogenic Organisms of Concern in Chlorinated Aquatic Venues *(continued on next page)*

Organism	Illness	Route of Infection	Resistant To Chlorine	Environmental Biofilm Amplification	Test Method
***Pseudomonas aeruginosa*[1]**	• Hot Tub Folliculitis • Conjunctivitis • Pneumonia • Swimmer's Ear	• Skin • Eyes • Inhalation • Ears	• Yes when planktonic[2] • Yes when sessile in biofilms	Yes	• APHA Standard Method 9213 E-F • APHA Standard Method Rapid PCR test available
Enteric Bacteria	• Gastroenteritis • Hip and Knee joint replacement infections, replacement heart valve infections • Conjunctivitis • Pneumonia	• Fecal/Oral • Skin breaks • Eyes • Inhalation	• No when planktonic • Yes when sessile in biofilm	Yes	• APHA Standard Method for Coliforms 9221 A-F • APHA Standard Method 9260 A-L for specific pathogens • APHA pathogen specific PCR test • Bacteroides/Enterococci PCR tests under investigation by EPA to replace Coliforms
Legionella	• Legionnaires' Disease, Pontiac Fever • Hip and Knee joint replacement infections, replacement heart valve infections	• Inhalation • Skin breaks	• Yes when planktonic[3] • Yes when sessile in biofilm	Yes	• APHA Standard Method 9260 J • CDC/ISO Method is Gold Standard • APHA Standard Method • Rapid PCR test
***Mycobacterium avium* complex (MAC)**	• Hypersensitivity pneumonitis • Dermatitis	• Inhalation • Skin Breaks	• Yes when planktonic • Yes when sessile in biofilm	Yes	• APHA Standard Method 9260 M • Rapid PCR
***Staphylococcus aureus* & Methicillin resistant *Staphylococcus aureus* (MRSA)**	• Conjunctivitis • Antibiotic resistant skin infection possibly fatal	• Eyes • Skin Breaks	• No when planktonic • Yes when sessile in biofilm	Yes	• APHA Standard Method 9213 B 6 • and 7 • Rapid PCR test

Organism	Illness	Route of Infection	Resistant To Chlorine	Environmental Biofilm Amplification	Test Method
Naegleria fowleri	• Primary amoebic meningoencephalitis *(uncommon but high mortality rate)*	• Water accidentally inhaled in nose or pharynx	• Yes when planktonic	Yes	• APHA Standard • Method PCR test
Acanthamoeba	• Conjunctivitis and Keratoconjunctivitis *(may cause blindness particularly in contact lens wearers)*	• Eye, skin, mucous membranes	• Yes when sessile in biofilm	Yes	• APHA Standard Method 9711 C
Cryptosporidium* and *Giardia	• Gastroenteritis • Biliary Tract Infections • Reactive Arthritis	• Fecal/Oral • Inhalation • Inhalation	• (Oo)cysts are resistant in planktonic and sessile forms	Yes	• Standard Method 9711 B • APHA PCR test
Adenoviruses	• Conjunctivitis • Gastroenteritis	• Eyes • Fecal/Oral	• No	Unknown	• Cell culture • PCR
Enteroviruses	• Gastroenteritis • Viral meningitis	• Fecal/Oral	• No	Unknown	• APHA Standard Method 9510 • EPA Method 1615
Noroviruses	• Gastrointestinal	• Fecal/Oral	• No	Unknown	• EPA Method 1615 • RT-PCR Methods
Helminths and Roundworms	• Ascariasis • Baylisascariasis	• Fecal/Oral	• Cysts are resistant in planktonic and sessile forms	Yes	• APHA Standard Method 10750 • PCR tests available for species identification
Fungi	• Ringworm	• Skin	• Spores are resistant	Yes	• Culture and PCR tests

Table 4.7.3.6 Notes:

1. ***NOTE***
    a. Many elderly and/or immuno- compromised people use SPAS making them more susceptible to disease;
    b. *P. aeruginosa* can be tolerant of CHLORINE and is found in biofilm;
    c. Hot tub folliculitis is the most common illness associated with hot tubs; and
    d. Coliform testing is not an indication of *P. aeruginosa* contamination;
    e. Since this is a non-reportable disease, we have no information on the incidence of disease.
2. Grobe S, Wingender J, & Flemming H. (2001) Capability of mucoid *Pseudomonas aeruginosa* to survive in chlorinated water. International Journal of Monitoring & Testing and Public Health, *204*, 139-142.

    Price D, Ahearn DG. Incidence and persistence of *Pseudomonas aeruginosa* in whirlpools. J Clin Microbiol. 1988 Sep;26(9):1650-4.

    Clements W. (Ed.) (2000) *ASHRAE guideline: Minimizing the risk of legionellosis associated with building water systems*. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc.

3. Muraca P, Stout J, & Yu V. (1987) Comparative assessment of chlorine, heat, ozone, and UV light for killing *Legionella pneumophila* within a model plumbing system. Applied and Environmental Microbiology, 53(2), Retrieved from http://aem.asm.org/cgi/reprint/53/2/447.

    Clements W. (Ed.) (2000) *ASHRAE guideline: Minimizing the risk of legionellosis associated with building water systems*. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc..

It is not feasible or cost effective to test for all infectious organisms. Therefore MAHC Annex Table 4.7.3.6 identifies those organisms which have readily available test methods and/or cause illnesses that are common, very serious, or fatal. It is important to note that these test methods may not allow for rapid remediation, decision making, or public health intervention on a timely basis.

The Heterotrophic Plate Counts *(HPC)* method has not been included in the list of microbial water quality tests in MAHC Annex Table 4.7.3.6. While HPC data are generally a good indicator of microbial water quality and efficacy of POOL operations *(e.g., water treatment)*, this parameter has been reported to show no correlation to the presence of *Legionella*[265], planktonic pathogens[266], or the presence of biofilm[267]. HPC tests *(as do all culture tests)* under-report the actual concentration of viable bacteria. Therefore, it is recommended that the use of this test be restricted for assessing the level of planktonic, non-pathogenic bacteria only. HPC data are not sufficient to assess the public health risk of POOLS, SPAS, and waterparks[268].

Since the MAHC is intended to be a living document with changes anticipated as our knowledge increases, it is prudent to acknowledge that a paradigm shift is occurring in the world of microbiology that likely will impact how pathogen testing will be conducted and interpreted in the future. Culture tests are gradually being replaced with culture-independent test methods such as Polymerase Chain Reaction *(PCR)* testing and microarray testing. Years ago when PCR was first used commercially, the cost of the tests was prohibitively expensive. Now test costs have decreased and are competitive with culture dependent tests. A recent development is the commercialization of microarray testing which can screen for the presence of a wide variety of bacterial and viral pathogens without the need for an isolation step. However, the costs associated with microarray testing are prohibitively expensive as of this MAHC publication.

In addition to the use of standard culture-based fecal indicator bacteria (FIB) tests in recreational water testing (i.e., total and fecal coliforms, *E. coli* and *Enterococcus*), EPA provides recommended criteria values for states that want to use a quantitative polymerase chain reaction (qPCR) method for *Bacteroides* and *Enterococcus* testing as a possible replacement for these culture tests. In addition, EPA has developed a qPCR method for *E. coli* which is being tested at Great Lakes Beaches. Two of the most compelling reasons for why some states would consider the use of the qPCR method are::

- Incubation times for culture tests prevent quick decision-making to minimize public exposure to water with a potentially elevated disease risk, and

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265 Hodgson M, et al. (1996) Prevalence of Legionella bacteria in building water systems. In IAQ 96. Paths to Better Building Environments. Conference of the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. Atlanta.
266 Paulson D. (Ed.) (2010) Applied biomedical microbiology: A biofilms approach. Chapter 8: Matias F, et.al., Disinfection and its influence on biofilm ecology . Chapter 9: Goeres D, Understanding the importance of biofilm growth in hot tubs. Boca Raton, Fl: CRC Press.
267 Donlan R, et al. (2002) Biofilms: survival mechanisms of clinically relevant microorganisms. Clinical Microbiology Review, 15, 167-93.
268 Costerton JW. (2007) The biofilm primer. Germany: Springer-Verlag.1-97.

- Molecular tests are generally considered to have higher specificity *(lower false positive rates)* than traditional culture tests.

PCR can be a good method for investigating whether pathogenic microbes were present in AQUATIC VENUES *(e.g., sampling filter backwash)* since the technique detects the DNA of pathogens regardless of whether they are live, dead, or viable-but-not-culturable. Another benefit is that PCR culture tests can be completed in hours versus days. However, while PCR can be effective for determining whether pathogens have been present in an AQUATIC VENUE, the technique is less effective as a measure of DISINFECTION effectiveness since it detects DNA from both viable and non-viable organisms. New techniques, such as the use of propidium monoazide *(PMA)* have been reported to enable PCR to characterize the viability status of microorganisms, so in the future PCR may be an effective option for DISINFECTION studies[269].

4.7.4 Water Replenishment System

A WATER REPLENISHMENT SYSTEM allows for POOL water to be removed from the POOL and properly disposed of so that it can be replaced with fresh water containing lower concentrations of dissolved CONTAMINANTS. A WATER REPLENISHMENT SYSTEM should be used to control the dissolved organic CONTAMINANT concentrations *(e.g., sweat, oils, chlorination by-products, and urine)* and dissolved inorganics *(e.g., salts and metals)* because POOL filtration systems are not effective at removing dissolved CONTAMINANTS.

4.7.4.1 Discharge and Measure

A means of intentionally discharging and measuring or calculating the volume of discharged POOL water *(in addition to the filter backwashing system)* should be provided and designed to discharge a volume of water of up to four gallons *(15 L)* per BATHER per day per facility through an air gap. Knowing pump GPM and knowing how much time one is backwashing can be used to calculate the volume discharged. Water replacement or replenishment at a rate of eight gallons *(30 L)* per BATHER per day per AQUATIC VENUE[270,271,272] have been widely used. PWTAG[273] states that as much as half of the recommended amount could be associated with filter backwashing. There does not appear to be any research to support the use of the 30 L/day/BATHER number used abroad. So, since 4 gal/day/BATHER is roughly half of this amount *(and typically met by filter backwashing alone)*, it seems like a reasonable place to start incorporating this practice into operations. A requirement could be made once the science is there to support a higher or lower value. With a WATER REPLENISHMENT SYSTEM in place, AQUATIC FACILITY operators will be able to experiment with higher WATER REPLENISHMENT rates to obtain improved water *(and indoor air)* quality. It should also be easy to comply with any

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269 Brescia CC, et al. (2009) Cryptosporidium propidium monoazide-PCR, a molecular biology-based technique for genotyping of viable Cryptosporidium oocysts. Applied and Environmental Microbiology, 75:6856-6863.
270 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.
271 WHO. Guidelines for Safe Recreational Water Environments: Vol. 2- Swimming Pools and Similar Environments. 2006. WHO Press, Geneva, Switzerland. Available at http://www.who.int/water_sanitation_health/bathing/bathing2/en/. Accessed on April 22, 2016.
272 Gregory R. Bench-marking Pool Water Treatment for Coping with Cryptosporidium. Journal of Environmental Health Research. 2002;1(1):11-18.
273 PWTAG. Swimming Pool Water: Treatment and Quality Standards for Pools and Spas, 2nd Ed. 2009. Micropress Printers, Ltd. ISBN: 0951700766.

future regulations related to WATER REPLENISHMENT as only the flow rate would require adjustment. WATER REPLENISHMENT for a large AQUATIC FACILITY would be based on the number of BATHERS in the entire AQUATIC FACILITY *(not the total number swimming in a particular aquatic venue on a given day since most BATHERS are expected to distribute the BATHER COUNT over a range of aquatic venues and/or rides on a given day)*. However, WATER REPLENISHMENT should be proportional to the number of BATHERS in each individual treatment system. It would not be allowable to send to waste all of the water from the WAVE POOL and none from the other attractions *(unless the water was shared through a combined aquatic venue treatment system)*.

4.7.4.1.1 Alternate Systems

The CODE allows for use of alternate systems to meet the intent for removal of organic compounds. Currently, the MAHC is not aware of such systems.

4.7.5 Spas

4.7.5.1 General

Portable SPAS are not excluded from use in public settings. However, the design, operation, and maintenance of portable SPAS must conform to this CODE.

4.8 Decks and Equipment

4.8.1 Decks

4.8.1.1 General Standards for All Decks

4.8.1.1.2 Lifeguard Placement and Safety Considerations

See MAHC 4.6.5.1 and 6.3.3.1.1 for operational considerations in design.

4.8.1.1.2.1 Deck Clearance

Four feet *(1.2 m)* of clearance would allow for safe movement of a QUALIFIED LIFEGUARD roaming or for extrication in case of an emergency. This is consistent with the design guidance of the MAHC.

4.8.1.1.2.2 Access Points

In locations where PERIMETER DECK is non-contiguous and the clearance is not at least four feet *(1.2 m)*, such as where fencing is provided around elevated POOL edges and LAZY RIVERS, locations for lifeguards to safely access the POOL edge should be required. This facilitates a safe entry rather than climbing over any fence or other obstruction.

4.8.1.1.2.3 Bather Zone Surveillance

Designers have historically added AQUATIC FEATURES that are not readily visible on a site plan nor are their effects self-evident until installed during construction. This could result in additional lifeguards to facilitate zone coverage or create small blind spots. For this reason, this line item was added for the designer to consider.

4.8.1.1.6 Concrete Decking

See American Concrete Institute Standards Reference 302.1 R-80, Guide for Concrete Floor and Slab Construction.

4.8.1.2 Standards for Perimeter Decks

The term "PERIMETER DECK" refers to the area around and immediately adjacent to the POOL. This area is the wettest area of the DECK and extends out from the edge of the POOL a maximum of 4 feet *(1.2 m)* or out to DECK drains, whichever is farther. Finish materials for the PERIMETER DECK must be suitable for the POOL environment, non-toxic, and substantially impervious. See MAHC 4.8.1.4.

