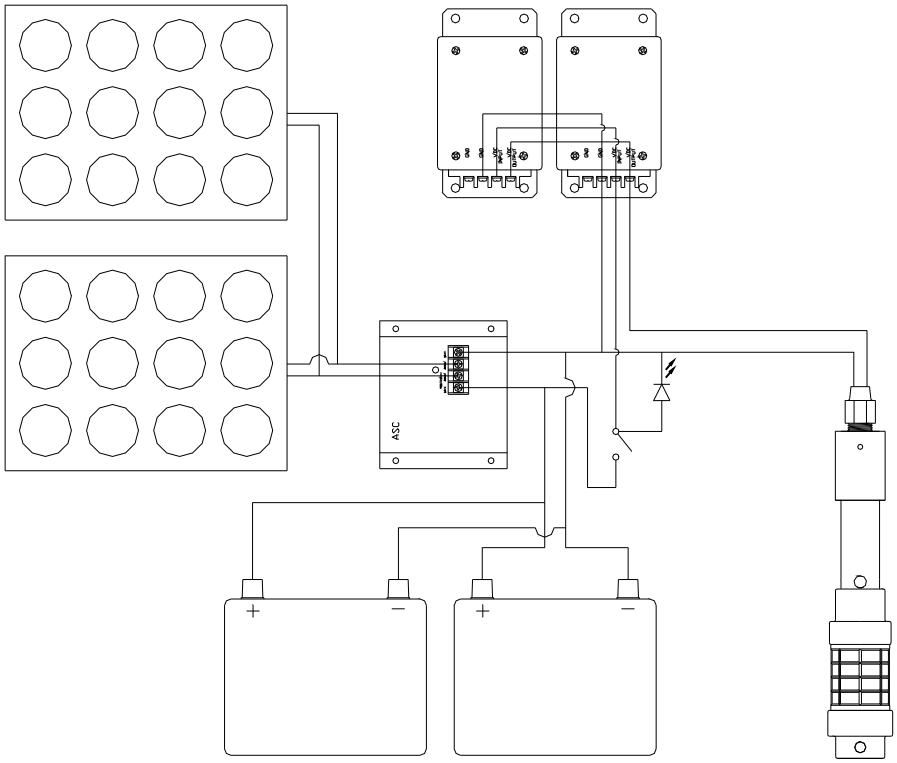
Installation, Operation, and Maintenance Manual

For the Aquachlor AC25 Solar



On-site sodium hypochlorite generator

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System Overview

The Aquachlor system provides a 0.6% solution of sodium hypochlorite. This is an effective water disinfectant that eliminates waterborne diseases like cholera, typhoid fever, hepatitis, amoebic dysentery, bacterial gastroenteritis, and others. The relatively low concentration of equivalent chlorine has been chosen to be friendly to the environment and safe to the operator while maintaining a high disinfecting power.

The system consists of a generating cell, a source of electricity for the generating cell, and a brine tank. The generating cell electrolyzes the brine into a solution of sodium hypochlorite. The generating cell is sealed in a PVC housing. Depending on the application, the source of electricity may be municipal alternating current or solar direct current

Technical Specifications

Generating Electrode	**AC25D**
Production cycle	8 hours
Average equivalent chlorine production	25 grams per hour
Equivalent chlorine	200 grams per cycle
Equivalent chlorine concentration	6 grams per liter
Consumption per cycle	
Salt	1000 grams
Electricity	1.60 kWh
Water	33 liters
Dimensions	
Electrode size	66 cm long
Cable length	213 cm
Weight	2.5 kg
Power Supply	
Type	DC-to-DC converter
Solar Panel	2 x Siemens SP75
Energy Storage	Lead-Acid, Deep Cycle battery
Output	9VDC, 17A
Additional equipment required	
Storage Battery	150 amp-hour, 12V, deep cycle
Polypropylene tank	80 to 120 liters

