Sodium Hypochlorite

General Information for the Consumer

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Odyssey Manufacturing Co.

Manufacturers of Ultra-Chlor Bulk Sodium Hypochlorite

1484 Odyssey Massaro Boulevard Tampa, FL 33619

Phone 800-ODYSSEY (Florida Only) Fax 813-630-2589

website: www.odysseymanufacturing.com

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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:

Cl_2	+	2 NaOH	=	NaOCl	+	NaCl	+	H_2O
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:

$$NaOCl + 2KI + 2HAc = I_2 + NaCl + 2KAc + H_2O$$

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

$$Cl_2 + 2KI = I_2 + 2KCl$$

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.

Trade % = 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.

Weight % available chlorine = gpl / (10 x specific gravity)
Or Trade % / specific gravity

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 chorine into its equivalent as sodium hypochlorite by multiplying the ratio of their respective molecular weights:

Weight % available chlorine x $NaOCl/Cl_2$ = weight % NaOCl
where $NaOCl/Cl_2$ = 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_2

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.

2.4.1 Chlorate Formation Decomposition Pathway

The dominant pathway is as follows:

$$3NaOCl = 2NaCl + NaClO_3 \text{ (Chlorate)}$$

Chlorate Formation can be created can be created two major ways: (1) At time of Production; and (2) After Production as part of normal degradation.

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 (i.e., "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.

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:

$$\text{Rate} = K2(OCL^-)^2 \quad \text{(Reference 6.1)}$$

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^{nd} 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 southern US where there are higher temperatures and thus higher decomposition rates, the Purchaser would typically specify a minimum of 120 GPL available chlorine. In the northern US where there are lower temperatures, the Purchaser would typically specify a minimum of 150 – 160 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.

2.4.2 Oxygen Formation Decomposition Pathway

The minor decomposition pathway of sodium hypochlorite is as follows:

$$2NaOCl = 2NaCl + O_2$$

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, especially if it contains heavy metals or the piping transit time is too long. 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 problem is the experience of some producers and consumers with PVC ball valves and piping exploding occurs when the valves are shut and piping sections are isolated for long periods of time for piping exposed to heat. The explosion occurs 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 of 5% - 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 Manufacturing

3.1 Bulk Sodium Hypochlorite

"Bulk" Sodium Hypochlorite is produced from the reaction of chlorine gas (Cl_2) and sodium hydroxide (NaOH) in a reactor using a continuous method or a batch method. The source of the chlorine gas may be a railcar, returned chlorine cylinders ("sniff" bleach) or from an adjacent chlor-alkali plant (which manufactures chlorine and caustic using a divided cell electrolysis process). The following is a summary of the reaction:

$$Cl_2 + 2\ NaOH = NaOCl + NaCl + H_2O$$

Typically, bulk sodium hypochlorite is manufactured in delivered strengths of 120 – 160 GPL. At higher strengths, the reactor used to make the sodium hypochlorite will "salt-up" at strengths in the 170 – 200 GPL range. Some manufacturers are now making a "low-salt" sodium hypochlorite which can be manufactured in ranges of 210 – 250 GPL.

3.2 On-Site Sodium Hypochlorite Generation (OSHG)

Sodium Hypochlorite can also be produced on-site through an open cell electrolysis process using an on-site sodium hypochlorite generation (OSHG) system. There are four major manufacturers of these systems in the United States: (1) Underground Solutions (formerly Process Solutions) MicrOclor; (2) Siemens OSEC; (3) W&T ClorTec; and (4) MIOX OSG. The MicrOclor system now has the majority of the installations in the United States because of its vertical, vented to atmosphere cell design which has revolutionized the industry by solving the chronic safety problem of hydrogen gas removal. These systems produce a weak nominal 0.8% solution. The following is a summary of the reaction:

$$NaCl + H_2O = NaOCl + H_2$$

4.0 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, perchlorate and sodium bromate levels, and utilizing correct storage and handling of the product, the following benefits are achieved:

- Low perchlorate levels in the delivered sodium hypochlorite (perchlorate is believed to be a carcinogen)
- Low chlorate levels in the delivered sodium hypochlorite (chlorate is believed to be a carcinogen)
- Low bromate levels in the delivered sodium hypochlorite (bromate is believed to be a carcinogen)
- 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.

4.1 Strength

The strength of the sodium hypochlorite is determined by titration. See Reference 6.2 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.

