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I. Introduction

Spas or whirlpools are hot pools having between 95 to 102°F water temperature into which air is blown.

When installing a whirlpool there are two fundamental systems from which to choose.

1. Jacuzzi System

With this concept water is pumped across several jets located in the walls or floors of the pool. Air is mixed into the pressurized water stream with a modulating compressor. This system offers a massaging effect through the pressurized water current, which is accentuated by the air bubbles. The massaging effect is directed locally by the water/air jets.

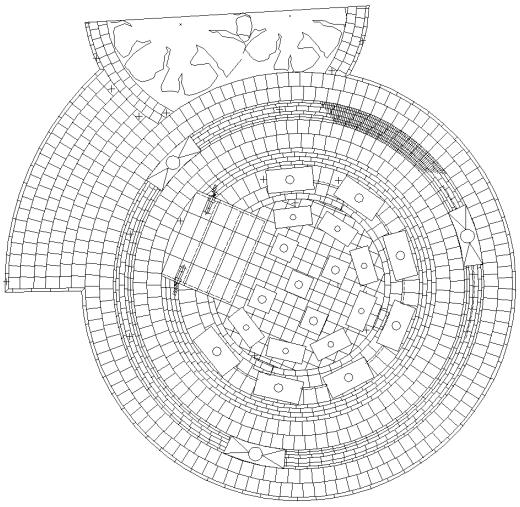
2. Len-Gordon System

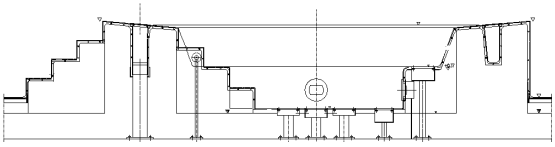
With this concept the spa floor and bench contain around 70 air outlets (holes) per square meter with a diameter of roughly 4 mm each. Air is equally distributed over the entire surface area of the pool. This system is used in a variety of arrangements in public swimming pools.

The effect of bubbling the complete spa water surface creates an even massaging or gentle massaging effect. Frequently these systems are delivered as glass fiber reinforced acrylic, ready-to-install, factory-built elements. In new construction projects the whirlpool can be constructed from poured in place concrete. In this case the air is blown-in through built-in air plenums in the spa bench and walls. These plenums are enclosed by perforated nylon coverings. There are also whirlpools which contain both Jacuzzi and Len-Gordon systems. Then the bather can choose which type of massaging effect to experience.

Photo from above a built-up whirlpool. The jets are switched off for the photo. The plates in the seat and floor allow an even flow of air upwards. The entire whirlpool offers jet action, not limited to individual nozzles. There is a 100% over the rim gutter system to wash away impurities from the surface. This results in significantly cleaner water than whirlpools using skimmers.

Design for the built-up whirlpool shown above. The tile layout matches and the plants are located as designed. Notice the piping connections to the bottom of the whirlpool are precisely located as designed.





Cool - Down

When a spa or whirlpool is used at a facility (just as with saunas or steam rooms) it overheats the bathers body. A convenient means of cooling-down the body must always be present. Providing a cool water submerging pool next to the spa where the water temperature is maintained between 60-70°F is optimal.

The popularity of these pools by the pool guests is very high. Therefore, they are often thought of as a necessary feature at public swimming facilities. However, when the number of bathers in the spa exceeds the water treatment capacity, which is often the case hygienic problems can arise.

The overloading of spas and whirlpools and the resulting unsatisfactorily hygienic water conditions are usually caused by the following:

