

# Sodium Hypochlorite

## General Information for the Consumer

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## 1.0 Introduction

The purpose of this handbook is to provide the consumer an understanding of the chemical properties of sodium hypochlorite and to further assist the consumer in the purchase, storage, use and handling of the product and associated equipment.

## 2.0 Chemistry of Sodium Hypochlorite

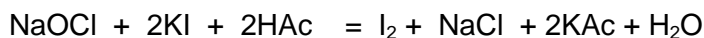
Reacting chlorine and sodium hydroxide produce Sodium Hypochlorite:



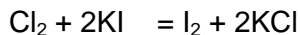
Chlorine Sodium Hydroxide Sodium Hypochlorite Sodium Chloride Water

### 2.1 Relationship between Oxidizing Power of Chlorine and Sodium Hypochlorite

Many consumers are currently replacing chlorine gas with sodium hypochlorite as the oxidizing or disinfecting agent. In order to calculate how much sodium hypochlorite is required to replace the oxidizing power of chlorine, the following example is provided. If a sodium hypochlorite is used to oxidize iodide in a solution of acetic acid, the following reaction occurs:



If chlorine is used to react with the same amount of iodide, the following reaction occurs:



Therefore, a molecule of sodium hypochlorite will oxidize the same amount of iodide as a molecule of chlorine.

### 2.2 Terms Used to Define the Strength of Sodium Hypochlorite

Depending upon the region of the world, manufacturer, or industry, the sodium hypochlorite strength can be identified using several different definitions. The terms to define the sodium hypochlorite strength commonly used in the industry are as follows:

#### 2.2.1 Grams per Liter (GPL) of Available Chlorine

The weight of available chlorine in grams in one liter of sodium hypochlorite is known as the GPL or gpl. This weight is determined by analysis and testing methods are available from many sources. Refer to reference 5.2.

#### 2.2.2 Trade Percent of Available Chlorine

A term often used to define the strength of commercial bleaches. It is identical to grams per liter of available chlorine except the unit of volume is 100 milliliters not one liter. Therefore the result is one tenth of the grams per liter.

$$\text{Trade \%} = \text{gpl available chlorine} / 10$$

#### 2.2.3 Weight Percent of Available Chlorine

Dividing the trade percent by the specific gravity of the solution gives weight percent of available chlorine.

$$\begin{aligned} \text{Weight \% available chlorine} &= \text{gpl} / (10 \times \text{specific gravity}) \\ \text{Or Trade \%} &/ \text{specific gravity} \end{aligned}$$

## 2.2.4 Weight Percent of Sodium Hypochlorite

The weight percent of sodium hypochlorite is the weight of the sodium hypochlorite per 100 parts of solution. It can be calculated by converting the weight percent of available chlorine into its equivalent as sodium hypochlorite by multiplying the ratio of their respective molecular weights:

$$\text{Weight \% available chlorine} \times \text{NaOCl/Cl}_2 = \text{weight \% NaOCl}$$

where  $\text{NaOCl/Cl}_2 = 74/71$  or 1.05

Weight % sodium hypochlorite = gpl available chlorine x 1.05/(10 x specific gravity)

or = trade % x 1.05 / specific gravity

or = weight % available chlorine x 1.05

Since sodium hypochlorite is sold based on the strength of the product, it is critical to specify exactly which term is used to define the strength of the product.

## 2.3 Ratio of Gallons of Sodium Hypochlorite to Pounds of Chlorine Used

In order to buy sodium hypochlorite in amounts equal to the current use of chlorine, it is convenient to determine what strength of sodium hypochlorite in one gallon will equal one pound of chlorine.

Using the definition of GPL of available chlorine (weight of available chlorine in grams per liter of bleach) the following conversion is useful:

120 GPL available chlorine =

120 gpl x 3.785 liters/gallon x 2.205 pounds/1000grams = 1 pound/gallon available Cl<sub>2</sub>

Therefore, one gallon of sodium hypochlorite at 120 GPL will equal one pound of chlorine and it has the equivalent oxidizing power.

Other equal terms

120 GPL available chlorine = 12 Trade percent

or 12/ 1.165 = 10.30 weight percent available chlorine

or 10.30 x 1.05 = 10.82 weight percent sodium hypochlorite

**Caution:** Each manufacturer will produce sodium hypochlorite with different specific gravity due to the variation in the amounts of excess caustic, chlorates and salt. Therefore, the consumer must know the exact specific gravity of each delivered load of sodium hypochlorite in order to verify the strength of the solution in weight percent. *Thus, most consumers and producers calculate the strength in terms of Trade Percent Available Chlorine or Grams Per Liter of Available chlorine because the accuracy of the test methods to determine these values is not dependent upon the accuracy of the specific gravity of the product.* Do not assume the specific gravity when testing the strength of the sodium hypochlorite.

**In summary, if the process used one pound of chlorine, the process will use one gallon of sodium hypochlorite at strength of 120 GPL available chlorine.**

If sodium hypochlorite is purchased in any other strength, the same conversion can be used to determine pounds per gallon of available chlorine in the solution.

## **2.4 Sodium Hypochlorite Decomposition**

The consumer must understand the reasons for decomposition of sodium hypochlorite to successfully purchase and utilize the product. Sodium hypochlorite typically decomposes due to heat (the degradation rate doubles for every 10 degrees Fahrenheit above 70 degrees Fahrenheit), ultraviolet light, and contaminants. All of these factors play an equally important role in decomposition. Heat and ultraviolet effects can be minimized by system design while contaminants effect can by minimized through the purchase of a high quality sodium hypochlorite. There are two decomposition pathways of sodium hypochlorite. The dominant pathway is as follows:



This decomposition can be created can be created two major ways.

### **2.4.1 Chlorate Formation Path #1**

If during production of the sodium hypochlorite the reaction of chlorine and caustic occurs in a low pH region of the reactor (typically less than 10 pH), hypochlorous acid is formed. This will result in chlorate formation. This process is accelerated dramatically in high temperature areas, which occur when sodium hypochlorite is manufactured using a "batch" process. Refer to references listed.

In most batch production systems for sodium hypochlorite that originated in the 50's and 60's, high levels of chlorate are produced during the reaction process because of the difficulty in controlling the localized pH and temperature in all areas of the reactor. This production method is still at least partly used by most manufacturers because this is how they remove leftover chlorine gases (e.g., "sniff gases") from returned chlorine cylinders. During the 70's, 80's and 90's, many manufacturers have also installed continuous production sodium hypochlorite plants resulting in good control of the pH at the reaction point and thus reduced chlorate formation. However, it should be noted that within the continuous sodium hypochlorite manufacturing group, individual methods of operation would affect the levels of chlorate produced during the reaction.

It should also be noted that the strength of sodium hypochlorite produced during the reaction would also affect the levels of chlorate. However the method of manufacturing, the higher the strength of sodium hypochlorite produced, the higher the initial levels of chlorate produced.

### **2.4.2 Chlorate Formation Path #2**

Sodium hypochlorite after production will decompose due to initial strength and pH, storage temperature, sunlight, and contaminants such as heavy metals and suspended solids such as calcium and magnesium.

The normal rate of sodium hypochlorite decomposition without sunlight, heavy metals and contaminants (all of which can be easily controlled) with a pH of 11-13 can be expressed as:

$$\text{Rate} = K_2(\text{OCL}^-)^2 \text{ (Reference 5.1)}$$

Therefore the strength of the bleach and the levels of chlorate throughout the storage period can be calculated using the predictive chemical-modeling program created by Gilbert Gordon and Luke Adam. (Reference 5.1)

The major point to understand from this rate of decomposition formula is sodium hypochlorite has a 2<sup>nd</sup> order rate of decomposition. This means that 200-gpl available chlorine sodium hypochlorite will decompose 4 times faster than 100-gpl available chlorine sodium hypochlorite if all other factors such as storage temperature are the same.

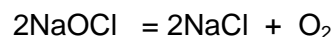
The reason this rate of decomposition must be understood by the consumer is that typically sodium hypochlorite is delivered at approximately 120 gpl or 160-gpl available chlorine. Due to the basic chemistry of sodium hypochlorite, 160 gpl will decompose 1.8 times faster than 120-gpl sodium hypochlorite and therefore chlorates will be generated 4 times quicker. If chlorate is an issue in the final product, then the specified delivered bleach should always be the lowest practical strength the supplier can manufacture and deliver and the practical strength the purchaser can store. Therefore, in the US and Canada, the Purchaser would typically specify a minimum of 120 GPL available chlorine.

It is critical for the consumer to carefully specify the strength of sodium hypochlorite to be purchased. The length of storage time and temperature must determine the strength chosen. If the consumer is using the product in an application that chlorate levels are important, this formation must also be considered.

