Enrique Naya López

Maintenance of a Swimming Pool Water Circuit

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A swimming pool is a place for enjoying, relaxing, and competing among other things. There are many different kinds and types of swimming pools of different sizes, colors, shapes, and materials, etc. As a result, it is important to take care of the water circuit of a swimming pool.

This thesis explains all the equipment that contribute to the automation of the circuit maintenance and water treatment of a swimming pool for an optimization of the resources that makes a swimming pool more efficient in water treatment terms.

The thesis is based on many different manuals and information gathered from different companies related to swimming pools. Conclusions have also been made based on values of pH, chlorine, and temperature which are needed for a perfect work of the swimming pool automation.

Automated cleaning of swimming pools and insertion of chemical have many advantages. They are inexpensive because they reduce time and money spent on maintenance and waste of water. It is also possible to adapt new products and eliminate old ones, and it is safer. With these automatic systems it is possible to see the data values of the temperature, chlorine and pH of a swimming pool at any given moment and the user can decide if he/she wants to improve the system and make conclusions based on usage parameters.

The system is really helpful because making mistakes in products supplies can be avoided which is important because water needs to be in a perfect condition, including the filter system so it can filtrate and clean the water when it is needed.

Keywords	Swimming pool automation system, pH, chlorine, temperature, dosage system, water treatment

Contents

1 Introduction

A swimming pool is a place for enjoying, leisure, relaxing, and having fun with the family and friends. Furthermore, a swimming pool can be a place to exercise and have different kind of competitions. There are many different kinds and types of swimming pools: they are of different shapes, sizes, structures, depths, colors, designs, and materials.

Automated swimming pool cleaning and insertion of chemicals bring many benefits:

- Cost reductions
- Streamlining work
- Reducing the time and money spent on maintenance
- Flexibility to adapt to new products
- Decreasing of pollution and environmental damage
- Increasing the security (safety) of systems
- Protection of workers
- Safer disinfection
- Avoidance of deterioration of the pool water when the pool is not used for a long time
- The quality of the pumps ensures quiet operation because of the mechanical design
- Increase in the number of warning signs alerts if there is any unexpected change

With this system it is possible to have continuous data values that are read and make conclusions based on these values, and improve the water system based on usage parameters (rush hour, kind of audience, and kind of usage every moment).

This system is really helpful for the maintenance technicians, because it allows them to perform ongoing follow-up. Mistakes can be avoided in the product supply which is important because the water needs to be in a good condition. Likewise, the system controls the filter performance avoiding saturation of dirt and allowing it an excellent

filtration all the time. The temperature is always controlled which prevents any unnecessary cooling and it can optimize the use of energy. The levels of water are always correct to avoid having to replace what was previously wasted unnecessarily.

Figure 1. Swimming pools type. Data gathered from SWIM & DREAM [1].

Figure 1 shows a good example of a swimming pool where this system could be implemented.

With this system it is possible to perform ongoing follow-up from a distance by using data acquisition programs, via networks, and via telephone, optimizing service times and maximizing control.

2 Water Treatment

The water treatment equipment are intended to ensure that the pipes of the pools have water at all times of a quality that does not put users of the pool under bacteriological or chemical risk. For the treatment of the pool different chemical products of dangerous characteristics have to be used such as:

- Disinfectants unsterilized chlorine (sodium hypochlorite)
- Disinfectants stabilized chlorine (sodium dichloroisocyanurate)
- Chlorinated disinfectants (ultraviolet radiation)
- Flocculants

[2,1]

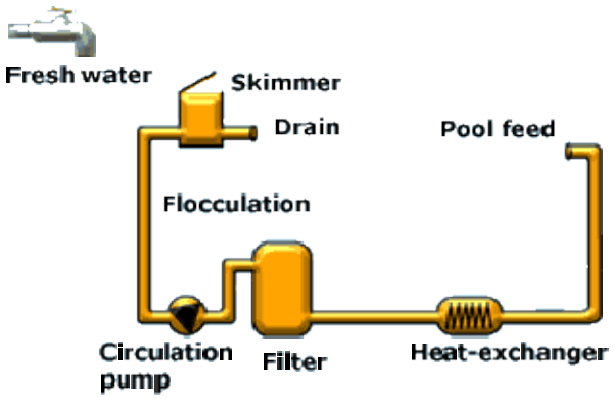

Figure 2. Simplified water circuit treatment. Data gathered from Bayrol [3].

In figure 2, a simplified circuit of a swimming pool can be seen which demonstrates what has to be done to the water to purify it.

Moreover, the swimming pool must have a continuous collection system that allows uniform recirculation of the entire water surface and an injection control system of fresh water and recycled water. The phases of water treatment are:

- Collecting surface water overflows (skimmers) and collecting bottom water down the drain from the bottom
- Filtration through a sieve to retain large particles in suspension

- Pumping to push the water through the filter and return it to the pool
- Filtration to retain the finer particles
- Water heating in heated pools
- Dosage of disinfectants and pH corrector
- Returning the treated water into the pool through a driving entrance [4]

2.1 Legionella

Legionella is a bacterium that lives in stagnant water with a wide temperature range. Its grow this facilitated by the presence of organic matter and it multiplies in temperatures between 20 and 45 °C. In these temperatures and with the appropriate nutrients the bacterium multiplies itself and infects human beings via aerosols.

The Legionellosis is an illness due to the Legionella that is transmitted in two ways: the Legionnaires´ Disease (a serious disease with pneumonia) and the Pontiac Fever (with symptoms similar to a cold).

RD 865/2003 is the legislation valid nowadays in Madrid, Spain. This legislation defines the Legionellosis high-risk water features and establishes revisions required for the elimination or decreasing the legionella concentration in the water systems such as showers, towers and condensers and swimming pools with movement and agitation of water like spas, Jacuzzis [5].

The Legionella lives in conditions of under 20 ºC but it does not multiply dangerously. This is how Legionella lives in nature, in rivers and lakes [6].

It is recommended to keep the water cold for human beings, under 20 ºC, and the accumulators of the showers, towers and condensers, and swimming pools with movement and agitation of water such as spas, Jacuzzis, over 70 ºC.

If there is any kind of outbreak of Legionellosis, the services of the inspection of the Environmental Health and Public Health proceeds to do an extraordinary revision of the condition of the water system, the auto control system situation, and the residual disin-

fectant level. If any deficiency appears by law, the water system might have to be closed due to a high-risk for the public health [7].

3 Description of System

Figure 3 shows another circuit of a swimming pool. This one is more complex than the other, in order to see some other elements that can be found in a normal circuit.

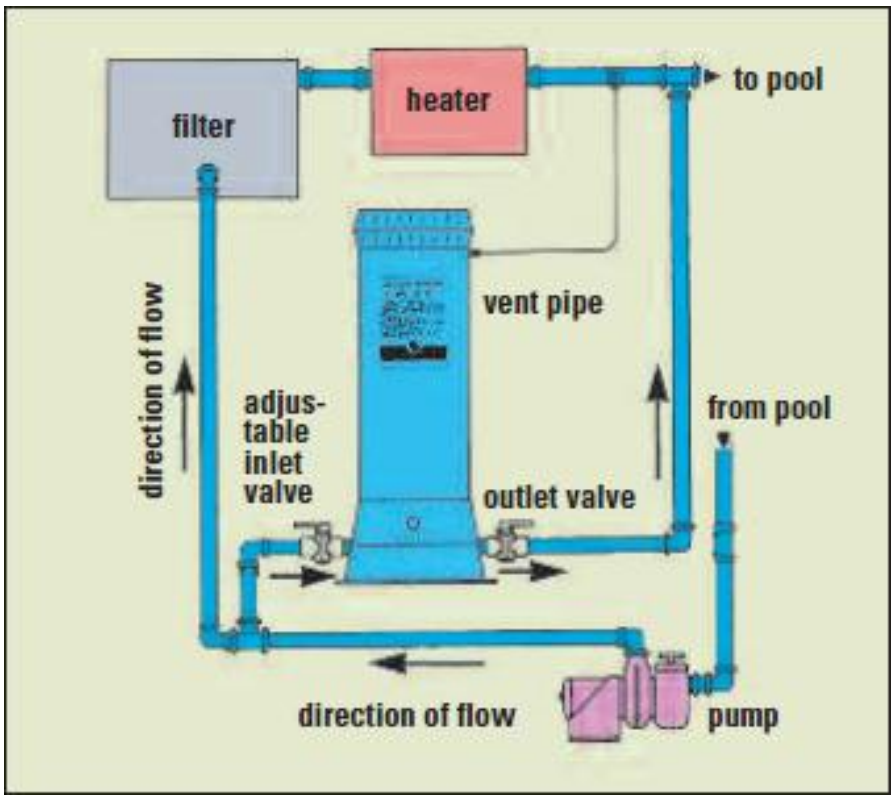

Figure 3. Simplified diagram of the system. Data gathered from Bayrol Aquabrome [8].

The water in the pool, as this is overflowing, goes to the pickup canal and reaches the compensation tank. In the compensation tank there is a level viewer to indicate the amount of water it has. If it exceeds a maximum limit, the excess water will drain through an overflow. On the contrary, if the level is low, it has to be filled through the water inlet valve.