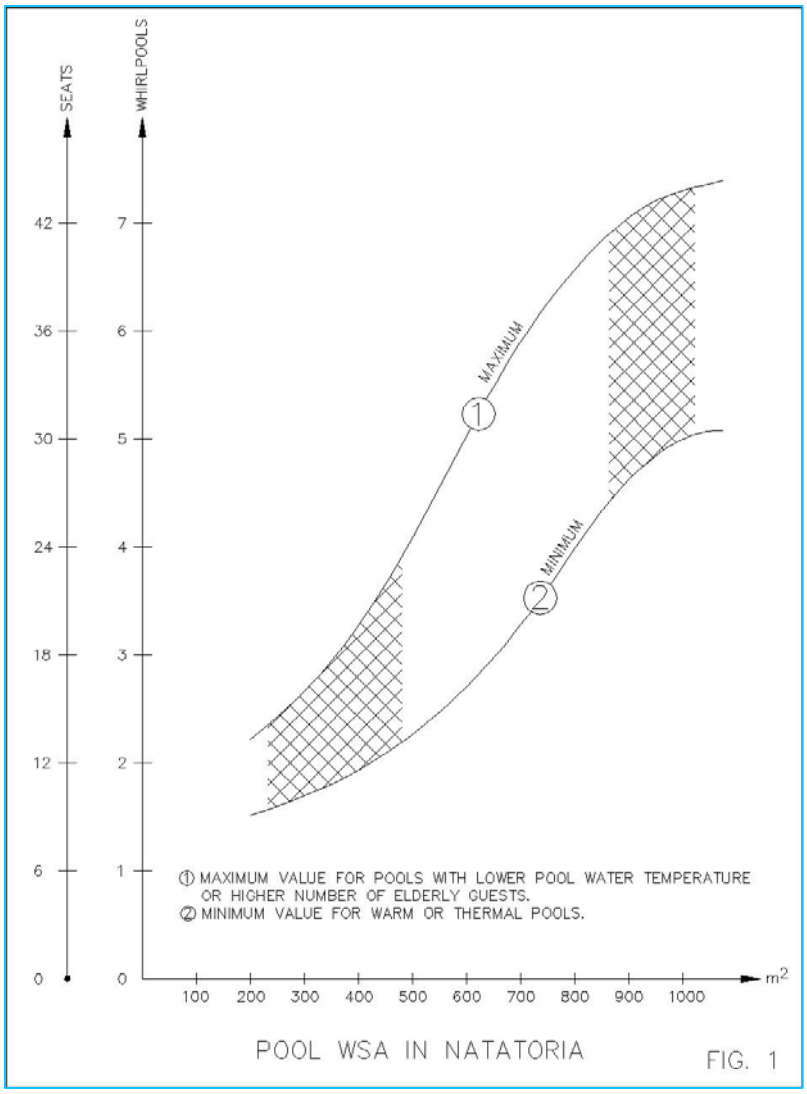
- *Whirlpool(s) area too small in relation to the number of pool visitors*
- *Whirlpool(s) water volume per Whirlpool occupant (bather) too small.*
- *Insufficiently sized whirlpool water circulation rate.*
- *Insufficiently sized water treatment system.*
- *Malfunctioning component/system operation.*

II. Requirements

Over-crowding and therefore overloading of the whirlpool can only occur when there are more bathers in the pools than for which they were designed.

The large appeal which the public maintains toward whirlpools makes the sizing of the whirlpool an important task. If the whirlpool WSA or quantity is too small for a facility, then it will almost certainly be overcrowded and overloaded. On the other-hand if too many whirlpools are provided then the cost rises beyond the actual use and the benefits are never realized.

The question is therefore put forth, ***"How many whirlpools does a certain facility need?"***



At this point it becomes necessary to analyze the bathers habits, and formulate considerations for the sizing of whirlpools.

The following example illustrates this solution:

In a leisure natatorium there are 240 people in the bathing area. The average visitor remains at the pool for 2 hours. This gives a visitation value of 120 people/hr.

If each second visitor uses the whirlpool at the end of their visit, then this gives a bather loading for the whirlpool of 60 people/hr or 1 person/min. Using a whirlpool use time of 10 minutes, a whirlpool with adequate space for 10 people is required. When the air compressor is switched on intermittently with 10 minutes "on" and

10 minutes "off", then a whirlpool with adequate space for 20 people is required.

Additional Remarks

The example mentioned above is valid when every second visitor uses the whirlpool. Experience has shown that this assumption is not always true and can still lead to whirlpool overloading.

III. Planning of Whirlpools

The detail planning required for whirlpools naturally directs designers towards purchasing factory-built whirlpools and products.

3.1 Prefabricated Whirlpools

These factory-fabricated pools are usually built from glass fiber reinforced acrylic material. In public pools only prefabricated whirlpools with 100% overflow gutters should be considered. The overflow rim is necessary so that the water displaced by submerged bathers can flow quickly over the rim. Overflow problems are experienced by prefabricated pools without the 100% overflow configuration because the pool volume is only 65-105 gallons per seat (See Table 4).

