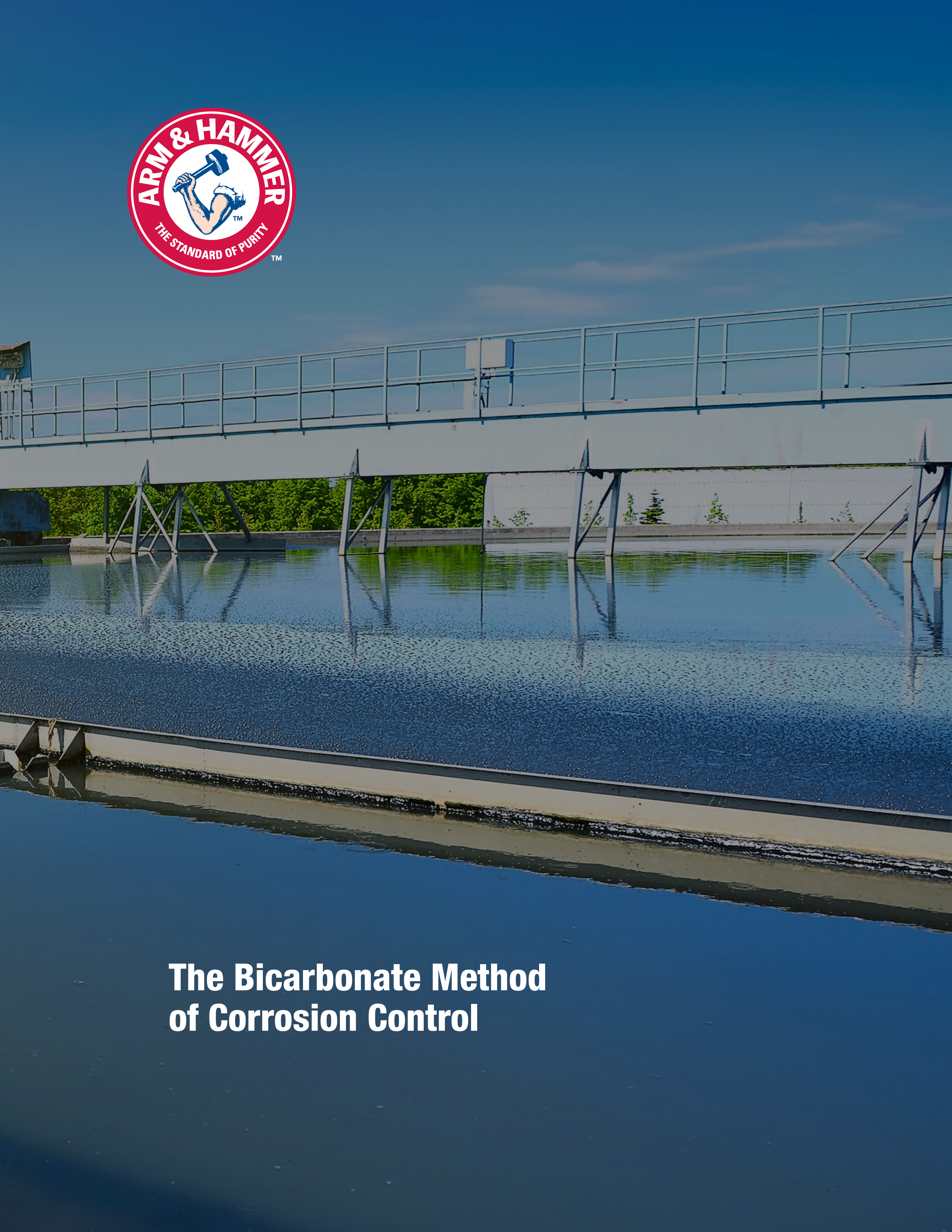


The Bicarbonate Method of Corrosion Control

Introduction

Drinking water suppliers in many parts of the United States and Canada are challenged in meeting the drinking water standards for lead and copper – not because their source water is contaminated with these metals, but almost paradoxically, because of high purity and lack of dissolved minerals in the water. Such water is considered corrosive and aggressively attacks and dissolves metals it comes in contact with. Unfortunately for the water supplier and consumer, these are the metals in the distribution system and residential plumbing and fixtures.

Rainwater is essentially devoid of any minerals and it is naturally acidic because of its tendency to dissolve carbon dioxide from the atmosphere as it falls to earth. The dissolved carbon dioxide reacts with the water to form carbonic acid. Other constituents and pollutants in the atmosphere such as nitrogen and sulfur compounds will also be absorbed by the falling rainwater further increasing its acidity and lowering its pH.

In areas of the country where geological substrates contain limestone, a well-understood buffering process occurs as acidic rainfall percolates through the soil to collect in a reservoir or aquifer. As the water permeates the limestone-containing subsoils, some of the acidic hydrogen ions react with the calcium carbonate from the limestone to form bicarbonate ions. The bicarbonate ions provide a natural buffering effect that stabilizes the pH in a favorable (less aggressive) neutral region and prevents further dramatic shifts in pH.