The water in the filter tank flows into the pump and passes through the filter where the particles and impurities the water has get filtrated. If it is detected that the pressure filter is greater than recommended, cleaning has to be undertaken. From the filter the water goes to the UV reactor, where the water disinfection comes by UV radiation, ensuring better sanitation. Then the concentration of chlorine / bromine (here it is used chlorine) and pH are measured, and they are controlled by an automatic system, dosing chlorine and pH necessary to maintain the stable values. (The chlorine level should

be in the range of 4.0-6.0 ppm, pH be between 7.2 to 7.6). The dosage in the case of chlorine is produced by opening and closing an electro valve at the outlet. There it is a deposit that is supersaturated of Chlorine. PH control takes place via a peristaltic pump metering the quantity of a product that counteracts the deviation of the set point value. The next step is the heating circuit. Here it is performed by exchangers, and in this case the energy generated (heat) in the condenser of the cooling equipment of the pool is also used. The set point temperature of a spa pool is around 34 º C, regulated by an automatic system, which consists of a three-way motorized valve that blends hot water to achieve the desired temperature.

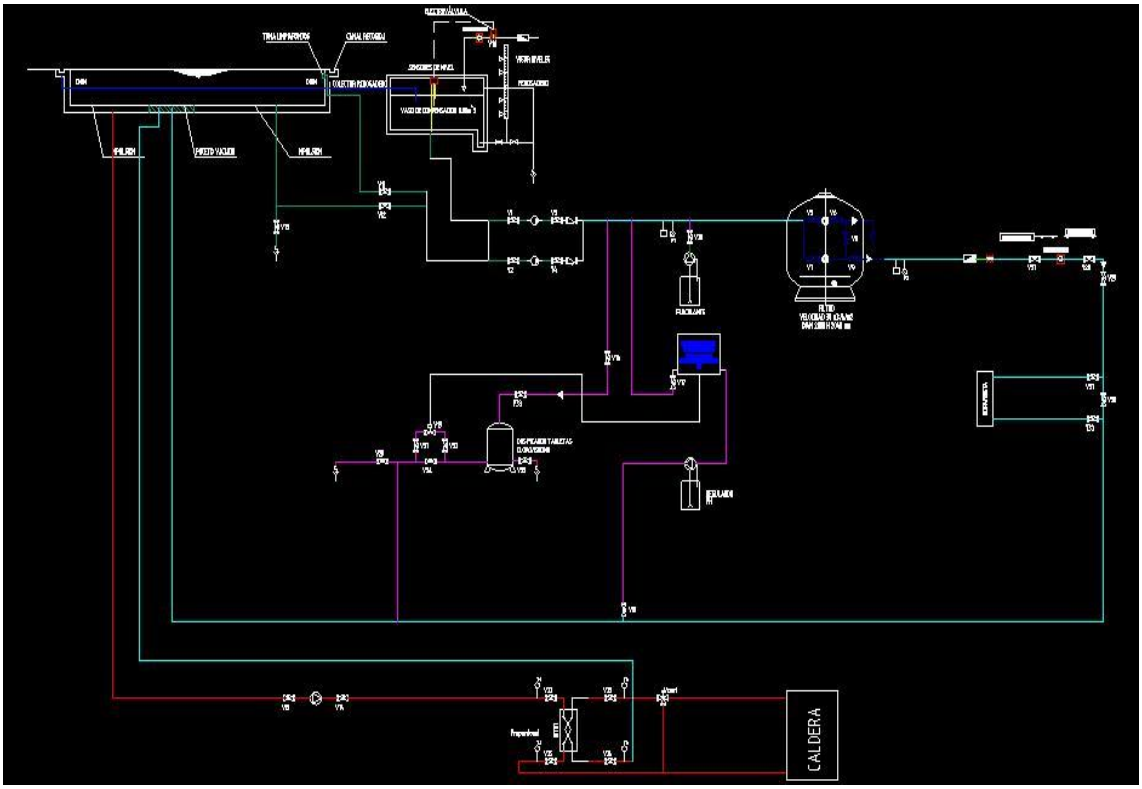

Figure 4. Pool system diagram.

Figure 4 represents the plan for the swimming pool, with all the steps the water follows, the compensation tank with all the sensors, the filter with all the valves, the ultraviolet system, the chlorine and pH dosage system, and the heater system with its own plate heater exchange.

Figure 5 represents all the steps of the circuit of the water. This float chart has been drawn for making programming easier and simpler.

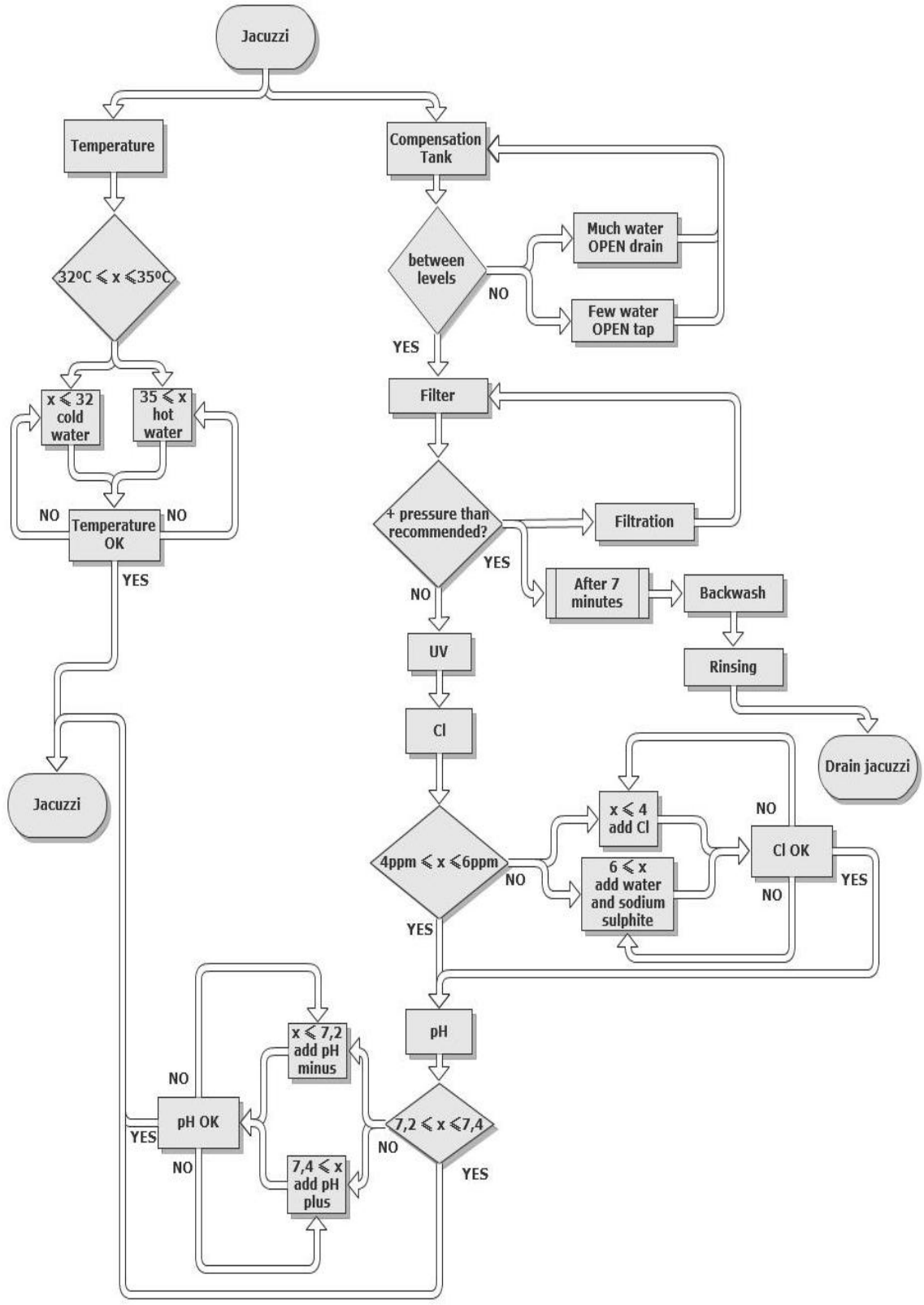

Figure 5. Pool float chart diagram.

The filtration can also be performed at the pool bottom, having another branch for filtering water from the drain box. There is also a circuit connected to the pump suction filter, which is used to connect a bottom cleaner. The amount of input water and filtered water is measured by two separate counters which will allow determining if the filtration flow rates are correct, and the renewed amount of water which is required by legislation.

3.1 Size of Equipment

The values drawn and taken [10] by law for this pool are:

Table 1. Swimming pool values.

Pool Shell	
Water top	44m^2
Pool volume	55m^2
Time for changing water	0.5 hours
Recirculation volume	110 m^3/h
Filtrate surface	3.14 m^2

Table 1 presents all the values for the different operations the swimming pool has.

3.2 Characteristics of Equipment

The filtrate system chosen is of silica and anthracite because of their high percentage of dirt holding. The filters are made with anticorrosive materials such as polyester and fiber glass.

The dosage and the performance of chlorine and pH will be automatic and will be inside the filtrate circuit.

The filtrate elements of suction and discharge will be placed so that there are no areas of the vessel without water movement to ensure the proper functioning of the system.