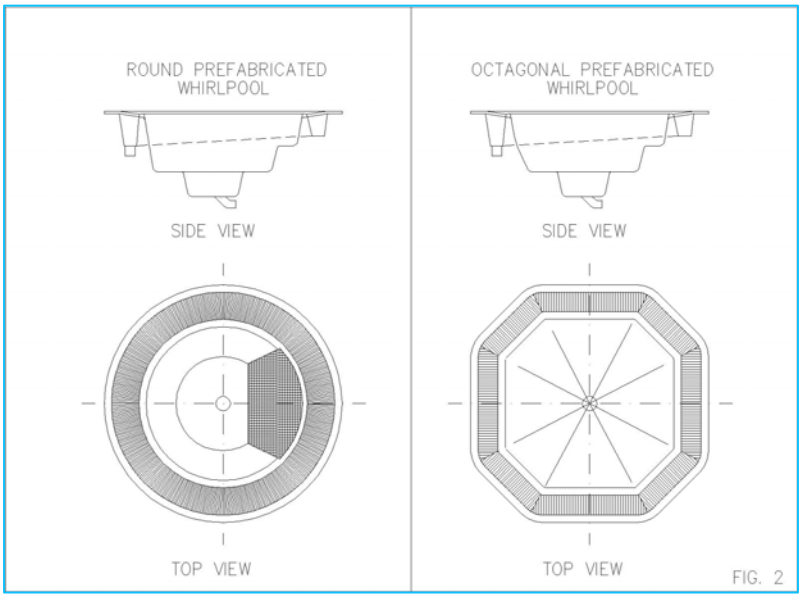
3.2 Concrete Spas

Spas can be individually constructed from cast-in place or gunnite sprayed concrete. This allows the shape and tile color to be coordinated with its surroundings. In addition, it can be individually constructed to fit the size and needs required. The air can be introduced through built-in plenums, which are enclosed by perforated nylon coverings.

3.3 Whirlpool Shape and Design

Naturally there are a wide variety of possibilities for the shape and design of whirlpools in the natatorium. Most whirlpools fall into one of the following categories:

- Whirlpools placed at a higher elevation than the adjacent pool with the water surface between 18 - 30 inches above the finished floor. Eventually arranged as a group of spas with varying water surface elevations.
- Whirlpools built-into the pool frame, usually between 8 - 12 inches above the pool water surface elevation, so that the whirlpool is optically integrated into the entire water surface area.
- Whirlpools built-into the pool itself, so that the bather can swim into the enclosure. Usually called a “Grotto”, where the walls extend 6 - 8” above the pool water surface elevation. In this case the whirlpool (Grotto) water temperature is the same as the pool with built-in leg and back massage jets built-into the walls and with an air plenum floor and jacuzzi jets for foot massage.



3.4 Hygienically Improving the Water Quality by Increasing the Water Surface Area

Whirlpools are recommended for both new construction as well as renovations in public pools. These whirlpools should be constructed to provide a water volume of 250 gallons per seat.

These whirlpools can then be designed with niches or free form style. Larger round spas offer a favorable situation, the middle area contains no jets or air plenums. This creates a water buffer and reduces water displacement. It is important to limit the number of whirlpool seats in relation to the water volume.

Figure 2 shows example whirlpool forms which can be pre-fabricated or individually constructed and have been used in public swimming facilities.

Summary

During the planning and construction of whirlpools it is proven from experience that good hygienic performance follows when the number of seats are sensibly related to the number of visitors to the pool, and that a minimum volume of 250 gallons per seat is made available.

Under these conditions reasonable whirlpool water treatment system costs can also be maintained with good, hygienic pool water quality.

1. Natatoria with pools with normal water temperatures ranging from 80 - 86°F

- 3 to 5 whirlpool seats places per 1000 square feet of WSA.
- Suggested whirlpool seats according to water surface area follows:

Natatoria Pool WSA	Whirlpool Capacity (Persons)	Recommended number of whirlpools w/6 places each
2,500 sf	7 - 13	2
5,000 sf	15 - 25	3 - 4
7,500 sf	22 - 37	4 - 5
10,000 sf	30- 50	5 - 6

2. Pools with higher temperatures ranging from 86 - 120°F as in thermal pools:

The number of seats for whirlpools with water temperatures at 100°F can be reduced according to Figure 1.

The aforementioned sizing considerations for sizing the whirlpool are the preliminary values which must be refined during the design of each facility.

IV. Water Treatment

The very small water volume of whirlpools creates a high and quickly changing loading situations, which places unusually difficult requirements on the whirlpool water treatment

system. Shutting-off the chlorine disinfection in fully loaded whirlpools causes the free chlorine residual concentration drops to zero within 1 or 2 minutes.

