On-Site Sodium Hypochlorite Generation

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Abstract

In this manuscript the on-site generation of sodium hypochorite for water and wastewater disinfection will be examined. The objective of this paper is to familiarize the reader with the equipment and operational requirements necessary for on-site sodium hypochlorite generation systems. This manuscript will review the following topics relative to on-site generation systems:

- Understand the basic equipment requirements necessary for on-site generation of sodium hypochorite,
- Understand the basic design considerations for in sodium hypochorite systems, and
- Understand the operation and maintenance requirements of on-site generation systems.

Keywords

On-Site Generation, Sodium Hypochlorite, Hypochlorite, Disinfection, Wastewater and Water

Introduction/Origins of On-Site Sodium Hypochlorite Generation

On-site generation of sodium hypochlorite can be accomplished using electrolyzer systems. In these systems, crystallized salt is dissolved and used for electrolysis. The electrolysis cells are designed for very low brine feed flow rates, narrow electrode gaps, and produce sodium hypochlorite concentrations approaching one percent. The following narrative discusses the principles of operation associated with on-site sodium hypochlorite generation systems.

General Description - On-site sodium hypochlorite generation systems can be used for any application requiring chorine or chloramines as a part of the disinfection regimen. A typical system schematic is shown in Figure 1. These systems are designed to provide 1 to 3 days of stored sodium hypochlorite. They also are designed with excess product storage to assure that disinfection capacity is always available to the end user. To accommodate these requirements systems are generally configured with the following components and operate in the manner described below.

- Water softener: Essential for removal of calcium and magnesium from the feed water.
- Salt dissolver: Provides the required salt solution for electrolysis.
- Electrolyzer cell or cells: Electrolyzes the dilute brine solution.
- DC power rectifier: Provides the Direct Current for electrolysis.
- Storage tanks: Product storage to meet dosing requirements as well as any excess capacity essential to assure continuous dosing capabilities.
- Hydrogen dilution blowers: Provided to dilute the byproduct hydrogen produced during

the electrolysis process.

- Dosing pumps with dosing controls: Provides the needed disinfection dose based upon the chlorine residual or flow rate of a receiving stream.
- Cell cleaning system: Used to remove the calcarious material deposited on the cell cathodes during the production process.
- Central control panel: Performs the system production control function.

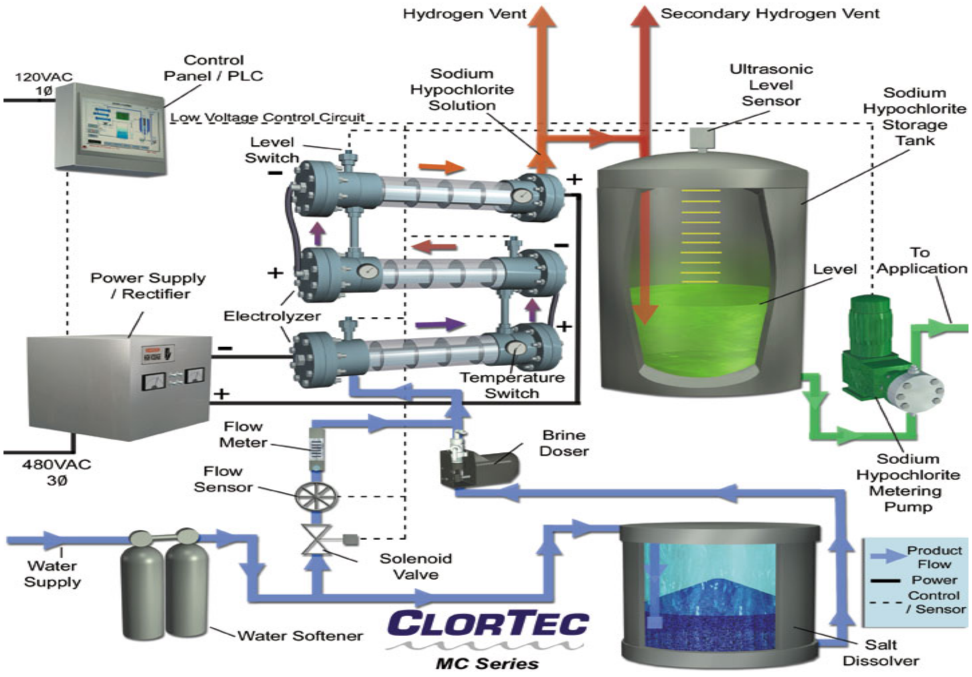

Figure 1. Typical On-Site Sodium Hypochlorite System (http://www.clortec.com).