One of the best methods to reduce decomposition is to store the sodium hypochlorite at a lower strength than the delivered strength. This is generally only an acceptable solution if the Purchaser desires to store large amounts on-site (e.g., 45 - 60 days) because routine deliveries are not readily available, they are in a very warm climate **and** the tanks are in the direct sunlight. If the product is diluted with water, only soft water should be used since typical untreated sources will add suspended solids and other contaminants and may precipitate out calcium carbonate. If 60-gpl sodium hypochlorite is stored in lieu of 120 gpl, the rate of decomposition is decreased by a factor of 4. Most studies in the State of Florida have found that the potential sodium hypochlorite consumption savings (e.g., 1% – 3%) per year **are not offset** by the combination of capital expense for twice the bulk storage and water softening equipment, increased building size (if applicable), and the O&M expenses of the softened water equipment.

### 2.4.3 Minor decomposition pathway for Sodium Hypochlorite

The minor decomposition pathway of sodium hypochlorite is as follows:



The major reason for this decomposition is heavy metal contamination such as nickel or copper. However, increasing strength, temperature, decreasing pH, and exposure to light will also increase rate of this pathway and a loss of sodium hypochlorite.

Although oxygen is a minor pathway for sodium hypochlorite decomposition, it can cause major problems for the consumer. If oxygen is formed in pump casings during the off cycle, the pumps can “oxygen lock” just like a pump that is not primed and still has air in the casing. This oxygen formation will cause the pump not work until the casing is vented. Also, many piping systems and instrumentation systems can become “oxygen locked” when the product is not flowing if it contains heavy metals. This can be a major

problem if the piping layout is such that the oxygen can not migrate to the high points of the system and be self venting. Another major problem is the experience of some producers and consumers with PVC ball valves and piping exploding when the valves are shut and piping sections are isolated for long periods of time. This is due to the extremely high pressures that can be created inside the PVC ball when the heavy metals decompose the bleach. Some manufacturers sell ball valves with pre-drilled holes in the ball which vent to the upstream side. This hole can also be easily drilled at installation. Piping should be designed to eliminate the possibility of “locking in” sodium hypochlorite between two valves for long periods of time with no means of venting. In addition to potential damage to the chemical feed equipment, valves and piping systems, the most important impact of oxygen formation is the loss of chlorination during this event.

The consumer must understand that oxygen problems can be virtually eliminated by purchasing high quality sodium hypochlorite with only trace amounts of nickel, copper, iron and suspended solids using correct storage, piping design and handling of the product.

When the sodium hypochlorite is used in the household at typical strengths between 5% to 6% by weight, the bleach must not contain heavy metals since the containers are typically not vented and any oxygen formation will result in the storage bottles building excessive oxygen pressure. This problem will result in a product that can not safely be sold since the containers may fail during transportation and handling. Sodium hypochlorite sold in strengths of 9% to 10% by weight by pool stores typically have vented caps installed.

### **3.0 Sodium Hypochlorite Quality**

When purchasing sodium hypochlorite, the consumer must be concerned with the product quality. The Purchaser has control of the product quality with respect to bleach strength and quality. By specifying a high quality sodium hypochlorite that has only trace amounts of nickel, copper, iron and suspended solids, minimum sodium chlorate and sodium bromate levels, and utilizing correct storage and handling of the product, the following benefits are achieved:

- Low chlorate levels in the delivered sodium hypochlorite
- Low bromate levels in the delivered sodium hypochlorite
- Decomposition of the product can be reduced and therefore chlorate formation will be reduced and product savings will result
- Settling and buildup of the suspended solids will be eliminated in the tanks, pumps, piping and instruments
- Negligible amounts of oxygen will be produced (e.g., “off-gassing”)
- Safety of the piping systems is improved in PVC piping systems by eliminating the source of valve and line ruptures
- Existing insoluble compounds coating and plugging feed system will be reabsorbed in the sodium hypochlorite feed solution and future problems are eliminated.

Therefore the following items must be addressed as part of the Purchaser’s specification and during the quality testing of the product after it is received. See Reference 5.4.



### **3.1 Strength**

The strength of the sodium hypochlorite is determined by titration. See Reference 5.2 for highly various procedures. The "Highly Accurate" method should be used if possible. Various commercial test kits are also available but most are not very accurate.

Since the specified delivered strength of the product can affect chlorate levels, the Purchaser must consider the strength of the delivered product when specifying the sodium hypochlorite. It is important for the Purchaser to use a standard nomenclature such as trade percent available chlorine when specifying the strength of the product.

### **3.2 Excess Sodium Hydroxide (a.k.a., Caustic)**

The strength of the excess caustic or alkalinity of the solution is determined by titration. See Reference 5.2.

The minimum amount of excess caustic is 0.10% by weight which is approximately 11.5 pH. Any amount of excess caustic below 0.10% will cause the pH of the solution to drop below a pH of 11.5 and will result in a rapid rate of decomposition and product instability. In higher temperature environments (e.g., Florida), the instability also occurs at a higher pH and excess caustic. Therefore, a minimum excess of caustic of .15% and pH of 12 should be specified to minimize product instability and degradation.

If the sodium hypochlorite will be diluted and stored after the consumer receives it, the initial excess caustic percentage must be higher than the 0.04% since dilution will decrease the excess caustic percentage of the solution.

At higher levels of excess caustic above .4%, decomposition rates can begin to increase and rapidly accelerate above .5%. Therefore, a maximum excess caustic of .40% should be specified. Also, depending on the application for the sodium hypochlorite, the higher levels of pH may result in a required pH adjustment in the process and can result in scaling of piping.

### **3.3 Sodium Carbonate**

Sodium Carbonate is in the solution of sodium hypochlorite by the nature of the process but if the sodium hypochlorite has low suspended solids it does not have an effect on the use of sodium hypochlorite and in some cases will make the product more stable. Sodium carbonate comes from some sodium hydroxide depending on which type of manufacturing process is used. It is also formed when air comes in contact with sodium hydroxide and it may be added in the manufacturing process.

The only case sodium carbonate may be a problem to the user is if the product has a high level of suspended solids. Then the sodium carbonate will help to collect the suspended solids into large enough particles to drop from the solution and coat the bottom of tank, pumps, and piping with insoluble compounds. Over time this will result in a system that needs frequent servicing due to plugged pumps, piping and instrumentation. Although sodium carbonate is typically tested in the bleach solution, levels of up to 1% by weight would not be a reason for rejection since sodium carbonate in bleach is in solution and by itself will not precipitate unless the levels are very high. Please refer to the suspended solids testing discussed below.

### **3.4 Specific Gravity**

The specific gravity of the solution is the ratio of the weight of the solution with respect to water. If the product has a specific gravity of 1.165, a gallon of this sodium hypochlorite weighs 9.72 pounds.

Sodium hypochlorite specific gravity will vary due to the amount of excess caustic and salt in the solution. Specific gravity is not necessarily an indicator of product strength as it typically is when purchasing sodium hydroxide (a.k.a., caustic). It may be used as an indicator on a newly delivered load of sodium hypochlorite because it is unlikely the manufacturer is delivering sodium hypochlorite that has been sitting around for a long time. However, for sodium hypochlorite that has been sitting in a storage tank for an undetermined amount of time, the specific gravity will only slightly decrease over time because the primary decomposition pathway products of chlorate and salt are still in the solution. The slight decrease is only due to the oxygen off-gassing.

Most tables that show the gpl of available chlorine and the specific gravity of the solution were created 40-50 years ago and are shown with excess caustic much higher than current levels of sodium hydroxide. The reason excess caustic levels have decreased is the manufacturing techniques have improved and the endpoint control of the chlorine and caustic reaction is better. In particular, many manufacturers now produce the product with a “continuous” as opposed to a “batch” plant.

These older tables will typically show 120 gpl available chlorine with 0.73 % by weight excess caustic which results in a specific gravity of 1.168. If the excess caustic is removed, the specific gravity will be 1.157. Typically, the sodium hypochlorite produced by a continuous process will have a minimum of 0.2% by weight which would result in a specific gravity of 1.160 at 120 gpl. Additional information can be found in the titration procedures available as noted in Reference 5.2.

### **3.5 Suspended solids**

Currently, some customers are generally ignoring suspended solids in the product unless visible contaminants exist in the product when it is received. However, this is a very big mistake. Suspended solids in the product at the time of delivery are typically not visible and normally do not change the color of the product an appreciable amount. However, during storage and pumping of the product, these suspended solids will become larger and drop out of solution into the storage tanks and onto the pumps, piping, valves, and instrumentation. Over time these suspended solids can make the feed systems non-functional and will result in costly maintenance in order to remove them as well as create a public health problem in water treatment and wastewater treatment plants due to the lack of chlorination/disinfection. Additionally, the suspended solids lead to significantly higher product degradation rates.

A test for suspended solids is available (see Reference 5.3) that is quick and the results can be duplicated from location to location. This test simply passes one liter of product through a 0.8 micron filter cloth under 20” of mercury vacuum and the time to filter is noted. If the product passes the test in 3 minutes or less, the product has negligible suspended solids and can be accepted from the producer.