As this naturally treated water enters the distribution system, the prevalent bicarbonate ions react with exposed metals such as lead and copper. A tenacious carbonate or hydroxy carbonate film is formed on the metal surface, a natural corrosion inhibiting system protecting the metal from further attack.

Unfortunately, many geologic drainages have soils lacking neutralizing minerals and the water collected in these reservoirs will be acidic with little if any bicarbonate alkalinity.

Various studies have found that the corrosive nature of these waters can be greatly reduced by adjusting pH and alkalinity to values similar to those found in watersheds with alkaline mineral deposits. In fact, minimum corrosion occurs when the pH is in the range of 7.5 to 8.5, which corresponds to maximum bicarbonate ion species as shown in the graph on the next page.

Introduction

The Bicarbonate Method of Corrosion Control as developed by Church & Dwight Co., Inc. was specifically designed to treat corrosive source waters which are acidic and bicarbonate alkalinity deficient. By utilizing what nature has taught us and optimizing with good science, the bicarbonate method helps water suppliers to successfully meet lead and copper limits for potable water.

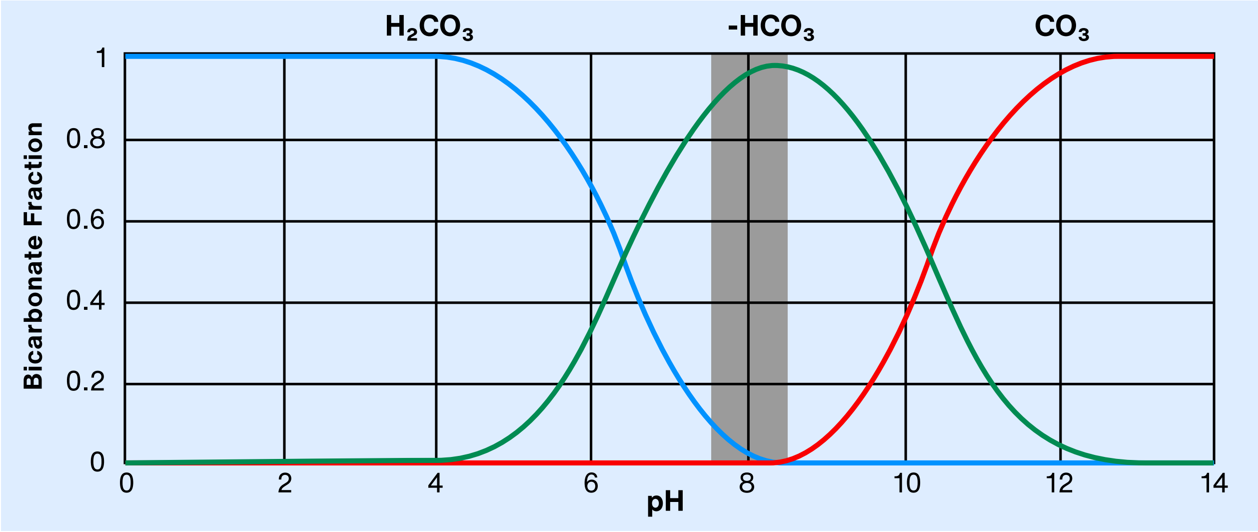
Waters that are only mildly acidic and lacking bicarbonate alkalinity can be treated simply by addition of sodium bicarbonate.

Waters that are more acidic (pH<6.5) may be treated first with caustic or calcium hydroxide to increase the pH to near neutral, then adding sodium bicarbonate to provide the desired alkalinity.

In either case the **target alkalinity is 30ppm as $CaCO_3$.**

For each 10ppm increase in alkalinity (as $CaCO_3$)	Add 150 pounds of Arm & Hammer™ Sodium Bicarbonate per million gallons of water treated

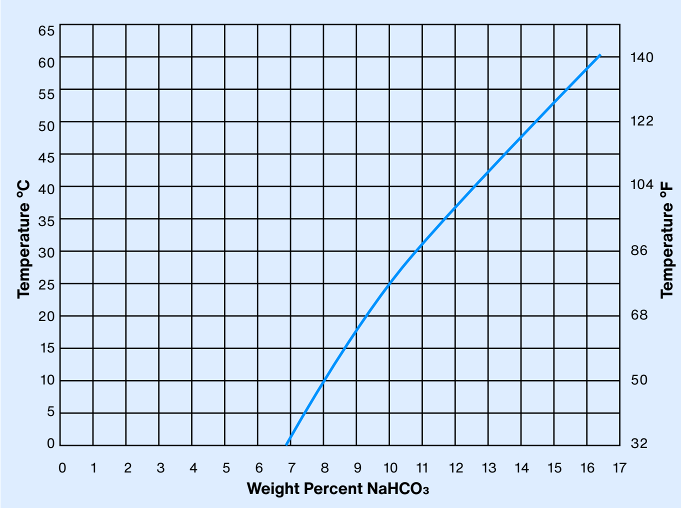
Distribution of Total Carbon Dioxide, Bicarbonate and Carbonate vs. pH



How to Design and Operate a Bicarbonate-Based Corrosion Control System

The purpose of this section is to describe in general terms how to design and operate a bicarbonate-based corrosion control system. For the administrator or supervisors, it will provide a feel for the simplicity and economy of the process. For the consulting and plant engineers, it will provide a basic understanding from which a detailed design and cost estimate will flow.