A simple on-site generation system operation begins with the client's domestic water supply flowing through the water softener where the water hardness is reduced. A portion of the softened water is added to the salt dissolver to make a concentrated salt brine solution of approximately 300 grams/liter. The concentrated salt brine is then mixed with the main stream of softened water to produce a final brine concentration of approximately 3% (30 grams/liter) salt concentration. This final brine solution is then pumped through the electrolyzer cell. The cell electrolyzes the final brine solution into sodium hypochlorite as per the following equation:

$$NaCl + H_2O + 2e = NaOCl + H_2$$

$$3.5\text{ lbs} + 15\text{ gal.} + 2.5\text{ KwH} = 0.8\ \%\ NaOCl$$

The sodium hypochlorite solution produced by the electrolyzer is then forced by the incoming water pressure to flow to the storage tank. Sodium hypochlorite from the storage tank is used as a supply source for dosing pumps. These pumps are operationally controlled by either a residual analysis or a flow-pacing signal to supply sodium hypochlorite to the point of disinfection application. Electrolyzer cell cleaning frequency varies from one month to six months. Cell cleaning is accomplished using either hydrochloric or sulfamic acid at a concentration ranging from 5 to 10 percent. Please note, feed water total hardness should always be less than 50 mg/L as calcium carbonate in the cell feed to control monthly cathode acid cleaning.

On-site generation systems are susceptible to water temperatures less than 15^{o}C. If water temperatures are less than 15^{o}C, the water temperature must be raised by adding some form of heat exchanger to the outlet of the cell. The inlet feed water is passed through one side of the exchanger and heated product through the opposing side. Exchangers are sized to assure that the system inlet water is heated to at least 15^{o}C.

Standard On-Site Sodium Hypochlorite Generation Equipment

Electrolytic Cells - Electrolytic cells capable of producing sodium hypochlorite have been in existence on a laboratory scale for well over 100 years. Cell equipment before the invention of Dimensionally Stable Electrodes (DSA) was very inefficient, cumbersome and costly. While several anode electrode materials (e.g., carbon and platinum), were used for commercial chlorine manufacture prior to the invention of DSA, none could produce an electrolyzer cell that provided reliable on-site sodium hypochlorite generation. The dimensionally stable anode was developed by an independent scientist named Henry Beer in 1967.

DSA development simplified cell designs to allow cost efficient production of sodium hypochlorite on-site. In the early 1970's, J.E. Bennett developed an un-separated electrolyzer using the dimensionally stable anode. This cell was patented by Diamond Shamrock Corporation. Since the 1970's, many electrolytic cell design variations have become available in the marketplace.

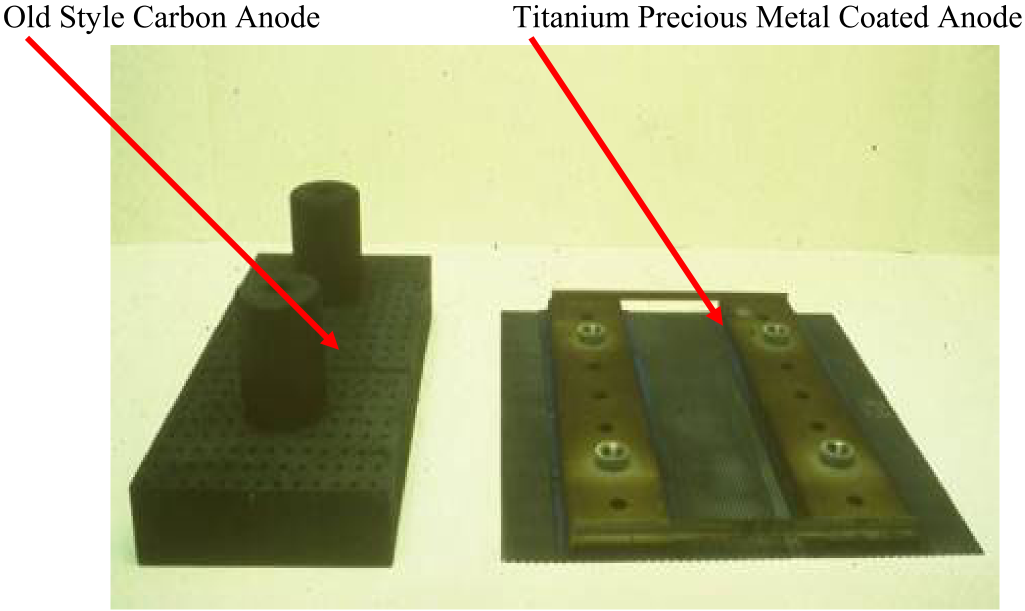

Figure 2 Dimensionally Stable Electrode (Anode) Photograph

Electrolytic cells may be designed having monopolar or bipolar electrode configurations. Each of these design configurations are discussed below.

A **monopolar cell** consists of an anode (direct current positively charged member) and cathode (direct current negatively charged member) each joined to the power source by a separate power connection. These electrodes are separated by a space that allows the salt solution to flow between the plates for electrolysis to occur. Multiple electrodes may be connected to a common input connection in a parallel configuration within each electrolyzer assembly. Each electrode set polarity is the defined by its' connection polarity, anodes only on the positive connection and cathodes only on the negative connection.

Bipolar electrodes differ from those discussed above in that each electrode will serve as both an anode and a cathode. The bipolar cell design will have terminal electrodes for the positive and negative power input points and interstitial bipolar electrodes. Direct current is delivered to the positive DSA coated terminal electrode face, emitted from that electrode face through the brine solution, is received on the cathode face of the adjacent plate and passes through the plate to the anode face of the same electrode. Each electrode has a DSA coated portion and a non-DSA coated portion. Current flow through the cell proceeds alternately through each bipolar electrode set in the cell to the non-DSA coated cathodic terminal electrode.