The bleach producer has two completely different methods to use to achieve the required test results depending upon their method of manufacture:

- 1) [Special Filtering] The first method of manufacturing is from a producer using chlorine from railcars (or from returned chlorine cylinders using “sniff” gas), 50% caustic from railcars and tap water. Since the suspended solids can not be controlled during production due to the number of variables, the final product must be filtered in an extremely high efficient filter system filtering particles in the

submicron size levels. Normally this is accomplished with a filter aided filter system using perlite or diatomaceous earth as the filter media. It is not possible to achieve the required level of filtering using cartridge filtering due to cost, flow rate capabilities of the cartridge systems, and particle size limitations. In rare cases, manufacturers have achieved the required level of filtering with cartridge filters when they incur the additional expense of using membrane grade caustic and soft water to make their bleach and their source water is relatively pure.

- 2) [Superior Process] The second method of manufacturing is from a producer producing chlorine using a membrane cell process with vapor chlorine direct from chlorine cells reacted with caustic direct from the cells that has been diluted with demineralized water that is piped directly to a continuous sodium hypochlorite machine. In this method, the chlorine and caustic is not shipped via railcar but is manufactured as part of one continuous sodium hypochlorite manufacturing process. Since the caustic and chlorine at the point of manufacture is extremely pure and the water has no contaminants, the final product will be ultra pure and will have negligible suspended solids, since it is not picking up any contaminants from evaporators to increase the caustic strength from 33% to 50%, from metal piping, or from railcars and other transportation handling mechanisms.

### 3.6 Sodium Chlorate

Sodium chlorate is currently not regulated by the EPA. Toxicological information on the chlorate ion is limited with only acute chlorate toxicity having been addressed (see Reference No. 5.5). Under the Disinfectant/Disinfection By-Products Rule, the EPA has expressed its intention to set allowable chlorate ion levels. In the meantime, chlorate ion levels should be kept as low as possible. The typical limit of chlorate in the delivered bleach is 1500 mg/liter or ppm equivalent. Testing for sodium chlorate is not easily done and only a qualified laboratory is used. All samples should be shipped to the laboratory packed in dry ice to avoid additional decomposition before the sample is analyzed. See References 5.2.

As discussed above, the producer can control the amount of chlorate formed during production by limiting the final strength of the product, temperature of production and controlling pH during reaction. The producer can also help control the chlorate by delivering the product a short time after production. If the product is of high purity, further reductions of chlorate will be achieved. Chlorate levels are considerably lower for **continuous** manufacturing processes as opposed to a **batch** system.

### 3.7 Nickel & Copper

Typical specifications of nickel and copper are 20 PPB (parts per billion) or less. Unless the manufacturer has a high purity product, these levels will not be achieved. As discussed above, these heavy metals will decompose the product and a maximum level should be specified and periodically test for.

The 50% caustic used in sodium hypochlorite production contains nickel. The primary means of contamination is from the salt used by chlor-alkali plants and the chlor-alkali plants themselves, which use nickel evaporators to concentrate the 32% caustic solution off of the cells to 50% for shipment. Additionally, some methods of production for sodium hydroxide result in higher levels of nickel and therefore carryover to the final product.

Copper is introduced in the sodium hypochlorite usually due to copper water lines used for process water piping or dilution water. If the manufacturer and consumer can avoid copper in the incoming water and process systems then copper is usually not a problem.

Since the heavy metals can be filtered out, the Purchaser can specify the amounts of heavy metals in the delivered product. A low heavy metal content is usually an indication that very little suspended solids are in the final product. However, the level of suspended solids must also be specified and tested for in accordance with Reference 5.3.

### **3.8 Iron**

Typical specifications for iron are less than 0.4 PPM. The iron levels found in the normal product are not only a factor in the decomposition of the product, they have been known to cause severe maintenance problems by plating out on system components such as ORP probes. If the iron levels exceed approximately 1 PPM, the sodium hypochlorite will start to turn a slight red brown color. The higher the iron content, the more pronounced the color change and usually the higher the level of suspended solids. The presence of iron is very evident on the .8 micron filter paper because of a reddish-brown color using the aforementioned suspended solids test.

If the iron is less than 0.4 PPM, typically the only manufacturing process this can be achieved by is for the producer to use high quality filtration. This iron level specification is another method the Purchaser can use to verify the product is of high quality.

### **3.9 Bromate**

On December 16, 2001, the U.S. EPA began to regulate bromate levels in potable (drinking) water for most systems as part of Phase I of the Disinfection Byproducts Rule of the Safe Drinking Water Act. The maximum concentration level (MCL) for sodium bromate, a known carcinogen, has been set at 10 ppb, and will apply to all drinking water systems beginning in January of 2004. Under current ANSI/NSF Standard 60 guidelines, only 50% of this amount can come from the sodium hypochlorite. This amount has been slated to be lowered to 30% in January of each subsequent year but because only about 10% of sodium hypochlorite manufacturers can meet this standard this has not as of yet been implemented. The primary source of bromate in drinking water is from the reaction of ozone and bromide ions found in raw (untreated) water. Sodium bromate can be found in sodium hypochlorite and comes from bromide in the salt used to make the caustic and chlorine that is used to make the sodium hypochlorite. For example, based on a maximum 12 ppm chlorine feed rate, bromate levels in 12.5 Trade Percent sodium hypochlorite should be limited to 25 ppm in order to meet the proposed 30% limit.

High quality bleach made from chlorine and caustic that uses salt with minimal amounts of bromide (e.g., evaporated salt) can easily meet this specification. However, many manufacturers are unable to meet these new bromate regulations without switching their chlorine and caustic sources. Until the marketplace regulates bromate, the manufacturers will not alter their manufacturing processes! If the consumer has a choice, they should choose a sodium hypochlorite supplier that uses caustic and chlorine manufactured from evaporated salt.

## **4.0 Transportation, Storage, and Handling Sodium Hypochlorite**

After all the above items have been addressed on the quality of the purchased sodium hypochlorite, the consumer must also verify the correct transportation, storage and handling of the product at the user site.

### **4.1 Transportation**

#### **4.1.1 Tanker Trailers**

Tanker Trailers are tanks mounted on a frame with wheels with a fifth wheel connected to a truck tractor. These trailers are used to deliver large volumes of bleach to a customer's site. Most of the equipment used is capable of delivering from 4,400 to 5,100 gallons at one time. These tankers can be of many different designs and the structural tank can be of steel or fiberglass reinforced plastic (FRP). However, they must all have materials in contact with the product that are resistive to sodium hypochlorite.

There are many different materials of construction used as the corrosion barrier for the sodium hypochlorite to eliminate damage to the structural tank and to eliminate contamination of the product. Some of these liners include rubber, PVC, Halar®, Tefzel®, and other non-metallic material. FRP tanker trucks are very successful for hauling sodium hypochlorite when the entire container is made of FRP with the correct construction methods. However, steel tankers lined with FRP should not be used due to the differences in expansion rates with respect to temperature changes. The industry trend in Canada and in the United States has been the replacement of steel lined tankers with FRP tankers over the past ten years due to the long life of the FRP tanker. The FRP trailer has over 30 years of use and it has been proven to be the best choice for sodium hypochlorite if constructed correctly.

Since failure of these liners will result in damage to the tanker, the owner of the tanker should be inspecting the liners on an annual basis. If required, repair and replacement of the liner should be done if any damage is detected during these inspections.

If a liner should start to fail during the yearly period between inspections, the purchaser may notice two changes in the product received. First, if the tanker is steel with a liner, the iron content of the bleach will increase over time when that tanker is used for delivery. Second, failure of a liner may result in an increase in suspended solids. A third change will be noticed if the liner is rubber and that is the sodium hypochlorite will be very discolored and dark in color (e.g., "black" bleach).

From a consumer's perspective, a liner failure does not result in any problems other than the increase in suspended solids and the metals. However, as discussed previously, these both have detrimental effects to the quality of the sodium hypochlorite. The owner of the tanker should be notified of any changes of product quality that may be a result of a defective liner as soon as possible. The consumer should reject further deliveries from this tanker until it has been shown to be re-lined.

The Purchaser should specify that the tankers be thoroughly cleaned before each delivery if the manufacturer uses its tankers for hauling another product such as sodium hydroxide or if the sodium hypochlorite manufacturer is using a common carrier in lieu of its own delivery fleet.

#### **4.1.2 DOT Exempt Polyethylene tanks**

In the United States, polyethylene tanks of 300-600 gallons with or without steel structure or other frames are used to ship bleach. Distributors mount up to eight of these tanks on the back of a flatbed truck or ship them inside enclosed trailers. The tanks (a.k.a. totes) are either offloaded or the bleach is pumped out of them into the customer's tanks.

#### **4.1.3 55, 30, 15 and 2.5 gallon Drums and Containers**

In the United States, sodium hypochlorite is transported in small quantities in a various size drums and containers. All of the containers should have vented caps unless a high quality sodium hypochlorite is used. Regardless of the manufacturer, a high quality sodium hypochlorite will reduce the amount of washing of the containers before refilling.

### **4.2 Storage Tanks**

#### **4.2.1 Materials of Construction**

Many different types of materials are used for construction of storage tanks for sodium hypochlorite. Three main types of the materials used are linear high-density polyethylene (HDLPE), cross-linked polyethylene (XLPE) and fiberglass-reinforced plastic (FRP). Other choices include chlorobutyl rubber lined steel and titanium. In some countries where these materials are not readily available or the manufacturing quality is suspect, cubical concrete tanks lined with PVC have been successfully used.