4 Temperature of Swimming Pool

The plate heat exchanger is a device that recovers the heat present in a fluid transferring it to another fluid. The two fluids cannot get in contact with each other because they are separated by metallic sheets. These sheets, called plates, are very thin and wrinkled and consume the maximum amount of heat per unit area. The plate heat exchanger is made to ensure the exchange of heat in maximum safety. The plate heat exchangers have the following elements, as can be seen in figure 6 [12]:

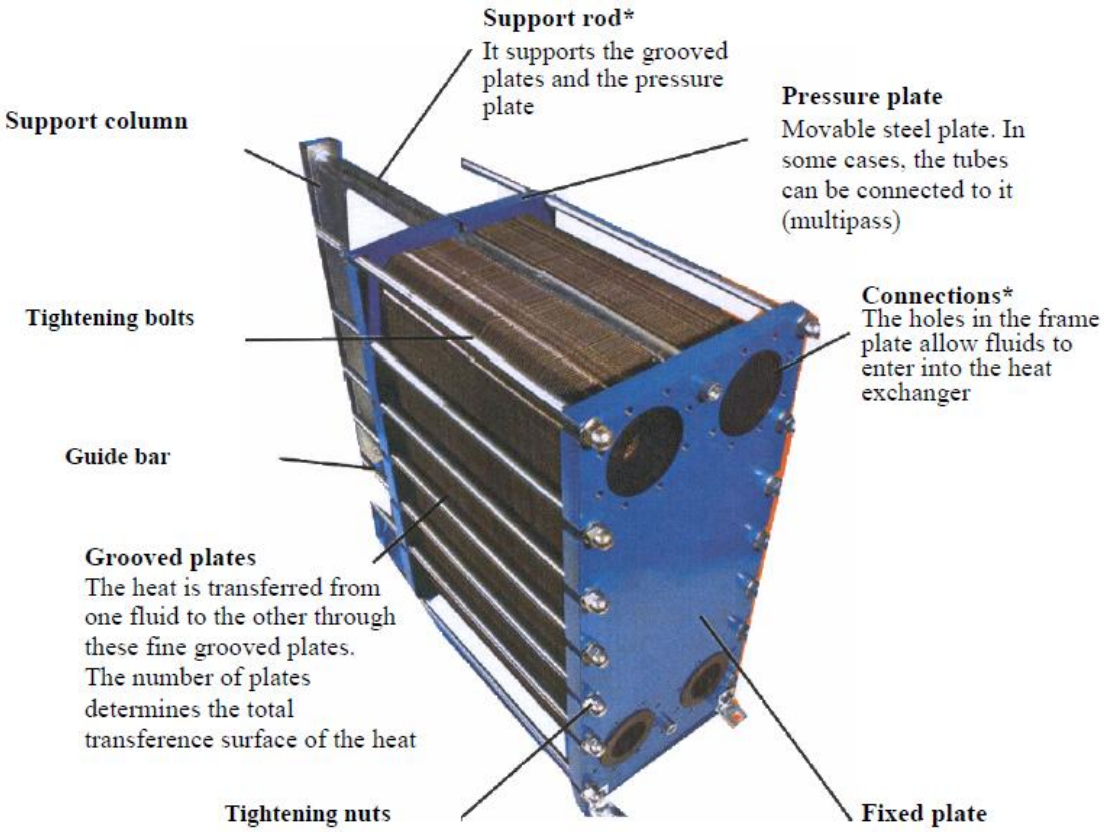

Figure 6. Heater system. Data gathered from Astral Pool plate exchanger manual [13,3].

Figure 7 shows how to make a plan for this kind of system. T1, T2, T3 and T4 are temperature gauges, which show the temperature of the water, and check if the value is correct. INT01 is the plate heat exchanger, which works as it is explained before. Figure 7 demonstrates valves which are used to open or closed the valves as needed, and at the right there is a boiler in case hot water is needed.

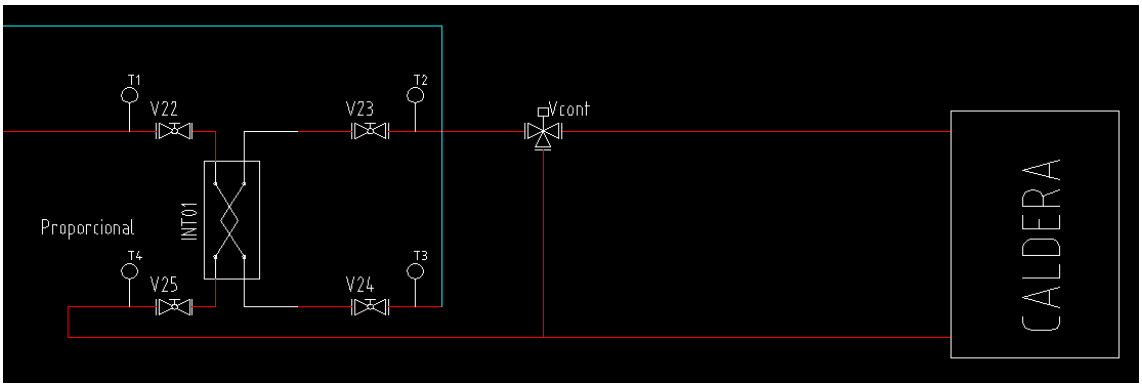

Figure 7. Heater system diagram.

Figure 8 is made for easier comprehension while programming, when the steps of the water sensor are working out when the system is on. The temperature is measured and if it is under 32 ºC, the heating system proceeds to provide hot water. On the other hand, if the temperature is over 35 ºC, the sensor detects it and the heating system proceeds to provide cold water to the water circuit.

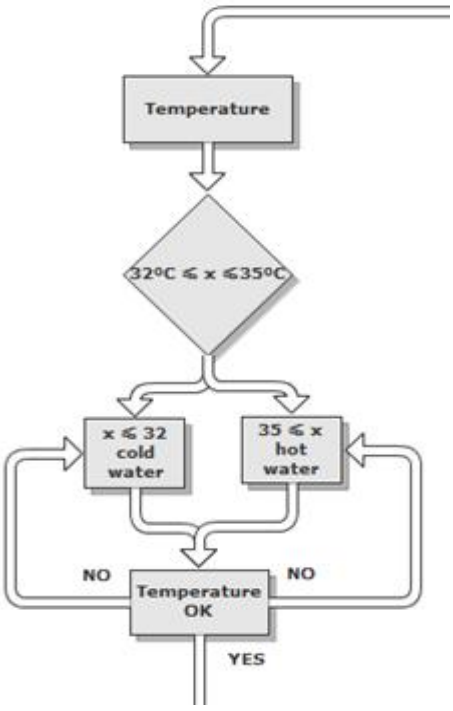

Figure 8. Heater system diagram.

The temperature system is really important in order to have optimum conditions for bathing.

5 Compensation Tank

In order to keep the water level and recollect from the overflow from the pool, the regulator level will be installed, in which new water will be added and water of the filtrate equipment will suctioned. These level deposits will be close in order to avoid condensations in the engine room. The volume of the regulator deposit for the pool is 88 m^3

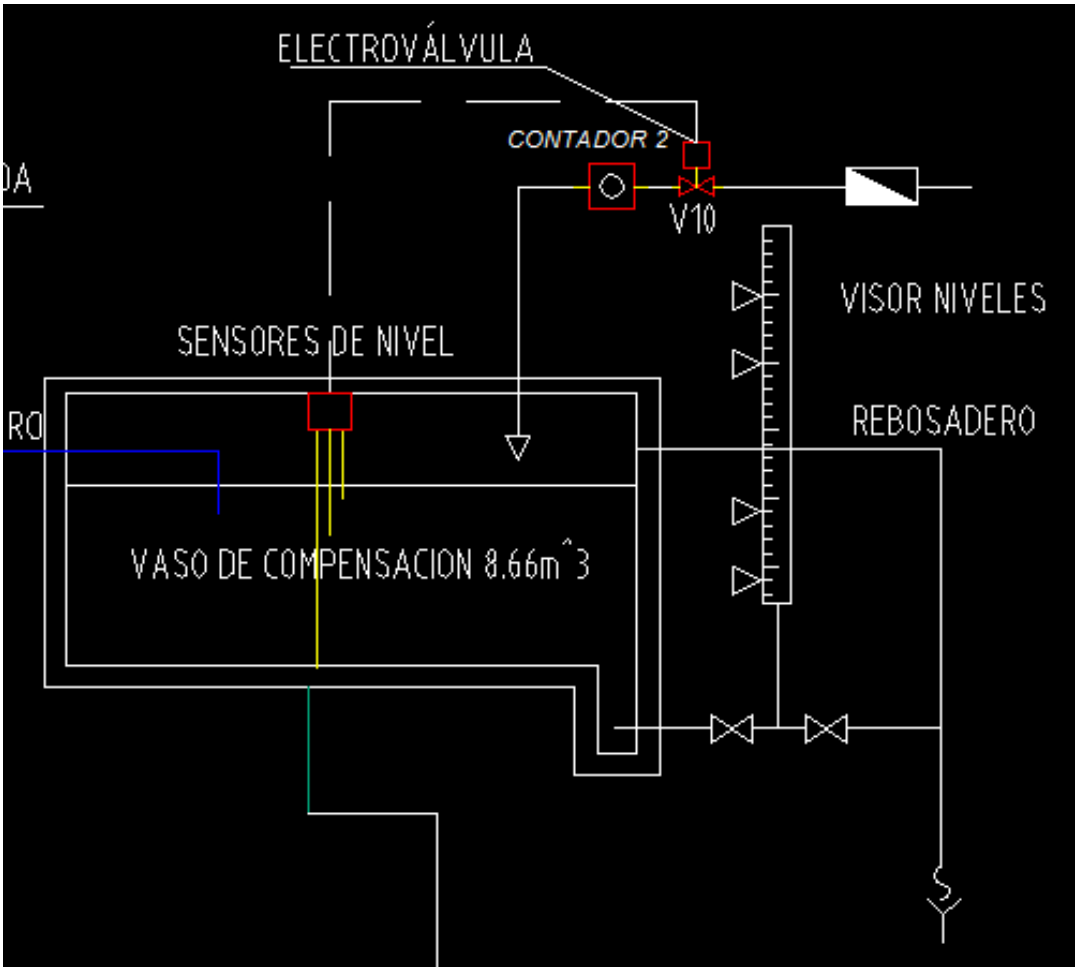

Figure 9. Compensation tank diagram.

