Fluoridation

Fluoride is a naturally occurring element found in small but varying amounts in water, air, soil, plants, and animals. Water fluoridation is the deliberate addition of fluoride into drinking water in accordance with scientific and dental guidelines. When used appropriately, fluoride is a safe and effective agent that can be used to prevent dental cavity formation. However, fluoride above 2.0 parts per million (ppm) may result in enamel fluorosis in developing teeth. Scientific research on the subject began in the 1930s and continues today to establish optimal fluoride levels in drinking water.

REGULATIONS

Minnesota Statutes require all municipal water supplies to maintain a fluoride concentration of 0.9 ppm to 1.5 ppm, with an optimum level of 1.2 ppm. The Safe Drinking Water Act established a fluoride Maximum Contaminant Level (MCL) of 4.0 ppm to protect against crippling skeletal fluorosis and a Secondary MCL (SMCL) of 2.0 ppm to protect against enamel fluorosis.

Fluoride must be fed with equipment that conforms to Minnesota standards, and to prevent an overfeed of fluoride; it must be fed through a break box. Municipal water supplies must test for fluoride concentration daily using an approved analytical method. Records of these results must be kept by the water supplier and reports submitted monthly to MDH. A quarterly fluoride water sample must be submitted to MDH every three months. This sample serves to verify that optimum fluoride levels are being maintained and to check the water supplier's testing equipment accuracy.

FLUORIDE CHEMICALS

The most commonly used fluoride compound is hydrofluosilicic acid. Other commonly used fluoride compounds are sodium fluorosilicate and sodium fluoride.

Fluoride compounds must conform to American National Standards Institute / NSF International and American Water Works Association standards. The water supplier should insist that the chemical supplier furnish only compounds that meet these standards. The water supplier should also periodically request Material Safety and Data Sheets and chemical composition test results from the chemical supplier.

Several factors must be considered in selecting a fluoride chemical. For suppliers that use a powder or crystal form, the solubility of the chemical in water is important since the chemical must dissolve readily in water and remain in the solution. Operator safety and ease of handling must also be considered, as well as storage and feeding requirements and, of course, cost.

Hydrofluosilicic acid must be handled cautiously. It is very dangerous, can cause burns, and produces acidic fumes that must be vented to the atmosphere. These acidic fumes can etch glass on gauges, corrode electrical equipment and irritate skin. Sodium fluoride is the easiest chemical to feed because of its uniform solubility in water.

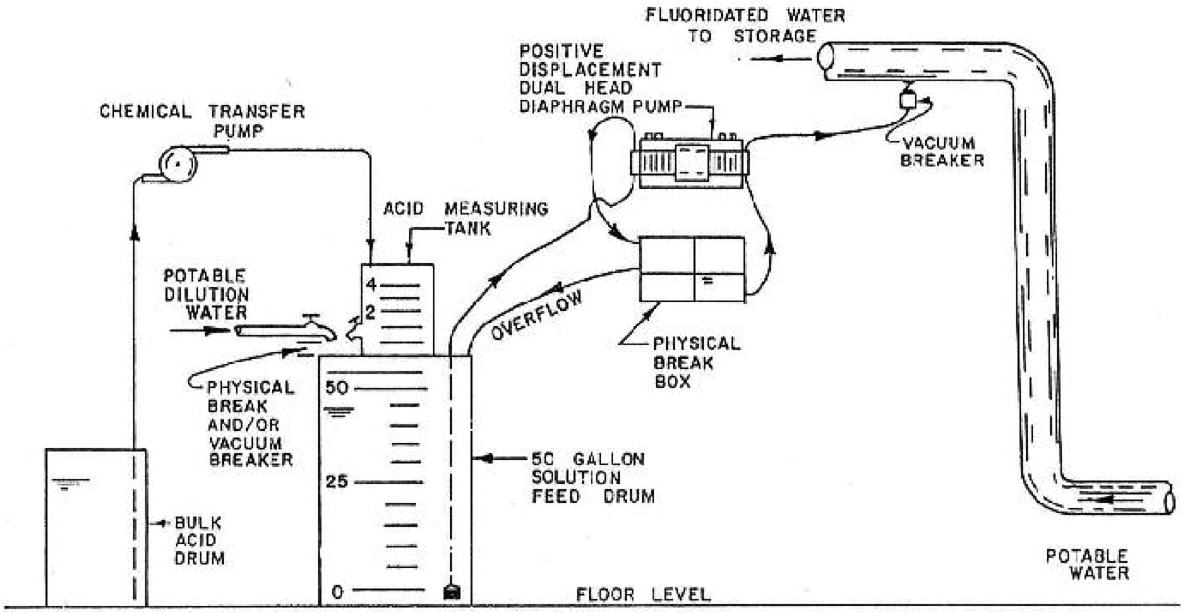
	Sodium Silicofluoride Na_2SIF_6	Sodium Fluoride NaF	Hydrofluosilicic Acid H_2SIF_6
Form powder powder or crystal liquid	Molecular Weight 188.1 42 144.1	Commercial purity % 98-99 95-98 22-30	Fluoride Ion % 60.7 (100%) 45.3 (96%) 79.2 (100%)
Purity % 59.8 (98.5%) 43.4 (96%) 23.8 (30%)	Density 55–72 lb/ft^3 65–90 lb/ft^3 10.5 lb/gal	Solubility in water % 0.76 4.95 100	pH of saturated solution 3.5 7.6 1.2