Typical cell configurations are shown in Figure 3 below. Cell designs are divided into many basic categories as follows:

Flat plate type bipolar cells that utilize a ‘filter press’ configuration wherein one face of each electrode is anodic and the other face cathodic.

Flat plate bipolar arrangements in an FRP, PVC or Acrylic tube/pipe having individual compartments within the cell and a terminal electrode set for each DC power connection.
Flat plate monopolar arrangements in a rectangular Rubber lined steel, FRP, PVC or Polypropylene body having electrode connections from one side to allow connection to both the positive and negative DC power connections.
Tubular bipolar arrangements of Titanium. In this cell, the inner tube is bipolar and the outer tubes are monopolar. The bipolar tube is half coated half non-coated. An opposite polarity monopolar outer tube mate to each bipolar section is where the DC power is connected to the cell.

Cell performance is defined as the power efficiency to produce one pound (kilogram) of chlorine equivalent. This performance is controlled by several variables; seawater salt content, seawater temperature, seawater flow rate, anode coating, cathode type, cell current density, and the number of cells connected in series hydraulically. Because most cells today use very similar anode coatings and cathode types, the dominant variables affecting performance, in order of importance, are; number of cells in series, cell operating current density and feed temperature.

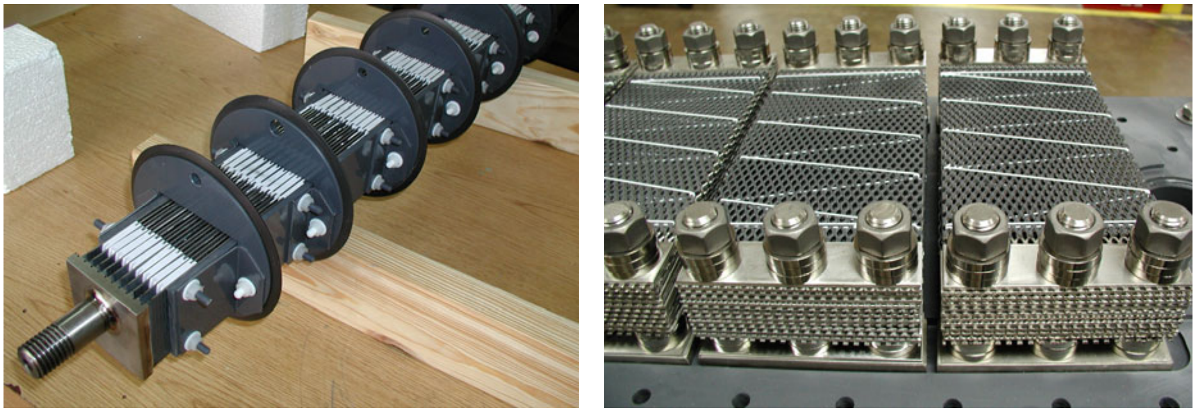

Figure 3 Typical Bipolar Electrode Configurations

As the number of cells in series in increased the product concentration increases. At concentrations above 2.0 grams per liter (0.2%) operating current efficiency falls below 80% regardless of the variable combination employed. This reduction in efficiency translates to increased power consumption.

A high product concentration does not increase disinfection performance nor does it improve the system cost structure. The need for the electrolyzer cell and DC rectifier is obvious since, without both pieces of equipment, no electrolysis is possible. The following narrative is a discussion of the ancillary equipment to the cell/rectifier combination.

It is not essential for on-site generation systems to include a water softener and have high quality salt for the cell-rectifier system to function. However, if these recommendations are not followed, the cathodic deposits from the salt and water may accumulate in the cell. These deposits will close the electrode gap, causing reduced electrolysis and electrode degradation. Consequently, frequent acid cleaning is necessary to protect the electrodes. Otherwise, a probable reduction in cell electrode life could result. Such deposits retain an alkaline layer on the anode surface that renders the coating inactive. This coating activity loss is referred to as ‘coating passivation’.

Cell cleaning is an essential part of a system maintenance program. Salt and water contain calcarious material which reacts with the cathodic alkaline layer. Calcium and magnesium are the elemental materials that cause the deposits. The predominant deposit in on-site generation systems is calcium carbonate. These different deposits are caused by differences in the cell feed brine. Brine system feed has high calcium levels and essentially a somewhat neutral pH since drinking water is the source water. Although both deposit forms are easily removed by hydrochloric acid, the carbonate form in the on-site generation system is more quickly dissolved shortening the cleaning cycle. Most electrolysis systems are supplied with an acid cleaning system consisting of a tank, pump, and associated piping and valves. Please note that cell cleaning must be performed on the schedule recommended by the electrochlorinator vendor to assure an adequate life from the electrolyzer cell system.

Hydrogen dilution fans are considered part of all systems, yet their importance is defined by the system location and local conditions. For example, many systems are designed without fans because they are located away from ignition sources. Other systems use open top tanks to allow the hydrogen to separate and disperse. On-site generation systems typically have closed tanks; therefore fans are required (as shown in Figure 4) for normal dilution, although some tanks may be directly vented.