4.8.1.3 Drains

4.8.1.3.1 Slope

Table 4.8.1.3 Minimum Slopes for Drainage

Surface	Minimum Slope
Smooth finishes; such as tile, hand-finished concrete & lightly-broomed concrete	$^{1}/_{8}$ inch per foot *(3.2 mm/30.5 cm)*
Moderately textured finishes; such as exposed aggregate or medium-broomed concrete	$^{1}/_{4}$ inch per foot *(6.4 mm/30.5 cm)*
Heavily textured finishes; such as brick *(where permitted)*	$^{3}/_{8}$ inch per foot *(9.5 mm/30.5 cm)*

MAHC Table 4.8.1.3 was created after reviewing and refining information from existing state CODES and established STANDARDS. Fundamentally, these sources all seek to eliminate standing water from the DECK, typically recognizing that smoother surfaces convey water more efficiently than rougher ones. Relating slopes to texture, rather than specific materials, provides the ability for any otherwise suitable DECK material or finish to be considered by the adopting jurisdiction.

There is an inherent conflict in sloping of DECKS. Steeper slopes provide more construction tolerance and surety in conveying water, particularly in active soil conditions. Shallow slopes are required to meet accessibility guidelines – particularly for cross-slopes. It is the intent of this section to encourage positive and proper drainage without running afoul of accessibility guidelines.

4.8.1.3.3 Cross Connection Control

Consult local AHJ regarding specific chemical handling and use to properly dispose, including discharge to the watershed or sanitary sewers where appropriate.

4.8.1.3.3.2 No Drain

This requirement prevents sewage from backing up into the AQUATIC VENUE water. This isolates the treated system and does not allow mixing of other sources of water that could contaminate.

4.8.1.4 Materials / Slip Resistance

4.8.1.4.2 Slip Resistance

Industry STANDARDS have changed to reflect a more accurate method for determining slip resistance which has been adopted by the Tile Council of North America (TCNA). Historically, "slip resistance" has been defined as having a minimum coefficient of friction of 0.6 for all wet surfaces and 0.8 for ramped surfaces. This static coefficient of friction is often linked to ADA. However, ADA did not set a requirement but rather referenced accessibility guidelines in the appendix that recommended (not required) a value of 0.6, but failed to specify a means of measurement. The recommended 0.6 value is all but meaningless without a testing method. The test method previously called for in the industry is ASTM C1028 in ANSI A137.1. The C1028 method was affected by a phenomenon called "stiction" when measuring two very smooth surfaces. This led to false expectations of slip resistance when the rubber sensor used to test for SCOF was in the presence of moisture. In Section 9.6 of ANSI A137.1-2012, the dynamic coefficient of friction, or DCOF, is now measured. The DCOF is essentially the resistance or force that must be overcome to keep one object, already in motion, moving over another object. The test is called the DCOF AcuTest and the aforementioned "stiction" effect is eliminated. The DCOF AcuTest is also more repeatable than the 1028 method. The TCNA tested over 300 surfaces and found that on average a 0.60 SCOF correlated to a DCOF of 0.38. There have also been a number of studies done in Germany determining that the COF for reliable traction is 0.2 to 0.3, depending on the individual. When factoring in different "slippery" conditions and how different people can move on the surface, it has been determined that a minimum DCOF of 0.42 is appropriate and is now included in ANSI 137.1 for level INTERIOR SPACES expected to be walked upon when wet.

4.8.1.4.3 Carpet

Carpet and artificial turf have been found to be inappropriate finish materials for the wettest area immediately around the POOL, i.e. PERIMETER DECK. Although the materials that carpet is manufactured from are durable and do not support mold growth, when they are installed over a relatively impermeable surface, water flows very slowly through the carpet. Soil and CONTAMINANTS entering into the carpet are not easily removed. Since the carpet stays wet longer, soil and CONTAMINANTS remain in the carpet, and mold and algae growth can occur. Therefore carpeting is not an acceptable finish material in the wet PERIMETER DECK.

Finish materials for the PERIMETER DECK should not block DECK drains or impair water flowing to DECK drains.

Carpeting may be installed beyond the DECK drains, i.e. DRY DECK.

4.8.1.4.4 Wood

Properly treated or composite wood materials may be a suitable material for DRY DECKS provided all other DECKING requirements are maintained. Fasteners must be regularly inspected to ensure structural integrity and that all heads are flush or recessed into the DECK surface.

4.8.1.4.5 Dry Deck

Regional materials, local practices, and particular facility design intentions vary widely with respect to DRY DECK. This section intends to provide the opportunity for regulatory oversight of DRY DECK, without limiting these variables best understood by AHJ.

4.8.1.4.6 Landscaping

It is acknowledged that landscaping near AQUATIC VENUES is not an uncommon practice in enhancing an AQUATIC VENUE environment. Landscape materials themselves and the design of special AQUATIC VENUES vary so widely as to require special consideration with respect to landscaping. This section intends to provide the opportunity to allow landscaping, but only through the lens of the AHJ.

The landscaping materials are not intended to be placed in the wet PERIMETER DECK area. It is assumed here that the POOL DECK will be designed and sloped to prevent drainage from landscaping materials from reaching the POOL.

For an outdoor AQUATIC VENUE, it is not possible to prevent wind from moving dirt, bugs, plant material, etc. around and perhaps into the AQUATIC VENUE. The landscape designer must consider the type and location of landscape materials placed inside or outside of an outdoor AQUATIC VENUE ENCLOSURE.

Textured Surface

The walking surface should not be rough so as to cause injury or discomfort to BATHERS.

ANSI defines where a trip hazard is considered as a level change that is greater than ¼ inch *(6.4 mm)*. Other definitions include an abrupt or unexpected level change in surfaces.

4.8.1.5 Deck Size/Width

Traditional AQUATIC VENUES should be surrounded by clear DECK space to allow for operational flow *(foot traffic)* as well as space to perform in the event of an emergency situation. Non-traditional AQUATIC VENUES such as LAZY RIVERS, WAVE POOLS, etc. are not required to have clear space around due to the need to control access by providing a BARRIER to block access into unapproved entry areas. Both guarded and unguarded AQUATIC VENUES should have the same clear space requirements.

4.8.1.5.1 Perimeter Deck

4.8.1.5.1.1 Width

The four foot *(1.2 m)* unobstructed DECK area is intended to ensure a minimum clear area for emergency access and care around the POOL. Examples of obstructions include but are not limited to INFINITY EDGES, ADA transfer walls, and curbs.

4.8.1.5.1.2 Perimeter Decking

Most POOLS require continuous DECKS in order to safely accommodate circulation of all BATHERS in the AQUATIC VENUE.

4.8.1.5.1.3 Unguarded Aquatic Venues

Unguarded AQUATIC VENUES require special consideration for DECK access.

- Option 1 assures the entire perimeter is available for assistance.
- Option 2 allows for incorporation of leisure amenities and AQUATIC VENUE features such as "INFINITY EDGES" and landscaping, while maintaining assurance that the entire AQUATIC VENUE can be reached with STANDARD SAFETY equipment.

Individual requests for variance could accommodate different designs.

4.8.1.6 Wing Walls or Peninsulas

4.8.1.6.1 No Perimeter Deck

A WING WALL or PENINSULA is intended to provide separation of different areas in a POOL. The separated areas may have differing uses, flow rates, currents, or water depths.

4.8.1.6.2 Perimeter Overflow System

The MAHC Committee defines WING WALLS as interior elements of the POOL and interior to the POS, so the MAHC did not feel it was appropriate to say that WING WALLS longer than some specified length should require POSs. It would be a function of the width of the WING WALL as to whether or not it can be properly constructed. If the POOL has a gutter system, it would probably need four feet *(1.2 m)* of width to get a normal trough on either side. SKIMMERS could be achieved for narrower walls because they could be staggered.

4.8.1.6.3 Pool Perimeter

WING WALLS do not contribute to the overall POOL perimeter so should not be included in AQUATIC VENUE perimeter calculations that are used as part of multiple critical design calculations.

4.8.1.6.5 Deck Drainage

The MAHC did not feel that DECK drains should be required on WING WALLS since they are considered part of the POOL and not subject to regular foot traffic. As for DECK level POOLS, the WING WALLS would be at or below water level making drains impractical.

4.8.1.7 Islands

A seven foot *(2.1 m)* minimum clearance overhead is required since it is consistent with requirements of building CODE minimum ceiling clearances.

4.8.1.8 Heated Decks

Heated DECKS are occasionally used in cold climates to provide pedestrian paths to and around outdoor heated AQUATIC VENUES. This section provides that when heated DECKS or snow-melt systems are provided, a minimum slope must be uniformly provided. Clear delineation is required because icy areas and/or pathway edges near otherwise DRY DECK poses an unsafe condition.

4.8.2 Diving Boards and Platforms

4.8.2.1 Diving Envelope

This CODE is designed to encourage POOLS to be built to the STANDARDS of the agency that will certify the diving at the AQUATIC FACILITY. The CODE dimensions are purposely a compilation of the most conservative STANDARDS of diving envelope dimensions and are in no way intended to supersede the certifying agencies dimensions, but instead are intended to be used only when there is no certifying agency for the AQUATIC FACILITY.

Since NCAA, USA Diving, and FINA do not have STANDARDS for boards less than one meter in height, the State of Michigan table *(R325.21.33, Table 1),* shown below as MAHC Table 4.8.2.2, was revised to the most conservative STANDARD found for 0.5-meter and 0.75-meter boards. These minimum dimensional requirements were then dictated to be more conservative in certain instances based largely on interpolations.

Concerning use of diving boards higher than 1-meter, these boards are not recommended for non-competitive use. However, if the boards are constructed to this CODE or NCAA STANDARDS, then non-competitive use can be allowed under careful adult supervision or with QUALIFIED LIFEGUARDS on duty. However, non-conformance with these STANDARDS is unsafe for recreational diving purposes.

4.8.2.2 Steps and Guardrails

Table 4.8.2.2: Diving Platform Areas

Diving Board Dimensions				
Board Height	1.64 ft. *(0.5 m)*	2.46 ft. *(0.75 m)*	3.28 ft. *(1.0 m)*	3.84 ft. *(3.0 m)*
Board Length	10.0 ft. *(3.05 m)*	12.0 ft. *(3.66 m)*	16.0 ft. *(4.88 m)*	16.0 ft. *(4.88 m)*
Board Width	20.0 in. *(50.8 cm)*	20.0 in. *(50.8 cm)*	20.0 in. *(50.8 cm)*	20.0 in. *(50.8 cm)*

Dimensions of Components Related to Diving Wells					
Letters below refer to MAHC Figures 4.8.2.2.1 & 4.8.2.2.2		***Minimum Dimensions***			
A	**Distance from plummet back to pool wall**	3.0 ft. *(0.91 m)*	4.5 ft. *(1.37 m)*	6.0 ft. *(1.83 m)*	6.0 ft. *(1.83 m)*
B	**Distance from plummet to pool wall at side**	10.0 ft. *(3.05 m)*	10.0 ft. *(3.05 m)*	10.0 ft. *(3.05 m)*	11.5 ft. *(3.51 m)*

C	**Distance from plummet to adjacent plummet**	8.83 ft. *(2.69 m)*	8.83 ft. *(2.69 m)*	8.83 ft. *(2.69 m)*	8.54 ft. *(2.60 m)*
D	**Distance from plummet to pool wall ahead**	26.0 ft. *(7.92 m)*	27.83 ft. *(8.48 m)*	29.58 ft. *(9.02 m)*	33.67 ft. *(10.26 m)*
E	**Height, board to ceiling at plummet & distances F and G**	16.0 ft. *(4.88 m)*	16.0 ft. *(4.88 m)*	16.0 ft. *(4.88 m)*	16.0 ft. *(4.88 m)*
F	**Clear overhead distance behind and each side of plummet**	8.0 ft. *(2.34 m)*	8.0 ft. *(2.34 m)*	8.0 ft. *(2.34 m)*	8.0 ft. *(2.34 m)*
G	**Clear overhead distance ahead of plummet**	16.0 ft. *(4.88 m)*	16.0 ft. *(4.88 m)*	16.0 ft. *(4.88 m)*	16.0 ft. *(4.88 m)*
H	**Depth of water at plummet**	9.5 ft. *(2.90 m)*	10.75 ft. *(3.28 m)*	12.0 ft. *(3.66 m)*	12.5 ft. *(3.81 m)*
J	**Distance ahead of plummet to depth K**	12.0 ft. *(3.66 m)*	14.25 ft. *(4.34 m)*	16.5 ft. *(5.03 m)*	19.75 ft. *(6.02 m)*
K	**Depth at distance J ahead of plummet**	8.75 ft. *(2.67 m)*	10.0 ft. *(3.05 m)*	11.28 ft. *(3.44 m)*	12.17 ft. *(3.71 m)*
L	**Distance at each side of plummet to depth M**	8.0 ft. *(2.34 m)*	8.13 ft. *(2.48 m)*	8.25 ft. *(2.51 m)*	9.92 ft. *(3.02 m)*
M	**Depth at distance L on each side of plummet**	9.08 ft. *(2.77 m)*	10.33 ft. *(3.15 m)*	11.63 ft. *(3.54 m)*	12.17 ft. *(3.71 m)*
N	**Maximum slope to reduce height E**	30°	30°	30°	30°
P	**Maximum floor slope to reduce depth ahead of K, to the sides of M, or back to pool wall behind H**	3:1	3:1	3:1	3:1