4.2 Excess Sodium Hydroxide (a.k.a., Caustic)

The strength of the excess caustic or alkalinity of the solution is determined by titration. See Reference 6.2.

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 0.20% and pH of 12.5 should be specified to minimize product instability and degradation for a 120 GPL solution. The “ideal range” for excess caustic should be between 0.30% and 0.40% for a 120 GPL solution.

If the sodium hypochlorite will be diluted and stored after the consumer receives it, the initial excess caustic percentage may be higher than the 0.40% since dilution will decrease the excess caustic percentage of the solution.

At higher levels of excess caustic above 0.45% (for a 120 GPL solution), decomposition rates can begin to increase and rapidly accelerates above 0.50%. Therefore, a maximum excess caustic of 0.45% should be specified for a 120 GPL solution (except for plants either receiving a 150 GPL solution or diluting the hypochlorite and then the maximum should be 0.50%). 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.

Excess caustic is not necessary for sodium hypochlorite product stability for low strength (typically about 0.8%) produced from on-site sodium hypochlorite generation (OSHG) systems.

4.3 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 has 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. It may be formed in the customer’s tank as well during the off-loading process from carbon dioxide and carbon monoxide in the air used to pressurize the tanker.

The only case sodium carbonate may be a problem to the user is if the product has a high level of suspended solids or in a tank where the level of suspended solids has slowly accumulated over many years. 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 that look and feel like paper. Over time this will result in a system that needs frequent servicing due to plugged pumps, piping and instrumentation. The solution is to empty the tank through a bag filter and pressure wash the tank to remove the remaining sodium carbonate.

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 or there are high levels of suspended solids. Please refer to the suspended solids testing discussed below.

4.4 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.

4.5 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 6.3) 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 25" 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 used to manufacture the sodium hypochlorite 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. This is because the chlorine and caustic 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.

4.6 Sodium Chlorate

Sodium chlorate is currently not “directly” regulated by the EPA. Toxicological information on the chlorate ion is limited with only acute chlorate toxicity having been addressed (see Reference No. 6.5). Under the Disinfectant/Disinfection By-Products Rule, the EPA has expressed its intention to set allowable chlorate ion levels. Many state rules specify practices to limit the amount of chlorate and chlorate formation. In the meantime, ANSI/NSF Standard 60 now specifies the maximum amount of chlorates for a given dosage. Most state regulatory agencies that regulate drinking water required producers to get a third party certification that its product(s) meet the ANSI/NSF Standard 60. Thus, these third party certifiers are now testing the sodium hypochlorite it intends to certify for sodium chlorate on an annual basis and setting maximum feed rates for each product that it certifies based on a maximum chlorate rate. Thus, chlorate ion levels are should be kept as low as possible. The typical limit of chlorate in the delivered bleach is 1,500 mg/liter or ppm equivalent for 120 GPL sodium hypochlorite and 2,000 mg/liter for 150 GPL sodium hypochlorite. 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.

4.7 Nickel & Copper

Typical specifications of nickel and copper are 20 PPB (parts per billion) or less each. 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.

4.8 Iron

Typical specifications for iron are less than 0.35 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 0.35 PPM, the hypochlorite is either filtered or made from a chloralkali-bleach plant.

4.9 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, was set at 10 ppb, and became effective for all drinking water systems beginning in January of 2004. Under current ANSI/NSF Standard 60 guidelines, only 30% of this amount can come from the sodium hypochlorite. The primary source of bromate in drinking water is from the reaction of ozone and bromide ions found in raw (untreated) water. Bromate can be found in sodium hypochlorite and comes from bromine in the chlorine and caustic used to make sodium hypochlorite. The bromine comes from the bromide ion found in the salt used to make the caustic and chlorine. In a chlor-alkali plant which uses diaphragms (i.e., makes diaphragm grade caustic), 80% of the bromine produced goes into the caustic and only 20% goes into the chlorine. In a chlor-alkali plant which uses membranes or a mercury cell plant (i.e., makes membrane grade caustic), 80% of the bromine produced goes into the chlorine and only 20% goes into the caustic.

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 30% limit. The sodium hypochlorite manufacturer can limit the bromate levels in the hypochlorite by selecting chlorine and caustic suppliers that have low amounts of bromine. For example, using membrane grade caustic and diaphragm cell chlorine will yield lower levels of bromine. For chlor-alkali plants that make hypochlorite, selection of the salt used (i.e., salt low in bromide) will result in lower bromate levels. Until the marketplace regulates bromate more closely, the sodium hypochlorite manufacturers will not alter their manufacturing processes or raw material sources to lower bromate levels!