Theory of operation

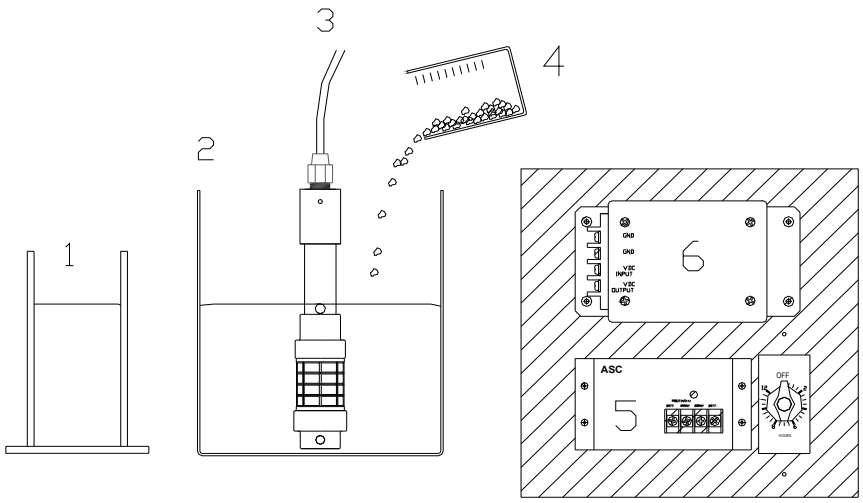
Chlorine gas, Cl_2, disinfects water by hydrolyzing according to the following reaction, and forming the active ingredient hypochlorous acid, HOCl.

$$Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$$

The Aquachlor system generates a hypochlorite bleach solution from brine that, like chlorine gas, produces hypochlorous acid.

$$2NaCl + 3H_2O \rightarrow HOCl + NaOH + 2H_2$$

Figure 1



1 Cleaning container
2 Electrolysis container
3 Generating cell
4 Salt container
5 Charge regulator
6 DC-to-DC converter

Precautions

All instructions should be read and understood before attempting to install, wire, operate, and maintain the equipment.

First Aid

- **Eye Burns** (due to contact with sodium hypochlorite, acid, or vinegar) wash the eyes with running water for 10 minutes. Seek professional treatment.
- **Skin Burns** (due to contact with sodium hypochlorite or acid.) Wash the affected area with running water for 10 minutes. Seek professional treatment.
- **Oral Ingestion of sodium hypochlorite.** Do not induce vomiting. Give milk, ice cream, or an antacid. Seek professional treatment immediately.
- **Oral Ingestion of acid or vinegar**. Do not induce vomiting. Seek professional treatment immediately.

Installation

Equipment Description

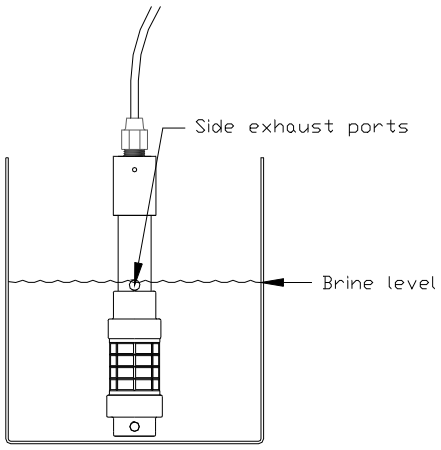
The main components of the Aquachlor sodium hypochlorite generating station consist of the generating cell, a source of direct current for the cell, several recipients resistant to brine and sodium hypochlorite, and possibly adequate laboratory equipment for verification of the sodium hypochlorite concentration.

ESE provides the sodium hypochlorite generating cell, the photovoltaic panel, the charge controller, and the DC to DC converter. A deep-cycle lead-acid battery and a small water recipient resistant to sodium hypochlorite and brine are necessary for proper operation. These may be obtained locally. Tanks constructed of polypropylene or polyethylene are adequate. Metallic tanks or fiberglass containers are not adequate.

Installation Precautions

- Locate the DC to DC converter, the solar panel, and the battery charger away from the vapors that escape from the process container (opposite direction of the predominant wind.)
- Locate the DC to DC converter away from the possibility of liquid spills.
- Make sure the generating cell is properly connected. Reversing the polarity of the cell will permanently damage the electrode.
- Hydrogen is a byproduct of hypochlorite generation. Install the system in a well-ventilated area, preferably with crossed ventilation for proper evacuation of hydrogen.