Figure 4 Typical Sodium Hypochlorite Storage Tanks with Hydrogen Dilution Fans

Although pumps typically require very little maintenance, they are essential to effective system performance. Whether they supply water to the system or product to the dosing point routine maintenance is required to assure system reliability.

On-Site sodium hypochlorite systems will normally have only product dosing pumps. Generally, they are positive displacement pumps to overcome system dosing point pressures. Variable speed drive controls are common to assure correct product addition. Some systems may require a centrifugal pump on the inlet water supply to boost the pressure due to low resident system pressure. These pumps interface with the control scheme for operation whenever the system is in operation.

Instrumentation - System instruments are designed to provide continuous system monitoring for conditions outside acceptable operating limits. They also form an essential part of the control and safety logic.

All electrolysis systems are designed to have water and brine flow indication, cell level sensors, cell temperature sensors, tank level indication, hydrogen fan indication, and dosing point residual indication. All of these sensors can, depending in the vendor’s control logic design, have alarm and shut down set points. Systems from all vendors will have the same general alarm and status indicators to confirm proper operation. With few exceptions, each of these alarm situations will shut down system operations to prevent serious damage to the equipment or hazard to the personnel.

Water and brine flow meters are essential to confirm a generally accepted water to brine ratio of 10:1. Flow alarms are required to be certain that the cell temperature does not exceed 140^{o}F (60^{o}C) or cell damage will occur.

Generally, two operating set points and two alarm points are used for tank level instruments. The operating set points maintain the tank level by operating the system via the control scheme. The low-level alarm set point will stop the pumps and alarm while maintaining generator operation. A high-level alarm setting will alarm and stop generator operation.

Residual analysis or ORP analysis is often applied to control dosing pumps or, in the case of seawater systems, DC rectifier operating current. Analog signals are used through a PID controller to assure stable operation of the pump or rectifier. Historically, residual analysis has been the control method of choice, however, as instrumentation becomes more sophisticated ORP is becoming more accepted. The use of chloramines for residual maintenance in water systems requires the comparison of free to combined chlorine concentrations.

DC Power Rectifiers - Three major types of rectifier units used in electrocatalytic sodium hypochlorite generation are described in this section.

Figure 5 is a photograph of a tap switch voltage control rectifier - These units have no accurate current control mechanism. Rectifier control is provided from transformer primary tap points using a multipoint click switch regulator. The regulator varies the input voltage to the transformer resulting in a secondary voltage variation. For this reason, the rectifier current varies as the solution temperature or salt content changes the cell resistance. For units of this type it is very important that the system has a closely maintained feed water temperature and salinity level.

Figure 5 Tap Switch Voltage Control Rectifier

Figure 6 is a photograph of a thyristor rectifier - Thyristor rectifiers, often called SCR (silicon control rectifier) controlled, are the most commonly used for electrolysis cells where more than 100 amp DC service is required. Thyristor designs allow the use of AC input voltages up to 11,000 volts and normal 50 or 60 Hertz requirements. Most Thyristor rectifier designs operate in the range of 75 to 90 percent efficiency at a power factor of 0.7 to 0.85 when at full load.

Figure 6 Typical SCR (Thyristor) Rectifier

Figure 7 is a photograph of a switching power supply - Switching power supplies operate at a high frequencies, normally in the range of 10 to 200 kilohertz. While there are large units that will accept 480 volt 3 phase input power, normally this type of rectification operates with 110/220volt AC single phase power. High frequency devices will have a power factor of 0.99 and efficiencies of 75-85%. Higher output systems will eventually be available and should be utilized to assure further reductions in operating cost. Switching power supplies offer the advantage of a very small transformer resulting from a high operating frequency.

Figure 7 Typical Switching Power Rectifier in Control Panel

Tap switch rectifiers have very simple controls. The current is adjusted via individual AC line taps. These line taps adjust the transformer secondary line voltage by making the transformer slightly out of balance between each phase.

SCR power supplies have numerous configurations. The two dominant configurations are for rectifiers having Thyristors (SCR's) on the AC line before the transformer and those having Thyristors (SCR's) after the transformer.

Switching power supplies are all electronic by design thus have similar controls to SCR type supplies. Most units are designed for DC voltage control that relates to their usage in the computer power supply industry.

Cooling - While a myriad of cooling schemes exist in sodium hypochlorite generation (e.g., air, water and oil), by far the most common cooling method is fan operated forced air cooling shown in Figure 8. Local environmental and safety conditions will determine the cooling method most acceptable for reliable equipment life.