Figure 4.8.2.2.1: Diving Platform Longitudinal Section

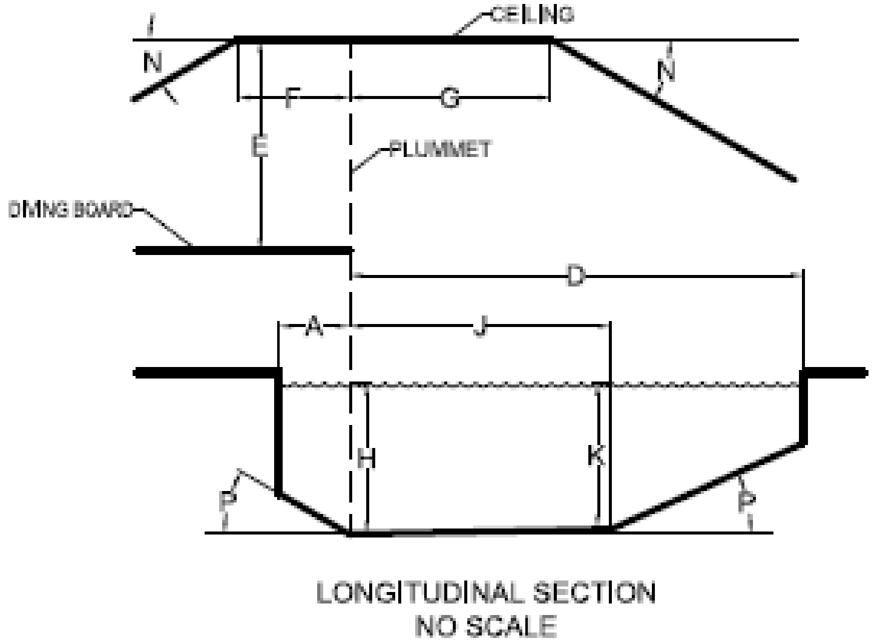
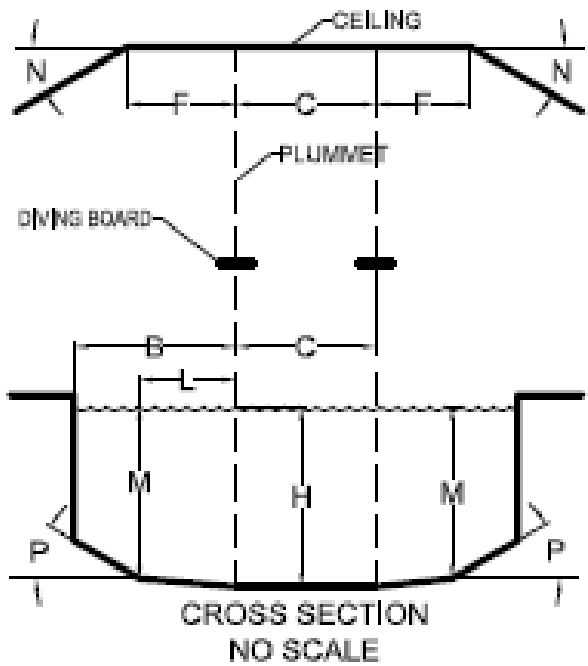


Figure 4.8.2.2.2: Diving Platform Cross Section



4.8.3 Starting Platforms

4.8.3.1 Conform to Standard Codes

The intent is to require a minimum 4 foot *(1.2 m)* water depth under the starting platform and the oversight of an aquatics governing body *(e.g. FINA, USA Swimming, NCAA,* *NFSHSA, YMCA, etc.)* or a coach or instructor. FINA, USA Swimming, NFHS, and the NCAA allow 4 feet *(1.2 m)* at starting platforms.

Although there are some national data on SCIs in general, data on diving-specific SCIs are limited, particularly for SCIs involving public POOL-related competition diving.

General Data on Spinal Cord Injuries: For SCIs in general, approximately 40 SCIs/million population occur each year in the US *(about 12,400 injuries for 2010)* with approximately 4.5% related to diving injuries.[274] SCIs are a catastrophic public health problem leading to disability and decreased life expectancy[275] with a large economic and social burden for those who suffer the injury[276,277].

Non-Deck Level Diving, Competition Diving, and SCIs: Data related to SCIs occurring as a result of competition diving off starting platforms are limited. Since starting platforms are several feet above the POOL, the entering velocity of swimmers is greater than for DECK level diving making it more difficult to alter trajectory once executed[278]. One large study investigated 74 SCIs in non-competitive divers occurring with use of springboards and/or jumpboards; 45% of the POOLS were public[279]. Of these injuries, 12.2% occurred in water less than 4 feet *(1.2 m)*; 66.2% occurred in water less than 5 feet *(1.5 m)*; 94.6% occurred in water less than 6 feet *(1.8 m)*. All SCIs occurred in water of less than 7 feet *(2.1 m)*. The MAHC requires that starting blocks be removed, if possible, or blocked off to prevent recreational divers from using them when not in use by competitive swimmers.

Data demonstrates that competitive swimmers can be trained to perform shallow water dives from starting blocks to reduce the risk of SCIs[280,281,282]. As a result, competitive aquatics governing bodies *(e.g., FINA, U.S.A. Swimming, NCAA, NFSHSA, YMCA)* allow starting blocks to be placed over water as shallow as 4 feet *(1.2 m)* in depth as long as competition is conducted under the auspices of the governing body or by a coach or instructor. A progressive training regimen can be used so that diver training is conducted in deeper water until the diver has mastered the technique before the certified personnel approve their starting block entries into shallower depths[283]. However, further data are needed on the adequacy of an intervention, like training, that relies on correctly

274 DeVivo MJ. Epidemiology of traumatic spinal cord injury: trends and future implications. Spinal Cord. 2012 May;50(5):365-72.
275 Blanksby BA, et al. Aetiology and occurrence of diving injuries. A review of diving safety. Sports Med. 1997;23(4):228-46.
276 Blanksby BA, et al. Aetiology and occurrence of diving injuries. A review of diving safety. Sports Med. 1997;23(4):228-46.
277 Borius PY, et al. Cervical spine injuries resulting from diving accidents in swimming pools: outcome of 34 patients. Eur Spine J. 2010 Apr;19(4):552-7.
278 Albrand OW, et al. Underwater deceleration curves in relation to injuries from diving. Surg Neurol. 1975;4(5):461-4.
279 Gabrielsen MA, et al. Diving injuries: The etiology of 486 case studies with recommendations for needed action. 1990. Nova University Press, Ft. Lauderdale, FL.
280 Blitvich JD, et al. Dive depth and water depth in competitive swim starts. J Swimming Res. 2000;14:33-39.
281 Cornett AC, et al. Start depth modification by adolescent competitive swimmers. Int J Aquatic Res Educ. 2012;6:68-79.
282 White JC, et al. Competitive swimmers modify racing start depth upon request. Int J Aquatic Res Educ. 2011;5:187-198.
283 Cornett AC, et al. Teaching competitive racing starts: Practices and opinions of professional swim coaches. Int J Aquatic Res Educ. 2012;6:156-170.

performing a technique to prevent injury; aquatics governing bodies state they have not documented injuries since this progressive training regimen has been adopted. However, it is noted that high speed video of competing athletes during competition dives from starting platforms illustrates the following:

- About 3% of athletes diving into 4 feet *(1.2 m)* of water[284] *(the POOL had the minimum depth recommended for athletes using starting blocks)* touched the bottom;
- Nearly half approach within 0.5 meters *(1.6 ft)* of the bottom;
- Over half exceeded head speed thresholds deemed possible to cause severe head trauma; and
- There was some anecdotal information suggesting some divers touched intentionally.

Conversely, filming of athletes diving into 7.5 feet *(2.3 m)* of water *(the POOL studies exceeded Olympic competition depths of 6.5 feet (2.0 m) below starting platforms)* showed that very few swimmers approach to within even one meter *(3.3 ft.)* of the POOL bottom[285]. These data suggest that injury risk from using starting platforms is likely to be higher for older, presumably heavier, or inexperienced divers, particularly when diving into shallower depths.

Future Directions and Research

The MAHC recommends that these national data be re-analyzed with aquatics in mind to gather more detailed information on SCIs related to diving in treated AQUATIC VENUES, particularly public AQUATIC VENUES to further inform this discussion. Future analysis of national data should be undertaken, if possible, to assess the occurrence of SCIs in competitive swimmers and platform heights and water depths at which the injury occurred. Analysis of data in peer-reviewed publications or reports collected by aquatics governing groups on SCIs and other diving injuries would also be important to understand POOL-specific diving injuries occurring in competitive swimmers and the efficacy of current progressive training or other interventions.

4.8.4 Pool Slides [N/A]

4.8.5 Lifeguard- and Safety-Related Equipment

4.8.5.2 Safety Equipment Required at all Aquatic Facilities

4.8.5.2.1 Emergency Communication Equipment

A communication device is required in the Operations *(MAHC 5.0)* section of the MAHC, but it also needs to be considered in the design so the designer can plan for the wiring for such devices. Consider larger facilities or other types of facilities who may have a phone in the nearby building. Consider a telephone labeled with location of phone/address. Some facilities may be so equipped to properly respond to an event and

284 Cornett AC, et al. Racing start safety: Head depth and head speed during competitive starts into a water depth of 1.22m. Int J Aquatic Res Ed. 2010;4:365-378.
285 Cornett AC, et al. Racing start safety: Head depth and head speed during competitive starts into a water depth of 2.29m. Int J Aquatic Res Ed. 2011;5:14-31.

phones may not be required. Large AQUATIC FACILITIES with lifeguard/trained response may not need phones installed everywhere. The intent is for BATHERS to have access to a phone to call for help when help is not necessarily part of the AQUATIC FACILITY operation.

QUALIFIED LIFEGUARDS or other emergency response staff are to be trained and may have communication devices such as whistles or radios which initiate their emergency response which includes the ability to contact outside emergency personnel when necessary. Often AQUATIC VENUES can be at a distance from support personnel and the designer should consider methods for personnel to communicate whether via radio, telephone, intercom, or other method. For alternate communication systems or devices, the intent is that an emergency phone or communications system or device is immediately available to PATRONS from all AQUATIC VENUES within an AQUATIC FACILITY. Some alternate communication systems might include a handset or intercom system to a location that is constantly manned whenever the AQUATIC VENUE is open for use *(e.g. a front desk at a hotel, the check in desk at a fitness club, or other continuously manned location)*; a commercial emergency contact device that connects to a MONITORING service, or directly to 911 dispatch; or devices that alert multiple staff on site when activated *(e.g. pagers systems, cellular telephone systems and radio communication alert systems)*. Also see MAHC 5.8.5.2.1 for additional requirements.

4.8.5.3 Safety Equipment Required at Facilities with Lifeguards

4.8.5.3.1 Lifeguard Chair and Stand Placement

This section refers to only those chairs that are permanently installed and does not indicate that a permanent chair or stand is required. The location of the chairs must give the QUALIFIED LIFEGUARD complete visibility to all parts of the zone of PATRON surveillance. The number of chairs is determined by the ability to provide surveillance of the AQUATIC VENUE by creating zones of PATRON surveillance. It is intended that the designer should be working with an aquatic consultant or the owner/operator to make sure the location of chairs and stands allows for clear line of sight.

4.8.5.3.2 Lifeguard Chair and Stand Design

Chairs and stands are exposed to elements; therefore, they should be made to withstand the environment. The intent for such a chair is to facilitate better surveillance and such the chair should be elevated sufficiently above the heads of BATHERS to have a better view and combat glare. Considerations for the SAFETY of QUALIFIED LIFEGUARDS using these chairs should include access and egress as well as BARRIERS to unauthorized access if installed at an elevation.

4.8.5.3.3 UV Protection for Chairs and Stands

Protection from UV radiation exposure can include a shade attached to the stand, a shade structure external to the stand, or other types of shade such as surrounding features. The designer should consider which method will be employed to provide UV protection for the stand.

4.8.6 Barriers and Enclosures

4.8.6.2 Construction Requirements

4.8.6.2.1 Discourage Climbing

Many POOL CODES refer to a 4 inch (10.2 cm) sphere in the body of the CODE. From a building CODE perspective, this is not consistently enforced and these CODES don't regulate that small of an opening. Building CODES allow STANDARD 2 ¼ inch (5.7 cm) mesh fencing and is not necessarily specific for AQUATIC VENUES. Building CODES typically dictate minimum height and proximity to property lines - unless it's a fall issue. With AQUATIC FACILITIES, we are mainly concerned with discouraging unauthorized entry / break-ins.

4.8.6.2.2 Emergency Exit Paths

It is the intent of this section to prevent emergency egress routes from exposing building occupants to unguarded AQUATIC VENUE areas. It is not the intent of this section to permanently segregate multiple AQUATIC VENUES on the same site. Temporary or seasonal ENCLOSURES *(properly maintained and employed)* may be used to segregate paths of egress from a building or adjacent AQUATIC VENUE to SAFETY. For example, where a seasonal outdoor AQUATIC VENUE is operated in conjunction with a year-round indoor AQUATIC VENUE, a seasonal exit pathway separation ENCLOSURE may be used to maintain exiting in the off-season. During the outdoor swim season *(when the outdoor* AQUATIC VENUE *is in operation)*, it is acceptable to egress via the AQUATIC VENUE DECK to EXIT GATES.

4.8.6.2.4 Height

The MAHC discussed this issue at length. The prevailing "BEST PRACTICE" in the industry is for 4 foot *(1.2 m)* high fencing around unguarded AQUATIC FACILITIES. However, the MAHC decided to make the BARRIER height the same for all AQUATIC FACILITIES *(6 feet or 1.8 meters)* since 4 foot fences are scalable even with smaller mesh. Generally, even unguarded AQUATIC FACILITIES have some hours of use and these POOLS also need to discourage use outside of operational hours by youth and others. The MAHC's collective logic was that if an AQUATIC FACILITY is designed for unsupervised use at all times then there is no real advantage to a fence higher than 6 foot *(i.e., 8 foot or taller)*.