Figure 2



The Aquachlor generating cell consists of a series of highly specialized electrodes encased in a protective shell. When the appropriate current is applied, the electrodes incite an electrochemical reaction whereby the brine solution is converted into a solution of sodium hypochlorite. The cell has been designed to operate using a direct current. It is important to supply the cell with the correct current at the correct polarity. Excessive current, incorrect polarity, and improper maintenance will damage the cell. The solar power source converts sunlight into electricity to be used in the hypochlorite generating process.

The system consists of a photovoltaic panel, a battery charge controller, a lead-acid storage battery, and a DC to DC converter. The solar panel harnesses the available sunlight and converts it into electrical energy. The panel continuously charges the lead-acid battery through the charge controller. The charge controller automatically regulates the charge level of

the storage battery. The DC to DC converter limits the current supplied by the battery to the generating cell.

The electrolysis tank holds the brine solution and the generating electrode. In this tank that the brine is converted into sodium hypochlorite. Efficient operation of the hypochlorite generating system depends on proper selection of this tank. It should be made of a material resistant to sodium hypochlorite and salt, such as PVC or Polypropylene.

The tank should contain the brine batch without danger of spills and have a well-ventilated cover to prevent debris from entering the brine. In addition, the water level should be within the side exhaust ports of the generating electrode when the electrode is immersed in the brine (See **figure 2**). Proper placement of the water level is necessary for adequate flow of brine through the generating electrode.

The brine preparation tank is desirable but not necessary. In it the salt is dissolved in a small quantity of water prior to mixing into the brine batch. The volume of this tank is not specific. It should, however, be small and easily handled. Usually a two-gallon pail is adequate.

The salt measuring container is used in lieu of a scale to weigh the salt for brine preparation. It should have permanent volumetric graduations corresponding to the weight of the salt in the container. Since the bulk density of the salt will depend on the locally available salt, each container should be calibrated individually.

The electrode cleaning container stores and cleans the generating electrode while it is not in use. This container is filled with pure vinegar or with a 3% solution of hydrochloric acid (muriatic acid).

IMPORTANT: USE OF ACID CONCENTRAITONS HIGHER THAN 5% WILL PERMANENTLY DAMAGE THE GENERATING ELECTRODE AND WILL VOID THE WARRANTY. COMMERCIALLY AVAILABLE HYDROCHLORIC ACID TYPICALLY HAS A CONCENTRATION SEVERAL TIMES HIGHER THAN 5%, AND MUST BE PROPERLY DILUTED TO BE USED FOR ELECTRODE CLEANING PURPOSES.

Installation Overview

The Aquachlor Generating System has been designed for permanent installation. Proper care must be exercised for portable use of the system. Installation should be performed only after reading and understanding the installation manual, and only by qualified personnel.

Installation consists of obtaining the additional necessary equipment, selection of an adequate site, installation of the photovoltaic panel, and completion of the electrical connections.

Site Selection

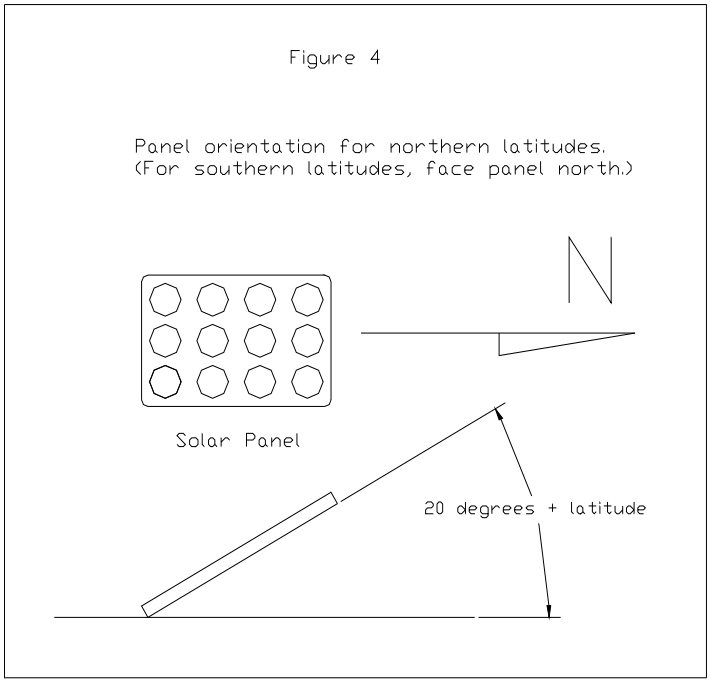
The permanent site for the sodium hypochlorite generating system should be selected considering the requirements, the operating parameters, and the safety considerations of the generating system.

