Sodium Hypochlorite
General Information Handbook

1.0 Introduction

The consumer of sodium hypochlorite requires an understanding of the product from a chemical and handling perspective. The information below is a brief summary of the product and is intended to assist the consumer to buy the best product, and to store and handle it correctly.

2.0 Chemistry of Sodium Hypochlorite

Reacting chlorine and sodium hydroxide will 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 with sodium hypochlorite as the oxidizing agent. In order to calculate how much sodium hypochlorite is required to replace the oxidizing power of chlorine, the following example is provided. If sodium hypochlorite is used to oxidize iodide in a solution of acetic acid, the following reaction occurs:

NaOCl + 2KI + 2HAc = I2 + NaCl + 2KAc + H2O

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

Cl_2 + 2KI = I2 + 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

In various parts of the world, sodium hypochlorite strength is identified using five common definitions that result in different numbers for the answer although the oxidizing power is the same (i.e. the sodium hypochlorite strength is the same). Although there are other definitions used, due to the infrequency of use, these definitions will not be discussed. The terms to define the sodium hypochlorite strength commonly used in the industry are as follows:

2.2.1 Grams per Liter of Available Chlorine

The weight of available chlorine in grams in one liter of sodium hypochlorite solution. This weight is determined by analysis. Testing methods are available from many sources. Powell has worked with many of these methods and has posted our preferred method on our website at www.powellfab.com. This method was developed to help reduce the typical problems associated with the procedures.

2.2.2 Grams per Liter of Sodium Hypochlorite

The weight of sodium hypochlorite in grams in one liter of sodium hypochlorite solution. It can be calculated by converting the grams per liter available chlorine into its equivalent as sodium hypochlorite by multiplying the ratio of their respective molecular weights:

Grams per liter available chlorine x $NaOCl/Cl_2$ or x 74/71 or 1.05 = grams per liter sodium hypochlorite

2.2.3 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 % Available Chlorine = gpl available chlorine / 10

2.2.4 Weight Percent of Available Chlorine

Dividing the trade percent by the specific gravity of the solution gives weight percent of available chlorine. Typically density measurements will result in errors of 0.5 to 1.0% (i.e. 10% could be 9.90% to 10.10%) when converting from gpl available chlorine to weight percent available chlorine.

Weight % Available Chlorine = gpl Available Cl_2 / (10 x specific gravity)
or Trade % Available Cl_2/ specific gravity

Note: When measuring the specific gravity, measure it at the same temperature as the temperature of the bleach sample used in the bleach strength test.

2.2.5 Weight Percent of Sodium Hypochlorite

The weight percent of sodium hypochlorite is the weight of the sodium hypochlorite per 100 parts of solution. It can be calculated by converting the weight percent of available chlorine into its equivalent as sodium hypochlorite by multiplying the ratio of their respective molecular weights:
Note: When measuring the specific gravity, measure it at the same temperature as the temperature of the bleach sample used in the bleach strength test.
Weight percent available chlorine x $NaOCl/Cl_2$ or x 74/71 or 1.05 = weight percent NaOCl

Weight percent sodium hypochlorite

$$= \frac{\text{gpl available chlorine} \times 1.05}{(10 \times \text{specific gravity})}$$

$$\text{or} = \frac{\text{trade \% Available } Cl_2 \times 1.05}{\text{specific gravity}}$$

or = weight percent 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 calculate the volume and the strength required to replace the oxidizing power of existing chlorine applications, the strength of the sodium hypochlorite purchased must be converted to the equivalent pounds of available chlorine.

For Example:

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 Av. Cl_2 x 3.785 liters/gallon x 2.205 pounds/1000 grams = 1 pound/gallon available Cl_2

Therefore, one gallon of sodium hypochlorite at 120 gpl available chlorine strength will have the oxidizing power as one pound of chlorine.

Other equal terms:

120 gpl available chlorine = 12 Trade percent

or 12/ 1.168* = 10.27* weight percent available chlorine

or 10.27* x 1.05 = 10.79* 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, all test procedures by both the producer and the consumer should calculate the bleach strength in grams per liter available chlorine. Therefore, if gpl available chlorine is used as the indication of sodium hypochlorite strength, the accuracy of this measurement is not dependent on the accuracy of the specific gravity measurement of the product.

If other strengths of sodium hypochlorite are utilized such as 160 gpl, the amount of available chlorine per gallon is the ratio of the new strength versus 120 gpl. Therefore, 160 gpl to 120 gpl (160/120) is 1.333 and the amount of available chlorine per gallon is 1.333 pounds per gallon since 120 gpl has 1#/gallon of available chlorine.