4.8.6.2.4.3 Other Barriers Not Serving as Part of an Enclosure

The 42 inch *(1.1 m)* BARRIER height is consistent with STANDARD building CODE requirements for a guardrail, which serves substantially similar purposes. This height provides for consistency across CODES for like appurtenances.

4.8.6.3 Gates and Doors

This section is intended to address large AQUATIC FACILITIES where there may either be multiple AQUATIC VENUES, multiple grade elevations, or both. EXIT GATES must be provided to permit adequate emergency egress. For example, an AQUATIC FACILITY with ten AQUATIC VENUES split between different grade elevations should have the required number of exits spaced reasonably around the perimeter and not all at one grade elevation.

4.8.6.3.7 Unguarded Pools

The National Center for Health Statistic's Anthropometric Reference Data for Children and Adults: United States, 2007–2010[286] demonstrates the mean height of a 6-year old child in the U.S. is 47 inches (119.3 cm) and the mean height for a 5-year old is 44.8 inches (113.7 cm). If one adds the reach height of a 5- to 6- year old child above the head this is approximately 54 to 57 inches. Raising latch heights from 3.5 ft (42 inches, 1.1 m) to 4.5 ft (54 inches, 1.4 m) will put the latch out of the average 5-year old child's reach.

4.8.6.4 Indoor Aquatic Venues

4.8.6.4.3 Indoor and Outdoor Aquatic Venues

If a seasonal AQUATIC VENUE is on the same property as an AQUATIC VENUE operated outside of that same season, PATRONS need to be prevented from accessing the closed AQUATIC VENUES.

4.8.6.4.4 Wall Separating

A minimum overhead clearance of 6 feet 8 inches *(2.0 m)* is required since it is consistent with requirements of building CODE minimum doorway clearances. Materials that do not pose a possibility of physical injury may be suspended from the structure to help contain the INDOOR AQUATIC FACILITY environment.

4.8.6.5 Multiple Aquatic Venues

Rationale of 24 inch *(61.0 cm)* deep rule is that if adjacent water is not substantively deeper than the WADING POOL, there is no need to segregate the two. If it is the only AQUATIC VENUE within the facility, then normal fencing and perimeter ENCLOSURE requirements would apply. If WADING POOLS are a part of a larger facility with other types of AQUATIC VENUES, then the requirements proposed in MAHC 4.12.9.2 would apply.

4.8.7 Aquatic Venue Cleaning Systems

The MAHC encourages draining SPAS for cleaning. A vacuum likely would not be required for very small AQUATIC VENUES, such as SPAS less than 75 square feet *(7.0 m^2)*. A simple wall brush with pole can adequately and efficiently clean the floor.

4.8.7.1 No Hazard

Pumps shall not exceed 3 horsepower because the suction hydraulic of a larger pump through the small vacuum tubing would force the pump to operate at unacceptable hydraulic conditions. Strong suction forces provide a greater risk for bodily harm in the event of a vacuum system mishap.

POOL vacuum systems must use suitably-sized pumps, proper diameter vacuum hoses, and reasonable hose lengths to provide optimum hydraulics for vacuuming operations. Conventional suction requirements call for a maximum 15 feet *(4.6 m)* of water at a flow of 4 gpm per lineal inch of suction cleaner head for the total suction head loss.

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286 Fryar CD, Gu Q, Ogden CL. Anthropometric reference data for children and adults: United States, 2007–2010. National Center for Health Statistics. Vital Health Stat 11(252). 2012. Accessed at http://www.cdc.gov/nchs/data/series/sr_11/sr11_252.pdf

4.8.7.6 GFCI Connection

Not allowing extension cords prevents the possibility that the high voltage power supply unit has enough cord to potentially be dragged into the POOL causing a potential SAFETY risk.

The power cord length needs to be shorter than the distance between the receptacle and the edge of the POOL in order to prevent the power supply from accidentally entering the POOL water while connected.

4.9 Filter/Equipment Room

4.9.1 Equipment Room

4.9.1.1 General Requirements

Building CODE speaks to minimum door widths from an egress standpoint which is typically narrower. The height is consistent with building CODE requirements.

4.9.1.2 Construction

- See International Mechanical Code Section 304.1.
- See NEC Article 110-26 : *Minimum Clearances*.
- See NFPA 54 National Fuel Gas Code Section 8.1.2.

4.9.1.4 Ventilation

- See International Mechanical Code Section 502.

4.9.1.5 Markings

Pipes may be color coded according to use with either labels or a reference chart; directional arrows with permanent labeling on the pipes; or by other means deemed suitable by the AHJ.

4.9.1.6 Equipment Rooms Containing Combustion Equipment

Due to the CORROSIVE nature of chemicals being used in the water treatment process, it should be expected that all equipment, especially combustion equipment and any ancillary components, experience corrosion. A breach in the combustion chamber or failure of the combustion air damper could lead to carbon monoxide release into the EQUIPMENT ROOM which can prove fatal to occupants.

The carbon monoxide detectors, listed and labeled in accordance with UL 2075, should be tested, at a minimum, semiannually to ensure their operability. All combustion chambers, combustion dampers, and ancillary items associated with the combustion system, should be inspected annually to ensure they are intact, operating correctly, and not in danger of corroding through.

Inspections should be carried out by qualified parties. Where local health *(POOL)* inspectors do not have the proper training or knowledge to perform these tests and boiler inspections, operators should contract for the required tests and inspections by qualified parties. Health inspectors should review the facility's paperwork to confirm that they have had the required tests and inspections completed.

Installed

No CODE language exists for this section since the MAHC defers to other CODES but the rationale for some of it is still included in the Annex.

No items should be installed, nor shall STORAGE be planned for any items, within the minimum clearances of a COMBUSTION DEVICE, as defined by the manufacturer, or within the minimum clearances as defined the National Fuel Gas Code or other applicable CODE, whichever are greater.

- See International Mechanical Code Sec. 304.1.
- See NFPA 54 National Fuel Gas Code Sec. 8.1.2.

Increased Ventilation

Rooms containing combustion equipment may be subject to requirements for increased ventilation and combustion-air intake, as specified by the National Fuel Gas Code or other pertinent CODES. The EQUIPMENT ROOM should be so constructed as to allow for the planned equipment, or should be modified as necessary.

Where an EQUIPMENT ROOM contains combustion equipment which uses equipment-room air for combustion, no other equipment should be so installed as to reduce the room air pressure beyond the acceptable air-intake pressure range for the combustion equipment.

- See International Mechanical Code Section 701.

Noxious Gasses

All practical flames produce carbon monoxide or nitrous oxides. There is very little chance of being rid of both of them at the same time. Neither is good for human health. The key is to dilute combustion products and send them up the flue. This does not always work where equipment-room air pressure is lower than outdoor air pressure. Some COMBUSTION DEVICES work by natural draft *(buoyancy of hot gases)* and cannot tolerate any pressure difference. Other COMBUSTION DEVICES have higher pressure differences which they can overcome.

Where an EQUIPMENT ROOM contains combustion equipment which uses EQUIPMENT ROOM air for combustion, air-handling equipment should not use the room as a plenum. Exceptions may include where the combustion equipment is listed and labeled for the expected use, such installation shall be acceptable where approved by the AHJ.

- See International Mechanical Code Sec. 701.

Plenum Room

A plenum room uses the EQUIPMENT ROOM as the intake duct for HVAC equipment. Thus, it will have a low air pressure while the HVAC equipment is operating. For an INDOOR

AQUATIC FACILITY, the incoming air would contain halogen compounds, e.g. chloramines, and thus should never be used as combustion air.

Where an EQUIPMENT ROOM contains combustion equipment which uses a draft hood, air-handling equipment should not use the room as a plenum. Exceptions may include where the combustion equipment is listed and labeled for the expected use, such installation shall be acceptable where approved by the AHJ.

- See International Mechanical Code Sec. 701.

Lowered Room Pressure

In this situation, there is a tendency for the lowered room pressure to pull combustion products back down the flue into the room, and thus spread them everywhere.

Rooms containing combustion equipment are also subject to requirements for separation from CHEMICAL STORAGE SPACES.

4.9.1.7 Separation from Chemical Storage Spaces

Largely, building STANDARDS do not speak to AQUATIC VENUES; for example, the dangers that chemical fumes pose to combustion equipment.

4.9.1.7.1 Equipment

4.9.1.7.1.1 Contaminated Air

Combustion equipment, air-handling equipment, and electrical equipment should not be exposed to air contaminated with CORROSIVE chemical fumes or vapors.

- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See Chimney Safety Institute of America *(Plainfield, IN)*: *Proper Venting of Gas Fueled Appliances,* 2010.
- See NFPA National Fuel Gas Code (2002) Section 8.1.6.
- See Propane Council *(Washington, D.C.)*: Instruction Sheet IV - *Identifying and Correcting Burner Problems.*

4.9.1.7.1.2 Equipment Restrictions

Spaces containing combustion equipment, air handling equipment, and/or electrical equipment and spaces sharing air distribution with spaces containing such equipment shall not at the same time be used as CHEMICAL STORAGE SPACES. Exceptions may include equipment listed and labeled for use in that atmosphere shall be acceptable, where approved by the AHJ.

- See: ANSI/ACCA Manual SPS 2010 Section 1-6.
- See: International Mechanical Code Section 304.1

4.9.1.7.1.3 Isolated

Spaces containing combustion equipment, air-handling equipment, and/or electrical equipment and spaces sharing air distribution with spaces containing such equipment shall be isolated from CHEMICAL STORAGE SPACE air.

- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See International Mechanical Code Section 304.1.

4.9.1.7.2 Doors and Openings

4.9.1.7.2.1 Between Equipment and Chemical Storage Spaces

A door or doors should not be installed in a wall between such EQUIPMENT ROOMS and an interior CHEMICAL STORAGE SPACE.

- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See International Mechanical Code Section 304.1.

4.9.1.7.2.2 No Openings

CHEMICAL STORAGE SPACE door*(s)* must not be left open. This is important to controlling air pressure ratios, keeping CORROSIVE gases out of COMBUSTION DEVICES, and keeping children away from hazards.

There should be no ducts, grilles, pass-throughs, or other openings connecting such EQUIPMENT ROOMS to CHEMICAL STORAGE SPACES.

- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See International Mechanical Code Section 304.1.

4.9.1.7.2.3 Indoor Aquatic Facility Air

Spaces containing combustion equipment, air-handling equipment, and/or electrical equipment and spaces sharing air distribution with spaces containing such equipment should be isolated from INDOOR AQUATIC FACILITY air. Exceptions may include equipment listed for the atmosphere, which may be acceptable.

- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See Chimney Safety Institute of America *(Plainfield, IN)*: *Proper Venting of Gas Fueled Appliances,* 2010.
- See NFPA National Fuel Gas Code (2002) Section 8.1.6.
- See Propane Council *(Washington, D.C.)*: Instruction Sheet IV - *Identifying and Correcting Burner Problems.*

Combustion equipment cannot be allowed to intake halogen compounds, because acids will form in the flue and destroy it, allowing carbon monoxide and other combustion products to enter the occupied space.

4.9.1.7.2.4 No Openings

There should be no ducts, grilles, pass-throughs, or other openings connecting such spaces to an INDOOR AQUATIC FACILITY. Exceptions may include HVAC equipment which is rated for INDOOR AQUATIC FACILITY atmosphere and which serves only that INDOOR AQUATIC FACILITY shall be acceptable.

Note: *Ducts which connect the INDOOR AQUATIC FACILITY to the duct connections of air handlers should not be construed as connecting the air-handler space to the INDOOR AQUATIC FACILITY.*

- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See International Mechanical Code Section 304.1.

4.9.1.7.2.5 Openings / Gaps

Where building construction leaves any openings or gaps between floors and walls, or between walls and other walls, or between walls and ceilings, such gaps should be permanently sealed against air leakage.

- See ANSI/ACCA Manual SPS 2010 Section 12-3.

4.9.1.7.3 Indoor Aquatic Facility Access

4.9.1.7.3.1 Floor Slope

Where a door or doors must be installed in a wall between an EQUIPMENT ROOM and an INDOOR AQUATIC FACILITY, the floor of the EQUIPMENT ROOM should slope back into the EQUIPMENT ROOM in such a way as to prevent any equipment-room spills from running under the door into the INDOOR AQUATIC FACILITY. Exceptions may include:

- This may be met by a floor all of which is at least four inches below the level of the nearest part of the INDOOR AQUATIC FACILITY floor.
- This may be met by a continuous dike not less than four inches high located entirely within the EQUIPMENT ROOM, which will prevent spills from reaching the INDOOR AQUATIC FACILITY floor.

Note: Equipment-room floor drains may be required and all designs shall be compliant with ADA as they may be applicable.

Cleaning Supplies

Even if POOL chemicals and cleaning supplies are not in the EQUIPMENT ROOM, there is a very good chance that other fluids may be *(e.g. ethylene-glycol heating fluids, petroleum refrigeration oils, polyol-ester refrigeration oils, alkyl-benzene refrigeration oils, other lubricants, caustic or acidic coil cleaners, etc.)*.

4.9.1.7.3.2 Automatic Closer

Such door or doors should be equipped with an automatic closer. The door, frame, and automatic closer shall be installed and maintained so as to ensure that the door closes completely and reliably without human assistance.

4.9.1.7.3.3 Automatic Lock

Such door or doors should be equipped with an automatic lock. Such lock shall require a key or combination to open from the INDOOR AQUATIC FACILITY side. Such lock should be so designed and installed as to be opened by one hand from the inside of the room under all circumstances, without the use of a key or tool.

4.9.1.7.3.3.1 Restrict Access

Such doors should be equipped with permanent signage warning against unauthorized entry.

4.9.1.8 Other Equipment Room Guidance

4.9.1.8.1 Access Space

Where ventilation, air filtration, or space dehumidification, heating, or cooling for an INDOOR AQUATIC FACILITY is by mechanical equipment located in an EQUIPMENT ROOM, adequate access space should be provided to allow for inspection and service.