Figure 9 shows the compensation tank, to see if the water is at the right level or not. This can be seen with the level sensor (yellow lines). If there is too much water, the valve for the drain will be open until the compensation tank has again the correct level of water. On the other hand, if there is little water, an electro valve will be open in order to get more water to the compensation tank. Also with the level viewfinder, the water level can be checked.

Figure 10 shows a float chart diagram that demonstrates that there are only two options and whether the levels are correct. When the levels are not correct, there can only be two possibilities, too much water or very little water, as mentioned in the description of figure 9.

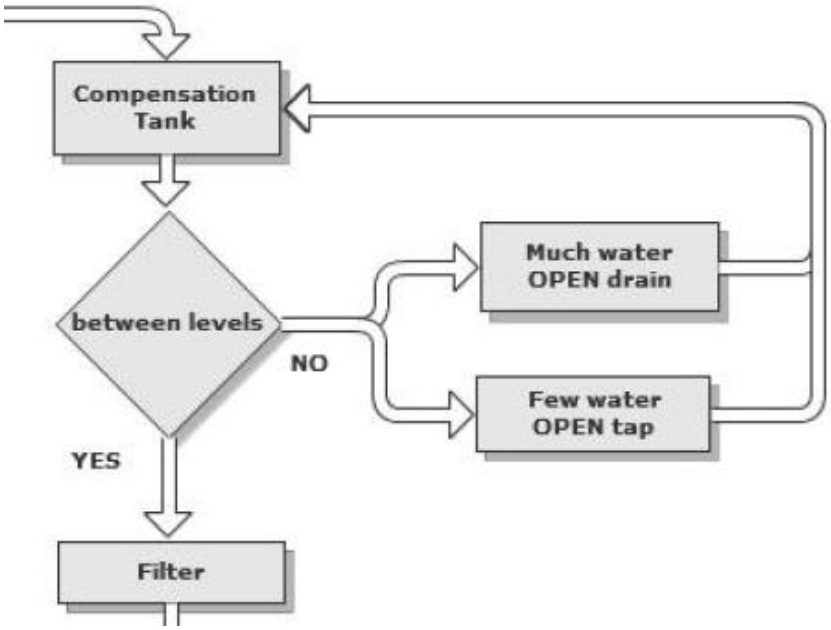

Figure 10. Compensation tank float chart diagram.

Without the compensation tank, the automation of the swimming pool will not be as effective as it is. Otherwise there will be too much water and money is wasted.

6 Filtration of Water

The filtering and the circulation of the water are the key actions to maintain a healthy and clean environment for activities such as swimming and relaxing. The water is guided through a pump which pushes it to the filter and removes particulates and impurities. Water cleaning is completed by chemical or physical treatment.

A correct water filtration considerably reduces the amount of products necessary for treating water. Once finished, the water returns to the pool in perfect swimming conditions.

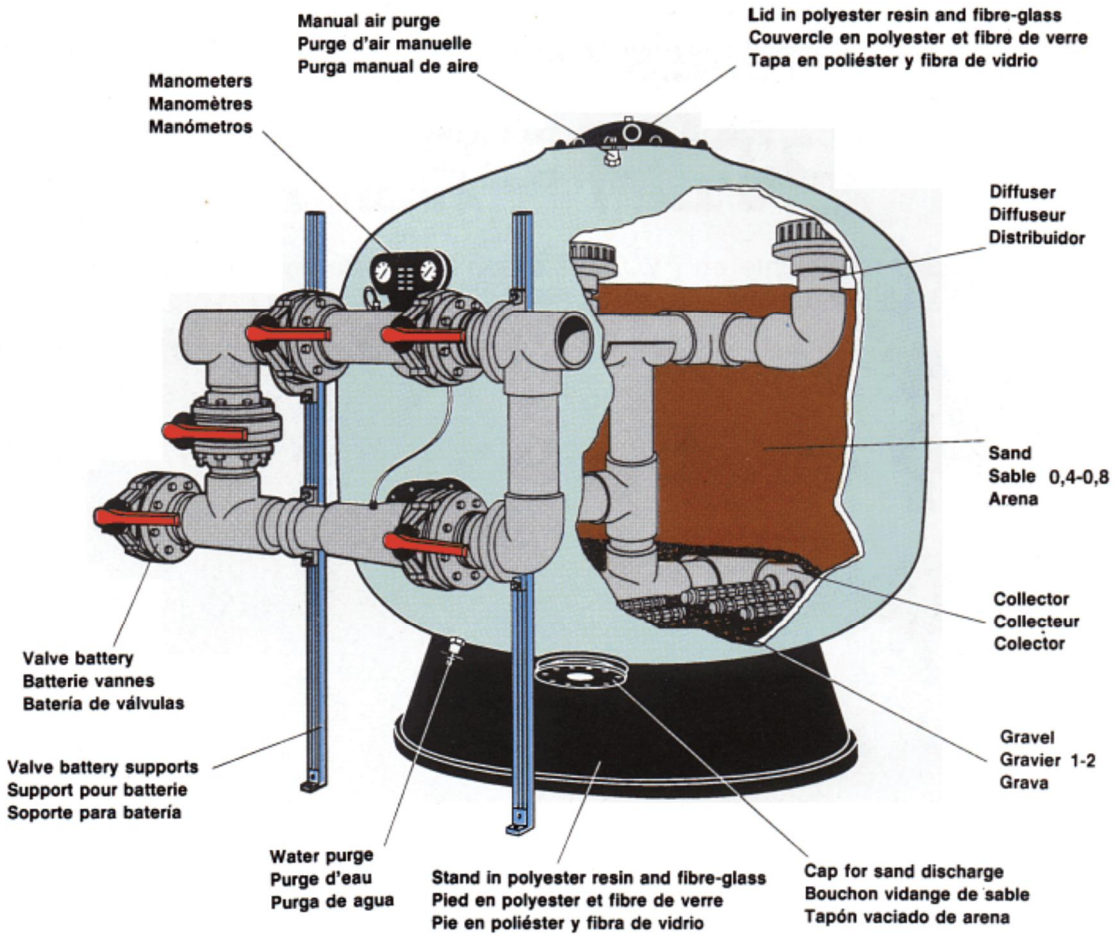

Figure 11. Heater system diagram. Data gathered from Astral Pool filter manual [14,3].

It can be seen in figure 11 what a filter looks like, with all the elements and valves for making it function correctly, such as filtering, cleaning, and rinsing.

For a correct operation of the water filtration, the filter has to follow the next steps with the pump always switched off:

Table 2. Filter positions valves. Data gathered from Astral Pool filter manual [14,5].

Position	1	2	3	4	5
Filtration	Closed	Opened	Opened	Closed	Closed
Backwash	Opened	Closed	Closed	Opened	Closed
Rinsing	Closed	Opened	Closed	Closed	Opened
Drain	Opened	Opened	Closed	Closed	Closed
Closed	Closed	Closed	Closed	Closed	Closed

Table 2 shows the positions of the valves for all the steps.

6.1 Filtration

The valves have to be in the position shown in the chart above. During the filter working it is recommended to check the input and output pressure gauges and make a backwash when the pressure difference is the same or more than 0.8 – 1 Kg/cm^2.

As the filter is removing the bacteria from the water, it gets dirty. The input pressure gauge experiences a higher pressure. Meanwhile the output pressure gauge experiences a lower pressure.

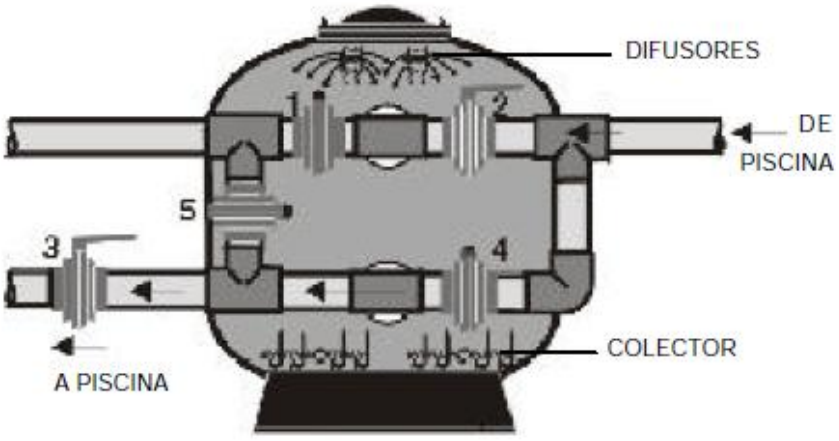

Figure 12. Filter valves position. Data gathered from Astral Pool filter manual [14,3].

In figure 12 the position of the valves for the filtration step can be seen. Water coming out with little pressure in the filter position might be caused by the filter having a lot of dirt and needing a backwash. The pressure of the filter can be checked on the gauge of the filter.

6.2 Filter Backwash

The valves have to be in the position shown in the chart above. This step must be performed after some filtrations, due to the filter picks up impurities and solid deposits that the water brings with it. After several times, these impurities and solid deposits blocks the water channels, so it is necessary to clean the filter for a good performance of the system.

Normally this step is made after 7 minutes.

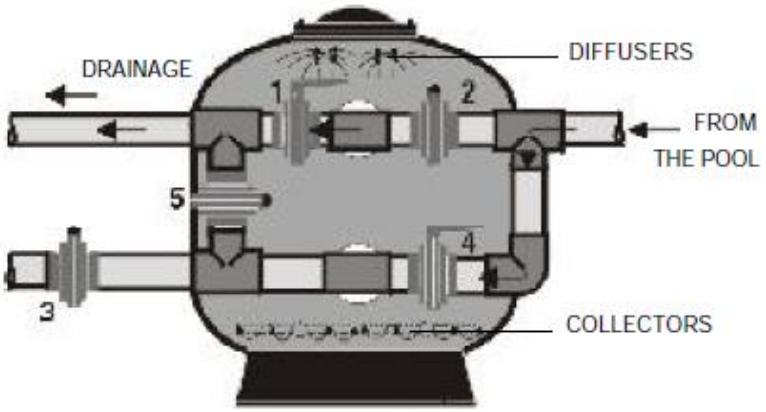

Figure 13. Backwash valves position. Data gathered from Astral Pool filter manual [14,4].