FLUORIDATION SYSTEMS

Fluoride can be added to water in liquid or powder form. In liquid form, a chemical pump adds the fluoride in a controlled dosage. In powder form, a dry feeder adds the chemical to a water solution which is then added to the water.

Type of Feeder	**Chemical Used**	**General Rate Range**
Gravimetric (dry feeder)	Na_2SIF_6	2 to 5,000 pounds per hour (lb/hr)
Volumetric (dry feeder)	Na_2SiF_6	0.02 to 5,000 lbs/hr
Piston or centrifugal metering pump	H_2SIF_6 NaF	18 to 5,000 lbs/ hr
Diaphragm metering Pump – mechanical	H_2SIF_6 NaF	9 to 2,500 gallons per day (gal/d)
Diaphragm metering Pump – Electronic	H_2SIF_6 NaF	0.2 to 96 (gal/d)
Peristaltic metering Pump	NaF	0.5 to 85 (gal/d)

HYDROFLUOSILIC ACID FEED



A typical hydrofluosilicic feed system includes:

Displacement Pump

A dual head or 2 single headed positive displacement pump designed of a corrosion-resistant material. If the pump discharges to an open tank with an airbreak such as a clearwell or filter, the double-head pump is not required. The airbreak will prevent any chance of back siphonage.

Break Box

A break box is required to prevent an overfeed of fluoride chemical. This is a single compartment tank with one head of the pump discharging into one side and the second head using that same compartment as the suction for the pump that discharges to the feed point. This box must be made from acid resistant material that can withstand the corrosion of the hydrofluosilicic acid. There is an overflow line back to the day tank. (Corrosion-resistant shelving should be used for mounting feed pumps and the breakbox).