- See International Mechanical Code Section 304.1.
- See NEC Article 110-26 : *Minimum Clearances*.
- See NFPA 54 National Fuel Gas Code Section 8.1.2.

4.9.1.8.1.1 Size Requirements

The access spaces should be the greater of:

- Those required by OSHA, NEC, National Fuel Gas Code, or other official requirements; or
- The equipment manufacturer's recommendations.

4.9.1.8.2 Adequate Space

Where ventilation, air filtration, or space heating or cooling for an INDOOR AQUATIC FACILITY is beside mechanical equipment located in an EQUIPMENT ROOM, adequate space for required straight lengths of duct shall be provided as the greater of those described in AMCA 201, SMACNA Duct Manual, ACCA Manual SPS Sec. 13, or the equipment manufacturer's recommendations.

- See Air Conditioning Contractors of America Manual SPS Section 13.
- See Air Movement and Control Association AMCA 201.
- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See SMACNA Duct Manual.

4.9.1.8.3 Minimize Hazards

- See 29 CFR Part X 1926.1053(b)(9) (OSHA).
- See ANSI/ACCA Manual SPS 2010 Section 1-6.

4.9.1.8.4 Refrigeration Equipment

Most refrigerants are heavier than air. When released from containment, most will evaporate rapidly, expanding greatly in the process. If a large enough amount is released, it could displace air to above head-height. For this reason mechanical CODES usually require refrigerant-release to the outdoors when the amount of refrigerant exceeds some fraction of the occupied volume.

4.9.2 Chemical Storage Spaces

POOL-chemical associated injuries have been routinely documented.[287,288,289,290,291] For 2007-2008, 32 POOL chemical--associated health events that occurred in a public or residential setting were reported to CDC by Maryland and Michigan. These events resulted in 48 cases of illness or injury; 26 *(81.3%)* events could be attributed at least partially to chemical handling errors *(e.g., mixing incompatible chemicals)*. ATSDR's HSEESS received 92 reports of hazardous substance events that occurred at AQUATIC FACILITIES. More than half of these events *(55 [59.8%])* involved injured persons; the most frequently reported primary contributing factor was human error. Estimates based on CPSC's NEISS data indicate that 4,876 *(95% confidence interval [CI]: 2,821–6,930)* emergency department *(ED)* visits attributable to POOL chemical--associated injuries occurred in 2012; the most frequent diagnosis was poisoning *(2,167 ED visits [95% CI: 1,219–3,116])*. CDC has developed recommendations to reduce the risk of chemical-associated injuries at AQUATIC FACILITIES.[292] Designers and aquatics staff should read and consider findings and recommendations developed from investigations related to POOL chemical-related injuries. See "CDC Recommendations for Preventing Pool Chemical-Associated Injuries" at the following website: http://www.cdc.gov/healthywater/swimming/pools/preventing-pool-chemical-injuries.html.

The design for CHEMICAL STORAGE SPACE was included in the initial version of the MAHC Ventilation and Air Quality module AIR HANDLING SYSTEM design posted for public comment. It was removed in the revised indoor AIR HANDLING SYSTEM design area of the MAHC as part of revising the definition of an INDOOR AQUATIC FACILITY for which the AIR HANDLING SYSTEM does not include CHEMICAL STORAGE SPACE or other space outside the negative pressure zone around the AQUATIC VENUE. However, the building of an INDOOR AQUATIC FACILITY will still require consideration of the ventilation of CHEMICAL STORAGE SPACES using separate AIR HANDLING SYSTEMS.

Chemicals, typically stored in AQUATIC FACILITIES for the purpose of maintenance and water treatment, can create ventilation hazards for PATRONS and staff. International Mechanical Code and International Fire Code provide very specific guidance on the construction and AIR HANDLING SYSTEM design of these areas. Often AQUATIC FACILITIES store chemicals in the pump room, but the operational STORAGE of these chemicals should

287 CDC. Acute illness and injury from swimming pool disinfectants and other chemicals --- United States, 2002—2008. MMWR Morb Mortal Wkly Rep. 2011;60(39):1343-1347.
288 CDC. Pool chemical—associated health events in public and residential settings---United States, 1983-2007. MMWR Morb Mortal Wkly Rpt. 2009;58(18):489-493.
289 Hlavsa MC, et al. Pool chemical–associated health events in public and residential settings — United States, 2003–2012, and Minnesota, 2013. MMWR Morb Mortal Wkly Rep. 2014;63(19):427-30.
290 Anderson AR, et al. The distribution and public health consequences of releases of chemicals intended for pool use in 17 states, 2001-2009. J Environ Health. 2014;76(9):10-5.
291 Hlavsa MC, et al. Surveillance for waterborne disease outbreaks and other health events associated with recreational water use — United States, 2007–2008. MMWR Surveill Summ 2011;60:1-37.
292 CDC. Recommendations for Preventing Pool Chemical-Associated Injuries. Accessed at http://www.cdc.gov/healthywater/swimming/pools/preventing-pool-chemical-injuries.html.

be limited to what is necessary for immediate use. Back up supplies should be appropriately stored and maintained in a separate area designed according to the above STANDARDS.

Other key areas to consider for proper CHEMICAL STORAGE would include:

- Follow local building CODES and/or ASHRAE Standards or STANDARDS such as NFPA 5000: Building Construction and Safety Code requirements, or IBC Section 307.
- Separate the AIR HANDLING SYSTEMS for the CHEMICAL STORAGE SPACE and pump room from the rest of the building.
- Separate the AIR HANDLING SYSTEM for the AQUATIC VENUE area from the rest of the building.
- If an older AQUATIC FACILITY does not have separate AIR HANDLING SYSTEMS for the CHEMICAL STORAGE SPACE and pump room as well as the AQUATIC VENUE area, consider installing emergency heating, ventilating, and air conditioning *(HVAC)* cutoffs in these areas.
- Ensure that the CHEMICAL STORAGE SPACE, pump room, and AQUATIC VENUE area are well-ventilated.
- Ventilate the CHEMICAL STORAGE SPACE, pump room, and AQUATIC VENUE area to the outside.

4.9.2.1 Outdoor / Indoor Storage

4.9.2.1.3 Dedicated Space

The number of required CHEMICAL STORAGE SPACES should be as necessary to allow safe STORAGE of the chemicals present.

Additional Space

Where the listing, labeling, or SDS of chemicals indicates incompatibility of STORAGE with other chemicals present, other CHEMICAL STORAGE SPACE(S) should be provided.

- See ANSI/ACCA Manual SPS 2010
  - Section 1-6.
  - Section 12-3.
- See Calcium Hypochlorite, Sodium Hypochlorite, Muriatic Acid, BCDMH, etc., have NFPA 704 health rankings of 3
- See CDC. Recommendations for Preventing Pool Chemical-Associated Injuries accessed at http://www.cdc.gov/healthywater/swimming/pools/preventing-pool-chemical-injuries.html.
- See EPA Oswer 90 008.1 *Chemical Emergency Preparedness and Prevention Advisory SWIMMING POOL CHEMICALS: Chlorine*.
- See International Mechanical Code
  - Section 502.8.4.
  - Section 502.9.2.
- See Narnes, David, “Swimming Pool Chemical Safety”, http://www.ehow.com/way_5406877_swimming-pool-chemical-safety.html

- See NFPA 704 “Hazard Identification System” for chemical rankings.

4.9.2.1.4 Eyewash

It is the intent to allow re-fillable eyewash bottles and not require plumbed emergency eyewashes and SHOWERS unless required by the AHJ.

4.9.2.1.4.1 AHJ Requirements

The intent is to allow some flexibility since installation in the CHEMICAL STORAGE SPACE may be prone to failure due to corrosion. External eye wash stations should be close and easily found such as in a location outside the door that all staff must walk past. The MAHC will continue to look for data supporting a maximum distance from the door.

4.9.2.2 Construction

As applicable, the STANDARDS of NFPA 400, the IFPC, and the IBC shall prevail. This STANDARD is not intended to provide relief from these other regulations, but to provide BEST PRACTICE where these regulations are not adopted or enforced. The more stringent STANDARD shall prevail as applicable.

4.9.2.2.3 Floor

The floor or DECK of the CHEMICAL STORAGE SPACE should be protected against substantial chemical damage by the application of a coating or sealant capable of resisting attack by the chemicals to be stored.

4.9.2.2.6 No Openings

Other than a possible door, there should be no permanent or semi-permanent opening between a CHEMICAL STORAGE SPACE and any other INTERIOR SPACE of a building intended for occupation.

- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See ANSI/ACCA Manual SPS 2010 Section 12-3.
- See International Mechanical Code Section 502.
- See NFPA 704 Hazard Identification System.
- See SDS Health Hazard Data
    - Calcium Hypochlorite.
    - Hydrochloric Acid.
    - Muriatic Acid.
    - Sodium Hypochlorite.

4.9.2.3 Exterior Chemical Storage Spaces

As applicable, the STANDARDS of NFPA 400, the IFPC, and the IBC shall prevail. This STANDARD is not intended to provide relief from these other regulations, but to provide BEST PRACTICE where these regulations are not adopted or enforced. The more stringent STANDARD shall prevail as applicable.

4.9.2.3.2 Fencing

Such part of an outdoor space as does not join a wall of a building should be completely enclosed by fencing that is at least 6 feet *(1.8 m)* high on all other sides.

4.9.2.4 Chemical Storage Space Doors

As applicable, the STANDARDS of NFPA 400, the IFPC, and the IBC shall prevail. This STANDARD is not intended to provide relief from these other regulations, but to provide BEST PRACTICE where these regulations are not adopted or enforced. The more stringent STANDARD shall prevail as applicable.

4.9.2.4.1 Signage

Given the high turnover rate or potential for employees to travel between workplaces at some AQUATIC FACILITIES, it would seem prudent to require a posting of the SDS location. Specifying the location of the SDS on the actual entry door to the chemical space may help reduce time for a response to an event. It further strengthens the requirements of OSHA:

> ***1910.1200(g)(8)***
>
> The employer shall maintain in the workplace copies of the required safety data sheets for each hazardous chemical, and shall ensure that they are readily accessible during each work shift to employees when they are in their work area(s). (Electronic access and other alternatives to maintaining paper copies of the safety data sheets are permitted as long as no barriers to immediate employee access in each workplace are created by such options.)
>
> ***1910.1200(g)(9)***
>
> Where employees must travel between workplaces during a workshift, i.e., their work is carried out at more than one geographical location, the material safety data sheets may be kept at the primary workplace facility. In this situation, the employer shall ensure that employees can immediately obtain the required information in an emergency.
>
> ***1910.1200(g)(10)***
>
> Safety data sheets may be kept in any form, including operating procedures, and may be designed to cover groups of hazardous chemicals in a work area where it may be more appropriate to address the hazards of a process rather than individual hazardous chemicals. However, the employer shall ensure that in all cases the required information is provided for each hazardous chemical, and is readily accessible during each work shift to employees when they are in their work area(s).

- See NFPA 704 “Hazard Identification System”.

4.9.2.4.2 Emergency Egress

This usually takes the form of a kick-out panel in the door. When trapped, a person can sit down and kick out the panel, creating an opening usually about six inches *(15.2 cm)* narrower than the door and about 28 inches *(71.1 m)* high. Since these are used in most ENCLOSURES where a person can be trapped *(e.g. walk-in freezers)* the volume is high enough for additional expense to be minimal. Trapping could happen in several ways, but the most common is binding of the door to the jamb. Corrosion products can build up inside a metal door between the jamb and the wall, forcing the jamb away from the wall and toward the door. At some point the door will either fail to open or fail to close.

4.9.2.4.3 Interior Door

- Safety Data Sheets, Health Hazard & Spill Data
  - Sodium Hypochlorite.
  - Calcium Hypochlorite.
  - Hydrochloric Acid.
  - Muriatic Acid.

4.9.2.4.4 Equipment Space

- See ANSI/ACCA Manual SPS 2010 Section 1-6.
- See ANSI/ACCA Manual SPS 2010 Section 12-3.
- See Canadian Standards Association C22.2.
- See Chimney Safety Institute of America, Plainfield, IN
  - Proper Venting of Gas Fueled Appliances, 2010
- See NEC Art. 110.11: *Deteriorating Agents*.
- See NEMA 250.
- See NFPA National Fuel Gas Code (2002) Section 8.1.6
- See Propane Council (Washington, D.C.)
- Instruction Sheet IV: *Identifying and Correcting Burner Problems.*
- See Underwriters Laboratory
  - Section 50.
  - Section 508.

4.9.2.4.4.1 Corrosive

Combustion equipment cannot be allowed to intake halogen compounds, because acids will form in and destroy the flue. Air-handlers have strong negative air pressures inside them. This will draw in any CONTAMINANTS around the cabinet and distribute throughout the ducted system.

4.9.2.4.5 Interior Opening

4.9.2.4.5.2 Automatic Locks

Most locks for employee-only doors in public buildings would qualify, since such locks must lock automatically from the outside, but cannot require a key or tool for exit. Examples of suitable lock types would include, but not be limited to, the locks on hotel-room doors, the lock on the door of a personnel-file STORAGE room, the lock on a janitor's closet, etc.

- See ANSI/ACCA Manual SPS 2010
  - Section 1-6.
  - Section 4-4.

- Section 12-3.

4.9.2.5 Interior Chemical Storage Space

As applicable, the STANDARDS of NFPA 400, the IFPC, and the IBC shall prevail. This STANDARD is not intended to provide relief from these other regulations, but to provide BEST PRACTICE where these regulations are not adopted or enforced. The more stringent STANDARD shall prevail as applicable.

4.9.2.5.1 No Air Movement

- See ANSI/ACCA Manual SPS 2010 Section 4-4.