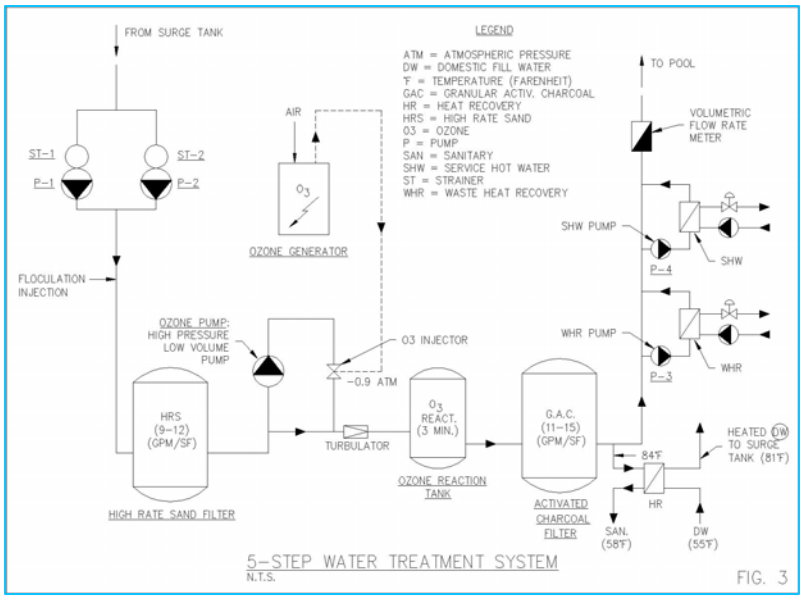
The high water circulation rate (turnover) required for whirlpool means that the bather practically sits in a treated water current.

A balance of the pool water quality due to pool water mixing which causes the water treatment regulation system to fluctuate around the water quality setpoints is not found in a whirlpool. Instead a precise and continuous regulation of the chlorine concentration, pH-value and whirlpool water heating system is necessary.

On the basis of examinations made in Austria and Germany as well as practical experience, according to the accepted state-of-knowledge, the following requirements have been formulated:

4.1 Whirlpool

- In prefabricated whirlpools the maximum number of occupants which the whirlpool water treatment system was designed to handle must be posted in order to minimize overloading.
- Individually constructed whirlpool should have a water volume of 250 gallons per whirlpool seat. In addition, the forming of the bench should be minimized for the number of occupants which the whirlpool water treatment system was designed to handle. Experience has shown that seldom do bathers stand in the middle of the whirlpool.
- The treated water should be distributed in the lower half of the whirlpool form and the displaced water should leave the whirlpool via the 100% overflow rim. The air compressor piping must rise at some point at least 3 feet above the whirlpool water elevation. This eliminates the possibility for chlorinated pool water to enter the compressor works. When the compressor starts the compressed air should be diverted for 15 seconds until the compressor reaches full speed then the value should reposition pressurizing the piping.
- The 100% overflow rim should encompass the entire whirlpool circumference, so that an immediate displacement of water can be relieved and that a continual flow of water to the surge tank is ensured.
- The whirlpool should be built at a higher elevation than the pool deck to ensure that water and disinfectant used to clean the deck, and does not flow into the whirlpool water treatment system.



4.2 Water Treatment Performance

Higher concentrations of impurities are found in whirlpool water due to the higher temperature and massaging effect on the human body. As mentioned in other papers by the same author and available from B2E Consulting Engineers, P.C. the standard impurity concentration allowed in the spa is 6 g Km_n0_4. From this a specific water circulation rate of 3 m^3/person can be calculated. Further the bather frequency must be considered, which amounts to 3/hr (3 bathers/hr).

Whirlpool Water Circulation Rate

Each whirlpool seat requires a water circulation rate of 3 x 3 = 9 m^3/h (40 gpm).

Example: Spa with 4 seats

V = 4 x 9 = 36 m^3/h (160 gpm)

In addition, energy can be conserved when the whirlpool pump has two speeds. During occupied hours the pump runs at full speed and at night at reduced (half) speed.