Day tank

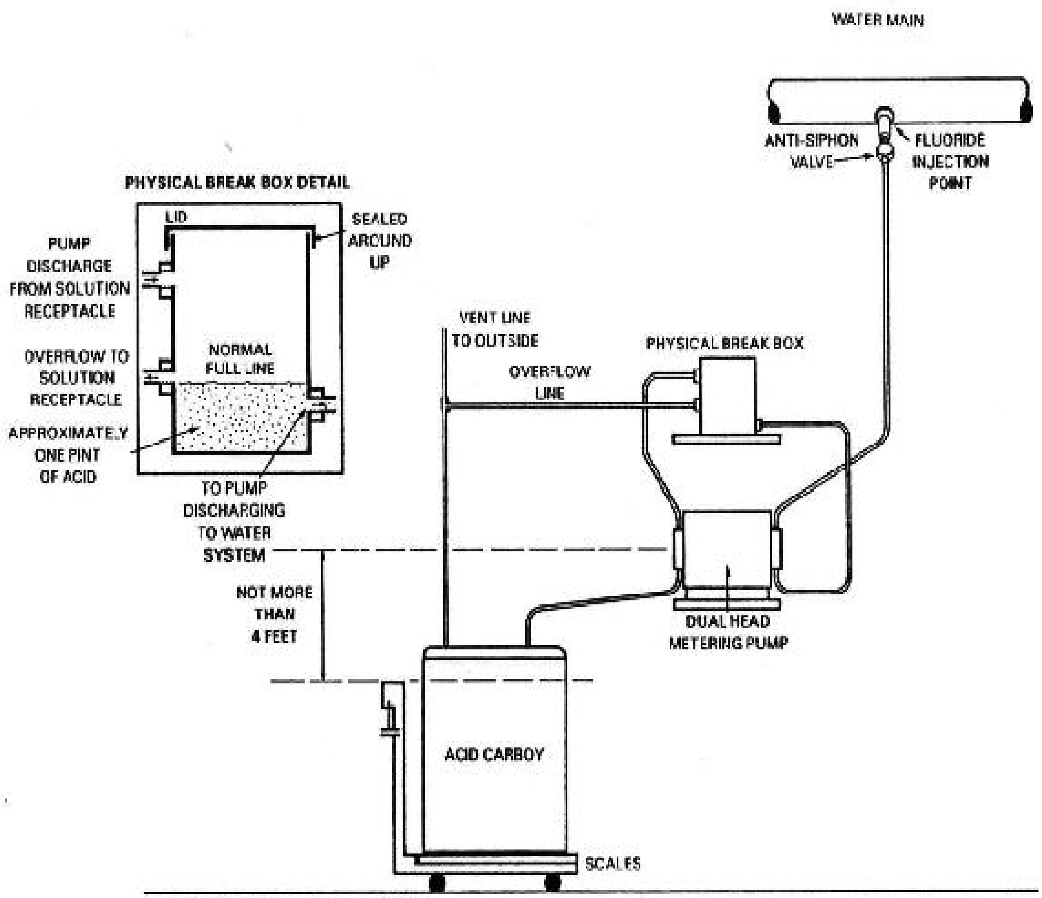
The solution or day tank is generally a calibrated polyethylene tank that can withstand the corrosivity of an acid. This tank generally holds at least 50 gallons of fluoride solution. It should be calibrated in one-gallon units. The solution tank should be sealed and vented to the outside.

Chemical

Whenever possible, full-strength chemical should be fed. If it isn’t, a method for diluting the acid with water is needed. The dilution can be done manually; otherwise, a transfer pump is required to move the acid needed to make up the solution from the storage tank to the dilution tank. A water source is also needed and must be protected from cross-connection.

Safety and Ventilation

When working on the fluoridation system, the operator needs to use safety equipment consisting of neoprene apron, gloves, and goggles. Ventilation must be provided. An exhaust fan and solution-tank vents help protect against indoor acid fumes which could etch glass and corrode electrical equipment. All tank vents should be terminated outside the building.



*Courtesy of Minnesota State Department of Health

Amount of Fluoride in Hydrofluosilicic Acid

The weight of a hydrofluosilicic acid solution is found by multiplying the weight per gallon by the percent of purity (a gallon of hydrofluosilicic acid has a density of 10.3 pounds per gallon). Most commercially available hydrofluosilicic acid contains 23-25 % pure acid.

Weight of pure acid = Weight per gallon x percent purity

= 10. 3 lb hydrofluosilicic acid solution/gal x 0.24

= 2.47 lb hydrofluosilicic acid/gal

Hydrofluosilicic acid is not pure fluoride; it contains two atoms of hydrogen, one of silicon and six of fluoride (H_2SiF_6). The percent of pure fluoride in the acid is found by calculating the molecular weight of the acid and dividing the molecular weight of the fluoride by the total molecular weight of the acid.

$$\text{Percent pure fluoride} = \frac{\text{Atomic weight of fluoride atoms within molecule}}{\text{Molecular weight of hydrofluosilicic acid } (H_2SiF_6)}$$

$$= \frac{(6 \text{ F atoms x } 19 \text{ F atomic weight})}{((2 \text{ x } 1) + (1 \text{ x } 28.1) + (6 \text{ x } 19))} \text{ x } 100\% = 79\%$$

<u>Feed calculations</u>

The size of the feed pump is determined by:

- The required rate of feed from the well or plant (gallons treated).
- The natural fluoride concentration in the raw water.
- The percentage of purity and availability of fluoride in the chemical.