4.10 Perchlorate

Perchlorate affects the ability of the thyroid gland to take up iodine. This would affect the functions of the thyroid gland and its performance in the body. Perchlorate is a product of sodium hypochlorite decomposition. The longer hypochlorite is kept by the utility before use, the more likely the significant increase in perchlorate. Also, the development of perchlorate's use in rocket propellants and the improper disposal of wastes from the manufacture of these propellants has been a cause for the appearance of perchlorate in raw water supplies.

The U.S. EPA has issued preliminary rule-making statements that they intend to regulate perchlorate in drinking water because of its adverse health effects. Currently, they have issued an advisory limit of 15 ppb in each liter of drinking water. Perchlorate is currently regulated in several state including California, New Jersey and Massachusetts. In the meantime, ANSI/NSF Standard 60 now specifies the maximum amount of perchlorates for a given dosage. Most state regulatory agencies that regulate drinking water required producers to get a third party certification that its product(s) meet the ANSI/NSF Standard 60. Thus, these third party certifiers are now testing the sodium hypochlorite it intends to certify for sodium perchlorate on an annual basis and setting maximum feed rates for each product that it certifies based on a maximum perchlorate rate. Thus, each utility should specify maximum perchlorate levels in the delivered hypochlorite to less than 15 ppm. At this rate and assuming an 8 mg/L chlorine dose, this would raise the perchlorate levels in the drinking water by 15 ug/L or 15 ppb which is the EPA Health Advisory Limit.

5.0 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.

5.1 Transportation

5.1.1 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 rubber-lined 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 or liner 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 fifteen years.

Since failure of these corrosion barriers or 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 in a steel-lined tanker should start to fail during the yearly period between inspections, the purchaser may notice three 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).

If the corrosion barrier in an FRP tanker should start to fail during the yearly period between inspections, the purchaser may notice fiberglass pieces in the sodium hypochlorite. For this reason, the customer should have either a strainer or bag filter on the incoming fill line to their tanks and they should inspect this strainer or filter after each delivery. Additionally, the distributor making the delivery should have a strainer on the tanker piping as well which should be inspected after each delivery.

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 and can plug the feed equipment. 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.

5.1.2 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 (a.k.a. “Megatainers” or “IBC’s”). Distributors mount up to eight of these tanks on the back of a flatbed truck or ship them inside enclosed trailers. These “containers” are either offloaded at the customer’s site or the sodium hypochlorite is pumped out of them into the customer’s tanks.

5.1.3 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.

5.2 Storage Tanks

5.2.1 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. Lined concrete tanks have also been used to store large quantities of low strength sodium hypochlorite produced from on-site sodium hypochlorite generation.

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.

5.2.2 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 both cross-linked tanks along with linear tanks can be used 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 tank lives are based on a hot weather climate like Florida. Tank lives will increase the farther north one goes. Based on the relatively short live span of these tanks, they 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, 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 "upsize" the cracked fitting and install a plug and then put in a new fitting on another spot on the tank. In either case, upsizing the fitting typically only increases the life of the tanks by anywhere from 6 months to two years. 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. It is not recommended to try to weld a cracked tank anywhere near the bottom of the tank as the tank will certainly fail again at the same spot in less than thirty (30) days. However, welding cracks has helped prolong HDLPE tank life when the crack is on the top or crown of the tank.

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 6-36 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.

5.2.3 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 10 – 12 years 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. Additionally, tank manufacturers who are certified by ASME RTP-1 should only be used. Strong consideration should be given to purchasing FRP tanks which are certified as RTP-1. This certification involves a lot of additional "QA Procedures" to build the tank and typically adds about $2,500 - $10,000 to the cost of the tank but is probably worth it to ensure a high quality tank. If an FRP tank is re-lined, one will typically get an additional 6 – 8 years out of the tank. Temperature plays a large role in determining the life of a tank. If possible, FRP tanks should be located indoors in an air-conditioned environment to maximize the life of the tanks.

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 6.6 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.

5.2.4 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.

5.2.5 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.