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

2.4 Sodium Hypochlorite Chemistry for Less than 22.4% Sodium Hydroxide Feedstock

Sodium hypochlorite is produced from reacting chlorine and sodium hydroxide. Typically either 32% or 50% strength with water addition the sodium hydroxide is diluted first and cooled and the chlorine is added using oxidation reduction potential electrodes for end point control of excess sodium hydroxide. The strength of the dilute caustic determines the strength of the sodium hypochlorite assuming the excess caustic remains the same such as a typical 0.5% by weight.

When sodium hypochlorite is produced using dilute caustic greater than approximately 22.4% by weight, the salt produced will be high enough concentration to precipitate out of solution. When sodium hypochlorite is made by traditional methods with the dilute caustic greater than 22.4%, the salt coming out of solution will create problems in the process by plugging heat exchangers, tanks, and reactors.

2.4.1 Sodium Hypochlorite Chemistry for Less than 200 gpl Available Chlorine

If the amount of chlorine, sodium hydroxide and water used to make any strength of sodium hypochlorite at strength less than 200 gpl is desired. Please go to http://www.powellfab.com/technical_information/interactivetools.aspx. This sodium hypochlorite information will work well for bleach that contains the normal amounts of salt in solution and is not a "Low Salt" product. If the bleach is low salt the density will be lower than regular bleach.

Bleach will decompose due to ionic strength, pH, temperature, time, and heavy metal content. Powell has two programs for use in the decomposition review of regular bleach. Both programs are noted on the Powell website http://www.powellfab.com/technical_information/interactivetools.aspx. These two programs work for up to 200 gpl available chlorine or approximately 16.5% NaOCl. Either program allow decomposition programing with unfiltered and filtered sodium hypochlorite. In these programs, the unfiltered sodium hypochlorite is approximately 400 ppb of nickel and 65 ppb of copper and the filtered product is calculated at approximately 10 ppb of nickel and copper.

2.4.2 Sodium Hypochlorite Chemistry for > than 200 gpl available chlorine

However, Powell has a patented process that allows for the sodium hypochlorite production of 380 gpl available chlorine with only approximately 8% by weight NaCl. This process chlorinates a mixture of 50% caustic and 190 gpl available chlorine. The effective strength of the caustic chlorinated is approximately 39%. This reaction produces salt crystals that can be removed from the solution. The salt is recycled to either a chlorine plant or is dried and sold as a high purity salt.

By removing the salt, the ionic strength of the solution is reduced and the half life of the sodium hypochlorite is approximately doubled compared to regular bleach at the same strength and temperature.

In order to learn more about the high strength low salt bleach process please refer to: http://www.powellfab.com/products/contsys/contsys_hypo.aspx. A power point and white papers will offer additional information within this page.

If comparisons of regular bleach versus low salt bleach is desired, Powell offers a decomposition spreadsheet to assist this comparison http://www.powellfab.com/technical_information/tools/hsls_decomp.aspx.

In summary, low salt bleach offers many advantages such as increased half life, reduced chlorate and perchlorate concentrations, lighter weight, improved formulations and reduced shipping cost.

2.4 Sodium Hypochlorite Decomposition

The consumer must understand the reasons for decomposition of sodium hypochlorite to successfully purchase and utilize the product and to eliminate "oxygen locking" and piping systems plugging.

There are two decomposition pathways of sodium hypochlorite.

The dominant pathway is as follows:

$3NaOCl = 2NaCl + NaClO_3$ (Chlorate)

This decomposition can be created two major ways.

2.4.1 Sodium Hypochlorite Decomposition by Chlorate Formation Path #1

If during the production of 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. Refer to Section 5.0 References.

In most batch production systems for sodium hypochlorite using the original methods common in the 1950 & 1960's, high levels of chlorate can be produced during the reaction process. Since the 1970's, most manufacturers have converted to continuous production of sodium hypochlorite 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 will greatly affect the levels of chlorate produced during the reaction. For example, if packed towers are utilized for the reaction of caustic and chlorine, high levels of chlorates can be expected if the excess caustic in the column drops below approximately 1.5% by weight excess.

It should also be noted that the strength of sodium hypochlorite produced during the reaction will also affect the levels of chlorate. Regardless of the method used in the sodium hypochlorite production, that production method will create high levels of chlorates if higher strengths of sodium hypochlorite are produced.

2.4.2 Sodium Hypochlorite Decomposition by Chlorate Formation Path #2

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

The normal rate of sodium hypochlorite without salt, sunlight, heavy metals and contaminants (which can be easily controlled) with a pH of 11.86-13 can be expressed as:

Rate = $K2\,(OCl^-)^2$ (Reference #1)

Therefore the strength of the bleach during storage and the amounts of chlorate can be calculated using the predictive chemical-modeling program created by Gilbert Gordon and Luke Adam. (Reference #1)

2.4.2.1 Method #1 to Reduce Sodium Hypochlorite Decomposition Chlorate Formation Path #2

As indicated by the decomposition formula, sodium hypochlorite has a 2nd order rate of decomposition. This means that a 200 gpl available chlorine sodium hypochlorite solution without salt will decompose 4 times faster than 100 gpl available chlorine sodium hypochlorite if all other factors such as storage temperature are the same.