<u>Example</u>

Assume a well pump has a flow of 1,000 gallons per minute (gpm) and runs for 24 hours. The fluoride concentration needed is 1.2 parts per million (ppm); the natural fluoride concentration is 0.1 ppm. A 25 percent hydrofluosilicic acid solution having a pure fluoride content of 79 percent and a density of 10.4 pounds per gallon is used. How many gallons of acid per day must be added to raise the concentration to 1.2 ppm?

$$\text{Pounds fluoride} = \frac{\text{gallons to be treated}}{1{,}000{,}000} \text{ x } 8.34 \text{ lb/gal x concentration (dosage)}$$

$$= \frac{1{,}000 \text{ gal/min x } 1{,}440 \text{ min/day}}{1{,}000{,}000 \text{ gallons/Mgal}} \text{ x } 8.34 \text{ x } (1.2 \text{ ppm} - 0.1 \text{ ppm})$$

$$= \frac{12.01 \text{ Mlb}}{\text{Day}} \text{ x } 1.1 \text{ ppm}$$

= 13.21 pounds per day pure fluoride needed

Pounds fluoride per gallon = weight/gallon x (% acid/100) x (% purity/100)

$= 10.4 \text{ lb/gal} \times 0.25 \times 0.79$

$= 2.05 \text{ \# fluoride/gallon}$

$$\text{Gallons per day} = \frac{\text{pounds per day}}{\text{pounds per gallon}}$$

$$= \frac{13.21 \text{ pounds per day}}{2.05 \text{ pounds per gallon}}$$

= 6.44 gallons hydrofluosilicic acid solution per day

The pump purchased should be sized so that the required amount of acid per day is in the mid-range of its capacity. This will give a more accurate feed. If the water flow is less than 100 gpm, acid may be diluted; however, in most cases--even with a low flow--a pump small enough to feed accurately can be purchased. Dilution is not recommended. The pump should be sized to accommodate low flow. The chemical feed equipment must be wired to start and stop with the well pump so that chemical is fed only when water flows.

Operation and Maintenance

Operation of the pumping equipment is simple, but anything mechanical occasionally breaks down. In most cases, diaphragm pumps are operated by either electronic or mechanical controls. Electronic pumps are becoming more popular because of their reliability and versatility. Electronic pumps can accurately deliver very small volumes because both the length of the stroke and its frequency can be finely adjusted. Mechanical pumps are typically immersed in oil and require more maintenance.

When the pump operating the diaphragm moves a given distance for each stroke, it opens the check on the suction side, allowing a given amount of acid to flow into the pump. The amount of acid will depend on the volume of the cavity that the diaphragm movement creates. When the diaphragm reverses the stroke to expel the acid, the suction check closes and the discharge check opens, allowing the acid to flow away from the pump.

Maintenance of the pumping equipment involves the replacement of the check valve balls, diaphragm gaskets, and related parts. Most operators should be able to repair the pump without too much trouble; however, if the power source is the problem, it may require an electrician or the pump supplier's service representative.

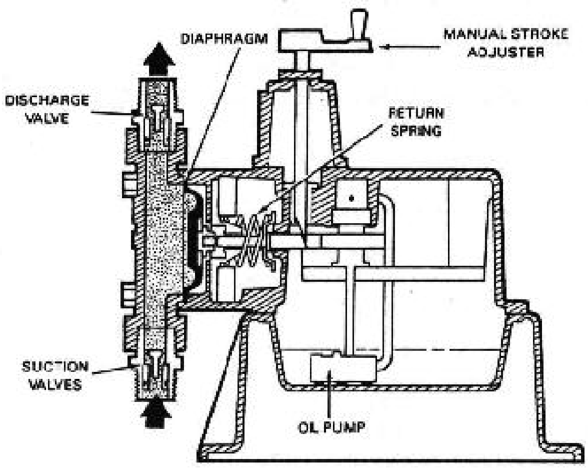
Installation

Prior to the start-up of the equipment, the operator should make sure:

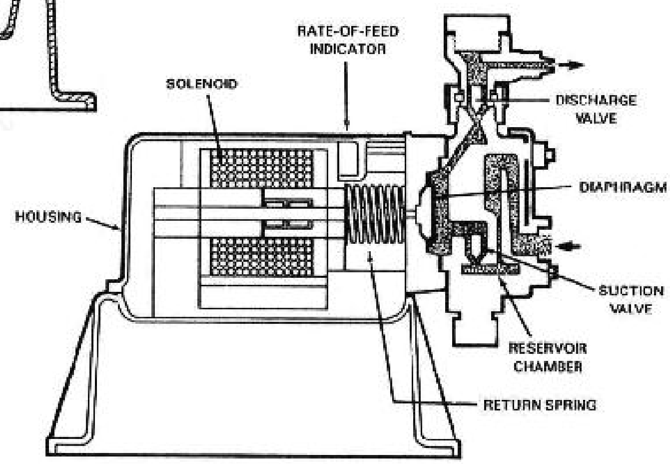
- Chemical is injected into the water system at the lower half of a discharge pipe located downstream of the pump. The injection pipe located in the lower half of the pipe will prevent corrosion of the pipe.

- Power supply for the feed pump is activated by the well or water-pumping equipment so the fluoride pump will start and stop the same time as the water pump.
- All valves on discharge side of feed pump are open to allow chemical flow.