The photovoltaic panel should be permanently mounted at a location protected from debris, impact, and tampering. In addition, for maximum effectiveness, the panel should be mounted at a location with direct sunlight throughout the day, and without shade.

In order to achieve the best year-round performance, the photovoltaic panel should be installed at the correct tilt-angle. Generally, this angle is equal to the site latitude plus 20^{o}, with the panel facing south in northern latitudes, and facing north in southern latitudes. See **figure 4**.

The generating system is not immune to the elements. In particular, the DC-to-DC converter is electronic and susceptible to damage from moisture. In addition, the generating process produces a small amount of hydrogen gas, which is vented to the atmosphere. Select a site that will protect the converter from rain and moisture. The site should have adequate ventilation to ensure rapid evacuation of the hydrogen gas. The equipment should not be located in an area where open flames or sparks are present

The sodium hypochlorite produces inherent hazards in the generating process. Access to the equipment must be restricted to personnel properly trained and aware of these hazards. Choose a site that can be



secured from access by those not trained to use the equipment. In particular, ensure that those unaware of the hazards, such as children and animals, have no access to the equipment.

Layout

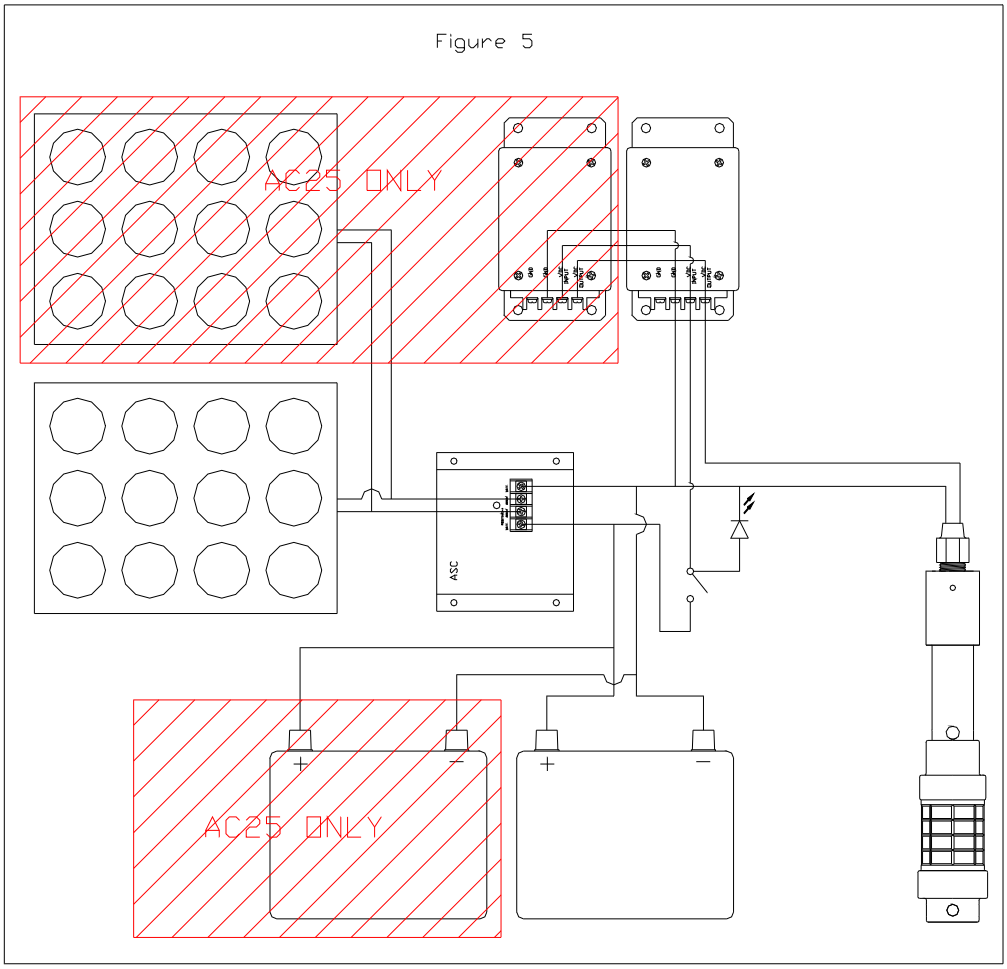
The placement of the DC-to-DC converter is very important to ensure the longevity and safety of the generating system. It should be located above the ground on a sturdy shelf or table. Under no circumstances should it be located over any liquid recipient, where it may fall and be damaged.