4.3 Treatment System

5-step or complex ozone water treatment process should be installed, because whirlpools have higher impurity loading than normal pool loading

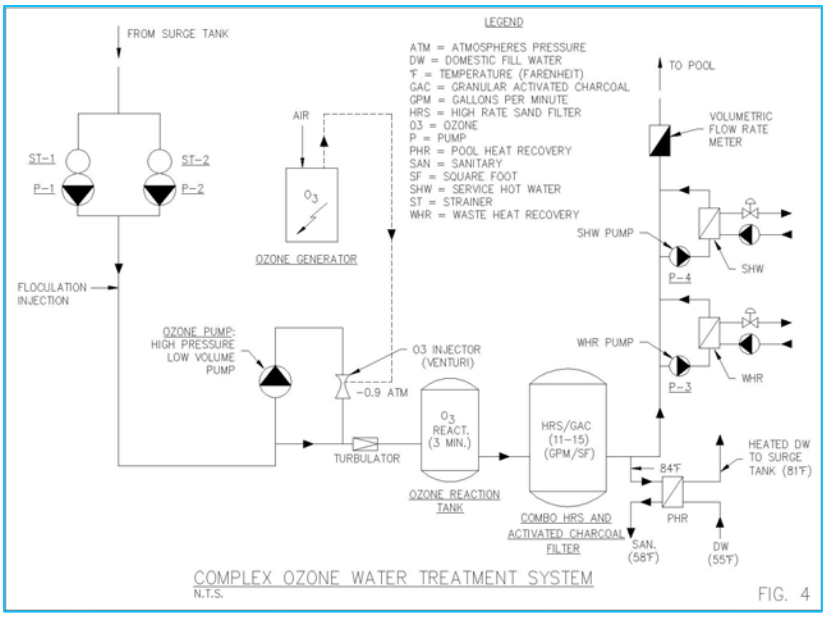
Flocculation - High rate sand Filtration - Ozonation - Activated charcoal filtration - Chlorination

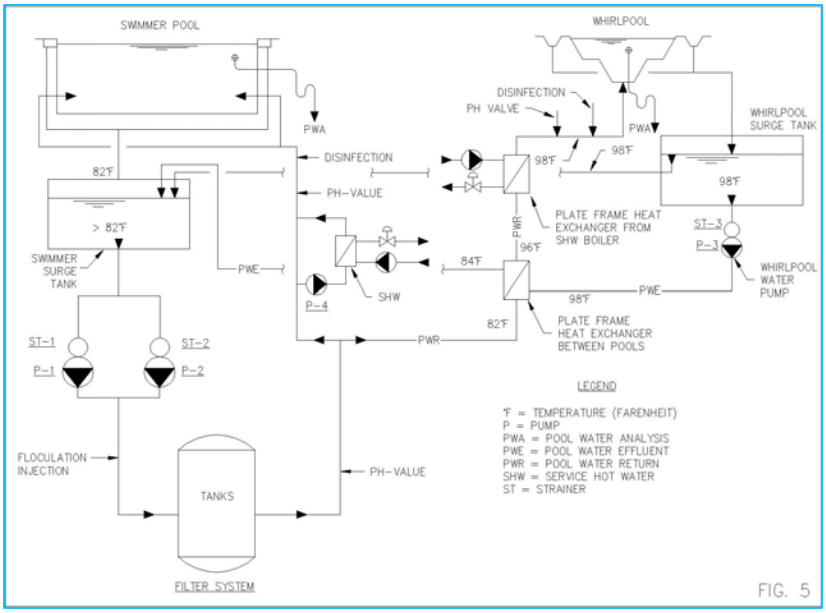
Even though a better treatment system is installed, no reduction of the whirlpool water circulation rate, as with normal pools, is recommended. (See Figure 3, Schematic Diagram of a 5-Step Treatment System and Figure 4 Complex Ozone Treatment System.)

4.4 Alternatives

As an alternative to the previously described whirlpool water treatment system, there exists the possibility to combine the whirlpool water treatment system with the swimming pool.

This combination is hygienically advantageous, however, it creates a problem with the heat balance of the system.





In order to avoid overheating the swimming pool from whirlpool water overflow a primary/secondary heat exchanger is necessary. A suggested system construction is shown in Figure 5.

The heat exchanger can be sized for a whirlpool water temperature of 100°F and a pool water temperature of 82°F so that the whirlpool water overflow is reduced to 84°F.

The given heating capacity of the whirlpool amounts to 36m^3/h (160 gpm) for each 1°C (1.8°F) rise in temperature or 41.8 kW.

A carefully constructed heat balance regarding the heating energy supplied to the whirlpool and heat loss in the swimming pool is necessary to avoid overheating the swimming pool.