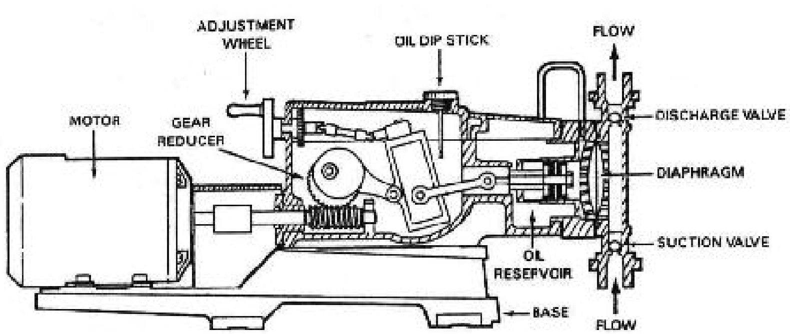
DIAPHRAGM METERING PUMP



TYPICAL ELECTRONIC METERING PUMP



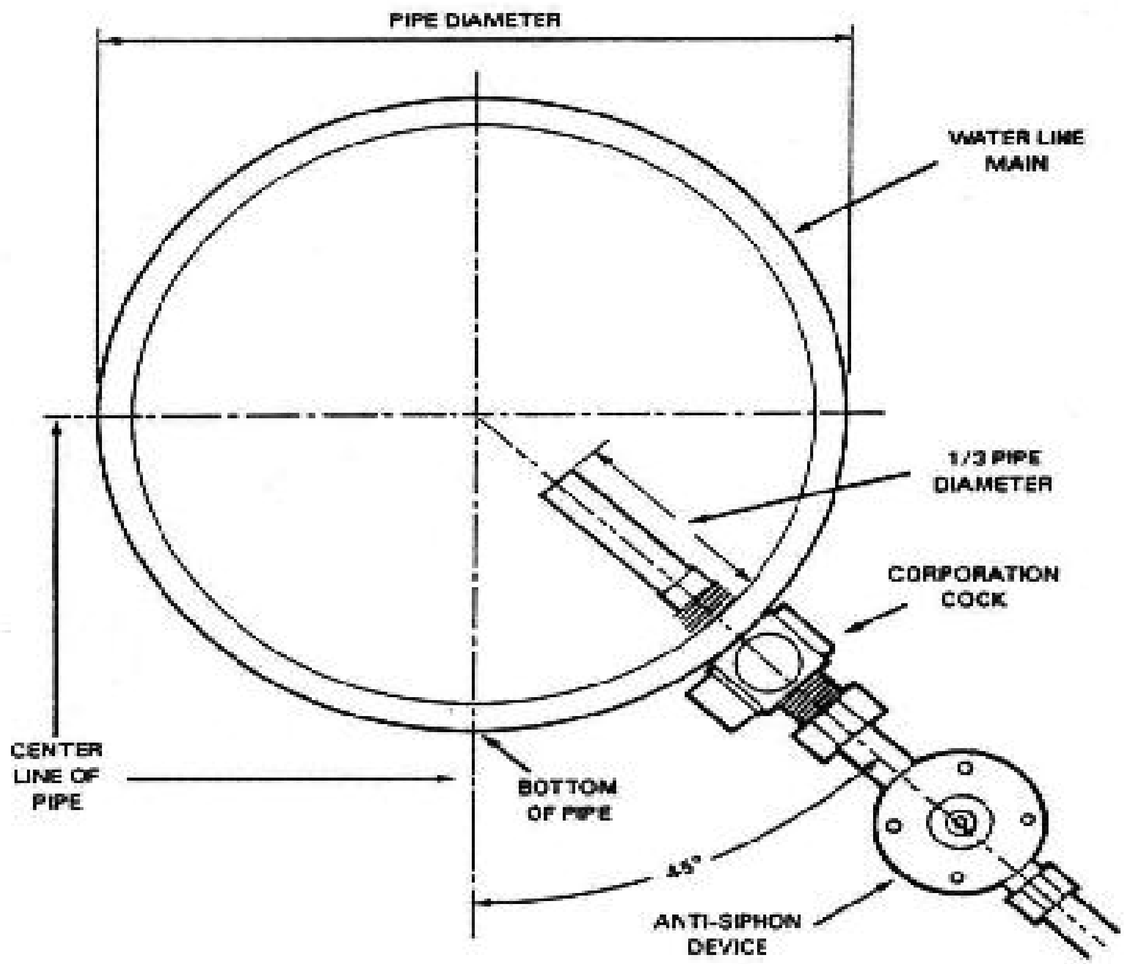
TYPICAL HYDRAULIC DIAPHRAGM METERING PUMP



Once these items are checked, and corrected, an operator should:

- Prime the feed pump with potable water, and run the pump at full capacity until all air has been bled from the lines.
- Use a graduated cylinder and stop watch to calibrate the feed rate of the pump and make any necessary adjustments.
- After the feed has started, check the water samples for the proper fluoride concentration. These samples should be taken at least 100 feet from the point of fluoride application.

FLUORIDE INJECTION POINT



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Troubleshooting

If low fluoride concentration is detected, and if the problem is determined to be related to low pump output (not an error in the feed calculations), the following possible causes should be investigated:

- Low pump setting - An increased pump setting may solve the output problem.
- Trapped air or loss of prime - If air is found in the chemical feed lines, determine how it entered. It might be due to a faulty seal, a tubing or fitting leak, air suction due to a depleted feed solution supply, or other similar causes.
- Ruptured diaphragm - A ruptured diaphragm should be replaced immediately since an acid leak can cause internal pump damage.
- Clogged tubing or valves - Make sure liquid flows freely through the system.

If the pump is operating properly and a low concentration is detected, the cause must lie in the feed solution or water pumpage rate and you should check:

- Proper feed dilutions - Prepare a small amount of the proper solution concentration. Feed this into the system and test for the actual fluoride concentration.
- Pump rate - Check the meter with a stop watch for a given length of time.