Wiring

Complete installation as follows:

1.Using 18AWG wire, connect the solar panel(s) to the charge controller on the solar power panel. If more than one panel is used, connect them in a parallel configuration. That is, the positive lead from each panel will connect to the positive terminal on the charge controller, and the negative lead from each panel will connect to the negative terminal on the charge controller. Polarity is important.

2. Connect the alligator clips from the solar power panel to the corresponding posts on the lead-acid battery. Polarity is important. Connect the red clip to the positive (+) terminal, and the black clip to the negative (-) terminal.
3. Connect the terminals of the generating cell to the terminals on the solar power panel marked "CELL". Polarity is important. The red terminal from the generating cell connects to the terminal marked "+" on the solar power panel. The black terminal from the generating cell connects to the terminal marked "-" on the solar power panel. This step has been performed at the factory for the AC5 system.



Operation

Operating Precautions

- Do not smoke or have open flames close to the equipment.
- Avoid contact of the solution with eyes or skin.
- Avoid the solution contacting clothes.
- Do not operate the electrode longer than recommended. Doing so is wasteful and will eventually decrease the concentration of sodium hypochlorite in the solution.
- The water used for the brine solution should be free of visible particles and solids. If necessary, this water should be strained with a coarse-cloth filter.

Modes of operation/ Overview

Your Aquachlor sodium hypochlorite generating cell relies on the rapid flow of solution created by the generation of hydrogen gas for proper operation. The electrode was designed to function under this natural flow condition. It follows that the electrode generates sodium hypochlorite in batches only. This, however, should not be a limitation, since judicious selection and installation of the solution tanks could ensure a continuous supply of sodium hypochlorite for use in continuous treatment systems.

To operate the system, first dissolve a predetermined amount of salt in a specific volume of water. Water volume and salt amount may be determined from table 1. The generating electrode is then immersed in the in the brine, and the power to the DC-to-DC converter is activated. After a predetermined amount of time the brine solution will have been converted into a solution of sodium hypochlorite. It is this solution that is used to disinfect water for drinking.

Materials

Only water, salt, and electricity (or sunlight) are required for the production of sodium hypochlorite. The water for the electrolysis tank should be as particle-free as possible. Although it does not need to be free of microorganisms, it should contain no visible particles. Likewise, the salt should be as pure as possible. Salt impurities increase the rate of calcium build-up on the cathode, requiring more frequent cleaning.

1. Brine preparation

Table 1

total chlorine (grams)	water volume (liters)	salt (grams)	Cycle time (hours) AC5	AC25
10	1.67	50	2	
15	2.50	75	3	
20	3.33	100	4	
25	4.17	125	5	1
30	5.00	150	6	
35	5.83	175	7	1.4
50	8.33	250		2
75	12.50	375		3
100	16.67	500		4
125	20.83	625		5
150	25.00	750		6

Fill the brine tank with the water and measure 30 grams of common salt for each liter of water used. Mix the salt into the water and agitate continuously until all of the salt has dissolved. This will produce a 3% brine solution. On occasion it is helpful to grind the salt or to pre-dissolve it in a separate container.