4.9.2.5.2 Electrical Conduit System

An interior CHEMICAL STORAGE SPACE that shares any building surface *(wall, floor, ceiling, door, etc.)* with any other INTERIOR SPACE or that shares an electrical-conduit system with any other space should be equipped with a ventilation system that maintains the air pressure in the CHEMICAL STORAGE SPACE below that of any other INTERIOR SPACE by 0.05 to 0.15 inches *(1.3 to 3.8 mm)* of water pressure, or by such greater pressure difference as should be necessary to ensure that all air movement through building surfaces or conduits should be toward the CHEMICAL STORAGE SPACE.

Note 1: This can usually be accomplished by maintaining the air pressure in the CHEMICAL STORAGE SPACE at least 0.05 I.W.C. to 0.15 I.W.C. below that of any adjoining space and below that of any space connected to the CHEMICAL STORAGE SPACE by an electrical conduit system. Larger pressure differences may be needed in special cases.

Note 2: Where:

- All conduits passing through the CHEMICAL STORAGE SPACE use only threaded joints within the CHEMICAL STORAGE SPACE, and
- All conduits terminating in the CHEMICAL STORAGE SPACE
  - Are effectively sealed, and
  - Use only threaded joints within the CHEMICAL STORAGE SPACE, the specified air-pressure difference need not include the air pressures of INTERIOR SPACES which do not share a building surface with the CHEMICAL STORAGE SPACE.

4.9.2.5.2.2 Pressure Difference

This pressure difference should be maintained by a continuously operated exhaust system used for no other purpose than to remove air from that one CHEMICAL STORAGE SPACE.

4.9.2.5.2.4 Alarm

- See ANSI/ACCA Manual SPS 2010:
  - Section 1-6.
  - Section 4-4.
  - Section 12-3.

- See *ASHRAE Handbook: HVAC Applications, 2011, Places of Assembly, Natatoriums,* Section 4.6: *Ventilation Requirements.*
- See International Mechanical Code:
- Section 502.1.See Safety Data Sheets, Health Hazard Data:
    - o Calcium Hypochlorite.
    - o Hydrochloric Acid.
    - o Muriatic Acid.
    - o Sodium Hypochlorite.

4.9.2.6 Air Ducts in Interior Chemical Storage Spaces

4.9.2.6.1 No Air Movement

- See International Mechanical Code:
    - o Section 502.1.
- See ANSI/ACCA Manual SPS 2010:
    - o Section 1-6.
    - o Section 4-4.

Ducts should not be shared between spaces. Should the blower stop or fail, there would be cross-contamination.

4.9.2.8 Combustion Equipment in Interior Chemical Storage Spaces

- See NFPA National Fuel Gas Code (2002) Section 8.1.6
- See Chimney Safety Institute of America, Plainfield, IN
    - o *Proper Venting of Gas Fueled Appliances*, 2010
- Propane Council, Washington DC
    - o Instruction Sheet IV: I*dentifying and Correcting Burner Problems*

4.9.2.11 Gaseous Chlorination Space

Many current jurisdictions closely regulate the use of gas CHLORINE from a disaster preparation and response standpoint. This can make CHLORINE gas use prohibitive from a regulatory standpoint to the point that its use is difficult to justify.

4.9.2.12 Windows in Chemical Storage Spaces

4.9.2.12.1 Not Required

These windows are sometimes built into the door, although not always. *(There are fire-rated doors with windows.)* Such windows may serve several purposes.

4.9.2.12.2 Requirements

Such windows are usually installed for free lighting, although there can be drawbacks. Some chemicals may react on exposure to sunlight.

4.10 Hygiene Facilities

4.10.1 General

Language similar to this section is found in most state CODES.

4.10.1.2 Minimum to Provide

During 2011–2012, 36 *(81.8%)* of 44 treated recreational water–associated outbreaks of diarrheal illness were caused by *Cryptosporidium*[293]. These cryptosporidiosis outbreaks tend to disproportionately affect children under five years of age and can cause community-wide outbreaks[294]. Infectious *Cryptosporidium* OOCYSTS' extreme CHLORINE tolerance allows them to survive for 2.4–10.6 days when free CHLORINE levels are maintained at 1–3 mg/L[295,296]. The OOCYSTS small size *(4.5 µm x 5.5 µm)* also allows them to bypass typical sand and cartridge filters[297]. While SECONDARY DISINFECTION SYSTEMS or SUPPLEMENTAL TREATMENT SYSTEMS can inactivate the OOCYSTS, these UV and ozone treatment systems are circulation dependent[298,299,300,301,302].

Thus, changing BATHER behavior in the following ways are needed to help prevent cryptosporidiosis outbreaks:

- Enforcement of policies that exclude swimmers with diarrhea,
- Swimmer education about hygienic swimming behaviors *(e.g., taking a CLEANSING SHOWER before entering the water, not swallowing the water)*, and
- Using secondary or supplemental DISINFECTION.

Chloramines

During January–March 2007, over 660 BATHERS and aquatic staff at a waterpark experienced respiratory symptoms and eye irritation caused by chloramines.[303] Chloramines form when free CHLORINE OXIDIZES nitrogenous compounds *(e.g., sweat, urine, and personal care products)* that wash off BATHERS' bodies. Chloramines can

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293 Hlavsa MC et al. Outbreaks of Illness Associated with Recreational Water — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2015;64(24):668-72.
294 CDC. Communitywide cryptosporidiosis outbreak--Utah, 2007. MMWR Morb Mortal Wkly Rep. 2008;57(36):989-93.
295 Shields, et al. Inactivation of Cryptosporidium parvum under chlorinated recreational water conditions. J Water Health 2008;6(4):513–20.
296 Murphy JL, et al. Effect of cyanuric acid on the inactivation of Cryptosporidium parvum under hyperchlorination conditions. Environ Sci Technol 2015;49:7348-55
297 Smith H. Diagnostics. In: Fayer R, Xiao L, eds. Cryptosporidium and cryptosporidiosis. 2nd ed. Boca Raton, Florida: CRC Press, 2008:173–207.
298 Betancourt WQ, et al. Drinking water treatment processes for removal of Cryptosporidium and Giardia. Vet Parasitol. 2004;126(1-2):219-34.
299 Craik SA, et al. Inactivation of Cryptosporidium parvum oocysts using medium- and low-pressure ultraviolet radiation. Water Res. 2001;35(6):1387-98.
300 Rochelle PA, et al. The response of Cryptosporidium parvum to UV light. Trends Parasitol. 2005;21(2):81-7.
301 Corona-Vasquez B, et al. Inactivation of Cryptosporidium parvum oocysts with ozone and free chlorine. Water Res. 2002;36(16):4053-63.
302 Korich DG, et al. Effects of ozone, chlorine dioxide, chlorine, and monochloramine on Cryptosporidium parvum oocyst viability. Appl Environ Microbiol. 1990;56(5):1423-8.
303 CDC. Respiratory and ocular symptoms among employees of a hotel indoor waterpark resort — Ohio, 2007. MMWR 2009; 58(4):81-85.

volatilize into the air where it can accumulate in air of indoor AQUATIC VENUES. One in five *(17%)* American adults reports having ever urinated in a POOL[304], and elite athletes can sweat over 700 mL/h[305]. Rinsing off in the SHOWER for 60 seconds and wearing bathing caps significantly decreases the amount of total organic carbon and total nitrogen[306]. Studies also suggest that UV treatment can reduce chloramine levels in the water[307,308].

Accumulation of chloramines in the air at indoor treated recreational WATER VENUES can be reduced with the following practices:

- Policies that require showering before entering the water,
- Swimmer education about hygienic swimming behaviors *(e.g., taking a RINSE SHOWER and using the toilet before entering the water, not urinating in the POOL, and wearing bathing caps)*, and
- Using UV water treatment and improving ventilation.

4.10.1.5 Theoretical Peak Occupancy

The minimum number of RINSE SHOWERS and CLEANSING SHOWERS should have PLUMBING FIXTURE counts correlated directly to the THEORETICAL PEAK OCCUPANCY IN MAHC 4.1.2.3.5. Any PLUMBING FIXTURE counts above this should be accordance with the AHJ's requirements.

4.10.2 Location

4.10.2.1 Distance

The intent of this CODE item is to discourage PATRONS from drinking POOL water and encourage them to keep themselves hydrated. The intent is also to encourage PATRONS to use the HYGIENE FACILITIES rather than urinating in the POOL or changing diapers at the side of the AQUATIC VENUE or on AQUATIC VENUE furniture. Restrooms need to be easily accessible and available to PATRONS of AQUATIC VENUES so that they will use restrooms rather than urinating or defecating in the VENUE water, which is common. Compared with other public locations, people feel that it is more acceptable to "pee in the POOL" and not use sanitary facilities for the bodily function. This may not be possible in large waterparks, however, they can possibly be located within 300 feet *(91 m)* from the AQUATIC VENUE. The distance needed for parents to walk or carry children less than 5 years of age should be shorter *(200 ft or 61 m)* to ensure use. These distances are found in multiple state or local CODES including Wisconsin, Oregon, Florida, and New York. When possible, it is preferable to have a bathroom on the same floor as the AQUATIC VENUE; however, it is not required at this time in the MAHC.

304 Wiant C. A snapshot of swimmer hygiene behavior. Int J Aquat Res Ed. 2011;5(3):244-245.
305 Cox, et al. Body mass changes and voluntary fluid intakes of elite level water polo players and swimmers. J Sci Med Sport. 5,3 (2002): 183-193.
306 Keuten MG, et al. Definition and quantification of initial anthropogenic pollutant release in swimming pools. Water Res. 2012 Jul;46(11):3682-92.
307 Cassan D, et al. Effects of medium-pressure UV lamps radiation on water quality in a chlorinated indoor swimming pool. Chemosphere 2006;62(9):1507-13.
308 Li J, et al. UV photodegradation of inorganic chloramines. Environ Sci Technol 2009;43(1):60-5.

Drinking water should be available so that PATRONS, especially young children, are less likely to drink POOL water and to ensure that PATRONS are kept well-hydrated.

4.10.2.2 Children Less than Five Years of Age

There are specific types of AQUATIC VENUES that pose an INCREASED RISK of fecal contamination of the water and transmission to BATHERS such as WADING POOLS, WATER ACTIVITY POOLS, INTERACTIVE WATER PLAY VENUES, or other AQUATIC VENUES designed primarily for children less than five years of age. For these AQUATIC VENUES, diaper changing areas should be located directly adjacent to the kiddie areas to promote use.

It is especially important that HYGIENE FACILITIES be available to these INCREASED RISK groups. Children less than five years of age have the highest incidence of diarrheal illness and are more likely to be a source for spreading RWIs.

4.10.3 Design and Construction

Language similar to this section is found in most state CODES.

4.10.3.2 Floor Base

The purpose of coving is to prevent water splashing on the wall when mopping. Six inches *(15.2 cm)*, a common height, was taken from building CODE.

- For further information, also see the FDA Model Food Code for Kitchens.

4.10.3.3 Floor Drains

4.10.3.3.1 Opening Grill Covers

Holes in floor drain cover openings need to be sized to prevent small children's toes from becoming entrapped when walking over them.

4.10.3.3.2 Sloped to Drain

Floors not sloped to drain have been shown to allow bacterial growth on indoor and outdoor AQUATIC VENUE POOL DECKS.

4.10.3.5 Hose Bibb

The purpose of these hose bibs is to permit adequate cleaning of SHOWER and toilet facilities and to permit cleaning of any spills occurring in the HYGIENE FACILITY. See also MAHC 6.5 for further rationale.

4.10.4 Plumbing Fixture Requirements

Language similar to this section is found in most state CODES.

4.10.4.1 General

4.10.4.1.1 Protected

It is fundamental that there be no cross connections between safe *(potable)* and unsafe *(non-potable)* water supplies. All hose bibbs should be equipped with a vacuum breaker to prevent back siphonage. This CROSS-CONNECTION protection can also be achieved at lavatories and laundry tub washing facilities through an air gap. As a general rule, the INLET pipe is terminated at a distance about four times the diameter of the pipe and not less than four inches *(10.2 cm)* above the maximum overflow level of the PLUMBING FIXTURE rim.

4.10.4.1.3 Toilet Counts

Facilities in jurisdictions with requirements governing the number of sanitary facilities should follow those requirements. AQUATIC FACILITIES with an average PATRON load of over 100 persons should follow the IPC. Facilities with average PATRON loads of less than 100 persons should follow either the IPC or UPC. The IPC may require significantly more toilet facilities for women than for men.

Gender Potty Parity

Previous issues of the nation's model consensus CODE mandated an equal amount of toilet FIXTURES for both men and women. Newer versions of the CODE will likely provide recommendations that increase the minimum required facilities for women.

Potty Parity discussion from Reasons to Adopt the 2000 IPC, developed by the ICBO as an informational aid to CODE officials and the public.

The IPC requires far less HYGIENE FIXTURES for various types of occupancies than the UPC. This is contrary to the "potty parity" movement which demands more FIXTURES for women's toilet rooms to avoid the long waiting lines. The UPC also provides more WCs and urinals in most men's toilet rooms than the IPC and assures adequate WCs by limiting the number that can be deleted by installing additional urinals.

The authors of the ICBO have suggested that the provisions of the UPC reflect what the "potty parity movement" called for. The IPC is based upon research. The provisions of the IPC do address the issue of "potty parity" and reflect studies by Dr. Sandra Rawls at the University of Virginia, the Stevens Institute of Technology, the National Restaurant Association, and the ASPE Research Foundation. The issue of "potty parity" is mostly an issue in assembly buildings with large occupant loads, especially where there is a period of high demand such as at intermission at a theater or at halftime at a football stadium. The "potty parity" is not an issue for occupancies where there is no instantaneous demand on the FIXTURE usage. IPC Table 403.1 reflects requirements for twice as many PLUMBING FIXTURES in the ladies' room compared with the men's room, when the type of occupancy demands such a count. In occupancies where the factors do not demand such an increase, the CODE does not require it. It should also be pointed out that part of this issue arises because of some CODES requiring both WCs and urinals within the men's restroom. Therefore, the numbers for men were somewhat higher. The IPC does not have a mandatory requirement for urinals. It will generally require the same number of PLUMBING FIXTURE in the men's and women's restrooms. However, when two or more WCs are required, the IPC will permit up to 67 percent of the FIXTURES to be replaced by urinals.

