TRUSTED BRAND
PROVEN PERFORMANCE

THE BICARBONATE METHOD OF CORROSION CONTROL

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I. INTRODUCTION

Drinking water suppliers in many parts of the United States and Canada will have a hard time meeting the new drinking water standards for lead and copper — not because their source water is contaminated with these metals, but almost paradoxically, because of this high purity and lack of dissolved minerals. Such water is considered corrosive or aggressive, and it will eventually satisfy this aggression by attacking whatever it comes in contact with. Unfortunately for the water supplier and consumer, this hunger is often satisfied by metals in the distribution system and in the residential plumbing and fixtures themselves.

Rain water is essentially devoid of any minerals, but it is naturally acidic because of its tendency to dissolve carbon dioxide from the atmosphere as it falls to the earth. The dissolved carbon dioxide reacts with the water to form carbonic acid, which dissociates to form a bicarbonate ion ($-HCO_3$) and an acidic ion (H+). Other acid constituents in the atmosphere such as nitrogen or sulfur trioxides will also be absorbed by the falling rainwater, increasing its acidity and lowering its pH.

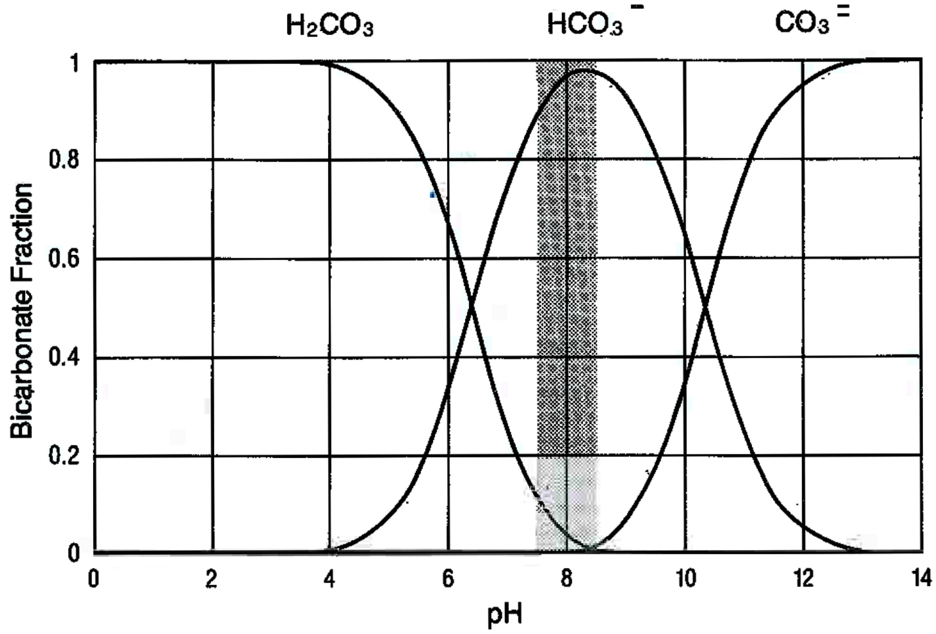
In areas of the country where geological substrates contain limestone, a well-understood buffering process occurs as this acidic rain water percolates through the soil to its respective reservoir or aquifer. As the water permeates the limestone-containing subsoils, some of the active hydrogen ions react with the calcium carbonate substrates to form more bicarbonate ions. These bicarbonate ions provide a natural buffering effect that stabilizes the pH in a favorable neutral region and prevents dramatic shifts in pH which could result from the absorption of other acidic compounds.

Furthermore, as this naturally treated water enters the distribution system, the prevalent bicarbonate ions will react with exposed metals such as lead and copper. The result is the formation of a tenacious carbonate or hydroxy carbonate film on the metal surface, creating nature's own corrosion inhibiting system and protecting the metal from further corrosion.

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

Various studies have shown 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 ($-HCO_3$) ion species as shown in the adjacent graph.