Figure - Solubility of Sodium Bicarbonate in Water



Philosophy

The design concept is intended to minimize labor and material handling concerns by providing a process which can be easily automated, and which has a very high degree of reliability, using equipment and processes familiar to water treatment plant operators.

This is accomplished by using a "day tank" concept in which the sodium bicarbonate solution required to provide a full 24 hours of alkalinity adjustment is made up once per day, requiring one hour or less of operator labor. The solution is metered into the treated water flow at a proportional rate. The relatively high solubility and handling ease of sodium bicarbonate makes this concept feasible. The same design concept can be utilized for systems of approximately 100,000 gallons per day to those greater than 10 million gallons per day.

How to Design and Operate a Bicarbonate-Based Corrosion Control System

Basis

For simplification we have assumed a typical water supply containing 10 ppm of alkalinity as $CaCO_3$. The design of the corrosion control process is to continuously add 20 ppm of bicarbonate alkalinity to approach the optimum value of 30 ppm.

Since alkalinity concentration is a linear function, any of the values given can be adjusted to a specific alkalinity requirement with simple proportioning. For example, if your system requires only 15 ppm adjustment multiply the base case quantities by 15/20 or 0.75.

The base case however is truly typical and will apply directly to many water supplies.

The base case also assumes a bicarbonate feed solution of 7.5%. This represents a saturated solution at 40°F or approximately 95% saturated at 50°F. For solution temperatures below 50°F, the concentration should be reduced to 7%. Conversely at 70°F, a 9% solution can be utilized.

Handy Conversions

A 7.5% Sodium Bicarbonate ($NaHCO_3$) Solution	Contains 0.625 pounds of $NaHCO_3$ per gallon of solution
	Contains 45,000 ppm of bicarbonate alkalinity (as $CaCO_3$)

To increase bicarbonate alkalinity by 20 ppm requires	48 gallons of 7.5% $NaHCO_3$ Solution per 100,000 gallons of water
	29 Gallons per hour of 7.5% $NaHCO_3$ Solution per 1,000 gallons per minute of water flow
	300 pounds of sodium bicarbonate (dry) per 1,000,000 gallons of water

How to Design and Operate a Bicarbonate-Based Corrosion Control System

Systems Up To 5 Million Gallons per Day

Sodium Bicarbonate is received in 50-pound bags, packed 55 bags per 48 in. x 40 in. pallet for a net 2750 pounds.

A tank which will contain the amount of 7.5% Sodium Bicarbonate solution necessary to feed the supplemental alkalinity to the water system is filled with water to the operating level and a top mounted mixer is activated. Mixer power, blade size and tank baffling should be adequate to ensure complete suspension and mixing of bicarbonate. Sodium bicarbonate bags are cut open and the contents manually added to the tank. A dust control hood is recommended. For each million gallons of system capacity, 300 pounds (six bags) of sodium bicarbonate is required along with 480 gallons of water.

The sodium bicarbonate will completely dissolve within minutes. The metering pump which delivers the sodium bicarbonate solution to the distribution system is started. The rate of bicarbonate solution flow is controlled at 480 gallons per 1 million gallons of water being treated or 29 gallons per hour for each 1,000 gallons per minute of water flow.

Sizing Recommendations

Minimum mixer size – The minimum practical system size is determined by the smallest sodium bicarbonate package size of 50 pounds. (Of course, very small systems can be designed around consumer packaged "baking soda" in one-pound to four-pound containers.) Eighty gallons of water are required to dissolve 50 pounds of sodium bicarbonate. Considering room for a mixer and some freeboard, the minimum tank size becomes nominally 100 gallons or roughly 2 feet in diameter by four feet tall. This tank would then contain solution sufficient to treat up to 167,000 gallons of water per day per the base case.

The table below can be used to guide estimates of required mixing tank size.

Flat-Bottomed Cylindrical Tank Capacity:
Gallons / Foot of Height vs. Tank Diameter in Feet

Tank Diameter in Feet	Gallons per Foot of Height
2	24
3	53
4	94
6	212
8	376

Examples of Tank Sizing for 1 to 5 Million Gallons per Day Systems

System Size MGD	Tank Capacity + 25% Freeboard (Gallons)	Tank Diameter (ft.)	Tank Height (ft.)
1	600	4	6.5
2	1200	4	13
		6	6
5	3000	6	15
		8	8

How to Design and Operate a Bicarbonate-Based Corrosion Control System

Metering

The metering pump should have a turn-down ratio of at least 3:1 to handle minimal winter and maximum summer flows.