5.2.6 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. A concrete block wall, even if it is poured, typically offers a very poor containment since it is much more porous than a poured wall and will typically leak out sodium hypochlorite. 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 "tub" 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 $1.00 - $1.50 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, mineral acid and fuel tanks. 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 because the permitting rules incorporate the Ten State Standards which requires containment. Additionally, most sodium hypochlorite suppliers in Florida will not deliver to a tank unless it has containment because of liability reasons. Additionally, some Florida counties (notably Broward and Alachua), through ordinance or the building or fire code, regulate the placement and containment requirements for all chemical storage tanks including sodium hypochlorite. In any case, good engineering practice dictates that containment or double-walled tanks be utilized. The containment guidelines above are typically applied to amounts of storage over the Reportable Quantity (RQ) for a Spill which is approximately 100 gallons (based on 120 GPL sodium hypochlorite).

5.2.7 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 hypchlorite 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, overfilling 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)); or (2) Large Water Treatment or Wastewater Treatment plants with a single large bulk storage tank.

5.2.8 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 $1,000 to $4,000 depending on the manufacturer and size of the tank. FRP, Galvanized Steel and SS316 (this is the order of preference for longevity) “feet” should be used for the tie-down systems with SS316 or galvanized steel cables. These materials hold up best over time.

5.2.9 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.

5.2.10 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 6' 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 which inevitably will leak at some point. Typical pricing for rubber hose compatible with sodium hypochlorite vary from $10 to $20 per foot. The "K-flex" can be attached to a PVC connector with glue (i.e., "socket welded"). Only the "blue glue" (see 4.5.1) should be used for this application, however. Another option is a flexible connection constructed of Teflon with a spring wrapped around it with flanges on either end. These fittings tend to be very expensive. The installer should confirm the amount of vertical and horizontal deflection before using these fittings. One manufacturer (Snyder) makes 2" and 3" HDLPE flexible connections for the bottom of their tanks which work fairly well and are slightly less expensive than the flanged flexible fittings but they take up a lot more room.

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 (if possible). Off-gassing 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. These tables were developed based on 12 Trade Percent (120 GPL) sodium hypochlorite solution. The piping sizes can be increased or decreased without any adverse effects if using a 0.8% OSHG system sodium hypochlorite solution.

TABLE 5.2.10.1: 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 peristaltic chemical feed pump(s). This distance should be minimized to the maximum extent possible.

Note 2: The "0 ft." distance is the recommended piping size 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. These lines are typically smaller to maintain a suction lift.

TABLE 5.2.10.2: 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'	¼"-½"	½"	½"	½"	¾"	¾"	¾"	1"	1"	2"
10'	¼"-½"	½"	½"	½"	¾"	¾"	¾"	1"	1"	2"
25'	½"	½"	½"	½"	¾"	¾"	¾"	1"	1"	2"
50'	½"	½"	½"	¾"	¾"	¾"	¾"	1"	1"	2"
75'	½"	½"	¾"	¾"	¾"	¾"	¾"	1"	1"	2"
100'	½"	½"	¾"	¾"	¾"	¾"	¾"	1"	1 ½"	2"
150'	½"	¾"	¾"	¾"	¾"	¾"	1"	1"	1 ½"	2"
200'	½"	¾"	¾"	¾"	1"	1"	1"	1"	1 ½"	3"
300'	¾"	¾"	1"	1"	1"	1"	1"	1 ½"	2"	3"
500'	¾"	1"	1"	1"	1"	1 ½"	1 ½"	1 ½"	2"	3"

Note 1: Maximum Distance recommended is about 500' (including allowance for 90 degree elbows). This distance should be minimized if possible. However, 12% sodium hypochlorite has been successfully pumped up to 800'. 0.8% sodium hypochlorite solutions have been successfully pumped to up to 1,400'.

Note 2: The "0 ft." distance is the recommended piping size from the transition of the feed line to each individual pump itself.