The choice of materials depends on available capital, tank location, and required service life. Some tanks may only last 3-5 years, others if properly specified and maintained could last 20-30 years. The only material known for over 30 years service life is titanium.

#### **4.2.2 Polyethylene**

These tanks should be manufactured out of linear high density (HDLPE) or cross-linked polyethylene (XLPE). Historically, cross-linked polyethylene tanks were used to store sodium hypochlorite. In the late 90's, many cross-linked tanks failed prematurely. Based on this rash of failures, the Chlorine Institute and many suppliers began recommending that only "linear" high-density polyethylene tanks only be used to store sodium hypochlorite. The cause of these failures is now believed to have been traced to the resin manufacturer and many suppliers, along with the Chlorine Institute, are now recommending that cross-linked tanks can be used along with linear tanks for sodium hypochlorite storage. Typically, the XLPE and HDLPE tanks are vertical cylindrical construction with a flat bottom and domed top. There are polyethylene tanks engineered and manufactured that are specifically designed for the storage of sodium hypochlorite. Some of these tanks even incorporate chemically resistant liners. Other manufacturers have a special resin for sodium hypochlorite. Tanks that are to be used outside should have some form of UV protection. Some manufacturers even build tanks with special UV resistant resin although exterior paint will also help provide UV protection.

The linear polyethylene tanks are very competitively priced. However, these tanks typically have a service life of 4 - 7 years if exposed to direct sunlight although with frequent painting this service life may be extended to 6 - 9 years. The tank's life indoors may be extended to 6 - 9 years but they should only be placed indoors if they can be accessed for replacement when they fail. These tanks should not be used in a

construction application that allows for no easy replacement of the tank upon failure. The major source of failure is at fittings on the sides of the tanks. Often times the tank can be returned to service if the crack at a fitting connection is removed by upsizing to the next fitting size. While this solution may work in the short run, often times the tank will ultimately fail later at this same point because of the increased stress of the heavier fitting on the side of the tank. If the tank can be rotated or the piping reconfigured, another option would be to “upsized” the cracked fitting and install a plug and then put in a new fitting on another spot on the tank. All exterior fittings on the side of the tanks should be supported with proper pipe supports to reduce the stress on the tanks at this common failure point. However, supports should be installed such that some horizontal expansion of the tank is allowed for when it is filled after being completely empty (a.k.a. “tank squatting”). Not allowing for the lateral expansion of the tanks is the major source of tank cracking on the bottom fittings of bulk storage tanks.

Cross-linked polyethylene tanks are generally more expensive than linear polyethylene tanks. This is due to the higher cost of resin and the differences in the manufacturing process of the tanks. The cross-linked tanks are generally more structurally sound because of their crystalline structure and are not as susceptible to a catastrophic failure. They can also withstand higher temperatures, although this is generally not an issue with sodium hypochlorite storage. However, despite its increased strength, there is not wide agreement in the sodium hypochlorite industry on whether the useful life of the cross-linked polyethylene tank is any greater than a linear high-density polyethylene tank. This is an issue that must be continued to be studied.

One of the major problems with polyethylene tanks have to do with the outlet fittings on the bottom of the tanks (i.e., below the liquid level). For the best solution below the liquid level of the tanks, an integrally molded in, full drain fitting is probably the best solution. This fitting allows attachment to the lowest point on the tank without metals or other materials contacting the sodium hypochlorite and the exact same material that the tank is manufactured from. Flanged fittings with titanium bolting should be used if the tank does not have an integrally molded in, full drain fitting for larger tanks. Titanium or PVC bulkhead fittings can also be used but they tend to not be as reliable as a flanged fitting although this is probably arguable as well. Above the liquid level such as for the tank vent or the fill-line, PVC bulkhead fittings are acceptable. Schedule 80 PVC bulkhead fittings with viton o-rings below the liquid level are typically used on small tanks (e.g., less than 5,000 gallons) and in applications where downtime due to repairs on the fittings are acceptable (e.g., customer has more than one storage tank). While titanium fittings basically last forever, PVC fittings are less expensive and because they weigh less, put less stress on the side of the tanks. Thus, they may be preferred for smaller tanks. Viton® gaskets should be used for sodium hypochlorite. EPDM gaskets should not be used with sodium hypochlorite bulkhead fittings because of their relatively short life when in contact with sodium hypochlorite (e.g., typically 6-9 months). Since polyethylene tanks do not have a uniform vertical wall thickness, care should be taken when selecting areas to install fittings. Some manufacturers provide flat areas and also molded fittings on the side of the tanks that can be a real advantage in minimizing future problems.

Many installations utilize titanium 150# flat faced backing flange with titanium bolts welded in the flange. A Viton® full faced gasket is used between the backing flange and the inside tank wall. The flange is located at a flat spot on the tank wall (typically 90 degree locations) and holes are drilled for the bolts and the center is bored to meet the

ID of the flange. On the outside of the tank, a gasket and valve can then be applied which when tightened will compress the inside gasket and seal the connection.

#### **4.2.3 Fiberglass Reinforced Plastic**

The use of fiberglass tanks for storage of sodium hypochlorite is common and if designed properly can be one of the best choices for storage of the product. However, if improperly specified and constructed, it can be one of the worst choices. A well-specified and properly constructed FRP tank can last 20 years or more with corrosion barrier inspections typically every two years with minor repairs as required. An improper design and construction will result in corrosion barrier failure and structural damage in 2-3 years requiring complete replacement of the tank. Unfortunately writing a proper specification is no guarantee to purchasing a quality tank. Workmanship can still be defective. The tank manufacturer should be carefully selected based on their previous track record of supplying tanks for sodium hypochlorite service and not based on their seeming willingness to agree to follow an engineer's specification.

Typical specifications for FRP tanks should include hand laid up or "ortho wound" construction. Filament wound is sometimes used because it is less expensive but it is not recommended since failure of the corrosion barrier in a filament wound tank will result in the sodium hypochlorite wicking around the continuous strands of glass used in the structural portion of the tank. This will result in weakening of the structural portion of the tank, which may result in a catastrophic failure of the tank.

Vinyl resin is used for the both the corrosion barrier and structural layers of the tank with the inside of the tank corrosion barrier starting with 2 nexus veils. The final corrosion barrier is catalyzed with a BPO/DMA cure system and a 4 hour post cure.

For detailed specifications of FRP tanks for sodium hypochlorite, refer to the Reference 5.6 for source material information.

There has been success with dual laminate FRP tank using PVC and other materials for the corrosion barrier. If this method of construction is used, the best source of specifications is from the manufacturer of the tank. Consideration should be given to the detection of a liner failure before damage to the outside FRP vessel can occur. Only hand laid-up or ortho winding should be considered for the FRP vessel for the same reasons as above.

#### **4.2.4 Rubber Lined Steel**

Rubber lined steel tanks have been successfully used for sodium hypochlorite storage using chlorobutyl linings of typically ¼" thickness. These linings require a skilled applicator and heat curing. Unfortunately, depending on the brand of rubber and the skill of the applicator the service life is normally 3-6 years at which time the liner may require total replacement.

Liner replacements can be done in the field so inside locations of the tanks are not a problem. However, if the liner failure is not recognized in time, the steel tank will be chemically attacked by sodium hypochlorite resulting in iron contamination of the product.

For these reasons, rubber lined tanks are not typically used in sodium hypochlorite storage although they may be used in a processing tank for reasons of structural integrity due to pressure requirements.



#### **4.2.5 Titanium**

Titanium storage tanks are the best choice of material for sodium hypochlorite. The grade typically used is commercially pure grade 2. However, the cost of titanium storage tanks is prohibitive unless there is a very unusual requirement for virtually unlimited service life with no failures allowable. Normally, titanium tanks are only used for process tanks to handle special applications such as pressure reactors or small process tanks if time for repairs can not be tolerated.

#### **4.2.6 Containment Areas**

Good engineering practice dictates that all sodium hypochlorite storage tanks should be placed on a suitable concrete foundation and surrounded by a containment area capable of holding at least 110% of the volume of the largest tank in the containment area. A poured concrete wall and floor usually offers the best form of containment. Another option is to use a concrete block wall for containment although the concrete block wall is much more porous than a poured wall. If a block wall is used, the wall should be coated with some sort of sealant to prevent spilled bleach from leaching through it or under it. There is no perfect sealant; marcite is probably the best solution although most people use a 2-part epoxy paint because it is easier to apply. Rubber-based pool paints can also be used although these offer the least amount of sealant protection. Both the poured concrete wall and the block wall should be anchored to the concrete slab with rebar and poured solid to protect against the liquid force from a catastrophic tank failure. For smaller storage tanks, a polyethylene containment liner can be purchased from most tank companies. This is usually a more economic option for smaller storage tanks that are not part of a "tank farm". The cost of the HDLPE containment is comparable to the cost of the tank it contains (approximately \$1.20 per gallon). Another option to using containment is to use a double-walled tank. Many tank manufacturers make this product and these tanks can be good choices for areas where there is not enough room for both the tank and containment (e.g., small chlorine handling buildings or shelters).