However, at a constant temperature, the rate of NaOCl decomposition is also be affected by the total ionic strength of the solution. Since salt is produced in the reaction of chlorine and caustic, this increase in ionic total strength increases the decomposition rate. In practice, a factor of 2 decrease in concentration produces nearly a factor of 5 decrease in decomposition rate at any given temperature with a pH range of approximately 11 to 13.

One other important concept in bleach decomposition is that due to the total ionic strength, once a 200 gpl available chlorine solution decomposes to a 100 gpl solution, the 200 gpl decomposition rates are much greater than a 100 gpl available chlorine solution. Therefore, for any given strength and temperature, over time the higher strength product will eventually be lower in available chlorine strength than the lower strength product since it's decomposition rate is greater.

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 depending on the locality it is produced and sold. Due to the basic chemistry of sodium hypochlorite, 160 gpl will decompose approximately 1.8 to 2.0 times faster than 120 gpl sodium hypochlorite. Therefore chlorates will be generated much more quickly. Since sodium hypochlorite strength and chlorate is always an issue in the final product, the specified delivered bleach should always be the lowest practical strength the supplier can manufacture and deliver cost effectively.

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 critical, the chlorate formation must also be considered.

Typically, for any storage over one week it is advisable for the end user to greatly reduce the decomposition of the stored product. One of the best methods to reduce decomposition is to store the sodium hypochlorite at a lower strength than the delivered strength. The product must be diluted with soft water. Plant water, well water, or city water must not be used in order to prevent the addition of the total dissolved and suspended solids and other contaminants with the untreated water. If 60 gpl sodium hypochlorite is stored in lieu of 120 gpl, the rate of decomposition is decreased by a factor of approximately 5.

Another benefit the consumer can receive is reduced cost of transportation. Since 160 gpl available chlorine has 1/3 more available chlorine than 120 gpl, more available chlorine can be transported per shipment if purchased at the 160 gpl strength. Therefore, if high strength sodium hypochlorite is produced and then diluted at the consumer's site, the price per pound of available chlorine can be reduced.

In many parts of the world, higher strengths of bleach are available from the producer such as 180 gpl available chlorine and if so, even higher reduction in costs can be expected if the consumer can add the soft water in the storage tanks.

2.4.2.2 Method #2 to Reduce Sodium Hypochlorite Decomposition Chlorate Formation Path #2

It is common in many small installation systems of sodium hypochlorite tanks to only have one tank for storage. It is also common to leave some amounts of residual bleach in the storage tanks and then when a new delivery of sodium hypochlorite is received, the new bleach is mixed into the existing old bleach. **This is not an acceptable practice.**

For example:

> Assume the storage tank is 8,000 gallons in volume.
> Assume the old bleach remaining in the tank is 2000 gallons.
> Assume the old bleach was delivered at 120 gpl available chlorine, it is now one week old, and now it has decomposed to 100 gpl.
> Assume the new bleach is 120 gpl and is a shipment of 5000 gallons.

After mixing of the old bleach with the new bleach, the final mixed solution will be approximately 114 gpl available chlorine with higher levels of chlorate due to the old bleach decomposition.

> Assume a week later (remains at the same ambient conditions as the previous week) the same amount of bleach of 2000 gallons remains.

Now the 2000 gallons of stored bleach will be lower than 100 gpl (for example 95 gpl) since it was lower to start with due to the dilution of the old with the new.

Therefore, it is critical for the end user to always have two tanks for storage and use sodium hypochlorite out of each tank to the lowest level before any new bleach is received. The two tanks should be alternated in use for the best results. Bleach strength cannot be maintained and cannot be controlled if this is not done.

2.4.2.3 Method #3 to reduce Sodium Hypochlorite Decomposition Chlorate Formation Path #2

In many countries it is common to ship strong sodium hypochlorite (> 60 gpl available chlorine) very long distances in hot climates and store it a week or two before final sales to the end user. If this is a common practice for the supplier, the end result will be a delivered product that is low in strength. **This is not an acceptable practice.**

All bleach decomposition is dependant on temperature. For any given temperature, the higher the strength, the faster it decomposes. In order to completely understand the decomposition of bleach with respect to strength versus temperature, please refer to the AWWA research document "Minimizing Chlorate when Hypochlorite is the Chlorinating Ion." In summary, for every 10°C increase in storage temperature, the sodium hypochlorite will decompose at an increased rate factor of approximately 3.5.

Another relative indication of bleach decomposition is the rate constants (k2) of sodium hypochlorite decomposition. Below is a table to show these rate constants of decomposition with respect to strength and temperature.