In figure 13 the position of the valves for the backwash step can be seen. After cleaning the water, the dirty water is removed by the drain.

6.3 Rinsing

The next step (rinsing) must be done after the backwash. The objective of the rinsing is to remove all the waste from the drain that remains during the backwash step. This operation should be done approximately every 3 minutes and prevent that no dirty water is in the swimming pool.

For doing this step the valves have to be in the position shown in table 2 and immediately afterwards, return to the filtration position.

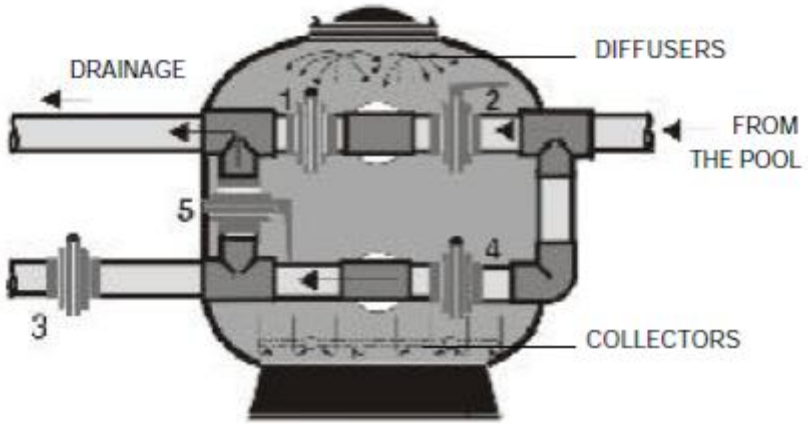

Figure 14. Rinsing valves position. Data gathered from Astral Pool filter manual [14,4].

In figure 14 the position of the valves for the rinsing step can be seen. After several years of cleaning and rinsing, the water in the filter, the silica and anthracite need to be replaced.

6.4 Drain

It is only needed when the swimming pool is empty, in case of not having a drain directly connected to the sewer. For doing this step the valves have to be in the position shown in table 2.

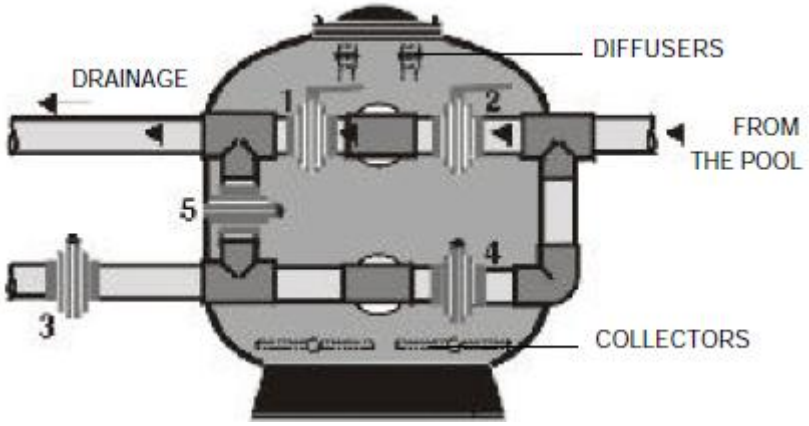

Figure 15. Drain valves position. Data gathered from Astral Pool filter manual [14,4].

In figure 15 the position of the valves for the draining step can be seen. For the drain step the overflow channel, pool cleaner, and skimmers need to be closed, in order to avoid the entrance of air.

6.5 Closed Valves for Maintenance

The performance of this step has to be made with the valves closed. The closed step is only used when maintenance of the filter has to be made. Figure 16 shows the position of the valves when the maintenance is needed.

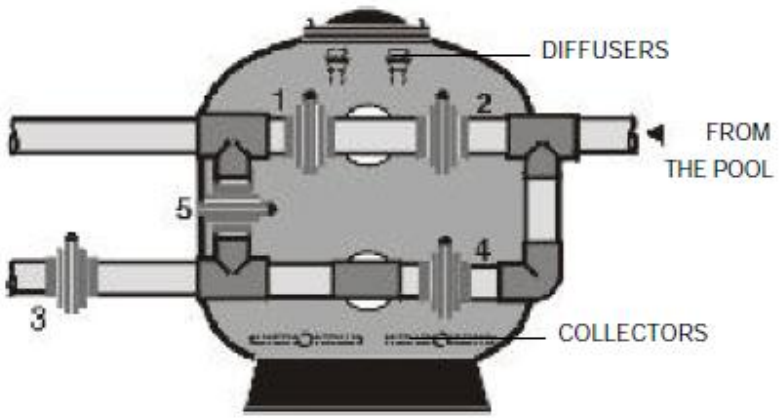

Figure 16. Closed valves position. Data gathered from Astral Pool filter manual [14,5].

In figure 17, every time the water goes to the filter, it gets filtrated to return to the swimming pool as clean water. After 7 minutes (this is usually what manufacturers recommend), backwash and rinsing have to be performed in order to have an effective filtration.

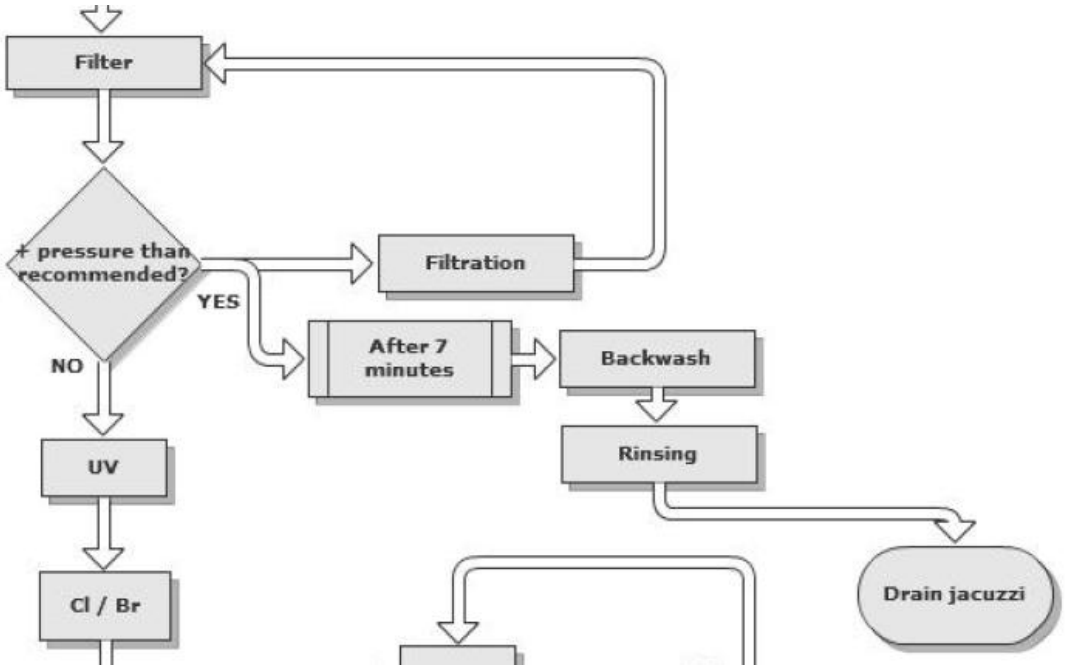

Figure 17. Filter float chart diagram.

The filter system is one of the most important parts at the time of having the water clean. Without this system, all the dirty things that get accumulated in the water would be difficult to remove, and finally the conditions of taking a bath would not be optimal.

6.6 Filter Maintenance

Water quality is essential, and for that the filter requires maintenance and regular cleaning. In a dirty filter, germs multiply and finally these germs go into the swimming pool. Also calcareous deposit can get formed.

To support this maintenance, the best way is to used recycled glass, because it has a smooth surface, and bacteria can hardly adhere; therefore, finer particles and organic residues are easier to filter.

7 Ultraviolet

Ultraviolet radiation (UV) is used as a germicide, and it aims to remove all the micro-organisms that are still in the water. Also it removes the irritation of the eyes and the skin, and the bad smell in indoor swimming pools.

The UV occupies wavelengths between 100nm and 400nm in the electromagnetic spectrum between x-rays and visible light as can be seen in figure 18.

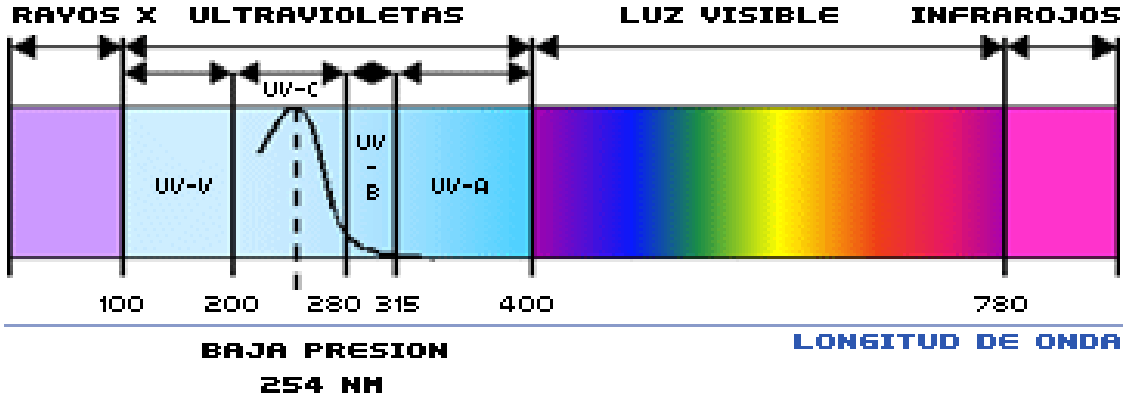

Figure 18. Ultraviolet wavelength. Data gathered from Oxicom Ultraviolet information [15].