In the State of Florida, there is no requirement in the Florida Administrative Code to register the sodium hypochlorite tanks or provide containment as is the case with caustic and hydrochloric acid tanks respectively. However, the Florida Department of Environmental Protection (FDEP) has made sodium hypochlorite tank containment a requirement for most permit applications for water treatment and wastewater treatment plants. Additionally, some counties, through ordinance or the building or fire code, regulate the placement and containment requirements for any type of bulk chemical storage tanks. In any case, good engineering practice dictates that containment or double-walled tanks be provided and most sodium hypochlorite manufacturers will not make deliveries unless the Purchaser's tanks have containment or are double-walled. The containment guidelines above would apply to amounts of storage over the Reportable Quantity (RQ) for a Spill which is approximately 100 gallons.

#### **4.2.7 Storage Tank Design Considerations**

The placement of sodium hypochlorite storage tanks involves a variety of factors. As previously discussed, the tanks should be located in an area to accommodate a concrete foundation with appropriate containment. Adequate room for the use of a tie-down system should be considered for outdoor storage (although frankly the tank is not going anywhere in a hurricane if it is at least 1/3 full). Ideally, storage tanks should also be located indoors or under some sort of shelter to minimize decomposition from

temperature effects and UV rays. The use of existing foundations and/or buildings is also recommended to lower installation costs.

There are a variety of factors involved when sizing the sodium hypochlorite tanks. First, a consumer can usually get better pricing if they are willing to take the entire tanker of sodium hypochlorite from the manufacturer. Since the tanker may contain up to 5,100 gallons, this usually means having a minimum capacity of 2-3,000 gallon tanks or one 6,000-gallon tank. However, since sodium hypochlorite decomposes over time, it is usually not best to store more than thirty (30) days on-site at one time. For unprotected outdoor storage, it is recommended not to store more than 14-21 days on-site at one time. In general, a two to three weeks storage supply is more than adequate for most consumers including water treatment and wastewater treatment plants. Another factor in sizing the tanks is fitting them in existing locations to save on installation costs. For example, many consumers who have switched from chlorine gas to sodium hypochlorite have existing shelters that not only have foundations but also offer UV and heat protection to the tanks. Typically, multiple shorter tanks fit into these shelters.

Yet another consideration is using two storage tanks in lieu of a single storage tank for reliability. This ensures that if there is a problem with one of the tanks the other tank is available. The use of a single storage tank is generally not preferred unless space considerations come into play or the process use can withstand some downtime. Some consumers also use a small day tank for their feeder pump head in addition to storage tanks. In general, Day Tanks do not offer any benefits since accurate daily readings can be obtained from bulk storage tanks and most users have other systems to prevent over feeding the chemical such as flow meters or chlorine analyzers (this is generally not an issue with sodium hypochlorite anyway). On the other hand, overflowing of Day tanks and day tank failure is a common problem, especially among water treatment plants and thus their use should be minimized except in the following two scenarios: (1) To independently calculate usage rates for different processes pulling from the same bulk storage tanks (e.g., co-located water treatment and wastewater treatment plants pulling from the same storage tank(s)); (2) Large Water Treatment or Wastewater Treatment plants with a single large bulk storage tank.

#### **4.2.8 Storage Tank tie-downs**

Outdoor or exposed sodium hypochlorite storage tanks should be filled with liquid or tied down with an appropriate tie-down system in the event of a hurricane or other similar natural disaster. There are a variety of tie-down system designs depending on the tank manufacturer. Some run down the side of the tanks and others are located out away from the tanks. Most tank manufacturers sell a tie-down system for their tanks. Typically these tie-down systems range in price from \$200 to \$1,000 depending on the manufacturer and size of the tank.

#### **4.2.9 Miscellaneous Tank Components**

The tank should be mounted on a properly designed foundation or support system designed for the total load. Tank access issues should be considered with regard to manway location, handrails and ladders. Sufficient lighting should be provided. Tank level indication and should be considered which could be visual (e.g., sightglass or translucent tank) or by instrumentation (ultrasonic or pressure level sensor). Alarm set points should be carefully thought out on instrumentation.

#### 4.2.10 Piping from Bulk Storage Tanks

Most polyethylene tanks expand or “squat” when filled with sodium hypochlorite anywhere from ½” to 2” in diameter. This causes “stress” on any bottom bulkhead fitting and its associated piping leading out of the tank. A flexible coupling or flexible piping should be used on the discharge of the tank. The least expensive solution is to use a 3’ to 5’ section of K-flex or flexible PVC. This material is inexpensive (\$2 per foot) but should have an isolation valve near each end to facilitate replacement when required. Rubber hose certified by the manufacturer to be compatible with sodium hypochlorite is also acceptable. Rubber hose is typically more difficult to work with and requires connections to hose barbs and clamps. The “K-flex” can be attached to a PVC connector with glue (i.e., “socket welded”). Typical pricing for rubber hose compatible with sodium hypochlorite vary from \$10 to \$20 per foot.

As previously discussed, one of the sodium hypochlorite decomposition pathways is to give off oxygen. Oxygen can accumulate and eventually block lines in improperly designed piping systems both in the suction and discharge piping of metering pumps. This problem can be partially alleviated by installing vents on the high points in these lines, minimizing the number of bends in the pipe, minimizing the total pipe run and designing the piping such that it slopes back to the vented tank. This is obviously not a problem with large centrifugal pumps but rather in smaller applications involving metering pumps because of their limited suction lift capabilities to overcome this air blockage. Sizing the piping too small causes air to come out of solution because of too high a velocity and too large it allows the sodium hypochlorite to sit too long. The following tables should be used “as a guide only” when sizing piping to metering pumps from bulk storage tanks and from metering pumps to injection points to optimize the size of the piping. Each row represents the total length to the pump from the bulk storage tank and to it should be added 5’ for every 90-degree turn in the piping above two 90-degree turns. On the second Table it includes the distance from the pump to the injection point. Each column is the total chemical metering pump feed rate. Final design sizes should be determined taking into account the specifics of each application.

TABLE 4.2.10.1: RECOMMENDED SCHEDULE 80 PVC PIPING SIZES FROM THE BULK STORAGE TANKS TO THE CHEMICAL FEED EQUIPMENT

	2 gph	5 gph	10 gph	20 gph	30 gph	50 gph	70 gph	100 gph	200 gph	500 gph
TOP	¼”	¼”	3/8”	½”	½”	¾”	NO	NO	NO	NO
0’	¼”-½”	½”	½”	½”	¾”	¾”	¾”	1”	1 ½”	2”
10’	½”	¾”	¾”	1”	1”	1 ½”	1 ½”	1 ½”	2”	3”
20’	½”	¾”	1”	1”	1 ½”	1 ½”	1 ½”	1 ½”	2”	3”
30’	½”	1”	1”	1 ½”	1 ½”	1 ½”	1 ½”	1 ½”	3”	4”
40’	¾”	1”	1”	1 ½”	1 ½”	1 ½”	1 ½”	2”	3”	4”
50’	¾”	1”	1”	1 ½”	1 ½”	1 ½”	2”	2”	3”	4”
60’	1”	1”	1 ½”	1 ½”	1 ½”	2”	2”	2”	3”	4”
70’	1”	1”	1 ½”	1 ½”	2”	2”	2”	2”	3”	4”

- Note 1: Maximum Distance recommended is about 35’ unless using a peristaltic chemical feed pump. The Distance should be minimized if possible.
- Note 2: The “0 ft.” distance is the recommended piping size on the pump skid or from the transition of the feed line to each individual pump itself.
- Note 3: The “TOP” distance can be used to size the line when pulling out of the top of a bulk storage tank.

TABLE 4.2.10.2: RECOMMENDED SCHEDULE 80 PVC PIPING SIZES FROM THE CHEMICAL FEED EQUIPMENT TO THE INJECTION POINT

	2 gph	5 gph	10 gph	20 gph	30 gph	50 gph	70 gph	100 gph	200 gph	500 gph
0'	1/4"-1/2"	1/2"	1/2"	1/2"	3/4"	3/4"	3/4"	1"	1"	2"
10'	1/4"-1/2"	1/2"	1/2"	1/2"	3/4"	3/4"	3/4"	1"	1"	2"
25'	1/2"	1/2"	1/2"	1/2"	3/4"	3/4"	3/4"	1"	1"	2"
50'	1/2"	1/2"	1/2"	3/4"	3/4"	3/4"	3/4"	1"	1"	2"
75'	1/2"	1/2"	3/4"	3/4"	3/4"	3/4"	3/4"	1"	1"	2"
100'	1/2"	1/2"	3/4"	3/4"	3/4"	3/4"	3/4"	1"	1 1/2"	2"
150'	1/2"	3/4"	3/4"	3/4"	3/4"	3/4"	1"	1"	1 1/2"	2"
200'	1/2"	3/4"	3/4"	3/4"	1"	1"	1"	1"	1 1/2"	3"
300'	3/4"	3/4"	1"	1"	1"	1"	1"	1 1/2"	2"	3"
500'	3/4"	1"	1"	1"	1"	1 1/2"	1 1/2"	1 1/2"	2"	3"

Note 1: Maximum Distance recommended is about 500' (including allowance for 90 degree elbows). The Distance should be minimized if Possible. Sodium Hypochlorite has been successfully pumped up to 700'

Note 2: The "0 ft." distance is the recommended piping size on the pump skid or at the transition from each individual pump itself.