2. Cell activation

Before introducing the cell in the brine solution, make sure there is no power flowing to the DC-to-DC converter(s). Turn the timer knob counterclockwise to the off position. The red LED above the timer should be off.

Once the brine has been prepared, introduce the generating cell into the electrolysis tank and turn the timer knob clockwise to the desired cycle time. The electrolysis time depends on the volume of water in the electrolysis tank. This time is tabulated on table 1 above.

WARNING: INTRODUCING THE ELECTRODE INTO THE BRINE SOLUTION WHILE THE POWER TO THE TRANSFORMER IS ON SUBJECTS THE TRANSFORMER AND THE ELECTRODE TO AN UNDUE LOAD. THIS WILL EVENTUALLY DAMAGE BOTH COMPONENTS.

The generating cell should be producing hydrogen, which is visible as a white-colored foam that exits through the cells exhaust ports. The red LED above the timer should be glowing.

3. End of Generating Cycle.

The timer will automatically disconnect the generating cell at the end of the cycle. The cell should be removed from the electrolysis tank immediately after the cycle has expired.

Once the cycle has expired, the concentration of equivalent chlorine in the electrolysis tank should be at least 6 grams per liter, or 0.6%. This solution will be used for disinfecting of the drinking water supply. The amount of disinfectant to use depends on many factors and should be determined by a person knowledgeable in the field and familiar with the application.

WARNING: REMOVING THE GENERATING CELL FROM THE ELECTROLYSIS TANK WHILE THE POWER TO THE TRANSFORMER IS ON SUBJECTS THE TRANSFORMER AND THE ELECTRODE TO AN UNDUE LOAD. THIS WILL EVENTUALLY DAMAGE BOTH COMPONENTS.

4. Recharging of Battery

The battery charge controller automatically controls the Charge State of the lead-acid battery. The photovoltaic panel should always be connected to the charge controller, and the charge controller should always be connected to the battery, even if the generating cell is not being used.

For the AC5 system at tropical latitudes, the photovoltaic panel provided is capable of replenishing the energy consumed during seven hours of operation. On the other hand, the lead-acid battery specified can supply current to the hypochlorite generator for approximately 20 hours without recharging. Thus the system may be used on a daily basis for seven hours each day, or it may be used longer on any particular day, provided the corresponding amount of time is allowed for recharging the battery.

For the AC25 system at tropical latitudes, the photovoltaic panels provided are capable of replenishing the energy consumed during three hours of operation. On the other hand, the lead-acid battery specified can supply current to the hypochlorite generator for approximately 9 hours without recharging. Thus the system may be used on a daily basis for three hours each day, or it may be used for six hours every other day.

Maintenance

MAINTENANCE PRECAUTIONS

- Power to the generating electrode must be off while the electrode is in the cleaning solution.
- Rinse the generating electrode thoroughly with water after removal from the storage container and prior to immersion in the electrolysis tank.
- Never combine the cleaning solution with the sodium hypochlorite solution.

Overview

Impurities both in the salt and in the water used in the brine in accumulate on the cathode within the generating cell. This accumulation must be cleaned periodically using a dilute solution of acetic acid (vinegar) or hydrochloric (muriatic) acid. If this accumulation is not removed, it will eventually short-circuit the generating cell, rendering it inoperable, and will overload the transformer, damaging it irreparably.

The generating cell should be cleaned **every day,** or following each use**,** in the following manner:

1. Thoroughly rinse the generating cell with clear water.
2. Submerge the lower 9" of the generating cell into pure white vinegar, or into a 3% solution of hydrochloric acid. See figure 2.
3. After at least 15 minutes, remove the cell from the acid and rinse thoroughly with clear water.

IMPORTANT: NEVER MIX THE CLEANING SOLUTION WITH SODIUM HYPOCHLORITE. NEVER USE UNDILUTED ACID TO CLEAN THE ELECTRODE. THIS WILL DAMAGE COMPONENTS INSIDE THE CELL.

