White Paper Series

Water Disinfection: Chlorine vs. Saltwater Systems

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Original Date:

October 3, 2014

Revision Date:

Abstract

The purpose of this paper is to provide a response to the commonly asked question, “Salt versus Chlorine?” As part of this response the operation of salt chlorine generation and chlorine systems will be discussed in an effort to provide an understanding of how the two systems work to achieve their main purposes, water sanitation and disinfection. The pros and cons will be evaluated and **CLOWARD** H_2O’s professional opinion will be provided.

Chlorination Systems

Salt Chlorine Generation

The functioning principle behind salt chlorine generation is to use electrolysis to generate chlorine gas from salt that is dissolved into water. Dr. Alison Osinski summarizes salt chlorine generation as, “Electrolytic cells, or more properly called ‘chlorine generators’, change non iodized salt or low calcium and magnesium salt – salt pellets like those used in water softeners or for making home-made ice cream, into chlorine gas. Electricity is applied to salt dissolved in water to form hypochlorous acid (the active sanitizing ingredient in chlorine), sodium hypochlorite (liquid chlorine made from chlorine gas and sodium hydroxide), and hydrogen gas.” (Osinski, 2010).

Figure 1 In-Line Salt Chlorine Generator

An Electrolytic cell has three key components: two electrodes (a cathode and an anode) and an electrolyte. In the most common case of chlorine generation the electrolyte is the pool water containing dissolved salt (NaCl). An electrical current is applied to the electrodes, a redox reaction occurs. “When driven by an external voltage [hydrogen] (H^+) ions flow to the cathode to combine with electrons to produce hydrogen gas in a reduction reaction. Likewise, [hydroxide] OH^- ions flow to the anode to release electrons and an H^+ ion to produce oxygen gas in an oxidation reaction” (Wikipedia, 2014). When the current is passed through the salt water the anode oxidizes the chloride ions (Cl^-) to form chlorine gas (Cl_2). The sodium (Na^+) ions react with hydroxide (OH^-) ions to form sodium hydroxide (NaOH). In general terms one pound of chlorine can be produced from approximately 1.67 pounds of salt.

In-Line Generators

This is the most common type of generator on the market. This system consists of an electrolytic cell that is plumbed as a side stream to the filtration line after the filter and a power supply with a controller. Each cell has a chlorine output capacity based upon the quantity chlorine it can produce. This rating is a function of the salinity of the pool water, size of the cell, and the power delivered to the cell by the power supply. If t chlorine demand in a pool is greater than the capacity that one cell can produce, then multiple cells are specified to reach the demand.

The power supply provides the needed current for reactions to occur, while the controller is used to adjust the power output and to switch the polarity of the electrodes (for units designed to be “self cleaning”. Periodically switching the polarity of the electrodes extends their functional life by reducing the buildup of scale. Other accessories that are provided with these systems include salinity probes and a flow switches.

With in-line generators the pool water must have a clean salinity, usually in the range of 3,500 to 5,000 parts per million (ppm). The salinity of the ocean is approximately 34,000 ppm or 34 parts per thousand (ppt). In order to reach this level of salinity salt must be added to the pool water. This is most commonly accomplished by manually feeding granular salt that has been dissolved in a bucket into the pool. Some systems may have a method in place to automatically inject a brine solution into the pool to maintain the proper salinity. If salinity is not kept within the correct range, then damage to the generator may occur.

Off-Line Generators

There are two types of off-line generators. The first type uses a diaphragm or brine system. The electrolytic cell principle is still used only two chambers separated by a diaphragm membrane are used to store the electrolyte, usually a brine solution on one side and distilled water on the other. Electricity is passed through the electrodes and the reaction splits the salt in the brine solution releasing chlorine gas that bubbles to the surface. The gas is collected and then used in the pool. The current carries the sodium through the membrane into the distilled water and forms sodium hydroxide and hydrogen. The hydrogen is vented off to atmosphere.

The other type of system is known as a MIOX system. This system essentially creates liquid chlorine (sodium hypochlorite) on site using salt, water and electricity. A brine solution is passed through an electrolytic cell to form sodium hypochlorite and mixed oxidant solution into a storage tank. The sodium hypochlorite is then injected into the pool in the same manner as liquid chlorine.

Chlorine Systems

Chlorine has been the standard method for treating pools since the early 1900's. The methods for introducing chlorine to the water have evolved over this time period. "Chlorine gas was first registered in the U. S. in 1948, as a disinfectant for use in swimming pools…" (US EPA, 1999) Chlorine gas is the purest form of chlorine; it is also the most dangerous form. There are very few facilities that use chlorine gas systems because of the associated hazards of the material itself.

Figure 2 Liquid Chlorine Feed System

Sodium hypochlorite (NaOCl), as known as liquid chlorine, is one of the most common forms of chlorine used today. For pool applications a concentration of 10-12% is typically used. Sodium hypochlorite is applied in swimming pools for water disinfection and oxidation. It is a good oxidizer and with a few notable exceptions is highly effective against microorganisms in water. "Hypochlorous acid is produced by the reaction of sodium hydroxide with chlorine gas. In water, the so-called 'active chlorine' is formed" (Lenntech, 1998-2014). Liquid chlorine systems require a bulk storage tank and a chemical feed pump. Liquid chlorine has a storage shelf life of about 30 days, gradually becoming less effective.

Erosion feed chlorine used solid chlorine tablets or granules that are slowly dissolved in the water to release chlorine into a pool system. There are two common chemical forms of solid chlorine: Calcium Hypochlorite (Cal-Hypo) and Trichloroisocyanuric Acid (Trichlor). Depending upon the manufacturer of the tablet the composition varies slightly, but is in the range of 65-70% available chlorine. The remaining percentage is composed of inert ingredients and soluble salts.