#### 4.2.11 Miscellaneous Tank Fittings/Connections

Regardless of the type of tank selected, the number of tank penetrations should be minimized to avoid future maintenance and tank failure problems. On polyethylene tanks, tanks typically fail (e.g., crack) at the bottom bulkhead or flanged fittings. On FRP tanks, the flanged connections often crack the first time the gasket is changed. In most cases, but not all, this is caused by the repair crew "over-torquing" the bolts on the flanged connection. All tanks should be vented and the vent must be equal to or larger than the size of the fill line (typically the vent should be 2" or 3"). Generally, a 3" vent should be used on all tanks larger than 2,500 gallons. A 4" vent should only be used on very large tanks (over 5,500 gallons) because it weighs so much it puts a lot of stress on the top of the tanks. The vents should have a vinyl mesh insect bug screen glued on the end to keep insects out of the tank. The tank should also have a fill line. Typically, the fill line should be 2" with a male chem-lock fitting on the end; consideration should be given to using a 3" fill line for applications where the fill line is run a long way (e.g., >75') or where lined pipe is used. The fill line should fill from the top of the tank; not the side or bottom. Bottom and side fill fittings put a lot of stress on the side of tank leading to failure, can cause back siphoning, and take a lot longer to fill the tank. The fill line should not be run to the bottom of the tank unless a 2" line is needed to frequently pump out the tank as well; not a likely scenario for most users. If required by local code or regulation, an overflow connection with a pipe to a suitable containment basin should be used. Without an overflow connection, the sodium hypochlorite would run out of the vent. If possible, the overflow connection should be placed on the top of then tank to minimize stress on the side of the tank. The tank should have a man-way at the top for inspection, tank pump-out with a sump pump and to facilitate installation of any bulkhead or flanged fittings. A minimum man-way of 16" is required for personnel entry for tank inspection although a 24" or larger man-way is preferred. FRP tanks will often have inspection man-ways on the side in lieu of the top. This is not possible on polyethylene tanks for structural reasons. Generally, tank entry into most polyethylene tanks is not required, the exception may be to replace certain types of fittings on double-walled tanks

or to retrieve materials inadvertently dropped in the tank. Should tank entry be required, all appropriate Confined Space procedures should be used including draining out all of the sodium hypochlorite, flushing the tank and use of a respirator. Separate fittings (bulkhead on polyethylene tanks and flanged on FRP tanks) are often used to install sight-glasses to check tank levels. Consideration should be given to installing the sight-glass off of the line feeding from the bottom of the tank to minimize the number of tank penetrations. All tanks should have sight-glasses if the liquid level is not visible through the tank or on a small tank through the removed man-way cover. Complete reliance on ultrasonic level detectors is not satisfactory in that experience has shown that tanks will occasionally be overfilled when the detector fails or “hangs up”. Pressure level sensors should not be used because in general they have a very poor track record with regard to premature failure. Care should be taken when using the “reverse” sight-glasses in lieu of a clear Schedule 40 PVC or glass sight-glass which feeds using gravity from the bottom. Many of the reverse sight-glasses have an extremely high failure rate because the sodium hypochlorite usually eats through the rope holding the weight in about 6 - 9 months. Separate fittings (bulkhead on polyethylene tanks and flanged on FRP tanks) are often used to install drains to check tank levels. Consideration should be given to installing the drains off of the line feeding from the bottom of the tank to minimize the number of tank penetrations. Tanks can be pumped out completely using a drain connection or a sump pump inserted through the man-way to facilitate clean-out, inspection, repairs or tank replacement. A separate drained fitting at the tank’s low point is not required, although would make pumping out the tank easier. In general, if the user intends on using a high quality sodium hypochlorite, there will not ever be a need to cleanout the tanks on a periodic basis. If a poor quality sodium hypochlorite is used, the tanks must be cleaned out at least annually and the tank is liable to contain 6” to 12” of sludge. This sludge is filled with metals and should be disposed of as hazardous waste.

### **4.3 Materials of construction**

#### **4.3.1 Incompatible materials of construction**

If the wrong materials of construction are used in any portion of the process system, contamination of the product will occur resulting in accelerated decomposition and additional oxygen formation.

All metals should be avoided except titanium, tantalum, silver, gold, and platinum. Metals such as stainless steel, Hastolloy®, Monel®, brass, or copper should be avoided at all cost. Hastolloy®-C, has been used for springs in some parts (e.g., ball check valves) and typically the springs last about 12 months before requiring replacement.

These incompatible metals can be found in pumps, pump seals and water flush lines, electrodes in magnetic flow tubes, diaphragm seals for gauges and switches, temperature wells, and common piping elements such as hose connections, support clamps and valves.

Very small amounts of an incompatible metal will result in large amounts of product decomposition and oxygen formation. The consumer must review each component in the pumping and piping system including all instruments to ensure no incompatible materials are used.

#### **4.3.2 Compatible materials of construction**

For metals in contact with sodium hypochlorite, the majority of construction for all process equipment is titanium. Tantalum is used for electrodes in magnetic flow meters and diaphragm seals. Silver and platinum is used for electrodes used to measure oxidation-reduction potential. There should be no other metal in contact with sodium hypochlorite.

For non-metallic materials in contact with sodium hypochlorite, the list includes PVC, Teflon®, Tefzel®, Kynar®, polyethylene and FRP. Other plastic materials may be used for special applications such as PPL. CPVC has been used successfully by many people in the past although after a many years of use, it has a tendency to get brittle (e.g., become “plasticized”) and can shatter if anything heavy is dropped on it.

Many of the non-metallic materials are used as liners inside of metals. The non-metallic provides the corrosion protection and the metals provide the structural strength. There are few systems using typically PVC liners with FRP as the structural component.

Any non-metallic exposed to the sun must have a UV barrier on all exterior components. A paint system designed for UV protection is the least expensive and when FRP is utilized, a gel coat is the typical method. Since these paint systems or gel coats will deteriorate over time, they must be reapplied as required.

## **4.4 Pumps**

### **4.4.1 Types and Applications**

The choice of pumps for sodium hypochlorite depending on the application can be separated into centrifugal and positive displacement such as diaphragm or peristaltic. In all applications, the only metal acceptable is titanium. However, many non-metallic pumps can be used with or without the structural metal or FRP component. Typically, centrifugal pumps are used as transfer pumps and positive displacement pumps are used as metering pumps.

One of the best pumps for sodium hypochlorite is a titanium centrifugal pump. However, these pumps are expensive compared to other choices and the design can not avoid the use of seals. There are many good seals available for these pumps and the Purchaser should refer to the manufacturer for detailed recommendations. However, any good seal will typically only last 3-5 years and will require replacement. Since good seals are expensive, depending on the application a less expensive magnetic drive pump can be used and even though the pump will not last as long, total cost of operation will be less than a titanium pump.

For other centrifugal applications, the best choice of pump may be a lined steel magnetic drive pump. Linings of Teflon®, Tefzel® and other non-metallic materials are used. These pumps may only last from 3-5 years but depending on the pump, 2 or 3 pumps with spare parts can be purchased for the same cost as a titanium pump. If a magnetic drive pump is used, a power monitor must be used to prevent dry running of the pump and damage to the shaft and bearings. For transfer pumps such as from a bulk storage tank to a day tank, inexpensive (e.g., \$600 to \$1,000) centrifugal magnetic drive pumps that last six months to one year may be the most economical choice.

Diaphragm pumps are the most commonly used metering pump for water and wastewater treatment plant applications for plants above 1 MGD. Most of these pumps

have a manual dial(s) to set the feed rate by either the stroke length, pump speed or both. Additionally, many of these pumps come with an option to “pace” the feed rate using a 4-20 ma input signal (e.g., based on output from a flow meter, chlorine analyzer or PLC Computer/Distributed Control System/SCADA system). There are many choices of diaphragm pumps for small flow applications as well. Many choices for the pump housings are available and successful. The diaphragm is typically made of Teflon® faced material with EPDM, Viton® or other rubber backing. If the diaphragm is made exclusively of a rubber compound are used, Viton® is the preferred choice. EPDM is moderately successful but is not the recommended choice. Diaphragm pumps typically require a flooded suction and thus should be fed from the bottom of the storage tank to avoid losing prime. However, in smaller applications, many users have successfully “pulled” out of the top of the storage tanks but it may be difficult to consistently maintain a prime on the pumps and a good foot valve (i.e., check valve) on the bottom of the piping or tubing leading from the pump down into the liquid is essential to avoid losing prime and air-binding the feed pump. Depending on the manufacturer and model, most diaphragm pumps typically have from 2’ to 10’ of suction lift. If diaphragm pumps are used, they should be part of a regular preventative maintenance program where they are “overhauled” every 12 –24 months depending upon the brand of pump selected (this period may be as frequently as weekly or monthly if a poor quality sodium hypochlorite is used). This maintenance should consist of replacing the ball check valves and their associated seats in the discharge and suction of the pump, replacement of the diaphragm and gasket, and general clean-out of the pump internals.