Dosification

Table 2

Tank Capacity		Dosage of the Solution of NaOCl at 0.6% concentration								
		2 PPM			3 PPM			4 PPM		
Gals.	Ltrs.	Ltrs.	Gals.	grams of Cl_2	Ltrs.	Gals	grams of Cl_2	Ltrs.	Gals.	grams of Cl_2
1321	5000	1.67	0.44	10.00	2.50	0.66	15.00	3.33	0.88	20.00
1981	7500	2.50	0.66	15.00	3.75	0.99	22.50	5.00	1.32	30.00
2642	10000	3.33	0.88	20.00	5.00	1.32	30.00	6.67	1.76	40.00
3302	12500	4.17	1.10	25.00	6.25	1.65	37.50	8.33	2.20	50.00
3963	15000	5.00	1.32	30.00	7.50	1.98	45.00	10.00	2.64	60.00

4623	17500	5.83	1.54	35.00	8.75	2.31	52.50	11.67	3.08	70.00
5000	18927	6.3	1.67	37.85	9.5	2.50	56.78	12.6	3.33	75.71
6000	22712	7.6	2.00	45.42	11.4	3.00	68.14	15.1	4.00	90.85
7000	26498	8.8	2.33	53.00	13.2	3.50	79.49	17.7	4.67	105.99
8000	30283	10.1	2.67	60.57	15.1	4.00	90.85	20.2	5.33	121.13
9000	34069	11.4	3.00	68.14	17.0	4.50	102.21	22.7	6.00	136.27
10000	37854	12.6	3.33	75.71	18.9	5.00	113.56	25.2	6.67	151.42
16000	60567	20.2	5.33	121.13	30.3	8.00	181.70	40.4	10.67	242.27

One liter of 0.6% sodium hypochlorite solution mixed into 6000 liters of water will produce a 1PPM concentration of equivalent chlorine in the water. Likewise, to produce a 2 PPM concentration of equivalent chlorine in the water, add 2 liters of 0.6% sodium hypochlorite solution to 6000 liters of water.

DOSE: 2 PPM		
LITERS	**DROPS**	**TABLESPOONS**
1	**7**	
5	**33**	
10	**67**	
20	**133**	**2**
40	**266**	**4**

Verification

The concentration of the sodium hypochlorite solution produced needs to be verified periodically to ensure its effectiveness. There are several methods whereby this may be achieved although only the Iodometric and the Drop-Dilution methods are described here. The Iodometric method is the more accurate of the two, although it requires more laboratory equipment. The Drop-Dilution method provides a good estimate of the free chlorine, and requires less equipment.

Iodometric Method

Equipment

1. .01N $Na_2S_2O_3$ solution
2. 10% KI solution
3. 50% H_2SO_4 solution
4. Starch indicator
5. 125 ml flask
6. 5ml graduated pipet
7. 10ml graduated pipet
8. 25ml buret
9. glass dropper

Procedure

1. Using a 10ml pipet, add 20 ml of 10% KI solution to 125-ml flask.
2. Using dropper, add 6 drops of 50% H_2SO_4 solution (0.3 ml).
3. Using 5ml pipet, quickly add 3-ml of sample. Solution should turn color.
4. Using buret, titrate immediately with .01N $Na_2S_2O_3$ solution to a light yellow color.
5. Add three drops of starch indicator solution.
6. Finish titration with .01N $Na_2S_2O_3$ solution until colorless.

Calculation of available chlorine concentration from titration results:

Concentration of available chlorine in grams per liter
=(ml of thiosulfate used) x(normality of thiosulfate solution)x(1000)x(35.5)/(ml of NaOCL sample)

Drop-Dilution method

Equipment

1. 5ml graduated pipet
2. 10 ml test tubes (2)
3. DPD colorimetric method chlorine test kit (common test kit for swimming pools).
4. Distilled water.

Procedure

1. In a 10ml test tube, add 1ml of sample to 9 ml of distilled water.
2. To second 10ml test tube, add 0.1 ml of the solution above to 9.9 ml of distilled water.
3. Test this solution with DPD colorimetric test kit according to its instructions.

Calculations

No calculations are required. The scale of the test kit, which is graduated in PPM, may be interpreted directly as grams per liter.