The rate of bicarbonate solution flow into the treated water is maintained at a constant rate. If the treated water flow is controlled manually, such as estimated from a calendarized demand chart, and flow is into an intermediate storage reservoir, then the solution can be controlled manually at a proportion of 29 gallons per hour of solution per 1,000 gallons per minute of water flow.

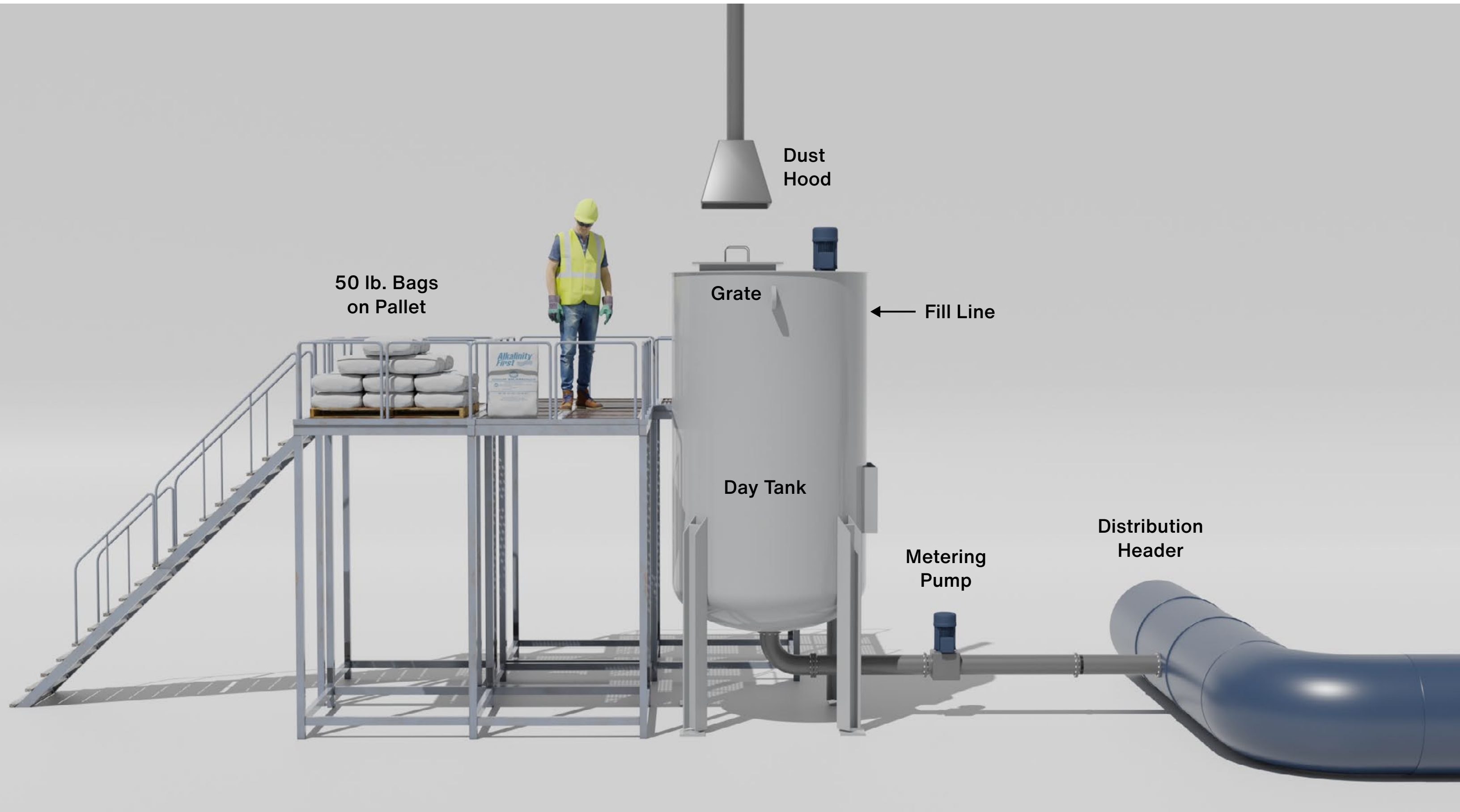
If water flow is strictly by demand and cannot be controlled, then it must be metered. A flow sensor on the meter output is used to control the flow of bicarbonate solution at the ratio of 29 gallons per hour per 1,000 gallons per minute of water flow.

Storage

Assuming the treatment plant would keep a 7-day supply of sodium bicarbonate on hand, storage space (single-stacked) is estimated to the right.

System Size MGD	Bags/Day (50 lb)	Pallets for 7 Days Use	Storage Space Sq Ft
1	6	1	20
2	12	2	40

Figure - 5 MGD or Less



How to Design and Operate a Bicarbonate-Based Corrosion Control System

Systems of 6 To 10 Million Gallons per Day

Sodium bicarbonate is received in 1-ton bulk sacks (Sacks are also supplied on 48 in. x 40 in. pallets). The tank is designed to hold one sack of sodium bicarbonate. The hours of capacity in the tank will vary but, in general, the day tank concept still holds.