According to its wavelength there are three types of bands: UV-A, UV-B, UV-C.

- UV-A: This band goes from 320 nm to 400 nm. It is the nearest to the visible spectrum and it is not absorbed by the ozone.
- UV-B: This band goes from 280 nm to 320 nm. It is almost absorbed by the ozone, but there are some beams that arrive to the Earth's surface.
- UV-C: This band goes from 200 nm to 280 nm. This is the band that provides the germicide action associated with the UV disinfection, and the maximum disinfection happens at 265 nm.

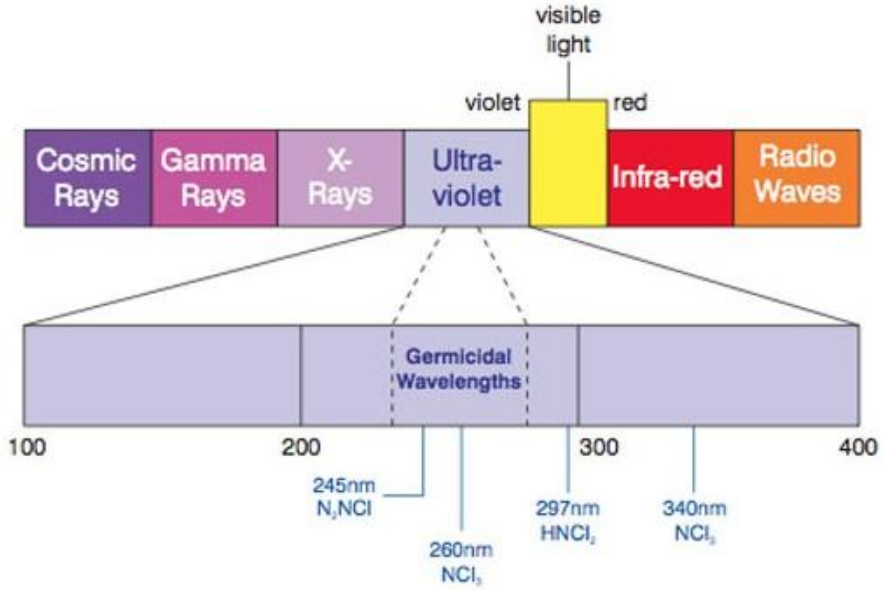

Figure 19. Ultraviolet germicidal wavelength. Data gathered from A-Kroll Ultraviolet [16].

The UV light as a part of the sunlight spectrum is a powerful natural disinfectant, as can be seen in figure 19; the wavelength values of UV light are between 200 and 300. The swimming pool water treatment systems generate this UV light with most disinfectant power of the spectrum, obtaining cleaner water and environment [16].

The UV systems produce UV photons, which are absorbed by the DNA molecules. With a dose of UV high enough, there is such a genetic disorder that the micro-organisms die.

The main action of the UV systems is to remove virus, bacteria, mold and their spores, in order to reduce the risk of transmitting stomach, skin and respiratory system infections to the swimmers. These UV systems also have an important second action: starting the photochemical reactions and photo-oxidants that cause the removal of the chloramines and a wide range of components responsible for the smells in swimming pools.

There are two kinds of UV lamps:

- One of low pressure that emits radiation in 254 nm;

- One of medium pressure. As can be seen in figure 20, it covers the whole UV light spectrum. This wavelength variety improves significantly the quality of bactericides and oxidants of UV light. With this lamp all the chloramines are destroyed, breaking them into innocuous elements. This lamp also has an integrated cleaning system. This is because of the creams and oils used by the swimmers which are creating a thin lawyer in the lamp and decreasing its performance [17,1].

Figure 20. Ultraviolet lamp. Data gathered from Oxicom Ultraviolet product [17,1].

This system is also used in other areas, such as soft drinks production, seaside platforms, in pharmacy and, in sterilization of surgical material.

8 Chlorine of Swimming Pool

Chlorine is a chemical element with atomic number 17 and atomic of weight 35.453 amu, it is located in the group of halogens in the periodic table of the chemical elements, and its symbol is Cl [18].

In normal conditions and in pure form dichloride (Cl_2) is formed. Chlorine is one of the most common elements in the Earth's crust (0.045% of chlorine) [19].

Chlorine is a highly reactive gas and it is mortal venom in its own pure form, but mixed with sodium it is not harmful for the human being. It is really important for the water purification in disinfectants and bleach. It is used as a disinfectant to kill all the germs that there are in the water, apart from being used also as a bleach of tissues and paper [20].

8.1 Chlorine for Disinfecting Swimming Pool

Chlorine is used as an antiseptic. In the oxidation process it also eliminates the organic impurities [20].

The advantages for using chlorine are:

- Chlorine products do not contain lime, they have neutral pH.
- High efficiency at high temperatures and high soil conditions.
- Chlorine products are dissolved without any residue and they does not form any deposit, neither do they clog the filter.

There are many different chlorine products. There are some that can be used with all kinds of filters, with every size, and they can be located in different parts of the circuit of the swimming pool. For some other products it is going to depend on the filter, if the filter has soil. There are some other products that have to be dosed by specific m^3. There are also some other chlorine products that have to be placed directly in the water, or in the skimmer, in the prefilter of the pump. These products can be granulated, powder, pills, tablets, or liquid.

8.2 Description of the Sensor

The Chlorine sensor is an amperometric sensor for the water treatment. It is designed to determine the residual level of inorganic chlorine in water. The measuring probes are based on an amperometric system of an open cell without middle liquids for the electrochemical reaction.

It is made of materials that ensure a perfect operation:

- Reuse of wastewater
- Disinfection of normal water

Figure 21. Chlorine sensor. Data gathered from ITC Chlorine manual [21].

Figure 21 shows how this sensor works. The chlorine reduction happens in the gold electrode (W), and it is where the voltage is applied from the value the reference electrode Ag/AgCl (R) gives. The counter electrode (C) completes the electrical circuit by the lecture of the intensity. To get the best balance signal, there is another electrode (of gold also), which is going to be GND and its purpose is to eliminate every residual current that can be in the water because of the low intensity of the current generated [21].

8.3 Specifications

These are the characteristics of the sensor:

- The products it analyzes are Cl_2, NaClO, $Ca(ClO)_2$
- The body of the sensor is made of PVC
- It is a system of four electrodes:
    - The work electrode: Au
    - The referential electrode: Ag/AgCl
    - The counter electrode: Au

- The GND electrode: Au

- The lecture scale is between 0.02 and 3.00 mg/l
- The precision of the sensor is ±2%
- The working conditions for the sensor are:
  - Temperature from 0 ºC to 40 ºC
  - The conductivity is between 50 and 300 uS/cm
  - Maximum pressure is 6 bar
  - It has two salinities:
    - <500 ppm Cl^-.
    - <500 ppm SO_4^{2-}
- The time for the polarization is approximately 30 minutes

8.4 Dosage of Chlorine

The level of chlorine has to be between 3.0 and 5.0 ppm. Figure 22 describes how these values can be achieved.

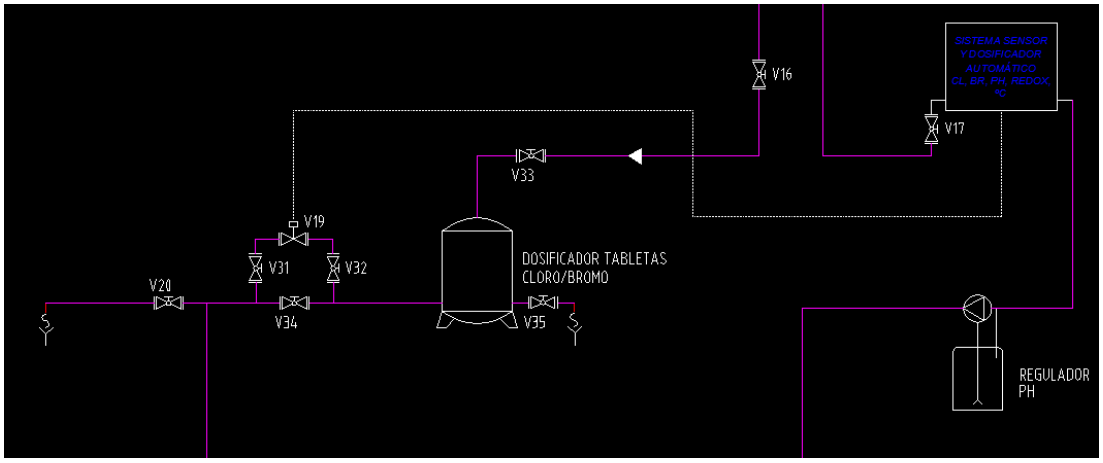

Figure 22. Chlorine system diagram.

The dosage of chlorine is produced by an opening and closing system of an electro valve which is located after a deposit saturated of chlorine.