Sodium Hypochlorite (NaOCl) Weight %

Temperature (°C)	15.89	13.46	10.82	7.93	4.74
55	250	189	138	98.2	65.5
45	80.7	58.7	43.9	30.2	19.3
35	23.1	17.0	12.2	8.43	5.45
25	6.33	4.68	3.22	2.19	1.58
15	1.65	1.15	0.80	0.53	0.30

From the data it is indicated that storage of bleach at approximately 60°F (15°C) will greatly reduce the decomposition of the bleach. Therefore, if bleach decomposition is a problem in storage and shipping, in many cases the problem can be solved by cooling the stored bleach before shipping, and if necessary cooling it upon receipt at the distribution center.

At the production facility it is relatively easy to chill the bleach with a chilled water system and plate and frame heat exchangers. However, at the customer's site or distribution location, it is usually easier to install the storage tanks, transport tote tanks, drums, and bottles in a well insulated room or building and install air conditioning to cool the room.

If the time from production to receipt at the final site is kept to a minimum it is common to not chill the bleach during the storage at the production site and during shipping, but to keep the bleach in an air conditioned room after receipt.

In order to determine your best option, each application has to be reviewed based on bleach strength, storage temperature, and storage time.

2.4.3 Minor decomposition pathway for Sodium Hypochlorite

Although oxygen created by the decomposition of sodium hypochlorite is a major problem for the consumer of bleach, it is a minor decomposition pathway of sodium hypochlorite with respect to the rate of decomposition and bleach strength.

This pathway is as follows:

$2NaOCl = 2NaCl + O_2$

This oxygen formation will occur and is a problem if the heavy metals in the sodium hypochlorite are not removed immediately after the production. Refer to section 3.5.

The most common reason for this decomposition pathway and the heavy metal content is poor quality sodium hypochlorite supplied by the producer. If the heavy metals (such as nickel and copper) are not removed after production, the oxygen pathway will exist in relatively high amounts. Increasing strength and temperature, decreasing pH, and exposure to light in combination with the heavy metals will increase the rate of this oxygen formation and increase the loss of the sodium hypochlorite.

Oxygen formation created by poor quality sodium hypochlorite must be avoided by the consumer. The purchase of high purity, high quality bleach can be accomplished by writing detailed product specifications and then enforcing these specifications once the product is purchased. (Refer to www.powellfab.com.)

Oxygen will cause major problems for the consumer. If oxygen is formed in pump casings when the pump is not operating, the pump can "oxygen lock" similar to one that is not primed with air still in the casing. This oxygen formation will cause the pump not to work until the casing is vented. Since pumping systems are not typically designed to easily vent this oxygen, it is typically a time consuming process. During the time the pumps are not operating with flow, damage to pump seals and bearings in magnetic drive pumps will occur since the pump is operating "dry" and it will create large maintenance expenses. The most important impact of this oxygen formation is the lack of chlorination during this event.

Some of the other symptoms of oxygen formation are piping systems and instrumentation systems can become "oxygen locked" when the product is not flowing and contains heavy metals. This is a major problem if the piping layout is such that the oxygen cannot migrate to the high points of the system and vent. Loss of flow measurement will occur if some types of flow meters become "oxygen locked".

One last indication of this problem is the experience of some producers and consumers with PVC ball valves "exploding" when the valves are closed. This is due to the extremely high pressures created inside the PVC ball when the heavy metals decompose the bleach. This problem has occurred often enough that one PVC ball valve manufacturer is offering a "blowout proof" bleach ball valve. This valve has a hole drilled on the upstream side of the ball valve. **In order to eliminate this potential safety problem, simply purchase bleach that has been filtered and contains extremely low levels of heavy metals.**

Oxygen formation is virtually eliminated by purchasing high quality sodium hypochlorite with only trace amounts of nickel, copper and suspended solids, and by correct storage and handling of the product. When the sodium hypochlorite is used in the household at typical strengths to 7% by weight, the bleach must not contain heavy metals since the containers are not vented and any oxygen formation will result in the storage bottles building excessive oxygen pressure. This problem will result in a product that cannot safely be sold since the containers may fail during transportation and handling. These containers can be recognized on the grocery store shelves by the swelling or ballooning of the container.

3.0 Sodium Hypochlorite Quality

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

- Low chlorate levels in the delivered sodium hypochlorite
- Decomposition of the product can be reduced and therefore chlorate formation will be reduced
- Settling of the suspended solids will be eliminated in the tanks, pumps, piping, and instruments
- Negligible amounts of oxygen will be produced
- 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 during the quality testing of the product received:

3.1 Strength

The strength of the sodium hypochlorite is determined by titration. See Section 5.0 References.

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 grams per liter available chlorine when specifying the strength of the product.