Relationship of the species distribution diagram to the titration curve for the carbonate system at 25°C



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 scarce in bicarbonate alkalinity. By utilizing what nature has taught us and optimizing with good science, the bicarbonate method will help many water suppliers to successfully meet EPA's lead and copper criteria.

Waters that are only mildly acidic but devoid of bicarbonate alkalinity can have corrosion successfully controlled simply by increasing the alkalinity to approximately 30 ppm as $CaCO_3$ using pure sodium bicarbonate. The required dosage is 150 pounds of sodium bicarbonate to each million gallons of water for a 10 ppm increase in alkalinity as $CaCO_3$.

Waters that are more acidic (pH < 6.5) may be treated first for pH adjustment using an inexpensive but high-purity alkali such as sodium hydroxide or calcium hydroxide, followed by alkalinity adjustment using pure sodium bicarbonate.

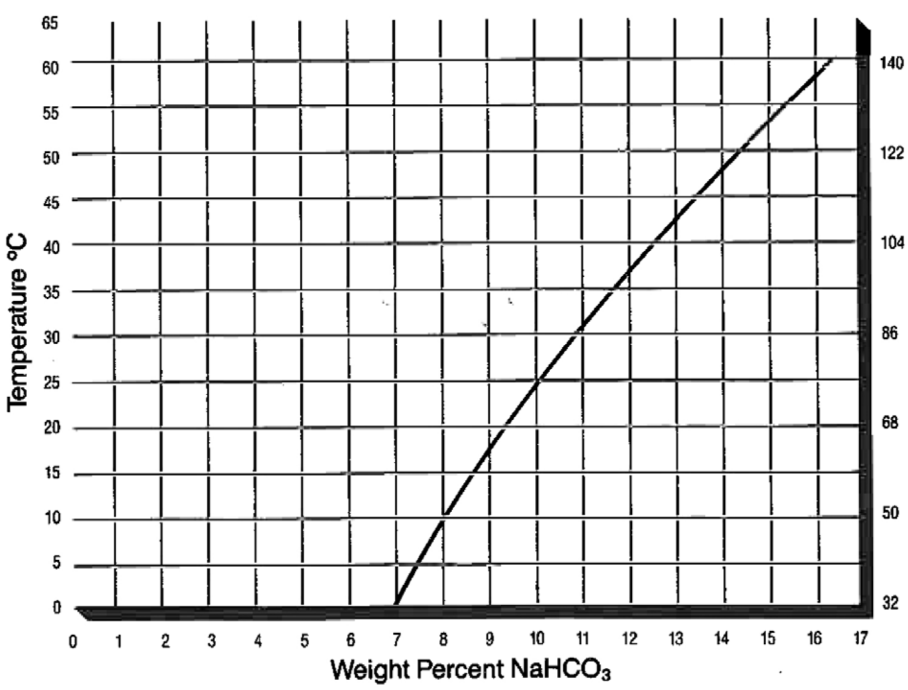
II. DESIGNING AND OPERATING SODIUM BICARBONATE ADDITION SYSTEMS FOR POTABLE WATER CORROSION CONTROL

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.

PHILOSOPHY

The design concept is 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 solution required to provide a full 24 hours of alkalinity adjustment is made up once per day, requiring one hour less of operator labor. After this, the bicarbonate 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 viable. Once the bicarbonate is in solution form, it can be easily metered into the distribution network by pumps and metering systems familiar to water treatment operators. The same design concept can be utilized for systems of less than 100,000 gpd to those greater than 10 MGD.

Solubility of sodium bicarbonate in water



BASIS

For simplification we have assumed a “typical” water supply into the corrosion treatment plan containing 10 ppm of alkalinity as $CaCO_3$. The design of the corrosion control process is to continuously add 20 ppm of bicarbonate alkalinity as $CaCO_3$ to approach the optimum value of 30 ppm. Since alkalinity is a linear function, any of the quantities given can be adjusted to a specific alkalinity requirement by using a factor calculated from rationing the required alkalinity to 20 ppm. For example, if your system requires only 15 ppm of $CaCO_3$ 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 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% $NaHCO_3$ solution:

- Contains 45,000 ppm of bicarbonate alkalinity as $CaCO_3$
- Contains 0.625 pounds of $NaHCO_3$ per gallon of solution

Forty-eight gallons of 7.5% $NaHCO_3$ solution are required to increase 100,000 gallons of water by 20 ppm as $CaCO_3$, or 29 gph for each 1,000 gpm of water flow.