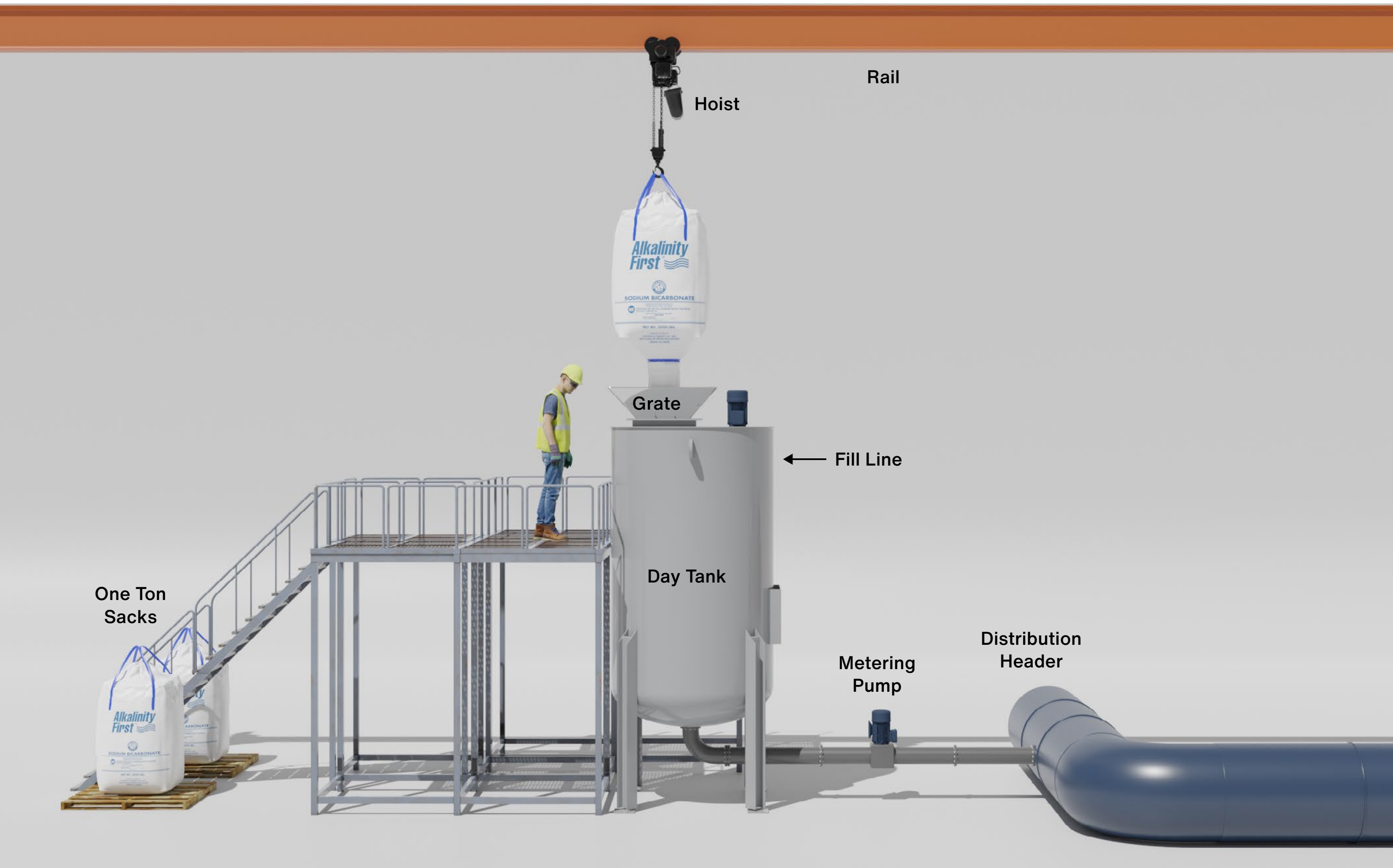
The 1-ton sacks are hoisted by a winch on a monorail and positioned over the day tank. The contents are dumped during a period of several minutes into the well-mixed day tank.