3.2 Excess Sodium Hydroxide (Caustic)

The strength of the excess caustic or alkalinity of the solution is determined by titration. See Section 5.0 References.

The minimum amount of excess caustic in normal applications is 0.3 gpl, which is approximately 11.86 pH. If the specific gravity of the sodium hypochlorite were 1.20, the 0.3 gpl excess caustic would be 0.025% by weight. Any amount of excess caustic below the 11.8 pH will cause the pH of the solution to drop over time and will result in a much faster rate of decomposition.

If the sodium hypochlorite will be diluted and stored after the consumer receives it, the pH must be higher than the 11.86 pH since dilution will decrease the pH of the solution. However, in practice this should never be a problem due to the amount of excess caustic in the sodium hypochlorite from the producer.

Higher levels of excess caustic above 13 pH or 4.0 gpl will produce a slightly higher rate of decomposition than excess caustic levels from 11.86 to 13.0 pH. The 4.0 gpl relates to 0.35% by weight excess caustic if the specific gravity of the sodium hypochlorite is 1.20.

3.3 Sodium Carbonate

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

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

3.4 Specific Gravity

The specific gravity of the solution is the ratio of the weight of the solution with respect to water. If the product has a specific gravity of 1.2, a gallon of this sodium hypochlorite weighs 10.00 pounds. The specific gravity of the bleach with the same strength may vary due to the amount of excess caustic in the solution.

Most tables that show the gpl of available chlorine and the specific gravity of the solution were created over 50 years ago and are shown with excess sodium hydroxide much higher than current levels of sodium hydroxide. The reason excess sodium hydroxide levels have decreased is the manufacturing techniques have improved and the endpoint control of the chlorine and caustic reaction is better.

The old tables will typically show 120 gpl available chlorine with 0.73 % by weight excess caustic which results in a specific gravity of 1.168 at 20°C. If the excess sodium hydroxide is removed, the specific gravity will be approximately 1.157. Typically, the sodium hypochlorite produced by a continuous process will have approximately 0.2% by weight excess sodium hydroxide and this would result in a specific gravity of 1.160 at 120 gpl. These numbers assume the salt is in the solution with the bleach and very small levels of chlorate exist in the solution. Additional information can be found in the titration procedures available as Section 5.0 References.

3.5 Suspended solids & Heavy Metals Removal

Currently many customers are 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.

A test for suspended solids is available (see Section 5.0 References, 5.6 Suspended Solids Quality Test for Bleach Using Vacuum Filtration) that is quick and the results can be duplicated from location to location. This test simply passes one liter of product through a 0.8 micron filter cloth under 20” of mercury vacuum and the time to filter is noted. If the product passes the test in 3 minutes or less, the product has negligible suspended solids and can be accepted from the producer.

The bleach producer has two completely different methods to use to achieve the required test results. The first method of manufacturing is from a producer using chlorine from railcars, 50% caustic, and soft water. Since the suspended solids cannot 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 sub-micron size levels. Normally this is accomplished with a filter aided filter system using perlite or diatomaceous earth as the filter media. Rarely is the required level of filtering accomplished using cartridge filtering due to cost, flow rate capabilities of the cartridge systems, and particle-size limitations.

The second method of manufacturing is from 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 softened or demineralized water. Since the caustic and chlorine at the point of manufacture is extremely pure and the water has virtually no contaminants, the final product will be ultra-pure, it will have negligible suspended solids, and the bleach produced will pass the suspended solids test in less than 3 minutes.

3.6 Parts per million of chlorate

The typical limit of chlorate in the delivered bleach is 1500 mg/liter (1500 PPM). The testing for the chlorate is not easily done and usually a qualified laboratory is used. See Section 5.0 References.

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 with low levels of suspended solids and heavy metals, further reductions of chlorate will be achieved.

As discussed in previous sections, the chlorates can be minimized by reduction of the strength of the product during final storage and reduction of the final storage temperature.

3.7 Parts per million of nickel & copper

Typical specifications of nickel and copper are 50 PPB (Parts Per Billion) or less. Unless the manufacturer has a high purity product, these levels will not be achieved. As discussed above, these heavy metals will decompose the product and should be specified. If the bleach is extremely well filtered, typical nickel and copper content will be less than 10 PPB each.

Nickel is in the 50% sodium hydroxide used in production. Some methods of production for sodium hydroxide result in higher levels of nickel and therefore carry over 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. The manufacturer and consumer can avoid copper in the process system and copper is not usually a problem.

Since the heavy metals can be filtered out with submicron filter aided filter systems, 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 is in the final product. However, the level of suspended solids must also be specified and tested.

3.8 Parts per million of iron

Typical specifications of iron are for less than 0.5 PPM. The iron levels found in the normal product are not a factor in the decomposition of the product. However, if the iron levels exceed more than 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.