Three hundred pounds of sodium bicarbonate are required to raise the alkalinity of 1 million gallons of water by 20 ppm as $CaCO_3$.

GALLONS PER FEET OF HEIGHT TANK CAPACITY

Tank diameter (ft.)	Gallons/ft.
2	24
3	53
4	94
6	212
8	377

II. DESIGNING AND OPERATING SODIUM BICARBONATE ADDITION SYSTEMS FOR POTABLE WATER CORROSION CONTROL (CON'T)

SYSTEMS UP TO 5 MGD

Sodium bicarbonate is received on pallets of nominal 2,000-pound weight in 50-pound paper bags.

A day tank which will contain 24 hours' worth of sodium bicarbonate solution is filled with treated water to the operating level and a top-mounted mixer is activated. Sodium bicarbonate bags are manually broken and contents dumped into the day tank. A dust control hood is recommended. For each MGD of system capacity, six bags (300 pounds) of sodium bicarbonate addition is required along with 480 gallons of solution capacity.

The sodium bicarbonate will completely solubilize within minutes; however, it is acceptable to begin metering the solution during bicarbonate addition as long as the day tank is properly agitated.

The metering pump which delivers the sodium bicarbonate solution to the distribution system is started. The rate of solution flow is controlled by the rate of treated water flow in the ratio of 480 gpm or 29 gph for 1,000 gpm.

SIZING RECOMMENDATIONS

Minimum 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). Eight 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 4 feet tall. This tank would then contain the necessary solution to treat up to 167,000 gallons of water per day.

Storage — A minimum five-day storage space is needed for the sodium bicarbonate. Allow 20 sq. ft. per pallet space. Pallets can be double stacked if lift equipment is available.

System size MGD	Bags (50#) per day	No. of pallet spaces for 5 days storage	Sq. ft. storage space
1	6	1	20
2	12	2	40
5	30	4	80

Tankage — Tanks should be properly baffled to assure adequate mixing.

System size MGD	Gallons capacity	Diameter	Height (ft.)
0-0.15	100	200	4
1	600	4	6.5
2	1,200	6	8
5	3,000	8	8

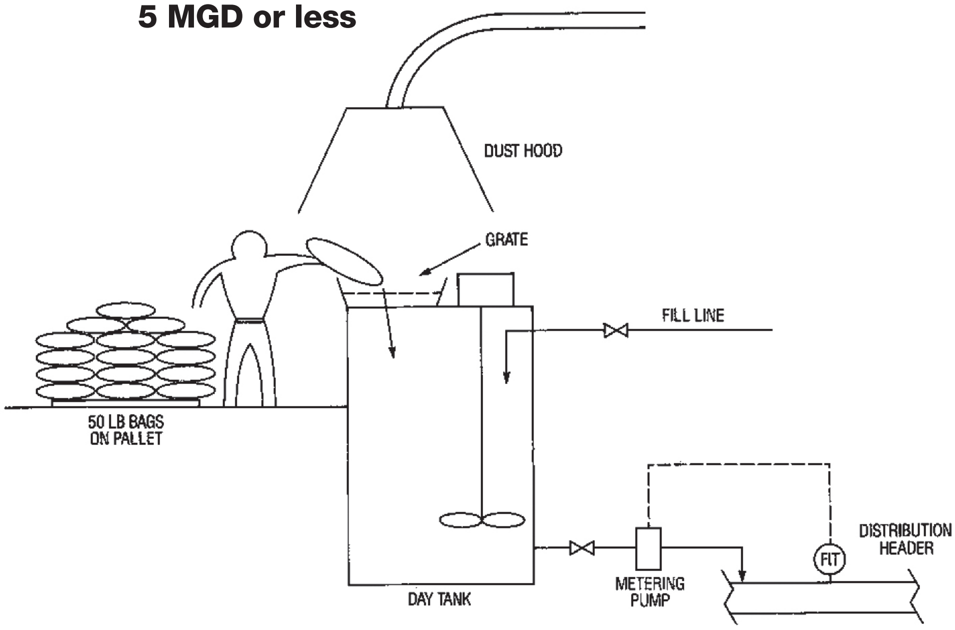
Mixing — A mixer, preferably top-mounted to minimize leak potential and to facilitate maintenance, is needed.