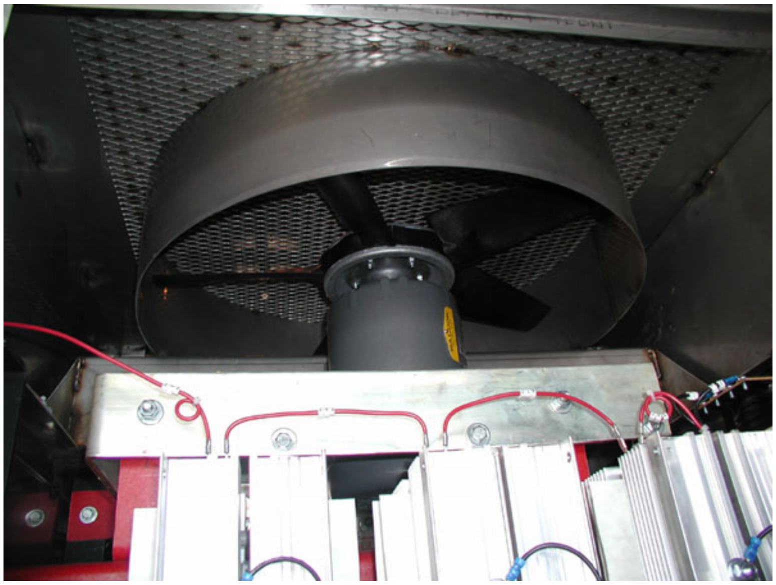

Figure 8 Typical SCR (Thyristor) Rectifier Cooling Fan Arrangement

Rectifier units are designed to operate at maximum ambient temperatures of 105 to 125°F (40 to 50°C) to assure that control and power electronics can survive possible installed environmental service stresses. All DC power systems are designed around these temperatures, unless more stringent specifications are necessary resulting from local conditions.

Maintenance - While minimal maintenance is required for water and oil cooled systems, regular oil and closed loop cooling media inspections must be performed. Each manufacturer should provide inspection guidelines to assure that the inspector will detect problems before they become equipment failure incidents. Forced air cooled systems require; quarterly cooling fan and motor inspection; quarterly filter screen cleaning; semi-annual wire and cable termination connection inspection and DC device and transformer cleaning. It is best to use a compressed air nozzle for cleaning transformers and DC devices.

Water Softening - The water softener's use in on-site sodium hypochlorite generation systems is prevention of calcium and magnesium hardness salts from depositing on the negatively charged cathodic electrode. As will be discussed later, systems can be operated without softened water, however, the potential for electrode damage becomes highly probable unless frequent stringent maintenance procedures are followed.

Water softening via ion exchange utilizes the replacement of calcium and magnesium ions in the water by an equivalent number of sodium ions. This system eliminates the undesirable characteristic of calcarious deposits because sodium salts do not form hardness type scales on the cathodic eledtrode.

The water softener contains a cation (negatively charged resin) exchange resin which is the same as used in home water softeners.

Water hardness may expressed as grains per gallon. One grain per gallon is equal to 17.1 parts per million (ppm) per grain. For example, water with 10 grains of hardness will be equal to 171 parts per million.

On-site generator manufacturers provide the water softener with their equipment to assure the customer will achieve long reliable cell electrode service from the cell electrodes. Softeners also reduce the need for chemical cleaning since a significant portion of the calcium material is resident in domestic potable water rather than the salt used in the electrolysis process.
An example of water softener importance is as follows. The water has 100 mg/l hardness and the salt has 1,500 mg/l for the cell feed material. The salt is dissolved to a 30% solution to form a solution hardness 550 mg/l, 1500 mg/l x 0.3 + 100 mg/l. This solution is then further diluted by a 10:1 ratio therefore the salt contributes 55 mg/l (1/10th of 550 mg/l) and the water contributes 100 mg/l. As you can see above the electrolyzer cell is exposed to 3 times the hardness when no water softener is installed in an electrolyzer system.

Salt Storage-Dissolver Tanks - Salt dissolver systems are designed to meet a myriad of sizes, brine demands and filling methods. Dissolver units are available in three designs to meet sizing needs. These units vary from tank type dissolvers, as shown in Figure 9, to high capacity pit dissolvers. Smaller system dissolvers are sized for 3 to 7 days between refills while large dissolver systems are designed for a minimum of 15 days storage to minimize delivery requirements. Level control systems use float assemblies or electric conductance probes to control salt dissolver water addition using one of the following:

- Float type systems
- Conductance probes are inserted in a stand pipe assembly on the outside of the tank via a flange near the bottom of the tank.

Figure 9 Typical Salt Dissolver

Salt Addition - Salt addition methods are determined by tank design. Small tanks, up to 2000 pound capacity, are normally filled manually from 50 pound (23 kilogram) bags. Salt delivery in these cases is usually by palletized bags to minimize bag handling.

Large tanks are filled by another method altogether. The quantity of salt required demands more efficient delivery methods. Most tanks used on large electrolyzer systems utilize blower trucks delivering 20 tons of salt each. A schematic of this system in shown in Figure 10 The delivery line is usually 4 inches in diameter designed of aluminum having a smooth long radius into the top of the tank. The interconnection between the tank and truck is made using a cam-lock quick disconnect. The air is discharged from the tank through a line with a bagged end to collect the light salt dust blown out of the tank during the transfer procedure. Salt transfer is an easy operation, however, it is important to assure that both inlet and outlet lines always remain clear of obstructions. General maintenance procedures applying to salt dissolvers can be found in the appendix to assist you with frequently asked questions.