Some specifications require the iron level to be less than 0.5 PPM. Typically the only method this can be achieved is for the producer to use high quality filtration. This iron level specification is another method the purchaser can use to verify the product is of high quality. High level iron content in bleach can be filtered using submicron filter aided filter systems.

4.0 Transportation, Storage, and Handling Sodium Hypochlorite

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

4.1 Transportation of Sodium Hypochlorite

4.1.1 Tanker Trailers

Tanker trailers are tanks mounted on a frame with wheels with a fifth wheel connected to a truck tractor. These trailers are used to deliver large volumes of bleach to the customer’s site. Most of the equipment used is capable of delivering from 4,000 to 6,000 US gallons at one time. These tankers can be of many different designs and the structural tank can be of steel or fiberglass reinforced plastic (FRP). However, they must all have materials in contact with the product that are resistive to sodium hypochlorite.

There are many different materials of construction used as the corrosion barrier for the sodium hypochlorite to eliminate damage to the structural tank and to eliminate contamination of the product. Some of these liners include rubber, PVC, Halar®, Tefzel®, and other non-metallic material. FRP tanker trucks are very successful for hauling sodium hypochlorite when the entire container is made of FRP with 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. In the US and Canada, FRP tank trailers are replacing rubber lined steel as the material of construction due to the long life of the FRP trailer. The FRP trailer has had 30 years of use and it has been proven when the FRP trailers are constructed correctly, they are the best choice for sodium hypochlorite.

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

If a liner should start to fail during the yearly period between inspections, the purchaser may notice two changes in the product received. First, if the tanker is steel with a liner, the iron content of the bleach will increase over time when that tanker is used for delivery. Second, failure of a liner may result in an increase in suspended solids.

From a consumer’s perspective, other than meeting the suspended solids and the metals testing, a liner failure does not result in any problems. However, the owner of the tanker should be notified of any changes of product quality that may be a result of a defective liner so repairs can be made to the trailer.

The purchaser should specify that the tankers be cleaned if the tanker is contaminated. The only time this may be an issue is if the company delivering the sodium hypochlorite is back hauling other compatible products such as sodium hydroxide and if it contaminants the product.

4.1.2 Flat Bed Trailer Tanks

In some countries the bleach is hauled long distances, but the customer may only require 2,000-3,000 US gallons of bleach but also require 2,000-3,000 gallons of sodium hydroxide. In these cases 2,000 – 3,000 US gallon tanks can be built on skids and two can be mounted on the same flat bed trailer.

The materials of construction of these tanks are the same as the tanker trailers. The same information which applies to the tanker trailers; also applies to the flatbed trailer tanks.

4.1.3 DOT Exempt Polyethylene Tanks

In the US, polyethylene tanks of 300-600 gallons US with or without structure steel frames are used to ship bleach. These are put inside of enclosed trailers or flat beds. If the customer needs only 500-600 gallons per week, these are very useful containers for shipment.

4.1.4 55 Gallons & Smaller Containers

Sodium hypochlorite is transported in small quantities in various plastic containers ranging from small ½ gallon bottles to 55 US gallons. In these size containers, it is usual for the container to be constructed with a plastic having UV protection. Some of the small containers will have vented caps to allow oxygen to be vented but the small household bleach bottles are usually non-vented and the bleach must be of high quality and filtered with a submicron filter aided filter system.

Regardless of the type of container, if it is returned to the manufacturer for refilling, high quality bleach that has been filtered will reduce the amount of washing required of the containers before refilling.

4.2 Storage

4.2.1 Materials of Construction

Many different types of materials are used for construction of storage tanks for sodium hypochlorite. Two main types of the materials used are linear and crosslinked polyethylene and fiberglass reinforced plastic. 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 flexible plastic liners such as PVC have been successfully used.

The choice of materials depends on available capital, tank location, and required service life. Some tanks may only last 3-5 years and, if properly specified and maintained, could last 10-15 years. The only material noted for over 30 years of service life is titanium.

4.2.2 Installation and Design Considerations

There are many design considerations for a successful installation. Some of these considerations are as follows:

- Mount the tank on a properly designed foundation or support system designed for the total load.
- Design each tank installation for the seismic, wind and snow load area the tank is to be located.
- Properly anchor the tank to the foundation.
- Install flexible connections to all sidewall tank outlets before connecting to permanent piping systems and allow expansion for piping systems on top nozzles.
- Review tank level indication and alarm requirements and supply as required.
- Review tank overflow and vent requirements and design as required.
- Review tank manway, handrails, and ladder requirements and design as required.
- Provide sufficient lighting for safe working conditions.
- Provide all storage vessels with containment for liquid leaks as required.