Metering — The metering pump should have a turn-down ratio of at least 3-to-1 to handle minimal winter and maximum summertime recommended 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 rate can be controlled manually at a proportion of 29 gph of solution per 1,000 gpm 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 the bicarbonate solution at the ratio of 29 gph per 1,000 gpm of water flow.

5 MGD or less



II. DESIGNING AND OPERATING SODIUM BICARBONATE ADDITION SYSTEMS FOR POTABLE WATER CORROSION CONTROL (CON'T)

SYSTEMS 6 MGD TO 10 MGD

Sodium bicarbonate is received in 1-ton bulk sacks. 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.

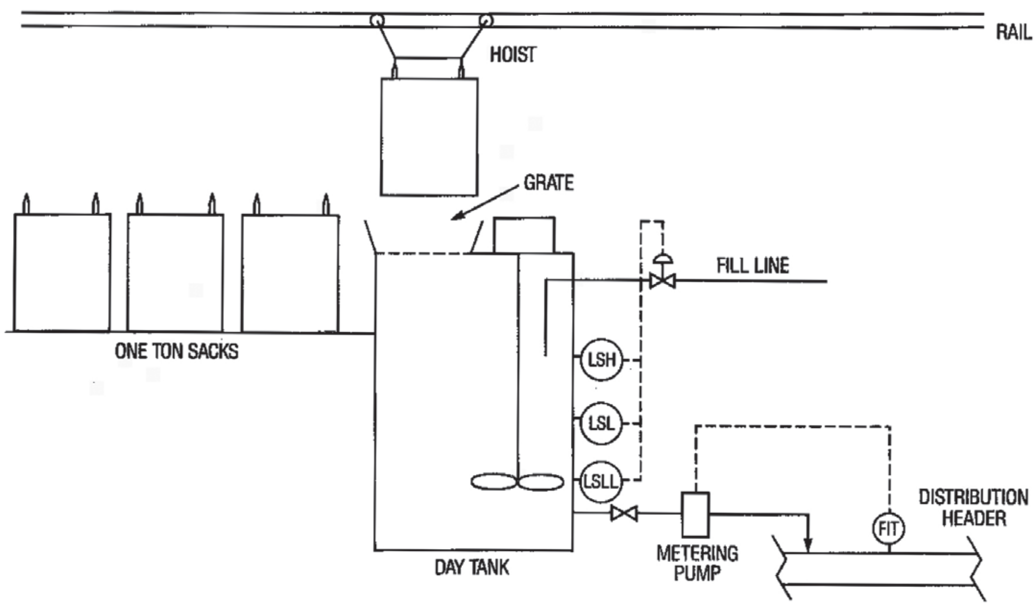
The 1-ton sacks are hoisted by a winch on a monorail and positioned over the day tank. The contents are dumped during a period of several minutes into the well-mixed day tank.