Example:

Spa - 36 m3/h (160 gpm)
Swimming Pool - 82°F
Whirlpool Operation ≈10 hours

This operating scenario requires that the swimming pool volume must be 50,000 gallons minimum, so that the heat rejected from the spa is dissipated. If the spa was combined with a smaller swimming pool, then a heat pump would be necessary to remove the excess heat energy on the swimming pool side after the heat exchanger and use it to preheat the whirlpool water return.

4.5 Surge Tank

The surge tank is sized to handle the volumetric flow rate of the constant pool water effluent (overflow) as well as the instantaneous displacement from bathers entering the pool. Surge tanks which are undersized cause problems because the tank may allow more water than necessary overflow into the sanitary system. A surge tank that is over-dimensioned creates no advantage to system operation at some additional cost to the owner.

Especially important is the possibility to adequately clean the surge tank. Since the whirlpool system is operated with a higher water temperature. Higher quantities of fats and cosmetics are circulated in the water. These compounds are eventually found caked to the inside walls of the surge tank. A smooth finish surface inside the surge tank allows the tank to be cleaned more easily than a rough concrete finish. A tile surface has proven to be the lowest life-cycle cost and most hygienic solution.

4.6 Controlling the Disinfection System

A whirlpool which has a relatively small water volume is more quickly loaded with impurities from bathers and allows much less time for the residual disinfectant to take effect. For this reason special measures should be considered for controlling the disinfection process in whirlpools.

Consider the following example. A 475 gallon, 4 person whirlpool with a pool water circulation rate of 160 gallons per minute allows a water pass-thru time of 3.0 minutes.

$$\frac{\text{475 gallon}}{\text{160 GPM}} = \text{2.97 minutes}$$

This creates a challenging problem for the pool designer. Only a constant control and quick acting pool water analysis system using quantitative measurement of the chlorine concentration (photometric or amperometric) is able to constantly