4.2.3 Polyethylene

These tanks can be of linear or crosslinked polyethylene construction and usually the tanks are vertical cylindrical construction with flat bottom and domed top. Some manufacturers have a special resin for sodium hypochlorite. Outside tanks should have UV protection and should be painted white.

These tanks are very competitively priced. However, since these tanks may have a service life of 5-7 years, they should typically be used in location, inside or outside, where they can be easily replaced when they fall. These tanks should not be used in a construction application that allows for no easy replacement of the tank upon failure.

The major problem with polyethylene tanks are the outlet fittings below the liquid level. In the past, bulkhead fittings have been used of PVC construction. However, below the liquid level of the tanks, titanium bulkhead fittings should be used with titanium bolting. Above the liquid level, PVC bulkhead fittings are acceptable. PVC bulkhead fittings below the liquid level may be used on small tanks and in applications where downtime due to repairs on the fittings is acceptable. Viton® gaskets are used.

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. Refer to www.powellfab.com for detailed information of this method of installation.

4.2.4 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 one of the worst choices. A well-specified and properly constructed FRP tank can last 10-15 years or more with corrosion barrier inspections typically every two years with minor repairs as required. An improper design and construction will result in corrosion barrier failure and structural damage in 3-5 years requiring complete replacement of the tank.

Typical specifications for FRP tanks would include hand laid up or “ortho wound” construction. Since failure of the corrosion barrier in a filament wound tank would result in the sodium hypochlorite wicking around the continuous strands of glass used in the structural portion of the tank, weakening of the structural portion of the tank filament wound may result in a catastrophic failure of the tank.
Vinyl ester 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 corrosion barrier should not be used for structural design. The corrosion barrier is catalyzed with a BPO/DMA cure system and a 4 hour post cure.

There has been success with dual laminate FRP tanks 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 and the FRP portion of the tank should match all specifications of an FRP only tank in case the PVC lines should fail.

4.2.5 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 type 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 and structural damage to the tank.

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

4.2.6 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 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 cannot be tolerated.

4.3 Materials of construction

4.3.1 Incompatible materials of construction

If the wrong metals materials of construction are used in any portion of the process system, contamination of the product will occur resulting in accelerated decomposition and potential 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. 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 and valves.

Although copper piping is typically used for industrial applications for water supplies and the discharge piping from water softeners, this piping should not be used for dilution water in either the bleach production or the consumer facility for dilution of caustic or bleach. Very small amounts of an incompatible metal will result in large amounts of product decomposition and oxygen formation. The consumer must review each component in the pumping and piping system including all instruments to ensure no incompatible materials are used.

4.3.2 Compatible materials of Construction

For metals in contact with sodium hypochlorite, the majority of construction for all process equipment is titanium. Tantalum is used for electrodes in magnetic flow meters and diaphragm seals. Silver and platinum are used for electrodes to measure oxidation-reduction potential. There should be no other metal in contact with sodium hypochlorite except in rare, special applications where platinum/iridium and titanium/palladium combinations will be used. For non-metallic materials in contact with sodium hypochlorite, the list includes CPVC, PVC, Teflon®, Tefzel®, Kynar®, Halar, polyethylene, FRP and copolymers such as “Section 4.5.2”.

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

4.4 Pumps

Depending on the application, the choice of pumps for sodium hypochlorite can be separated into centrifugal and positive displacement such as diaphragm. 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.

One of the best centrifugal pumps for sodium hypochlorite is a titanium pump. However, these pumps are expensive compared to other choices and the design cannot avoid the use of seals. There are many good seals available for these pumps and the purchaser should refer to the manufacturer for detailed recommendation. However, any good seal will only last typically 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. Even though the pump will not last as long, total cost of operation will be less than a titanium pump.

Therefore, for 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 3-7 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.

There are many choices of diaphragm pumps for small flow applications. Many choices for the pump housings are available and successful. The diaphragms can be of Teflon® or some rubber compounds. However, if rubber compounds are used, Viton® is the preferred choice. EPDM is successful but may not have as long as service life as Viton®.

There are other types of pumps available and they may be used for special applications. Pump choices should be made based on manufacturer’s recommendations and customer satisfaction.

4.5 Piping

4.5.1 PVC & CPVC

Typical choice for low-pressure piping is PVC or CPVC Schedule 80 socket welded pipe and fittings. Do not use threaded joints for sodium hypochlorite connections if possible. Over time, a threaded joint will have a tendency to leak. In addition, threading the pipe reduces it structural integrity.

PVC or CPVC piping should not be used for high pressure (typically over 50 to 60 pounds) since failures result in potential injury. If higher pressures are used with PVC or CPVC, use soft start motors on pumps. Slow opening and closing valves should be used if automated valves are used to start and stop flows. Velocities in PVC or CPVC sodium hypochlorite piping systems should not exceed 7 feet/second and better results will be achieved if the velocities are kept less than 5 feet/second. Care must be taken to use an industrial grade cleaner and glue for the PVC or CPVC and to follow the manufacturer's installation instructions. PVC or CPVC installed outside must have UV protection.