System Size MGD	Hours of Capacity per Tank Load
6	27
7.5	21
10	16

Sizing Recommendations

Tank size – 8 ft. diameter by 12 ft. height, capacity = 4,500 gallons

Figure - 6 To 10 Million Gallons per Day



Systems Larger than 10 Million Gallons per Day

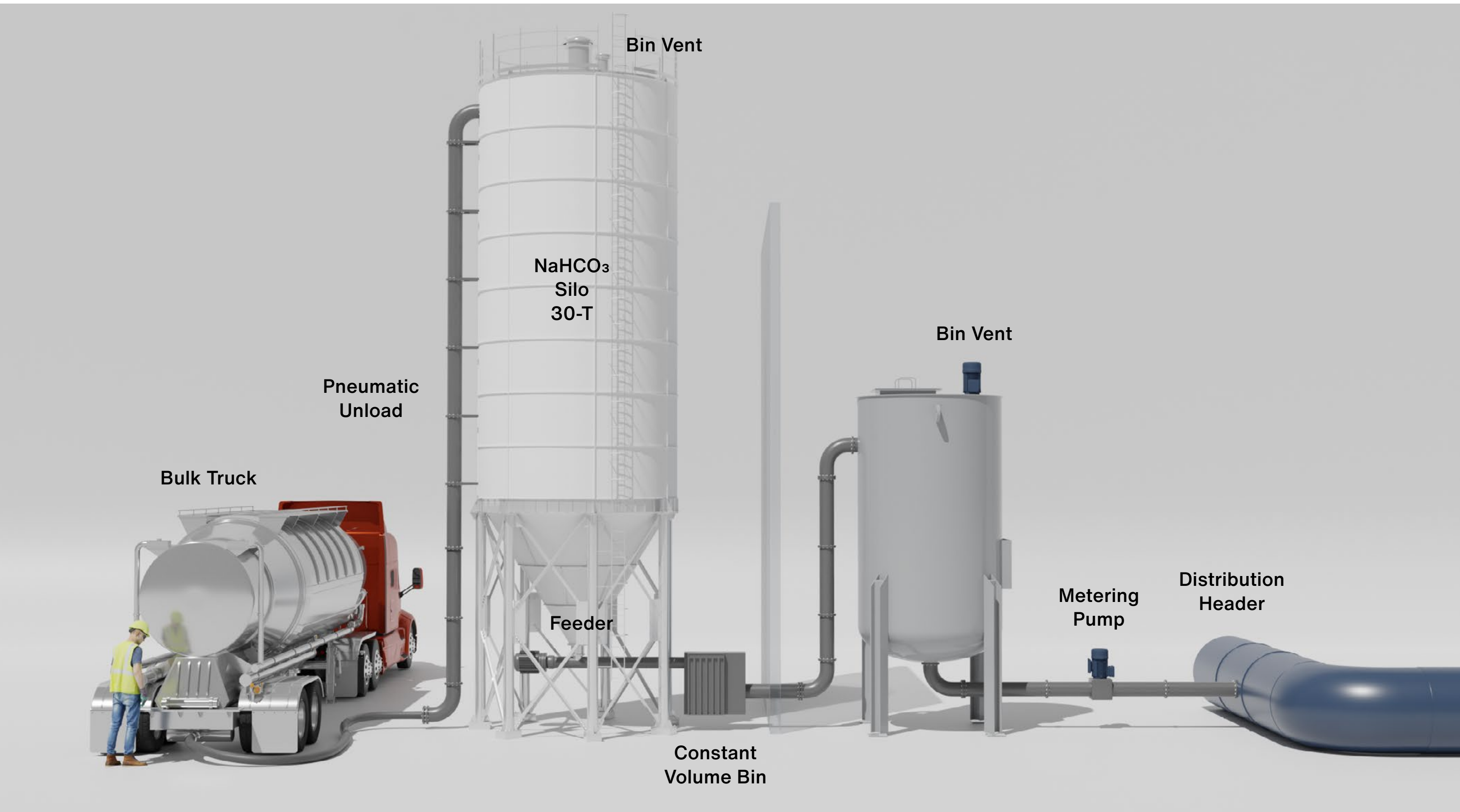
Sodium Bicarbonate is delivered in bulk and pneumatically conveyed to a 30-Ton silo. The mixing tank is a standard 4500-gallon unit, 8 feet in diameter by 12 feet high, with a top-mounted mixer. The tank is equipped with high-level, mid-level and low-level sensors.

At low level (25% of tank capacity) a water fill valve is opened automatically and begins filling the tank. At mid-level, a charge of sodium bicarbonate (1400 pounds) is delivered by dense phase pneumatic conveyor to the agitated tank. At high level, the automatic water valve closes.

Metering from the tank takes place continuously. There is no starting or stopping of the metering pump. Solution is metered to the water distribution system at the rate of 29 gallons per hour per 1000 gallons per minute of water flow. The only variable is the cycle time of the of the feed/fill system.

System Size MGD	Pounds $NaHCO_3$ / Day	Cycle Time (Hours)
10	3,000	11.2
25	7,500	4.5
50	15,000	2.25