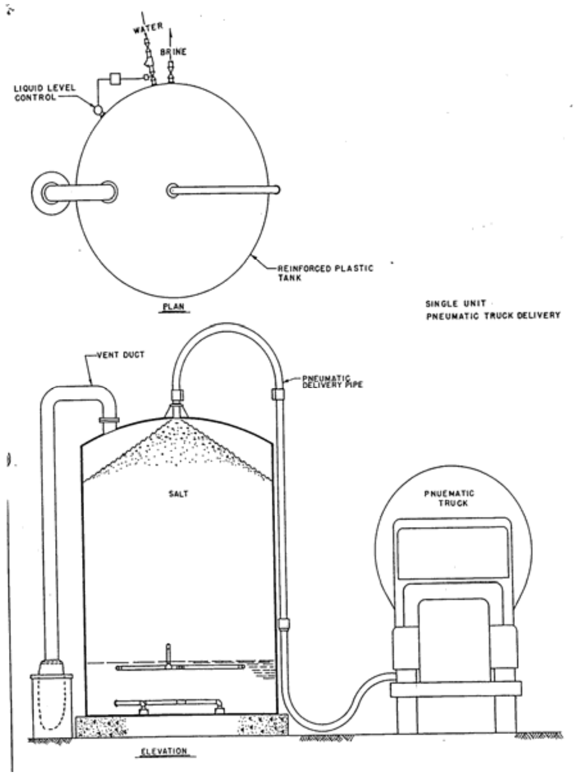

Figure 10 Schematic of Blower Truck Salt Delivery.

Product Storage - Storage tanks allow the system operate at full capacity to achieve optimum performance, provide hydrogen gas removal and, as is specific system applicable, provide backup product supply during periods of maintenance down time.

Product Dosing - Electrolysis systems will generally have diaphragm or hose type positive displacement pumps serving chlorination dosing requirements. These pumps do not have flow sensors to confirm dosing operations are functioning properly. Dosing control and monitoring are carried out by the system's residual analysis equipment outputting an analog feedback signal. Systems used for water well disinfection will not normally have any residual analysis because the well operates at a constant flow therefore the dosing pump has a "set and forget" condition.

Centrifugal pump designs - Centrifugal pumps are only considered where large product volumes are required.

Unusually large systems will have centrifugal pump dosing systems. When centrifugal pumps are used in a system, flow monitors may be applied. Such pump systems are designed to have a flow monitor where the level of output is set greater than 35% of pump rated flow to prevent pump damage. A centrifugal pump's output control is normally via a discharge control valve in turn controlled by the analog signal from a residual analyzer. Care must be taken in the engineering phase to assure that the system is not so oversized to cause nuisance pump shut off from low output flow. Standard motor controls meeting local electrical codes are used to protect the drive equipment in all pump circuits regardless of pump design.

Diaphragm type positive displacement pumps - Diaphragm pumps are most often used in dosing systems having less than 200 pounds (90kg) chlorine capacity per day.

Peristaltic hose type positive displacement pumps - Peristaltic pumps operate on the principal of rollers collapsing a hose to create a vacuum drawing in fluid and discharging at elevated pressures. These pumps utilize variable speed motor controls with either VFD or SCR drive controllers. No check valves are required since the roller position acts to prevent fluid backflow. Pressures of 230 psi (16 kg/cm2) can be achieved when using these pumps.

Hydrogen Handling Practices - Hydrogen is produced on all on-site Sodium Hypochlorite generators. As you have seen on page 3-2, hydrogen is a byproduct of the electrolysis process with virtually 100% electrolytic efficiency at the cathode.

As hydrogen is produced in the cell it combines with dissolved air and oxygen generated from the chlorine inefficiency of chlorine production at the anode. The undiluted gas exiting the cell is approximately 3% air and oxygen therefore is below the lower explosive limit (LEL) of 4.0% in an air environment. The explosive range of hydrogen with air is between 4.0% and 74.20%. In an oxygen environment the explosive range is 4.65% to 93.9%.

Air dilution requirements are dependent on the system output and tank type. Although one cell design separates the hydrogen within the cell allowing its' hydrogen to be directly vented to atmosphere without the need for air dilution all others include the hydrogen in the product stream to the storage tank.

On-Site Sodium Hypochlorite Generation Applications - Sodium Hypochlorite systems have been used in drinking water and waste water applications since their early development. Electrolytic cell development in the early 1970's started the search for plants where this radically new concept would be accepted. The result was to sell a few drinking water and wastewater plants in the United States with entrepreneurial managers operational systems in the late 1970's.

These systems were successful in proving on-site systems as a viable alternative to chlorine gas for water treatment plants. The most severe obstacle was the cost of chlorine gas through out the United States. Plant users could not operate this equipment cost effectively when compared to the cost of chlorine gas.

Presently, water utilities are converting to on-site generation for small to moderate plants particularly where plant upgrades are taking place. This changeover continues to evolve slowly as the technology becomes more accepted and as the advantages of small systems installed at remote well sites or centralized in housing developments become evident. It is also useful to note that approximately 80% of all drinking water systems in the United States require less than 500 pounds of chlorine per day.