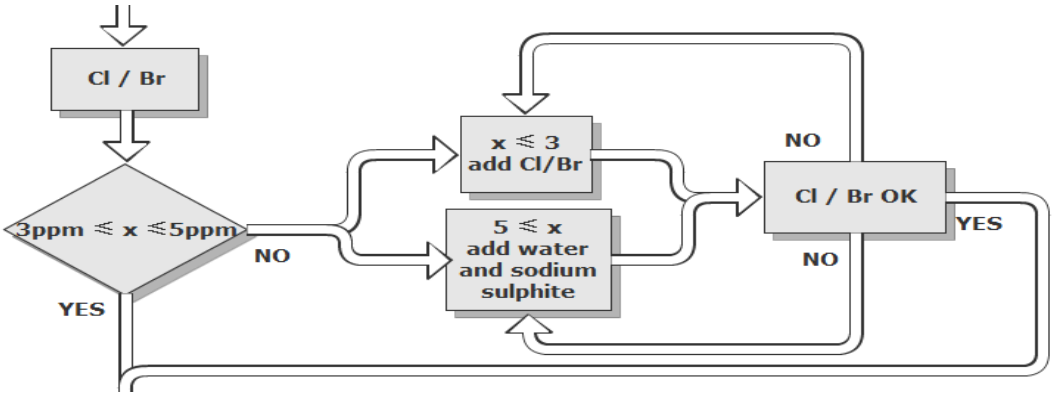

Figure 23. Chlorine float chart diagram.

Figure 23 describes the process of getting the values for having the water in the right conditions. If the value is under 3.0, the system will add Chlorine. On the other hand, if the value is over 5.0, the system will add water, or if the system is really sophisticated it can add sodium sulphite.

9 pH of Swimming Pool

pH is a measure of acidity or alkalinity of a dissolution. The pH indicates the hydrogen ion concentration [H3O+] in certain substances. It is defined as the logarithm of the hydrogen ion concentration, H+ [22]:

$$pH = -\log[H^+]$$

The scale of pH is between 0 and 14, 7 being the neutral solution.

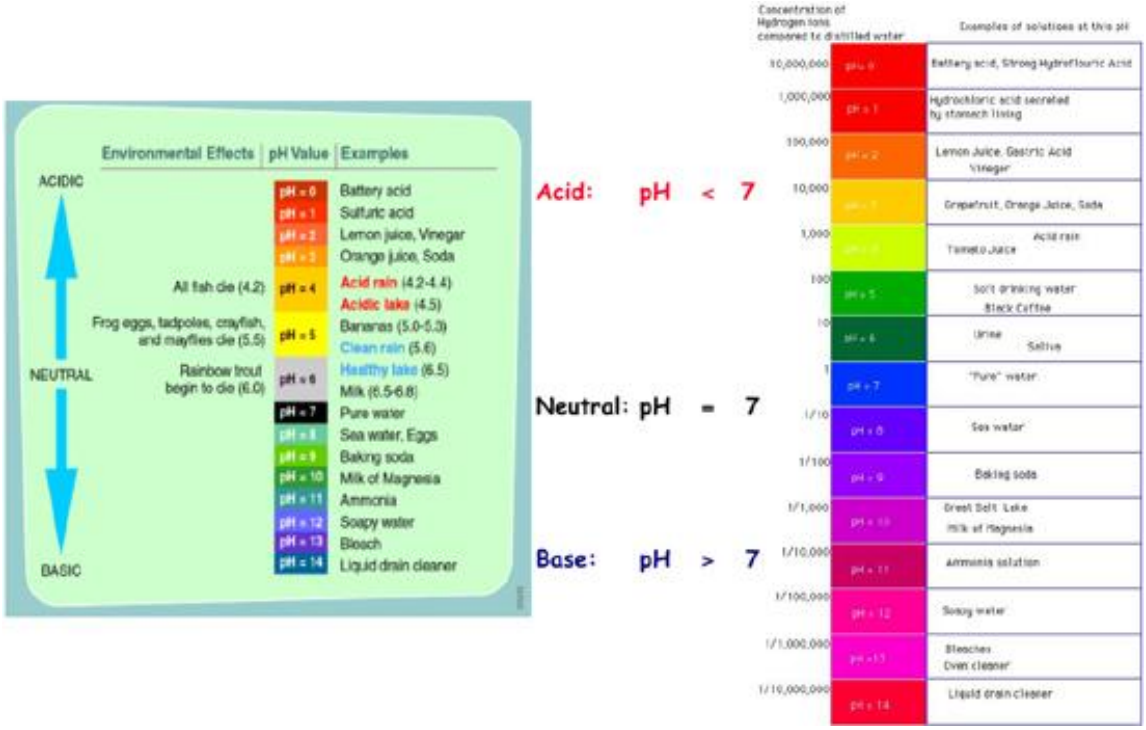

Figure 24. Scale of pH. Data gathered from PH [23,11].

Figure 24 shows that if pH is under, 7 there will be acid, as the value moves away from pH 7, it becomes increasingly acidic. For example a solution with pH 1is more acidic or stronger than one having pH value 6.

If the pH is over 7 there will be the basic solutions, which are more basic as moves away from pH 7. For example, a base with pH 14 it is stronger or more basic than another one having pH value 8.

Solutions with pH 7 will be considered as neutral.

- Acids

The acid is a substance capable of gaining electronic pairs, and giving protons when it gets dissolved in water. Its main characteristic is the presence of hydrogen ion in its own molecule.

- Base

Salts are ionic compounds made by a cation different than the hydrogen ion, and salts are made when the acids react with the bases.

- Neutralization

Neutralization is the reaction of an acid with a base for making salt and water.

9.1 Regulation of pH in swimming pools

pH regulation is the first step to have clean water. That is why the pH always has to be in the correct range. The range for a swimming pool is 7.0 – 7.6, but the best range for having the best conditions is 7.2 – 7.4. Figure 25 is made for easier comprehension at a programming time.

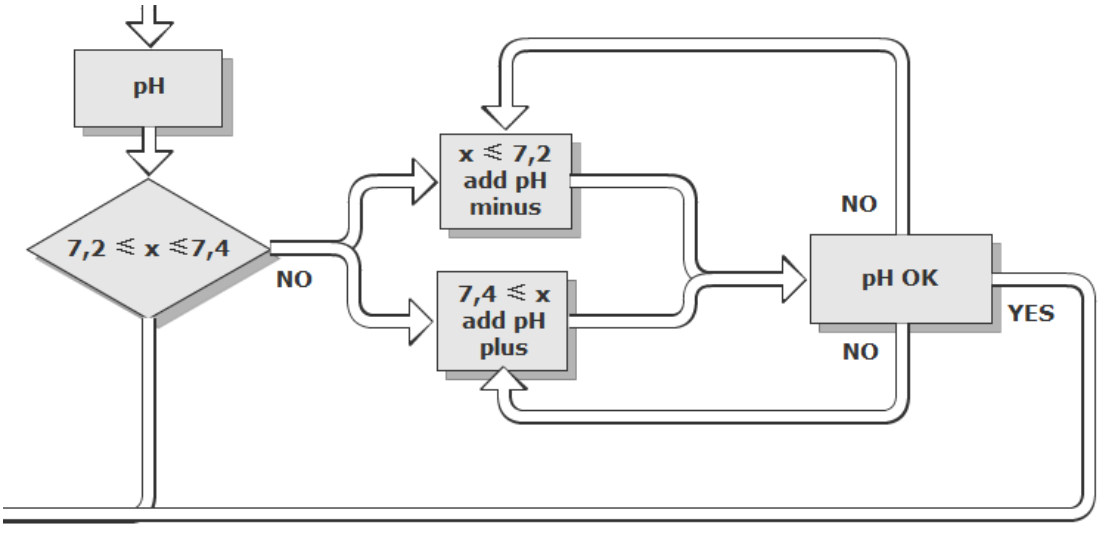

Figure 25. pH float chart diagram

If the water is under pH 7.0, the main things that can occur are:

- Skin irritation and irritation of the eyes.
- Metal corrosion.
- Acid water attacks the joints.
- Flocculation gets worse.
- Water turbidity increases.

If the water is over pH 7.6, the main things that can occur are:

- Skin irritation and irritation of the eyes.
- Decrease of the disinfecting effect.
- Calcareous precipitation.
- Flocculation gets worse.
- Growth of algae and bacteria.

To increase the pH, sodium carbonate or sodium bicarbonate need to be added. On the other hand to decrease the pH, it is necessary to add hydrochloric acid or sodium bisulfate.

Some points to consider:

- Water cannot be added into the acid, because the acid has to be diluted in a huge volume of water.
- Contact between hydrochloric acid and sodium hypochlorite must be avoided, because chlorine gas appears.
- The addition of a product in order to correct the pH is done by a peristaltic pump connected to the water recirculation after the filter.

9.2 pH Products

The best products for a correct pH regulation are [8]:

- pH-Minus: It is used when the pH is over 7.6. It is a granulated acid, with easy and faster dissolution, and a good chemical pure.

- pH-Plus: Unlike pH-Minus it is used when the pH is under 7.0. It is an alkaline dust of faster dissolution to increase and establish the pH value.

9.3 Potentiometer or pH Meter

This instrument consists of the neutralization of the acid (or base) with a certain quantity of base (or acid) of a known concentration.

It can also be measured by a potentiometer, measuring the difference of potential between two electrodes: a reference electrode (usually made of silver chloride) and a glass electrode [24].

9.4 Specifications of the Sensor

Figure 26 shows how a pH sensor looks like.

Figure 26. pH sensor. Data gathered from Vernier pH sensor [25].

These are the characteristics of the sensor:

- The sensor has an epoxy body, and it is gel-filled, sealed, and Ag/AgCl.
- It takes 1 second's response time90% of the final reading.
- The temperature range goes from 5 ºC to 80 ºC.
- The range of the pH is 0 – 14.
- At 25 ºC the output is 9.2 mV/pH

- The resolution of the sensor:
    - For 13-bit resolution the pH sensor gives 0.025 pH units.
    - For 12-bit resolution the pH sensor gives 0.005 pH units.
    - For 10-bit resolution the pH sensor gives 0.02 pH units.
- The pH isopotential is at pH 7 when the temperature has no effect.