5.2.11 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 sometimes crack the first time the gasket is changed. In most cases, but not all, this is caused by the repair crew "over-torqueing" the bolts on the flanged connection. A torque wrench should be used and in no case should 25 ft*lbs be exceeded when torqueing the bolts on these flanges. 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"). For plastic tanks especially, it is strongly recommended that the vent line be upsized at least one size larger than the fill line. Generally, a 3" vent should be used on all tanks less than 5,000 gallons. Consideration should be given to increasing this to a 4" vent if the tank can handle the additional weight of the vent or if the vent is to be run outdoors (i.e., not a simple U-vent). A 4" U-vent should be used on large tanks (over 5,000 gallons) and if the vent line is run out of the building and can be supported consideration should be given to using a 6" vent for larger tanks. Some tank manufacturers specify the required size vents in their Tank Installation Instructions and will not honor a tank warranty if the specified vent size is not used. The vents should have a 24-mesh 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., >50') 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. They also can stir up sediment on the bottom of the tank leading to feed pump failure. An overflow connection with a pipe to a suitable containment basin should be used if practical (this is not always practical to install, particularly with double-walled tanks). High limit switches or floats tied to a local alarm or a requirement to have the customer monitor the fill process (along with the delivery driver) both help to minimize the likelihood of a tank being overfilled. The overflow should be placed as high up as possible on the tank to maximize the amount of usable storage space in the tank. Without an overflow connection, the sodium hypochlorite would run out of the vent and/or the tank man-way if there is no overflow. 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 22" or larger man-way is strongly preferred. Most HDLPE tank manufacturers offer the 16" man-way as their standard and a 22" man-way as an option for an additional $100 - $200. FRP tanks will often have inspection man-ways on the side in lieu of the top. This is preferred because it facilitates future tank relining. Most FRP Tank repair companies will not reline a tank if it does not have a side access manway because of safety concerns relative to the workers doing the relining. It is not possible to install a side man-way 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 (or gas-free the tank and monitor air quality if no respirator is used). 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 (on a small tanks a "dipstick" can be used instead of a sight-glass to measure level through the man-way cover). Complete reliance on ultrasonic or radar 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 in sodium hypochlorite applications. 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 - 12 months and it requires a tank entry to replace the rope or cable. 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 several inches of sludge. This sludge is filled with metals and should be disposed of as hazardous waste.

5.3 Materials of construction

5.3.1 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, Hastolley®, Monel®, brass, or copper should be avoided at all cost. Hastolley®-C, has been used for springs in some parts (e.g., ball check valves) and typically the springs last about 12 – 24 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.

5.3.2 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® (a.k.a. PVDF), 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.

5.4 Pumps

5.4.1 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. However, several entities have installed “looped systems” where hypochlorite is fed into the loop by a centrifugal pump and rotameters are used to feed the hypochlorite from the loop at each injection point.

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., $800 to $1,400) centrifugal magnetic drive pumps that last six months to two years 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 million gallons per day (MGD). There are three types of diaphragm pumps: (1) Hydraulic; (2) Mechanical; and (3) Solenoid. 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). Typically, this 4-20 ma input signal changes the pump speed but some manufacturers make pumps that can automatically regulate the stroke length as well. 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 is 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 –36 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. These pumps are a good choice when the storage tanks are located >30' from the feed pumps. They are not typically a good choice when pumping into pressurized systems (i.e., >50 psi) because the tube life is severely impacted. Historically, larger peristaltic pumps using hoses (>100 gph) have been very expensive to purchase and operate due to the high cost and frequency of the hose replacement.

Gear pumps have historically been used to successfully pump viscous and heavy products such as polymer. Some customers have had success with them in pumping weaker 0.8% hypochlorite solutions. Some manufacturers are touting their use for higher strength (12 Trade Percent) sodium hypochlorite applications but there is not enough data in the marketplace to support whether this is viable or not.

New products are entering the marketplace, however, and this may change customer preferences. In any case, pump choices should be made based on manufacturer's recommendations, proven track records, specific applications and customer satisfaction.

5.4.2 Auxiliary Equipment

To save wear and tear on the pumps and their associated components, 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. Three-roller Peristaltic pumps do not initially require a backpressure valve but as the hoses or tubes wear they become susceptible to siphoning as well (our experience is that the two-roller peristaltic pumps are very susceptible to siphoning). Additionally, the use of this equipment when 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 5 gph of sodium hypochlorite and is absolutely required for diaphragms pumps in excess of 10 gph. The only exception would be the new digital dosing diaphragm pumps which do not appear to require pulse dampeners up to 70 gph feed rates. They are also recommended for peristaltic pumps feeding more than 10 gph as their use appears to extend tube life. 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 150 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 or to prime the pump when the system is initially started up. 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 solenoid pumps are used, the solenoid pump will stop pumping when it reaches the flow of liquid is stopped. Mechanical Diaphragm and peristaltic pumps will keep pumping, however, until the system weak point (which may or may not be the pump) gives out. 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.

A pressure gage should be placed on the discharge of each metering pump (or at least on the discharge piping) to set any pressure relief valves, backpressure valves and to monitor for calcification buildup, scaling or other blockages on the feed line. Additionally, the pressure gage may detect a piping failure on the discharge piping.

Strong consideration should be given to using a "pump skid" whereby the feed pumps and 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 using day laborers to do piping 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.