4.5.2 Polyethylene Piping Systems

Asahi makes a polyethylene piping system with the description of PE100-RC. It is a fusion welded piping system and it has ratings to 150 PSIG and a good selection of fittings. This piping system should be considered when designing sodium hypochlorite piping systems.

4.5.3 Lined Pipe

For high pressure or very long service life, a lined piping system typically of Teflon® is used including carefully designed expansion joints. Linings are usually PTFE and fittings and pipe are a 150# flanged design. These systems are expensive but can result in 20-30 year service life. Other liners can be used such as Kynar®, Tefzel®, and Halar. However, considering cost, service life, and successful applications, PTFE appears to be the best choice.

4.5.4 Titanium Pipe

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

4.5.5 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.

If FRP is the piping system of choice, then location of a qualified FRP piping manufacturer who has the experience and knowledge to specially fabricate this FRP must be located. The FRP specifications for the pipe would be very similar to the FRP tanks.

4.6 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 plug, ball, or butterfly valve should be considered. Gear drives are recommended in high torque applications to reduce the stress on the nozzle connection.

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

Only flanged or socket welded valves should be used. Do not use threaded. Union style ball or diaphragm valves provide a leak path past the O-ring seal at the union joint and should be avoided unless the valve can be easily replaced and downtime is not important.

4.7 Gaskets

When low torque is required for non-metallic systems, Viton® or expanded Teflon® (WR Gore) should be used. EPDM is a second choice and will work. The harder Teflon® gaskets should not be used in a low torque application.

Expanded Teflon® gaskets may be used 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 with acceptable results.

4.8 Instrumentation

There are many types of instruments used for sodium hypochlorite service. Most plastic or plastic lined materials such as PVC, CPVC, Teflon®, Tefzel®, Halar, and other materials will work well for the instrumentation construction. However, when metal is used in any part of the construction, only titanium or tantalum components can be used for contact with the sodium hypochlorite. For pH, ORP and magnetic flow meter electrodes, silver, platinum, gold, tantalum, or titanium are the only materials acceptable if a metal is required.

Since even small amounts of nickel will decompose sodium hypochlorite rapidly, Hastelloy® must never be used. Hastelloy® in most corrosion books under sodium hypochlorite may indicate an acceptable corrosion rate for equipment components. However, the nickel from the Hastelloy® will decompose the product. Understand 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.

5.0 References

5.1 Minimizing Chlorate Ion Formation in Drinking Water when Hypochlorite Ion is the Chlorinating Agent
Published by American Water Works Association (AWWA) Research Foundation
Prepared by Gilbert Gordon and Luke Adam, Miami University, Oxford, Ohio & Bernard Bubnis, Novachem, Oxford, Ohio
Available at: AWWA Research Foundation

5.2 Bleach Stability and Filtration (3306)
Presented at AWWA Water Quality Technology Conference, November 1996
Prepared by Gilbert Gordon, Miami University, Oxford, Ohio & Bernard Bubnis, Novachem, Oxford, Ohio
Available at: www.powellfab.com

5.3 Bleach Decomposition: Manual Calculation Method (3305)
Prepared by Bernard Bubnis, Novachem, Oxford, Ohio
Available from Powell Fabrication & Manufacturing, Inc.

5.4 Effectiveness of Filtering Liquid Bleach (3670)
Prepared by Hung A Pham, Miami University, Oxford, OH
Available at: www.powellfab.com

5.5 The Weight Percent Determination of Sodium Hypochlorite, Sodium Hydroxide, Sodium Carbonate and Sodium Chlorate in Liquid Bleach (1250)
Prepared by Bernard Bubnis, Novachem, Oxford, Ohio
Available at: www.powellfab.com

5.6 Suspended Solids Quality Test for Bleach Using Vacuum Filtration (3370)
Prepared by Bernard Bubnis, Novachem, Oxford, Ohio
Available at: www.powellfab.com

5.7 Liquid Sodium Hypochlorite Specification (99)
Prepared by Powell Fabrication and Manufacturing, Inc.
Available at: www.powellfab.com

5.8 Sodium Hypochlorite Safety and Handling, Pamphlet 96
Prepared by The Chlorine Institute, Inc.
Available at: www.cl2.com

Powell
Fabrication & Manufacturing, Inc.
740 East Monroe Road
St. Louis MI 48880
Phone: 888.800.2310 (Toll Free)
989.681.2158 (Local)
Fax: 989.681.5013
email: info@powellfab.com
website: www.powellfab.com

810.10212015
I:\Intranet\Marketing\SaleLit\PrintPDF's\SodiumHypo