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

6–10 MGD



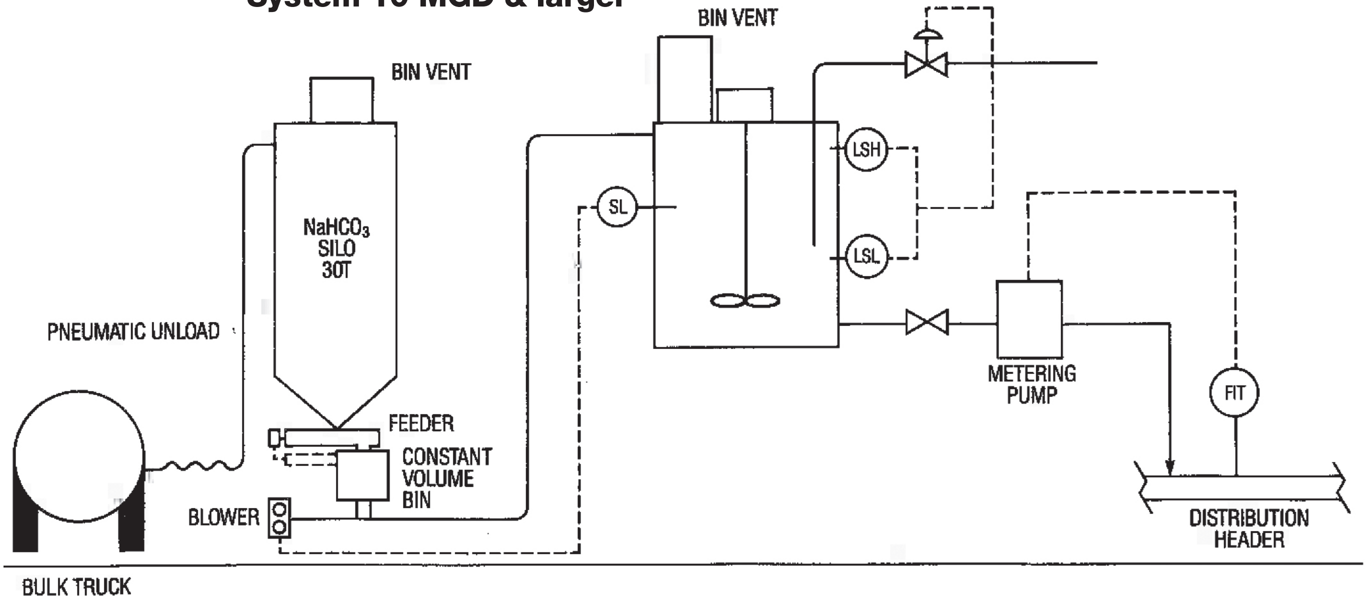
SYSTEMS LARGER THAN 10 MGD

Sodium bicarbonate is delivered in bulk and pneumatically conveyed to a silo. The mixing tank is a standard 4500 gallon, 8 ft. diameter by 12 ft. high tank with a top-mounted mixer. The tank is equipped with a high-level, mid-level and low-level sensor. 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 (1,400 pounds) is conveyed 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 gph per 1000 gpm of flow.

The only variable is the cycle time of the feed/fill system and the residence time of the solution in the tank.

MGD	Pounds $NaHCO_3$/D	Cycle time (hours)
10	3,000	11.2
25	7,500	4.5
50	15,000	2.25