Figure 3 Erosion Chlorine Feeder

The equipment used typically consists of an erosion feeder that stores the chlorine tablets. The feeder is plumbed into a side stream of the filtration system. Water is circulated through the erosion feeder where it dissolves the tablet into the water stream, which is then mixed with the full filtration stream. There are also variations to this process where a chlorine solution tank is implemented and then chlorinated water is distributed as needed.

What Are the Differences

Chlorine is Chlorine

The primary idea in evaluating the difference between Salt Chlorine Generation and Chlorine Systems is that regardless of the system the pool water is being sanitized by chlorine. The water is not being sanitized or oxidized by salt. Chlorine is being made by using electricity and salt. (Osinski, 2010) The major difference is how chlorine is stored and introduced to the treatment system. With salt generation systems chlorine is created on site with very little if any storage. Chlorine systems require a storage tank or room to store buckets of tablets.

Meeting Peak Demand

Chlorine systems have a supply of chlorine so that when the bather load causes a sudden chlorine demand, more chlorine can be supplied to meet the increase demand. With salt chlorine systems if the demand raises quickly the system can only supply at the rate it is created, which can easily be surpassed. Reputable manufacturers will recommend that supplemental chlorine dosing (liquid chlorine) system be provided in pools that expect to see large fluctuations in bather load. (TMI Salt Pure Corporation, 2013) For this reason alone a salt chlorine system is not acceptable for most resort environments or for heavy use pools such as in water parks.

System Maintenance

Chlorine Systems require that the storage tanks be filled regularly and verify that the chemical feed pump is operating correctly.

Salt Chlorine Generator requires regular maintenance on the electrolytic cell. The reason the electrolytic cell requires maintenance is due to electrochemical reactions that occur in the cell. The electrodes, also referred to as plates or blades, are commonly constructed of a titanium plate with a platinum coating. The coating may vary by manufacturer, but the material is a precious metal. As the cell operates the reaction causes calcium to plate out forming scale on the electrodes. Many cells have a “self cleaning” feature, which cause the polarity of the power supply to periodically reverse. By reversing the polarity, calcium, which is attracted to the anode, will release from the now positive electrode. However, over time the coating will become pitted and calcium will begin to fill in the pitted areas becoming trapped even when the polarity changes. To prevent excessive build up most manufacturers recommend that the plates be soaked in a mild acid solution to dissolve the calcium deposits and thus restoring the full effectiveness of the plate. Eventually the plates will need to be replaced. According to information published by ChlorKing, they recommend cell replacement every three years or so. For a 25 lb/day unit (ESTK 25) the cell replacement cost is $9,200 (ChlorKing, Inc, 2014).

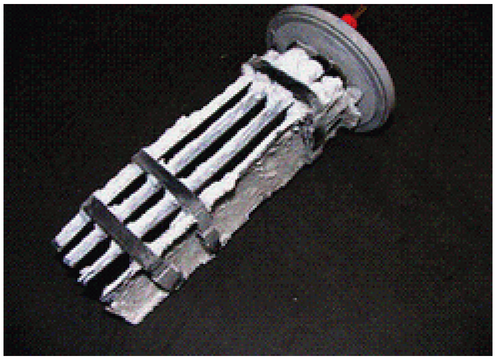

Figure 4 Scale deposits on a cell

The typical maintenance procedure for cleaning a cell includes the following steps: removing the cell from the manifold, disassembling the cell, soaking the electrodes in an acid solution for the recommended period of time, reassembling the cell, and replacing the cell into the manifold. Depending upon the number of cells required for a particular system this process can become quite laborious. This level of maintenance should occur at least twice a year, depending upon operation time and calcium levels in the water.

Increased Corrosion Potential

Water in general will cause corrosion. Corrosion is accelerated when the salinity of the water increases, causing galvanic corrosion potential and chloride attack on metals exposed to the water. Salt Chlorine systems need a salinity of 3,500 to 5,000 ppm for proper operation compared with typical potable water in the United States, which is normally less than 100 ppm (Engineering Tool Box, 2014).

Corrosion is most noticeable on stainless steel handrails, light bezels, and fasteners there is also an impact to metal components in the treatment equipment. With the increase in popularity of Salt Chlorine Generation heater manufacturers have provided additional warranty limitations. Raypak, Inc modified their limited warranty to include the following language in the warranty exclusions:

> “This Limited Warranty does NOT apply; … 10. To damage, malfunction or failures resulting from misuse or neglect, including to but not limited to, freeze-ups, operating the Heater with the cabinet door off, having flow restrictions or obstructions between the Heater outlet and the pool/spa, electrolysis due to an improperly installed salt chlorine generator, or not maintaining a proper chemical balance (pH level must be between 7.4 and 7.6 and total alkalinity between 100 and 150 ppm. Total Dissolved Solids (TDS) must be no greater than 3000 ppm. In salt water chlorinated pools, TDS must be no greater than 6000 ppm)” (Raypak, Inc, 2013).

Some heater manufacturers will even recommend marine grade (Titanium) heat exchangers to minimize the risk of corrosion from the increase salinity.

Conclusion

As with most equipment selection, proper application is the key to a successful system design. We believe that there are proper applications for both traditional and “salt” Chlorine Systems. Salt Chlorine Systems are very appropriate for residential pools and lightly used commercial applications. For most commercial applications it is our opinion that traditional liquid or tablet Chlorine Systems are the best option.

In applications where the owner is looking for options to reduce chlorine use we recommend the use of secondary disinfection systems, such as ozone. Ozone is a powerful oxidizer that does a majority of the sanitization and oxidation work in the pool water, in turn reducing the amount of chlorine required. Salt Chlorine Generator manufacturers also recognize the benefits of secondary disinfection and may offer these systems as part of their packages.

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