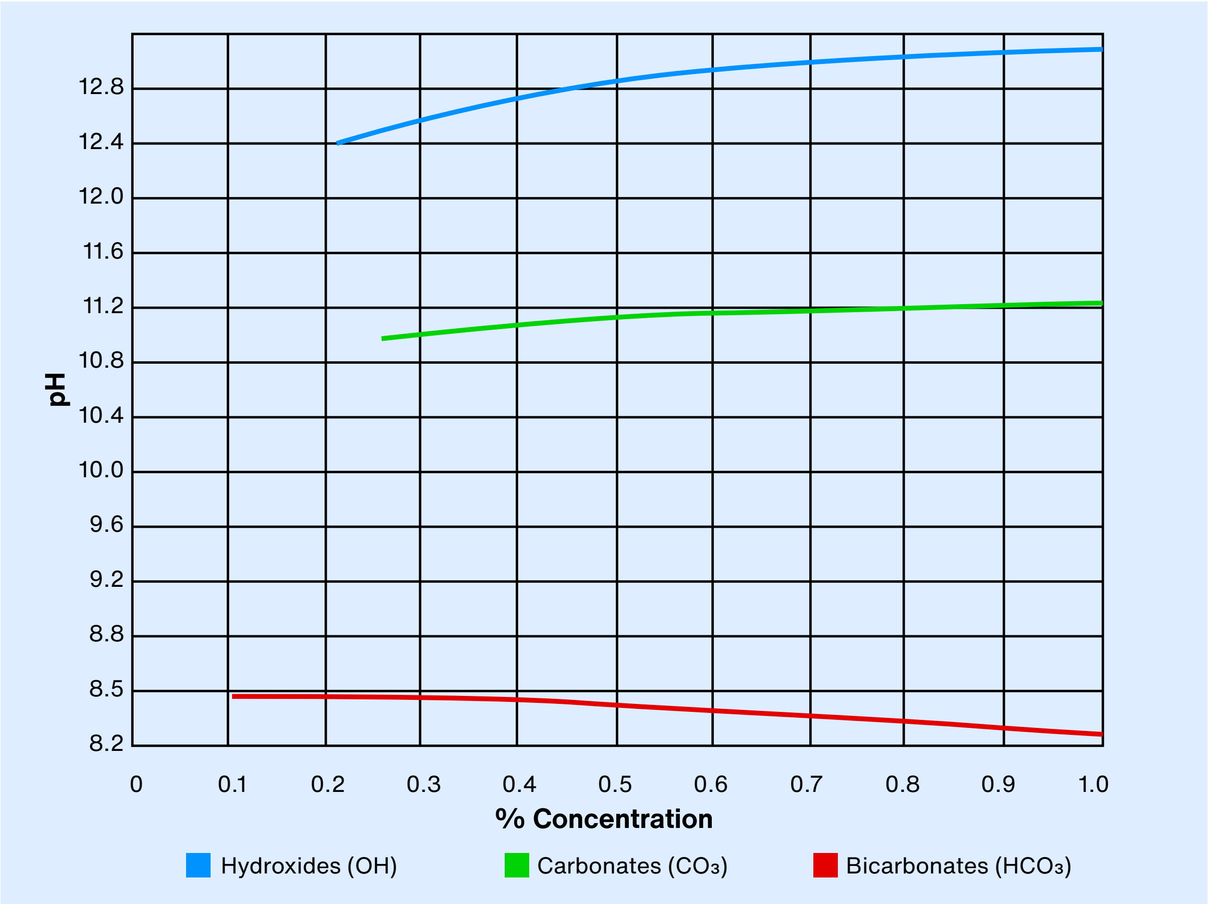
Figure 10 Million Gallons per Day & Larger



pH Adjustment

Adjusting your water to 30 ppm of bicarbonate alkalinity as $CaCO_3$ should by itself insure that the pH of the finished water is above 7 and reduce its corrosivity. However, for optimum film formation and corrosion control it may be necessary to control your pH in the range of 8.0. If your water contains a high degree of acidity, it may take a fairly strong alkali to obtain this elevated pH. There are a variety of alkalis available that can perform this task inexpensively. Lime is the least expensive form of alkali in most locations, but its extremely low solubility requires that it be fed in slurry form which makes sensitive pH adjustment difficult at best. Our recommendation is to use sodium-based alkalis such as sodium hydroxide in solution form or sodium carbonate in powder form. If sodium sensitivity is an issue, the corresponding potassium compounds can be easily substituted.