On-Site Sodium Hypochlorite System Design Considerations

On-site sodium hypochlorite systems are typically used for disinfection of drinking water (wells or surface water), wastewater disinfection, cooling water applications or for food processing operations. With very few exceptions, most of these sites are indoor installations where climate control is not a design issue. Low water temperature or pressure can be a problem for hypochlorite systems. Sites with feed water colder than 60° F (15°C) may require one to warm the water to help prevent premature electrode coating failure. Another problem is caused by water colder than 40°F (5°C) is a reduction in cell performance efficiency. Here again one must increase the feed water temperature to maximize performance. Low water pressure requires the installation of a booster pump in the water feed system. Pressures below 40 psig are not normally acceptable for reliable hypochlorite system operation.

To get the most efficient operation from on-site electrolyzer cells, the cell feed temperature and the temperature rise through the cell are best controlled between 60° F (15°C) and 95°F (35°C). Having maintained the feed water temperature and cell temperature rise in this range one should also reduce the sodium chlorate in the product caused by chemical inefficiency reactions and localized electrode reactions. It may be difficult to control inlet water temperature on small remote sites. Therefore, is usually applied to sites of over 50 pounds per day.

Larger systems usually include tanks of several thousand gallons (greater than 10 cubic meters) in the hypochlorite generation system. Excessive sun and increased temperature in the product hypochlorite storage tanks will cause accelerated degradation due to increased temperature and UV-light exposure. Fiberglass tanks have a less severe degradation problem than translucent tanks because they tanks are protected by an exterior white gel coat. Also, proper anchoring of larger tanks is essential to account for high wind loads.

Available AC power at the site is important to system design to ensure the correct DC power supply. Wells and small system sites will most often have single-phase power, larger sites three-phase power. In any of these situations, the control panel will operate from 110 volts or less using a step down transformer to achieve the lower voltage. In all cases, the power service at each installation must be sufficient to assure that the AC feed line current is acceptable and meets all codes when all the equipment is in operation.

System sizing is normally based upon a system's daily demand for disinfectant at peak flow conditions. Equipment requirements must then be defined by the necessary dosing residual, the desired excess on-site generator production capacity, whether redundant generator equipment is important, the excess storage capacity to meet Class 2 reliability, and the dosing control scheme employed.

Having defined the production requirements, equipment sized for 100% of necessary capacity is advisable. A more suitable size would be 50% to 70% of a generator's rated capacity. If the sodium hypochlorite production requirement is very large, it's advisable to put in multiple systems of smaller capacity, for example, three units of 50% generation capacity. This design allows the performance of maintenance without loss of production capacity.

Redundant tanks are the accepted standard for on-site hypochlorite generation installations. These tanks provide backup storage and allow for bulk commercial hypochlorite storage in the rare event that the on-site system is inoperable for any length of time. The installation should include a mixing system to enable commercial hypochlorite dilution to a 1% solution for proper dosing control. The diluted commercial grade hypochlorite solution will have a lower rate of degradation than commercial grade hypochlorite.

Dosing control schemes are available in three basic formats, manually adjusted, flow paced, and residual paced. There are instances where it is desirable to combine flow and residual pacing. This combination is accomplished using a Programmable Logic Control (PLC) system. Well sites will most often have a manually adjusted dosing system since the well pump flow is constant and the hypochlorite product has a stable concentration. Flow and residual pacing require an analog signal be sent to the control panel in turn signaling the variable speed drive on the dosing pump to adjust the flow to the proper residual. Part of the PLC function is to control the disinfection dose rate of change to prevent severe oscillations in the concentration of disinfectant applied.

An average dose of one to five milligrams per liter of sodium hypochlorite is the generally required for potable water. Wastewater dosing may vary up to ten milligrams per liter. Isolated cases exist where the potable water dose required for a reasonable residual can be much higher. Two examples of this increased dosage requirement are for iron and manganese control and to treat for high ammonia levels (e.g., potable water doses up to 40 milligrams per liter of sodium hypochlorite may required to remove ammonia through breakpoint chlorination.

Dosing volume and pressure will define the pump type required. Small systems will generally use a diaphragm pump for sodium hypochlorite application. Systems greater than 100 pounds per day will often use positive displacement "hose" pumps capable of higher volumes. PVDF, Teflon, Viton, titanium, Hastelloy ‘C’, and ceramic are the construction materials of choice for pumps. Money on these materials will serve as an insurance policy to assure reliable system operation.

Local Regulations and Codes - Electrical codes can be particularly onerous when care is not taken in the review process. Generally, local regulations regarding the generation of hydrogen gas are not an issue since the generated hydrogen is diluted to less than 2% of the lower explosive limit. Safety interlocks are also included in the system to ensure the system can not be operated with flow through the cell.

Site Type - Site location and environmental conditions may control the approach taken to provide reliable equipment. As well, locations will most assuredly have very high densities of dust and dirt during dry conditions. With a few exceptions, large systems, over 1,000 pounds per day (450 kilograms per day) are installed indoors and protected from the sun.

Local Environmental Conditions - Ambient air temperature and humidity should characterize material designs for the DC power supply and the control panel; the cooling method and media are important considerations to insure reliable operation. Equipment exposure to temperatures well below zero is not likely without proper freeze protection. On the other hand high temperatures will damage equipment if cooling methods such as shading and air conditioning are not employed.