Care should be taken when selecting the pump manufacturer and model and when sizing the diaphragm pumps for use with sodium hypochlorite. As previously discussed, one of the sodium hypochlorite decomposition pathways is to give off oxygen. Diaphragm pumps are susceptible to “vapor-locking”; but only if the system is not properly designed or a poor quality sodium hypochlorite manufacturer is selected. Depending upon the manufacturer and model, some diaphragm pumps can get vapor-locked running at 40% of their rating, others can run as low as 2%-3% of their rating before getting “vapor-locked”. In general, the most common source of vapor-locking of pumps is sizing the diaphragm pumps too big. Bigger is not always better!

Peristaltic pumps using tubes are very popular for small package water and wastewater treatment applications. These pumps are easy to install and service. They are commonly self-priming and can operate dry. One advantage is that chemicals are not exposed to air or moving parts. Another advantage is that they can be fed from the top of the storage tanks. A third advantage is that they are not as susceptible to off-gassing of sodium hypochlorite as diaphragm pumps. Peristalsis occurs when the rotation of the rollers around the inside of the diameter of the tube housing compresses and dilates the pumping tube. This eliminates diaphragms of foot valves while allowing the system to be completely self-priming. At this time in the State of Florida, these pumps are not commonly used for larger water and wastewater plants (above 1 MGD). Historically, larger peristaltic pumps have been very expensive to purchase and operate (due to the high cost and frequency of the hose replacement). New products are entering the marketplace, however, and this may change. On the other hand, in the smaller water and wastewater plants with feed rates less than 100 gpd, the cost of the replacement tubes is only a five or six dollars. In any case, pump choices should be made based on manufacturer’s recommendations, applications and customer satisfaction.

#### 4.4.2 Auxiliary Equipment

To save wear and tear on the pumps and their associated components, Y-strainers should be placed on the suction side of the pumps. Even if a high quality sodium hypochlorite is used, the strainers are designed to catch PVC shavings from occasional piping repairs.

An anti-siphon or backpressure valve should also be used on the discharge of all pumps, particularly with diaphragm metering pumps, to prevent the level in the bulk storage tank from bleeding through the pump when it isn't running and to prevent the tank level from impacting the actual pump feed rate. Additionally, the use of this equipment, if properly set, will extend the life of the metering pump components.

Use of pulse dampeners is strongly recommended for the discharge of diaphragm pumps when feeding in excess of 12 gph of sodium hypochlorite and is absolutely required for diaphragm pumps in excess of 20 gph. It is acceptable to run a large diaphragm pump for a short time without the use of a pulse dampener until they can be repaired or replaced, but extended use without using one will cause the wear parts in the diaphragm pump to prematurely fail (e.g., ball check valves, seats and threaded connections) and cause system piping leaks. The pulse dampener should be placed directly on the discharge of the pump as it does little good to place several feet downstream of the pump on the discharge piping. In addition to acting as a system "shock absorber", pulse dampeners also will level out the discharge of the pumps into a continuous stream rather than "spurts". The use of pulse dampeners with peristaltic pumps can be beneficial but is not as critical to the system operation with these types of pumps. Pulse dampeners should also be used as an "inlet stabilizer" on the suction of any diaphragm pump which is in excess of 100 gph.

Bleed valves or bleed piping should be installed on the discharge of a diaphragm pump to facilitate clearing the air out of a "vapor-locked" pump. Generally, bleeding 100 ml to 200 ml is satisfactory to clearing the air out of the pump and returning it to service.

Pump discharge pressure relief valves are recommended for most applications when using metering pumps. If the pump is capable of pumping against over 100 psi, a pressure relief valve should definitely be used to prevent causing either immediate piping failure or weakening the piping system leading to subsequent failures. The relief valve can be pumped back to the suction side of the pump or back to the bulk storage tank. Either solution is acceptable. It is generally not that critical to use a pressure relief valve with solenoid diaphragm pumps rated for less than 100 psi because most simply stop pumping.

Pressure gages should be placed on the discharge of most metering pumps depending upon the application to set pressure relief settings, backpressure settings and to monitor for calcification buildup, scaling or other blockages on the feed line.

Strong consideration should be given to using a "pump skid" whereby all of the auxiliary equipment, including a NEMA 4X electrical box for all of the power and control wiring, would be housed, on typically a welded PVC frame. The pump skid has the following advantages: (1) It puts all of the auxiliary equipment in a very small area; (2) Is portable and can be easily relocated; (3) Removes the need to have a large wall area set aside to



mount equipment; (4) Significantly reduces any chance of having “vapor-lock” and “off-gassing” issues with sodium hypochlorite systems because the piping is designed properly; (5) Takes advantage of shop machining and workmanship as opposed to the “Low Bidder” contractor who does not specialize in doing the intricate piping on a daily basis; (6) Minimizes propensity of sodium hypochlorite to cause piping leaks because of its highly corrosive nature; (7) Facilitates system maintenance; and (8) Less expensive in long-run when installation and maintenance costs are factored in.

## **4.5 Piping**

### **4.5.1 Poly Vinyl Chloride (PVC) Pipe**

Typical choice for low-pressure piping is PVC Schedule 80 socket welded (e.g., glued) pipe and fittings. Do not use threaded joints for sodium hypochlorite connections unless it can not be avoided. If threaded connections must be used, threads must be new, sharp and secured with a caustic resistant Teflon tape or paste. Since tape quality tends to be inconsistent, specify a Mil Spec P-27730A-rated tape. Only 1-2 wraps should be made on the threads. If more wraps are made, this causes the fittings to crack over time.

Generally, sodium hypochlorite should be pumped “neat” without the use of “carry water”. For “neat” applications, pipe size should be carefully selected to maintain a sodium hypochlorite flow velocity of between .5 feet/second and 7 feet/second. A slower velocity will contribute to gasification and crystallization, whereas a higher velocity will contribute to a shearing effect that will separate the sodium hypochlorite into alternating slugs of gas and liquid thereby shortening the life the chemical feed equipment and resulting in potential air-lock of the pumps and impacting the accuracy of the downstream dosing. Better results will be achieved if the velocities are kept between 1.5 feet/second and 7 feet/second. Another consideration for pipe sizing is that the sodium hypochlorite molecule in the piping should be “moved” through the system in four hours or less to prevent buildup of gases and unnecessary product degradation. To maintain flow velocity, ells, bends, tees (to a lesser degree), and alternating of piping sizes should be avoided as much as possible.

PVC piping should not be used for high pressure, typically above 100 psi, since failures may result in potential injury. For larger systems with transfer pumps that operate at pressures above 50 psi and use PVC, the use soft start motors on pumps and slow opening and closing valves if automated valves are used to start and stop flows is recommended. Care must be taken to use an industrial grade cleaner and glue for the PVC and to follow the manufacturer’s installation instructions. PVC installed outside should have UV protection (e.g., paint).

The following installation instructions are recommended to ensure “leak-free” joints:

- Machine cut the PVC pipe. Completely “debur” and sand the edges of the pipe.
- To fit the tapered socket, bevel the end of the PVC pipe between .0625 and .0938 inches (1.563 to 2.345 mm) for pipes up to 8 inches (200 mm) in diameter.
- Lightly sand tapered socket to ensure that it is completely “deburred”.
- Use industrial grade cleaner to clean the end of the pipe such as MEK cleaner.
- Apply primer to the female fitting.
- Apply primer to the male fitting.

- Reapply primer to the male fitting (surface must be kept wet from previous steps).
- Apply glue to the pipe using a brush with a width half the diameter of the pipe (too small of a brush will let the primer or glue evaporate before the application can be finished; too large of a brush can result in excess glue in the pipe after assembly).
- Apply glue to the female fitting.
- Reapply glue to the pipe.
- Insert pipe to bottom of fitting with a quarter turn.
- Hold for 30 seconds.

Note: Use the gray IPS Weld.On CPVC 724 plastic pipe cement if time permits. The glue should be allowed to cure for at least 24 hours. If time more critical, use E-Z Weld.On Wet "R" Dry 725 glue (for PVC). This glue will thoroughly dry in about two hours and piping can be put into service in 10 minutes for low pressure applications. When gluing the K-flex or flexible PVC into a PVC union or connector, the 725 glue should be used because it is more flexible and springy.

Other piping systems of non-metallic materials can be used; the best is probably Kynar®. Kynar requires a much higher level of expertise for installation and maintenance since each connection must be threaded or welded. A complete review of the piping systems with the manufacturer should be done if one of these alternative materials is used. Additionally, the use of Kynar® typically adds about four times to the cost of the installation. Also, all connections with Kynar piping must be either welded with a Kynar welder or threaded. Socket welding with glue cannot be used.