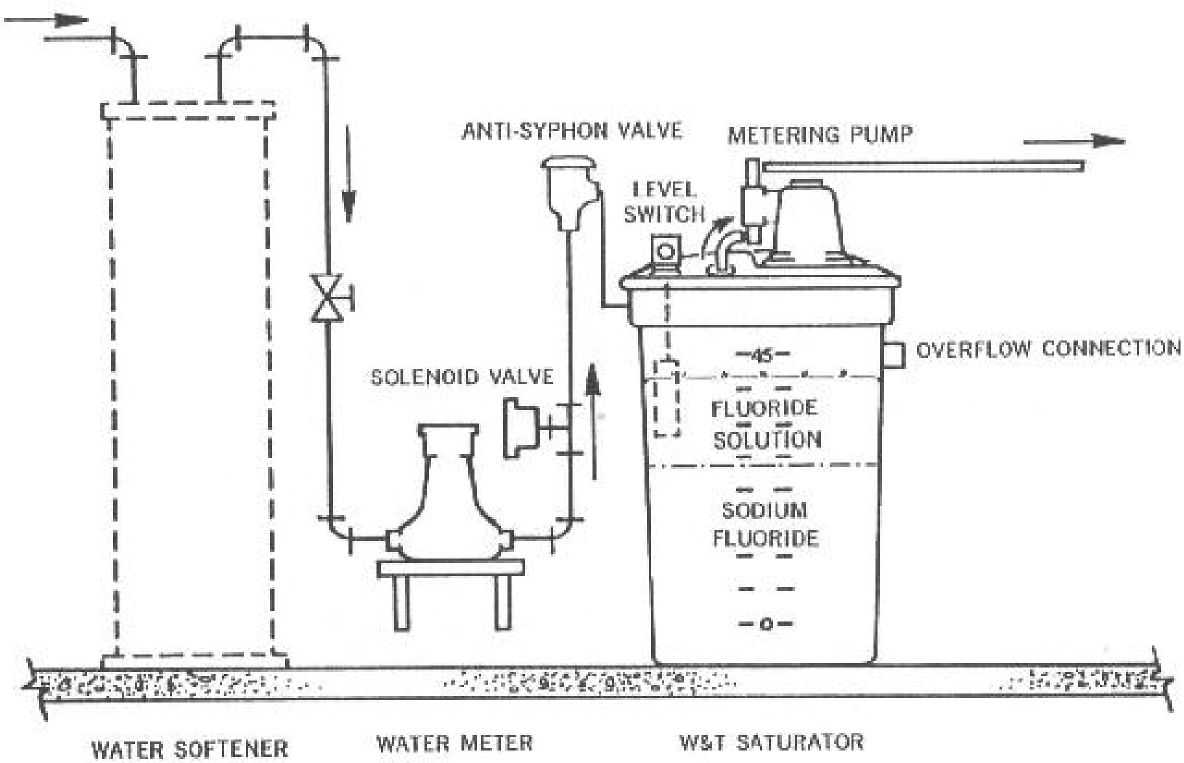
If the pump is operating properly and a high concentration is detected, the cause may be high pump output. The pump setting is too high or the fluoride solution is being siphoned into the water piping. Siphoning is less likely to be the problem since most solutions are added at the discharge side of a well pump against higher pressure. However, siphoning might occur if pressure is lost in the water system. A break box in provided in the feed system to safeguard against excessive feed due to siphoning action.

SODIUM FLUORIDE FEED

In a fluoride saturator, the incoming water becomes saturated with sodium fluoride as it percolates up through the granulated sodium fluoride bed. This provides a 4% sodium fluoride solution. This solution is injected into the water supply at a rate calculated to maintain a fluoride concentration of 1.2 ppm.

Installation

To prevent scale formation, a softener should be used to soften the makeup water for the saturator when the hardness exceeds 75 ppm as calcium carbonate or 4.4 grains. This softened incoming water should then go through a water meter, a solenoid valve, or a flow control valve and a backflow preventer. The water is piped into the saturator through a diffuser system. A constant water level is maintained inside the saturator by means of a float connected to a liquid level switch. The upward flow rate should not exceed 2 gpm. The tank should be filled manually each day while recording the amount used so that the level remains constant.



Operation and Maintenance

To operate the saturator, the following steps should be taken:

- Mark the outside of the saturation tank at the five-inch level. This is the minimum depth of sodium fluoride needed in the tank to maintain a four-percent solution. Add additional sodium fluoride when it reaches this line.
- Turn on the power source for the valves to allow the water to fill the tank and begin to dissolve the sodium fluoride. The flow of water should shut off automatically when the proper level is reached in the saturator. There should be a minimum of 1 foot of water above the sodium fluoride bed.
- Submerge the chemical feed pump suction line just below the water surface and start the pump. Set the pump at the desired feed rate (which will have to be calculated).

The saturator should be cleaned periodically according to the following procedures:

- Allow the system to operate without adding chemical until the fluoride bed is depleted to a point that the diffuser is exposed.