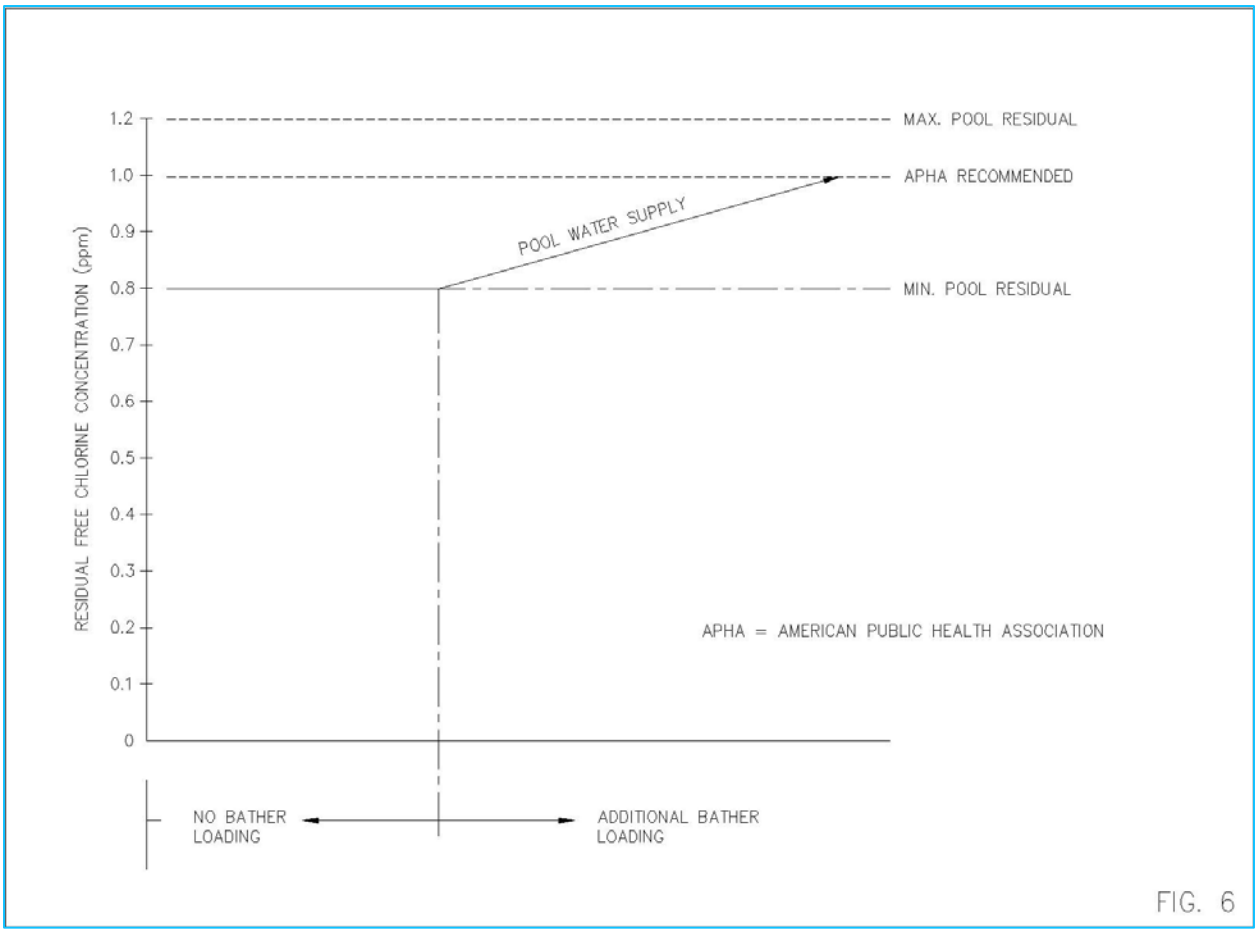


FIG. 6

maintain the desired chlorine concentration of 0.8-1.2 ppm in the whirlpool. The oxidation-reduction potential method of regulating chlorine injection is not suitable or recommended for whirlpools for this reason.

The pool guests sit in a clean water current which after 3 minutes, as mentioned in the previous example, once again flows over the rim and into the effluent gutter back to the surge tank. Providing high pool water circulation rates for whirlpools with high bather loads and corresponding higher chlorination requirements can help to reduce excessive chlorine concentrations in the pool water return to the whirlpool.

Depending on the actual bather load, a chlorine concentration of 0.8-1.2 ppm in the pool water return piping is suitable when sizing the pool water circulation rate in accordance with the methods discussed previously in this paper. (See illustration 6 - Changing the Chlorine Concentration in the Pool Water Return (Clean Water) as a Function of the Bather Load).

It is self explanatory that such a system will provide a safe, uninterrupted disinfection during the operation (Basis Chlorination).

4.7 Regulation of the pH-Value

The effect of the circulation of compressed air through the whirlpool will cause CO_2 gas to escape. Once the air compressor serving the whirlpool is switched on, the pH-value of the water immediately rises. In response a greater quantity of muratic acid or carbon dioxide must be added to correct the water pH. Therefore, a good fast acting means of chemical control is also required.

4.8 Fresh Water Intake

The quantity of fresh water intake of design circulation water flow rate required, depends on how often the whirlpool is drained and cleaned. From experience the fresh water intake flow rate for whirlpools should be between 15 - 25 gallons per bather per day.

4.9 Heat Recovery

A carefully planned heat recovery system should be planned to offset the cost of providing fresh water intake. (See figure 7: Heat Recovery Constant Waste Water- Domestic Water Intake System Arrangement).

4.10 Heating

In order to calculate the heating capacity of the system, evaporation from the whirlpool should be considered. Experience indicates that the evaporation from whirlpools is roughly 50 lb/sf hr., however, this value must be calculated (verified) individually. This evaporation rate is valid for whirlpools with air injection and massaging jet pumps with a water temperature of 99°F and a room air temperature of 82-86°F DB/50 - 55% RH.