System 10 MGD & larger

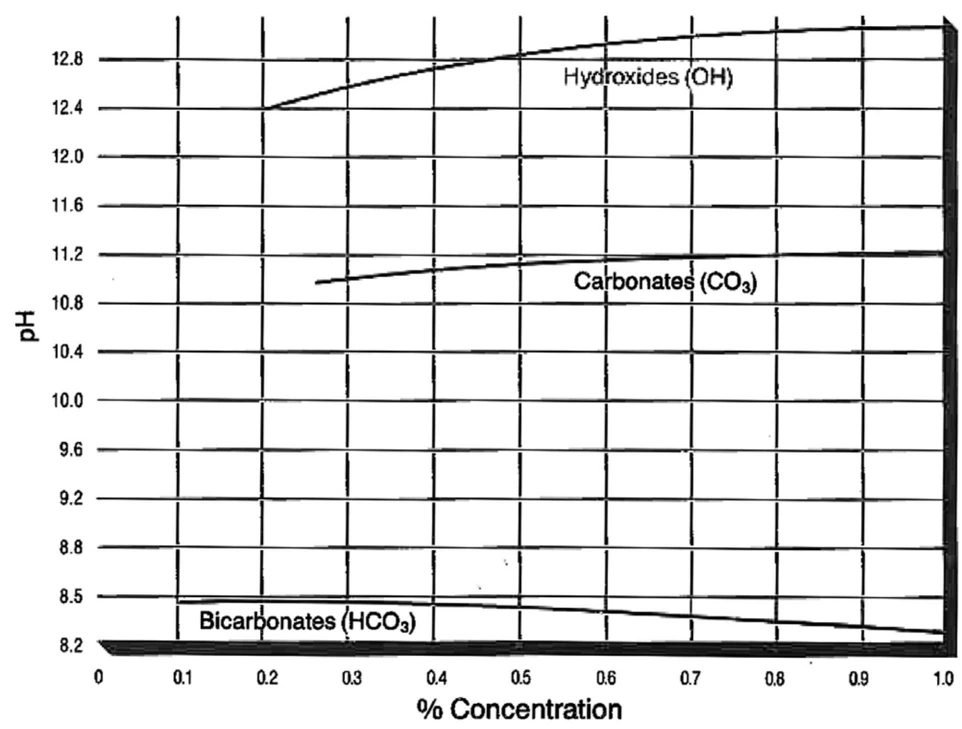


II. DESIGNING AND OPERATING SODIUM BICARBONATE ADDITION SYSTEMS FOR POTABLE WATER CORROSION CONTROL (CON'T)

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

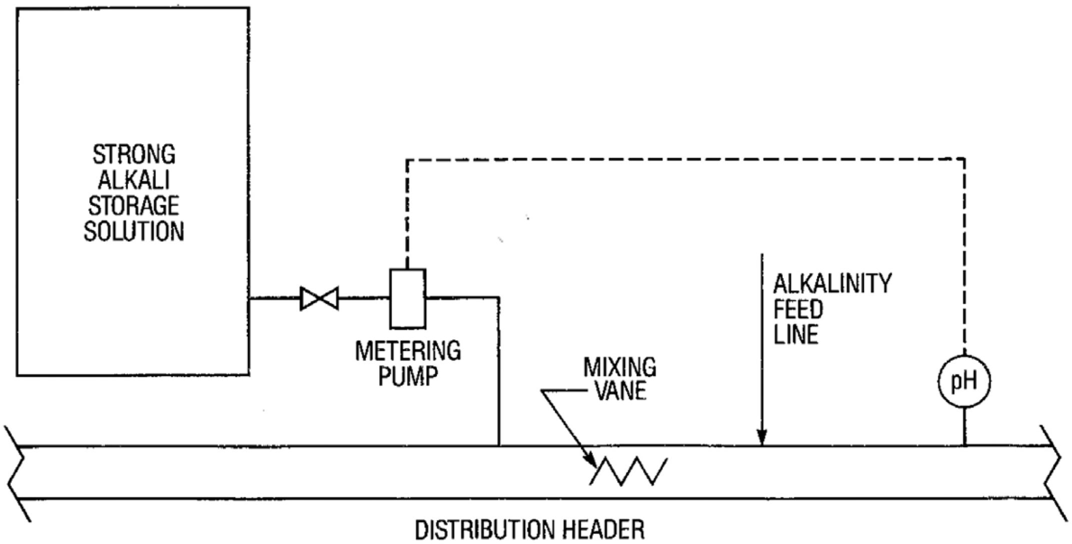


Sodium and potassium hydroxide are usually sold as concentrated solutions ranging from 25% to 50% solids. Since they are both very strong alkalis they usually need to be added only in small quantities; a little bit goes a long way. For example, a 55-gallon drum of 50% NaOH used to supply 4 ppm as NaOH 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- and 100-pound paper 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



III. RESIDUAL BENEFIT OF THE BICARBONATE METHOD

Many drinking water corrosion control treatments will create new problems in the waste water treatment plan (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.

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