- Disconnect the power to the level control. Allow the chemical pump to run until only about one foot or less of solution remains above the fluoride bed.
- Remove the cover from the saturator.
- Remove the drain plug and allow the tank to drain. Agitation or stirring may be necessary to loosen the hardened material. Be careful not to damage the diffuser. The diffuser assembly can be removed if it is not embedded in the fluoride bed.
- If you are draining to a septic system or gravel pocket from a floor drain you should dilute the solution with running water while draining or, consider draining to a municipal sanitary sewer system.
- Rinse the inside of the tank to remove any built up deposits.

CHEMICAL HANDLING AND SAFETY

Operating a fluoridation system, especially one using hydrofluosilicic acid, involves handling corrosive liquids. Hazards may be reduced greatly by following some simple safety precautions and general housekeeping rules:

- Appropriate personal protective equipment must be used when handling chemicals or working with fluoridation equipment. These include such items as face shields, neoprene goggles, gloves, and aprons.
- Splashed acid is dangerous to the body, especially the eyes. An eye-wash station and deluge shower must be present at all fluorosilicic acid installations, and should be located as close as possible to the fluoridation equipment.
- Keep storage containers and tanks clearly labeled and chemicals separated.
- Keep your chemical area clean and free of obstructions. An accident is less likely in a clean area.

OPERATIONAL REPORTS

MDH requires a monthly operation report from each water supply regarding operation of fluoridation systems. It is recommended that water systems test the natural background fluoride concentration of their water sources regularly, and perform the following daily.

- Analyze distribution system sample fluoride concentrations.
- Calculate finished water pump flows from meter readings.
- Calculate fluoride amount used.
- Record findings on the MDH Monthly Fluoridation Report, which must be submitted to MDH the beginning of each month.

FLUORIDE TESTING

The SPADNS method, measures the change of color intensity in the SPADNS reagent when a sample containing fluoride is added. The change can be measured by comparison with color standards provided with a SPADNS test kit or by photometric measurements using a color meter. Some chemicals other than fluoride may interfere with the SPADNS test result and cause faulty readings. Polyphosphate is the most common chemical used in drinking water that will give you a false high reading.

Fluoride electrode and a meter indicate the fluoride concentration. Other chemicals usually do not interfere with this test method.

MINNESOTA MDH DEPARTMENT OF HEALTH

SECTION OF DRINKING WATER PROTECTION
Fluoridation Monthly Report (Single Well)

See Instructions on Reverse Side to Complete Form

PWS ID#	Month of	
Name of Facility	Street	
City	Operator Name (Please Print)	Zip Code
Signature	Title	Phone #
Fluoride Chemical Used	Raw Water Fluoride Concentration mg/L	Water Source

Date	Meter Reading (1000 gal)	Pumpage (1000 gal)	Amount of Solution or Compound Used per Day (gal / lbs)	Fluoridation Analysis	
				Tested Fluoride Concentration (mg/L)	Sampling Point on Distribution System
Day #	1	2	3	4	5
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Copy to be sent back each month to: Minnesota Department of Health, Community Water Supply Unit, P.O. Box 64975, St. Paul, Minnesota 55164-0975

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FI-Single Rev. 11/2008

INSTRUCTIONS FOR FILLING OUT THE FLUORIDATION MONTHLY REPORT (Single Well)

Column Number

Column Number	
1	**Daily water meter reading in thousands of gallons.**
2	**Pumpage in thousands of gallons: daily meter reading minus the previous day's meter reading.**
3	**The total number of gallons of fluoride solution used per day or the total pounds of fluoride compound used if you are using sodium fluorosilicate.**
4	**Your tested fluoride concentration of the treated water. These tests are to be run daily. Do not composite samples.**
5	**Sample location: the sample is to be taken on the distribution system and at different locations each day.**

NOTE: THE RAW WATER FLUORIDE CONCENTRATION SHOULD BE TESTED MONTHLY.

COMMENTS:

Send Fluoridation Monthly Report (Single Well) to:

Minnesota Department of Health
Community Water Supply Unit
PO Box 64975
Saint Paul, MN 55164-0975