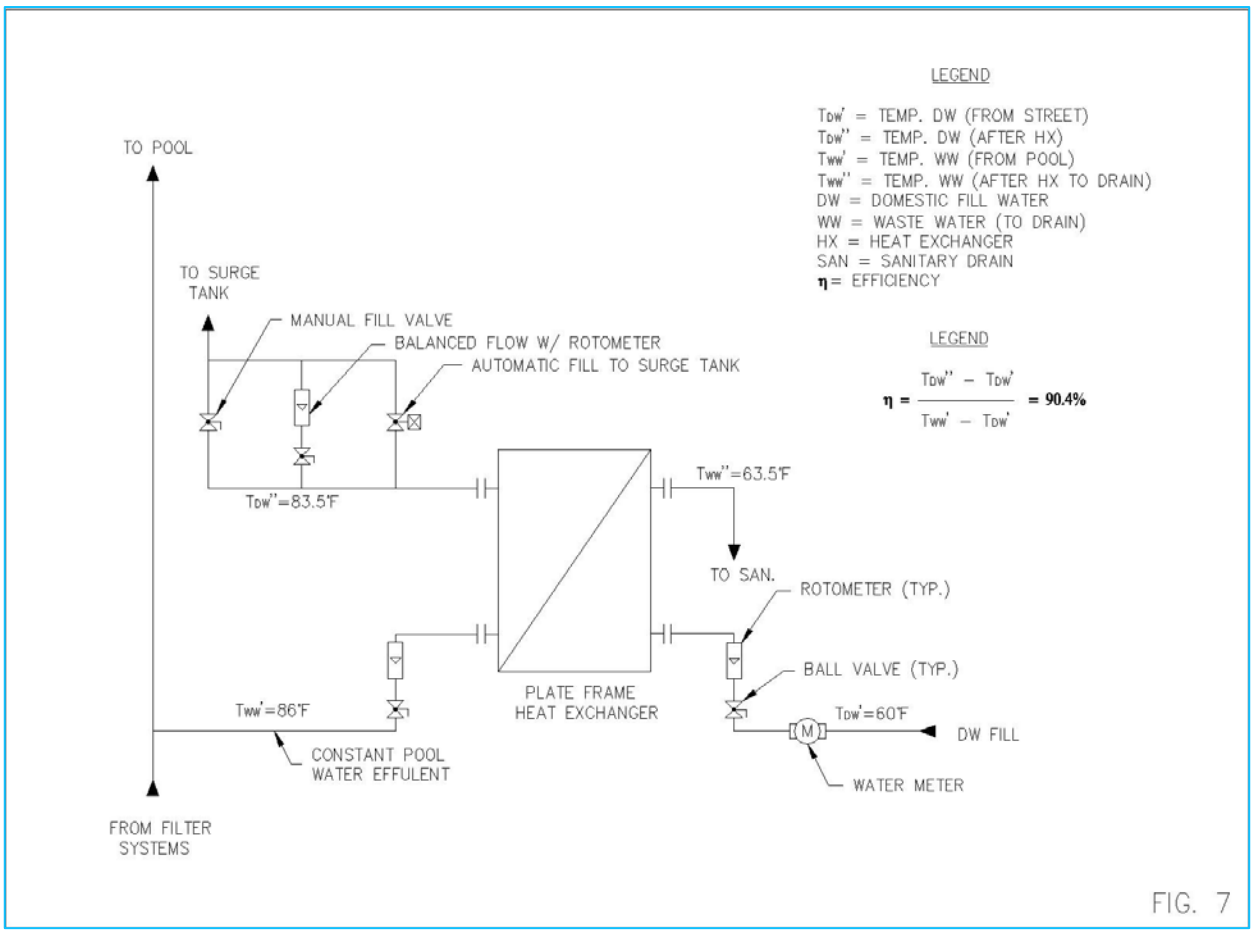


FIG. 7

5.0 Operational Recommendations

The following recommendations should be considered when designing whirl-pool systems.

- *Before starting the whirlpool system, the chemical storage tank and necessary safety precautions should be made. (During normal daily operation it is almost impossible to avoid an interruption to the whirlpool and inconvenience to pool guests if the disinfection system requires maintenance).*
- *Drain the whirlpool daily and clean and disinfect it if high bather loads are experienced. The surge tank should be drained and cleaned weekly.*
- *After normal operating hours backwash the filters daily and make it ready for the next days operation. During night operation allow the water temperature to drop and reduce the water circulation rate.*
- *Balance the fresh water intake rate based on the number of bathers and results of the pool water analysis (minimum 15 to maximum 25 gallons per person per day).*
- *Perform water quality tests by hand at least 3 times per day during normal operation and once after normal operating hours.*
- *Run the whirlpool between 98 - 102°F during the day. Allow the pool temperature to sink to roughly 86°F at night.*
- *Recommended bather duration 20 minutes maximum,*
- *Post a sign which indicates the maximum allowable number of bathers.*
- *Maintain residual free chlorine concentration in the whirlpool between 0.8-1.2 ppm as required by local and state health code requirements.*
- *Provide adjustable automatic control for 10 minutes at a time after 5 minute duration off. This helps to clean the whirlpool for other bathers with an expected changeover of 4 times per hour. Experience has showed that during the time the air is off the whirlpool is seldom used. This also reduces the load on the mechanical dehumidification equipment.*
- *Keep a pool water quality log for both hand measurements as well as automatically registered data.*
- *Ensure with the design that the backwash water used contains at least 0.8 – 1.2 ppm residual free chlorine.*

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