- For additional supporting information, see IPC: *A Guide for Use and Adoptio*n: http://lorisweb.com/CMGT235/DIS_11/plumbing%20code%20use%20ICC.pdf.

Some differences between the IPC and UPC CODES on this issue are as follows:

International Plumbing Code:

- Utilizes a fixed PLUMBING FIXTURE to OCCUPANT LOAD ratio.
- Does not mandate urinals for men.
- Allows up to 67% of the requirement for WCs to be substituted for urinals.
- Establishes a separate FIXTURE calculation factor for men and women. In some cases twice as many FIXTURES are required for women compared with men.
- No arbitrary parity requirement.

Universal Plumbing Code:

- Utilizes a variable PLUMBING FIXTURE to OCCUPANT LOAD ratio.
- Requires urinals to be installed based on a FIXTURE to OCCUPANT LOAD ratio. Does not allow for one to one substitutions. For each urinal added over what is required, you may have one to one substitutions up to 2/3 of what is required.
- Requires the total number of WCs for women to be equal to the total number of WCs and urinals for men.

4.10.4.2 Cleansing Showers

The purpose of CLEANSING SHOWERS described in this section is to remove dead skin, sweat, nitrogenous waste, and perianal fecal material before BATHERS enter the POOL. This is best done through nude showering using warm water and soap.

An average of 0.14 grams of fecal material can be found on a person's peri-anal surface *(the amount of feces for children ranges from 0.01-10 grams and for adults 0.0001 to 0.1 g[309])*. Therefore, fecal contamination of the perianal area is common. This contamination may include the CHLORINE-tolerant parasite *Cryptosporidium*[310,311] which is not inactivated by routine disinfectant levels required in AQUATIC VENUES. Since the effectiveness of most halogen-based disinfectants is reduced by the presence of organic material, the purpose of CLEANSING SHOWERS is to reduce the inorganic, organic, and fecal load introduced into POOLS.

4.10.4.2.1 Count

The THEORETICAL PEAK OCCUPANCY *(MAHC 4.1.2.3.5)* has been accounted for in the one SHOWER per sex per 4000 square feet *(372 m^2)*. This assumes using oneBATHER per 20 square feet *(1.9 m^2)*, so at 4000 square feet, there will be one SHOWER per 200 BATHERS. Further research on this topic is recommended and can be addressed in future versions of the MAHC.

4.10.4.2.3 Location

309 Gerba CP. Assessment of enteric pathogen shedding by bathers during recreational activity and its impact on water quality. Quant Micro. 2000;2:55-68.
310 Shields JM, et al. The effect of cyanuric acid on the disinfection rate of Cryptosporidium parvum in 20-ppm free chlorine. J Water Health. 2009 Mar;7(1):109-14. doi: 10.2166/wh.2009.008.
311 Murphy JL, et al. Effect of cyanuric acid on the inactivation of Cryptosporidium parvum under hyperchlorination conditions. Environ Sci Technol 2015;49:7348-55.

The placement of the SHOWERS is intended to encourage BATHERS to see and use the SHOWERS before they enter the water.

4.10.4.2.4 Enclosed

Entryways to CLEANSING SHOWER compartments shall be enclosed to provide privacy. Individual SHOWER stall curtains and doors are not required. Providing privacy for CLEANSING SHOWERS promotes BATHER cleansing prior to entering AQUATIC VENUES.

4.10.4.2.6 Exemption

"Residential settings" includes condos, apartments, and homeowners associations but does not apply to individual residential POOL settings. The intent is for BATHERS to use their rooms/homes for a CLEANSING SHOWER; however, one RINSE SHOWER on the DECK is required at these AQUATIC FACILITIES encouraging BATHERS to shower prior to entering water if a BATHER had not already done so.

4.10.4.3 Rinse Showers

The purpose of the RINSE SHOWERS is to remove inorganic material such as sand or dirt that can bind with CHLORINE and reduce the amount for other pathogen inactivation. Rinsing with water also removes BATHER'S CONTAMINANTS such as sweat, hygiene products, deodorant, hair spray, etc. Rinsing off in the SHOWER for 60 seconds and wearing bathing caps significantly decreases the amount of total organic carbon and total nitrogen[312].

A RINSE SHOWER can be taken on the DECK in open SHOWERS by the AQUATIC VENUE using ambient temperature water so dirt and other CONTAMINANTS are rinsed off before entering the water.

4.10.4.3.3 Floor Sloped

Floors of RINSE SHOWERS shall be sloped to drain waste water away from the AQUATIC VENUE and any landscaping areas if present. The intent is to prevent landscaping materials from being tracked back or washed into the AQUATIC VENUE area.

4.10.4.3.4 Large Aquatic Facilities

The intent is to encourage BATHERS to see and use the RINSE SHOWERS before they enter the water.

4.10.4.3.5 Beach Entry

The intent of having at least four showerheads every 50 feet *(15.2 m)* at a beach entry allows multiple people to rinse off at the same time. Showerheads could be provided as wall units, pedestals *(one pedestal could have four showerheads or two pedestals could have two showerheads each)*, allowing AQUATIC FACILITY owners to have versatility in design.

4.10.4.3.6 Lazy River

312 Keuten MG, et al. Definition and quantification of initial anthropogenic pollutant release in swimming pools. Water Res. 2012 Jul;46(11):3682-92.

BATHERS enter LAZY RIVERS only in designated areas; therefore locating RINSE SHOWERS near these entrances facilitates rinsing before entering the LAZY RIVER.

4.10.4.3.7 Waterslide

BATHERS congregate into queue lines for access to WATERSLIDES. Providing a RINSE SHOWER on the DECK of a queue line encourages use prior to entering the water.

4.10.4.4 All Showers

The intent is to encourage use of showering prior to entering an AQUATIC VENUE. Large AQUATIC FACILITIES, based on their THEORETICAL PEAK OCCUPANCY, would require a large number of CLEANSING SHOWERS which would put an economic burden on these facility types. The MAHC acknowledges CLEANSING SHOWERS are more expensive to install than RINSE SHOWERS, therefore as long as the required number of showers is met, AQUATIC FACILITIES can decide which type of SHOWER is conducive for their PATRONS.

In addition, the 2012 ISPSC Section 609.3.1 allows flexibility on the ratio of CLEANSING to RINSE SHOWERS above 7,500 square feet of water surface area.

4.10.4.5 Diaper-Changing Stations

The material in this section addresses diapering of infants and young children. These are the age groups most commonly involved in contamination of recreational water that can lead to outbreaks of illness associated with recreational water. Although some older persons must wear diapers the incontinence is not likely to be associated with a diarrheal illness so the risk of infection from adults is much less than that from children. Therefore, we do not believe that special regulations are needed for elderly BATHERS. Current DIAPER-CHANGING UNIT designs do not supply all the features needed for sanitary and efficient diaper changing and clean-up to minimize spreading pathogens further in the AQUATIC FACILITY.

The MAHC defines a DIAPER-CHANGING STATION to include the following:

- A DIAPER-CHANGING UNIT,
- An adjacent hand washing sink,
- Soap with dispenser,
- Trash receptacle, and
- Necessary cleaning materials for the DIAPER-CHANGING UNIT.

4.10.4.5.1 Each Facility

4.10.4.5.1.1 Hand Wash Sink

HAND WASH STATIONS are required adjacent to DIAPER-CHANGING STATIONS to promote use after using the toilet/urinal or changing diapers. Facilities will have one year after adoption on this MAHC section to install a plumbed sink with soap and dispenser, hand drying device/or paper towels and dispenser, and trash receptacle.

4.10.4.5.1.2 Portable

If a permanently plumbed hand wash sink is not economically feasible to install, a portable HAND WASH STATION can be used as a substitute for one year. Portable HAND WASH STATIONS are used at temporary events and include a water and waste tank that requires frequent refilling and draining for continual use.

4.10.4.5.2 Conform

There appear to be two different configurations of DIAPER-CHANGING UNITS currently available and suitable for this setting. The first type, a fold-down commercial unit commonly mounted on the wall, is addressed by ASTM F2285-04: *Consumer Performance Standards for Commercial Diaper-Changing Stations*. The second type, a free-standing unit, is addressed by *Caring for Our Children (CFOC): National Health and Safety Performance Standards: Guidelines for Out-of-Home Child Care Programs (http://nrckids.org)*.

A major difference between these two designs is that ASTM F2285-04 calls for restraining straps while CFOC prohibits the use of straps and relies on a 3 inch *(7.6 cm)* lip to keep children from falling off. Both designs have inherent problems. The problems with straps are associated with cleaning and possible hanging hazard. The problem with a 3 inch *(7.6 cm)* lip is that they are not available on fold-up units. The MAHC language does not discriminate between these two designs, but the unit used should conform to one of these two STANDARDS.

4.10.4.5.3 Unisex

Increasingly, many AQUATIC VENUES are providing family dressing areas and caregiver rooms to attend to family needs. This provision permits parents to attend to the needs of small children of the opposite sex.

4.10.4.5.4 Trash Can

Trash receptacles are needed to help maintain cleanliness around the DIAPER-CHANGING STATION for any disposable changing unit covers, diapers, sanitizing wipes, or disposable paper towels.

4.10.4.6 Non-Plumbing Fixture Requirements

4.10.4.6.4 Lockers

While some lockers are designed to sit directly on the floor, other lockers may need to be elevated. This prohibits water accumulation beneath the lockers. Such accumulation can lead to the growth of mold, mildew, and slime build up. The MAHC has gone with the current industry STANDARD of 3.5 inches *(8.9 cm)* high but recommends moving to a new STANDARD of 6 inches *(15.2 cm)* to allow better access, cleaning, and drying under the lockers.

4.10.4.6.6 Dryers / Paper Towels

Hand drying devices or paper towel dispensers should be located adjacent to the hand washing sinks to facilitate use. To prevent overcrowding, they may be positioned to move users away from the sink and toward the exit. In childcare settings, the dispensers and devices are usually within arm’s reach of the sink.

4.10.5 Provision of Suits, Towels, and Shared Equipment

Although providing reusable bathing suits is no longer common, many AQUATIC FACILITIES provide PATRONS with towels and other shared equipment. The purpose of this wording STANDARD is to ensure that these AQUATIC FACILITIES provide adequate equipment and space in their design and construction for laundering, sanitizing, and drying these items.

4.10.6 Foot Baths

FOOT BATHS with standing water allow the buildup of organic material and bacterial and fungal growth and can lead to the spread of pathogens.

4.10.7 Sharps

This section was included to address AQUATIC VENUES that provide PATRONS with sharps, especially razors, so that safe disposal is assured. Approved sharps containers are rigid, leak-proof, puncture resistant boxes of various sizes made of hard red plastic. They have a lid that can be securely sealed to keep contents from falling out, and they are clearly marked with the bio-hazard symbol. OSHA regulations describe the design and use of sharps containers for a variety of settings.

Businesses are required by OSHA to deposit sharps into a sharps container that complies with OSHA regulations in order to protect employees. Once that container is full, it must be disposed of according to state and federal regulations.

4.11 Water Supply / Wastewater Disposal

4.11.1 Water Supply

4.11.1.1 Public Water System

4.11.1.1.1 Other Sources

PUBLIC WATER SYSTEMS include community water systems, non-transient non-community water systems, or transient non-community water systems with some noted exceptions.

There are several lake and spring sources around the country that have been used for decades to supply water to AQUATIC FACILITIES. As long as the source water quality does not significantly change and can be treated by the AQUATIC FACILITY equipment to protect the health and SAFETY of PATRONS, it can be allowed.

4.11.1.1.2 Condensate / Reclaimed Water

The steps necessary to make reclaimed water meet source water STANDARDS are beyond the scope of the MAHC. These steps are set by the state and federal agencies that set requirements for drinking water.

This would be up to the AHJ and local conditions. The MAHC felt that, especially considering recent affinities towards sustainability, reclaiming condensate would be acceptable as long as this water met the same STANDARDS as incoming domestic water *(even if this required UV or other disinfectants, filters, etc.)*. A provision for deferring to the AHJ ruling based on locale was important to us as well. For instance, this may be more of a politically important issue in Arizona or Nevada than in other areas of the country. Non-potable use for this water is in keeping with water as a limited resource.

4.11.1.2 Sufficient Capacity

This requirement is for when AQUATIC FACILITIES choose to be open when backwashing *(e.g., they can backflush one filter while still maintaining filtration through another system; operating without the RECIRCULATION SYSTEM running is prohibited)*. A facility may choose to regulate when their backwash cycles occur *(such as at closing)*. Many fully automated backwash systems for HRS filters are programmed to backwash at night when the facility is closed and there are no other demands on the source water coming into the facility. Alternatively, QUALIFIED OPERATORS may choose for an all deep 50 meter POOL to just backwash one filter at a time and allow make-up water to reestablish rim flow before doing the next one, as opposed to doing all six or eight tanks sequentially.

4.11.2 Fill Spouts

For example, a fill spout located under a diving board or next to a ladder or handrail is less likely to be a trip hazard or be a hazard to swimmers coming up from below.

4.11.3 Cross-Connection Control

An air gap can be provided through a fill spout at the side of an AQUATIC VENUE, through water supply piping over the edge of an open balance tank or surge tank, or over a fill stand pipe that is connected to the side of an AQUATIC VENUE.