9.5 Sensor Operation

The pH sensor that is used in the swimming pool measures the activity of the hydrogen ion. The voltage meter converts it into a value of pH to determine if the values are correct or not.

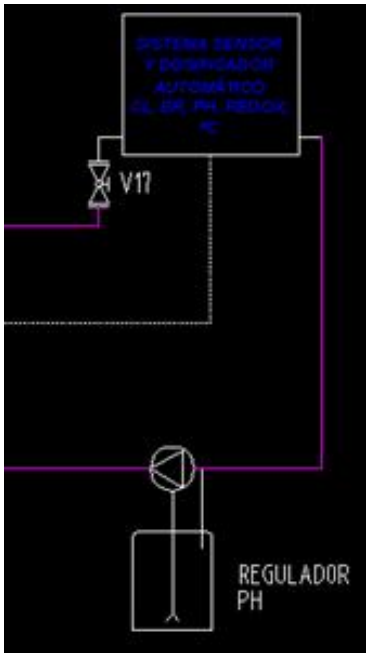

Figure 27. pH regulator system diagram

As it is shown in figure 27, the pH is controlled by an automatic system in the swimming pool circuit, and this control is done by dosing the product with a peristaltic pump when the water has a wrong value.

10 Pool Controller

The pool controller is a cell, with a measuring range between 0 and 10 ppm of free chlorine and it has a maximum of 8bar pressure.

Basically, the chlorine probe acts as a chemical battery. It has a copper foil and a spiral of platinum. Chlorine circulates between them, generating an electric current, which is the one that will be used to check the chlorine level in the water [27,1].

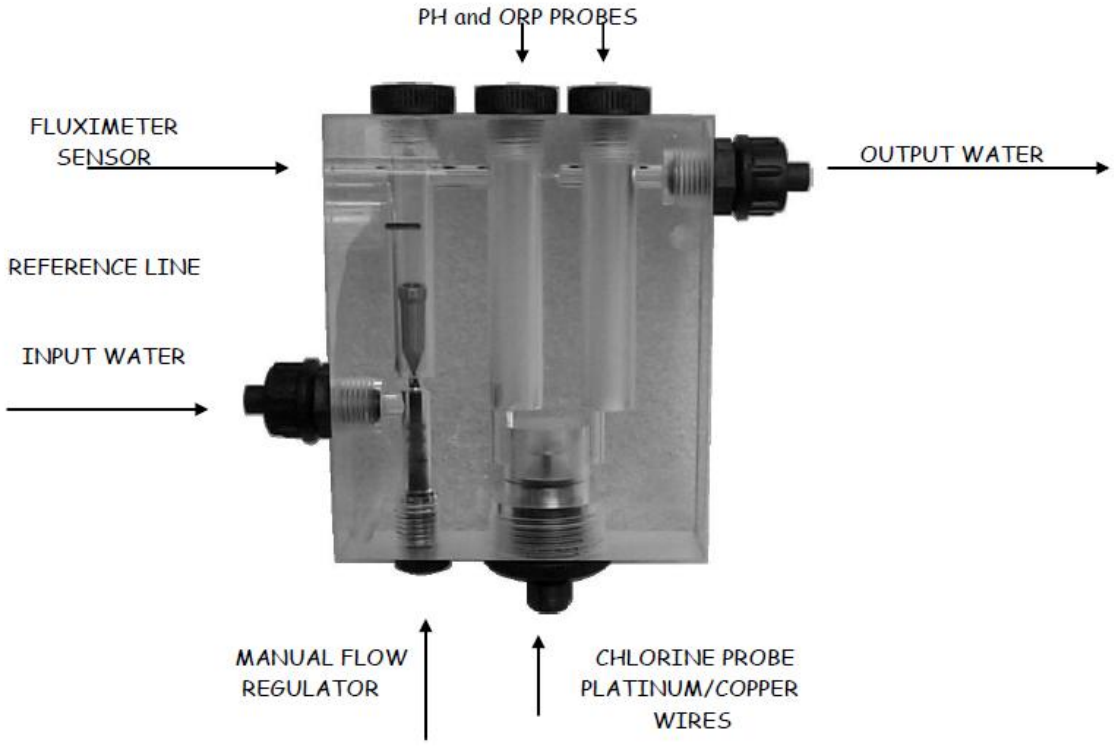

Figure 28. Pool controller cell. Data gathered from Hytechaquade Controller [27,1].

Figure 28 shows what a pool controller looks like. It is a self-cleaning cell. There are about 30 glass beads moving through the copper surface when the water circulates in it, so that it prevents the chlorine oxide, the copper foil and other elements depositing in it such as fat from the creams bathers because these creams hinder the correct operation of the cell.

The analysis chamber has a flow detector, and the probe for operating needs a flow between 30 and 50 liters per hour depending on the water pressure and chemical characteristics.

Ideally, the balls of the analysis chamber rotate horizontally without becoming compact, and the panel should always be mounted as horizontally as possible so that the balls do not waste the copper surface.

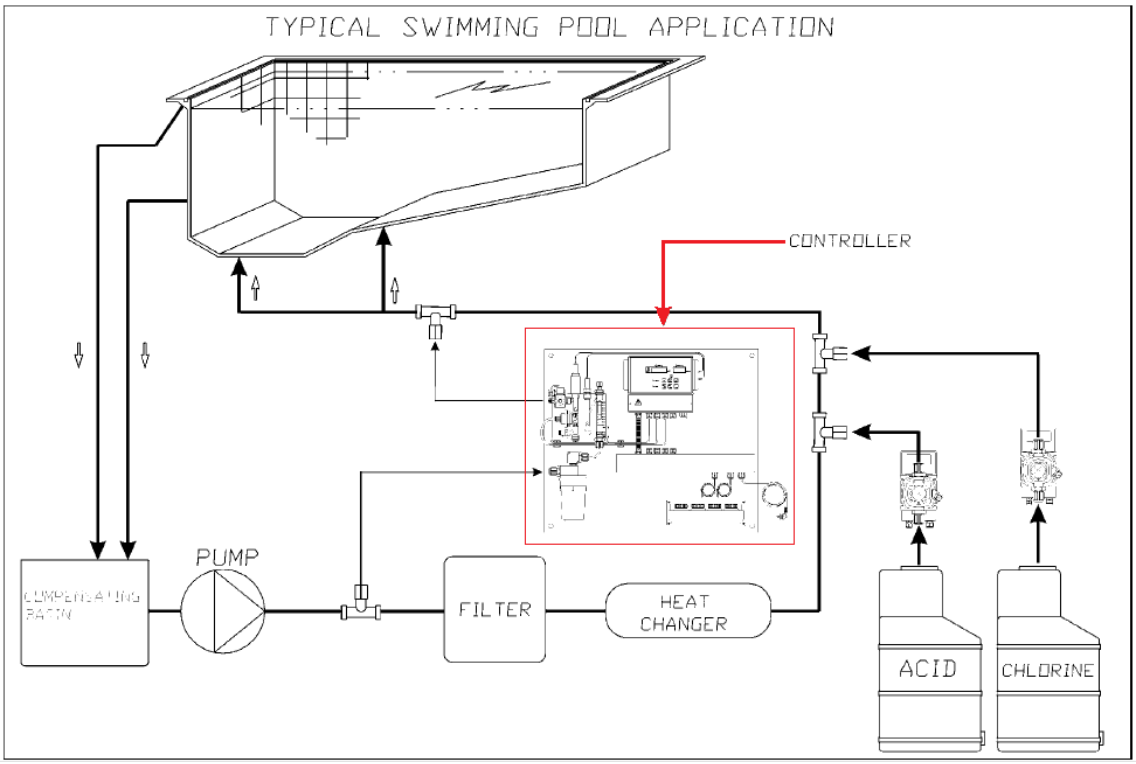

Figure 29. Typical swimming pool application. Modified from Astral Pool [28,7].

Figure 29 shows how the controller is located in a swimming pool, with all its equipment. The picture also shows the container of chlorine, for dosing it. The chlorine operation works with an electro valve system. Because of warning all the chemical containers need to be separated at least 2 meters from the controller equipment.

11 Conclusion

Due to constant innovation nowadays in technology, what is looked for is an improvement in the quality of life of people. Apart from the considerable number of advantages that these innovations offer, it is important to invest in these elements:

- Saving money and energy
- Involving an optimization in terms of expenditure that is concerned
- Constant quality control regarding purity and water safety

This thesis has aimed to describe all the elements that contribute to the automation of a circuit maintenance and water treatment of swimming pools for them to operate perfectly, and for them to achieve the best performance, and to preserve them in the best possible conditions. The chapter of water treatment describes all the products that can be added to maintain the water in a good condition. In addition, all the Spanish laws needed have been described in this chapter in order not to have low quality water or problems with the water system so that people do not get sick. The following chapters describe all the elements that are important for the maintenance of swimming pools and needed for efficient and correct water treatment.

After having completed the thesis, one can realize where technology can go. Until recently, this comfort and optimization of these resources were unthinkable, yet today these resources can be improved considerably, and the elements described in the thesis can be controlled from almost anywhere with the pushing of a key or a button or from a mobile phone. So as the innovation increases, new elements can be added to the circuit described in this thesis in order to improve its performance and operation.

Finally, it can be concluded that all the necessary elements for a correct circuit automation of a pool and the maintenance of the system are known, and with the purpose of this is the well-being and enjoyment of pool users, saving energy and resource optimization.

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