Water temperatures are important to consider in sodium hypochlorite systems because the anode coatings are sensitive to temperatures below 60^{o}F (15^{o}C). In cold water, the electrode coating is affected by the increased oxygen concentration in the water. This increased oxygen concentration results in increased oxygen generation by the anode. To overcome this problem, several methods may be employed (e.g., reduction in the operating current density and changes to the electrode coating) to allow the use of higher oxygen concentrations in the water.

Pipe, valves and fittings must be designed for severe sun exposure (UV rays) and ozone conditions in rare occasions. PVC pipe will usually surface harden under these conditions and result in embrittlement, normally not a problem unless the pipe receives a severe impact. The affects of both UV and ozone on PVC pipe may be controlled by painting the pipe. Nearly any latex paint, preferably a light color, will serve to block UV and ozone effectively. With weather exposure FRP pipe surfaces may expose glass fibers. Painting FRP pipe may also solve these problems. However, specific painting steps may be necessary for effective painting. These steps may include the use of specific wash coat primers to ensure good paint adhesion.

FRP tanks should have a white gel coat as provided by the tank manufacturer to prevent gradual surface degradation when used for brine or hypochlorite storage. Steel fabrications should always be seal welded to eliminate crevice corrosion problems. The long-term corrosion control benefits may justify the minor added cost of seal welding. Painting fabricated steel requires coatings having at least a three-part system. This system provides a zinc base coat to provide severe duty protection. Properly prepared and painted steel will withstand very harsh salt environments and random hypochlorite exposure.

Available Water Pressure - System water supplies are determined by the source water pressure. Systems with less than 40 psi water pressure require booster pumps.

Dosing Point Pressure Requirements - Systems having high dose point pressure requirements require independent dosing pumps. The dosing tank serves as a positive suction head pump supply and will usually require air fans to dilute the byproduct hydrogen.

Dosage Control Methods - Pump configurations for dosing systems most often used are: a single pump in continuous dose operation, a single pump in shock dose operation, and a single pump for continuous operation using a second 'continuous' operation capable pump for shock dosing purposes. In all cases, regardless of the site, each pump in operation has a second pump in position to support failure occurrences.

Power Supply Requirements - Three-phase supply power varies from more common 380, 415, and 460 volts to 4,160, 6,600, and 11,000 volts available. Systems having large DC power units will frequently use 4,160 or greater voltage for large onshore plants. Designers often prefer to use high voltage power, when available, to allow the use of smaller sized cabling resulting from lower AC operating line currents and existing high voltage switch gear. Depending upon the plant power distribution system, control voltage power is stepped down from the higher source power by a transformer to 110 or 220 volts from the main power supply line. Power also may be supplied separately from an independent source.

Residual Control - Automated control is normally achieved by using a chlorine residual analyzer. This instrument sends an analog 4-20 mA signal to a controller or the PLC control system with a control scheme that in turn provides an analog signal to the DC rectifier for current control. The control loop is essential to prevent the DC rectifier current oscillation caused by control sensitivity.

Operation and Maintenance of On-Site Sodium Hypochlorite Generation Systems

This section provides the reader with practical electrochlorination system installation, operation, and maintenance requirements. These requirements are for reference only and in no way are intended to usurp supplier recommendations. Please note, No consideration is given in this discussion to civil installation requirements.

The lists below are general requirements to install an on-site hypochlorite generation system, provide estimates of equipment and manpower, and the approximate time to install the system size noted. One will then have a reasonable order of magnitude to judge the requirements for larger or smaller system installation requirements.

Mechanical and electrical installation requirements, hydraulic pressure testing, and commissioning time requirements for either a system of 1200 pounds chlorine equivalent per day are shown in Tables 1, 2, and 3, respectively.

Table 3-1: Equipment Weight

Equipment Qty	Description	Estimated Dry Weight (Lbs)
1	Cell System	1,800
1	DC Rectifier	1,200
1	System Control Panel	500
1	40 Ton Dissolver	1,500
2	20,000 Gallon Tanks	1,500
2	Dosing Pumps	150

Table 3-2: Equipment Installation Requirements

Installation	Installation Duration	Manpower
Set equipment	1 week	6 people + 1 supervisor
Pipe installation	2-3 weeks	3 people + 1 supervisor
Install Electrical	2-3 weeks	3 people + 1 supervisor

Note: Equipment setting requirements assume use of a 20 ton truck crane and a front end loading fork truck

Table 3-3: Equipment Testing Requirements

Testing	Test Duration	Manpower
Hydro test	3-5 days	2 people + 1 supervisor
Electrical test	3-5 days	2 people + 1 supervisor
Commissioning tests	3-5 days	1 person + 1 supervisor
Performance tests	1-3 days	1 commissioning engineer

A full discussion of the following items is included in Chapter 3 of the Water Environment Federation Disinfection Training Manual.

- System Startup and Operation,
- Pre-commissioning Checklist,
- On-Site Sodium Hypochorite Generation System General Commissioning Procedure, and
- Trouble Analysis.