Splash guards are simply a means to keep fill water from splashing onto adjacent floors and walls. Water cannot be siphoned into the potable water supply through a properly designed splash guard. A proper design often consists of a concentric pipe that is a larger diameter than the fill pipe and that is open to the atmosphere at the top and bottom.

Because of the potential for back pressure or back siphonage, any potable water piping connected directly to any AQUATIC VENUE piping must have an RPZ. Some permitting agencies or CODES may allow pressure vacuum breakers or atmospheric vacuum breakers on water supplies not connected to the POOL piping but supplying potable water to the AQUATIC VENUE through a submerged INLET in the AQUATIC VENUE.

The pressure vacuum breaker would be located upstream of the shut-off valve.

The atmospheric vacuum breaker would be located downstream of the shut-off valve.

The AHJ may allow an elimination of an air gap to control splashing or flow of AQUATIC VENUE wastewater outside the receiving sump onto the EQUIPMENT ROOM floor. This can be accomplished by extending the AQUATIC VENUE wastewater pipe below the rim of the sump. This can be approved if the wastewater disposal pipe from the AQUATIC VENUE does not have a sealed connection to the sewer piping. This constitutes an air break.

An air break can be justified for the worst case scenario of a sewer backup at the AQUATIC VENUE wastewater sump. During a sewer backup, sewage cannot back pressure into AQUATIC VENUE piping through an air break. Further, if the sewage is above the AQUATIC

VENUE waste pipe outlet when the AQUATIC VENUE is operating, the normal pressure of the POOL piping leaks AQUATIC VENUE water towards the sewer, preventing the AQUATIC VENUE piping from siphoning wastewater. If the AQUATIC VENUE is not operating, then there is no pressure or suction in the piping that could create a condition for siphoning sewage.

If the permitting agency does not allow an air break, they may allow an air gap with a splash guard.

4.11.4 Deck Drains and Rinse Showers

4.11.5 Sanitary Wastes

4.11.6 Pool Wastewater

AQUATIC VENUE waste streams *(including filter backwash water and AQUATIC VENUE drainage water)* should be discharged through an air gap to sanitary sewers, storm sewers, drain fields, or by other means, in accordance with local municipal and building official recommendations including obtaining all necessary permits. The discharge should occur in a manner that does not result in a nuisance condition.

Each waste line should have a unique air gap. Waste lines from different sources *(e.g. AQUATIC VENUE, spa, overflow, sump pump, etc.)* should not be tied together, but multiple waste lines may discharge into a common sump or receptacle after an air gap.

4.11.6.2 Ground Surface

Filters work to reduce the level of pathogens in the AQUATIC VENUE water by retaining the pathogen in the filter. As a result, AQUATIC VENUE backwash water has been demonstrated to contain detectable pathogen levels *(e.g., Cryptosporidium and Giardia)*.[313,314,315] Therefore, filter backwash water should be considered waste water requiring appropriate disposal.

4.11.6.4 Separation Tank for Precoat Media Filters

If local or state CODES prohibit disposal of backwash filter media *(perlite, cellulose or diatomaceous earth)* directly to sanitary sewer, a separation tank may be recommended. The separation tank is to be designed for the conditions of the specific facility filtration system. The separation tank should be designed to accommodate the volume of water and spent media recommended for at least a single backwash *(media change)*, without overflowing. The separation tank may include separation screens or a settling pit to allow for the spent media to be removed and properly disposed of according to AHJ requirements.

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313 Shields JM, et al. Prevalence of *Cryptosporidium* spp. and *Giardia* intestinalis in Atlanta metropolitan area swimming pools. Emerg Inf Dis 2008;14:948-950.
314 Schets FM, et al. *Cryptosporidium* and *Giardia* in swimming pools in the Netherlands. J Water Health. 2004 Sep;2(3):191-200.
315 Murphy JL, et al. Effect of cyanuric acid on the inactivation of *Cryptosporidium parvum* under hyperchlorination conditions. Environ Sci Technol 2015;49:7348-55.

4.12 Specific Aquatic Venues

4.12.1 Spas

4.12.1.2 Maximum Water Depth

SPAS are designed for sitting and the expectation is that it will not be over the average 11-year-old child's head. That depth is about 48 inches *(1.2 m)*. The MAHC felt that 24 inches *(61.0 cm)* is reasonable since it is half of the maximum depth previously stated *(48 in or 1.2 m)* and would allow for the vast majority of the population to sit comfortably with their head above water. The MAHC also consulted the ISPSC and their maximum depth of 28 inches *(71,1 cm)* is pulled from APSP which has been utilized by the industry for some time. The Committee recommends additional studies to determine if decreasing the SPA seating depth is necessary.

4.12.1.3 Handholds

Even though a person is seated in a SPA, a sufficient number of positive handholds are needed to assist with standing up. Handholds at the edge of the SPA above the water line are visible and easily reachable.

4.12.1.5 Perimeter Deck

This is to provide adequate area for life saving and rescue purposes. The AHJ may allow a smaller rescue area based on the assessment of a local emergency rescue agency.

SPAS elevated for transfer wall or other purposes need to be provided with an effective BARRIER so that the elevated wall is not used as a platform to access an adjacent AQUATIC VENUE. An effective BARRIER shall be one that does not allow BATHERS to walk on the elevated wall.

Small and/or narrow SPAS are examples where the AHJ may allow a relief from the 50% minimum DECK requirements. The rationale is that if a SPA is of a limited size or width then it can be entirely be guarded effectively from one side or one location.

4.12.1.5.4 Elevated Spas

For example, if an elevated SPA is next to or within 4 feet *(1.2 m)* of another AQUATIC VENUE, a guard rail or post-and-rope system would be a couple of options as effective BARRIERS which would discourage PATRONS to use this elevated wall to jump into the other AQUATIC VENUE.

4.12.1.7 Temperature

Temperatures above 104˚F are essentially inducing a fever in the BATHER'S body as internal temperature rises. It also causes birth defects in fetuses so that pregnant women, particularly in their first trimester, should consult their physician before using. Further research is needed to understand the potential role of SPA use early in pregnancy and associated birth defects. See MAHC Annex 5.7.4.7.2 for further discussion.

4.12.1.10 Timers

The "Fifteen Minute Rule" – complies with most state CODES. The timer for the hydrotherapy pump is for the SAFETY of the BATHERS. Longer times can be hazardous to BATHERS and the therapy pump shutting off at least reminds the BATHER to get out and reset the timer.

4.12.1.11 Emergency Shutoff

Emergency shutoffs should be located between 5 feet *(1.5 m)* and 50 feet *(15.2 m)* and within sight of the SPA structure.

4.12.2 Waterslides and Landing Pools

4.12.2.1 Design and Construction

The designs of WATERSLIDES are governed by amusement ride regulations such as ASTM that have appropriate experience. However, the design of the LANDING POOL along with associated water quality and circulation is regulated by this STANDARD.

4.12.2.4 Exit into Landing Pools

Present practices for safe entry into LANDING POOLS include:

- A water backup, and
- A deceleration distance.

4.12.2.9 Drop Slides

DROP SLIDES are being highlighted because of one incident that resulted in a fatality in Massachusetts. WATERSLIDES, particularly those that drop BATHERS into the water *(versus being delivered to a water entry point)*, from a height above the water require diligent MONITORING by staff at the top of the SLIDE and the water entry point to ensure there is adequate SPACING between SLIDE users so that people do not land on top of each other. Each SLIDE user must have time to move out of the collision zone before another SLIDE user is allowed down the SLIDE. The incident cited above resulted in the drowning of a SLIDE user and a multi-day period to discover the victim because of the high turbidity of the water.

4.12.3 Wave Pools

The WAVE POOL will still have side wall ladders for egress purposes *(and therefore partial trafficking)* and the MAHC still felt that "NO DIVING" signage should still be required for all areas around the WAVE POOL regardless of water depth due to the freeboard.

4.12.4 Therapy Pools

4.12.5 Lazy Rivers

4.12.5.2 Access and Egress

4.12.5.2.1 Means

Since there is moving water in a LAZY RIVER, less frequent means of ingress/egress are acceptable. The moving water propels people around a LAZY RIVER quickly and with less effort to the next means of egress.

LAZY RIVERS can be several hundred feet long. They are often constructed with side walls that make it difficult to exit the water. This distance will make it so that a BATHER will never be more than 75 feet *(22.9 m)* from an exit. The distance to the nearest exit for a large regular POOL can be as much as 50 feet *(15.2 m)*. This distance can be farther for a LAZY RIVER because of the current. If water is flowing at 1 to 4 feet/second around the river, then a person floating around a river will never be more than 2.5 minutes from a means of egress.

4.12.5.2.3 Deck

LAZY RIVERS are of necessity closed *(or mostly closed)* loops. The wall for the inside of a LAZY RIVER loop is an ISLAND which may be designed for people but is most often not. Therefore, a PERIMETER DECK is only needed for the outside of the river loop, or only on one side of the river.

4.12.5.2.4 Bridges

Seven feet *(2.1 m)* minimum clearance overhead is required since it is consistent with requirements of building CODE minimum ceiling clearances.

Most LAZY RIVERS are closer to 3.5 feet *(1.1 m)* deep making the clearance 7.5 feet *(2.3 m)* if you adhere to the 4 foot *(1.2 m)* clear requirement above the water surface. The MAHC chose 7 feet *(2.1 m)* because it is the typical building CODE minimum height requirement for ceilings whereas the 6 foot 8 inches *(2 m)* minimum clearance is usually only applicable to doorways.

4.12.6 Moveable Floors

4.12.6.3 Safety

4.12.6.3.1 Not Continuous

Examples of adequate SAFETY precautions for entering the other area of the AQUATIC VENUE include but are not limited to the following:

- A moveable BULKHEAD, located at least at the water surface, to enclose the area of the MOVEABLE FLOOR;
- A highly visible floating line installed over the MOVEABLE FLOOR surface, two feet *(61.0 cm)* in front of the end of the MOVEABLE FLOOR. A four inch *(10.2 cm)* wide contrasting marking shall be provided at this leading edge; and
- A railing system that shall be anchored into the MOVEABLE FLOOR.

4.12.6.3.2 Underside

When the MOVEABLE FLOOR is not continuous over the entire surface area of the POOL, access to the underside of the MOVEABLE FLOOR shall be denied when it is not flush with the POOL floor. Examples of adequate measures to prevent access under the MOVEABLE FLOOR include but are not limited to the following:

- Position a BULKHEAD at the end of the MOVEABLE FLOOR;
- Have a trailing ramp that hinges to the MOVEABLE FLOOR and extends to the POOL floor.

4.12.6.4 Movement

There are no U.S. regulations on MOVEABLE FLOORS. This velocity was obtained from European design STANDARDS.

- European Standard EN 13451-11:2004.

4.12.7 Bulkheads

4.12.7.2 Entrapment

All BULKHEAD parking positions should be designed such that QUALIFIED LIFEGUARDS can see under 100% of the BULKHEAD from their station on the POOL DECK.

4.12.7.5 Gap

BULKHEADS designed with greater gaps may result in BULKHEADS veering off its intended path.

4.12.7.6 Handhold

During FINA sanctioned events, full height touchpads will be on most BULKHEADS. But the majority of BULKHEADS in the U.S. allow for wide holes at the waterline for handholds and USS / NFSHSA / NCAA touchpads which are hung from these holes and are below the waterline. Touchpads aren't normally installed during normal operating hours. End wall concrete parapets that cantilever over the gutter that require full height FINA touchpads for those level of competitions do not negate the requirement for handholds *(though behind)* in these locations.

4.12.7.9 Width

Any BULKHEAD that is intended for foot traffic for use by officials shall be at least one meter *(3 feet and 3 inches)* wide which is the current minimum width provided by commercial manufacturers.

4.12.7.9.1 Starting Platforms

Any BULKHEAD that dictates starting platforms shall be installed shall be at least three feet and nine inches (1.1 m) wide in order to allow for sufficient trafficking space for officials and athletes behind the starting platforms.

4.12.8 Interactive Water Play Venues

4.12.8.3 Sloped

An example for an acceptable design solution would be a diverter valve installation.

4.12.8.10 Hazard

While consistent with many state CODES, the MAHC has determined that this topic needs more research regarding water velocity and eye SAFETY[316].

4.12.8.12 Signage

Since there is no standing water on INTERACTIVE WATER PLAY VENUES, depth markers and "NO DIVING" warning signs are not required.

This was included because it deviates from the regular marking and warning signage requirements for typical AQUATIC VENUES as stated in this CODE. Other signage requirements such as diaper changing reminders and "Do Not Drink" would likely be appropriate.

4.12.9 Wading Pools

4.12.9.2 Barrier

A more stringent requirement is stipulated for separating WADING POOLS from other BODIES OF WATER *(compared with the spacing between other AQUATIC VENUES)* is due to the fact that the predominant users of WADING POOLS are small toddlers, most of whom cannot swim, and the inherent dangers posed by larger and deeper POOLS in close proximity.

4.12.9.2.2 Shallow Water

Rationale of 24 inches *(61.0 cm)* deep rule is that if adjacent water is not substantively deeper than the WADING POOL, there is no need to segregate them.

4.12.10 Other Aquatic Features

The industry continues to evolve with new AQUATIC FEATURES coming into the market place that are not yet specifically addressed in the MAHC or other CODES. Features such as climbing walls, inflatables, and play structures are now available for installation at aquatic facilities. The intent of this section is to provide a basis for acceptance for installation and use of different AQUATIC FEATURES versus prohibition of installation and use of AQUATIC FEATURES not specifically identified/specified in the MAHC due to an absence of specific criteria. This allows an avenue to compliance until such a time that the MAHC is updated as appropriate with AQUATIC FEATURE specific criteria.

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316 Duma SM, et al. Eye injury risk from water stream impact: biomechanically based design parameters for water toy and park design. Curr Eye Res. 2012 Apr;37(4):279-85.