pH Values of Solutions

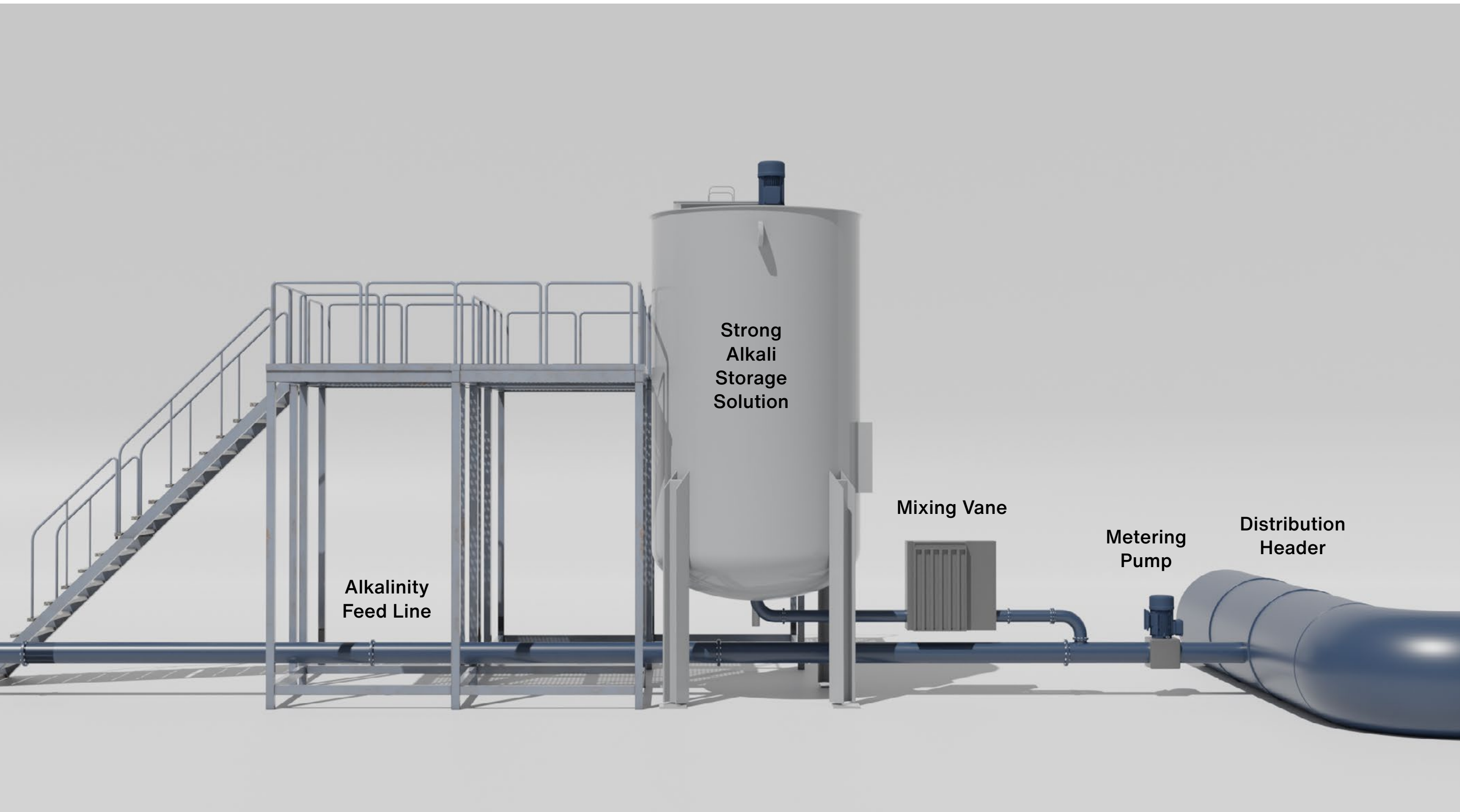


Sodium and potassium hydroxide are usually sold as concentrated solutions ranging from 25% to 50% solids. Since they are both very strong alkalis they usually need to be added only in small quantities; a little bit goes a long way. For example, a 55-gallon drum of 50% NaOH used to supply 4 ppm as NaOH for pH control will treat approximately 9 million gallons of water.

Smaller water treatment plants may prefer to use less caustic alkalis such as sodium or potassium carbonate for pH adjustment. These materials are safer to handle than the hydroxide and can be purchased in powder form in 50-pound bags. Since they are both very soluble materials, a day tank concept similar to the sodium bicarbonate systems described can be utilized simply and effectively.

To control pH, a pH sensor is placed in the distribution system piping downstream of the alkalinity adjustment. A signal from the pH probe will control the output from the caustic metering pump. If the pH of the raw water is relatively constant, it is possible to manually set the flow of caustic proportional to the treated water flow as we did for alkalinity control. However, since the addition of just a little excess caustic will increase pH dramatically, it is desirable to install a high-pH alarm set at pH 9 which will automatically shut off the metering pump.

pH Control System



Residual Benefit of the Bicarbonate Method

Many drinking water corrosion control treatments will create new problems in the waste water treatment plant (WWTP) by increasing metals (e.g., zinc) in the residue sludge, or phosphates in the liquid effluent. The bicarbonate method has only positive effects at the WWTP. Alkalinity supplied in the sewered drinking water will help to maintain critical pH in the water and sludge digestion processes by neutralizing organic acids which are the byproduct of bacterial digestion. The bicarbonate method adds no heavy metals of its own and reduces the influence of metals from the water loop by its passivating film formation.

Abbreviations, Acronyms, Chemical Formulas Used

Abbreviations, Acronyms, Chemical Formulas Used Throughout	
$CaCO_3$	Calcium Carbonate, standard to measure alkalinity in water
CO_3	Carbonate ion
FIT	Flow Indicator Transmitter
Ft.	Foot
$-HCO_3$	Bicarbonate ion
H_2CO_3	Carbonic Acid (formed by carbon dioxide in water)
In.	Inch
LSH	Level Switch - High
LSL	Level Switch - Low
LSLL	Level Switch Low Low
LSM	Level Switch - Mid
MGD	Million Gallons per Day
$NaHCO_3$	Sodium Bicarbonate
ppm	Parts per million
T	Ton

Disclaimer

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