5.5 Piping

5.5.1 Poly Vinyl Chloride (PVC) Pipe

Typical choice for low-pressure piping is Schedule 80 PVC 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. Schedule 40 PVC may be used for vent lines.

Generally, sodium hypochlorite should be pumped "neat" without the use of "carrier 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 these applications, consideration should be given to using Schedule 80 CPVC or one of the piping systems discussed later in this chapter. 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). Typically Schedule 80 PVC only lasts about 10 – 12 years in hypochlorite service before it begins to develop leaks causing by cracking of the pipe from embrittlement (this is a byproduct of continuous hypochlorite exposure).

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.

5.5.2 Chlorinated Poly Vinyl Chloride (CPVC) Pipe

Schedule 80 CPVC piping can be used for sodium hypochlorite use and has better strength (for higher pressures) and UV ratings (for piping exposed to UV). However, it has one serious drawback in hypochlorite applications in that it becomes very brittle over time from hypochlorite exposure and can shatter like glass if bumped. This is only likely in the 7 – 9 year range as far as age of the piping. Since it is about twice the cost of Schedule 80 PVC and has this severe embrittlement issue, it is generally not recommended for sodium hypochlorite use.

5.5.3 Alternate Plastics to PVC Piping

Other piping systems of non-metallic materials can be used; the best is probably Kynar® (a.k.a. PVDF). Kynar requires a much higher level of expertise for installation and maintenance since each connection must be threaded or fusion 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 to six times to the cost of the installation. Also, all connections with Kynar piping must be either fusion welded with a Kynar welder or threaded. Socket welding with glue cannot be used. A less expensive alternative material to kynar is HDPE piping which is typically about 2 – 3 times the installed cost of PVC. This piping must also be fusion welded.

HDPE piping has not been shown to last any longer than Schedule 80 PVC piping in sodium hypochlorite applications.

5.5.4 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.

5.5.5 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. These piping systems are typically only used in sodium hypochlorite manufacturing facilities because of their high cost.

5.5.6 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.

5.6 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 SS316 piping supports on the piping near the end due to the stress on these lines. Unfortunately, FRP uni-strut or PVC U-brace material does not hold up over time with heavy pipe (>4”) as it tend to compress and lead to piping failures. Therefore, SS316 strut should be used for pipe supports for piping over 4”.

5.7 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 using butterfly valves since they do not tend to bind up like larger ball valves do. Anything 4” or over should use butterfly valves. The Asahi Type 21 ball valve and Asahi Type 57 butterfly valves are probably the best valves in the marketplace for sodium hypochlorite use. These valves have built-in seat adjustments and have more o-rings than any other valve in the marketplace. Diaphragm valves are not recommended because of their high cost and high failure rates in sodium hypochlorite usage.

5.8 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 chorine 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 will cause any hardness in the carrier 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 50 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 10 ppm as calcium carbonate and the pH of the resulting solution be maintained less than 9. Another option to using eductors with relatively high hardness (e.g., above 50 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.

5.9 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.

5.10 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 should not 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.

5.11 Handling

Sodium Hypochlorite is considered a hazardous material at any strength (Department of Transportation CFR 49). Even thought 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 the local area Building Code and the NFPA-1 Fire Code. Sodium Hypochlorite Storage Areas do *not* require fire sprinkler systems since it is not defined as an oxidizer in NFPA-1, Article 3.5.192 or 70.1 or Appendix B (2015 Edition). Additionally, most Building Codes do not regulate sodium hypochlorite storage in any manner. For example, the 2009 Supplement to the 2007 Southern Building Code (SBC) defines the term "corrosive": "**CORROSIVE**: A chemical that causes visible destruction, or visible alterations in, living tissue by chemical action at the point of contact. A chemical shall be considered corrosive if, when tested on the skin of albino rabbits by the method described in DOT n 49CFR, Part 173.137, such a chemical destroys or changes irreversibly the structure of the tissue at the point of contact following an exposure period of four hours. This term does not refer to action on inanimate surfaces." The bottom line is the sodium hypochlorite is not a corrosive by this very definition since it doesn't cause any visible destruction or visible alterations of the living tissue. Sodium hypochlorite is considered "corrosive" to metal surfaces in the common use of the word but the SBC Supplement definition clearly states that this measure doesn't apply since metals are inanimate objects. Therefore, the provisions of SBC 307.6 (or other articles) do not apply to sodium hypochlorite storage. Additional information can be found in Reference 6.7.

6.0 References

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