#### **4.5.2 Lined Pipe**

For high pressure applications or to achieve a very long service life, a lined piping system typically consisting of steel piping with Teflon® or Kynar® liners should be used. For this type of design, fittings and pipe are a 150# flanged design. These systems are expensive but can result in 20-30 year service life. Typical applications include heavy industrial facilities such as pulp and paper or power plants.

#### **4.5.3 Titanium Pipe**

Lightweight schedule 5 and 10 titanium pipe can be used for very long runs for sodium hypochlorite. These are welded systems with carefully designed expansion joints. In some larger piping systems, titanium can be a cost effective method of piping compared to a lined pipe system and better performance can be achieved since most flanged joints are avoided.

#### **4.5.4 Fiberglass Reinforced Poly (FRP) Pipe**

Standard FRP available from the typical manufacturer is not successful in sodium hypochlorite applications. If the pipe is specified and manufactured correctly with the right materials, corrosion barriers and catalysts systems, FRP can be successful. However, the normal purchaser of pipe and fittings does not have the expertise for these FRP piping systems and they should be avoided.

### **4.6 Pipe Supports**

In general, pipe supports should be placed every 24" to 48" on storage tank fill lines and at least every 48" on all other lines. Many local codes require support every 48" but requirements can vary. Fill-lines are subjected to a lot of stress because the sodium

hypochlorite is typically off-loaded from the delivery tanker with air and thus should have supports much more frequently in the first few feet of pipe from the fill connection. As recommended previously, bulkhead fittings on the sides of storage tanks should be properly supported to minimize the stress on the side of the storage tank but still allow for the squatting of the tank when it is filled. FRP uni-strut or PVC U-brace material is preferred for use with sodium hypochlorite since it is compatible with sodium hypochlorite although fill lines should probably have metal piping supports on the piping near the end due to the stress on these lines.

## **4.7 Valves**

In general the valve materials should match the piping system in similar construction for compatibility and weight considerations. However, the first tank valve on the outlet of the storage tank should be of very high quality and a lined steel or PVC plug, ball, or butterfly valve should be considered. Vented, true-union ball valves should be considered for isolation valves for pipe that is exposed to the hot sun or for situations where high quality sodium hypochlorite is not available in the marketplace. In general, it is good engineering practice whenever using ball valves with sodium hypochlorite to drill a small hole in the downstream side of the valve to allow the escape of any gas that may build up in the line. Many manufacturers also sell valves with these holes pre-drilled.

Many different types of valves have been successful in sodium hypochlorite. However, seats should typically be Teflon® and rubber compounds should be Viton® for O-rings and diaphragms.

Ideally, only flanged or socket welded valves should be used. Do not use threaded connections. However, many users use a “union-style” ball or diaphragm valve to facilitate replacement for a valve failure. While these valves provide a leak path past the O-ring seal at the union joint in the event of failure, they can be used if the valve can be easily replaced and a small amount of downtime (e.g., 1-2 minutes) is not important. Ball valves tend to work extremely well in sizes of 2” or smaller and are typically used in this application. For larger valves, consideration should be given to other types of valves.

## **4.8 Eductors**

Eductors may be used for sodium hypochlorite feed applications in lieu of pumps for uses such as in water or wastewater treatment plants. The main advantage to using eductors is to minimize conversion costs from chlorine gas to sodium hypochlorite since chlorine gas is typically fed through an eductor system. In this application the eductor would be required to be changed out but most of the piping could be re-used and the cost of pumps could be avoided. A second advantage may be enhanced mixing at the point of application (e.g., clarifier weir in a wastewater treatment plant). A final advantage may be for applications where no electrical power is available or for emergency situations. However, the use of eductors to feed sodium hypochlorite can cause any hardness in the sodium hypochlorite and “carry water” to precipitate out as calcium carbonate and plug not only the eductor but the downstream piping as well. Typically, eductors will only work in applications where the carry water has a relatively low hardness level (e.g., less than 150 ppm) and the volume of carry water is relatively high to the volume of sodium hypochlorite that it carries (e.g., to minimize the increase in the pH of the carry water). To ensure the successful operation of an eductor, it is

recommended that only “softened” water be used and that the total hardness be kept less than 40 ppm and the pH of the resulting solution be maintained less than 9. Another option to using eductors with relatively high hardness (e.g., above 150 ppm) is to frequently clean the eductors and downstream piping. This is typically done with a weak acid solution and care must be taken to avoid off-gassing of chlorine from any contact with the sodium hypochlorite. Additionally, it is best to minimize the length of piping that the sodium hypochlorite is “carried” before the injection point (e.g., contact chamber). Eductors are typically used where no automatic mode of control to regulate flow with a 4-20 ma signal is required. If automatic control is required, the cost of the control valves will probably equal or exceed the cost of diaphragm feed pumps and thus the use of eductors may not be the most economic choice.

#### **4.9 Gaskets**

When low torque is required for non-metallic systems, Viton® or expanded Teflon (WR Gore) should be used. Rubber gaskets coated with silicone are also a second choice that will work as well. EPDM gaskets should not be used unless frequent replacement (e.g., every six to nine months) is not considered burdensome. The harder Teflon® gaskets should not be used in a low torque application.

Teflon® gaskets are a good choice for lined pipe systems mating to a titanium flange such as pumps and heat exchangers.

Due to cost considerations, plate and frame heat exchangers use EPDM have provided acceptable results despite more frequent replacement.

#### **4.10 Instrumentation**

The most important item concerning instrumentation is that only titanium, tantalum, or nonmetallic components be used for contact with the sodium hypochlorite. For pH, ORP and magnetic meter electrodes, silver, platinum, gold, tantalum or titanium are the only materials acceptable if a metal is required.

Since only small amounts of nickel will decompose sodium hypochlorite rapidly, Hastelloy must never be used. Hastelloy in most corrosion books under sodium hypochlorite may indicate an acceptable corrosion rate for equipment components. However, the nickel from the Hastelloy will decompose the product. It must be realized that corrosion tables indicate corrosion rates for the metal in a given product and no consideration is provided for the effect on the product.

Since there are many types of instrumentation applications, no attempt is made to review all of them. However, in critical flow applications typically magnetic flow or mass flow instrumentation is used and flow is controlled with very high quality lined steel ball or globe style valves with 50 to 1 turn down ratios. These valves are typically air to open, spring to close with 4-20 mA positioners. Electrically driven control valves are only moderately successful for long service life applications and may not provide the desired control.

#### **4.11 Handling**

Sodium Hypochlorite is considered a hazardous material at any strength (Department of Transportation CFR 49). Even though it is largely composed of water, it should be

handled with due care using of aprons or chemical resistant clothing and goggles in a well-ventilated area. It should be store in vented, closed containers that provide protection from direct sunlight if possible. It should be kept separated from incompatible substances and should not be stored near acids, heat, or oxidizable materials or organics. When handling, it should not be mixed with other cleaning agents that may liberate chlorine gas vapors (e.g., acidic agents). An emergency eyewash station and safety shower should be available anywhere the solution is likely to be handled and at in particular at the loading station for the bulk storage tanks.

The product should be stored and handled in accordance with all current regulations and standards including NFPA 430 Code for the Storage of Liquid and Oxidizing Materials. Additional information can be found in Reference 5.7.

## 5.0 References

### 5.1 **Minimizing Chlorate Ion Formation in Drinking Water when Hypochlorite Ion is the Chlorinating Agent**

Published by American Water Works Association (AWWA) Research Foundation

Prepared by Gilbert Gordon and Luke Adam, Miami University, Oxford, Ohio & Bernard Bubnis, Novatek, Oxford, Ohio

Available at: AWWA Research Foundation

### 5.2 **The Weight Percent Determination of Sodium Hypochlorite, Sodium Hydroxide, Sodium Carbonate and Sodium Chlorate in Liquid Bleach (1250)**

Prepared by Bernard Bubnis, Novatek, Oxford, Ohio

Available at: [www.odysseymanufacturing.com](http://www.odysseymanufacturing.com)

### 5.3 **Suspended Solids Quality Test for Bleach Using Vacuum Filtration (3370)**

Prepared by Bernard Bubnis, Novatek, Oxford, Ohio

Available at: [www.odysseymanufacturing.com](http://www.odysseymanufacturing.com)

### 5.4 **Liquid Sodium Hypochlorite Specification**

Adapted for use from East Bay M.U.D. (City of Oakland Utilities Dept.)

Available at: [www.odysseymanufacturing.com](http://www.odysseymanufacturing.com)

### 5.5 **Health Effects of Disinfectants and Disinfection By-products**

Prepared by R.J. Bull and F. Kopfler

Available at AWWA Research Foundation

### 5.6 **Sodium Hypochlorite Fiberglass Reinforced Plastic (FRP) Storage Tank Specification (250spec)**

Adapted for use by Odyssey Manufacturing Co.

Available at: [www.odysseymanufacturing.com](http://www.odysseymanufacturing.com)

### 5.7 **Sodium Hypochlorite Safety and Handling, Pamphlet 96**

Prepared by The Chlorine Institute, Inc.

Available From: The Chlorine Institute, Inc. ([www.cl2.com](http://www.cl2.com))